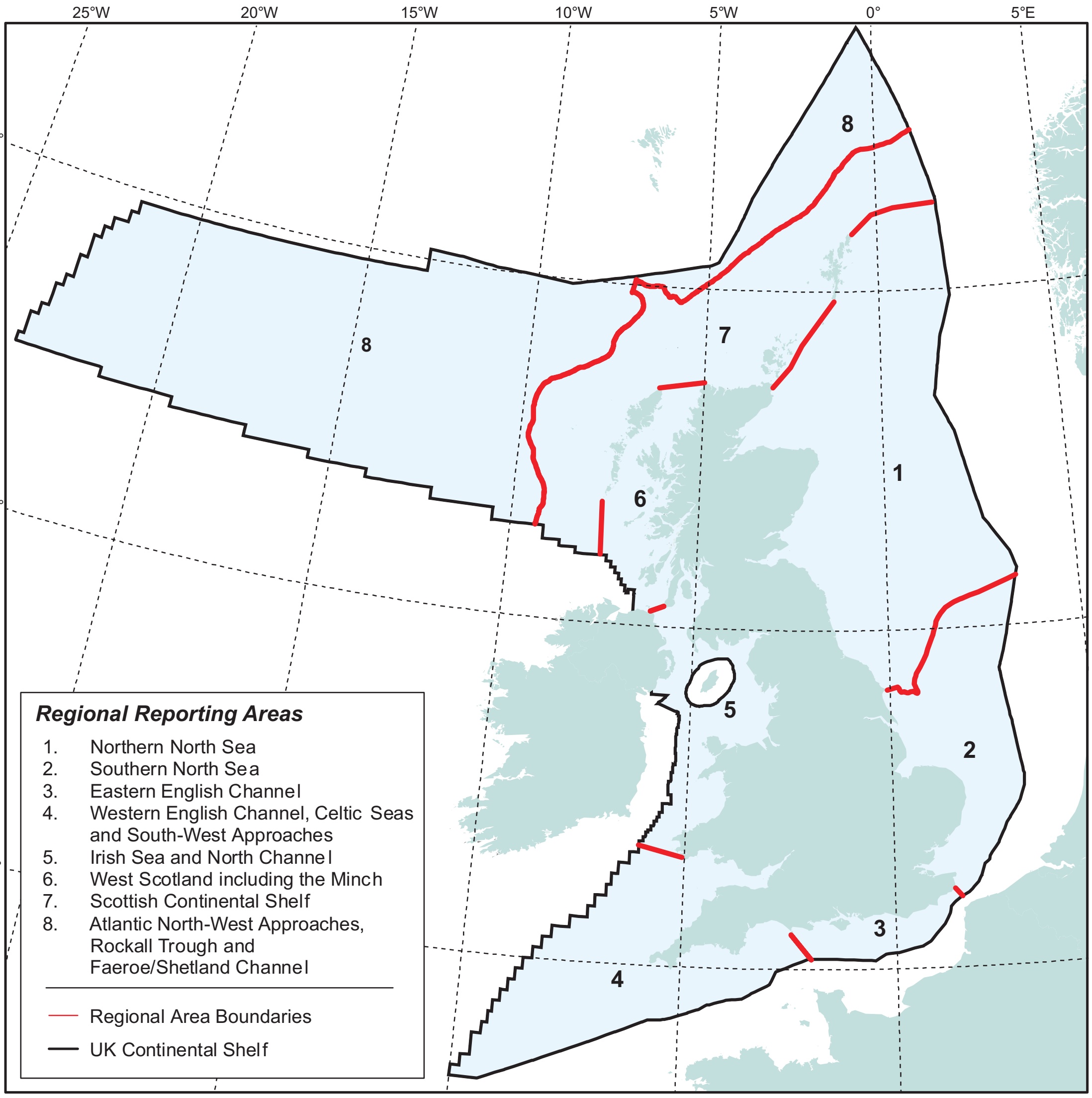
1: Marine Environment Quality

MEMG contribution to
Charting Progress - an Integrated Assessment
of the State of UK Seas
(The 1st of 5 Reports)



Note: The exact limits of the UK Continental Shelf are set out in orders made in Section 1(7) of the Continental Shelf Act 1994.

The Regional Reporting Areas around the UK

This report is one of five that have been produced to provide detailed scientific assessment in support of '*Charting Progress – an Integrated Assessment of the State of the UK Seas*'; published by the Department for Environment, Food and Rural Affairs on behalf of the UK Government and Devolved Administrations in March 2005.

The five reports in the series are as follows:

1: Marine Environment Quality
2: Marine Processes and Climate
3: Marine Habitats and Species
4: Marine Fish and Fisheries
5: Integrated Regional Assessment

All reports can be found on the Defra website: www.defra.gov.uk

The 1st of 5 reports produced to support **Charting Progress** – an Integrated Assessment of the State of UK Seas

Marine Environment Quality

Marine Environment Monitoring Group

2005

Contents

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Preface

This report forms the Marine Environment Monitoring Group (MEMG) sectoral contribution to the Defra State of the Seas Report (Defra, 2005).

MEMG is a management group with representation from all UK Government organisations with statutory marine environmental protection monitoring obligations. The Group is chaired by a representative from the Centre for Environment, Fisheries and Aquaculture Science (CEFAS). Its aim is to ensure that environmental quality monitoring of the marine environment is conducted in a co-ordinated way, is as cost-effective as possible and meets national and international requirements.

The core members of MEMG are representatives from the following organisations:

Centre for Environment, Fisheries and Aquaculture Science (CEFAS);
Department for Environment, Food and Rural Affairs (Defra);
Environment Agency (EA);
Department of Agriculture and Rural Development (Northern Ireland) (DARD);
Environment and Heritage Service (Department of Environment (NI)) (EHS);
Fisheries Research Services Marine Laboratory (FRS);
Scottish Environment Protection Agency (SEPA);
The National Assembly for Wales (Environment Division) (NAW);
Scottish Executive Environment and Rural Affairs Department (SEERAD);
Sir Alister Hardy Foundation for Ocean Sciences; (SAHFOS);
Joint Nature Conservation Committee (JNCC);
Inter-Agency Committee on Marine Science and Technology (IACMST).

This report presents information on the current status of marine environmental quality in the UK, in relation to human activities. It covers fish and fisheries, aquaculture, nutrients and eutrophication, hazardous substances, microbiological contamination, oil and oil-based contaminants, radioactivity, construction and aggregate extraction, litter, navigation dredging and dredged material relocation and shipping impacts and non-indigenous species.

Where possible, the DPSIR approach has been used, providing information on Driving forces (human activities causing pressures), Pressures (e.g. inputs), State (e.g concentrations of contaminants), Impact (e.g. changes in the ecosystem) and Response (e.g. different policy options). The DPSIR approach is a framework of indicators of change, which are an integral part of an ecosystem approach and the assessment and monitoring of human activities. MEMG and Defra have been developing this approach for UK marine monitoring over the last few years and it is an ongoing process. A number of indicators are used tentatively in this report, where agreed indicators are not yet available, progress with their development is discussed.

OSPAR has pursued its commitment to the ecosystem approach to management by the identification of ecological goals and objectives (EcoQOs), for representative parts of the marine ecosystem. Where applicable, these are also discussed. However, EcoQOs are still under development and evaluation and in many cases appropriate UK datasets are not yet available.

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Executive summary

The Government's first report on marine stewardship, Safeguarding Our Seas, was published in May 2002 and outlined the strategy for the sustainable development and conservation of our seas. The report recognised the importance of an ecosystem-based approach to management of the marine environment in delivering its vision of 'clean healthy, safe, productive and biologically diverse oceans and seas'. The report sets out a framework to deliver the vision through improved co-ordination of marine monitoring with the aim of supporting better integrated assessments of the state of the UK marine environment at regular intervals.

The commitment by Defra and the appropriate Departments in the Devolved Administrations to produce an up-to-date comprehensive report on the quality and status of UK marine waters will be in the form of a State of the Seas Report, the first of which will be published in 2005. To take this forward a steering group was established, chaired by Defra, with representatives from the four UK Marine sectors, namely, Marine Environmental Quality, Marine Processes and Climate, Marine Habitats and Species, and Marine Fish and Fisheries.

Status reports produced by each of the 4 sectors will provide the basis for the integrated assessment. This is the report for the Marine Environmental Quality Sector, co-ordinated by the Marine Environment Monitoring Group (MEMG), which co-ordinates marine environmental quality monitoring in the UK.

The report focuses on the impacts of human activities on the marine environment and its resources, providing an assessment of current status and trends, based on current knowledge and information. The report makes use of data from a number of monitoring programmes and other sources. To some extent difficulties have arisen because data is held by a large number of organisations and there is no central repository that could help co-ordinate the many information sources. In other cases, there was insufficient data for assessment and/or, consistent and comparable data was not available across the UK. These issues will be addressed as soon as practicable to facilitate future State of the Seas reports.

In the case of Chapter 3 on hazardous substances, the majority of the data presented is from the UK National Marine Monitoring Programme (NMMP), developed by the MEMG. This is an UK co-ordinated monitoring programme, supported by quality assurance schemes, which ensures the data is of good quality and comparable across the UK. The programme has been running since the early 1990s, and the temporal trend phase was initiated in 1999. The data presented in this report are for the years, 1999-2002. Four years data is insufficient to determine statistically significant trends and therefore data is generally presented as a mean of the 4 years. However, the data is often sufficient to give indications on whether there are likely to be environmental problems. More powerful trend data will become available in the future as the programme continues and datasets are expanded.

The State of the Seas integrated assessment is presented on the basis of eight Regional Seas (see Figure 1), and a holistic assessment Where possible, regional variations are highlighted in this report using the relevant Regional Sea area numbers shown in Figure 1. In some cases, the available data is not suited to this approach, for example data on hazardous substances and nutrients. In this instance, data may be presented by different regional areas or on a national basis.

The following summarises the findings of this report regarding the current status of the environmental quality of UK marine waters.

FISH AND FISHERIES

Fishing has had the major impact on fish stocks over the past 50-100 years. In most regions, the level of fishing on demersal stocks remains too high and if maintained, will continue to lead to unsustainable fisheries in the long term. In key pelagic stocks, management action has been successful in reducing fishing mortality and these stocks have increased substantially over the past decade. Throughout the regions, valuable *Nephrops* stocks also continue to be exploited at sustainable levels.

Once stocks become depleted, then other sources of mortality such as predation and environmental factors including climate change may become more important. In these situations, it may be necessary to reduce fishing mortality even more severely in order to ensure that stocks can rebuild to safe biological levels.

- TACs alone have not been successful in regulating fishing mortality rate on a number of stocks and management increasingly includes direct effort control (days at sea), technical measures and recovery plans. The UK has actively implemented decommissioning to reduce fishing effort, and legislated for the introduction of square mesh panels in *Nephrops* trawls.

- Over the past decade the stock status of some key demersal species has deteriorated. In contrast there has been significant improvements in the state of pelagic species such as herring.

- In the North Sea, four of the eight main demersal stocks are considered to be harvested unsustainably or at risk of being harvested unsustainably. The cod stock remains at historically low levels and is subject to emergency management measures and a recovery plan from 2005. However, herring stocks have increased substantially and *Nephrops* are exploited sustainably.

- Over the past decade Irish Sea cod and whiting stock status has deteriorated, causing concern for stock collapse. The recovery plan for Irish Sea cod includes a lower TAC, a closed area, effort regulation and other technical measures. It was introduced in 2000 and is still in place.

- Most demersal stocks in the Southwest Approaches are harvested outside precautionary limits. The northern hake stock is the subject of a management recovery plan introduced in 2004 that includes a lower TAC and technical measures (mesh size restrictions). A recovery plan for Celtic Sea cod is under consideration.

- Haddock and Nephrops in the west of Scotland are harvested sustainably but the status of many of the other demersal species are either uncertain or considered to be at low historical levels. Cod in VIa is below the Precautionary Limit Reference point (B_{lim}) and is subject to a recovery plan.

Many factors can cause changes in the abundance and distribution of fishes, including natural variation, biological interactions and human activities. Activities that are known to affect the structure and diversity of fish communities include fishing, changes to habitat quality caused by, for example, pollution, eutrophication and habitat destruction, and the introduction of non-native species. Time-series datasets have provided some valuable insights into changes in the marine environment during the past century. Determining the relative impacts of these various factors is difficult, however, and whereas many studies have demonstrated a correlation between environmental variables and biological indices, there are few cases that prove causal relationships.

Commercial exploitation of fish also has impacts on the wider marine environment. These impacts include those on the abundance, size and genetic diversity of target species, on seabed habitats and non-target animals such as marine mammals, fish and benthic fauna that are also caught during fishing operations, on the genetic diversity of both species and populations, and on the food web itself.

- Fishing affects non-target species caught as by-catch, and has caused reductions in large bodied and vulnerable species such as skates and rays.

- Monitoring programmes to determine the quantity and composition of discarded catches are in place in many UK fisheries.

- Many larger target and bycatch species in the North Sea and Irish Sea are now reduced to <10% of their expected abundance without fishing, and the mean weight of fish has declined.

- Bycatches of common dolphins in the bass fishery and harbour porpoises in the North Sea gill net fisheries are a concern, and mortality rates are thought to exceed ASCOBANS advised limits.

- The distribution of fishing activity is patchy. Some areas are repeatedly trawled each year while others are fished less than once in 7 years.

- Unfished areas with low levels of natural disturbance are more vulnerable to fishing than naturally dynamic areas that are trawled regularly.

- The natural biogeographic trend from the SW to NE of the British Isles, and the recent changes in climate, can lead to difficulties in identifying ecosystem changes caused by fishing.

- Life-history characteristics of some deep-sea fishes will make them susceptible to over-exploitation.

AQUACULTURE

The majority of open cage finfish aquaculture is carried out in semi enclosed sea lochs on the west coast of Scotland, and in Shetland with marine salmon farm sites concentrated in the west and north of Scotland. Very little marine fish farming is carried out on the east coast of Scotland or around England and Wales, where the predominant aquaculture is shellfish. Finfish culture has been increasing over the last 10-15 years and although salmon remains the dominant species, culture of new species; halibut, cod and haddock is expected to increase significantly over the next 5-10 years. The pressures of aquaculture on the environment include particulate organic wastes, nutrient excretion and medicinal chemicals mainly used to control sea lice.

Environmental monitoring at fish farms is required of fish farm operators by SEPA or the EA as a condition of discharge consents. SEPA and the EA also carry out audit monitoring surveys and additional work (mainly Scottish) to assess the effectiveness of statutory controls and assess the impacts of aquaculture in international contexts.

Key indicators relating to aquaculture are those being developed under the OSPAR Comprehensive Procedure for the current assessment of eutrophication.

Statutory controls and Environmental Quality Standards are in place to ensure that significant impacts are restricted to the immediate vicinity of fish farm cages and there are a number of strategies underway, or proposed, within the UK and the EU, designed to achieve the sustainable development of aquaculture.

Current status

- Total quantities of particulate organic matter and N discharges from fish farms have increased over the last 10-15 years as the industry has expanded. This is despite consistent improvements in aquaculture technology and in the efficiency of feed utilisation.

- Monitoring in Scottish sea lochs showed that the total area of seabed impacted by organic waste is generally small and impacts rarely extend beyond 50 m from the cages.

- In recent surveys of fish farms, winter N:P ratios did not exceed OSPAR eutrophication assessment criteria at any sites surveyed. Winter N:Si ratios exceeded levels thought to influence phytoplankton species composition at one loch in the Western Isles of Scotland and all areas surveyed in the Shetlands. Chlorophyll a levels were spatially and temporally variable and concentrations of toxic/nuisance algae were insufficient to cause adverse effects.

- Planktonic copepods and sediment-associated organisms are at greatest risk of effects from the use of medicinal chemicals in fish farms. To date, no effects have been detected at the species or community level related to chemical usage.

- Sea lice are a major problem in salmon farms and there is concern that the numbers of larval lice in the environment may be one factor in the historic decline in wild sea trout and salmon stocks on the west coast of Scotland. Better management and improvements in sea lice treatments are reducing the sea lice load on farmed fish.

- The potential for genetic interaction between escaped farmed fish and their wild conspecifics and possible consequential adverse effects on fitness and productivity of progeny are of concern. At present, there is insufficient information to assess the precise scale or significance of such interactions in UK waters. There are a number of ongoing studies to address this issue.

EUTROPHICATION

Nutrient inputs to the marine environment, result from a variety of human activities, including the manufacture and usage of fertilisers, human and animal wastes and the burning of fossil fuels. In the right conditions, nutrient enrichment can promote the growth of plants and lead to an undesirable disturbance, i.e. eutrophication can occur.

Nitrogen and phosphorus inputs (the waterborne loads from land based sources) are monitored nationally under the Riverine Inputs and Direct Discharges (RID) programme and reported annually to OSPAR. Nutrient concentrations in marine waters are monitored at least annually (Winter Nov-Feb) as part of the NMMP and under other monitoring programmes in order to fulfil national and international obligations such as those arising from The OSPAR Strategy to Combat Eutrophication and various EC Directives (Nitrate, Urban Waste Water Treatment). There is no comprehensive monitoring of chlorophyll a, but limited data is available from the NMMP and the long-term CPR surveys provide a surrogate measurement of chlorophyll a using the Phytoplankton Colour index.

Key indicators relating to nutrients are described in the OSPAR Comprehensive Procedure for the assessment of eutrophication (which is currently undergoing revision). In addition, OSPAR has proposed a number of Ecological Quality Objectives (EcoQOs) for managing nutrient enrichment. These are still under development and refinement and are yet to be applied as a pilot study in the North Sea.

Current Status

- The distribution of human populations and intensive agricultural activity determines those areas that experience the most significant pressure due to nutrient input. The areas with the highest pressure are the transitional and coastal waters of southern, eastern and north-western England.

- The pressures due to direct inputs of nitrogen and phosphorus have reduced nationally by 35% and 50%, respectively since 1990. There is no evidence of reductions in riverine inputs, these inputs are closely linked with riverine flows. This reflects the importance of managing the diffuse inputs of nutrients from land run-off in the future.

- The pressure due to diffuse input varies with rainfall and river flow rates. Increasing river flow in some critical areas has led to nitrogen inputs being maintained at previous levels despite changes in management. The land ‘buffer’ for nitrogen implies that change of input can only happen in the long term.

- Nutrient pressure is different in the different regions. 40% of river borne nutrients enter the North Sea South area.There has been a 60% reduction in the input of nitrogen to the North Sea North since 1990. This is in contrast to the marginal reduction to the North Sea South area.

- Although the coastal waters of southern, eastern and north-western England and the inner Bristol Channel are enriched with nitrogen and phosphorus, the correlation with nutrient input is weak. The reducing nutrient inputs are not reflected in detectable reduction in the winter nutrient concentration in the sea. This reflects the importance of the oceanic inventory of nutrients in UK coastal and offshore waters. One study in the Irish Sea may show a decline in phosphorus with declining input.

- The level of phytoplankton biomass in coastal waters falls below the OSPAR Comprehensive Procedure criterion reflecting that despite nutrient enrichment the growth may be limited by light availability and by loss to the food chain and the environment. Undesirable disturbance of the balance of organisms and water quality appears to be limited in UK marine waters.

- Significant long-term changes relating to the NAO are occurring at a regional level. These changes affect the growth of plants and the type of plants that are favoured. Disentangling changes due to nutrient enrichment and changes due primarily to regional change is a science priority.

- Anthropogenic nutrient related change has occurred in some enclosed estuarine environments and harbours such as the Ythan estuary, Chichester, Langstone and Portsmouth harbours. Further work is required to fully understand the risk posed by nutrients for the ecological integrity of estuaries.

- In principle, human interference with the nitrogen and phosphorus cycles presents a widespread threat to the marine environment. However, despite the level of nutrient enrichment in some UK waters, there is evidence that undesirable disturbance to the balance of organisms and to water quality has not occurred.

- The potential significance of nutrient enrichment, combined with the accelerated regional changes taking place, point to the requirement for better evidence and better understanding of the ecosystem consequences of nutrient input.

HAZARDOUS SUBSTANCES

Some substances are toxic, persistent and have a tendancy to bioaccumulate and consequently, if they reach the marine environment have the potential to present a hazard to marine life. OSPAR and the EU have developed selection and prioritisation mechanisms to identify those substances of highest concern for priority investigation and control.

Inputs of a number of OSPAR priority action chemicals [mercury (Hg), cadmium (Cd), copper()lead (Pb), zinc (Zn) and lindane (g-HCH)] to the marine environment from land-based sources are monitored nationally under the Riverine Inputs and Direct Discharges programme, for annual submission to OSPAR. Environmental concentrations of hazardous substances are monitored annually under the NMMP, in water (Hg, Cd, Cu, Pb, Zn, HCH), sediments [Hg, Cd, Cu, Pb, Zn, polychlorinated biphenyl (PCB) congeners 28, 52, 101, 118, 138, 153, 180 and a range of polycyclic aromatic hydrocarbons (PAH) compounds] and biota [arsenic (As), silver (Ag), Hg, Cd, Pb, Cr, Cu, Ni, Zn, CB congeners 28, 52, 101, 118, 138, 153, 180 and a range of PAH compounds]. These data fulfil national and international monitoring requirements under OSPAR and EU Directives. Pilot surveys of some priority substances not routinely monitored under the NMMP, such as brominated flame retardants and alkylphenols have been carried out at selected NMMP sites and estuaries around England a Wales to provide information in support of the OSPAR strategy for hazardous substances.

A number of biological and biological effects techniques (biological community structure, EROD, fish disease and liver histopathology, sediment and water bioassays) are deployed annually under the NMMP to measure the effects of hazardous substances on marine life. Some additional techniques, such as metallothionien, imposex, DNA adducts and bile metabolites are deployed at selected sites by laboratories skilled in these techniques.

Monitoring of hazardous substances in marine mammals is carried out as part of the UK Marine Mammal Strandings Programme to fulfill commitments under ASCOBANS (the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas).

Key indicators for hazardous substances include:

- inputs of hazardous substances to the marine environment (tonnes per year); emissions of hazardous substances (tonnes per year);
- concentrations of hazardous substances compared to Environmental Quality Standards (EQS);
- concentrations of hazardous substances compared to Background Reference Concentrations (BRCs);
- concentrations of hazardous substances compared to Ecotoxicological Assessment Criteria (EACs);
- univariate indicators of biological community structure;
- multivariate indicators of biological community structure and biotic indicators (ITI and AMBI).

OSPAR has adopted a specific target to cease discharges, emissions and losses of hazardous substances by the year 2020. The EC Water Framework Directive requires all surface waters (including transitional and coastal waters) to meet good ecological status by 2015 and includes a 20 year cessation target for discharges, emissions and losses of hazardous substances.

Current status

- Total riverine and direct inputs of Hg, Cd, Cu, Pb, Zn and γ-HCH to coastal waters have reduced by 20%-70% since 1990 and atmospheric emissions of the same chemicals have reduced by 50%-95% since 1990.
- Concentrations of Hg, Cd, Cu, Pb, Zn and γ-HCH in waters are below EQSs in the vast majority of areas.
- However, concentrations of Hg, Cd, Cu, Pb and Zn in both water and sediments are elevated above background concentrations (i.e. pristine) in most areas, particularly in industrialised estuaries, in many cases as a result of historical inputs.
- Concentrations of Hg, Cu, Pb, CBs and PAHs in sediments are above EACs in a number of areas, particularly in industrialised estuaries. Concentrations of Cd and Zn are generally below EACs in most areas, except for some estuaries on the east coast of England.
- Contaminated sediments from localised areas in some industrialised estuaries were toxic to test organisms, but there was no direct correlation between concentrations of hazardous substances and benthic community structure.
- Concentrations of Hg in dab were close to background at approximately 50% of the sites monitored, but remain above background in areas such as the Mersey, Liverpool Bay and the Thames.
- Concentrations of Hg, Cd, Pb and CBs in mussels were above background at most sites, whilst concentrations of Cu and Zn were generally not above background.
- Concentrations of PAHs in mussels were below the EAC in all areas, but concentrations of CBs in mussels were above the upper EAC at ~30% of sites.
- Highest concentrations of hazardous substances in biota were found in industrialised estuaries and adjacent areas with a known history of contaminant inputs. High concentrations of Cd were also found in fish liver from the offshore Dogger Bank site.

- Biological effects such as increased enzyme activity (EROD), DNA adducts and elevated levels of fish disease and liver tumours were found in some fish populations from areas found to have high concentrations of hazardous substances in sediments and biota.

- Research on endocrine disruption in the marine environment found some feminisation of flounder, resulting in egg protein production in males, but this seems to be declining in some areas. The key substances implicated as causing the effects were natural substances such as the human female sex hormone 17beta-oestradiol and synthetic chemicals such as nonylphenols.

- Imposex in dogwhelks was widespread, but effects on reproduction appear only to be significant within a few hundred metres of point source discharges of TBT.

- There are some indications which suggest that there may be a causal relationship between elevated concentrations of PCBs and mercury in blubber and infectious disease mortalities in marine mammals.

MICROBIOLOGICAL MONITORING

There are three national microbiological monitoring programmes undertaken in the UK marine environment. These are related to the requirements of the EC Bathing Waters Directive, Shellfish Waters Directive and Shellfish Hygiene Directive. The concentrations of faecal indicator bacteria are measured in seawater and/or shellfish and assessed against standards set under the directives.

Bathing waters are sampled weekly during the bathing season, between May/June and September. Shellfish waters are sampled a minimum of quarterly throughout the year and shellfish harvesting areas are sampled monthly

Key indicators are:
- percentage of bathing waters meeting mandatory standards;

- percentage of bathing waters meeting guideline standards;

- classification status of designated shellfish harvesting areas;

- percentage compliance of designated shellfish waters with the guideline standard.

For England and Wales, the Government has expressed an objective, for shellfish harvesting areas, to achieve at least class B standard (require purification, relaying or heat treatment to meet class A) in all areas designated under the Shellfish Waters Directive.

Current status
Bathing Waters:
- In 2003, 98% of UK identified bathing waters met the mandatory standards and 74% met guideline standards, an increase in compliance of 21% and 45% respectively, since 1990. This largely reflects investment in improvements in sewage treatment and infrastructure.

- Continuing failures of bathing water mandatory standards are seen at a small number of sites in Region 1(Flamborough North Landing and Staithes - Yorkshire), Region 4 (Blue Anchor West - Somerset and East Looe - Cornwal) and Region 5 (Heysham Half Moon Bay - Lancashire, LLangrannog - Wales, Brigh House and Rockcliffe - Solway and Ethricke Bay - Bute).

Shellfish Harvesting areas:
- In 2003, in England and Wales, 85% of shellfish beds achieved B classification or above, an increase from 71% in 1999 and a positive move towards meeting the Government's objective. In Scotland and Northern Ireland, the figures were 98% and 100% respectively.

Shellfish Waters:

- The available data and standards for shellfish waters are not consistent throughout the UK making comparisons difficult.

OIL AND OIL-BASED CONTAMINANTS

Oil and oil-based contaminants reach the marine environment from a variety of sources including; rivers and run off from land, atmospheric fall out, the offshore oil and gas industry and accidental spills.

There is no comprehensive monitoring of inputs of oil or oil-based contaminants. Selected PAHs are monitored annually under the NMMP in sediments from dedicated sites and in shellfish. The Food Standards Agency also monitors PAHs in shellfish from time to time. Monitoring of sediment hydrocarbon contamination related to oil industry discharges has been carried out in the past; more recent monitoring is mainly connected with decommissioning programmes. Surveys of PAHs in sediments from Fladden ground, an accumulative area in the central North Sea, were carried out by FRS in 1989 and 2001.

Monitoring of oil spills from oil and gas installations and shipping is achieved through mandatory reporting procedures.

Key indicators related to oil and oil-based contaminants are:

- Oil spills from offshore installations and shipping (tonnes per year);

- OSPAR has proposed an EcoQO relating to the impacts of oil spilt in the marine environment. The proportion of oiled common guillemots found dead or dying on beaches should be 10% or less of the total found dead or dying in all areas of the North Sea. Implementation of this EcoQO is still under discussion.

Through OSPAR, the UK has committed the offshore industry to a 15% reduction in the quantity of oil discharged in produced water by 2006, relative to the level of discharge in 2000

Current Status

- The largest inputs of oil-based hydrocarbons to the marine environment are from land-based sources, reaching the sea via rivers, runoff and from the atmosphere. Refinery inputs to rivers have declined approximately 20-fold since 1981 and volatile emissions of PAH to the atmosphere from land-based sources have reduced by approximately a factor of 4 since 1990.

- The second largest (though significantly lower) source of oil discharge to the marine environment is via the offshore oil and gas industry. Although the sources have approximately halved in recent years and inputs of oil associated with drill cuttings have now ceased following controls, the volume of produced water has increased, although the industry's performance in processing the discharges of water has improved considerably by reducing the concentration to an average of around 21 mg per litre. The overall effect is that the quantity of oil entering the sea has remained fairly constant. The oil is well dispersed and does not constitute an oiling hazard.

- Accidental spills of oil from shipping in the open sea and from offshore installations constitute a small proportion of overall inputs, though they may have some local importance. The tonnages spilt from the two sources are generally of a similar magnitude.

- Preliminary monitoring studies of offshore sediments remote from the likely impact of oil installations show PAH concentrations to have declined by 70% from 1990-2000.

RADIOACTIVITY

Radioactivity has both natural and anthropogenic sources. Natural radiation stems from the decay of primordial radionuclides in the earth's crust and from interactions with cosmic radiation in the atmosphere. Such radionuclides can be found in enhanced concentrations both due to natural processes and as a result of industrial practises (e.g. oil and gas production, phosphate processing). Artificial radionuclides have 4 main sources: weapons testing; nuclear accidents (e.g. Chernobyl); offshore dumping of liquid and solid waste; and, direct discharges from industrial processes (e.g. nuclear fuel reprocessing, production of pharmaceutical radio-isotopes).

Discharges of artificial radionuclides from nuclear establishments are subject to authorisation by the environment agencies, and discharge limits are subject to review. Site operators are required to carry out environmental monitoring as a license condition, in addition to the independent monitoring carried out by the environment agencies. The principle concern is to protect human health and the assessment process is comprehensive and long-standing. The programmes include measuring radionuclide concentrations in a range of foodstuffs, depending on a number of factors including: the habits of the critical group (i.e. most exposed group of individuals) at each site; and the type and quantities of radionuclides discharged. In addition, measurements are made of concentrations in sediments, water and other biota from around the UK coast, as indicators of the distribution of radionuclides in the environment, and to estimate exposure from other pathways (e.g. use of seaweed as a soil conditioner). These are supplemented by direct measurements of external exposure in intertidal areas and as a result of handling contaminated materials. Observations generally are made on an annual, quarterly or monthly basis, depending on the nature of the exposure pathways. A wide range of radionuclides is included, with half-lives ranging from a few days to tens of thousands of years (e.g. ^{3}H, ^{99}Tc, ^{137}Cs, plutonium, ^{241}Am). The most significant source results from nuclear fuel reprocessing at Sellafield, and this is reflected in the number and frequency of observations in the Irish Sea. Sellafield tends to mask contributions from other sources. Comprehensive assessments have been made of the potential effects of chronic radiation exposure on marine organisms. These concluded that there were unlikely to have been significant effects at the population level, even during the time of maximum discharges.

Key indicators for radioactivity include:

- discharges and disposals of radionuclides to the marine environment (TBq per year) and gaseous emissions of radionuclides (TBq per year);

- comparison of monitoring data between nuclear site operators and Government agencies;

- concentrations of radionuclides in foodstuffs and indicator materials;

- measurement of dose rates and contamination over intertidal areas.

Targets

- In 1998, Ministers of the UK Government signed the Sintra Statement which included a commitment that discharges, emissions and losses of radioactive substances are reduced, by the year 2020, to where the additional concentrations in the marine environment above historic levels resulting from such discharges, emissions and losses are close to zero. A UK strategy to implement the Sintra agreement was published in 2002.
- To reduce the Sellafield authorised discharge limit of 99Tc to 10 TBq a^{-1} by 2006, in response to socio-economic concerns particularly in Scandinavia.
- In England and Wales, the issue of licences to operators for the disposal of dredged material is only granted where the radioactivity associated with the disposal operation is below de minimis levels (0.01 mSv or less) of exposure.
- The relevant dose limit for member of the public is 1 mSv per year for whole body. The mean dose received by the 'critical group' is compared with the dose limit. The critical group represent those who are most exposed to radiation.
- It is intended to bring about a progessive reduction in human exposure such that critical doses will be less than 0.02 mSv from 2020 onwards.

Current status

- Discharges of radionuclides from Sellafield have decreased significantly since the 1970s, as a result of various measures. In most cases current discharges are at least 100 times lower than peak discharges in the 1970s.

- Discharges of technetium-99 from Sellafield rose significantly in 1994, peaking in 1995. Following the installation of the Enhanced Actinide Removal Plant (EARP), levels have subsequently declined. The successful plant-scale trial of a novel treatment to reduce 99Tc discharges further (using tetraphenylphosphonium bromide, TPP), announced in April 2004, means that discharge reductions below 10 TBq a^{-1} will take place 2 years ahead of schedule.

- Present concentrations of ^{137}Cs in seawater are only a small percentage of those prevailing in the late 1970s. Concentrations in the North Sea, are significantly less than those observed in the Irish Sea. Remobilisation from sediments contaminated by historical discharges is now the predominant source of ^{137}Cs and plutonium to the water column.

- Highest concentrations of radionuclides in sediments occur in the Eastern Irish Sea, close to the Sellafield outfall.

- Radionuclide concentrations in biota have fallen in response to reductions in discharges, except for technetium-99, which increased in response to increased discharges after 1994. However, recent monitoring shows levels declining in response to lower inputs.

- Individual radiation exposures from all authorised releases are generally low and well within international dose limits.

- Exposure to chronic irradiation is not believed to have had a significant effect on marine organisms, at the population level.

CONSTRUCTION AND AGGREGATE EXTRACTION

Marine Aggregate Extraction

Much of the seabed surface around the English and Welsh coastline comprises of sand and gravel in various proportions. Where these resources are present in sufficient quantity, are of the right composition and are accessible to commercial dredgers, they may be considered for exploitation as a source of aggregate for the construction industry, to supplement land-based sources, or as a source of material for beach nourishment. Marine aggregate extraction is carried out in English, Welsh and Northern Irish waters; there are no active extraction sites at present in Scottish waters

To ensure conformity with licence conditions, the location of dredging activities is monitored by means of electronic monitoring systems (EMS) fitted on board dredgers. There is no co-ordinated monitoring of the impacts of aggregate extraction, or the physical and biological recovery of extraction sites, but limited data is available from a number of studies.

Key indicators for marine aggregate extraction:

- Area dredged annually;

- Quantity landed annually;

- Dredging intensity.

The Government objective is that dredging activities do not significantly harm the environment or fisheries or unacceptably affect other legitimate users of the sea.

Current status

- In 2003, the total area licenced for marine aggregates was 1245 km^2 of which 890 km^2 was dredged, but in practice 90% of the activity took place in just 45.7 km^2.

- The quantity of marine aggregate landed from around England and Wales peaked in 1989 and has since remained relatively stable at ~23 million tonnes per annum.

- Largest tonnages of sand and gravel are extracted from the east and south-east coasts of England. However, this is likely to change as substantial aggregate resources have been discovered in the Eastern English channel, which could provide resources for at least 25 years at current levels of demand and provide >50% of the predicted future requirement.

- Analysis of trends in the impacts of marine aggregate extraction is limited by the availability of relevant data. The current requirement for Environmental Impact Assessments as part of licensee monitoring commitments, should improve this.

- There is evidence of progress towards measures that will help achieve the Government's objective, notably in recent reductions in the area licensed for dredging.

Coastal Development

Much of the UK coastline has been modified as a result of coastal development of varying scales, including port developments, waterfront projects, re-development of fishing ports and industrial areas and structures for recreational purposes. The impacts of constructions on the marine environment are largely physical and localised and are dependent on the scale of the development. In England and Wales, the majority of construction licences applications are now for small scale harbour works, whilst in Scotland and Northern Ireland the majority of licence applications are for sea outfalls.

There are no key indicators for coastal development. Potential environmental impacts of constructions are assessed as part of the licensing process under the Food and Environment Protection Act (FEPA) 1985. The overall objective is to protect the marine environment, human health and other legitimate uses of the sea.

Renewable Energy

There is considerable political pressure for Government to develop and deploy renewable energy technologies in response to the Kyoto Agreement. The most advanced technology is the harnessing of wind power and there is increasing pressure for large-scale development to be placed offshore rather than onshore. Other technologies are being developed, such as marine tidal and wave turbines and these sources of renewable energy are recognised as being potentially significant in the future.

All consented developments have monitoring conditions attached, however offshore wind power is a relatively new development and with only one wind farm completed and the second under construction, very little monitoring data has yet been generated.

The UK has a target for 10% of its electricity supply to come from renewable sources by the year 2010. In, December 2003 DTI announced an additional target of 15% by 2015

Current status

- There are currently 11 consented offshore wind farm sites, each of 10km^2, accommodating a maximum of 30 turbines per site.

- To date only 1 wind farm has been constructed at North Hoyle, off the North Wales Coast, with a second under construction at Scroby Sands, off Great Yarmouth. Construction of the remaining consented (Round 1) sites is expected to be complete by 2004/2005.

- The current consented generation capacity from offshore wind farms is 660 MW, 5.5% of the 2010 target. The 15 proposed sites in the second round off proposals could make a further significant contribution to the 2010 target. These farms will be much larger than the first round.

- Further research and development linked to post construction monitoring is required to advance our knowledge and understanding of the potential environmental impacts of wind farms.

LITTER

Litter is a serious and persistent environmental problem, posing a hazard to beach users, recreational water users and wildlife. In September 2001, 8.3 tonnes of litter was collected from 141 km of beaches around the UK. Litter is solely man-made and therefore preventable.

The Marine Conservation Society's annual Beachwatch surveys is the best long-term dataset, providing some indications of the trends in litter on UK beaches. The National Aquatic Litter Group (NALG), a consortium of partners including the EA, SEPA and EHS (NI) has a standardised monitoring and assessment protocol for assessing the aesthetic state of beaches. A range of parameters is measured, including sewage- related debris, gross and general litter, potentially harmful debris, oil, dog faeces and large accumulations of litter. There is a four-grade classification scheme from A (very good) to D (poor). Annual surveys were carried out by the EA in 2000-2002 at all designated bathing waters in England and Wales.

Key indicators for litter are:
- Number of items pre km of beach – Beachwatch surveys (MCS);

- Aesthetic quality of beaches –overall grade (NALG).

Current status
- Despite a decline in the last 4 years, current levels of beach litter (per km) remain ~50% higher than in 1994

- In 2000, 77% of coastal bathing waters beaches were graded A or B (very good or good) in beach aesthetic surveys, rising to 82% in 2002. The number of grade D beaches fell from 10% to 5% over the same period.

NAVIGATION DREDGING AND DREDGED MATERIAL RELOCATION

There is an estimated 150 ports in the UK of which 100 are commercially active. Owners and operators are required to maintain dredged access for shipping operations for exporting goods and transporting passengers. Approximately 25-40 million wet tonnes of dredged material, is removed annually from access channels, ports, marinas and harbours and deposited in ~150 licensed disposal sites.

Licensing authorities control the number of disposal sites in order to minimise the extent of impacts on the seabed. Samples of dredged material are routinely screened for a range of contaminants including; metals, TBT, CBs and PAH, prior to issuing a disposal licence, as part of the licensing process. Regular monitoring of the impacts at disposal sites is targeted, focusing on key sites receiving large quantities of material and those which are adjacent to conservation interests, e.g. Roughs Tower, Tyne, Liverpool Bay, Moray Firth, Aberdeen and North Channel. Other locations are monitored in response to localised concerns.

Potential key indicators for dredging and dredged material relocation have been identified, but have not as yet been tested and validated. Examples of potential indicators include:
- quantity of dredged material deposited;

- percentage of material beneficially replaced;

- TBT-induced imposex in whelks;

- sediment mobility.

There are no targets for dredged material, but the licensing authorities have an objective to reduce the amount of material deposited at sea.

Current status

- Since 1992, there has been a slight increase in the overall quantity of dredged material deposited to sea each year. Current levels are ~25-40 million wet tonnes per annum

- There is a wide variation in dredging requirement in different UK regions. More than 60% of all dredged material is deposited in the Southern North Sea (Region 2) and the Irish Sea (Region 5)

- Only an average of 1% of material dredged for disposal at sea is currently reused beneficially in the marine environment. Practitioners and operators are collaborating on research and development, that may result in an increase in the percentage of material used in beneficial use

- Monitoring has demonstrated that impacts are mostly confined within the boundaries of the disposal sites and indicate that sea disposal is an acceptable option

INTRODUCTION OF NON-NATIVE SPECIES

The major routes of introduction of non-native species to UK marine waters are associated with shipping i.e. ballast water and hull fouling. Aquaculture operations are thought to be the next main route of introduction. Once introduced to an area, a species may spread to other areas by continued transport via shipping

The introduction of all non-native species raises legitimate concerns, but the major concern is with problem species such as the Chinese mitten crab, which can cause potentially costly damage due to its habit of using soft embankments for burrows.

Current status

- More than half of the 50 non-native species found in British waters, are estimated to have been introduced in association with shipping

- The International Maritime Organisation (IMO) adopted a Ballast Water Convention in February 2004 that aims to reduce the risk of introducing non-native species via ballast water

- Climate change impacts in the marine environment will mean that there are large biogeographic shifts in species.

1. Fish and fisheries

KEY POINTS

A full assessment of the commercially exploited stocks, an evaluation of the status of fish populations in UK waters, and a summary of the direct and indirect effects of fishing, are presented in the separate sectoral report 'Fish and Fisheries'. The main points have been included earlier as part of the Executive Summary of this report.

Aquaculture:

- **Total quantities of particulate organic matter and N discharges from fish farms have increased over the last 10-15 years as the industry has expanded. This is despite consistent improvements in aquaculture technology and in the efficiency of feed utilisation.**

- **Monitoring in Scottish sea lochs showed that the total area of seabed impacted by organic waste is generally small and impacts rarely extend beyond 50 m from the cages.**

- **In recent surveys of fish farms, winter N:P ratios did not exceed OSPAR eutrophication assessment criteria at any sites surveyed. Winter N:S ratios exceeded levels thought to influence phytoplankton species composition at one loch in the Western Isles of Scotland and all areas surveyed in the Shetlands. Chlorophyll a levels were spatially and temporally variable and concentrations of toxic/nuisance algae were insufficient to cause adverse effects.**

- **Planktonic copepods and sediment-associated organisms are at greatest risk of effects from the use of medicinal chemicals in fish farms. To date, no effects have been detected at the species or community level related to chemical usage.**

- **Sea lice are a major problem in salmon farms and there is concern that the numbers of larval lice in the environment may be one factor in the historic decline in wild sea trout and salmon stocks on the West Coast of Scotland. Better management and improvements in sea lice treatments are reducing the sea lice load on farmed fish.**

- **The potential for genetic interaction between escaped farmed fish and their wild conspecifics and possible consequential adverse effects on fitness and productivity of progeny are of concern. At present, there is insufficient information to assess the precise scale or significance of such interactions in UK waters. There are a number of ongoing studies to address this issue.**

1.1 AQUACULTURE

INTRODUCTION

The aquaculture industry plays a major role in providing fish and shellfish products to consumers from an increasing variety of species. The industry is market led and there is a major drive to diversify from mainly Atlantic salmon production to other cultured species including rainbow trout, brown trout, halibut, cod and haddock. Cultivated shellfish species include mussels, oysters, scallops and queens, Aquaculture produces high quality, high value fish and shellfish with health benefits. Produce is available year round at a consistent quality and freshness and replaces the void left by reduced wild stock production in niche markets, the so-called fish-gap.

Production and species

Fish and shellfish production worldwide has been increasing steadily at around 10% per year since about 1990. However, production from wild capture fisheries has been more or less static for the last decade and the increase in the total amount of fisheries products available to consumers is mainly accounted for by increases in production from aquaculture. Open cage finfish cultivation, primarily of salmon, is mainly carried out in the semi-enclosed sea lochs, voes, sounds and bays around the west and north of Scotland, including both the mainland and the island groups and has been increasing over the past 10–15 years (Table 1.1). There is very little marine fish farming on the east coast of Scotland and currently a presumption against further development to protect wild salmonid interests.. The highest concentration of marine finfish production isin Shetland Occasionally marine farms are land-based, with seawater pumped ashore to tank facilities but these are usually specialised broodstock units or hatcheries for developing marine species, such as halibut or cod. There is very little marine fish farming in England and Wales, where the predominant marine aquaculture is of shellfish including oyster, cockles, mussels and scallops (Table 1.2). In Scotland mussel production is dominant especially in Shetland and Strathclyde. The Strathclyde region also produces almost all the Pacific and native oysters but production has remained fairly constant at ~3 million/yr. The culture of marine species such as halibut, cod, haddock, and trout is gradually becoming more established and is expected to increase over the next few years. Cod production is expected to increase to more than 5,000 tonnes within the next five years and it is anticipated that halibut production will increase to perhaps 1,000 tonnes in the near future and haddock production attain 10,000 tonnes over the next 10 years.

The aquaculture industry makes a major contribution to the rural economy of Scotland. Most production is centered in coastal areas, particularly in the Highlands and Islands, where viable jobs are created that keep small communities sustainable.

Table 1.1. Annual production of Atlantic salmon (tonnes) during 1986-2002 and projected production in 2003 (From FRS finfish production survey 2002)

Year	Tonnes	Percentage difference	Year	Tonnes	Percentage difference
1986	10,337	-	1995	70,060	9
1987	12,721	23	1996	83,121	19
1988	17,951	41	1997	99,197	19
1989	28,553	59	1998	110,784	12
1990	32,351	13	1999	126,686	14
1991	40,593	25	2000	128,959	2
1992	36,101	-11	2001	138,519	7
1993	48,691	35	2002	145,609	5
1994	64,066	32	2003	176,596*	

*Farmers' estimate of projected tonnage based on stocks currently being on grown

Table 1.2. Production (tonnes) of farmed shellfish in the UK in 2000 and 2002 (From Shellfish News no: 13 and 16, CEFAS 2002 and 2003)

	Scotland		England		Wales		Northern Ireland		UK Total	
	2000	2002	2000	2002	2000	2002	2000	2002	2000	2002
Pacific oyster	247	249	297	380	16	12	-	335	560	976
Native oyster	4	15	115	116	0	-	-	-	119	156
Scallops	39	39	0	0	-	-	-	-	39	39
Queens	58	19	-	-	-	-	-	-	58	19
Mussels	2,003	3,236	6,131	1,424	5,093	10,962	1,095	728	14,322	16,350
Clams	-	-	28	42	-	-	2	14	30	56
Cockles	-	-	147	147	-	-	-	-	147	147

CURRENT POLICY/ LEGISLATION

Establishing a fish or shellfish farm requires that the business and site be registered for fish health purposes. Fish farm operators require a discharge Consent, limiting the tonnage of fish and the quantities of medicines that can be discharged (The Control of Pollution Act 1974, Part II), together with a lease from the Crown Estate Commissioners. In Scotland, applications also need to comply with The Locational Guidelines for Fish Farms, established by the Scottish Executive and natural heritage concerns.

Certain new, or modifications to existing, fish farms are subject to Statutory Instrument No 367: The Environmental Impact Assessment (Fish Farming in Marine Waters) Regulations 1999, which implement the EU EIA Directive (85/337/EEC). Shellfish farms are not subject to EIA Regulations, but the quality of the designated waters in which they are grown in is controlled through the EC Directive on the Quality of Shellfish Growing Waters (79/923/EEC) (The Surface Waters (Shellfish)(Scotland) regulations (1997) and the EC Shellfish Hygiene Directive (91/492/EEC).

The UK is committed to a range of international agreements which guide management action. These include the OSPAR Convention (OSPAR Commission, 1992), which seeks to prevent and eliminate pollution and to take measures necessary to protect the maritime area against the adverse effects of human activities, to safeguard human health, conserve marine ecosystems and, when paracticable, restore marine areas which have been adversely affected. They also include a number of commitments under the NASCO Convention (NASCO, ONL(94)53) to minimise the impacts of salmon aquaculture on wild salmon stocks. The management of aquaculture must take account of the EH Habitats (92/43/EEC) and Birds Directives (79/409/EEC), particularly the listing of wild salmon and of freshwater mussels (which rely on salmonids for the distribution of their larvae) as Species of Community interest, and of particular marine habitats.

Within the European Community, aquaculture is covered by the Common Fisheries Policy (CFP) and is regarded as an increasingly important industry. Under the current review of the CFP, the Commission proposes a strategy of aquaculture designed to assure the availability of healthy products to the consumer, promote an environmentally sound industry and create employment in fishing-dependant areas. UK aquaculture is one of the largest producers in the European Community, contributing 30% by volume of the Community's total production, and the Scottish aquaculture industry represents 90% by value of all UK aquaculture.

In 2003, the Scottish Executive published a Strategic Framework document for the aquaculture industry in Scotland (Scottish Executive, 2003). The framework sets out objectives and priority actions to achieve sustainable development of aquaculture in Scotland taking economic, environmental, social and stewardship aspects as its guiding principles.

The Scottish Executive, the Department for the Environment, Food and Rural Affairs (Defra) and the Welsh Assembly are working together to produce a GB-wide strategy to promote the health and welfare of animals kept by man. The strategy will suppor the commercial viability of the aquaculture sector and the health and welfare status of its stock.

PRESSURES AND IMPACTS

a) Organic matter

The effects of particulate organic wastes from finfish aquaculture on the seabed close to the farms are insignificant to the wider environment if well managed, but the nutrient enhancement and chemical residues have the potential to cause effects on a wider scale. Particulate organic matter discharges from aquaculture in Scottish coastal waters have increased over the last 10 – 15 years, as the industry has grown However, statutory controls are in place to ensure that any significant impacts on the seabed and its associated fauna are restricted to the immediate vicinity of fish farm cages. This is achieved by, a process of predictive modeling prior to the granting of discharge consents and necessary leases, followed by post-development monitoring of the seabed. Organic enrichment of the seabed under fish farms can cause changes in sediment composition, increased microbial production characterised by reduced redox potential and deoxygenation, and changes in the biodiversity of the benthos.

A graduated scale of effects can be seen from sediments away from farms that receive normal detrital inputs that have a diverse fauna, to sediments under farms that may show increasing levels of organic enrichment. As organic inputs increase, faunal diversity also initially increases as the enhanced food supply provides opportunities for the expansion of existing populations and the immigration of new species. However, increasing inputs lead to progressive elimination of the larger, deeper-burrowing and longer-lived animals and expansion of smaller, rapidly growing opportunist species. Further deterioration of the physical and chemical conditions can lead to the surface sediments become anoxic. Under such conditions only a small number of specialist taxa can survive, mainly small annelid and nematode worms, such as *Capitella capitata* and *Malacoceros fuliginosa*, which may flourish in huge numbers. Where anaerobic processes occur close to the sediment surface, dense white mats of sulphide oxidising bacteria (*Beggiatoa* sp) can occur. The intensity of these effects varies considerably between farms and is dependent on the hydrodynamics in the area; in some high energy sites there can be minimal benthic modification. As mentioned above, the footprint of the farm is usually very small compared to the total area of seabed within a loch and rarely extends beyond 50 m of the cages. In the vast majority of Scottish sea lochs, the total area of impacted seabed is small (median 0.97%) and regulatory controls ensure that impacts are restricted to the immediate vicinity of fish cages. The rate of recovery of the seabed after farming is variable, but in Scottish waters this may take around two years. Similar effects may be seen under suspended shellfish farms.

b) Nutrients

Some of the nitrogen given to farmed fish in their feed is released to the surrounding waters as dissolved nutrient nitrogen. The remainder of nitrogen from the feed is incorporated into fish growth, or released in particulate form, either as waste feed pellets or as faecal material. Nitrogen in particulate form will settle on the seabed, usually in the vicinity of the fish farm cages and a proportion of this nutrient source will ultimately be re-mineralised and contribute to the soluble inorganic nitrogen loading of the receiving waters.

Consistent improvements in aquaculture technology have led to a reduction in nutrient and organic matter discharges per tonne of fish produced in Scottish coastal waters. However, such improvements have not been sufficient to mitigate fully against the growth of the industry. Consequently the total discharge of nutrients from aquaculture in Scottish coastal waters has increased over the past 10-15 years. It has been suggested that nutrient inputs from salmon farms may contribute to harmful algal blooms in coastal waters and also to lead towards eutrophication. Consequently, nutrient inputs to coastal waters from fish farms are coming under increasing levels of scrutiny, both nationally and internationally (eg through the OSPAR Comprehensive Procedure for assessment of eutrophication status).

There is evidence that perturbations of nutrient ratios can affect the relative abundance of planktonic algal species . Significant increases in winter N:P ratios may result in phosphorus limitation to phytoplankton growth, with potential consequences for community structure, since some species may be able to tolerate phosphorus limitation better than others. Such perturbations are considered to increase the potential risk of toxic or nuisance species. In recent surveys of aquaculture areas, winter nutrient N:P ratios were found not to exceed OSPAR criteria at any of the surveyed areas. There was no significant relationship between winter nutrient N:P ratios and the predicted level of nitrogen enhancement arising from the fish farm.

Elevated levels of available nitrogen can also result in silica (Si) limitation during algal growth. Elevated N:Si ratios have been shown to result in changes in phytoplankton species composition shifts, a dominance of smaller diatoms or flagellates and a shift from diatoms to flagellates (which may be toxic or nuisance species) (Harada *et al*., 1996; Williams and Egge, 1998). Winter N:Si ratios were found to exceed levels thought to influence phytoplankton species composition at one loch in the Western Isles and all areas surveyed in Shetland, which could be due to high background N:Si ratios in offshore Shetland waters.

Area averaged chlorophyll a levels can become elevated in lochs and voes. However, chlorophyll *a* is very spatially and temporally variable and the occasional exceedence of monthly, time-averaged background values by spot samples (e.g. during periods of high productivity in spring) is therefore to be expected. Phytoplankton from the surface 10 m have been sampled in aquaculture areas around Scotland and showed a high degree of spatial and temporal variability both within and between the areas surveyed. The phytoplankton observed were typical of Scottish waters and included potential toxic/nuisance species. The concentrations of such species were unlikely to be sufficient to cause adverse effects to economically important fish or shellfish stocks in the majority of lochs; exceptions to this during summer months include lochs that do not currently support fish farming.

c) Chemical usage

Intensive fish farming requires the use of medicinal chemicals to keep the fish healthy. These are predominantly used to control sea lice infestations at salmon farms. Studies so far indicate that if these medicines have ecosystem effects they are either difficult to separate from the natural variability present in such systems or are below the limits of detection of the methods currently available. However, investigations are continuing and the results from longer time scales may show some trends.

