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Proposals for potential modifications to the Bird of Prey Monitoring Scheme

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1. Executive summary

The Bird of Prey Monitoring Scheme (PBMS) covers a long-term monitoring programme that examines the levels of pollutants in selected (primarily avian) wildlife species in Britain. It was instrumental in securing the phased withdrawals of the permitted uses of organochlorine insecticides and has since provided a measure of the effectiveness of regulatory bans in reducing the exposure of wildlife. The PBMS has expanded over the years and currently monitors carcasses and/or eggs of particular species for organochlorine (OC) pesticides, polychlorinated biphenyls (PCBs), mercury and second-generation rodenticides (carcasses only). Since 1974, the PBMS has been the subject of a series of contracts (known as the Wildlife and Pollution contracts) from the Nature Conservancy Council (NCC) and subsequently from the Joint Nature Conservation Committee (JNCC).

Some of current activities reported under the Wildlife and Pollution contracts address issues that have declined in importance in terms of conservation and regulation. This report describes a suite of new activities that could be incorporated into the PBMS to address crucial gaps in the understanding of contemporary wildlife and pollution issues and to maximise the usefulness of the PBMS to regulators and policy-makers. These activities include: widening the numbers and types of compounds monitored; improving the link between environmental residue data and toxicity for compounds already monitored; identifying unknown compounds in birds; and using data from the scheme to identify contamination hotspots on a national scale. The OSPAR list of chemicals for priority action has been used as a guide to which additional compounds it may be most important to monitor. Activities that can be introduced into the PBMS immediately have been highlighted.

Some of the activities considered require additional specific resources. However, others are longer-term monitoring activities for which additional resources may be limited. It is proposed that the PBMS could alter the frequency of monitoring for any one compound or suite of compounds from a yearly to a multi-year basis. Different suites of compounds could be analysed on a 2-3 year rolling cycle for example. The resources released would allow an expansion of the breadth of the PBMS.

A fuller analysis of the impacts of any change in reporting frequency should first be undertaken before it is implemented. It is recommended that a statistical review of the long-term datasets available for organochlorine pesticides, PCBs, mercury and rodenticides is undertaken. The aim of this review would be to determine whether the long-term temporal changes in residues detected by analysing birds on a year by year basis would have been identified (and with what degree of precision) if sampling had been on a two, three, four or more year basis. The review should be coupled with an outline of how new analyses/species will be incorporated into the PBMS in the intervening years should a multi-year cycle prove feasible. This outline would be based on feedback from conservation and regulatory agencies about their requirements and would take account of the practicalities of applying existing monitoring methodologies already employed by such agencies.

2. Background and aims

The Bird of Prey Monitoring Scheme (PBMS) covers a long-term monitoring programme that examines the levels of pollutants in selected avian wildlife species in Britain. The programme began over 35 years ago when there were serious concerns over the effects of organochlorine (OC) insecticides and organomercury fungicides on various bird and mammal species. This early work demonstrated the effects of the OCs, particularly on raptors, and was instrumental in securing the phased withdrawals of the permitted uses of these insecticides. The programme has continued to quantify levels of these insecticides in predatory and fish-eating birds since then, thereby providing a means of measuring the effectiveness of regulatory bans in reducing the exposure of wildlife.

Since 1974, the PBMS has been the subject of a series of contracts (known as the Wildlife and Pollution Contracts) from the Nature Conservancy Council (NCC), and subsequently from the Joint Nature Conservation Committee (JNCC). These contracts have been carried out by the Institute of Terrestrial Ecology (ITE) (now the Centre for Ecology and Hydrology (CEH)). Over the years, the PBMS expanded to encompass a range of other contaminants and pesticides, thereby reflecting contemporary conservation and regulatory concerns. Investigations have been made into the levels of industrial polychlorinated biphenyls (PCBs), following their identification as pollutants in 1966. These have been measured both in birds of prey and in the eggs of marine predators: gannet *Morus bassanus* eggs are regularly collected biennially from two colonies and, when available, from other sites. The levels of mercury, which may derive from agricultural or industrial sources, have also been tracked in various bird species. In recent years, investigations have been made into the effects of the newest generation of rodenticides on barn owls *Tyto alba*. The work on surveillance of rodenticide residues in barn owls has recently been used to advise the Advisory Committee on Pesticides of possible enhanced risks to birds of prey from this group of pesticides. In addition, the contract supports a wildlife incident investigation service, which can examine the causes of unexpected mortality incidents that are not obviously related to oil pollution or to agricultural pesticides.

The programme of the JNCC contracts was the subject of an official review in 1992 between the JNCC and the country agencies, a further science review in October 1993 and a third review considered by the Joint Committee in December 1996. Currently, there are concerns over the environmental hazards posed by new groups of chemicals, including potential endocrine disrupters, and the mounting evidence of widespread exposure of vertebrate wildlife to some pesticides, such as second-generation rodenticides. In the light of such concerns, there was a further review of the JNCC contract in 2000/2001, to which an earlier draft of the present report contributed.

The aim of this report is to carry out an initial analysis of ways in which the PBMS may be adapted to: (a) contribute effectively to our understanding of crucial gaps in contemporary wildlife and pollution issues; (b) be presented in such a way as to maximise its usefulness to regulators and accessibility to and influence on policy-makers. The report briefly summarises activities under the existing JNCC contract (Section 3), evaluates the ways in which the PBMS can be modified to examine the impacts of other compounds or maximise information gathered on compounds already within the scheme (Section 4) and examines the consequences of implementing such changes (Section 5). Finally, recommendations are made as to possible changes that could be implemented immediately.

3. Current activities under the scheme

Current activities under the Wildlife and Pollution contract consist of surveillance of residues of organochlorine insecticides, their metabolites, PCBs, rodenticides, and mercury in the tissues and eggs of a range of seabirds and predatory and freshwater birds. This provides data on the presence, level, and possible effects of these compounds in wildlife. It also enables the JNCC and country agencies to monitor trends and advise on the effectiveness of measures to restrict the use and entry into the environment of some of these compounds.The specific tasks are:

a. *To analyse organochlorine and mercury residue levels in the livers of sparrowhawk* Accipiter nisus *and heron* Ardea cinerea. These species are used because they are considered representative top predators for the terrestrial (sparrowhawk) and freshwater (heron) environments. Because of their position in the food-chain, top predators are sensitive biomonitors of changes in the environmental concentrations of contaminants that bioconcentrate along the food-chain. Furthermore, sparrowhawks were one of the species most affected by exposure to organochlorine insecticides (Newton 1986) and so monitoring of this species also served a clear conservation purpose.

The bodies of sparrowhawks and herons (and other predatory bird species) are sent in by volunteer collectors. Brief post-mortem investigations are carried out on the carcasses (to determine likely cause of death) and the liver from each sparrowhawk and heron is analysed for organochlorine insecticides, their metabolites, PCBs and mercury. This work is fundamental to the core programme of long-term analyses and is carried out on up to a total of 60 organochlorine and 60 mercury liver analyses (combined total of both species) in any one year. Volunteer collectors are encouraged by the provision of information on their specimens and by the publication of the data as a whole.

Analyses, funded by ITE/CEH as part of its core research, have also been carried out on the other species or for additional contaminants in some years (for example, see Newton *et al.* 1993; Erry *et al.* 1999). Although this work was not specifically funded by the NCC/JNCC, most of these data have also been included for information in the annual JNCC Wildlife and Pollution reports.

b. *To analyse for the same pollutants as in carcasses (3a above) the eggs of gannet, merlin* Falco columbarius, *and west coast golden eagle* Aquila chrysaetos *and sea eagle* Haliaeetus albicilla *as supplied to CEH, accepting that in some years no eggs of some of the species may be received.* Golden eagle and sea eagle eggs are monitored because these species are rare and populations of both are potentially at risk from exposure to organochlorine pesticides and PCBs. Merlin eggs are monitored because OC pesticides had particularly marked effects on eggshell thickness, reproductive success and population numbers in this species (Newton et al. 1999b). Gannet eggs are monitored primarily to provide information on changing levels of contaminants in piscivorous birds that are exposed through marine food-chains. Gannet eggs are analysed as available from up to three colonies. Efforts are made to encourage provision of suitable material for this part of the study.

