International Council for the Exploration of the Sea

CM 1980/E:15
Marine Environmental Quality Committee

RESULTS OF A MUSSEL WATCH PROGRAMME IN ENGLAND AND WALES 1977 AND 1978

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ABSTRACT

As part of its work on marine environmental protection the Ministry of Agriculture, Fisheries and Food's, Fisheries Laboratory at Burnham on Crouch, undertook mussel surveys in England and Wales in 1977 and 1978. Trace metal, organochlorine pesticide and PCB residues and petroleum hydrocarbon concentrations were determined. The 1977 survey was restricted to the south coast of England; the 1978 survey comprised about 90 samples covering the whole of England and Wales.

The results of the surveys showed that the contaminant concentrations in general reflected the expected environmental concentrations of the compounds of interest: samples from areas with significant anthropogenic inputs such as industrial estuaries contained the highest concentrations: samples from areas influenced mainly by natural sources contained much lower contaminant concentrations. The surveys establish the practicability of a mussel watch approach to monitoring in an England and Wales context and the suggestion is made that future work should be designed around local more intensive surveys rather than the broad approach followed by the 1978 survey.

INTRODUCTION

Contamination of U.K. marine coastal waters by compounds such as trace metals, organochlorine residues and petroleum hydrocarbons has been investigated for a number of years. Most of the substances of interest have sea-water concentrations in the range 10^{-9} to 10^{-12} g l^{-1} and although analytical techniques are available, or being developed to measure these low concentrations, few are suitable for routine use. Also, analysis of a single sea-water sample merely reveals what is present at the time and not what occurred previously. In order to overcome the problems associated with trace contaminant analysis of sea-water, a number of workers have looked at the analysis of benthic organisms which concentrate a variety of contaminants and act as integrators of exposure levels over a period of weeks or months, (Goldberg, 1975, 1978; Davies and Price, 1978; Davies and Pirie, 1978; Holden, 1973; Morris and Bale, 1974; Bryan, 1979; Bryan and Hummerstone, 1973). While it seems very unlikely that any one class of organism will satisfy all of the criteria required of an indicator organism, mussels possess many of the basic qualities and have been used fairly successfully in a number of programmes

(Goldberg, 1978; Capelli et al., 1978; Majori et al., 1978; Phillips, 1976).

The Ministry of Agriculture, Fisheries and Food's, Fisheries Laboratory at Burnham on Crouch has been interested for a number of years in contamination of the marine environment and has produced reports on contaminant concentration in fish and shellfish landed in England and Wales (Portmann, 1979; Murray, 1979). As part of these investigations, and in collaboration with the Department of Agriculture and Fisheries for Scotland who have already reported their results to ICES, a small scale mussel survey of the south coast of England was undertaken in 1977 and a more extensive survey covering the whole of England and Wales was carried out in 1978. This paper presents the results of these two surveys and comments briefly on their significance and the form that any future mussel surveys should follow.

SAMPLING

The sampling sites for both surveys were chosen so as to provide adequate geographical coverage commensurate with the analytical facilities available. Samples were collected from both commercially and non-commercially exploited mussel beds. As far as possible samples were collected from mid-tide level and comprised at least 50 individuals of average size at each site. 1977 samples were maintained in clean sea water for 24 hours to allow purging of the gut contents. They were then despatched, deep-frozen, to the laboratory. 1978 samples were posted alive to the laboratory and kept for 24 hours in settled sea water prior to extraction and analysis.

EXTRACTION AND ANALYSIS

Metals

All samples were digested using a mixture of concentrated nitric acid and hydrogen peroxide. Concentrations of zinc and copper were then determined directly by flame atomic absorption spectrophotometry (AAS). Concentrations of lead and cadmium were determined by flame AAS following complexation with ammonium tetramethylene dithiocarbamate and extraction of the complex into 4-methyl-2-pentanone. Mercury was determined by an automated flameless technique (Lawson and Kirkwood, 1980).

Pesticides and PCBs

Organochlorine pesticides and PCBs were analysed by packed column gas chromatography utilising electron capture detection. The method used was based on that of Holden and Marsden (1969).

Hydrocarbons

Concentrations of specific hydrocarbons were determined using a Finnigan 3200-6110 capillary gas chromatograph-mass spectrometer-data system combination. The procedure was similar to that described previously (Law, 1978). Total

hydrocarbon concentrations (THCs) were determined by spectrofluorimetry (UVF), using a method based on that adopted for use in the IGOSS project (IOC/WMO, 1976).

