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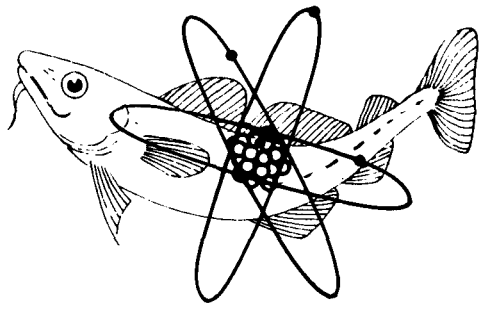
MINISTRY OF AGRICULTURE FISHERIES AND FOOD

DIRECTORATE OF FISHERIES RESEARCH

AQUATIC ENVIRONMENT MONITORING REPORT



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This report has been compiled by A. Franklin, B.Sc. of the MAFF Fisheries Laboratory, Burnham-on-Crouch, Essex, CMO 8HA, from whom copies can be obtained.

Staff responsible for the projects described in this report are listed in Appendix 2.

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FOREWORD

Reports on individual monitoring programmes, which are being undertaken in the field of aquatic environment protection by the Directorate of Fisheries Research (DFR), Aquatic Environment Protection Division 2, at Burnham-on-Crouch, have been produced in the past at irregular intervals and in a variety of separate publications. It was considered that improvements would take place in the provision of such information to interested parties by the regular production of a single report, which included data on all major ongoing monitoring projects undertaken in a particular year. The present publication is the first to have been produced for such a purpose and covers the period 1984-1987. It is envisaged that annual reports will be issued once the backlog to 1989 is cleared.

Information on all major projects will be included, but the detail of reporting will vary, depending on how far particular programmes have advanced and whether publication is anticipated elsewhere. In the present report, for example, sections covering the work on contaminants in sea water vary from a progress report on trace metals to a full set of results for the studies on hydrocarbons.

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Deputy Director
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Directorate of Fisheries Research

BACKGROUND TO THE WORK

The Fisheries Laboratory at Burnham-on-Crouch forms a Section of the Aquatic Environment Protection Division of the Directorate of Fisheries Research within the Ministry of Agriculture, Fisheries and Food (MAFF). The Laboratory is responsible for most aspects of investigation into non-radioactive contamination of the marine environment. This responsibility stems from MAFF's involvement in fish stock management. As an essential adjunct to the management of stocks *per se* it is clearly necessary, firstly to establish that the product, fish or shellfish, is safe to eat, and secondly to ensure that the viability of the stocks is not being affected by pollution. This report shows that, despite much that is written to the contrary, there are few cases of either sort of problem around England and Wales.

Stemming from its interests in the well-being of fish and shellfish stocks, MAFF has a number of specific monitoring responsibilities under various Acts of Parliament. The most direct of these is a duty to license and control the disposal of land-generated wastes from ships at sea. The statutory requirements for this are laid down in Part II of the Food and Environment Protection Act 1985 (Great Britain - Parliament, 1985). Among the duties specified by this Act is a requirement to monitor the quality of disposal sites to ensure that the disposal activity is not having an unacceptable impact on the marine environment of that location. This work also enables the UK to demonstrate compliance with the requirements of the Oslo and London Dumping Conventions (Great Britain - Parliament, 1972(a,b)) which regulate disposal of wastes to sea at an international level. Some examples of these monitoring investigations are described in this report.

Less direct responsibilities stem from the Control of Pollution Act 1974 (Great Britain - Parliament, 1974) (now the Water Act 1989, Great Britain - Parliament, 1989) and the various Acts and Regulations relating to the conduct of the offshore oil and gas industry and the shipping industry. In order to service its own direct needs and those of other Government Departments in relation to these Acts, the laboratory conducts a programme of more general environmental quality monitoring. This programme also produces valuable background information on the quality of the marine environment, against which the quality of disposal sites can be assessed. Such studies cover sea water and sediments as well as marine organisms, and a wide range of chemical determinands are measured each year in a very wide range of samples. A large proportion of this information is collected in accordance with procedures agreed under the auspices of organisations such as the International Council for the Exploration of the Sea, the Joint Monitoring Group of the Oslo and Paris Commissions and the North Sea Task Force. As such, they contribute to the database on the status of the marine environment around north-western Europe.

In relation to particular measures of control, the Burnham Laboratory undertakes monitoring to demonstrate compliance with the European Community's Directive on mercury discharges, and similar requirements under the Paris Commission. It also undertakes work to assess the effectiveness of measures taken, under Part III of the Food and Environment Protection Act (Great Britain - Parliament, 1985), to regulate the use of anti-fouling paints containing tributyltin (TBT).

Finally, this report also provides details of the results of monitoring to assess the levels of paralytic shellfish poisoning (PSP) toxins in mussels along the eastern coast of the UK. Although previously conducted at Burnham, this work is currently being carried out at the Fish Diseases Laboratory Weymouth, but is reported here because it comes under the Commission dealing with non-radioactive pollution. It is likely to be transferred back to Burnham in due course, once the effectiveness of a chemical technique has been proven. PSP is a naturally-occurring toxin produced by certain species of microalgae and has a long history of sporadic incidence along the north-east coast of England. It can prove fatal in high concentrations and, although in most years the levels do not reach those requiring closure of the fishery, a regular monitoring programme must be maintained for human health protection purposes.

1. MONITORING OF CONTAMINANTS IN MARINE BIOTA, 1985-1987

1.1 Introduction

Results from DFR's monitoring programmes for contaminants in fish and shellfish have been published at regular intervals; the most recent paper covered the period from 1977-1984 (Franklin, 1987). The present report covers the period from 1985-1987 (a few previously unpublished results from 1984 have also been included, to fill gaps in information) and concentrates on the information obtained on geographical variations in contaminant concentrations found around the coast of England and Wales. Data gathered for time trend analysis purposes will be reported on at a later date, when an adequate run of data is available. Much of the information reported here was collected as part of the UK's contribution to a 1985 'Baseline' (i.e. geographical trends) Survey of Contaminants organised by the International Council for the Exploration of the Sea (ICES). Some areas have been revisited since that time and it is the most recent data which are available at the time of writing which have been included in the tables. Sites and areas from which fish and shellfish samples were collected are shown in Figure 1.

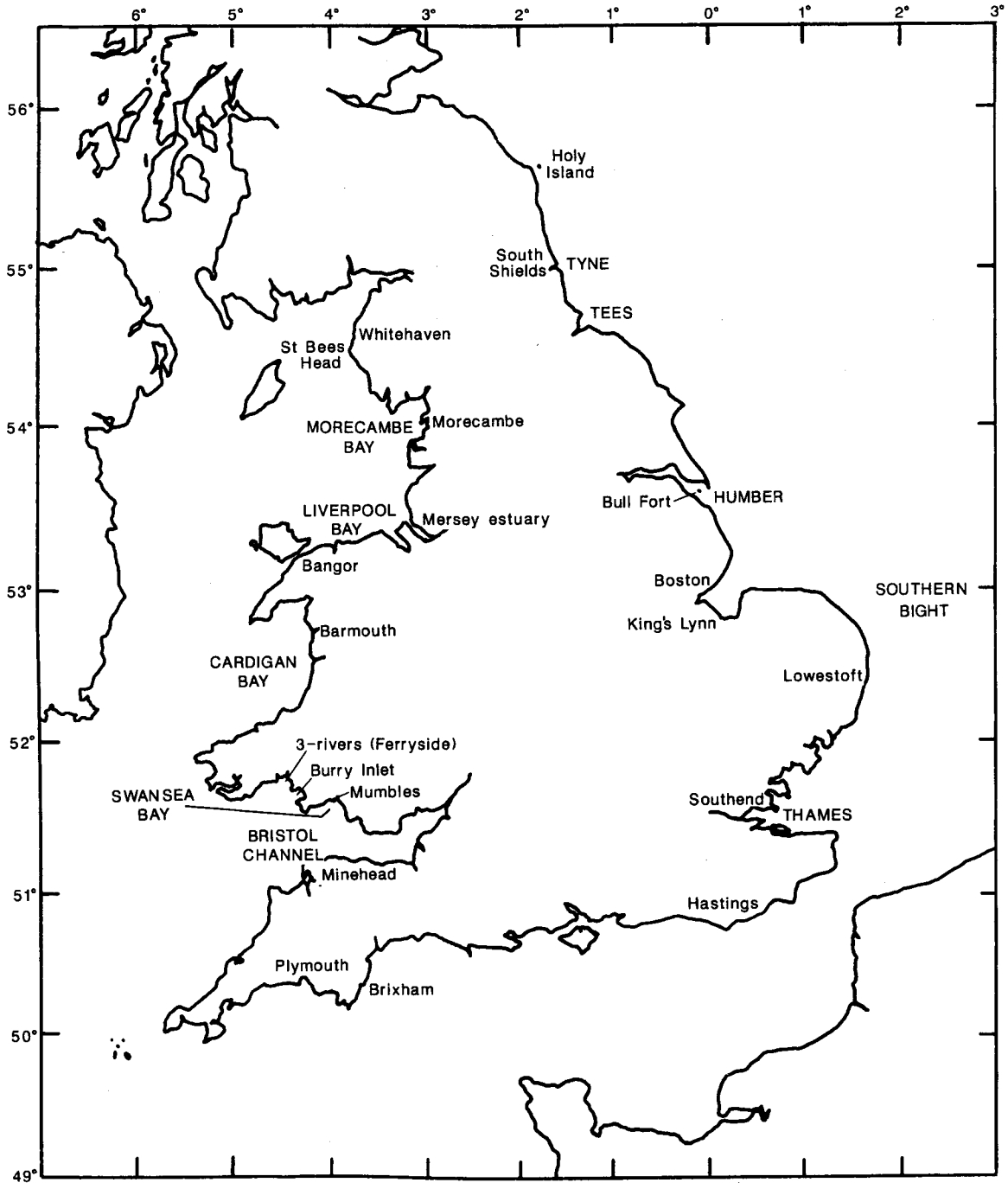

Figure 1. Sites and areas from which fish and mussel samples were obtained.

1.2 Methods

1.2.1 Sampling

There are seven 'core' species in the Burnham monitoring programme: two roundfish [cod (*Gadus morhua*) and whiting (*Merlangius merlangus*)], four flatfish [plaice (*Pleuronectes platessa*), sole (*Solea solea*), dab (*Limanda limanda*) and flounder (*Platichthys flesus*)] plus the blue mussel (*Mytilus edulis*). Samples of as many of these species as possible were obtained from each major coastal region. Many of the mussel samples were collected from areas other than those in which commercial gathering takes place. Such non-commercially exploited stocks were sampled, because mussels are good indicator organisms and they provide a useful means of monitoring the extent of environmental contamination.

Fish muscle tissue was analysed for the metals mercury, copper and zinc but, for the organochlorine pesticides and PCBs, fish liver tissue was used (this was chosen because such compounds tend to accumulate in fatty tissues, such as liver). Where relatively high residues of pesticides/PCBs were found in the liver, analysis of the corresponding muscle tissue was also undertaken. Previous work has indicated that cadmium and lead are present in fish muscle at very low concentrations and certainly below the limits of detection of the methodology routinely employed at the Burnham Laboratory. These metals were, therefore, only analysed for in the mussel (on a whole tissue basis).

Duplicate samples of pooled tissue were generally analysed; in some areas (e.g. where previous work had indicated that contaminant concentrations were likely to be high) analysis of individual specimens was undertaken.

1.2.2 Analysis

Concentrations of copper, zinc, cadmium and lead were determined by conventional flame atomic absorption spectrophotometry (AAS) of a solution prepared from a nitric acid digest. Mercury was determined by an automated cold vapour AAS technique based on the method of Kirkwood (1976).

Analyses were made for the following organochlorine residues: HCB, αHCH and γHCH, dieldrin, pp DDE, pp TDE, pp DDT and PCB's. Following n-hexane soxhlet extraction of the fish and shellfish tissues, residues were determined by capillary gas chromatography, using electron capture detection after alumina and silica column 'clean-up' and separation. PCBs have been quantified as the formulation Aroclor 1254; in future, data will also be available on individual chlorinated biphenyls, commencing with the seven on an ICES primary list (ICES, 1986). Full details of the methodology employed by the Burnham Laboratory are given in Harper *et al.* (1989) and Allchin *et al.*, (1989).

1.3 Results

The contaminant concentrations found in fish tissue are listed in Tables 1, 2 and 3 and metal levels in mussels are in Table 4. All concentrations are expressed on a wet tissue weight basis. The percentage of dry matter in muscle and of fat (lipid) in liver are included to allow conversion of the data to a dry and lipid weight basis, respectively. Where analysis of duplicate bulked samples of tissue has been undertaken, both results are listed in the table, below the mean. Where analysis of individual fish was carried out, the range of contaminant values in the sample is given below the mean.

Evaluation of the results has been assisted by reference to standards or guidelines which have been developed for the various contaminants by organisations such as the European Commission, the Joint Monitoring Group (JMG) of the Oslo and Paris Commissions and the Food and Agriculture Organisation (FAO) (Codex Alimentarius). These, together with the general food standard regulations and guidelines which apply in England and Wales, are summarised in Appendix 1. Also shown are the ranges of levels of the contaminants which, on the basis of past experience, would normally be expected to occur in samples of fish and shellfish taken from inshore areas around England and Wales which are not subjected to any particular sources of contamination. Expressions such as low, moderate and high are used in the text when comparisons are made with these expected ranges. The terms 'lower', 'medium' and 'upper' have a special connotation and refer to guidelines developed by the JMG of the Oslo and Paris Commissions. These guidelines refer to the ranges of contaminant concentrations which would be expected to occur, based on the results submitted by all of the countries which participate in the Joint Monitoring Programme (JMP) of the two Commissions. They do not necessarily imply any risk to human health or to the environment, but are used simply to indicate relative levels of contamination with a view to a possible need for action. Thus, if levels are in the 'upper' category, investigation to establish the source of contamination would be considered to be of much higher priority than would be necessary if the levels found were in the 'lower' category. It should also be noted that many of the samples of mussels were taken purely for indicator purposes and, as such, do not necessarily represent commercially exploited stocks.

Table 1. Concentrations of metals (mg kg $^{-1}$wet weight) in fish muscle tissue.

Area of capture/ species	Month and year of capture	No of fish	Mean length (cm)	Hg	Cu	Zn	% dry matter in muscle
Tyne							
Cod	Nov-85	20	41.1	0.05 (0.05;0.05)	0.4 (0.40;0.40)	3.3 (3.2;3.3)	20
Whiting	Nov-85	25	30.3	0.06 (0.07;0.05)	0.35 (0.38;0.32)	3.3 (3.2;3.3)	24
Plaice	Nov-85	25	35.4	0.05 (0.04;0.05)	0.32 (0.30;0.34)	3.8 (3.7;3.8)	21
Dab	Jul-86	10	21.6	0.06 (0.05;0.06)	< 0.1 -	4.2 (4.2;4.2)	21
Flounder*	Mar-86	7	26.6	0.04	0.4	5.6	20
*1 analysis only							
Tees							
Cod	Nov-86	25	38.6	0.04 (0.04;0.04)	0.23 0.23;0.23)	3.2 (3.2;3.2)	19
Whiting*	Nov-86	25	32.7	0.06	0.19	3.5	24
Plaice	Nov-86	25	31.9	0.05 (0.04;0.06)	0.24 (0.24;0.24)	4.3 (4.8;3.8)	21
Sole	Nov-86	10	32.3	0.13 (0.14;0.12)	0.14 (0.15;0.13)	4 (4.0;3.9)	21
Dab	Nov-86	14	23.6	0.07 (0.06;0.07)	0.19 (0.18;0.20)	4.3 (4.2;4.3)	22
*1 analysis only							
Humber							
Cod	Jun-86	25	32.7	0.09 (0.04-0.15)	0.21 (0.04-0.40)	4 (3.3-4.6)	20
Whiting	Dec-87	25	33.4	0.08 (0.08;0.08)	0.25 (0.25;0.25)	3.7 (3.6;3.7)	20
Plaice	Jul-85	25	23.6	0.03 (0.02-0.05)	0.12 (0.08-0.33)	4 (3.1-5.3)	21
Sole	Jun-86	23	30	0.11 (0.04-0.31)	0.25 (0.14-0.46)	3.4 (2.9-4.0)	19
Dab	Jun-86	9	27.4	0.22 (0.09-0.37)	0.25 (0.18-0.33)	4.2 (3.4-4.8)	19
Flounder	Jun-86	25	30.8	0.13 (0.03-0.38)	0.16 (0.07-0.34)	6.8 (5.0-9.5)	17
Southern Bight (NE of Lowestoft)							
Cod	Jul-87	25	48.2	0.08 (0.03-0.17)	0.17 (0.08-0.26)	3.5 (3.1-4.0)	19.5
Whiting	Feb-84	25	29.9	0.15 (0.16;0.14)	0.25 (0.24;0.25)	3.5 (3.0;3.9)	21
Plaice	Dec-87	25	33.8	0.05 (0.02-0.10)	0.2 (0.08-0.30)	4.4 (3.1-6.3)	19
Thames (Outer Estuary)							
Cod	Mar-87	25	38.6	0.07 (0.07;0.06)	0.34 (0.39;0.28)	3.3 (3.4;3.2)	20
Whiting	Sep-85	25	32.6	0.15 (0.15;0.14)	0.26 (0.26;0.26)	2.9 (2.9;2.8)	19
Plaice	Jun-86	25	27.6	0.04 (0.04;0.03)	0.29 (0.29;0.28)	5.6 (5.8;5.4)	21
Sole	Jul-87	25	26.4	0.08 (0.08;0.08)	0.21 (0.22;0.20)	4.5 (4.5;4.4)	21
Dab	Jul-87	13	25.7	0.09 (0.09;0.09)	0.18 (0.18;0.17)	5.1 (5.2;4.9)	20
Flounder	Jun-86	25	30.3	0.12 (0.13;0.11)	0.29 (0.29;0.29)	7.2 (7.1;7.3)	21
Eastern Channel (Hastings)							
Whiting	Oct-85	5	27.9	0.18 (0.07-0.37)	0.25 (0.20-0.29)	3.6 (3.2-4.1)	18
Plaice	Oct-85	5	25.3	0.08 (0.06-0.10)	0.26 (0.20-0.30)	5.5 (4.6-6.9)	21
Sole	Oct-85	4	23	0.05 (0.03-0.07)	0.45 (0.19-0.68)	5.0 (3.7-6.9)	26
Dab	Oct-85	5	22.5	0.09 (0.06-0.13)	0.30 (0.20-0.47)	4.7 (3.8-5.6)	22
Flounder	Oct-85	6	24.6	0.09 (0.06-0.19)	0.29 (0.24-0.39)	9.3 (6.7-11)	20
Western Channel (Plymouth)							
Cod	Dec-85	4	71.7	0.17 (0.15;0.19)	0.18 (0.10;0.25)	3.3 (3.3;3.2)	20
Whiting	Dec-85	7	33.2	0.16 (0.17;0.15)	0.39 (0.40;0.38)	3.1 (3.0;3.1)	22
Plaice	Dec-85	12	32.6	0.08 (0.08;0.08)	0.20 (0.15;0.25)	4.2 (4.1;4.2)	20
Sole*	Oct-85	25	24.9	0.04 (0.04;0.04)	0.38 (0.30;0.45)	3.5 (3.4;3.6)	22
Dab	Dec-85	5	27.5	0.08 (0.07;0.08)	0.32 (0.33;0.30)	4.1 (4.0;4.1)	-
Flounder	Dec-85	15	32.0	0.11 (0.11;0.10)	0.28 (0.30;0.25)	3.9 (3.9;3.9)	19

*Sole from Brixham

Table 1. Continued.

Area of capture/ species	Month and year of capture	No of fish	Mean length (cm)	Hg	Cu	Zn	% dry matter in muscle
Bristol Channel							
Whiting	Oct-87	25	35.1	0.13 (0.13;0.12)	0.25 (0.22;0.27)	2.7 (2.7;2.7)	21
Plaice	Oct-87	19	33.2	0.06 (0.06;0.06)	< 0.1 -	4.6 (4.5;4.6)	23
Sole	Oct-87	14	35	0.08 (0.07;0.09)	< 0.1 -	3.7 (3.5;3.8)	22
Dab	Oct-87	25	25.3	0.06 (0.06;0.06)	< 0.1 -	4.6 (4.1;5.0)	23
Swansea Bay							
Cod	Jun-85	4	29.9	0.07 (0.07;0.07)	0.33 (0.29;0.35)	4.1 (3.9;4.2)	22
Whiting	Sep-86	22	32.6	0.07 (0.07;0.07)	0.22 (0.21;0.22)	3.1 (3.1;3.0)	20
Plaice	Sep-86	16	30.3	0.05 (0.04;0.05)	0.3 (0.30;0.29)	4.5 (4.5;4.5)	21
Sole	Sep-86	3	27.9	0.04 (0.04;0.04)	0.14 (0.13;0.15)	4 (4.0;4.0)	22
Dab	Jun-86	25	25.9	0.1 (0.10;0.10)	0.34 (0.33;0.34)	5.9 (5.9;5.8)	20
Flounder	Jun-86	25	29	0.1 (0.09;0.10)	0.4 (0.43;0.37)	8 (8.2;7.8)	19
Cardigan Bay							
Whiting	Nov-85	25	31.6	0.14 (0.15;0.13)	0.08 (0.10;0.05)	3.3 (3.6;3.0)	21
Plaice	Nov-85	25	28.8	0.09 (0.09;0.09)	0.25 (0.29;0.20)	4 (4.1;3.8)	22
Sole	Dec-84	25	27.3	0.06 (0.06;0.05)	0.15 (0.20;0.10)	4.3 (4.3;4.3)	22
Dab	Nov-85	25	25.6	0.08 (0.07;0.08)	0.35 (0.30;0.40)	3.8 (3.6;3.9)	21
Liverpool Bay							
Cod	Sep-87	25	37.2	0.25 (0.14-0.56)	< 0.1 -	3.1 (3.0;3.2)	21
Whiting	Sep-87	39	33.2	0.34 (0.13-0.70)	0.18 (0.19;0.17)	3.2 (3.3;3.1)	19
Plaice	Sep-87	25	30.8	0.18 (0.12-0.27)	0.29 (0.30;0.28)	3.7 (3.8;3.6)	19
Sole	Sep-87	25	25.8	0.14 (0.06-0.39)	0.35 (0.35;0.34)	4.1 (4.0;4.1)	22
Dab	Sep-87	25	24.9	0.19 (0.04-0.40)	0.2 (0.20;0.19)	3.8 (3.9;3.7)	21
Flounder	Mar-87	31	30	0.28 (0.06-0.66)	0.47 (0.47;0.47)	4.9 (4.9;4.8)	18
Morecambe Bay							
Cod	Jun-87	22	30.6	0.2 (0.12-0.27)	0.22 (0.14-0.46)	3.4 (2.9-3.8)	20
Whiting	Jun-87	25	31.8	0.33 (0.14-0.50)	< 0.1 -	3.3 (3.3;3.3)	15
Plaice	Jun-87	25	29.1	0.16 (0.15;0.17)	0.17 (0.16;0.17)	4.7 (4.6;4.7)	20
Sole	Jun-87	25	27.1	0.18 (0.17;0.19)	0.22 (0.22;0.21)	4.3 (4.3;4.3)	20
Dab	Jun-87	25	26.2	0.19 (0.18;0.20)	0.17 (0.17;0.17)	4 (4.0;3.9)	21
Flounder	Jun-87	25	33.4	0.29 (0.11-0.58)	0.23 (0.23;0.22)	5.8 (5.7;5.9)	18
St Bees Head							
Cod	Nov-85*	24	42.1	0.12	0.22	2.9	20
Whiting	Nov-85	24	31.4	0.12 (0.12;0.11)	0.21 (0.22;0.20)	2.9 (3.0;2.8)	19
Plaice	Nov-85	25	31.9	0.04 (0.04;0.04)	0.19 (0.14;0.24)	4 (3.9;4.0)	21
Dab	Nov-85	14	22.5	0.14 (0.14;0.13)	0.14 (0.15;0.12)	4.5 (4.2;4.7)	23

* One result only

1.3.1 Mercury

Concentrations in, or approaching, the JMG 'upper' level were found only in Liverpool and Morecambe Bays. These areas are subject to discharges from chloralkali plants and thus to provisions of EC Council Directive 82/176 EEC, on Limit Values and Quality Objectives for Mercury Discharges by the Chloralkali Electrolysis Industry (European Communities, 1982, 1984). Data have, therefore, had to be submitted annually to the EC since 1982 to indicate compliance with the Environmental Quality Standard (EQS) of 0.30 mg mercury kg^{-1} of representative wet fish flesh.

For this purpose, each individual fish species' concentration is weighted according to the quantity of that particular species landed from the area in question and an overall representative area mean concentration is then calculated. The weighted mean mercury concentrations calculated for the years covered by this report were as follows:

	1985	1986	1987
Liverpool Bay	0.23	0.20	0.20
Morecambe Bay	0.21	0.25	0.23

i.e. in all three years the standard was met at both sites.

1.3.2 Copper

Levels in fish muscle were within expected ranges (i.e. up to 0.6 mg kg^{-1} wet weight) from all areas. The highest concentration found in mussels (from the mouth of the Tees) at 4.4 mg kg^{-1} wet weight was less than one quarter of the Food Standards Committee's recommended limit (see Appendix 1).

1.3.3 Zinc

Highest levels in fish muscle were, as usual, found in flounder. In this species, zinc concentrations up to 10 mg kg^{-1} wet weight can be expected and all values found were within this range. Levels in other species were generally well below 6.0 mg kg^{-1}.

The maximum concentration of zinc found in mussels was 36 mg kg^{-1} wet weight (from the Tyne). Levels in samples from commercially fished areas were generally very much less than this concentration and all were under half the Food Standards Committee's guideline value of 50 mg kg^{-1} (see Appendix 1).

1.3.4 Cadmium

Levels in the 'upper' JMP category have been found previously in three areas - Humber Estuary, Bristol Channel/Swansea Bay and off Whitehaven (Franklin, 1987); similar results were obtained in the present survey. Frequent monitoring of these sites will be maintained to ensure that up-to-date information is available. More information on the extent of cadmium contamination of these regions can be found in Section 2 of this report. The concentrations of cadmium, in all of the commercially fished areas which were sampled, were in the 'lower' JMP category.

1.3.5 Lead

The highest concentrations were found in mussels taken off the north-east coast of England and in the Western Channel. In no samples did levels approach the Food Regulations 1979 limit for shellfish (see Appendix 1) of 10 mg kg^{-1} wet weight and many of the samples from commercially fished areas were at or below the detection limit of the analytical method employed.

1.3.6 Organochlorine pesticides/ PCBs

In fish liver tissue, pesticide concentrations above expected ranges were found only in the Humber [γ HCH and dieldrin in cod taken in 1986 (values for 1987 were lower- see Table 2)], Liverpool Bay (dieldrin, DDE and TDE in whiting) and Morecambe Bay (DDE and TDE in whiting).

PCB levels in fish liver tissue were in the 'upper' JMP category in whiting, plaice and dab from Liverpool Bay and in whiting and dab from Morecambe Bay.

Concentrations in fish muscle from these areas were much lower than those in liver (Table 3), often by a factor of 100, and give no cause for concern.

Table 2. Concentrations of organochlorine pesticides/PCBs (mg kg^{-1} wet weight) in fish liver tissue.

Area of capture/ species	HCB	α HCH	γ HCH	Dieldrin	pp DDE	pp TDE	pp DDT	PCB	% fat in liver
Tyne									
Cod	0.028 (0.028;0.028)	0.013 (0.012;0.013)	0.012 (0.011;0.012)	0.07 (0.07;0.06)	0.12 (0.13;0.10)	0.072 (0.069;0.074)	0.12 (0.11;0.12)	0.56 (0.54;0.57)	49
Whiting	0.023 (0.025;0.021)	0.024 (0.023;0.025)	< 0.001 -	0.12 (0.12;0.11)	0.12 (0.12;0.11)	0.15 (0.15;0.15)	0.2 (0.21;0.18)	0.34 (0.36;0.32)	68
Plaice	0.006 (0.006;0.006)	0.005 (0.005;0.005)	0.002 (0.002;0.002)	0.007 (0.008;0.006)	0.019 (0.019;0.018)	0.006* -	0.017 (0.016;0.017)	0.11 (0.11;0.11)	14
Dab	0.004 (0.004;0.004)	< 0.001 -	< 0.001 -	0.01 (0.01;0.01)	0.021 (0.021;0.021)	< 0.001 -	< 0.001 -	0.051 (0.050;0.052)	6
Flounder*	0.045	0.006	0.001	0.049	0.033	0.036	0.007	0.20	7
Tees									
Cod	0.019 (0.016;0.022)	0.018 (0.013;0.022)	0.038 (0.023;0.053)	0.076 (0.067;0.085)	0.12 (0.11;0.12)	0.14 (0.11;0.17)	0.043 (0.039;0.016)	1.2 (1.1;1.2)	47
Whiting	0.03 (0.029;0.031)	0.025 (0.023;0.027)	0.015 (0.016;0.013)	0.11 (0.10;0.12)	0.18 (0.16;0.19)	0.064 (0.063;0.064)	0.062 (0.061;0.063)	2.5 (2.1;2.8)	73
Plaice	0.003 (0.003;0.003)	0.002 (0.002;0.001)	0.002 (0.003;0.001)	0.011 (0.008;0.013)	0.008 (0.009;0.007)	0.003 (0.004;0.001)	0.002 (0.002;0.001)	0.067 (0.081;0.052)	8
Sole	< 0.001 -	< 0.001 -	< 0.001 -	0.023 (0.022;0.023)	0.014 (0.014;0.014)	0.021 (0.020;0.022)	< 0.001 -	0.026 (0.027;0.025)	8
Dab	0.016 (0.016;0.016)	0.014 (0.013;0.014)	0.008 (0.006;0.009)	0.084 (0.084;0.084)	0.039 (0.040;0.037)	0.024 (0.024;0.024)	0.024 (0.024;0.023)	0.037 (0.032;0.042)	26

*1 analysis only for flounder and ppTDE in plaice

Table 2. Continued.