As with the carcass analysis, analyses of eggs of additional species have been funded by ITE/CEH as part of its core research in some years (for example, see Newton *et al.* 1989) and most of these data have again also been included for information in the annual JNCC Wildlife and Pollution reports.

c. *To assess the exposure and hazards of rodenticides to barn owls by means of analysis of the tissues (liver) of owls found dead.* The possible problems of second generation anticoagulant rodenticides (brodifacoum, difenacoum, bromadiolone, flocoumafen) to barn owl populations are examined by analysing up to 30 barn owl livers in any one year. Red kite *Milvus milvus* poisonings are investigated by the Wildlife Incident Investigation Scheme which reports pesticide poisoning incidents in the UK (Barnett *et al.* 2000), but the livers from individual kites that were not poisoned are analysed for second-generation rodenticides by the PBMS.

d. *To collate contemporary and past data, as appropriate, to monitor trends in residues determined in objectives a) to c), assess the effectiveness of any restrictions on the uses of these compounds, and discuss the implications of the residues for individuals and populations.*

e. *To initiate studies on the pathological condition and pollutant residues in birds and mammals, should large numbers be found dead or dying in situations that implicate pollutants other than agricultural chemicals or oil.*

4. The potential of the scheme to investigate other environmental contaminants and address new areas of current concern

This section examines the ways in which the chemical analysis and/or the presentation of data for compounds currently monitored under the PBMS can be improved so as to enhance the usefulness of the scheme to regulatory bodies and conservation agencies. It also examines the potential of the PBMS to monitor a range of additional contaminants. The selection of which additional compounds should be considered was based on two criteria: (i) those that the JNCC have specifically enquired about, (ii) compounds included on the OSPAR List of Chemicals for Priority Action (Table 4.1). There is considerable overlap between these two lists. It is not possible within the limited scope of this exercise to assess in detail the potential for using the PBMS to monitor all the chemicals listed in Table 4.1, and only compounds considered to be of major importance are evaluated. These are often characterised by their relatively high persistence, bioaccumulation potential and biological activity. The PBMS is likely to prove a good monitor for such chemicals as they are usually readily transferred through food-chains and bioconcentrate in top predators. A further list of chemicals (Section 8) is included to provide a guide as to which additional compounds might also be considered important in terms of requirements for monitoring in future. These have been derived from the OSPAR list and evaluated on the basis of various selection criteria but are not discussed further in the present report.

There were three main aims when considering each class of compounds. These were:

i) to consider whether it is feasible to monitor the compounds using analytical techniques at CEH or elsewhere;

ii) to discuss the relative value of monitoring different compounds in terms of the potential hazard and risk they pose to wildlife;

iii) to examine whether such monitoring would be of value to regulatory bodies and conservation agencies.

4.1 Polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs)

Dioxins and furans are released into the environment as a result of pyrolysis of a wide range of chlorinated organic chemicals, including polyvinyl chloride (PVC). The potential health risk posed by these compounds to wildlife and particularly to humans is well known because of large-scale publicity following major accidental releases, such as at Seveso. The toxic effects of these compounds are mediated through the *Ah* receptor, as are those of other polyhalogenated aromatic hydrocarbons, such as PCBs. Localised higher environmental loading from sources such as incinerators may increase the risk to wildlife down-wind and to marine mammals and birds, if they significantly affect inputs to the marine ecosystem. Strict limits on incinerator emissions were instituted in 1996 but these and other (local and diffuse) sources are still likely to be adding to environmental concentrations to some extent.

There is very little information on dioxin levels in birds in the UK and no information on changes in the degree of contamination in birds over time.

Table 4.1 Compounds about JNCC has expressed an interest in terms of monitoring using the PBMS and the OSPAR list of Chemicals for Priority Action

JNCC queries	OSPAR list of Chemicals for Priority Action
dioxins	polychlorinated dibenzodioxins (PCDDs)
	polychlorinated dibenzofurans (PCDFs)
PCB congeners, and unknown peaks	polychlorinated biphenyls (PCBs)
polycyclic aromatic hydrocarbons (PAHs)	polycyclic aromatic hydrocarbons (PAHs)
polybrominated flame retardants	brominated flame retardants
	Pentachlorophenol (PCP)
	short-chain chlorinated paraffins (SCCP)
	hexachlorocyclohexane isomers (HCH)
	mercury and organic mercury compounds
	cadmium
	lead and organic lead compounds
	Organic tin compounds
	nonylphenol/ethoxylates (NP/NPEs) and related substances
	certain phthalates
rodenticides	
molluscicides	
biochemical and physiological biomarkers	
anthelminthics	

The toxicity of compounds that acts through the *Ah* receptor is often expressed as a Toxic Equivalency Factor (TEF). This is an order of magnitude estimate of the toxicity of that compound relative to that of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), the most potent dioxin congener (Ahlborg *et al.* 1992; van den Berg *et al.* 1998). TEF values are used in conjunction with concentration data to calculate Toxic Equivalent (TEQ) concentrations in environmental samples. The TEQ for each compound is calculated by multiplying the TEF by the concentration of the compound. The TEQ values for certain dioxin-like polychlorinated biphenyls (PCBs) are often similar to or exceed those of many PCDDs and PCDFs in wildlife because PCBs are more abundant and are bioaccumulated to a greater extent by wild vertebrates. Thus, although dioxins and furans are highly toxic, they may not necessarily be of any greater toxicological significance for wildlife than more abundant PCBs (see also Section 4.1.2). No serious wildlife concerns with regard to PCDDs and PCDFs appear to have been identified in the UK.

The PBMS could be used for monitoring dioxins and furans. CEH does not currently have a capacity to analyse for these compounds. Analyses of samples from the PBMS could be sub-contracted out but this will be expensive on a commercial basis (probably over £500 per sample). It is recommended that any such work be preceded by a structured pilot study to determine whether such analyses are merited on the grounds of the frequency of occurrence and magnitude of residues (and associated TEQs) in birds of prey relative to other environmental contaminants.

4.2 Polychlorinated biphenyls (PCBs)

Production of PCBs ceased in the mid-1970s and their use in new equipment was banned from 1986 in the UK. The target for disposal of all remaining PCBs in the UK was mid-2000, and is 2010 for the EU as a whole. Thus, if the restrictions on use and the strategies for disposal are successful, it might be expected that exposure of wildlife to these compounds would decrease over the next few years. However, the actual and future rate of release of PCBs from landfill and sealed systems is uncertain. Current monitoring carried out as part of the PBMS therefore provides a measure of the outcome of the recent UK and international efforts to remove these compounds from the environment.

PCBs consist of 209 individual congeners, which vary in the number and position of chlorine atoms on the biphenyl rings. This results in congeners varying in their physico-chemical and toxicological properties. Currently, PCBs are quantified for the Wildlife and Pollution Contract by Gas Chromatography with Electron-Capture-Detection (GC-ECD). This is a widely used and highly sensitive technique. In most current studies that detect PCBs by GC-ECD, PCB tissue concentrations are reported on an individual congener basis, as the sum of a specified number of congeners, as matched concentrations or as total concentrations. A matched concentration is the sum area under all peaks on the gas chromatogram for the sample that match (on the basis of relative retention times) peaks that occur on a chromatogram for a technical-grade PCB mixture, such as Aroclor 1254. Total PCBs in samples are calculated as the sum area under all quantifiable peaks on the gas chromatogram other than those peaks known to be OC insecticides. Thus, total PCB concentrations in tissues are usually higher than matched PCB concentrations because totals can include PCB congeners not present in the technical-grade PCB mixture used to calculate the matched concentration. However, total PCB concentrations may include peaks for compounds that are not PCBs.

Currently, tissue and egg concentrations of PCBs are reported on a total PCB basis for the Wildlife and Pollution contract. Reporting on a congener basis was not possible with the analytical technologies available when the PBMS first started monitoring PCBs. Reporting on a total PCB basis has been maintained so that the long-term continuity of the database was preserved and temporal trends within the data were apparent.

Over the last 2-3 years, CEH has been investigating possible modifications to the PBMS with respect to information on PCBs. As a result, examples in this report of what might be done to change the PBMS have been given much greater coverage with respect to PCBs than other compounds. The suggestions with regard to PCBs should be regarded as indicative (and good examples) of the ways the PBMS can be typically modified for many contaminants. There are four specific ways in which analysis of PCBs using the PBMS could be developed to increase its usefulness to regulators, and accessibility to and influence on policy-makers.