RESULTS AND DISCUSSION

1977 Survey

Samples were collected from thirteen sites from Dymchurch to Teignmouth along the south coast of England (Figure 1). All the samples were analysed for trace metals, organochlorine residues and petroleum hydrocarbons. The results are presented in Tables 1 and 2.

The organochlorine residue concentrations were uniformly low: the α and γ isomers of HCH and dieldrin were rarely present above their level of detection of 0.002 mg kg^{-1}. DDT and its metabolites DDE and DDD were present at detectable levels in all but two samples, but in all cases the concentrations were low and present in roughly equal concentrations. The PCB concentrations showed the greatest range; concentrations varying by a factor of six. The highest concentrations occurred in the samples from Southampton Water, an area receiving industrial wastes.

The striking feature of the hydrocarbon results was the large elevation of two to four ring polycyclic aromatic hydrocarbon concentrations in Southampton Water, peaking in samples from Hythe and Hamble Spit in the central part of the estuary. At Hamble Spit, for example, the total concentration of naphthalenes measured was 0.93 mg kg^{-1}, that of phenanthrenes 3.2 mg kg^{-1}, and that of the dibenzothiophenes 8.4 mg kg^{-1}. The corresponding figures at Hill Head, in the Solent, were 0.034, 0.38 and 1.5 respectively; at Plymouth they were 0.002, 0.002 and 0.004 mg kg^{-1} respectively. Two to four ring polycyclic aromatics and a wide range of alkylated derivatives, are common constituents of petroleum oils. Southampton Water is an industrialised estuary, with shipbuilding and repairing facilities, a busy harbour, and a large oil refinery any or all of which could contribute to the high concentrations found in the mussels.

The trace metal concentrations were generally low and well within the range of concentrations expected in mussel samples collected from areas free from significant anthropogenic sources of trace metals. The concentrations showed little systematic spatial variation although there was a slight indication of higher copper and zinc concentrations in the samples collected from Southampton Water.

1978 Survey

The results are presented in Tables 3, 4 and 5 and the positions of the sampling sites are shown in Figure 2. All the samples were analysed for trace metals (Hg, Cd, Pb, Zn and Cu) and the results were calculated on both a wet and dry basis. Selected samples were analysed for petroleum hydrocarbons and organochlorine pesticide (Dieldrin, α and γ HCH, DDD, DDE and DDT) and PCB residues.

The organochlorine pesticide and PCB residue concentrations were low, usually less than 0.01 mg kg^{-1} and 0.1 mg kg^{-1} respectively and often less than the detection limit of 0.002 mg kg^{-1} and 0.05 mg kg^{-1} respectively (Table 3). There was some indication of elevated organochlorine residue concentrations in the samples collected from industrial estuaries, the maximum concentrations of dieldrin (0.031 mg kg^{-1}), DDE (0.023 mg kg^{-1}), DDD (0.060 mg kg^{-1}) and PCB (0.15 mg kg^{-1}) occurring in the samples from the Mersey Estuary. No samples were taken on North Sea coasts.

The THC's of mussel samples varied from 6.3 mg kg^{-1} wet weight Ekofisk crude oil equivalents at Portmadoc, to 150 mg kg^{-1} at Whitstable in the outer Thames Estuary (Table 4). High values were also found at Blyth (130 mg kg^{-1}) and South Shields (60 mg kg^{-1}) on the northeast coast. Industrial, maritime and domestic sewage discharges into the Tyne, Tees and Thames rivers are likely to be the sources of most of this contamination. The south coast samples clearly showed signs of contamination, though at lower concentrations than those found on the east coast. No mussels from Southampton Water were analysed in 1978, and unfortunately no direct comparisons can be drawn with 1977 data, but two samples of clams (Mercenaria mercenaria) taken from that area in 1978 had THC's of 130 and 180 mg kg^{-1} wet weight Ekofisk crude oil equivalents. The six west coast samples in general showed less signs of contamination, the one exception being the sample from Fleetwood (83 mg kg^{-1}).