Area of capture/ species	HCB	α HCH	γHCH	Dieldrin	pp DDE	pp TDE	pp DDT	PCB	% fat in liver
Humber									
Cod*	0.026 (0.027;0.025)	0.016 (0.015;0.016)	0.092 (0.089;0.094)	0.34 (0.34;0.34)	0.31 (0.33;0.29)	0.36 (0.38;0.33)	0.019 (0.019;0.019)	2.9 (3.0;2.8)	30
Whiting	0.03 (0.028;0.031)	0.019 (0.021;0.017)	0.024 (0.024;0.023)	0.15 (0.14;0.15)	0.15 (0.14;0.15)	0.11 (0.11;0.11)	0.018 (0.019;0.016)	1.6 (1.5;1.6)	56
Plaice+	0.003 (0.003;0.003)	0.02 (0.019;0.021)	0.007 -	0.028 (0.029;0.027)	0.016 (0.014;0.017)	0.026 (0.025;0.026)	0.009 (0.008;0.009)	0.16 (0.16;0.15)	9
Sole	< 0.001 -	0.03 (0.031;0.029)	0.004 (0.004;0.004)	0.021 (0.021;0.021)	0.015 (0.015;0.014)	0.021 (0.021;0.021)	0.009 (0.008;0.009)	0.42 (0.41;0.43)	2
Dab	0.013 (0.013;0.013)	0.009 (0.010;0.008)	0.006 (0.006;0.005)	0.1 (0.11;0.09)	0.13 (0.12;0.13)	0.09 (0.095;0.084)	0.009 (0.009;0.009)	0.33 (0.32;0.34)	8
Flounder	0.004 (0.004;0.004)	0.013 (0.013;0.012)	0.008 (0.008;0.008)	0.051 (0.052;0.050)	0.049 (0.051;0.046)	0.12 (0.12;0.12)	0.008 (0.005;0.010)	0.4 (0.41;0.38)	3

* 1987 values for γHCH = 0.017 and for dieldrin = 0.14 (mg kg-1 wet weight); +1986 value for γHCH

Southern Bight (NE of Lowestoft)

Cod	0.018 (0.005-0.037)	0.019 (0.001-0.033)	0.014 (0.005-0.027)	0.089 (0.022-0.29)	0.072 (0.008-0.25)	0.051 (0.015-0.13)	0.048 (0.005-0.28)	2.3 (0.54-10.6)	36
Whiting*	0.018 (0.008-0.027)	0.021 (0.013-0.042)	0.018 (0.010-0.034)	0.22 (0.076-0.47)	0.23 (0.083-0.94)	0.12 (0.041-0.30)	0.18 (0.033-0.64)	2.3 (0.70-7.8)	46
Plaice	0.001 (0.001-0.002)	0.016 (0.001-0.031)	0.006 (0.001-0.010)	0.014 (0.009;0.018)	0.011 (0.005-0.020)	0.01 (0.001-0.016)	0.007 (0.001-0.014)	0.11 (0.035-0.15)	8

*23 only analysed for pesticides

Thames (Outer Estuary)

Cod	0.024 (0.024;0.024)	0.011 (0.010;0.011)	0.031 (0.031;0.030)	0.26 (0.28;0.24)	0.15 (0.15;0.15)	0.11 (0.11;0.11)	0.052 (0.052;0.051)	2.2 (2.2;2.1)	26
Whiting	0.012 (0.013;0.011)	0.009 (0.009;0.008)	0.011 (0.010;0.011)	0.12 (0.12;0.12)	0.24 (0.24;0.23)	0.16 (0.17;0.14)	0.034 (0.038;0.030)	3.7 (3.8;3.6)	48
Plaice	0.004 (0.004;0.004)	0.003 (0.003;0.003)	0.007 (0.006;0.007)	0.031 (0.032;0.030)	0.023 (0.022;0.024)	0.005 (0.005;0.005)	0.007 (0.007;0.006)	0.35 (0.35;0.35)	16
Sole	< 0.001 -	< 0.001 -	0.002 (0.002;0.001)	0.009 (0.009;0.009)	0.01 (0.01;0.01)	< 0.001 -	0.002 (0.002;0.002)	0.19 (0.19;0.19)	4
Dab	0.005 (0.005;0.004)	0.004 (0.004;0.004)	0.01 (0.010;0.010)	0.068 (0.071;0.064)	0.051 (0.052;0.049)	0.016 (0.016;0.015)	0.016 (0.016;0.016)	0.9 (0.92;0.88)	24
Flounder	0.002 (0.002;0.002)	< 0.001 -	0.004 (0.003;0.004)	0.088 (0.088;0.087)	0.03 (0.030;0.030)	0.015 (0.015;0.014)	0.009 (0.009;0.008)	0.32 (0.32;0.31)	8

Eastern Channel (Hastings)

Whiting	0.009 (0.008;0.009)	0.026 (0.024;0.027)	0.021 (0.022;0.020)	0.062 (0.063;0.061)	0.23 (0.23;0.23)	0.017 (0.016;0.017)	0.12 (0.11;0.12)	3 (3.0;3.0)	39
Plaice*	< 0.001	0.004	0.003	0.002	0.004	0.003	0.006	0.054	6
Sole	NA	NA	NA	NA	NA	NA	NA	NA	
Dab	0.006 (0.006;0.005)	0.012 (0.014;0.009)	0.008 (0.010;0.006)	0.012 (0.016;0.007)	0.023 (0.025;0.020)	0.004 (0.004;0.003)	0.059 (0.025;0.092)	0.27 (0.34;0.20)	30
Flounder*	< 0.001	0.003	0.002	0.003	0.019	0.002	0.005	0.2	2

*1 analysis only for pesticides
NA Not analysed (insufficient tissue)

Western Channel (Plymouth)

Cod	0.019 (0.018;0.019)	0.01 (0.009;0.010)	0.012 (0.012;0.012)	0.14 (0.14;0.13)	0.17 (0.16;0.18)	0.006 (0.009;0.003)	0.16 (0.15;0.17)	3.4 (3.4;3.8)	55
Whiting	0.025 (0.025;0.024)	< 0.001 -	0.017 (0.018;0.016)	0.14 (0.14;0.13)	0.22 (0.20;0.23)	0.16 (0.16;0.16)	0.22 (0.21;0.22)	3.6 (3.6;3.5)	57
Plaice	0.003 (0.002;0.003)	< 0.001 -	< 0.001 -	0.011 (0.011;0.010)	0.003 (0.003;0.003)	< 0.001 -	< 0.001 -	0.21 (0.21;0.21)	5
Sole*	< 0.001 -	< 0.001 -	< 0.001 -	0.003 (0.003;0.003)	0.003 (0.002;0.003)	< 0.001 -	0.004 (0.004;0.003)	0.3 (0.28;0.31)	5
Dab	0.003 (0.003;0.003)	< 0.001 -	< 0.001 -	0.016 (0.014;0.018)	0.11 (0.11;0.11)	< 0.001 -	0.006 (0.004;0.007)	0.24 (0.23;0.24)	11
Flounder	0.004 (0.004;0.004)	0.001 (0.001;0.001)	0.002 (0.001;0.003)	0.036 (0.039;0.033)	0.013 (0.012;0.013)	0.019 (0.019;0.019)	0.055 (0.053;0.056)	0.5 (0.50;0.50)	8

*Sole from Brixham

Bristol Channel

Whiting	0.014 (0.014;0.014)	0.011 (0.009;0.012)	0.013 (0.013;0.012)	0.063 (0.063;0.063)	0.11 (0.11;0.11)	0.039 (0.039;0.039)	0.035 (0.034;0.035)	3.4 (3.4;3.4)	61
Plaice	0.005 (0.005;0.005)	0.002 (0.002;0.002)	0.005 (0.005;0.004)	0.02 (0.019;0.021)	0.017 (0.016;0.018)	0.038 (0.037;0.038)	0.008 (0.007;0.009)	0.58 (0.57;0.58)	20
Sole	< 0.001 -	0.001 (<0.001;0.002)	< 0.001 -	0.016 (0.017;0.015)	0.014 (0.014;0.013)	0.025 (0.025;0.025)	0.02 (0.017;0.022)	0.65 (0.63;0.67)	15
Dab	0.004 (0.004;0.004)	0.005 (0.005;0.004)	0.007 (0.006;0.007)	0.027 (0.024;0.029)	0.018 (0.020;0.015)	0.051 (0.054;0.047)	0.019 (0.019;0.019)	0.63 (0.65;0.60)	31

Swansea Bay

Cod	0.013 (0.010;0.015)	< 0.001 -	0.009 (0.009;0.009)	0.27 (0.25;0.28)	0.055 (0.058;0.052)	0.087 (0.085;0.088)	0.037 (0.024;0.050)	1.9 (1.5;2.3)	18
Whiting	0.012 (0.011;0.013)	< 0.001 -	< 0.001 -	0.14 (0.15;0.13)	0.14 (0.14;0.14)	0.042 (0.041;0.043)	0.015 (0.013;0.017)	3.2 (3.1;3.2)	52
Plaice	0.002 (0.002;0.002)	< 0.001 -	0.003 (0.003;0.003)	0.012 (0.010;0.014)	0.009 (0.009;0.009)	0.005 (0.005;0.005)	0.007 (0.006;0.008)	0.4 (0.40;0.39)	14
Sole*	< 0.001	< 0.001	< 0.001	0.052	0.009	0.029	0.003	0.094	5
Dab	0.003 (0.003;0.003)	< 0.001 -	0.002 (0.002;0.002)	0.056 (0.054;0.058)	0.022 (0.022;0.022)	0.008 (0.007;0.008)	0.006 (0.005;0.006)	0.88 (0.86;0.89)	14
Flounder	0.003 (0.002;0.003)	< 0.001 -	< 0.001 -	0.021 (0.020;0.022)	0.017 (0.017;0.017)	0.058 (0.055;0.060)	0.015 (0.013;0.017)	0.42 (0.42;0.42)	3

* 1 analysis only for pesticides

Table 2. Continued.

Area of capture/ species	HCB	α HCH	γHCH	Dieldrin	pp DDE	pp TDE	pp DDT	PCB	% fat in liver
Cardigan Bay									
Whiting	0.002 (0.002;0.001)	0.011 (0.011;0.011)	0.011 (0.010;0.011)	0.068 (0.069;0.067)	0.051 (0.053;0.049)	0.1 (0.10;0.10)	0.051 (0.053;0.049)	2.8 (2.9;2.6)	66
Plaice	0.002 (0.002;0.001)	0.002 (0.002;0.002)	0.002 (0.002;0.001)	0.01 (0.010;0.009)	0.003 (0.003;0.002)	0.009 (0.009;0.009)	0.003 (0.003;0.002)	0.11 (0.12;0.10)	7
Sole	< 0.001 -	< 0.001 -	< 0.001 -	0.036 (0.030;0.042)	0.002 (0.002;0.002)	0.017 (0.014;0.019)	0.003 (0.001;0.004)	0.053 (0.056;0.050)	5
Dab	0.,003 (0.003;0.003)	0.005 (0.005;0.005)	0.004 (0.004;0.004)	0.035 (0.035;0.035)	0.006 (0.006;0.005)	0.006 (0.006;0.006)	0.006 (0.006;0.006)	0.25 (0.26;0.24)	28
Liverpool Bay									
Cod	0.017 (0.018;0.016)	< 0.001 -	0.03 (0.031;0.029)	0.11 (0.11;0.11)	0.41 (0.44;0.38)	0.24 (0.25;0.22)	0.25 (0.25;0.25)	3.7 (3.9;3.5)	30
Whiting*	0.026 (0.028;0.023)	0.021 (0.020;0.022)	0.015 (0.014;0.015)	0.33 (0.39;0.27)	0.51 (0.51;0.50)	1.4 (1.2;1.5)	0.19 0.23;0.15)	5.1 (5.4;4.8)	47
Plaice	0.008 (0.008;0.007)	0.019 (0.018;0.019)	0.014 (0.013;0.014)	0.042 (0.042;0.042)	0.064 (0.065;0.063)	0.061 (0.061;0.060)	0.006 (0.005;0.006)	1.2 (1.2;1.2)	20
Sole	< 0.001 -	< 0.001 -	<0.001 -	0.017 (0.015;0.018)	0.027 (0.024;0.030)	0.035 (0.033;0.036)	0.004 (0.004;0.004)	0.59 (0.53;0.64)	6
Dab	0.012 (0.012;0.011)	0.015 (0.016;0.013)	0.014 (0.015;0.013)	0.046 (0.048;0.044)	0.091 (0.091;0.090)	0.044 (0.046;0.041)	0.022 (0.020;0.023)	2.2 (2.3;2.1)	34
Flounder	0.017 (0.014;0.020)	0.008 (0.008;0.008)	0.007 (0.006;0.008)	0.053 (0.052;0.054)	0.076 (0.068;0.083)	0.25 (0.24;0.25)	0.005 (0.005;0.005)	1 (0.8;1.2)	6
* 17 fish analysed for pesticides									
Morecambe Bay									
Cod	< 0.001 -	0.034 (0.034;0.034)	0.034 (0.034;0.034)	0.13 (0.15;0.11)	0.35 (0.35;0.35)	0.22 (0.22;0.22)	0.016 (0.015;0.016)	2.9 (2.9;2.8)	27
Whiting	0.025 (0.025;0.025)	0.011 (0.012;0.010)	0.004 (0.003;0.004)	0.27 (0.28;0.26)	0.83 (0.81;0.85)	2.2 (2.1;2.3)	0.1 (0.072;0.13)	6.8 (6.5;7.0)	20
Plaice	0.007 (0.006;0.007)	0.003 (0.003;0.003)	0.008 (0.011;0.004)	0.019 (0.019;0.019)	0.036 (0.015;0.057)	0.07 (0.059;0.081)	0.018 (0.014;0.021)	0.71 (0.64;0.77)	12
Sole	< 0.001 -	0.002 (0.002;0.002)	0.002 (0.002;0.001)	0.008 (0.007;0.008)	0.016 (0.013;0.019)	0.03 (0.027;0.032)	0.004 (0.003;0.004)	0.27 (0.26;0.27)	4
Dab	0.01 (0.011;0.009)	0.004 (0.003;0.004)	0.007 (0.008;0.006)	0.059 (0.063;0.054)	0.1 (0.11;0.09)	0.019 (0.018;0.019)	0.021 (0.020;0.021)	1.8 (1.9;1.6)	26
Flounder	0.015 (0.013;0.016)	0.007 (0.005;0.008)	0.004 (0.003;0.004)	0.037 (0.038;0.035)	0.08 (0.075;0.085)	0.12 (0.11;0.13)	0,020 (0.019;0.020)	0.79 (0.63;0.95)	16
St Bees Head									
Cod*	0.012	0.01	0.01	0.1	0.06	0.03	0.004	1.6	43
Whiting	0.023 (0.022;0.023)	0.024 (0.024;0.024)	0.012 (0.011;0.012)	0.13 (0.12;0.13)	0.31 (0.30;0.32)	0.12 (0.12;0.12)	0.17 (0.17;0.17)	4 (4.0;3.9)	65
Plaice	0.002 (0.002;0.002)	< 0.001 -	< 0.001 -	< 0.001 -	0.006 (0.006;0.006)	< 0.001 -	< 0.001 -	0.037 (0.035;0.038)	7
Dab	0.006 (0.006;0.006)	< 0.001 -	< 0.001 -	0.085 (0.087;0.083)	0.044 (0.045;0.043)	0.065 (0.069;0.061)	0.042 (0.042;0.041)	0.29 (0.29;0.28)	36
* One result only									

Table 3. Concentrations of organochlorine pesticides and PCBs in fish muscle (mg kg $^{-1}$ wet weight).

Area	Species	Month and year of capture	HCB	α HCH	γHCH	Dieldrin	pp DDE	pp TDE	pp DDT	PCB	% Fat
Tyne	Flounder	Mar-86	0.005	< 0.001	< 0.001	0.005	0.002	0.001	0.001	0.019	< 1
Humber	Cod	Jun-86	< 0.001	< 0.001	< 0.001	0.002	< 0.001	< 0.001	< 0.001	0.015	< 1
Humber	Whiting	Dec-87	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 1
Liverpool Bay	Cod	Sep-87	< 0.001	< 0.001	< 0.001	< 0.001	N/R	< 0.001	< 0.001	0.011	< 1
Liverpool Bay	Whiting	Sep-87	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.002	0.007	< 1
Liverpool Bay	Plaice	Sep-87	< 0.001	< 0.001	< 0.001	0.004	0.002	0.002	0.003	0.048	< 1
Liverpool Bay	Dab	Sep-87	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.014	< 1
Liverpool Bay	Flounder	Mar-87	< 0.001	< 0.001	< 0.001	0.002	0.002	0.004	0.004	0.043	< 1
Morecambe Bay	Whiting	Jun-87	< 0.001	< 0.001	< 0.001	0.002	< 0.001	< 0.001	0.002	0.015	< 1
Morecambe Bay	Dab	Jun-87	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.012	< 1

N/R. No result obtained (1988 value <0.001).

1.4 Conclusions

The results of these monitoring surveys confirm previous DFR findings that considerable variation in fish contaminant levels exists around the coasts of England and Wales.

The results give little indication of serious contamination in North Sea and Channel areas. General levels of contamination remain greatest in the north-eastern Irish Sea off the north-western English coast, with relatively high levels of mercury in fish muscle and DDT and PCBs in fish liver from Liverpool and Morecambe Bays. However, even in these areas, the environmental quality standard for mercury laid down by the EC and the Paris Commission (see Appendix 1) continues to be met, and the concentrations of pesticides/PCBs in fish muscle tissue give no cause for concern from a human consumption standpoint.

It is, however, apparent from work recently carried out in Cardigan Bay, that some marine mammals, particularly small cetaceans, can accumulate relatively high body burdens of organochlorines (Morris *et al.*, 1989). Whilst the levels are not generally as high as those encountered in the Wadden Sea or Baltic Sea,where high concentrations of PCB in seal tissues have been linked with the widespread infertility observed in common seals from both areas (Reijnders, 1986) and with sterility in grey seals and ringed seals in the Baltic (Helle *et al.*, 1976a,b), concentrations in fish from the

Table 4. Concentrations of metal contaminants in mussels(mg kg $^{-1}$ wet weight).

Area of capture	Month and year of capture	Number of mussels	Mean length (cm)	Hg	Cu	Zn	Cd	Pb	% dry matter
Tyne (South Shields)	Jun-85	51	4.4	0.03 (0.02;0.04)	1.3 (1.3;1.3)	36 (35;36)	0.11 (0.11;0.11)	2.9 (3.0;2.7)	16
Tees mouth (North Shore)	Mar-85	50	4.3	0.05 (0.05;0.05)	4.4 (4.5;4.3)	32 (31;33)	0.19 (0.19;0.19)	2.6 (2.9;2.3)	18
Humber (Bull Fort)	Aug-87	50	4.5	0.06 (0.06;0.05)	1.3 (1.3;1.2)	30 (29;30)	0.78 (0.76;0.80)	< 0.6 -	14
Southern Bight (nr Lowestoft)	Aug-85	50	4.3	0.03 (0.03;0.03)	1.3 (1.3;1.2)	23 (23;23)	0.15 (0.14;0.16)	0.7 (0.7;0.7)	14
Thames (Southend)	Oct-86	50	4.4	0.03 (0.03;0.03)	2.1 (2.3;1.9)	20 (21;19)	0.33 (0.33;0.33)	1.3 (1.3;1.2)	20
Eastern Channel (Hastings)	Nov-85	50	4.6	0.03 (0.03;0.03)	1.5 (1.5;1.4)	17 (17;16)	0.12 (0.10;0.14)	1.1 (1.0;1.1)	19
Western Channel (Plymouth Harbour)	Mar-85	50	3.9	0.02 (0.02;0.02)	3.2 (3.2;3.2)	32 (32;32)	0.26 (0.23;0.29)	3.5 (3.4;3.5)	14
Bristol Channel (Minehead)	Aug-87	50	3.8	0.09 (0.09;0.08)	1.6 (1.6;1.6)	21 (21;21)	1.1 (1.1;1.0)	0.6 (0.6;0.6)	14
Swansea Bay (Mumbles)	Oct-86	50	4.6	0.03 (0.03;0.03)	1.2 (1.1;1.3)	26 (27;25)	0.93 (1.0;0.85)	1.6 (1.5;1.6)	16
Cardigan Bay (Barmouth)	Jul-85	50	4.3	0.02 (0.02;0.02)	1.5 (1.6;1.4)	25 (25;24)	0.28 (0.27;0.28)	2.6 (2.6;2.6)	20
Liverpool Bay (Mersey Estuary)	Oct-85	34	4.7	0.09 (0.10;0.08)	1.9 (1.8;1.9)	30 (30;29)	0.42 (0.43;0.40)	1.4 (1.1;1.7)	15
Morecambe Bay (Morecambe)	Jul-85	50	4.1	0.06 (0.06;0.06)	2.5 (2.4;2.5)	21 (20;21)	0.28 (0.28;0.28)	1 (0.9;1.0)	23
St Bees Head (Whitehaven)	Jun-87	50	4.3	0.05 (0.05;0.05)	2.6 (2.6;2.5)	20 (19;20)	3.9 (4.0;3.8)	2.5 (2.5;2.5)	13
Commercial areas									
Holy Island	Jul-85	50	5.5	0.03 (0.03;0.02)	1.1 (1.1;1.1)	16 (16;16)	0.12 (0.12;0.12)	< 0.6	14
Wash (Boston)	Sep-85	44	4.5	0.02 (0.02;0.02)	1.8 (1.8;1.8)	12 (13;11)	0.12 (0.13;0.11)	< 0.6	20
Wash (Kings Lynn)	Sep-85	50	4.6	0.01 (0.01;0.01)	1.7 (1.7;1.7)	14 (14;14)	0.1 (0.11;0.08)	< 0.6	18
Burry Inlet (Llanelli)	Jun-85	50	3.4	0.02 (0.02;0.01)	1.5 (1.5;1.4)	18 (18;18)	0.3 (0.29;0.31)	0.7 (0.6;0.8)	15
3-Rivers area (Ferryside)	Jul-85	50	4	0.01 (0.01;0.01)	1.5 (1.5;1.5)	17 (17;17)	0.21 (0.20;0.21)	0.7 (0.6;0.7)	16
Bangor	Jun-85	25	5.1	0.06 (0.06;0.06)	1.4 (1.4;1.4)	20 (20;19)	0.29 (0.27;0.30)	1.5 (1.6;1.4)	18

Irish Sea do give some cause for concern in relation to the well-being of certain coastal populations of dolphins and porpoises. Monitoring will, therefore, continue and efforts will be made to reduce inputs where possible.

2. MONITORING OF TRACE METALS IN SEA WATER, 1985-1987

2.1 Introduction

The overall distribution of trace metals in the waters of England and Wales has not been examined for a number of years. During the period 1985-1987, methods of sampling, preparation and analysis have been improved as the importance of contamination from equipment and from outside sources, as well as adsorption on to sample containers, has been recognised. Improved methods of sampling, preservation and analysis have been developed and checked both by intercalibration and against certified reference materials; reference stations have been visited and sampled. Such techniques were employed on a number of cruises undertaken between 1985 and 1987, in order to establish the distribution of trace metals in the waters around the coastline of England and Wales, and in order to contribute to the Baseline Survey of Contaminants organised by the International Council for the Exploration of the Sea (ICES).

2.2 Methods

One of the major sources of error, in the determination of natural levels of trace elements in sea water, is

contamination associated with the sampling apparatus. A method of obtaining contamination-free samples was, therefore, developed employing a polytetrafluoroethylene (PTFE) pump to draw water, via perfluoroalkoxy (PFA) tubing, from a buoy positioned away from the sampling vessel. The system is described in detail elsewhere (Harper, 1987). Samples were analysed using differential pulse anodic stripping voltametry (DPASV), for cadmium and lead, and by cold vapour atomic absorption spectrophotometry (CVAAS), for mercury. The analysis for mercury was in some cases also extended to the various types of mercury present (reactive dissolved, total dissolved and total in unfiltered water) using a simple pre-treatment stage. Although not completed, work was carried out on the development of methods for copper by DPASV and zinc by cathodic stripping voltametry (CSV). The analytical methods used are described in detail in Harper *et al.* (1989).

2.3 Results

The areas mentioned in Section 2 are shown in Figure 2. The combined results from the three cruises carried out during this period have been used to produce the distributions found in Figures 3 to 7. The contours were defined from mean concentrations measured during eight successive cruises. Where individual measurements exceed the typical concentration of adjacent waters, they are highlighted.

2.3.1 *Dissolved cadmium*

Dissolved cadmium exhibits conservative behaviour in seawater (i.e. concentrations reduce proportionately with dilution processes). Concentrations gradually attenuate with increasing distance from the coast and the higher concentrations are generally associated with inputs from large estuarine sources. The Humber, Thames, Severn and Mersey give rise to the higher concentrations measured (up to 500 ng l^{-1} in the inner Severn Estuary), with the Tyne, Tees and Southampton Water seen as smaller point sources (Figure 3).

A large point source is also associated with discharges from the outfall of a phosphate plant near St. Bees Head, north-eastern Irish Sea. The plant processes foreign phosphate ore which is known to be contaminated with cadmium.

Concentrations of cadmium were also elevated above typical values in a small number of samples from the outer Thames Estuary (up to 45 ng l^{-1}) and Dogger Bank (up to 50 ng l^{-1}). The former may be associated with periodic inputs of sewage sludge and dredged spoil to the Barrow Deep and South Falls disposal grounds. There is no obvious explanation for the latter anomaly, although the area shows elevated levels of other metals and other workers have reported that the Dogger Bank is an area in which contaminants appear to accumulate in the sediments (Delbeke and Joiris, 1987).

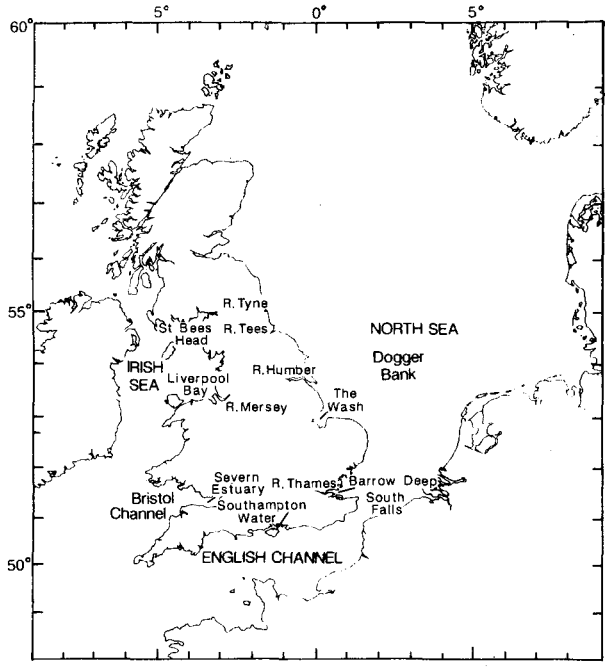

Figure 2. Sites from which trace metal samples were obtained.

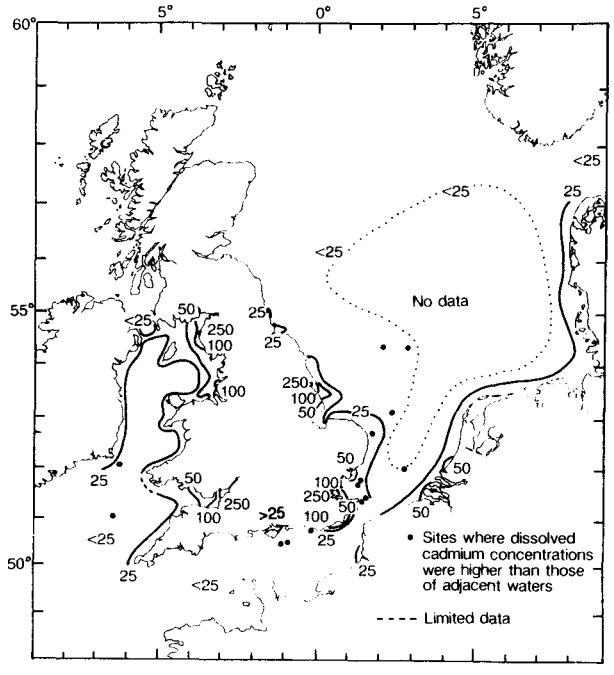

Figure 3. The distribution of dissolved cadmium (ngl^{-1}).

Remote from coastal areas, the concentration of dissolved cadmium was less than 25 ng l^{-1}, with the lowest recorded value being 8 ng l^{-1}.

All of the concentrations found were well within the UK water quality standard for protection of fish and other life for dissolved cadmium in coastal waters of 2.5 µg l^{-1} (Gardiner and Mance, 1984).

2.3.2 *Dissolved lead*

The distribution of dissolved lead in sea water (Figure 4) also reflects the dilution of inputs from estuaries and point sources; however, the effect is moderated by the affinity of lead for suspended particulate material, and perhaps also by atmospheric inputs. Such factors result in a complex distribution of dissolved lead concentrations around the UK coast. In the highly turbid Severn and Humber Estuaries, scavenging by the very high levels of particulates in the water leads to variable concentrations of 56 to 10,000 ng l^{-1} and 11 to 70 ng l^{-1}, respectively.

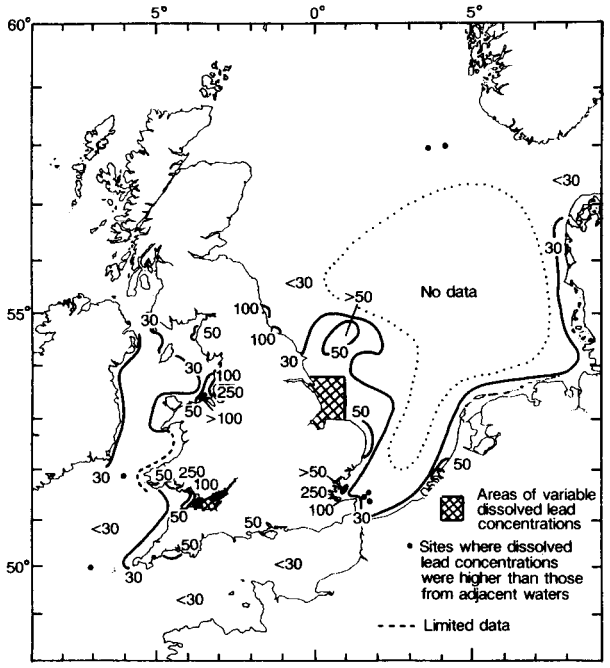

Figure 4. The distribution of dissolved lead (ng l^{-1}).

Concentrations of dissolved lead to the north east of the Humber remain relatively high, despite the scavenging and diluting potential of the water. Atmospheric inputs from the industrialised areas of the north east of England may perhaps account for this discontinuity.

The distribution of lead in the Thames Estuary is dominated by dilution, with point sources having local influence. Concentrations up to 100 ng l^{-1} are seen in the immediate vicinity of the Barrow Deep sewage-sludge disposal site and, although only for a few samples, up to 90 ng l^{-1} over the South Falls dredged-spoil disposal site (Harper, 1988). The UK standard for protection of fish and other life, of 25 µg l^{-1} for dissolved lead in coastal waters is well above the concentrations found (Gardiner and Mance, 1984).

2.3.3 *Dissolved copper*

The data for dissolved copper concentrations have been limited thus far to the Bristol Channel/Severn Estuary, where the distribution observed is similar to that seen for lead. Because particulate material has some influence on the distribution of the dissolved phase of copper, such a finding is not unexpected. Concentrations approach about 3.0 ng l^{-1} at a salinity of 22 practical salinity units (psu). In contrast, open ocean regions have a concentration of about 0.1 µg l^{-1} (D. J. Harper unpublished data).

2.3.4 *Mercury*

Three forms of mercury have been measured in the water column: reactive dissolved; total dissolved; and total (unfiltered). The term dissolved mercury refers to that fraction of the sample which passes through a glassfibre filter (GF/F). Reactive dissolved mercury is defined as that dissolved mercury which can be reduced to Hg^{o} by acidification and treatment with tin (II) chloride, and which approximates to the ionic and weakly complexed inorganic metal. Total dissolved mercury is defined as that which is reducible by acidic tin (II) chloride after oxidation with bromine and which approximates to all dissolved forms of mercury, including strongly complexed and organic forms. Total (unfiltered) mercury is defined as that which is reducible after bromine oxidation with no prefiltration.

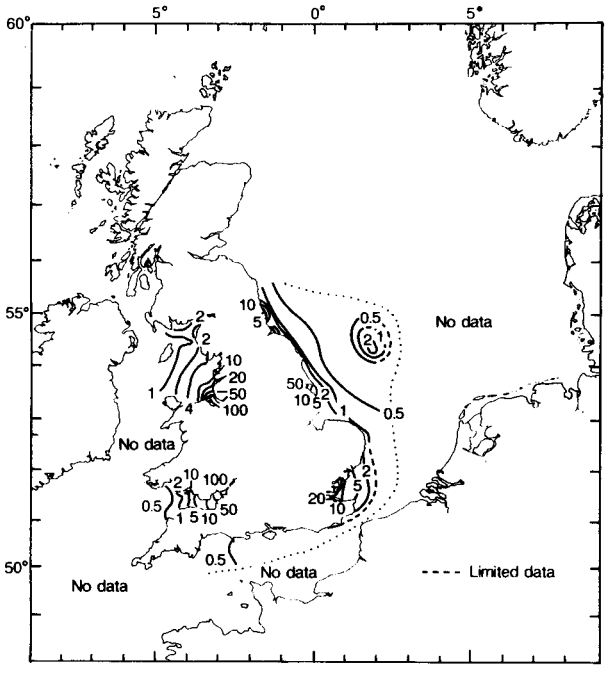

Figure 5. The distribution of total mercury in unfiltered water (ng l^{-1}).

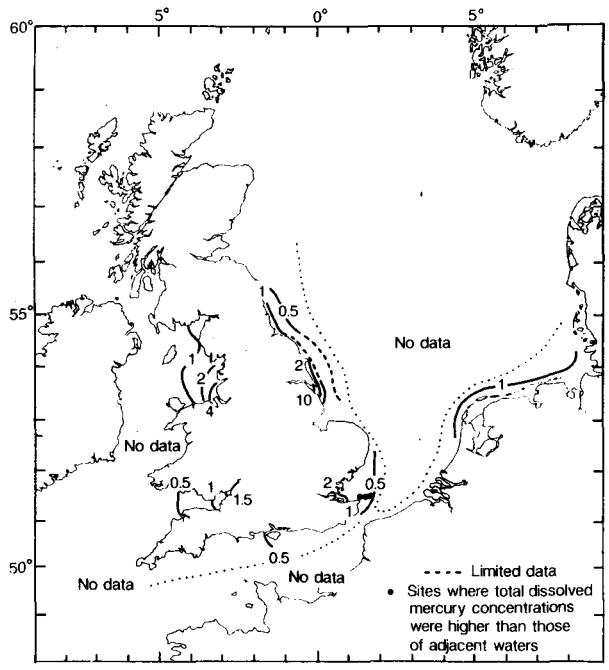

Figure 6. The distribution of total dissolved mercury (ng l^{-1}).

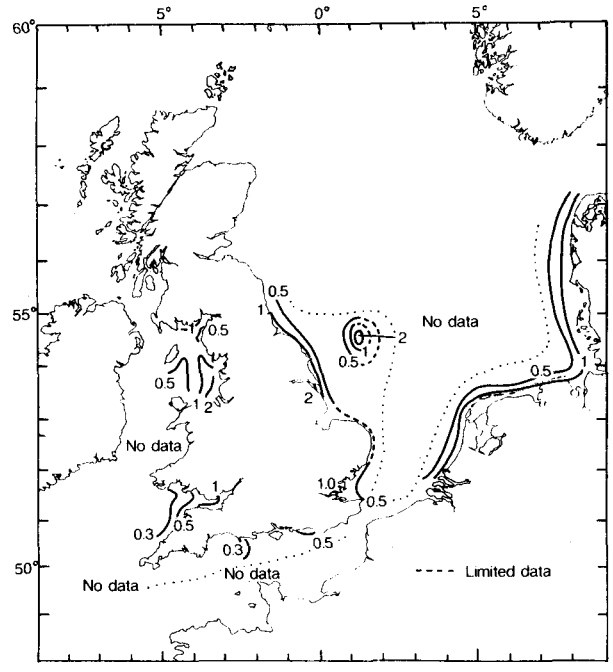

Figure 7. The distribution of reactive dissolved mercury (ng l^{-1}).

Mercury has a great affinity for suspended particulate material. Consequently, estuarine and point sources of the metal are quickly adsorbed by sediments. In the turbid waters of Liverpool Bay and the Bristol Channel, total (unfiltered) mercury concentrations can exceed 200 ng l^{-1} and 150 ng l^{-1}, respectively, (Figure 5). However, removal to particulates ensures that dissolved mercury concentrations remain low, despite the large inputs which have occurred in the past (Figures 6 and 7).

Other features to note include an increase in the total dissolved mercury concentration in some samples taken from the dredged-spoil disposal ground at South Falls in the outer Thames Estuary. The source of the elevated concentrations may be attributable to the disposal of dredged spoil. Concentrations of both total (unfiltered) and reactive dissolved mercury are also elevated over the Dogger Bank. As with the other metals, there is at present no explanation for these higher concentrations, the area not being known to be subject to any recent sources of input either of any form of waste or from other sources. The increase in concentration is not large, although it covers an appreciable area.

The quality objective set by the European Community for protection of marine and other life in coastal waters is a concentration of 0.3 µg l^{-1} of dissolved mercury (European Communities, 1982), which is considerably greater than the concentrations found.

2.4 Conclusions

Baseline distributions of cadmium, lead, and mercury have been described for UK waters. The distribution of copper has been studied to a lesser extent. A number of areas with elevated concentrations of trace metals have been identified as being predominantly associated with estuarine inputs. However, all values found fall well below Environmental Quality Standards for the protection of marine life.

3. MONITORING OF HYDROCARBONS IN SEA WATER, 1984-1987

3.1 Introduction

Samples of sub-surface (1m) water were collected for hydrocarbon analysis during a number of cruises carried out from 1984 to 1987. The aims were two-fold: firstly, to provide data for the ICES Baseline Survey of Contaminants (1985-1987); and, secondly, to extend, and to some extent repeat, an earlier baseline survey conducted by the Burnham Laboratory (Law, 1981) following a change of extraction solvent from dichloromethane to pentane. This change was made so as to improve comparability of results with those of other European workers using hexane as an extracting solvent, because dichloromethane can yield considerably higher results under certain circumstances (Law *et al.*, 1987). Pentane has similar properties to hexane in terms of extraction efficiency and its use as a solvent for fluorescence spectroscopy, but has a lower boiling point. Thus, concentration of solutions in pentane by rotary evaporation is easier and quicker than for those in hexane, and losses of lower boiling components are smaller. This is particularly important in relation to investigations of oil and gas exploitation activities, where the components of some low toxicity base-oils used in drilling muds can contain hydrocarbons as small as C8.

