Fisheries Research Services Contract Report No. 16/06

COLLECTION AND ANALYSIS OF SHELLFISH FLESH FROM SCOTTISH INSHORE AND OFFSHORE HARVESTING AREAS FOR CHEMICAL CONTAMINANTS

FSA (SCOTLAND) PROJECT CODE: S14026

A D McIntosh, A E Craig, M Russell, L Webster, L A Phillips, E J Dalgarno, S Devalla, C D Robinson, and I M Davies

SEPTEMBER 2006

Fisheries Research Services
Marine Laboratory
375 Victoria Road
Aberdeen AB11 9DB

CUSTOMER: FOOD STANDARDS AGENCY (SCOTLAND)

FSA (SCOTLAND) PROJECT CODE: S14026

COLLECTION AND ANALYSIS OF SHELLFISH FLESH FROM SCOTTISH INSHORE AND OFFSHORE HARVESTING AREAS FOR CHEMICAL CONTAMINANTS

SEPTEMBER 2006

A D McIntosh, A E Craig, M Russell, L Webster, L A Phillips, E J Dalgarno, S Devalla, C D Robinson, and I M Davies

Fisheries Research Services, Marine Laboratory
375 Victoria Road, Aberdeen, AB11 9DB

NON-TECHNICAL SUMMARY

The Food Standards Agency (Scotland) (FSA(S)) has conducted a survey of polycyclic aromatic hydrocarbons (PAHs), heavy metals, chlorobiphenyls (CBs) and pesticides in commercially exploited shellfish species from both inshore and offshore locations in compliance with the Shellfish Hygiene Directive which includes the requirement to assess a range of elements for end product quality in shellfish offered for sale for human consumption.

Summary of percentage of samples within EC and other guideline concentrations

	Mussels	Oysters	Scallop muscle	Scallop gonad
	n =14	n = 5	n = 10	n = 10
Metals [1]				
Hg	100%	100%	100%	100%
Cd	100%	100%	100%	100%
Pb	100%	100%	100%	100%
CBs [2]	93%	100%	100%	90%
PAH [3]	100%	100%	100%	100%
Pesticides	100%	100%	100%	100%

[1] EC Commission Regulations
[2] Environmental Assessment Criteria (established for mussels)
[3] as benzo[*a*]pyrene

The key facts of this survey are:

- Concentrations of PAHs, 12 metals (chromium, manganese, nickel, cobalt, copper, zinc, arsenic, selenium, silver, cadmium, mercury and lead), CBs and pesticides were determined in 29 samples of bivalve molluscs, comprising 14 mussels, 6 Pacific oysters and 10 scallops (both adductor muscle and gonad tissue).
- Concentrations of contaminants were found to be similar to those reported in previous studies.
- Intake of PAHs from the consumption of shellfish at the concentrations reported is considered to be of low concern for human health.
- This survey does not raise health concerns from the consumption of shellfish in respect of metals, CBs and pesticides.

SUMMARY

1. A total of 29 shellfish samples, comprising 14 mussel (*Mytilus edulis*), 5 oyster (*Crassostrea gigas*) and 10 scallop (*Pecten maximus*) samples were collected from five coastal regions and seven offshore locations around Scotland during January to March 2006.

2. The concentrations and composition of polycyclic aromatic hydrocarbons (PAHs) and the concentrations of trace metals (TM), chlorobiphenyls (CBs) and organochlorine pesticides (OCPs) were determined in all three species.

3. The total measured PAH concentration in 12 out of the 14 mussel samples analysed was less than 150 ng g^{-1} wet weight. One of the remaining samples had a total PAH concentration in excess of 250 ng g^{-1} wet weight.

4. All oyster samples returned PAH concentrations less than 150 ng g^{-1} wet weight.

5. The total measured PAH concentrations in scallop adductor muscle were, with one exception, all less than 50 ng g^{-1} wet weight tissue while the total measured PAH concentrations in scallop gonad tissue were all greater than 50 ng g^{-1} wet weight.

6. No samples exceeded 10 ng g^{-1} wet weight benzo[*a*]pyrene, the maximum concentration allowed under Commission Regulation (EC) 208/2005.

7. Trace metal concentrations in mussels generally did not exhibit a high variance between sites but concentrations of some of the elements exceeded natural background [reference] concentrations. All trace metal concentrations determined in mussels and scallop adductor tissues were within the EEC Guideline and Imperative concentrations. Oyster tissue concentrations of copper and zinc were found to be higher than those in mussels. The other elements were generally lower than those found in mussels. Concentrations of trace metals in scallop adductor muscle were, without exception, lower than the corresponding gonad tissue samples.

8. Chlorobiphenyl and organochlorine pesticide concentrations determined in mussels were, with one exception, within the Environmental Assessment Criteria (EAC) established by OSPAR for mussels. An EAC has not been established for either oysters or scallops, but CB concentrations were, with one exception, within the EAC established for mussels and within ranges found in previous studies.

9. In respect of consumption of shellfish and their impact on health, benzo[*a*]pyrene (B[*a*]P) is one of the PAHs in the highest category of concern regarding its possible carcinogenic effects. It is concluded that the concentrations of B[*a*]P in shellfish found in this survey, combined with the intake from an average diet, are within concentrations considered as being of low concern for human health.

   The concentrations of lead, cadmium and mercury, chlorobiphenyls and organochlorine pesticides determined in all shellfish samples from this survey do not raise health concerns in respect of consumption by the general public.

INTRODUCTION

The European Union (EU) Shellfish Hygiene Directive (91/492/EEC) includes the requirement to assess a range of elements for 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.

Chemical contaminants, such as polycyclic aromatic hydrocarbons, trace metals, chlorobiphenyls and organochlorine pesticides, in the marine environment can be accumulated in the tissues of shellfish (scallops, mussels, oysters, cockles, etc.). If humans then consume contaminated shellfish species either in large quantities or over a sustained period of time, there is a risk that both acute and chronic effects (such as chemical poisoning and long-term systemic effects) related to specific contaminants can occur. In order to protect public health, Member States are required to adopt appropriate surveillance measures regarding the presence of chemical contaminants in foodstuffs.

PAHs are amongst the compounds present on the Oslo and Paris (OSPAR) Commission List of Chemicals for Priority Action and the EU Water Framework Directive List of Priority Hazardous Substances. Sixteen PAHs[1] have been identified as priority environmental pollutants by the US Environmental Protection Agency (US EPA).

Polycyclic aromatic hydrocarbons (PAHs) are found throughout the environment in air, water, soil and all living things and therefore in food. Some PAHs enter the environment from naturally occurring sources such as from active volcanoes, fires of all types (bush, forest, agricultural, home heating, cooking, etc) and natural seepage from oil and gas deposits. The majority of PAHs entering the environment are from industrial and other commercial activities such as emissions from petroleum refineries, fossil fuel power plants (coal, oil), coal-tar production plants, coking plants, bitumen and asphalt production plants, paper mills, wood products manufacturers, aluminium production plants, industrial machinery manufacturers and motor vehicle exhaust. All these sources may directly or indirectly contaminate air, soil and water. PAHs can enter the aquatic environment from atmospheric fallout, land run-off, industrial and wastewater treatment plants, general shipping activity and offshore spillage from oil and gas exploration and exploitation.

Due to the multiple sources and diversity of compounds that comprise the PAHs, the chemistry can be complex. In simple terms, the PAHs can be divided into groups which have certain characteristics. PAHs are frequently quoted as concentrations of the 2- to 6-ring parent and branched compounds in units based on wet tissue. The PAHs with smaller molecular weights (2- and 3-ring structures) are more volatile and can, for example, cause acute tainting, especially in aquatic food sources. Naphthalene, for example, is slightly soluble in water and as such can be absorbed by finfish through the gills. The larger molecular weight PAHs are considered more toxic with some regarded as probable human carcinogens, therefore, as molecular weight increases, the potential carcinogenicity of PAHs generally also increases, and acute toxicity decreases. The PAH compounds, dibenz[*a,h*]anthracene (1930) and benzo[*a*]pyrene (1932), are notable for being the first chemicals to be identified as carcinogens. The majority of PAHs in the aquatic environment are particle bound and associated with suspended organic matter. Filter feeding molluscs are exposed to both water and suspended particulate material and so are exposed to the full range of PAHs.

[1] US EPA sixteen PAHs identified as priority environmental pollutants: naphthalene, acenaphthene, acenaphthylene, fluorene, anthracene, phenanthrene, fluoranthene, pyrene, benz[*a*]anthracene, chrysene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, dibenz[*a,h*]anthracene, benzo[*g,h,i*]perylene and indeno[1,2,3-*cd*]pyrene

Environmental PAH input falls broadly into petrogenic and pyrogenic sources. Petrogenic PAHs tend to show higher proportions of alkyl substituted (branched) to parent compounds whilst the pyrogenic PAHs tend to show higher proportions of parent compounds. The pattern of PAH compounds in a sample can therefore give some information regarding their source(s). Parent compounds tend to degrade more quickly than the alkyl substituted (branched) compounds and therefore the ratio of parent to branched compound can provide some indication of temporal exposure.

The hydrophobic nature and low biodegradability of PAHs can result in an accumulation in lipid rich tissues of organisms generally greater than the concentrations in the surrounding environment.

Commission Regulations (EC) provides that maximum concentrations of polycyclic aromatic hydrocarbons (PAH) be set for certain contaminants in foodstuffs in order to protect public health. Currently only benzo[*a*]pyrene is covered by these Regulations. The Scientific Committee on Food (SCF) has used benzo[*a*]pyrene as a marker for the occurrence and effect of carcinogenic (any substance or agent that promotes cancer) PAH in food. However, the SCF has concluded that a number of PAHs[2] are capable of causing genetic mutation and of contributing to the development of tumors (genotoxic carcinogens), in laboratory studies, and in view of the non-threshold effects of genotoxic substances the concentrations of PAH in foods should be reduced to as low as reasonably achievable (ALARA) and the Committee on Carcinogenicity (COC) has advised that exposure to genotoxic carcinogens should be as low as reasonably practicable (ALARP). In toxicological assessments of dietary PAHs, the Joint (FAO/WHO) Expert Committee on Food Additives (JECFA) also concluded that B[*a*]P could be used as a marker for the carcinogenic PAHs found in food and that margins of exposure between estimated levels of dietary intake of B[*a*]P and the levels of B[*a*]P in PAH mixtures (found to cause cancer in animal studies) indicated a low concern for human health (JECFA/64/SC).

Trace metals, sometimes referred to as heavy metals, are widespread in the environment from natural geological sources and industrial activities. Some trace metals can be related to specific sources such as copper for industrial heavy oil combustion, lead for traffic, cadmium and zinc for refuse incineration plants and cadmium and copper for the cement industry. Trace metals enter the aquatic environment from natural geological sources, land run-off, industrial and wastewater treatment plants and atmospheric deposition from, for example, smoking chimneys.

Some metals are found naturally at low concentrations in, or associated with, animal and plant cells and tissues. They are a necessary part of good nutrition and are essential to human health although they can be toxic if ingested in excess quantities. For example, iron is involved in energy metabolism as an oxygen carrier in hemoglobin, and zinc is a cofactor in over 100 enzyme reactions. In high doses, they may be toxic to the body or produce deficiencies in other trace metals; for example, high levels of zinc can result in a deficiency of copper, another metal required by the body. Other trace metals include magnesium, chromium and selenium. Trace metals in living organisms are depleted through energy expenditure and replenished in animals by eating plants and replenished in plants through the uptake of nutrients from the soil in which the plant grows.

Commission Regulations (EC) provides that maximum concentrations must be set for certain contaminants in foodstuffs in order to protect public health. Of the metals, currently only lead, cadmium and mercury are covered by these Regulations.

[2] PAH highlighted to be carcinogenic by the Scientific Committee on Food for which further investigation of the relative levels in certain foods is required: benz[*a*]anthracene; benzo[*b*]fluoranthene; benzo[*j*]fluoranthene; benzo[*k*]fluoranthene; benzo[*g,h,i*]perylene; benzo[*a*]pyrene; chrysene; cyclopenta[*c,d*]pyrene; dibenz[*a,h*]anthracene; dibenzo[*a,e*]pyrene; dibenzo[*a,h*]pyrene; dibenzo[*a,i*]pyrene; dibenzo[*a,l*]pyrene; indeno[1,2,3-*cd*]pyrene and 5-methylchrysene

There is a vast amount of information in the open literature on the fate, behaviour, toxicity and bioaccumulation of chlorinated biphenyl (CB) compounds in the aquatic environment. Readers are directed to more extensive reviews such as US EPA (1984) and WHO (2003) for a more detailed explanation of the data and reported values. CBs are persistent organic pollutants and have entered the environment through both use and disposal and despite active research spanning five decades, extensive regulatory actions, and an effective ban on their production since the 1970s, CBs remain a focus of environmental attention. CB mixtures have been used for a variety of applications, including dielectric fluids for capacitors and transformers, heat transfer fluids, hydraulic fluids, lubricating and cutting oils, and as additives in pesticides, paints, carbonless copy paper, adhesives, sealants, plastics, reactive flame retardants, and as a fixative for microscopy. The chemical and physical stability of CBs has been responsible for their continuing low-level persistence in the environment, decades after regulations were imposed to control environmental contamination. The extent to which CBs are toxic remains controversial.

There are no documented cases of human death due to acute CB exposure. The most commonly observed health effects in people exposed to industrial accidents involving CBs are skin conditions such as chloracne, rashes, eye discharge, swelling of the upper eyelids, hyperpigmentation of the nails and skin, numbness of limbs, weakness, muscle spasms and chronic bronchitis. These symptoms, which are similar to those associated with poisoning by a variety of chlorinated organic compounds, are believed due to the dioxins and furans that normally contaminate PCBs. Studies in exposed workers have shown changes in blood and urine that may indicate liver damage. CB exposures in the general population are not likely to result in skin and liver effects. Studies have also shown that animals that ate food containing large amounts of CBs for short periods of time had mild liver damage and some died. Animals that ate smaller amounts of CBs in food over several weeks or months developed various kinds of health effects, including anemia; acne-like skin conditions; and liver, stomach, and thyroid gland injuries. Other effects of CBs in animals include changes in the immune system, behavioural alterations, and impaired reproduction. CBs are not known to cause birth defects.

It has been reported that women who were exposed to relatively high levels of CBs in the workplace or ate large amounts of fish contaminated with CBs had babies that weighed slightly less than babies from women who did not have these exposures (Fein, 1984). Babies born to women who ate CB-contaminated fish also showed abnormal responses in tests of infant behaviour such as problems with motor skills and a decrease in short-term memory, lasted for several years (Grandjean *et al*., 2001). Other studies suggested that the immune system was affected in children born to and nursed by mothers exposed to increased levels of CBs. The most likely way infants will be exposed to CBs is from breast milk (Faroon, *et al*.,2001). Transplacental transfers of CBs have also been reported.

The term pesticides has a very broad definition which embraces herbicides, fungicides, insecticides, rodenticides, soil-sterilants, wood preservatives and surface biocides among others. Statutory powers to control pesticides are contained within Part III of (Food and Environment Protection Act (FEPA). Section 16 of the Act describes the aims of the controls as being to protect the health of human beings, creatures and plants; safeguard the environment; secure safe, efficient and humane methods of controlling pests and make information about pesticides available to the public.

One of the best known pesticides has been DDT which was introduced as a safer alternative to the lead and arsenic compounds which had been used before. DDT is an example of a widely used (and maybe misused) pesticide. DDT, and a number of related compounds, wherein the chemical, due to its stability and fat solubility, bio-accumulates in the fatty tissues of organisms. Also, DDT may biomagnify which causes progressively higher concentrations in the body fat of animals further up the food chain. A number of the organochlorine pesticides have been banned from most uses worldwide and globally they are controlled via the Stockholm Convention on Persistent Organic Pollutants. These

include: aldrin, chlordane, DDT, dieldrin, endrin and heptachlor. Concentrations of aldrin, DDT (and its metabolites: pp-TDE and pp-DDE), dieldrin, endrin and isodrin have been measured in water, sediments and biota as part of the National Monitoring Programme (NMP) at sites in estuaries and coastal waters throughout the UK (MPMMG 1998).

There are no substantial scientific studies so far which prove that DDT is particularly toxic to humans, compared to other widely-used pesticides. DDT can be applied directly to clothes and used in soap, with no demonstrated ill effects. Indeed, DDT has on rare occasions been administered orally as a treatment for barbiturate poisoning. Doses as high as 285 µg/g taken accidentally did not cause death, but such large doses did lead to prompt vomiting. One dose of 10 µg/g can result in illness in some people.

With regard to bivalve molluscs, the Food Standards Agency (Scotland) (FSA(S), carries out checks on compliance with the maximum permissible levels of a variety of contaminants, including those covered by Commission Regulation (EC) 466/2001 (such as lead, cadmium and mercury) and those specified in the Shellfish Hygiene Directive 91/492/EEC (such as zinc and silver). FSA(S) also has on-going programmes to monitor for biotoxins and *E. coli* in shellfish and potential toxin producing phytoplankton in water. In addition, surveys regarding chemical contaminant concentrations in shellfish from Scottish waters have been undertaken between 2001 and 2004 (FRS Reports 8/01, 10/01 and 12/01 and FSA(S) Project Codes S02013 and S12001).

The current project was designed to provide new data on the concentrations of priority contaminants in harvested shellfish and an opportunity to assess the contaminant concentrations in a number of shellfish species throughout Scottish coastal waters in relation to previous data and current Commission Regulation standards.

Blue mussels (*Mytilus edulis*) have been used extensively, in the UK, Europe, and elsewhere, as sentinel indicator species for monitoring exposure to chemical contaminants. They grow naturally in most coastal areas and are harvested for consumption in many areas representing a wide range of environments. Therefore, this monitoring programme is primarily based on mussels.

The Pacific oyster (*Crassostrea gigas*) is not native to the UK and is farmed mainly in the Strathclyde and Highland Regions. Although it is not found in as many geographical locations as the blue mussel, due to the commercial value of the oyster market, analyses have also been carried out on this species.

Due to the commercial value of the wild king scallop (*Pectin maximus*) fishing industry in Scotland, a limited sampling programme was carried out on this species. For each site sampled, the adductor muscle and gonad tissue of the wild scallops were analysed separately because scallops can be consumed both with the roe on (adductor muscle and gonad) and roe off (adductor muscle only).

Mussels and oysters are farmed in a wide range of inshore waters, including some areas which may be exposed to varying degrees of contamination. The locations sampled during this project reflect the distribution of shellfish harvesting areas representative of the Scottish shellfish industry. The locations sampled cover both sites which have been sampled previously, to look at any temporal trends, and others which provide information on the wider distribution of contaminants throughout the Scottish shellfish farming industry.

There are scallop fisheries in most areas around Scotland and its islands. The fishery for scallops in Scottish waters started in the early 1930s and is now the second most valuable shellfish species landed in Scotland. Most scallops are caught by vessels towing scallop dredges. In shallow inshore waters scallops are sometimes caught by divers, and in a few areas they are farmed commercially. Scotland presently takes about half the total UK scallop landings. The sample locations reflected the spatial distribution of this species.

Offshore environmental contamination is less of an issue in respect to shellfish than to those wild or cultivated in inshore waters.

All samples were analysed for polycyclic aromatic hydrocarbons (PAHS) (2- to 6-ring parent and branched PAHS), trace metals (Cr, Mn, Co, Ni, Cu, Zn, As, Se, Ag, Cd, Hg and Pb), chlorobiphenyls (CBs) (ICES 7 and a further 21 CBs) and organochlorine pesticides (OCPs; HCB, α-HCH, γ-HCH, dieldrin, endrin, DDD, DDE and DDT, chlordenes and chlordanes) using methods which are fully accredited (at FRS, Laboratory number 1964N) by the United Kingdom Accreditation Service (UKAS) to ISO 17025.

MATERIALS AND METHODS

Sampling strategy

All shellfish exhibit similar seasonal variation in tissue lipid content, generally rising with the onset of maturation and then reducing post spawning. There is a strong correlation between lipid content and the concentration of particularly, lipophillic contaminants. Samples were, therefore, planned to be collected when tissue lipid concentrations were expected to be at a maximum (ie during January to March 2006).

FRS and FSA(S) met and agreed a sampling strategy for the survey. FRS would liaise with Environmental Health Officers and production site managers to facilitate the collection of mussels and oysters which would then be delivered to the FRS ML. Samples of scallops would be collected under the direction of FSA(S) and delivered to FRS. Samples received at FRS would then come under the control of the FRS Marine Laboratory Quality System. Mussels and oyster would be shucked as whole tissue. FSA(S) confirmed that scallops were to be analysed separately as adductor muscle and gonad tissue.

The mussel and oyster sampling sites were chosen, in consultation with the FSA(S), to reflect the commercial importance of the products and to provide representative geographical coverage of the main shellfish production areas in Scottish coastal waters.

In 2004, the Scottish Shellfish Regional Production (FRS, 2004) was:

	Mussels		**Oysters**	
Region (see Figure 1)	(tonnes)	% of market	(animals)	% of market
Strathclyde	1,193	28.3	2,828,000	78.9
Highland	398	9.4	736,000	20.5
Western Isles	443	10.5	0	0
Shetland	2,188	51.8	2,000	0.06
Orkney	1	0.02	20,000	0.56
Totals	**4,223**		**3,586,000**	

Sampling sites were selected from the five designated regions (Figure 1). Some locations, which had been sampled previously, were chosen to provide data on temporal contaminant differences. Sites from where samples were unavailable were substituted by samples from similar or other areas.

FRS contacted the Environmental Health Officers of the relevant regions and, where appropriate, the production site managers of the agreed sampling sites, in December 2005 to outline the requirements of the project. Sampling instructions and sample containers were dispatched to the relevant contact persons in the regions. The samples of mussels and oysters for PAH and CB/OCP analysis were double wrapped in aluminium foil, and those for trace metal analysis placed in plastic sealable bags. Both samples were then placed in a polypropylene box with lid, labelled with sample point, and date collected, wrapped securely in packaging paper and returned to FRS ML.

Samples of mussels and oysters were collected from production areas in proportion to their market share as outlined below.

Production area	Mussels	oysters
Strathclyde	4	3
Highland	2	1
Western Isles	-	-
Shetland	8	1
Orkney	-	-

The sampling locations (Figure 1) and dates are summarised in Table 1; 19 samples (comprising 14 mussel samples and 5 oyster samples) were collected and delivered to FRS ML during the period January to March 2006.

Scallop sampling locations were selected by FSA(S) to reflect the market value of the landings as outlined below.

	% of market (2004)	samples collected
East Coast	21.4	E6
North East (Moray Firth)	17.6	M2
Orkney	2.2	O18
Shetland	8.0	-
North West (Hebrides and Minches)	29.4	H3, H5, H6; SM1, SM2, SM3, SM10, SM11
West of Kintyre (Jura)	9.6	J5 and J6
Irish Sea	6.7	-
Clyde	5.1	C5 and C8

The FSA(S) chartered commercial fishing vessels to provide trawled scallop samples from seven areas (Figure 2). The locations and sampling dates are summarised in Table 2.

In addition to the sample requirements outlined above, FSA(S) had commissioned the Central Sciences Laboratory (CSL), York, to undertake additional analyses on the shellfish tissues. These additional analyses were taken into account when requesting samples.

Sample processing

Upon receipt at FRS ML, samples of shellfish were shucked, homogenised and frozen according to standard protocols. Twenty-five mussels from each sample location were measured, the lengths recorded (Figure 3), opened and the wet tissue shucked into a clean polypropylene beaker and weighed. The pooled tissue was homogenised and an aliquot transferred into solvent washed aluminium cans for subsequent PAH and CB/OCP analyses. The samples for TM analysis were stored in plastic vials. All homogenates were labelled and stored in a deep freeze at -20^{o}C (±2^{o}C) until required for analyses. The remainder of the sample was transferred to a container supplied by CSL, labelled appropriately and stored frozen at -20^{o}C (±2^{o}C) until being dispatched to CSL.

Oysters from each sampling location were opened and the wet tissue shucked into a clean polypropylene beaker, weighed, homogenised and processed as outlined above.

Scallops from each sampling location were opened and the adductor and gonad tissue removed separately and processed as outlined above. For some of the samples supplied there was insufficient wet tissue available to meet all analytical requirements. As a result of this, and following consultation with FSA(S), some samples were pooled to provide sufficient material (Table 2).

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 phenyl polysiloxane 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^{o}C and the oven temperature was held constant for 3 minutes. Thereafter, the temperature was raised at 20^{o}C *per* minute up to 100^{o}C. This was followed by a slower ramp of 4^{o}C *per* minute up to a final temperature of 270^{o}C. The MSD was set for selective ion monitoring (SIM) with a dwell time of 50 ms. A total of 29 ions (McIntosh *et al*., 2004) plus the six internal standard ions (Webster, *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 were 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 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 µg l^{-1} multi-element standards (except for mercury, at concentrations of 0.5, 1, 5 and 10 µg l^{-1}) 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 were calculated from replicate analysis of low standards. Quality assurance was further demonstrated through successful participation in QUASIMEME Laboratory Performance Studies.

CHLOROBIPHENYLS AND PESTICIDES

The shellfish tissues (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 ethers 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) 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 (HP5, 60 m x 0.25 mm id, 0.25 :m film thickness; Agilent, Stockport, England, UK) along with an uncoated pre-column (2.5 m x 0.53 mm id). 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-dichlorobenzyl 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.

RESULTS AND DISCUSSION

POLYCYCLIC AROMATIC HYDROCARBONS

The full analytical data sets for total measured (2- to 6-ring parent and branched) PAH concentrations determined in the tissues from the three species sampled from the named areas within each region are presented in:

- Mussels: Appendix 1a (pages xvi and xvii)
- Oysters: Appendix 2 (page xviii)
- Scallop adductor muscle: Appendix 3a (pages xix and xx)
- Scallop gonad tissue: Appendix 3b (pages xxi and xxii)

The PAH concentrations are summarised in Table 3.