The trace metal concentrations (Table 5) varied quite considerably, even in mussel samples from adjacent areas, but it is possible to indicate where elevated environmental concentrations are likely to occur. The majority of these are associated with industrial estuaries where the presence of elevated environmental levels are well established. However some of the areas identified have not previously been considered as areas with a high trace metal content whereas some samples from areas expected to be polluted did not always contain elevated levels of all the trace metals examined. A summary of the areas where the mussel samples contained elevated trace metal concentrations has been compiled by comparing the average value for all data with the value for each particular site. Values exceeding the mean value are included in the following table, excepting those showing only slight elevation.

Areas of elevated trace metal concentrations - England and Wales

Northeast - Blyth to Scarborough	Hg, Cd, Pb, Zn, Cu
The Wash	Cu
Thames Estuary - west Mersea to Whitstable	Hg, Cd, Zn, Cu
Southeast - Shoreham to Poole	Hg, Cd at Poole only
Southwest - north coast Cornwall	Zn, Cu, slight elevation of Cd
Bristol Channel	Hg, Cd, Pb, Zn, Cu
North Cardigan Bay	Hg, Pb
Mersey	Hg, Cd, Pb, Zn, Cu
Liverpool Bay	slight elevation Hg, Cd, Pb, Zn, Cu
Northwest - Barrow-in-Furness to Maryport	Major elevation Cd, slight elevation Hg, Zn, Cu

The Mersey Estuary, the Tyne/Tees area, the Bristol Channel and to a lesser extent the Thames Estuary show up clearly as areas containing above average concentrations of a wide range of trace metals which are probably attributable to industrial inputs. Other areas such as Liverpool and Morecambe Bays, the northeast and southeast show elevated concentrations of a more limited number of trace metals which are also almost certainly of industrial origin. Bearing in mind the close proximity of these areas to major industrial inputs, it is interesting to note the limited area within which their effects (for some metals at least) can be detected e.g. the absence of above average levels of lead in the Thames Estuary samples. Samples from some areas such as those from the southwest of England also contained elevated concentrations of a limited number of trace metals e.g., zinc and copper. Unlike samples from industrial areas, the origin of these elevated concentrations is thought to be natural, (Webb et al., 1978) brought about by the weathering of geological strata containing relatively high concentrations of trace metals. The cause of the high concentration of copper in the mussel samples collected from the Wash is unknown, however there is some doubt about the use of mussels as indicators of copper contamination (Phillips, 1976).

COMPARISON WITH TRACE METAL CONCENTRATIONS IN SEA-WATER

The distribution of trace metal concentrations in sea water (P. G. W. Jones and C. W. Baker, - personal communication) show some agreement with the trace metal concentrations found in mussels in this study. Where areas received significant industrial inputs such as the Thames and Mersey Estuaries, Liverpool Bay and the Bristol Channel, elevated trace metal concentrations occurred in both water and mussels. However, at a number of other sites where the mussel data indicated the presence of elevated environmental levels, the trace metal concentrations in the water were relatively low, e.g., the southwest of England. It seems therefore that investigation of the trace metal concentrations in mussel tissues provides not only a more sensitive indicator of the environmental trace metal concentrations than direct analysis of the sea water but also an indication of the biological availability of the trace metals.

Although we have some information on THC's in U.K. marine waters (Law, 1979, 1980) it is difficult to make similar comparisons for hydrocarbons as insufficient samples were taken close inshore.

CONCLUSIONS

The MAFF mussel surveys established the practicability of the mussel watch concept in England and Wales and provided a snapshot of the trace contaminant concentrations in the coastal marine environment of England and Wales. Such a picture is not available from the results of the regular fish and shellfish surveys conducted by the Burnham-on-Crouch laboratory because the samples are

collected at different times of the year: the shellfish samples are limited to commercial stocks and hence the distribution is irregular, while the fish are collected on a highly selective basis and cannot represent the immediate coastal zone. There is little further to be gained from repeating such a large-scale mussel survey in the near future, but if used on a local, more intensive scale, the mussel watch technique should prove useful in identifying in greater detail sources of pollution.

The pathways followed by a contaminant once it enters the marine environment are as yet poorly understood. A clear understanding of at least the major pathways is essential for the development of a sound management policy for the use of the marine environment for the disposal of industrial and domestic wastes. An intensive survey on a local scale using either indigenous mussel populations or introduced uncontaminated caged mussels from a single stock should provide a useful tool for the identification of biologically available contaminants. Studies of this nature should be considered as a priority task in any future mussel watch type programme.