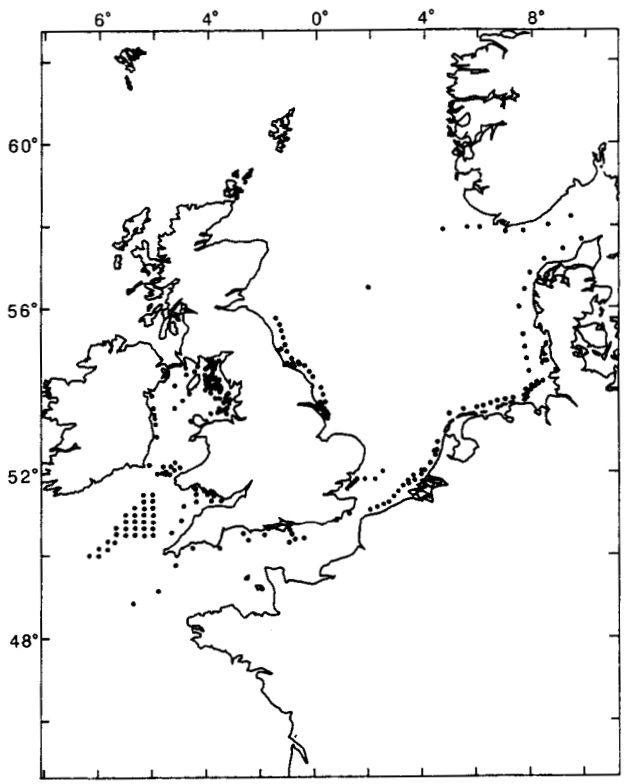

Figure 8. Locations of the hydrocarbon monitoring stations mentioned in this report.

3.2 Methods

Samples were collected between December 1984 and April 1987. Full details of the methods used are given elsewhere (Law *et al.*, 1988). Briefly, unfiltered water samples collected from 1 m depth by means of a shallow water sampler, constructed of glass and PTFE, were extracted with pentane, the extracts were dried, and the total hydrocarbon concentration (THC) was determined by fluorescence spectroscopy (Ex λ 310 nm, Em λ 360 nm) against an Ekofisk crude oil standard. An estimate of the reproducibility of the method is given with the full description of the methods (Law *et al.*, 1988); the results of 'at-sea' bilateral comparisons, carried out with two other European laboratories, have been published elsewhere (Law *et al.*, 1987). All results reported in this publication were individually blank-corrected; blank values were in the range 0.3 to 0.4 μg l^{-1}.

3.3 Results and Discussion

Samples were taken from a total of 295 stations occupied during seven research cruises, on the MAFF research vessels *CLIONE* and *CIROLANA* and the charter vessel *PRINCE MADOG*, including seven anchor stations in Liverpool Bay and the eastern Irish Sea. A plan showing the location of all station positions is given at Figure 8; Figure 9(a-d) shows enlarged sections which allow the detail of the positions to be seen. The tables of results are organised by individual

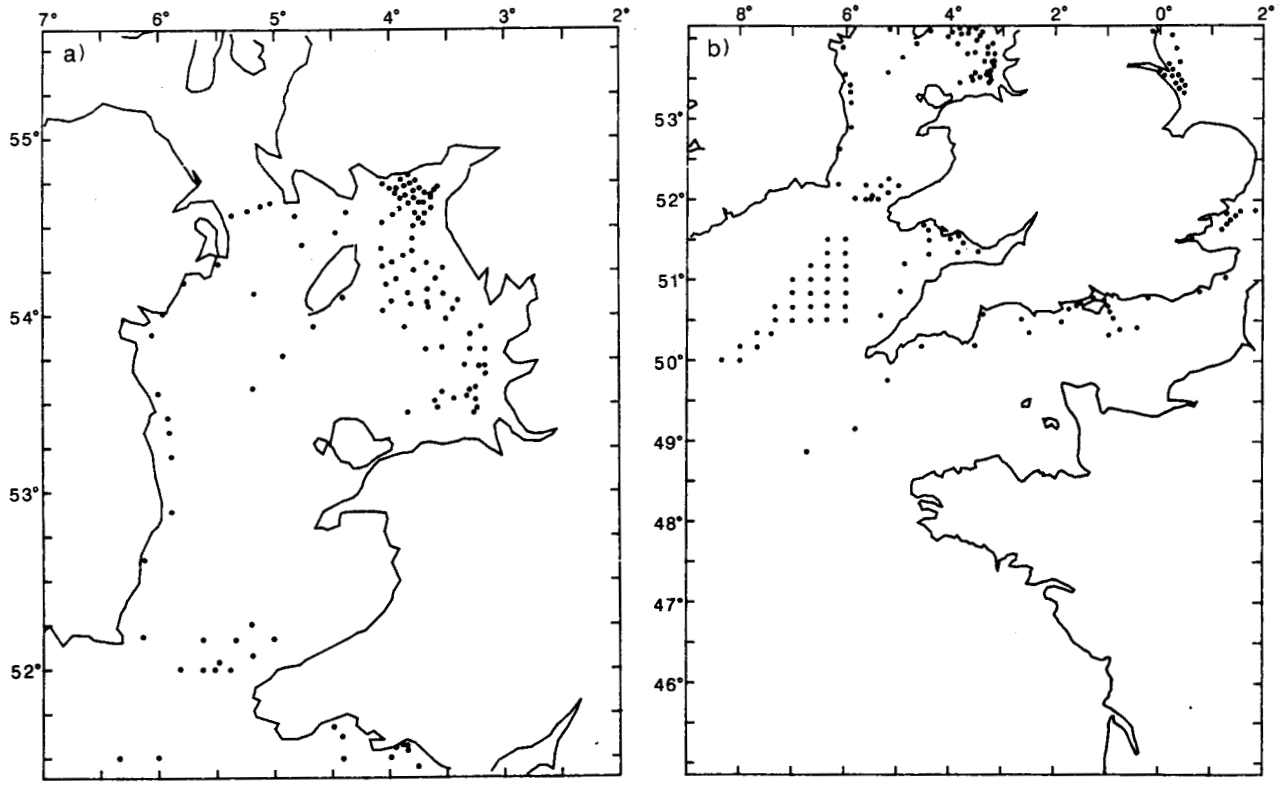

Figure 9. Enlarged section of Figure 8, showing hydrocarbon monitoring stations for: (a) Irish Sea; and (b) English Channel.

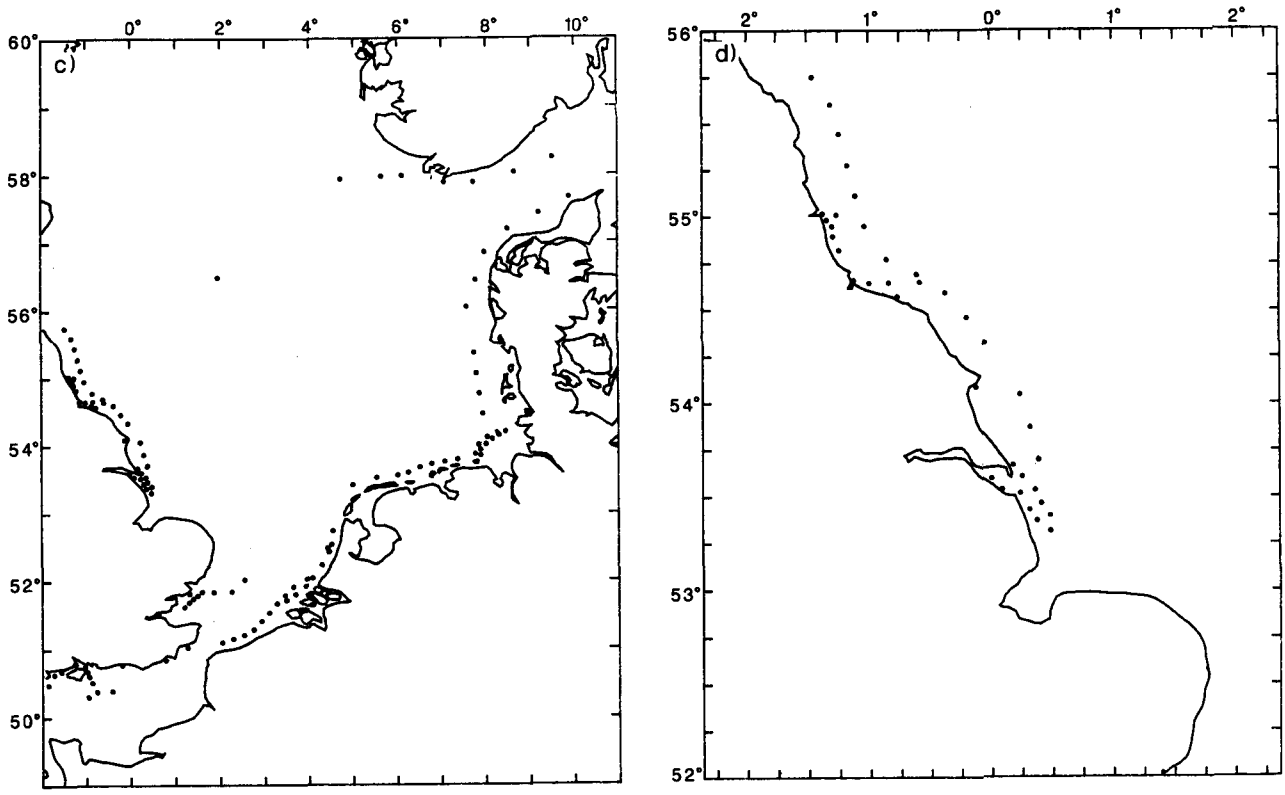

Figure 9. Continued. Enlarged sections of Figure 8 showing hydrocarbon monitoring stations for: (c) North Sea and (d) north-east coast of England.

cruise, and this section will follow the same plan, the cruises being considered in chronological order.

Concentrations of the order of those typically encountered (i.e. a few μg l^{-1}) are well below those likely to be acutely toxic, although the possibility of particular fractions of certain oils exerting a chronic effect at such levels cannot be excluded. Concentrations are also well below the levels that would give rise to aesthetic problems as a result of surface slick formation.

3.3.1 *CLIONE Cruise 14a, 2-6 December 1984*

The results of the analyses of the water samples are given in Table 5. The main aim of this cruise was to obtain samples of surface sediment from oil and gas exploration areas in the Celtic Sea before the start of exploratory drilling. These sediments were to be stored as baseline samples for use in assessing the impact of future development. To date, no exploitable reserves have been discovered in this area and the sediment samples, therefore, have not been analysed, but they will continue to be held in store at -20°C. The majority of THCs in water in this area were low, at <2 μg l^{-1}. A few higher THCs, of up to 7.8 μg l^{-1}, were also found but these exhibited no apparent pattern and probably resulted from shipping activities.

Table 5. THC results from sub-surface (1 m) unfiltered water from the Celtic Sea, CLIONE cruise 14a, 2-6 December 1984, (μg l^{-1} Ekofisk crude oil equivalents).

Station	Positon	Depth (m)	THC
1	50 30.0'W 5 59.9'W	84	1.1
2	50 40.0'N 6 00.0'W	88	2
3	50 50.0'N 5 59.8'W	100	1
4	51 00.0'N 5 59.9'W	96	0.8
5	51 10.0'N 5 59.8'W	97	0.8
6	51 20.0'N 6 00.0'W	99	1
7	51 30.1'N 6 00.1'W	100	1
8	51 30.0'N 6 20.1'W	102	0.8
9	51 20.0'N 6 20.1'W	114	7.8
10	51 10.0'N 6 19.9'W	112	1.1
11	51 00.0'N 6 20.2'W	98	1
12	50 50.0'N 6 21.1'W	97	0.8
13	50 40.2'N 6 20.0'W	100	1.3
14	50 30.0'N 6 19.9'W	98	1.6
15	50 00.0'N 8 20.0'W	130	1.4
16	49 59.9'N 8 00.0'W	118	1
17	50 10.0'N 8 00.0'W	106	1.2
18	50 09.9'N 7 39.9'W	110	<0.4
19	50 20.3'N 7 39.9'W	106	1.2
20	50 20.0'N 7 24.0'W	104	0.8
21	50 30.1'N 7 19.0'W	107	1.3
22	50 30.0'N 6 59.9'W	107	1.9
23	50 30.0'N 6 40.0'W	102	2.4
24	50 40.0'N 7 20.1'W	106	3.7
25	50 39.9'N 6 59.9'W	102	1.4
26	50 40.0'N 6 39.9'W	98	1.1
27	50 50.1'N 6 40.0'W	100	1.5
28	50 50.2'N 7 00.1'W	105	2.7
29	51 00.1'N 7 00.0'W	98	1.2
30	51 00.2'N 6 40.0'W	98	1.3
31	51 10.1'N 6 40.1'W	106	1.5
32	52 00.0'N 5 37.0'W	108	1.4
33	52 10.1'N 5 37.0'W	95	1.2
34	52 09.9'N 5 20.0'W	84	1.3
35	52 15.0'N 5 11.7'W	62	1.2
36	52 10.0'N 5 00.2'W	50	1.9
37	52 04.7'N 5 11.6'W	52	6.4
38	51 59.9'N 5 23.2'W	66	2.1

3.3.2 *PRINCE MADOG cruise 27, 24-28 June 1985*

The results of this survey are given in Table 6. The survey was intended to extend the coverage to the northern part of the eastern Irish Sea, following initial work carried out in 1982-1983 in the area between the Isle of Man and Liverpool Bay. That work was undertaken as a pre-development survey intended to establish a benchmark for contamination levels in the area prior to the establishment of the Morecambe Bay gas field (Law *et al.*, 1989). Samples were collected between the Solway Firth and the northern development area of the gas field. High THCs, >10 μg l^{-1} and up to 110 μg l^{-1}, were found at some stations in the Solway Firth, but all such samples had high particulate loadings. This fact was reflected in the synchronous spectra obtained for these samples (stations 4, 6, and 8 to 10). THCs >10 μg l^{-1} in other samples (stations 33, 46, and 52) were also due to particulate adsorbed hydrocarbons.

Table 6. THC results from sub-surface (1 m) unfiltered water from the Irish Sea, PRINCE MADOG cruise 27, 24-28 June 1985, (μg l^{-1} Ekofisk crude oil equivalents).

Station	Position	Depth (m)	THC
1	54 02.8'N 3 39.5'W	28	1
2	54 31.5'N 3 41.8'W	28	3.5
3	54 33.1'N 3 44.0'W	28	3.5
4	54 34.8'N 3 46.1'W	27	59
5	54 34.7'N 3 41.1'W	22	2.4
6	54 36.6'N 3 37.9'W	18	14
7	54 40.1'N 3 37.9'W	19	1.6
8	54 41.2'N 3 38.1'W	17	110
9	54 42.6'N 3 35.9'W	20	10
10	54 43.9'N 3 34.5'W	17	18
11	54 38.4'N 3 43.9'W	21	3.3
12	54 38.4'N 3 41.7'W	18	2.6
13	54 41.8'N 3 41.7'W	18	1.1
14	54 43.2'N 3 43.6'W	14	1
15	54 45.9'N 3 46.1'W	18	1.6
16	54 47.8'N 3 49.8'W	18	2.7
17	54 46.1'N 3 53.1'W	20	1.3
18	54 44.7'N 4 02.7'W	28	1.4
19	54 43.1'N 3 59.3'W	30	1.5
20	54 41.5'N 3 56.3'W	40	2.3
21	54 43.2'N 3 55.7'W	30	4.6
22	54 44.1'N 3 51.5'W	26	2.1
23	54 44.9'N 3 48.8'W	28	2.7
24	54 42.4'N 3 46.9'W	28	6.1
25	54 40.7'N 3 50.9'W	32	7.7
26	54 39.7'N 3 53.8'W	35	1.8
27	54 40.0'N 3 46.7'W	22	2.7
28	54 38.1'N 3 49.5'W	27	4.2
29	54 36.2'N 3 54.2'W	35	1.6
30	54 34.1'N 3 57.6'W	30	1.3
31	54 31.5'N 4 03.0'W	47	3.5
32	54 30.4'N 3 47.0'W	27	1.5
33	54 26.0'N 3 47.6'W	36	13
34	54 21.8'N 3 47.8'W	42	1.9
35	54 20.1'N 3 52.3'W	42	3.3
36	54 18.0'N 3 58.1'W	25	1.4
37	54 16.5'N 4 03.0'W	22	2.4
38	54 10.4'N 4 01.2'W	28	3.1
39	54 12.2'N 3 56.0'W	31	4.3
40	54 15.2'N 3 47.1'W	38	1.3
41	54 17.7'N 3 40.3'W	40	1.2
42	54 16.1'N 3 32.0'W	29	2.8
43	54 12.4'N 3 35.7'W	35	1.5
44	54 08.8'N 3 39.9'W	37	1.8
45	54 07.5'N 3 50.2'W	30	1.9
46	54 04.5'N 3 58.8'W	41	13
47	54 03.7'N 3 48.5'W	48	2
48	54 04.3'N 3 40.0'W	38	2.4
49	54 07.2'N 3 31.4'W	30	5.5
50	54 04.9'N 3 24.5'W	25	5
51	54 01.9'N 3 26.9'W	25	4
52	53 58.7'N 3 30.2'W	30	90

3.3.3 *CLIONE cruise 14, 8-29 November 1985*

The results of the THC in water analyses are given in Table 7. This was the first cruise specifically intended for the ICES Baseline Survey of Contaminants and covered the North Sea area, including a visit to the Skagerrak reference station. In the absence of comprehensive intercomparison data prior to the survey, the

Table 7. THC results from sub-surface (1 m) unfiltered water from the North Sea, CLIONE cruise 14, 8-29 November 1985, (μg l^{-1} Ekofisk crude oil equivalents).

Station	Position	Depth (m)	Salinity (psu)	Temperature (°C)	THC
2	53 35.9'N 0 0.19'E	7	28.08	8.63	47
3	53 32.4'N 0 05.3'E	13	30.46	8.7	12
4	53 31.3'N 0 14.2'E	9	32.81	8.91	6.6
5	53 26.0'N 0 18.5'E	14	33.07	9.06	3.8
6	53 22.3'N 0 22.3'E	13	33.04	9.03	5.9
7	53 18.9'N 0 28.6'E	14	33.39	9.73	4.2
8	53 24.2'N 0 28.9'E	16	34.26	9.68	2.7
9	53 28.2'N 0 24.7'E	12	34.27	9.82	1.8
10	53 32.5'N 0 21.3'E	12	34.28	9.89	2.6
11	53 36.6'N 0 15.2'E	12	34.26	9.75	2.7
12	53 40.5'N 0 10.8'E	12	34.28	9.54	2.4
13	54 05.3'N 0 07.8'W	8	34.25	9.06	6.1
14	54 38.9'N 0 35.0'W	45	34.45	9.42	2
15	54 34.2'N 0 46.0'W	25	34.03	8.17	8.5
16	54 38.9'N 0 50.1'W	27	34.36	9.23	4.8
17	54 38.8'N 0 59.9'W	25	34.21	8.63	3.1
18	54 39.6'N 1 07.4'W	11	34.07	8.42	3.1
19	54 49.4'N 1 14.5'W	23	34.17	8.96	5
20	54 53.9'N 1 17.9'W	22	34.09	8.86	4.6
21	54 57.0'N 1 17.9'W	26	34.1	8.82	4.2
22	54 59.3'N 1 20.5'W	26	34.11	8.58	4
23	55 01.0'N 1 22.8'W	17	34.29	8.62	4.8
24	55 00.9'N 1 15.9'W	42	34.41	9.14	3.3
49	56 29.0'N 1 58.9'E	79	34.83	9.14	1.1
63	57 54.8'N 4 44.9'E	94	34.28	9.06	0.8
64	57 57.6'N 5 39.8'E	220	34.08	9.26	1.1
65	57 58.0'N 6 07.5'E	296	33.63	8.91	1.1
66	57 52.4'N 7 05.2'E	415	32.84	8.29	1.3
67	57 52.2'N 7 44.2'E	491	31.79	7.76	0.7
68	58 01.0'N 8 40.0'E	531	31.76	6.84	1.8
69	58 13.7'N 9 31.0'E	653	32.63	7.73	0.8
70	57 39.1'N 9 53.9'E	27	34.73	9.42	2.2
71	57 24.9'N 9 12.6'E	20	34.74	8.85	1.5
72	57 10.5'N 8 30.8'E	30	33.92	7.96	0.9
73	56 50.0'N 8 00.1'E	23	34.05	8.07	0.6
74	56 25.8'N 7 47.6'E	25	33.39	7.93	0.7
75	56 01.6'N 7 35.7'E	23	33.64	8.36	1
76	55 20.8'N 7 45.1'E	20	32.7	7.93	1
77	55 02.7'N 7 48.5'E	17	31.15	6.76	1.6
78	54 45.1'N 7 52.2'E	14	30.04	6	1.2
79	54 27.2'N 7 57.3'E	17	30.07	6.64	1.2
80	54 11.7'N 8 27.1'E	10	30.01	4.73	1.2
81	54 08.2'N 8 18.3'E	14	29.42	5.72	1.3
82	54 04.9'N 8 09.5'E	17	29.74	5.94	1.8
83	54 00.0'N 8 01.1'E	28	29.95	6.27	1.6
84	53 55.2'N 7 53.8'E	22	32.19	8.51	1.8
85	53 50.6'N 7 53.9'E	10	30.71	5.97	0.3
86	53 51.1'N 7 46.8'E	16	31.2	6.86	1.6

Table 7. Continued.

Station	Position	Depth (m)	Salinity (psu)	Temperature (°C)	THC
87	53 59.3'N 7 51.7'E	32	30.45	6.76	2
88	54 05.7'N 8 02.7'E	23	29.82	6.22	1.6
89	54 10.0'N 8 16.0'E	16	30.32	5.97	2.2
90	53 47.4'N 7 22.1'E	17	31.13	5.87	4.2
91	53 45.4'N 7 04.5'E	15	31.43	6.56	3.1
92	53 43.5'N 6 47.6'E	17	32.13	5.97	2.7
93	53 40.5'N 6 31.8'E	17	32.46	5.56	2.7
95	53 36.0'N 6 15.9'E	14	32.29	4.95	2.6
96	53 33.9'N 6 02.1'E	20	32.52	5.3	3.1
97	53 31.5'N 5 32.5'E	19	33.24	6.09	3.1
98	53 24.9'N 5 01.3'E	21	33.38	7.32	1.6
99	52 44.0'N 4 33.4'E	19	32.63	7.11	3.3
100	52 31.9'N 4 30.9'E	14	31.18	6.85	4.6
101	52 29.0'N 4 27.2'W	17	31.33	6.98	4.2
102	52 26.0'N 4 28.1'E	13	31.14	7.04	4.2
103	52 14.1'N 4 18.0'E	15	31.49	7.14	4
104	52 02.6'N 4 04.3'E	13	32.05	8.3	4
105	52 01.6'N 3 58.1'E	21	31.19	8.01	5
106	51 56.4'N 3 55.7'E	13	31.78	8.02	3.7
107	51 48.4'N 3 41.9'E	11	32.23	6.98	4.6
108	51 43.1'N 3 29.2'E	13	33.27	7.6	4.4
109	51 06.2'N 2 03.5'E	33	34.7	9.62	1.5
110	51.09.3'N 2 18.2'E	21	34.44	8.32	2.4
111	51 12.9'N 2 32.9'E	20	33.54	6.82	3.7
112	51 17.7'N 2 45.8'E	17	32.94	5.8	5.7
113	51 25.1'N 2 56.3'E	24	33.19	6.63	5.2
114	51 32.5'N 3 07.0'E	33	33.45	7.56	2.9
115	51 40.3'N 3 17.5'E	16	33.7	8.18	2.9
116	51 47.5'N 3 28.3'E	26	33.75	8.51	2.4
117	51 55.0'N 3 39.1'E	21	33.46	8.3	1.5
118	51 47.0'N 1 28.7'E	21	34.63	8.77	5.7
119	51 44.0'N 1 23.1'E	21	34.55	7.62	4.4
120	51 40.9'N 1 18.3'E	17	34.8	6.99	3.9
121	51 36.9'N 1 12.8'E	22	34.91	6.78	5.2
122	51 30.5'N 0 37.8'E	17	32.18	5.49	8.5
123	51 30.4'N 0 32.7'E	16	28.38	6.18	17
124	51 27.3'N 0 26.0'E	13	23.8	7.42	37
125	51 27.8'N 0 19.7'E	12	19.74	8.3	63
126	51 49.2'N 1 18.5'E	9	34.26	5.65	6.3
127	51 50.2'N 1 34.3'E	20	34.89	9.02	2.4
128	51 50.6'N 1 51.1'E	22	34.93	9.61	0.9
129	51 50.8'N 2 15.0'E	45	35.03	10.67	9.6
130	52 01.4'N 2 31.7'E	42	34.99	10.7	1.5

ICES organisers designated three reference stations at which stable concentrations of contaminants, particularly metals, could be expected in the deep water. Participants were encouraged to visit one of these sites in order that results obtained by different laboratories could be compared. The other three stations were west of Shetland, in the Bay of Biscay, and in the Sargasso Sea.

THCs of up to 47 μg l^{-1} (station 2) were encountered around the mouth of the River Humber and again showed the influence of particulates (see also Law *et al.*, 1987). Inshore, along the north-east coast of England, THCs of up to 8.5 μg l^{-1} were recorded (station numbers up to 24). A single THC measurement, made in the central North Sea near the Fulmar oilfield, gave 1.1 μg l^{-1} (station 49), and further north towards the Norwegian coast THCs were low, at 0.7 to 1.8 μg l^{-1} with 0.8 μg l^{-1} at the reference station (station 69). Low THCs, < 2.2 μg l^{-1}, were also recorded along the Danish coast and in the German

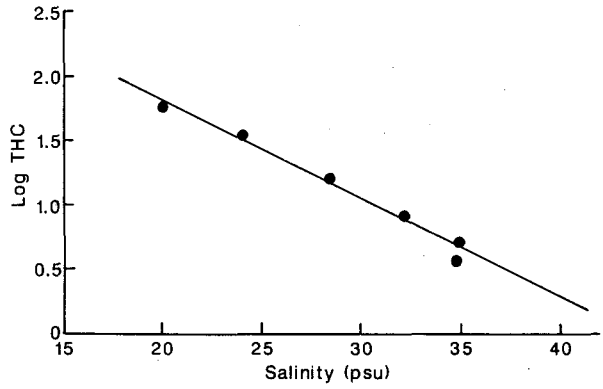

Figure 10. Plot of log THC against salinity for the Thames Estuary, CLIONE cruise 14, 8-29 November 1985.

Bight (stations 70 to 89). These are lower than those recorded on the north-east coast of England, where sampling was undertaken closer to the coast. In foreign waters, coastal state constraints dictated that sampling be conducted further than 3 miles from the shore. THCs rise on approaching the narrower waters of the Southern North Sea and the major river inputs from the Rivers Rhine, Meuse and Schelde. Off the coasts of the Netherlands, Belgium and France, they were in the range 1.5 to 5.7 μg l^{-1} (stations 90 to 117). In the Thames, THCs were from 3.9 μg l^{-1} in the outer estuary to 63 μg l^{-1} in the inner estuary off Tilbury (station 125). Plotting these results against salinity gave the plot shown in Figure 10, in which a good correlation is seen between salinity and log THC. Regression analysis of these data yielded the linear relationship:

$$\log THC = 3.365 - 0.0769 \times \text{salinity}$$

with a correlation coefficient (r) of 0.992. This relationship extrapolates to a THC at zero salinity of 2.32 mg l^{-1}, but it must be stressed that no data have been obtained below a salinity of 20 psu. As the shape of the THC/salinity curve is so obviously non-linear, it seems likely that the log relationship is due to particle interactions, and this behaviour may change markedly higher up the estuary. In the western waters of the Southern Bight, THCs were at 0.9 to 2.5 μg l^{-1}, with the exception of station 126 inshore in only 9 m of water (6.3 μg l^{-1}), and station 129 which was close to the Noord Hinder traffic separation scheme [i.e. in an area of major shipping activity (9.6 μg l^{-1})].

3.3.4 *CLIONE* cruise 4, 12 March-1 April 1986

The results obtained from analysis for THCs in water are given in Table 8. This was the second cruise undertaken in connection with the ICES Baseline Survey. Stations 1 to 13 were sampled on passage through the Solent; THCs were at 1.0 to 3.5 μg l^{-1},

Table 8. THC results from sub-surface (1 m) unfiltered water from the Irish Sea and English Channel, CLIONE cruise 4, 12 March-1 April 1986, (μg l^{-1} Ekofisk crude oil equivalents).

Station	Position	Depth (m)	Salinity (psu)	Temp. (° C)	THC
1	50 22.9'N 0 44.8'W	63	34.62	5.97	1.6
2	50 31.0'N 0 52.9'W	28	35	5.79	1
3	50 36.0'W 0 56.9'W	45	34.75	4.39	2.2
4	50 40.0'N 0 59.0'W	17	34.66	3.97	3.3
5	50 43.7'N 1 03.1'W	31	34.47	3.7	2.4
7	50 47.1'N 1 16.4'W	23	33.44	3.62	2.7
8	50 45.5'N 1 23.2'W	14	33.39	3.68	2.7
9	50 43.2'N 1 29.8'W	27	33.74	3.77	2.9
10	50 40.8'N 1 34.9'W	31	33.72	3.84	3.5
11	50 38.1'N 1 43.0'W	27	33.79	3.89	2.2
12	50 28.9'N 1 51.8'W	41	34.41	5.12	1.4
13	50 20.6'N 2 28.2'W	57	34.63	5.72	1.3
14	49 45.0'N 5 10.1'W	93	35.26	8.88	1.3
16	50 33.0'N 5 19.0'W	59	35.21	8.29	1.2
17	50 51.1'N 4 57.0'W	63	35	7.26	1.1
18	51 11.1'N 4 52.1'W	57	34.57	6.66	1.6
19	51 18.9'N 4 24.2'W	47	33.5	5.77	2.1
20	51 21.0'N 3 28.1'W	29	30.64	4.54	16
21	51 20.0'N 3 51.0'W	34	32.54	5.28	6.4
22	51 26.9'N 3 45.0'W	24	31.21	4.69	14
23	51 32.4'N 3 50.3'W	13	31.13	4.88	26
24	51 34.0'N 3 51.0'W	11	30.99	4.93	14
25	51 34.4'N 3 53.0'W	11	30.88	4.98	16
26	51 33.7'N 3 56.8'W	17	30.72	5.05	16
27	51 30.0'N 3 59.4'W	27	31.23	4.84	12
28	51 29.9'N 4 24.3'W	41	32.35	5.33	3.8
29	51 37.0'N 4 24.9'W	25	32.17	5.32	3.2
30	51 40.4'N 4 29.3'W	21	31.94	5.03	2.5
31	52 00.1'N 5 30.9'W	107	34.16	7.15	1.7
32	52 02.6'N 5 28.8'W	93	34.13	7.22	0.8
33	52 00.2'N 5 49.0'W	104	34.27	8.3	0.8
34	53 27.0'N 3 50.1'W	33	33.38	4.78	1.9
37	53 27.0'N 3 15.8'W	19	32.39	4.72	4.5
38	53 31.2'N 3 14.9'W	15	32.25	4.72	12
42	53 31.0'N 3 36.2'W	37	33.42	4.95	2.1
43	53 34.0'N 3 32.1'W	39	33.46	5.17	1.7
56	53 43.0'N 3 20.8'W	29	32.94	4.19	2.5
57	53 42.9'N 3 13.0'W	15	32.53	4.34	3.6
58	53 40.0'N 3 09.8'W	12	31.38	4.84	6.6
59	53 42.9'N 3 10.2'W	11	31.84	4.58	5.1
60	53 48.5'N 3 10.0'W	15	31.6	4.91	5.1
61	53 48.5'N 3 17.9'W	21	32.29	4.53	3.4
62	53 56.0'N 3 12.3'W	18	32.21	5.18	3.6
63	53 53.6'N 3 17.9'W	18	32.1	5.1	3.2
64	53 49.1'N 3 32.5'W	28	32.96	5.07	1.7
65	53 48.5'N 3 41.0'W	38	33.25	5.46	0.9
66	53 56.0'N 3 52.2'W	42	33.33	5.34	0.9
67	54 01.7'N 4 03.0'W	44	33.63	5.72	1
68	54 22.7'N 4 03.7'W	41	33.65	5.25	1.6
69	54 28.2'N 4 27.5'W	36	34.24	6.77	1.6
70	54 35.0'N 4 22.1'W	53	33.11	5.31	1.7
71	54 05.9'N 4 23.9'W	34	34.03	7.05	1.3
72	53 56.0'N 4 39.5'W	53	34.18	6.88	1.1
73	53 33.3'N 6 00.0'W	27	34.17	6.85	2.2
74	53 53.3'N 6 03.4'W	30	34.3	6.91	2
75	54 00.6'N 5 57.4'W	28	34.09	6.7	1
76	54 11.1'N 5 47.1'W	28	33.91	6.41	1.3
77	54 17.3'N 5 28.7'W	50	34.08	6.8	0.6
78	54 28.6'N 5 23.4'W	40	34.1	6.81	1.1
79	54 33.9'N 5 21.7'W	76	34.12	6.91	0.9
80	54 35.4'N 5 13.5'W	149	34.06	6.84	0.9
81	54 37.0'N 5 06.8'W	204	34.08	6.75	1
82	54 38.0'N 5 01.8'W	97	33.88	6.44	0.9
83	54 33.7'N 4 48.8'W	73	33.62	6.18	0.6
84	54 23.8'N 4 45.3'W	37	33.88	6.58	0.5
85	54 07.0'N 5 10.2'W	130	33.85	6.79	0.8
86	53 46.1'N 4 55.3'W	73	34.07	6.83	1.2
87	53 35.1'N 5 11.0'W	65	33.95	6.98	1.3
88	53 25.0'N 5 55.0'W	28	34.1	6.93	1.4
89	53 20.1'N 5 54.2'W	35	34.24	6.96	1.1
90	53 11.9'N 5 53.2'W	37	34.24	6.99	1.2
91	52 53.2'N 5 53.2'W	31	33.91	6.42	0.8
92	52 37.0'N 6 07.4'W	20	34.01	6.87	1.8
93	52 11.0'N 6 08.3'W	77	34.72	7.61	0.9
94	50 10.1'N 4 31.2'W	67	35.11	7.72	1.3
95	50 18.9'N 4 09.9'W	33	34.87	7.46	2.7
96	50 12.0'N 3 45.9'W	36	34.49	7.33	2.5
97	50 10.3'N 3 31.2'W	66	34.84	7.28	2.3
98	50 19.0'N 3 32.7'W	29	34.58	7.27	1.5
99	50 32.0'N 3 27.1'W	21	34.58	7.21	1.6
100	50 34.0'N 3 23.8'W	21	34.46	7.26	1.6
101	50 30.2'N 2 38.4'W	42	34.38	6.65	1.2
103	50 34.0'N 2 22.0'W	27	34.75	6.84	0.8
104	50 47.2'N 0 11.8'W	17	34.71	6.67	1
105	50 44.9'N 0 19.5'E	22	34.09	6.36	2.2
106	50 48.8'N 0 32.1'E	13	34.22	6.14	2.5
107	50 51.0'N 0 47.0'E	15	34.61	6.5	2.5
108	51 01.8'N 1 17.1'E	30	34.81	6.55	1.5

compared with 0.5 to 2.0 μg l^{-1} measured during a cruise in 1984 (Fileman and Law, 1988). In the Bristol Channel (stations 16 to 27), THCs were low along the south coast, at 1.1 to 1.6 μg l^{-1}, and elevated along the north coast, up to 26 μg l^{-1} off Port Talbot in Swansea Bay. All inshore stations along this shore had THCs >10 μg l^{-1}, the probable cause being a combination of the greater population and industrial activity of South Wales and higher suspended particulate loadings. In Liverpool Bay (stations 34, 37, 38, 42, 43, and 56 to 65), elevated THCs were encountered off the River Dee (4.5 μg l^{-1}), off the River Ribble(5.1 and 6.6 μg l^{-1}) and off the Mersey (12 μg l^{-1}). However, concentrations declined rapidly with increasing distance from the coast, falling to around 2 μg l^{-1} at 20 miles offshore and 1 μg l^{-1} 25 to 30 miles north west of the Mersey. This area was studied in rather more detail during *CIROLANA* cruise 4a/87 by means of a number of anchor stations; results from that cruise are reported below. In the north-eastern Irish Sea, north and east of the Isle of Man, THCs were relatively low at 1.3 to 1.7 μg l^{-1}, and very low near the coast of Northern Ireland and in the North Channel (stations 75 to 84) (0.5 to 1.3 μg l^{-1}). South of the Isle of Man and along the Irish coast (stations 85 to 93), THCs of 0.8 to 1.8 μg l^{-1} were recorded. Further discussion on the results for stations in the English Channel (stations 94 to 108) can be found in Law *et al.* (1987).