Zooplankton, especially copepods, are most likely to be affected by soluble medicines, administered as bath treatments, if they come into contact with the plume of used treatment after it has been released from the cages. Significant declines in copepod abundance and consequent reductions in their grazing rates could potentially result in environmental problems, perhaps including algal blooms. To date, no such effect has been detected at the species or community level, and changes in the composition of the zooplankton communities that have occurred during sampling campaigns have been unrelated to sea lice treatments. Advection (by water currents), natural patchiness and normal species seasonal succession patterns appear to be the most influential factors affecting the changes seen in community composition.

Sediment associated organisms are most likely to be affected by chemicals that adhere to particulate matter or ‘in-feed’ medicines deposited on the seabed. Benthic communities in the organically enriched sediments below fish farm cages are generally dominated by small worms, which play a vital role in remineralising waste products. A recent study on the effects of one chemical used, emamectin benzoate, on infaunal polychaetes indicated that predicted sediment concentrations are unlikely to adversely affect polychaete communities below fish farm cages.

Antifoulant products are painted or washed onto fish farm nets and structures to retard the build up of fouling organisms. Currently, 19 of the 24 antifoulant products registered for use in Scottish aquaculture are copper based, either as copper, copper oxide or copper sulphate. These copper-based products exhibit effective antifouling activity against barnacles, tube worms and most algal fouling species. The copper can be released from the painted nets, when they are first placed onto cage rafts after re-treatment, producing metallic slicks. The use of copper-based antifoulants is likely to increase and there may be reason for concern because of the accumulation of copper in sediments below fish farms, and its potential toxicity to benthic organisms. However organically enriched fish farm sediments characteristically have a high biological oxygen demand and negative redox potential, which lead to sulphate reduction. Under these conditions, metals such as copper and zinc are less likely to be biologically available.

d) Sea lice

Salmon farms in Scotland are affected by sea lice, *Lepeophtheirus salmonis* and to a lesser extent *Caligus elongatus*. Sea lice are a major problem for salmon farmers in terms of fish health, costing the industry in the region of £15-30 million per annum.

Anglers and conservationists are also concerned, as excessive background lice larval numbers are potentially a factor in the decline in wild sea trout and salmon stocks on the west coast of Scotland. However better management, improved liaison and cooperation between stakeholders and improvements in sea lice treatments are reducing the sea lice load on farmed fish.

e) Escapees
Escaped fish from mariculture developments have the potential to interbreed with their wild counterparts and many studies are ongoing into the precise effects of this interaction. This is an issue of concern because wild salmon and their farmed cousins have very different levels of genetic variability. Wild salmon have a high level of genetic diversity both within and between populations and there are many distinct populations of salmon with a relatively low rate of mixing between them. Farmed salmon arise from relatively few wild strains and thus show lower overall variability. When farmed fish escape they can breed with wild fish. While the offspring of the interbreeding of wild and escaped farmed salmon may benefit from hybrid vigour, recent research in Ireland indicates that this is not passed to the next generation due to outbreeding depression with resultant lower fitness and productivity in subsequent generations (McGinnity *et al.*, 2003). In the case of some new species, for example cod, the majority of the breeding stock is still taken from the wild and genetic differences between farmed and wild stocks are less of a concern in this species.

FISH FEED

All finfish aquaculture currently requires wild caught fish sourced globally to produce fishmeal and fish oil which are used as raw materials for fish feed. This raises sustainability questions, especially as 34% of the fish are sourced from fish stocks such as the Peruvian Anchovy fishery that are susceptible to El Niño events and only 17% of fishmeal is currently produced from fisheries by-products. Efforts however have been made to mitigate these problems by using vegetable proteins and oils as much as possible and by using more fishmeal sourced from by-products and wild stocks certified by the Marine Stewardship Council as being well managed. Fish oil can be replaced by up to 50% vegetable oil for most species. The PEPPA (Perspectives of Plant Protein Use in Aquaculture) project found that up to 75% of fishmeal can be replaced with a mixture of plant proteins, including corn gluten and wheat, without having major consequences on the growth of the fish.

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2. Eutrophication

KEY POINTS

- **The distribution of human population and intensive agricultural activity determines those areas that experience the most significant pressure due to nutrient input. The areas with the highest pressure are the transitional and coastal waters of southern, eastern and north-western England.**

- **The pressure due to direct inputs of nitrogen and phosphorus have reduced nationally by 35% and 50%, respectively. There is no evidence of reductions in riverine inputs. These inputs are closely linked with riverine flows. This reflects the importance of managing the diffuse inputs of nutrients from land run-off in the future.**

- **The pressure due to diffuse input varies with rainfall and river flow rates. Increasing river flow in some critical areas has led to nitrogen inputs being maintained at previous levels despite changes in management. The land 'buffer' for nitrogen implies that change of input can only happen in the long term.**

- **Nutrient pressure is different in the different regions. 40% of river borne nutrients enter the North Sea South area. There has been a 60% reduction in the input of nitrogen to the North Sea North since 1990. This is in contrast to the marginal reduction to the North Sea South area.**

- **Although the coastal waters of southern, eastern and north-western England and the inner Bristol Channel are enriched with nitrogen and phosphorus the correlation with nutrient input is weak. The reducing nutrient inputs are not reflected in detectable reduction in the winter nutrient concentration in the sea This reflects the importance of the oceanic inventory of nutrients in UK coastal and offshore waters. One study in the Irish Sea may show a large decline in phosphorus with declining input.**

- **The level of phytoplankton biomass in coastal waters falls below the OSPAR Comprehensive Procedure criterion reflecting that despite nutrient enrichment the growth may be limited by light availability and by loss to the food chain and the environment. Undesirable disturbance of the balance of organisms and water quality appears to be limited in our waters.**

- **Significant long term changes are occurring at a regional level. These changes which affect the growth of plants and the type of plants that are favoured are related to changes in the NAO. Disentangling changes due to nutrient enrichment and changes due primarily to regional change is a science priority.**

- **Anthropogenic nutrient related change has occurred in some enclosed estuarine environments and harbours such as the Ythan estuary, Chichester, Langstone and Portsmouth harbours. Further work is required to fully understand the risk posed by nutrients for the ecological integrity of estuaries.**

- **Human interference with the nitrogen and phosphorus cycles presents a widespread threat to the marine environment. Despite the level of nutrient enrichment in some regions of UK waters there is evidence that undesirable disturbance to the balance of organisms and to water quality has not occurred.**

- **The potential significance of nutrient enrichment combined with the accelerated regional changes taking place, point to the requirement for better evidence and better understanding of the ecosystem consequences of nutrient input.**

INTRODUCTION

Human activities have greatly increased the amount of nutrients, especially nitrogen, that circulate through the earth system (Galloway *et al*., 2003). The main reasons for this are the manufacture of fertilizer to increase crop plant production, nutrients added to aquatic systems from human and animal waste and nitrogen derived from the burning of fossil fuels (UNEP, 2004). Although the route may be complex, much of the nutrients released or a result of human activity will eventually pass into the coastal and wider marine environment. There is increasing concern about the threat that this poses to the health of the marine ecosystem and to marine biodiversity.

Nutrients, given the right conditions, can promote a process called eutrophication. This involves the growth of aquatic plants and if too much or the wrong type of growth occurs in the wrong place or at the wrong time then problems can arise that impact on the health of the marine ecosystem. International concern has already led to the better identification of the problem and, in the most obvious cases, action is being taken at a regional (OSPAR) or European (EC) level through a range of legislation and agreement (Box A).

Eutrophication is defined as “the enrichment of water by nutrients, especially by compounds of nitrogen and phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned” (EEC, 1991). The definition of eutrophication used in OSPAR adds to this by referring ‘to the undesirable effects resulting from anthropogenic enrichment by nutrients’. The latter qualification is important as elevated concentrations and effects similar to those associated with eutrophication (as defined) are natural phenomena that result in some of the most important productive regions of the oceans with significant fisheries, for example, off the west coasts of South America and Africa. It is only possible to control the ‘undesirable disturbances’ that result from manageable human activities.

The issue of human induced eutrophication is not new but has a history that extends back to the major societal changes that occurred with the industrial revolution in the 19th Century (Billen, 1999) and it is notable that the UK pioneered the management of the consequences of improved sewage treatment on coastal waters (eg Lett and Adeney, 1908). The greatly increased rate of nutrient mobilisation in the last few decades is the driver for today’s concerns.

CONSEQUENCES OF INCREASING NUTRIENT SUPPLY

The primary consequences of increased nutrient supply affect the growth of phytoplankton, macroalgae and aquatic plants. This growth is regulated by biological, chemical and physical factors. Of the chemical factors, nitrogen and phosphorus (and to a lesser extent silicon) may only be available in limited amounts, and if other conditions are favourable, the growth of phytoplankton, macroalgae and aquatic plants may be limited by their supply (Figure 2.1). An increase in nutrient supply will produce an increase in growth and plant biomass. Nutrients are also subject to many biogeochemical processes. Some of these processes recycle fixed nutrients making them available for further plant growth. The opportunity for growth is also influenced by climatic conditions, affecting temperatures and light. Long-term trends in global climate have been shown to influence large-scale changes in phytoplankton growth (Reid *et al*., 1998).

The secondary consequences of nutrient supply, which may equate with the undesirable disturbances we seek to manage, include: changes in relative dominance of different photosynthetic organisms, changes in phytoplankton species composition, oxygen depletion leading to changes in or the death of aquatic animals, and change in human amenity such as the formation of algal scums on beaches. There is also concern that problems associated with toxic algae can be increased by nutrient enrichment. These effects have both ecological and economic consequences.

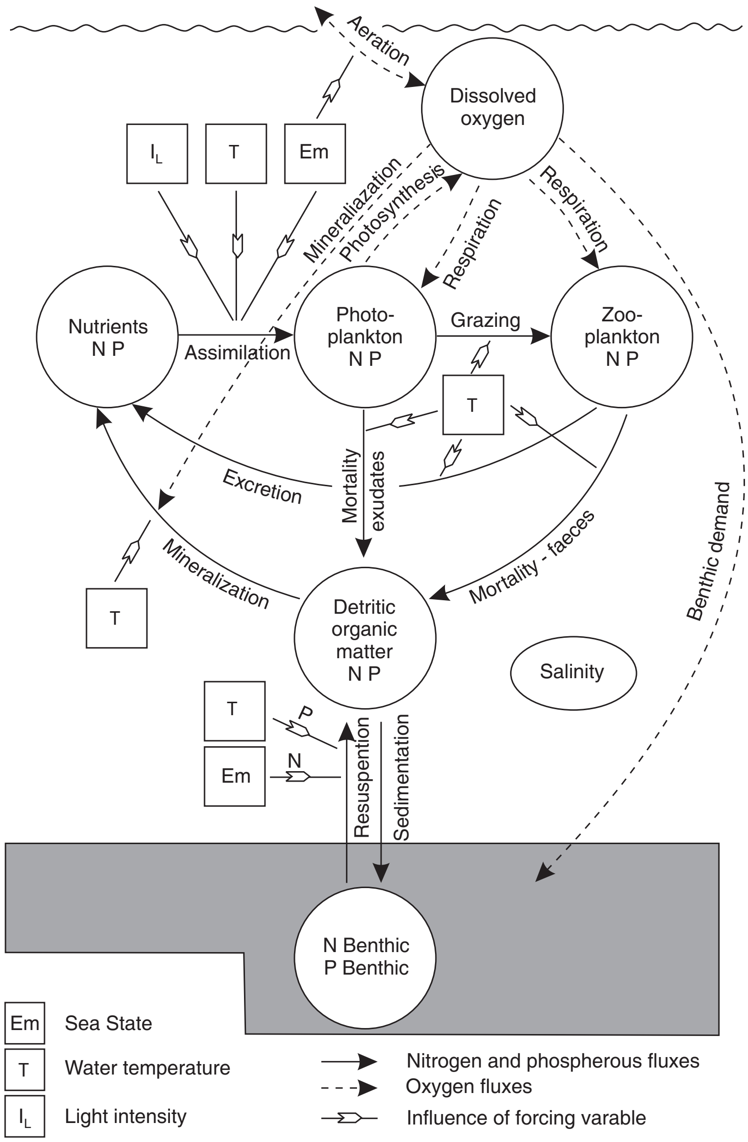

Figure 2.1. A schematic of the cycle of nutrients in marine pelagic and benthic ecosystems

BOX A. Legislation

The following legislative measures have been adopted to control inputs of nutrients and to combat the effects of eutrophication:

- 91/676/EEC Nitrates Directive. This Directive aims to protect waters against pollution caused by nitrates from agricultural sources. If water bodies are found to be Polluted Waters (eutrophic) then a Nitrate Vulnerable Zone is identified. Action plans to control the agricultural sources of nitrate are required in the catchment areas draining to the polluted water.

- 91/271/EEC Urban Waste Water Treatment Directive (UWWT). This Directive lays down minimum standards for sewerage systems and treatment, which vary according to the size of the population served and nature of the receiving water. If the water body is found to be eutrophic or which in the near future may become eutrophic if protective action is not taken then the area must be designated as a 'sensitive area'.

- The OSPAR Strategy to Combat Eutrophication requires the application of reduction measures in respect of those sources of nutrients that contribute, directly or indirectly, to a Problem Area in the OSPAR maritime area. Where an area is designated as a Potential Problem Area the OSPAR strategy calls for preventive action.

- 2000/60/EEC Water Framework Directive (WFD). This Directive aims to achieve good ecological status in water bodies by 2015. The WFD does not specifically mention eutrophication but under the WFD, the primary difference between 'good' and 'moderate ecological status' for plant quality elements in coastal waters is linked to the terms 'accelerated growth' and 'undesirable disturbance'. In water bodies that fail to meet good ecological status a programme of measures must be implemented.

- 92/43/EEC Habitats Directive. This directive aims to contribute to ensuring bio-diversity through the conservation of natural habitats and of wild fauna and flora. Measures are designed to maintain or restore, at favourable conservation status, natural habitats and species of wild fauna and flora of Community interest and take account of economic, social and cultural requirements and regional and local characteristics.

PROGRESS WITH INDICATORS

Identifying waters that are subject to eutrophication and showing undesirable disturbance, or that are at risk has proved to be a demanding task as the observations we are able to make are influenced by a complex, competing set of factors. For example, the growth of phytoplankton, macroalgae and aquatic plants is affected by nutrient and light availability but the amount of biomass measured also depends on loss through grazing and physical exchange.

There is, however, a wealth of scientific experience in using available data to assess whether nutrient pressure is leading to an accelerated growth state that has undesirable impacts on the health of the ecosystem. It is essential to be able to complete this chain of cause and effect if we are to correctly identify specific responses and distinguish between anthropogenic and natural environmental change.

The current state-of-the-art in marine eutrophication assessment is the OSPAR Comprehensive Procedure (see Box B). The Comprehensive Procedure provides a set of indicators but requires further development, especially of the biological elements and in the light of ecological quality considerations, but forms the basis for our current assessment of environmental quality.

BOX B. Harmonised assessment criteria and their respective assessment levels

Assessment parameters		
Category I	**Degree of nutrient enrichment**	
	1	**Riverine total N and total P inputs and direct discharges (RID)** Elevated inputs and/or increased trends (compared with previous years)
	2	**Winter DIN- and/or DIP concentrations** Elevated level(s) (defined as concentration >50% above salinity related and/or region specific background concentration)
	3	**Increased winter N/P ratio (Redfield N/P = 16)** Elevated cf. Redfield (>25)
Category II	**Direct effects of nutrient enrichment (during growing season)**	
	1	**Maximum and mean chlorophyll *a* concentration** Elevated level (defined as concentration >50% above[1] spatial (offshore)/ historical background concentrations)
	2	**Region/area specific phytoplankton indicator species** Elevated levels (and increased duration)
	3	**Macrophytes including macroalgae (region specific)** Shift from long-lived to short-lived nuisance species (e.g. Ulva)
Category III	**Indirect effects of nutrient enrichment (during growing season)**	
	1	**Degree of oxygen deficiency** Decreased levels (< 2 mg l^{-1}: acute toxicity; 2 - 6 mg l^{-1}: deficiency)
	2	**Changes/kills in zoobenthos and fish kills** Kills (in relation to oxygen deficiency and/or toxic algae) Long term changes in zoobenthos biomass and species composition
	3	**Organic carbon/organic matter** Elevated levels (in relation to III.1) (relevant in sedimentation areas)
Category IV	**Other Possible effects of nutrient enrichment (during growing season)**	
	1	**Algal toxins (DSP/PSP mussel infection events)** Incidence (related to II.2)

Assessment procedure: An appropriate set of parameters is selected for the area under assessment, these will be region specific. A positive result (parameter breaches assigned criterion) for any parameter in each category results in a positive value for that category. A problem area is identified if all three categories are positive (Category IV is included with category III but weighting is low given the current low level of certainty over the use of this parameter.

[1] Other values less than 50% can be used if justified.

OSPAR, following a request from North Sea Ministers (Bergen Declaration, 2002), is piloting a set of ecological quality objectives that may form the basis of future ecosystem assessments. There is a sub-set of these indicators the, so called, EcoQOs-eutro that have been derived from the OSPAR Comprehensive Procedure and may be used for eutrophication assessment.

2.1 NUTRIENT INPUTS

Aquatic pathways

Nutrient inputs, in the dissolved and particulate components of the waterborne loads of nutrients nitrogen and phosphorus from land based sources, provide an indicator of pressure relating to the risk of marine eutrophication. Data on UK inputs of nutrients over the period since 1990 have been collected under the OSPAR Riverine Inputs and Direct Discharges (RID) programme. Discussion of the inputs data is based on six main catchment areas, which relate to those used for reporting UK inputs data to OSPAR (Figure 2.2).

For the purposes of this report, consideration is given to the riverine and direct inputs of orthophosphate-phosphorus and of total nitrogen. It should be noted that riverine inputs include waste-water discharges and diffuse losses within the catchment upstream of the monitoring point. Direct inputs reflect the loads from waste-water discharges to coastal waters and estuaries downstream of the riverine monitoring point. The UK RID data reports do not provide an estimate of the diffuse source loads from the land areas downstream of the monitoring point and they do not make any estimate of retention within sediments or losses of nitrogen to air, i.e. that part of the nutrient input which ceases to contribute to nutrient enrichment of waters at risk of eutrophication. Omission from the input estimates of the diffuse inputs downstream of the riverine monitoring point leads to a small underestimate of inputs which is compensated by the overestimate resulting from not taking into account retention.

On a national scale, direct inputs of phosphorus and nitrogen have reduced by about 50% and 35% respectively since 1990 but riverine inputs have not decreased. Riverine inputs are influenced significantly by flow and for the last five years (1998-2002) that inputs data are available riverine flow rates have been above the long-term average.

In order to evaluate UK nutrient inputs and the influence of flow on the riverine components, there is benefit in considering the data on a regional scale. Figures 2.3 and 2.4 show nitrogen and phosphorus inputs and related riverine flow rates for each of the six sea areas (Figure 2.2) around the UK.

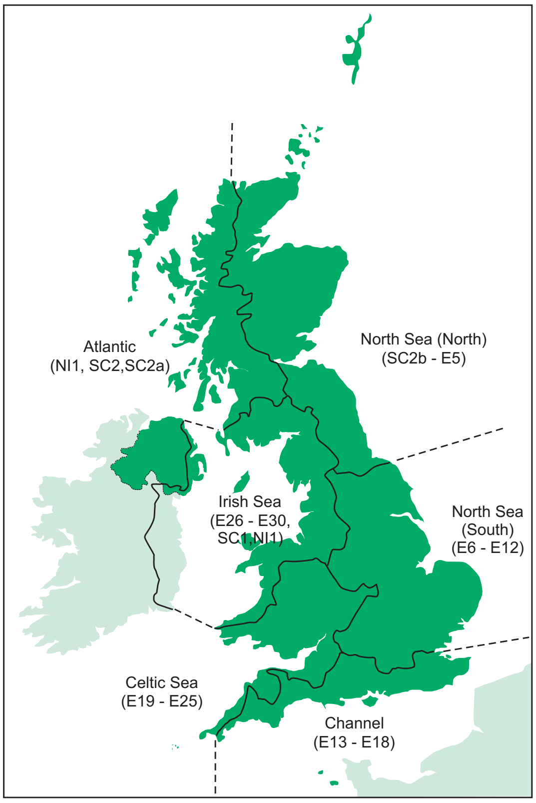

Figure 2.2. UK catchment areas relating to OSPAR sea areas used for reporting UK inputs of nutrients. (Corresponding ICES zones indicated)

Direct inputs of both nitrogen and phosphorus to each of the six sea areas have reduced, reflecting the national picture. A substantial reduction (about 60%) of nitrogen inputs to the North Sea North contrast with the marginal reduction of nitrogen inputs to the North Sea South. Generally these reductions in direct inputs reflect improvements to treatment of sewage and industrial discharges resulting from the implementation of the Urban Waste Water Treatment Directive. The greater reductions in direct phosphorus inputs coincide with the progressively increasing use of phosphate free detergents since 1990.

Consideration of the riverine inputs of phosphorus and nitrogen to the six sea areas around the UK shows that the riverine flow variability has most influence on the pattern of inputs to the North Sea South, the Channel and Celtic Sea areas. For these three areas there is a distinct increase

Figure 2.3. Nitrogen inputs and related riverine flow rates for each of the six sea areas (Figure 2.2)

in the flow rates over the period. Consequently, without flow adjustment, it is difficult to determine any underlying trends.

In absolute terms, the riverine inputs of nutrients to the North Sea South area are the most significant, accounting for about 40% of the total riverine inputs from the UK. This reflects the high population density and intensity of agricultural activity in the corresponding catchment areas.

Atmospheric pathways

Nitrogen can also reach the marine environment via the atmospheric pathway and is a relevant pressure when consideration is given to the risks of eutrophication in a marine area. Deposition of nitrogen on UK marine waters is a function of emissions from various land areas (not just the UK) and from various sea based sources, such as shipping. Given this mix of UK and non-UK sources, it is convenient to consider UK emissions to ascertain progress made by the UK in reducing this 'atmospheric pathway' pressure.

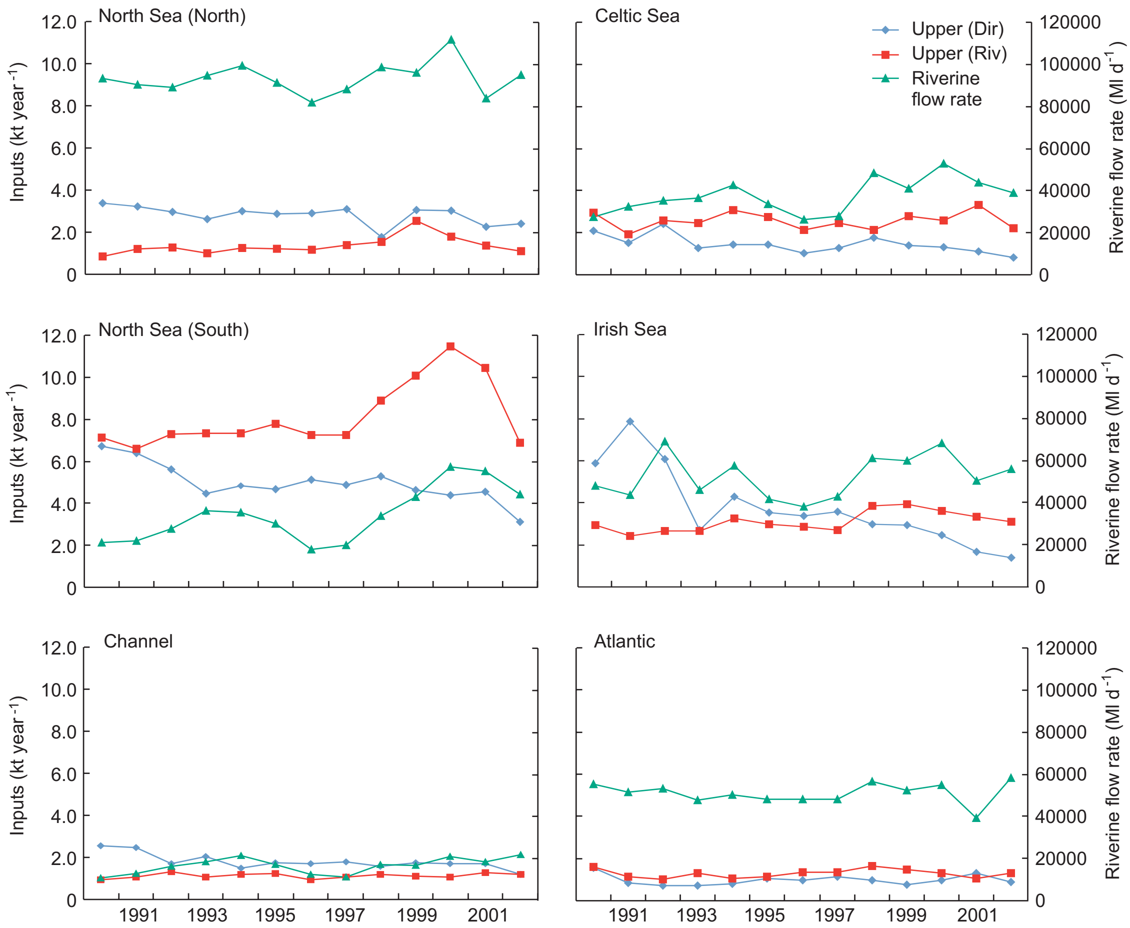

Figure 2.4. Phosphorus inputs and related riverine flow rates for each of the six sea areas (Figure 2.2)

There are two principal components in the emissions of nitrogen, reduced nitrogen and oxidised nitrogen. The former, which includes ammonia from agricultural sources, is the smaller component; the latter, which includes the nitrogen arising from combustion process such as energy generation and transport, is the larger. Generally, as shown in Figure 2.5(a and b) which is based on EMEP data (Coleman, 2002, Dore *et al*., in prep), there has been a slight reduction in the reduced nitrogen emissions since 1990 and a more substantial reduction in the oxidised nitrogen emissions. Overall, as shown in Figure 2.5(c), UK emissions of nitrogen have reduced by about 35% during the period 1990-2002.

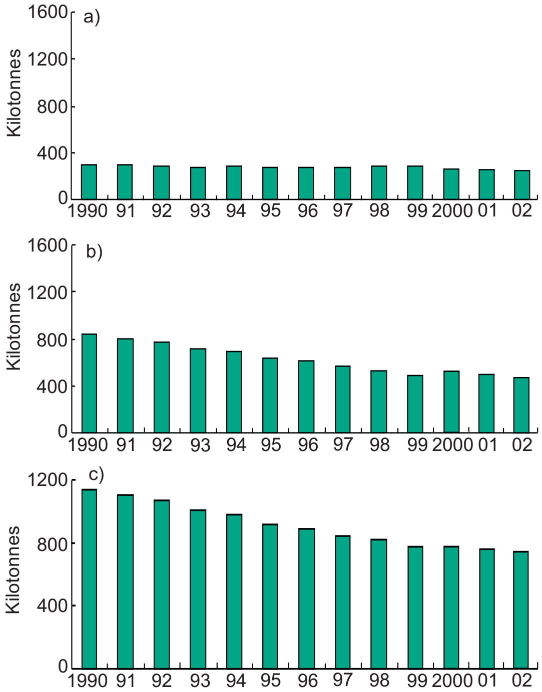

Figure 2.5. UK emissions (N kt y^{-1}) of (a) ammonia, (b) oxides of nitrogen and (c) reduced and oxidised nitrogen

2.2 WINTER NUTRIENT CONCENTRATIONS

An average of winter (November-February) concentrations is used to show changes in the levels of nutrients in coastal waters. The maximum concentration of DIN and DIP occurs in winter when biological activity is relatively low and, for coastal and transitional waters, the input of land run-off is high. The winter concentration (measured at a time between November and February depending on region) acts as a benchmark to allow comparisons and may act as an indicator of probable plant growth during the ensuing growth season. Recognising that freshwater is an important vector for nutrient input and that freshwater input affects the environment for plant growth, we have structured our assessment on the basis of salinity in line with OSPAR guidance. Coastal waters are defined by salinity between 30 and 34 and offshore waters as salinity greater than 34. The data have been assessed using the common assessment criteria for different sea regions as applied in the OSPAR Comprehensive Procedure. Table 2.1 illustrates the derivation of the background used for assessment of the waters around England and Wales. The background concentrations used for Scotland are higher (8 – 10 μM DIN, > 0.8 μM DIP, 4 μM Si) reflecting the regional difference. In general, lower concentrations are used to introduce a degree of caution and to take account of the loss of nitrogen through dentrification that occurs as the Atlantic water flows over the shelf.. The thresholds are set at 50% above a background that represents the base Atlantic seawater present in that region. Examples of the changes that have occurred over time in some representative areas of UK seas are shown in Figures 2.6 and 2.7.

Table 2.1. Derivation of winter nutrient assessment criteria based on background Atlantic concentrations

Nutrient concentration (μM)								
Nitrate + Nitrite			Phosphate			Silicate		
Mean	Range	+ 50%	Mean	Range	+ 50%	Mean	Range	+ 50%
7.20	5.25–9.90	**10.80**	0.45	0.34–0.65	**0.68**	3.27	2.30–5.15	**4.91**

Mean and range data were derived from winter Atlantic seawater concentration measured at shelf break in February 1994, 1998 and January 1999 (N). February 1994 and 1998 (P and Si) (see Gowen *et al*., 2002).
Different background concentrations have been used in different regions in concordance with the OSPAR Comprehensive Procedure.

Regions that are distant from the coast are not, generally, influenced by freshwater inputs but reflect inputs from the Atlantic Ocean. This is readily shown by the winter nutrient concentrations in the offshore areas of the North Sea (Table 2.2); concentrations are similar to the background concentration used to set the assessment criteria.

In contrast, Dissolved Inorganic Nitrogen (DIN) concentrations in coastal areas are influenced by freshwater inputs. Highest concentrations were recorded off the South East coast of England, in the Bristol Channel and in Belfast Lough, areas where, for some, historical inputs of DIN have been high (see Figure 2.6). Irrespective of the specific assessment criteria, winter DIN concentrations were high in all coastal areas with the exception of the coastal waters of the North Sea North area. Dissolved Inorganic Phosphorus (DIP) concentrations reflect the trends observed for DIN (see Figure 2.7). The clear message emerging is that extensive areas of the coastal waters of England and Wales are enriched by nutrients derived from land-based sources.

Table 2.2. Concentration of dissolved inorganic nitrogen (DIN) and phosphorous (DIP) for offshore areas (Salinity >34). Records represent winter averages between 1960 and 1996

	DIP (μM)	DIN (μM)
North Sea North	0.51 ± 0.07	4.91 ± 1.60
North Sea South	0.71 ± 0.13	9.42 ± 2.21
NE Atlantic	0.59 ± 0.12	8.67 ± 1.23

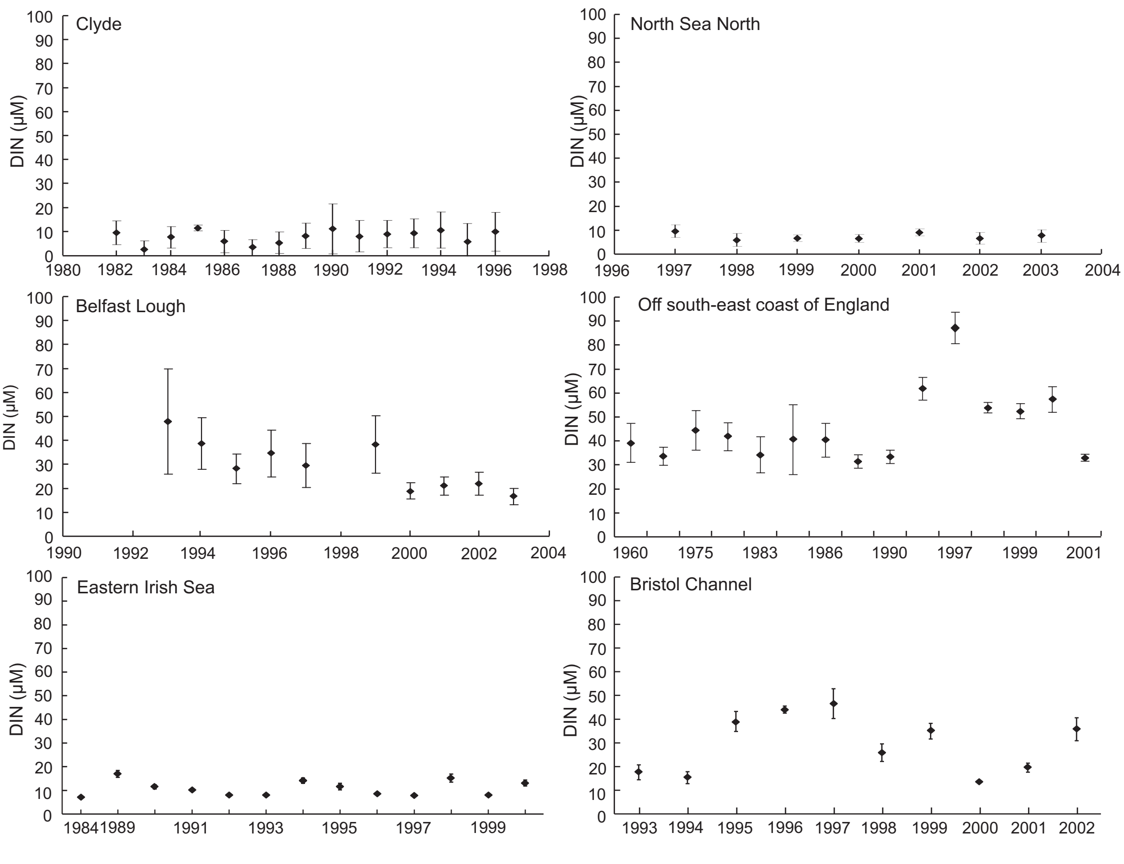

Figure 2.6 Coastal (salinity = 30-34) Dissolved Inorganic Nitrogen concentrations for six regions across the UK

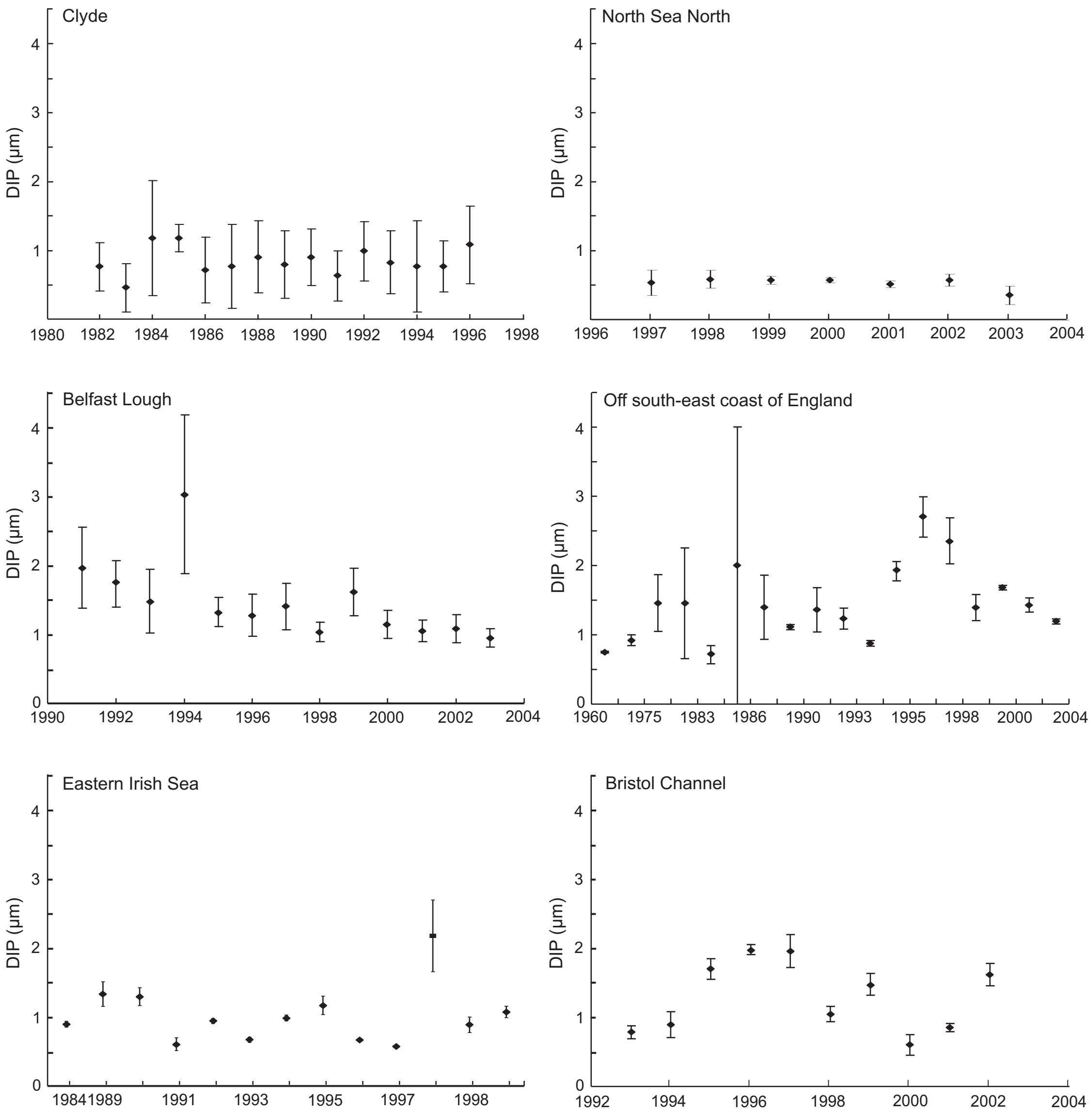

Figure 2.7. Coastal (salinity =30-34) Dissolved Inorganic Phosphorus concentrations for six regions across the UK

2.3 CHLOROPHYLL *a*

Chlorophyll a concentrations are used as a well established, if imperfect, indicator of phytoplankton biomass present in the water. Phytoplankton growth and biomass has a distinct annual cycle driven mostly by the seasonal availability of light. This pattern has a characteristic maximum in spring with lower concentrations in winter and summer.The coastal areas of the North Sea, Bristol Channel, Clyde Sea and Belfast Lough do not generally exceed 10 μg Chl l^{-1} [the regional OSPAR assessment criterion (growing season means) – see Figure 2.8] however, in contrast, this level has been exceeded on occasion in the Eastern Irish Sea. We have less data about chlorophyll concentration and generally shorter time series of information than for nutrients.

The Continuous Plankton Recorder (CPR) survey does not measure chlorophyll but does provide a qualitative estimate of plankton growth through a measure of 'greenness'. This helps to

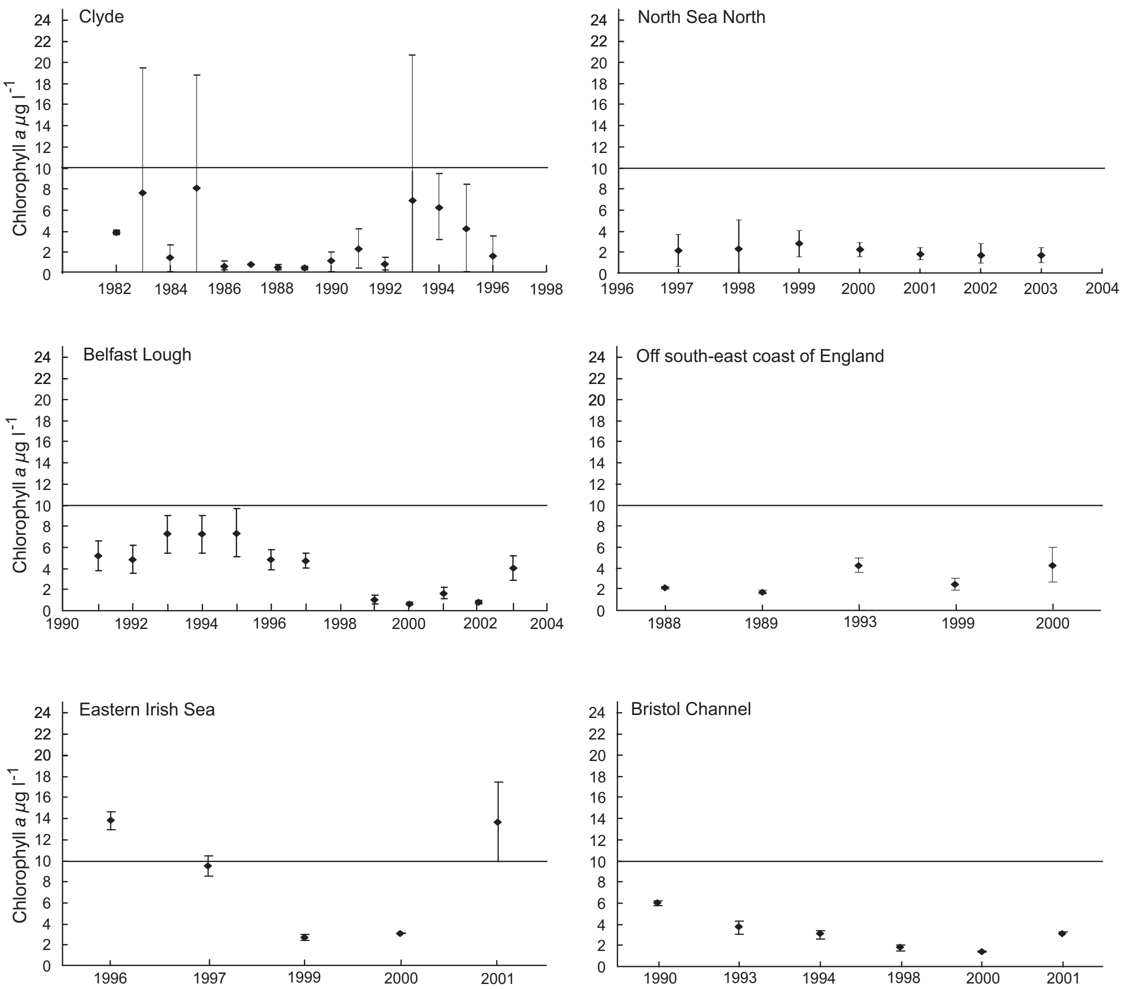

Figure 2.8. Coastal (salinity =30-34) Chlorophyll *a* concentrations for six regions across the UK

extend our understanding of the dynamics of the phytoplankton in both space and time. The CPR provides one of the few long-term systematic surveys of biology available for the waters of north-west Europe.

These data show that there has been a considerable increase in the 'greeness' index over the last decade in certain regions of the north-east Atlantic and North Sea (Figure 2.9). Particularly high stepwise increases were seen after the mid-1980s in the North Sea and west of Ireland between 52°N and 58°N (Reid *et al.*, 1998). The increase in phytoplankton biomass was in the region of 3-4 standard deviations above the long-term mean (1960-1995) which included a >90% rise in phytoplankton biomass over the winter months (Edwards *et al.*, 2001). A key message to be taken from this data is that the pattern of change in the North Sea, which could be taken as evidence of the effects of nutrient enrichment, occurs over a broader scale including areas of the Atlantic. The pattern of change does not reflect the pattern of major anthropogenic nutrient input and it has been concluded that the change represents the effects of regional change (Edwards *et al.*, 2001).

2.4 PHYTOPLANKTON INDICATOR SPECIES

A number of potentially harmful and nuisance phytoplankton taxa have been identified from the CPR survey and are listed in Table 2.3. One of the most investigated nuisance taxon in the North Sea is the colony forming alga *Phaeocystis* spp.

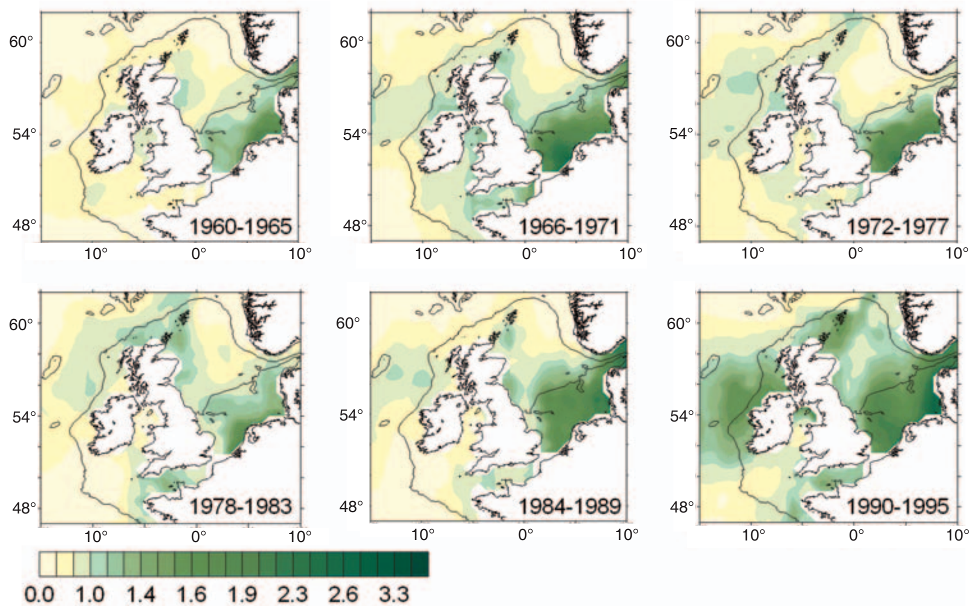

Figure 2.9. Geostatistical estimates of the mean spatial distribution of phytoplankton colour (index of phytoplankton biomass from the Continuous Plankton Recorder Survey) in six year periods from 1960-1995. Edwards (2000)

Table 2.3. Known harmful and nuisance plankton taxa recorded by the CPR survey in the North Atlantic and around UK coastal waters

Species/genus	Associated harmful/nuisance effects	Time-series
Plankton potentially toxic at low biomass		
Dinophysis spp	Diarrhetic shellfish poisoning (DSP)	1948 –
Gonyaulax spp	Unspecified toxicity	1965 –
Prorocentrum micans	Diarrhetic shellfish poisoning (DSP) Discolouration and hypoxia/anoxia	1948 –
Pseudo-nitzschia spp	Amnesic shellfish poisoning (ASP)	1948 –
Plankton causing potential nuisance at high biomass		
Ceratium furca	Hypoxia/anoxia	1948 –
Coscinodiscus wailesii	Production of mucilage	First recorded in 1977 (invasive)
Phaeocystis spp	Production of foam and mucilage. Hypoxia/ anoxia	1946 – (presence/absence)
Nitzschia closterium (now *Cylindrotheca)*	Production of foam and mucilage	1948 –
Chaetoceros spp	Gill clogging	1948 –
Skeletonema costatum	Gill clogging	1948 –
Other potential nuisance plankton		
Noctiluca scintillans	Discolouration and hypoxia/anoxia	1981 –

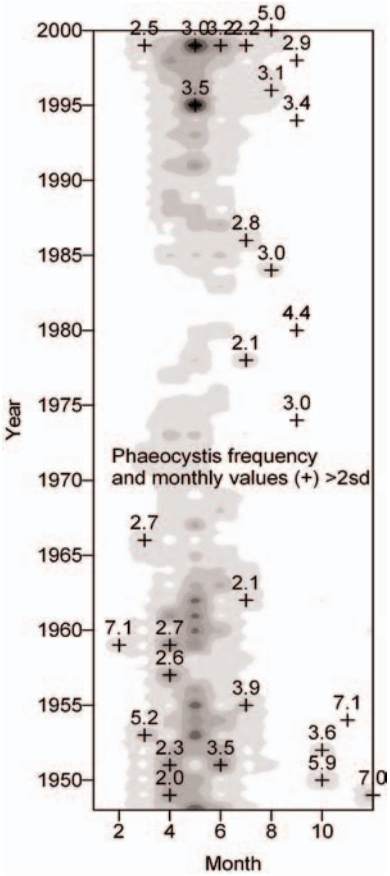

Figure 2.10. Monthly means of *Phaeocystis* spp. % frequency in the North Sea from 1948-2000. Values with crosses indicate frequencies >2 Standard Deviations above long-term monthly mean, highlighting unseasonably large blooms

Extensive blooms of this alga occur regularly in the southern North Sea area adjacent to the continental coast. The natural habitat of this genus is in the well-mixed freshwater influenced margins of the land. The long-term monthly variability of *Phaeocystis* for the North Sea is shown in Figure 2.10. Whereas *Phaeocystis* was particularly common in the 1950s it declined through the 1960s and 1970s. Since the mid 1980s, however, *Phaeocystis* spp. has increased in the North Sea and has been frequently recorded over the last few years. For example, 1999 was an exceptional year with a number of large blooms.

It has been suggested that increases in *Phaeocystis* spp abundance could be attributed to increased nitrogen and phosphorus inputs (Lancelot *et al*., 1987) and this may be the case in nutrient enriched coastal waters. However, similar patterns were found in other regions of the north-east Atlantic, suggesting the patterns were caused by regional climatic change, mirroring the patterns observed for the 'greeness' index.

It is important to recognize that these harmful and nuisance phytoplankton taxa are not diagnostic of eutrophication, though changes in bloom frequency and biomass may result from nutrient enrichment and therefore, form a part of the assessment 'tool-kit'. The causative link between nutrient enrichment and the presence of toxin producing algae is even more problematic. These organisms and the toxins they produce are a cause for concern as they can find their way into edible shellfish and pose a threat to human food safety.

2.5 MACROALGAE

Excessive growth of the opportunistic green macroalgae Enteromorpha can represent an undesirable disturbance resulting from nutrient enrichment. The habitats that can be affected are shallow, often semi-enclosed, basins with a large intertidal area consisting of soft sediment. There are relatively few of these habitats in the UK and some of these have been identified as problem areas. They are included in Table 2.4 together with areas identified for other reasons. A broader suite of information on macro-algae will be used for assessing ecological status under the Water Framework Directive.

2.6 OXYGEN

Hypoxia and anoxia can result from the sedimentation and enhanced oxygen demand of increased organic matter production especially in areas where there is restricted exchange of oxygen with the atmosphere. The most susceptible areas are the deep water basins of fjords and stratified regions of the shelf seas. Hypoxic and anoxic benthic environments are not recent or uncommon phenomena and all marine sediments are anoxic below a certain depth from the sediment surface. However, most UK transitional, coastal and offshore marine waters are well mixed and unlikely to suffer from this ultimate effect of nutrient enrichment. A recent UNEP report (UNEP, 2004) has highlighted the problem of hypoxia resulting from nitrogen enrichment and includes information about sites in UK waters. These are sites where lowered oxygen concentrations are expected from the

Table 2.4. Near-shore problem areas

OSPAR Sea Area	Area Name	Location	OSPAR Initial assessment
North Sea	Ythan Estuary	Scotland	Problem Area
North Sea	Lindisfarne NNR Area	England NE Region	Problem Area
North Sea	Seal Sands, Tees Estuary	England NE Region	Problem Area
Channel	Pagham Harbour	England S Region	Problem Area
Channel	Chichester Harbour	England S Region	Problem Area
Channel	Langstone Harbour	England S Region	Problem Area
Channel	Portsmouth Harbour	England S Region	Potential Problem Area
Channel	Holes Bay/Poole Harbour *(NB Holes Bay is a small part of Poole Harbour embayment)*	England SW Region	Problem Area / Potential Problem Area
Channel	The Fleet	England SW Region	Potential Problem Area
Channel	Truro, Tresillian and Fal Estuaries	England SW Region	Problem Area
Celtic Sea	Taw Estuary	England SW Region	Problem Area
Celtic Sea	Tawe	Wales	Problem Area
Celtic Sea	Loughor Estuary	Wales	Potential Problem Area
Irish Sea	Inner Belfast Lough & Tidal Lagan Impoundment	Northern Ireland	Problem Area

eco-hydrodynamics and evidence is still required to determine if the situation is being changed by anthropogenic factors. There is a relative paucity of systematic information about the variation in bottom water and sediment oxygen concentrations in UK waters, a question being addressed in the design of future monitoring programmes. However, it is clear that most UK coastal waters are well mixed and unlikely to suffer from serious oxygen deficiency.

DISCUSSION

The distribution of nutrient input is not uniform across the UK. The inputs of nitrogen and phosphorus are highest along the coasts of south-east, east and north-west England and from the Severn to the Bristol Channel. This distribution reflects the disposition of human population and the intensity of agricultural land use and determines the level of risk to regional coastal waters. Thus the greatest pressure due to nutrient input is experienced in the areas noted above. However, at a more local scale there is considerable variation and the level of pressure experienced by different estuaries can vary by over an order of magnitude (Nedwell *et al*., 2002).

The pressure on the seas around the UK due to phosphorus input has declined but the pressure due to nitrogen input has not changed significantly. The changes in pressure vary between regions and with the source of the nutrient. Direct discharges to marine waters of nitrogen and phosphorus have declined by 35% and 50%, respectively, since 1990. This results from the introduction of measures under the Urban Waste Water Treatment Directive and, for phosphorus, the effect of the increasing use of phosphate-free household detergents. The difference between regions can be marked. For example, overall nitrogen inputs to the North Sea North have declined by about 60% in contrast to the North Sea South where there is no reduction. We are only just beginning to understand the implications of changing climatic conditions on the diffuse input of nitrogen to the sea. Considerable variation, and indeed a significant increase in rainfall over the last few years for southern England make it more difficult to determine the effect of measures already taken due to the 'buffering' capacity of the nitrogen reservoir already held on land. Reducing the pressure due to diffuse nitrogen sources can only take place over the longer term.

There is a general relationship between the location of high nutrient input and high winter nutrient concentration in the regional coastal waters though, in detail, this depends on the hydrodynamics of the receiving water. The closer to source the more likely it will be that nutrient concentration will relate directly to the input but for most of these regions coastal and offshore nutrient concentration is related to the variation in the in-flowing Atlantic oceanic water. The coastal and transitional waters of southern, eastern and north-western England and the inner Bristol Channel are nutrient enriched based on the first application of the OSPAR Comprehensive Procedure criteria. The significant downward trends in nutrient input to some regions does not lead to an equally un-ambiguous decline in measured nutrient concentration which is not suprising given the inherent variability in the observations and dominance in most regions of the natural inventory of nutrients in the sea. Gowen *et al*. (2002) report the only observations of declining marine concentrations of DIP which coincide with a decline in P input. This important observation derives from one of the few long time series of data available for an area of UK waters in the Irish Sea.