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Table 1. 1977 "Mussel Watch" programme. Trace metal and organochlorine residue concentrations (mg kg^{-1} wet weight)

Location	No Analysed	Size range (mm)	Date	Hg	Cd	Pb	Zn	Cu	∝ HCH	ϑ HCH	Dieldrin	DDE	DDD	DDT	PCB	% Lipid
Dymchurch	50	30-40	Oct	0.04	0.3	0.5	17	1.6	<0.002	<0.002	0.002	0.009	0.009	0.010	0.10	2.0
Hastings	50	40-50	Oct	0.02	0.3	0.6	16	1.2	0.005	<0.003	0.002	0.005	0.006	0.008	0.10	0.8
Bexhill	84	30-50	Oct	0.03	<0.2	0.7	19	1.8	<0.002	<0.002	<0.002	0.004	0.004	0.006	0.07	0.9
Shoreham	50	40-50	Oct	0.15	<0.2	1.0	14	1.0	<0.002	<0.002	<0.002	0.005	0.004	0.007	0.10	0.6
South Lancing	37	30-40	Oct	<0.02	<0.2	0.4	11	1.4	0.005	<0.002	0.010	0.010	0.006	0.010	0.10	1.2
Hill Head	13	50-60	Oct	<0.02	0.2	0.6	13	1.3	<0.002	<0.002	<0.002	0.002	<0.002	<0.002	0.05	0.4
Southampton Water:																
Solent Breezes	4	30-60	Oct	0.02	0.2	0.6	13	2.0	<0.005	<0.003	0.002	0.005	0.004	0.007	0.10	0.6
Hamble Spit	10	40-50	Oct	0.02	0.2	1.0	22	1.4	<0.002	<0.002	<0.002	0.004	0.002	<0.002	0.10	2.0
Netley	5	40-70	Oct	<0.02	0.3	1.4	27	1.7	<0.002	<0.002	<0.002	0.004	0.006	0.004	0.10	0.8
Cracknore Hard	37	40-65	Oct	0.02	<0.2	0.8	17	1.5	<0.002	<0.002	0.004	0.006	0.009	0.004	0.30	1.2
Hythe	5	45-60	Oct	<0.02	<0.2	0.5	20	1.9	<0.002	<0.002	<0.002	0.005	0.004	0.002	0.20	1.8
Starcross	34	40-50	Oct	<0.02	<0.2	0.7	10	1.2	<0.002	<0.002	<0.002	0.003	0.003	0.003	0.10	1.2
Teignmouth	39	40-50	Oct	0.03	<0.2	1.8	14	1.0	<0.002	<0.002	<0.002	0.003	0.003	0.003	0.10	1.8

Table 2. Hydrocarbons in *Mytilus* tissues (mg kg^{-1} wet weight)