Mussels

Total measured PAH concentrations of between <50 ng g^{-1} and 150 ng g^{-1} wet weight tissue in post-spawning mussels can be considered as typical background/reference values. PAH concentrations of between 50 ng g^{-1} and 150 ng g^{-1} wet weight can be considered as background for pre-spawning mussels (Webster *et al*., 2003). However, the PAH distribution is also of relevance when making such judgements. Mussel tissue PAH concentrations in the range 150 – 250 ng g^{-1} wet weight may indicate an acute exposure or low-level chronic exposure to PAH contaminants. PAH concentrations >250 ng g^{-1} wet weight tissue are likely to be indicative of a more severe (eg emergency) or long term chronic exposure.

Of the fourteen mussel samples analysed, five (36%) had total measured PAH concentrations less than 50 ng g^{-1} wet weight, seven samples (50%) contained between 50 and 150 ng g^{-1} wet weight PAH, one sample contained between 150 and 250 ng g^{-1} wet weight PAH and one sample (Loch Ryan) had a concentration greater than 250 ng g^{-1} wet weight PAH (Figure 4).

The total measured PAH concentration determined in all mussel samples ranged from 26.9 ng g^{-1} wet weight tissue (Catfirth, Shetland Islands) to 264.7 ng g^{-1} wet weight tissue (Loch Ryan) and demonstrated considerable variability in concentration both within and between regions (Table 3; Figure 4).

The 'total measured PAH' provides general information on exposure levels but no information on the components summed to yield this value. The proportions of individual compounds, or groups of compounds, making up the total may vary considerably between sample locations. A number of individual PAH component concentration ratios have been used to distinguish between petrogenic and pyrogenic sources (Webster, *et al*., 2003), for example phenanthrene/anthracene (P/A), fluoranthene/pyrene (Fl/Py) and methylphenanthrene/phenanthrene (MP/P). Webster *et al*., (2003) discusses their application to analyses of mussels from various locations in Scotland where ratios of MP/P greater than 2 suggests a petrogenic source while P/A less than 10, and Fl/Py greater than 1 indicate pyrogenic sources. The mussel samples from Loch Striven, Loch Ryan and Whalwick had MP/P ratios of 3.3, 2.9 and 3.1 respectively. Nine of the fourteen mussel samples had Fl/Py ratios greater than 1.

The PAH percentage composition can further assist in the determination of possible types of PAH contamination. The PAH percentage composition observed in mussels varied both within and between regions (Figures 5a and 5b). These data can be simplified by comparing the more volatile PAHs (2- and 3-ring structures) with the potentially more toxic PAHs (∑4- to 6-ring structures). A 'typical' PAH percentage composition is observed in mussels from an established reference site, Loch Etive, based on analyses over a number

of winter sampling periods (Figure 6a) (Webster *et al.*, 2006), against which percentage composition distributions at other locations can be compared (Figures 6a and 6b).

While there were broad similarities between many of the mussel samples, the percentage PAH composition profiles determined in mussels from certain areas could be considered as 'atypical', compared to those from Loch Etive, as exemplified by the percentage PAH composition in mussels from Lochs Ryan and Leven (Figure 7). The percentage composition of naphthalenes (2-ring PAH compounds) ranged from 2.1% in mussels from Loch Leven to 21.9% in mussels from Lee Voe, Shetland. The composition of 3-ring PAH ranged from 10.9% (Loch Leven) to 36.6% (Loch Ryan) and the composition of the sum of 4- to 6-ring PAH ranged from 41.4% (Whalwick) to 84.1% in mussels from Loch Leven.

Lochs Ryan, Striven and to a lesser extent, Whalwick were further characterised by a higher than average proportion of DBTs (Figures 5a and 5b). The percentage composition of the 3-ring PAH compounds was >20% in three out of six mainland mussel samples and seven of the eight Shetland samples.

Mussels from Loch Leven exhibited a characteristic PAH pattern, specifically a predominance of 5-ring PAHs (Figure 5a). This is a direct result of the historical PAH input from an aluminium smelter into the loch that closed in 2001. PAH is a component of the coal tar pitch used to bind the carbon electrodes previously used at the smelter. The diagnostic ratio Fl/Py (0.89) did not indicate a pyrogenic source and the ratio MP/P (2.1) was not significantly greater than 2 to suggest a petrogenic source.

The Commission Regulation (EC) No 208/2005, amending Regulation (EC) No 466/2001 as regards polycyclic aromatic hydrocarbons, having taken regard of the EC Scientific Committee on Food (SCF) conclusion that benzo[*a*]pyrene could be used as a marker for the occurrence and effects of carcinogenic PAH in food, has determined a maximum concentration of 10 ng g^{-1} wet weight for benzo[*a*]pyrene for bivalve molluscs. None of the mussel samples analysed had a benzo[*a*]pyrene concentration greater than 10 ng g^{-1} wet weight.

The well recognised toxicity of some PAHs and related compounds has led to the development of benzo[*a*]pyrene equivalent factors to assess the combined risk from PAH compounds that have similar mechanisms of exerting their toxicity (Law *et al*., 2002). The resulting benzo[*a*]pyrene equivalents (B[*a*]PEs)[3] can be used in developing risk-based consumption limits for food containing PAHs. B[*a*]PE values derived for mussels in this current survey ranged from <1.0 to 13.2 ng g^{-1} (Table 3).

Data from the risk-based consumption limits model suggest that for an acceptable risk level of 10^{-5}, B[*a*]PE values of >10 ng g^{-1} would permit the consumption of less than two (114 g) meals per month (McIntosh *et al*., 2004). For populations who regularly consume large quantities of mussels, the consumption of less than two (114 g) meals per month may be unrealistic. Mussels, and other harvested shellfish species, are normally sold to markets for distribution to commercial outlets. This results in the dilution of any potential contaminants that may be present from time to time in specific shellfish populations and therefore reduces further any potential risk to the consumer.

Twelve mussel samples (86%) had derived B[*a*]PE values < 5 ng g^{-1}, and only one sample of mussels, from Loch Leven, returned a B[*a*]PE value (13.2 ng g^{-1}) >10 ng g^{-1}. It is pertinent to note that the mussels with the highest total measured PAH concentration, those from Loch Ryan (264.7 ng g^{-1} wet weight), had a B[*a*]PE value of <5 ng g^{-1}. This

[3] B[*a*]PE are the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz[*a*]anthracene, chrysene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, dibenz[*a,h*]anthracene, benzo[*g,h,i*]perylene and indeno[1,2,3-*cd*]pyrene multiplied by their respective toxicity equivalency factors (Nisbet and LeGoy, 1992)

highlights the need to assess PAH composition and not rely simply on total concentration for assessments.

Provisional background assessment concentrations (BACs), developed by OSPAR (2004), for PAH in mussels are reproduced, for information, in Table 4, together with the data obtained during this survey. If adopted, these BACs will be used to test whether mean (PAH) concentrations meet OSPAR environmental objectives that contaminant concentrations can be considered close to background values.

Many of the PAH concentrations determined in mussels from the Scottish mainland were greater than the Background Concentrations (BCs) and the Background Assessment Concentrations (BACs). Equivalent concentrations determined in mussels from the Shetland Islands were generally lower and closer to the BC and BAC concentrations (Table 4).

OYSTERS

The five oyster samples analysed had total measured PAH concentrations between 50 and 150 ng g^{-1} wet weight PAH (Table 3).

The total measured PAH in oysters from the five sites samples ranged from 52.4 ng g^{-1} wet weight tissue in oysters from the Loch nan Ceol (Highland, Lochaber) to 132.5 ng g^{-1} wet weight tissue in oysters from Loch Fyne. The percentage composition of 3-ring PAH in oysters from Loch nan Ceol was 21.4% compared to 14.3% in oysters from Loch Fyne. Conversely, the percentage composition of 5-ring PAHs in oysters from Loch nan Ceol was 22.3% compared to 26.9% in oysters from Loch Fyne. The PAH composition distribution presented as the proportion of 2-, 3- and 4- to 6-ring PAHs for all oyster samples exhibited the same 'typical' pattern (Figure 8) as described earlier in this report. The benzo[*a*]pyrene concentrations in oysters ranged from 0.4 – 0.5 ng g^{-1} wet weight tissue, with one concentration of 1.7 ng g^{-1} wet weight tissue (Loch Fyne) and therefore were within the Commission Regulation (EC) No 208/2005 limit of 10 ng g^{-1}. B[*a*]PE values derived for oysters ranged from 1.0 to 5.5 ng g^{-1} and are similar to values recorded previously (McIntosh *et al*., 2003). These values fall within acceptable limits and would present little or no risk to consumers.

SCALLOPS

The PAH concentrations determined in scallop adductor muscle and gonad tissue from the seven locations sampled are summarised in Table 3.

All scallop adductor muscle samples analysed, with one exception, Clyde (C5), had total measured PAH concentrations less than 50 ng g^{-1} wet weight. The total measured PAH in scallop adductor muscle ranged from 10.4 ng g^{-1} wet weight in scallops from the Moray Firth (M2) to 55.0 ng g^{-1} wet weight measured in Clyde (C5) scallops (Figure 9).

Of the ten scallop gonad tissue samples analysed, eight samples contained between 50 ng g^{-1} and 150 ng g^{-1} wet weight PAH and two samples (both from the Clyde) contained >150 ng g^{-1} wet weight PAH (Figure 9). The highest total measured PAH in scallop gonad tissue, 250.0 ng g^{-1} wet weight was recorded in animals from the Clyde (C5), the lowest gonad tissue value, 57.2 ng g^{-1} wet weight, was measured in scallop gonad tissue from the Moray Firth (M2).

Gonads, due to their higher lipid content (mean 2.7% lipid, SD 0.36), contain higher concentrations of PAHs than the adductor muscle (mean 0.7% lipid, SD 0.2) from the same samples. This was the case without exception for all the samples analysed. The gonad tissue/adductor muscle PAH ratio ranged from 4.05 (SM10/11) to 5.75 (O18) with a mean ratio of 5.01.

The variation in the 2- to 6-ring PAH percentage composition determined in scallop adductor muscle and gonad tissue is shown in Figures 10 and 11. In scallop adductor muscle, the 5-ring PAH percentage composition ranged from 18.0 – 43.2% (mean 35.4%; SD 6.9). The 5-ring PAH percentage composition in gonad tissue ranged from 8.0 – 29.1% (mean 23.2%; SD 6.3). When the PAH composition of scallop adductor muscle and gonad tissue is presented as the proportion of 2-, 3- and 4- to 6-ring PAHs, the 'typical' pattern observed in mussels can also be seen, for most of the samples, as an increasing proportion going from the 2-ring to 3-ring and 3-ring to 4- to 6-ring PAHs (Figures 12 and 13). This is evident for both scallop adductor muscle and gonad tissue from M2, C8, J5/6, and SM03. The pattern for scallop adductor muscle from E6 and C5 (Figure 12) and gonad tissue from H3/4/5, SM1/2 and SM10/11 (Figure 13) is clearly different to this 'typical' pattern.

One scallop gonad sample, from the Clyde (C5), had a benzo[*a*]pyrene concentration of 5.8 ng g^{-1} wet weight. The concentrations of benzo[*a*]pyrene determined in scallop gonad tissue in this survey were generally lower than those recorded in the 2002 survey (McIntosh, *et al*., 2003).

With one exception, B[*a*]PE values derived in both scallop adductor muscle (0.4 – 4.1 ng g^{-1} wet weight) and gonad tissue (1.4 – 7.9 ng g^{-1} wet weight) fall within the acceptable range of less than 10 ng g^{-1} wet weight presenting little or no risk to consumers. The one exception was one B[*a*]PE value derived in scallop gonad tissue from the Clyde, (C5), which had a value of 13.2 ng g^{-1} wet weight. Three of the four B[*a*]PE values determined in the scallop gonad tissue from the temporal samples were lower than in the 2002 survey (Table 3).

The maximum concentration of benzo[*a*]pyrene (B[*a*]P) determined in shellfish samples from this survey, would indicate that several portions of shellfish per week would be required to produce intakes of B[*a*]P similar to that from an average diet. The combined intake of B[*a*]P from shellfish and from the rest of the (average) diet is within the concentrations viewed by JEFCA as being of low concern for human health.

TRACE METALS

The full analytical data sets for the trace metals determined in the tissues from the three species sampled from the named areas within each region are presented in Appendix 4 (page xxiii).

MUSSELS

Commission Regulation 221/2002 setting maximum permissible concentrations for contaminants in specific foodstuffs, Guideline and Imperative limits for shellfish in Scotland (Henderson and Davies, 2001) and previous data on metal concentrations in mussels (Brown and Balls, 1997; McIntosh *et al*., 2003), are detailed in Table 5. The specific data in Table 5 cover 12 elements, although previous study data and food/environmental standard limits are only available for some of these elements.

Trace metal distribution in mussels showed that concentrations generally do not exhibit high variance between sites, with the exception of mussels from Loch Ryan, (Dumfries and Galloway), and were generally within ranges previously reported for mussels from Scottish coastal waters (Brown and Balls, 1997; McIntosh, *et al*., 2003, McIntosh, *et al*., 2004). Zinc concentrations determined in mussels from Shetland were higher (12.3 – 22.8 µg g^{-1} wet weight) than those determined in mussels from the Strathclyde and Highland regions (7.9 – 11.5 µg g^{-1} wet weight). There were no significant differences in other trace metal concentrations from the different regions. The concentrations of chromium, manganese, nickel and lead in mussels from Loch Ryan were all greater than the

concentrations of these elements measured in mussels from the other sampling sites. The average concentration of cadmium determined in mussels from Shetland and Loch Ryan was greater than in mussels from Argyll and Bute and the Lochaber areas.

There are currently only Background/Reference Concentration (B/RC) and Commission Regulation values for cadmium and lead. The B/RC (OSPAR 2000) for cadmium in mussels is 0.07 – 0.11 μg g^{-1} wet weight and the Commission Regulation (221/2002/EC), setting maximum concentrations for certain contaminants in foodstuffs, is 1.0 μg g^{-1} for cadmium in bivalve molluscs. The concentration of cadmium in the mussels sample from Loch Ryan was 0.13 μg g^{-1} wet weight and the range for cadmium in Shetland mussels was 0.09 – 0.17 μg g^{-1} wet weight (Figure 14).

The Commission Regulation (221/2002/EC) also applies to lead for which the maximum level is currently 1.5 μg g^{-1} wet weight for bivalve molluscs. The B/RC (OSPAR 2000) for lead in mussels is 0.01 – 0.19 μg g^{-1} wet weight. The concentrations of lead determined in mussels were all less than 1.5 μg g^{-1} wet weight. The concentration of lead determined in mussels from Loch Ryan was 0.61 μg g^{-1} wet weight. Lead concentrations in other mussels samples ranged from 0.10 – 0.27 μg g^{-1} wet weight (Figure 15).

OYSTERS

Trace metal distribution in oysters generally exhibited little difference between sites. Three of the five oyster samples had copper values exceeding the Guideline (3.0 μg g^{-1} wet weight) and Imperative (6.0 μg g^{-1} wet weight) values for shellfish. The Committee on Medical Aspects of Food Policy (COMA) has set a RNI (the amount of a nutrient which is sufficient for almost all individuals and exceeds the requirement of most people and habitual intakes above RNI are almost certain to be adequate) of 1.2 mg day^{-1} for copper. The Committee on Toxicology of Chemicals in Food, Consumer Products and the Environment (COT) (MAFF, 1998) considered that an intake of 1.4 mg day^{-1} copper from the average UK diet was not a cause for toxicological concern. Four of the five oyster samples had zinc concentrations exceeding the Guideline (50.0 μg g^{-1} wet weight) and Imperative (100.0 μg g^{-1} wet weight) values for shellfish. Oysters contain more zinc, per serving, than any other food. The Recommended Dietary Allowance (RDA), the average daily dietary intake level that is sufficient to meet the nutrient requirements of healthy individuals, for zinc is 11 mg. The cadmium concentrations determined in oysters ranged from 0.10 – 0.32 μg g^{-1} wet weight (Figure 16). The oysters from Loch Fyne exhibited higher values of Cu, Zn, As and Cd compared to the other sites. Loch Fyne is known to have an elevated background concentration of trace metals probably due to the presence of manganese nodules associated with the sediments and its proximity to historic inputs from the Clyde basin.

SCALLOPS

The concentrations of trace metals determined in scallop adductor muscle and gonad tissue were all within the given Guideline and Imperative values for shellfish. Cadmium concentrations in scallop adductor muscle ranged from 0.18 – 0.30 μg g^{-1} wet weight and in scallop gonad tissue from 0.12 – 0.77 μg g^{-1} wet weight (Figure 17) and were all greater than the (OSPAR 2000) B/RC (developed for mussels) for cadmium, 0.07 – 0.11 μg g^{-1} wet weight. Lead concentrations determined in the edible portions of scallops were below the Commission Regulation level of 1.5 μg g^{-1} wet weight.

Chlorobiphenyls (CBs)

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

- Mussels: Appendix 5a (pages xxiv and xxv)
- Oysters: Appendix 5b (page xxvi)
- Scallop adductor muscle: Appendix 5c (page xxvii)
- Scallop gonad tissue: Appendix 5d (page xxviii)

MUSSELS

The sum of ICES 7 CB concentrations in mussels ranged from 1.7 ng g^{-1} wet weight in the sample from Baltasound Harbour to 8.09 ng g^{-1} in mussels from Ronas Voe, both in Shetland. Environmental Assessment Criteria (EAC), based on the ICES 7 CBs (CBs 28, 52, 101, 118, 153, 138 and 180) recommended by the European Union Community Bureau of Reference can be used to assess data and identify potential areas of environmental concern. 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 mussel samples, with the one exception (Ronas Voe), returned values less than 7.5 ng g^{-1} (Figure 18).

OYSTERS

The sum of ICES 7 CB concentrations in oysters ranged from 2.40 ng g^{-1} wet weight in the sample from Loch nan Ceol (Highland, Lochaber) to 5.07 ng g^{-1} wet weight in oysters from Gruinart, Islay. The sum of ICES 7 and total CB concentrations in oysters generally did not exhibit a high variance between sites. The sum of the ICES 7 CBs in oysters were within the EAC range established specifically for mussels (Figure 19).

SCALLOPS

The sum of ICES 7 CBs in scallop adductor muscle ranged from 1.23 ng g^{-1} (SM3) to 2.82 ng g^{-1} wet weight (M2) and 2.04 ng g^{-1} (O18) to 7.79 ng g^{-1} wet weight (C5) for the gonad tissue samples. The sum of the ICES 7 CBs in both scallop adductor muscle and gonad tissue were, with one exception (gonad tissue from C5) within the EAC range established specifically for mussels (Figure 20). The total (as defined earlier in this report) CB values for scallop adductor muscle ranged from 2.18 ng g^{-1} wet weight for the sample from SM3 to 5.44 ng g^{-1} for the sample from the Moray Firth (M2). The total CB values for scallop gonad tissue ranged from 2.47 ng g^{-1} wet weight for the sample from SM10/11 to 15.2 ng g^{-1} for the sample from the Clyde, C5.

As with PAHs, the total measured concentration of CBs is a mixture of congeners. They consists of a biphenyl molecule with more than one chlorine atom substituted in the biphenyl nucleus and are manufactured by the chlorination of biphenyls in the presence of a suitable catalyst. The commercial mixtures of CBs, such as Aroclor, are designated by four digit numbers of which the first pair designate the category of CBs and the second pair of digits designate the approximate percentage of chlorine, e.g. Aroclor 1242 has 42% chlorine, equivalent to the composition $C_{12}H_7Cl_3$ and is a liquid, while Aroclor 1260 is 60% chlorine, equivalent to $C_{12}H_4Cl_6$ and is a solid. CB's are very resistant to chemical and bio-chemical degradation, their stability increases with the degree of chlorination and therefore they persist in the environment. Individual CB congeners can differ in their persistence. It has been established that microorganisms degrade mono and di-chlorinated biphenyls relatively rapidly whilst higher chlorinated biphenyls, with three or more chlorine atoms, are generally quite persistent, highly lipophilic (soluble to 10% in fat), resistant to biodegradation and extremely stable in the environment.

CB's are practically insoluble in water, whereas they dissolve easily in hydrocarbons, fats and other organic compounds and they are readily absorbed by fatty tissues. The risk of human exposure to CB's is due to their persistent nature and from the consumption of contaminated food, as well as from inhalation and skin absorption in work environments. CB's accumulate in the fatty tissues, such as the liver, of humans and other animals and may cause toxic effects (WHO, 1993). The skin and liver are the major sites of CB's cytological effects, but the gastrointestinal tract, the immune system and the nervous system are also targets.

The primary exposure to CB's is from consuming fish from contaminated water, but also from exposure through other foods (Smith and Gangolli, 2002). Of the ICES 7 CB congeners, those of importance from a human health viewpoint are CBs 118 and 138 (5 and 6 chlorine atoms respectively) which stimulate the production of bio-activate enzymes and CB 52 (4 chlorine atoms) which is frequently found at high concentrations in environmental samples or animal tissues.

The mussel samples from Lochs Striven and Etive and Parkgate and Baltasound Harbour (Shetland) exhibited similar ICES 7 CB conger percentage composition profiles where the congeners 52 and 101 (4 and 5 chlorine atoms respectively) provided the greater contribution (Figures 21a and 21b), while the mussels from Loch Ryan and Ronas Voe had a greater percentage composition of 6 chlorine atom congers (CB 138 and 153) (Figures 21a, 21b and 21c).

ORGANOCHLORINE PESTICIDES (OCPS)

- Mussels: Appendix 6a (pages xxix and xxx)
- Oysters: Appendix 6b (page xxxi)
- Scallop adductor muscle: Appendix 6c (page xxxii)
- Scallop gonad tissue: Appendix 6d (page xxxiii)

MUSSELS

The sum of the DDTs ranged from 0.23 ng g^{-1} in mussels from the Catfirth, Shetland, to 3.55 ng g^{-1} wet weight in the sample from Loch Striven (Figure 22). Dieldrin concentrations determined in mussel samples ranged from 0.16 ng g^{-1} wet weight (Whalwick, Shetland) to 0.82 ng g^{-1} wet weight (Loch Striven, Strathclyde). The distribution of dieldrin and sum of DDT concentrations across the regions is shown in Figure 22. The concentrations of other pesticides determined were generally less than the limit of quantitation.

OYSTERS

The sum of DDTs in oysters ranged from 0.34 ng g^{-1} wet weight (Loch nan Ceol) to 2.82 ng g^{-1} wet weight in the sample from Loch Fyne and the dieldrin concentrations determined in oyster samples ranged from 0.18 to 0.63 ng g^{-1} wet weight (Figure 23). The sum of the chlordanes ranged from trace (South Shian) to 3.69 ng g^{-1} wet weight in the sample from Baltasound Voe. The concentrations of other pesticides determined in oysters were generally less than the limit of quantitation.

SCALLOPS

Pesticide concentrations determined in scallop adductor muscle and gonad tissue samples were generally less than the limit of quantitation. The concentrations of dieldrin in scallop adductor muscle samples were close to the limit of quantitation. Dieldrin concentrations determined in scallop gonad tissue ranged from 0.29 ng g^{-1} wet weight (Outer Hebrides) to 1.49 ng g^{-1} wet weight in the sample from the Clyde, C5 (Figure 24). The sum of DDTs determined in scallop adductor muscle ranged from trace to 0.20 ng g^{-1} wet weight.

Scallop gonad tissue DDT concentrations ranged from 0.41 ng g^{-1} wet weight in the sample from the Moray Firth to 2.74 ng g^{-1} wet weight in the sample from Clyde, C5 (Figure 25).

The NMP has specified the determination of dieldrin, aldrin and endrin. The most common compound in biological samples is dieldrin. Other 'drins' tend to revert to dieldrin in the natural environment and are unlikely to be found unless the organism has been recently exposed. Only data for dieldrin were reported at concentrations greater than the limit of detection. Dieldrin was detected in all samples analysed, except one scallop adductor muscle sample.

CONCLUSIONS

A total of 29 shellfish samples, comprising 14 mussel samples, 5 oyster samples and 10 scallop samples (10 adductor muscle and 10 gonad tissue), were collected during the period December 2005 to March 2006. The concentrations of polycyclic aromatic hydrocarbons (PAHs), trace metals, chlorobiphenyls (CBs) and organochlorine pesticides (OCPs) were determined in the soft tissues.

The total measured PAH concentration in 12 of the 14 mussel samples analysed was less than 150 ng g^{-1} wet weight. One sample returned a total PAH concentrations greater than 250 ng g^{-1} wet weight. Atypical results, either with respect to PAH concentration (eg Loch Ryan) or PAH distribution (eg Loch Leven) were readily accounted for either in terms of a defined PAH pattern indicating a possible recent source of PAHs or known historical input to the area.

All but one sample of oysters contained PAHs at a concentration less than 100 ng g^{-1} wet weight.

All but one sample of scallop adductor muscle contained PAHs at a concentration less than 50 ng g^{-1} wet weight. All but three samples of scallop gonad tissue contained PAH at a concentration greater than 100 ng g^{-1} wet weight. The PAH concentrations in scallop gonad were, without exception, greater than in the corresponding adductor muscle.

Trace metal distribution in mussels, oysters and scallop tissues showed that, with a few exceptions, the concentrations generally do not exhibit a high variance between sites.

Some mussel samples exhibited Cu, Cd, Hg and Pb concentrations greater than the current OSPAR background concentrations. Concentrations of lead and cadmium were less than the current EC Commission Regulations in all samples analysed.

In all tissues analysed, mercury concentrations were low, being at or below the limit of detection (0.015 µg g^{-1} wet weight).

Zinc concentrations in the oyster samples were greater than in the other shellfish tissues analysed.

The CB concentrations determined in 75% of the mussels were within the Environmental Assessment Criteria established by OSPAR for mussels (0.75 - 7.5 ng g^{-1} wet weight for the 3ICES 7 CB congeners). Only one mussel sample exceeded 7.5 ng g^{-1} wet weight. 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, concentrations of HCB and ∀-HCH were below the detection threshold or limit of quantification. Dieldrin and DDT were detected in mussel, oyster and scallop tissue samples.