Although it might be expected that nutrient enrichment would lead to enhanced, and in some cases, excessive growth of plants this can only be demonstrated in a few locations. The most obvious examples are relatively small, shallow coastal basins such as Langstone and Chichester Harbours, next to the Solent, and the Ythan Estuary near Aberdeen where extensive growth of the opportunistic green seaweeds (Enteromorpha spp) occurs. None of the coastal water regions exemplified in this report shows phytoplankton biomass in excess of the relevant OSPAR Comprehensive Procedure criteria though the north-east Irish Sea is an area of ongoing concern as the concentration of chlorophyll do sometimes exceed the threshold. The concentration of chlorophyll a, which is taken to represent phytoplankton biomass, is determined by a number of time dependant factors including the light available for growth and the loss of biomass to the foodchain and the environment. Most of the coastal waters of the UK are dynamic and this results in greater turbidity, which will reduce light available and limit the growth of plants as well as contributing to the dispersal of biomass. These factors help to lower the susceptibility of these waters to the undesirable disturbance due to nutrient enrichment.

A significant factor that is often ignored in eutrophication assessments is regional change due to variations in the climate. It is clear that these changes can have a profound effect on the overall growth of plants and on specific types of plants. There is more to be done in disentangling the story that underlies climate and nutrient driven change and this should be seen as a priority if we are to tackle any perceived undesirable disturbance with the most appropriate measures.

The threat to the marine environment posed by human interference in the nitrogen and phosphorus cycles is widespread but that threat is only realized when environmental conditions are favourable. In general, and despite the level of nutrient enrichment in the regions around the UK, there is good evidence that undesirable disturbance has not occurred. However, given the potential significance of the threat and the accelerated change in UK seas there is a continued need to deliver both better evidence and better understanding of the ecosystem consequences of nutrient input.

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3. Hazardous substances

KEY POINTS

- **Total riverine and direct inputs of Hg, Cd, Cu, Pb, Zn and γ-HCH to coastal waters have reduced by 20%-70% since 1990 and atmospheric emissions of the same chemicals have reduced by 50%-95% since 1990.**
- **Concentrations of Hg, Cd, Cu, Pb, Zn and γ-HCH in waters are below EQS in all areas.**
- **However, concentrations of Hg, Cd, Cu, Pb and Zn in both water and sediments are elevated above background concentrations (i.e. pristine) in most areas, particularly in industrialised estuaries, in many cases as a result of historical inputs.**
- **Concentrations of Hg, Cu, Pb, CBs and PAHs in sediments are above EACs in a number of areas, particularly in industrialised estuaries. Concentrations of Cd and Zn are generally below EACs in most areas, except for some estuaries on the East Coast of England.**
- **Contaminated sediments from localised areas in some industrialised estuaries were toxic to test organisms but there was no direct correlation between concentrations of hazardous substances and benthic community structure.**
- **Concentrations of Hg in dab were close to background at approximately 50% of the sites monitored, but remain above background in areas such as the Mersey, Liverpool Bay and the Thames.**
- **Concentrations of Hg, Cd, Pb and CBs in mussels were above background at most sites whilst concentrations of Cu and zinc were generally not above background.**
- **Concentrations of PAHs in mussels were below the EAC in all areas, but concentrations of CBs in mussels were above the upper EAC at ~30% of sites.**
- **Highest concentrations of hazardous substances in biota were found in industrialised estuaries and adjacent areas with a known history of contaminant inputs. High concentrations of Cd were also found in fish liver from the offshore Dogger Bank site.**
- **Biological effects such as increased enzyme activity (EROD), DNA adducts and elevated levels of fish disease and liver tumours were found in some fish populations from areas found to have high concentrations of hazardous substances in sediments and biota.**
- **Research on endocrine disruption in the marine environment found some feminisation of flounder, resulting in egg protein production in males, but this seems to be declining in some areas. The key substances implicated as causing the effects were natural substances such as the human female sex hormone 17β-oestradiol and synthetic chemicals such as nonylphenols.**
- **Imposex in dogwhelks was widespread but effects on reproduction appear only to be significant within a few hundred metres of point source discharges of TBT.**
- **There are some indications which suggest that there may be a causal relationship between elevated concentrations of CBs and mercury in blubber and infectious disease mortalities in marine mammals.**

INTRODUCTION

A very large number of chemicals are essential for the efficient working of modern society. Chemicals are widely used in water treatment (eg disinfectants and flocculents) agriculture (pesticides and fertilizers), in industry (in the production of a diverse range of materials and products, eg plastics, resins and solvents) in the transport sector (eg hydrocarbons, paints and tyres) and in the health sector (pharmaceuticals, drugs and biocides). Chemicals are also produced during industrial processes, and as products of combustion (eg PAHs, and dioxins). Many chemicals are also naturally occurring (eg lead and mercury compounds).

It is estimated that there are well over 100,000 chemicals currently on the market, and many of these are produced and used in high volumes.

As well as their many advantages, the use of chemicals has disadvantages, and the main problem for the marine environment is that some of them are toxic (T) to marine life. If they are also persistent (P), they can remain in the environment long enough to be assimilated into biota. Furthermore, if they are bioaccumulative (B), they can be stored in the tissues of marine animals where they become concentrated, and can pass up the food chain and be found in significant concentrations in top predators. There are also some chemicals known as endocrine disruptors which can adversely affect the hormone systems of organisms resulting in adverse effects on health (eg the feminisation of male fish). Until recently, concern has focussed on single substances, but it is now clear that mixtures of substances, even if individual substances are at low concentrations, can cause significant biological effects.

In recent years, it has been broadly recognised that it is the PBT chemicals which pose the highest threat to the environment. In order to target these chemicals of concern, the Convention for the Protection of the Marine Environment of the North East Atlantic (the OSPAR Convention) and the European Community have developed selection and prioritisation mechanisms which have screened the various international databases containing information on production volumes and properties of chemicals using specific cut-off values for the P, B and T parameters in order to select out those chemicals of highest concern which can be subjected to further detailed investigation and control.

In order to discover the real impact or potential of such chemicals on the marine environment, it is necessary to carry out a risk assessment which entails a detailed assessment of the sources, the amounts released and pathways of the chemical to various compartments to ascertain how and whether it will enter the marine environment. This gives a scientific foundation for developing the appropriate control measures. Such assessments are normally complemented by monitoring programmes that give insights into environmental exposure and can, over time, indicate whether the control measures are effective.

Policy on controlling hazardous substances is increasingly driven by international, but particularly by European Union legislation. Since the 1980s, when concern about hazardous substances started to mount, a large number of EC regulations and directives which control various aspects of hazardous substances have been adopted in a somewhat peacemeal fashion. However, in 1998 (the OSPAR Convention) adopted a specific target to cease the discharges emissions and losses of hazardous substances by 2020. This has stimulated a more integrated approach to the management of hazardous substances and the following key pieces of legislation are either in place or under development.

- The evolving EC Chemicals Policy, which includes a proposal for the Registration, Evaluation and Authorisation of Chemicals (REACH) going onto the market
- The EC Water Framework Directive, which requires all surface and ground waters (including transitional and coastal waters) to meet good ecological status by 2015, and includes a 20 year cessation target for priority hazardous substances
- The Integrated Pollution Prevention and Control Directive which requires that all large industrial installations are applying best available techniques for minimising and eliminating polluting substances

- The EC Existing Substances Regulation which, *inter alia*, carries out risk assessments on hazardous substances identified by Member States, and has recently with OSPAR developed a specific tool for assessing the risks of substances to the marine environment.
- The Marketing and Use Directive which can ban or restrict the use of specified chemicals on the market

There are also Directives covering pesticides, pharmaceuticals and veterinary medicines, although these do not have marine environmental protection goals incorporated into them.

PROGRESS WITH INDICATORS

In order to show that marine ecosystems are healthy it is necessary to have a series of indicators against which targets can be assessed, and policies can be measured and to carry out appropriate monitoring programmes. The current drivers for these programmes are:

- national assessment and surveillance programmes on substances under investigation
- monitoring of specified substances required by OSPAR
- monitoring required under various EC directives

For the marine environment the following indicators HAVE BEEN PROPOSED, and the subsequent sections of this report show their current status.

It is acknowledged that still more needs to be done and that indicators are needed to
- Demonstrate the progress of moving towards cessation targets for particular substances
- Ensure that marine ecosystems are healthy, particularly in respect of mixtures of hazardous substances in low concentrations.

INDICATORS OF CHEMICAL QUALITY

- **Concentrations of hazardous substances compared to Environmental Quality Standards (EQSs)**

EQSs are concentrations below which a substance is not believed to be detrimental to aquatic life. These were originally developed for the EC Dangerous Substances Directive (76/464/EEC). The concept is now well established and is incorporated into the Water Framework Directive (60/2000/EC). EQSs are derived using acute toxicity tests on organisms at different trophic levels. To provide a safety factor, the EQS is set substantially below the concentration observed to have a toxic effect on the test organisms. EQSs vary for each substance and can be different for fresh, estuarine or coastal waters. EQSs for the most toxic substances (List 1 EC Dangerous Substances Directive or Annex 1 substances in the EC Water Framework Directive) are set at a European level. The EQSs for less toxic substances are set nationally.

EQSs for water have been used in this report, however it should be noted that these are currently under review, for 33 substances, under the Water Framework Directive. EQSs have not yet been developed for sediments and biota where the ‘EQS’ is simply a standstill clause (i.e. no upward trends in concentrations). This presents a difficulty when interpreting data in sediments and biota and is recognised as an area that needs further development.

- **Concentrations of hazardous substances compared to Background Reference Concentrations (BRCs)**

BRCs were adopted by OSPAR in 1997 OSPAR 97/15/1, Annex 5 for contaminants in seawater, sediment and biota, as assessment tools for use in Quality Status Reports. BRCs were developed by examining typical concentrations of both naturally occurring and man-made contaminants in remote parts of the OSPAR maritime area. In general, man-made substances are expected to have a background concentration of zero. However, due to their persistence and long-range transport, many substances are detected in remote areas. For naturally occurring substances, the BRC is the range of concentrations that would be anticipated in the absence of any human activity.

Assessments made against the current OSPAR BRCs should be treated with caution. Reservations have been expressed over the current BRCs, due to the difficulties in deriving and applying such assessment criteria over wide geographical areas. In particular, BRC values need to take account of natural variability, for example, in the geology for coastal sediments. OSPAR has recognised that the current values require revision and put in place a process that culminated in a Workshop in this area in February 2004.

- **Concentrations of hazardous substances compared to Ecotoxicological Assessment Criteria (EACs)**

EACs were also adopted by OSPAR in 1997 OSPAR 97/15/1, Annex 6. EACs are the concentrations of substances above which there may be impacts on biota. They are used to identify potential areas of concern and to prioritise substances for attention. The concepts behind EACs and EQSs are similar, however EACs exist for a number of substances in sediments and biota.

As with BRCs, assessments made against current EACs should be treated with caution. Concentrations of a contaminant below the EAC for that contaminant do not guarantee a safe situation. On the other hand, it is not compelling that biological effects occur where an EAC is exceeded. This can only be established through biological investigations in the field. Current EACs were reviewed along with BRCs at the OSPAR workshop in February 2004. Indications are that existing EACs will be replaced by new criteria developed using improved methodologies now available for effect assssment.

INDICATORS OF BIOLOGICAL QUALITY

Benthic community data are summarised using complex staistical treatments that yield simple indices of quality:

- **Univariate Indicators**

These summarise the fauna composition. Examples are the number of taxa (T), abundance of taxa (A), evenness of taxa distribution (J'), and diversity measured by the Shannon-Wiener index (H').

- **Multivariate Indicators**

Multivariate statistics examine the similarity between different sites in terms of species composition. These similarities can then be examined against environmental variables to link changes in species composition with pollution.

- **Biotic Indices**

These summarise the way the fauna functions. Two biotic indices are used in this report: the UK Infaunal Trophic Index (ITI) and the AZTI Marine Biotic Index (AMBI). The ITI was developed to distinguish the impact of organic deposits from municipal sewage discharges on infauna in fully marine environments.

Biological effects indicators are being developed. A recent workshop examined the JAMP suite of biological effects techniques, the data sets available and their suitability for indicator reporting. It concluded that imposex in dogwhelks, fish disease, EROD, oyster embryo bioassay and sediment bioassays were suitable for immediate development for indicator reporting, but that bile metabolites and metallothionein still require substantial development.

3.1 INPUTS

AQUATIC PATHWAY

Inputs of hazardous substances, ie the dissolved and particulate components of the waterborne loads from land based sources, provide an indicator of pressure on marine areas and the biota therein, which can be directly or indirectly affected by those hazardous substances. Data on UK inputs of hazardous substances over the period since 1990 are available from information submitted to OSPAR under the Riverine Inputs and Direct Discharges (RID) programme.

For the purposes of this report, consideration is given to the totals of the riverine and direct inputs of five heavy metals and lindane. It should be noted that riverine inputs include waste water discharges and losses within the catchment upstream of the monitoring point. Direct inputs reflect the loads from waste water discharges to coastal waters and estuaries downstream of the riverine monitoring point. The UK RID data reports do not provide an estimate of the diffuse source loads from the land areas downstream of the monitoring point.

Following the convention used in OSPAR RID data assessments, the means of corresponding lower and upper estimates of inputs are used when considering the patterns of change in UK hazardous substances inputs. Generally, there are differences between the upper and lower estimates: for heavy metals these are not excessive but for lindane, the differences have been progressively increased since the early 1990s, generally reflecting the very low concentrations now found in rivers and effluents.

Figure 3.1 gives an indication of the levels and patterns of change in UK inputs on a national scale. Over the period 1990-2002, totals of riverine and direct inputs of mercury and cadmium have reduced by about 60%, and the inputs of copper and zinc by about 35%. Inputs of lead have only reduced by some 10-20% since 1990. However, it should be noted that the start date of this time series for lead is such that it does not capture the large reductions in inputs during the late 1980s. (Data reported at the Fifth North Sea Conference shows that between 1985 and 1990, UK inputs of lead fell by some 60%).

Lindane (γ-HCH) inputs have reduced by about 70% but, as noted above, concentrations are low, with most values below the limit of detection in recent years. Consequently, there are large differences between the lower and upper estimates of inputs. Therefore, the absolute levels and the pattern of change in inputs in lindane are less certain.

Total inputs of hazardous substances (especially those of lead and copper) are influenced by the variability of the riverine component of inputs, which is affected by flow. For the last five years (1998-2002) that inputs data is available, riverine flow rates have been above the long-term average.

ATMOSPHERIC PATHWAY

Hazardous substances can also reach the marine environment via the atmospheric pathway. The deposition of any hazardous substance could be a significant pressure, depending upon the scale and location of the area subject to deposition and the scope for significant concentration of the substance concerned. Deposition on UK marine waters is a function of emissions from various land areas (not just the UK) and from various sea based sources, such as shipping. Given this mix of UK and non-UK sources, it is convenient to consider UK emissions to ascertain progress made by the UK in reducing this atmospheric pressure.

(It is of interest to note that, when the absolute levels of the inputs and the emissions of hazardous substances are compared, there is a reasonable degree of parity in the corresponding loads – except for lindane where the atmospheric pathway loads are of the order 100 times the aquatic pathway loads).

For all hazardous substances under consideration there have been significant reductions in UK emissions over recent years – Figure 3.2. For the heavy metals over the period since 1985, mercury and cadmium emissions have reduced by about 80% and those for lead, copper and zinc have reduced by about 95%, 60% and 50% respectively. For lindane, where data is only available since 1990, emissions have reduced by over 80%.

These reductions reflect the changes in industrial practices and tighter controls on emissions. The very large reductions in the emissions of lead also reflect the major shift from the use of lead based petrol in the mid to late 1980s.

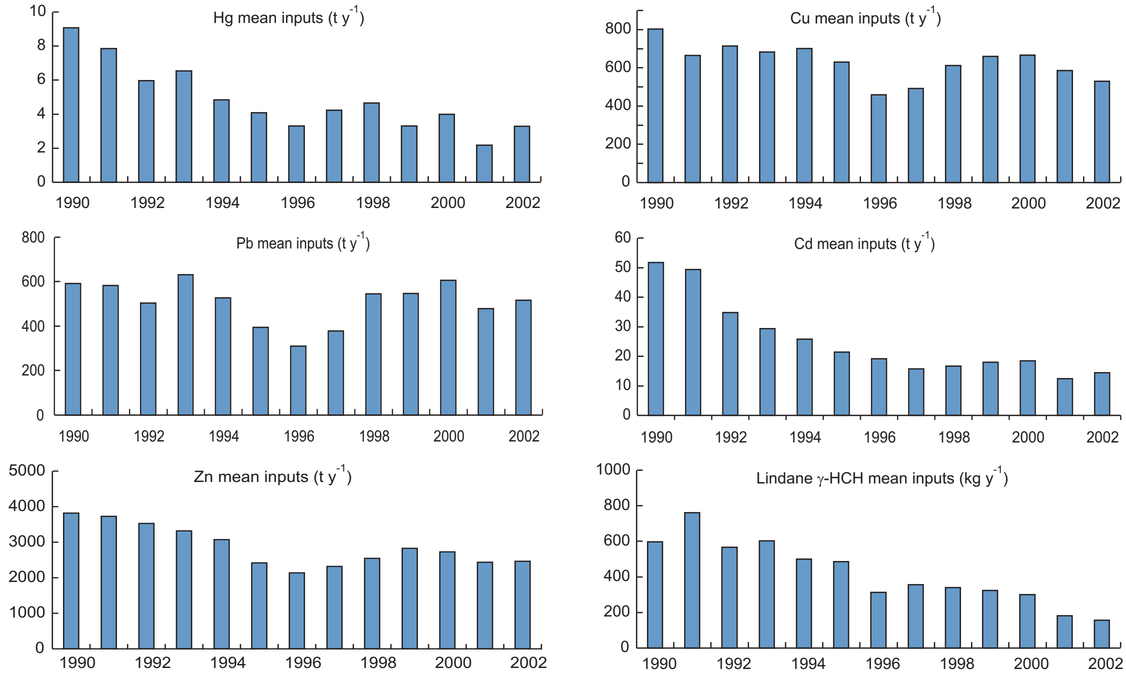

Figure 3.1. UK inputs of hazardous substance to marine waters 1990-2002 (following the convention used in OSPAR assessments, the means of lower and upper estimates of inputs have been used)

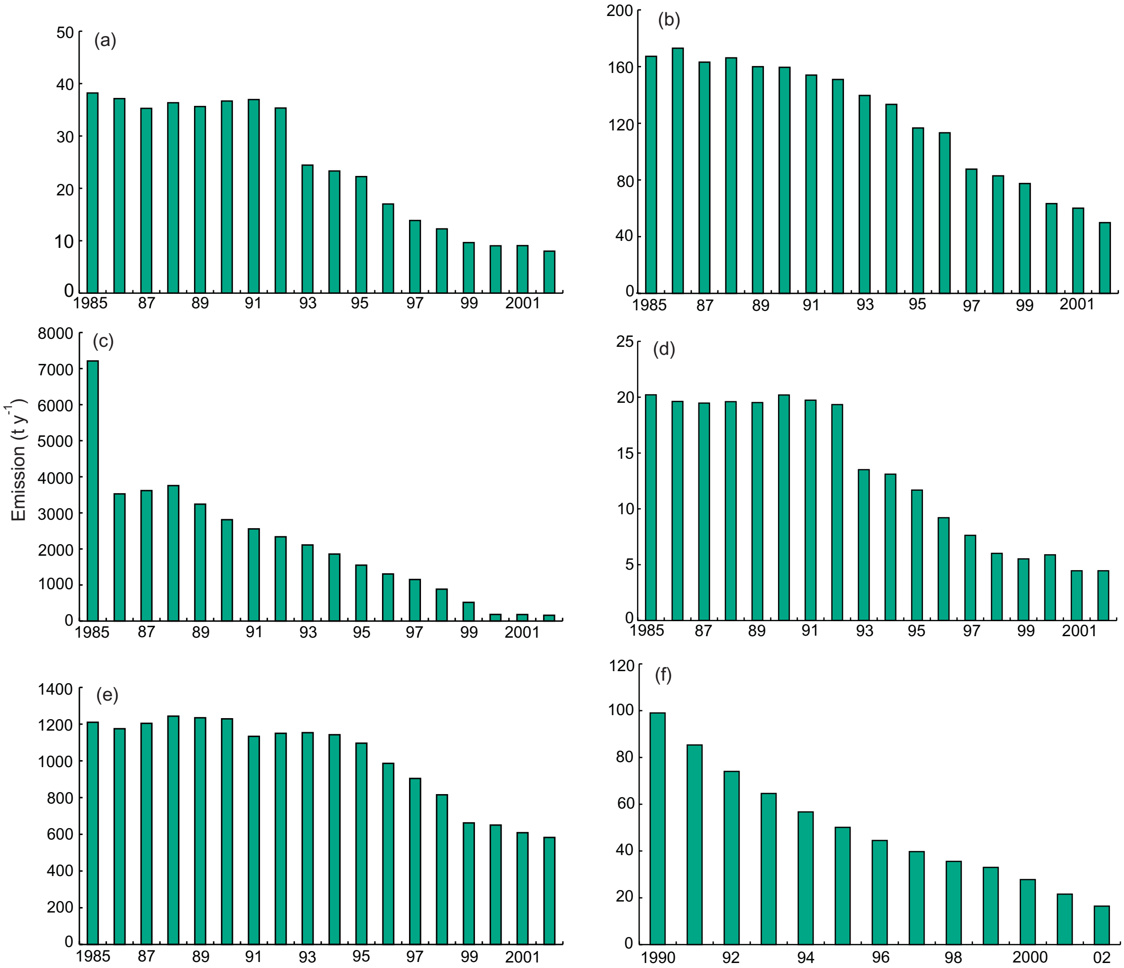

Figure 3.2. Emissions of (a) mercury, (b) copper, (c) lead, (d) cadmium, (e) zinc and (f) lindane (γ-HCH)

3.2 CONCENTRATIONS OF HAZARDOUS SUBSTANCES IN WATER

Concentrations of contaminants in marine waters are compared with the Environmental Quality Standards (EQSs) set in response to the EC Dangerous Substances Directive (76/464/EEC) (see Table 3.1). Under the Directive, discharges containing dangerous substances and their receiving waters are monitored.

Estuarine concentrations of contaminants are dominated by riverine and direct (industrial and sewage effluent) inputs. Atmospheric deposition of contaminants is less significant, although it is of major importance to the North East Atlantic as a whole (OSPAR Commission, 2000). Salinity is an important variable as concentrations of metals, such as cadmium and copper, tend to decrease with increasing salinity as they are diluted in outer estuaries and offshore waters (OSPAR Commission, 2000c). However, since data are only reported here for the national background reference ('control') site in most estuaries, these gradients are not shown in the present data set.

3.2.1 METALS

Metals concentrations in waters collected from around the UK during 1999-2002 as part of the National Marine Monitoring Programme and at background sites monitored under the EC Dangerous Substances Directive are compared to the EQSs, BRCs and EACs in Table 3.1.

Although compliance with EQSs is assessed by comparison with annual average concentrations, the results reported here are presented as median concentrations for consistency with other contaminant groups.

The EACs have no legal significance and should only be used for the preliminary assessment of chemical monitoring data, with the aim of identifying potential areas of concern (OSPAR Commission, 2000a).

Median metals concentrations in waters were below the EQSs in all areas (see Table 3.1) However in 2003, the monitoring carried out for the Dangerous Substances Directive (500+ sites) in England and Wales, indicated failure to meet List II metal standards at 19 individual sampling points. Essentially all of these were for copper the majority of which were in the Thames estuary. Monitoring for the Shellfish Waters Directive indicated exceedance of the zinc standard at 8 out of 119 designated shellfish waters. It is thought that the cause may be the use of sacrificial anodes in marinas to prevent corrosion.

Table 3.1. Metals in waters in comparison to EQSs and EACs

Metal	Range of Median Concentrations ($\mu g\ l^{-1}$)	BRC ($\mu g\ l^{-1}$)	EAC ($\mu g\ l^{-1}$)	EQS ($\mu g\ l^{-1}$)
Arsenic	1.1-3.0	-	1-10	25
Boron	700-4,086	-	-	7,000
Cadmium	0.012-0.25	0.008-0.025 (N) 0.009-0.012 (S)	0.01-0.1	2.5
Chromium	0.157-1.5	-		15
Copper	0.738-4.73	0.05-0.09 (N) 0.14-0.36 (S)	0.005-0.05	5
Mercury	0.003-0.011	0.0002-0.0005 (N)	0.005-0.05	0.3
Nickel	0.345-3.05	0.20-0.25 (N) 0.18-0.26 (S)		30
Lead	0.086-5.98	0.01-0.020 (N) 0.01-0.017 (S)	0.5-5.0	25
Zinc	1.26-26.2	0.25-0.45 (N) 0.17-0.28 (S)	0.5-5.0	40

Note: BRC ranges labeled (N) and (S) are for the Northern and Southern North Sea areas.

Mercury

Sources of mercury include industrial effluents and use in products such as dental fillings, batteries, lighting and medical instruments, although the release of mercury from historically contaminated dredged material may now be the largest source in the UK (OSPAR Commission, 2000).

Although mercury concentrations were below detection levels of 0.010 $\mu g\ l^{-1}$ in most areas, values in several industrialized estuaries in England are well above the upper BRC and close to above the upper EAC. These values ranged from 0.030 $\mu g\ l^{-1}$ in the Medway, 0.030-0.080 $\mu g\ l^{-1}$ in the Thames (both in Region 2) and 0.041-0.045 $\mu g\ l^{-1}$ in the Wear (Region 1) to 0.041-0.143 $\mu g\ l^{-1}$ in the Mersey (Region 5), indicating potential for concern in these areas.

Cadmium

Cadmium in discharges from the non-ferrous metals and fertiliser industries has been reduced and further action on cadmium in waste, phosphate fertilisers and releases from metal industries has been recommended (OSPAR Commission, 2002).

Cadmium concentrations are in the same general range as the BRC for the Northern North Sea (Region 1). In the Severn Estuary (Region 4), concentrations have decreased from almost 0.4 $\mu g\ l^{-1}$ in 1995 to about 0.09 $\mu g\ l^{-1}$ in 2001, falling below the upper EAC but still about four times higher than the upper BRC. Historical contamination of the Severn was caused by metal smelting in Avonmouth and south Wales.

Lead

Although lead is widely used in the manufacture of plastics and batteries, its use has declined in recent years. Estuarine concentrations of dissolved lead are expected to be low, due to the tendency of this metal to bind to particulate matter. Lead concentrations were similar to the EAC range in most areas, but high compared to the upper BRC in the Tyne and Tees estuaries (Region 1), with concentrations up to 6 $\mu g\ l^{-1}$.

Copper

Copper concentrations in 2001 were similar to those in 1995, reflecting the lack of reduction in inputs from rivers, industrial and sewage effluents to estuaries. Median concentrations were below the EQS but greater than twice the upper BRC.

Zinc

Zinc inputs have shown little change since 1995. Concentrations in waters in estuaries are typically an order of magnitude above the BRC range and slightly higher than the EAC range.

CONCLUSIONS/DISCUSSIONS

In summary, metals concentrations in waters from estuaries and coastal waters around the UK are elevated above background levels, as would be expected, due to local industrialisation. Despite this, concentrations of cadmium, lead and zinc are not sufficiently high to give cause for concern in their own right. Only for mercury in the Medway estuary in the Eastern English Channel (Region 3), the Thames in the Southern North Sea (Region 2), the Wear estuary in the Northern North Sea (Region 1) and the Mersey estuary in the Irish Sea (Region 5)is there cause for concern that adverse biological effects may arise.

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3.2.2 ORGANIC COMPOUNDS

Hexachlorocyclohexane (HCH)

Technical hexachlorohexane (HCH) contains α-, β-, δ- and γ-HCH isomers although only the γ-isomer (lindane) has significant insecticidal properties. Lindane was used extensively as an agricultural pesticide until 2002, when its use was banned in the EU. Its sale and supply were also banned in the UK. Inputs of lindane declined by 60-80% between 1990 and 2001.

HCH (α-, β–, γ-HCH isomers) is included on the OSPAR List of Chemicals for Priority Action and is also classed as a Priority Hazardous Substance under the Water Framework Directive (WFD). Monitoring is carried out on water samples collected quarterly from around the coast of the UK. Data is available from surveys carried out between 1999 and 2002 (MEMG, 2004), although not all stations have data reported for all years.

Where results for organic compounds in water were reported, concentrations were extremely low as organic compounds have limited solubility in water. Many of the results were below detection limits and only total HCH generally exceeded the limit of detection and approached the EQS value of 20 ng l^{-1} (Figure 3.3).

Concentrations ranged from 4.8 to 16.7 ng l^{-1} with the highest total HCH found in the Wash and the Thames Estuary (Region 2). A strong North - South gradient in total HCH has been observed in offshore UK waters, with concentrations being lowest off Scotland (~0.3 ng l^{-1} off NW Scotland) to between 1 and 2 ng l^{-1} in the South Eastern North Sea (Region 2) and the English Channel (OSPAR Commission, 2000).

No BRCs have been derived for organic compounds in water but EACs are available for lindane (γ-HCH) in water (0.5-5 ng l^{-1}).

Highest lindane concentrations were found in the Wash (Region 1). Concentrations were lower in other English estuaries with the lowest concentrations found in the Forth and Tay estuaries (Region 1).

OTHER ORGANIC COMPOUNDS

Monitoring carried out under the Dangerous Substances Directive indicated a number of failures to meet standards for List II organic compounds. By far the most common was tributyltin (29 failures at a variety of sampling points around the English coast) with a few failures for endosulphan, cyfluthrin and azinphos – methyl.

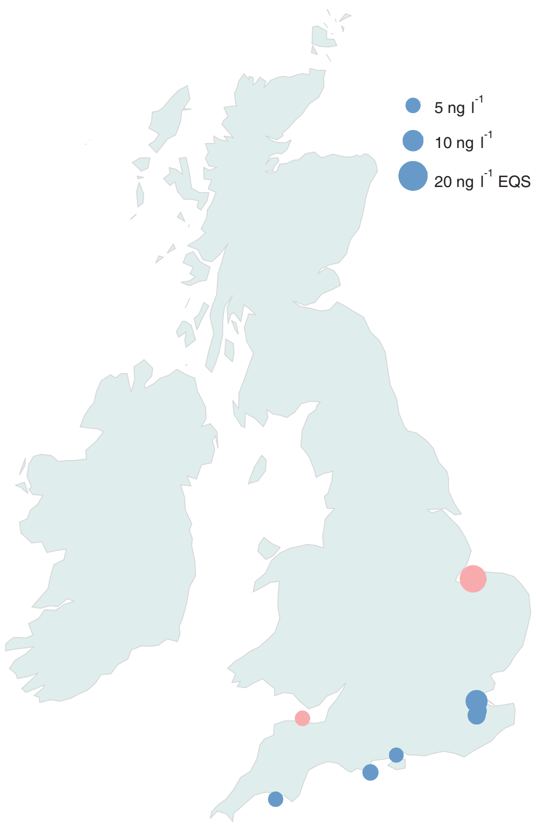

Figure 3.3. concentration of total HCH (ng l^{-1}) in water and their relationship to the EACs. Pink circles – concentration above upper EAC, blue circles – concentration below upper EAC

CONCLUSIONS/DISCUSSION

Concentrations of measured organic compounds in water were below EQSs at all sites. Concentrations of lindane were above the EAC in the Wash and the Thames Estuary indicating that these are areas of potential concern.

It is to be expected that concentrations of HCH (including lindane) will decrease due to the ban in 2002 but, because of its persistence in the marine environment, it is likely to be detected for some time to come. Additional monitoring of this substance may be required to meet WFD requirements.

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Alkylphenolethoxylates in Water

Alkylphenol polyethoxylates (APEOs) are non-ionic surfactants used extensively in commercial and domestic applications. As well as being one of the most widely used substrates in industrial detergents, they are also used in such diverse applications as paint additives, wetting agents and contraceptives (Heemken *et al*., 2001).

In the UK, in 1993, it was estimated that the total consumption of APEOs was 15-19,000 tonnes per annum (Department of the Environment, 1993) and that approximately 37% of these were discharged into rivers and estuaries, mainly via sewage effluents.

Alkylphenolethoxylates (APEs) degrade rapidly to alkylphenols (APs – nonylphenol and octylphenol) and most environmental data is for nonylphenol (NP) and octylphenol (OP). Currently there are no BRCs or EACs established for alkylphenols (APs) but Maximum Allowable Concentrations (MACs) for NP and OP are 2.5 $\mu g\ l^{-1}$ and for the NP mono- and di-ethoxylates together are 7.7 $\mu g\ l^{-1}$ (CEFAS, 2001).

In England and Wales water and sediment sampling was carried out in 1998 and 1999 at a time when domestic use of APEOs was being phased out. 52 samples were taken in 1998 and 48 samples in 1999.

Limits of detection of the methods reported here are 0.01 $\mu g\ l^{-1}$ for NP and OP and 0.06 $\mu g\ l^{-1}$ for the NP mono- and di-ethoxylates (sum of).

In 1998, NP concentrations ranged from below the limit of detection (LOD) to 5.2 $\mu g\ l^{-1}$ (CEFAS, 2001). Only five sites were above 1 $\mu g\ l^{-1}$ for NP (the Tyne, Tees and Humber Estuaries, near the Isle of Man and Amble, on the NE coast). Of these, only 3 exceeded the MAC limit (Amble, SE Isle of Man (Region 5) and the Tees Outfall (Region 1)) (Figure 3.4(a)). Concentrations of NP mono- and di-ethoxylates (sum of) ranged from below the LOD to 8.1 $\mu g\ l^{-1}$, with the maximum detected at Amble, which was the only site above the MAC limit (Figure 3.4(b). OP ranged from below the LOD to 4.1 $\mu g\ l^{-1}$ with most sites less than 0.2 $\mu g\ l^{-1}$. The Tyne NMMP site, Tyne Southern Reference site, the Tyne disposal site and the Humber/Wash NMMP site were all above the MAC limit (Figure 3.4(c)).

Source of data: CEFAS surveys.

In 1999, NP concentrations were above the LOD for all samples, ranging from 0.03 to 6.6 $\mu g\ l^{-1}$ (CEFAS, 2003). Tees Dabholm Gut (Region 1) had the highest concentration and was the only site to exceed the MAC limit. NP mono- and di-ethoxylate (sum of) was also above the LOD at all sites and ranged from 0.14 to 13 $\mu g\ l^{-1}$. The MAC limit was exceeded at one site only, the Tees Dabholm Gut, which was not sampled in 1998. The highest sample from 1998, Amble, was not sampled in 1999. OP concentrations were also above the LOD in all samples, ranging from 0.01 to 1.7 $\mu g\ l^{-1}$ and again most sites were below 0.2 $\mu g\ l^{-1}$. OP concentrations did not exceed the MAC limit at any sites.

CONCLUSIONS/DISCUSSION

For the sites that were monitored in both years all NP and the majority of OP concentrations had decreased in 1999.

The majority of the highly contaminated sites were in coastal or estuarine waters with areas of high industrial activity, indicating that the contamination could originate from industrial or domestic discharges. Continuation of monitoring is required to compare results and verify their consistency, the next step, assessing the significance of APEs and APs in the aquatic environment, can be undertaken. As APEs are phased out in industry the proportion of contamination from industrial versus domestic sources should become clearer.

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Department of the Environment, (1993). Uses, fates and entry to the environment of nonylphenol ethoxylates. Final Report.

Figure 3.4. Spatial distribution of alkylphenol and alkylphenol ethoxylate concentrations in marine and coastal waters around England and Wales for 1998 and 1999 of (a) total nonylphenols, (b) total mono- and diethoxylates and (c) total octylphenol

CEFAS, 2001. Monitoring and surveillance of non-radioactive contaminants in the aquatic environment and activities regulating the disposal of wastes at sea, 1998. Science Series, Aquatic Environment Monitoring Report, CEFAS Lowestoft, 53: 75pp.

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Heemken, O.P. *et al*. (2001). The occurrence of xenostrogens in the Elbe river and North Sea. *Chemosphere*, 45: 245-259.

3.3 CONCENTRATIONS OF HAZARDOUS SUBSTANCES IN SEDIMENTS

Trace metals that enter the marine environment as a result of inputs from rivers, direct discharges, from the atmosphere or other sources ultimately end up in marine sediments.

Metals in marine sediments are associated with the fine-grained aluminosilicates, a major constituent of which is aluminium. This element is not regarded as a contaminant, and its abundance in marine sediments is related to the geology of the sediment. The relative abundance of other metals to aluminium are expressed as metal/aluminium ratios. These are used to compare sediments from different geographical areas having different geologies and to indicate enrichment due to inputs of metals as a result of man's activities.

Metals concentrations in sediments are assessed in two ways, firstly to establish whether metal/aluminium ratios are 'close to background' or elevated in comparison to ratios typically found in uncontaminated sediments, and secondly in relation to whether there is potential for concern due to the absolute metals concentrations, by comparing these with EACs. OSPAR BRCs and EACs for metals in fine-grained marine sediments (OSPAR Commission, 2000a) are shown in Table 3.2.

Where data are compared to BRCs, the circles are coloured blue if the upper 90% confidence limits on the median concentrations are less than twice the upper BRC, indicating the concentrations are 'close- to- background'. The circles are coloured pink if the upper 90% confidence limits exceeed twice the upper BRC.

Where compared to EACs, the circles are coloured blue if the upper 90% confidence limits on the median concentrations are less than the upper EAC, indicating that concentrations are 'unlikely to cause harm to the marine ecosystem'. The circles are coloured pink if the upper 90% confidence limits exceed the upper EAC.

3.3.1 METALS

Mercury

Median mercury/aluminium ratios for 1999-2002 are shown in Figure 3.5. Concentrations were close to background in very few areas around the UK, with the lowest ratios in the Moray Firth and offshore from the Tay/Forth estuaries, in the Northern North Sea area (Region 1), and in the Solway Firth in the north-east Irish Sea (Region 5). Elevated ratios were recorded at most sampling sites around the UK, both in coastal areas and estuaries. The highest ratios were measured at sites in the Tamar in the western English Channel (Region 4), due to local mineralization, and in industrialised estuaries with historically contaminated sediments, such as the Clyde in the Minches and West Scotland Sea area (Region 6), the Forth and Tees in the Northern North Sea area

Table 3.2. OSPAR BRCs and EACs in marine sediment

Metal	BRCs (metal/aluminium ratios, x10^{-4})	EACs (mg kg^{-1} dry weight)
Mercury	0.0034-0.0066	0.05-0.5
Cadmium	0.007-0.03	0.1-1.0
Lead	1.8-4.0	5-50
Copper	2.2-5.7	5-50
Zinc	8.8-18	50-500

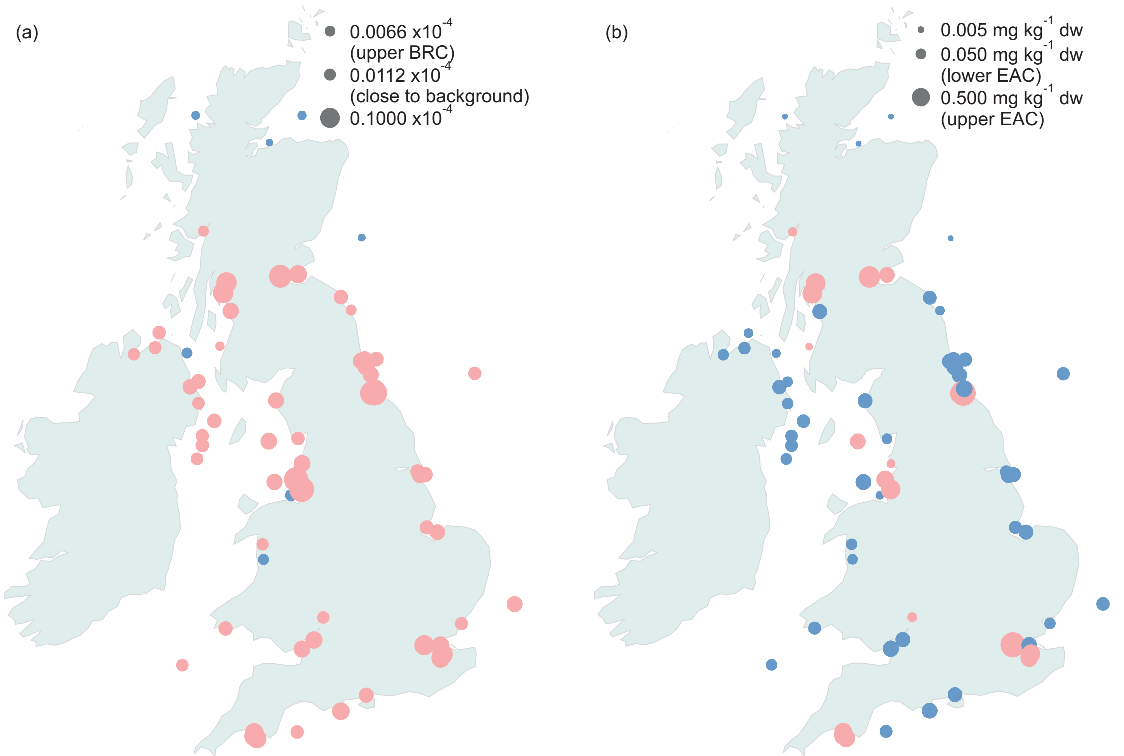

Figure 3.5. (a) Mercury/aluminium ratios relative to their BRCs and (b) mercury concentrations relative to their EACs

(Region 1), and the Thames in the Southern North Sea area (Region 2), with the highest values in the Mersey estuary in the Irish Sea area (Region 5).

Absolute mercury concentrations are shown in comparison to the EAC (see Figure 3.5(b)). Median mercury concentrations were below the upper EAC in most Regional Sea areas, with the lowest concentrations in the Moray Firth and offshore from the Tay/Forth estuaries in the Northern North Sea area, and in the Solway Firth in the north-east Irish Sea. Elevated mercury concentrations above the upper EAC were recorded in several areas, with values more than five times higher than the EAC in the Tees estuary in the Northern North Sea area, and in the Thames estuary in the Southern North Sea area.

Sediment mercury/aluminium ratios are 'close to background' only in parts of the Northern North Sea and north-east Irish Sea areas. Sediment mercury concentrations give rise to concern in several industrialised estuaries, due to historical contamination, notably the Tees estuary in the Northern North Sea area (Region 1), and the Thames estuary in the Southern North Sea area (Region 2) and the Mersey in the Irish Sea area (Region 5).

Cadmium

Cadmium/aluminium ratios were 'close to background' (below twice the upper BRC) in several areas (Figure 3.6(a)). However, several industrialized estuaries showed ratios elevated above twice the upper BRC, and some to more than five times the upper BRC. The highest ratios were several times higher than the upper BRC at 0.208 in the Tees and 0.305 in the Wear, in the Northern North Sea area (Region 1), and 0.216 in the Mersey and 0.403 in the Ribble, in the Irish Sea (Region 5).

Cadmium concentrations were below the upper EAC threshold in most UK estuaries and coastal waters (Figure 3.7(a)). However, levels were above the upper EAC at 1.39, 1.48 and 1.69 mg kg^{-1} dry weight in the Tees, Wear and Tyne estuaries respectively, in the Northern

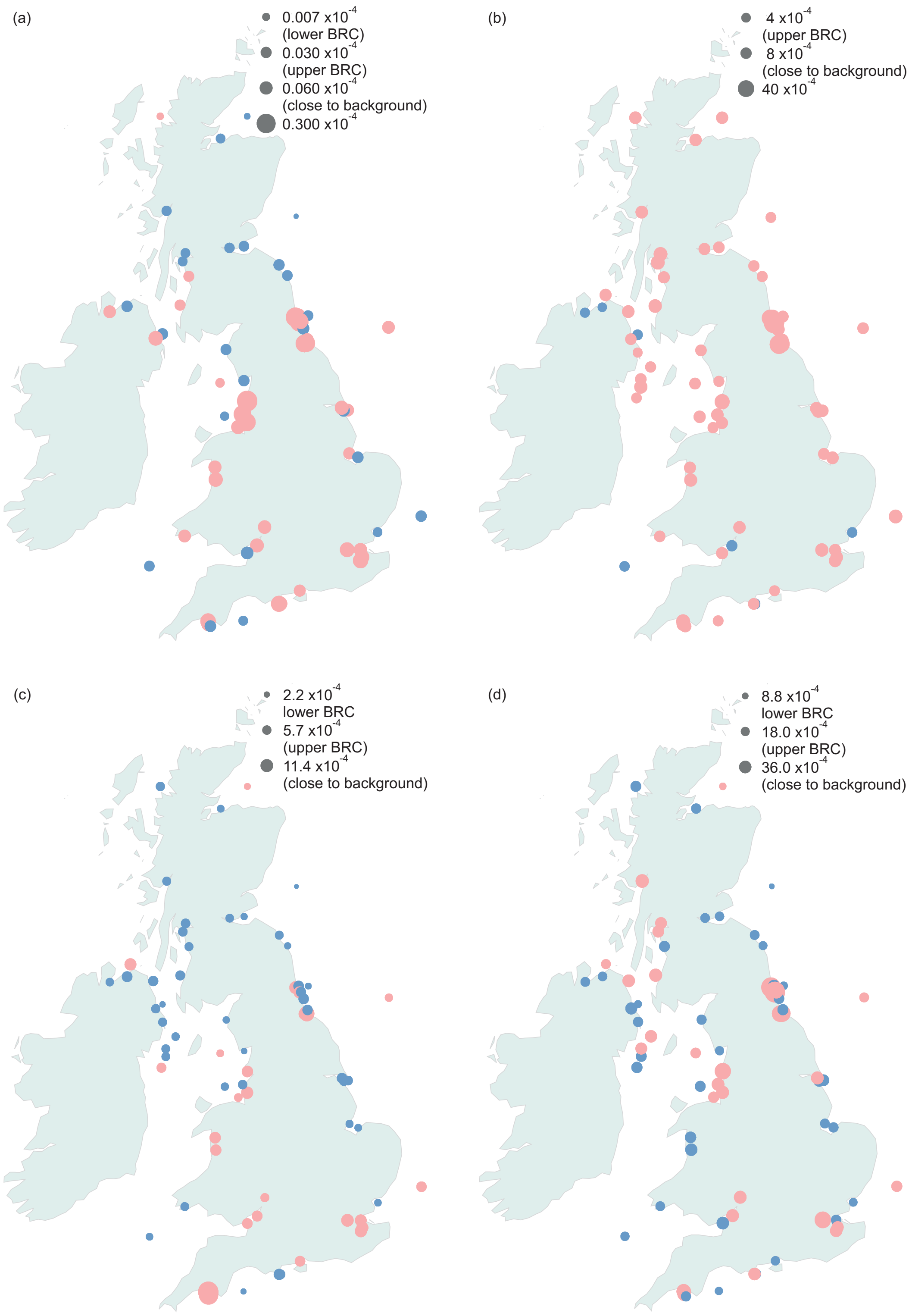

Figure 3.6. (a) cadmium, (b) lead, (c) copper and (d) zinc/aluminium ratios relative to their BRCs

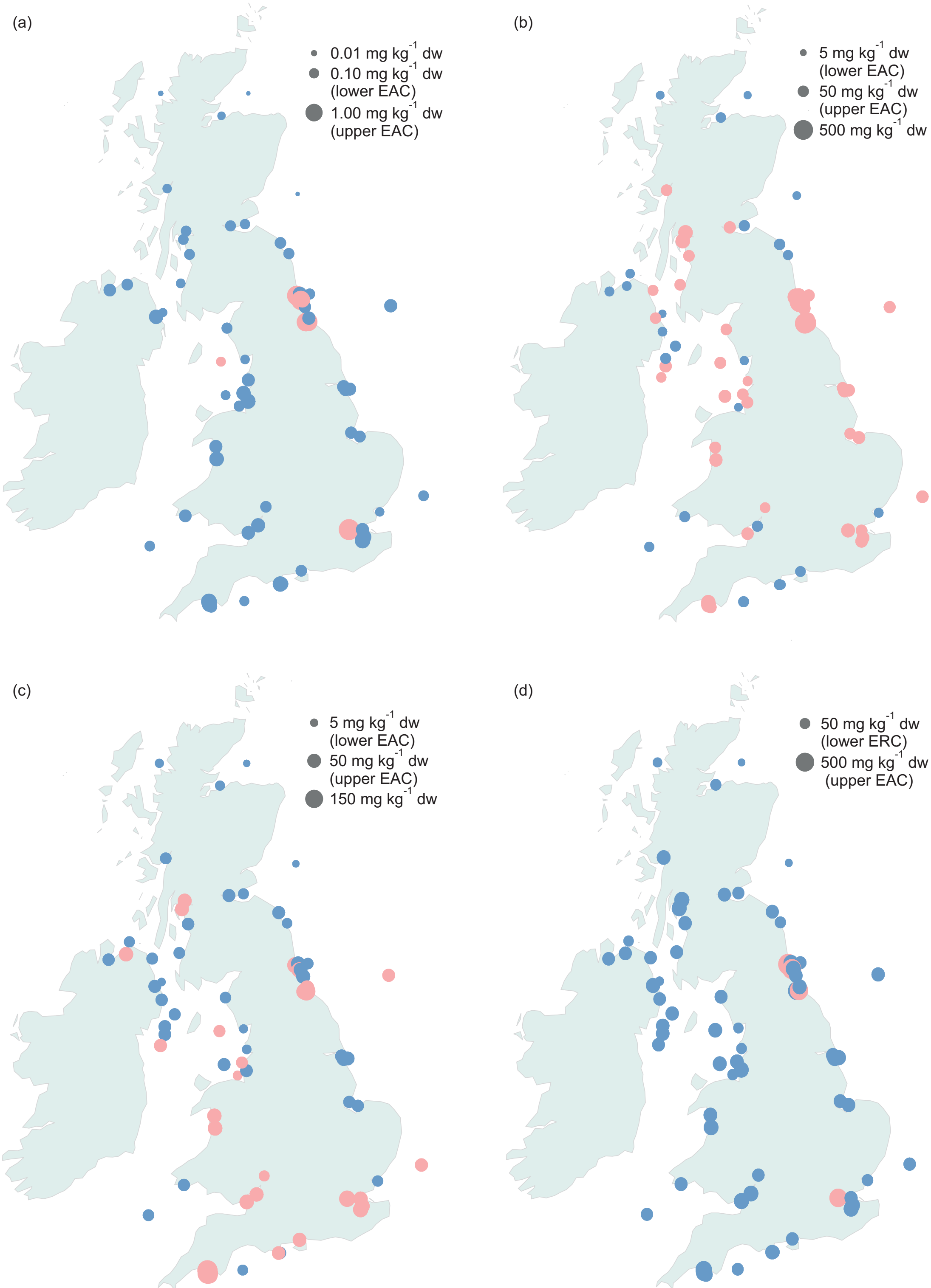

Figure 3.7. (a) cadmium, (b) lead, (c) copper and (d) zinc concentrations relative to their EACs

North Sea area, and 2.12 mg kg^{-1} dry weight in the Thames, in the Southern North Sea area, identifying these industrialised estuaries as potentially of concern.

Lead

Lead/aluminium ratios were high in most areas, above twice the upper BRC (Figure 3.6(b)). The highest values were more than 5 times higher than the upper BRC at 20 in the Tamar in the western English Channel (Region 4), 44 in the Tyne, 72 in the Tees and 100 in the Wear estuaries, in the Northern North Sea (Region 1), and 28 in the Ribble, in the Irish Sea (Region 5).

Lead concentrations were below the upper EAC in coastal sediments off north and east Scotland in the Northern North Sea area, in the western English Channel and Celtic Sea, and at some sites off Northern Ireland and in the Irish Sea (Figure 3.7(b)). However, concentrations were high, above the upper EAC, in industrialised estuaries in several sea areas, such as the Tyne, Wear, Tees, Humber, Thames, Medway, Severn, Mersey, Belfast Lough and Clyde. Sediment lead levels were also elevated as a result of local mineralization, in the Tamar estuary in the western English Channel, in the Dovey estuary near Aberystwyth, and off the Isle of Man. The highest lead concentrations of 495 mg kg^{-1} and 549 mg kg^{-1} in the Tees and Wear estuaries in the Northern North Sea area were more than 5 times higher than the upper EAC, indicating these to be particular areas of concern.

Copper

Copper/aluminium ratios showed a clear north-south split for the UK, with levels 'close to background' around Scotland and Northern Ireland. Concentrations were higher in industrialised estuaries and coastal sediments around England and Wales. The highest ratio was more than 5 times higher than the upper BRC in the Tamar in the western English Channel (Region 4), at 31, due to local mineralization and industrial activity (Figure 3.6(c)).

Sediment copper concentrations were low in several areas (Figure 3.7(c)), and slightly elevated in Southampton Water in the Eastern English Channel, in Cardigan Bay and other parts of the Irish Sea. Concentrations were above the upper EAC in the range 50-121 mg kg^{-1}, in industrialized estuaries such as the Tyne, Wear, Tees, Thames and Medway. The highest sediment copper concentration was 203 mg kg^{-1} in the Tamar, due to local mineralization.

Zinc

Marine sediments in most areas around the UK were contaminated by zinc (Figure 3.6(d)). Zinc/aluminium ratios were more than 3 times the upper BRC value in the Ribble estuary, in the Irish Sea (Region 5), in the Thames (Region 2) and in the Tees (Region 1). The highest ratios of 94 and 103, more than 5 times above the upper BRC, were in the Tyne and Wear estuaries (Region 1).

In contrast, zinc concentrations were below the upper EAC in most areas (Figure 3.7(d)). Concentrations are close to or above this threshold in the Tees (494 mg kg^{-1}), in the Wear (564 mg kg^{-1}), and in the Tyne (664 mg kg^{-1}), all in the Northern North Sea area.

CONCLUSIONS/DISCUSSIONS

Sediment metal/aluminium ratios were elevated above background in most sea areas for mercury and lead. The distributions of cadmium, copper and zinc were broadly similar, with elevated concentrations mainly restricted to industrialized estuaries.

In comparison to EACs, elevated lead concentrations in sediments in most sea areas, particularly in industrialised areas, give rise to concern that adverse biological effects may arise. The distributions of mercury and copper were broadly similar, with elevated concentrations mainly restricted to industrialized estuaries. Sediment cadmium and zinc concentrations were generally low, with levels below the EACs in most areas, except for the Tyne, Wear, Tees and Thames.