4.2.1 Reporting PCB data on a congener-specific and TEQ basis

As part of its internal research programme, CEH has been increasing its capability to discriminate individual PCB concentrations. We now have the capability to individually report the concentrations of 35 individual congeners. These include those congeners that are predominantly found in vertebrate tissues and the coplanar non, mono and di-*ortho* substituted coplanar congeners that have greatest toxicological potency and have TEF values assigned to them.

Total PCB concentrations have declined in sparrowhawks and herons but not in kestrels *Falco tinnunculus* monitored under the PBMS over the period 1963-98 (Newton *et al.* 1999a). Thus, this monitoring has indicated that regulatory bans on PCB production have resulted in an overall reduction in exposure/accumulation of total PCBs in some top avian predators, although not in all. However, changes in total PCB concentrations do not indicate whether there has been any consistent temporal change (decrease or even increase) in the toxicity of accumulated PCBs (as determined by TEQ values) in top predators. Measurement of total PCBs also does not give any indication of whether PCB toxicity varies significantly between species. Regular reporting of PCB data on a congener-specific and TEQ basis would provide information on the levels of the most potent PCB congeners and their relative toxicity to top predators, how this varies between species, and whether it is actually declining over time.

A move towards congener-specific and TEQ reporting needs to be preceded by preliminary work. This should include determination of whether concentrations of coplanar congeners and total TEQ values vary significantly between kestrel and sparrowhawk. These two species comprised the bulk of the carcass analyses carried out under the PBMS before 1998, after which kestrel was dropped from the programme. Analysis of analytical data already gathered (but not analysed) by CEH for a limited number of congeners could be undertaken to determine whether sparrowhawk or kestrel might be the better species in which to monitor congener residues and TEQs. It would also be necessary to determine whether total PCBs are correlated significantly with any one specific congener or any group of congeners. This would be important so that total PCB concentrations could still be estimated and so preserve the continuity of the long-term dataset for changes in exposure of top predators to PCBs generally. Again, this could be achieved by analysis of existing limited data already gathered by CEH.

In the context of examining whether the toxicity of PCB residues in raptors has changed over the last 30 years, it would also be possible to reanalyse frozen tissues for birds from the PBMS tissue archive for specific congener concentrations and TEQ values. This might involve in the first instance analysing all birds of one species collected in specific years between 1965 and 2000.
Reporting data routinely on a congener-specific and TEQ basis is currently analytically feasible under the existing PBMS scheme and facilities at CEH Monks Wood. It would require some limited additional resources in terms of time spent on analytical data processing and recurrent costs. Such increases would be small, however, relative to existing analytical costs, but would represent a major enhancement in terms of value of information from the scheme. The preceding preliminary studies described above using existing CEH datasets and a study that involved retrospective examination of changes in TEQ values over a 1965-2000 timeframe would both be one-off exercises.

4.2.2 Analysis of spatial variation of PCBs residues within the UK

CEH has already conducted extensive research into the potential for the PBMS to quantify spatial variation across Britain in PCB contamination and to identify ‘hotspots’ of contamination. This has involved spatial resolution of PCB residue data in kestrels and sparrowhawks across the country; an example of the initial data analysis is given in Figure 4.1.

CEH analysis so far suggests that there may be hotspots in particular industrial centres but relatively high PCB levels have also been detected in birds from relatively remote areas, such as the Scottish highlands.

Current research effort is focused on developing statistical techniques to determine whether apparent hotspots of contamination are real clusters of birds with high residues or simply occur by chance. This work requires further development of the spatial analysis and so far has only been tried using a dataset for the sum of a small number of PCB congeners over a limited six-year time period. It is anticipated that this approach can be developed using CEH’s larger dataset for PCB residues in birds collected between 1970 and 2000. This would provide better resolution of spatial variation in PCB contamination and how this has changed over the last 30 years. These data could be used to indicate likely sources of bioavailable PCBs and so provide valuable information to regulators, such as the Environment Agency (EA) and Scottish Environment Protection Agency (SEPA), who are charged with assessing and controlling environmental discharges of these contaminants. This type of work requires specific, targeted, resourcing for a one-off investigation.

It is also possible to apply the same statistical techniques to other datasets collected under the PBMS (see Section 4.7).

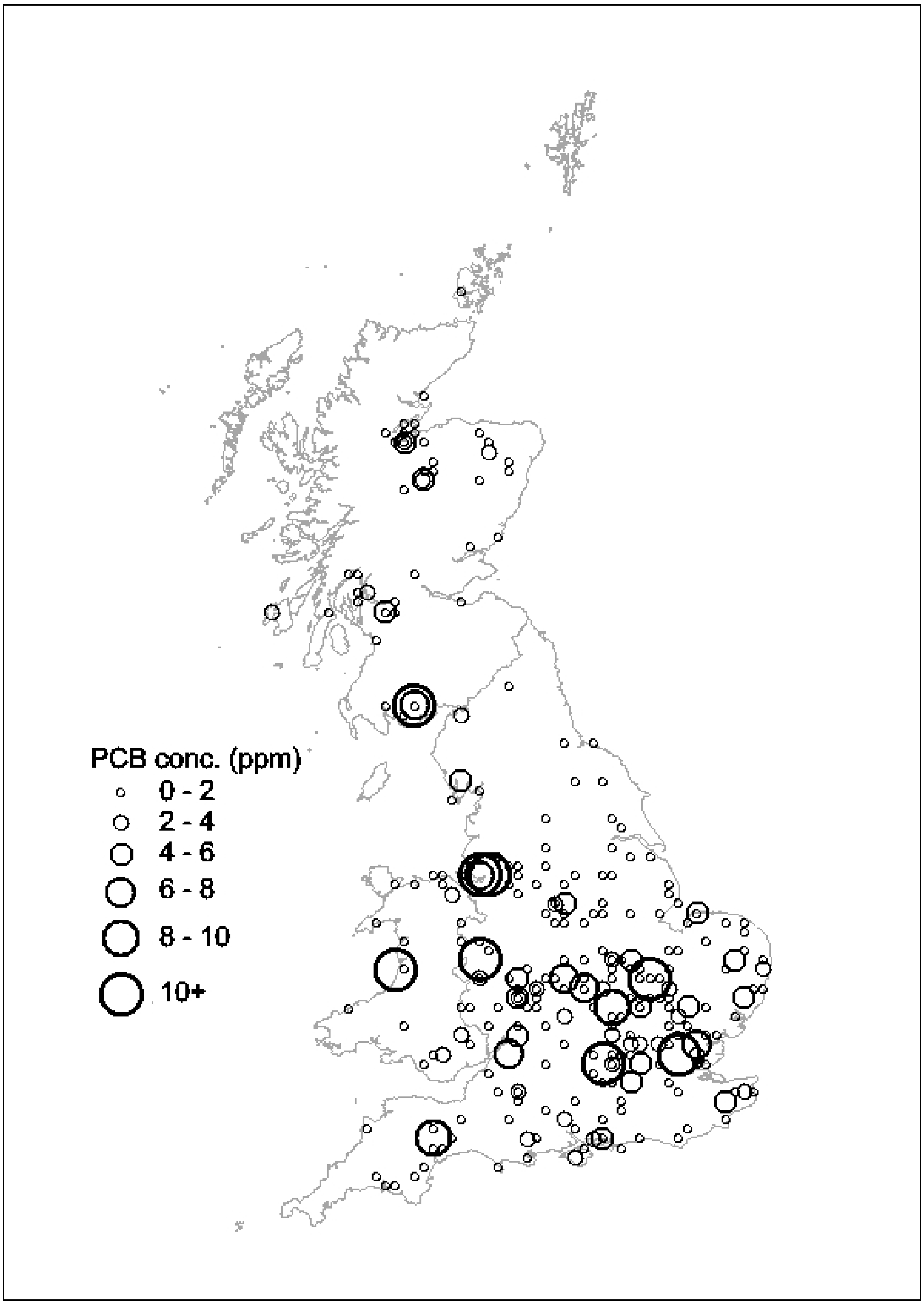

Figure 4.1. PCB concentrations in sparrowhawks from across Britain in the 1990s. Each circle represents contamination found in an individual sparrowhawk liver, collected between 1993 and 1998.