In respect of the impact on health from the consumption of shellfish, benzo[*a*]pyrene concentrations found in this survey, combined with the intake from an average diet, are considered as being of low concern for human health.

The concentrations of lead, cadmium and mercury, chlorobiphenyls and organochlorine pesticides determined in all shellfish samples from this survey do not raise health concerns in respect of consumption by the general public.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance given, and the contributions made by Environmental Health Officers of the regions and their field staff for the collection of the mussel and oyster samples, Gillian Packer and Margaret McKenzie for sample preparation and Colin Moffat for his constructive editorial comments.

REFERENCES

Brown, F.M.J. and Balls, P.W. 1997. Trace Metals in Fish and Shellfish from Scottish Waters. *Scottish Fisheries Report No 60,* 37pp.

Commission Regulation (EC) No 221/2002 amending Regulation (EC) No 466/2001 setting maximum levels for certain contaminants in foodstuffs as regards lead, cadmium and mercury in certain fishery products.

Commission Regulation (EC) No 208/2005 amending Regulation (EC) No 466/2001 (setting maximum levels for certain contaminants in foodstuffs) as regards polycyclic aromatic hydrocarbons.

Faroon, O., Keith, M.S., Jones, D. and de Rosa, C. 2001. Effects of polychlorinated biphenyls on development and reproduction. *Toxicol Ind Health*. 2001. **17**, 63–93.

Fein, G.G. Prenatal Exposure to Polychlorinated Biphenyls: Effects on Birth Size and Gestational Age. *Journal of Pediatrics*, Vol. 105, 1984, p. 315-320.

Grandjean, P., Weihe, P., Burse, V.W., Needham, L.L., Storr-Hansen, E., Heinzow, B., Debes, F., Murata, K., Simonsen, H., Ellefsen, P., Budtz-Jorgensen, E., Keiding, N. and White, R.F. Neurobehavioural deficits associated with PCB in 7-year-old children prenatally exposed to seafood neurotoxicants. *Neurotoxicol Teratol.* 2001. **23**, 305–317.

Henderson, A and Davies, I.M. 2001. Review of the Regulation and Monitoring of Aquaculture in Scotland, with Emphasis on Environmental and Consumer Protection. *FRS Marine Laboratory Report No 01/2002*.

Joint (FAO/WHO) Expert Committee on Food Additives. (2005). Sixty-fourth meeting. Rome, 8-17 February 2005. Summary and conclusions. *JECFA/64/SC*

Law, R. J., Kelly, C., Baker, K., Jones, J., McIntosh, A. D. and Moffat, C. F. 2002. Toxic equivalency factors for PAH and their applicability in shellfish pollution monitoring studies. *J. Environ. Monit*., 2002, **4**, 383-388.

MAFF, 1998. Cadmium, mercury and Other Metals in Food. Food Surveillance Paper No 53. Surveillance Paper Series. The Stationery Office.

McIntosh, A.D., Webster, L., Bredzinski, X and Moffat, C.F. 2003. Measurement of chemical contaminants in shellfish from Scottish waters. FSA (Scotland) Project Code: SO2013. *FRS Marine Laboratory Report No 02/2003*.

McIntosh, A.D., Moffat, C.F., Packer, G. and Webster, L. 2004. Polycyclic aromatic hydrocarbon (PAH) concentration and composition determined in farmed blue mussels (*Mytilu edulis*) in a sea loch pre- and post-closure of an aluminium smelter. *J. Environ. Monit*., 2004, **6**, 209-218.

McIntosh, A.D., Russell, M.A., Webster, L., Packer, G., Phillips, L.A., Dalgarno, E.J., Devalla, S., Robinson, C.D. and Davies, I.M. 2004. Sampling and analysis for Chemical Contaminants in Shellfish from Scottish Inshore and Offshore Harvesting Areas. FSA (Scotland) Project Code: S12001. *FRS Marine Laboratory Report No 13/2004*.

MPMMG (Marine Pollution Monitoring Management Group). 1998. National Monitoring Programme Survey of the Quality of UK Coastal waters. Marine Pollution Monitoring Management Group, Aberdeen, ISBN 0 9532838 36).

OSPAR, 2000. Quality Status Report 2000. OSPAR Commission, London, 108pp.

OSPAR, 2004. OSPAR/ICES Workshop on the Evaluation and Update of Background Reference Concentrations (BRCs) and Environmental Assessment Criteria (EACs).

Scottish shellfish farm production survey 2004. FRS 2005.

Smith, A.G. and Gangolli, S.D. 2002. Organochlorine chemicals in seafood: occurrence and health concerns. *Food Chem Toxicol* 2002, **40:**767-779.

US EPA. 1984. Ambient Water Quality Criteria Polychlorinated Biphenyls - 1980. EPA Report No 440/5-80-068.

Webster, L., Angus, L.,Topping, G., Dalgarno and Moffat, C. F. 1997. Long-term monitoring of Polycyclic Aromatic Hydrocarbons in Mussels (*Mytilus edulis*) Following the *Braer* Oil Spill. *Analyst,* December 1997, **122**, 1491-1495.

Webster, L., McIntosh, A. D., Dalgarno, E. J., Megginson, C., Shepherd, N. J. and Moffat, C. F., 2003. The polycyclic aromatic hydrocarbon composition of mussels (*Mytilus edulis*) from Scottish waters. *J. Environ. Monit*., **5**, 150-159.

Webster, L., Russell, M., Packer, G. and Moffat, C.F. 2006. Long term monitoring of polycyclic aromatic hydrocarbons (PAHs) in blue mussels (*Mytilus edulis*) from a remote Scottish location. *Polycyclic Aromatic Compounds*, 2006, **26**, 1-16. In press.

WHO (World Health Organization) 2003. Polychlorinated biphenyls : Human health aspects. Concise International Chemical Assessment Document 55.

Figure Legends

TABLE 1

Mussel and oyster sampling locations and delivery dates. This Table should be read in conjunction with Figure 1 which shows the geographical locations from where the samples were obtained.

Region and location	Number of sites	Site Name	Date samples received at FRS ML
Mussel Sampling Locations			
Strathclyde Region Argyll and Bute	3	Loch Striven (Troustan) Loch Etive Lismore (Eilean Dubh)	10 March 2006 2 February 15 February
Dumfries and Galloway	1	Loch Ryan	14 February
Highland Lochaber	2	Glenuig Bay Loch Leven	1 February 16 February
Shetland	8	Parkgate Ronas Voe Lee Voe Baltasound Harbour Whalwick Catfirth Wadbister Vaila Sound (Linga)	24 January 24 January 24 January 24 January 23 March 23 March 23 March 23 March
Oyster Sampling Locations			
Strathclyde Argyll and Bute	3	South Shian Islay (Loch Gruinart) Loch Fyne	17 January 31 January 9 March
Highland Lochaber	1	Loch nan Ceol	1 February
Shetland	1	Baltasound Voe	21 March

TABLE 2

Scallop sampling locations and delivery dates. This Table should be read in conjunction with Figure 2 which shows the geographical location from where the samples were obtained.

Area	**Scallop Sampling Locations**		
Location	Number of sites	Site Name	Date samples received at FRS ML
East Coast	1	E 6	10 December 2005
Moray Firth	1	M 2	5 February 2006
Orkney	1	O 18	25 January 2006
Hebrides	1	H 3 [(1)] H 5 [(1)] H 6 [(1)]	7 February 2006 16/17 January 2006 17/18 January 2006
Clyde	2	C 5 C 8	1/2 February 2006 1 February 2006
Jura	1	J 5 [(2)] J 6 [(2)]	21 January 2006 14 January 2006
South Minch	3	SM 01 [(3)] SM 02 [(3)] SM 03 SM 10 [(4)] SM 11 [(4)]	14 January 2006 15 January 2006 16 January 2006 21 January 2006 22 January 2006

[(1)] H 3, H 5 and H 6 were pooled as I sample

[(2)] J 5 and J 6 were pooled as I sample

[(3)] SM 01 and SM 02 were pooled as I sample

[(4)] SM 10 and SM 11 were pooled as I sample

Table 3 Summary of PAH concentrations (ng g^{-1} wet weight tissue) in mussels, oysters and scallops (adductor and gonad) sampled in (December 2005 for E6 scallops) January to March 2006.

Region	Total measured PAH [1] concentration/range in tissue	% 3-ring PAH [2]	% 4- to 6-ring PAH [3]	% 5-ring PAH	B[*a*]PE [4]
Mussels					
Strathclyde Argyll and Bute	57.3, 58.8 and 244.3	20.6 [5]	64.1 [5]	23.0 [5]	1.5 – 5.6 mean=2.9
Dumfries and Galloway	264.7	36.6	41.9	7.8	4.2
Highland Lochaber	28.9 and 145.7	16.4 [5]	73.2 [5]	34.8 [5]	0.7 and 13.2
Shetland	26.9 – 98.4 Median – 41.3 (n=8)	27.9 SD=3.3	50.1 SD=7.5	16.5 SD=3.1	0.6 – 1.2 mean=0.9
Oysters					
Strathclyde Argyll and Bute	59.2, 62.0 and 132.5	23.0 [5]	66.9 [5]	19.7 [5]	1.0 – 5.5 mean=2.6
Highland Lochaber	52.4	21.4	64.5	22.3	1.3
Shetland	65.6	32.9	54.3	12.8	1.0
Scallops adductor muscle					
	Total measured PAH concentration/range in scallop adductor muscle	% 3-ring PAH	% 4- to 6-ring PAH	% 5-ring PAH	B[*a*]PE
East Coast	24.2	17.8	77.3	36.8	1.2
Moray Firth	10.4	14.4	83.7	37.5	0.6
Orkney	11.0	14.5	77.3	30.9	0.4
Hebrides	34.5	33.3	47.2	18.0	0.6
Clyde	55.0 and 30.9	8.3 [5]	83.4 [5]	36.9 [5]	4.1 and 1.7
Jura	18.9	10.1	87.8	40.2	1.0
South Minch	21.8, 22.0 and 24.9	11.4 [5]	86.4 [5]	38.4 [5]	1.0 – 1.2 mean=1.1
Scallop gonad tissue					
	Total measured PAH concentration/range in scallop gonad tissue	% 3-ring PAH	% 4- to 6-ring PAH	% 5-ring PAH	B[*a*]PE
East Coast	138.7	19.3	70.9	23.9	6.8
Moray Firth	57.2	19.2	67.7	25.5	2.0
Orkney	63.2	18.7	55.9	16.6	1.4
Hebrides	146.6	38.5	32.2	8.0	1.4
Clyde	250.0 and 168.0	12.8 [5]	81.3 [5]	27.1 [5]	13.2 and 7.9
Jura	97.1	14.5	76.9	26.6	4.4
South Minch	100.8, 101.3 and 121.2	11.1 [5]	66.5 [5]	25.9 [5]	4.2 – 5.3 mean=4.9

[1] Total measured PAH – 2- to 6-ring parent and branched PAH compounds
[2] 3-ring PAH – sum of acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, C1 – C3 *m/z* 178
[3] 4- to 6-ring PAH – sum of 4-ring PAH – fluoranthene, pyrene, C1 – C3 *m/z* 202; benzo[*c*]phenanthrene, benz[*a*]anthracene, chrysene/triphenylene, benz[*b*]anthracene, C1 and C2 *m/z* 228; sum of 5-ring PAH – benzofluoranthenes, benzo[*e*]pyrene, benzo[*a*]pyrene, perylene, C1 and C2 *m/z* 252; dibenz[*a,h*]anthracene and sum of 6-ring PAH – indenopyrene, benzoperylene, C1 and C2 *m/z* 276
[4] B[*a*]PE – benzo[*a*]pyrene equivalent value - sum of 16 PAH compounds multiplied by toxic equivalency factors (Nisbet and LaGoy (1992))
[5] mean concentration

Table 4 Background Concentrations (BCs) and provisional Background Assessment Concentrations (BACs) for PAHs in mussels (ng g^{-1} wet weight) and mean concentrations of individual PAH compounds determined in mussels from the Scottish mainland and Shetland Islands.

PAH compound	ng g^{-1} wet weight (for mussels)		Range and mean PAH (ng g^{-1} wet weight) concentration in mussels	
	BC	***BAC***	**Scottish Mainland** n=6	**Shetland Islands** n=8
Naphthalene	0.2	1.1	0.2 - 0.8 mean=0.5	0.2 – 2.2 mean=0.6
Phenanthrene	0.9	4.9	1.6 – 7.2 mean=2.8	1.3 – 3.0 mean=2.1
Anthracene	0.2	0.4	TR – 0.8 mean=0.5	ND - TR
Fluoranthene	1.4	2.5	1.4 – 10.5 mean=4.6	1.5 – 2.4 mean=1.9
Pyrene	1.1	1.8	0.9 – 11.1 mean=4.8	0.8 – 2.1 mean=1.5
Benz[*a*]anthracene	0.3	1.1	0.3 – 3.5 mean=1.8	0.2 – 0.6 mean=0.4
Chrysene	1.3	3.4	1.4 – 10.6 mean=5.5	1.4 – 3.0 mean=1.9
Benzo[*a*]pyrene	0.2	0.7	0.3 – 5.1 mean=1.8	0.3 – 0.6 mean=0.4
Benzo[*ghi*]perylene	0.5	2.7	0.5 – 4.4 mean=2.0	0.4 – 1.0 mean=0.6
Indeno[123-*cd*]pyrene	0.4	1.6	0.3 – 2.5 mean=1.1	0.3 – 0.7 mean=0.4

Table 5 Background concentrations, Environmental Assessment Criteria (EAC), historical trace metal concentrations and Commission Regulation concentrations of trace metals in blue mussels.

		Cr	Mn	Co	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
Blue mussels background concentration ranges, µg g^{-1} wet weight [1]		NDA	NDA	NDA	NDA	0.76-1.10	11.6-30	NDA	NDA	NDA	0.07-0.11	0.005-0.01	0.01-0.190
Trace metal concentrations in mussels, µg g^{-1} wet weight [2]	Range	NDA	NDA	NDA	NDA	0.50-27.7	3.23-290	1.38-28.4	NDA	NDA	0.085-0.21	0.01-0.02	0.08-0.80
	Mean	NDA	NDA	NDA	NDA	2.19	22.4	7.1	NDA	NDA	0.106	0.01	0.273
Trace metal concentrations in mussels, µg g^{-1} wet weight [3]		0.1-2.7	0.67-12.8	<LoD-0.34	<LoD-1.96	0.74-2.32	10.7-27.8	1.5-2.7	0.32-1.35	<LoD	<LoD-0.22	<LoD-0.04	0.10-1.21
Maximum trace metal concentrations in mussels, µg g^{-1} wet weight [4]		NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA	1.0	0.5	1.5 [5]
Directive 79/923/EEC Standards for Shellfish, µg g^{-1} wet weight [6]	Guideline	1.2	ND	ND	1.0	3.0	50	6.0	ND	ND	1.0	0.2	3.0
	Imperative	4.0	ND	ND	3.0	6.0	100	20	ND	ND	3.0	0.6	10

[1] OSPAR 2000
[2] Brown and Balls, 1997
[3] McIntosh, *et al.*, 2004
[4] Commission Regulation (EC) No 466/2001
[5] Commission Regulation (EC) No 221/2002 (amending Regulation (EC) No 466/2001)
[6] Henderson and Davies, 2001

NDA – no data available; NR – not relevant in relation to the current (OSPAR) monitoring programme; LoD – limit of detection

Figure 1

Map of locations from where mussels and oysters were sampled during the period January to March 2006.

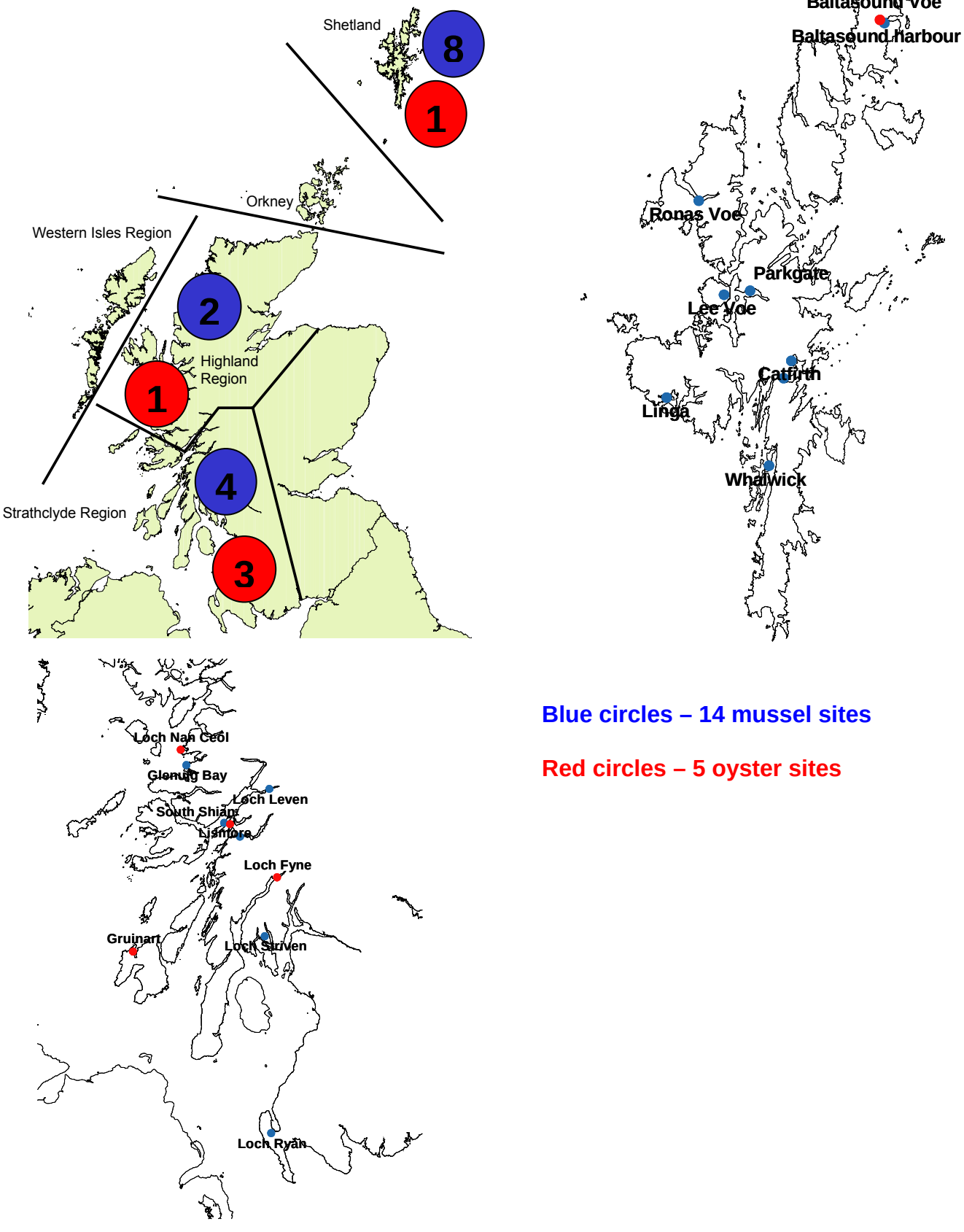


Figure 2

Map of locations from where scallops were sampled during the period December 2005 to February 2006.

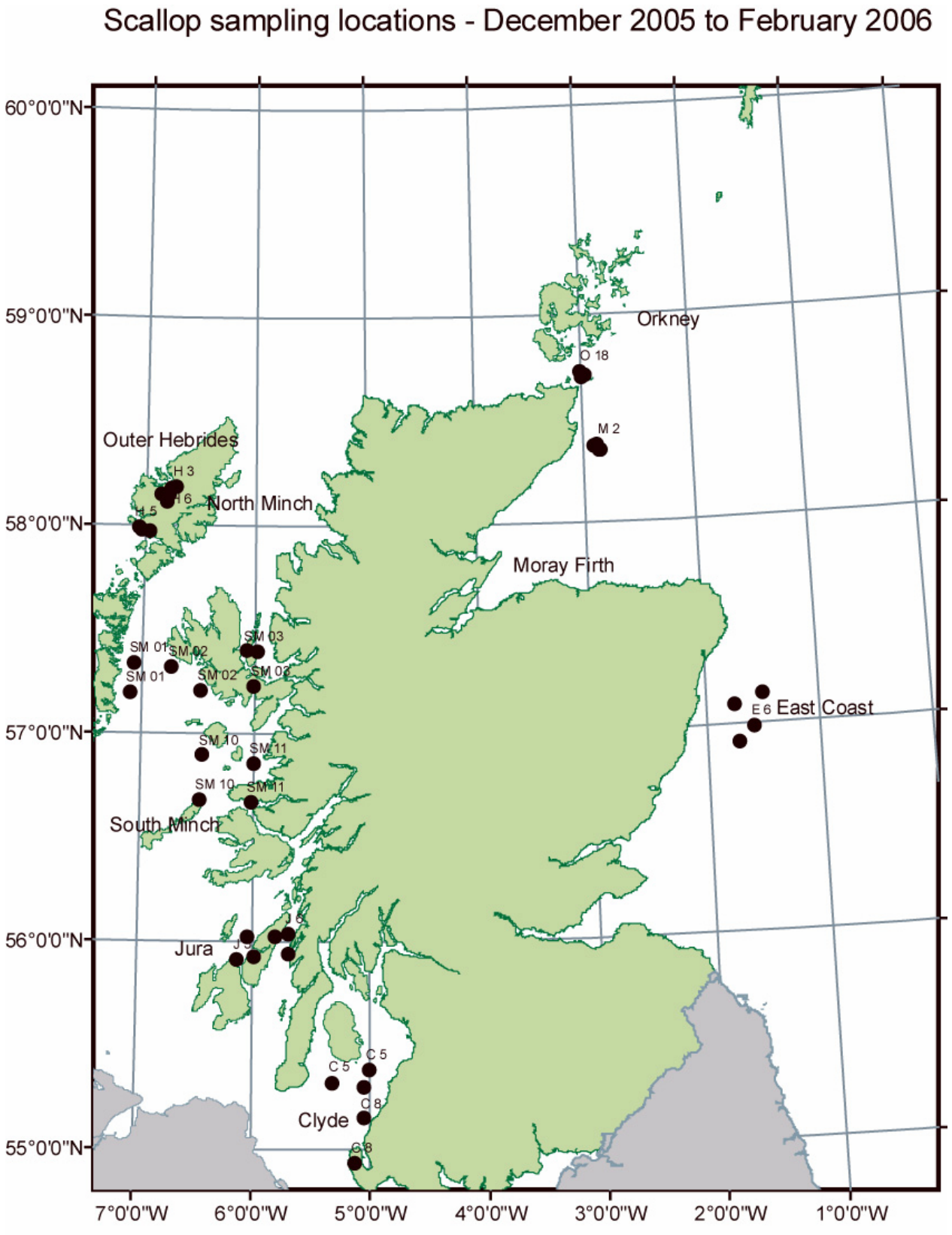


Figure 3 Variation in mussel lengths from the samples collected during the period January to March 2006.

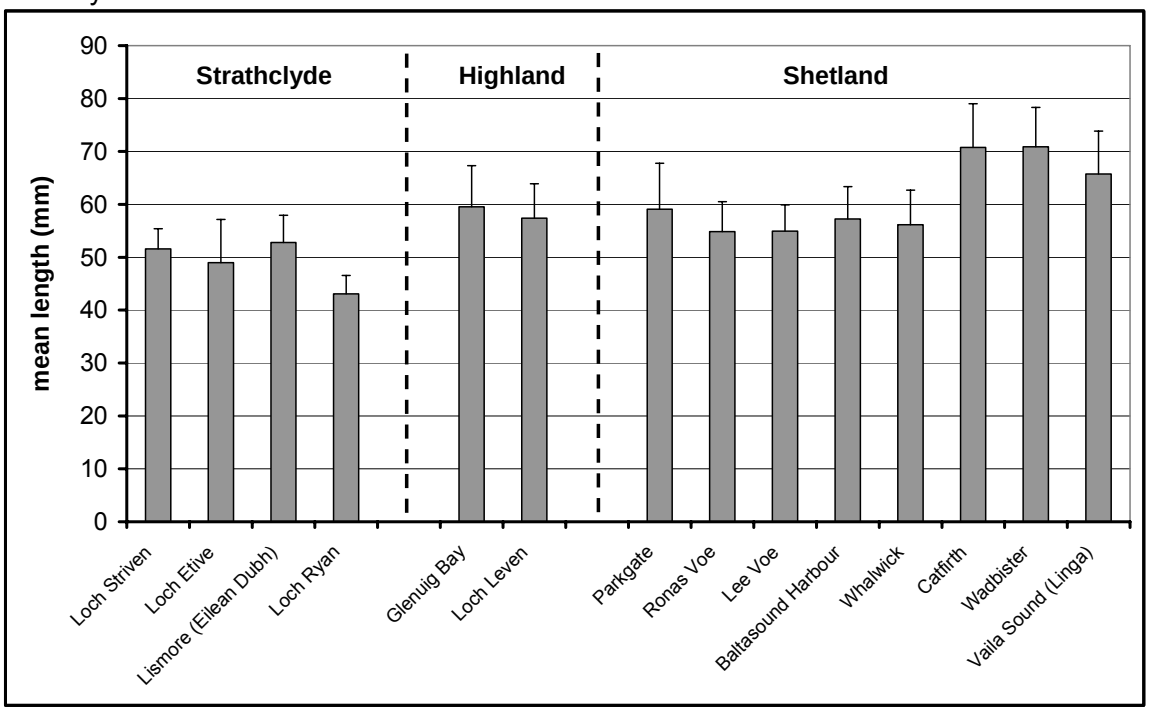


Figure 4 Variation in total measured PAH (ng g^{-1} wet weight tissue) concentrations in mussels from the fourteen locations sampled during January to March 2006. The dashed lines represent indicative concentrations for assessment; concentrations between <50 ng g^{-1} and 150 ng g^{-1} wet weight tissue can be considered as background for post-spawning mussels; between 50 and 150 ng g^{-1} wet weight can be considered as background for pre-spawning mussels. These concentrations are based on a long-term time series for mussels collected from Loch Etive on the Scottish west coast. The range 150 – 250 ng g^{-1} wet weight may indicate an acute exposure or low-level chronic exposure to PAH contaminants. PAH concentrations >250 ng g^{-1} wet weight tissue are likely to be indicative of a more severe (eg emergency) or long term chronic exposure.