3.3.5 *CLIONE cruise 13a, 7-11 November 1986*

On this cruise, the intention was to carry out studies of the dispersion of oily water discharges at the Auk and Argyll oilfields, but bad weather prevented work at all but one station. Nine replicate analyses were carried out on samples from repeated casts at one site off the north-east coast. The results are given in Table 9.

Table 9. THC results from sub-surface (1 m) unfiltered water from the north-east coast, CLIONE cruise 13a, 7-11 November 1986, (µg l^{-1} Ekofisk crude oil equivalents).

Station	Position	Depth (m)	THC
1	54 35.0'N 0 53.0'W	13	1.8
			2.1
			2.1
			2.1
	(9 replicate analyses)		2.1
			2.2
			2.2
			2.3
			2.5

3.3.6 *CLIONE cruise 3, 23 February-1 March 1987*

The results of the THC analyses are given in Table10. THCs were determined along a line from Berwick to near Spurn Point, at a distance of 10 miles from the coast, and the outer Humber Estuary. All THCs were low, in the range 0.7 to 1.5 µg l^{-1}, and similar to those found in the northern North Sea and along the Danish coast during *CLIONE* cruise 14/85.

Table 10. THC results from sub-surface (1 m) unfiltered water from the north-east coast, CLIONE cruise 3, 23 February-1 March 1987, (µg l^{-1} Ekofisk crude oil equivalents).

Station	Position	Depth (m)	Salinity (psu)	Temp. (°C)	THC
109	55 44.8'N 1 27.5'W	63	34.06	5.29	0.8
110	55 36.2'N 1 18.7'W	99	34.16	5.27	0.9
111	55 26.6'N 1 14.7'W	70	34.28	5.47	0.8
112	55 16.6'N 1 10.5'W	87	34.16	5.35	0.7
113	55 06.9'N 1 06.6'W	91	34.18	5.53	1
114	54 57.1'N 1 02.3'W	84	34.19	5.62	0.9
115	54 46.2'N 0 51.4'W	61	34.31	5.62	0.7
116	54 41.1'N 0 36.5'W	59	34.39	5.7	0.8
117	54 35.5'N 0 22.4'W	60	34.49	5.74	0.7
118	53 27.6'N 0 12.1'W	59	34.47	5.63	0.9
119	54 19.5'N 0 03.2'W	56	34.47	5.5	0.7
121	54 02.7'N 0 14.0'E	55	34.17	4.8	1.4
123	53 52.3'N 0 18.8'E	41	34.23	5.03	0.8
124	53 42.3'N 0 23.1'E	23	34.2	4.7	1.5

3.3.7 *CIROLANA cruise 4a, 8-18 April 1987*

In the course of this cruise, four stations were worked for THCs in the English Channel and Western Approaches: the results of the analyses are given in Table 11. The stations in the Channel were close to the median line and all THCs were low, at < 0.3 to 1.4 µg l^{-1}, with a decreasing trend to the west [stations 8, 10, 18 and 19; Table 11(a)]. In addition, seven anchor stations were occupied in Liverpool bay and the eastern Irish Sea, (stations 37, 43, 52, 57, 64, 70, and 75). The results from these stations are given in Table 11 (b-h). In general, THCs were higher close to the River Mersey and declined to the north and west.

Table 11(a). THC results from sub-surface (1 m) unfiltered water from the English Channel, CIROLANA cruise 4a, 8-9 April 1987 (µg l^{-1}Ekofisk crude oil equivalents).

Station	Position	Depth (m)	Salinity (psu)	Temp. (°C)	THC
8	50 23.9'N 0 25.2'W	51	35.12	8.04	1.4
10	50 18.3'N 0 57.2'W	72	35.15	8.07	0.8
18	49 08.3'N 5 47.3'W	117	35.36	10.16	0.5
19	48 51.5'N 6 42.7'W	138	35.34	10.41	< 0.3

Table11(b). THC results at the surface from anchor station 37, Liverpool Bay, (2 miles west of the Bar Light), CIROLANA cruise 4a, 12 April 1987 (HW Liverpool: 1010 h; LW 1658 h) (µg l^{-1} Ekofisk crude oil equivalents).

Time	Current		Salinity (psu)	Temp. (°C)	THC
	Speed (m s^{-1})	Direction (°)			
0730			32.24	6.07	3.7
0830			32.35	6.16	4.7
0930			32.43	6.29	3.3
1000					
1030			32.45	6.37	2.5
1100					
1130			32.44	6.58	2.4
1200					
1230	0.5	0	32.33	6.72	2.2
1300	0.55	0			
1330	0.5	20	32.17	7.12	4.6
1400	0.6	20			
1430	0.6	20	31.58	8.35	5.2
1500	0.6	30			
1530	0.3	30	31.19	6.94	11
1600	0.3	40			
1630	0.3	60	30.68	6.88	9.4
1700	0.15	80			
1730	0.4	90	30.84	8.06	9.2
1800	0.45	90			
1830	0.65	90	31.3	6.55	8.2
1900	0.9	100			
1930	0.9	100	30.92	7.2	9.5
2000	0.95	100			
2030			32.34	6.4	4.9

Table 11(c). THC results at the surface, from anchor station 43, Liverpool Bay (2 miles west of Great Burbo Flats), CIROLANA cruise 4a, 13 April 1987 (HW Liverpool: 1044h; LW: 1734 h) (µg l^{-1} Ekofisk crude oil equivalents).

Time	Current		Salinity (psu)	Temp. (°C)	THC
	Speed ($m\ s^{-1}$)	Direction (°)			
0730	0.7	110	29.89	7.04	14
0800	0.7	110			
0830	0.7	110	30.43	6.91	13
0900	0.55	115			
0930	0.4	120	30.61	6.94	NS
1000	0.2	140			
1030	0.2	190	30.95	6.69	10
1100	0.2	270			
1130	0.45	300	30.91	6.7	11
1200	0.55	290			
1230	0.65	290	30.61	6.84	10
1300	0.7	290			
1330	0.75	285	30.42	6.93	12
1400	0.65	290			
1430	0.8	290	30.29	7.02	17
1500	0.7	290			
1530	0.65	290	30.34	7	23
1600	0.5	290			
1630	0.35	290	30.12	7.49	23
1700	0.25	270			
1730	0.25	60	29.98	7.55	21
1800	0.25	100			
1830	0.4	110	30	7.61	16
1900	0.6	110			
1930	0.68	115	29.88	7.52	19
2000	0.78	120			
2030	0.75	120	30.18	7.33	15

NS. No sample.

Table 11(d). THC results at the surface from anchor station 52, Liverpool Bay (northern edge of new site Z), CIROLANA cruise 4a, 14 April 1987 (HW Liverpool: 1119h; LW:1811h) (µg l^{-1} Ekofisk crude oil equivalents).

Time	Current		Salinity (psu)	Temp. (°C)	THC
	Speed ($m\ s^{-1}$)	Direction (°)			
0730	0.65	105	30.5	7.22	7.6
0800	0.7	90			
0830	0.75	85	30.67	7.27	7.7
0900	0.7	100			
0930	0.6	100	31.62	6.99	4.8
1000	0.4	75			
1030	0.25	80	31.98	6.89	6.3
1100	0.15	75			
1130	0.05	335	31.95	6.99	4.6
1200	0.2	305			
1230	0.3	295	31.88	6.97	3.9
1300	0.45	300			
1330	0.65	300	30.99	8.18	5.8
1400	0.7	300			
1430	0.6	290	30.67	7.35	11
1500	0.5	290			
1530	0.4	290	30.65	7.32	11
1600	0.35	300			
1630	0.3	290	30.68	7.74	7.5
1700	0.1	280			
1730	0	-	30.53	8.07	7.7
1800	0	-			
1830	0.25	110	30.61	7.87	7.2
1900	0.45	110			
1930	0.55	110	30.69	7.66	6.3
2000	0.7	110			
2030	0.8	85	30.32	7.68	15

Table 11(e). THC results at the surface, from anchor station 57, Liverpool Bay (2.5 miles north west of Queen's Channel), CIROLANA cruise 4a, 15 April 1987 (HW Liverpool: 1154 h; LW: 1846 h) (µg l^{-1} Ekofisk crude oil equivalents).

Time	Current		Salinity (psu)	Temp. (°C)	THC
	Speed ($m\ s^{-1}$)	Direction (°)			
0930	0.75	110	31.36	7.25	10
1000	0.45	110			
1030	0.4	105	31.56	7.15	10,9.2
1100	0.25	100			
1130	0.2	95	31.71	7.3	7.5
1200	0	-			
1230	0.2	225	31.66	7.43	6.6
1300	0.3	285			
1330	0.5	285	31.55	7.28	5.9
1400	0.65	290			
1430	0.85	300	30.43	8.12	7.4
1500	0.8	300			
1530	0.75	300	30.47	8.19	10
1600	0.6	300			
1630	0.45	290	30.18	7.94	11
1700	0.35	290			
1730	0.25	280	30	8.01	12,12
1800	0.1	270			
1830	0	-	29.9	8.23	27
1900	0.25	90			
1930	0.4	90	29.48	7.98	26
2000	0.6	90			
2030	0.8	90	29.76	8.13	20
2100	0.95	110			
2130	0.9	110	31.06	7.7	8.7
2200	0.7	110			
2230	0.6	110	31.35	7.47	12

Table 11(f). THC results at the surface, from anchor station 64, Liverpool Bay (north western edge of old site Z), CIROLANA cruise 4a, 16 April 1987 (LW Liverpool: 0657 h; HW: 1231 h; LW: 1921 h) (µg l^{-1} Ekofisk crude oil equivalents).

Time	Current		Salinity (psu)	Temp. (°C)	THC
	Speed (ms^{-1})	Direction (°)			
0730	0.3	95	30.71	7.74	6.9
0800	0.45	100			
0830	0.5	90	30.81	7.71	7.7
0900	0.7	100			
0930	0.65	100	30.87	7.66	6.7, 6.9
1000	0.5	100			
1030	0.6	100	30.73	7.88	7
1100	0.4	90			
1130	0.2	90	30.89	7.76	7
1200	0.2	90			
1230	0	-	30.97	7.83	6.1
1300	0.2	285			
1330	0.35	295	30.81	8.33	6.1
1400	0.5	295			
1430	0.55	290	30.81	8.36	6.4
1500	0.6	280			
1530	0.6	280	30.71	8.54	6.2
1600	0.5	290			
1630	0.5	295	30.81	8.05	7.7, 8.3
1700	0.5	300			
1730	0.3	300	30.76	7.82	8.6
1800	0.1	290			
1830	0.15	290	30.7	8.86	6
1900	0	-			
1930	0.1	190	30.74	7.94	6.2
2000	0.3	145			
2030	0.5	120	30.72	7.88	5.9

Table 11(g). THC results at the surface, from anchor station 70, Liverpool Bay (mouth of the River Ribble), CIROLANA cruise 4a, 17 April 1987 (LW Liverpool: 0734 h; HW: 1310 h; LW: 1957 h) (µg l⁻¹ Ekofisk crude oil equivalents).

Time	Current		Salinity (psu)	Temp. (°C)	THC
	Speed (m s⁻¹)	Direction (°)			
0730	0.15	165	30.6	8.73	4.6
0800	0.25	135			
0830	0.2	95	30.19	9.24	5.4
0900	0.25	100			
0930	0.5	80	29.26	9.36	5.5
1000	0.55	75			
1030	0.6	75	29.68	9.65	3.9
1100	0.5	75			
1130	0.4	70	31.06	10.13	2.4
1200	0.25	60			
1230	0.1	30	31.26	8.18	4
1300	0.05	10			
1330	0.05	350	31.29	7.83	3.4
1400	0.15	285			
1430	0.25	280	31.3	7.98	2.8
1500	0.3	280			
1530	0.4	275	31.18	8.49	3
1600	0.4	280			
1630	0.45	275	30.94	9.17	3.8
1700	0.45	270			
1730	0.4	265	30.46	10.43	4.8
1800	0.3	265			
1830	0.25	255	29.89	9.27	4.6
1900	0.2	230			
1930	0.2	165	30.12	9.16	4.3
2000	0	-			
2030	0.2	130	30.16	9	3.2

Table 11(h). THC results at the surface, from anchor station 75, Liverpool Bay (sewage-sludge disposal ground), CIROLANA cruise 4a, 18 April 1987 (LW Liverpool: 0813 h; HW: 1352 h; LW: 2034 h) (µg l⁻¹ Ekofisk crude oil equivalents).

Time	Current		Salinity (psu)	Temp. (°C)	THC
	Speed (m s⁻¹)	Direction (°)			
0730	0.15	300	32.41	7.09	5.1
0800	0.1	285			
0830	0.15	40	32.4	7.14	4.2
0900	0.4	65			
0930	0.6	85	32.46	7.18	2.9
1000	0.8	90			
1030	0.95	100	32.5	7.45	2.1
1100	0.95	105			
1130	0.63	105	32.87	7.26	3.3
1200	0.6	90			
1230	0.4	100	32.98	7.31	2.7
1300	0.3	90			
1330	0.15	60	33.03	7.42	2.2
1400	0	-			
1430	0.15	285	33.03	7.37	1.7
1500	0.3	285			
1530	0.5	280	32.96	7.38	1.5
1600	0.6	290			
1630	0.65	300	32.76	7.38	1.5
1700	0.65	290			
1730	0.6	285	32.64	7.39	2
1800	0.5	285			
1830	0.5	285	32.53	7.31	3.8
1900	0.45	280			
1930	0.2	290	32.46	7.24	3.1
2000	0.15	300			
2030	0.15	350	32.42	7.21	2.9

When the THCs were plotted against salinity, the plot given as Figure 11 was obtained. This shows a dual relationship, in which two stations (75 and 70) clearly are different from the others. Station 75, the furthest offshore, represents the zone in which all waters are fully mixed. In this region, the salinities lie between 32.4 and 33 practical salinity units (psu) and the THC values are between 1.7 and 5.1 µg l⁻¹. Station 75 is around 20 miles from the Rivers Mersey and Ribble, and close to the sewage-sludge disposal ground in Liverpool Bay. Station 70 represents the outflow of water from the River Ribble, and shows lower THC values than those of the remaining stations, and similar to the range given for station 75.

The remaining stations (37, 43, 52, 57, and 64) reflect water from the Mersey (including the Dee, which was not studied separately on this occasion). Data from these stations were replotted on a log THC scale, and yielded results shown in Figure 12. As for the Thames data, which were quoted earlier, a good correlation is seen between log THC and salinity, and a linear relationship was obtained although, in this case, the gradient is very much steeper:

$$\log \text{THC} = 9.417 - 0.2749 \times \text{salinity}.$$

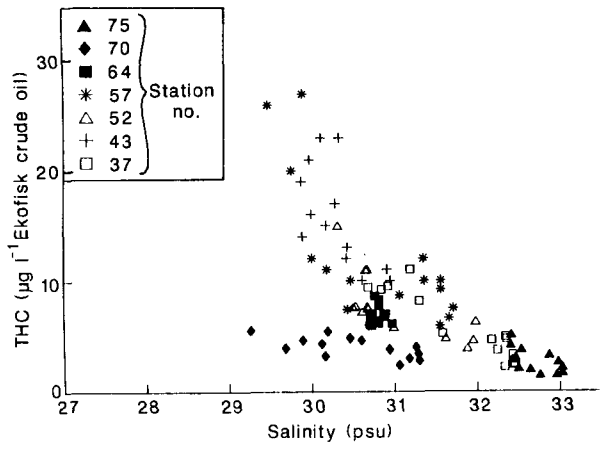

Figure 11. Plot of THC against salinity for Liverpool Bay, Cirolana cruise 4a, 7-20 April 1987.

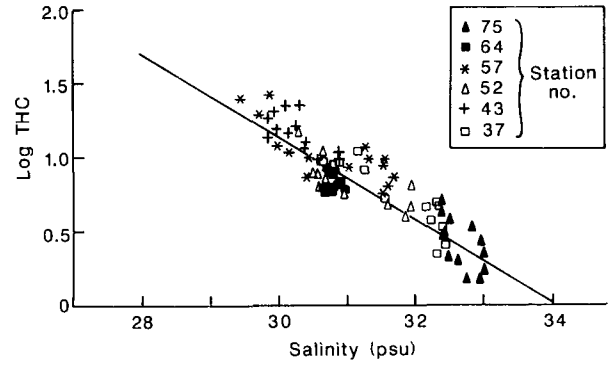

Figure 12. Plot of log THC against salinity for Liverpool Bay, Cirolana cruise 4a, 7-20 April 1987.

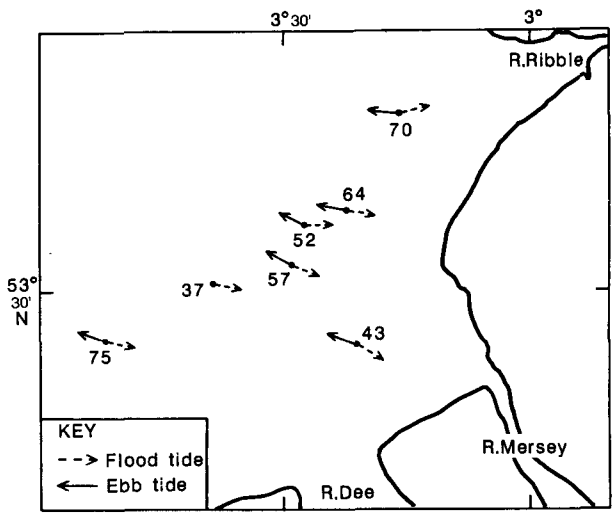

Figure 13. Locations of anchor stations in Liverpool Bay, CIROLANA, cruise 4a, 7-20 April 1987. The current directions at maximum flow on the ebb and flood tides are indicated by arrows.

The data are also more scattered and the correlation coefficient (r) is 0.890. In this case, extrapolation to zero salinity gives a nonsensical result, of 2.6 million mg l^{-1}. The lowest salinity investigated was, however, only 29.5 and more work in the estuaries would be needed to investigate the true behaviour of the hydrocarbons. This would also need to involve the analysis of specific hydrocarbons in order to elucidate details of their interactions with particulate material. A plan of the station positions showing the current directions at maximum flow on both ebb and flood tides is given at Figure 13. The flood tide direction only is shown for station 37, due to a failure of the current meter during the ebb tide. In the Tamar Estuary (south-west England) Readman *et al.* (1982) showed that polycyclic aromatic hydrocarbon concentrations were not significantly correlated with salinity, but could be correlated with both total and mineral suspended solids.

3.4 Total hydrocarbon (THC) and suspended particulate material (SPM) concentrations

From the foregoing account, it will be apparent that the relationship between THCs and concentrations of SPM is of some interest. Data on SPM concentrations are currently available for two cruises, *CLIONE* 14/85 and 4/86 (i.e. those undertaken in connection with the ICES Baseline Survey). Plotting THCs against SPM concentrations gave the graphs shown at Figure 14 (a-c), for the North Sea, the English Channel and the Irish Sea respectively. All plots show considerable scatter, with measurements being made predominantly at SPM concentrations below 30 parts/10^6. In the Channel and the Irish Sea, all results fall within this

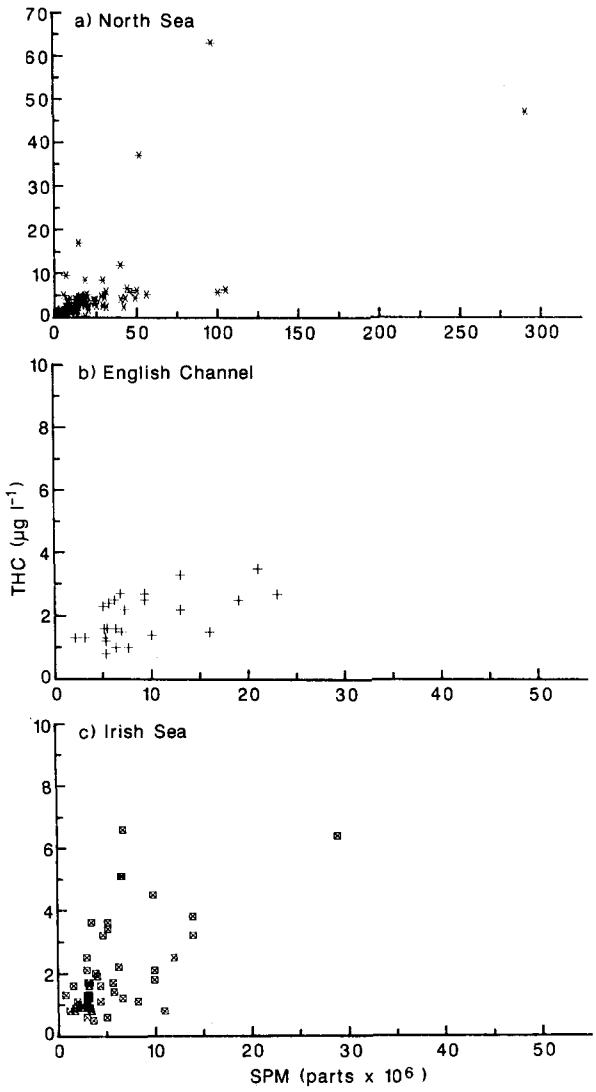

Figure 14. Plots of THC against SPM concentrations for CLIONE cruise 14, 8-29 November 1985 and cruise 4, 12 March-1 April 1986: a) North Sea; b) English Channel; and c) Irish Sea

area. In the North Sea, however, a number of determinations were made above this range, particularly in and around the Thames and Humber Estuaries.

Figure 15(a-b) shows THC/SPM plots for the Thames and Humber Estuaries respectively. Although data are few for the Thames, there is a clear linear relationship, albeit again with considerable scatter at low SPM concentrations. In Figure 15(b) a linear relationship may also be present but is much less clear. Considerable work remains to be done. Future work will be carried out by analysing a suite of specific hydrocarbons, chosen so as to represent the range of properties exhibited by these compounds in both dissolved and particulate forms. This should lead to a better understanding of the behaviour of hydrocarbons in estuaries and their relationship and interaction with particles.

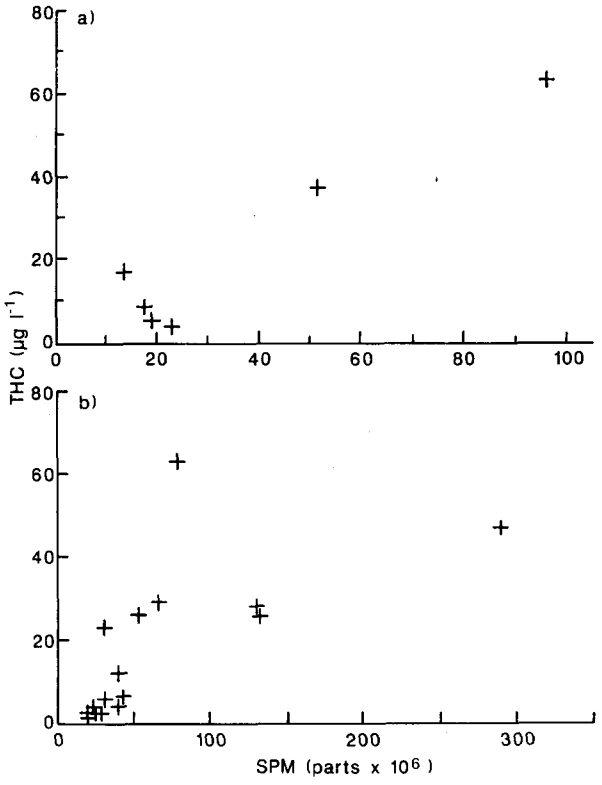

Figure 15. Plots of THC against SPM concentrations for CLIONE cruise 14, 8-29 November 1985 and cruise 4, 12 March-1 April 1986: a) Thames Estuary; and b) Humber Estuary.

3.5 Total hydrocarbon distributions

Figure 16 shows a histogram of the frequency of THC values occurring in the surveys reported here. The most common values fell within the 1.1 to 2 µg l^{-1} band. Of the 397 results recorded, 40% were at 2 µg l^{-1} or less and only 10% were at 10 µg l^{-1} or greater, despite many of the stations being close inshore.

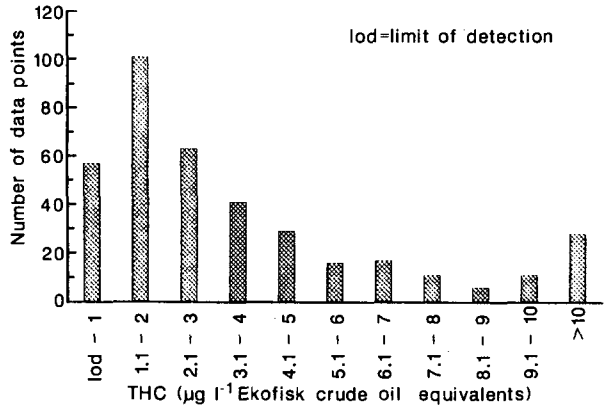

Figure 16. Histogram of all THC values reported (397 from 295 stations).

4. MONITORING OF THE EFFECTS OF GAS AND OIL EXPLORATION: *(i) STUDIES ON THE LEMAN AND THAMES GAS FIELDS, 1987*

4.1 Introduction

Sea-bed surveys, conducted under contract to operators of the Leman, Rough and Thames platforms in the southern gas fields of the North Sea, submitted in 1986 to the Department of Energy, appeared to show nearly uniform distributions of sedimentary hydrocarbons, with contamination apparently arising from drilling discharges being found up to 6000 m away from the platforms. This was unexpected, given the relatively few and shallow wells drilled, when compared with platforms in the northern North Sea oilfields, where steep concentration gradients had been established, and where contamination is seldom in evidence beyond 4000 m. Were these results survey artefacts (all were from the same contractor), or due to rapid redistribution of drilling materials by winnowing of fines in the shallower, more turbulent waters of the southern gas fields, or by burial or mass transport in mobile sediments? It was decided to survey the nature of the sediments, sedimentary hydrocarbons, and benthic fauna between Leman and Thames to try to answer these questions.

Sampling was carried out on 24 February 1987; the sampling positions are shown in Figure 17(a-b).

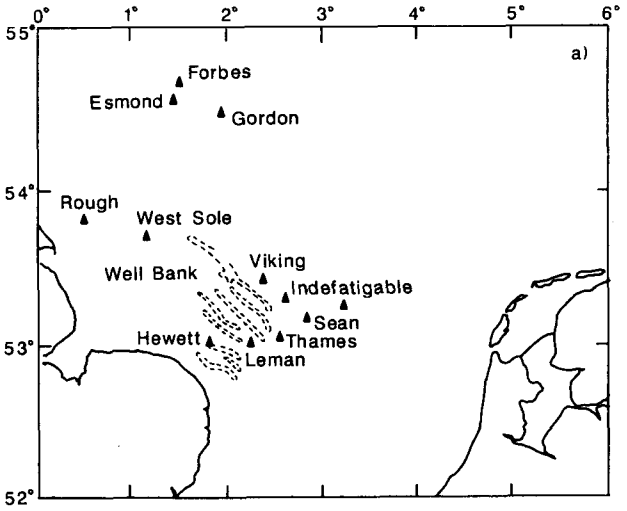

Figure 17. (a) The southern gas fields in the UK sector of the North Sea.

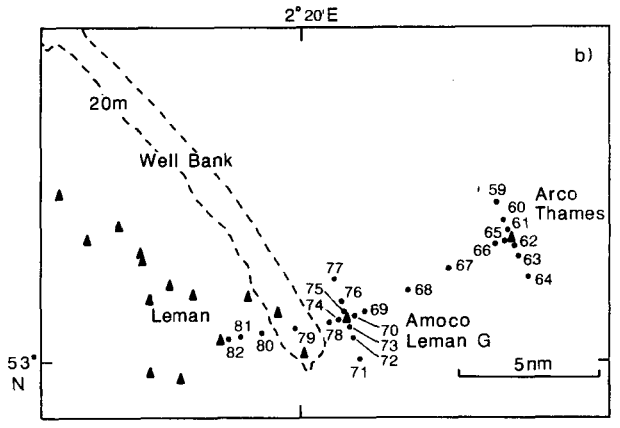

Figure 17. (b) Sampling positions for CLIONE cruise 3, 23 February-1 March 1987.

4.2 Hydrocarbon sampling and analysis

Full details of sampling and analytical methods are given in Law *et al.*, (1988) but, briefly, the outline is as follows. Samples of surface sediment were collected with a modified Day grab. Sub-samples were extracted after digestion with methanolic potassium hydroxide and analysed by means of fluorescence spectrometry (UVF) and capillary gas-liquid chromatography (GC).

4.3 Results

The results of the UVF analyses are given in Table 12, both as diesel equivalents (at 270/330 nm) and as Ekofisk crude oil equivalents (at 310/360 nm), to distinguish between fresh oils derived from drilling inputs and weathered residues. (Fresh oils contain a high proportion of low boiling point aromatic hydrocarbons, and yield higher concentrations at the lower wavelengths). In this case, few major differences were apparent between the two sets of results. The range of results extends from 0.9 to 90 μg g^{-1} dry mass against diesel and 1.2 to 75 μg g^{-1} dry mass against Ekofisk crude oil. In both sets of results, there is one particularly high concentration at station 61; otherwise only at station 76 are both concentrations greater than 10 μg g^{-1}. Results of analyses from replicate grabs performed at a number of stations show no great inhomogeneity, whilst replicates from a single grab sample show even closer agreement, as would be expected. The GC analyses indicate that only at station 61 can the hydrocarbon pattern be attributed to drilling discharges. Figure 18 shows the GC trace for station 61 and those from the base-oils used at Thames, both up to and since October 1985. Both base-oils have a similar boiling range, and the residues seen at station 61 represent weathered base-oils discharged with drill-cuttings and remaining on the sea bed for some time.

Table 12. Total hydrocarbon concentrations (μg g^{-1} dry mass) in surface sediments at the Leman and Thames gas fields, determined by fluorescence spectroscopy, CLIONE cruise 3, 23 February-1 March 1987.

Station	Sediment type	THC (diesel)+	THC (Ekofisk)Δ
59	Sand & shell	1.3	3
60	Sand & shell	2.9	3.5
61	Sand & shell #	90	75
62	Sand	4.9	5.7
63	Sand & shell	3.1	4.4
64	Sand, shell & mud	4.6	8.1
65	Sand & shell	2	2.6
66	Sand & shell	1.2, 1.2, 1.8 §	1.8, 1.9, 3.3 §
67	Sand & shell	1.1, 2.0, 2.5 §	1.4, 3.1, 4.0 §
68	Sand & shell	1.8, 4.6 §	3.0, 7.0 §
69	Sand & shell	1.2, 2.9, 4.3 §	1.7, 4.6, 6.6 §
70	Sand & shell	1.5	2.5
71	Sand & shell	3.2	5.8
72	Sand & shell	2.5	3.4
73	Sand & shell	3	3
74	Mud, shell & stones	6	12
75	Sand & shell	4	6.5
76	Sand, shell & clay	14	13
77	Sand & shell	1.2	1.9
78	Sand & shell	4.4	8.1
79	Sand	0.9, 1.0*	1.2, 1.3*
80	Sand	1.5	1.8
81	Sand	0.9	1.4
82	Sand & shell	4.8	5.3
	Range	0.9-90	1.2-75
	Mean	5.7	6.1
	SD	15.6	14.2

+ Excitation 270 nm, emission 330 nm
Δ Excitation 310 nm, emission 360 nm
§ Replicate grab samples from each station
* Separate sub-samples from the same sample jar
# Surface oxic layer over anoxic mud

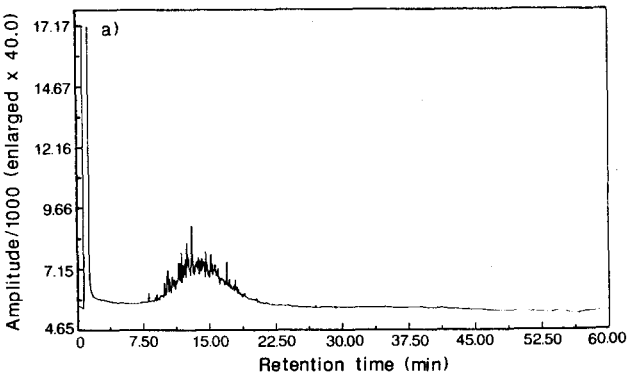

Figure 18. (a) Gas chromatogram of an extract of surface sediment from station 61, Clione cruise 3, 23 February- 1 March 1987.