The potential impact of the elevated sediment metals concentrations on ecosystem health in industrialized estuaries around the UK is addressed in Section 3.5, in terms of bioaccumulation, effects on the benthos and biological effects.

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3.3.2 ORGANIC COMPOUNDS

Polychlorinated biphenyls

Commercial formulations of polychlorinated biphenyls (PCBs), such as Aroclors, have been widely used in transformers, capacitors, hydraulic fluids and as plasticisers in paints, plastics and sealants. The inputs of PCBs to the marine environment include energy production, combustion industry, production processes and waste (landfill, incineration, waste treatment and disposal). Due to concerns about the environmental impact of PCBs, production in the UK ceased in the 1970s. Authorisation for use in closed systems continued until 1986 when sales of PCB formulations finally stopped in the UK. However, PCBs still enter the marine environment following the destruction and disposal of industrial plants and equipment, or from emissions from old electrical equipment and landfill sites.

PCBs are persistent and have the potential for long-range atmospheric transportation. As a result they are ubiquitous in the marine environment. Due to their low solubility and hydrophobic nature, PCBs tend to associate with particulate material.

There are 209 CB congeners of which the ICES 7 (CBs 28, 52, 101, 118, 153, 138, 180) were selected for measurement due to their relatively high concentrations in technical mixtures, wide chlorination range and persistence. Where all ICES 7 CBs are not measured CB 153 can be used as representative of all other CBs. CB 153 occurs in all technical formulations.

CB concentrations in sediment were measured at 61 sites around the UK under the NMMP Programme. The sum of the ICES 7 CBs and CB153 concentrations are summarised in Table 3.3. The lowest concentrations were found at the Tay/Forth offshore site (Region 1) and highest at Seacombe Ferry in the Mersey (Region 5). In general, the lowest concentrations for all of the ICES 7 CBs were found at the Scottish offshore and intermediate sites, and the highest in estuarine sites in England and Wales (Figure 3.8).

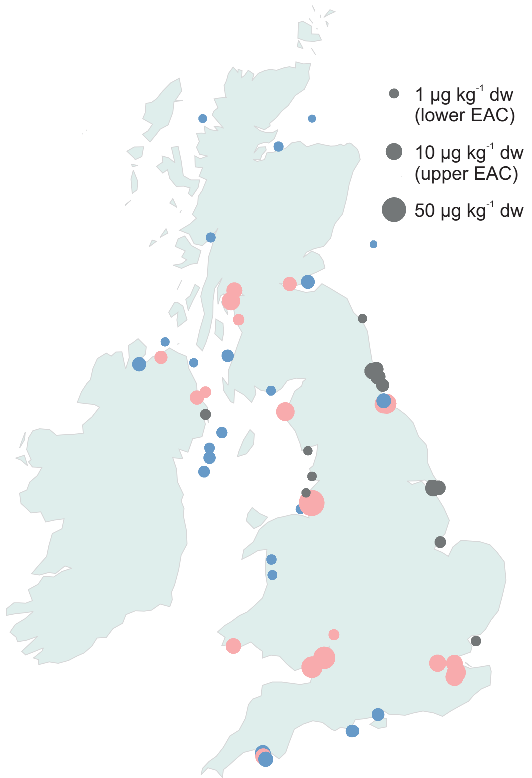

Figure 3.8. Concentrations of the sum of the ICES 7 CBs in sediment ($\mu g\ kg^{-1}$ dry weight) and their relationship to EACs. The size of the plotting circle increases with the concentration. The concentration is below the upper EAC at 24 of the 42 sites (blue circles). The pink circle indicates where concentrations are above the upper EAC. The grey circles indicate where only one years data is available but concentrations are below the upper EAC

Table 3.3. Summary of CB data for sediments

CB	EAC $\mu g\ kg^{-1}$ dry weight	Concentration range 1999-2002, $\mu g\ kg^{-1}$ dry weight	No. of sites assessed	Sites with concentration > upper EAC
CB 153	-	0.02 - 13.0	61	-
Sum of ICES 7 CBs	1 -10	0.30 - 63.8	59*	11

*Concentrations for the sum of the ICES 7 CBs were only reported for more than 1 year at 42 sites.

Currently there are no BRCs for CBs in sediment for the relevant areas. The EAC for the sum of the ICES 7 CBs ranges from 1 to 10 μg kg^{-1} dry weight. Only eleven sites had concentrations below 1 μg kg^{-1} dry weight (Figure 3.8). Four were Scottish intermediate and offshore sites (Minches (Region 6), Moray Firth, Forth/Tay (Region 1), Solway (Region 5)), two were in Northern Ireland (North Channel, North Antrim coast), one in Wales (Dee) all Region 5 and four in England (Northumberland coast (Region 1), Humber (Region 2), Mersey, Ribble (Region 5)). The concentration was above the upper EAC at eleven sites, one in Scotland (Clyde (Region 6)), two in Wales (Severn (Region 4)) and eight in England (Tees, Mersey, Cumbrian coast, Thames and Medway). At one site (Mersey) the median concentration was above 50 μg kg^{-1} dry weight.

CONCLUSIONS/DISCUSSIONS

CB concentrations in sediments from most sites are above the lower EAC. These data highlight that at inshore and estuarine sites CB concentrations continue to be of concern and monitoring of CB concentrations in the marine environment should continue.

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AlkylPhenols (APS)

Alkylphenol polyethoxylates (APEOs) are non-ionic surfactants used extensively in commercial and domestic applications. As well as being one of the most widely used substrates in industrial detergents, they are also used in such diverse applications as paint additives, wetting agents and contraceptives (Heemken *et al*., 2001).

In the UK, in 1993, it was estimated that the total consumption of APEOs was 15-19,000 tonnes per annum (Department of the Environment, 1993) and that approximately 37% of these were discharged into rivers and estuaries, mainly via sewage effluents.

Aklylphenolethoxylates (APEs) degrade rapidly to alkylphenols (APs – nonylphenol and octylphenol) and most environmental data is for nonylphenol (NP) and octylphenol (OP). Currently there are no BRCs or EACs established for alkylphenols. The LOD of the method used is 1 $\mu g\ g^{-1}$ for the NP mono- and di-ethoxylates, 0.2 $\mu g\ g^{-1}$ for NP and 0.01 $\mu g\ g^{-1}$ for OP. Sediment data are available from 44 sites sampled in 1998 and 89 sites sampled in 1999.

In 1998, almost all NP concentrations in sediment were below the Limit of Detection except for all of the sites within the Tees (Region 1), which had concentrations greater than 2 $\mu g\ g^{-1}$, reaching 42 $\mu g\ g^{-1}$ at the Tees Outfalls. Despite this high concentration within the Tees the Tees Bay area had levels of NP below the LOD, which could be due to either low adsorption onto the sandy sediments of the bay or poor transportation out of the estuary, further work is required on this aspect. NP mono- and di-ethoxylate concentrations (sum of) were below the limit of detection at all sites. OP concentrations ranged from below the LOD to 0.06 $\mu g\ g^{-1}$.

In 1999, NP values were below the LOD at most stations except for those within or around the Tees. The highest value was 30 $\mu g\ g^{-1}$ at the Tees Outfalls. NP mono- and di-ethoxylate concentrations (sum of) ranged from below the LOD to 20 $\mu g\ g^{-1}$ at the Tees Outfall, with the only stations above the LOD being in the Tees estuary. OP was found to be above the LOD at very few sites, and even at these sites it was generally below 0.02 $\mu g\ g^{-1}$

CONCLUSIONS/DISCUSSIONS

Concentrations of APEs and APs were low or undetectable at intermediate and offshore sites in both years and no further work is needed at these sites. Significant concentrations of alkylphenols have been found in the Tees estuary and at the dredged material disposal sites outside the mouth of the Tees. Data from a sediment core taken here indicates that for this site the normal transport and mixing processes, which would be expected to disperse the sediment and degrade AP concentrations, are being inhibited and that APs are building up in the sediment.

Currently there is a limited amount of data on APs and APEs in the Scottish marine environment although data from other areas indicates concentrations are decreasing.

Data Source: CEFAS Surveys

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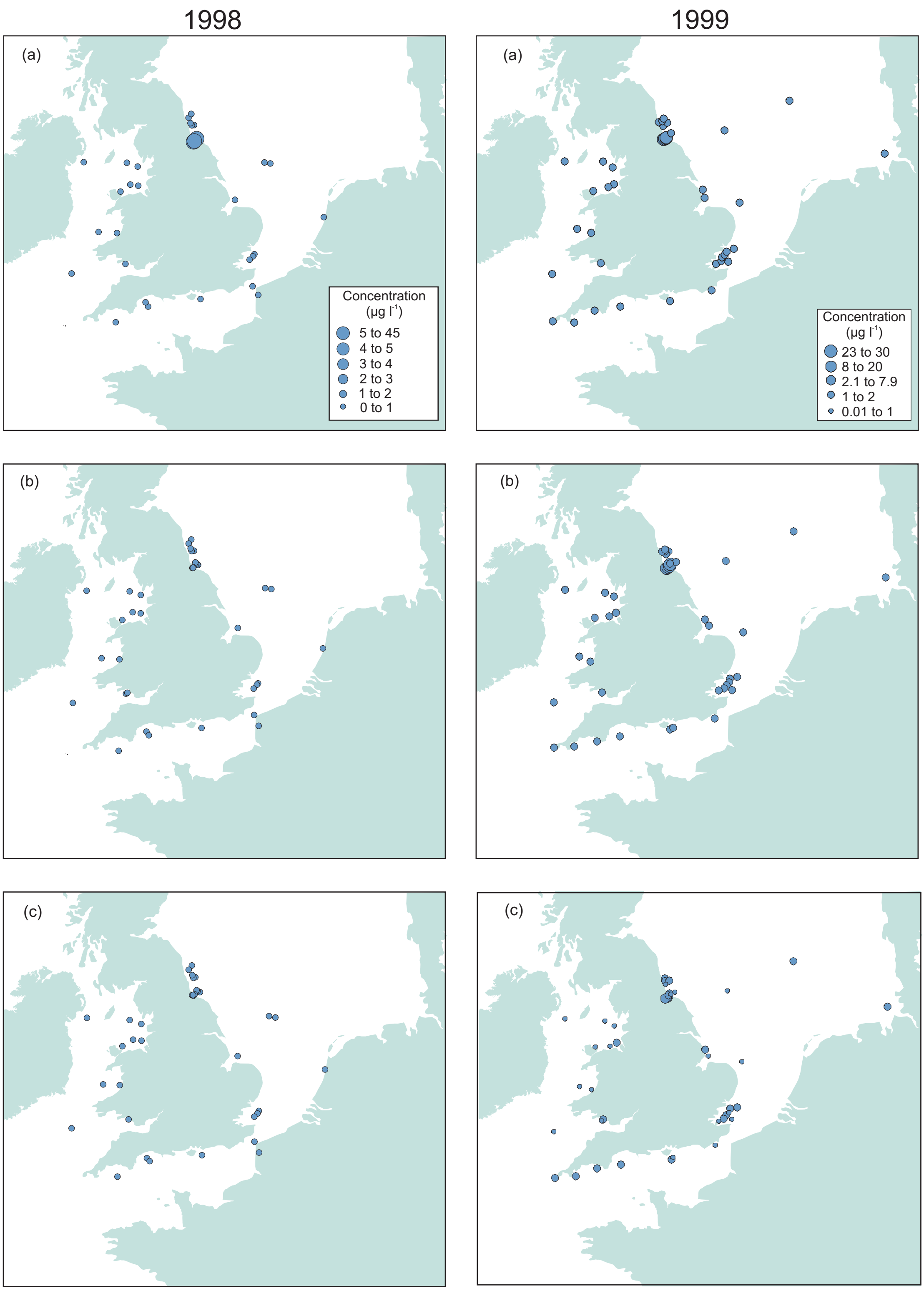

Figure 3.9. Spatial distribution of alkylphenol concentrations in marine and coastal sediments for 1998 and 1999 of (a) nonylphenols, (b) ethoxylates and (c) octylphenol

Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAH) are produced both naturally (e.g. in forest fires) and by man's activities. The major sources currently are from industrial and urban areas. Ten PAH compounds are determined routinely under the NMMP. Data are available for the period 1999-2002.

Summed PAH concentrations ranged from not detectable (e.g. in the offshore Moray Firth (Region 1) or barely detectable (e.g. at the outer Gabbard) to 207,000 $\mu g\ kg^{-1}$ dry weight in the River Medway at Sun pier in 1999 (both in Region 2). Concentrations at Sun pier in all three subsequent years (2000-2002) were approximately a factor of 50 times lower, and the variability between replicate samples within each year was much smaller than in 1999. EACs have been set by OSPAR for 8 of the 10 PAH determined (Table 3.4). The sum of the 10 PAH determined was >10,000 $\mu g\ kg^{-1}$ (approximately the sum of the 8 upper EAC values) at a number of sites – see Table 3.5: in the River Tyne at Hebburn, in the River Wear at Alexandra Bridge, in the River Tees both at Bamlett's Bight and at the no. 23 buoy (all Region 1), in the River Thames at Woolwich, in the River Medway at Burham (both Region 2), in the River Mersey at the Seacombe ferry and in Morecambe Bay and in the Bann estuary, NI (all in Region 5).

The upper EACs for individual PAH were exceeded for all the compounds for which they have been set, and in many cases the upper EAC was exceeded by a significant margin (Table 3.4 and Figure 3.10).

Table 3.4. EAC values for PAH (OSPAR)

PAH compound	upper EAC ($\mu g\ kg^{-1}$ dw)
naphthalene	500
phenanthrene	1000
anthracene	500
fluoranthene	5000
pyrene	500
benz[*a*]anthracene	1000
chrysene	1000
benzo[*a*]pyrene	1000

Figure 3.10 illustrates this graphically for pyrene and benzo[*a*]pyrene, for all individual samples analysed.

From Figure 3.10, it can also be seen that at sites where pyrene concentrations are elevated, concentrations of benzo[*a*]pyrene are also elevated and this tends to be case for all PAHs.

Figure 3.11 shows as an example, the spatial distribution of the mean sediment pyrene concentrations, relative to the EACs.

CONCLUSIONS/DISCUSSIONS

An assessment of the toxicological significance of the PAH concentrations has suggested that the most heavily contaminated sediments in UK estuaries are likely to be acutely toxic to certain sediment dwelling animals, and that

Table 3.5. Number of sites where the upper EACs were exceeded in each year (~65 sites sampled annually in total)

PAH compound	1999	2000	2001	2002
naphthalene	4	2	0	4
phenanthrene	4	4	4	10
anthracene	2	2	1	3
fluoranthene	1	0	1	4
pyrene	7	10	7	16
benz[*a*]anthracene	3	3	1	3
chrysene	2	4	2	4
benzo[*a*]pyrene	3	3	1	4

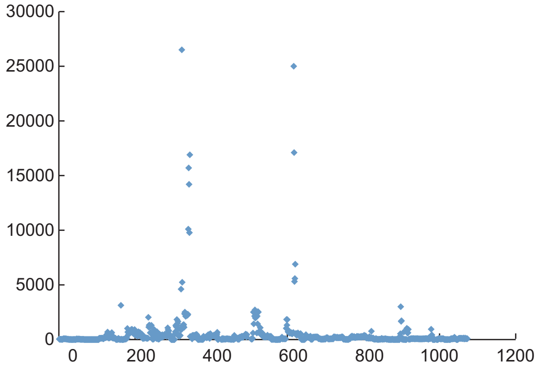

Figure 3.10(a). Pyrene concentrations in sediment. Lower EAC is 50 $\mu g\ kg^{-1}$ dry weight, upper EAC is 500 $\mu g\ kg^{-1}$. Maximum exceedance of upper EAC by a factor of ca. 140x at station 306 (Tees – Bamlett's Bight)

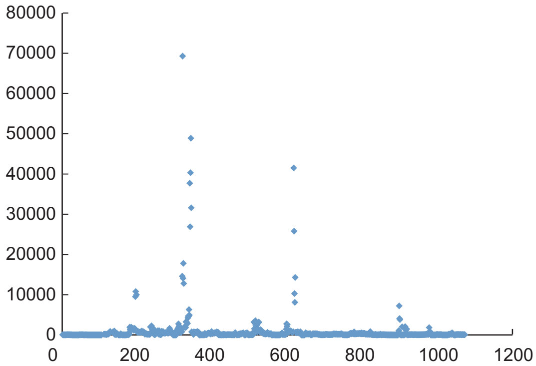

Figure 3.10(b). Benzo[a]pyrene concentrations in sediment. Lower EAC is 100 $\mu g\ kg^{-1}$ dry weight, upper EAC is 1,000 $\mu g\ kg^{-1}$. Maximum exceedance of upper EAC by a factor of ca. 25x at station 306 (Tees – Bamlett's Bight)

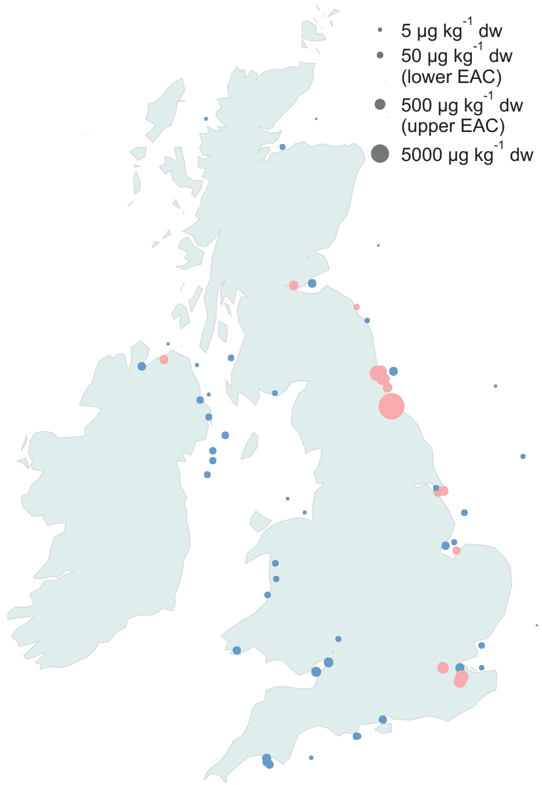

Figure 3.11. Pyrene relative to EACs

a wider range of industrialised estuaries may show chronic effects, including the induction of neoplastic liver disease (an early stage of cancer induction) in fish (Woodhead *et al*., 1999). The assessment of PAH concentrations by means of their carcinogenic potential, as benzo[*a*]pyrene equivalents, is described in the section on PAH in shellfish (Section 3.4.3), and this can also be applied to PAH in sediments. Concentrations exceeding 25,000 $\mu g\ kg^{-1}$ benzo[*a*]pyrene equivalents were observed at 3 locations; in the River Tees at Bamlett's Bight and at the no. 23 buoy, both in 2002 (Region 1), and in the River Medway at Sun pier in 1999 (Region 2). The work conducted to date demonstrates that some UK estuaries contain sediments which are heavily contaminated with PAH.

Brominated flame retardants

Bromine-based flame retardant products are applied annually to over 2.5 million tons of polymers, and approximately 70 brominated flame retardant chemicals account for a global consumption of over 300,000 tonnes per annum. In environmental studies, the initial focus was on one group of these compounds, the polybrominated diphenylethers (PBDEs). Within the EU, the production and use of some PBDE products has been discontinued, and more recent studies have concentrated on two other brominated products, hexabromocyclododecane (HBCD) and tetrabromobisphenol-A (TBBP-A).

PBDEs comprise three separate industrial products, known as the penta-, octa- and deca-mixes, with increasing bromine contents. These are simpler in composition than the corresponding PCB products, but include compounds with from 3 to 10 bromine atoms in each molecule. In a pilot survey conducted in 1995-96, tetra- and penta-BDE compounds were found in most sediment and biota samples analysed (Allchin *et al*., 1999). Deca-BDE was also found in a number of sediment samples, but was not detected in biota. High concentrations were found in samples from the Rivers Skerne and Tees, downstream of a plant at Newton Aycliffe at which PBDEs were manufactured, and in sediments of the lower Tees estuary (Region 1). Detectable concentrations of tetra- and penta-BDE compounds were found in the livers of fish from offshore reference sites, and high concentrations were evident in dab and flounder from Tees Bay (up to 1,500 $\mu g\ kg^{-1}$ wet weight for the sum of 3 BDE congeners).

Subsequently, a study of invertebrates and fish from the North Sea concluded that the estuary of the River Tees was a major source for tri- to hexa-BDE congeners, and that these compounds were accumulated within North Sea foodchains, from invertebrates to fish and marine mammals (Boon *et al*., 2002). Figure 3.12 shows the distribution of BDE congeners in two invertebrate species, seastars and hermit crabs, in the North Sea, and further highlights the influence of inputs from the River Tees. BDEs were also detected in dab liver from various UK sites, the maximum values for the sum of 15 congeners being 17, 130, 330 and 17 $\mu g\ kg^{-1}$ wet weight at the Dogger Bank (Region 1), Sole Pit (Region 2), Anglesey (Region 5) and Hastings (Region 3), respectively.

BDE compounds have been found in the blubber of marine mammals, at low concentrations in whale and dolphin species which feed in deep offshore waters and at much higher concentrations in dolphins and porpoises from coastal areas and the North and Irish seas (overall range 61 to 13,000 $\mu g\ kg^{-1}$ on a lipid basis) (Law *et al*., 2003). BDEs were found in a porpoise foetus at approximately 60% of the concentrations seen in its mother, indicating significant transfer of these compounds to the offspring before birth (and during suckling) in the same way as organochlorine compounds such as PCBs. In the porpoises, the BDE concentrations were estimated to be doubling every 5 years before the penta-mix PBDE formulation was phased out (Hites, 2003). Following EU restrictions on the penta- and octa-mix products, the concentrations of almost all BDE congeners are likely to fall in the future. The exception is the deca-BDE congener, whose use is continuing in Europe, and which is eventually deposited in sediments.

Initial studies of HBCD occurrence have been concentrated on freshwater fish from the Rivers Skerne and Tees (Region 1), above the tidal barrage and downstream of the manufacturing plant at Newton Aycliffe. As for the BDEs, high concentrations were found, and during 2004 analyses will be conducted for HBCD and TBBP-A in both marine fish and sediments. In late 2003, the impending closure of the Newton Aycliffe manufacturing site was announced, and subsequent production will be transferred to the USA.

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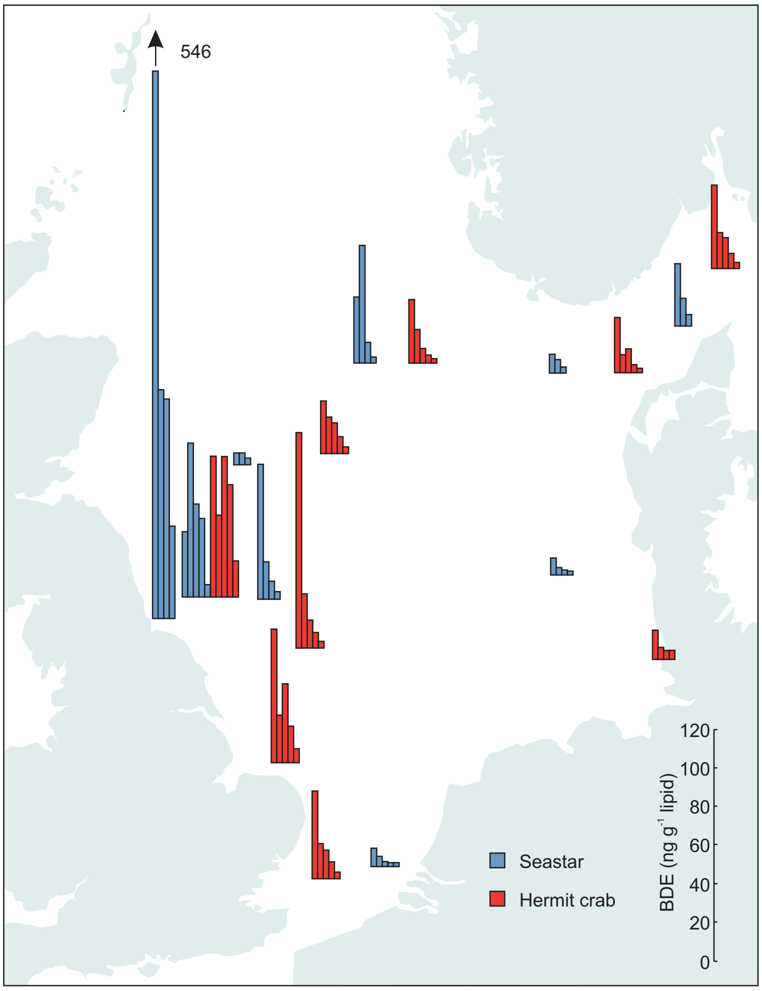

Figure 3.12. Lipid-normalized concentrations (ng g^{-1}) of the major PBDE congeners in seastars and hermit crabs

Law, R.J., Alaee, M., Allchin, C.R., Boon, J.P., Lebeuf, M., Lepom, P and Stern, G.A. (2003). Levels and trends of polybrominated diphenylethers and other brominated flame retardants in wildlife. *Environment International*, 29: 757-770.

3.4 CONCENTRATIONS OF HAZARDOUS SUBSTANCES IN BIOTA

Fish and shellfish absorb contaminants from their surroundings. Contaminants that cannot be excreted are accumulated over time as a body burden, integrating the fluctuations in the surrounding water and sediments.

The results quoted are a summary of the maximum and minimum concentrations recorded for determinands monitored during the 1999-2002 period. A strictly limited number of biota species are chosen on the basis of their widespread distribution, to reduce complications with inter-species variability - the flatfish dab (*Limanda limanda*), flounder (*Platichthys flesus*) or plaice (*Pleuronectes platessa*) and for shellfish, the blue mussel (*Mytilus edulis*).

3.4.1 METALS IN FISH AND SHELLFISH

Mercury in fish flesh
The BRCs for mercury in the flesh of flatfish are the range 30-70 $\mu g\ kg^{-1}$ wet weight.

The highest concentrations were in Region 5 in the Mersey estuary (338 and 174 $\mu g\ kg^{-1}$ wet weight) and Liverpool Bay (230 and 199 $\mu g\ kg^{-1}$ wet weight). Concentrations were also high in Region 2 at sites in the Thames estuary (227 and 212 $\mu g\ kg^{-1}$ wet weight). Concentrations were close to background at 23 of the 53 sites monitored. Results were similar to those reported in an assessment of 1993-95 NMMP spatial data (MPMMG, 1998).

Arsenic in fish flesh
There are no BRCs or EACs for arsenic in fish flesh. The results showed no clear pattern as in the spatial survey of 1993-95 (MPMMG, 1998). Some of the highest concentrations were in plaice from the offshore site in the Moray Firth (Region 1), suggesting that the levels reflect inputs from both anthropogenic and non-anthropogenic sources.

Cadmium and lead in fish liver
There are no BRCs or EACs for cadmium or lead in fish liver. Concentrations of cadmium in fish liver were generally below 150 $\mu g\ kg^{-1}$ wet weight, consistent with results reported by CEFAS (1998) for a spatial survey around England and Wales in 1995-96. Higher cadmium concentrations occurred in the Moray Firth, West Dogger area, Thames estuary and in Inner Cardigan Bay (175, 343, 180 and 335 $\mu g\ kg^{-1}$ wet weight respectively and Regions 1, 2, and 5).

Lead concentrations were below 200 $\mu g\ kg^{-1}$ wet weight at most sites. Higher concentrations, in the range 200-700 $\mu g\ kg^{-1}$ wet weight were found in dab or flounder from sites in the Tyne, Tees, Wear and Humber estuaries (Regions 1 and 2) and Cardigan and Morecambe Bay and North Antrim Coast (Region 5).

Metals in Mussels
Concentrations for nine metals (mercury, cadmium, lead, copper, zinc, nickel, chromium, arsenic and silver) were compared to BRCs; there are no EACs for metals in mussels.

Figure 3.13(a-e) shows the concentrations of mercury, cadmium, lead, copper and zinc, in mussels, for 1999-2002.

Mercury, cadmium and lead concentrations exceeded the BRCs at most sites. However, copper and zinc concentrations were generally below the BRCs (see Figure 3.13(a-e)).

The lowest mercury concentration was slightly above the upper BRC at 14.5 $\mu g\ kg^{-1}$ wet weight in the Tamar estuary (Region 4). Concentrations above 50 $\mu g\ kg^{-1}$ wet weight occurred on the Northumberland and Durham Coasts (Region 1) and in the Blackwater and Thames (Region 2), and Mersey estuaries and in Morecambe Bay (Region 5).

The lowest cadmium concentration was recorded in the Wash (Region 2), at 102 $\mu g\ kg^{-1}$ wet weight. Low concentrations were also recorded in the Tay Estuary and in Poole Harbour (Region 1 and 3 respectively). Concentrations were close to background at 10 sites. Concentrations above 500 $\mu g\ kg^{-1}$ wet weight occurred in the Humber, Thames and Severn Estuaries (Regions 2 and 4 respectively).

The lowest lead concentration was within the BRC range, at 147 $\mu g\ kg^{-1}$ wet weight in Lough Foyle (Region 5). Concentrations were close to background at only two sites. Concentrations were above 1,000 $\mu g\ kg^{-1}$ wet weight in the Tyne, Tees and Forth estuaries and Northumberland and Durham Coast (Region 1) the Tamar estuary (Region 4) and the Clyde estuary and Morecambe Bay (Region 5).

Figure 3.13. Median (a) mercury, (b) cadmium, (c) lead and (d) copper concentrations in mussels relative to their BRCs

(e)

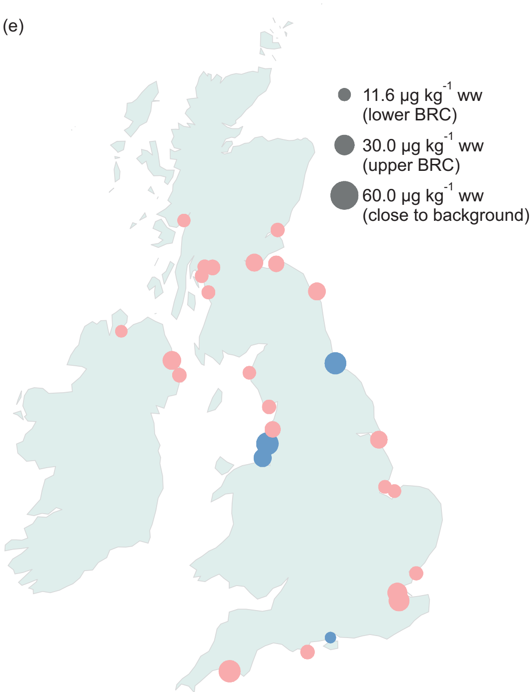

Figure 3.13(e). Median zinc concentrations in mussels relative to their BRCs

Concentrations of copper and zinc were generally low.

The minimum and maximum concentrations for arsenic, chromium, nickel and silver in mussels for 1999-2001 are listed in Table 3.6 There are currently no BRCs, EACs or EQSs available for these metals in mussels.

The high chromium concentrations in the Clyde estuary (Region 5) were consistent with previous results (Burt *et al*., 1992; Miller, 1986).

CONCLUSIONS/DISCUSSIONS

The fish data showed results consistent with previous reports, with greater than background mercury concentrations in Region 5; the Mersey estuary, Liverpool Bay and Morecambe Bay as a result of discharges of mercury from the chlor-alkali industry. Cadmium and lead concentrations in fish liver were generally low, with higher concentrations, typically in industrialised estuaries. Relatively high concentrations of cadmium were also measured at the Dogger Bank in Region 2.

Concentrations of several metals were elevated in mussels, mainly in industrialised estuaries.

Table. 3.6. Maximum and minimum concentrations of determinands in fish and shellfish from UK sites sampled during 1999-2002. ($\mu g\ kg^{-1}$ wet weight except for CBs in dab liver which are in $\mu g\ kg^{-1}$ lipid weight).

Species	Tissue	Determinand	Min			Max		
			Reporting area	Site	Value	Reporting area	Site	Value
Dab	liver	Cd	3	Poole Harbour	22	2	Dogger	343
Dab	liver	Pb	3	Poole Harbour	22		N Antrim Coast	647
Dab	liver	CB28	2	Thames	2.4	5	Mersey	94
Dab	liver	CB52	2	Thames	3.3	2	Thames	221
Dab	liver	CB101	2	Thames	2.1	2	Thames	486
Dab	liver	CB118	2	Thames	2.7	5	Liverpool Bay	462
Dab	liver	CB138	6	Minches	18	5	Red Wharf	794
Dab	liver	CB153	6	Minches	24	2	Thames	1230
Dab	liver	CB180	2	Thames	2.4	2	Thames	575
Dab	liver	Data assessment ΣICES 7CB	2	Thames	108	2	Thames	3690
Dab	muscle	As	6	Bann Estuary	465	1	Tay/Forth	18400
Dab	muscle	Hg	6	Lough Foyle	5.1	5	Mersey	337
Mussel	whole	CB28	1	Tay	0.07	1	Forth	0.8
Mussel	whole	CB52	1	Tay	0.10	5	Mersey	1.4
Mussel	whole	CB101	1	Tees	0.10	5	Mersey	2.7
Mussel	whole	CB118	1	Tees	0.10	4	Tamar	2.6
Mussel	whole	CB138	6	Lough Foyle	0.39	4	Severn	7.2
Mussel	whole	CB153	6	Lough Foyle	0.49	4	Severn	9.0
Mussel	whole	CB180	5	Firth of Clyde	0.08	4	Severn	2.4
Mussel	whole	Data assessment ΣICES 7CB	1	Tay	1.4	4	Severn	24
Mussel	whole	As	3	Poole Harbour	970	5	Strangford Lough	3430
Mussel	whole	Cd	2	Wash	101	4	Severn	1500
Mussel	whole	Cr	2	Wash	110	5	Clyde	2150
Mussel	whole	Cu	5	Dee	923	3	So'ton water	5580
Mussel	whole	Pb	6	Lough Foyle	147	1	Tyne	4160
Mussel	whole	Ni		West Coast	113		Medway	838
Mussel	whole	Zn	3	So'ton water	8580	1	Tyne	37700
Mussel	whole	Hg	2	Humber	12	1	Durham Coast	74
Mussel	whole	Ag			<50	5	Belfast Lough	260

3.4.1 CBs IN FISH AND SHELLFISH

CBs in fish liver
CB data in fish liver are normally reported on a lipid weight basis. Figure 3.14 shows the concentration for the sum of the ICES 7 CBs, normalised to lipid. Concentrations range from 132 μg kg^{-1} lipid weight in the Solway Firth (Region 5) to 3,700 μg kg^{-1} lipid weight in the Thames estuary (Region 2). The highest concentrations occur in the Thames, Medway and Mersey estuaries and Liverpool and Morecambe Bays (Regions 2 and 5).

Currently there are no BRCs for CBs in fish liver. The EAC for ICES 7 CBs for fish (whole) is 1-10 μg kg^{-1} wet weight, however, there is no firm EAC available for fish liver.

Fish liver from Scottish sites contains the highest proportion of lower chlorinated CBs, with CB52 and 101 dominating the profiles. This suggests a predominantly atmospheric input. Most estuarine sites contain a higher proportion of the more highly chlorinated CBs, with the hexa-CBs dominating (CB 138 and 153). In coastal areas, particulate bound waterbourne sources dominate and therefore there is a higher proportion of the more hydrophobic, highly chlorinated CBs. In the open sea, atmospheric deposition is more significant and therefore the less chlorinated CBs tend to dominate the profiles.

Results of a previous spatial survey (1993-95) are not strictly comparable being reported on a wet weight basis, for CB 153 only. The highest concentrations occurred in fish liver from Liverpool Bay (Region 5).

CBs in mussels
CB concentrations in mussels collected between 1999 and 2002 were assessed for twenty-six inshore and estuarine sites, on a wet weight basis. The results are shown in Table 3.6 for the sum of the ICES 7 CBs. The lowest concentration for the sum of the ICES 7 CBs occurred in the Tay Estuary (Region 1) and the highest in the Severn and Mersey estuaries (Regions 4 and 5).

The OSPAR BRC for the sum of the ICES 7 CBs in mussels is 0.35-1.7 μg kg^{-1} wet weight. At many sites the median concentrations of the sum of the ICES 7 CBs were above twice the upper BRCs. The highest median concentrations for

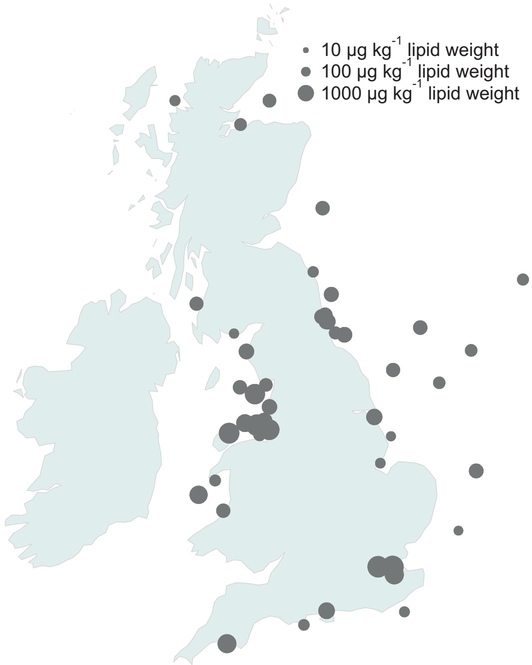

Figure 3.14. Concentrations of ΣICES 7CBs in fish liver

the sum of the ICES 7 CBs, with values above 10 μg kg^{-1} wet weight were found in the Medway, Southampton Water, Tamar, Severn, Mersey and Clyde estuaries (Regions 2, 3, 4 and 5)

EACs have been established for the sum of the ICES 7 CBs for mussels, with a range of 5-50 μg kg^{-1} dry weight. For comparison, this range was converted to a wet weight basis using a conversion factor of 0.15 (based on the median water content of mussels of 85%). The concentrations for the sum of the ICES 7 CBs were above the upper EAC of 7.5 μg kg^{-1} wet weight at 9 out of 26 sites.

CONCLUSIONS/DISCUSSIONS

There are currently no BRCs or EACs for CBs in fish liver. Concentrations were highest (about 3 mg kg^{-1} lipid weight) in the Thames estuary (Region 2) and in Liverpool Bay (Region 5).

In mussels, CB levels were above background for many samples. Concentrations were above the upper level EAC in about 30% of samples.

TEMPORAL TRENDS

The dataset asessed covered the 1999-2002 period, an inadequate time-period for any trends in contaminants to become apparent. An assessment of temporal trends of contaminants in biota was undertaken by the OSPAR Commission for the whole NE Atlantic area in 1998, covering data collected in the 1976-96 period.

For UK fish data submitted from Southern Bight of the North Sea (Region 2) and Liverpool Bay (Region 5) trends were noted;

- a significant downward trend in concentration in some fish from both areas for mercury in flesh and HCB, DDT and dieldrin in fish liver
- a significant downward trend in concentration of PCBs in the livers of some fish from the Southern Bight (Region 2) and a downward but not significant trend in Liverpool Bay (Region 5)

Few additional data have become available since 1996 due to scarcity of fish of the required size/ species; a reassessment of all available data is due in 2005.

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3.4.3 PAH IN SHELLFISH

PAH data were available for 20 stations, with between 1 and 4 years of measurements. Concentrations of the sum of the 10 parent PAH determinands ranged from 8.4-682 μg kg^{-1} wet weight. The highest concentrations were found in the Clyde Estuary (Region 5) (note: only one year's data was available for this site so data is excluded from Figure 3.15) and the lowest in Poole Harbour (Region 3). Summed PAHs exceeded 100 μg kg^{-1} wet weight on the Northumberland coast, to the Tees, Medway, Tamar, Severn and Mersey estuary (Region 1, 4 and 5). For all PAH determined, concentrations were below the provisional OSPAR EACs. EACs are based on the direct acute toxicity of PAH to marine life and this suggests that such toxic effects are not likely at the sites studied.

PAH are of concern, from a human health perspective in shellfish that are sold commercially as some of the PAH can be transformed to carcinogenic metabolites. An approach that allows the assessment of the overall carcinogenic potential of the PAH concentrations is the calculation of benzo[*a*]pyrene equivalents from the measured data. Only 7 of the 10 PAH determined in these samples have been assigned toxic equivalency factors, from which the benzo[*a*]pyrene equivalent concentration (BaPE) can be calculated. The highest BaPE values occurred in the Clyde estuary (Region 5)(25-33 μg kg^{-1} wet weight benzo[*a*]pyrene equivalents. At most other sites the BaPE values are less than 1033 μg kg^{-1} wet weight benzo[*a*]pyrene equivalents, but this value is exceeded in some samples from the Northumberland Coast and the Tees and Mersey estuaries (Region 1 and 5). Figure 3.15 shows the spatial distribution of concentrations of pyrene. As is the case for the other contaminant data collected in the 1999-2002 period, the datasets cover too short a period to allow temporal trends to be assessed.

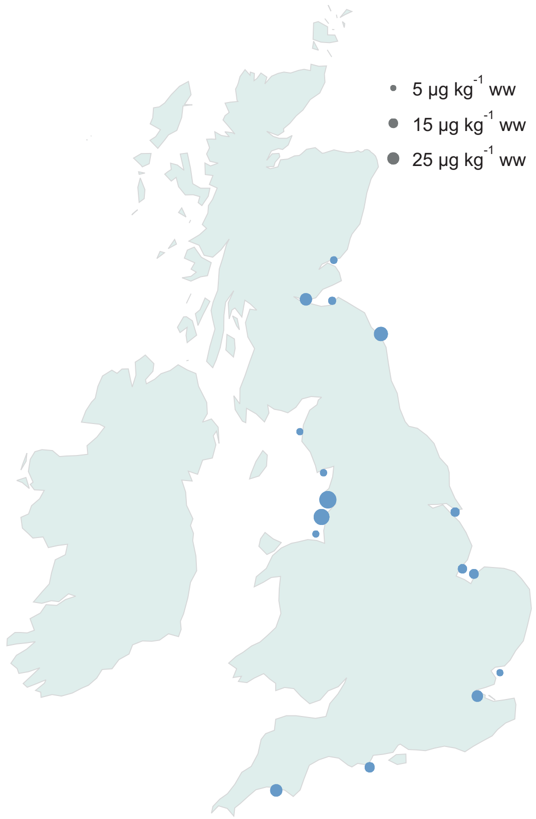

Figure 3.15. Concentrations of Pyrene in shellfish

CONCLUSIONS/DISCUSSIONS

For PAH determined, mussel tissue concentrations were below the provisional EAC, in spite of PAH concentrations in sediments exceeding the upper EACs at several of the sites monitored.

3.4.4 CONTAMINANTS IN MARINE MAMMALS (UK MARINE MAMMAL STRANDINGS PROGRAMME – UKMMSP)

The UKMMSP is funded by Defra as a part of its commitments under ASCOBANS (the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas). More than 20 species of marine mammals have been studied under the UKMMSP, but the primary species for investigation is the harbour porpoise (*Phocoena phocoena*). This is because it is the most widely distributed of the small cetaceans, as can be seen from both sightings and strandings information.

Between 1990 and 2002, 588 harbour porpoises stranded on the coastline of England and Wales and 45 retrieved directly following entanglement in commercial fishing gear (by-catch) were autopsied using standardised methodology. Contaminant levels were determined in selected animals (Bennett *et al.*, 2001, Jepson *et al.*, 1999, Jepson, 2003).

Spatial and temporal trends

Blubber levels of organochlorine pesticides declined significantly between 1989 and 2001 whereas levels of polychlorinated biphenyls were both significantly higher and more stable over time, despite their use having been controlled for over 20 years.

Levels of chromium, nickel and lead in liver also showed significant temporal declines whereas silver levels increased during the 1990s. Lead is no longer used as a petrol additive, and one might expect discharges of silver to reduce in the future as digital photography takes a larger share of the market from traditional film.

Levels of polychlorinated biphenyls, organochlorine pesticides, chromium and nickel were lower in Scottish porpoises, whilst lead levels were significantly higher in porpoises from Wales, presumably due to inputs from historic mining activity. See examples for polychlorinated biphenyls and butyltins (Figures 3.17-3.22). For butyltins, levels in the Channel, a major shipping route, are higher than elsewhere.

Contaminants and infectious disease mortality

Pathological investigations identified a range of causes of death in harbour porpoises in UK waters. By-catch, the most common cause of mortality in this study, is now globally recognised as an important threat to harbour porpoise

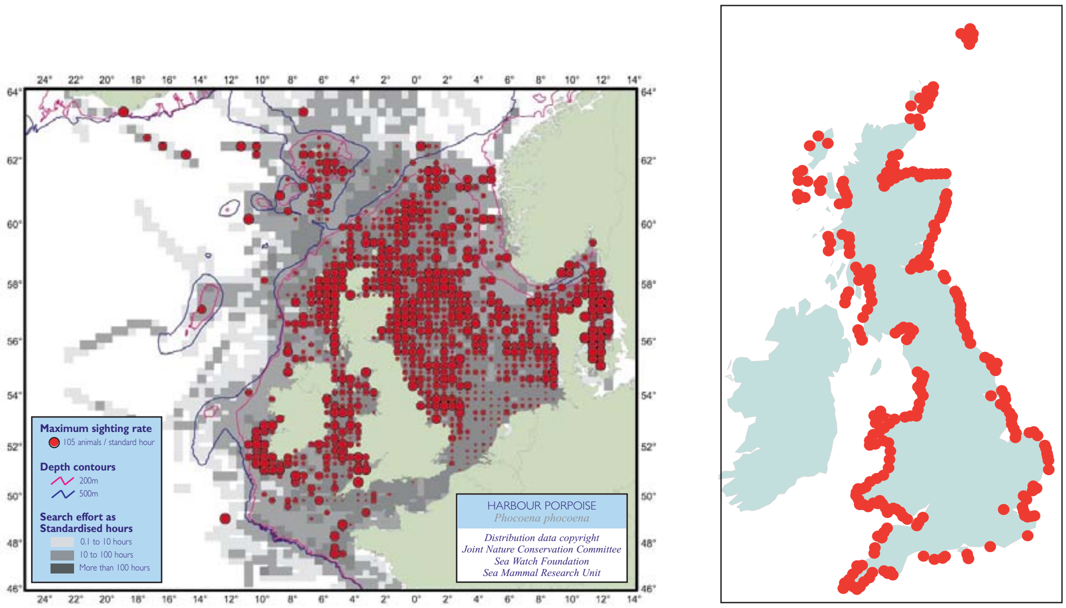

Figure 3.16. Sightings rates (numbers per standard hour) of harbour porpoises reproduced from Reid *et al.*, (in press). Data collected over a 20 year time period, all months, from numerous platforms. Search effort (hours of observation) is indicated by shaded squares, sightings rates by red circles with area proportional to rate. Gross corrections for the effect of sea state have been applied

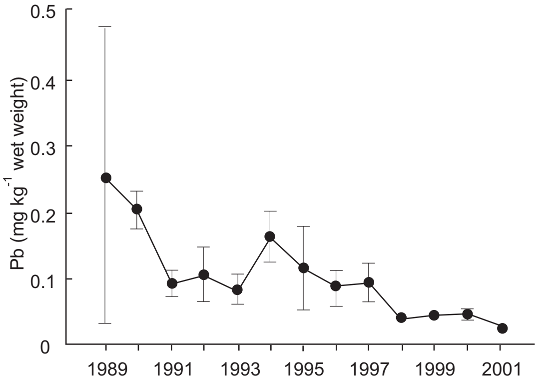

Figure 3.17. Annual variation in hepatic Pb concentrations 1989-2001. Bars = 1 Standard error

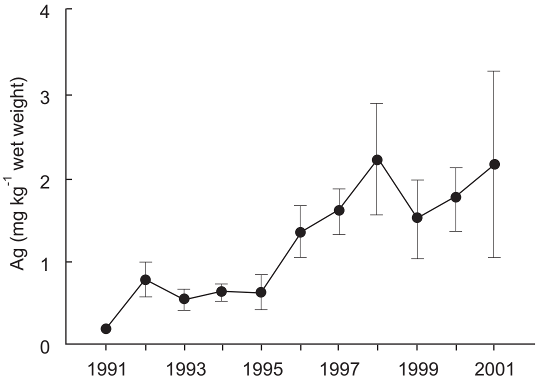

Figure 3.18. Annual variation in hepatic Ag concentrations. Bars = 1 Standard error

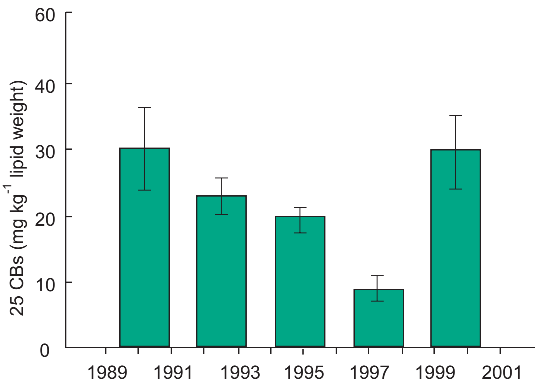

Figure 3.19. Spatial distribution of Σ25CBs levels. Bars = 1 Standard error

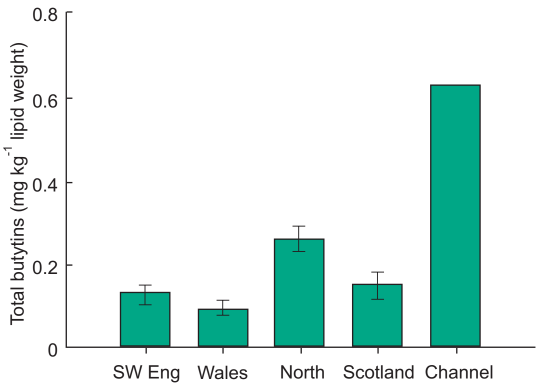

Figure 3.20. Spatial distribution of total butyltins. Bars = 1 Standard error

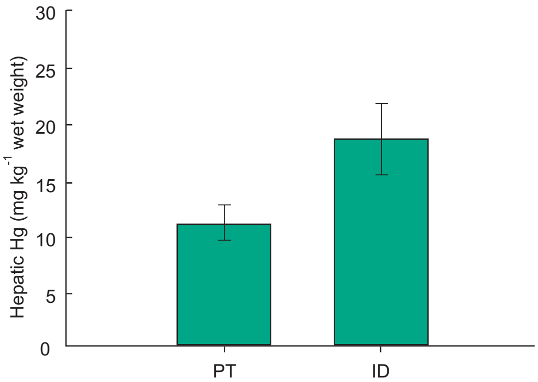

Figure 3.21. The mean liver Hg concentration (mg kg^{-1} wet weight) was significantly greater in the infectious disease (ID) group (n=79) compasred to the physical trauma (PT)group (n=151). Bars = 1 Standard error

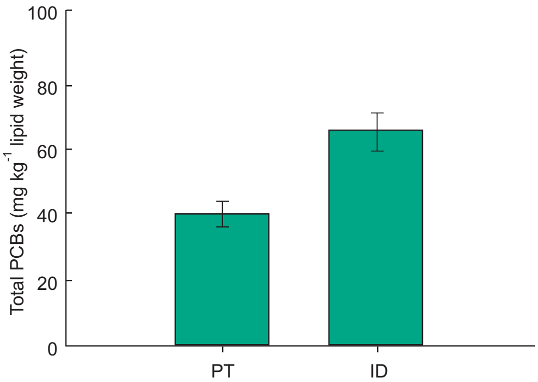

Figure 3.22. Total PCB levels are significantly greater in the infectious disease group (ID) (n=62) compared to the physical trauma group (PT) (n=92) within individuals with total PCB levels >17 mg kg^{-1} lipid weight. The bars represent 1 Standard error

populations. Statistical associations consistent with causal relationships were observed between elevated concentrations of both polychlorinated biphenyls and mercury and infectious disease mortality. Levels of mercury and polychlorinated biphenyls were higher in animals which died of infectious disease than those which were by-caught, and, for polychlorinated biphenyls only, were above a proposed threshold of effect defined from studies in other mammals such as mink.

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Reid *et al.* (in Press)

3.5 CONTAMINANT SPECIFIC BIOLOGICAL EFFECTS

3.5.1 LIVER PATHOLOGY IN FISH

The presence of liver pathology in marine flatfish is routinely used in biological effects monitoring programmes. The presence of macroscopic liver nodules or tumours and microscopic pre-neoplastic and neoplastic pathologies are significant biological end-points following exposure to organic contaminants. As such, their presence in wild populations is highly significant. In combination with biomarker data measuring exposure to genotoxins (EROD and bile metabolites) and damage at the molecular level (DNA adduct formation) a more thorough understanding of the process leading to liver nodule development is gained.

Although the range of liver pathology in flatfish is large and includes changes associated with the presence of pathogens, non-specific degeneration and tissue repair, most attention is given to categories indicative of contaminant exposure. In increasing severity these include foci of cellular alteration (FCA), benign tumours (for example adenoma and cholangioma) and malignant tumours (carcinoma). Since macroscopic tumours may take many months or years to develop, the use of histology to detect these pathologies provides a sensitive tool to identify microscopic tumours and their precursor lesions. Sampling and disease reporting protocols follow quality assurance guidelines established internationally (Bucke *et al*., 2003, Feist *et al*., 2004).

Liver nodules in dab (Figure 3.23) are most prevalent at sites in Liverpool Bay and Cardigan Bay (Region 5), at Flamborough and West Dogger (Region 2). They are also present in most other Regions at lower prevalence levels. At most locations no clear trends in prevalence have been confirmed although the incidence appears to be declining at Flamborough and Rye Bay (Regions 2 and 3) since 2001 and increasing in Liverpool Bay and Cardigan Bay sites (Region 5) since 2000 and 1995 respectively. A range of pre-neoplastic and neoplastic pathology is present in dab from all sites where macroscopic nodules are recorded, but in addition these are also detected at lower levels in liver tissue from dab sampled from reference locations where macroscopic nodules are rare.

Figure 3.23. Liver tumour

In dab from the Rye Bay reference location (Region 3) a greater proportion of livers appeared normal compared to other sites and only few pre-neoplastic and benign lesions are present. In contrast, the proportion of dab sampled from the West Dogger and Liverpool Bay sites exhibiting neoplastic pathology was considerably higher. At Cardigan Bay the proportion of fish displaying pre-neoplastic lesions and benign tumours has increased mirroring the increase in macroscopic tumours observed.

Similar pathological changes in flounder from estuarine locations sampled during 2002 have also been demonstrated. In particular, FCAs were recorded in fish from most locations (see Figure 3.24). However, neoplastic lesions were only seen in a single fish from the Mersey and Thames estuaries. Macroscopic nodules were absent.