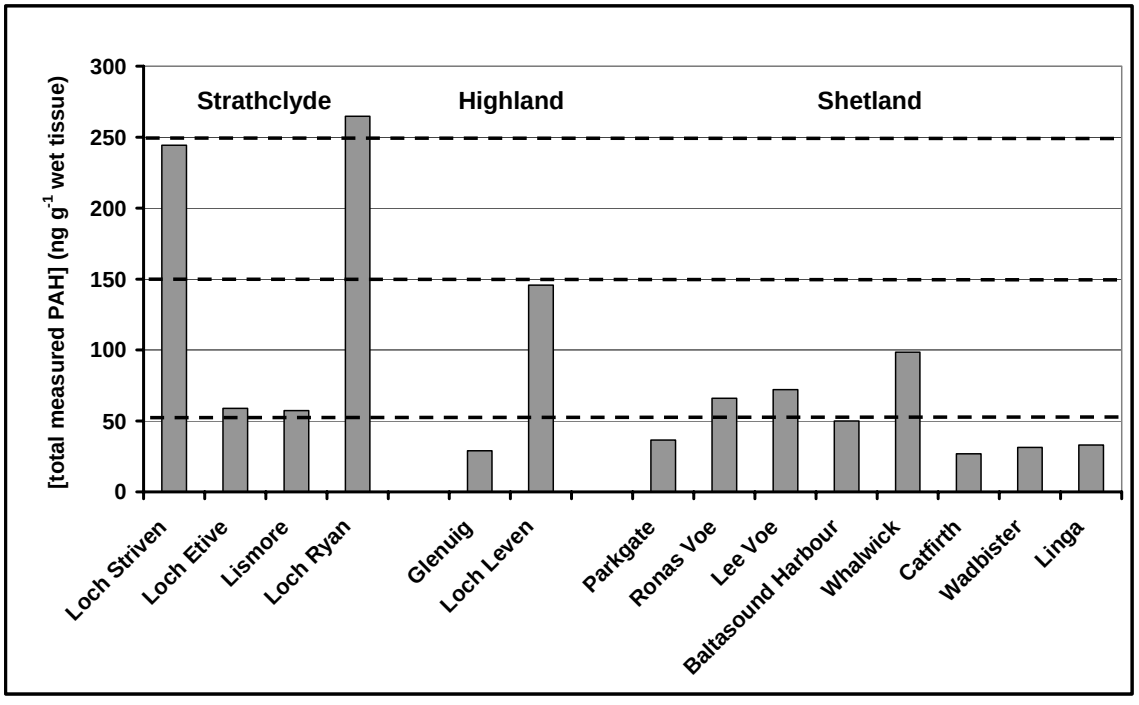


Figure 5a Variation in percentage composition of the 2- to 6-ring PAH compounds in mussels from the Strathclyde and Highland Regions.

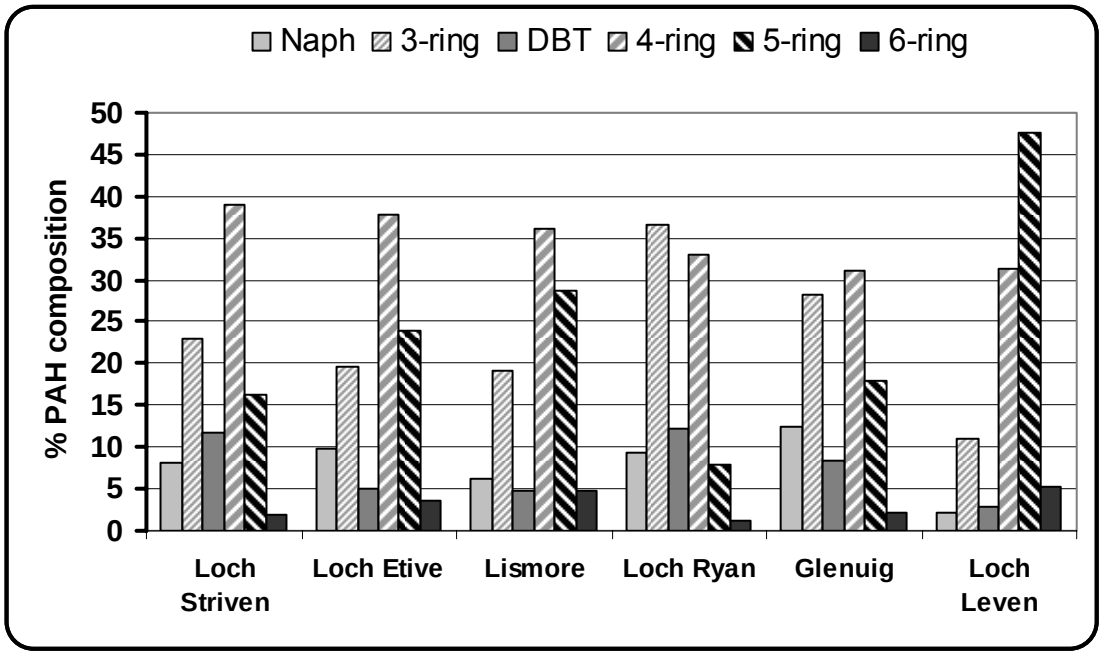


Figure 5b Variation in percentage composition of the 2- to 6-ring PAH compounds in mussels from the Shetland Islands.

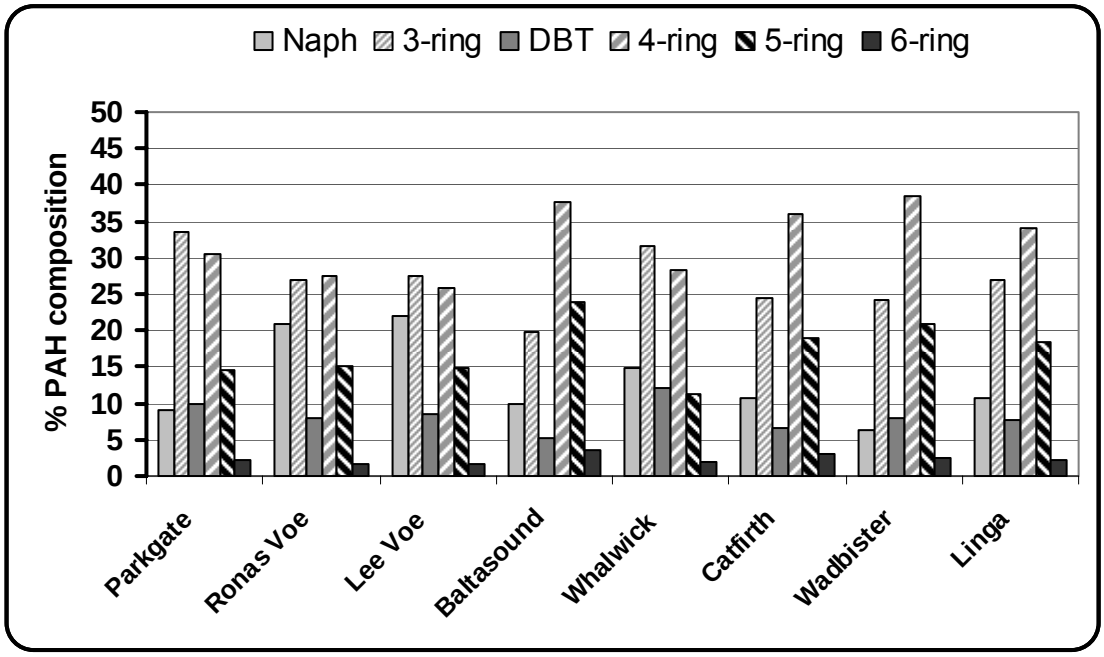


Figure 6a Variation in percentage composition of the 2-ring, 3-ring and 4- to 6-ring PAH compounds in mussels from the Strathclyde and Highland Regions. The data from Loch Etive is time averaged (November to March) over the period 1999 to 2005.

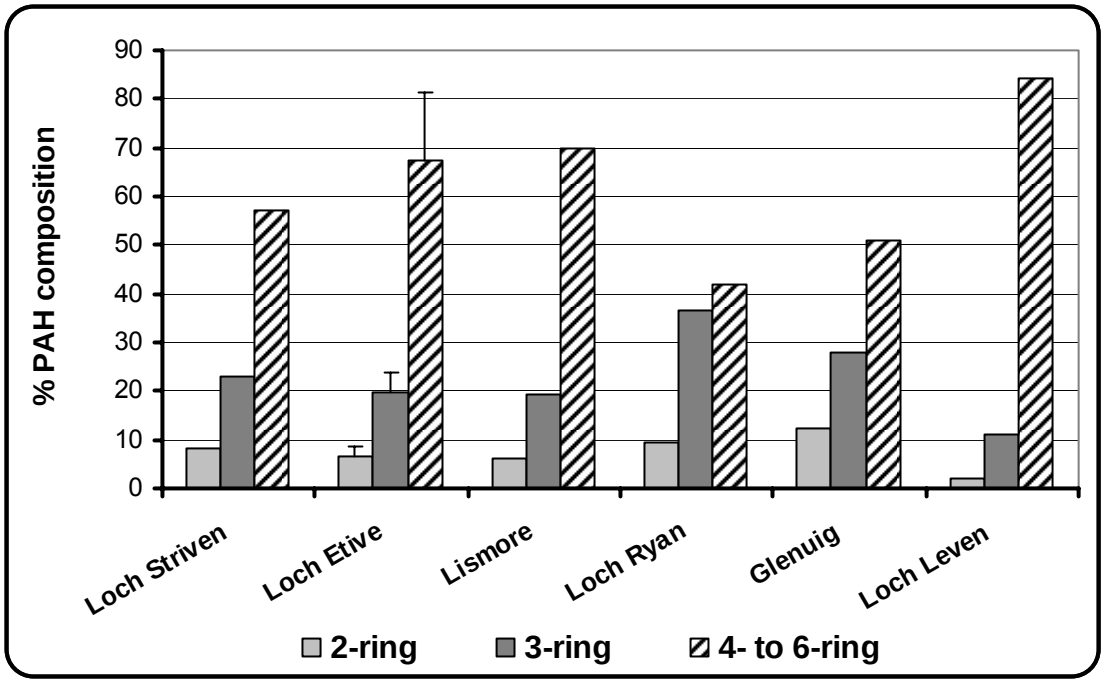
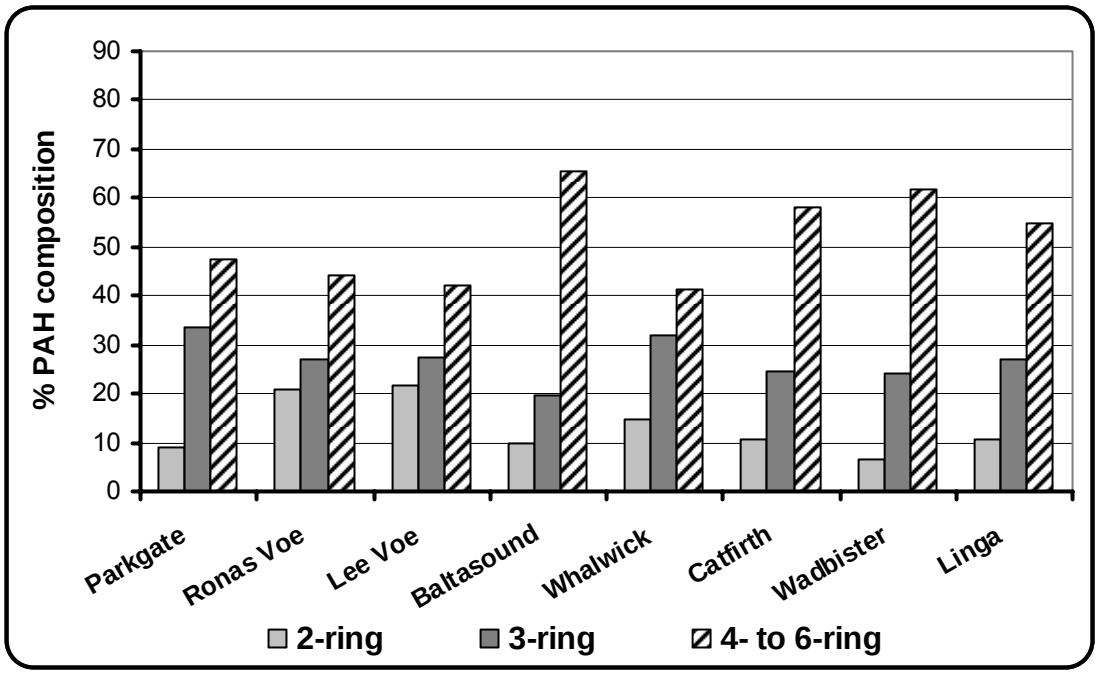


Figure 6b Variation in percentage composition of the 2-ring, 3-ring and 4- to 6-ring PAH compounds in mussels from the Shetland Islands.



2-ring compounds – ∑ naphthalene, 2-methyl naphthalene, 1-methyl naphthalene and C2-C4 naphthalenes

3-ring compounds – ∑ acenaphthylene (152); acenaphthene (154); fluorene (166); phenanthrene (178), anthracene (178), C1-C3 178

4- to 6-ring compounds - ∑ fluoranthene (202), pyrene (202), C1-C3 202; benzo[*c*]phenanthrene (228), benz[*a*]anthracene (228), chrysene/triphenylene (228), benz[*b*]anthracene (228), C1-C2 228; benzo[*b*]fluoranthene (252), benzo[*k*]fluoranthene (252), benzo[*e*]pyrene (252), benzo[*a*]pyrene (252), perylene (252), C1-C2 252; dibenz[*a,h*]anthracene (278); indenopyrene (276), benzoperylene (276), C1-C2 276.

Figure 7 Variation in percentage composition of the 2-ring, 3-ring and 4- to 6-ring PAH compounds in mussels from Loch Etive, a reference site, Loch Ryan and Loch Leven, both of which exhibit atypical PAH percentage distribution. The data from Loch Etive is time averaged (November to March) over the period 1999 to 2005.

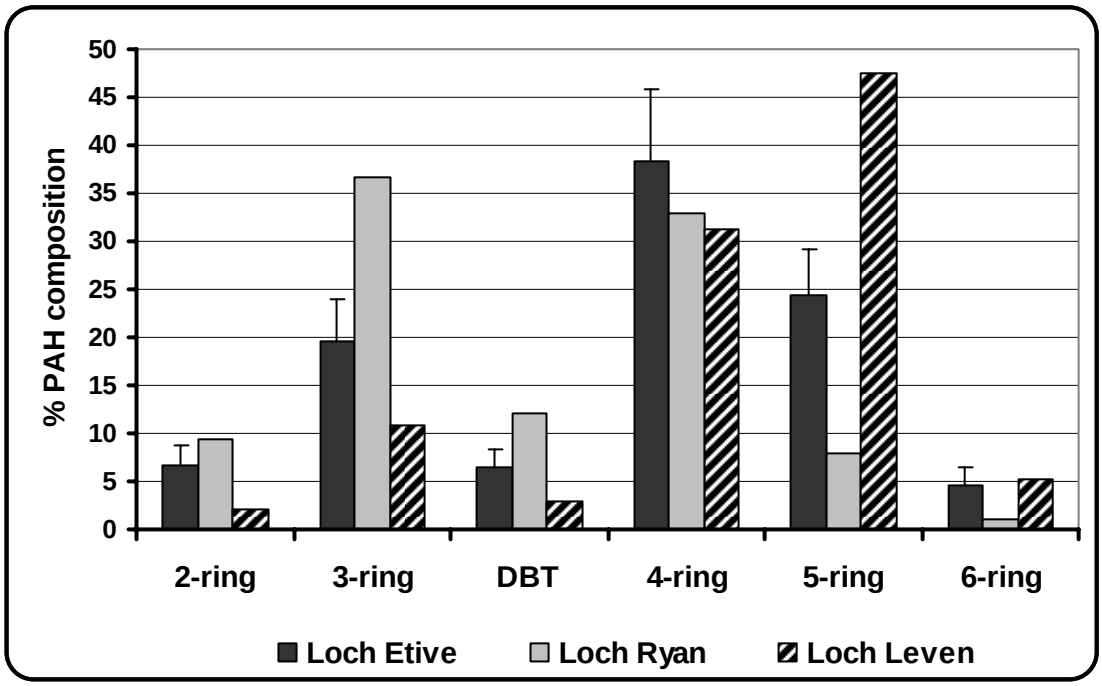


Figure 8 Variation in percentage composition of the 2-ring, 3-ring and 4- to 6-ring PAH compounds in oysters from the five locations sampled during January to March 2006.

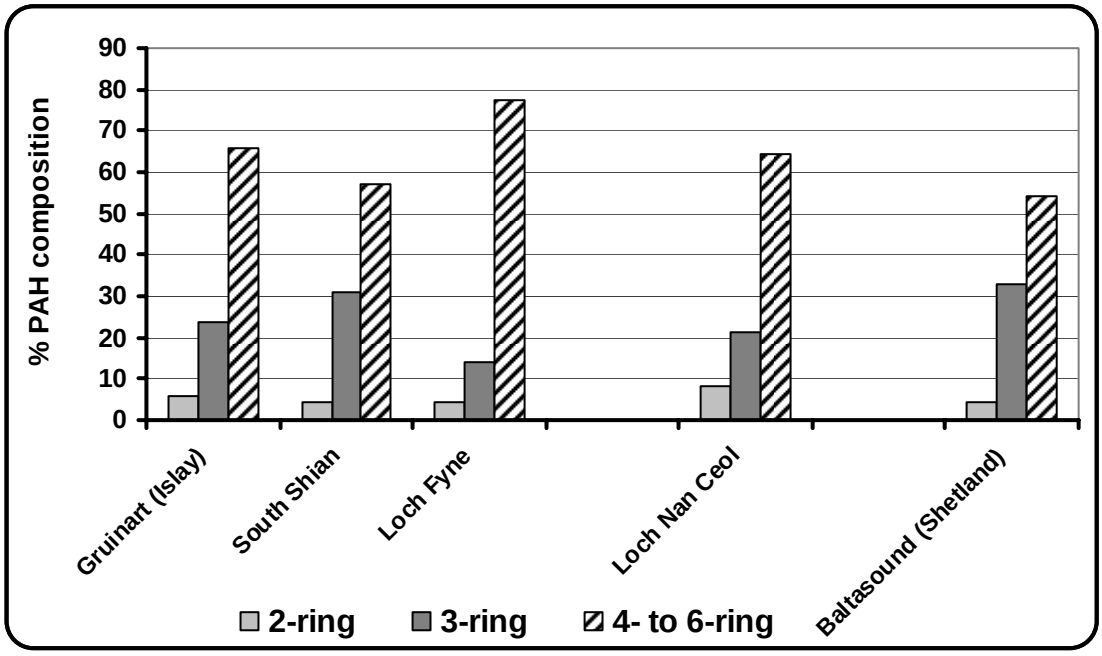


Figure 9 Variation in total measured PAH (ng g^{-1} wet weight) concentrations in scallop adductor muscle and gonad tissue from the ten locations sampled during December 2005 to February 2006.

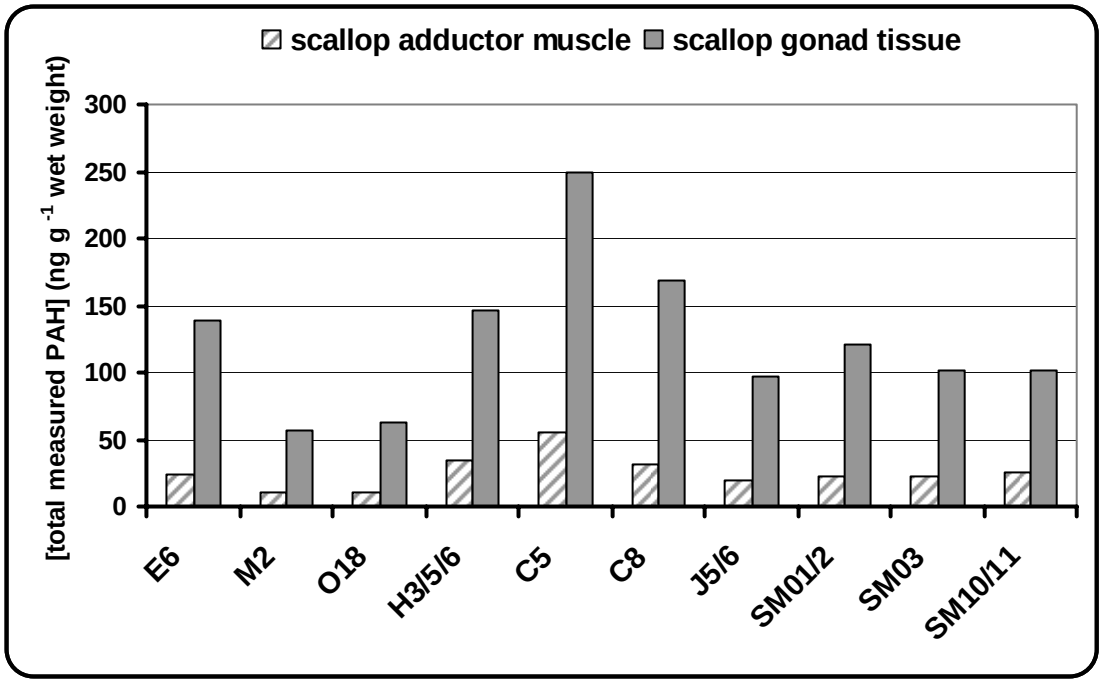


Figure 10 Variation in percentage composition of the 2- to 6-ring PAH compounds in scallop adductor muscle from the ten locations sampled during December 2005 to February 2006.

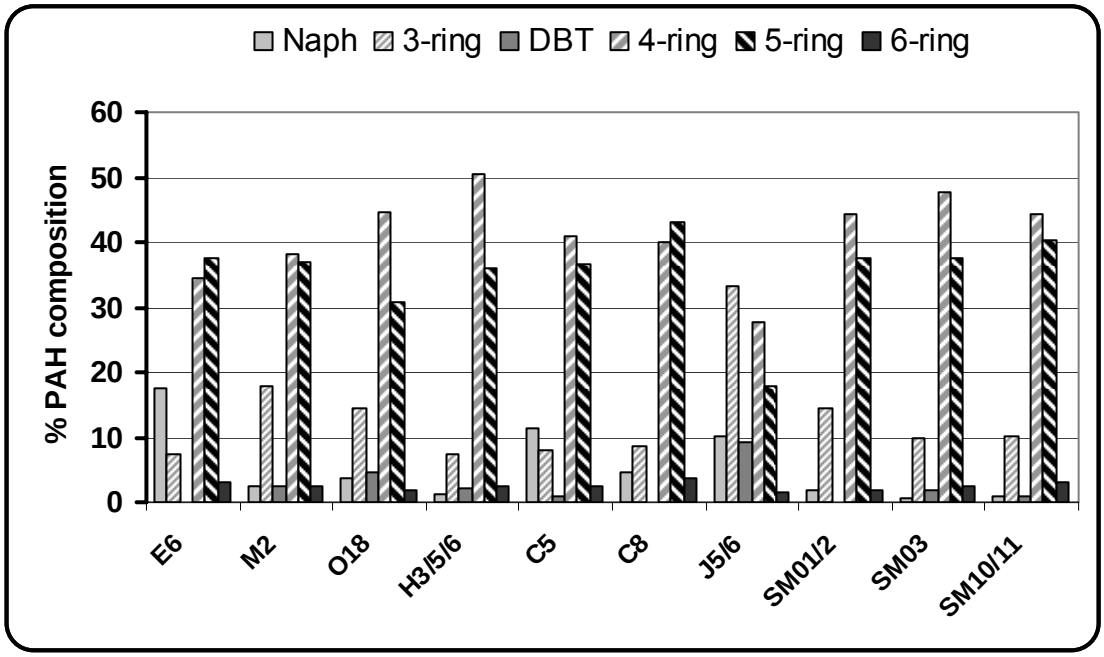


Figure 11 Variation in percentage composition of the 2- to 6-ring PAH compounds in scallop gonad tissue from the ten locations sampled during December 2005 to February 2006.