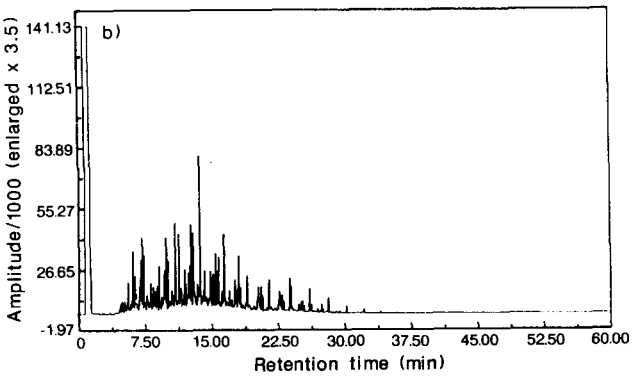

Figure 18. (b) Gas chromatogram of the drilling mud base-oil in use at the Thames gas field up until October 1985.

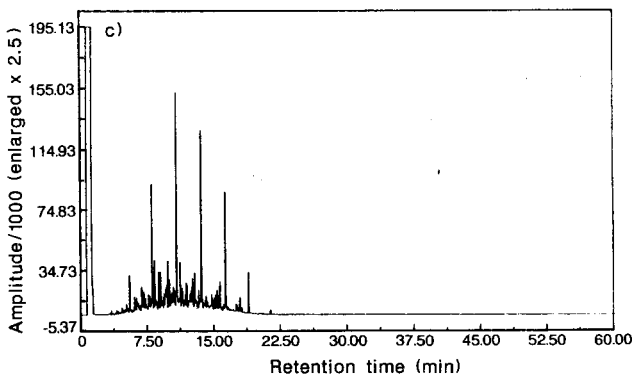

Figure 18. (c) Gas chromatogram of the drilling mud base-oil in use at the Thames gas field after October 1985.

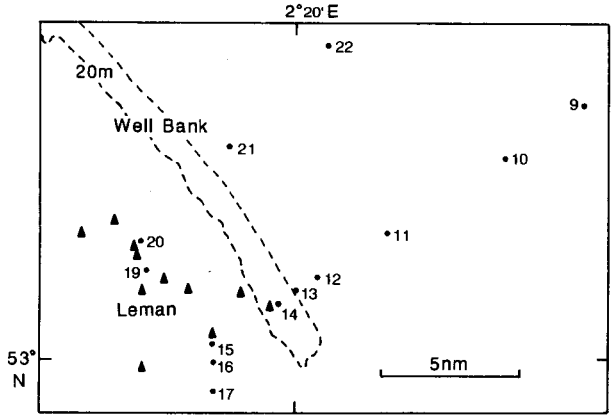

Figure 19. Sampling positions for CLIONE cruise 9, 12-16 July 1982.

Table 13. Total hydrocarbon concentrations (µg g^{-1} dry mass Ekofisk) in surface sediments at Indefatigable and Leman gas fields, determined by fluorescence spectroscopy, CLIONE cruise 9, 12-16 July 1982

Station	Sediment	THC (Ekofisk)
1	Sand and clay	14
2	Sand and clay	15
3	Sand	11
4	Clay and sand	14
5	Sand and shell	5.5
6	Sand and shell	2.8
7	Clay and sand	15
8	Sand	1.1
9	Clay and sand	28
10	Sand and stones	18
11	Moorlog and sand*	87
12	Sand and shell	6.9
13	Sand and mud	10
14	Sand	7.4
15	Sand and shell	3.3
16	Sand and clay	18
17	Sand and mud	5.7
18	Sand, mud and shell	5.4
19	Sand and shell	10
20	Sand and shell	20
21	Sand and mud	17
22	Sand and shell	13
23	Sand, mud and shell	7.8
24	Sand and shell	8.4
25	Sand and shell	21
26	Sand	6.5
	Range	1.1 to 87
	Mean	14.3
	SD	16.2

*A deposit containing wood

Samples were previously collected in this area in 1982, before drilling began at Thames; the sampling positions are shown in Figure 19. The results of the UVF analyses are given in Table 13 . Although the maximum value was similar to that found in 1987 (87 vs. 75 µg g^{-1}) the results in general were higher in 1982, with few values below 3 µg g^{-1} and many above 10 µg g^{-1}. Thus, if there is any trend in concentrations with time, it is downwards. Unfortunately, no GC analysis of these earlier samples was conducted.

4.4 Substrates

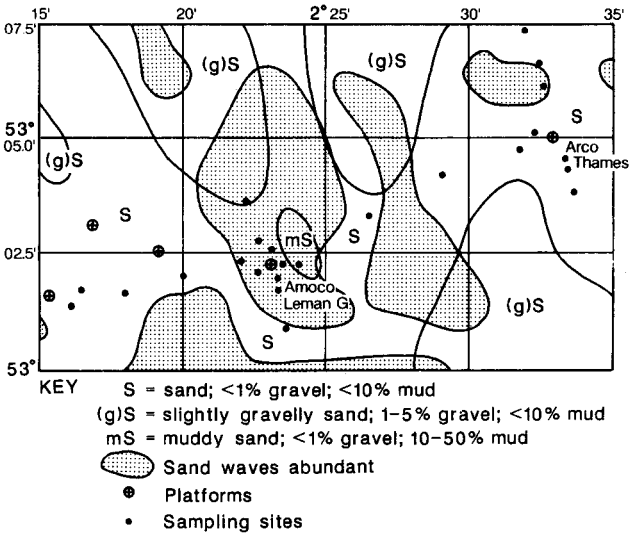

Figure 20. Substrates in the survey of CLIONE cruise 3, 23 February-1 March 1987 (after the British Geological Survey, 1987).

The substrates from the vicinity of Leman and Thames appear to be remarkably uniform (Figure 20). Clean or slightly muddy, medium-grained sand persists throughout the area; shell debris exists at all stations, forming around 5% of the sample volume at most sites, rising to 20% and exceptionally 50% at certain stations adjacent to Leman. Most of this is bivalve shell, but live bivalves are only rarely encountered in the grab samples. Clay balls were observed in the grab taken at station 73 and stones at station 75 (Figure 17b).

4.5 Bathymetry and hydrography

According to British Geological Survey data (1987), the sea floor around Thames is irregular and gently undulating from 30 to 40 m below lowest low water Spring Tide levels. West of station 67, however, numerous NW-SE trending tidal sand banks or shoals exist, the crests of which reach to within 20 m of the water surface, separated by troughs of over 40 m depth. A patch of sandwaves, 2-4 m in amplitude, occurs in the vicinity of Leman, encompassing stations 69-78 (Figures 17(b) and 20).

Dominant transport directions parallel the banks; the maximum speed of tidal streams along them is 1 m s^{-1} during spring tides and around half that speed at neap tides. As large sandwave development is thought to be initiated at around 0.60 m s^{-1} (Johnson *et al.*, 1982), daily shifting of such bedforms in the area of Leman should occur for much of the year. Net sand transport directions are to the NW.

4.6 Benthos

All taxa retained on a 1 mm mesh were identified where possible to species level, except for Nemertine worms and certain Actiniaria (sea anemones).

4.6.1 Abundance and diversity

The number of species recorded at each station ranged from 6 at station 70 to 28 at station 74. A broadly similar trend is exhibited by the total number of individuals recorded from each site, which is very low at station 80 (15 individuals) but moderate at station 74 (380 individuals). Marked variations in species and individual abundance occur at the stations around Leman though variation across the area as a whole is not pronounced (Figure 21). Species diversity reflects this pattern: maximum values of the diversity index H^1 (Shannon and Weaver, 1949) occur at stations 76 and 73 (3.71 and 3.62 respectively), while minimum values of 0.94 and 1.20 occur at stations 70 and 72. Outside this area, diversity values are less variable and mostly range from 2.5 to 3.4 (Figure 22).

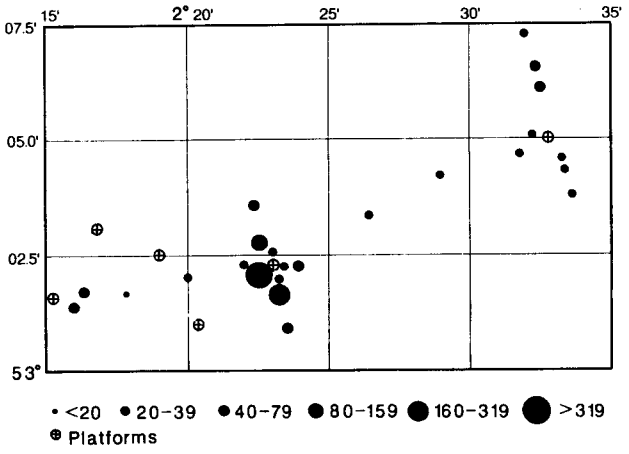

Figure 21. Numbers of individuals (per 0.1 m²) found on CLIONE cruise 3, 23 February-1 March 1987.

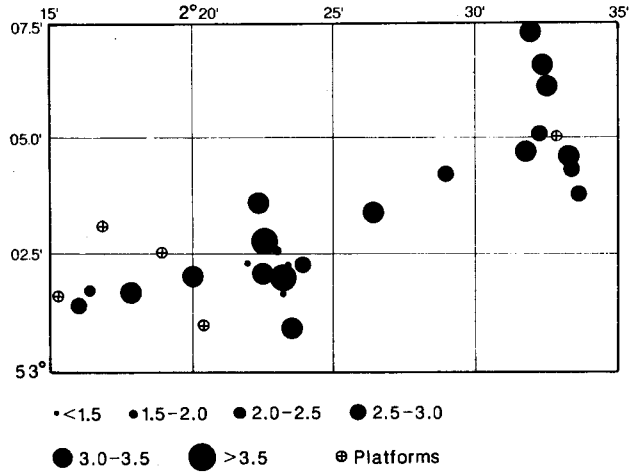

Figure 22. Diversity index over the 1987 survey area.

Species diversity may be regarded as an indicator of the degree of stress (whether natural or anthropogenic) to which a community is subjected; highest values indicate stable 'non-stressed' communities, while the most highly stressed (low diversity) communities are frequently characterised by the overwhelming numerical dominance of one or a few species.

All of the soft-sediment assemblages in this area are stressed to some degree, probably by the high speed of the tidal streams and a general instability of the substrates. The notable absence of large sedentary bivalves supports this contention. The assemblages at stations 70, 72, 75 and 78 in particular appear to reflect very unstable substrates. Each is dominated by the polychaete worm *Ophelia limacina*, a species commonly found in mobile, fine- to medium-grained sand. Yet interspersed with them (at stations 71, 73, 74 and 76) are assemblages of relatively high diversity, including abundant brittle-stars (*Ophiura albida*), numerous small sea anemones, various motile epibenthic polychaetes and occasional hydroid colonies, indicating greater substrate stability. Thus, there is a marked heterogeneity in the benthos surrounding Leman, which may be a consequence of sampling within a sand wave field. The assemblages of stations 70, 72, 75 and 78 may comprise those species inhabiting the sand waves themselves, whilst those at stations 71, 73, 74 and 76 may be located within troughs between waves or, possibly, associated with substrates over which the waves are migrating. Outside this area, the benthos is typical of unstable sandy deposits but no clear relationships or trends can be discerned.

There is no evidence for any widespread effects on the benthos from the gas-field developments nor for the proliferation of 'pollution-indicator' species close to the platforms. The possibility of localised effects cannot be ruled out, but a more intensive survey with sample replication would be required to delineate any gradients.

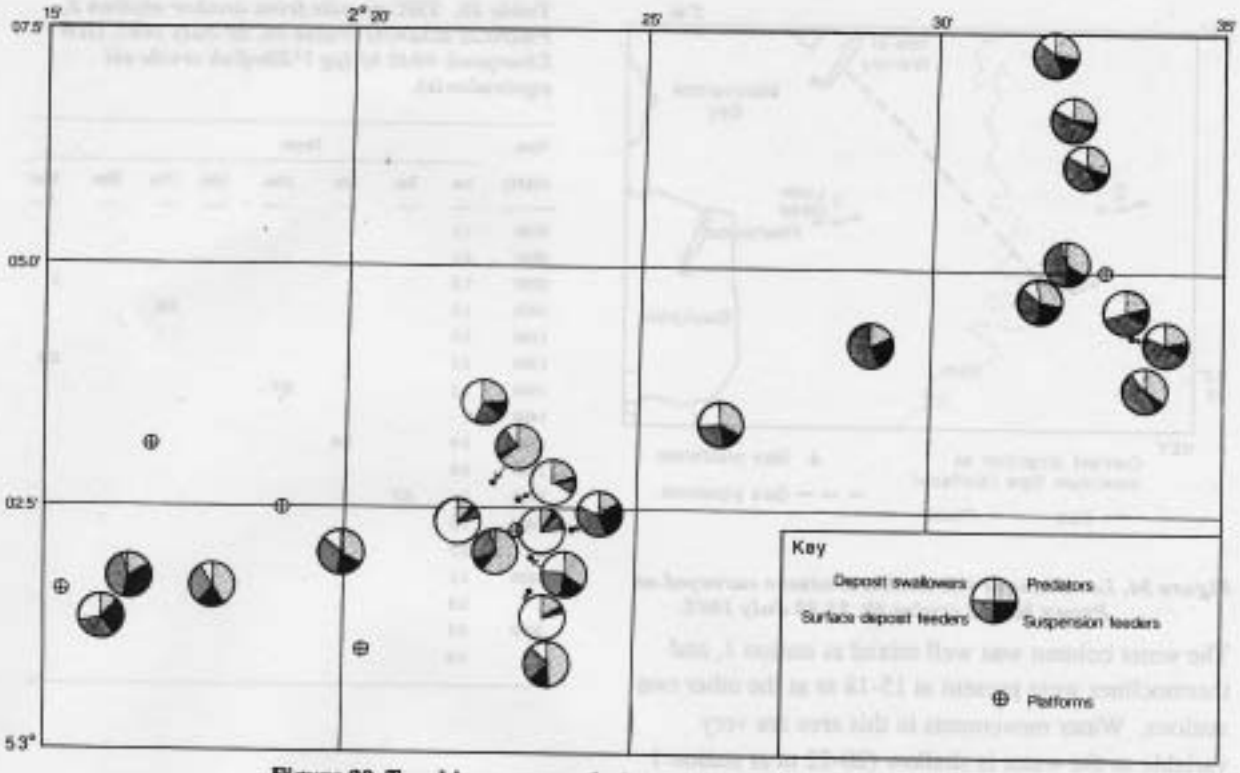

Figure 23. Trophic group analysis over the 1987 survey area.

4.6.2 Trophic group analysis

Using a variety of literature sources, all taxa recorded were assigned to one or more of the four trophic groups: predators, suspension feeders, surface deposit feeders and deposit swallowers. These groups correspond with those used by Pearson (1971). The relative proportions of each of these groups varies according to the character of the substrate. Throughout the area, there is a notable paucity of sessile suspension-feeding biota, except for occasional hydroid and bryozoa fragments. This supports the view that the substrate is generally unstable and lacking in relatively immobile attachment points for such species. No marked trends or variations in feeding groups are apparent between the stations, except for the dominance of deposit swallowers (as a direct result of the abundance of *O. limacina*) at stations 70, 72, 75 and 78 (Figure 23).

4.7 General conclusions

It would appear that, in this region of the southern gas fields, turbulence and unstable or mobile sediments quickly disperse discharged drilling materials away from the typical platforms so that, together with the fact that relatively few wells are drilled at each site, the normal concentration gradients established around multi-well sites in the northern oil fields are not maintained. In short, the uniformity in sedimentary hydrocarbon concentrations indicated by the contractor's surveys was confirmed. Whether this uniformity also applies to very large multi-well developments in this region will be tested by MAFF's monitoring of Ravenspurn (*CIROLANA* cruise 5/88 and subsequent cruises), but it seems probable that in such 'high energy' areas any anthropogenic influences may be subsidiary to the effects of natural processes on the benthos, except on a very local scale. The question then arises whether statutory sea-bed monitoring around drilling rigs and platforms in areas of mobile sediments, or even in 'high energy' areas, should still be required. It could be that resources would be better devoted [by a central body such as the United Kingdom Offshore Operators Association (UKOOA)] to the tracing of pathways, and identification of possible sinks, for materials derived from the southern gas fields in general.

(ii) STUDIES ON THE MORECAMBE BAY GAS FIELD, 1987

4.8 Introduction

These studies were conducted as part of an ongoing investigation of the environmental impact of development of the Morecambe Bay gas field, and involved work at three 13-hour anchor stations which were occupied on 21-23 July 1987. The first of these was to the east of the gas field, in the Lune Deep at the entrance to Morecambe Bay; the other two were adjacent to the central and northern complexes of the gas field installations. The positions are shown in Figure 24, which also indicates the current directions observed at maximum tidal flow in the surface waters.

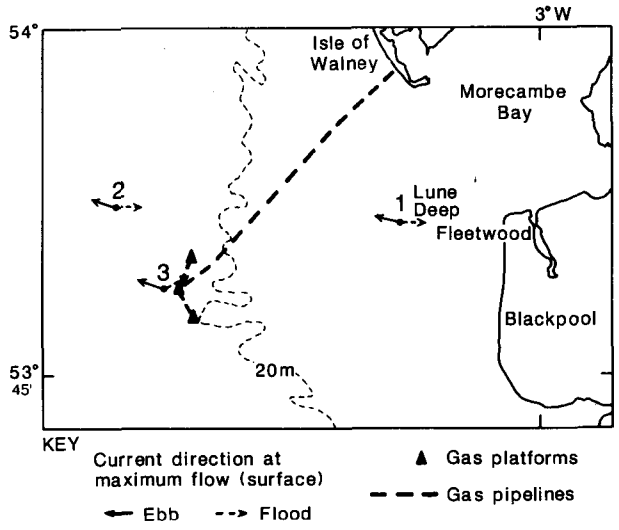

Figure 24. Locations of the anchor stations surveyed on PRINCE MADOG cruise 40, 21-23 July 1987.

The water column was well mixed at station 1, and thermoclines were present at 15-18 m at the other two stations. Water movements in this area are very variable as the water is shallow (20-22 m at station 1 and 35-40 m at stations 2 and 3) and strong winds can influence water movements throughout the water column.

4.9 Results

The results of analyses of water samples taken at hourly intervals from the three anchor stations are given in Tables 14-16. Highest THCs were in all cases seen in the sub-surface (1 m) water with lower concentrations at depth. There was no evidence of a hydrocarbon concentration gradient across the thermocline at stations 2 and 3. Tidal currents were more pronounced near the surface at all three stations, and did not behave similarly throughout the water column.

Table 14. THC results from anchor station 1, PRINCE MADOG cruise 40, 21 July 1987, (HW Liverpool: 0735 h). (μg l⁻¹ Ekofisk crude oil equivalents).

Time	Depth							
(GMT)	1m	3m	5m	10m	16m	17m	20m	30m
0700	14							
0800	3.4						1.9	
0900	1.3							
1000	1.6							
1100	5.9				1			
1200	1.5							
1300	1.6							
1400	77							
1500	9.1				1.1			
1600	5.5							
1700	3.4							
1800	21							
1900	4.3							
2000	4							

Table 15. THC results from anchor station 2, PRINCE MADOG cruise 40, 22 July 1987, (HW Liverpool: 0843 h) (μg l⁻¹ Ekofisk crude oil equivalents).

Time	Depth							
(GMT)	1m	3m	5m	10m	16m	17m	20m	30m
0700	1.1							
0800	2.1							
0900	1.5							1
1000	1.1					0.6		
1100	1.3							
1200	1.1							0.9
1300	1.1			0.7				
1400	1							
1500	0.9		0.6					
1600	0.8							
1700	1	0.7						
1800	1.1							
	0.7							
1900	1.1							
	0.9							
2000	0.8							
	0.9							

Table 16. THC results from anchor station 3, PRINCE MADOG cruise 40, 23 July 1987, (HW Liverpool: 0939 h) (μg l⁻¹ Ekofisk crude oil equivalents).

Time	Depth							
(GMT)	1 m	3m	5m	10m	16m	17m	20m	30m
0700	1.6							
0800	1.3							0.6
0900	1.1						0.4	
1000	1.3			0.6				
1100	1.1		0.7					
1200	1.2							
	1.3							
1300	1.3							
1400	1							
1500	0.9							
1600	1							
1700	0.9							
1800	0.9							
1900	1.1							
2000	1.0							

The results obtained during this cruise will be discussed in more detail at a later date, with other data from the gas field study which has now been ongoing since a pre-exploitation survey in 1982-1983, the results of which have been published (Law *et al.*, 1989).

To date, the subsequent surveys indicate that the gas field development has had little or no impact on the north-eastern Irish Sea, mainly because no oil-based drill-muds have been used in the drilling of development wells.

5. DISPOSAL AT SEA (DAS) GROUP, FIELD ASSESSMENT STUDIES, 1985-1987

5.1 Introduction

The work carried out by the DAS Group during the period 1985-1987 is summarised in Table 17 which gives a complete list of the disposal ground surveys carried out in these years. This assessment is divided into four sub-sections (5.2-5.5) each giving examples of studies of one of the following operations: disposal of sewage sludge from ships; disposal of dredged material; solid industrial waste disposal; and aggregate extraction. The right-hand column of Table 17 indicates the study from which the data are taken and the nature of the data collected in the course of the studies concerned.

Table 17. Disposal ground surveys carried out in the period 1985-1987.

Area	Date	Studies described in section 5 of this report
Roughs Tower	Feb-85	
Barrow/Thames	85	- Three sediment surveys through the year
Tyne	Feb-85	- Tomato pip and bacterial distribution; metals in fine sediment.
Tees	Mar-85	
Humber	Mar-85	
Roughs Tower	Jun-85	- Side-scan sonar survey.
South Falls	Jun-85	- Metals in sediments.
Barrow/Thames	Jun-85	- Surface-dwelling fauna; infauna
Liverpool Bay	Aug-85	
Liverpool Bay	Sep-85	
Thames	86	- Three sediment surveys through the year.
Liverpool Bay	Apr-86	
Humber	Jun-86	
Tyne	Jun-86	- Tomato pip and bacterial distribution; numbers of taxa.
NE Coast	Jun-86	
Wearmouth	Jul-86	
Tees	Jul-86	- Side-scan sonar survey; sediment 'ground-truth'
Wearmouth	Jul-86	- Side-scan sonar and echo-sounder surveys.
Liverpool Bay	Sep-86	
Site Z	Sep-86	
Plymouth	Oct-86	- Baseline sediment quality.
Swansea Bay	Oct-86	
Bristol Channel	Oct-86	
Thames	87	- Four sediment surveys through the year.
Tyne	May-87	- Changes in sediment quality with time.
Humber	May-87	
Liverpool Bay	Sep-87	- Core and beam trawl samples.
Bristol Channel	Oct-87	
Exeter	Oct-87	
Nab	Oct-87	
Roughs Tower	Oct-87	- Side-scan sonar survey.
Additional work		
Hastings Shingle Bank	Oct 86) Oct 87)	- Aggregate extraction survey with side-scan sonar.

5.2 Disposal of sewage sludge from ships

5.2.1 Thames Estuary

The Barrow Deep disposal site receives about five million wet tonnes of sewage sludge each year from Thames Water sewage treatment works at Beckton and Crossness in East London. For operational reasons, the waste is usually released within two hours of low water. A detailed study of the dispersal of sludge in the Outer Thames Estuary was undertaken several years ago (Talbot *et al.*, 1982). In summary this showed that, after release, sludge moves towards the south west with the rising tide; it then passes along the Barrow Deep and around the East Barrow sand (Figure 25).

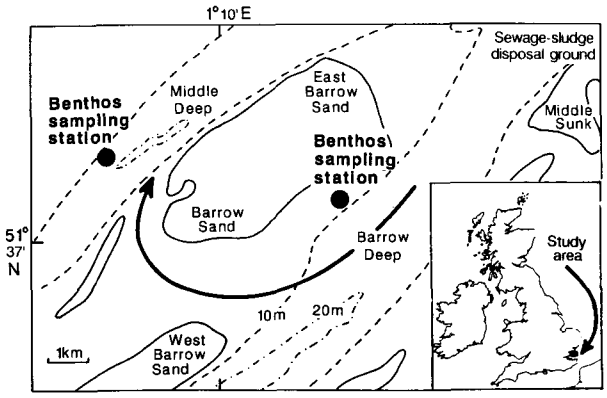

Figure 25. The Barrow Deep, showing the direction of sewage sludge transportation and the location of sampling areas for benthic analysis.

The sediment composition and infauna have been monitored by DFR in known areas of sludge settlement with the objective of identifying and, if possible, quantifying changes in sediment chemistry and benthos with time. This work complements the less frequent spatial surveys which DFR carries out in the area. It is also useful in determining the most appropriate time of year for large-scale spatial investigations.

In addition to this monitoring work, an investigation was conducted in June 1985 to examine spatial differences in surface-dwelling fauna in relation to sludge disposal, and to assess the utility of trawl sampling in biological monitoring.

Infaunal studies: The sampling site was located on the northern margin of the Middle Deep (Figure 25) at about 20 m depth, and was selected on grounds of its relative stability (sandy sediments in the central parts of the Channels tend to be sparsely populated because of tidally-induced disturbance), ease of quantitative sampling, and proximity to the sewage-sludge disposal ground.

On each occasion, five 0.1 m^2 Day grab samples were taken, and the macrofauna from each, retained on an 0.5 mm mesh sieve, were preserved for later analysis. Sub-samples of sediment for particle size and metals analyses were also taken.

The sediment consisted of muddy sand with a moderate shell content. In classical terms, the fauna corresponds with a shallow-water *Abra* community, and finds a

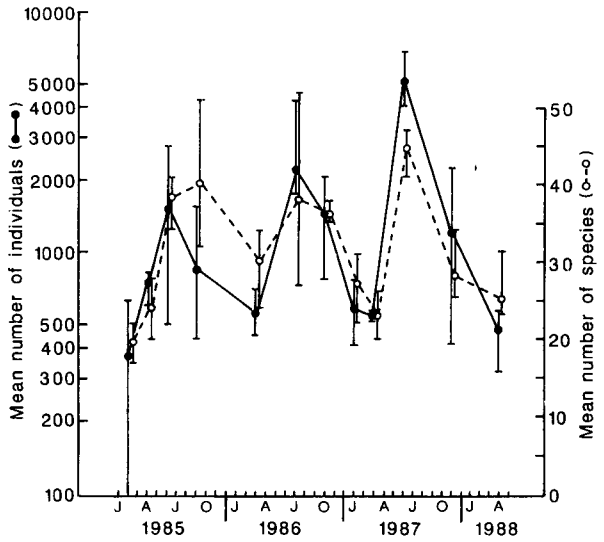

Figure 26. The Thames Estuary (Middle Deep), showing trends in benthic counts from Day grab samples: arithmetic means and ranges of numbers per 0.1m²

notable parallel with inshore muddy sand assemblages in Liverpool Bay, which are also regularly sampled on DFR surveys of disposal sites (see Norton *et al.*, 1984).

Figure 26 demonstrates regularity in seasonal changes, with peaks in abundance and numbers of taxa occurring in the summer months due to larval recruitment, followed by overwintering mortality to lowest population densities in early Spring. There are, respectively, approximately 10-fold and 2-fold differences between these extremes. It is important to note that the contribution of juveniles, both to the densities and range of taxa encountered in the summer months, can add considerably to sample processing time. Moreover, a number of these animals do not survive to adulthood and can be considered as 'chance' occurrences. Thus, annual sampling of the smaller populations of larger-sized overwintering survivors, prior to the period of maximum recruitment of juveniles to the 0.5 mm sieve mesh size, would seem to provide the best option for routine assessment of the scale of any net effect of the disposal operation.

An alternative would be regular seasonal sampling, but this may not be feasible at all disposal grounds. Additionally, while a general knowledge of seasonal cycles is important for the interpretation of natural variability from one sampling occasion to another, experience indicates that in most cases annual sampling at the same time of year is adequate to monitor the progress of significant benthic changes in response to waste disposal.

Future work will also involve a comparison with trends at a shallow, muddy sand site in the Barrow Deep, where periodic accumulations of sludge particles are known to occur. Annual sampling in March is continuing at both this site and that in the Middle Deep.

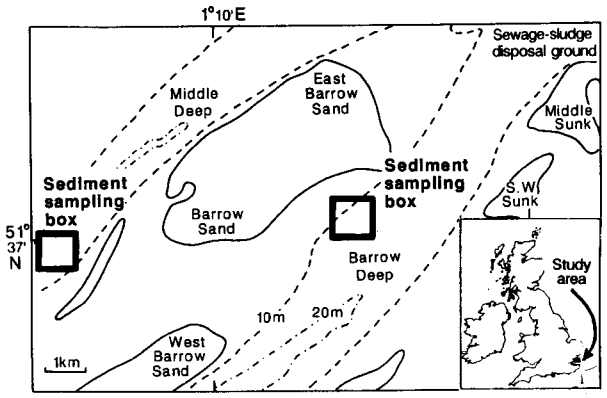

Figure 27. The Barrow Deep, showing the location of samples analysed for metals.

Sediment quality: Two areas in the Barrow and Middle Deeps (Figure 27) were examined to detect sludge metal accumulation in the sediments. Both sites were shown by Talbot *et al.* (1982) to be areas of sludge settlement and are, therefore, useful indicators of any sludge build-up.

The Barrow Deep site is located to the south east of the East Barrow Sand in an area of sand. Settled fines will be the only significant metal-bearing component of the sediment and, therefore, any accumulation of fine particles will be apparent as an increase in the metal content of the whole sediment.

The second site is located in the Middle Deep and is also in the path of the dispersing sludge; however, the sediment type in this area is muddy sand and may, therefore, represent a long-term sink for fine particulates.

Table 18. Chemical quality of sediments in the vicinity of the Barrow Deep sewage-sludge disposal ground. Mean value of five samples collected on various dates at the sites shown in Figure 25.

Box	Date	Hg	Pb	Cu	Zn	Cr	Ni
Middle Deep	6-Dec-84	0.05	23	3.1	44	15	5.4
	25-Sep-85	0.13	18	5.7	42	16	6.6
	11 Mar 86	0.05	15	4.6	37	15	6.8
	16-Jul-86	0.1	22	6.8	41	11	7.3
	2-Oct-86	0.07	15	4.3	32	12	5
	4-Feb-87	0.08	22	5.7	50	15	7.2
	22-Apr-87	0.1	19	5.7	43	15	6.6
	3-Jul-87	0.1	33	6.3	56	11	7.7
	30-Nov-87	0.06	22	3.7	40	10	5.2
Barrow Deep	15-Apr-85	0.06	11	4	27	12	4.7
	25-Sep-85	0.06	12	5.7	34	15	5.8
	18-Mar-86	0.08	12	6.5	35	17	7.2
	2-Oct-86	0.04	7.9	3.4	23	12	4.8
	4-Feb-87	0.03	6.6	3.2	21	11	5.2
	22-Apr-87	0.07	9.9	3.6	23	8	4.2
	3-Jul-87	0.06	8	4.1	24	8	3.6
	30-Nov-87	0.06	6.6	3.5	17	8	4.4

Note: Concentrations are the results of whole sediment analysis (mg kg^{-1})

Grab samples were taken on several occasions, in the period 1984-1987, at five randomly positioned sampling points within these defined areas, and the surface 0-1 cm of the sediment was analysed. The sediment was digested using *aqua regia* and metals determined using atomic absorption spectrophotometry (Harper *et al.*, 1989). The results of these analyses are shown in Table 18 and are expressed as the mean concentrations found in the group of five samples collected on each occasion at each of the two sites.

There are no consistent trends apparent in the metal contents of the sediments over the three-year survey period, indicating that there is no long-term accumulation of sludge-derived metals in the surface sediments at these sites. There is some suggestion that the concentrations of metals, such as zinc, (Figure 28) show fluctuations, possibly caused by temporary accumulations of metal-bearing fines. Such accumulations appear to be transitory in nature and are not evident for all of the trace metals examined. The lack of demonstrable accumulation indicates that some form of removal process must occur. At present, it is not clear how much of the fines are removed by horizontal dispersion and how much by burial, but work on this topic is still underway.

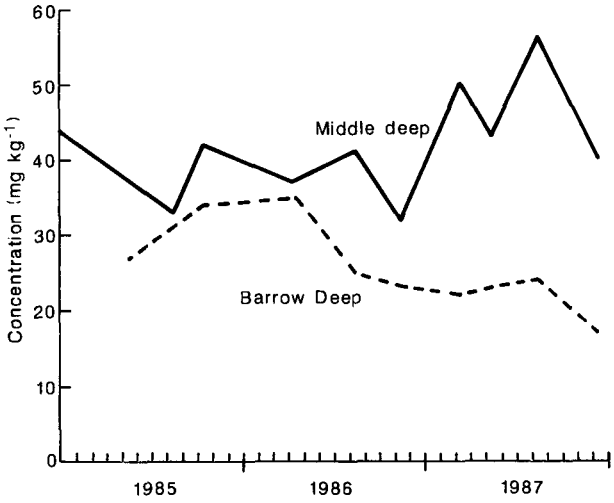

Figure 28. Temporal variations in zinc concentrations in sediments in the Barrow and Middle Deeps.

Epifauna from beam trawls: An exploratory survey was conducted in June 1985 to examine spatial differences in surface-dwelling fauna in relation to sludge disposal, and to assess the utility of trawl sampling for the field assessment of biological effects - an approach which had not previously been attempted in this area.