	Plymouth	Teignmouth	Starcross	Hythe	Cracknore Hard	Hamble Spit	Hill Head	South Lancing	Shoreham	Bexhill	Hastings	Dymchurch
n-C_{11}	0.040	0.220	0.001	0.580	0.260	0.810	0.920	0.010	0.120	0.050	0.230	ND
n-C_{12}	0.190	0.420	0.010	0.590	0.340	0.620	0.760	0.090	0.160	0.110	0.310	0.210
n-C_{13}	0.004	0.012	ND	0.710	0.170	0.970	0.300	0.010	ND	ND	0.320	ND
n-C_{14}	0.002	0.030	0.003	0.400	0.250	0.650	ND	0.010	ND	0.005	0.470	0.190
n-C_{15}	ND	0.064	ND	ND	0.480	1.31	0.130	0.110	0.110	0.080	0.430	1.79
n-C_{16}	0.008	0.012	ND	ND	0.093	1.72	0.040	0.010	ND	0.020	0.290	0.460
n-C_{17}	0.004	0.045	0.200	0.022	0.088	2.18	0.080	0.030	0.160	0.040	0.290	1.01
PRISTANE	0.009	0.062	0.012	0.280	0.350	1.03	0.050	0.050	0.170	0.090	0.400	0.710
n-C_{18}	0.013	0.015	0.010	0.023	0.015	1.89	0.020	0.004	ND	ND	0.300	0.710
PHYTANE	0.002	0.082	0.030	0.250	0.380	1.62	0.090	0.060	0.160	0.110	0.480	0.200
n-C_{19}	0.002	0.032	ND	ND	0.042	1.88	0.100	0.003	ND	ND	0.060	0.170
n-C_{20}	0.001	0.034	ND	ND	0.046	1.55	ND	ND	ND	ND	0.090	0.210
n-C_{21}	0.001	0.039	ND	0.045	0.120	1.38	0.080	0.008	0.050	0.060	0.070	0.060
n-C_{22}	ND	0.031	0.012	0.089	0.200	1.18	0.060	ND	ND	ND	0.050	ND
n-C_{23}	ND	0.020	0.012	0.100	0.370	0.810	0.030	ND	0.140	ND	0.020	ND
n-C_{24}	ND	0.013	0.012	0.100	0.550	0.530	0.030	ND	ND	0.180	0.008	0.300
n-C_{25}	ND	0.007	0.024	0.084	0.810	0.260	0.020	ND	ND	ND	0.003	ND
Biphenyl	<0.001	ND	<0.001	ND	ND	0.001	0.003	0.001	ND	ND	ND	ND
Naphthalene	<0.001	0.001	ND	ND	ND	ND	0.002	0.001	0.001	0.001	0.002	0.001
methyl-naphthalene	<0.001	0.004	<0.001	ND	ND	ND	ND	0.005	ND	0.003	0.140	0.005
dimethyl-naphthalene	0.001	0.012	0.004	0.240	0.016	0.130	0.002	0.006	0.015	0.006	0.190	0.003
trimethyl-naphthalene	0.001	0.016	0.007	1.020	0.160	0.800	0.030	0.016	0.024	0.019	0.260	0.062
Phenanthrene	<0.001	0.005	0.004	ND	ND	0.11	0.008	ND	ND	0.002	ND	0.017
methyl-phenanthrene	0.001	0.014	0.008	0.530	0.200	1.52	0.120	0.014	0.023	0.001	0.056	0.015
dimethyl-phenanthrene	0.001	0.006	0.012	0.760	0.330	1.61	0.250	0.014	0.038	0.040	0.040	0.011
Dibenzothiophene	<0.001	<0.001	<0.001	0.024	0.004	0.028	0.002	0.001	0.002	ND	0.004	0.005
methyl-dibenzothiophene	0.001	0.011	0.008	0.700	0.210	1.51	0.200	0.011	ND	0.009	0.084	0.032
dimethyl-dibenzothiophene	0.002	0.030	0.025	2.16	0.840	3.96	0.690	0.034	0.090	0.090	0.140	0.080
trimethyl-dibenzothiophene	0.001	0.022	0.033	1.44	0.820	2.89	0.560	0.018	0.170	0.100	0.090	0.060
Fluoranthene	<0.001	0.003	0.003	0.033	0.054	0.032	0.014	0.028	0.061	0.038	0.008	0.003
Pyrene	<0.001	0.003	0.006	0.016	0.160	0.098	0.019	0.019	0.074	0.044	0.010	0.009
Benz(a)anthracene	ND	0.002	<0.001	0.006	0.004	0.003	<0.001	<0.001	0.004	0.002	ND	<0.001
Chrysene + Triphenylene	ND	0.007	0.001	0.031	0.012	0.022	0.001	0.001	0.008	0.003	ND	ND
2,3 Benzanthracene	ND	<0.001	<0.001	0.003	0.003	<0.001	ND	<0.001	0.001	<0.001	ND	ND
Benzo (b+k) fluoranthene	ND	0.016	<0.001	0.010	0.005	0.005	<0.001	<0.001	0.003	0.003	ND	ND
Benzo(e)pyrene	ND	0.001	<0.001	0.016	0.004	0.004	<0.001	<0.001	0.002	0.001	ND	ND
Benzo(a)pyrene	ND	0.002	<0.001	0.002	0.001	<0.001	ND	ND	<0.001	<0.001	ND	ND
Perylene	ND	0.001	<0.001	0.001	<0.001	<0.001	<0.001	ND	ND	ND	ND	ND

ND = Not detected

Table 3. England and Wales "mussel watch" programme 1978, organochlorine pesticide and PCB residue concentrations (mg kg^{-1} wet weight)