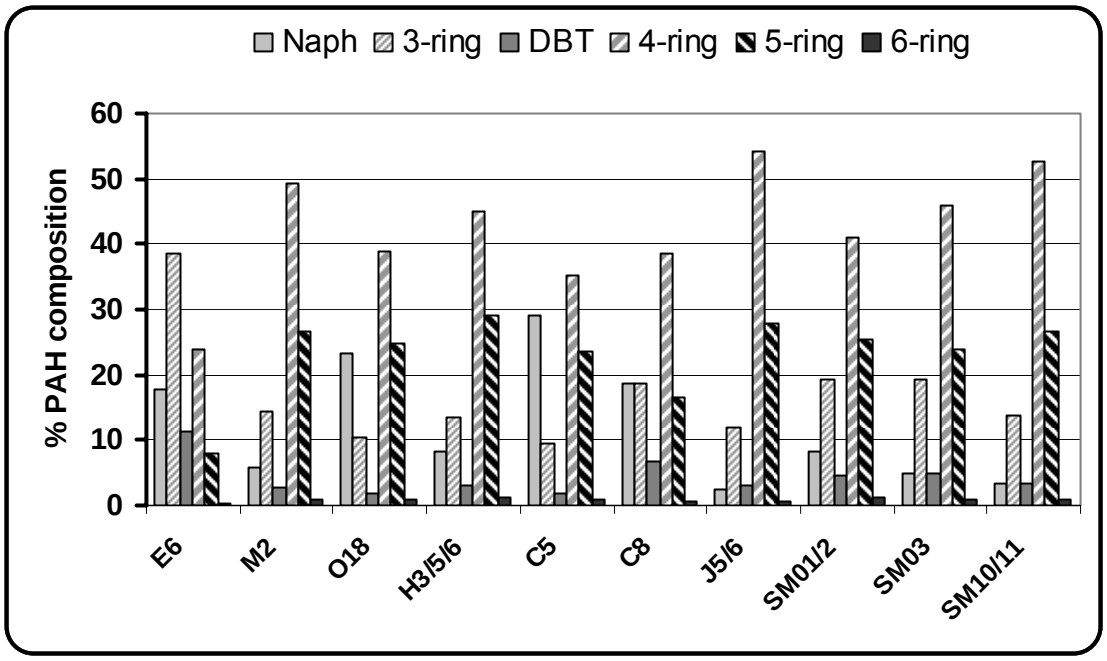


Figure 12 Variation in percentage composition of the 2-ring, 3-ring and 4- to 6-ring PAH compounds in scallop adductor muscle from the ten locations sampled during December 2005 to February 2006.

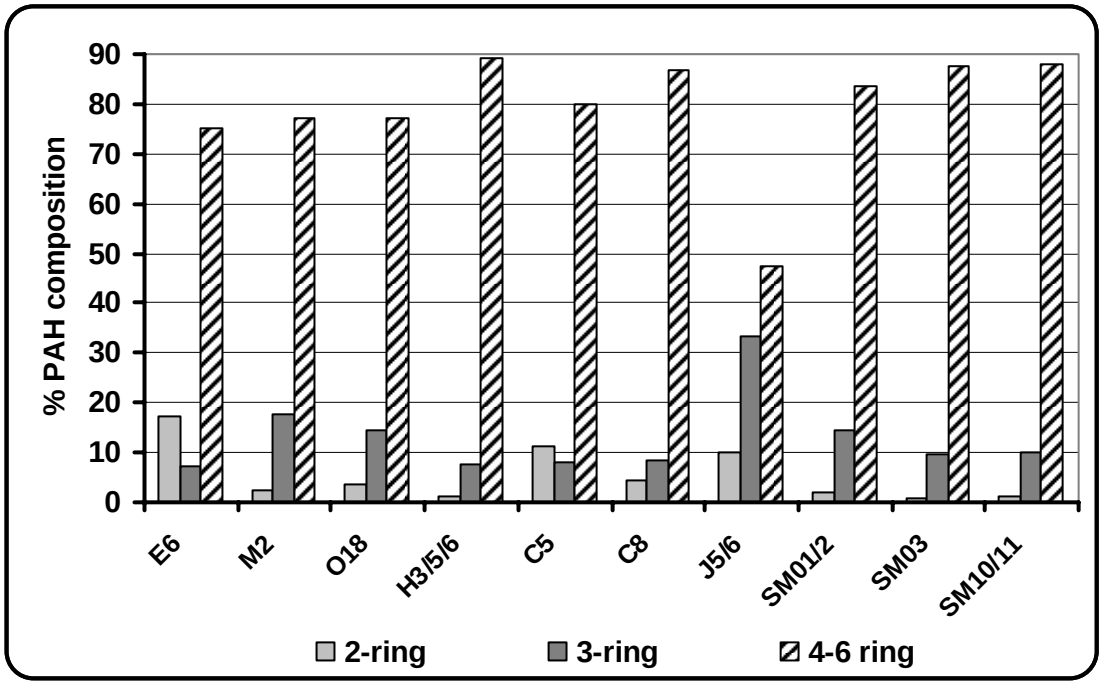


Figure 13 Variation in percentage composition of the 2-ring, 3-ring and 4- to 6-ring PAH compounds in scallop gonad tissue from the ten locations sampled during December 2005 to February 2006.

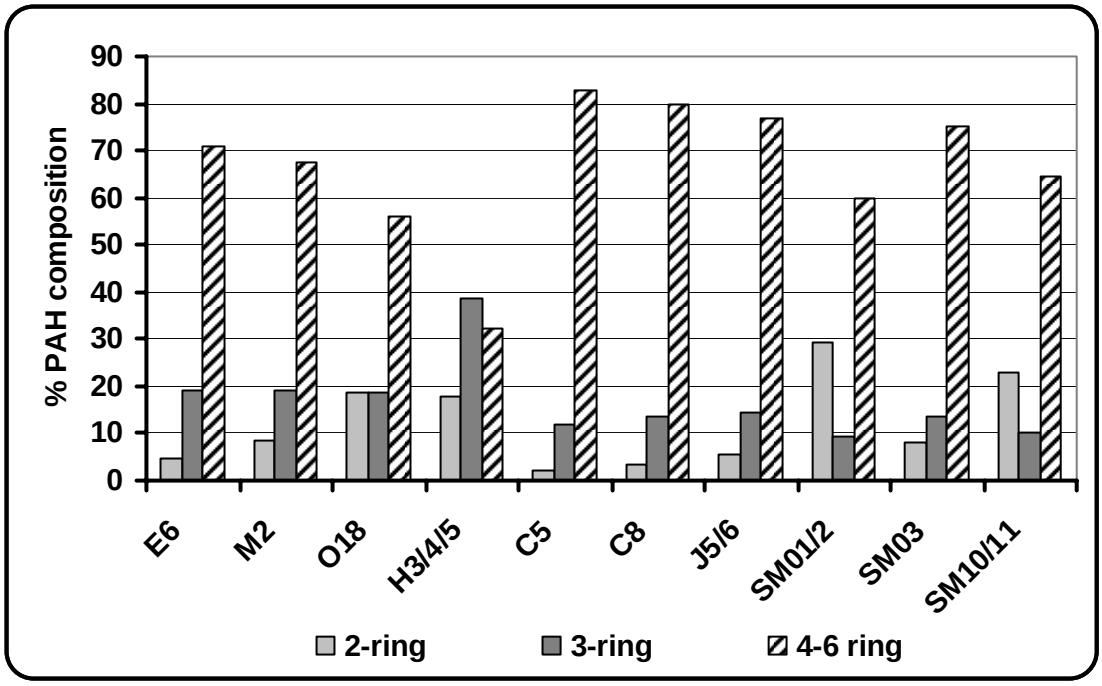


Figure 14 Variation in cadmium concentrations (µg g^{-1} wet weight) in mussels from the samples collected during the period January to March 2006. The shaded area represents the B/RC (OSPAR 2000) for cadmium in mussels of 0.07 – 0.11 µg g^{-1} wet weight.

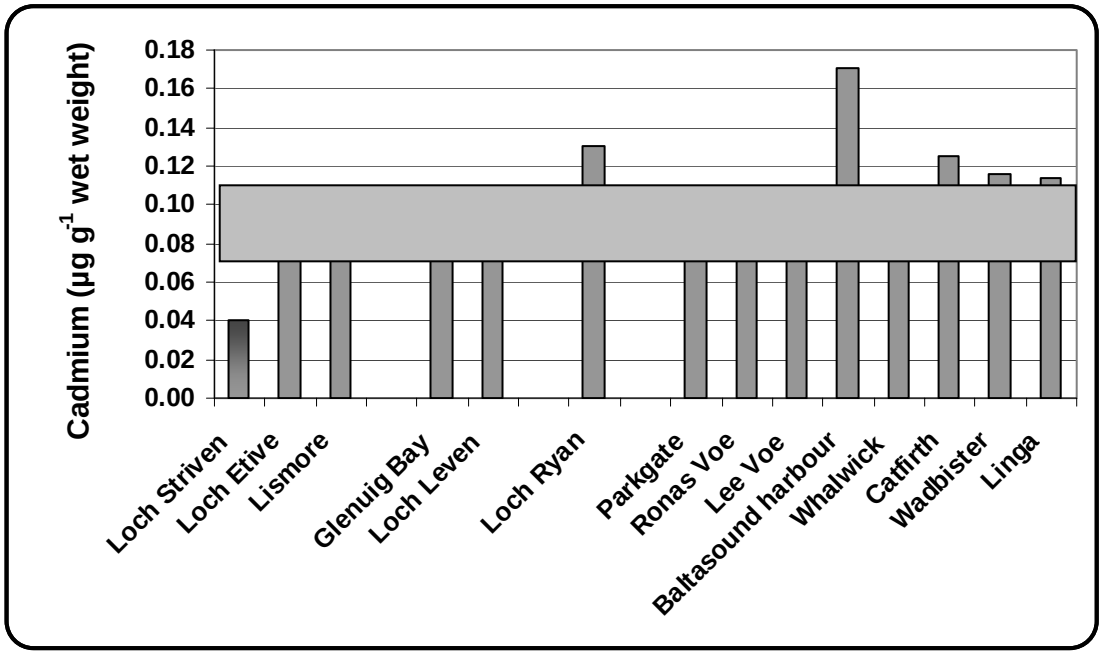


Figure 15 Variation in lead concentrations (µg g^{-1} wet weight) in mussels from the samples collected during the period January to March 2006. The shaded area represents the B/RC (OSPAR 2000) for lead in mussels of 0.01 – 0.19 µg g^{-1} wet weight.

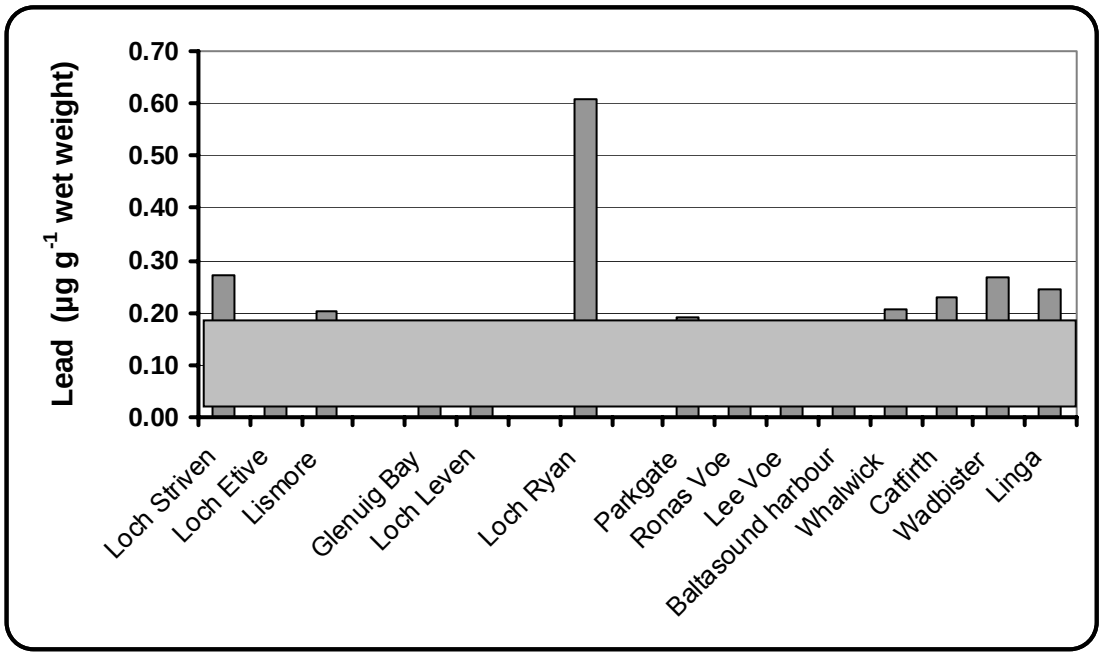


Figure 16 Variation in cadmium concentrations (µg g^{-1} wet weight) in oysters from the samples collected during the period January to March 2006. The shaded area represents the B/RC (OSPAR 2000) for cadmium in mussels of 0.07 – 0.11 µg g^{-1} wet weight.

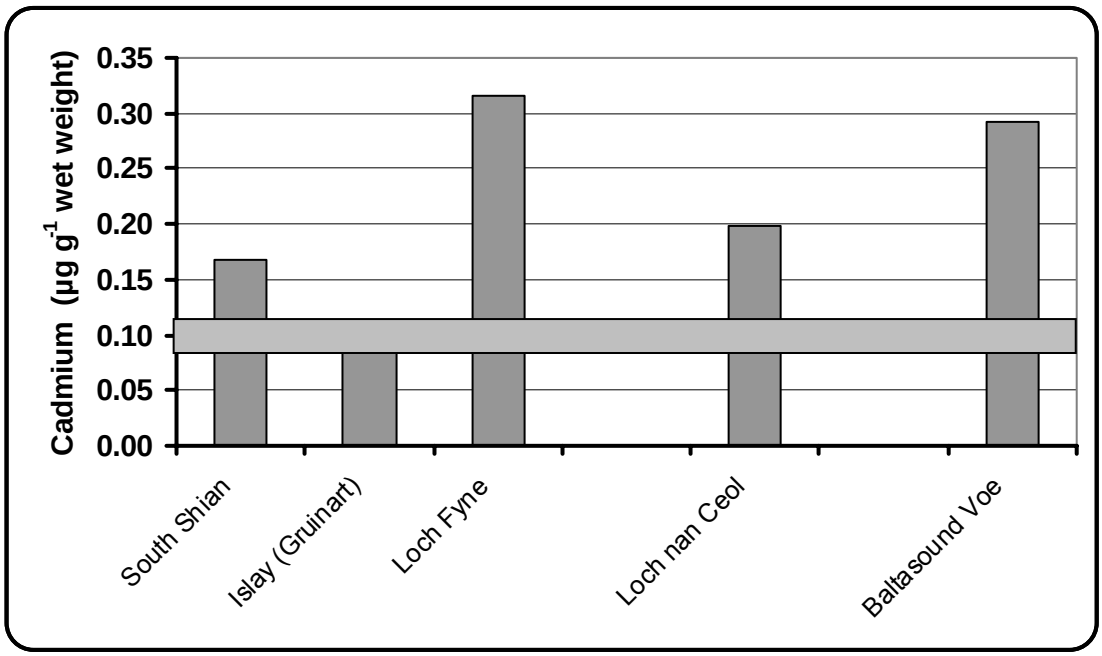


Figure 17 Variation in cadmium concentrations (µg g^{-1} wet weight) in scallop adductor muscle and gonad tissue from the samples collected during the period December 2005 to February 2006. The shaded area represents the B/RC (OSPAR 2000) for cadmium in mussels of 0.07 – 0.11 µg g^{-1} wet weight.

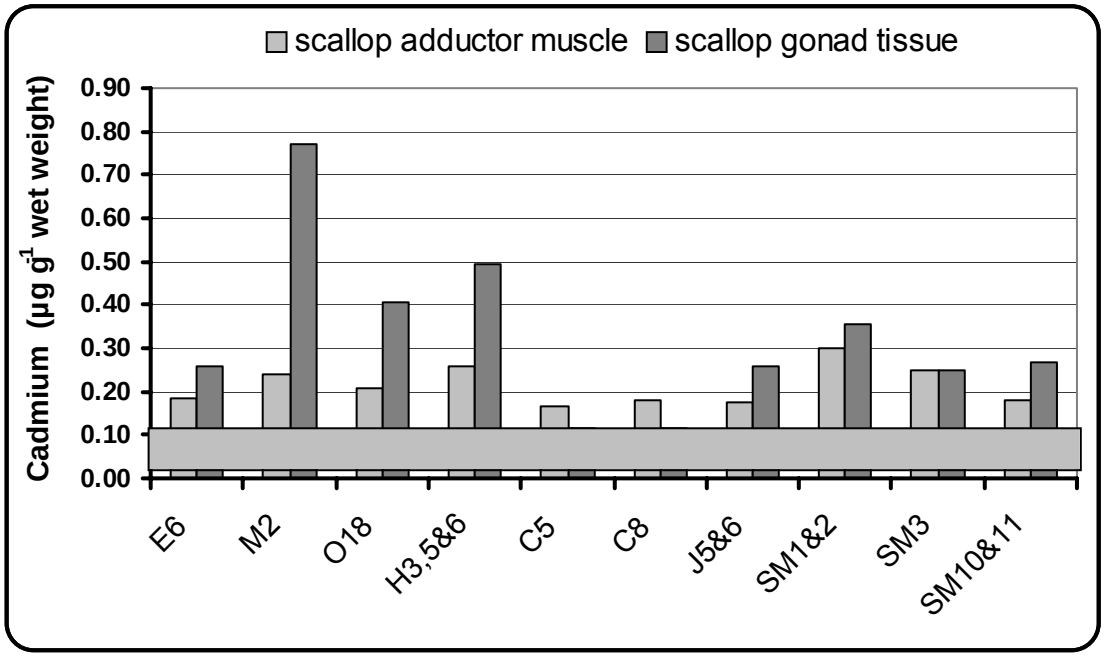


Figure 18 Variation in sum of ICES 7 CB congeners (ng g^{-1} wet weight) in mussels from the samples collected during the period January to March 2006. The shaded area represents the Environmental Assessment Criteria (EAC) for the sum of the ICES 7 CBs for blue mussels which has a range of 0.75 – 7.5 ng g^{-1} wet weight.

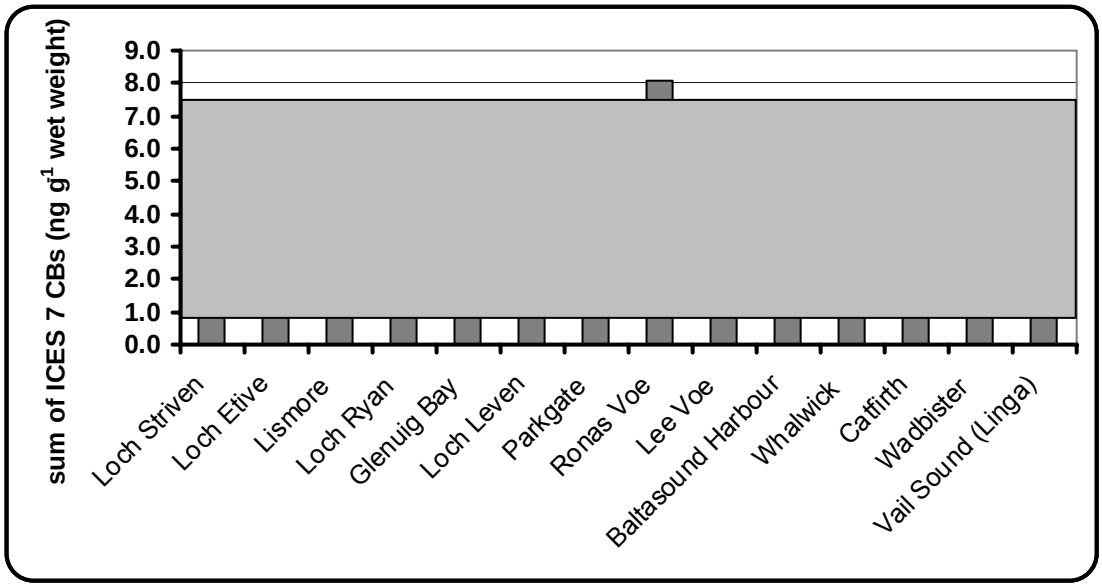


Figure 19 Variation in sum of ICES 7 CB congeners (ng g^{-1} wet weight) in oysters from the samples collected during the period January to March 2006. The shaded area represents the Environmental Assessment Criteria (EAC) for the sum of the ICES 7 CBs for blue mussels which has a range of 0.75 – 7.5 ng g^{-1} wet weight.

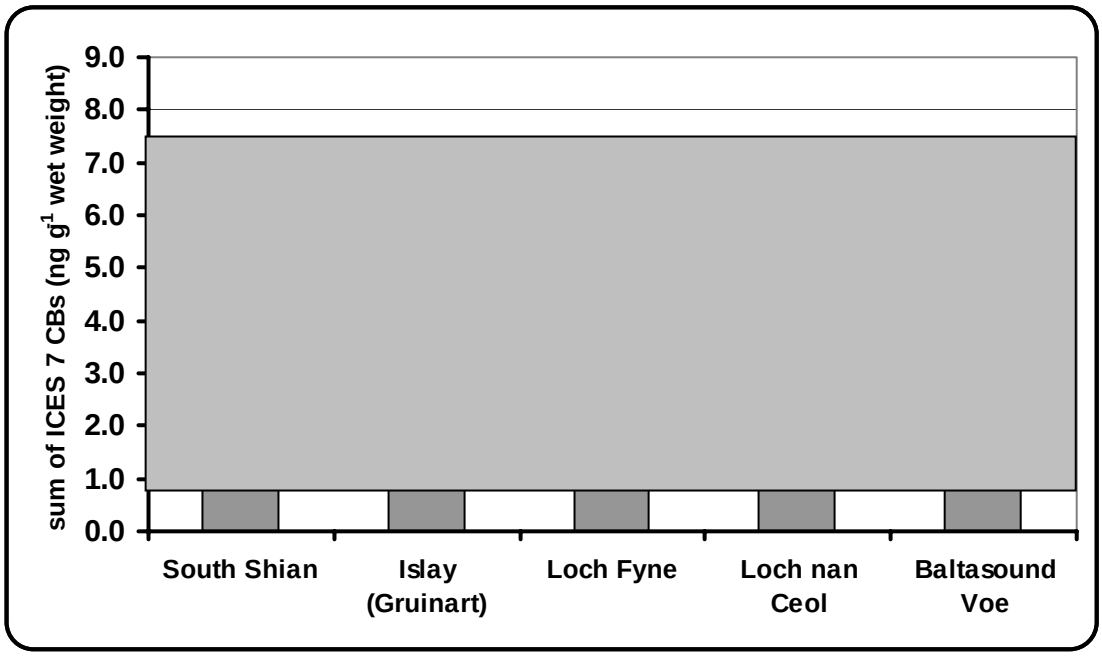


Figure 20 Variation in sum of ICES 7 CB congeners (ng g^{-1} wet weight) in scallop adductor muscle and gonad tissue from the samples collected during the period December 2005 to February 2006. The shaded area represents the Environmental Assessment Criteria (EAC) for the sum of the ICES 7 CBs for blue mussels which has a range of 0.75 – 7.5 ng g^{-1} wet weight.

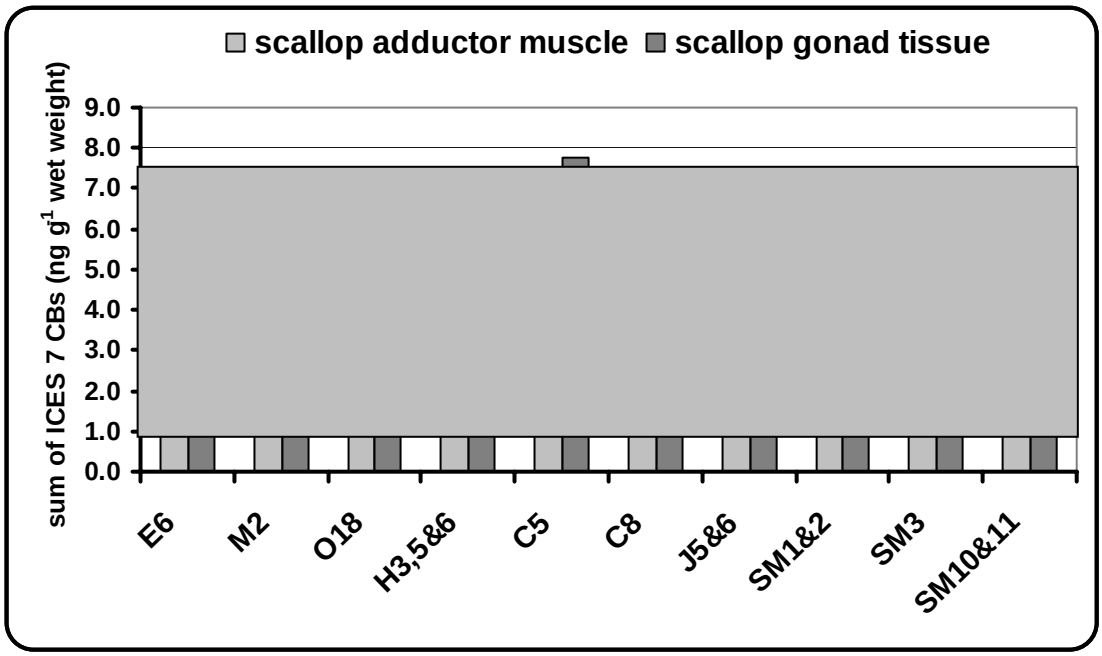


Figure 21a Variation in percentage composition of the ICES 7 chlorobiphenyl congeners in mussels from three locations around Scotland collected during January and March 2006.

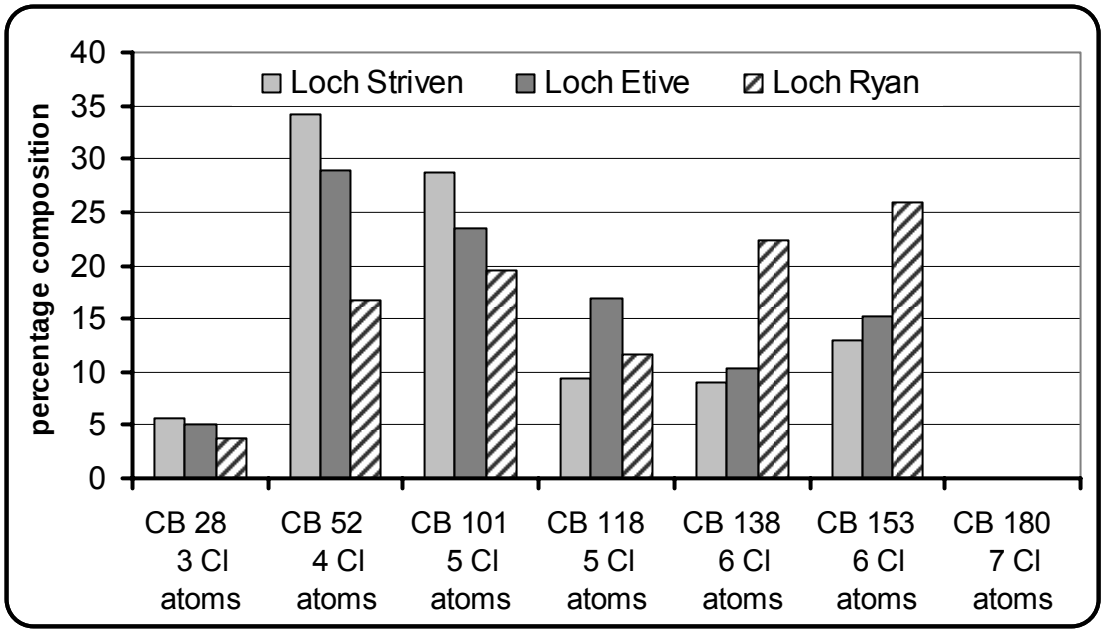


Figure 21b Variation in percentage composition of the ICES 7 chlorobiphenyl congeners in mussels from three locations in Shetland collected during January 2006.