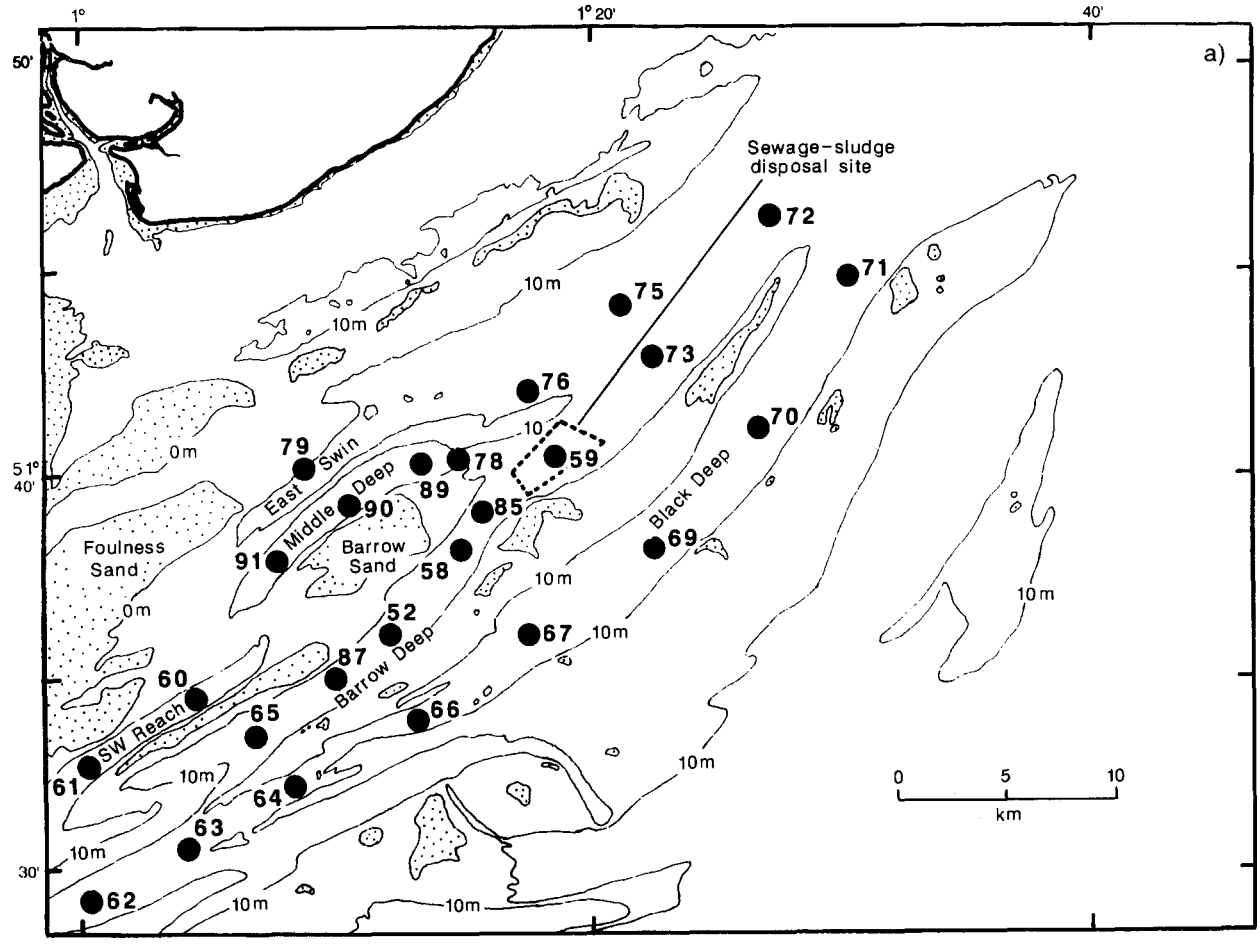

Figure 29. Thames beam trawl surveys in 1985: (a) sampling stations.

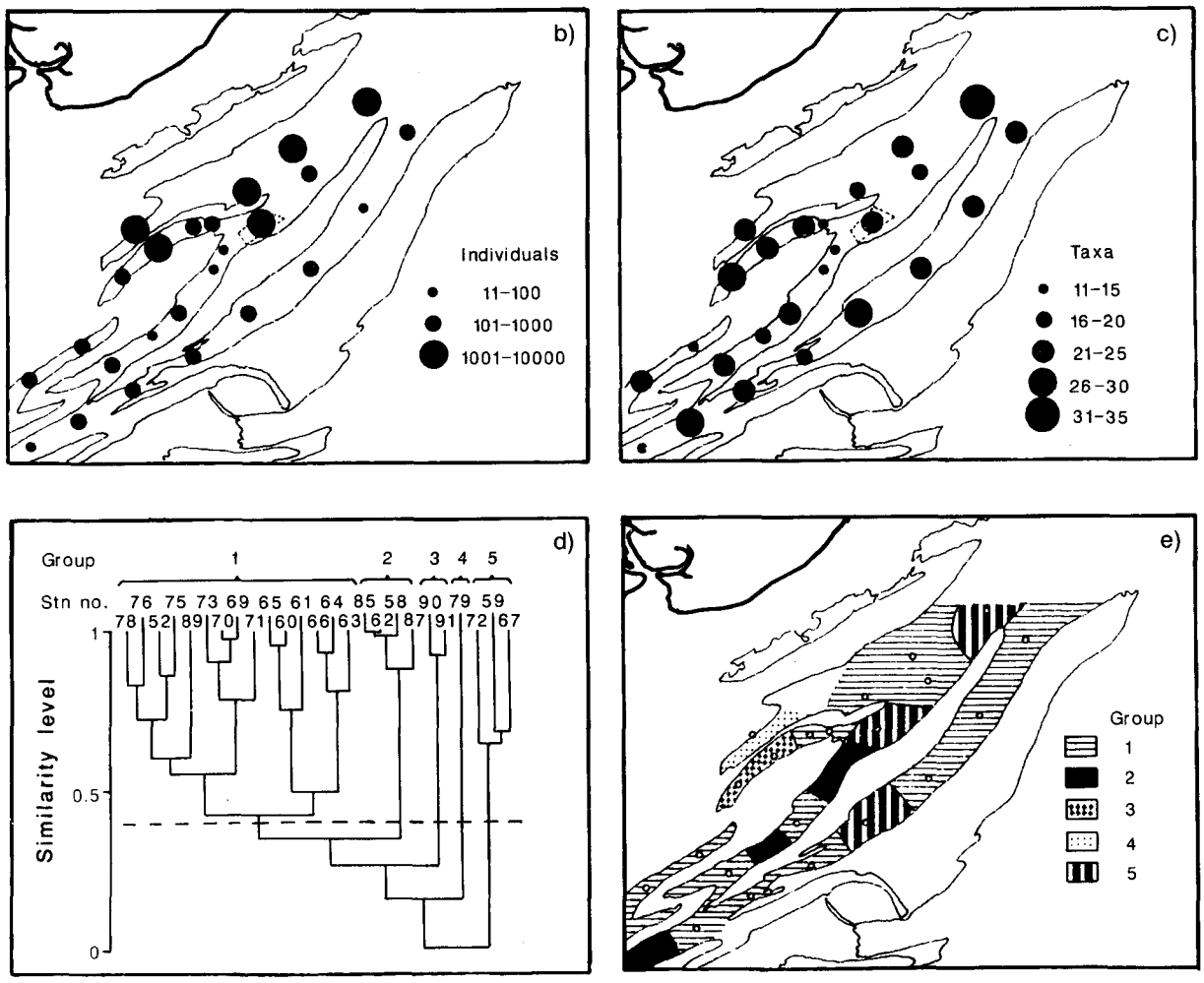

Figure 29. Continued. Thames beam trawl surveys in 1985: (b) numbers of individuals; (c) numbers of taxa; (d) dendrogram from cluster analysis; and (e) plot of station clusters.

At each of the sites shown in Figure 29(a), a standard Lowestoft 2 m beam trawl with fine-mesh cod end liner (Riley *et al.*, 1986) was towed for approximately 0.5 km. The contents were transferred to a 5 mm mesh frame, and the animals were identified and enumerated on deck ('problem' specimens were returned to the laboratory for later attention).

In Table 19, the abundances (standardised to 0.5 km tows) are coded on a logarithmic scale. Colonial taxa - such as hydroids - are coded as to whether present or absent. 'Chance' occurrences of infaunal taxa were excluded.

Soft sediments prevail in the general vicinity (see Norton *et al.*, 1981). The occurrence in samples of non-living material is shown in Table 20. Artefacts (e.g. fragments of cloth and paper, and cigarette filters) which might be associated with sludge disposal, were found in small quantities at a number of sites in the Barrow Deep. Noticeable quantities of shell (particularly oyster, cockle and mussel) were found in the Middle Deep, and at the seaward end of the Barrow Deep. Coal and clinker were present at several sites. The occurrence of larger stones and brick at a location in the Black Deep accords with its use at one time for the disposal of dredgings as well as for sewage sludge.

Figure 29(b and c) shows generally higher abundances at, and seaward of, the disposal site; low abundances and numbers of taxa occur immediately inshore of the disposal site, and at the southern end of the Black Deep.

The dendrogram output from a cluster analysis (employing squared Euclidean distance as a similarity measure, and Ward's minimum-variance method for sorting) is given in Figure 29(d). Five groups were identified at an arbitrary similarity level of 0.4 and these are plotted in Figure 29(e). The majority of stations clustered within Group 1, which can be further sub-divided into an inshore and an offshore component. A notable distinction in an otherwise similar species complement is the more frequent occurrence of the bryozoan *Alcyonidium* at the inner stations; this provides a food-source for the sea-slug *Acanthodoris* which is unique to stations within this sub-group.

Table 19. Thames beam trawl survey in 1985 for the Middle and Barrow Deeps : faunal abundances.

Taxon	Area and station											
	Middle Deep				Barrow Deep							
	78	89	90	91	72	73	59	85	58	52	87	65
Chlorophyceae spp												
Hydroida spp	*	***	***	**	***	**	***	**	*	*	**	**
Alcyonium digitatum					**							
Adamsia palliata									*	*		
Anthozoa spp	1		2	3	2		3	1			2	2
Aphrodita aculeata		1									1	
Sabellaria spinulosa		*	*	*			*				*	**
Pomatoceros triquetar					**		***					
Balanus crenatus		**	*	*		*	**	*	*	*	*	**
Idotea linearis	1	2							1			
Pandalus montagui			2	3	5	3	4				1	2
Hippolyte varians												
Athanas nitescens												
Crangon spp	4	3	4	4	4	4		3	2	4	3	4
Philocheras trispinosus		2		1			2			1		
Galathea intermedia												
Porcellana longicornis				1								
Pagurus spp	3	4	3	3	3	3	4	2	2	2	3	3
Corystes cassivelaunus				2							1	
Cancer pagurus					2		1					
Liocarcinus puber												
Liocarcinus arcuatus					1		2					
Liocarcinus pusillus												
Liocarcinus holsatus	2	3	3	3	3	2	2	1	1	2	2	
Carcinus maenas	2		2	2						1		
Pilumnus hirtellus					1							
Hyas coarctatus					3		3					
Macropodia sp		3	3	4	2	2			1			2
Nymphon rubrum					2	2						1
Pycnogonum littorale			1								1	
Loricata sp				2								
Crepidula fornicata	1	3		3	1		3			2	1	
Buccinum undatum		2		2	2		3	1		1		
Acanthodoris pilosa												2
Dendronotus frondotus					1							
Facelina sp												
Aeolida papillosa		2					2					
Modiolus barbatus					2							
Mytilus edulis							1					
Sepiola atlantica	2		3	3		2			1	1		2
Flustra foliacea					***	*		*				
Alcyonidium sp	*	*	*	*	*				*	**	*	**
Bryozoa spp								*			*	
Asterias rubens	2	3	4	4	3	2	4	2		2	2	2
Ophiura spp		4	3	3	2			2			3	1
Psammechinus miliaris			1		1	4	2	4			1	
Ascidiacea sp												
Scyliorhinus canicula					2							
Raja clavata												1
Raja montagui												
Syngnathus acus												
Trisopterus luscus			1	1	1	2				2		2
Merlangius merlangus					1	2	1		1	2		1
Ciliata mustela												
Pomatoschistus sp	3	3	3	2	2	3	2	1	1	1		2
Callionymus lyra		1			1							
Pholis gunnellus				2	1		1					
Trigla gurnardus												
Agonus cataphractus		2	1	1	2			1	1	2	1	2
Liparis sp		2	2	2		2						
Limanda limanda	2	3	3	3	1	2	2		1	3		3
Pleuronectes platessa		2	2	2		1				2	2	
Microstomus kitt			2	2							1	
Solea solea	1	1	1	2		1			2		2	

Abundance scale: 1 = 1; 2 = 2-10; 3 = 11-100; 4 = 101-1,000; 5 = 1,001-10,000; * = present; ** = common; *** = abundant

Table 19. Continued. Thames beam trawl survey in 1985 in the SW Reach, Black Deep and East Swin : faunal abundances.

Taxon	Area and station												
	SW Reach		Black Deep								East Swin		
	60	61	71	70	69	67	66	64	63	62	75	76	79
Chlorophyceae spp													***
Hydroida spp	*	**	*	*	*	**	*	**	*	*	**	*	***
Alcyonium digitatum						**							
Adamsia palliata													
Anthozoa spp	1	4				2	2	3	2	1	1		2
Aphrodita aculeata							1		1		1	2	
Sabellaria spinulosa								*	*			*	
Pomatoceros triqueter			**			***							
Balanus crenatus	*		*	*	*			**	**	*	**		*
Idotea linearis						1		1					5
Pandalus montagui	2		3	1	2	4	2	2	3		2	2	
Hippolyte varians						2							
Athanas nitescens							1						
Crangon spp	4	4	3	3	3	3	3	3	4	3	4	4	5
Philocheras trispinosus					2	2		2					
Galathea intermedia					1								
Porcellana longicornis					1	2	1	1					
Pagurus spp	1	2	3	3	3	3	2	3	3	1	4	4	2
Corystes cassivelaunus											2		2
Cancer pagurus								1					
Liocarcinus puber						1							
Liocarcinus arcuatus						1		1					
Liocarcinus pusillus		1			1	1					1	2	
Liocarcinus holsatus		1	2	2	2	2	2	2	3	2	3	3	2
Carcinus maenas		2							1				2
Pilumnus hirtellus								2					
Hyas coarctatus					1	3	1	2	2				3
Macropodia sp		2	1		2	3	2	2	2	2		2	
Nymphon rubrum							2						3
Pycnogonum littorale		2								1			
Loricata sp		2	1										
Crepidula fornicata					1	2		1	2		2	2	
Buccinum undatum			3			2		1	2		2	2	
Acanthodoris pilosa		2					3	3	3				
Dendronotus frondotus													
Facelina sp		1				1							
Aeolida papillosa													
Modiolus barbatus													
Mytilus edulis					1	2							
Sepiola atlantica	2	2		1		1			2	1	2	2	
Flustra foliacea		*							*	*	*	*	*
Alcyonidium sp		**	*	*	*	*	**	***	***	*	*	*	***
Bryozoa spp		*			*				*				***
Asterias rubens		3	3	2	2	3	3	3	4	1	3	4	1
Ophiura spp			2	1	2	1	1	1	3	2			5
Psammechinus miliaris		1	4	1	2	4							1
Ascidiacea sp						2							
Scyliorhinus canicula													
Raja clavata				1									
Raja montagui				1									1
Syngnathus acus													1
Trisopterus luscus	2	2	2	2	2					1	3		3
Merlangius merlangus	2		1	1	1				1				
Ciliata mustela		1											
Pomatoschistus sp	3	3	2	3	2	2		2	3	2	3	2	3
Callionymus lyra									1				
Pholis gunnellus													
Trigla gurnardus				1									
Agonus cataphractus	1	2	1	2	2	1	1		2		3		2
Liparis sp		1											
Limanda limanda	3	3	2	2	2	2	2	2	3		2	3	
Pleuronectes platessa													
Microstomus kitt			1					1					
Solea solea				1			1		1		2		3

Abundance scale: 1 = 1; 2 = 2-10; 3 = 11-100; 4 = 101-1,000; 5 = 1,001-10,000; * = present; ** = common; *** = abundant

Table 20. Thames beam trawl survey, 1985: non-living 'by-catch' in beam trawl samples.

Area	Station	Stone	Wood	Clinker	Coal	Shell	Artefacts
Middle Deep	78			*	*	**	
	89					**	
	90		*		*	**	
	91		*			**	
Barrow Deep	72	*		*		**	
	73			**	**	***	*
	59		*	***		***	*
	85	*	*			*	*
	58		*	*	*		*
	52		**			*	*
	87			*		*	
	65		*				
SW Reach	60						
	61			**	*		
Black Deep	71	*		*		*	
	70				*	*	*
	69		*		**		*
	67	**		*			
	66			*			
	64					**	
	63			*		*	
	62				*		*
East Swin	75					*	
	76					*	
	79					*	

* = present; ** = common; *** = abundant

Group 2 includes improverished stations immediately inshore of the Barrow disposal site, and may suggest an impact of sewage-sludge disposal in the zone of initial settling at the sea bed. Group 3 comprises two stations with a more rich fauna located in the Middle Deep. The fauna at station 79 (Group 4) is characterised by abundant populations of the brittle-star *Ophiura*, and the isopod *Idotea*, in association with colonial hydroids and the sea-lettuce *Ulva*. Also occurring at this site were quantities of the bryozoan *Electra pilosa* in its erect (rather than the usual encrusting) form. This is believed to be the first such record for the UK coastline (P. J. Hayward, University College Swansea, personal communication; see also Ryland and Hayward, 1977). This rich assemblage might indicate local enhancement in the supply of organic matter along the margin of the East Swin.

Stations within Group 5 (which include those at the Barrow and now-disused Black Deep disposal sites) were characterised by high abundances of the pink shrimp *Pandalus*, the spider crab *Hyas* and the green sea urchin *Psammechinus*, and the presence of *Alcyonium* ('dead men's fingers') and the calcareous tube-worm *Pomatoceros*. Such occurrences are indicative of coarser substrates.

Trawl sampling for epifauna appears to be a useful method for field assessment of the biota in such 'high energy' areas, not least because of the relatively rapid return on sampling effort. A more intensive quantitative sampling programme, with replication at target sites, is planned.

5.2.2 Tyne

There are several disposal sites off the Tyne. The sewage-sludge disposal site receives approximately 500,000 wet tonnes of sewage sludge annually. The site was commissioned in 1980 and earlier work to 1984 was reported in Rees *et al.* (1985). This included Day grab sampling of the sediments and benthic fauna

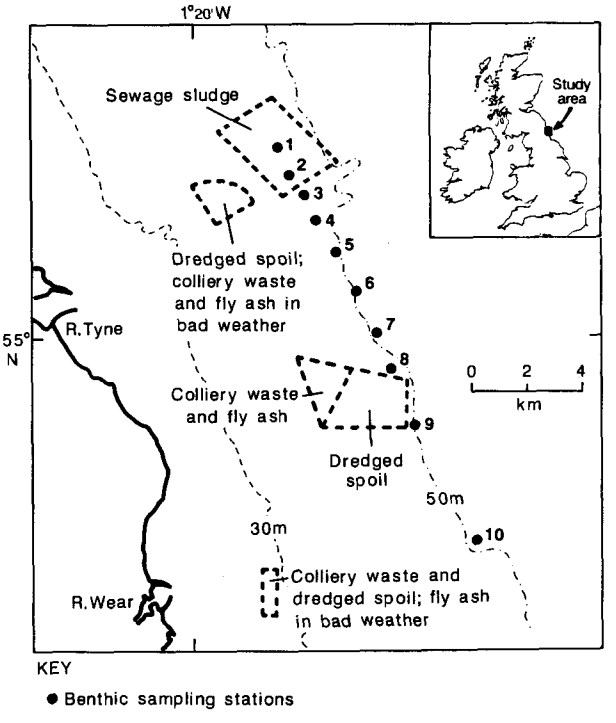

Figure 30. Benthic sampling stations off the Tyne. Sites currently in use for sea disposal are specified.

along a transect running south of the disposal ground (Figure 30). This transect was designed in the knowledge that tidal currents tend to run parallel to the coastline in this area, and the net residual is southward, at least in surface waters. An added advantage of sampling along the 50 m contour was the reduction in extraneous environmental influences associated with variation in depth and substrate type.

Monitoring studies - which have included grab, core and beam trawl sampling, and towed underwater camera sledge - have continued on an annual basis, and some of the findings from 1985 to 1987 surveys are given below.

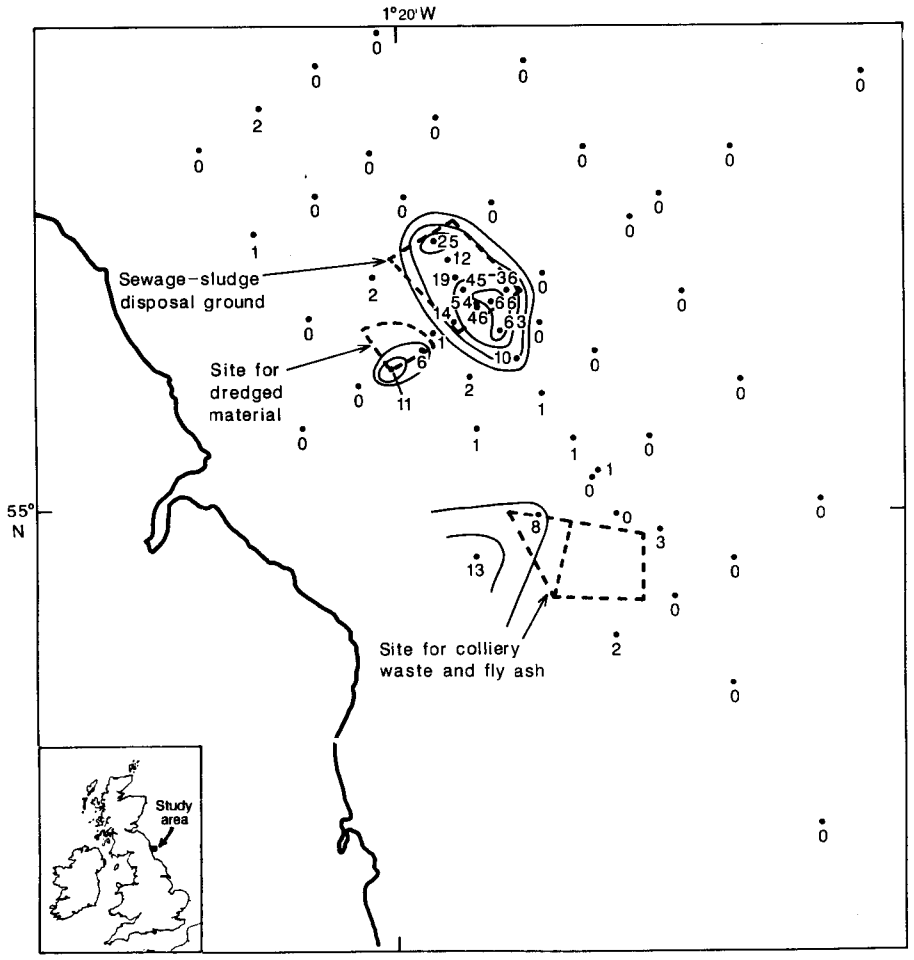

Figure 31. Distribution of tomato pips in sediments around the Tyne sewage-sludge disposal site.

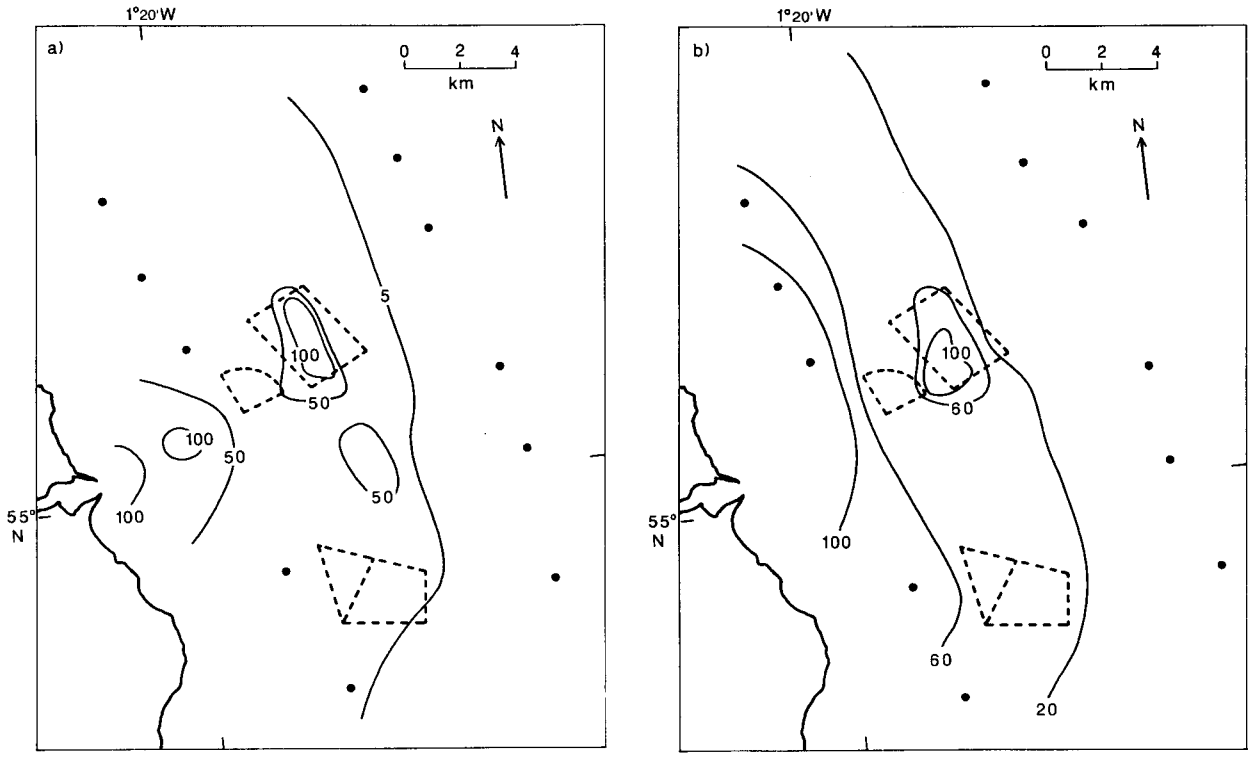

Figure 32. Distribution of faecal bacteria in sediments around the Tyne sewage-sludge disposal site: (a) Escherichia coli; and (b) faecal streptococci.

Sediment samples taken by Day grab from a grid of stations have been examined for indicators of sewage sludge, including tomato pips and faecal bacteria (Figures 31 and 32). These parameters show the zone of initial impact of the sludge.

It should be noted that elevated counts of tomato pips occur in the vicinity of disposal sites for dredged material as well as that for sewage sludge. This can be accounted for by their presence in Tyne Estuary sediments, the source of much of the dredgings. High bacterial counts are confined to the zone between the shore and the disposal ground, suggesting little offshore transport of the sewage sludge in this area.

A survey repeating that of Rees *et al.* (1985) along the transect of Figure 30, was conducted in June 1986 and trends in the main faunal components are shown superimposed upon the earlier 1984 results in Figure 33. The overall elevation in numbers, apparent in 1986, can largely be accounted for by natural seasonal effects (see sub-section 5.2.1); it is notable, however, that the overall pattern is similar to that of 1984 with enhanced numbers at, and just to the south of, the disposal site. Interestingly, the clearly discernible elevation in counts of tomato pips, in June 1986 relative to 1984, may reflect a seasonal shift in human diet - such a cyclical change has been observed during summer and winter sampling of the Forth sewage-sludge disposal grounds (M. Elliott, personal communication). Presently, experimental work is in progress concerning the longevity of tomato pips in marine sediments. Along with an examination of longer-term trends in counts for such sludge artefacts in sediments off the Tyne, this should help to elucidate the nature of the relationship between sewage-sludge disposal and accumulation at the sea bed.

As in 1984, no clear trend emerges in numbers of taxa. This, along with the absence of any successional changes towards over-abundance of classical 'pollution indicator' species, supports our earlier conclusions that no gross effects of enrichment are yet apparent. However, as this site has only received sludge in significant quantities since about 1980, it is important that close observation is kept on the progress of any future changes.

Sampling of the epifauna with a 2 m beam trawl has continued to the present and has demonstrated the undesirable local presence of larger sewage-sludge-derived artefacts (e.g. sanitary towels), a situation which should be rectified by the installation of screening facilities prior to loading of the sewage sludge for disposal at sea.

The concentrations of various metals have been determined in the fine fraction of sediments collected in 1985 off the north-east coast. In this case, the

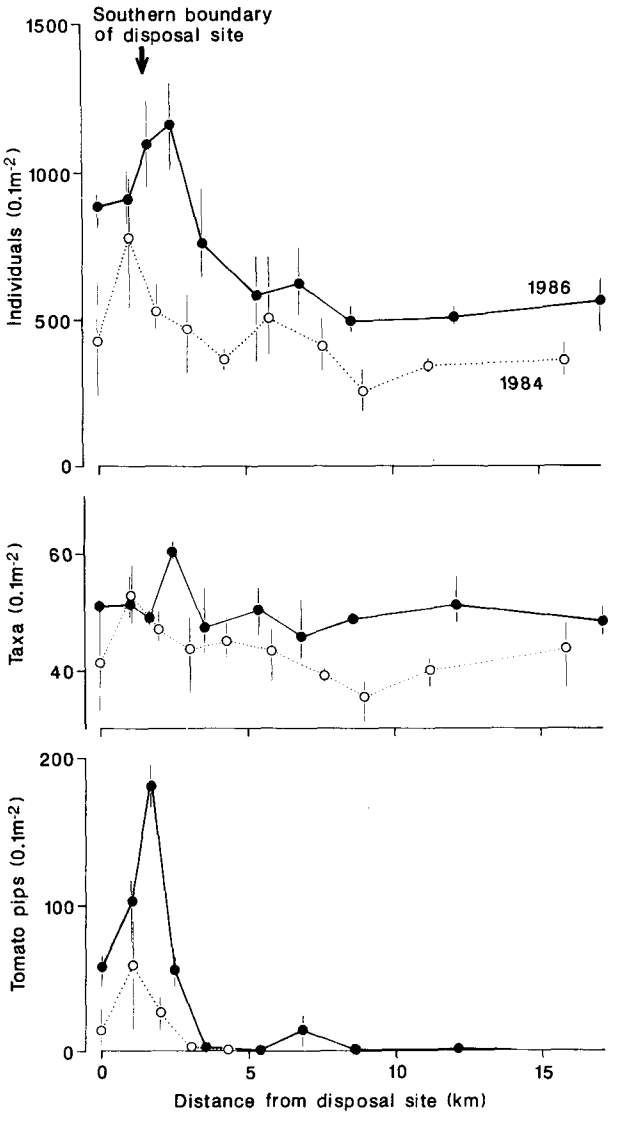

Figure 33. Numbers of individuals, taxa (polychaetes, molluscs and echinoderms only) and tomato pips along the Tyne transect in February 1984 and June 1986 ($\bar{x}$+range).

sediments were sieved at 90 μm to extract the fines and thereby eliminate as much as possible of the variability caused by coarse non-contaminant-bearing sediment (largely sand).

Figure 34 (a-f) shows the concentrations of various metals across the area. The dominant features of all the metal distributions are the influence of the River Tyne, near to which sediment metals are elevated, and the marked decrease in sediment metals with distance from the shore. A component of these metals is undoubtedly derived from anthropogenic sources in the area. However, it should be noted that the Tyne drains a heavily mineralised zone of the Pennines (Webb, 1978) and, therefore, some of the sediment metal elevations near the coast will be due to natural factors. There is little evidence of elevated metal concentrations at the sewage-sludge disposal site, although it must be remembered that disposal began only four years before this survey and it would be premature to conclude that accumulation is not going to occur.

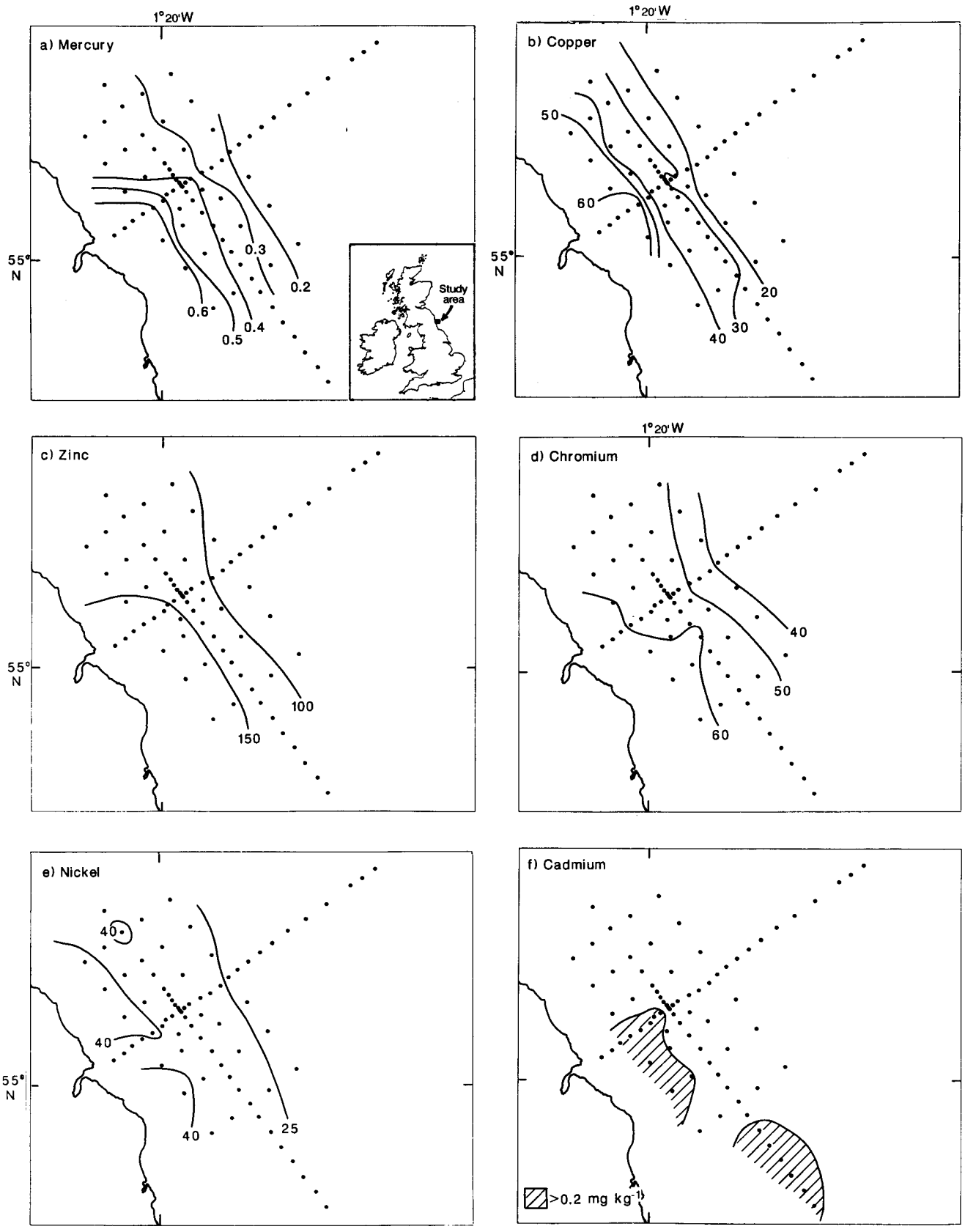

Figure 34. Concentrations of metals (mg kg^{-1}) in the <90 μm fraction of the sediments off the River Tyne in 1985.