Area	No. analysed	Weight (g)	Size range (mm)	∝ HCH	ɣ HCH	Dieldrin	DDE	DDD	DDT	PCB	% Lipid
West Mersea	51	94	34-36	All concentra-		0.008	0.004	0.008	<0.002	<0.05	1.0
Burnham-on-Crouch	50	93	18-35	tions at or less		0.008	0.006	0.005	0.004	<0.05	1.0
Southend	50	111	35-50	than the limit		0.010	0.005	0.008	0.005	<0.05	1.0
Whitstable	82	128	29-47	of detection of		0.004	0.003	0.004	<0.002	<0.05	<1
Lee on Solent	52	231	47-70	0.002 mg kg^{-1}		0.003	<0.002	<0.002	<0.002	<0.05	<1
Poole	75	370	38-56	"	"	0.003	<0.002	0.004	<0.002	<0.05	<1
Whitesand	50	745	37-61	"	"	<0.002	0.013	<0.002	0.065	<0.05	1.0
St Austell	46	54	12-42	"	"	<0.002	0.004	<0.002	0.068	<0.05	1.0
Helford	50	83	10-38	"	"	0.006	<0.002	0.006	0.004	<0.05	1.0
Mousehole	50	30	5-28	"	"	<0.002	<0.002	<0.002	<0.002	<0.05	1.0
Newlyn	54	122	14-36	"	"	0.008	0.004	0.005	<0.002	<0.05	1.0
Minehead	50	38	26-39	"	"	0.008	<0.002	<0.002	<0.002	0.10	1.0
Swansea	50	63	35-52	"	"	0.004	0.006	0.005	0.005	<0.05	<1
Rhossilli (Worms Head)	50	50	34-45	"	"	<0.002	<0.002	<0.002	<0.002	<0.05	<1
R. Mersey (Princes Jetty)	72	74	24-37	"	"	0.031	0.023	0.060	<0.002	0.15	1.5
Lytham St Anne	50	370	49-72	"	"	0.016	0.011	0.030	<0.002	0.05	1.5
Fleetwood	50	150	32-65	"	"	0.012	0.006	0.006	<0.002	<0.05	1.0
Heysham	50	160	30-50	"	"	0.005	<0.002	0.006	<0.002	<0.05	1.0
Morecambe	50	118	35-50	"	"	0.010	0.004	0.012	<0.002	<0.05	1.5

Table 4. England and Wales "mussel watch" programme 1978, total hydrocarbon concentrations (mg kg^{-1} wet weight Ekofisk crude oil equivalents)

Area	No. analysed	Weight (g)	Size range (mm)	Hydrocarbons	% Total solids
Berwick on Tweed	50	322	44-65	39	16.5
Ashington Blyth	53	180	35-49	130	13.9
South Shields, Trow rocks	55	38	8-29	62	16.2
Scarborough	50	119	29-56	25	14.8
Boston	49	400	52-70	8.7	15.0
Walton on the Naze	56	357	39-56	11	21.0
West Mersea	51	94	34-46	18	18.2
Whitstable Flats	82	128	29-47	150	18.2
Hastings	54	190	43-53	60	20.7
Exe Estuary	45	313	52-68	31	18.2
Newlyn	54	122	14-36	46	17.7
Barnstaple	51	437	57-81	13	25.9
Swansea, Mumbles	50	63	35-52	26	16.7
Portmadoc	56	632	38-73	6.3	14.4
Fleetwood	50	150	32-65	83	14.3
Bowness on Solway	55	221	34-57	18	23.4

Table 5. 1978 "mussel watch" programme, trace metal concentrations (mg kg^{-1})