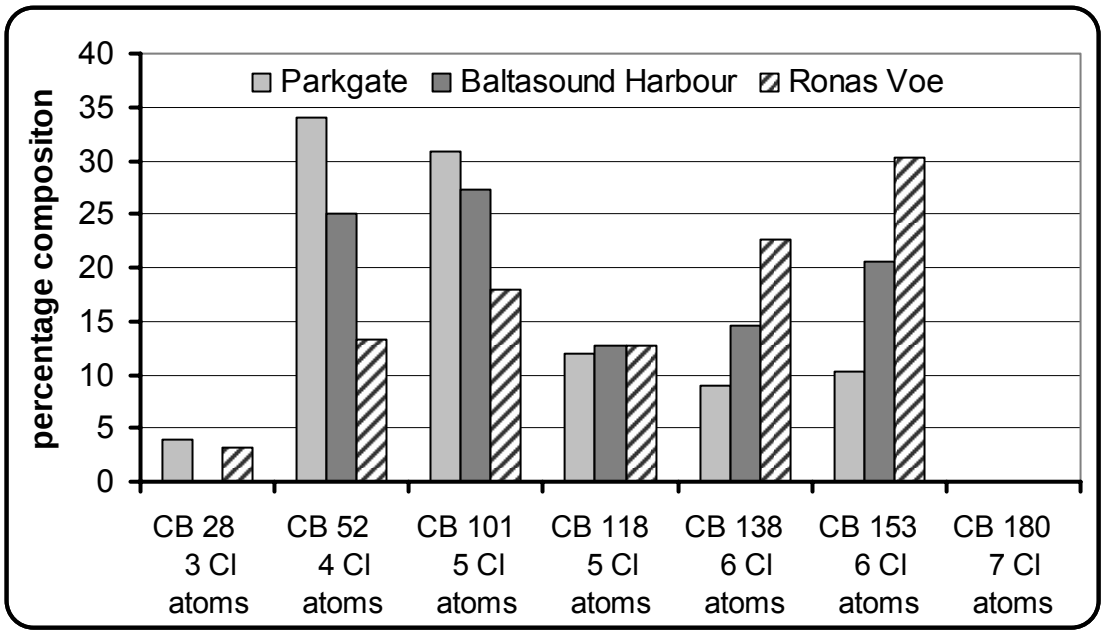


Figure 21c Variation in percentage composition of the ICES 7 chlorobiphenyl congeners in mussels from three locations around Scotland collected during January and March 2006.

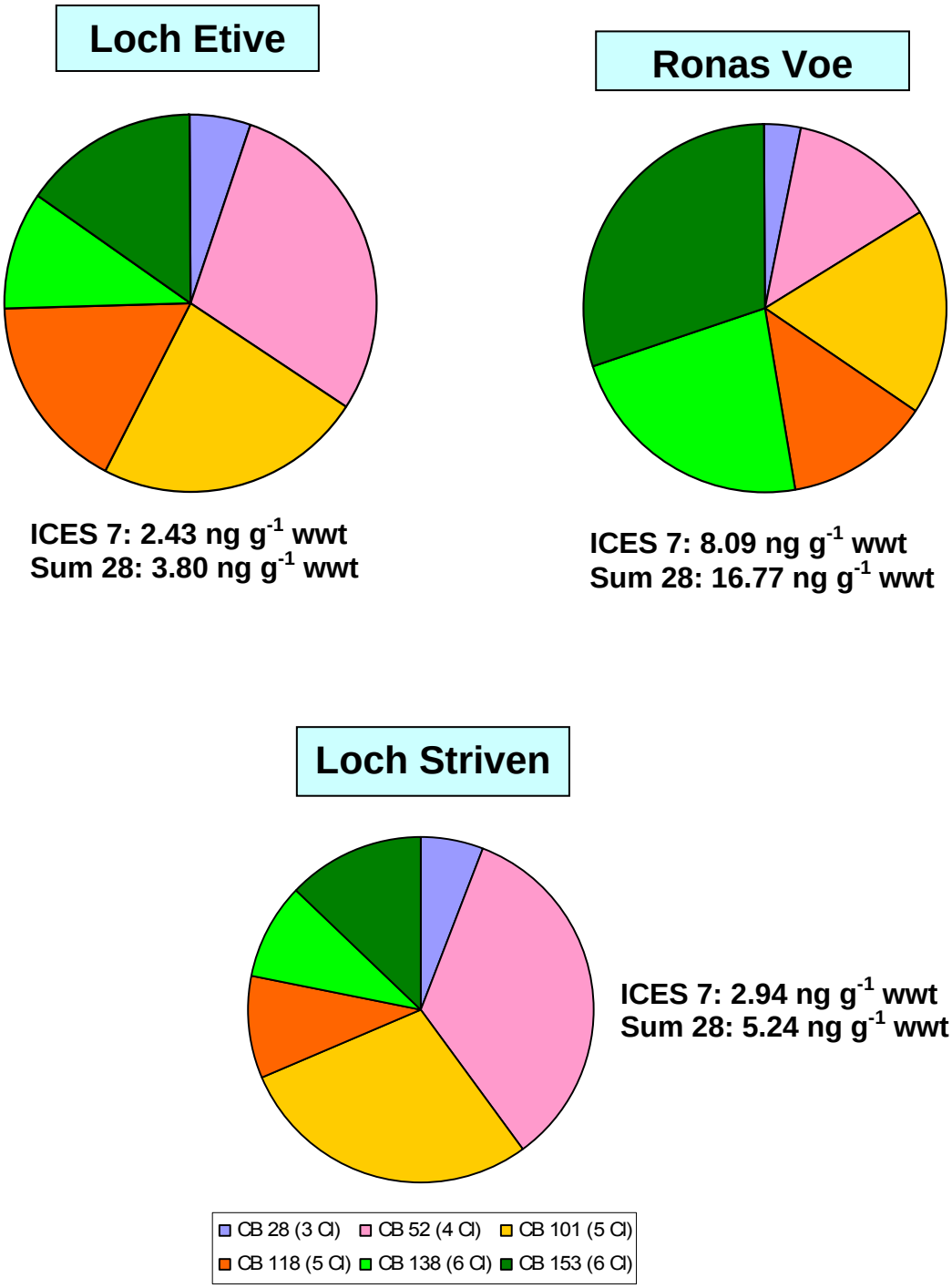


Figure 22 Variation in dieldrin concentration and the sum of DDTs (ng g^{-1} wet weight) in mussels from the samples collected during the period January to March 2006.

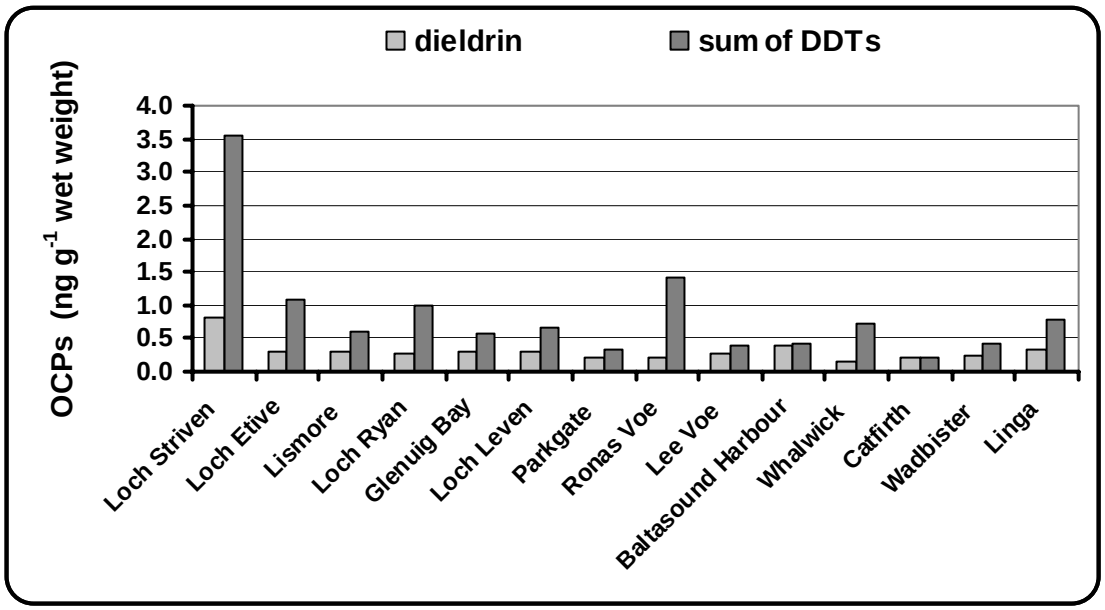


Figure 23 Variation in dieldrin concentration and the sum of DDTs (ng g^{-1} wet weight) in oysters from the samples collected during the period January to March 2006.

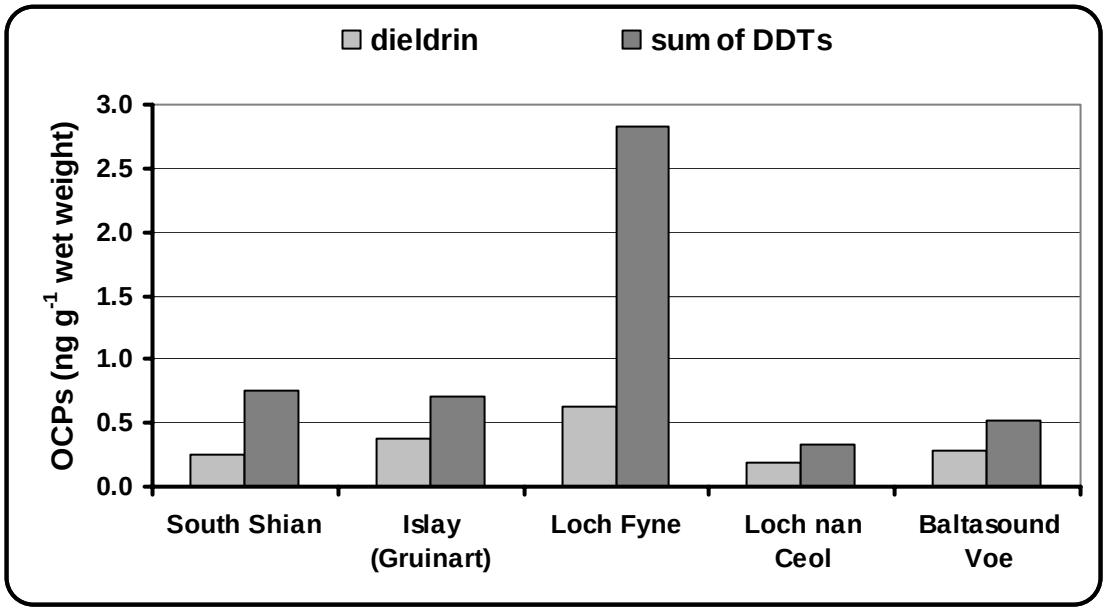


Figure 24 Variation in sum of dieldrin (ng g^{-1} wet weight) concentration in scallop adductor muscle and gonad tissue from the samples collected during the period December 2005 to February 2006.

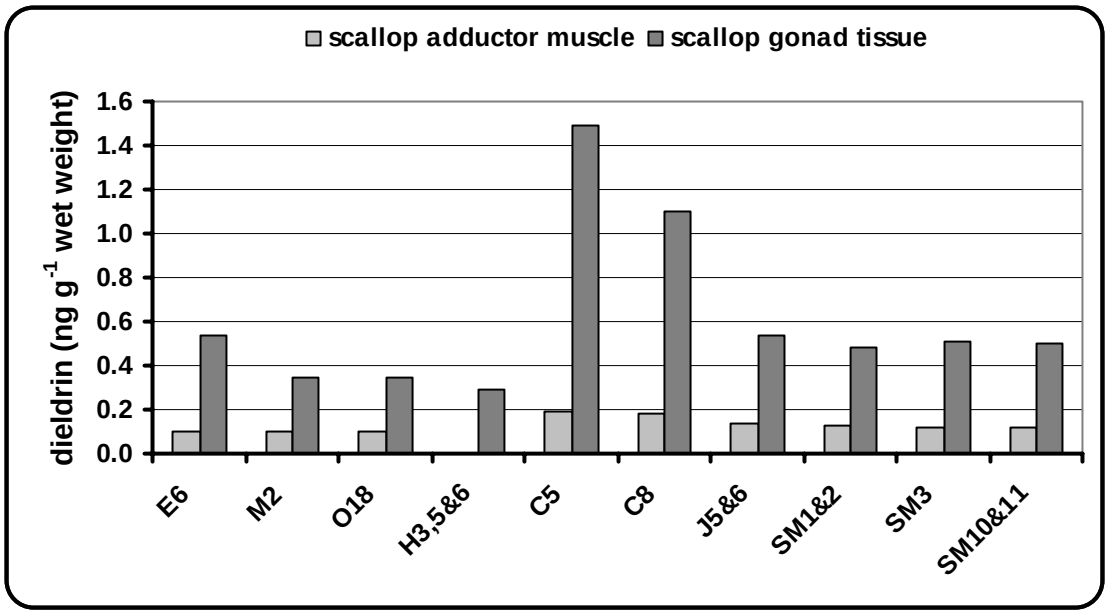
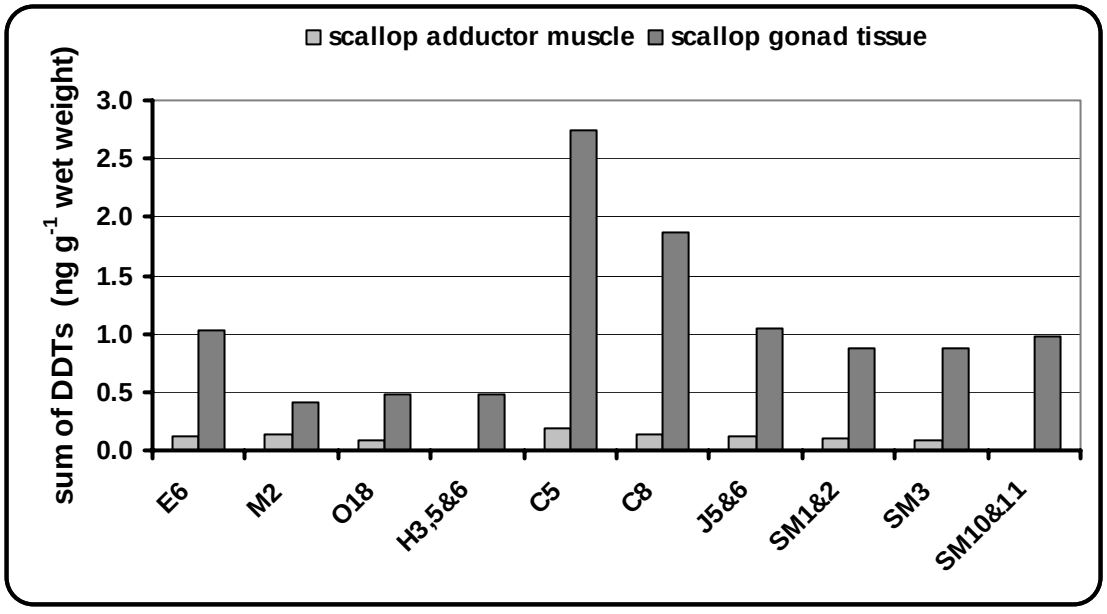


Figure 25 Variation in sum of DDTs (ng g^{-1} wet weight) in scallop adductor muscle and gonad tissue from the samples collected during the period December 2005 to February 2006.



Appendix 1a

PAH concentration (ng g^{-1} wet weight tissue) in mussels sampled in February and March 2006

	Strathclyde: Argyll and Bute			Dumfries and Galloway	**Highland**: Lochaber	
	Loch Striven	Loch Etive	Lismore (Eilean Dubh	Loch Ryan	Glenuig Bay	Loch Leven
Naphthalene	0.7	0.6	0.4	0.8	0.2	0.4
2-Methyl Naphthalene	1.8	0.4	0.3	1.1	0.2	0.2
1-Methyl Naphthalene	1.2	0.3	0.2	0.7	0.2	0.2
C2 Naphthalenes	5.8	1.8	1.1	4.7	0.9	0.8
C3 Naphthalenes	4.9	1.5	0.9	6.3	0.8	0.8
C4 Naphthalenes	5.7	1.2	0.7	11.2	0.4	0.7
TOTAL Naphthalenes	20.1	5.8	3.6	24.8	2.7	3.1
Acenaphthylene (152)	TR	TR	ND	TR	ND	ND
Acenaphthene (154)	0.2	TR	TR	0.4	TR	TR
Fluorene (166)	0.5	0.3	0.3	0.9	0.3	0.3
subtotal	0.7	0.3	0.3	1.3	0.3	0.3
Phenanthrene (178)	2.6	2.0	1.8	7.2	1.6	1.7
Anthracene (178)	0.2	TR	ND	0.8	ND	TR
C1 178	8.5	2.9	2.8	21.0	1.7	3.5
C2 178	19.9	3.7	3.2	35.2	1.5	5.2
C3 178	24.0	2.7	2.9	31.4	1.2	5.2
TOTAL 178	55.2	11.3	10.7	95.6	6.0	15.6
Dibenzothiophene	0.3	0.2	TR	0.8	0.2	TR
C1 Dibenzothiophenes*	2.4	0.6	0.5	3.9	0.4	0.5
C2 Dibenzothiophenes*	12.8	1.2	1.2	13.9	0.8	2.0
C3 Dibenzothiophenes*	13.3	1.0	1.0	13.4	0.5	1.7
TOTAL DBTs	28.8	3.0	2.7	32.0	1.9	4.2
Fluoranthene (202)	8.2	1.7	2.3	10.5	1.4	3.4
Pyrene (202)	9.8	1.5	1.7	11.1	0.9	3.8
C1 202	17.6	3.0	3.8	18.6	2.1	8.5
C2 202	14.0	2.3	2.7	11.8	1.2	5.3
C3 202*	8.8	1.9	1.7	6.8	0.8	2.5
TOTAL 202	58.4	10.4	12.2	58.8	6.4	23.5
Benzo[*c*]phenanthrene (228)	2.5	0.4	0.6	1.6	0.3	1.4
Benz[*a*]anthracene (228)	3.4	1.1	0.7	3.5	0.3	1.9
Chrysene/Triphenylene (228)	10.6	3.0	2.3	8.6	1.4	7.2
Benz[*b*]anthracene (228)*	0.7	ND	ND	0.6	ND	TR
C1 228	10.6	3.2	2.5	8.1	1.3	8.2
C2 228	9.3	4.1	2.4	6.1	1.1	3.4
TOTAL 228	37.1	11.8	8.5	28.5	4.4	22.1
Benzofluoranthenes (252)	16.6	6.3	7.6	8.2	2.9	35.0
Benzo[*e*]pyrene (252)	13.6	2.4	4.3	4.8	1.7	17.6
Benzo[*a*]pyrene (252)	2.2	0.6	0.8	1.8	0.3	5.1
Perylene (252)	1.1	1.1	0.6	0.9	0.2	1.7
C1 252	4.9	2.8	2.6	3.6	1.1	8.3
C2 252*	1.0	0.9	0.6	1.2	0.2	0.7
TOTAL 252	39.4	14.1	16.5	20.5	6.4	68.4
Dibenz[*a,h*]anthracene (278)	0.2	TR	TR	0.2	ND	0.8
5-ring total	39.6	14.1	16.5	20.7	6.4	69.2
Indenopyrene (276)	1.3	0.8	0.9	0.9	0.3	2.5
Benzoperylene (276)	2.7	1.0	1.6	1.7	0.5	4.4
C1 276*	0.4	0.3	0.3	0.4	TR	0.4
C2 276*	TR	ND	ND	TR	TR	0.4
TOTAL 276	4.4	2.1	2.8	3.0	0.8	7.7
Total (2- to 6-ring PAH)	244.3	58.8	57.3	264.7	28.9	145.7

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

Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 1a (cont.)

PAH concentration (ng g^{-1} wet weight tissue) in mussels sampled in January and March 2006

	Locations in Shetland							
	Whalwick	Linga	Catfirth	Wadbister	Lee Voe	Parkgate	Ronas Voe	Baltasound harbour
Naphthalene	2.2	0.2	0.4	0.5	0.4	0.3	0.4	0.5
2-Methyl Naphthalene	2.5	TR	0.2	0.3	0.7	0.3	0.6	0.3
1-Methyl Naphthalene	1.2	TR	0.2	0.2	0.4	0.2	0.4	0.2
C2 Naphthalenes	4.0	0.7	0.8	1.1	4.8	1.2	4.2	1.3
C3 Naphthalenes	2.7	0.7	0.8	1.1	4.9	1.0	4.3	1.1
C4 Naphthalenes	1.9	0.5	0.5	0.7	4.6	0.9	3.9	1.1
TOTAL Naphthalenes	14.5	2.1	2.9	3.9	15.8	3.9	13.8	4.5
Acenaphthylene (152)	0.3	ND	ND	ND	TR	TR	TR	TR
Acenaphthene (154)	TR	TR	TR	TR	TR	TR	TR	TR
Fluorene (166)	0.4	0.4	0.2	0.3	0.6	0.3	0.5	0.5
subtotal	0.7	0.4	0.2	0.3	0.6	0.3	0.5	0.5
Phenanthrene (178)	2.2	1.7	1.3	1.4	3.0	1.7	2.6	2.7
Anthracene (178)	TR	TR	ND	ND	TR	TR	TR	TR
C1 178	6.8	2.0	1.9	2.4	5.3	2.5	4.8	3.7
C2 178	10.9	2.2	1.8	2.6	6.3	3.0	5.6	5.1
C3 178	10.6	1.7	1.4	2.1	4.6	2.4	4.2	4.8
TOTAL 178	30.5	7.6	6.4	8.5	19.2	9.6	17.2	16.3
Dibenzothiophene	0.2	0.2	TR	0.2	0.4	0.2	0.3	0.3
C1 Dibenzothiophenes*	1.4	0.4	0.3	0.4	1.2	0.5	1.0	0.7
C2 Dibenzothiophenes*	5.3	1.1	0.9	1.2	2.7	1.2	2.4	2.2
C3 Dibenzothiophenes*	5.1	0.9	0.6	0.8	1.8	0.9	1.6	1.8
TOTAL DBTs	12.0	2.6	1.8	2.6	6.1	2.8	5.3	5.0
Fluoranthene (202)	2.3	2.2	1.6	1.5	2.4	1.4	2.3	1.7
Pyrene (202)	1.5	1.4	0.9	0.8	1.9	1.4	1.8	2.1
C1 202	4.7	2.2	1.6	1.4	3.4	2.4	3.4	3.3
C2 202	4.8	1.3	1.2	1.2	2.3	1.6	2.2	1.9
C3 202*	3.7	1.1	0.5	1.0	1.2	1.1	1.2	0.9
TOTAL 202	17.0	8.2	5.8	5.9	11.2	7.9	10.9	9.9
Benzo[*c*]phenanthrene (228)	0.6	0.4	0.4	0.3	0.6	0.3	0.6	0.4
Benz[*a*]anthracene (228)	0.5	0.3	0.3	0.2	0.6	0.4	0.6	0.6
Chrysene/Triphenylene (228)	3.0	1.4	1.5	1.4	2.4	1.5	2.5	1.8
Benz[*b*]anthracene (228)*	TR	ND	ND	ND	ND	ND	ND	ND
C1 228	3.3	1.2	1.0	1.0	2.1	1.3	2.0	1.5
C2 228	3.4	1.2	0.7	0.9	1.7	1.1	1.5	1.1
TOTAL 228	10.8	4.5	3.9	3.8	7.4	4.6	7.2	5.4
Benzofluoranthenes (252)	4.9	3.1	2.3	2.7	4.5	3.0	4.3	3.5
Benzo[*e*]pyrene (252)	3.4	1.9	1.3	1.6	2.8	1.5	2.7	1.7
Benzo[*a*]pyrene (252)	0.5	0.4	0.3	0.3	0.5	0.4	0.5	0.6
Perylene (252)	0.3	0.3	0.4	0.2	1.0	0.6	0.9	0.2
C1 252	1.4	0.9	0.6	0.6	1.4	0.9	1.2	1.1
C2 252*	0.5	0.3	0.2	0.2	0.5	0.3	0.3	0.2
TOTAL 252	11.0	6.9	5.1	5.6	10.7	6.7	9.9	7.3
Dibenz[*a,h*]anthracene (278)	TR	ND	ND	ND	TR	ND	ND	TR
5-ring total	11.0	6.9	5.1	5.6	10.7	6.7	9.9	7.3
Indenopyrene (276)	0.7	0.3	0.4	0.3	0.4	0.3	0.4	0.4
Benzoperylene (276)	1.0	0.5	0.4	0.4	0.8	0.5	0.7	0.7
C1 276*	0.2	TR	TR	ND	TR	TR	TR	TR
C2 276*	ND	ND	ND	ND	ND	ND	ND	ND
TOTAL 276	1.9	0.8	0.8	0.7	1.2	0.8	1.1	1.1
Total (2- to 6-ring PAH)	98.4	33.1	26.9	31.3	72.2	36.6	65.9	50.0