4.2.3 Identification of unknown contaminants in birds

Preliminary work by CEH comparing total PCBs in birds with Aroclor-matched PCB concentrations indicate that Aroclor 1254-matched PCB concentrations account for only some 75% of the total PCBs recorded in sparrowhawks during the 1990s (Figure 4.2). The difference between Aroclor-matched and total PCBs may in part result from congeners in the total PCB values not being present in Aroclor 1254. However, some of the differences are probably due to peaks of unknown compounds. There is currently no information on what those compounds are and whether they are likely to pose a significant toxic risk to birds.

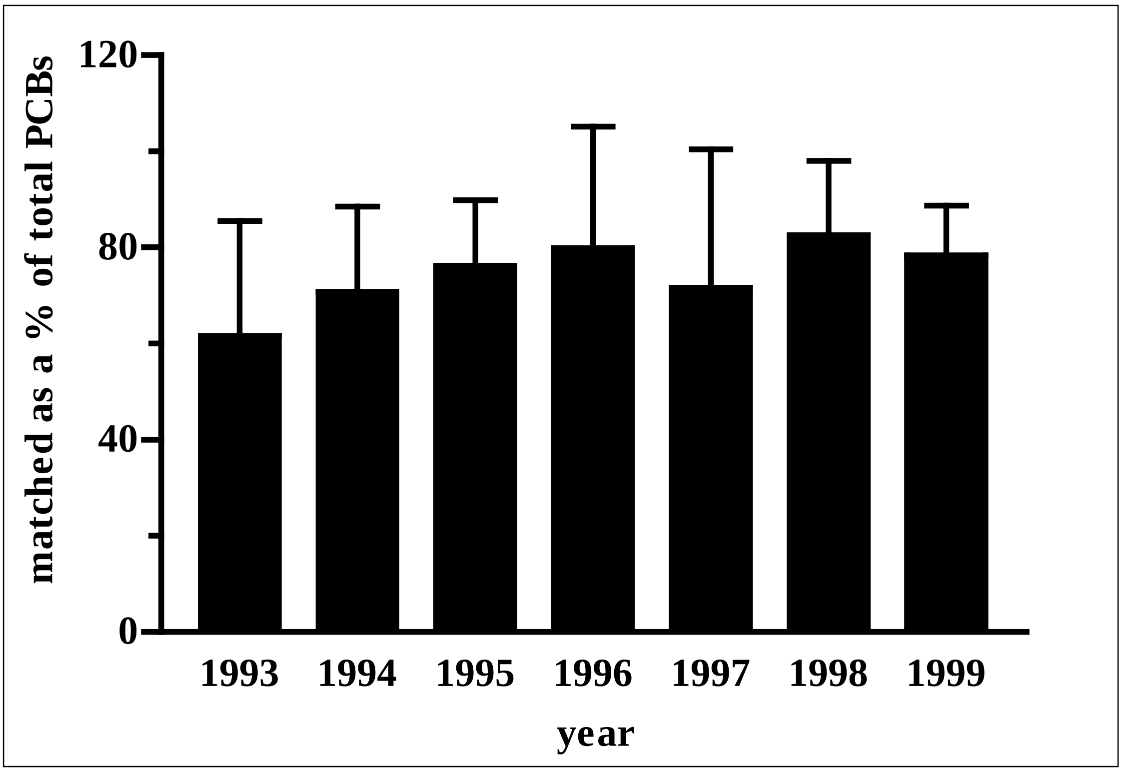

Figure 4.2. Mean (±SD) Aroclor 1254-matched PCB liver concentrations expressed as a % of total PCB concentrations for sparrowhawks collected between 1993 and 1999.

The tissues of birds that contain large unknown peaks can be identified from the data held by CEH. Archived liver tissue from these birds could be reanalysed using gas chromatography with mass spectrometry (GC-MS). Identification of unknown peaks is carried out on a mass-specific basis and uses spectral libraries held in the GC-MS software.

Characterisation of unknown peaks in birds previously collected would be a specific one-off exercise. Alternatively, this work could be accommodated within the existing PBMS scheme by reduction or termination of other activities in specific years (see Section 5). Any commitment to analyse otherwise unresolved peaks during current analyses would incur greater analytical costs because of the need to reanalyse material by GC-MS rather than GC-ECD (but see Section 4.2.4) and the exploratory nature of the identification.

4.2.4 Analysis of PCBs using GC-MS techniques

Analysis of PCBs using GC-MS rather than GC-ECD techniques has the advantage that identification is based on the mass of the compound and so has greater certainty than GC-ECD techniques that rely on matching the retention times of peaks in samples with those in standards. Analysis of all samples by GC-MS would also facilitate identification of unknown peaks (see Section 4.2.3) on a routine basis. By its nature, analysis using GC-MS results in concentrations being reported on a congener-specific basis (as recommended in Section 4.2.1). GC-MS techniques have not been used regularly for the PBMS analysis because it is only recently that both analytical techniques and instrument technology have developed sufficiently to give analysis at the required level of sensitivity.

A transfer of analytical techniques from GC-ECD to GC-MS (using negative chemical ionisation with select ion monitoring (SIM), the most sensitive form of ionisation for GC-MS determination of organochlorine compounds) is possible with existing facilities and capabilities at CEH Monks Wood, although such transfer would require additional developmental work. Sample cleanup would need to be improved, as GC-MS methods are more susceptible to interference. This may involve development of a two- or three-stage cleanup included gel permeation chromatography, which would allow separation of PCBs from PAHs and dioxins. Some method development may also be needed, as current methods with GC-MS cannot detect lower chlorinated congeners, although these rarely occur in kestrels and sparrowhawks analysed by the PBMS (Wienburg, unpublished data). Method validation and cross-calibration between old and new methodologies would also be required so that the capability to analyse long-term trends in the dataset (that spanned across periods of methodology change) is preserved.

Transfer of analysis to an GC-MS basis would require additional initial resourcing for method development and cross-calibration studies. A complete move to GC-MS determinations is also likely to result subsequently in a higher unit cost per sample as the analyses are more labour-intensive, although increasing automation in future years could reduce this.

4.3 Polycyclic aromatic hydrocarbons (PAHs)

PAHs are another homologous series of globally distributed environmental contaminants about which there is considerable concern because of their known toxic effects (WHO 1998). Environmental contamination of PAHs arises from incomplete combustion of organic materials during industrial processes and other human activities. PAH contamination of soils from Rothamsted Experimental Station increased approximately five-fold between 1846 and 1980, although environmental inputs from some sources may be falling (WHO 1998). Food-chain transfer of PAHs into birds and their eggs has been demonstrated (e.g. Shore *et al.* 1999b, and references therein) and these compounds have been shown to embryotoxic and teratogenic in birds in the laboratory. However, there is little information on spatial and inter-specific variation or on actual effects in wild species.

CEH has the capacity to monitor for PAHs. However, monitoring PAH residues in bird carcasses collected under the PBMS is not considered feasible because metabolism of these compounds is relatively rapid in vertebrates (WHO 1998). In contrast, it would be feasible to monitor for PAH residues in eggs. Some studies on PAH contamination in seabird eggs have already been carried out by CEH (Shore *et al.* 1999b). Seabird eggs could be a particularly useful monitor of PAH contamination in estuarine and coastal areas, where there may be industrial discharges and contamination from oil, as PAHs are transferred through aquatic trophic pathways. A further reason for using eggs as a monitoring tool is because of the embryotoxicity of PAHs and so eggs are a key receptor for these compounds.

Collection and analysis of eggs of species such as shag *Phalacrocorax aristotelis* and cormorant *Phalacrocorax carbo* from sites around the UK would provide data on PAH contamination at coastal (and in the case of cormorant, some freshwater) sites. Heron eggs would also provide a monitor of contamination of freshwater systems. Gannet eggs, already collected under the PBMS, would also provide a measure of PAH contamination although this would relate to PAH contamination of marine systems more widely. Monitoring of eggs of terrestrial species would provide an indication of the exposure of terrestrial top predators although whether eggs from birds of prey rather than from passerine or other species would be a better monitor would have to be investigated.