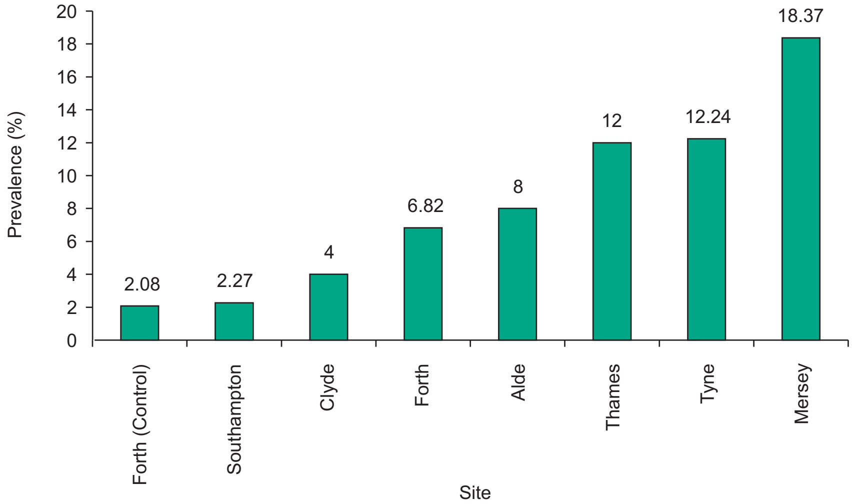

Figure 3.24. Prevalence of hepatocellular foci of cellular alteration (FCA) in flounder, by site

Glossary

Adenoma - a benign tumour of glandular tissue (including liver).

Aetiology – the cause of a disease or condition.

Carcinoma - a malignant tumour derived from epithelial cells.

Cholangioma - a benign tumour of bile ducts.

Epidermal hyperplasia/papilloma - an externally visible disease appearing as pale raised areas of skin. Possibly caused by a virus.

Hemangioma - a benign tumour of endothelial (lining) cells.

Hyperpigmentation - condition of increased pigmentation where the upper surface exhibits dark green/black areas (increased numbers of pigmented cells containing melanin). On the underside, affected areas mainly appear white with some melanisation.

Liver nodule - a discrete pathology of the liver greater than 2 mm in diameter.

Lymphocystis - a disease caused by an iridovirus giving rise to multiple small nodules, usually on the surface of the fish.

Neoplasia - an abnormal mass of tissue.

Toxicopathic lesion – pathology caused by toxicants.

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3.5.2 VITELLOGENIN EXPRESSION IN ESTUARINE MALE FLOUNDER

Some substances disrupt the normal endocrine processes of fish. The potential effects of endocrine disrupting chemicals in the sea were first recognised after fresh waters research associated oestrogenic chemicals originating from domestic sewage and industrial discharges, with various biological effects. Initial monitoring showed that similar impacts were occurring in estuaries. The potency of many endocrine disrupting chemicals, their ubiquity in sewage effluents and their potential for interfering with normal reproduction in fish led to the initiation of the Endocrine Disruption in the Marine Environment (EDMAR) research programme, in 1998.

Early research had shown that some fish species, particularly rainbow trout, roach and flounder, showed signs of exposure to exogenous oestrogenic (feminising) substances, as indicated by the presence of the female yolk protein vitellogenin (VTG) in blood plasma and intersex in male fish, where testicular tissue contains eggs in various stages of development (Figure 3.25). In light of this work, the EDMAR, a joint initiative between the Department for Environment Food and Rural Affairs, Government agencies and the chemical industry's Long Range Research Initiative, was the first large scale, and most detailed, research to establish whether such changes were occurring in marine life, where they were occurring, what was causing them, and what the consequences were.

The project found that endocrine disruption does occur in some marine species in certain locations, but not at other sites and that further work needs to be done to determine why this is and what the consequences are, if any.
The research, which looked at several fish species and some invertebrates in estuaries and coastal waters around the UK, found mainly that:

- some feminisation of flounder has taken place resulting in egg protein (VTG) production in males - but this seems to be declining in some areas;
- there were signs of feminisation in blenny fish in some estuaries;
- feminisation of migratory salmon and trout does not seem to be a problem;

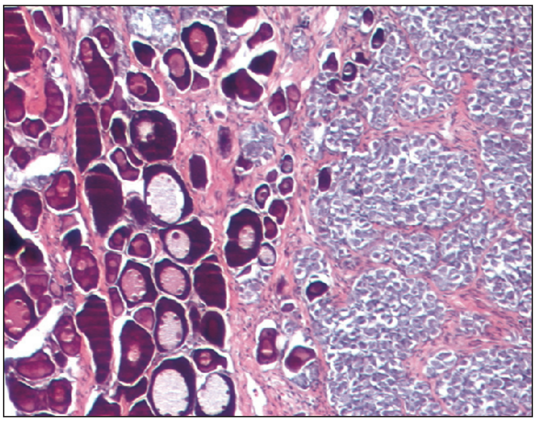

Figure 3.25. Testis histology from an intersex male flounder showing developing oocytes in the testicular tissue

- crabs and shrimps do not appear to show any endocrine disruption effects when exposed to the sort of chemicals that cause feminisation in vertebrates (e.g. fish and mammals).
- the key substances implicated as causing the observed effects were natural substances such as the human female sex hormone 17ß-oestradiol and synthetic chemicals such as nonylphenol.

The EDMAR final report is available for downloading at: http://defraweb/environment/chemicals/hormone/report.htm

The most widespread evidence of endocrine disruption is the expression of VTG and presence of intersex in male fish. This condition has been recorded at a number of UK estuaries including
including the Mersey (Region 5), Tyne (Region 1) and Clyde (Region 6) at up to 20% prevalence (Figure 3.26).

Plasma VTG concentrations were elevated in male flounder from a number of the estuaries (Figure 3.26). The highest levels (>10^7 ng ml^{-1}) were recorded in the Tees and Mersey estuaries. Occasional high levels (>10^5 ng ml^{-1}) were also observed in the Tyne, Clyde and Forth.

Reduction in plasma VTG concentrations has been noted in male flounder captured near the Howden sewage treatment outfall (Tyne) following

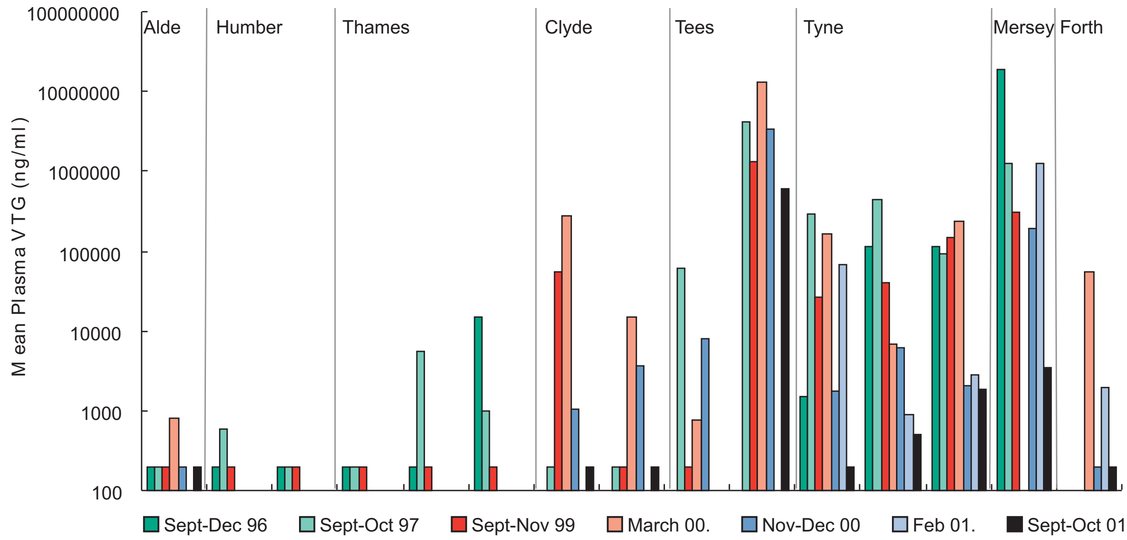

Figure 3.26. Mean plasma VTG (ng ml^{-1}) in male flounder from estuarine surveys between 1996 and 2001

the introduction of secondary treatment in 2000. Conversely, the concentrations in plasma of male fish captured adjacent to a discharge in the Tees estuary (Region 1) seem not to have declined even though reduction and treatment of the effluents has also occurred there.

3.5.3 ORGANO TIN-SPECIFIC EFFECTS IN GASTROPOD MOLLUSCS

The main inputs of tributyltin (TBT) compounds to the sea arise from their use as biocides in antifouling paints on the hulls of vessels, from which, TBT slowly leaches into the surrounding water. The presence of TBT-based antifoulants is currently only permitted on vessels more than 25 m length (but will be banned completely in 2008), but historically TBT was widely used on smaller vessels, yachts and fish farm equipment.

Females of the common dogwhelk, *Nucella lapillus*, show the most sensitive response to TBT exposure by developing male sexual characteristics, principally the development of a penis and vas deferens. In severe cases, this condition (imposex) can lead to sterility and death of the females, and subsequently to declines in dogwhelk populations as breeding is impaired. The degree of imposex can be expressed as the Relative Penis Size Index (RPSI%) which summarises the average degree of development of a penis by females, and the Vas Deferens Sequence Index (VDSI). The latter can take values between 0 and 6. Values above 4 indicate that some of the females in a sample are unable to reproduce. OSPAR has developed detailed guidelines for the use of imposex in monitoring programmes along with assessment criteria and ecological quality objectives based on the level of this response (OSPAR, 1998).

Comprehensive spatial surveys of TBT effects on gastropods around the UK coastline were carried out between 1992 and 1998 (Harding *et al.,* 1992, 1998). These showed that the effects of TBT exposure in dogwhelks were evident all around the UK, but that effects were generally low (VDSI <4) at sites more than a few hundred metres from point sources of TBT. Such levels of effect equate to OSPAR assessment classes B & C indicating a TBT specific effect is evident but there are no effects at the population level. The 1997 West Coast data is shown in Figures 3.27 and 3.28. At

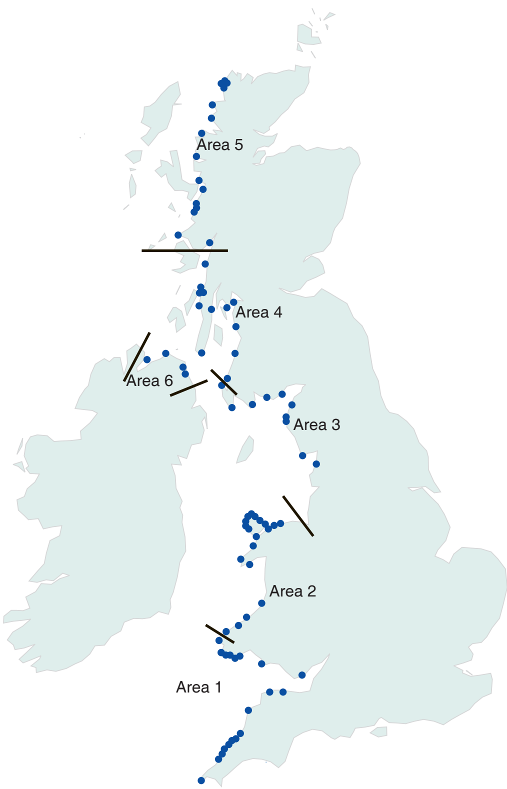

Figure 3.27. Stations in western coastal areas sampled for organotin specific effects (*Nucella lapillus*) in 1997

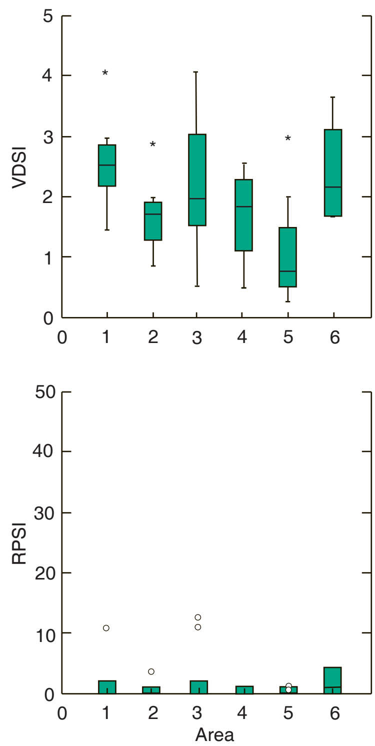

Figure 3.28. Level of imposex (VDSI and RPSI) in *Nucella lapillus* from western coastal waters in 1997. Data are pooled by coastal area

eight sites removed from TBT point sources on the East and South coasts and in the immediate vicinity of known point sources of TBT in Western coastal waters, sterile females may be present in the population (OSPAR assessment class D). Twenty three of the sites on the East and South coasts of the UK have been subject to two surveys to show temporal trends over a 5 year period. The level of imposex response in dogwhelks was found to decrease at the majority of sites over this time period. It is expected that such downward trends will continue following the banning of organo-tin based antifoulants on large vessels in 2008.

Downward temporal trends in imposex response in dogwhelks are also evident from a long-term monitoring programme at the Sullom Voe oil terminal in Shetland. This oil terminal received a

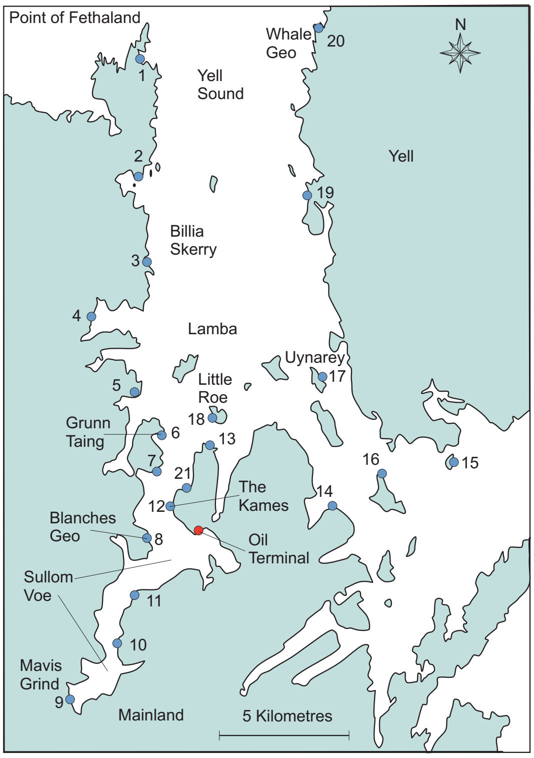

Figure 3.29. Stations in Sullom Voe and surrounding areas where *Nucella lapillus* were sampled to monitor for organotin specific effects (1987-2001)

large number of tankers in the early 1980s, but shipping traffic declined in the area from 1984 to 1990 and has since remained fairly constant. Between 1985 and 2001, dogwhelks have been assessed for imposex at 21 sites in Sullom Voe and the surrounding area (Figure 3.29). The highest levels of imposex (approximately 4, indicating the potential for population level effects – Class D) were found within the Voe near the terminal and decrease with distance from the source of contamination. Over approximately 15 years the level of imposex both in the Voe and surrounding area has declined, with the greatest decrease noted between 1991 and 1993 (Figure 3.30).

Offshore effects of TBT on gastropods have also been surveyed at some specific sites. Inputs of TBT to offshore areas may come from dumping of harbour dredge spoil materials, anchorages and shipping lanes. Effects from all these potential sources have been investigated in the Firth of Clyde during 2003 using the common whelk (*Buccinum undatum*) (Figure 3.31). The level of imposex (Penis Classification Index) in this species was found to be low at shipping lanes and a disused sewage dump site (Garroch Head), but higher at a harbour dredge spoil site (Cloch Point) and the most frequently used large vessel anchorages in the upper Firth. (Figure 3.32).

Common whelks are not known to be sterilised by exposure to TBT and have a less sensitive imposex response than dogwhelks. However, the level of response at Clyde anchorages and the dredge spoil dump site were not considered to reflect a level of contamination that would cause sterility in the most sensitive gastropod species (PCI <2, OSPAR assessment class C).

In order to measure any future improvement of the level of organotin specific effects in gastropods following the complete ban on TBT based antifoulants in 2008, the UK will conduct update the comprehensive coastline surveys of a few years ago to provide a baseline measure of effects. Particular attention will be paid to effects in the vicinity of point sources of TBT (large vessel ports) and also effects on offshore species.

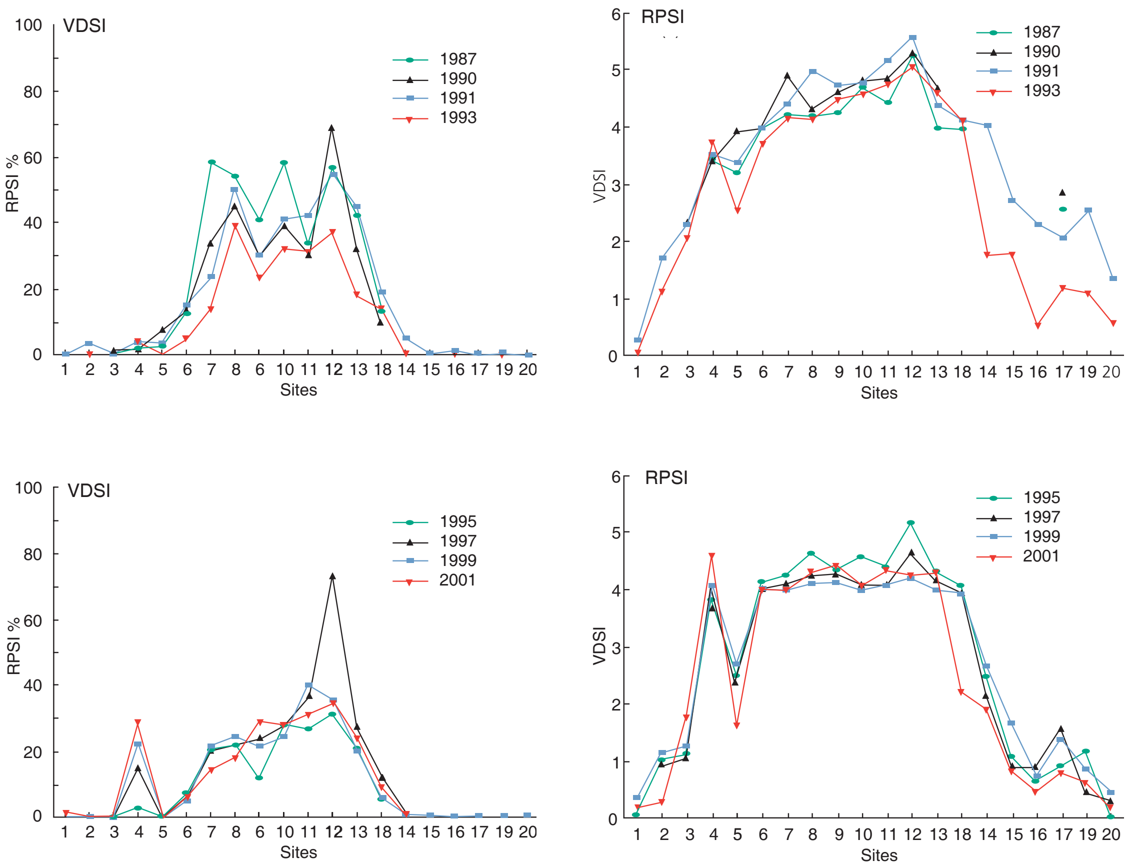

Figure 3.30. Level of imposex (VDSI, RPSI) in *Nucella lapillus* from Sullom Voe and surrounding areas (1987-2001)

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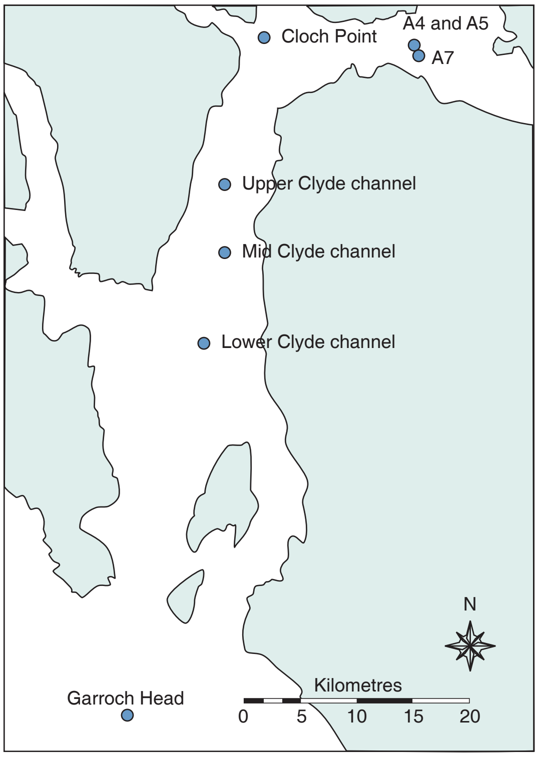


Figure 3.31. Location of *Buccinum undatum* sampling sites in the Firth of Clyde area, May and November, 2003. Mid-trawl locations shown

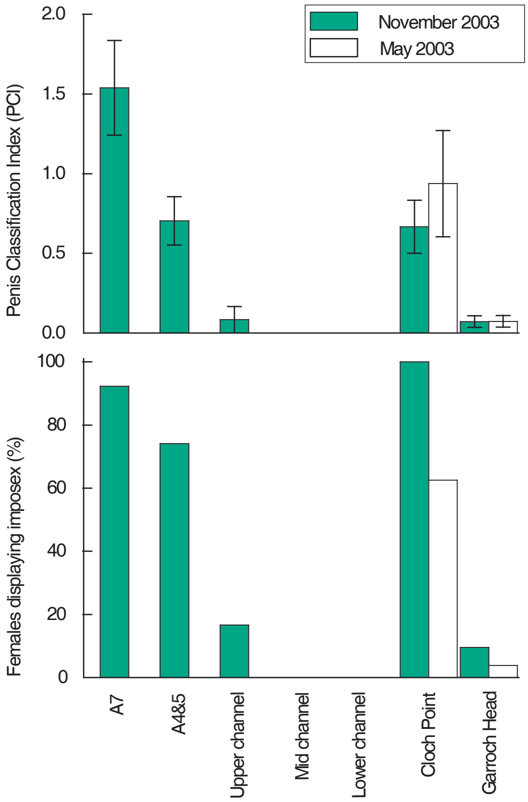


Figure 3.32. Tri-butyl tin specific effects on *Buccinum undatum* at various sites in the Firth of Clyde, May and November, 2003. Penis classification indices (PCI) and proportion of females displaying imposex are given for large vessel anchorage (A7, A4&5), shipping channel (Upper, Mid and Lower Clyde channel) and dump sites (Cloch Point and Garroch Head). PCI data are presented as means ± SEM

3.5.4 EROD AND BILE METABOLITES

Some of the most biologically significant groups of contaminants in the benthic marine environment are the polycyclic hydrocarbons (PAH), the planar polychlorinated biphenyls (PCB), the dibenzo-p-furans and the dioxins. These compounds are extremely hydrophobic, they tend to become associated with fine sediments and benthic fish may therefore experience higher exposure than pelagic fish. When absorbed into fish these substances all induce synthesis of the mono-oxygenase enzymes known as the cytochrome P450 group, which are found predominantly in liver cells. The synthesis of these enzymes can be measured by the activity of ethoxyresorufin-O-deethylase (EROD) in fish liver (expressed as pM/min/mg protein). As these substances are degraded by the liver they appear as PAH metabolites in the bile which can also be measured. Some of the degradation products of these substances may also be harmful in their own right, in particular they can bind with the genetic material (DNA) in the nucleus of cells (measured as DNA adducts). DNA mutations are linked to the initiation of liver tumours and precursor lesions, such biological effects can be measured using liver histopathology as described below in section 3.6.

EROD activity in Dab (*Limanda limanda*)
Dab were collected offshore on Research Vessel cruises between 1999 – 2001. EROD activity was analysed by the method of Burke and Mayer (1974) as described by Stagg *et al.* (1995).

Mean EROD activities were calculated for each site for each year (male and female values amalgamated) and are presented in Figures 3.33(a)-(c).

In 1999 fish were collected from 17 sites in May. EROD levels were higher in males than females at all sites, 6-7 times higher at some sites (Off Tees, Flamborough and NW Dogger (Region 1)). The highest male:female EROD ratios were recorded in the North Sea.

These inter-sex differences in EROD relate to sampling in early May, close to the end of the spawning period. The reproductive cycle of North Sea dab is: pre-spawning (Sept-Dec), spawning (Jan-April), post-spawning (May) and resting (June-August) (Kirby *et al.*, 1999) with some year to year variability. Male levels are highest during the spawning period and lowest during the post-spawning/resting phase (May to August); females do not show as strong a trend (Lange *et al.*, 1999).

In male fish, high levels were found off Morecambe, St Bees Head and Outer Cardigan Bay (1854, 1617 and 1574 pM/min/mg protein respectively) (Figure 3.33(a)). High values were also found in females at the Liverpool Bay and Irish Sea stations (Region 5) but were low in the North Sea.

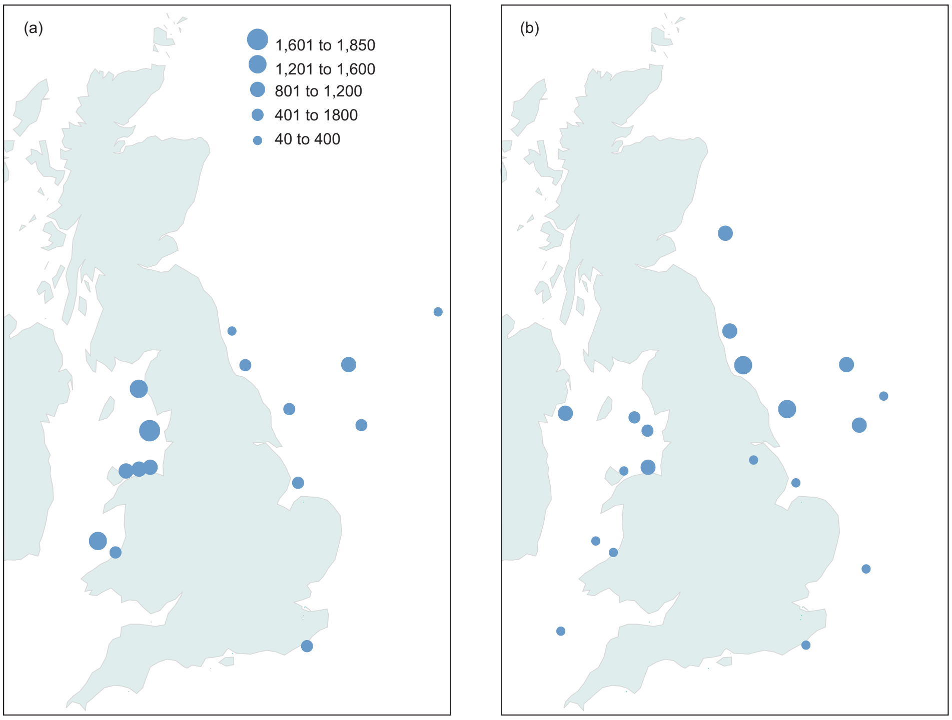
In 2000, dab were sampled at 19 sites in June. The data were similar for both sexes, reflecting the reproductive state of the fish at the time.

The highest mean values on the East Coast were off Tees, off Flamborough, West Dogger, off Humber and in the Firth of Forth, with 1570, 1253, 1147, 1047 and 1014 pM/min/mg protein respectively (Figure 3.33(b)). Highest values on the West Coast were at near-shore sites in Liverpool Bay (Off Morecambe and Burbo Bight) and Dundrum Bay, east coast of Ireland. Low mean values were found at the South of Humber (46 pM/min/mg protein) and Rye Bay (Region 3)(134 pM/min/mg protein) sites.

The 2000 data generally relate to known areas of organic contamination although correlations of size and reproductive parameters with EROD suggest that the recorded activities may also have been influenced by non-contaminant factors.

In 2001, dab were sampled from 19 sites in June/July. The data showed, overall, slightly reduced EROD values (Figure 3.33(c)) with mean values below 1000 pM/min/mg protein. The highest values (~800 pM/min/mg protein) were found in the east and northeast. Low values were again recorded in samples from Rye Bay and Cardigan Bay.

Liver EROD activity and PAH metabolites in bile of flounder (*Platichthys flesus*)
The previous data reports EROD activity in dab. Dab is an offshore species and in estuaries an alternative flatfish species is used, the flounder (*Platichthys flesus*). Direct comparison of EROD activity between the two species cannot be made since the EROD activity in flounder for the same toxicant stimulation is ten times less.



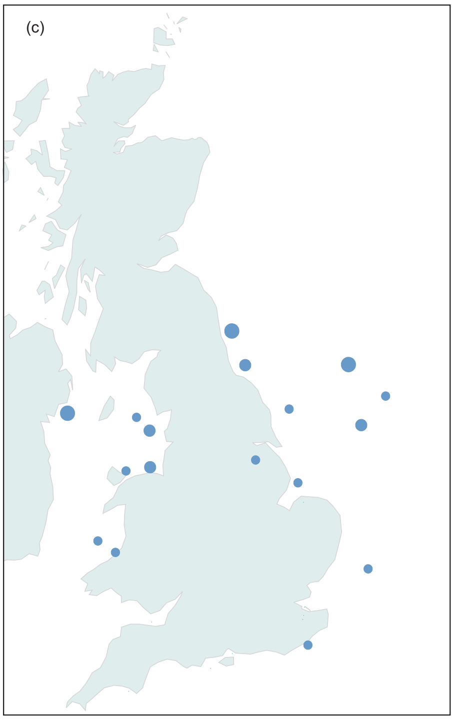


Figure 3.33. Mean EROD activity (pM/min/mg protein) in dab in (a) 1999, (b) 2000 and (c) 2001

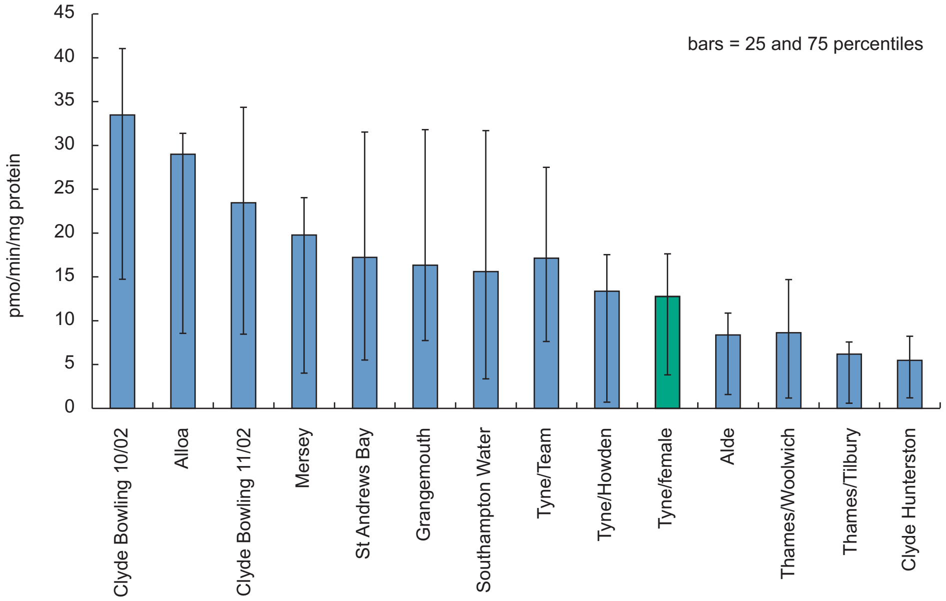


Figure 3.34. Hepatic EROD activity in male flounder

During September-December 2002, 9 estuaries areas around the UK were surveyed and samples of liver and bile taken from flounder for analysis. Bile was sampled for the analysis of PAH metabolites by the synchronous fluorometric spectrometric method of Ariese *et al.* (1993).

Overall levels of hepatic EROD activity in male fish were similar to, but slightly lower (means <35 pmol/min/mg) than levels seen in flounder during previous monitoring programmes in some of the estuaries sampled (Kirby *et al.*, 1999). There were few significant differences between

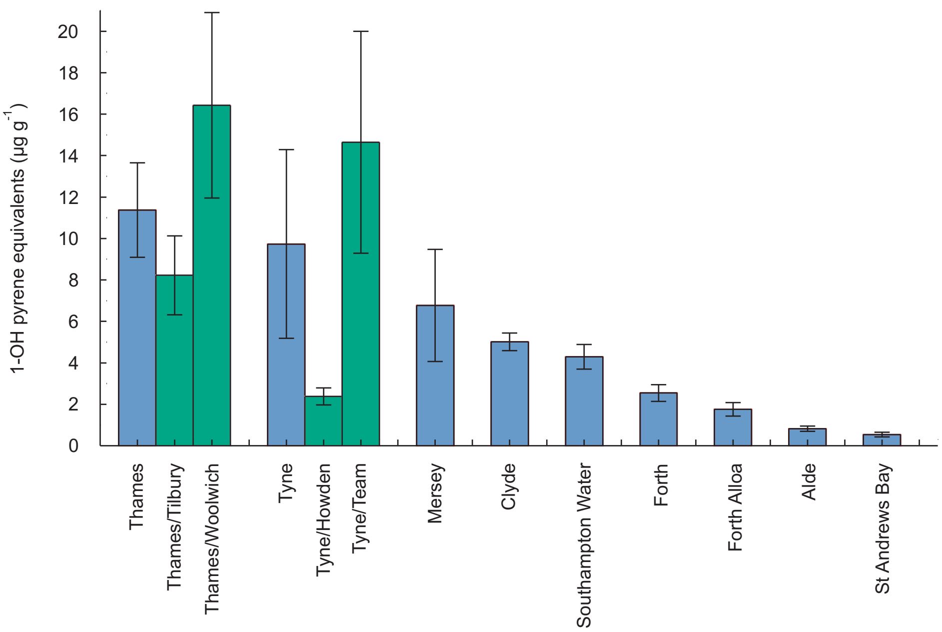


Figure 3.35. Biliary PAH metabolites in male flounder, expressed as 1-OH pyrene equivalents

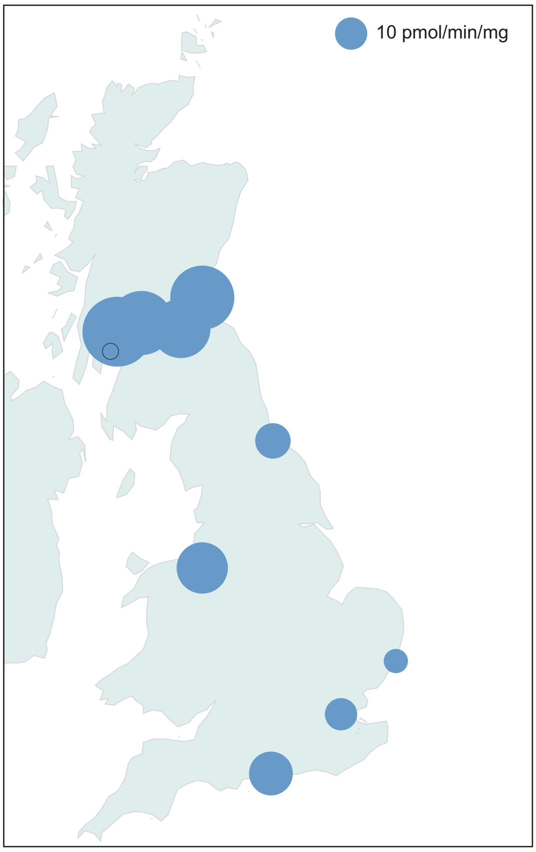


Figure 3.36. Mean hepatic EROD activity of male flounder (*Platichthys flesus*) sampled from UK estuaries / Firths, 2002

Figure 3.37. Mean PAH metabolites (1-OH pyrene equivalents) in bile of flounder (*Platichthys flesus*) sampled from UK estuaries / Firths, 2002

the estuaries, although, notably, the English control site (Alde) and fish from the Hunterston site in the Clyde demonstrated significantly lower levels of activity than fish from the upper Bowling region of the Clyde (Figure 3.34, $P<0.0001$) and Figure 3.36.

Bile metabolite levels were more variable between estuaries, with the control sites in England (Alde) and Scotland (St Andrews Bay) demonstrating the lowest levels of 1-OH pyrene equivalents in bile (Figure 3.35, $P<0.0001$) and Figure 3.37. Significant differences were also noted between sites within the Tyne and Thames estuaries.

Preliminary attempts to correlate bile metabolite levels and liver EROD activity indicate that there is no strong relationship between these two biological effects measurements in any of the areas surveyed.

CONCLUSIONS/DISCUSSIONS

EROD activity measured in dab and flounder were consistent with exposure to mixed function oxidase inducing compounds and generally reflected areas of known organic contaminant input. There are too few data to comment fully on trends as indicators of contaminant distributions. This work should continue to provide spatial and temporal data to describe the environmental quality of the seas around the UK.

Further work should be undertaken to investigate the relationship between EROD activity and bile metabolite measurements.

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3.5.5 DNA

In fish, DNA adducts are formed when genotoxic chemicals (e.g. metabolites of PAHs, benzo[a]pyrene and benzo[*a*]anthracene) bind to DNA bases (ACTG). If left unrepaired or mis-repaired these DNA adducts may go on to cause permanent alterations to the genome (gene mutation). Such chemical modification of the DNA is considered to be one of the initial steps of in the formation of cancerous pathologies in fish and mammals. A causal link between sediment PAH-contamination and DNA adduct formation and liver pathology in benthic fish species has previously been demonstrated. An association between PAH exposure, DNA adduct formation and cancerous lesion development in fish has also been revealed by a number of field and laboratory studies in both Europe and North America. Analysis of DNA adducts in liver therefore provides a sensitive biomarker of PAH exposure. In addition, DNA adducts are relatively persistent once formed and can persist for months and therefore are not necessarily indicative of recent exposure and are more likely to reflect cumulative exposure

Examples of surveys of DNA adduct levels in flatfish (dab, *Limanda limanda*, and flounder, *Platichthys flesus*) are shown in Figures 3.38 and 3.39. Analysis was carried out by 32P-postlabelling assay for DNA adducts (Randerath *et al*., 1981).

DAB COLLECTED FROM COASTAL AND OFFSHORE NMMP SITES

In the example given in Figure 3.38 (1998) adducts were detected at all sites apart from outer Cardigan Bay. The DNA adduct profiles indicated exposure to complex mixtures of genotoxins and the levels varied both spatially and temporally. However in later surveys dab caught in outer Cardigan Bay during 1999 and 2000 contained profiles characteristic of exposure to complex mixtures of carcinogenic metabolites.

It is clear that coastal dab are exposed at some times and in some places to sufficient genotoxins to induce detectable levels of DNA adducts. Dab migrate through unpolluted and polluted waters, so it is not possible to link specific sites to the induction of DNA adducts.

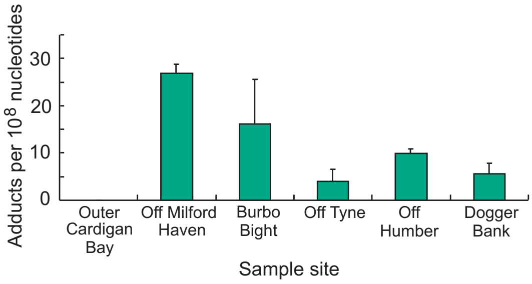

Figure 3.38. Liver DNA levels collected from Dab (*Limanda limanda*) from offshore locations. No adducts found in Outer Cardigan Bay in 1998

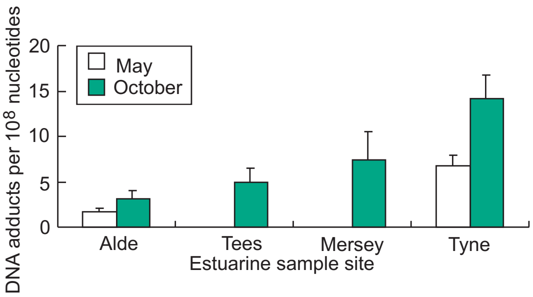

Figure 3.39. Liver DNA levels in flounder collected from UK estuaries in 2000

FLOUNDER COLLECTED FROM THE ALDE, TYNE, TEES AND MERSEY.

Significantly higher levels of adducts were detected in the contaminated Tyne estuary compared with fish from the Alde (reference site) during both spring and autumn. PAH bile metabolite analysis of flounder caught in May and October confirmed that fish were exposed to higher levels of PAH compared with those in the Alde. Differences between adduct levels in the Mersey and Tees during the autumn were not statistically significant but were elevated compared to the Alde.

DNA adduct data are likely to reflect local contamination because flounder are usually found in their home estuaries for up to 8 months of the year. Fish from the Tyne in spring and autumn revealed aromatic or hydrophobic DNA adducts in the liver, typical of exposure to a complex mixture of PAHs. This supports previous work (Lyons *et al*., 1999) showing that Tyne fish stocks are exposed to high levels of sediment-associated PAH and that a proportion of the bioavailable PAHs was being metabolised to carcinogenic metabolites. Significantly, Tyne flounder show more pre-cancerous lesions, specifically hepatocellular foci of cellular alteration, (see Section 3.5.1) compared with fish from unpolluted sites (Stentiford *et al*., 2003).

CONCLUSIONS/DISCUSSION

Dab and flounder both exhibited patterns of DNA adducts indicative of exposure to complex mixtures of PAH. However, it may be that other environmental contaminants were contributing to the overall genotoxic response.

The migration of dab is a complicating factor. DNA adducts are persistent and the detection of DNA adducts in dab at a particular location may be a consequence of previous exposure to contaminants elsewhere. This highlights the need for integrated monitoring where biomarkers of recent exposure over days or weeks, such as EROD and bile metabolites, are used alongside DNA adducts reflecting cumulative contaminant exposure over months.

DNA adducts are associated with increases in pre-cancerous and cancerous lesions in marine flatfish. Around the UK, some dab and flounder populations are being exposed to carcinogenic contaminants partly responsible for their observed pre-cancerous lesions.

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3.5.6 METAL-SPECIFIC BIOLOGICAL EFFECTS IN FISH

Marine organisms have developed a range of strategies to cope with different concentrations of essential or toxic metals. In general, detoxification depends on the conversion of toxic forms into less toxic bound forms. The bound forms may be stored safely and subsequently excreted.

One detoxification mechanism is the induction of metallothioneins (MT). Formation of Metallothionein is a natural response to exposure to certain metals, particularly mercury, copper, cadmium and zinc. The presence of MT is an indication of exposure to these metals, rather than a measure of subsequent health. MT is usually measured in the liver of fish, as this normally contains the highest concentrations of inducing metals.

Offshore

Initial surveys of MT in dab from offshore sites have shown high variability at sites, with factors of 10 or more between the maxima and minima, making statistical comparisons difficult. The data indicate that concentrations tend to be higher in females than in males, but show no correlation between the concentrations in males and females at each site.

Metal concentrations in the fish livers showed results consistent with previous reports, with greater than background mercury concentrations in the Mersey estuary, Liverpool Bay and Morecambe Bay (Region 5), as a result of historical discharges of mercury from the chlor-alkali industry. Cadmium and lead concentrations were generally low, with higher concentrations in fish from industrialised estuaries. Relatively high concentrations of cadmium were also measured in fish from the Dogger Bank in the North Sea (Region 1).

Overall, the relationship between metal concentrations in dab liver and metallothionein concentrations was not strong, however, statistically significant correlations were found between metallothionein and the concentrations of zinc, copper, mercury and cadmium in females. The concentration of metallothionein in males was statistically significantly correlated with copper and lead.

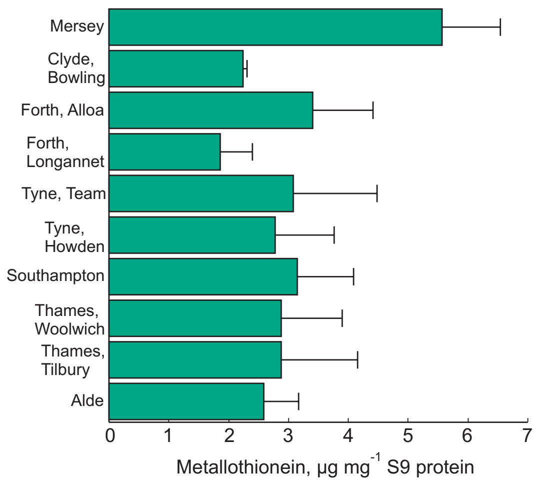

Figure 3.40. Hepatic Metallothionein concentrations in male flounder (*Platichthys flesus*) from estuarine sites around the UK, 2002

Inshore

Metallothionein concentrations measured in male flounder from 9 inshore areas around the UK, in 2002, (Alde estuary [reference site], Thames estuary, Southampton Water, Mersey estuary, Tyne estuary, St. Andrews Bay, Firth of Forth, Firth of Clyde and Belfast Lough) showed no statistically significant differences when compared to the Alde as reference, except for the Mersey where concentrations were elevated (Figure 3.40). The data is difficult to interpret, as there is no associated data for the concentrations of metals in fish liver.

Metallothionein content of mussel (*Mytilus edulis*)

Naturally occurring populations of mussels were sampled from sites in the study estuaries. The concentrations of metallothionein were determined as a measure of bioavailability of Cd, Cu and Zn. (George and Olsson, 1994).

Mussels were collected from Brancaster (control site, N. Norfolk) in February 2002. Additional populations were collected from Brancaster and from the Clyde, Mersey, Southampton, Tees (Field sands) and Thames during 2003.

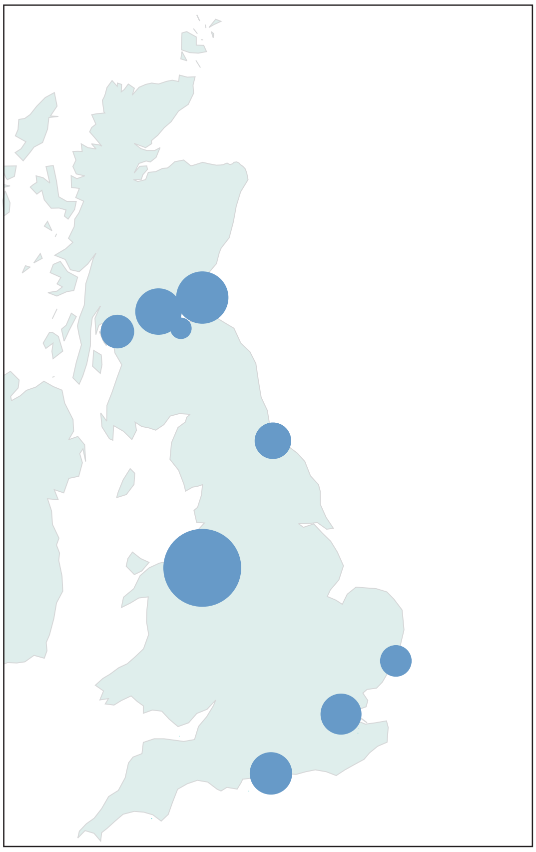

Figure 3.41. Hepatic Metallothionein data for male flounder grouped by estuary/ Firth. 2002

Metallothionein concentrations were approximately 2- to 3-fold higher in mussels from the Clyde and Thames and slightly less than 2-fold higher in the Southampton population, than those from the Tees and Mersey.

Further investigations of seasonal variations are required before the results can be fully interpreted. However, an interesting preliminary observation is that the mussel metallothionein results do not correlate with those for flounder livers. In the latter, only the Mersey fish displayed elevated MT concentrations. In mussels, MT concentrations were not elevated in this estuary but were significantly elevated in the Clyde and Thames estuaries. These findings may reflect different feeding behaviours (benthic invertebrates vs. filter feeding) and therefore availability to different compartments of the ecosystem. Possible correlations with chemical analyses now need to be investigated.

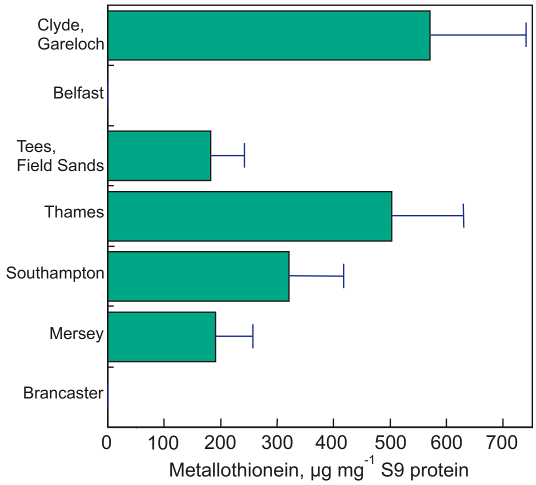

Figure 3.42. Hepatopancreas Metallothionein Content of natural populations of Mussels (*Mytilus edulis*) sampled in June 2003 from UK estuaries

CONCLUSIONS/DISCUSSION

The results of this work are as yet inconclusive and further investigations are required to enable the data to be fully interpreted.

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3.6 NON-SPECIFIC BIOLOGICAL EFFECTS

3.6.1. OYSTER EMBRYO BIOASSAY

The oyster embryo bioassay has been used for over ten years to measure general water quality status in UK waters. Embryos of the oyster, *Crassostrea gigas* are exposed to discrete water samples for 24 hours and their success to develop normally to 'D' hinge larvae is a measure of biological water quality The exposure period, though short, embraces intense cellular activity in which a number of critical physiological and biochemical processes may be impaired, causing abnormal growth or development of embryos. Poor 'D'-larval development indicates poor water quality which may caused by everything from lethal effects to subtle interferences with embryonic development.

Previous CEFAS results show that poor water quality in the UK has only been observed in estuarine waters. In 1999-2001, seventeen estuarine sites around the English and Welsh coasts were monitored routinely for oyster embryo toxicity, covering all major estuaries in England and Wales. Temporal detail is varied but all sites were sampled on more than one occasion. A small study produced data for the Clyde estuary.

Water of low salinity was modified to bring it within the optimal range for oyster development (salinity 22-35). Results are expressed as Percentage Net Response (PNR), the net abnormality in the sample relative to the 'background' response in a control exposure to artificially prepared seawater. In general, a PNR value of or close to 0 indicates the measured response of the sample is similar to that of the controls. A negative value indicates the water quality is better than the control. Poor water quality is defined when PNR values (usually >10) are statistically different from the reference sea water. A PNR value of 100 occurs when the sample is highly toxic and all the embryos have either died or shown abnormal development over the 24h exposure period.

At all 17 sites there was at, one time or another, toxicity (positive PNR). In the majority of estuaries the toxicity was occasional, showed no trend, and does not indicate a sustained deterioration in biological water quality.

Time series from 1999 to 2001 from the Tyne and Wear estuaries each displayed significant toxicity (PNR >20%) on one occasion but little or no effect on other occasions. The Tees estuary (Phillips Buoy) showed significant effects in 1999, but none thereafter.

No significant effects were observed in samples taken from the Humber estuary at Spurn Head.

Effects were recorded at Mucking in the Thames estuary throughout 1999 and 2000 but only one survey showed a significant PNR value (May 2000), whereas all samples in 2001 showed little effect. Low toxicity was found in the Medway and Southampton Water, with the exception of one sample from Sun Pier on the Medway in Feb 2001 (PNR 39%). Other sites on the Medway (Burham) and in Southampton Water (East site 515, Brambles) were only surveyed during 2000.

There were low PNR values in South West and Welsh estuaries, especially Poole Harbour South Deep, few of these results exceeded 10%, and none indicated serious deterioration in water quality (PNR >20%).

At the five sites in the North West of England, results from 2001 revealed no significant toxicity in the Mersey or Ribble estuaries, or from coastal sites.

The Clyde was surveyed three times from May to August in 1999 along a 30 km transect from the tidal weir in Glasgow. Water quality was investigated at 1, 3, 4, 6 and 9 metres, to reflect the stratified nature of the estuary. This was spatially a more detailed study than the English ones, but covers a considerably shorter time period.

There was no toxicity in the first surveys in May and early August but the third survey in mid-August showed significant toxicity (PNR >20%) at the Kelvin confluence (2 mile station, 6 m depth), and at Rothesay Dock (6 mile station, 2 m and 6 m depth).

CONCLUSIONS/DISCUSSION

UK estuarine biological water quality measured by toxicity to oyster embryo-larval development was generally very good. The oyster embryo larval test is a robust measure of the biological water quality of discrete water samples. However, because of temporal and spatial variability at sampling sites (samples were collected quarterly

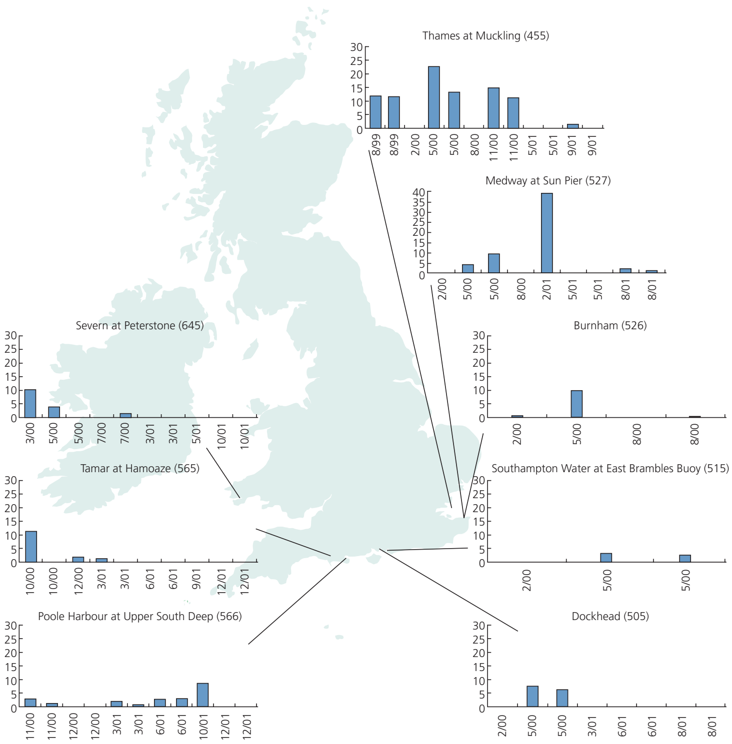

Figure 3.43. Oyster embryo larval development results: Southern England and Wales, 1999-2001

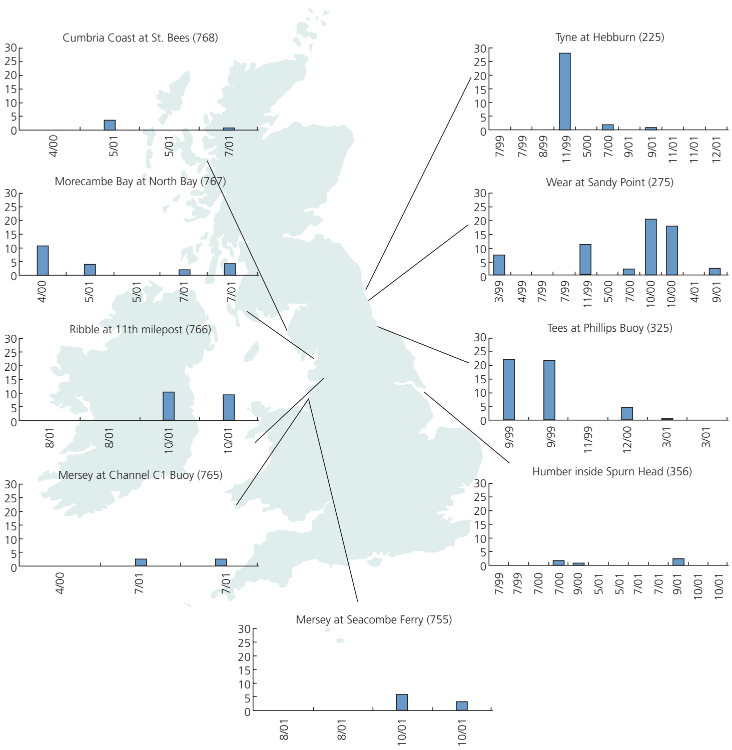

Figure 3.44. Oyster embryo larval development results: Northern England, 1999-2001 Summary

at a limited number of sites in each estuary), it is difficult to draw conclusions on biological water quality of an entire estuary, or on temporal trends. It is notable that in similar surveys 10 years ago measurements of between 50 to 100 PNR were measured, but in the surveys reported here the maximum PNR recorded was 39.