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

Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 2

PAH concentration (ng g^{-1} wet weight tissue) in oysters sampled in January to March 2006

	Strathclyde: Argyll and Bute			**Highland**: Lochaber	**Shetland**
	South Shian	Islay (Gruinart)	Loch Fyne	Loch nan Ceol	Baltasound Voe
Naphthalene	0.2	0.3	0.3	0.2	0.3
2-Methyl Naphthalene	TR	0.3	0.4	0.3	0.2
1-Methyl Naphthalene	TR	0.2	0.3	0.2	TR
C2 Naphthalenes	0.8	1.0	1.6	1.2	0.7
C3 Naphthalenes	0.8	0.8	1.6	1.1	0.8
C4 Naphthalenes	0.8	0.7	1.3	1.3	0.7
TOTAL Naphthalenes	2.6	3.3	5.5	4.3	2.7
Acenaphthylene (152)	ND	ND	TR	ND	TR
Acenaphthene (154)	TR	0.2	TR	TR	TR
Fluorene (166)	0.3	0.6	0.4	0.3	0.4
subtotal	0.3	0.8	0.4	0.3	0.4
Phenanthrene (178)	1.7	3.8	1.9	1.4	2.0
Anthracene (178)	ND	ND	TR	ND	TR
C1 178	4.1	3.8	3.8	2.4	4.4
C2 178	6.5	3.3	5.8	3.5	7.6
C3 178	6.6	2.4	7.0	3.6	7.2
TOTAL 178	18.9	13.3	18.5	10.9	21.2
Dibenzothiophene	0.2	0.3	TR	TR	0.2
C1 Dibenzothiophenes*	0.7	0.6	0.8	0.6	0.7
C2 Dibenzothiophenes*	2.0	1.2	2.3	1.4	2.7
C3 Dibenzothiophenes*	1.8	0.7	2.1	1.1	2.1
TOTAL DBTs	4.7	2.8	5.2	3.1	5.7
Fluoranthene (202)	2.7	6.7	7.0	2.2	4.3
Pyrene (202)	2.1	3.5	6.8	1.3	3.5
C1 202	4.7	6.2	10.5	3.5	5.7
C2 202	3.0	2.7	7.3	2.6	2.8
C3 202*	1.5	1.0	4.2	2.0	1.1
TOTAL 202	14.0	20.1	35.8	11.6	17.4
Benzo[*c*]phenanthrene (228)	0.5	0.7	1.5	0.3	0.7
Benz[*a*]anthracene (228)	0.7	0.6	2.4	0.5	0.8
Chrysene/Triphenylene (228)	3.3	4.6	9.0	2.9	4.0
Benz[*b*]anthracene (228)*	ND	ND	0.4	ND	TR
C1 228	2.9	2.6	8.9	3.0	2.4
C2 228	2.1	1.6	7.1	3.1	1.3
TOTAL 228	9.5	10.1	29.3	9.8	9.2
Benzofluoranthenes (252)	6.0	4.6	18.7	6.5	4.9
Benzo[*e*]pyrene (252)	2.9	2.1	8.5	2.2	2.3
Benzo[*a*]pyrene (252)	0.5	0.4	1.7	0.5	0.4
Perylene (252)	0.3	0.3	1.4	0.3	TR
C1 252	1.4	0.9	4.6	1.9	0.8
C2 252*	0.2	TR	0.5	0.3	TR
TOTAL 252	11.3	8.3	35.4	11.7	8.4
Dibenz[*a,h*]anthracene (278)	TR	ND	0.3	TR	TR
5-ring total	11.3	8.3	35.7	11.7	8.4
Indenopyrene (276)	0.3	0.2	0.8	0.3	0.2
Benzoperylene (276)	0.4	0.3	1.3	0.4	0.4
C1 276*	ND	ND	TR	ND	ND
C2 276*	ND	ND	TR	TR	ND
TOTAL 276	0.7	0.5	2.1	0.7	0.6
Total (2- to 6-ring PAH)	62.0	59.2	132.5	52.4	65.6

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

Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 3a

PAH concentration (ng g^{-1} wet weight tissue) in scallop adductor muscle sampled in January and February 2006

	East Coast (E6) sampled in Dec 2005	Moray Firth (M2)	Orkney (O18)	Outer Hebrides (H3,5&6)
Naphthalene	TR	TR	TR	TR
2-Methyl Naphthalene	TR	TR	TR	TR
1-Methyl Naphthalene	TR	TR	TR	TR
C2 Naphthalenes	0.3	TR	0.2	0.5
C3 Naphthalenes	0.3	0.2	0.2	1.2
C4 Naphthalenes	TR	TR	TR	1.8
TOTAL Naphthalenes	0.6	0.2	0.4	3.5
Acenaphthylene (152)	ND	ND	ND	TR
Acenaphthene (154)	ND	ND	ND	ND
Fluorene (166)	TR	ND	TR	TR
subtotal	TR	ND	TR	TR
Phenanthrene (178)	0.6	0.3	0.3	0.7
Anthracene (178)	ND	ND	ND	ND
C1 178	0.8	0.4	0.3	2.6
C2 178	1.0	0.4	0.4	4.4
C3 178	1.9	0.4	0.6	3.8
TOTAL 178	4.3	1.5	1.6	11.5
Dibenzothiophene	TR	ND	ND	TR
C1 Dibenzothiophenes*	TR	TR	TR	0.5
C2 Dibenzothiophenes*	0.3	TR	0.2	1.3
C3 Dibenzothiophenes*	0.3	TR	0.3	1.4
TOTAL DBTs	0.6	TR	0.5	3.2
Fluoranthene (202)	1.1	0.5	0.5	0.9
Pyrene (202)	0.8	0.3	0.3	0.8
C1 202	1.2	0.5	0.5	1.7
C2 202	0.7	0.3	0.5	1.3
C3 202*	0.4	0.2	0.6	0.9
TOTAL 202	4.2	1.8	2.4	5.6
Benzo[*c*]phenanthrene (228)	0.2	TR	TR	TR
Benz[*a*]anthracene (228)	0.4	TR	TR	0.2
Chrysene/Triphenylene (228)	1.5	0.8	0.8	1.1
Benz[*b*]anthracene (228)*	ND	0.7	ND	ND
C1 228	1.4	0.7	0.7	1.3
C2 228	1.5	0.6	1.0	1.4
TOTAL 228	5.0	2.8	2.5	4.0
Benzofluoranthenes (252)	4.5	2.2	1.7	2.2
Benzo[*e*]pyrene (252)	1.5	0.8	0.6	0.8
Benzo[*a*]pyrene (252)	0.7	0.3	0.2	0.3
Perylene (252)	0.5	TR	TR	1.9
C1 252	1.2	0.6	0.5	0.8
C2 252*	0.5	TR	0.4	0.2
TOTAL 252	8.9	3.9	3.4	6.2
Dibenz[*a,h*]anthracene (278)	TR	TR	ND	ND
5-ring total	8.9	3.9	3.4	6.2
Indenopyrene (276)	0.3	0.2	0.2	0.2
Benzoperylene (276)	0.3	TR	TR	0.3
C1 276*	TR	ND	ND	ND
C2 276*	ND	ND	ND	ND
TOTAL 276	0.6	0.2	0.2	0.5
Total (2- to 6-ring PAH)	24.2	10.4	11.0	34.5

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

Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 3a (cont.)

PAH concentration (ng g^{-1} wet weight tissue) in scallop adductor muscle sampled in January and February 2006

	Clyde (C5)	Clyde (C8)	Jura (J5&6)	South Minch (SM1&2)	South Minch (SM3)	South Minch (SM10&11)
Naphthalene	TR	TR	TR	1.0	0.3	0.9
2-Methyl Naphthalene	TR	TR	TR	0.8	0.2	0.6
1-Methyl Naphthalene	TR	TR	ND	0.6	TR	0.4
C2 Naphthalenes	0.2	TR	TR	0.9	0.3	0.6
C3 Naphthalenes	0.3	0.2	0.2	0.5	0.2	0.3
C4 Naphthalenes	0.2	TR	TR	TR	TR	TR
TOTAL Naphthalenes	0.7	0.2	0.2	3.8	1.0	2.8
Acenaphthylene (152)	ND	ND	ND	ND	ND	ND
Acenaphthene (154)	ND	ND	ND	ND	ND	ND
Fluorene (166)	TR	TR	TR	TR	TR	TR
subtotal	TR	TR	TR	TR	TR	TR
Phenanthrene (178)	0.6	0.6	0.5	0.4	0.4	0.5
Anthracene (178)	ND	ND	ND	ND	ND	ND
C1 178	0.9	0.7	0.5	0.4	0.4	0.5
C2 178	1.2	0.8	0.4	0.4	0.5	0.5
C3 178	1.4	0.9	0.5	0.4	0.6	0.5
TOTAL 178	4.1	3.0	1.9	1.6	1.9	2.0
Dibenzothiophene	TR	ND	ND	ND	ND	ND
C1 Dibenzothiophenes*	0.2	TR	TR	TR	TR	TR
C2 Dibenzothiophenes*	0.5	0.3	0.2	TR	TR	0.2
C3 Dibenzothiophenes*	0.5	0.3	TR	TR	TR	TR
TOTAL DBTs	1.2	0.6	0.2	TR	TR	0.2
Fluoranthene (202)	2.2	1.5	1.1	0.7	0.8	1.0
Pyrene (202)	2.2	1.2	0.6	0.5	0.5	0.5
C1 202	3.0	1.8	1.0	0.8	1.0	1.1
C2 202	4.5	1.2	0.6	0.6	0.8	0.7
C3 202*	1.7	0.8	0.4	0.4	0.5	1.7
TOTAL 202	13.6	6.5	3.7	3.0	3.6	5.0
Benzo[*c*]phenanthrene (228)	0.5	0.3	0.2	0.2	0.2	0.2
Benz[*a*]anthracene (228)	1.3	0.6	0.3	0.3	0.3	0.3
Chrysene/Triphenylene (228)	4.1	2.6	1.5	1.2	1.3	1.5
Benz[*b*]anthracene (228)*	TR	ND	ND	ND	ND	ND
C1 228	3.8	2.2	1.3	1.3	1.5	1.5
C2 228	4.5	2.5	1.4	1.5	1.9	1.7
TOTAL 228	14.2	8.2	4.7	4.5	5.2	5.2
Benzofluoranthenes (252)	9.9	6.2	3.8	3.9	4.7	4.6
Benzo[*e*]pyrene (252)	3.1	2.1	1.6	1.8	1.9	1.8
Benzo[*a*]pyrene (252)	1.9	0.9	0.5	0.6	0.6	0.5
Perylene (252)	0.8	0.4	0.3	0.4	0.4	0.4
C1 252	3.3	1.7	1.2	1.3	1.5	1.4
C2 252*	0.6	0.3	0.2	0.2	0.4	0.4
TOTAL 252	19.6	11.6	7.6	8.2	9.5	9.1
Dibenz[*a,h*]anthracene (278)	0.2	TR	TR	TR	TR	TR
5-ring total	19.8	11.6	7.6	8.2	9.5	9.1
Indenopyrene (276)	0.7	0.4	0.3	0.3	0.4	0.3
Benzoperylene (276)	0.7	0.4	0.3	0.4	0.4	0.3
C1 276*	TR	TR	TR	TR	TR	TR
C2 276*	TR	ND	ND	ND	TR	ND
TOTAL 276	1.4	0.8	0.6	0.7	0.8	0.6
Total (2- to 6-ring PAH)	55.0	30.9	18.9	21.8	22.0	24.9

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

Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 3b

PAH concentration (ng g^{-1} wet weight tissue) in scallop gonad tissue sampled in January and February 2006

	East Coast (E6) sampled in Dec 2005	Moray Firth (M2)	Orkney (O18)	Outer Hebrides (H3,5&6)
Naphthalene	0.5	0.3	0.7	0.5
2-Methyl Naphthalene	0.6	0.4	1.3	0.6
1-Methyl Naphthalene	0.4	0.3	0.9	0.3
C2 Naphthalenes	2.0	1.2	4.0	3.6
C3 Naphthalenes	2.4	1.7	3.3	8.9
C4 Naphthalenes	0.8	0.9	1.6	12.2
TOTAL Naphthalenes	6.7	4.8	11.8	26.1
Acenaphthylene (152)	TR	ND	ND	0.2
Acenaphthene (154)	TR	TR	TR	TR
Fluorene (166)	0.7	0.4	0.7	0.6
subtotal	0.7	0.4	0.7	0.8
Phenanthrene (178)	4.5	1.9	1.9	3.4
Anthracene (178)	0.2	ND	TR	0.2
C1 178	5.6	2.5	2.3	12.8
C2 178	8.0	3.4	3.1	21.9
C3 178	7.7	2.8	3.8	17.4
TOTAL 178	26.0	10.6	11.1	55.7
Dibenzothiophene	0.4	0.2	0.3	0.4
C1 Dibenzothiophenes*	1.0	0.4	0.6	2.5
C2 Dibenzothiophenes*	3.3	1.4	1.7	8.1
C3 Dibenzothiophenes*	2.2	0.7	1.7	5.8
TOTAL DBTs	6.9	2.7	4.3	16.8
Fluoranthene (202)	8.9	3.3	2.7	3.7
Pyrene (202)	5.9	1.6	1.4	3.2
C1 202	9.5	3.1	3.4	7.2
C2 202	5.5	1.9	2.4	5.0
C3 202*	2.9	1.4	2.5	3.1
TOTAL 202	32.7	11.3	12.4	22.2
Benzo[*c*]phenanthrene (228)	1.5	0.5	0.4	0.5
Benz[*a*]anthracene (228)	4.0	1.0	0.9	1.0
Chrysene/Triphenylene (228)	9.9	4.3	3.8	3.9
Benz[*b*]anthracene (228)*	0.4	ND	ND	TR
C1 228	8.3	3.2	3.2	3.9
C2 228	7.1	3.1	3.7	3.5
TOTAL 228	31.2	12.1	12.0	12.8
Benzofluoranthenes (252)	20.5	9.6	6.6	5.7
Benzo[*e*]pyrene (252)	4.4	2.0	1.4	1.4
Benzo[*a*]pyrene (252)	2.6	0.8	0.6	0.6
Perylene (252)	1.2	0.2	0.3	2.5
C1 252	3.6	1.7	1.3	1.3
C2 252*	0.6	0.3	0.3	0.2
TOTAL 252	32.9	14.6	10.5	11.7
Dibenz[*a,h*]anthracene (278)	0.3	TR	TR	TR
5-ring total	33.2	14.6	10.5	11.7
Indenopyrene (276)	0.7	0.4	0.2	0.2
Benzoperylene (276)	0.6	0.3	0.2	0.3
C1 276*	TR	ND	ND	ND
C2 276*	ND	TR	TR	TR
TOTAL 276	1.3	0.7	0.4	0.5
Total (2- to 6-ring PAH)	138.7	57.2	63.2	146.6

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

Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 3b (cont.)

PAH concentration (ng g^{-1} wet weight tissue) in scallop gonad tissue sampled in January and February 2006

	Clyde (C5)	Clyde (C8)	Jura (J5&6)	South Minch (SM1&2)	South Minch (SM3)	South Minch (SM10&11)
Naphthalene	0.4	0.5	0.6	9.8	1.9	6.5
2-Methyl Naphthalene	0.4	0.4	0.5	9.5	1.6	6.2
1-Methyl Naphthalene	0.3	0.3	0.4	5.3	0.9	3.4
C2 Naphthalenes	1.3	1.4	1.6	7.5	2.0	4.8
C3 Naphthalenes	1.9	1.8	1.7	2.5	1.3	1.8
C4 Naphthalenes	1.5	1.0	0.7	0.7	0.6	0.6
TOTAL Naphthalenes	5.8	5.4	5.5	35.3	8.3	23.3
Acenaphthylene (152)	TR	TR	TR	TR	TR	TR
Acenaphthene (154)	0.2	0.2	TR	TR	TR	TR
Fluorene (166)	0.8	0.8	0.6	0.5	0.5	0.5
subtotal	1.0	1.0	0.6	0.5	0.5	0.5
Phenanthrene (178)	4.4	4.2	3.3	2.5	2.9	2.5
Anthracene (178)	0.3	TR	TR	ND	ND	ND
C1 178	5.5	4.4	3.1	2.3	2.7	2.0
C2 178	8.7	6.4	3.6	3.0	3.8	2.7
C3 178	9.7	7.1	3.5	3.1	3.8	2.7
TOTAL 178	28.6	22.1	13.5	10.9	13.2	9.9
Dibenzothiophene	0.4	0.4	0.3	0.2	0.2	0.2
C1 Dibenzothiophenes*	1.0	0.7	0.4	0.3	0.5	0.2
C2 Dibenzothiophenes*	3.2	2.3	1.2	0.9	1.7	0.8
C3 Dibenzothiophenes*	3.1	2.0	0.9	0.7	0.7	0.7
TOTAL DBTs	7.7	5.4	2.8	2.1	3.1	1.9
Fluoranthene (202)	14.8	10.9	6.9	5.0	5.5	5.0
Pyrene (202)	13.6	7.9	3.7	2.7	3.0	2.6
C1 202	17.6	12.4	6.8	5.4	6.1	5.5
C2 202	11.7	7.7	4.4	3.8	3.9	3.3
C3 202*	7.9	4.9	2.5	2.7	2.9	2.2
TOTAL 202	65.6	43.8	24.3	19.6	21.4	18.6
Benzo[*c*]phenanthrene (228)	2.9	2.0	1.1	0.9	0.9	0.9
Benz[*a*]anthracene (228)	8.3	4.6	2.2	2.0	2.0	1.7
Chrysene/Triphenylene (228)	21.2	14.2	7.8	6.8	6.9	6.4
Benz[*b*]anthracene (228)*	1.2	0.3	0.2	TR	TR	TR
C1 228	17.7	12.0	6.6	6.7	6.9	6.1
C2 228	18.8	11.4	5.7	6.5	7.5	5.5
TOTAL 228	70.1	44.5	23.6	22.9	24.2	20.6
Benzofluoranthenes (252)	42.2	27.7	15.5	17.4	18.2	15.4
Benzo[*e*]pyrene (252)	10.5	6.5	3.7	4.0	4.0	3.7
Benzo[*a*]pyrene (252)	5.8	2.9	1.5	1.6	1.6	1.3
Perylene (252)	1.9	1.0	0.8	0.8	0.7	0.7
C1 252	7.6	5.4	3.5	4.0	4.1	3.2
C2 252*	0.9	0.7	0.6	0.6	0.6	0.5
TOTAL 252	68.9	44.2	25.6	28.4	29.2	24.8
Dibenz[*a,h*]anthracene (278)	0.4	0.3	0.2	0.3	0.3	0.2
5-ring total	69.3	44.5	25.8	28.7	29.5	25.0
Indenopyrene (276)	1.0	0.7	0.5	0.6	0.6	0.5
Benzoperylene (276)	0.9	0.6	0.5	0.6	0.5	0.5
C1 276*	TR	TR	TR	ND	TR	TR
C2 276*	TR	TR	TR	TR	TR	ND
TOTAL 276	1.9	1.3	1.0	1.2	1.1	1.0
Total (2- to 6-ring PAH)	250.0	168.0	97.1	121.2	101.3	100.8

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

Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 4

Trace metal concentration (µg g^{-1} wet weight tissue) in mussels, oysters and scallops sampled in January to March 2006

Mussels	Cr	Mn	Ni	Co	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
Strathclyde: Argyll and Bute												
Loch Striven	0.36	4.80	0.31	0.06	1.70	10.90	1.91	0.54	0.01	<LoD	0.02	0.27
Loch Etive	0.38	3.70	0.48	<LoD	0.83	9.90	1.04	0.36	ND	0.08	0.03	0.11
Lismore	0.61	4.70	0.18	<LoD	1.07	10.40	2.25	0.58	ND	0.09	<LoD	0.20
Highland: Lochaber												
Glenuig Bay	0.48	1.60	0.12	<LoD	0.74	11.30	1.61	0.46	0.01	0.08	<LoD	0.15
Loch Leven	0.18	1.70	<LoD	<LoD	0.88	7.90	1.77	0.41	0.01	0.09	0.02	0.10
Dumfries and Galloway												
Loch Ryan	0.97	3.92	0.86	0.20	1.30	11.50	1.88	0.42	0.07	0.13	0.04	0.61
Shetland												
Parkgate	0.23	0.70	0.23	<LoD	0.93	19.70	1.56	0.30	ND	0.09	<LoD	0.19
Ronas Voe	0.44	0.90	0.13	<LoD	1.20	15.00	1.72	0.39	ND	0.10	<LoD	0.18
Lee Voe	0.23	0.98	0.18	<LoD	1.21	14.60	1.83	0.36	0.13	0.10	0.02	0.18
Baltasound harbour	0.46	0.75	0.64	0.06	1.37	12.30	1.71	0.34	1.14	0.17	<LoD	0.15
Whalwick	0.21	0.97	0.13	<LoD	1.25	20.90	2.38	0.46	0.02	0.09	0.02	0.21
Catfirth	0.40	1.01	0.27	<LoD	1.06	22.80	2.01	0.39	0.02	0.13	<LoD	0.23
Wadbister	0.30	0.90	0.12	<LoD	1.26	20.40	1.91	0.40	0.02	0.12	<LoD	0.27
Linga	0.19	1.34	0.12	<LoD	1.19	20.40	1.98	0.41	0.01	0.11	<LoD	0.24

Oysters	Cr	Mn	Ni	Co	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
Strathclyde: Argyll and Bute												
South Shian	0.27	2.53	<LoD	<LoD	13.10	146.0	2.19	0.25	0.62	0.17	0.03	<LoD
Islay (Gruinart)	0.16	2.95	1.21	<LoD	5.37	95.60	2.40	0.29	0.78	0.10	0.02	0.12
Loch Fyne	0.11	2.11	0.12	<LoD	16.00	209.0	4.43	0.33	0.94	0.32	0.03	<LoD
Highland: Lochaber												
Loch nan Ceol	0.51	2.01	0.14	<LoD	9.21	195.0	2.98	0.31	0.67	0.20	0.02	<LoD
Shetland												
Baltasound Voe	0.27	1.31	0.44	<LoD	5.10	111.0	2.46	0.25	0.60	0.29	0.03	<LoD

Scallop adductor muscle	Cr	Mn	Ni	Co	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
East Coast (E6)	0.09	5.52	<LoD	<LoD	0.31	11.10	2.19	0.33	0.05	0.18	<LoD	<LoD
Moray Firth (M2)	0.05	3.47	<LoD	<LoD	<LoD	12.20	2.58	0.34	0.05	0.24	0.02	<LoD
Orkney (O18)	0.07	5.12	<LoD	<LoD	0.20	13.90	1.98	0.25	0.20	0.21	<LoD	<LoD
Outer Hebrides (H3,5&6)	0.03	1.60	<LoD	<LoD	0.20	11.80	1.74	0.18	ND	0.26	<LoD	<LoD
Clyde (C5)	0.05	7.18	<LoD	<LoD	0.22	13.00	1.67	0.29	0.06	0.17	0.03	<LoD
Clyde (C8)	0.10	6.07	<LoD	<LoD	0.21	12.10	1.63	0.27	0.03	0.18	0.02	<LoD
Jura (J5&6)	0.06	3.13	<LoD	<LoD	0.27	11.50	1.55	<LoD	1.11	0.18	<LoD	<LoD
South Minch (SM1&2)	0.11	7.80	<LoD	<LoD	0.20	11.90	1.74	0.30	0.04	0.30	<LoD	<LoD
South Minch (SM3)	0.09	5.50	<LoD	<LoD	0.18	11.70	2.44	0.34	0.02	0.25	<LoD	<LoD
South Minch (SM10&11)	0.09	3.40	<LoD	<LoD	0.18	11.00	1.92	0.24	0.02	0.18	<LoD	<LoD

Scallop gonad tissue	Cr	Mn	Ni	Co	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
East Coast (E6)	0.43	13.10	0.12	<LoD	3.02	31.60	2.44	0.93	0.19	0.26	<LoD	0.12
Moray Firth (M2)	0.72	12.91	0.16	<LoD	2.50	36.10	2.98	0.91	0.24	0.77	0.02	0.10
Orkney (O18)	0.38	16.55	0.16	<LoD	2.32	32.30	2.40	0.67	1.30	0.41	<LoD	0.12
Outer Hebrides (H3,5&6)	0.42	8.68	0.12	<LoD	1.96	29.30	2.19	0.58	0.19	0.49	<LoD	0.15
Clyde (C5)	0.34	10.31	<LoD	<LoD	2.69	32.70	2.46	0.70	0.40	0.12	<LoD	0.11
Clyde (C8)	0.29	8.00	0.12	<LoD	2.65	30.50	2.19	0.71	0.20	0.12	<LoD	0.13
Jura (J5&6)	0.25	18.60	0.14	<LoD	2.78	34.20	1.92	0.62	0.13	0.26	<LoD	0.26
South Minch (SM1&2)	0.37	17.50	0.16	<LoD	2.54	32.70	1.74	0.80	0.08	0.36	0.02	0.13
South Minch (SM3)	0.62	12.16	0.19	<LoD	3.20	34.80	4.43	0.95	0.32	0.25	0.02	0.24
South Minch (SM10&11)	0.39	14.80	0.14	<LoD	2.47	31.80	1.74	0.74	0.29	0.27	0.02	0.12

LoD = Limit of Detection (Co, 0.06 µg g^{-1}; Ni, 0.11µg g^{-1}; Se, 0.18 µg g^{-1}; Cd, 0.08 µg g^{-1}; Hg, 0.02 µg g^{-1}; Pb, 0.09 µg g^{-1} wet weight)
ND=not detected. Determination of Ag is currently not UKAS accredited and limits of detection have not been established

Appendix 5a

Chlorobiphenyl concentrations (ng g^{-1} wet weight) in mussels sampled in February and March 2006

	Strathclyde: Argyll and Bute			Dumfries and Galloway	**Highland**: Lochaber	
Determinand	Loch Striven	Loch Etive	Lismore (Eilean Dubh)	Loch Ryan	Glenuig Bay	Loch Leven
CB 31*	0.16	0.11	0.09	0.13	TR	TR
CB 28	0.17	0.13	0.10	0.15	TR	TR
CB 52	1.01	0.70	0.72	0.67	0.63	0.36
CB 49	0.20	0.13	0.11	0.17	0.10	TR
CB 44	0.30	0.22	0.24	0.22	0.16	0.12
CB 74	0.11	TR	0.10	0.10	TR	TR
CB 70	0.40	0.27	0.35	0.26	0.30	0.27
CB 101	0.84	0.57	0.75	0.78	0.63	0.61
CB 99*	0.28	TR	0.23	0.32	0.20	0.18
CB 97*	0.17	0.11	0.21	0.15	0.16	0.14
CB 110	0.42	0.33	0.53	0.51	0.40	0.42
CB 149	0.25	0.20	0.31	0.53	0.23	0.24
CB 118	0.28	0.41	1.17	0.46	0.51	0.39
CB 153	0.38	0.37	0.44	1.03	0.28	0.30
CB 132*	TR	TR	0.14	0.21	0.10	0.10
CB 105	TR	TR	0.10	0.13	TR	TR
CB 137*	TR	TR	TR	TR	TR	TR
CB 138	0.26	0.25	0.35	0.89	0.25	0.24
CB 158	TR	TR	TR	TR	TR	TR
CB 187	TR	TR	0.14	0.27	TR	TR
CB 183*	TR	TR	TR	TR	TR	TR
CB 128	TR	TR	TR	0.13	TR	TR
CB 156	TR	TR	TR	TR	TR	TR
CB 157*	ND	ND	TR	TR	ND	TR
CB 180	TR	TR	TR	TR	TR	TR
CB 170	ND	ND	TR	ND	TR	TR
CB 189*	ND	ND	ND	ND	ND	ND
CB 194	ND	ND	ND	TR	ND	ND
LoQ	0.10	0.10	0.08	0.09	0.08	0.08
∑ ICES 7	2.94	2.43	3.54	3.97	2.30	1.90
TOTAL	5.24	3.80	6.10	7.11	3.95	3.37

ND = not detected; TR = below limit of quantitation (LoQ)
Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 5a (cont.)