Measurement of PAHs in eggs already collected under the PBMS is feasible. Widening the species for which eggs are collected is also possible, and CEH has the capacity to undertake this, although pilot studies would be required first to determine which species are likely to prove the most effective monitors. Inclusion of monitoring of PAHs under the PBMS may have relevance to regulatory agencies such as the EA, SEPA and DEFRA which would benefit from the resulting environmental data. Such work could be incorporated into the current PBMS scheme by reduction or termination of other activities in specific years (see Section 5) or by additional funding.

4.4 Polybrominated flame retardants

These compounds are widely used and there are currently no controls on emissions. They are known to occur and persist in the marine environment. Of the brominated diphenyl ethers, it is primarily pentabromodiphenyl ether that is persistent and accumulates in wildlife (WHO 1994). Environmental concentrations of this compound may be rising; concentrations are known to have increased in fish and birds from Sweden (WHO 1994). Little is known about the effects of such accumulation. Polybrominated flame retardants are likely to be an early target for review and risk management under the Government's Chemicals Strategy.

Pentabromodiphenyl ether is determined in analytical samples using gas chromatography. It would be possible to analyse carcasses collected under the PBMS for this compound but appropriate analytical methodologies would first have to be developed. Inclusion of pentabromodiphenyl ether under the PBMS might be relevant for regulatory agencies such as the EA, SEPA and DEFRA. Such work could be incorporated into the existing PBMS scheme by reduction or termination of other activities in specific years (see Section 5) or would require separate additional funding.

4.5 Other organic compounds under the OSPAR list for priority actions

These compounds include hydrochlorocyclohexane (HCH) isomers, pentachlorophenol (PCP), short-chain chlorinated paraffins (SCCP), nonylphenol/ethoxylates (NP/NPEs) and related substances, and certain phthalates (Table 4.1). In terms of HCH isomers, the adaptation of existing methodologies that would be needed to report HCH isomers would be small and incur relatively little additional cost. Analysis of PCP is also feasible although some modifications in extraction procedures would be necessary. CEH Monks Wood has experience in analysing for both compounds in vertebrate tissues (Boyd *et al.* 1988; Shore *et al.* 1991). HCH and PCP are both used as pesticides and are highly toxic to birds and mammals but their use is becoming increasingly restricted in the UK and EU. Thus, the value of including these compounds in the PBMS surveillance is uncertain although it could be used to monitor the effectiveness of restrictions on use in reducing wildlife exposure.

It is beyond the scope of the present report to review the environmental significance and toxicity to wildlife of all the compounds listed in Table 4.1. Analysis of other organic compounds listed above that have not already been covered are all technically feasible using existing analytical facilities at CEH Monks Wood. Literature review would be first required to determine their priority in terms of nature conservation and hazard to wildlife, whether the PBMS would be a suitable monitor for these compounds, and whether analytical methods would have to be established within the CEH laboratory for these compounds or the analyses sub-contracted elsewhere.

In summary, all the other OSPAR priority listed organic compounds could be monitored using the PBMS. Monitoring of HCH isomers and PCP could be incorporated relatively easily under the existing organochlorine suite of analyses. The use of the PBMS to monitor the other organic compounds would require more substantial investment start-up costs and a feasibility study in terms of the suitability of the PBMS for such monitoring and development of analytical methods.

4.6 Metals, semi-metals and organo-metals

The metals included in the OSPAR list include mercury, lead, cadmium, tin and their organic forms. Arsenic is also a semi-metal over which there is substantial environmental concern. The PBMS can be used to monitor levels of all these metals in top predators. This has already been demonstrated for total mercury, which is currently reported under the existing Wildlife and Pollution Contracts, and also for total arsenic, where regional differences in residue levels were identified in kestrels and were a result of localised sources of contamination (Erry *et al.* 1999).

Analysis of total concentrations (as opposed to particular organo-forms) for any of these metals/semi-metals is straightforward and established methods exist already within the CEH analytical capability. Analysis of some metals, such as total tin, lead and cadmium can be done simultaneously using mass-spectrometric techniques, thereby reducing the analytical costs per element. Analytical costs for metals analysis is considerably lower than that for organic compounds.

Analysis of the organic forms of metals in raptors would be toxicologically relevant, as toxic potency often varies markedly with the species of the element; for instance methyl mercury is more toxic than inorganic mercury. Organic forms of metals are also often more readily transferred through food-chains, and top predators are likely to be good biomonitors for environmental levels. Analysis of the organic forms of these metals is feasible within the analytical capabilities at CEH although analytical methods would have to be first developed and proven.

Analysis of total concentrations for various metals within the existing scheme would require additional funding or could be funded by reduction or termination of other activities in specific years (see Section 5). The use of the PBMS to monitor organo-metals would require more substantial, targeted funding.

4.7 Rodenticides

Barn owls have been monitored for second-generation rodenticides under the PBMS since 1983 (Newton *et al.* 1999c). Red kites are also occasionally monitored for rodenticides under the PBMS, though additional funding has been needed when the number of analyses required has been substantial (Shore *et al.* 2000). The second-generation rodenticides have been the focus of monitoring in the PBMS because their persistence and potency enhance their potential to cause secondary poisoning in birds. The proportion of barn owls examined that contained residues of second-generation rodenticides has risen from 5% in 1983 to approximately 40% currently, reflecting the increased use of these compounds during this period. Barn owls and other predatory birds and mammals are considered to be at increasing risk of exposure, and possibly poisoning, because of increased rodenticide use and also the advent of resistance to some of these compounds. Resistance may lead to target species containing higher body burdens of rodenticide and being available for capture for longer because they die less quickly (if at all) after eating bait.

The barn owl and the red kite are two, but not the only, key non-target bird species that are likely to be secondarily exposed to rodenticides. Recent studies have shown that a diverse array of carnivorous mammals in Britain are exposed to rodenticides (McDonald *et al.* 1998; Shore *et al.* 1999a; Shore *et al.*, in press). This suggests that secondary exposure is unlikely to be solely through consumption of poisoned target species (rats *Rattus* spp. and house mice *Mus domesticus*), and there is probably a wider contamination of the prey base of carnivores in Britain than previously thought. Other birds of prey likely to be exposed include kestrel, tawny owl *Strix aluco*, and buzzard *Buteo buteo*. Some kestrels occasionally analysed under the PBMS have been found to contain rodenticide residues (Newton *et al.* 1999a) and buzzards have been secondarily poisoned by bromadiolone in France (Berny *et al.* 1997).

Kestrels were, and still are, collected in relatively large numbers (33 were received in 1999) as part of the PBMS, although they are not currently analysed for any contaminants and are no longer included in the Wildlife and Pollution contract. They could be easily be incorporated into the existing scheme for rodenticides. This is also true tawny owls and buzzards which are submitted to the PBMS, although usually in smaller numbers than kestrels (for example, 24 tawny owls and 8 buzzards were received in 1999). Of these species, the kestrel is the strongest candidate for rodenticide monitoring because populations are currently thought to be in decline and rodenticides could be a contributory factor. This species is one of the raptors that is most likely to be exposed to rodenticides because rodents comprise a high proportion of the diet. It would be possible to include kestrels (and/or other species) under the current structure of the PBMS through additional funding or reduction/termination of other activities in specific years (see Section 5).

The same resourcing methods could be used to support additional analysis of the unique dataset for barn owls. Such analysis might include examination of the spatial variation in rodenticide residues in owls to determine whether there are foci of contamination and whether the location and size of such foci are changing with time (see also Section 4.2.2. for similar analysis of PCB contamination in raptors). This information can be linked to usage data to identify how usage patterns influence the magnitude of exposure of non-target vertebrates of high conservation concern. Such information is likely to be of value to agencies such as DEFRA and the Health and Safety Executive (HSE) in that it would assist them in discharging their duties with regard to the environmental safety of these compounds.

CEH is currently funding an initiative to expand its analytical capabilities for rodenticides so that a number of first-generation as well as second-generation compounds are determined in samples. This is being done so that a more accurate picture of exposure of non-target species to anticoagulant rodenticides can be gathered; this is almost certainly underestimated at present in barn owls because first-generation compounds are not quantified. Furthermore, preliminary assessments suggest that some first-generation rodenticides may present a secondary-poisoning hazard, particularly to carnivorous mammals (Shore, unpublished data), and so it may become increasingly important to have a better understanding of the level of exposure of non-target species to all anticoagulant rodenticides. It is likely that the capability to analyse routinely for a wider range of rodenticide compounds will be developed within the next 12 months. Reporting these additional compounds for the Wildlife and Pollution Contract would involve relatively little additional resources.