The surveys on the Clyde highlight the variability of biological water quality with location, time and depth, and the need for detailed spatial surveys of each estuary prior to developing a longer-term temporal trend, monitoring programme.

3.6.2 SEDIMENT BIOASSAYS

Sediment bioassays measure the acute toxicity of pore water or contaminants bound to sediment, to sediment dwelling organisms. Two have been developed for this purpose using the polychaete *Arenicola marina* and the crustacean *Corophium volutator* (Thain and Bifield, 2002 and Roddie and Thain, 2002). Both animals live in the sediment: *A. marina* ingests sediment and *C. volutator* grazes on sediment particles. In the bioassays the animals are exposed under controlled conditions to collected sediments. In both bioassays, mortality is measured after 10 days, and feeding behaviour is also measured for *A. marina*.

Sediments bioassay data are available for 2001 for four estuaries, the Mersey (19 sites), Southampton Water (21 sites), Tyne (22 sites) (see Figure 3.45) and Tees (22 samples) (see Figure 3.46).

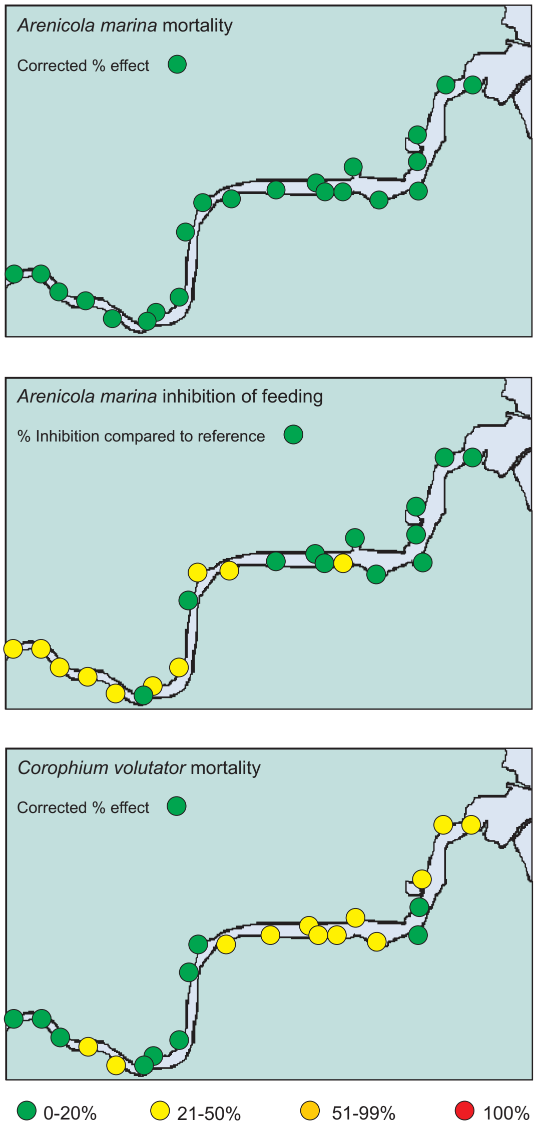

Figure 3.45. Sediment bioassay results for the Tyne estuary, 2001

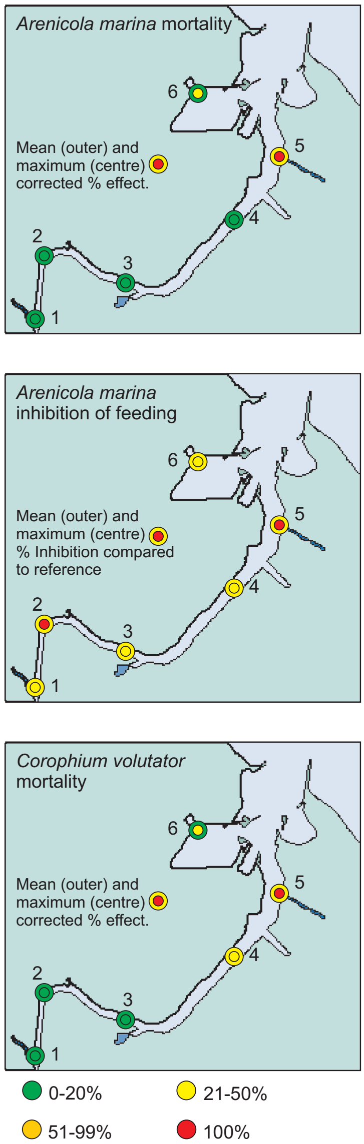

Figure 3.46. Sediment bioassay results for the Tees estuary, 2001. Sites 1, 2, 5 and 6: five samples taken at close proximity to known contaminant input. Sites 3 and 4: single sample taken in mid-channel

Twenty-one samples exhibited *C. volutator* mortality in excess of 20%, twelve of which occurred in samples from the Tees estuary (Region 1). *C. volutator* mortalities of 100% were recorded at three locations, one on Southampton Water (Region 4) and two on the Tees (Region 1). Four sediments exhibited mortality to *A. marina* in excess of 20%, all from the Tees estuary, one of which was 100%.

CONCLUSIONS/DISCUSSION

Localised sediment toxicity was recorded in all 4 estuaries surveyed. This work establishes a baseline for further monitoring in these estuaries. Where persistent toxicity is found complementary sediment chemical contaminant analysis will be necessary.

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3.6.3 FISH DISEASES

Measurement of disease conditions in individual fish provides an important integrative tool to monitor the overall health of fish populations. As such, the disease status of fish has been used as a general indicator of environmental stress affecting fish populations since the mid - 1980s. Target species have been selected mainly for their general availability and their susceptibility to external and internal disease conditions. Sampling and disease reporting protocols follow quality assurance guidelines established internationally (Bucke *et al*., 1996; BEQUALM, 2003). Species selected are the dab (*Limanda limanda*) for offshore areas and flounder (*Platichthys flesus*) for inshore and estuarine locations. The health status of commercial species such as cod (*Gadus morhua*) and plaice (*Pleuronectes platessa*) is also monitored but data on these species is less comprehensive. Externally, conditions used for monitoring include acute and healing ulcerations, lymphocystis, epidermal hyperplasia/papilloma and hyperpigmentation. Internally, liver lesions comprising nodules and larger tumours have become routine to assess (see Section 1.3.6). Offshore areas in the North Sea and Irish Sea have been monitored most consistently with information also available on the health of fish in the English Channel and western approaches. The health status of flounder from estuarine locations has also been monitored since 2001.

CONCLUSIONS/DISCUSSION

Diseases in dab remain at generally low levels with fish from Scottish waters having lower levels of disease than are found more generally in the North and Irish Seas. Overall, prevalence levels remain consistent in several areas (Anon, 2000, 2001). However, dab captured off Flamborough, on the Dogger Bank (Region 2) and in some areas of the Irish Sea (Region 5) continue to exhibit higher levels of disease than fish from a reference site in the eastern English Channel (Region 3). In addition, there has been a recent increasing trend in disease levels in dab from Cardigan Bay (Figure 3.47). Hyperpigmentation was a prominent condition in dab from several areas in the North Sea but had low prevalence in the Irish Sea and in the English Channel at Rye Bay. Ulceration was a common pathology in dab from several sites, with the highest prevalence on the Dogger Bank and from areas in the Irish Sea (including Liverpool Bay and Burbo Bight). External diseases in flounder from estuarine locations are present at low levels. Pathology of the liver and gonad associated with the presence of organic compounds and endocrine disrupting chemicals is present at several sites (see section. 3.6).

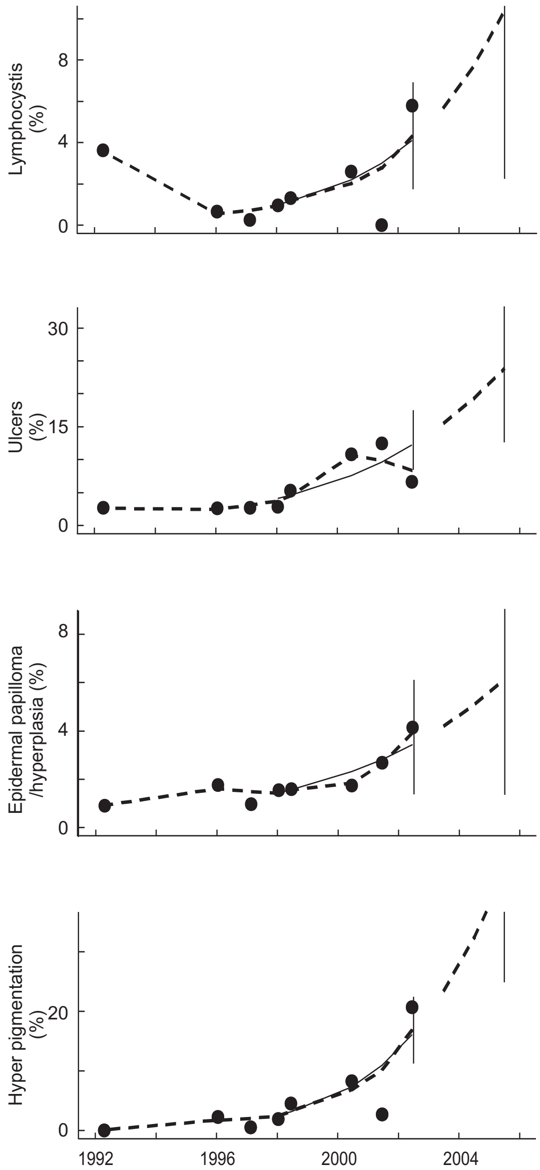

Figure 3.47. Trends in disease levels in dab from Cardigan Bay

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3.6.4 SHELLFISH DISEASES

Sampling and testing of native oysters (*Ostrea edulis*) from native stocks and farmed sites around the UK has been undertaken since 1993 in support of the application of approved zone status for the parasitic diseases Bonamiosis and Marteiliosis. Bonamia has been detected in three areas; from the Lizard to Start Point (Region 4); from Portland Bill to Selsey Bill (Region 3) and from Shoeburyness to Felixstowe (Region 2). The UK currently remains free from Marteiliosis.

Limited data is available on the health status of crustaceans from UK coastal waters. Shore crab (*Carcinus maenas*) and brown shrimp (*Crangon crangon*) from estuarine locations harbour infections caused by parasites and viral infections at most sites. Higher levels of the parasite *Microphallus primus* are present in crabs from the Alde estuary and Southampton water (Regions 2 & 3) compared to the Forth and Clyde estuaries (Regions 1 & 5). High prevalences of another parasite *Sacculina carcini* occur in crabs from Southampton water and the Forth estuary but not at other sites, including the Clyde, Tyne, Mersey and Alde estuaries. There is currently insufficient data to comment on trends and further studies are required to examine crustaceans from offshore locations to determine whether they harbour similar infections. Toxicopathic lesions have not been identified to date.

3.6.5. BENTHIC MACROFAUNA

Benthic macrofauna are the animals living within (infauna) or on (epifauna) the surface of the sediments. Benthic organisms are effectively sessile so act as integrators of the effects of environmental stresses, whether natural like salinity changes or due to contaminants. Benthic communities have long been studied as a measure of environmental quality (Holme and McIntyre, 1971). Although community responses to organic carbon have been described (Pearson and Rosenberg, (1978)) contaminant specific responses are less well known. A number of taxa such as the polychaetes *Capitella* species, *Manayunkia aestuarina* and *Aphelochaeta marioni* are known to act as indicators of highly stressed situations.

The NMMP programme samples ~60 stations around UK coastal waters. To allow comparison between localities and minimise the effects of salinity, estuarine and coastal sites were considered separately.

A number of univariate (single figure indices/measures) have been calculated for coastal and estuarine sites for 2000: number of species (S); abundance of all specimens (A); evenness (J'- allocation of abundance values across the species); and Shannon Wiener index (H' - a measure of diversity). Low evenness or Shannon Wiener diversity values are associated with samples dominated numerically by few species and may indicate a naturally stressed or anthropogenically impacted community.

The status of the benthic fauna is also assessed using functional indices which reflect a physiological response to the environment such as the UK infaunal trophic index (ITI, Codling and Ashley, 1992) and the AZTI marine biotic index (AMBI, Borja *et al*. 2000). The ITI classifies the fauna into different groups according to their mode of feeding, while the AMBI classifies the fauna according to their sensitivity to pollution. The ITI values range from 0 to100. Values of 60 or above are regarded as 'normal', between 60 and 30 as 'changed', and below 30 as 'degraded'. The AMBI scores range from 0 to 7 with low scores indicating an unstressed healthy benthic community, and high scores indicating stressed or polluted sites.

Multivariate (combining all species information into a small number of variables) methods of data analysis may provide a more sensitive measure of community change than univariate methods (Warwick and Clarke, 1991). Cluster analysis is used as a measure of similarity so as to identify groups of similar stations. Multidimensional scaling (MDS) is used to express this graphically. The MDS ordination plot arranges sites according to the similarity of their faunal composition, the most similar sites appearing closest together.

Figure 3.48, using the coastal sites, illustrates clearly the influence sediment grain size has on community structure.

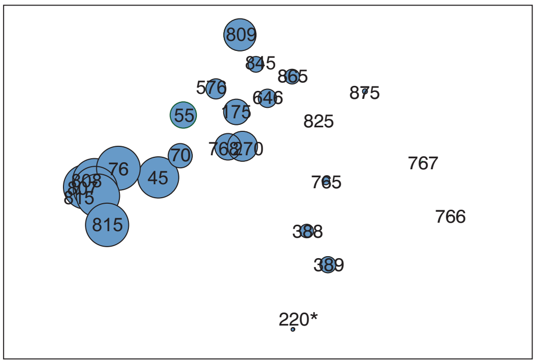

Figure 3.48. MDS plot of the NMMP 2000 coastal macrobenthic dataset and relative percentage silt/clay content of sediment. (Circle size indicates silt/clay content)

Coastal Sites

The maximum number of species is 94 at Strangford Lough (Region 5), while the minimum is only 3 at the Ribble, also Region 5. These sites also represented the maximum and minimum abundance of individuals, 2876 and 11 respectively. Other sites with low species numbers and abundance included the Irish Sea Buoy, Dundrum Bay and the North Antrim Coast (Region 5). The fauna at Strangford Lough is dominated by the porcelain crab *Pisidia longicornis*, associated with extensive beds of horse mussel, *Modiolus modiolus*. The dominant species at the Ribble site was a crustacean, *Haustorius arenarius*, which prefers mobile sand.

The Shannon Wiener diversity index ranges from 0.93 at the Ribble to 3.11 at Cloch in the Clyde (Region 5), a deepwater site with mixed sediment. The highest evenness, 0.95, is at Dundrum Bay. The lowest evenness of 0.45 off Humber/Wash (Region 2) relates to the dominance of the brittle star, *Amphiura filiformis*, accounting for 75% of the total abundance, but this site also has the highest ITI of 88.69, suggesting that it was not degraded. The lowest ITI, 7.5, recorded at an intertidal site, Budle Bay (Region 4), reflects the dominance of sub-surface deposit feeders ('opportunist species'), including the annelid worms *Capitella* species and *Tubificoides* species - indicating a degraded community impacted by organic enrichment. This site has the highest AZTI biotic index (5.68) because of the presence of these pollution tolerant species.

Estuarine Sites

The number of species varys from 2 at Purton in the Severn (Region 4) to over 60 at Tamar and Poole Harbour (Region 4). The highest abundance at Poole Harbour was over 100,000 invertebrates per 0.1 m^2. Abundance exceeds 10,000 individuals per 0.1 m^2 at sites in the Tweed, Tyne (Region 1).

Humber, Medway and Tamar estuaries. The macrofaunal communities at these sites were dominated by annelid worms including oligochaetes and the polychaetes *Capitella* species, *Manayunkia aestuarina* and *Aphelochaeta marioni*. These taxa indicate highly stressed estuarine environments with low salinities and some organic enrichment. Diversity and evenness indices range from 0.03 at Purton in the Severn to 2.22 at Warren Point in the Tamar and from 0.05 at Purton in the Severn to 1.90 in the Mersey respectively. Low diversity and evenness at Purton relate to the dominance of crustacean *Bathyporeia* species, 99.4% of the population. Comparatively high ITI and low AMBI at this site suggest that, despite the dominance of *Bathyporeia*, this community is natural rather than impacted.

Although both estuarine and coastal sites exhibit a wide range of AMBI, estuarine sites generally had higher AMBI, suggesting more stress either natural from salinity change or from contaminants or both.

Spearman Rank correlation analysis found significant correlations between the estuarine macrofauna data and sediment parameters but none with contaminant levels.

CONCLUSIONS/DISCUSSION

The data (collected in 2000) shows clearly the differences between estuarine and coastal sites. Estuarine sites had larger populations but lower diversity. The sieving of coastal samples with a 1 mm mesh and of estuarine samples with 0.5 mm mesh may account, in part, for the higher abundances seen in estuarine samples. Estuarine sites have lower ITI results than coastal ones, suggesting a community bias towards surface deposit feeders in estuaries and a larger proportion of surface-detrital or water column feeders at coastal sites. However, although the ITI was developed to distinguish the impact of organic sewage deposits on fully marine fauna, high riverine organic input to estuaries depresses ITI values naturally. Lower estuarine ITI values therefore do not necessarily indicate degraded communities.

Detailed examination of the coastal data showed that univariate measures vary widely. Sites with low diversity tend to occur in areas of coarse sediment such as Morecambe Bay (Region 5) and off the Humber/Wash (Region 2) or in very fine homogeneous sediment such as the north-western Irish Sea and Loch Linnhe (Region 5). The lack of correlation between macrofaunal patterns and sediment contaminants reflects the relatively uncontaminated character of the coastal sites.

The estuarine data suggested that sites with greater diversity, evenness and ITI are in areas with small salinity gradients, low sediment mobility and low organic enrichment. In contrast, high biotic index scores at sites with high abundance of opportunist species indicate modified or heavily modified benthic communities. Spearman rank correlation show that sediment particle size characteristics exert more influence on the macrofaunal communities than contaminants.

Many of the measures used above to provide a measure of the health of seabed communities are presently subject to ongoing research effort aimed at improving their sensitivity.

A joint project (CEFAS, FRS and The Senckenberg Institute, Germany) is currently underway to look at the benthic ecology of the western North Sea. During 2000-2002, 91 stations were sampled for benthic macrofauna and sediments (Figure 3.49). CEFAS work involved the re-sampling of stations off the English east coast occupied in 1986 as part of the ICES North Sea Benthos Survey (Kunitzer *et al*., 1992). Samples at five of these stations were kindly contributed by the Senckenberg Institute. FRS work involved stratified random sampling of the northern and eastern North Sea as part of an EU project (MAFCONS).

Defra is sponsoring the work-up of these samples and the interpretation of the data, as a contribution both to the UK 'State of the Seas' report and to an international collaborative initiative to re-appraise the status of the North Sea benthos following an earlier (1986) survey, under ICES auspices. A full account of the findings will be available on the Defra web-site in December 2004.

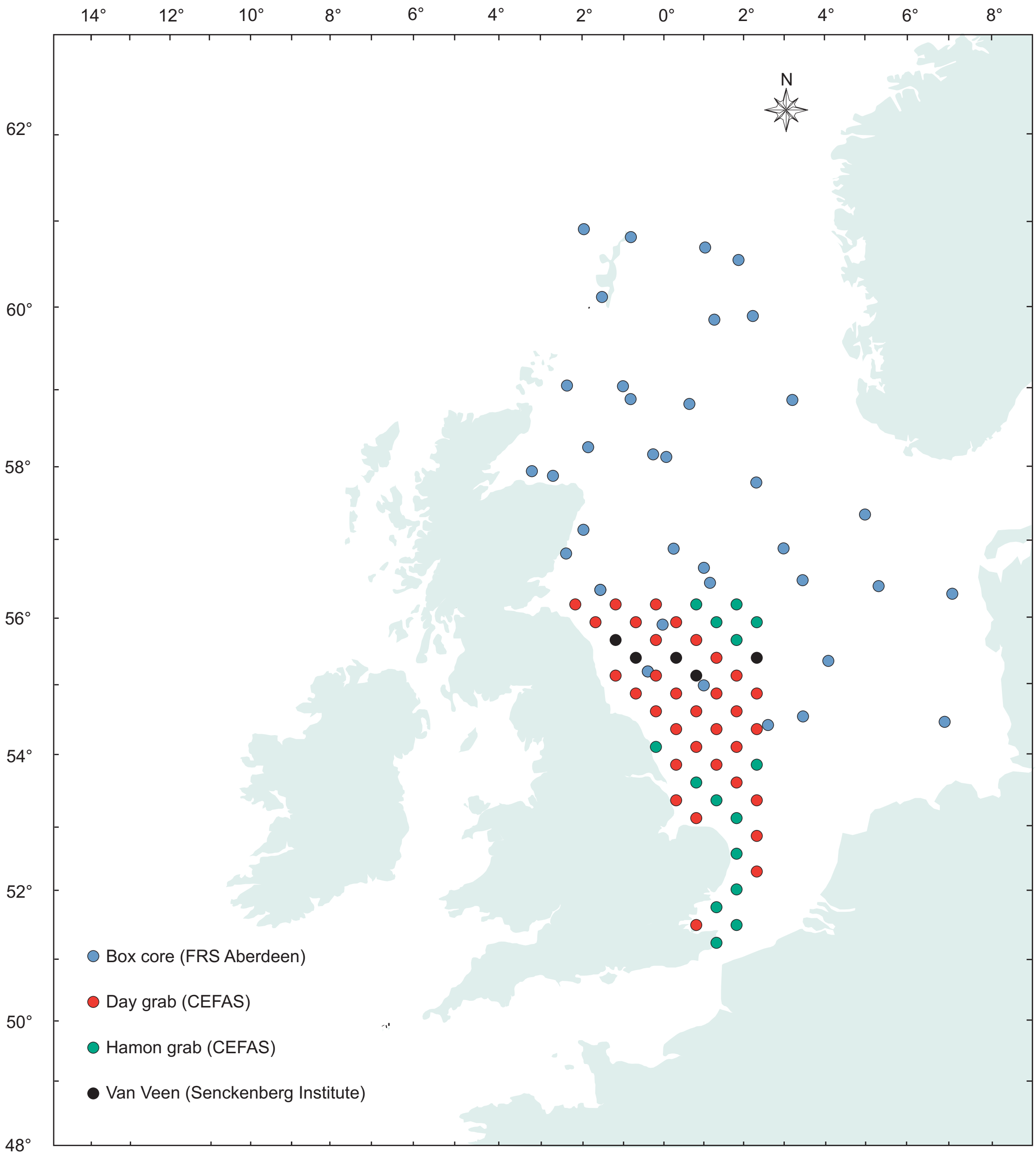

Figure 3.49. Locations of stations, principally in the western North Sea, sampled in the period 2000-2002

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4. Microbiological monitoring of the UK marine environment

KEY POINTS

Bathing Waters:

- **In 2003, 98% of UK identified bathing waters met the mandatory standards and 74% met guideline standards, an increase in compliance of 21% and 45% respectively, since 1990. This largely reflects investment in improvements in sewage treatment and infrastructure.**

- **Continuing failures of bathing water mandatory standards are seen at a small number of sites in Region 1 (Flamborough North Landing and Staithes - Yorkshire), Region 4 (Blue Anchor West - Somerset and East Looe - Cornwall) and Region 5 (Heysham Half Moon Bay - Lancashire, LLangrannog - Wales, Brigh House and Rockcliffe - Solway and Ethricke Bay - Bute).**

Shellfish Harvesting areas:

- **In 2003, in England and Wales, 85% of shellfish beds achieved B classification or above, an increase from 71% in 1999 and a positive move towards meeting the Government's objective. In Scotland and Northern Ireland, the figures were 98% and 100% respectively.**

Shellfish Waters:

- **The available data and standards for shellfish waters are not consistent throughout the UK making comparisons difficult.**

INTRODUCTION

There are three national microbiological monitoring programmes undertaken in the UK marine environment. These are related to the requirements of the Bathing Waters Directive, Shellfish Waters Directive and Shellfish Hygiene Directive. Each programme is organised separately for England & Wales, Scotland and Northern Ireland. The monitoring for the Bathing Waters and Shellfish Waters Directive is undertaken by the Environment Agency in England and Wales, the Scottish Environment Protection Agency in Scotland and the Environment and Heritage Service in Northern Ireland. The monitoring for the Shellfish Hygiene Directive is the responsibility of the Food Standards Agency. Standards are based on the concentration of faecal indicator bacteria in seawater or shellfish. These indicator bacteria have long been used to show the extent of contamination with faecal material, derived from human or animal sources. Historically, the principal sources of contamination demonstrated by the programmes have been continuous sewage discharges, but, as these have been improved, contamination due to intermittent discharges such as combined sewer overflows, and to land run-off (diffuse sources) has become relatively more important. Some areas of the UK, e.g. parts of Scotland, have not been subject to significant sources of human sewage contamination and the bacteria seen in the monitoring programmes are thought likely to derive from agricultural and other animal sources. Due to the filter-feeding behaviour of bivalve molluscan shellfish, microbiological and other contaminants may be found in concentrations many times greater than those in the surrounding seawater. It is now well documented that the consumption of shellfish exposed to sewage contamination may result in illness in humans. Currently, the small numbers of shellfish-related illness reported annually in the UK are due to Noroviruses which cause acute diarrhoea and vomiting.

Good quality bathing waters provide additional potential for growth in tourism and thus have a beneficial effect on local and regional economies. Good quality shellfisheries reduce the likelihood of illness resulting from shellfish consumption and are essential to the maintenance and growth of the shellfish industry.

4.1 MONITORING OF BATHING WATERS UNDER DIRECTIVE 76/160/EEC

The EC Bathing Waters Directive (BWD): 76/160/EEC) requires the identification and monitoring of bathing waters. The purpose of the Directive is to protect the environment and to improve the public health protection of bathers.

Bathing waters are defined as all running or still fresh waters or parts thereof and sea water, in which:

- bathing is explicitly authorized by the competent authorities of each Member State, or
- bathing is not prohibited and is traditionally practised by a large number of bathers;

and bathing season means the period during which a large number of bathers can be expected, in the light of local custom, and any local rules which may exist concerning bathing and weather conditions.

Some of the monitoring requirements relate to microbiology and these are summarised in Table 4.1 (European Economic Community, 1974). The Directive requires Member States to comply with the mandatory standards, whilst endeavouring to observe guideline standards, but not to take short-term action to protect bathers' health. Local authorities may post notices to inform the public of the results of testing.

In England and Wales, identification and monitoring is undertaken by the EA, in Scotland by SEPA and in Northern Ireland by EHS. Samples are taken at fixed monitoring points approximately weekly from May to September (June to September in Scotland and Northern Ireland). Samples are normally taken in 1 m of water and 30 cm below the surface and tested by standard methods (Standing Committee of Analysts, 2000).

Table 4.1. Microbiological standards under the Bathing Waters Directive

Parameter	G	Statistic	I	Statistic	Minimum sampling frequency
Total coliforms/100 ml	500	80% samples	10 000	95% samples	Fortnightly(1)
Faecal coliforms/100 ml	100	80% samples	2 000	95% samples	Fortnightly(1)
Faecal streptococci/100 ml	100	90% samples	-		(2)
Salmonella/1 l	-		0		(2)
Entero viruses PFU/10 l	-		0		(2)

G = guide, I = mandatory
(1) When a sampling taken in previous years produced results which are appreciably better than those in this Annex and when no new factor likely to lower the quality of the water has appeared, the competent authorities may reduce the sampling frequency by a factor of 2.
(2) Concentration to be checked by the competent authorities when an inspection in the bathing area shows that the substance may be present or that the quality of the water has deteriorated.
(3) These parameters must be checked by the competent authorities when there is a tendency towards eutrophication of the water.

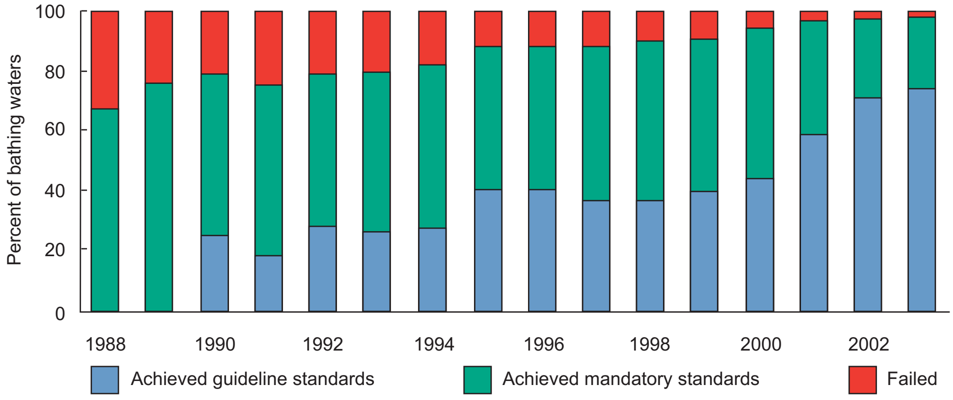

Figure 4.1. Bathing water compliance in England and Wales, 1988 to 2003 (source: Environment Agency)

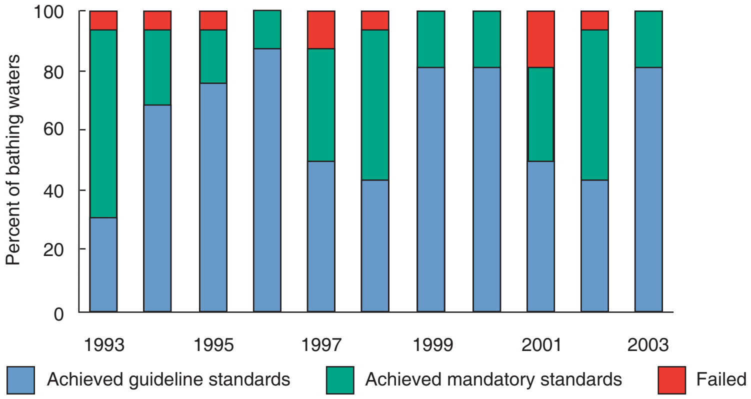

Figure 4.2. Bathing water compliance in Northern Ireland, 1993 to 2003

Bathing water status in the UK

Over all four countries of the UK there were 565 identified bathing waters in 2003, the vast majority (554) of which were coastal. Of the 565 waters sampled, 556 (98.4%) met the mandatory standards and 419 (74.2%) met guideline standards. This compares with 77.4% compliance with mandatory standards and 26.7% compliance with guideline standards seen in 1990.

Bathing water status in England and Wales

There were 489 bathing waters identified under the Directive in 2003. Of the 489 waters sampled during 2003, 483 (98.8%) complied with the mandatory standards and 367 (75.1%) with guideline standards. This compares to values of 78.1% and 25.1% compliance respectively in 1990 and largely reflects the investment in sewage improvements over the AMP1 (1990-1995) and AMP2 (1995-2000) investment programmes with many of the schemes targeted at meeting bathing water compliance (Figure 4.1).

Bathing water status in Scotland

There were 60 identified bathing waters in 2003. Of these, 57 (95.0%) complied with mandatory standards and 39 (65%) with guideline standards. This compared with figures of 69.6% and 26.1% for 1990.

Bathing water status in Northern Ireland

There were 16 identified bathing waters in 2003. Of these, all (100%) met the mandatory standards and 13 (81.3%) met the guideline standards. This compares to values of 93.8% and 68.8% in 1990 (Figure 4.2).

Regional considerations
Continuing failures of the mandatory standard are seen at a small number of sites in Regions 1, 4 and 5.

DISCUSSIONS

There have been ongoing discussions within the EU with regard to revision of the Bathing Waters Directive. Considerations have included tighter microbiological standards and more active management of bathing areas. The discussions have not yet resulted in agreed changes to the legislation, but any significant tightening of standards will obviously lead to more beach failures and a reduction in compliance rate compared with the 2003 figures given.

With respect to the current legislation, there will be a need to review the progress made in mandatory and guideline compliance subsequent to planned sewage improvements. Further improvement to bathing water quality may necessitate control of diffuse inputs and it would be valuable for this to be taken forward in concert with controlling their impact on shellfisheries (both from a shellfish hygiene and shellfish waters perspective).

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Standing Committee of Analysts (2000). The Microbiology of Recreational and Environmental Waters.

www.environment-agency.gov.uk

4.2 MONITORING OF SHELLFISH HARVESTING AREAS UNDER DIRECTIVE 91/492/EEC

The EC Shellfish Hygiene Directive (91/492/EEC) requires the classification of bivalve mollusc harvesting areas according to the levels of faecal indicator bacteria (European Communities, 1991). The purpose of this classification is to ensure that adequate shellfish processing occurs prior to consumption or that, in grossly polluted areas, shellfish are prevented from reaching the market for consumption. Harvesting areas are assigned to one of three categories, classes A, B or C. The level of pollution to which the shellfish have been exposed is determined by monitoring the concentration of faecal coliforms and/or *E. coli* in the shellfish flesh and intravalvular liquid. The criteria for the classes are given in Table 4.2. This table also lists the subsequent treatment to which shellfish of each class must be subjected. Areas considered unsuitable for the harvesting of bivalve molluscs (or bivalve molluscs and other shellfish) may be designated as Prohibited; this will include those areas which yield microbiological results exceeding the upper limit for class C. Fishing from a classified area may also be controlled in an emergency through the use of a temporary prohibition order. The rationale and approach to the classification monitoring programme for England and Wales has been described by Younger, *et al.* (2003) and procedures relevant to Scotland can be found on the FSA Scotland website at www.food.gov.uk/foodindustry/shellfish/shellharvestareas/shellclassscot.

Standard criteria are specified for sampling and sample transport. A standard test method is defined for the testing of shellfish for *E. coli* for classification purposes in the United Kingdom (Donovan, *et al*. 1998). The testing laboratories also have to be accredited by the United Kingdom Accreditation Service and participate in an External Quality Assurance scheme run by the Health Protection Agency.

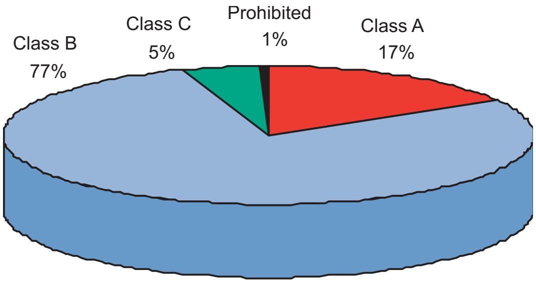

Figure 4.3. Percentage of UK shellfish harvesting areas in each class under the Shellfish Hygiene Directive

The data from the monitoring programme is reviewed on an ongoing basis and formal updates issued annually. The classification status of a shellfish bed may also be reviewed at other times if the data warrants.

The Government has expressed an objective of achieving at least class B standard in all areas which are designated under the Shellfish Waters Directive. Thus the classification status of harvesting areas has been acknowledged as an environmental indicator. However, it needs to be recognised that the relationship between water quality and shellfish quality is complex and that different shellfish species growing in the same body of water will concentrate faecal indicator bacteria to different extents (Lees and Nicholson, 1995).

In the following summaries, individual shellfish beds/sites have been counted once if different species have been given the same class but, if the different species have been assigned to different classes, each class has been included.

Table 4.2. Classification categories under the Shellfish Hygiene Directive

Class	Criteria	Requirements
A	<300 faecal coliforms or 230 *E. coli* per 100 g	Can be collected for direct human consumption
B	90% compliance with 6000 faecal coliforms or 4600 *E. coli* per 100 g	Must be purified or relayed to meet class A; may also be heat-treated by an approved method
C	<60,000 faecal coliforms per 100 g	Must be relayed for a long period (at least 2 months) to meet class A or B; may also be heat-treated by an approved method

Classification status in England and Wales
There are currently 78 classified production areas in England and Wales covering 249 beds or groups of beds. The production areas are indicated in Figure 4.4.

The percentages of the beds or groups of beds in each category are given below for the years 1999 and 2003.

	1999	2003
Class A:	5%	4%
Class B:	69%	81%
Class C:	23%	13%
Prohibited:	3%	2%

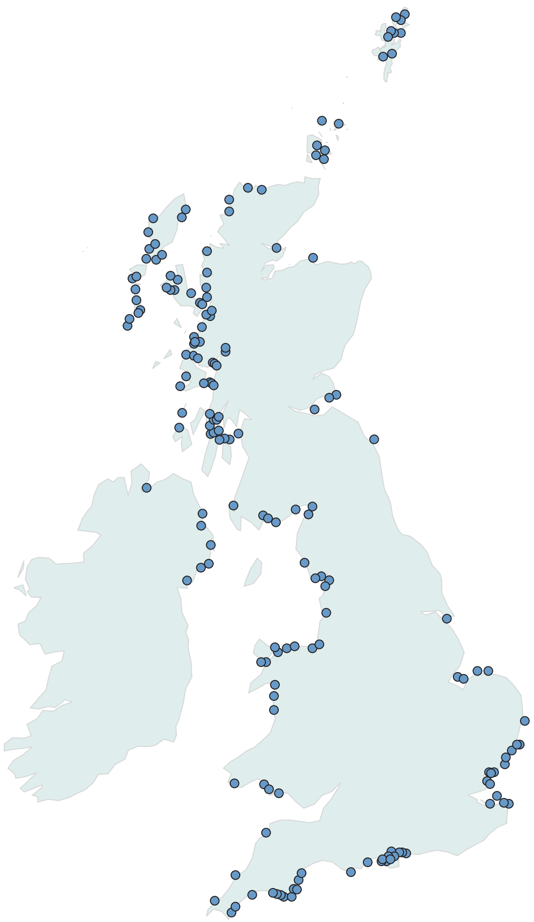

Figure 4.4. Classified bivalve mollusc production areas in the UK

There has been a general increase in the percentage of shellfish beds classified as B. These improvements have generally been associated with the completion of AMP2 sewage schemes and the impact of AMP3 schemes on the classifications is still awaited.

Classification status in Scotland
In the 2003 listing, there were 141 classified production areas covering 160 separately classified harvesting sites. The percentage of classified sites in each group category for 1999 and 2003 were:

	1999	2003
Class A:	38%	29%
Class B:	55%	68%
Class C:	7%	3%

In 2001, The Food Standards Agency Scotland assumed the role as the competent authority from the Scottish Executive Rural Affairs Department with subsequent changes being made to the way the classifications were undertaken. This may have affected the percentages in each class between dates. There are a higher proportion of sites with differential seasonal classifications (e.g. class A part of the year, class B the rest of the year) in Scotland than in England and Wales. In the 2003 classification listings the seasonal classifications were 61% in Scotland and 3% in England and Wales . In order to provide some consistency for comparison, seasonal classifications have been included at the worse of the two classification levels as this would normally be the category that would apply for a year round classification in the absence of a seasonal split. Irrespective of this, it can be seen that the microbiological quality in Scottish shellfish production areas is generally better than in England and Wales, reflecting the lower density of population, and thus fewer significant sewage discharges, in the surrounding catchments. It is thought that diffuse inputs contribute to the lower seasonal classifications.

Classification status in Northern Ireland
In the 2003 listing, there were 7 classified production areas covering 29 separately classified harvesting sites. The percentage of classified sites in each group category were:

Class A: 17%
Class B: 83%

None of the sites was classified on a seasonal basis.

Regional considerations

In general, the extent of microbiological contamination of shellfisheries, as revealed by the classification status, tends to be worse in England and Wales than in Scotland and Northern Ireland. Within England and Wales, a greater proportion of class C and prohibited areas occur in Regions 4 & 5. In Scotland, the class C areas are associated with the concentrations of population, and associated sewage inputs, in the Firth of Forth area on the East Coast (Region 1) and the Inverclyde region on the West Coast.(Region 5).

DISCUSSION

A large number of changes to sewage discharges are being undertaken in the vicinity of shellfisheries with the aim of reducing contamination. There is a need to review the impact of these changes, in order to determine whether the intended improvements have ensued, and to determine whether additional works are necessary. A review of, and probably improvements to, diffuse inputs impacting on shellfish harvesting areas may also be required.

Looking forward to possible changes to the public health controls on shellfisheries within Europe, it would be valuable to undertake baseline monitoring of UK shellfish production areas for putative viral indicators and pathogenic viruses.

This would be labour intensive and may be difficult to carry out routinely, which may eventually be what is required.

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Younger, A.D., Lee, R.J and Lees, D.N. (2003). Microbiological monitoring of bivalve mollusc harvesting areas in England and Wales - rationale and approach. In: Villalba A, Reguera B, Romalde JL and Beiras R (Eds). Molluscan Shellfish Safety. Consellería de Pesca e Asuntos Marítimos da Xunta de Galicia and Intergovernmental Oceanographic Commission of UNESCO pp 265-277.

4.3 MONITORING OF DESIGNATED SHELLFISH WATERS UNDER DIRECTIVE 79/923/EEC

The Shellfish Waters Directive (SWD); (79/923/EEC) is intended to protect or improve shellfish waters in order to support shellfish life and growth and thus contribute to the high quality of shellfish products directly edible by man. Shellfish in the context of the Directive covers both bivalve molluscs and gastropods, but not crustacea such as crabs and lobsters. The Directive sets out physical, chemical and microbiological water quality requirements with which designated shellfish waters must either comply or endeavour to meet. The Annex of the Shellfish Waters Directive includes a “Guideline” standard for faecal coliforms in shellfish flesh of 300 per 100ml of flesh and intravalvular liquid in 75% of samples. This is broadly similar to, but slightly laxer than, the requirements for class A under the Shellfish Hygiene Directive. The minimum sampling frequency specified in the Directive is quarterly. There are no microbiological standards for the water column itself in the SWD. However, in the UK, data is collected on the concentration of faecal coliforms in the water column in order to provide a comparison with sewage discharge design criteria. In the UK, there are currently 232 designated shellfish waters covering more than 4000 km^2.

The shellfish waters designations are kept under review in order to determine whether any additional areas need to be designated. A significant number of sewage improvement schemes have been identified to improve the designated waters, with the intention of meeting Government aspirations, to achieve at least class B under the Shellfish Hygiene Directive. This objective led to the definition of a design criterion of 75% compliance with 300 faecal coliforms/100ml of seawater. In Scotland, design criteria for proposed sewage discharges has been set at a lower level, 90% compliance with 100 faecal coliforms/100ml of seawater and this should result in compliance with the SWD guideline faecal coliform standard in shellfish flesh.

UK guideline compliance

Comprehensive monitoring data for faecal coliforms in shellfish flesh was only available to the drafting team with respect to Scotland. No evaluation could therefore be undertaken with respect to the guideline value in the SWD for England, Wales or Northern Ireland. In lieu of this, data on the concentration of faecal coliforms in seawater for these other parts of the UK were analysed with respect to a sewage scheme design objective identified in England and Wales.

England and Wales

Only very limited shellfish flesh faecal coliform data were available to the drafting team.

From 1999 there have been 119 designated shellfish waters in England and Wales. The number of shellfish waters sampled for faecal coliforms in the water column in each year from 1999 to 2002 inclusive are presented in Table 4.3, together with the number of samples failing to meet the guideline standard of 300/100ml are given below. The objective relates to presumed compliance with class B in shellfish flesh under the Shellfish Waters Directive.

Table 4.3. Number of waters failing the guideline standard

Year	Total number of sites sampled	Number failed	Percentage failed
1999	92	8	9%
2000	117	21	18%
2001	119	6	5%
2002	118	19	16%
Grand Total	446	54	12%

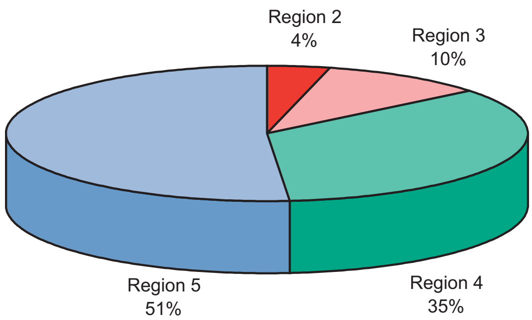

Figure 4.5. Percentage of English and Welsh designated waters in the Regional Seas failing the 300 faecal coliforms/100 ml seawater guideline standard from 1999-2002

Scotland

There are currently 104 designated shellfish waters in Scotland. A number of new designations had been made in 2000 and 2002.

The compliance with the guideline standard in the Directive is shown in Table 4.4.

Monitoring for faecal coliforms in seawater is not undertaken in Scotland in relation to designated shellfish waters.

Table 4.4. Compliance of Designated Shellfish Waters in Scotland with the guideline standard

Year	Total number of sites sampled*	Number failed	Percentage failed
1999	46	18	39%
2000	46	16	35%
2001	35	15	43%
2002	46	37	80%
Grand Total	173	86	50%

* This was the number of designated sites for which compliance could be determined based on the criteria in the Directive

Northern Ireland

There are currently 9 designated shellfish waters in Northern Ireland. Eight of these were monitored for faecal coliforms in the water column at a total of 31 sites in 2000 and 2001. In 2000 and 2001, a total of 124 samples were taken with none of the sites failing the 300/100 ml guideline standard for faecal coliforms.

Regional considerations

Over the four-year period from 1999 to 2002, the percentage of sites failing the 300/100ml guideline standard was highest in Regions 4 and 5 (see Figure 4.4). However, the percentage of failing sites fluctuated markedly by year.

There is only 1 English designated shellfish water in Region 1. This complied with the objective in all of the four years and has therefore been omitted from the figure. The Scottish designated waters which failed the guideline standard were located in areas 1 and 6. However, it should be stressed that the water quality required to meet this standard is much higher than the design objective against which the water monitoring results from the other constituent countries were assessed.

DISCUSSION

It is expected that the number of designated shellfish waters complying with the guideline standard should increase as sewage improvement schemes are implemented in the investment period to 2005. There is a need to review the effect of these schemes once they have been commissioned. Diffuse sources of contamination may need to be considered in order to obtain consolidation of the improvements, and to move towards further reductions in contamination of designated shellfish waters.

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European Communities, (1979). Council Directive 79/923 of 30 October 1979 on the quality required of shellfish waters. Official Journal of the European Community, L281(1979): 47-52.

5. Oil and oil-based contaminants

KEY POINTS

- **The largest inputs of oil-based hydrocarbons to the marine environment are from land-based sources, reaching the sea via rivers, runoff and from the atmosphere. Refinery inputs to rivers have declined approximately 20-fold since 1981 and volatile emissions of PAH to the atmosphere from land-based sources have reduced by approximately a factor of 4 since 1990.**

- **The second largest (though significantly lower) source of oil discharge to the marine environment is via the offshore oil and gas industry. Although the sources have approximately halved in recent years and inputs of oil associated with drill cuttings have now ceased following controls, the volume of produced water has increased, The overall effect is that the quantity of oil entering the sea has remained fairly constant.**

- **Accidental spills of oil from shipping in the open sea and from offshore installations constitute a small proportion of overall inputs. The tonnages spilt from the two sources are generally of a similar magnitude.**

- **Preliminary monitoring studies of offshore sediments remote from the likely impact of oil installations show PAH levels to have declined by 70% from 1990-2000.**

INTRODUCTION

Oil and oil based contaminants reach the marine environment from a variety of sources the most important of which are; rivers and run off from land, atmospheric fall out, the offshore oil and gas industry and accidental spills. As a consequence, oil inputs to the regional seas around the UK differ, for instance, those from shipping are primarily along navigation routes, atmospheric inputs are mainly to the North Sea due to the prevailing westerly winds and inputs from the offshore oil industry are mainly concentrated in the northern North Sea where the major oilfields are situated. Discussion of how oil based discharges and emissions compare and how they have changed with time, would require input data for all sources expressed on the same basis to be available but, for some sources eg rivers, this is not currently the case. Accurate estimation of inputs to the marine environment from some emissions eg of those from the atmosphere, is especially problematic.

The impacts that flow from different inputs are related not only to the quantity, but also to the way in which the oil is presented eg dispersed or on the sea surface as well as to their composition ie chemical type and structure. Animals which live on the sea surface or which have to break the sea surface to breathe or feed are most vulnerable to spilt oil. Animals which live in the water column or on the seabed are more susceptible to dispersed oil. Polycyclic aromatic hydrocarbons (PAH) are of particular concern due to their persistence, tendency to bio-accumulate, toxicity and mutagenic potential and are considered separately in this report (pages 66-67).Other substances that make up oil are more easily degraded and result in more transient effects.

The principal sources of oil and oil-based contaminants to the marine environment are discussed in more detail below.

LAND-BASED DISCHARGES

Although no comprehensive recent mass estimates have been located, it is thought likely that the greatest single input of oil based hydrocabons originates on land and is carried to sea by rivers, run off and the atmosphere. The major proportion is PAHs of pyrolitic origin, and petrogenic hydrocarbons are in the minority. Particular attention has been focussed on the control of refinery discharges to sea via rivers. Since 1981, the tonnages discharged by this route have fallen approximately 20 fold, from 6,900 tonnes to 330 tonnes per annum. As a consequence of past riverine, atmospheric and vessel related discharges, hydrocarbon contamination of sediments is greatest in nearshore and estuarine environments. Contamination of sediments in the wider marine environment is mostly thought to result from atmospheric inputs originating on land, from shipping and from discharges from the offshore oil and gas industry. The estimated discharge of atmospheric PAH loads and their change in time in the last ten years (Figure 5.1) shows that discharge levels have fallen approximately four fold in the last ten years, from ca 8,000 to ca 2,000 tonnes per annum.

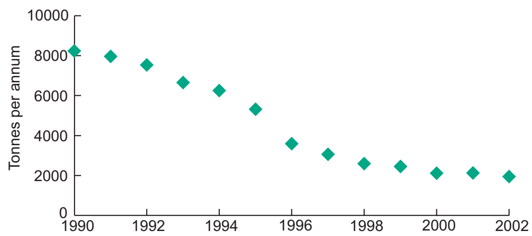

Figure 5.1. Volatile PAH emissions to the atmosphere

OIL AND GAS DISCHARGES

After land-based sources to rivers and the atmosphere, the next largest (although significantly lower) contributor to oil contamination of the marine environment is probably the offshore oil and gas industry. Oily discharges have historically been made to sea during offshore production via four routes; on drill cuttings, in produced water (PW), via flaring and from accidental spillages.

The trend in oil inputs from cuttings and PW discharges is illustrated in Figure 5.2. The banning of oil based mud contaminated cuttings discharges eventually lead to this source ending in 2001. In the last 10 years, the amount of PW discharged by UK industry has doubled to ca 270 million tonnes per year. Over the same period, however, and due to considerable commitment from UK industry, the average level of oil in PW has been reduced from ca 35 parts per million (ppm) to 21 ppm, much lower than the allowable standard over the period of 40 ppm. This has meant that the overall discharges of oil via the PW route have increased less than would otherwise have been the case. They now stand at ca 5,500 tonnes p.a. This oil is well dispersed and has little impact on surface dwellers. Through the auspices of OSPAR, the UK has committed its industry to a further 15% reduction of the 2000 discharge level by 2006.

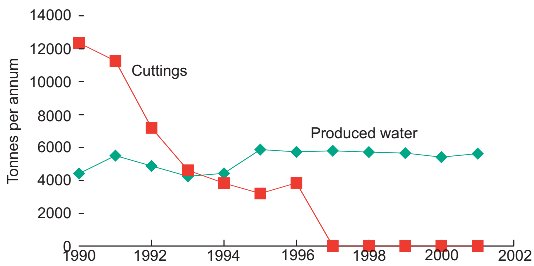

Figure 5.2. Operational oil discharges from the offshore industry

The management of cuttings piles contamination continues to be an area of oil industry focus not least in the context of decommissioning (see UKOOA JIP reports and the outcome of Phase III due at the end of 2004). Current indications are that there is little contaminant release from some piles and the best environment option may be to leave them in place. Alternative management options have been identified for other piles. Industry and government funded research to improve our understanding of PW effects is also continuing.

Historically, cuttings and PW discharges have contributed the greatest input. Flaring practice has continually improved and has been minimised to that which is operationally essential. The amounts of oil discharged to sea via the flaring route are minor (ca 10-15 tonnes p.a.). Reporting of spills is mandatory and the spill record of the UK industry is good. The number of spills reported has risen in recent years probably as a result of the comprehensive introduction of improved Environmental Management Systems.

Although spills are not infrequent (ca 300 - 400 p.a.) the average amount spilt is small. The overall amount of oil spilt is usually less than 100 tonnes p.a (Figure 5.3).