A scheme for measuring changes in sediment quality with time has been established at the Tyne sewage-sludge disposal site, based on a stratified random design. This design was first employed in 1987 and will be used in the future for the identification of any trends. Table 21 shows the mean concentration of metals in the < 63 μm fraction of the sediments from the Tyne collected in 1987. It should be noted that the size of sieve used changed between 1985 and 1987, in preparation for a harmonised self-monitoring scheme introduced by MAFF in 1988. Consequently, the results reported in Table 21 cannot be directly compared with those in Figure 34 (a-f).

Table 21. Metal concentrations in the < 63 μm fraction of sediment from the area of the Tyne sewage-sludge disposal ground in 1987.

	Metal concentration (mg kg^{-1})					
	Hg	Pb	Cu	Zn	Cr	Ni
Mean	0.33	114	54	147	58	37
S.D.	0.07	24.6	15.9	32.4	6.1	4

Note: All cadmium analyses were below the detection limit of the method used (0.2 mg kg-1)

Table 22. Metal concentrations in the < 63 μm fraction of sediment from the area of the Plymouth sewage-sludge disposal ground in 1986.

	Metal concentration (mg kg-1)					
	Hg	Pb	Cu	Zn	Cr	Ni
Mean	0.23	79	32	100	38	22
S.D.	0.07	45.3	10.7	9.5	3.9	2.2

Note: All cadmium analyses were below the detection limit of the method used (0.2 mg kg-1)

5.2.3 *Plymouth*

In 1986, a series of 21 sediment samples were collected from the vicinity of the sewage-sludge disposal ground off Plymouth Sound (Figure 35). The samples were taken from an area close to the disposal ground where sludge settlement is known to occur. Table 22 shows the mean values of metals in the < 63 μm fraction of the surface sediment. These data will form the baseline for a series of biennial measurements to examine changes in sediment quality.

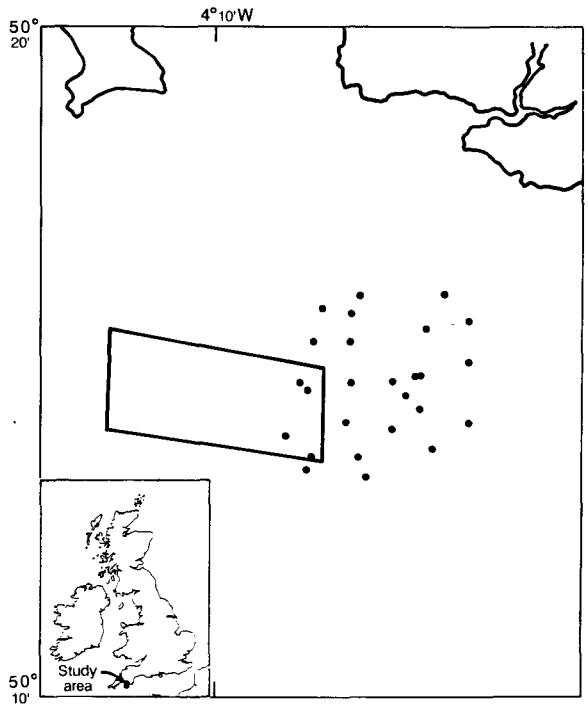

Figure 35. Plymouth sewage-sludge disposal ground and the location of sediment stations sampled in 1986.

5.2.4 *South Falls*

The South Falls disposal ground receives sewage sludge from Tilbury and Canvey, dredged material and industrial waste (sludge from sugar purification). The ground is situated in an area of large sand waves. Figure 36 (a-f) shows the results of a sediment survey carried out in 1985 and gives metal concentrations in the < 63 μm fraction of the sediment. Most metals are elevated in the vicinity of the disposal site, and there is some evidence of elevations to the north east and south west of the disposal ground in the direction of the main tidal axis.

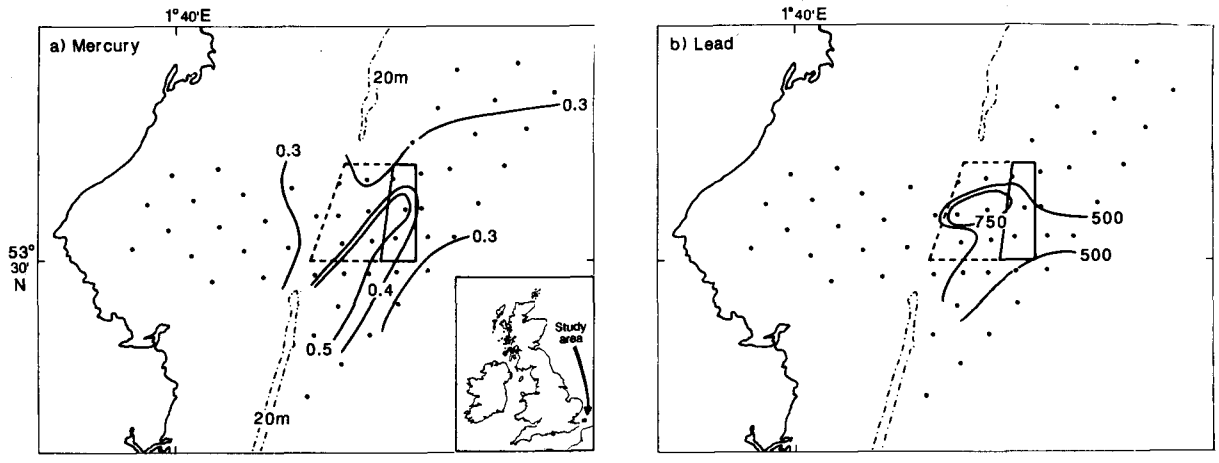

Figure 36. Concentrations of mercury and lead (mg kg^{-1}) in the <90 μm fraction of the sediment around the South Falls sewage-sludge disposal site in 1985.

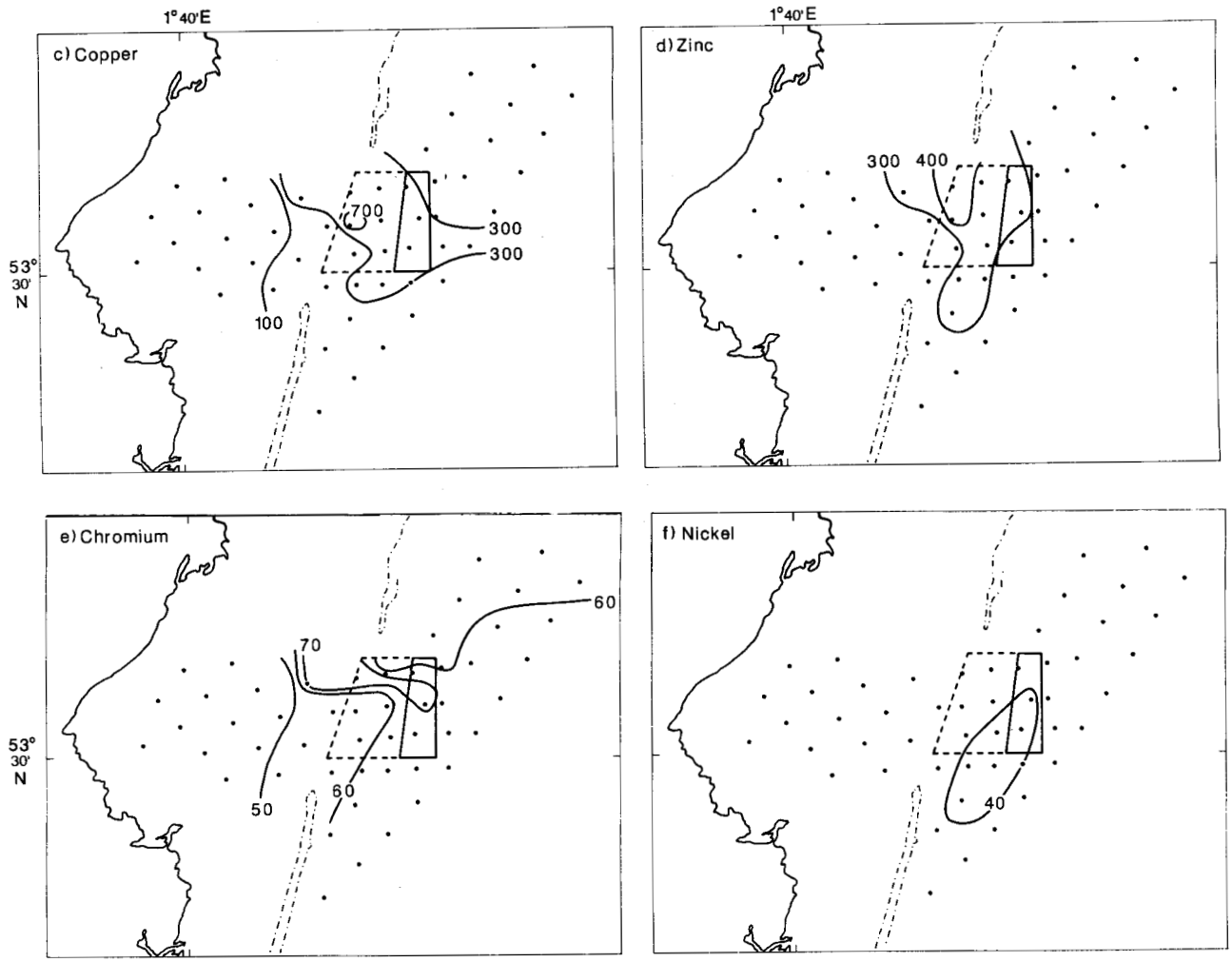

Figure 36. Continued. Concentrations of copper, zinc, chromium and nickel (mg kg^{-1}) in the <90 μm fraction of the sediments around the South Falls sewage-sludge disposal site in 1985

5.3 Disposal of dredged material

5.3.1 Liverpool Bay: Site Z

Approximately three million tonnes of dredged material from the Mersey Estuary and its approaches are deposited each year at Site Z in Liverpool Bay (Figure 37). This causes local elevations in sediment metal concentrations and periodic smothering of benthic fauna.

The effects of the disposal of dredgings on the sediments and benthos at Site Z were reported by Rowlatt *et al.* (1986). Apart from the direct effects of smothering within the spoil site, there was some evidence of enhancement in populations of the dominant species nearby, which may have been due to either the stabilising or nutritional properties of migrating dredged spoil. Since the results reported by Rowlatt *et al.* (1986) were obtained, further surveys using trawl, grab, core and underwater camera have been conducted in this area; some results from this work are given below.

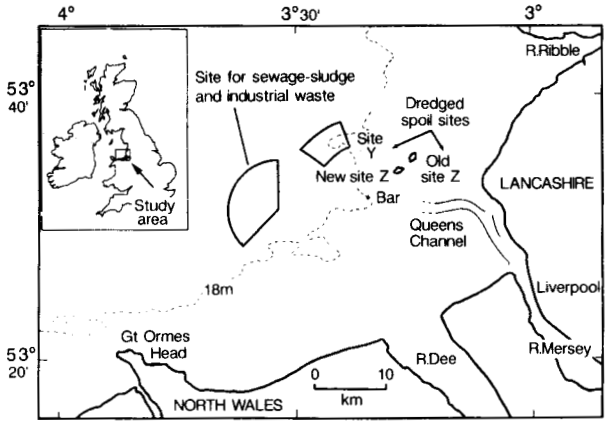

Figure 37. Liverpool Bay, showing the waste disposal sites (from Norton et al., 1984)

Recently deposited muddy sediments in the spoil ground were sampled in 1987 using a Tennant box corer. Redox profiles of core sub-samples showed that sediments rapidly approached anoxia with depth, a pattern which was matched by a core sample from an area of natural mud deposition in the Burbo Bight (Figure 38). This figure also indicates that recently

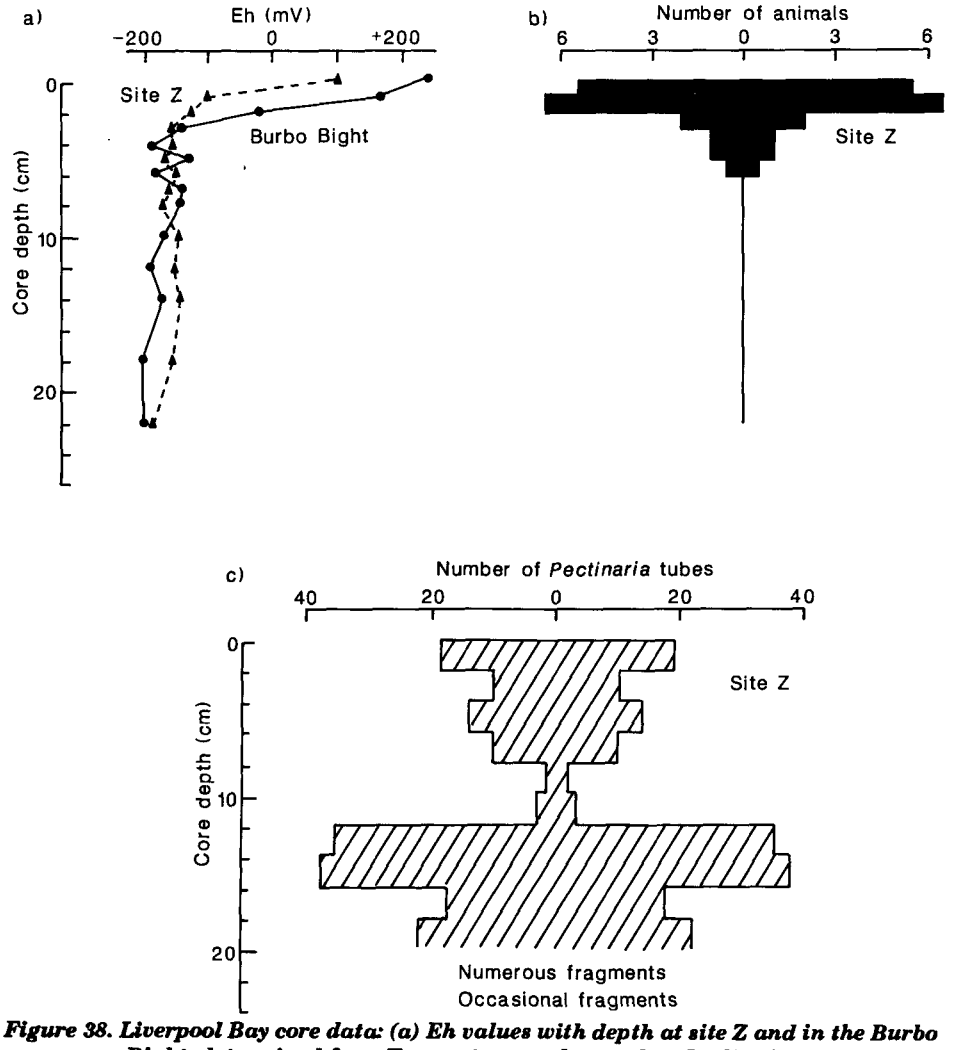

Figure 38. Liverpool Bay core data: (a) Eh values with depth at site Z and in the Burbo Bight, determined from Tennant core sub-samples; (b) distribution of animal counts with depth at Site Z; and (c) distribution of Pectinaria tubes with depth at Site Z.

colonised benthic fauna are confined to the oxic surface layer. The distribution of *Pectinaria* tubes suggests previous burial of a live assemblage as a result of spoil disposal. The dominant species in this area are the bivalve *Abra alba* and the polychaete *Pectinaria koreni*, both short-lived deposit-feeders. By their feeding and burrowing activities, coupled with annual cycles of recruitment and mortality, such animals may contribute to the dispersive process, under the dominant physical influences of wave and tidal action (see for example Eagle, 1975).

The species complement of epifauna, from beam trawl samples taken in 1985 and 1987, when ranked according to individual abundances and then plotted as cumulative curves (see Figures 39 and 40 and Lambshead *et al.*, 1983), show a marked percentage increase in dominance of the top-ranked species in a N-S direction. This was due to increased numbers of certain species, notably of the predatory mollusc *Philine*, the brittle-star *Ophiura* and the starfish *Asterias*, and may be attributable to the influence of River Mersey efflux. The effect of spoil disposal at the site was evidenced by a reduction in dominance of the first-ranked species [note the way in which curves C and C' cross over those for the northern Sites B and B' between taxon rank 1 and 2 (see Figure 40)]. However, there was no apparent effect on species variety, as can be deduced from the lateral extent of curves C and C', relative to others.

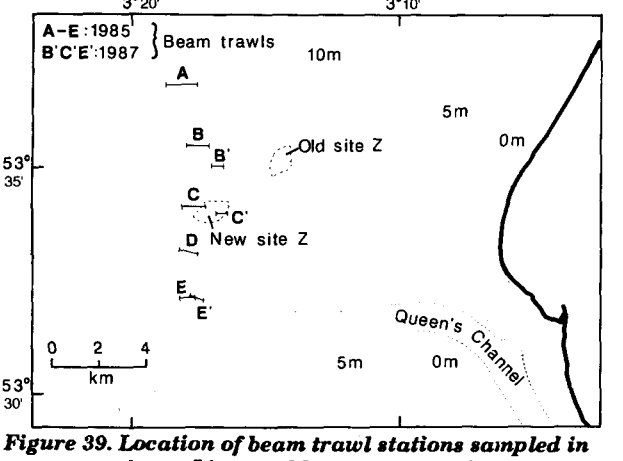

Figure 39. Location of beam trawl stations sampled in inner Liverpool Bay in 1985 and 1987.

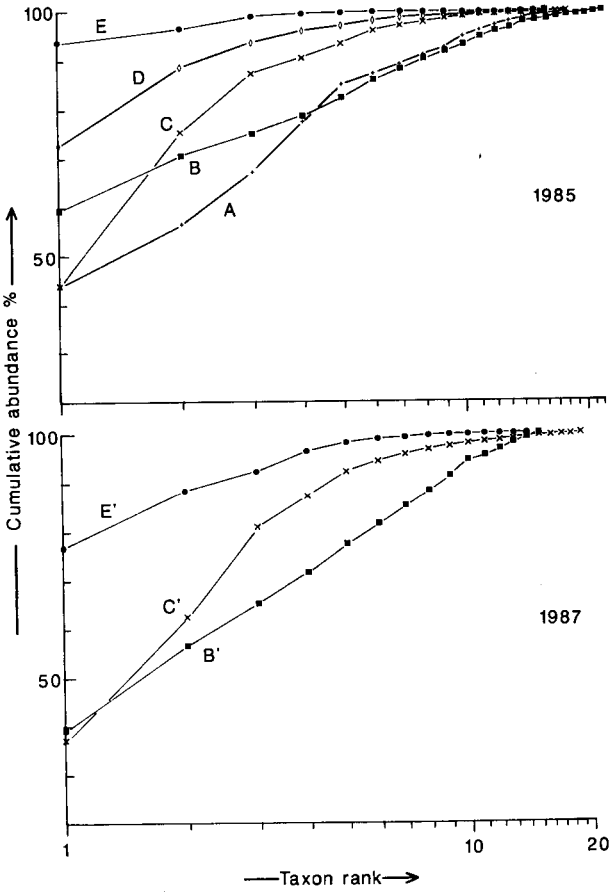

Figure 40. Ranked abundance curves for the epifauna from beam trawl samples in 1985 and 1987.

5.3.2 *Roughs Tower*

A detailed side-scan sonar survey of the Roughs Tower disposal ground and its surroundings was made in 1987, which supplemented two shorter surveys made in 1985. Figure 41 illustrates the grid used. On the basis of the sonographs produced and grab samples taken on surveys between 1980 and 1987, a generalised map has been drawn up of the sea-floor sediments at, and around, the disposal ground (Figure 42).

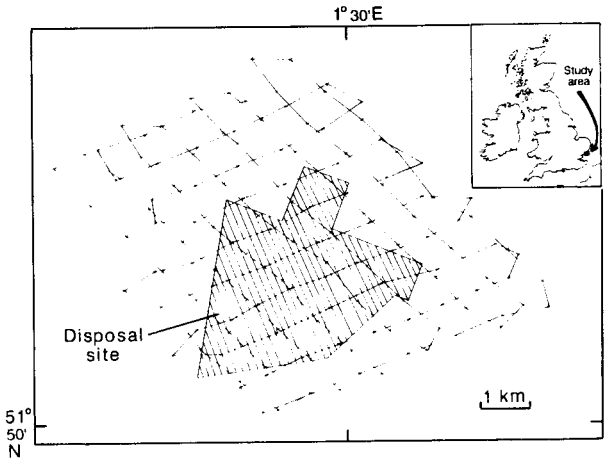

Figure 41. The Roughs Tower dredged material and sewage-sludge disposal ground, showing the track of a side-scan sonar survey in 1987.

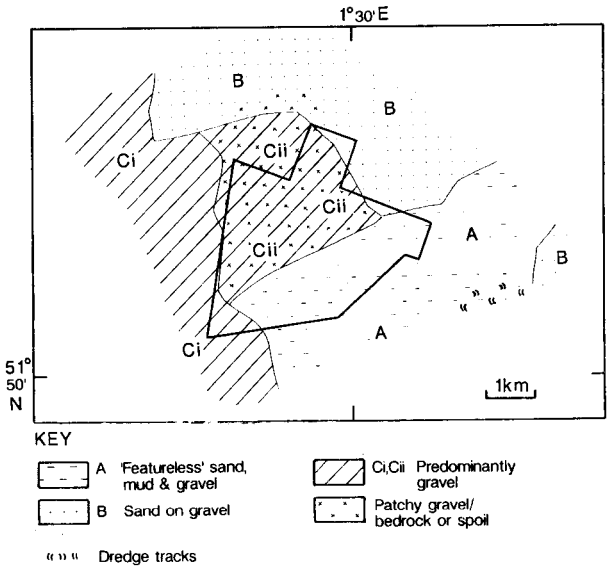

Figure 42. Sediment distribution around Roughs Tower, determined using side-scan sonar in 1987.

A mixture of gravelly and sandy substrates exists across the whole area with localised patches of more muddy sediment and possible mounds of dredged spoil. Four main bottom types may be discerned, characterised by the presence or absence of certain features on the side-scan records. These tend to merge into each other on the sea floor rather than change abruptly, but are drawn along specific lines on the map for the sake of clarity.

Facies A. Featureless Sediment: To the south west of the disposal site, and the surveyed region as a whole, few features are discernible on the sonograph, except for a small patch of irregularly disposed furrows on the sea floor which are probably indicative of sporadic trailer dredging. Locally, harder reflections occur, suggesting the presence of patches of sand waves or gravel or possibly weathered mounds of spoil, within the disposal ground.

Grab samples from this area show that the sea bed comprises sand and gravel in varying proportions plus mud in, and adjacent to, the disposal ground.

Facies B. Sand on Gravel: Along much of the north-western and north-eastern sides of the area, the sea floor, which is generally gravelly, is traversed by small fields of sand waves with wavelengths from 2-5 m. These fields are of limited size, from a few tens of metres in length and width up to about 500 m (perpendicular to current direction) and at least 2 km long. Most sand waves reflect current transport along NNE-SSW or NE-SW axes. The sonographs are not sufficiently extensive to say whether these fields are drawn out into sand ribbons. Lineation of the associated gravel floor indicates similarly directed bottom currents. Sand wave fields are uncommon in the disposal ground itself and, where present, are small and localised.

Facies C. Gravel: The sonographs of the remainder of the survey area indicate the sea floor to be rough and uneven and probably composed of gravel. Lineations on the sea floor are variable but mostly parallel residual current directions. Small fields of sand waves and patches of featureless sand and gravel occur sporadically across the area. The facies can be divided into the following two zones:

i) To the south west and in the southern corner of the disposal ground, the gravel is fairly featureless except for a crude lineation aligned at various attitudes to the current directions. Additionally, there are isolated outcrops of bedrock.

ii) Across the remainder of the disposal ground, and for up to 1.5 km to the north of it, the gravel is overlain by patches of material which produce irregular 'lumpy' reflections on the sonograph. These have a haphazard distribution and are variously aligned with respect to the bottom currents. The identity of these reflectors is unclear. Some may be raised hummocks of gravel or protruding bedrock. However, as clay is commonly present in grab samples from this area, it is also likely that

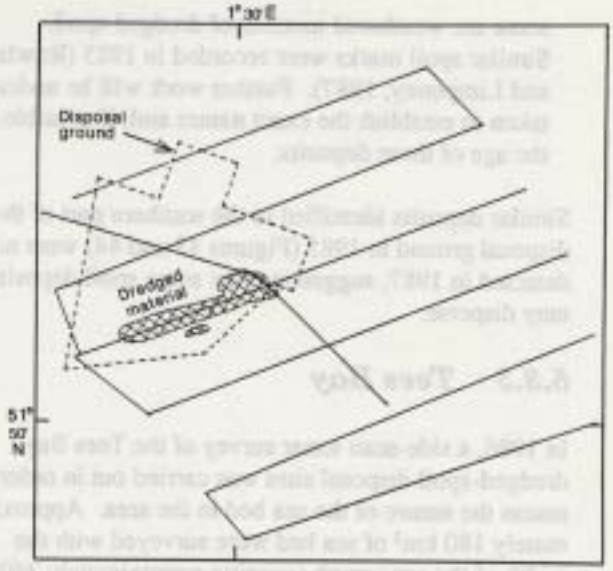

Figure 43. Tracks of side -scan sonar surveys around Roughs Tower, showing the distribution of mounds of dredged material in 1985.

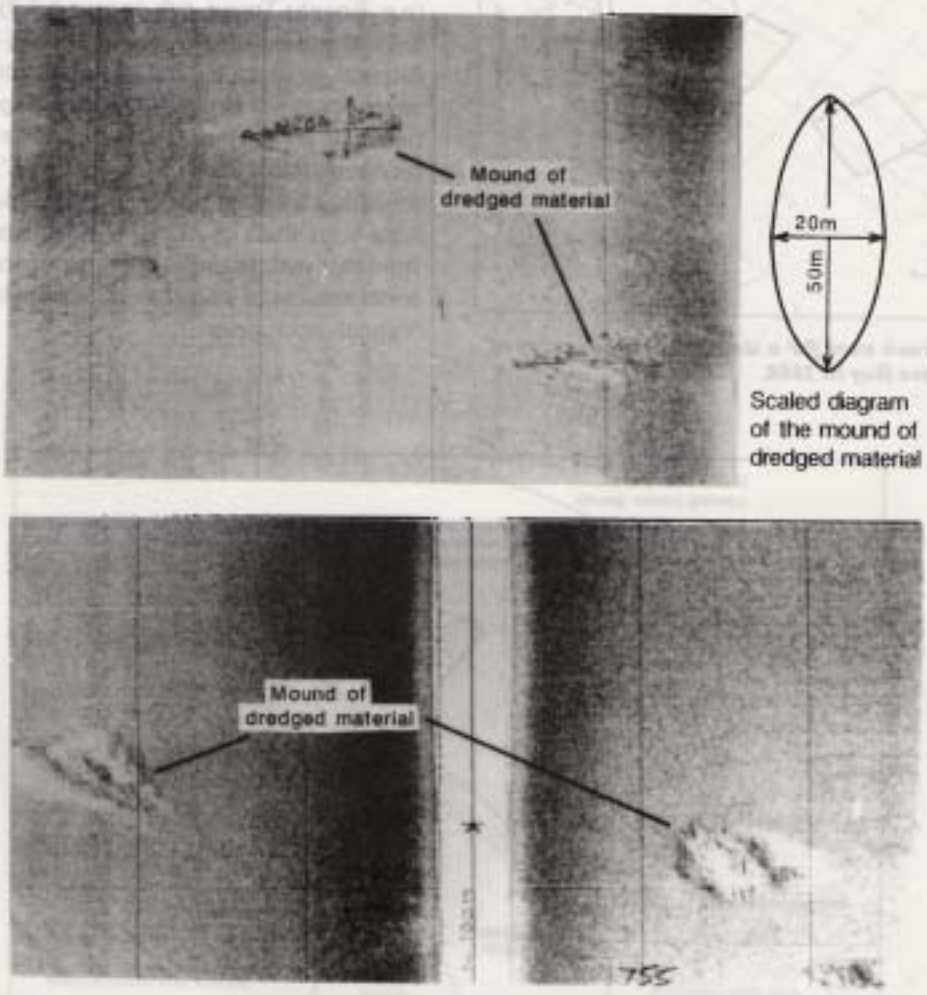

Figure 44. Side-scan sonar images of mounds of dredged material on the sea bed.

some are weathered mounds of dredged spoil. Similar spoil marks were recorded in 1985 (Rowlatt and Limpenny, 1987). Further work will be undertaken to establish the exact nature and, if possible, the age of these deposits.

Similar deposits identified in the southern part of the disposal ground in 1985 (Figures 43 and 44) were not detected in 1987, suggesting that some spoil deposits may disperse.

5.3.3 *Tees Bay*

In 1986, a side-scan sonar survey of the Tees Bay dredged-spoil disposal sites was carried out in order to assess the nature of the sea bed in the area. Approximately 180 km^2 of sea bed were surveyed with the width of the sonograph covering approximately 360 m (Figure 45). Results from grab surveys, carried out in 1986 and 1988, were used to provide 'ground-truth.'

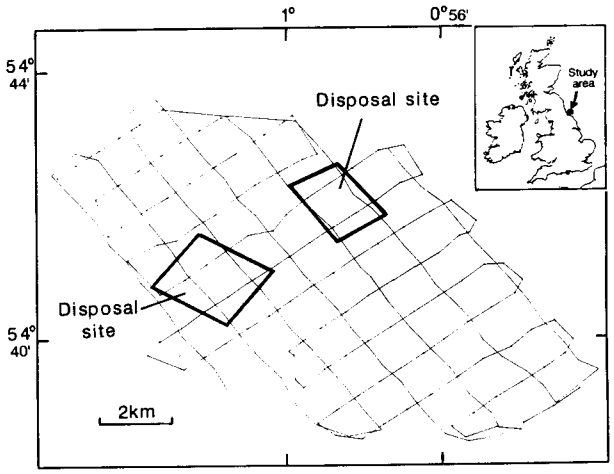

Figure 45. Track used for a side-scan sonar survey of Tees Bay in 1986.

Figure 46 shows the general sediment distribution in this area of highly variable substrates.

In the south, bedrock is exposed with limited mud and muddy sand occurring between rocky ridges. The sand forms faint ribbons in these isolated pockets, distinguishing the more sandy substrates from those that are predominantly muddy. Due to the faint nature of the ripples, it is not possible to ascertain a sea-bed residual current direction. Where the bedrock is extensively exposed, a general WNW-ESE strike can be observed. Some isolated folding can also be observed in the extreme SE part of the exposure. Towards the north and west, the bedrock is progressively more extensively covered by a muddy substrate, changing from bedrock with occasional mud/sand patches to mud/sand with occasional exposures of bedrock.

The central part of the survey area (that part covering the two disposal sites) is made up of generally rough ground, which also tends to predominate in the offshore site, with finer ground tending to be more common in the inner site. There are no discrete features indicating entire deposited loads of spoil, such as those observed at other dredged-spoil disposal sites (e.g. Roughs Tower, sub-section 5.3.2). Grab samples have identified spoil (rock, stones and clay) at both disposal grounds, but these are often covered with a veneer of sand. No spoil has been deposited at the outer site for the past three years. The inner site received almost 8 Mt of 'capital' and 'maintenance' dredgings between 1984 and 1987. Much of this would have been made up of silts and sand, mainly derived from the 'maintenance' dredging operations with a small amount of keuper marl and boulder clay from 'capital' operations.

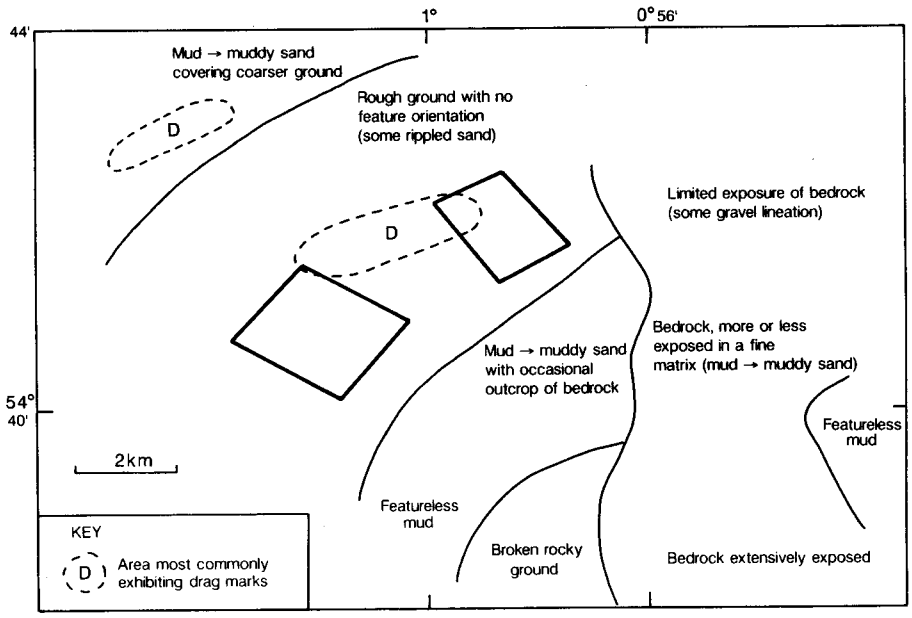

Figure 46. Generalised sediment distribution in Tees Bay, determined using side-scan sonar in 1986.