4.8 Molluscicides

Broadcast applications of molluscicides, and in particular those containing methiocarb as the active ingredient, can result in mortalities of non-target birds and mammals due to accidental primary exposure. Impacts on wood mouse *Apodemus sylvaticus* populations resulting from broadcast applications of methiocarb have been demonstrated (Johnson *et al.* 1991; Shore *et al.* 1997) and there is a potential risk of secondary poisoning of raptors eating poisoned mice (Shore *et al.* 1997).

Exposure to methiocarb and other anticholinesterases is often identified by quantifying the inhibition of cholinesterase in either blood or brain (e.g., see Dell'Omo *et al.* 1996). Organophosphate and carbamate pesticides are not accumulated to any great extent in the body tissues and confirmation of exposure through residue analysis usually involves analysis of the gut contents. However, this is not necessarily a reliable means of determining that exposure has occurred. Examination of Wildlife Incident Investigation Scheme (WIIS) data has shown that only 7-23% of animals that were exposed to carbamates and had depressed brain acetylcholinesterase activity contained detectable carbamate residues in the gut (Greig-Smith 1991).

Reliable and interpretable measurement of cholinesterase activity usually requires that samples are obtained from living or freshly killed animals and/or the time course of exposure relative to sampling is known. Lack of detectable cholinesterase depression in samples would not indicate that animals had never been exposed to anticholinesterases. Investigations into whether an animal had died as a result of exposure to an anticholinesterase would normally be carried out through the WIIS.

In conclusion, it is considered unlikely that the PBMS would be a useful tool to monitor exposure of wildlife to molluscicides or other anticholinesterase compounds.

4.9 Biochemical and physiological biomarkers of exposure

The use of non-specific and specific indicators of exposure to environmental stressors is becoming more widespread, for instance the development and adoption in some circumstances of Direct Toxicity Assessment by the Environment Agency. The development of non-specific biomarkers to indicate the impacts of environmental stressors would be of value to the Wildlife and Pollution contract. Such biomarkers could be used as an initial screening tool to direct subsequent targeted monitoring for particular contaminants. They would also enable conservation agencies to report on the 'health' of relevant species.

Biomarkers that could be measured might include cholinesterase activity (but see Section 4.8), induction of P450 oxidases, metallothionein concentrations in tissues, measures of genetic damage, etc. Measurement of many such biomarkers requires analysis of fresh or well-preserved material or knowledge of the time period of exposure (for example, see Section 4.8) and this may be problematic given the current means of obtaining bird carcasses and eggs. It may be possible that the PBMS could measure certain biomarkers, but a desk-based review is needed to determine exactly what would be feasible in terms of type of biomarker, robustness of measurement under conditions of tissue degradation, and the scope, specificity and relevance of the resultant information.

4.10 Anthelminthics

There has been some concern over specific veterinary products, including anthelminthics such as the avermectins, and their potential effects on wildlife. One concern over anthelminthics that enter the environment is their possible indirect effect on vertebrates, in that invertebrate prey abundance may be reduced. However, with regard to direct effects, it is unknown whether anthelminthics or other products are or are likely to be transferred through wildlife food-chains and reach top predators nor is it known whether any such transfer, should it occur, would be likely to result in harm.

Any consideration of using the PBMS to monitor veterinary products should be based on a critical literature study that uses existing data on these products to determine whether there is any hazard or risk to top predators. The EA is currently funding a review of risks to the environment from veterinary products. The need for any further review of particular aspects of secondary exposure of wildlife to anthelminthics should be re-evaluated following that EA review.

4.11 Incident monitoring

Investigations of wildlife mortality incidents have proved to be a good way of identifying environmental problems that can then be regulated or voluntarily controlled. Problems with the use and disposal of OC pesticides, PCBs, lead and alkyl lead first came to light through incident investigations that involved a wide range of species including birds of prey, wildfowl, waders, gulls, terns and many seabird species.

Under the existing Wildlife and Pollution Contract, there is provision to investigate mortality incidents but there is no prearranged programme of work or agreed decision-tree to decide what analyses should be undertaken. Samples have usually been analysed on an *ad hoc* basis for OC pesticides, PCBs and heavy metals. On one occasion, kittiwakes *Rissa tridactyla* washed ashore at Marsden, north-east England, were scanned by GC-MS (Newton *et al.* 1997).

When incidents were investigated, no reduction in other analyses that were reported under the Wildlife and Pollution contract arrangements took place. Such incident investigations are often time-consuming and disruptive in that they require rapid analysis of samples that are carried out at the expense of existing planned and funded work.

The need for a capability to investigate incidents is clearly important. However, it is becoming increasingly difficult to accommodate such investigations within the present arrangement. This is reflected by the small-scale activity in this area over the past few years under the Wildlife and Pollution contract. This lack of activity increases the probability that contaminant-induced mortality incidents will, in future, not be identified and the threat to wildlife of particular compounds or usage/emission processes may not be recognised.

Investigations of such wildlife incidents ideally should be flexible. They should work within an agreed decision tree that will act as a guide to ensure appropriate chemical analyses are carried out, given the specific nature of the incident. Alternatively, a fixed protocol can be employed where an agreed set of analyses is carried out, irrespective of the nature of the incident. The rigidity of this protocol has the advantage of consistency in investigation between incidents. However, it reduces the likelihood of discovering the exact causes of any contaminant-induced mortality, and is effectively a means of trying to eliminate specific contaminants as the cause of mortality.

It is recommended that the approach to investigation of non-pesticide related incidents is reviewed and guidelines to an agreed approach formulated.

4.12 Monitoring of disease status

A specific area where the PBMS could be developed further would be to increase the detail and scale of post-mortems carried out on submitted carcasses to determine disease status of birds. Some investigations into mortality patterns have been carried out (Newton *et al.* 1991; Newton *et al.* 1999d) but little has been published on disease status. The value of such investigations to nature conservation would be to provide a general measure of the 'health' of wildlife populations and identify changes in the nature, frequency or severity of disease. Such changes may be contaminant-induced (several classes of pollutants are known to be immunosuppressants) or the result of other anthropogenic activities.

5. Recommendations as to changes to the PBMS

In the previous section, a number of possible activities that could be carried out using the PBMS have been identified; they are summarised in Table 5.1. The activities fall into two general categories.

- Firstly, there are those activities that have targets achievable within a fixed time frame and, as such, require specific action outwith of the Wildlife and Pollution Contract. These are labelled in Table 5.1 as 'Specific (fixed-term) activities'. These activities are considered areas that might attract the interest or involvement of other agencies, such as DEFRA, EA, SEPA, who may require the specific outputs such work will produce.

- Secondly, there are activities that represent a change in what is currently being monitored using the PBMS and so would contribute to longer-term monitoring studies. These could potentially be incorporated into the current Wildlife and Pollution contract, depending upon resource availability and priority given to specific areas. In Table 5.1, these are listed under the heading 'Potential new monitoring to be incorporated into the PBMS'.

Some of the two types of activity are interlinked. This interlinking is apparent in Table 5.1, where activities are paired against each other.

Key questions that arise concern the resource savings that may result from terminating current activities and consequent loss of long-term continuity of data.

5.1 Consequences of terminating specific current activities

Two areas in which there is declining conservation concern are the levels of OC pesticides and total mercury in birds of prey and their eggs. Substantial savings in resources would only result from terminating this area of work if there was to be no monitoring of any organochlorines, including the PCBs and other OCs (HCH, PCP) that are on the OSPAR priority list. Continued monitoring of PCBs but not OC pesticides would save little as OC pesticides and PCBs are determined simultaneously using the same sample extraction, clean-up and analytical run. Savings made in data handling and interpretation costs would be small compared to the overall cost of the analysis. Exclusion of certain species from the analysis, as has already been done for the kestrel and could be done for the eggs of certain species, would provide some savings.

Termination of total mercury analysis would result in savings but mercury is on the OSPAR priority list and the analytical cost per sample is only approximately 20% that for the OCs/PCBs. Overall, costs savings would be relatively small (maximum £2-3K p.a.).