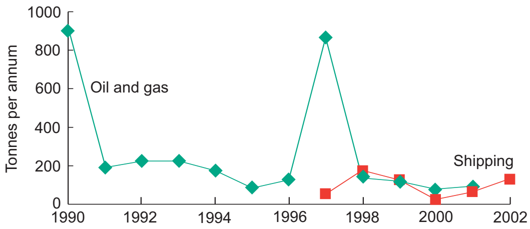

Figure 5.3. Oil spills from offshore installations and shipping in the open sea

SHIPPING DISCHARGES

Deliberate discharges of oil or oil/water mixtures from ships are prohibited within the North West European Waters Special Area, established by IMO in 1999 under MARPOL annex 1. This includes all the waters around the UK and its approaches. Information on accidental discharges from ships is compiled by the Advisory Committee on Protection of the Sea (ACOPS). In 2002, 703 discharges were identified from vessels and offshore installations. This represented a 3.7% increase on the same figures for 2001. The overall geographical distribution of oil discharges was similar to that seen in previous years and is mostly concentrated along navigation routes. Clusters of discharges were seen off the Norfolk and Suffolk coasts, in the Dover Strait and its approaches, in mid-Channel, off south Cornwall, and in the eastern Irish Sea and the North Channel (Figure 5.4 shows the information for 2001).

Two large scale spillages associated with vessel accidents in British waters have occurred in the last decade. The *Braer* grounding off the southern tip of Shetland in January 1993 led to the release of ca 85,000 tonnes of North Sea crude. As a consequence of the light nature of the oil and the extreme weather conditions at the time of grounding a conventional slick did not form and almost no oil was stranded on the shoreline. Thorough mixing of the oil into the water column in the turbulent conditions and the prevailing currents carried oil to the north and west towards Burra Haaf and to the south east of Fair Isle. At both locations, oil became deposited in sediments but without apparent toxic effect on benthic animals. Particular environmental and societal concern was associated with the contamination of those farmed salmon stocks in cages in the path of the spill (primarily the south-west coast) but direct mortalities were very slight. Salmon destined for market were culled under an agreed compensation scheme in order to preserve consumer confidence. Polycyclic aromatic hydrocarbons (PAH) were detected in some fish and shellfish (molluscs and crustaceans) particularly from the south-west coast (Topping et al 1997). In some cases e.g. wild fish, PAH concentrations rapidly returned to those for reference fish (<40 ng/g wet weight muscle). PAH concentrations in shellfish remained above those found in reference material for prolonged periods (Webster *et al*., 1997), especially when the shellfish (*Nephrops*) were obtained from an area of sediment deposition such as the Burra Haaf. Restrictions on the sale of *Nephrops* and mussels (*Mytilus edulis*) were not lifted until the first half of 2000. Ultimately, it was concluded that in all areas of concern, except for the rate of degradation of small areas of oil that remain in the fine sediments in deeper water to the west and south of Shetland, the long-term impact was minimal.

The *Sea Empress* grounded in the entrance to Milford Haven in West Wales in February 1996, losing 72,000 tonnes of Forties crude oil and 480 tonnes of heavy fuel oil. Despite a rapid response at sea in which 445 tonnes of oil dispersants were used, oil came ashore along 200 km of coastline. A ban was imposed on commercial and recreational fishing in the region, which is an area of international importance for its wildlife and natural beauty, and there was concern that tourism would be badly affected with an impact on the local economy. A massive shoreline operation managed to clean the main amenity beaches sufficiently for use during the Easter holiday period, and the ban on taking fish was lifted in May. Within 18 months of the spill, all restrictions on shellfisheries were also removed. Overall, the impact of the spill was much less than was to be expected from the quantity of oil spilt, largely as a result of the effective use of dispersants to treat freshly released oil (SEEEC, 1998).

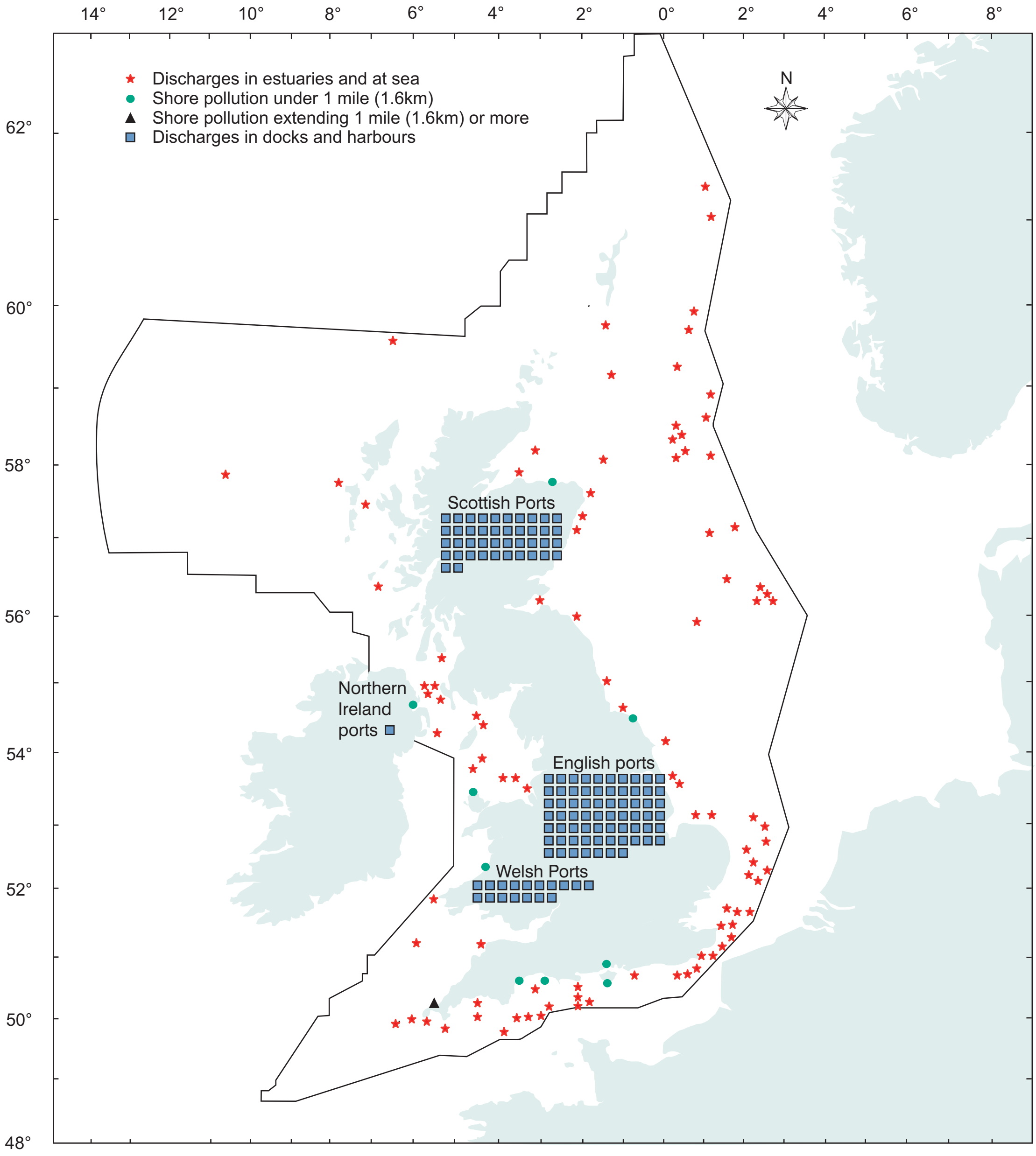

Figure 5.4. Locations of reported oil discharges attributed to vessels. Note: Data provided by ACOPS is the number of spills. These have been converted to estimates of quantity (for 6 years only) so that meaningful comparisons can be made between discharges of oil from ships and from other sources

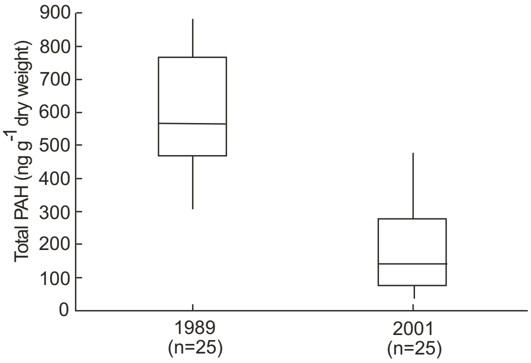

Figure 5.5. Boxplot of total PAH (ng g^{-1} dry weight) in Fladen ground sediments in 1989 and 2001 at 25 common sites

OTHER DISCHARGES

Small quantities of oil also reach the marine environment from dredge material inputs, from sewage and from natural seepage. Dredged material is routinely screened for its organic contaminant burdens prior to disposal, a practice which serves to minimise inputs. Sewage related discharges of oil, although never very great, have also decreased in the last decade as a result of the cessation of sewage sludge dumping at sea from 1998 and due to implementation of improved controls to comply with the Urban Waste Water Treatment Directive. Natural seepage was estimated as being less than 1 tonne per year in the 1993 OSPAR Quality Status Report.

MONITORING OF OIL BASED CONTAMINATION

The UK NMMP routinely analyses sediments from dedicated sites for their PAH burdens. Time series collection in estuaries e.g. the Clyde has begun but these have not been running long enough for trends to be evident. PAH burdens in biota are also monitored through the auspices of the Food Standards Agency.

Past monitoring of sediment hydrocarbon contamination related to oil industry discharges concentrated on the near field effects of cuttings piles discharges at the major drill sites. A pattern of very high concentrations in the immediate location (100 - 200 metres from the installation) of discharges with a transitional zone of decreasing contamination towards near background levels beyond that out to a distance of 1-2 km was typically observed. (for review see Kingston *et al.* report to UKOOA). More recent monitoring, mostly connected with decommissioning programmes, has shown that hydrocarbon contamination levels in the transitional zone are falling.

Increasing attention is now being directed towards detecting more subtle changes in contamination patterns in the wider marine environment of the North Sea. This will hopefully show whether contamination is decreasing with time (e.g. because OBM cuttings discharges have ceased) or increasing with time (e.g. because produced water discharges and overall atmospheric discharges are continuing).

A grid type survey of the Fladen ground, a potentially accumulative area of the central North Sea, was first conducted by FRS in 1989 and was repeated in 2001 (Russell *et al.*, 2005). PAH levels in sediments decreased by some 70% in the period (Figure 5.5). This reduction in PAH may have arisen from a decrease in petrogenic PAH input due to the cessation of OBM discharges on cuttings and improvements to PW controls. Most of the PAH burden seen in 2001 was of pyrogenic origin and could have resulted via atmospheric input from either oil and gas installations or all land based industrial and domestic sources. Further refinements of wider field monitoring are in progress including a move to random stratified surveys. To date these have been conducted in the Fladen and East Shetlands Basin areas of the North Sea and will hopefully form a basis against which future changes in oil contamination over time, can be assessed.

OSPAR has discussed the desirability of having a metric for the impacts of oil spilt in the marine environment and have defined an Ecological Quality Objective (EcoQO) regarding the proportion of oiled common guillemots among those found dead or dying on beaches. The proportion of such birds should be 10% or less of the total found dead or dying, in all areas of the North Sea. Implementation of this EcoQO is the subject of continuing discussion.

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6. Radioactivity

KEY POINTS

- **Discharges of radionuclides from Sellafield have decreased significantly since the 1970s, as a result of various measures. In most cases current discharges are at least 100 times lower than peak discharges in the 1970s.**

- **Discharges of technetium-99 from Sellafield rose significantly in 1994, peaking in 1995. Following the installation of the Enhanced Actinide Removal Plant (EARP), levels have subsequently declined. The successful plant-scale trial of a novel treatment to reduce 99Tc discharges further (using tetraphenylphosphonium bromide, TPP), announced in April 2004, means that discharge reductions below 10 TBq a^{-1} will take place 2 years ahead of schedule.**

- **Present concentrations of ^{137}Cs in seawater are only a small percentage of those prevailing in the late 1970s. Concentrations in the North Sea, are significantly less than those observed in the Irish Sea. Remobilisation from sediments contaminated by historical discharges is now the predominant source of ^{137}Cs and plutonium to the water column.**

- **Highest concentrations of radionuclides in sediments occur in the Eastern Irish Sea, close to the Sellafield outfall.**

- **Radionuclide concentrations in biota have fallen in response to reductions in discharges, except for technetium-99, which increased in response to increased discharges after 1994. However, recent monitoring shows levels declining in response to lower inputs.**

- **Individual radiation exposures from all authorised releases are generally low and well within international dose limits.**

- **Exposure to chronic irradiation is not believed to have had a significant effect on marine organisms, at the population level.**

INTRODUCTION

Radioactivity has both natural and anthropogenic sources. Natural radiation stems from the decay of primordial radionuclides in the earth's crust and from interactions with cosmic radiation in the atmosphere, and such radionuclides are ubiquitous in the marine environment (e.g. potassium-40 (^{40}K), ^{14}C, uranium-decay series, thorium-decay series). The anthropogenic input, which includes artificial radionuclides (e.g. plutonium isotopes), can be divided into 4 main categories: global fallout from weapons testing; nuclear accidents (e.g. Chernobyl, Komsomolets submarine); offshore dumping of liquid and solid waste (e.g. NE Atlantic, Kara Sea); and, direct discharges from industrial processes (e.g. nuclear power production, nuclear fuel production and reprocessing, production of diagnostic and pharmaceutical radio-isotopes, naval operations). In addition, naturally-occurring radionuclides can be found in enhanced concentrations both due to natural processes and as a result of industrial practises (e.g. oil and gas production, uranium mining, steel processing, phosphate processing). This is often referred to as TENORM (technologically enhanced naturally-occurring radioactive materials).

For the past 50 years direct inputs into UK coastal waters have been dominated by discharges into the eastern Irish Sea, from the fuel reprocessing plant at Sellafield. These have tended to mask the contributions of radionuclides from other sources, such as the 1986 Chernobyl accident. However, additional sources can be detected at some locations, for example, tritium (^{3}H) in the Bristol Channel from the Nycomed-Amersham radiochemical plant, Cardiff. Elsewhere, environmental levels are often difficult to distinguish from Sellafield and global fallout. All authorised releases of radioactivity are subject to regular monitoring. In all cases individual doses are well within international dose limits.

Some radionuclides are readily adsorbed onto sediment particles (e.g. plutonium, ^{241}Am) and their subsequent redistribution and behaviour is greatly influenced by sediment processes. Other radionuclides are relatively soluble in seawater and are transported in significant quantities via the North Sea and the Norwegian Coastal Current to the Arctic (e.g. ^{99}Tc, ^{129}I, ^{137}Cs).

TRENDS IN DISCHARGES FROM SELLAFIELD

Discharges and disposals from Sellafield are authorised by the environment agencies in the UK under the radioactive Substances Act 1993 (United Kingdom-Parliament, 1993). These authorised limits are reviewed periodically and details of discharges and disposals are available from public records held by environmental agencies. Discharges peaked in the 1970s, since when a number of counter measures have been introduced and the quantities of radionuclides discharged have changed markedly as a result of changes in throughput, chemical processes, storage and waste treatment. For example, the Site Ion Exchange Effluent Plant (SIXEP) was introduced in 1986 to control ^{137}Cs discharges, resulting in very considerable reductions. In 1994 the Thermal Oxide Reprocessing Plant (THORP) came into operation to allow the reprocessing of fuel from Advanced Gas-cooled (AGR) and Light Water (LWR) reactors. This resulted in modest increases in the discharge of tritium, ^{14}C, ^{60}Co, ^{90}Sr and ^{129}I.

In 1994 the Enhanced Actinide Removal Plant (EARP) was introduced. This was designed to reduce alpha and beta activity from effluents prior to discharge, and to treat Medium Active Concentrates (MAC) that had been accumulating on site as a result of the reprocessing of Highly Active Liquors. Concentrations of ^{106}Ru and the actinides (including uranium, plutonium and americium) were reduced significantly in the waste stream. However, the increased

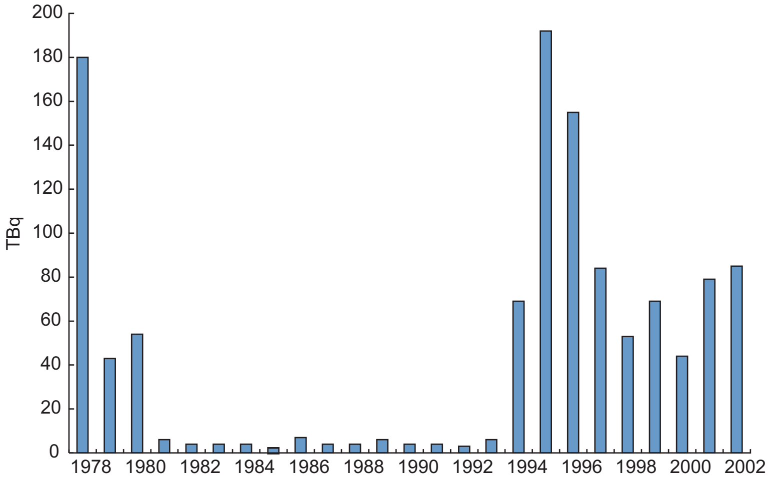

Figure 6.1. Discharges of technetium-99 from Sellafield

throughput resulting from the treatment of MAC led to increased discharges of ^{99}Tc (Figure 6.1), in contrast to the relatively low and uniform levels during the 1980s (2-7 TBq a^{-1}; authorised limit increased from 10 TBq a^{-1} to 200 TBq a^{-1} in 1994, (Hunt *et al*., 1997)). This led to higher concentrations of ^{99}Tc in UK coastal waters (Leonard *et al*., 1997) and subsequent increases throughout the North Sea. Technetium is likely to occur as the highly soluble pertechnetate form (TcO_4^-) in oxic seawater, and can be transported large distances under typical conditions in northern European waters (e.g. Aarkrog *et al*., 1987; Brown *et al.*, 2002; Kershaw *et al.*, 2004; Lindahl *et al*., 2003). The increased concentrations of ^{99}Tc in seawater, from 1994 onwards, resulted in significant but predictable increases in concentrations in biota, and consequent doses to members of the public from seafood consumption. Interest focussed on the higher levels of ^{99}Tc in lobsters, seaweed and other marine biota, and the potential socio-economic effects on the fishing industry (Defra, 2002). In response to these concerns, particularly from other European States, the authorised annual discharge limit was reduced from 200 to 90 TBq, from January 2000. It is intended to reduce this limit further to 10 TBq a^{-1} by 2006 (Defra, 2002), and to continue to investigate additional waste treatment options. This should be seen in the context of discussions between the contracting parties of the OSPAR Convention, who have agreed to an ultimate aim of reducing concentrations of artificial radioactive substances close to zero (Sintra Statement, OSPAR, 1998).

^{137}Cs DISTRIBUTION

Most recent Irish Sea ^{137}Cs data (Figure 6.2a) indicate that the concentrations observed along a large section of the British coastline, extending from Liverpool Bay to the Mull of Galloway (typically 20-100 mBq kg^{-1}), were significantly greater than those observed further south (typically 5-20 mBq kg^{-1}). The ^{137}Cs contours extend parallel to the Cumbrian coastline with some anticlockwise displacement towards the Mull of Galloway in the north and towards Liverpool Bay in the south. Comparison of ^{137}Cs concentrations in the North Channel and at the southern entrance to the northern Irish Sea shows the predominant northwards migration. The ^{137}Cs overall distribution is in line with that expected from our knowledge of mean surface water circulation in the Irish Sea (Dickson, 1987). The predominant flow of water is northward via input of Atlantic water from St. George's Channel to the west of the Isle of Man. A minor component of the flow enters the eastern Irish Sea to the north of Anglesey and moves anti-clockwise round the Isle of Man before rejoining the main flow to exit through the North Channel.

The ^{137}Cs concentrations observed here are only a small percentage of those prevailing in the late 1970s. Levels as high as 30,000 mBq kg^{-1} have been observed in the vicinity of the Sellafield outfall (Baxter *et al*., 1992) when discharges from Sellafield were substantially greater. Indeed, differences between the $^{137}Cs/^{90}Sr$ ratio in Sellafield discharges and seawater indicate that ^{137}Cs remobilisation, from sediments contaminated by large discharges in the 1970s, is presently the predominant (~90%) source term to the water column (Leonard *et al*., 1998). Results of ^{137}Cs in water from marine surveys have shown that the quantity of ^{137}Cs remobilised from the seabed, over the period 1994-1998, was in the range of 60-135 TBq $annum^{-1}$ (McCubbin *et al*., 2002).

Most recent North Sea ^{137}Cs data (Figure 6.2b) indicate that levels ranged from ~2 mBq kg^{-1} up to ~10 mBq kg^{-1} (i.e. 5 fold variation). Concentrations were, therefore, significantly less than those observed in the Irish Sea. Indeed, at some sampling sites, concentrations were only marginally elevated above the 'background' level (~2 mBq kg^{-1}) due to global fallout from atmospheric testing of nuclear weapons in the 1950s and early 1960s. These data also provide some indication that water flowing out of the Baltic Sea, as well as the Irish Sea, represents a continuing source of ^{137}Cs to the North Sea. This is because the Baltic Sea was more heavily contaminated than the North Sea by ^{137}Cs arising from the Chernobyl accident in 1986, together with the fact that the outflow from the Baltic Sea is restricted (Kershaw and Baxter, 1995).

^{3}H DISTRIBUTION

Levels of ^{3}H in the Irish Sea (Figure 6.2c) were below the limit of detection (<2 Bq kg^{-1}) for a large proportion of the survey area. However, the impact of discharges from Sellafield and the Heysham nuclear power plant was apparent along the Cumbrian and southern Scottish coastline, extending from Morecambe Bay in the south to Luce Bay in the north. Along this section ^{3}H concentrations were in the range 10-25 Bq kg^{-1}.

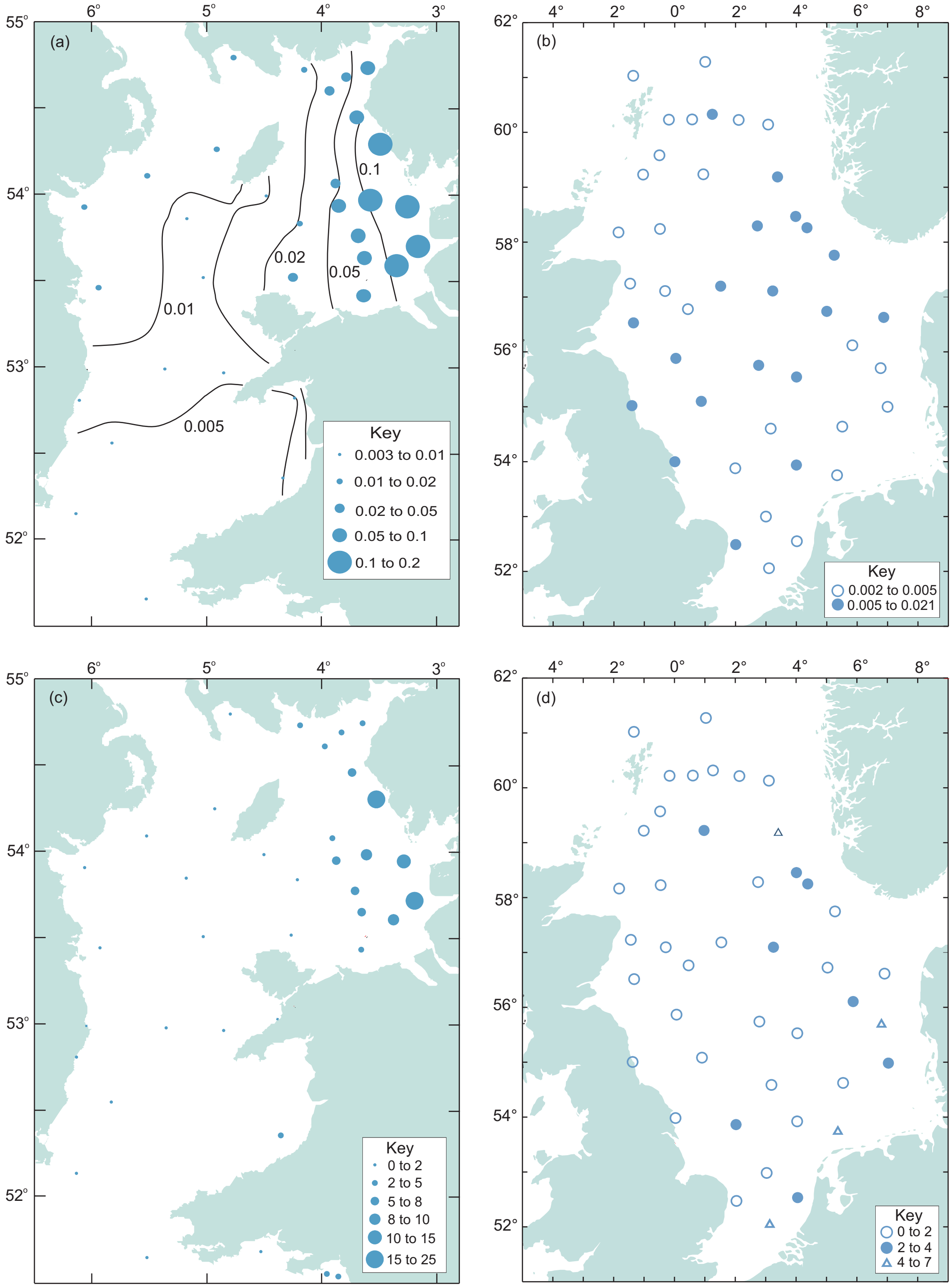

Figure 6.2. ^{137}**Cs (Bq kg^{-1}) and** ^{3}**H (Bq kg^{-1}) concentrations in surface seawater from the UK and European continental shelf. (a) Dissolved** ^{137}**Cs in the Irish Sea (September 2001), (b) dissolved** ^{137}**Cs in the North Sea (August-September 2000), (c)** ^{3}**H in the Irish Sea (September 2001), (d)** ^{3}**H in the North Sea (August-September 2000) (source: RIFE, 2002; RIFE, 2003)**

^{3}H concentrations in the North Sea (Figure 6.2d) were also below the limit of detection (<2 Bq kg^{-1}) for a large proportion of the survey area. The highest concentration (6.1 Bq kg^{-1}) was in waters bordering the continental coastline, possibly due to releases from the La Hague (France) nuclear fuel reprocessing plant.

Authorised liquid discharges of tritium (^{3}H) into the Severn Estuary/Bristol Channel include releases from the Nycomed-Amersham radiochemical plant. Bioaccumulation from water to seafoods has occurred as a result of the presence of organically bound tritium (OBT). Monitoring and research have targeted bioaccumulation in foodstuffs (McCubbin *et al.*, 2001; Williams *et al.*, 2001). A full review of monitoring data for tritium bioaccumulation has been undertaken (Rowe *et al.*, 2001).

^{99}TC DISTRIBUTION

^{99}Tc released by Sellafield follows the same transport pathways as ^{137}Cs, and other Sellafield radionuclides. The main difference is the lower concentrations observed, reflecting the relative quantities discharged. Once EARP started operation the rapid increase in concentration could be followed as the 'leading edge' of the EARP-related ^{99}Tc was transported across the Irish Sea and via the Scottish Coastal Current into the North Sea and towards the Arctic (Leonard *et al.*, 1997, 2001; McCubbin *et al.*, 2003; Kershaw *et al.*, 2004). The data have been used to help validate ocean circulation models of the NE Atlantic (e.g. Karcher *et al.*, 2004). Concentrations around the UK coast have started to decline following the reductions in the discharge since 1995.

OTHER RADIONUCLIDES

Of the long-lived radionuclides, plutonium and ^{241}Am were both discharged in considerable quantities up until the mid 1980s. Direct releases have declined steadily, with a step change in 1994 due to the commissioning of EARP. Both are readily adsorbed onto sediments but it has been possible to trace the transport of a dissolved fraction into the North Sea and beyond, as a result of careful sample collection and analysis. At present most of the plutonium in Irish Sea seawater results from remobilisation and release from the seabed and intertidal sediments. ^{129}I concentrations have increased as a result of THORP operations. This soluble radionuclide has been transported in a similar manner to ^{99}Tc, over considerable distances, and is a useful tracer of ocean circulation.

LEVELS IN SEDIMENTS

The subtidal sediments of the Irish Sea contain substantial amounts of artificial radionuclides, particularly caesium, plutonium and americium. The highest concentrations in surface sediments are close to the Sellafield outfall and in a zone of muddy sediments running parallel to the English coast. The area of fine-grained sediments to the west of the Isle of Man also has elevated concentrations (Figure 6.3). The eastern Irish Sea sediments are now the principal source of plutonium. The estimated total quantity of plutonium in sediments is about 200 kg. Although the subtidal sediments contain a much greater total amount of plutonium than the intertidal sediments the latter are more critical in terms of human contact.

Radionuclide concentrations in intertidal sediments have responded to the variation in discharges, the greatest changes occurring close to the source. Levels of ^{137}Cs in sediment have fallen steadily throughout the Irish Sea since the early 1980s, largely as a result of remobilisation and release into the water column. Changes in sediment-bound plutonium also reflect the slow redistribution of sediments away from the English coast to other parts of the Irish Sea, such as the large area of muddy sediments to the west of the Isle of Man. As these muddy sediments are slowly accumulating, they act as a long-term sink for plutonium and other long-lived and particle-reactive radionuclides. Accordingly, their response to decreased plutonium discharges will be considerably slower than in the case of caesium.

RADIONUCLIDE CONCENTRATIONS IN DREDGED MATERIAL

In England and Wales, Defra issues licences to operators for the disposal of dredged material under the Food and Environment Protection Act, 1985 (Great Britain Parliament, 1985). The protection of the marine environment is considered before a licence is issued. Since dredge material may contain radioactivity, assessments are undertaken where appropriate for assurance that there is no significant foodchain or other risk from the disposal. In Scotland, assessments are required for dredging

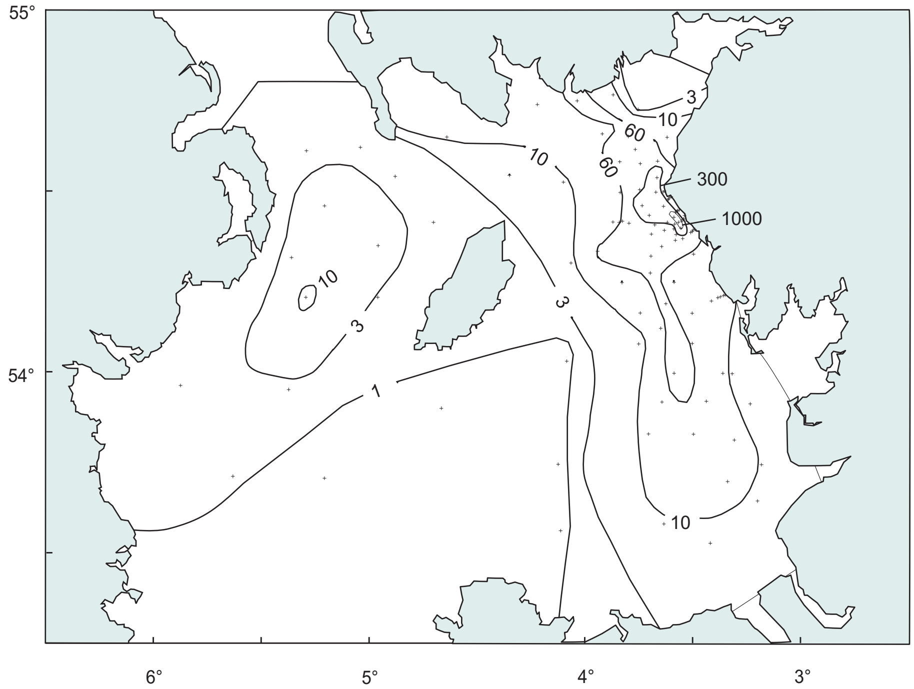

Figure 6.3. Inventory (kBq m^{-2}) of ^{239,240}Pu in the subtidal sediments of the Irish Sea, in 1995/96 (source: Kershaw *et al*., 1999).

operations from Naval Ports and applications are requested to submit relevant data to support individual applications. In 1999 and 2000, specific assessments were carried out for the disposal of dredged material from Whitehaven Harbour in Cumbria and the Tamar Estuary near Devonport. Whitehaven Harbour is known to contain significantly enhanced quantities of natural and artificial radionuclides as a legacy of spillage of phosphate ore whilst unloading ships and large discharges in the 1970s from Sellafield. The Tamar estuary contains low levels of artificial radionuclides due to discharges from the submarine related operations at Devonport and from other widespread sources such as weapon test fallout.

Assessment monitoring of these data indicated that the impacts of radioactivity associated with the disposals of material from Whitehaven Harbour and the Tamar estuary should not give cause for concern since they are small compared to other sources of radioactivity in the marine environment. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the International Atomic Energy Agency (IAEA, 1999).

LEVELS IN BIOTA

Seaweeds such as the bladder wrack (*Fucus vesiculosus*) are good indicators of soluble radionuclides such as caesium and technetium in the surrounding environment. Concentrations of ^{137}Cs in bladder wrack diminish with increasing distance from Sellafield and have fallen in response to reductions in the discharge. On the east coast of Ireland they decreased by approximately 20% per year during the period 1983 to 1986, and although the downward trend continues it is measured in fish and shellfish (Long *et al*., 1998). This trend is also evident in the eastern Irish Sea (Figure 6.4).

Concentrations of ^{99}Tc in seaweeds and the edible tissues of lobsters (*Homarus gammarus*) rose rapidly in response to the increased discharges after 1994. As with caesium, the concentrations decrease with increasing distance from Sellafield. Monitoring of seaweeds around Ireland during

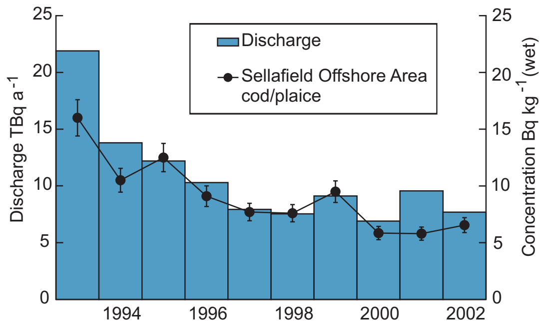

Figure 6.4. ^{137}Cs concentrations in fish,1993-2002. Source Smith *et al*. (submitted)

1997 showed concentrations of ^{99}Tc at sites on the east coast to be almost 30 times higher than the pre-1994 level. More recently, monitoring on the UK coast close to the discharge shows levels declining in response to lower inputs (Figure 6.5).

In general the concentrations of plutonium and americium are higher in shellfish than in fish. The most recent monitoring shows that their concentrations in fish and shellfish from routinely monitored sites in the Irish Sea are relatively stable due to the continuing remobilisation of these radionuclides from the subtidal and intertidal sediments.

RADIATION EXPOSURES

Studies of the uptake of radionuclides by marine organisms have been undertaken since the early 1960s. These have included the levels of ^{129}I, ^{106}Ru, ^{99}Tc, plutonium and ^{210}Po in a variety of fish, shellfish and seaweed. Calculation of doses to consumers of fish and shellfish has formed part of a comprehensive programme to assess the radiological impact of the Sellafield operations. Doses have varied according to the discharges and the critical groups involved. It is estimated that the highest individual doses, due mainly to radiocaesium, occurred in the mid-1970s (approximately 1.9 mSv yr^{-1}). This contrasts with estimated doses, due to ^{210}Po and ^{210}Pb in shellfish near the discharge point, of approximately 5 mSv yr^{-1} in the early 1980s as a result of phosphate waste discharged near Whitehaven.

The increased discharges of ^{99}Tc from Sellafield since 1994 have resulted in corresponding increases in the contribution of this radionuclide to the doses to seafood consumers. However, because of the low radiotoxicity of ^{99}Tc it contributes only about 15% of the total dose (man-made) due to radioactivity in Irish Sea fish and shellfish, still significantly less than the 65% attributable to ^{137}Cs. In Ireland the radiation dose in 1997 to a heavy consumer of seafood (73 kg of fish; 7.3 kg of shellfish) from the north-eastern

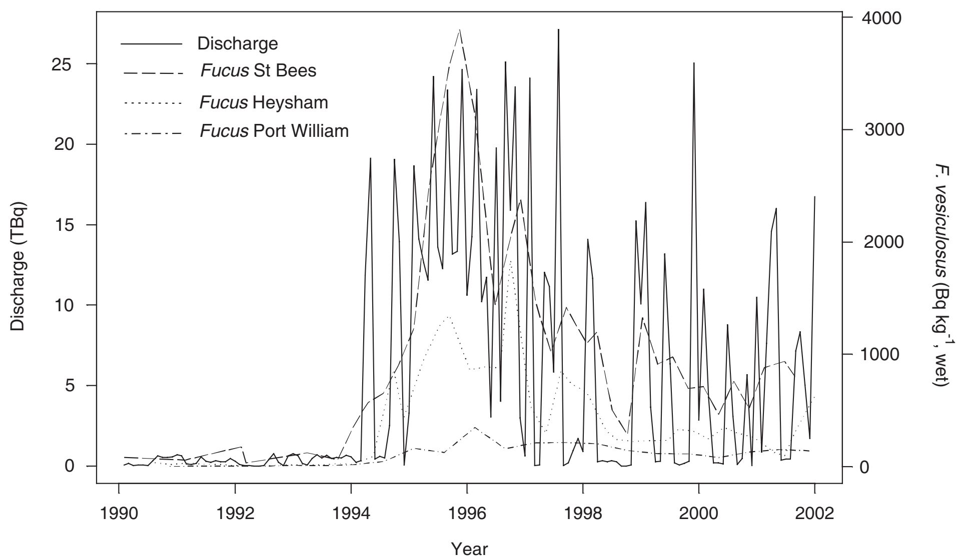

Figure 6.5. Concentration of ^{99}Tc (Bq kg^{-1} wet) in *F. vesiculosus* from the eastern Irish Sea, at St. Bees, Heysham and Port William, together with the monthly discharge (TBq) (source: Nawakowski *et al*., in press).

Irish Sea was estimated to be 1.4 μSv, whereas the corresponding figure for the early 1980s was 70 μSv (Long *et al*., 1998). The highest dose to consumers on the Cumbrian coast occurred in 1981, due mainly to plutonium and ^{241}Am in shellfish. The dose was reported to be 3450 μSv or 69% of the then recommended dose limit of 5000 μSv (using an enhanced gut transfer factor for plutonium). By 2002 the dose from artificial radionuclides had fallen to 190 μSv, with an additional 420 μSv due to enhanced natural radionuclides (^{210}Po, TENORM) from the legacy of the phosphate waste discharges (RIFE, 2003). Doses in the vicinity of nuclear power stations are much lower. For example, on the west coast of Scotland (Hunterston, Firth of Clyde), the exposure to the most exposed group of fish and shellfish consumers in 2002, including external radiation, was 17 μSv. These figures may be contrasted with average doses from all sources of radiation received by members of the public. For example, the average annual dose to a person in Ireland currently stands at about 3000 μSv (Long *et al*., 1998).

Reviews of available data on the effects of chronic radiation exposure on aquatic organisms indicate that the estimated dose rates to organisms in the north-eastern Irish Sea are unlikely to produce adverse effects at the population level. This applies even to historical dose rates that are likely to have been more than an order of magnitude greater than at present.

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7. Construction and aggregate extraction

KEY POINTS

Marine aggregate extraction:

- **In 2001, the total area of UK (E&W) waters dredged for marine aggregates was $979km^2$, but over 90% of the dredging activity took place in 13 km^2.**
- **The quantity of marine aggregate landed from around England and Wales peaked in 1989 and has since remained relatively stable at ~23 million tonnes per annum.**
- **Largest tonnages of sand and gravel are extracted from the east and south-east coasts of England. However, this is likely to change as substantial aggregate resources have been discovered in the Eastern English Channel, which could provide resources for at least 25 years at current levels of demand and provide >50% of the predicted future requirement.**
- **Analysis of trends in the impacts of marine aggregate extraction is limited by the availability of relevant data. The current requirement for Environmental Impact Assessments as part of licensee monitoring commitments, should improve this.**
- **There is evidence of progress towards measures that will help achieve the Government's objective, notably in recent reductions in the area licensed for dredging.**

Renewable energy:

- **There are currently 11 consented offshore wind farm sites, each of $10km^2$, accommodating a maximum of 30 turbines per site.**
- **To date only 1 wind farm has been constructed at North Hoyle, off the North Wales Coast, with a second under construction at Scroby Sands, off Great Yarmouth. Construction of the remaining consented (Round 1) sites is expected to be complete by 2004/2005.**
- **The current consented generation capacity from offshore wind farms is 660 MW, 5.5% of the 2010 target. The 15 proposed sites in the second round off proposals could make a further significant contribution to the 2010 target. These farms will be much larger than the first round.**
- **Current research projects are aiming to improve our understanding of the environmental impacts of wind farms. Continued research and development and post-construction monitoring is required to test predictions.**

7.1 MARINE AGGREGATE EXTRACTION

Much of the seabed surface around the England and Wales coastline is comprised of coarse material *i.e.* various proportions of sand and gravel (CIRIA, 1996). Where these resources are present in sufficient quantity, are of the right composition, and are accessible to commercial dredgers, they may be considered for exploitation as a source of aggregate for the construction industry, to supplement land-based sources, or as a source of material for beach nourishment (Singleton, 2001). Marine sand and gravel makes an important contribution to meeting the UK's demand for construction aggregate materials. It is particularly important in London and the south east of England where it accounts for almost a third of the total regional demand for sand and gravel.

The control of marine aggregate dredging in the UK under the Government View Procedure (GVP) dates back to 1968. Under this non-statutory system, the Crown Estate, as owners of most of the seabed, would only issue a dredging licence if the Government was satisfied following wide consultation, that predicted impacts on the environment were viewed to be acceptable. The level of information required to assess impacts has progressively increased as more has become known about the marine environment (Campbell, 1993; ODPM, 2002) (Vivian, 2003). The GVP was revised in 1989 and requires that an Environmental Impact Assessment (EIA) be undertaken by the dredging applicant as part of the application process for a dredging licence/permit. The GVP is an extended consultative process administered by the Office of the Deputy Prime Minister (ODPM) for England and the devolved administrations for Scotland, Wales and Northern Ireland. There will be a public consultation on Environmental Impact Assessment and Habitats (Extraction of Minerals by Marine Dredging) regulations . Under these Regulations, which will cover English, Welsh and Northern Irish waters, procedures for determining applications to dredge for minerals and enforcement conditions attached to permissions will be brought under statutory control. Environmental assessment guidelines have been developed by ICES and adopted by OSPAR.

Planning constraints are tending to restrict the extraction of sand and gravel (aggregate) from terrestrial sources and therefore attention is increasingly focussed on the importance of seabed resources to satisfy part of the demand for aggregates. The seabed is also recognised as the only viable source of material for beach recharge in coastal defence schemes. In recognition of this, the exploitation of marine resources is supported by national minerals policy, (ODPM, 2002), subject to environmental safeguards. As dredged material can often be landed close to the point of demand, this can also secure an environmental advantage by reducing the need for onward transport on the road network. In recent years there has been a gradual increase in the amount of material exported for use in the construction industry in countries such as the Netherlands, Belgium and France and exports to Europe are currently running at around 30% of the total.

Figure 7.1 shows the location of licensed marine extraction areas around England and Wales.

ANNUAL QUANTITY OF MATERIAL DREDGED

Extraction of the UK marine aggregate resource peaked in line with overall demand for aggregates in 1989 and has remained relatively steady in recent years at around 23 million tonnes per annum from around the England and Wales coastline (Table 7.1). There are 6 main dredging areas (Table 7.2). The largest tonnages of sand and gravel are extracted in the east and south coasts of England. In Wales and along western coasts of England sand cargoes predominate landings, principally to wharves in south Wales. There are no active dredging areas at present in Scottish and Northern Irish waters. There was no calcareous seaweed extracted from Crown Estate licences during 2003 but some material is extracted from within the Falmouth Harbour area.

Licences especially for fill contracts and beach replenishment were as follows in 2003:

- Contract Fill 923,770 tonnes
- Beach Replenishment 1,194,932 tonnes

Figure 7.1. Location of licensed marine aggregate extraction areas around the English and Welsh coastlines in January 2004 (Crown Estate, 2004)

Table 7.2. Marine aggregate (sand and gravel) extraction figures (tonnes) for 2003 (Includes aggregate and material for beach replenishment and fill contract)

Dredging area	Amount
Humber	3,109,604
East Coast of England	9,275,735
Thames	1,760,639
South Coast of England	5,904,125
South West Coast of England	1,619,852
North West Coast of England	470,962
Rivers and Miscellaneous	85,153
Total	22,226,070

Table 7.1. Historic patterns of marine aggregate extraction (tonnes) (Figures exclude beach replenishment and fill contracts)

Extraction Area	1993	1994	1995	1996	1997	1998
Humber	0	1,910,064	1,788,452	1,903,678	2,351,233	2,694,977
East Coast	9,812,236	9,384,860	10,497,352	9,306,920	9,397,705	8,923,562
Thames	1,223,190	2,001,208	1,661,324	1,115,597	1,125,921	862,834
South Coast	4,361,796	4,932,372	4,428,357	4,738,402	4,733,825	5,821,701
South West Coast	2,172,576	2,259,046	2,285,899	2,019,305	2,048,014	1,886,289
North West Coast	380,336	290,846	278,126	287,251	284,497	275,590
Rivers & Misc	12,651	14,491	14,114	21,784	18,587	6,238
Yearly Total	17,962,785	20,792,887	20,953,624	19,392,937	19,959,782	20,471,191

Extraction Area	1999	2000	2001	2002	2003	Total
Humber	2,840,261	3,122,080	2,933,623	2,710,881	2,928,366	25,183,615
East Coast	9,131,512	9,129,635	9,636,697	9,011,323	8,611,199	102,843,001
Thames	971,960	854,483	909,141	1,291,103	838,185	12,854,946
South Coast	5,885,332	5,613,538	5,628,008	5,399,080	5,658,262	57,200,673
South West Coast	1,719,803	1,602,394	1,549,431	1,467,122	1,515,241	20,525,120
North West Coast	355,044	316,090	421,068	482,270	470,962	3,842,080
Rivers & Misc	6,273	46,120	73,047	78,597	85,153	377,055
Yearly Total	20,910,185	20,684,340	21,151,015	20,440,376	20,107,368	222,826,490

Table 7.3. Amount of material (tonnes) extracted for beach replenishment projects in 2003

Dredging area	Amount
Dover	69,200
Happisburgh	664,536
Pevensey Bay	53,862
Poole (Sand Banks)	104,611
Shoreham	121,485
Skegness (Lincshore)	181,238
Total	1,194,932

In 2003, a total of 6.1 million tonnes was exported from the UK.

Summary of current licence position and forecasts for future exploitation of marine aggregates in 2004:

- 70 Extraction licences containing approximately 267 million tonnes of marine sand and gravel.
- 51 Production licence applications containing approximately 925 million tonnes of marine sand and gravel.
- 2 Current prospecting licences.

IMPACTS

Typically, marine aggregate in UK waters is dredged by trailer suction hopper dredgers and is carried out whilst the ship is underway leading to the production of shallow linear furrows approximately 1 to 3 m in width and generally 0.2 to 0.3 m in depth. Whilst the main method of dredging in the UK is through trailer dredging, a number of vessels in the UK fleet are also able to dredge by anchoring or remaining stationary over the deposit. This is usually referred to as static dredging and is employed in areas where the deposit is spatially restricted or locally thick (*e.g.* East of the Isle of Wight, in the Bristol Channel and off the North Wales coast). In this case, dredging usually results in saucer-shaped depressions, typically up to 8 to 10 m deep with slopes of ~5 degrees and 200 m in diameter.

Aggregate extraction can have a number of environmental effects on the seabed including the removal of sediment and the resident fauna, changes to the nature and stability of sediments accompanying the exposure of underlying strata, increased turbidity and redistribution of fine particulates (Newell *et al*., 1998). The activity is assessed not only from the standpoint of effects on the benthic fauna during and after the event of aggregate extraction, but also in terms of its effects on the wider resource including dependent fish/shellfish populations and associated fisheries, coastal processes and other legitimate interests such as conservation and recreation. These issues are addressed in Environmental Statements (ESs).

The length of time that trailer-dredged furrows or depressions created by static dredging will remain as distinctive features on the seabed depends on the ability of tidal currents or wave action to erode crests or transport sediments into them (van der Veer *et al*., 1985, Millner *et al*., 1977). Erosion of dredge tracks in areas of moderate wave exposure and tidal currents has been observed to take between 3 to >7 years (Millner *et al*., 1977, Kenny and Rees, 1996; Limpenny *et al*., 2002, Boyd *et al*., 2003).

Dredging can also lead to the production of plumes of suspended material. Material can arise from the mechanical disturbance of the seabed sediment by the draghead. However, the outwash of material from spillways from the vessel hopper can generate a far greater quantity of suspended material. A further source of suspended material results from the rejection of unwanted sediment fractions by screening activities.

Concern over the impacts of sand and gravel dredging goes back at least a century, particularly in relation to coastal impacts. However, concern over the potential environmental impacts of sand and gravel extraction goes back some 50 years and became a more significant issue from the 1960s onwards (see Shelton and Rolfe, 1972; Dickson and Lee, 1973, Millner *et al*., 1977; de Groot, 1979). Initial concerns focused on the potential impacts on the benthic macrofauna and consequential effects on fish resources and commercial fisheries.

The most significant consequence of marine aggregate extraction on the seabed is the removal of the substrata and the associated benthic fauna (ICES, 1992, 2001). Most studies on the effects of aggregate extraction have concentrated on establishing the rates and processes of macrobenthic recolonization upon cessation of dredging (Kenny *et al*., 1998, Desprez, 2000, Boyd *et al.,* 2003). These studies indicate, typically, that dredging causes an initial reduction in the abundance, species diversity and biomass of the benthic community.

Available evidence, largely obtained from experimental studies, suggests that substantial progress towards benthic 'recovery' could be expected within 2-3 years of cessation of dredging in sandy gravel habitats exposed to moderate wave exposure and tidal currents (Newell *et al*. 1998), although this period can be greater in areas dredged repeatedly (Boyd *et al.,* 2003).

As yet, co-ordinated studies on a wide geographical scale investigating the physical and biological recovery of commercial aggregate extraction sites in the UK are limited, although one study being carried out by CEFAS on behalf of the UK Government and a parallel investigation recently completed by the industry are addressing this issue. Initial findings indicate that information on the nature and rate of physical and biological recovery from one site cannot be uncritically applied to others. Therefore, there is a need to establish the long-term consequences and the scale of impact of marine aggregate extraction following cessation, in a greater range of habitats and historically subject to different dredging practices. Further work is also required to better understand the distribution of marine habitats through the production of broadscale habitat maps for the UK offshore, in order to improve decisions on the licensing of human activities and to provide a better basis for marine spatial planning.

TOTAL AREA LICENSED AND DREDGED

In recent years, dredging companies have released dredging licences for areas, which no longer yield significant returns. Additionally, in the awarding of many new licences, systems of zoning of dredging activity have been agreed, in order to limit the geographical scale of environmental impact during any one period, and to minimise disruption to fishing or other activities.

An essential requirement for the effective control of marine aggregate extraction is monitoring of the location of dredging activities to ensure conformity with the licence conditions. This has been achieved since 1993 by using an Electronic Monitoring System (EMS) fitted onboard dredgers. This device automatically records the date, time and position of all dredging activity, every 30 seconds, to disk. The information allows Government to monitor the location and timing of dredging activities to ensure compliance with particular licence conditions.

In 2003, the total area licenced was 1245 km^2 of which 890 km^2 was dredged, but in practice 90% of the activity took place in just 45.7 km^2.

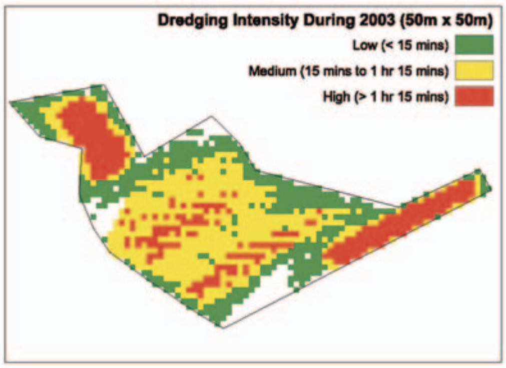

Figure 7.2. A map of a licensed marine extraction area showing the location of dredging activity derived from block analysis of Electronic Monitoring System records

RESPONSE

The UK Government has been developing statutory controls for sand and gravel dredging since 1997 and once implemented these regulations will replace the GVP (see earlier). The Government has also indicated that it wishes to see the continued use of marine resources, so long as it remains consistent with the principles of sustainable development (ODPM, 2002). To allow this, the dredging industry requires access to appropriate long-term resources to accommodate fluctuating markets and to permit investment in new dredgers and wharves. Substantial aggregate resources have been discovered in the central Eastern English Channel (~550 million tonnes) and if dredging is permitted in this area, then the industry expect that this will provide resources for at least 25 years at current levels of demand. The use of marine resources reduces the pressure to work land of agricultural importance or environmental and hydrological value and where materials can be landed close to the point of use, there can be additional benefits of avoiding long distance over-land transport. However, the benefits of using marine sand and gravel need to be balanced against the potential for significant environmental impacts.

The Governments objective is that dredging activities do not significantly harm the environment or fisheries or unacceptably affect other legitimate uses of the sea. The Government (ODPM 2002) considers that this balance can be achieved by:

- minimising the total area licensed/permitted for dredging;
- the careful location of new dredging areas;
- considering new applications in relation to the findings of an Environmental Impact Assessment where such an assessment is required;
- adopting dredging practices that minimise the impact of dredging;
- requiring operators to monitor, as appropriate, the environmental impacts of their activities during, and on completion of dredging; and
- controlling dredging operations through the use of conditions attached to the dredging licence or dredging permission.

Regional Analysis

Government predictions assume a level supply of marine aggregate production of 230 million tonnes nationally for the period 2001-2016 and this is divided regionally (Table 7.4).

This suggests a change from the historic position where 63% of material was dredged from the Southern North Sea, and 25% from the Eastern English Channel, to one where more than 50% of the requirement will be needed from the Eastern English Channel (Table 7.5).

Table 7.4. Predicted level of marine aggregate extraction production for 2001-2016

Region	Total Tonnage for 2001-2016 (Mt)
South East of England	120
London	53
East of England	32
South West	9
North West	4
Yorks and Humber	3
North East	9
E and W Midlands	Nil

From The National and Regional Guidelines for Aggregate Provision in England (June 2003).