Chlorobiphenyl concentrations (ng g^{-1} wet weight) in mussels sampled in January and March 2006

	Shetland Islands							
Determinand	Parkgate	Ronas Voe	Lee Voe	Baltasound Harbour	Whalwick	Catfirth	Wadbister	Vail Sound (Linga)
CB 31*	0.18	0.21	0.16	0.15	0.21	0.09	0.13	0.15
CB 28	0.20	0.26	0.18	ND	0.24	0.11	0.16	0.15
CB 52	1.68	1.07	0.83	0.42	1.68	0.62	0.70	0.94
CB 49	0.36	0.36	0.19	0.10	0.40	0.13	0.15	0.21
CB 44	0.58	0.43	0.24	0.15	0.61	0.23	0.27	0.28
CB 74	0.20	0.30	0.13	TR	0.24	0.10	0.11	0.11
CB 70	0.75	0.71	0.37	0.24	0.83	0.37	0.37	0.40
CB 101	1.52	1.46	0.69	0.46	1.79	0.70	0.81	0.81
CB 99*	0.50	0.70	0.21	0.14	0.59	0.23	0.21	0.25
CB 97*	0.35	0.39	0.14	TR	0.41	0.17	0.17	0.17
CB 110	0.98	1.13	0.37	0.28	1.10	0.49	0.52	0.47
CB 149	0.47	1.44	0.20	0.14	0.75	0.25	0.28	0.26
CB 118	0.59	1.03	0.26	0.21	1.04	0.31	0.35	0.31
CB 153	0.50	2.45	0.36	0.35	1.15	0.34	0.42	0.42
CB 132*	0.22	0.50	TR	TR	0.34	0.11	0.12	0.10
CB 105	0.17	0.37	TR	TR	0.30	TR	0.10	TR
CB 137*	TR	TR	TR	TR	TR	TR	TR	TR
CB 138	0.45	1.83	0.26	0.25	1.09	0.27	0.31	0.31
CB 158	TR	0.16	TR	TR	0.11	TR	TR	TR
CB 187	TR	1.19	TR	TR	0.17	TR	TR	TR
CB 183*	TR	0.39	TR	TR	TR	TR	TR	TR
CB 128	TR	0.28	TR	TR	0.21	TR	TR	TR
CB 156	TR	0.11	TR	TR	TR	TR	TR	TR
CB 157*	ND	TR	ND	ND	TR	ND	ND	ND
CB 180	TR	ND	TR	TR	TR	TR	TR	TR
CB 170	ND	TR	ND	ND	ND	TR	TR	ND
CB 189*	ND	ND	ND	ND	ND	ND	ND	ND
CB 194	ND	TR	ND	ND	ND	ND	ND	ND
LoQ	0.09	0.10	0.09	0.09	0.10	0.09	0.08	0.09
∑ ICES 7	4.94	8.09	2.57	1.70	7.00	2.36	2.75	2.94
TOTAL	9.71	16.77	4.58	2.90	13.25	4.53	5.18	5.34

ND = not detected; TR = below limit of quantitation (LoQ)

Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 5b

Chlorobiphenyl concentrations (ng g^{-1} wet weight) in oysters sampled in February and March 2006

	Strathclyde: Argyll and Bute			Highland: Lochaber	Shetland
Determinand	South Shian	Islay (Gruinart)	Loch Fyne	Loch nan Ceol	Baltasound Voe
CB 31*	0.08	0.14	0.14	0.12	0.14
CB 28	0.08	0.13	0.15	0.11	0.14
CB 52	0.46	0.88	0.99	0.78	0.94
CB 49	0.10	0.19	0.25	0.16	0.20
CB 44	0.18	0.31	0.37	0.21	0.34
CB 74	TR	0.13	0.16	TR	0.14
CB 70	0.23	0.49	0.50	0.30	0.50
CB 101	0.52	1.05	1.06	0.65	0.88
CB 99*	0.15	0.34	0.38	0.22	0.31
CB 97*	0.11	0.26	0.24	0.12	0.20
CB 110	0.31	0.73	0.71	0.32	0.61
CB 149	0.22	0.43	0.55	0.22	0.32
CB 118	0.52	1.90	0.53	0.34	0.42
CB 153	0.36	0.64	0.93	0.33	0.46
CB 132*	TR	0.20	0.19	TR	0.14
CB 105	TR	0.15	0.15	TR	0.11
CB 137*	TR	0.10	TR	TR	TR
CB 138	0.21	0.47	0.48	0.19	0.30
CB 158	TR	TR	TR	TR	TR
CB 187	0.12	0.15	0.35	TR	0.10
CB 183*	TR	TR	TR	TR	TR
CB 128	TR	TR	TR	TR	TR
CB 156	TR	TR	TR	TR	TR
CB 157*	ND	TR	TR	ND	ND
CB 180	TR	TR	TR	TR	TR
CB 170	TR	TR	TR	ND	TR
CB 189*	ND	ND	ND	ND	ND
CB 194	ND	ND	ND	ND	ND
LoQ	0.08	0.09	0.08	0.10	0.09
∑ ICES 7	2.15	5.07	4.14	2.40	3.15
TOTAL	3.66	8.69	8.13	4.07	6.26

ND = not detected; TR = below limit of quantitation (LoQ)

Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 5c

Chlorobiphenyl concentrations (ng g^{-1} wet weight) in scallop adductor muscle sampled in February and March 2006

Determinand	East Coast (E6) [1]	Moray Firth (M2)	Orkney (O18)	Outer Hebrides (H3,5&6)	Clyde (C5)	Clyde (C8)	Jura (J5&6)	South Minch (SM1&2)	South Minch (SM3)	South Minch (SM10&11)
CB 31*	0.13	0.11	0.09	TR	0.10	0.10	0.09	TR	0.09	0.11
CB 28	0.16	0.13	0.12	0.11	0.12	0.13	0.12	0.10	0.09	0.12
CB 52	0.95	1.07	0.72	0.69	0.83	0.66	0.68	0.56	0.45	0.85
CB 49	0.19	0.18	0.12	0.11	0.14	0.11	0.11	0.10	TR	0.16
CB 44	0.32	0.35	0.23	0.20	0.28	0.21	0.20	0.20	0.13	0.26
CB 74	0.12	0.11	0.09	TR	0.10	0.10	0.08	TR	TR	0.09
CB 70	0.47	0.43	0.29	0.26	0.38	0.32	0.30	0.28	0.17	0.32
CB 101	0.84	0.94	0.60	0.63	0.80	0.59	0.53	0.54	0.43	0.64
CB 99*	0.28	0.26	0.17	0.17	0.23	0.17	0.16	0.14	0.11	0.18
CB 97*	0.18	0.20	0.13	0.13	0.17	0.13	0.12	0.11	0.09	0.12
CB 110	0.50	0.59	0.33	0.31	0.50	0.31	0.35	0.31	0.23	0.34
CB 149	0.23	0.26	0.15	0.16	0.27	0.19	0.19	0.17	0.13	0.15
CB 118	0.31	0.31	0.19	0.24	0.30	0.34	0.44	TR	ND	ND
CB 153	0.23	0.19	0.12	0.15	0.29	0.19	0.14	0.13	0.13	0.15
CB 132*	0.12	0.12	TR	TR	0.12	TR	TR	TR	TR	TR
CB 105	0.09	TR	TR	TR	0.09	TR	TR	TR	TR	TR
CB 137*	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR
CB 138	0.23	0.19	0.12	0.14	0.27	0.17	0.15	ND	0.12	0.13
CB 158	TR	TR	TR	TR	TR	TR	TR	0.33	TR	TR
CB 187	TR	TR	TR	TR	0.12	TR	TR	TR	TR	TR
CB 183*	TR	TR	ND	ND	TR	TR	ND	TR	TR	TR
CB 128	TR	TR	ND	TR	TR	TR	TR	TR	TR	TR
CB 156	TR	TR	TR	TR	TR	ND	TR	TR	TR	TR
CB 157*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CB 180	TR	ND	TR	TR	TR	TR	TR	TR	TR	TR
CB 170	TR	ND	ND	ND	TR	TR	TR	TR	TR	TR
CB 189*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CB 194	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LoQ	0.08	0.09	0.08	0.09	0.08	0.08	0.08	0.08	0.08	0.08
∑ ICES 7	2.71	2.82	1.88	1.94	2.61	2.08	2.07	1.33	1.23	1.89
TOTAL	5.33	5.44	3.47	3.27	5.11	3.74	3.67	2.97	2.18	3.62

[1] East Coast (E6) sampled in Dec 2005

ND = not detected; TR = below limit of quantitation (LoQ)

Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 5d

Chlorobiphenyl concentrations (ng g^{-1} wet weight) in scallop gonad tissue sampled in February and March 2006

Determinand	East Coast (E6) [1]	Moray Firth (M2)	Orkney (O18)	Outer Hebrides (H3,5&6)	Clyde (C5)	Clyde (C8)	Jura (J5&6)	South Minch (SM1&2)	South Minch (SM3)	South Minch (SM10&11)
CB 31*	TR	TR	0.09	0.14	0.17	TR	0.09	TR	0.11	TR
CB 28	0.12	TR	0.10	0.15	0.20	0.14	0.09	TR	0.12	0.10
CB 52	0.68	0.51	0.72	1.15	1.39	0.66	0.63	0.56	0.56	0.09
CB 49	0.14	TR	0.14	0.23	0.26	0.15	0.11	TR	TR	TR
CB 44	0.28	0.22	0.27	0.49	0.59	0.32	0.28	0.26	0.26	0.11
CB 74	TR	TR	TR	0.13	0.25	0.14	TR	TR	TR	TR
CB 70	0.37	0.26	0.35	0.57	0.83	0.39	0.31	0.31	0.31	TR
CB 101	0.86	0.53	0.58	1.07	1.60	0.70	0.54	0.63	0.59	0.10
CB 99*	0.17	0.17	0.21	0.33	0.66	0.32	0.20	0.23	0.21	TR
CB 97*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CB 110	0.58	0.47	0.39	0.79	1.31	0.61	0.38	0.50	0.46	0.12
CB 149	0.43	0.22	0.16	0.30	1.04	0.49	0.17	0.20	0.19	TR
CB 118	0.50	0.34	0.25	0.83	1.03	1.44	5.01	1.77	1.90	1.30
CB 153	0.98	0.38	0.23	0.45	1.79	0.94	0.46	0.49	0.51	0.32
CB 132*	0.17	0.13	TR	0.15	0.42	0.19	TR	0.11	TR	TR
CB 105	0.14	TR	TR	0.13	0.36	0.18	TR	TR	TR	TR
CB 137*	TR	TR	TR	TR	TR	TR	0.15	TR	TR	TR
CB 138	0.85	0.31	0.15	0.32	1.30	0.72	0.33	0.35	0.37	0.20
CB 158	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR
CB 187	0.26	TR	TR	0.09	0.85	0.47	0.17	0.17	0.19	0.14
CB 183*	TR	ND	ND	ND	0.19	TR	TR	TR	TR	ND
CB 128	0.16	ND	TR	TR	0.22	0.13	TR	TR	TR	TR
CB 156	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR
CB 157*	TR	ND	ND	TR	TR	TR	TR	TR	TR	TR
CB 180	0.20	TR	TR	TR	0.48	0.25	0.10	TR	TR	TR
CB 170	TR	TR	TR	TR	0.23	0.14	TR	TR	TR	TR
CB 189*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CB 194	ND	ND	ND	ND	TR	TR	ND	ND	ND	ND
LoQ	0.11	0.10	0.09	0.09	0.12	0.12	0.09	0.11	0.11	0.08
∑ ICES 7	4.20	2.06	2.04	3.97	7.79	4.85	7.16	3.80	4.05	2.10
TOTAL	6.91	3.54	3.63	7.32	15.19	8.37	9.02	5.59	5.78	2.47

[1] East Coast (E6) sampled in Dec

ND = not detected; TR = below limit of quantitation (LoQ)

Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 6a

Organochlorine pesticide concentrations (ng g^{-1} wet weight) in mussels sampled in January and March 2006

	Strathclyde: Argyll and Bute			Dumfries and Galloway	**Highland**: Lochaber	
Determinand	Loch Striven	Loch Etive	Lismore (Eilean Dubh)	Loch Ryan	Glenuig Bay	Loch Leven
HCB	TR	TR	TR	TR	TR	TR
Aldrin	ND	ND	ND	ND	ND	ND
α-HCH	TR	TR	ND	TR	ND	ND
γ-HCH	0.11	TR	TR	TR	TR	TR
Heptachlor	TR	TR	TR	TR	ND	ND
α-Chlordene *	0.22	ND	TR	TR	TR	TR
γ-Chlordene *	ND	ND	TR	ND	ND	ND
Heptachlor Epoxide*	TR	TR	TR	TR	TR	TR
Oxychlordane	TR	TR	ND	TR	ND	TR
γ-Chlordane	TR	TR	ND	TR	ND	ND
o,p'-DDE	0.18	TR	TR	0.09	TR	TR
p,p'-DDE	0.33	0.60	0.35	0.49	0.56	0.19
α-Chlordane	0.20	0.10	TR	TR	TR	TR
T-Nonachlor	0.10	TR	TR	TR	TR	TR
Dieldrin	0.82	0.29	0.30	0.26	0.31	0.31
o,p'-DDD	0.64	TR	ND	TR	ND	ND
Endrin	TR	TR	TR	TR	TR	TR
p,p'-DDD	1.80	0.16	0.15	0.24	TR	0.12
o,p'-DDT	0.13	0.12	TR	TR	TR	0.26
p,p'-DDT	0.47	0.22	TR	0.16	TR	0.10
LoQ	0.08	0.08	0.10	0.08	0.10	0.10
TOTAL o,p'-DDE	0.18	TR	0.09	0.09	TR	TR
TOTAL Heptachlor*	TR	TR	TR	TR	TR	TR
Sum Chlordanes*	0.52	0.10	TR	TR	TR	TR
Sum DDTs	3.55	1.09	0.59	0.98	0.56	0.67

ND = not detected; TR = below limit of quantitation (LoQ)
Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 6a (cont.)

Organochlorine pesticide concentrations (ng g^{-1} wet weight) in mussels sampled in January and March 2006

	Shetland Islands							
Determinand	Parkgate	Ronas Voe	Lee Voe	Baltasound Harbour	Whalwick	Catfirth	Wadbister	Linga
HCB	TR	TR	TR	TR	TR	TR	TR	TR
Aldrin	ND	ND	ND	ND	ND	ND	ND	ND
α-HCH	TR	TR	TR	TR	TR	TR	ND	TR
γ-HCH	0.09	TR	TR	TR	TR	TR	TR	TR
Heptachlor	TR	TR	TR	TR	TR	ND	ND	TR
α-Chlordene *	0.34	0.23	0.51	0.58	0.10	0.18	0.19	0.16
γ-Chlordene *	ND	ND	ND	ND	ND	ND	TR	ND
Heptachlor Epoxide*	TR	TR	TR	TR	TR	TR	TR	TR
Oxychlordane	TR	TR	TR	TR	TR	TR	TR	TR
γ-Chlordane	ND	TR	TR	TR	TR	ND	ND	ND
o,p'-DDE	0.13	TR	TR	TR	TR	TR	TR	0.11
p,p'-DDE	0.00	1.26	0.30	0.20	0.42	0.23	0.30	0.34
α-Chlordane	0.16	TR	0.21	TR	0.15	0.13	0.14	0.25
T-Nonachlor	TR	TR	TR	TR	TR	TR	TR	0.09
Dieldrin	0.21	0.22	0.27	0.38	0.16	0.21	0.23	0.34
o,p'-DDD	TR	TR	TR	TR	TR	ND	ND	TR
Endrin	TR	TR	TR	TR	TR	TR	TR	TR
p,p'-DDD	TR	TR	TR	TR	TR	TR	TR	0.11
o,p'-DDT	TR	TR	TR	0.11	TR	TR	TR	0.10
p,p'-DDT	TR	TR	0.09	0.11	0.09	TR	TR	0.12
LoQ	0.08	0.08	0.08	0.08	0.08	0.10	0.10	0.08
TOTAL o,p'-DDE	0.34	0.16	TR	TR	0.21	TR	0.12	0.11
TOTAL Heptachlor*	TR	TR	TR	TR	TR	TR	ND	TR
Sum Chlordanes*	0.50	0.23	0.72	0.58	0.25	0.31	0.33	0.50
Sum DDTs	0.34	1.43	0.39	0.42	0.72	0.23	0.42	0.77

ND = not detected; TR = below limit of quantitation (LoQ)
Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 6b

Organochlorine pesticide concentrations (ng g^{-1} wet weight) in oysters sampled in January and March 2006

	Strathclyde: Argyll and Bute			Highland: Lochaber	Shetland
Determinand	South Shian	Islay (Gruinart)	Loch Fyne	Loch nan Ceol	Baltasound Voe
HCB	ND	TR	ND	ND	TR
Aldrin	TR	TR	TR	TR	TR
α-HCH	TR	ND	TR	TR	TR
γ-HCH	TR	TR	TR	TR	TR
Heptachlor	ND	ND	TR	TR	TR
α-Chlordene *	TR	0.30	0.11	TR	2.62
γ-Chlordene *	ND	ND	ND	ND	TR
Heptachlor Epoxide*	TR	TR	TR	TR	TR
Oxychlordane	ND	ND	TR	TR	ND
γ-Chlordane	ND	ND	ND	TR	ND
o,p'-DDE	TR	TR	TR	TR	TR
p,p'-DDE	0.36	0.27	1.13	0.20	0.22
α-Chlordane	TR	ND	0.12	0.09	1.06
T-Nonachlor	TR	TR	TR	TR	TR
Dieldrin	0.25	0.38	0.63	0.18	0.28
o,p'-DDD	ND	ND	0.10	TR	ND
Endrin	TR	TR	TR	TR	TR
p,p'-DDD	0.15	0.17	0.93	TR	TR
o,p'-DDT	0.15	0.17	0.20	TR	0.18
p,p'-DDT	0.09	TR	0.30	0.14	TR
LoQ	0.08	0.09	0.08	0.09	0.09
TOTAL o,p'-DDE	TR	0.11	0.16	TR	0.12
TOTAL Heptachlor*	TR	ND	TR	TR	TR
Sum Chlordanes*	TR	0.30	0.23	0.09	3.69
Sum DDTs	0.75	0.71	2.82	0.34	0.52

ND = not detected; TR = below limit of quantitation (LoQ)
Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 6c

Organochlorine pesticide concentrations (ng g^{-1} wet weight) in scallop adductor muscle sampled in February and March 2006

Determinand	East Coast (E6) [1]	Moray Firth (M2)	Orkney (O18)	Outer Hebrides (H3,5&6)	Clyde (C5)	Clyde (C8)	Jura (J5&6)	South Minch (SM1&2)	South Minch (SM3)	South Minch (SM10&11)
HCB	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
α-HCH	ND	ND	ND	ND	ND	ND	ND	TR	ND	ND
γ-HCH	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR
Heptachlor	TR	TR	TR	TR	TR	TR	TR	TR	0.12	TR
α-Chlordene *	TR	ND	ND	ND	ND	ND	ND	ND	ND	ND
γ-Chlordene *	0.11	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor Epoxide*	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR
Oxychlordane	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR
γ-Chlordane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
o,p'-DDE	TR	TR	0.08	TR	0.10	0.13	0.13	0.10	TR	TR
p,p'-DDE	TR	TR	ND	ND	TR	TR	ND	ND	TR	TR
α-Chlordane	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR
T-Nonachlor	ND	TR	TR	TR	TR	TR	TR	TR	TR	TR
Dieldrin	0.10	0.10	0.10	TR	0.20	0.19	0.13	0.12	0.12	0.12
o,p'-DDD	ND	ND	TR	ND	ND	ND	ND	ND	ND	ND
Endrin	TR	TR	TR	TR	TR	TR	TR	TR	ND	TR
p,p'-DDD	TR	TR	TR	TR	TR	TR	TR	ND	ND	TR
o,p'-DDT	TR	TR	TR	TR	TR	TR	TR	TR	ND	TR
p,p'-DDT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LoQ	0.10	0.09	0.08	0.09	0.08	0.10	0.09	0.09	0.09	0.08
TOTAL o,p'-DDE	0.11	0.13	0.08	TR	0.20	0.13	0.13	0.10	0.08	TR
TOTAL Heptachlor*	0.43	TR	TR	TR	TR	TR	TR	0.44	0.12	TR
Sum Chlordanes*	0.54	TR	TR	TR	TR	TR	TR	0.44	0.12	TR
Sum DDTs	0.11	0.13	0.08	TR	0.20	0.13	0.13	0.10	0.08	TR

[1] East Coast (E6) sampled in Dec 2005

ND = not detected; TR = below limit of quantitation (LoQ)

Results marked '*' are not included in the UKAS schedule for this laboratory

Appendix 6d

Organochlorine pesticide concentrations (ng g^{-1} wet weight) in scallop gonad tissue sampled in February and March 2006

Determinand	East Coast (E6) [1]	Moray Firth (M2)	Orkney (O18)	Outer Hebrides (H3,5&6)	Clyde (C5)	Clyde (C8)	Jura (J5&6)	South Minch (SM1&2)	South Minch (SM3)	South Minch (SM10&11)
HCB	ND	TR	TR	ND	ND	TR	TR	ND	TR	TR
Aldrin	TR	TR	TR	ND	TR	TR	TR	ND	TR	TR
α-HCH	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
γ-HCH	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR
Heptachlor	TR	0.23	TR	TR	TR	TR	TR	0.12	0.11	TR
α-Chlordene *	ND	ND	0.09	0.15	0.12	TR	0.13	ND	ND	TR
γ-Chlordene *	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor Epoxide*	TR	TR	TR	TR	TR	TR	TR	TR	TR	0.11
Oxychlordane	TR	TR	TR	TR	TR	TR	TR	TR	TR	0.11
γ-Chlordane	TR	TR	ND	ND	ND	TR	TR	TR	TR	TR
o,p'-DDE	TR	TR	0.08	0.10	TR	TR	TR	TR	TR	0.13
p,p'-DDE	0.85	0.27	0.17	0.28	1.08	0.74	0.37	0.42	0.46	0.37
α-Chlordane	TR	ND	ND	TR	ND	TR	ND	TR	TR	TR
T-Nonachlor	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR
Dieldrin	0.54	0.35	0.34	0.29	1.49	1.10	0.53	0.48	0.51	0.50
o,p'-DDD	ND	TR	TR	TR	0.40	0.21	0.12	0.13	0.13	0.13
Endrin	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR
p,p'-DDD	TR	TR	0.11	0.09	0.92	0.62	0.17	TR	0.12	0.13
o,p'-DDT	TR	TR	TR	TR	TR	0.12	0.22	0.15	TR	0.14
p,p'-DDT	ND	ND	ND	TR	ND	ND	ND	ND	ND	ND
LoQ	0.11	0.10	0.08	0.09	0.12	0.11	0.09	0.11	0.10	0.08
TOTAL o,p'-DDE	0.18	0.14	0.20	0.10	0.35	0.18	0.15	0.16	0.16	0.23
TOTAL Heptachlor*	TR	0.23	TR	TR	TR	TR	TR	0.12	0.11	TR
Sum Chlordanes*	TR	0.23	0.09	0.15	0.12	TR	0.13	0.12	0.11	0.22
Sum DDTs	1.03	0.41	0.48	0.47	2.74	1.87	1.04	0.87	0.88	0.98

[1] East Coast (E6) sampled in Dec

ND = not detected; TR = below limit of quantitation (LoQ)

Results marked '*' are not included in the UKAS schedule for this laboratory