Linear trough features were observed between the two disposal sites and also in an area further to the north. It is possible that they may have been caused by the dragging of anchors of moored vessels, although the possibility that they are marks left by heavy trawls cannot be ruled out.

5.3.4 *Swansea Bay*

Side-scan sonar and echo-sounder surveys were made of the Swansea Bay dredged-spoil disposal ground and the surrounding area in October 1986, to help determine the nature of the substrate, the fate of deposited spoil and the direction of ambient bottom currents. Bad weather forced abortion of the survey before the grid had been completed. Additionally, the swell caused a deterioration in the quality of the output produced during later stages of the survey. A track of the ground that was covered is shown in Figure 47.

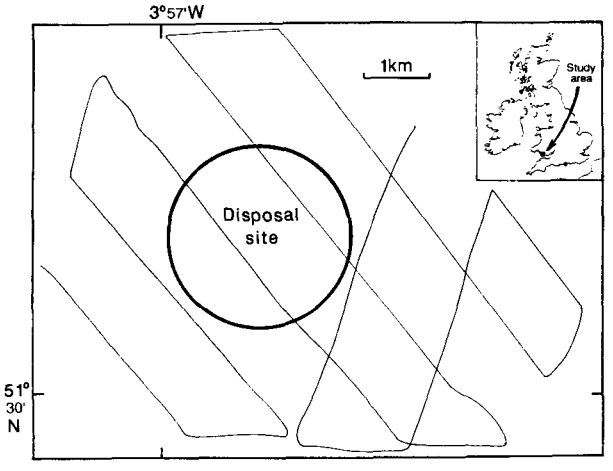

Figure 47. Track used for a side-scan sonar survey of Swansea Bay, 1986.

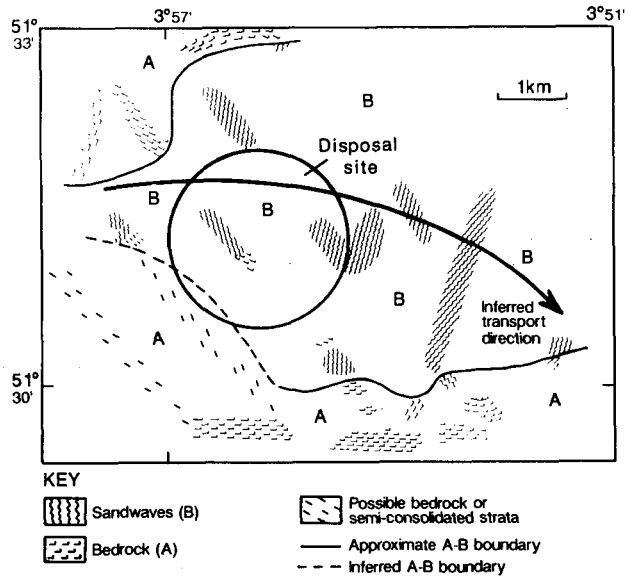

Figure 48. Generalised sediment distribution in Swansea Bay, determined using side-scan sonar in 1986.

Two distinct substrate types are apparent (see Figure 48):

(A) To the north west of the disposal site and along the southern edge of the area surveyed, the sea floor is predominantly rocky. This bed type produces sharp, hard, straight-edged reflectors on the sonograph, which generally parallel the trend of the strata in that region. In addition, the topography is rather rough and undulating. The most distinctive areas of outcrops are shown on the map. South west of the disposal site the reflections on the sonograph are similar in style to those of the north west but more faint and may indicate exposure of a different, softer lithology or of semi-consolidated Quaternary deposits. Sand patches occur locally.

(B) Over the remainder of the survey area, the sea floor is covered by sandy or muddy sediments of low relief, which produce a soft homogenous reflection on the sonograph. Locally, these sediments are organised into sand waves. The most distinct fields of sand waves are shown in the figure; less regular wave forms appear to cover much of the remaining area but are not shown, because of their indistinct nature. The wave length of the better formed sand waves ranges from 8 to 12 m. The transport direction implied by these bed forms is easterly, to the west of the disposal site, coming round to south easterly through and beyond the site to the east.

Occasional rocky patches exist within this area and on its eastern margin the sea floor appears to become slightly gravelly.

There is no evidence, on either the side-scan or echo-sounder records, of the presence of mounds of dredged spoil anywhere in the survey area or of any general sediment accumulation within the disposal ground. On the contrary, the low relief of the area and the presence of sand waves and occasional patches of bedrock within it suggest that dispersion of deposited spoil takes place.

5.4 Solid industrial waste disposal

5.4.1 *Wearmouth colliery waste disposal site*

Colliery waste is deposited at a site off Wearmouth in approximately 25 m of water (Figure 49 a-b). In 1986, a survey was undertaken to assess the quantity of minestone on the sea bed at the disposal site and the areal extent of the deposit.

The area containing the waste was identified using side-scan sonar surveys and its volume estimated using echo-sounder surveys. Figure 50 (a-c) shows the

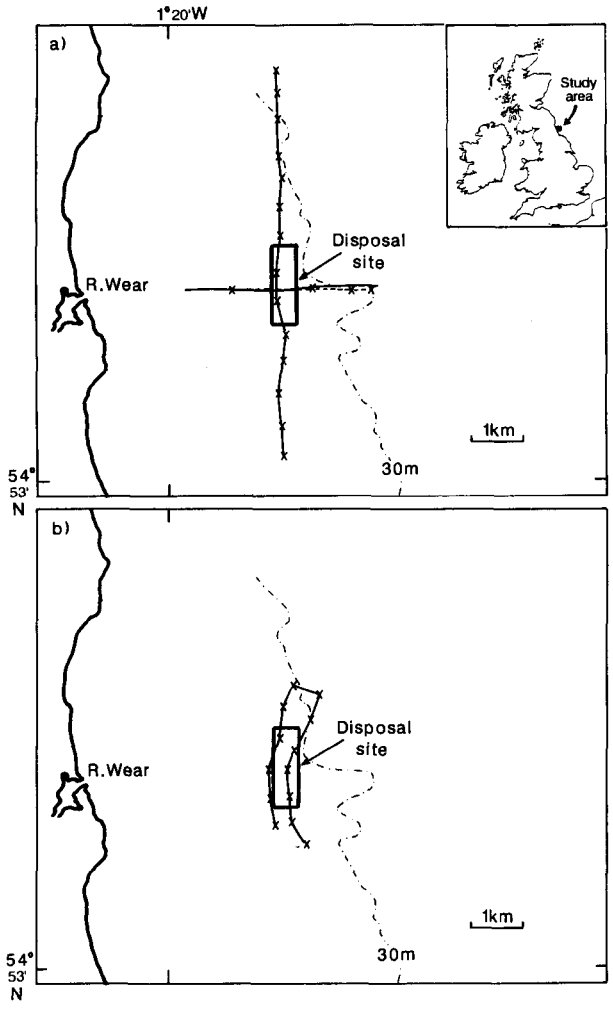

Figure 49. Track used for an acoustic survey of the Wearmouth colliery waste disposal site using: (a) side-scan sonar; and (b) echo-sounding techniques.

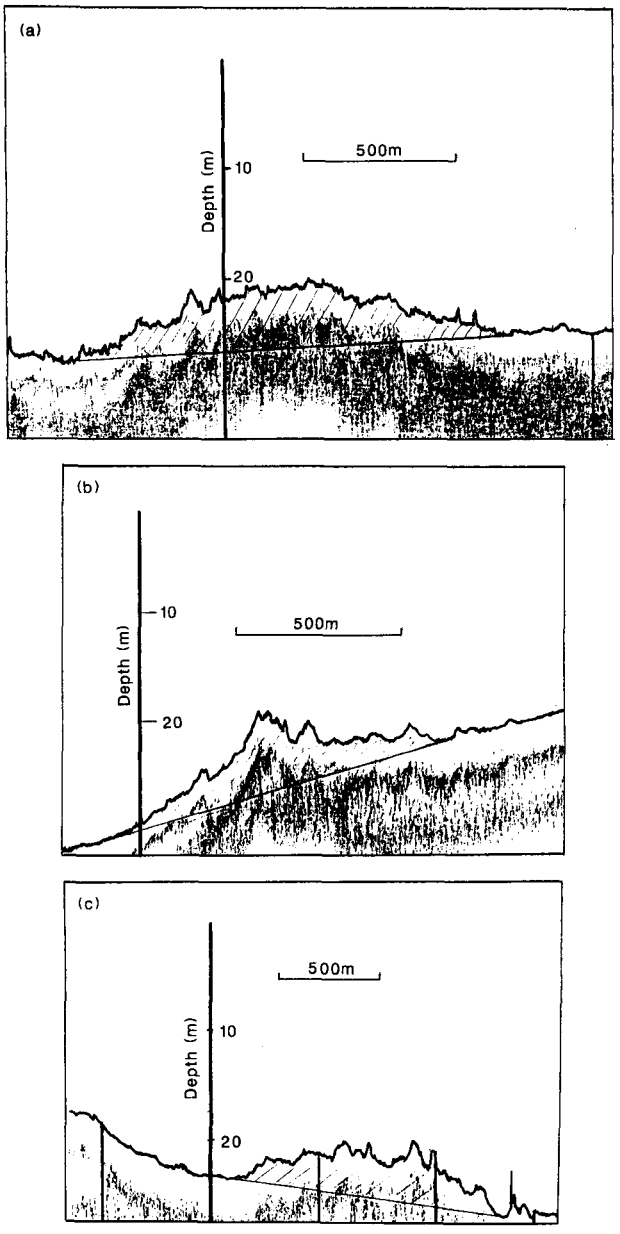

Figure 50. Echo-sounder transects across the Wearmouth colliery waste disposal site using: (a) north-south survey; (b) east-west survey; and (c) south-north survey.

bottom topography across the disposal ground and identifies the deposit as a flattened cone with a maximum height of 7 m above the sea bed.

The volume of the deposit is approximately 1.8 x 10^6 m^3 which equates to 3.2 x 10^6 t of minestone, assuming a bulk density of 1.8. In the eight years preceding the survey, 6.5 x 10^6 t of waste were deposited at the site. As some of the waste at the disposal ground was undoubtedly deposited prior to the eight years of records considered, it may be deduced that a significant portion of the deposited waste is transported away from the disposal site. Based on these data, British Coal carried out a more detailed assessment of dispersal from the site in 1987 (unpublished report).

5.5 Aggregate extraction

5.5.1 Hastings shingle bank

In the period under review, licences have been issued by the Crown Estate Commissioners for the extraction of aggregates from the Hastings shingle bank. Extraction has proceeded in a number of limited areas which are being closely monitored. Based on the results of these studies, further licences may be issued.

In 1986 and 1987, side-scan sonar surveys were carried out to investigate the sea bed characteristics and establish a baseline with which future work can be

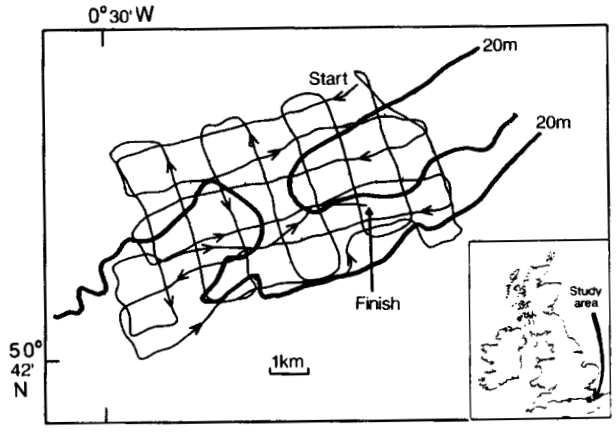

Figure 51. Track followed in a side-scan sonar survey of the Hastings Shingle Bank in 1986.

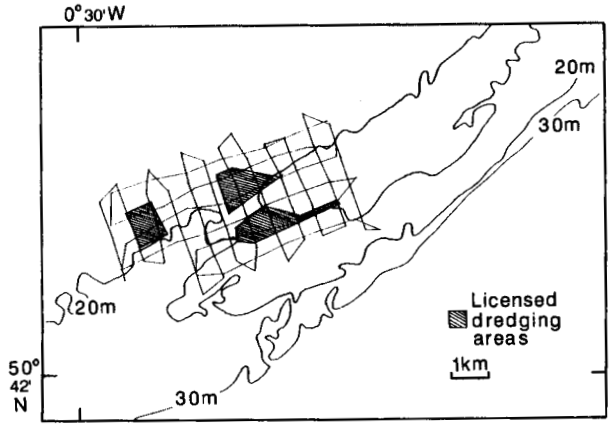

Figure 52. Track followed in a side-scan sonar survey of the Hastings Shingle Bank in 1987.

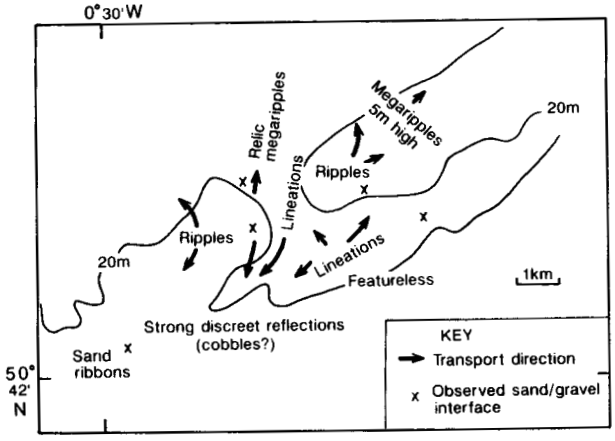

Figure 53. Hastings Shingle Bank, showing the main sedimentary features, as determined in 1986 using side-scan sonar.

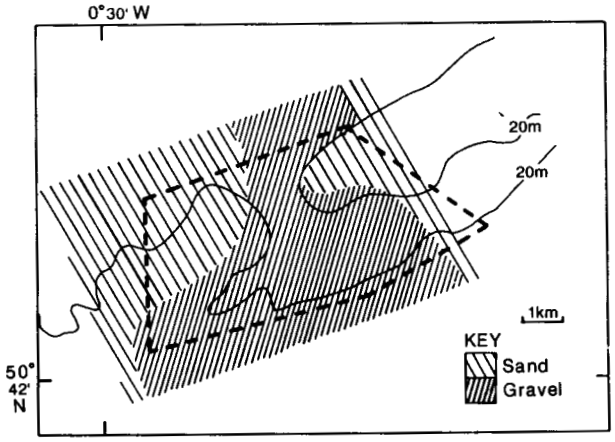

Figure 54. Hastings Shingle Bank, showing the general sediment distribution, as determined in 1986 using side-scan sonar.

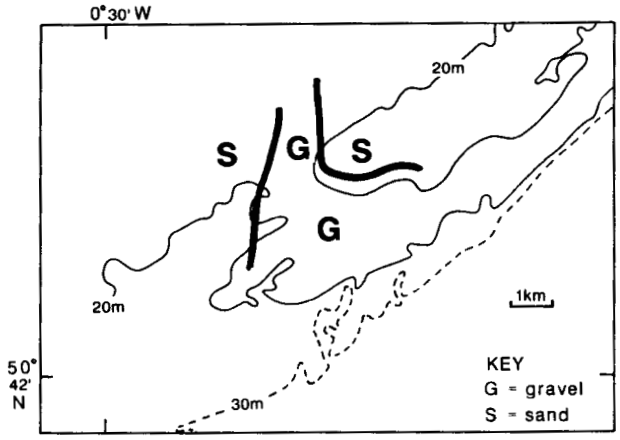

Figure 55. Hastings Shingle Bank, showing the main sediment boundaries, as determined in 1987 using side-scan sonar.

compared. This will allow an assessment of the physical effects of dredging and will be used to check that extraction has taken place only within the licensed areas.

In 1986, a reconnaissance survey was carried out covering the whole of the potential extraction area (Figure 51) while the 1987 survey (Figure 52) focused on the areas which were proposed for licensing in the early stages of extraction.

Figure 53 shows the distribution of the main sediment features on the bank, as determined by side-scan sonar surveys. Figure 54, for 1986, shows the general sediment distribution while Figure 55, for 1987, shows the precise sediment boundaries found in the northern part of the bank.

The fauna of the Hastings area has also been examined as the basis for future studies of the effects of aggregate extraction on biota. Gravel substrates were sampled in 1986 by means of towed scallop dredges and anchor dredges in order to describe the fauna living on and within sediments (see Rees, 1987). A comparison with a benthic survey conducted in 1972 in this vicinity (Shelton and Rolfe, 1972) provided no evidence for any structural change in faunal assemblages since that time.

6. MONITORING OF PARALYTIC SHELLFISH POISONING TOXIN IN MUSSELS: *Project with MAFF's Fish Diseases Laboratory, Weymouth*

6.1 Introduction

A marine dinoflagellate (*Alexandrium tamarense*), which occurs in the coastal waters of England and Scotland, produces potent neurotoxins. When bivalve molluscs ingest dinoflagellates of this type, they concentrate the toxins in their bodies and become toxic to mammalian consumers, although they themselves are little affected. Ingestion of toxic bivalves by man causes an illness known as paralytic shellfish poisoning (PSP) which can be fatal. Since these toxins are not denatured by cooking, the only practical measure to prevent PSP in man is to control harvesting and sale of shellfish, particularly bivalves, during periods of high toxicity. Shellfish become toxic when these dinoflagellates occur in high concentrations (blooms) in the area in which the shellfish feed. Blooms of toxic dinoflagellates occur in the coastal waters off north-east England and the east and west coasts of Scotland, between the months of April and August. Constant monitoring of toxin levels in shellfish is necessary because the blooms are unpredictable.

Samples of shellfish are taken by local environmental health officers from seventeen sites on the north-east coast of England and east coast of Scotland and three sites on the west coast of Scotland. The samples are sent to the Fish Diseases Laboratory, Weymouth, on a weekly basis for analysis by bioassay. When levels of toxins rise to levels which could affect man, the relevant Public Health Authorities are alerted so that appropriate action can be taken.

Table 23. Results of monitoring for paralytic shellfish poisoning in 1987.

Sampling station	Week ending										
	3-Apr	10-Apr	17-Apr	24-Apr	1-May	8-May	15-May	22-May	29-May	5-Jun	12-Jun
Montrose	*	*	*	0	*	0	*	0	*	0	*
Elie	*	*	*	*	0	*	0	*	0	*	0
Musselburgh	*	*	*	*	*	0	*	0	*	0	*
Loch Spelve	*	*	*	*	*	*	*	*	0	*	0
Loch Ryan	*	*	*	*	*	0	*	0	*	0	*
Argyll	*	*	*	*	*	0	*	*	*	*	*
Holy Island	*	*	*	*	*	*	0	Trace	178	206	0
Berwick Harbour	0	*	*	0	0	*	*	*	*	*	*
Budle Bay	*	*	*	0	*	0	*	0	178	183	*
Coquet Estuary	0	0	0	0	0	0	*	163	*	190	0
Cresswell	*	*	*	0	*	0	*	*	*	159	*
East Staithes	0	0	0	0	0	0	0	0	Trace	189	0
Trow Rocks	0	*	0	*	0	0	*	164	338	298	0
Sunderland	*	*	0	*	0	*	0	*	173	*	135
Hartlepool	0	*	0	*	0	*	0	0	*	0	*
Redcar	0	0	0	0	0	0	0	0	206	0	177
Saltburn	0	0	0	0	0	0	0	0	0	183	0
Whitby	*	*	0	*	0	0	*	*	*	*	*
Cornelian Bay	0	0	0	*	0	0	0	0	*	0	0
Scalby Mill	0	0	0	*	0	0	0	0	*	0	0

Table 23. Continued.

Sampling station	Week ending									
	19-Jun	26-Jun	3-Jul	10-Jul	17-Jul	24-Jul	31-Jul	7-Aug	14-Aug	21-Aug
Montrose	0	*	0	*	0	*	0	*	0	*
Elie	*	*	*	*	*	*	*	*	*	*
Musselburgh	0	*	*	*	*	*	*	*	0	*
Loch Spelve	*	*	*	*	*	*	*	*	*	*
Loch Ryan	*	*	0	*	0	*	0	*	0	*
Argyll	*	*	*	*	*	*	*	*	*	*
Holy Island	0	0	0	0	*	*	*	*	*	*
Berwick Harbour	*	*	*	*	*	*	*	*	*	*
Budle Bay	0	0	0	*	0	0	*	0	*	*
Coquet Estuary	*	0	0	0	*	*	0	0	0	0
Cresswell	0	*	0	0	*	*	*	0	0	0
East Staithes	0	0	0	0	0	0	0	0	0	0
Trow Rocks	0	0	0	*	0	*	0	0	0	*
Sunderland	0	*	0	*	0	*	*	*	0	*
Hartlepool	0	*	0	*	*	*	*	*	0	*
Redcar	0	0	0	0	0	*	0	0	0	0
Saltburn	0	0	0	0	0	*	0	0	0	0
Whitby	*	*	*	*	*	*	0	*	*	*
Cornelian Bay	0	0	0	*	*	0	0	*	0	*
Scalby Mill	0	0	0	0	0	0	0	*	0	*

* = not sampled; 0 = no toxin detected; toxin levels are expressed in mu/100g.

6.2 Methods

Once the samples have arrived in the laboratory, they are washed and approximately 50 g of meat and liquor are weighed into a beaker. An equivalent volume of dilute HCl is added and the whole macerated. The resultant liquid is then boiled for 5 min and allowed to cool. After centrifuging, the supernatant is ready for the bioassay. Female mice of 18-20 g are injected intraperitoneally with the acidified extract and observed for a reaction for up to 30 min. The death time and weight are recorded for each mouse. A calculation can then be made based on figures obtained from a table giving time and weight correction factors (unpublished data). This gives a level of toxins in 'mouse units per 100 g' (mu/100 g). The 'action level', or the level above which the shellfish are not safe for consumption, is set at 400 mu/100 g.

6.2.1 Chemical assay for PSP toxins

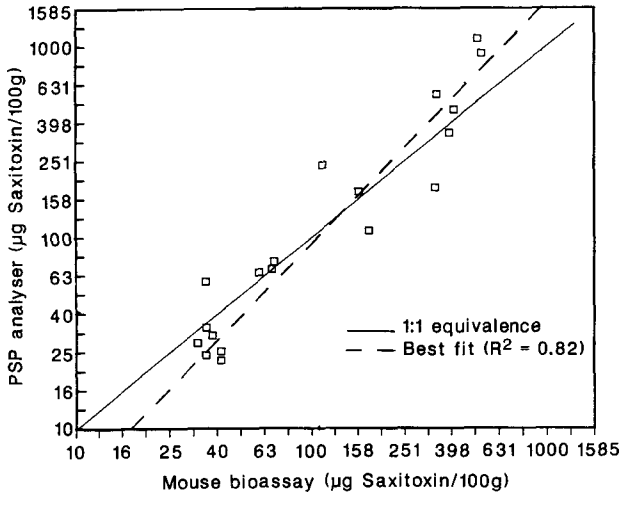

Figure 56. Graph of a mouse bioassay versus HPLC results of PSP toxin determinations in mussels.

A high-pressure liquid chromatography (HPLC) technique has been developed, which can separate and quantify individual PSP toxins. Comparisons carried out to date (Fileman, 1988) (Figure 56) suggest that the HPLC technique gives a good correlation with the mouse bioassay. Work will continue with the HPLC technique with a view to it replacing the mouse bioassay.

6.3 Results

The results for 1987, using the mouse test, can be seen in Table 23.

Toxin levels have not exceeded the action level of 400 mu/100 g since 1985. However, the phenomenon is so unpredictable that it will be necessary to continue with the monitoring programme.

7. MONITORING OF TRIBUTYLTIN (TBT): *Project with the Department of the Environment, London*

7.1 Introduction

A programme of field surveys for measurement of tributyltin (TBT) in estuarine water and indicator species has been carried out at Burnham-on-Crouch since 1982. Up to 1986, such surveys were restricted to six sites in the UK. However, following the introduction of measures to control the use of TBT on small boats in 1986 and 1987 [under the provisions of the Control of Pollution Act (1974) (Great Britain - Parliament, 1974) and The Food and Environment Protection Act (1985) (Great Britain - Parliament, 1985) respectively], the UK Department of the Environment and the Ministry of Agriculture, Fisheries and Food commissioned a more intensive research and monitoring programme, designed to measure the efficacy of the legislative action.

7.2 Methods

The programme was based on analysis of whole water samples, *Crassostrea gigas*, *Mytilus edulis* and sediments. Details of the sampling sites have been given by Abel *et al.* (1986), and analytical methodology has been published in a MAFF report (Waldock *et al.*, 1989).

7.3 Results

First results of baseline water analysis have been published (Waldock *et al.*, 1987, 1988; Waite *et al.*, in press).

One aim of the programme was to contrast decreases of TBT concentrations at highly impacted sites, such as marinas, with changes at sites traditionally used for mariculture. In 1985 and 1986, concentrations of TBT at marina sites were found to exceed microgram per litre values (i.e. higher than concentrations known to affect survival of larval fish, crustacea and molluscs). At more open sites, concentrations of TBT in water rose to approximately 100 ng l^{-1}, and tissues of captive indicator species contained concentrations in excess of 1 µg g^{-1} wet weight. In 1987, after introduction of control measures, concentrations in water and indicator species were found to be lower than those in previous years but in most areas were still more than half the former values (Figure 57). Preliminary results for 1988 show more marked reductions.

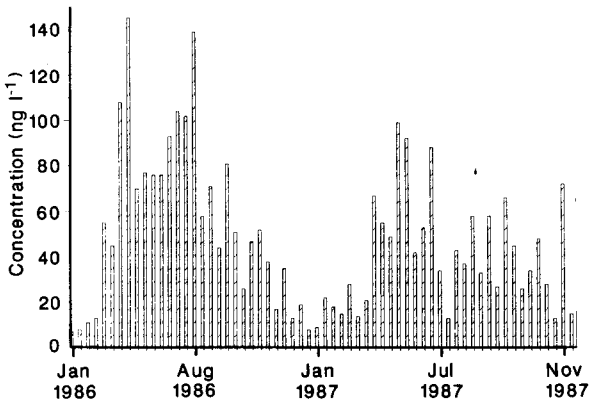

Figure 57. Organotin concentrations (ng l^{-1}) in the River Crouch in 1986-1987.

In studies on shipping, the contribution to environmental loadings of TBT from anchorages, harbours and dry docks were examined. During normal use, concentrations within harbours were generally low (less than 100 ng l^{-1}). However, waste water from dry docks contained up to milligram per litre concentrations, and discharges from dry dock areas were found to exceed 40 µg l^{-1}.

8. MONITORING OF CONTAMINANTS IN EELS: *Project with MAFF's Food Science Division, London*

8.1 Introduction

The Burnham-on-Crouch Laboratory took part in a national survey of organochlorine contaminants in eels carried out in 1986-1987 under the auspices of the MAFF Working Party on Pesticide Residues (MAFF, 1989). Twenty-three sites were initially sampled in England and Wales for this environmental survey, including a number of areas considered likely, from a knowledge of inputs, to be heavily contaminated with organochlorine pesticides and/or PCBs.

8.2 Methods

Samples were analysed using the methods referred to in Section 1.

8.3 Results

It was anticipated that, because of their fatty flesh, the levels of organochlorine residues would be considerably higher in eels than in other fish species, and this proved generally to be the case. In some areas, concentrations were very much greater than those encountered previously in fish tissue. A summary of the results is given in Table 24.

Advice was sought from the Department of Health on the potential risk to human consumers of eels. It was advised that any health concerns were likely to be related to intake of dieldrin. This advice was issued in October 1988 in a MAFF News Release (MAFF, 1988). Detailed results on the concentrations of contaminants found in eels were made available at the same time, on request (MAFF, unpublished data). A summary of the pesticide data was published by MAFF (MAFF, 1989).

Table 24. Residues of organochlorine pesticides/PCBs in eel muscle (mg kg^{-1} wet weight)

No of sites	Total number of eels analysed	Mean length (cm)	Mean % fat	HCB	α HCH	γ HCH	Dieldrin	pp DDE	pp TDE	pp DDT	PCBs
England											
21	206	46	12	Mean 0.007	0.03	0.05	0.3	0.1	0.05	0.07	0.47
				Site range (<0.001-0.04)	(<0.001-0.4)	(0.001-0.2)	(0.01-1.0)	(0.006-0.4)	(<0.001-0.3)	(<0.001-0.4)	(0.02-1.3)
Wales											
2	20	36	16	Mean 0.002	0.001	0.005	0.2	0.03	0.03	0.05	0.17
				Site range (0.001-0.002)	(<0.001-0.002)	(0.004-0.005)	(0.02-0.3)	(0.01-0.04)	(0.01-0.04)	(0.003-0.1)	(0.05-0.29)

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APPENDIX 1. Standards/guidelines for contaminants in fish and shellfish.

A1.1 Metals

(a) Mercury

The European and Paris Commissions have adopted an Environmental Quality Standard (EQS) for mercury, which requires that the mean concentration of mercury in the flesh of a representative sample of fish, locally caught from areas receiving significant inputs of mercury, shall not exceed 0.3 mg kg^{-1} on a wet weight basis (EEC Directives Nos 82/176 and 84/156 - European Communities, 1982 and 1984).

For the purposes of the Joint Monitoring Programme (JMP) of the Oslo and Paris Commissions, the following arbitrary, purely descriptive, guidelines have been adopted.

Level	Fish flesh and crustaceans	Molluscs
Lower	< 0.1 mg kg^{-1} wet weight	< 0.6 mg kg^{-1} dry weight
Medium	0.1-0.3 mg kg^{-1} wet weight	0.6-1.0 mg kg^{-1} dry weight
Upper	> 0.3 mg kg^{-1} wet weight	> 1.0 mg kg^{-1} dry weight

(b) Cadmium

There are no standards or guidelines in England and Wales for fish flesh. The expected values are <0.2 mg kg^{-1} wet weight.

The JMP guidelines for cadmium in mussels are as follows:

Level	Mussel tissue	Approximate equivalent
Lower	< 2 mg kg^{-1} dry weight	($\equiv$< 0.4 wet weight)
Medium	2-5 mg kg^{-1} dry weight	($\equiv$ 0.4-1.0 wet weight)
Upper	> 5 mg kg^{-1} dry weight	($\equiv$ > 1.0 wet weight)

From past DFR work, 'expected' values (i.e. using data from estuaries not known to be severely contaminated) would be up to 0.3 mg kg^{-1} wet weight for crustaceans but up to 10 mg kg^{-1} wet weight for crab 'brown' meat.

(c) Lead

From the Lead in Food Regulations 1979 (Great Britain - Parliament, 1979), lead in fish should not exceed 2.0 mg kg^{-1} wet weight, and lead in shellfish 10.0 mg kg^{-1} wet weight.

From past work, 'expected' values are 0.2-0.3 mg kg^{-1} wet weight in fish, up to 1.0 mg kg^{-1} wet weight in crustaceans, and up to 4.0 mg kg^{-1} wet weight in some molluscs.

(d) Copper

From the Food Standards Committee's Report on Copper (MAFF, 1956), revised recommendations for limits for copper content of food are as follows:

Levels of copper in food should not exceed 20 mg kg^{-1} wet weight (but higher levels in shellfish are permitted if copper is of natural occurrence).

From past DFR work, 'expected' levels in fish are up to 0.6 mg kg^{-1} wet weight (in excess of 1.0 mg kg^{-1} wet weight in fatty fish such as herring) up to 5.0 mg kg^{-1} wet weight for molluscs (with very much higher values for some gastropods) and 20-30 mg kg^{-1} wet weight for crustaceans.

(e) Zinc

From the Food Standards Committee's Report on Zinc (Ministry of Food, 1953), as a guideline:

Levels of zinc in food should not exceed 50 mg kg^{-1} wet weight (but higher levels are permitted in foods which naturally contain more than 50 mg kg^{-1}, such as herring and shellfish).

'Expected' values commonly found are up to 6.0 mg kg^{-1} wet weight in most fish flesh,(though up to 10 mg kg^{-1} in flounder and considerably more in fatty fish), up to 100 mg kg^{-1} wet weight in crustaceans and well in excess of 100 mg kg^{-1} wet weight for some molluscs.

A1.2 Pesticides/ PCBs

There are no standards in fish and shellfish from England and Wales.

(a) HCB

The 'expected' value is up to 0.10 mg kg^{-1} wet weight in fish liver.

(b) HCH

Codex Alimentarius Commission's maximum residue limit (MRL) (FAO/ WHO, 1987) is 2 mg kg^{-1} in meat fat for γ HCH. The 'expected' values are up to 0.05 mg kg^{-1} wet weight for each of α and γ HCH in fish liver.

(c) Dieldrin

Codex Alimentarius Commission's MRL is 0.2 mg kg^{-1} in meat fat. The 'expected' values are 0.2-0.3 mg kg^{-1} wet weight in fish liver.

(d) Total DDT

Codex Alimentarius Commission's MRL is 5 mg kg^{-1} in meat fat. The 'expected' values are up to 0.5 mg kg^{-1} wet weight for each of DDE, TDE and pp DDT in fish liver.

(e) PCBs

JMP guidelines are as follows (all mg kg^{-1} wet weight):

Level	Fish muscle	Cod[1] liver	Flounder[2] liver	Molluscs	Crustaceans
Lower	<0.01	<2.0	<0.50	<0.02	<0.01
Medium	0.01-0.5	2.0-5.0	0.50-1.0	0.02-0.10	0.01-0.05
Upper	>0.05	>5.0	>1.0	>0.10	>0.05

[1] Values used for all roundfish in this report.
[2] Values used for all flatfish in this report.

A1.3 References

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APPENDIX 2. Areas of monitoring mentioned in the text and staff responsible for the projects.

Section 1: Contaminants in marine biota

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Section 2: Trace metals in sea water

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Section 3: Hydrocarbons in sea water

R. J. LAW
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Section 4: Effects of oil and gas exploration:

Leman and Thames gas fields

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Morecambe Bay gas field

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Section 5: Disposal at sea

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Section 6: Paralytic shellfish poisoning

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Section 7: Tributyltin

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Section 8: Contaminants in eels

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