Progress towards meeting objectives

The increased demand for evaluations of environmental status at and around marine aggregate extraction sites, whether for Environmental Statements prepared by the industry or in connection with R&D and monitoring programmes, spans a period of about 10 years. As a consequence, the scope for analysing trends on the impacts of marine aggregate extraction operations is limited by the availability of relevant data. However, this should improve as more effort is directed at the assessment of environmental impacts as part of licensee monitoring commitments and as a result of targeted R&D programmes.

There is some evidence of progress towards the measures the Government feel will achieve its objectives, notably in recent reductions in the area licensed for dredging. The careful location of new dredging areas is examined as part of the assessment procedure and all new applications are considered in relation to Environmental Impact

Table 7.5. Quantities of aggregate extracted historically, and projected requirements to 2016

Regional Sea Area	Total extracted 1992-2002 (million tonnes)	% total	Projected requirement 2001-2016 (million tonnes)	% total
2	83	63	98	42
3	33	25	120	52
4	13	10	9	4
5	2	2	4	2
Total	131	100	230	100

Assessment. All new permits require operators to monitor the environmental impact of their activities and that dredging operations are controlled through the use of conditions attached to the licence. The adoption of dredging practices that minimise the impact of dredging will be informed by research into impacts and sea-bed rehabilitation

A body of case studies on the consequences of marine aggregate extraction over sufficiently long time-scales is also required to underpin the derivation of reliable and scientifically credible indicators. Such a need applies equally to many other human activities.

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7.2 COASTAL DEVELOPMENT

As an island nation it is not surprising that one in three people in the UK live within 10 km of the coastline (Defra, 2002)). The historical development of establishing communities and infrastructure along the coast has been driven by the need to access the water for economic livelihood and recreation. This subsequently created the need to protect community assets from the natural processes of waves and flooding. Economic drivers, such as exports, imports, tourism and fishing, continue to promote development of coastal assets. This historic use of the marine environment is also part of our cultural heritage and requires preservation. Coastal development and defence structures vary in scale and location but the combination of such has left an imprint on much of the UK coastline. It can be widely summarised that much of the UK coastline has been modified as a result of coastal developments.

RELEVANT NATIONAL AND INTERNATIONAL POLICY

The legislative framework and European Directives for environmental decision-making depend on the nature, location (terrestrial or marine) and scale of the proposal (Defra, 2002). These constraints are taken into account by the appropriate licensing authority.

A range of national planning policy guidance has been published to direct local planning authorities in the control of coastal development above the low-water mark. These documents are PPG20 in England, NPPG13 in Scotland, PPW in Wales and DOE Planning Policy statement 2/1997, Rural Development Strategy 1993 in Northern Ireland. Regular updates of these documents will be published as required.

Shoreline Management Plans (SMPS) are a key document in the delivery of sustainable coastal defences for coastal cells. The Flood and Defence department of Defra are working on developing a National Coastal Strategy, which will provide an initial report in 2004.

In most cases in marine waters, consideration of the proposal under The Food and Environment Protection Act 1985 (FEPA), statutory planning permission, conservation, safety and maritime cultural heritage agencies and approval from relevant owners of the seabed is required. The overall objective is the protection of the marine environment, human health and other legitimate uses of the sea.

Due to the nature of the coastal marine management there are multiple agencies, local community interests and complex legislative framework, which can have different objectives for providing comments or regulating coastal developments. UK Government recognises this and is working towards a review of Marine Legislation and is supporting the Integrated Coastal Zone Management (ICZM) stocktake, which will support a national coastal strategy.

METHODS, IMPACTS AND CONCERNS

The consequence of a developed coastline is the amount of existing users and the increased pressure on areas of wilderness or conservation. Collectively, space in the marine environment is a resource in high demand for both development and protection. Interference with other uses of the sea are also taken into account.

Environmental aspects considered in assessment include, but is not limited to, the physical environment of the proposed works in relation to fisheries resources, nature conservation sites, maritime culture (shipwrecks, prehistoric landscapes), potentially contaminated sediment, appropriate construction methodology, materials and timing of construction.

Access to current data regarding activities and uses of the marine environment is essential for effective evidenced based decision-making. Various agencies and researchers hold their own data sets, which means the data is sporadic and disjointed. There is a demand to underpin decision making with habitat mapping and to use national data for spatial planning to assist with strategic management of coastal resources.

Regulatory decisions need to have a balanced outcome and require environmental assessor's to consider the social and economic aspects of a proposal. Environmental mitigation is required if a proposal has been identified as having a potential adverse impact on the marine environment.

Each application for works in the marine environment is assessed on a case-by-case basis. As there is an increasing trend to concentrate coastal developments, intensifying the impact on the marine environment, assessors need to consider the impacts of associated developments and existing uses and users in the proposed area and their combined effects. New constructions, which can include scour protection, have the potential for interference with other legitimate activities such as fishing. Large-scale applications, such as port developments can trigger the requirements of additional assessment through the public inquiry process.

Examples of port regeneration schemes include Leith and Granton Ports in Scotland (Regional Sea 1). In England major developments include Felixstowe/Harwich Port Development and ABP Immingham Outer Harbour and Humber Sea Terminal, both later developments are on the Humber River (Regional Sea 2).

When an appeal is made a Public Hearing is conducted by the Planning Inspectorate (www.planning-inspectorate.gov.uk) to consider all parties evidence. A recent inquiry has reported in favour of the Thames Gateway development (Region 2).

Future developments in the marine environment could include underwater tidal generation, floating offshore windfarms, artificial reefs, marine reserves or exclusion zones. Research and development is needed to establish a scientific understanding of these new and innovative activities so decision makers are better informed when applications are made.

PROGRESS ON OBJECTIVES

The applications for construction licences, by categories, in England and Wales over the period 1999-2003 are shown in Figure 7.3. Over this four-year period proposals to build or modify structures within existing harbours is the most common. Currently in Scotland and Northern Ireland applications for the construction of sea outfalls are most numerous. Coastal protection applications are the second highest amount of proposals assessed in England and Wales, which supports the need to protect existing human assets along the coastline. Figure 7.3 can be interpreted to illustrate extensive coastal development, in fact, the nature of the majority of the harbour works are for small-scale projects.

CONSTRUCTION LICENCES IN ENGLAND AND WALES 1999-2003

- With existing users and increased demand much of the undeveloped coastline is subject to amenity and nature conservation designations, which constrain new developments.

- The discovery of many artefacts and the need to encourage sustainable use of the seabed and to ensure that the submerged historic environment does not suffer unnecessarily has led English Heritage to respond by supporting and co-funding a number of initiatives. In 2003 English Heritage and

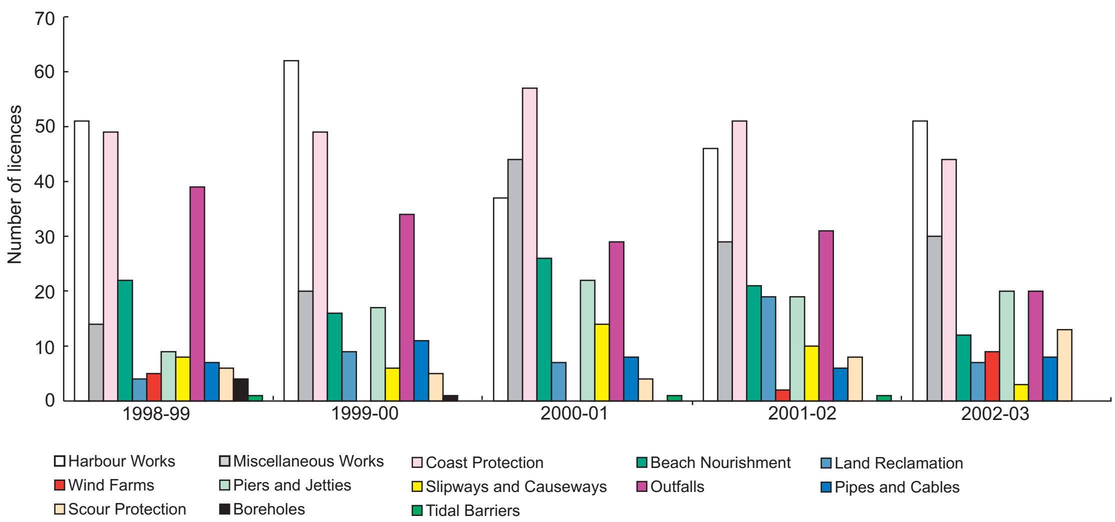

Figure 7.3. Construction licences in England and Wales, 1999-2003

the British Marine Aggregates Producers Association published *Dredging in the Marine Historic Environment*. This document is being followed up by a protocol for recording finds discovered unexpectedly during the on-shore processing of marine aggregates (Oxley, 2003, pers. comm.).

- Government licensing authorities recognise the need to develop tools to ensure that cumulative impacts are assessed effectively. This would be support by marine and coastal data management (CEFAS CoastMap News, 2003; Data Management Workshop 2002).

- Due to the nature of the coastal management there are multiple agencies, local community interests and complex legislative framework, which can have different objectives for licensing coastal developments. UK Government has recognised these aspects and is working towards a review of Marine Legislation and is supporting the ICZM stocktake, which support a national coastal strategy.

- Changes in approaches to assessing the perceived impacts of plans and projects will have to be considered in the light of the implementation of the Water Frame Work Directive (WFD)

- Defra aims to forecast future potential activities and their associated environmental impact. Several projects are focusing on the marine environment. This should trigger appropriate research and development for decision making.

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7.3 RENEWABLE ENERGY

The UK announced its renewable energy obligation in January 2002 and the Energy White Paper was presented to Parliament in February 2003, both in response to the Kyoto agreement. The short term aim is for 10% of UK electricity supply to come from renewable sources by the year 2010. Commitments have been made by the devolved administrations in meeting this target. Suppliers in the UK will be required to obtain an increasing proportion from renewable energies, year on year. In December 2003, DTI announced an additional target of 15% by 2015. Under Non-Fossil Fuel Obligation arrangements stability has been provided through long term contracts for the supply of renewable generators, which has increased investor confidence sufficiently to encourage the development of renewable energy projects.

There is therefore tremendous political pressure to develop and deploy renewable energy technologies. The most advanced of these technologies the harnessing of wind power. There are increasing pressures that large scale development be placed offshore rather than onshore where the conflicts are perceived to be more. There are other technologies and test facilities being developed to develop marine tidal and wave turbines for renewable energy generation. These sources are recognised as being potentially significant in the future.

To help put these figures into perspective were the 2010 target to be achieved solely by offshore wind resources this would mean the production of approximately 12,000 MW. A typical offshore turbine produces 2 MW (although turbines of up to 5 MW are in development) so 6000 turbines would be required which requires an area of sea bed of approximately 1200 km^2 (or 2400 km^2 for the 2020 target). The UK government estimated target for offshore wind is 7500 MW.

There are many agencies involved in the granting of permissions and consents for offshore wind farms. There are regional differences as to the agencies that are involved directly in the licensing processes, however the main consents are in the form of planning permission for landfall elements, FEPA licences for marine construction, electricity generation consents and Crown Estate consent amongst others.

OFFSHORE WIND FARMS

The first round of offshore wind farm proposals involved 18 potential sites (Figure 7.4), each of 10 km^2 and accommodating a maximum of 30 turbines per site. Of these 11 have received the necessary consents with the rest still under consideration. This equates to a consented generation capacity of approximately 660 MW from offshore wind (5.5% of the 2010 target). To date only one of these has been constructed (North Hoyle off the North Wales Coast) and although not at full capacity is generating electricity. Scroby Sands (off Great Yarmouth) is currently under construction. Construction of the remaining consented Round 1 sites is expected in 2004 and 2005.

With reference to the proposed Regional Sea Areas the following is the list of regional differences of numbers of turbines within specific regions.

Area 2 has 210 proposed turbines, Region 4 has 30 proposed turbines, Region 5 has 500 proposed turbines.

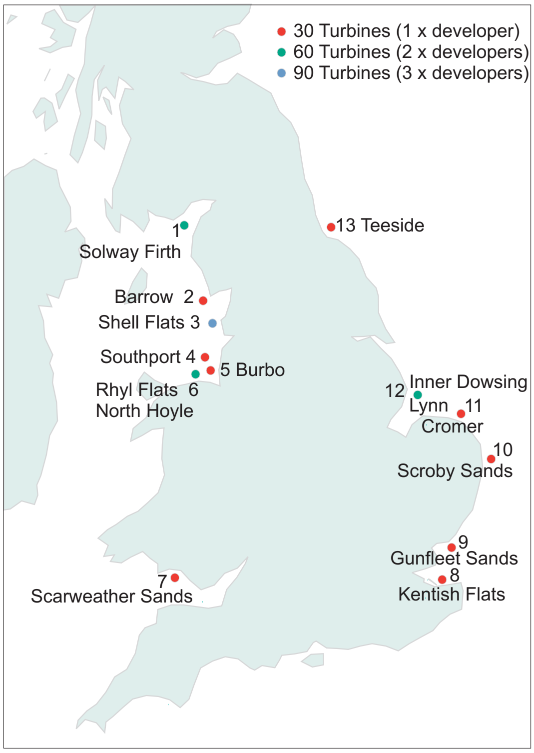

Figure 7.4. Proposed lease areas for Round 1 offshore wind farm developments

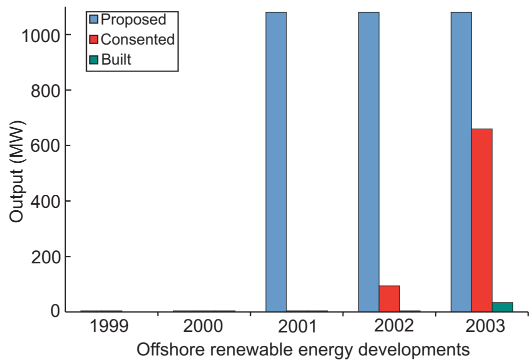

Figure 7.5. Proposed, consented and built electricity generation capacity from offshore wind in Britain over the last few years

In addition to the above Regions 1,5 and 7 have other renewable energy projects (experimental phase).

Offshore windfarm applications are required to have an EIA under UK and EU law The EIA process and the subsequent review of the Round 1 proposals by statutory consultees highlighted a number of key issues where further work was required to improve our knowledge and understanding. These key issues are:

- hydrodynamic and sedimentary processes (wave diffraction and guidance on sediment transport monitoring, need for adequate coastal processes modelling);
- fisheries (wind farm arrays as fish aggregation devices, displacement of fishing activity)
- nature conservation (introduction of new habitat)
- navigation (squeezing of navigable area, collision risks) and
- seascape (from shore, from vessels at sea).
- Electromagnetic Interference (EMI) with regard to power cables and noise and vibration effects on Cetaceans, pennipeds, fish and elasmobranchs.

All the EIAs undertaken for the Round 1 developments made predictions of the environmental impacts associated with the construction and operation so a programme of monitoring is now required to test these predictions with real data. All Round 1 developments therefore have mandatory monitoring conditions attached to their consents, however, with only one completed and one under construction very little data has so far been generated. Other studies, such as those funded by COWRIE, are investigating generic issues but similarly have yet to report. Such data are crucial in our understanding of the relationship between the construction of offshore wind farms and all compartments of the marine environment, to assist the planning and environmental decision making processes.

The first Strategic Environmental Assessment (SEA) approach for offshore wind energy developments was initiated by the DTI in 2002 and reported in May 2003. It reported on 3 strategic areas (Liverpool Bay, Regional sea 5, Greater Wash and Outer Thames, Regional Sea 2) and was set up to help identify suitable areas for development. After a call for expressions of interest the Crown Estate announced the proposed lease areas for Round 2 on 18 December 2003. There are 15 projects within the 3 strategic areas with generation capacity of between 5000 and 7169 MW that if constructed will make a significant contribution to the 2010 target. The scale and location of the Round 2 proposals mean that a Regional Environmental Assessment approach in addition to the EIAs for individual developments will be necessary.

OSPAR guidelines for offshore wind energy have been developed, highlighting many of the key issues relevant to licensing authorities in considering potential impacts.

The rapid growth of the renewable energy industry and the renewable energy targets commitments have put a demand on scientific understanding to ensure the safe environmental consenting of proposed windfarm sites. As mentioned above, in the case of COWRIE, there are initiatives to build the scientific understanding of potential impacts.

Any gaps in understanding of 'operational' impacts of offshore windfarms reflect the fact that this is a very new industry in the marine environment.

There is a need for continued research into possible impacts of this new industry through research and development and assessment of post construction impacts to inform consent and marine management decisions. Both industry and Government are taking pro-active steps in this regard.

8. Litter

KEY POINTS

- **Despite a decline in the last 4 years, current levels of beach litter (per km) remain ~50% higher than in 1994**
- **In 2000, 77% of coastal bathing waters beaches were graded A or B (Very good or good) in beach aesthetic surveys, rising to 82% in 2002. The number of grade D beaches fell from 10% to 5% over the same period**

Litter may be defined as visual and tangible pollution from the inappropriate disposal of waste. It is a serious and persistent environmental problem, posing a hazard to beach users, recreational water users and wildlife. It looks unsightly, spoils our enjoyment of Nature and may have serious economic impact on coastal communities. It is of great public concern and is largely preventable, as its source is solely anthropogenic. The general functioning of society, where the production of waste as an inevitable by-product, is the main driving force in the problem of litter pollution. Litter only arrives on our beaches because waste is allowed to escape into the environment.

Photo Copyright © Coastwatch

THE MAIN SOURCES OF LITTER

The Marine Conservation Society (MCS) in its 2003 'Beachwatch' report estimated that about 37% of collected litter items were attributable to tourism or beach visitors (Table 8.1). Fly tipping, the illegal deposit of any waste onto land, is also a common problem.

Sewage related debris is a problem on some beaches. About 1.5-2.0 billion sanitary protection products are flushed down UK toilets every year, with about 60-100 million condoms. Many of these end up in rivers, the sea and our beaches. The range of coastal litter reflects the wide range of contributory sources. Coastal litter was quantified by the MCS: a beach cleaning exercise at 194 sites in September 2001 found 11,894 crisp and sweet packets, 12,485 caps and lids, 9,507 plastic drink bottles, 6,647 cigarette stubs, 5,278 drink cans, 4,849 plastic bags, 6,389 bits of glass, 1,584 fast food containers, 1,126 balloons, 358 4 or 6 pack yolks. The total weight of litter debris collected from 141.3 km of beaches was 8.3 tonnes.

Table 8.1. MCS Beachwatch 2003 survey. Regional distribution of beach litter

	Regions								UK
	1	2	3	4	5	6	7	8	
Items/m	1.3	1.7	3.1	4.0	2.9	0.44	7.24	N/A	2.1
Total length surveyed (m)	31,338	26,207	15,469	13,977	19,976	5,000	100		134,293
No. Beaches surveyed	40	32	36	50	36	3	1		198
Sources (%)									
Beach visitors	41.3	44.2	32.9	34.7	32.3	23.6	9.4		36.7
Fishing	11.4	13.1	16.2	20.7	9.8	20.6	64.9		14.6
Sewage debris	4.9	2.2	6.0	3.0	21.7	2.5	1.0		7.8
Shipping	2.0	2.9	1.4	1.9	1.8	11.7	0.00		2.0

Region 1
Region 1 has the second lowest density of beach litter according to the MCS Beachwatch 2003 survey. The most significant sources of litter in Region 1 are beach visitors, responsible for 41.3% of all litter found, and fishing debris (11.4%).

Region 2
Beach visitors were the largest source of litter items found during Beachwatch 2003, comprising 44.2% of all litter found, the highest percentage of beach visitor litter compared to other regional seas. Region 2 had the lowest percentage of sewage related debris amongst all the regions with comparable data.

Region 3
Region 3 has the second highest density of beach litter according to the MCS Beachwatch 2003 survey. The most significant source of litter in the region are beach visitors, responsible for 32.9% of all litter found. Region 3 had the second highest percentage of sewage related debris (6.0%) found in all regional seas.

Region 4
Region 4 has the highest density of beach litter and double the UK average according to the MCS Beachwatch 2003 survey. The most significant sources of litter in this region are beach visitors, responsible for 34.7% of all litter found, and fishing debris (20.6%).

Region 5
Region 5 has a high density of beach litter, above the UK average according to the MCS Beachwatch 2003 survey. The most significant sources of litter in this region are beach visitors, responsible for 32.25% of all litter found, and sewage related debris (21.7%).
Region 5 had the highest average density of sewage related debris, which was largely due to extremely high levels on one particular beach.

Region 6
Very little beach litter data is available for this region, with only 3 beaches surveyed in the MCS Beachwatch 2003 survey. Beach visitors were the largest source of litter items found during Beachwatch 2003, comprising 23.6% of all litter found.
This was closely followed by fishing debris, which comprised 20.6% of litter items found. Region 6 consisted of the highest percentage of litter sourced to shipping (11.67%).

Region 7
Very little beach litter data is available for this region, with only 1 beach surveyed in the MCS Beachwatch 2003 survey. On this beach fishing debris was the major source of litter, comprising 64.9% of all litter items found. Region 7 also had the lowest percentage of beach visitors debris (9.4%) out of all seven regions.

Region 8
No data on marine litter levels is available for this region. Litter is known to occur offshore, but very little monitoring or research has been undertaken into offshore litter in the UK.

Shipping litter comes in many shapes and sizes. The International Convention for the Prevention of Pollution from Ships 1973, or MARPOL (2), was modified in 1978 and ratified in June 1994 by 69 countries, including the UK. It regulates the types and quantities of operational and cargo wastes that may be discharged from ship to sea, taking into account the ecological sensitivity of different sea areas. One requirement of the MARPOL ruling is that under no circumstances are plastics to be disposed of at sea. However, everyday domestic ship waste is often disposed of at sea rather than bringing it back into port for proper disposal –MCS estimate that 2% of litter collected during its Beachwatch survey could be attributed to this source (Table 8.1). Cargo, bulk and containerised, may wash overboard in storms and contributes substantial individual items of coastal litter, and poses a potential shipping hazard. Fishing nets and lines are lost by accident or are dumped deliberately. These items may either wash ashore or sink to the sea bottom.

STATE OF THE ENVIRONMENT

The MCS Beachwatch survey is the best long-term indication of trends on UK beaches. Despite a decline in litter in the last four years, it remains around 50% higher than in 1994 (Figure 8.1). The regional distribution of litter items in 2003 is shown in Table 8.1.

The National Aquatic Litter Group (NALG) is a consortium working to reduce litter pollution. The EA, SEPA and EHS are all partners. NALG has developed a standardised monitoring and assessment protocol for assessing the aesthetic state of beaches. The protocol has a standard survey unit and a four grade classification scheme from A (very good) to D (poor). This is based on the assessment of a range of parameters including sewage related debris, gross and general litter, potentially harmful debris, oil, dog faeces and large accumulations of litter.

During 2000-2002 the EA conducted annual snapshot surveys of each of its designated coastal bathing waters, using the protocol. For consistency, and to measure trends, the surveys were in July. In 2002, the survey covered 472 beaches (Figure 8.2).

Most beaches were graded A or B (very good or good) with 77% in 2000 rising to 82% in 2002. At

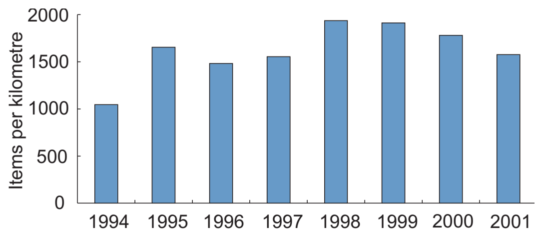

Figure 8.1. Beachwatch Surveys 1994-2001. Number of items per kilometre (Source: Marine Conservation Society)

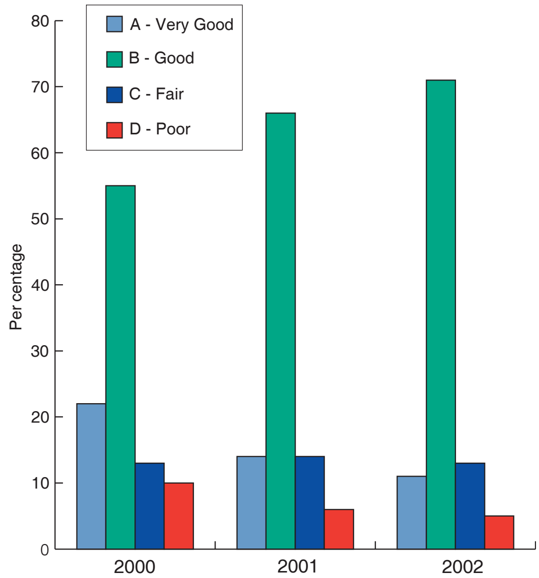

Figure 8.2. Beach Aesthetics Surveys (England & Wales) (Source: Environment Agency)

the same time, the number of grade D beaches fell from 10% in 2000 to 5% in 2002. Although these were ‘snapshot’ surveys, this is encouraging.

IMPACTS OF MARINE LITTER

Litter on our coasts may have a serious aesthetic, environmental, health and economic impact. Marine litter may kill and injure marine mammals, seabirds and other forms of marine and coastal life. Plastic litter kills an estimated 100,000 marine mammals and turtles world-wide every year - including 30,000 seals, and up to one million seabirds, either through entanglement or via ingestion.

An autopsy by the Cotentin Cetaceans Study Group and the University of Caen analysed the stomach contents of a whale stranded on a beach in Normandy, and found nearly a kilogram of plastic bags and packaging. They found one plastic and foil crisp bag and two supermarket plastic bags - all from the UK, seven coloured dustbin bag fragments, seven transparent bags and one food container.

Some litter is long-lived and active for decades. It consists to a very great extent of plastics, metal and glass, materials that do not break down easily or quickly.

RESPONSES TO LITTER POLLUTION

The key to controlling marine litter is to tackle it at source. The main regulatory control of shipping litter is MARPOL. Land sourced litter is controlled by a number of regulations, the most important of which are the Environment Act, 1990 (England, Scotland and Wales) and the 1994 Northern Ireland Litter Order. Another key theme is educational initiatives such as the ‘Bag it and Bin It’ campaign that aims to educate people into not flushing litter down the toilet to end up on our beaches and riverbanks. Encouraging participation in initiatives such as the MCS Beachwatch survey also helps to educate and inform the public about the problems of aquatic litter. The EA also seeks public participation in providing data on beach litter by helping to monitor beaches using the NALG protocol and entering such data directly onto its website through an interactive link.

The answer to reducing the threat, general unsightliness and costs of marine litter and debris is through a combination of regulation, education and co-operation between the public and interested groups and organisations.

9. Navigation dredging and dredged material relocation

KEY POINTS

- **Since 1992, there has been a slight increase in the overall quantity of dredged material deposited to sea each year. Current levels are ~25- 52 million wet tonnes per annum. (mean 35 million tonnes) over the period 1990-2002.**
- **There is a wide variation in dredging requirement in different UK regions. More than 60% of all dredged material is deposited in the Southern North Sea (Region 2) and the Irish Sea (Region 5).**
- **Only an average of 1% of material dredged for disposal at sea is currently reused beneficially in the marine environment. Practitioners and operators are collaborating on research and development, that may result in an increase in the percentage of material used in beneficial use.**
- **Monitoring has demonstrated that impacts are mostly confined within the boundaries of the disposal sites and indicate that sea disposal is an acceptable option.**

INTRODUCTION

The UK is an established maritime trading nation, which has social and economic drivers that require owners and operators to maintain a dredged access for shipping operations for exporting goods and transporting passengers. In total there is an estimated 150 ports of which 100 ports are commercially active (Department of Transport, 2003). Approximately 25-52 million wet tonnes of dredged material is being removed annually in the UK and deposited at sea in approximately 150 licensed disposal sites (Figure 9.1). These licences are issued under the Food and Environment Protection Act (FEPA) 1985 Part II Deposits in the Sea (Great Britain Parliament, 1985). The objective in controlling dredged material relocation in the marine environment is to protect the marine environment, human health and other legitimate uses of the sea.

During the dredging operation there is potential for direct interference with other users of the area, for example for navigation, fishing, conservation or amenity. The authorities permitting the dredging require account to be taken of such interference, and the operation to be planned to minimise it. The main environmental effects of a navigation dredging operation are likely to relate to morphological change, to sediment disturbance, and the resulting turbidity in the water column. If the sediment has high concentrations of contaminants associated with it, there is potential for contaminant redistribution, and sometimes contaminant release from the sediment into the water where it is more available for up-take by living organisms.

The choice of dredger influences the potential loss of sediment during the operation, and in some sensitive environments a dredger that has relatively low loss of sediment is required. Alternatively steps may need to be taken to minimise suspended sediment movement away from the dredging site by the use of silt curtains or other devices. Efforts to minimise sediment loss or movement from the dredged area would be applicable in areas close to shellfisheries, or eel grass beds for example, where sediment settling from the water column can have adverse effects. Not all dredged areas are so sensitive to sedimentation, and assessment of the potential impact, and consideration of the type of dredging equipment is made on a case-by-case basis. In some instances dredging has been restricted to certain times of year, An example of this occurred in the licence for a capital dredge at Holyhead in Wales (Region 5) in 2002, when blasting of rock was not allowed during the months of April to July inclusive to minimise the disturbance to breeding birds.

Long term effects on the marine environment resulting from morphological changes due to the dredging and subsequent changes to the hydraulic regime can include wave refraction sand reflection effects, the alteration of current and sediment transport paths and changes to siltation patterns. At Harwich on the east coast of England, the creation and subsequent deepening of the main access channel to the Port of Felixstowe was thought to have interrupted the sediment supply into the Orwell and Stour estuaries. Here, conditions were placed on dredged material placement licences to allow the relocation of dredged material into the estuaries upstream of the Port to increase the supply of upstream sediment required for maintaining intertidal and sub tidal marshes and banks. In this case conditions were formulated by Defra through consultation with EA, EN, CEFAS and other interested parties.

RELEVANT NATIONAL AND INTERNATIONAL POLICY AND OBJECTIVES

The OSPAR Convention guidelines states that only dredged material, inert material of natural origin and fish waste from industrial processing operations can be disposed of at sea. The management of dredged material and dredged material guidance in the London Convention requires an evaluation of all disposal options, including sea disposal. It is the licensing authorities objective to reduce the amount of material going to sea disposal. The licence application forms for sea disposal operations require an assessment of alternative disposal options to be considered by the applicant prior to the application being submitted. It is recognised that dredged material is a potentially valuable resource and in recent years in England and Wales, an average of 1% of the material dredged for sea disposal has been reused beneficially in the marine environment (Table 9.1). A similar trend can be shown in Scotland and Northern Ireland. Licensing authorities in England and Wales are contributing to research on the beneficial option use to explore alternatives to sea disposal (DECODE).

Table 9.1. Quantity of dredged materials (wet weight) deposited at sea and beneficially reused between 1992 and 2000 in England and Wales* (CEFAS, 2003)

Year	Total tonnage disposed in England and Wales	Beneficial use tonnage	% used beneficially
1992	24,243,998	20,800	0.08
1993	23,068,903	20,800	0.09
1994	37,219,028	40,950	0.11
1995	35,215,611	26,000	0.07
1996	48,513,953	36,140	0.07
1997	38,627,660	80,600	0.21
1998	31,814,916	226,000	0.71
1999	52,409,430	426,000	0.81
2000	28,257,192	245,000	0.87

* includes only those dredged materials for which applications for sea disposal were received.

Environmental issues and the impact of the dredging and disposal operation on other uses of the area are important considerations when permissions for dredging and disposal are sought. The move towards spatial planning offshore in the marine environment and towards Integrated Coastal Zone Management, ICZM, will mean that ultimately dredging and disposal projects should be considered alongside the very many other activities at the coast, and consideration will be given to the cumulative environmental impact of a wide range of activities. A number of potential environmental impacts of dredging and disposal activities are currently taken into account in the licence assessment process.

European Directives such as the Environmental Impact Assessment (97/11 EEC), Habitats and Species (92/43/EEC), the Wild Birds Directive (79/409/EEC), the Strategic Environmental Assessment Directive (85/337/EEC) and the Water Framework Directive (2000/60/EC) are taken into account by the appropriate licensing authority. Great effort has been made in the last ten years to establish whether sea disposal operations are likely to have a significant effect on a European Site (either individually or in combination with other plans or projects) and which are not directly connected with the management of the site. This means that licensed sea disposal operations, for example between the Sutors at the entrance to the Cromarty Firth in Scotland, (Region 1), which are scheduled to be undertaken within or adjacent to European sites such as Special Areas of Conservation (SACs) or Special Protected Areas (SPAS) must be reviewed in light of the requirements of the Conservation (Natural Habitats & C) Regulations 1994.

PROGRESS WITH INDICATORS

There is considerable current research effort to develop indicators in respect of most human activities including the effect of disposal of dredged material. Management and monitoring of dredging and disposal activities will be supported by development of key indicators. A range of reliable indicators is under development.

The characteristics of good indicators have been set out by the UK Government. They should be scientifically sound, easily understood, sensitive to the change that they intend to measure and be measurable and capable of being updated. Examples of indicators included quantity of dredged material disposed, percentage of material beneficially placed, TBT-induced Imposex in Whelks (*Buccinum undatum*) and sediment mobility.

A limitation to the use of environmental indicators is that in theory all indicators will be evaluated against well-established compliance criteria but in practice, the knowledge base is often insufficient, especially when confronted by significant site-specific variation in natural and human influences. This is particularly important in relation to biological indicators. As a result, the role of the expert judgement remains an essential component of the assessment process.

DREDGING

A distinction is made between capital and maintenance dredging. Capital dredging is the initial deepening of an area such as a channel, harbour or berthing facility. Maintenance or navigational dredging is the periodic removal of material, typically sand, silt and gravel deposited by nature through river flow, tidal currents or wave action in areas previously dredged.

Capital dredging projects have their own particular requirements. In addition to the legislative controls, many other factors may constrain the operation. The availability of funding to resource the development is a major consideration, since most UK ports are under private ownership, and both capital dredging and maintenance are at the expense of the port owners and operators. The availability of suitable dredging plant, in an increasing global market, is a consideration, as is the availability of suitable disposal sites for the potentially large volumes of dredged material. Increasingly developers attempt to use some of the dredged material within the construction elements of a project to maximise the re-use of suitable material, and to reduce quantities that require off site disposal. Virtually all capital dredged material from the UK which cannot be used beneficially either within the project, or nearby, is disposed of to sea in sites designated for the purpose.

Capital dredging can also include excavation of underwater trenches for cables, pipelines, tunnels and other engineering works. A major port may only need to undertake capital dredging projects every few years to accommodate changes in the patterns of trade and changes in the size of vessels to be accommodated (MEMG, 2003).

Some ports have engaged in various forms of maintenance dredging continuously for more than a hundred years. Recently, there has been a tendency for small to medium sized ports to dredge intermittently under contract instead of relying on their own vessels. In some locations maintenance dredging need only be undertaken once every five or ten years, in others on two or three occasions every year. In a few of the UK's major ports maintenance dredging is virtually continuous throughout the year. (MEMG, 2003). The majority of maintenance dredging licences are largely related to maintaining access and use of facilities.

SEA DISPOSAL

The regulatory authorities for the disposal of dredged material in England and Wales is Defra, in Scotland it is FRS, on behalf of SEERAD and in Northern Ireland it is the Department of the Environment for Northern Ireland (DOE(NI)). In order to dispose of dredged material in the sea a FEPA licence is normally required from these regulatory bodies. Not all licences issued under FEPA carry the requirement to monitor marine disposal of dredged material. The requirement for monitoring is determined by the licensing authority on a case by case basis. The nature of the actual, potential or perceived effects of dredging and dredged material disposal will in turn dictate the nature of the monitoring required (CEFAS 2003(a), MEMG, 2003).

ALTERNATIVE RE-USE

Over the last 10 years, dredging and disposal licensing authorities, conservation and environmental protection authorities in the UK have made a major contribution towards changing the view that only sand and gravel may be used beneficially. Fine-grained materials are now seen as a valuable resource for beneficial projects.

In contrast to the conventional sea disposal route, our relatively limited understanding of the biological impacts following the intertidal placement of fine-grained dredged material for habitat creation/improvement has previously confined this practice largely to small-scale, field trials. Information has previously been limited to several monitoring reports and a number of more focused studies conducted within the United States of America. However, the recent increased investment in UK-based R & D programmes to overcome this shortfall is slowly resulting in an improved understanding of the recovery rates and mechanisms. The invertebrate species inhabiting intertidal mudflats have been shown to display a great ability to quickly recolonise dredged sediments. However, studies are needed to determine their long-term impacts on the functional status of intertidal areas. This improved understanding may, in future, result in an increase in the percentage of dredged material used beneficially to increase (see Table 9.1) (CEFAS, 2003(b), Bolam *et al*., 2002).

Fine-grained dredged material has mainly been used for flood and coastal defence, sediment cell maintenance and habitat conservation or enhancement. However coarse dredged materials such as sand and gravel dredged during maintenance and capital operations have frequently been used beneficially, either within the project, or in other local schemes.

The requirement to achieve environmentally acceptable and economically beneficial reuse options for the management of dredged material is very desirable in order to retain and improve the economic viability of the UK's waterways and harbours.

ASSESSMENT PROCEDURE

The nature, quantity, physical characteristics and contaminant loading of the material and the implications for the marine environment are crucial factors in the assessment of proposals to deposit dredged material at sea.

The environmental concerns associated with the disposal of dredged material are linked to the operational classification of dredged material as either capital or maintenance. In practice the distinction between capital and maintenance material is not clear cut and often must be

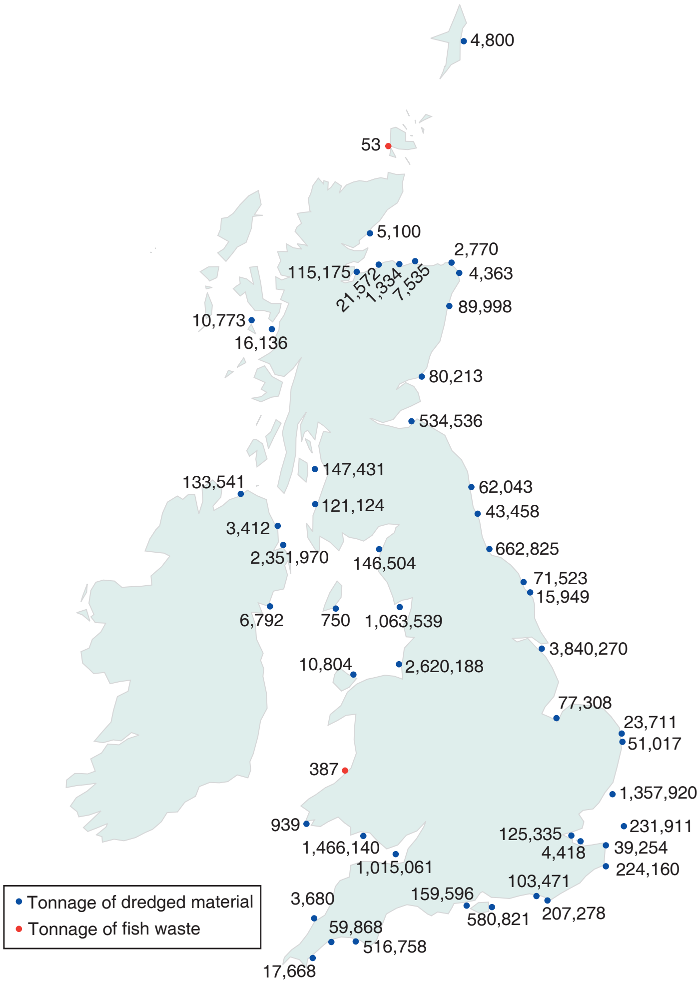

Figure 9.1. Amounts of dredged material deposited in tonnes dry weight in 2001. (CEFAS, 2003a), Closed circles correspond with the locations of individual sites or, where more than one is employed locally, (e.g., in the Humber and Clyde estuaries; Regional Seas 2 and 5) as an approximation to centres of activity

Table 9.2. Proportions of capital and maintenance dredged material deposited 2000-2002 in the UK (units are in wet tonnes) (Source: FEPA licence information from CEFAS and FRS)

Year Of Disposal	2000	2001	2002
Capital Dredging	5,890,141	4,266,331	1,093,997
Maintenance Dredging	27,161,884	31,032,509	29,969,616
Total	33,052,025	35,298,840	31,036,613

decided on a case by case basis. The distinction is important as it may reflect on the selection of a disposal site for the material.

Given the large number of disposal sites (Figure 9.1) and significant variations in the year-on-year usage, nature and quantity of materials deposited and the nature of the receiving environment, regular monitoring is being targeted at representative sites. Other locations are also monitored in response to where there is localised concern, the potential for adverse effects of contamination, or where disposal may have implications for conservation interests.

The data in Table 9.3 reflect the wide variation in dredging requirements in different UK regions, with more than 60% of all dredged material being deposited in Regions 2 and 5.

DREDGED MATERIAL QUALITY

Samples of dredged material are routinely screened for a range of contaminants. This range has been increased in recent years in line with tighter regulatory controls and now routinely includes Tri-butyl Tin (TBT) originating from anti-fouling paints. Occasionally, TBT concentrations have been sufficiently high (>1.0 mg kg^{-1} dry weight) to preclude sea disposal, for example, in the case of sediments near to dry dock facilities (Rees, NMMP). Better harbour practices have in recent years shown their worth, however, the reduction of contaminants at source is essential for a long-term solution. These approaches, which include bans on the use of potential contaminants such as TBT paints, should result in an overall decrease in the quantities of contaminants finding their way into dredged materials. The average concentration of some metal contaminants in UK dredged materials over the years 1986 to 2001 are shown in Figure 9.2. Reductions in mercury, copper and lead concentrations are apparent between 1986 and 1990.

Polycyclic aromatic hydrocarbons (PAH) are of concern environmentally, because they are toxic to marine organisms and some can cause cancers. PAH concentrations are high in the sediments in many heavily urbanised and industrialised UK estuaries, such as those of the north east coast of England (Blythe, Tyne, Wear and Tees) which have to be dredged in order to maintain navigational

Table 9.3. The quantities of dredged material disposed in each regional sea in 2001

Regional sea area	Quantity disposed 2001 dry tonnes	Number of sea disposal sites used
1	1,707,241	28
2	5,767,094	24
3	1,316,085	14
4	3,079,173	18
5	6,473,453	20
6	160,450	4

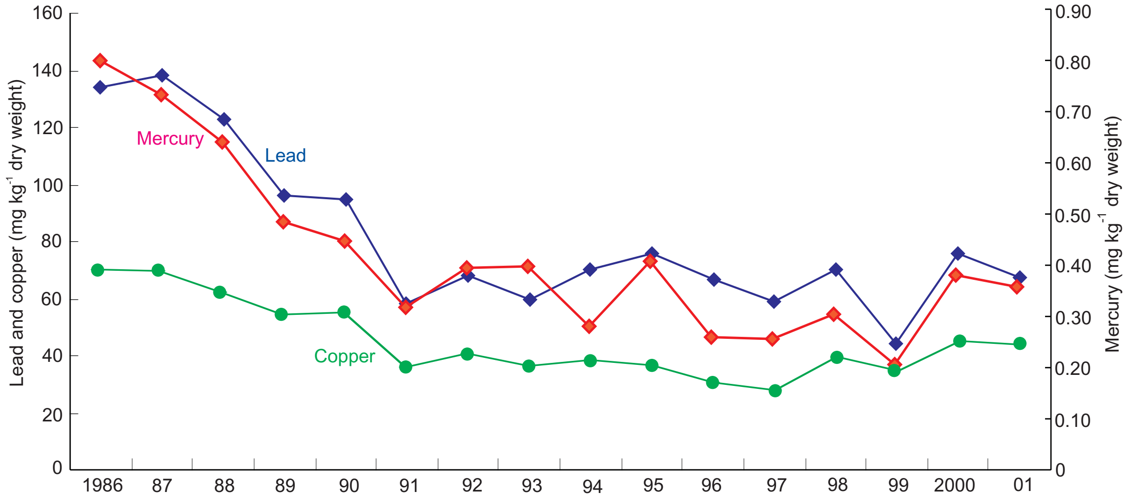

Figure 9.2. Mercury, copper and lead concentrations in UK dredged material

access to their ports. In addition, many of these sediments show acute or chronic toxicity which can be largely ascribed to their PAH content. Because of these concerns, active programmes are underway to assess PAH concentrations in dredged material around Scotland, England and Wales and to develop guideline values to assist with management of the disposal licensing process, and also to assess the possible impacts of disposal at offshore disposal sites to which contaminated material has previously been taken, such as those off the Tyne and the Clyde.

MONITORING OF DREDGED MATERIAL DEPOSIT SITES

A programme of monitoring of the impacts of dredged material disposal takes place in England, Wales, Scotland and Northern Ireland and is undertaken on behalf of the licensing authorities. A relatively small number of sites are monitored each year representing less than 10% of the total sites. The programme focuses on key disposal sites such as those at which large quantities are deposited, where there are long-term data sets and those adjacent to areas of conservation or other interest.

Whilst monitoring has succeeded in identifying local problems thereby contributing to their subsequent resolution, findings indicate that, in general, the option of sea disposal of dredged material is acceptable, subject to continued oversight of the activity (Rees, H, CEFAS).

REGIONAL MONITORING ACTIVITIES

Roughs Tower (Region 2)
An example of monitoring results from a sea disposal site, Roughs Tower, East Coast of England (Region 2), supported earlier predications concerning containment of material and limitation of ecological impacts to the near vicinity of disposal (Rees *et al.*, 2003). Furthermore, there was evidence of significant recovery from these impacts over time, including recolonisation of natural habitat by juvenile crabs and lobsters.

The deposited dredged material can change the nature of bed sediment, if it is of a different particle size and it can have a smothering effect on the benthic community as well as bringing new organisms to an area. An example of physical change is illustrated in Figure 9.3, the disposal site at Roughs Tower. The difference in appearance between the capital material (mounds of sands and gravel, with consolidated clay) and the surrounding seabed (predominantly stable, sandy gravel and mobile sand) is immediately apparent from the acoustic record (CEFAS, 2003(a)).

North Tyne and Souter Point sites off the Tyne (Region 1)
These sites are located at about 40 m depth, where the seabed is characterised by muddy sands (Figure 9.4). However, both sites have been modified by historical disposal of minewaste

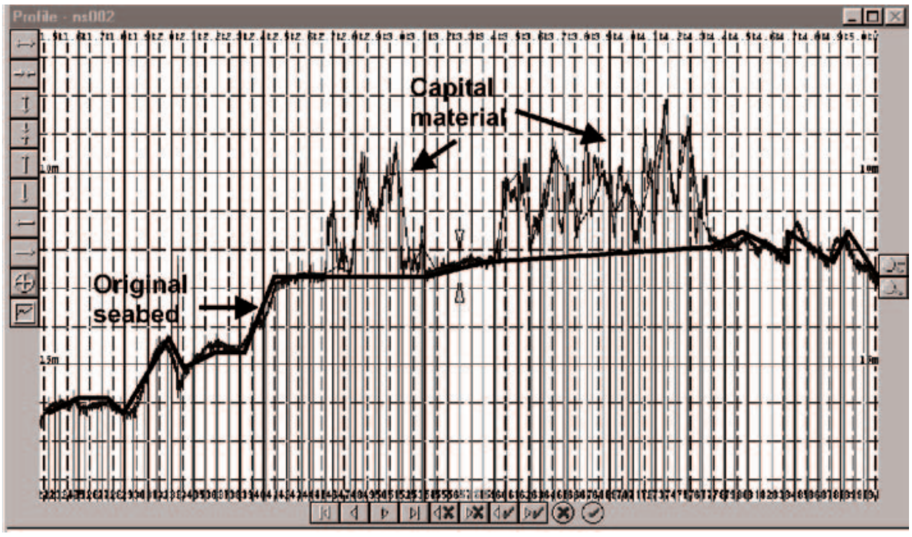

Figure 9.3. Bathymetric profile across the eastern part of the Roughs Tower disposal site produced from the survey carried out in 2000. The heavy black line depicts the approximate original seabed prior to capital disposal. Horizontal distance shown is approximately 2.5 km Depth graduations are in 1 m intervals. Data has not been corrected for tidal variation (CEFAS, 2003b)

and fly ash from power stations, giving rise to local accumulations of coarser material (Rees and Rowlatt, 1994). Currently, the sites jointly receive about 0.5 million wet tonnes mainly of maintenance dredgings from the Tyne estuary each year, although these amounts vary over time due to the periodic nature of 'capital' works.

Elevated TBT concentrations in sediments were found in the area, with the highest concentrations confined to the disposal sites and, in the case of Souter Point, at the western edge, indicating that disposal activity is concentrated there.

Site Z, in Liverpool Bay (Region 5)
This site is located at about 10 m depth in inner Liverpool Bay. Sediments are typically muddy sands that are periodically vulnerable to disturbance by wave action, and by tidal currents of up to 0.8 m per second. The site receives about 1.5 million wet tonnes of maintenance dredgings from the Mersey estuary each year, a considerable reduction over the long term. Material disposed of ranges from sand to mud according to source, and may contain elevated levels of organic matter and trace metals (Rowlatt, 1998; Rees *et al*., 1992,; Rowlatt and Rees, 1993; Somerfield et al., 1995). In the mid-1990s, there was evidence of shallowing at the centre of the site due to disposal practices. In response, the coordinates of the site were extended westward, which has ameliorated the problem.

Benthic assemblages are modified in the immediate vicinity of disposal, but even here, it is unusual to encounter azoic areas.

The North Channel Disposal Site (Region 5)
The North Channel Sea Disposal Site, situated 4 nautical miles outside Belfast Lough, receives approximately 300,000 to 500,000 wet tonnes of dredged material per year and has been assessed for TBT at this site and nearfield areas from 1999. The TBT analysis of the sediments have not shown any significant detectable concentrations (all <0.02 $\mu g\ g^{-1}$ dry weight) in or near the disposal site.

In the case of capital dredged material, the potential impact in the vicinity of the disposal site is likely to be physical, leading to smothering of existing benthos, alteration of existing sediment type and potential changes in seabed bathymetry.

Similarly, physical effects may also be associated with the disposal of maintenance material. Of additional concern is the potential release of contaminants to the marine environment and the potential for bioaccumulation and adverse biological effects.

Aberdeen Disposal Site (Region 1)
The Aberdeen disposal site, situated 1.4 nautical miles off the east coast of Scotland in 40 m of water, receives approximately 150,000-200,000 wet tonnes of maintenance dredged material (ranging from sand to mud) each year and a much smaller occasional quantity of capital material. The PAH and TBT analysis of the sediments show that these contaminants, associated with the disposal operations, extend beyond the southern margins of the disposal site consistent with the local hydrographic conditions. Imposex measurements of *Buccinum undatum* a routinely used sensitive biomarker specific to TBT exposure, show that there is currently no evidence to suggest that the disposal site is significantly contaminated with TBT.

SUMMARY OF PROGRESS TOWARDS OBJECTIVES

Through the imposition of controls on the quality of dredged material deposited at sea and effective feedback of information from monitoring programmes, significant progress has been made in meeting many of the objectives for controlling and monitoring deposits in the sea in terms of protecting the marine environment human health and legitimate uses and users of the sea. Progress is listed below:

There is a common approach to FEPA licensing activities in the UK which includes consistent assessment and monitoring approaches, therefore fulfilling the OSPAR and London Conventions. Licensing authorities seek to limit the number of sites for the purpose of reducing the extent of seabed impact.

The Group Co-ordinating Seabed Disturbance Monitoring (GCSDM) has recommended the sharing of good practice between legislators and practitioners and that data should be of an acceptable quality both for the evaluation of the activity and the sharing of information nationally and internationally.

Monitoring forms an important part of that management activity, checking that the impact is as predicted, that harm to the marine environment has been avoided, feeding back information into future assessment processes, and providing reassurance to other legitimate uses and users of the sea. However, only a small percentage are currently monitored regularly. At some sites data are collected but is not always worked up to a report stage. Some of this information could be called upon for further analysis if and when required, subject to resource limitations.

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10. Introduction of non-native species

KEY POINTS

- **More than half of the non-native species found in British waters are estimated to have been introduced in association with shipping.**
- **The International Maritime Organisation (IMO) adopted a Ballast Water Convention in February 2004 that aims to reduce the risk of introducing non-native species via ballast water.**

The risk of introduction of non-native species via ballast water and hull fouling is clear. Of the 50 non-native species that have been found in British waters over half have been introduced in association with shipping (Eno *et al*., 1997). The majority of the remainder are thought to have been associated with aquaculture operations. Whilst there are legitimate concerns about any introduced species, pragmatists are most concerned about problem species such as the Chinese mitten crab which is causing potentially costly damage through its habit of using soft embankments for burrows.

Once a species is introduced into an area its spread may be assisted by continued transport via shipping to other areas. For example, the Japanese or wire seaweed (*Sargassum muticum*), originally found in the Isle of Wight, has recently been found in Loch Ryan in Scotland where it is suspected to have been transported on ferries travelling from Northern Ireland (Scottish Natural Heritage, 2004; BBC, 2004). New species continue to be introduced into British waters, e.g. the skeleton shrimp *Caprella mutica*, which originates from Japan, has been found on the west coast of Scotland although its method of introduction is not clear (Kate Willis, Dunstaffnage Marine Laboratory, personal communication). Although many species will not survive the journey or be able to establish themselves in the new environment, there is a continuing risk that species will be introduced particularly if alternative antifouling measures are less effective than TBT.

In recognition of the risk of introducing species via ballast water, the IMO has been working for over a decade on an International Convention for the Control and Management of Ships' Ballast Water and Sediments. The convention was finally adopted in February 2004 and, once ratified, will require all vessels to undertake some form of ballast water management (see www.globallast.imo.org for further details). Initially, this will mean that for many vessels mid-ocean exchange will now be a mandatory rather than a voluntary measure. The convention aims to eventually have all vessels treating or managing their ballast water to a specific discharge standard. The treatment standard will be phased in over time depending on the age and size of the vessels. Although the convention allows for exemptions to be granted to some vessels on some routes, they would need to be based on risk assessments. These are currently being discussed.

A review of non-native species policy undertaken by the Department for Environment Food and Rural Affairs (DEFRA, 2003) makes several key recommendations. These include the need for a co-ordinated approach to non-native species policy, development of risk assessment approaches, codes of conduct to help prevent introductions, raising awareness, updating legislation and establishing monitoring schemes as well as policies for management and control of non-native species. ICES has also issued an updated Code of Practice on the Introductions and Transfers of Marine Organisms (see www.ices.dk). One commonly overlooked problem in monitoring status (ICES 2004) is the obvious difficulty associated with detecting novel species in the very earliest period after introduction and this is exacerbated by the limits on taxonomic expertise and funding.

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