The consequence of terminating any one specific component of the analyses currently carried out is that the long-term continuity of the database will be lost. The PBMS is the longest running national programme of its kind anywhere in the world and the findings stimulate considerable scientific and conservation interest internationally, as well as in Britain. From the perspective of understanding the processes by which chemicals move through the environment and exert effects on biota, such large-scale, long-term data sets are invaluable. Thus, any benefits of terminating aspects this long-term study should substantially outweigh the drawbacks of losing continuity of data.

Table 5.1 Summary of new specific and monitoring activities that can be incorporated into the PBMS. Monitoring activities highlighted in *italics* are those that could be implemented immediately.

Specific (fixed-term) activities	Potential new monitoring to be incorporated into the PBMS
Assessment of frequency of sampling needed for OCs and PCBs under the PBMS	
Pilot analytical study to determine the merits of monitoring for dioxins and furans	Monitoring of dioxins and furans
Preliminary study of existing data to determine whether sparrowhawk or kestrel is better monitor for PCB congeners and TEQs, whether congeners are correlated with total PCBs and to investigate the feasibility for monitoring congeners or reporting on a TEQ basis	*Reporting PCBs detected by GC-ECD on a congener-specific and TEQ basis as well as on a total PCB basis*
Analysis of archived tissues to determine temporal changes in PCB congener concentrations and TEQs	
Analysis of spatial variation in PCB and rodenticide residues within the UK	
Analysis of unknown peaks in previously collected and current carcasses	Analysis of unknown peaks as a regular exercise in the PBMS
Validation of methods for analysing organic compounds in birds and eggs by GC-MS	Analysis of organic contaminants by GC-MS
Feasibility study for PAH monitoring	*Monitor eggs of existing PBMS species for PAHs* Monitor eggs of new species for PAHs
Development of methods for analysis of pentabromodiphenyl ether and feasibility study	Monitoring for pentabromodiphenyl ether
	Monitoring for specific HCH isomers and PCP
Literature review of food-chain transfer and toxicity of other OSPAR-listed organic contaminants and development of analytical techniques	Monitoring for specific OSPAR priority-listed organic compounds
	Monitoring for totals of Cd, Pb, As, Sn.
Development of analytical techniques to separate and quantify organometallics	Monitoring for organo-forms of the above metals/semi-metals and of Hg.
	Analysis of kestrels (and other species such as tawny owl and buzzard) for second-generation rodenticides
Development of methodology in laboratory for quantifying first-generation rodenticides	Monitoring of first- as well as second-generation rodenticides
Assessment of use of biomarkers	Measuring biomarkers
Review of food-chain transfer and toxicity of veterinary products and development of analytical techniques	Monitoring for specific veterinary products
Investigation of disease status of birds	Disease monitoring

5.2 Proposal for a mechanism to incorporate new activities

If it is accepted that there is a desire to retain (and indeed enhance) information on PCBs (and perhaps specific OC pesticides) in birds of prey, there would appear to be a difficulty in incorporating new activities into the PBMS without significant additional resources. Some new aspects of monitoring may attract additional support from relevant regulatory agencies.

The flexibility and scope of the PBMS could be enhanced by carrying out analysis of OCs, PCBs and mercury on a multi-year cycle (for instance every two, three or four years) rather than every year. Other contaminants and/or species could be regularly monitored in birds in intervening years. In some instances, specific short-term studies could also be carried out in those years. Such an approach does not preclude subsequent replacement of certain species/analyses with others. This proposal has the advantage that full use will be made each year of the material collected and this information can be fed back to the volunteer collectors, as occurs currently. This is considered vital, as any impression given to volunteers that their efforts in collecting are wasted will result in a rapid decline in the numbers of carcasses being sent in.

The frequency with which compounds should be monitored (two/three/four or more yearly) then becomes a critical question. A statistical evaluation of the existing long-term datasets for OC pesticides, PCBs, mercury and rodenticides is required to determine whether the long-term temporal changes in residues detected by analysing birds on an annual basis would still have been identified (and with what degree of precision) if sampling had been less frequent.

5.3 Suggested immediate new activities for the Wildlife and Pollution Contract

It is proposed that the specific statistical review outlined above (together with production of a costed outline of potential changes to the PBMS) should be carried out as soon as possible as a one-off exercise.

Other changes that could be implemented immediately within the existing general framework of the PBMS are those highlighted in italics in Table 5.1. Consideration would need to be given to the resourcing implications for each of these activities.

6. Conclusions

A number of ways in which the PBMS might be adapted to increase its scope and flexibility have been highlighted in this report. The list is not exhaustive and other activities, that may meet specific requirements of regulatory and conservation agencies amongst others, are likely to be possible. The more detailed nature of the proposals with regard to PCBs reflects the effort already invested by CEH in exploring what information can be extracted from the PBMS with regards these compounds. Similar approaches are likely to be feasible for a number of other compounds.

The proposed statistical review of long-term datasets to evaluate appropriate sampling intensity should result in opportunities to broaden the scope of the PBMS by freeing resources for other activities in certain years. New analyses and/or species may then be incorporated into the PBMS, although it is likely that additional resources will be needed to fully address the range of reviews and new monitoring proposals which are eventually selected. Exactly which compounds and species should be considered for these activities will require a clear understanding of current concerns and requirements of conservation and regulatory agencies, and close consultation is needed.

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8. Appendices

Appendix 1: Compounds that may pose a risk to wildlife

Appendix 1 contains of list of 92 compounds derived from the full OSPAR list of 357 substances. The chemicals have been selected on the basis of their high production volume, but the list also includes additional substances that have already been regulated or voluntarily withdrawn. It is, therefore, a somewhat arbitrary selection and should not be taken as a definitive or exhaustive list of compounds that pose the greatest potential risk to wildlife. However, the list may be useful when considering which compounds should be monitored in the future using the PBMS.

The use and risk management/review status of each compound is given in the table. This includes whether the compound is banned or withdrawn or on the 1st or 2nd EU priority lists (which indicates that EU risk assessments are underway) or the 3rd EU priority list (risk assessment likely to be at an early stage). Appendix 1 also lists whether the compounds meet one or more of five risk criteria based on toxicity, persistence and bioaccumulation properties. The criteria are:

- The DETR-suggested criteria (persistence >60 days; bioaccumulation [log K_{ow}] >=5 [more or less equivalent to 100,000 times greater likelihood of the substance being in fat than in blood]; toxicity =< 1 mg/litre)
- A more stringent toxicity criterion (=< 0.1 mg/litre) with the same values for persistence and bioaccumulation
- A less stringent persistence criterion (>15 days) with the DETR values for bioaccumulation and toxicity
- A less stringent bioaccumulation criterion (log K_{ow} >=4; more or less equivalent to 10,000 times greater likelihood of the substance being in fat than in blood) with the DETR values for persistence and toxicity
- Less stringent criteria for **both** persistence and bioaccumulation (as above) with the DETR toxicity criterion

Finally, Appendix 1 indicates whether each compound is on the OSPAR list for priority action.

Appendix 1 List of compounds that may pose a risk to wildlife on the basis of their toxicity, persistence and bioaccumulation properties.

Common name	Use	Risk management/ review status	DETR suggested criteria	Toxicity trigger more stringent	Persistence trigger less stringent	Accumulation trigger less stringent	Persistence and accumulation less stringent	OSPAR list for priority action
Chlorinated paraffins (short-chain)	Plasticiser, metal-working fluids, flame retardants	Risk management agreed	x	x	x	x	x	x
Rosin: reaction products with formaldehyde		Occupational exposure only	x	x	x	x	x	
DDT	Insecticide	Banned	x	x	x	x	x	
TBTO	Antifoulant	Risk management in place; ban proposed	x	x	x	x	x	
Tetramethyl lead	Petrol additive	Risk management in place	x	x	x	x	x	x
1,2,3-trichlorobenzene	Dielectric fluids	ESR 1st Priority List	x	x	x	x	x	
Tetrabromobisphenol A	Fire retardant	ESR 3rd Priority List	x	x	x	x	x	x
Hexachlorobutadiene	Solvent and intermediate	ESR 1st Priority List	x	x	x	x	x	
HCB	Fungicide/intermediate	No longer manufactured as a fungicide. ESR 1st Priority List	x	x	x	x	x	
Anthracene	Intermediate for dyes	ESR 1st Priority List	x	x	x	x	x	
Dicofol	Pesticide	Registered in UK	x	x	x	x	x	
Cyclododecane	Mothproofer		x	x	x	x	x	
Distillates: coal-tar; heavy oils	Intermediate		x	x	x	x	x	x
Anthracene oil; anthracene paste, anthracene fraction	Intermediate		x	x	x	x	x	x
Polychlorinated biphenyls (PCB)	Dielectric fluids, lubricant oils	No longer manufactured in Europe; possible new environmental contamination. Risk management in place	x	x	x	x	x	x
Dieldrin	Insecticide	Banned	x	x	x	x	x	
Endrin	Insecticide	Banned	x	x	x	x	x	
Methoxychlor	Insecticide	No longer used in UK	x	x	x	x	x	
Heptachlor	Insecticide	No longer used in UK	x	x	x	x	x	
Hexachloronaphthalene		No longer manufactured	x	x	x	x	x	
2.3.7.8-tetrachlorodibenzo-p-dioxin	Dioxin	Not deliberately produced. High priority risk management agreed	x	x	x	x	x	x
White spirit	Solvent	Occupational exposure only concern	x	x	x	x	x	
Cyclododecatriene		Occupational exposure only	x		x	x	x	
Anthracene oil	Intermediate		x	x	x	x	x	x
Distillates (coal-tar): pitch, pyrene fraction	Intermediate		x	x	x	x	x	x
Pentachloronaphthalene		No longer manufactured	x		x	x	x	
Nitriles: coco		ESR 3rd Priority List	x	x	x	x	x	
Lindane	Insecticide	POPs list	x	x	x	x	x	
Pentachlorothiophenol	Antioxidant (synthetic rubbers)	ESR 3rd Priority List	x	x	x	x	x	
Terphenyl	Intermediate		x	x	x	x	x	

Common name	Use	Risk management/ review status	DETR suggested criteria	Toxicity trigger more stringent	Persistence trigger less stringent	Accumulation trigger less stringent	Persistence and accumulation less stringent	OSPAR list for priority action
Residues (coal-tar): pitch distn.	Intermediate		x	x	x	x	x	x
4-Nonyl phenol	Detergent precursor and breakdown product	ESR 1st Priority List	x		x	x	x	x
Pyridate	Herbicide	Registered in UK	x	x	x	x	x	
Diisopropylnaphthalene	Intermediate		x		x	x	x	
Tetrachloronaphthalene		No longer manufactured	x		x	x	x	
Heptachloronaphthalene		No longer manufactured	x		x	x	x	
Trichloronaphthalene		No longer manufactured	x		x	x	x	
Pentabromodiphenyl ether	Fire retardant	Risk management assessed	x		x	x	x	
Hexachlorocyclopentadiene	Intermediate	ESR 1st Priority List				x	x	
Chlorobenzene	Intermediate	ESR 2nd Priority list				x	x	
Endosulfan	Insecticide	No longer manufactured				x	x	
Dinitrotoluene	Intermediate	ESR 1st Priority List				x	x	
Dibutylcresol	Antioxidant (synthetic rubbers)	ESR 1st Priority List				x	x	
Octyl phenol	Detergent precursor and breakdown product	Equivalent to nonylphenol				x	x	x
Nitrophen	Herbicide	No longer manufactured				x	x	
Potassium dichromate	Salt	ESR 3rd Priority List				x	x	
Triallate	Herbicide	Registered in UK				x	x	
Tridemorph	Fungicide	Registered in UK				x	x	
Acenaphthene	Intermediate					x	x	x
Bis(2-hydroxy-3-tert-butyl-5-methylpentyl)methane	Antioxidant					x	x	
p-Phenylenediamine. N.N'-bis(1.4-dimethylpentyl)-	Antioxidant					x	x	
Diisononyl phthalate	Plasticiser					x	x	
Isodecyl diphenyl phosphate	Plasticiser					x	x	
Pentachlorophenol	Fungicide; insecticide; herbicide	Registered in UK				x	x	x
Dichlorobenzidine	Intermediate (dye)	ESR 2nd Priority list				x	x	
Chlorinated paraffins (medium-chain)	Solvent; lubricant component	ESR 2nd Priority List				x	x	
Diazinon	Insecticide	Registered in UK				x	x	
Bifenox	Herbicide	Registered in UK				x	x	
Aclonifen	Herbicide	Not registered in UK				x	x	
1.2.4-trichlorobenzene	Dielectric fluids	ESR 1st Priority List				x	x	
Camphene	Mothproofer	ESR 3rd Priority List				x	x	
Alpha pinene	Intermediate for synthetic pine oils					x	x	
Butyltoluene	Intermediate; solvent for resins	Neurotoxicity appears to be concern; only occupational exposure likely				x	x	
Hexamethyldisiloxane	Hydraulic fluid and intermediate (silicon oils)					x	x	
Hexahydrofarnesyl acetone						x	x	
Triphenylphosphine	Intermediate					x	x	

Common name	Use	Risk management/ review status	DETR suggested criteria	Toxicity trigger more stringent	Persistence trigger less stringent	Accumulation trigger less stringent	Persistence and accumulation less stringent	OSPAR list for priority action
Alcohols: C11-15-branched	Intermediate					x	x	
Tetrahydronaphthalene	Solvent	ESR 2nd Priority list				x	x	
Dichlorobenzene	Insecticide and fumigant	ESR 1st Priority List				x	x	
Diethylphosphite	Antioxidant (synthetic rubbers)	ESR 3rd Priority List				x	x	
Diphenyloctyl phosphate	Plasticiser	ESR 3rd Priority List				x	x	
Diphenyl ether	Intermediate (fire retardant)	Fire retardants assessed				x	x	
Isophoronediisocyanate	Intermediate (paints)					x	x	
Tetrachlorotoluene						x	x	
Trimethyl pentene						x	x	
Dodecylbenzenesulphonic acid	Detergent					x	x	
Chloroform	Solvent	ESR 1st Priority List				x	x	
Nitromethane	Solvent	POPs list				x	x	
Tetraethyllead	Petrol additive	Risk management in place			x		x	x
Diethylhexylphthalate	Plasticiser	ESR 1st Priority List			x		x	x
Bromoxynil	Herbicide	Registered in UK			x		x	
Zinc chloride	Metal salt				x		x	
Anthracene oil: anthracene paste	Intermediate				x		x	x
Anthracene oil: anthracene-free	Intermediate				x		x	x
Dodecene. branched (isododecene)	Intermediate				x		x	
Anthracene oil: anthracene paste; distn. lights	Intermediate						x	x
Diundecyl phthalate	Plasticiser						x	
4.6-Di-tert-butyl-3-methylphenol	Intermediate (resins and synthetic rubbers)							
Petroleum distillates	Intermediate						x	
Amines: C10-16-alkyldimethyl							x	
1.6-Hexanediamine. N.N'-bis(2.2.6.6-tetramethyl-4-piperidinyl)-	Antioxidant							
Dichlorobenzidine dihydrochloride	Intermediate (dyes)						x	

Appendix 2: Abbreviations used in the text

CEH	Centre for Ecology and Hydrology
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions (now DEFRA)
EA	Environment Agency
EU	European Union
GB	Great Britain (England, Scotland and Wales, excluding Northern Ireland)
GC-ECD	gas chromatography with electron-capture-detection
GC-MS	gas chromatography with mass spectrometry
HCH	hexachlorocyclohexane
HSE	Health and Safety Executive
ITE	Institute of Terrestrial Ecology (now Centre for Ecology and Hydrology)
JNCC	Joint Nature Conservation Committee
MAFF	Ministry of Agriculture, Fisheries and Food (now DEFRA)
NCC	Nature Conservancy Council
NP/NPE	nonylphenol/ethoxylates
OC	organochlorine
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention)
PAH	polycyclic aromatic hydrocarbons
PBMS	Bird of Prey Monitoring Scheme
PCB	polychlorinated biphenyls
PCDD	polychlorinated dibenzodioxins
PCDF	polychlorinated dibenzofurans
PCP	pentachlorophenol
ppm	parts per million
PVC	polyvinyl chloride
SCCP	short-chain chlorinated paraffins
SEPA	Scottish Environment Protection Agency
SIM	select ion monitoring
TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEF	Toxic Equivalency Factor
TEQ	Toxic Equivalent
UK	United Kingdom (England, Scotland, Wales and Northern Ireland)
WHO	World Health Organization
WIIS	Wildlife Incident Investigation Scheme