Location	No. analysed	Total weight (g)	Size range (mm)	Date	Hg		Cd		Pb		Zn		Cu	
					Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Berwick-on-Tweed	50	322	44-65	4.8.78	0.06	0.36	0.3	1.8	0.9	5.4	20	120	1.9	12
Holy Island	64	152	26-46	31.7.78	0.06	0.36	<0.2		0.5	3.0	14	84	1.0	6.0
Amble Harbour	56	565	36-68	9.8.78	0.05	0.23	<0.2		0.8	3.6	16	72	1.9	8.5
Ashington Blyth	53	180	35-49	31.7.78	0.09	0.64	0.7	5.0	0.9	6.4	30	220	1.5	11
South Shields	55	38	8-29	1.8.78	0.07	0.43	0.2	1.2	6.3	39	62	390	2.2	13
Hartlepool	52	170	30-46	31.7.78	0.12	0.75	0.4	2.5	0.6	3.7	40	250	1.0	6.3
Whitby	56	260	38-55	6.8.78	0.11	0.65	0.2	1.2	4.1	24	30	180	1.1	6.5
Scarborough	50	119	29-56	1.8.78	0.13	0.88	0.3	2.0	2.0	14	27	180	1.1	7.4
Boston	49	400	52-70	16.8.78	0.03	0.20	0.3	2.0	1.6	11	19	130	1.9	13
Kings Lynn	50	400	40-70	16.8.78	0.03	0.16	0.2	1.1	1.6	8.7	22	120	2.0	11
Hunstanton	50	343	45-67	21.8.78	0.04	0.18	<0.2		0.9	4.1	17	78	2.4	11
Brancaster Harbour	53	256	48-64	21.8.78	0.03	0.17	<0.2		1.1	6.3	17	100	1.1	6.4
Wells-in-Harbour	52	310	48-70	22.8.78	0.05	0.25	0.3	1.5	1.6	8	20	100	1.3	6.5
Blakeney Harbour	30	135	46-62	22.8.78	0.04	0.17	<0.2		1.0	4.3	20	87	1.7	7.4
Blythburgh	52	230	33-64	8.8.78	0.06	0.27	0.3	1.4	1.1	5.1	17	79	1.5	6.9
Walton-on-the-Naze	56	351	39-56	1.8.78	0.07	0.33	0.3	1.4	1.1	5.2	17	81	1.0	4.8
West Mersea	51	94	34-46	1.8.78	0.06	0.32	0.5	2.7	1.3	7.1	18	100	1.5	8.2
River Crouch - Burnham	50	93	18-35	2.8.78	0.30	1.6	0.5	2.7	0.7	3.8	29	160	2.0	11
Southend	50	111	35-50	15.8.78	0.07	0.39	0.7	4.0	1.5	8.5	36	200	2.5	14
Whitstable Flats	82	128	29-47	21.9.78	0.06	0.32	1.0	5.5	0.9	4.9	25	140	1.6	8.8
Deal	41	15	18-30	7.9.78	0.05	0.22	0.4	1.7	0.9	4.0	25	110	1.8	8.0
Dymchurch - St Mary's Bay	65	130	29-54	7.9.78	0.04	0.16	0.3	1.2	0.8	3.2	17	69	1.4	5.6
Hastings	54	190	43-53	7.8.78	0.05	0.24	<0.2		1.3	6.3	16	77	1.2	4.8
Eastbourne	50	185	50-58	31.8.78	0.03	0.17	0.2	1.1	0.7	4.0	14	80	1.3	7.5
Shoreham	51	149	44-54	8.8.78	0.20	1.3	0.2	1.3	1.5	9.6	15	95	1.1	7.0
Selsey	50	96	28-48	29.7.78	0.06	0.37	<0.2		1.1	6.9	10	63	1.5	9.5
Emsworth Channel	34	160	40-63	20.9.78	0.15	0.59	0.3	1.1	1.5	5.9	15	60	1.3	5.2
Hill Head - Lee-on-Solent	52	231	47-70	20.9.78	0.02	0.09	0.3	1.3	0.9	3.9	17	73	1.7	7.3
Poole	75	370	38-56	14.9.78	0.26	1.0	1.1	4.2	0.9	3.5	22	86	1.4	5.4
Exe Estuary	45	313	52-68	8.8.78	0.05	0.27	0.3	1.6	1.3	7.1	15	82	1.4	5.5
Teignmouth	50	386	56-74	5.9.78	0.04	0.16	0.5	1.9	1.8	6.9	17	66	1.7	6.6
Ermemouth - (Mothecombe)	50	99	15-40	3.8.78	0.08	0.31	0.3	1.3	1.4	6.3	22	100	1.4	6.2
Whitsand Bay - E of Rame Head,	50	745	37-61	3.8.78	0.06	0.28	0.3	1.4	3.8	18	50	240	1.0	4.7
Charlestown	46	54	12-42	4.8.78	0.04	0.21	0.2	1.0	4.7	24	53	270	1.5	7.7
Flushing	33	108	14-40	4.8.78	0.10	0.49	0.2	0.9	12	58	90	440	3.0	15
Helford Passage	50	83	10-38	4.8.78	0.05	0.20	<0.2		2.2	8.9	53	210	2.1	8.4
Mousehole	50	30	5-28	5.8.78	0.04	0.27	0.2	1.0	2.3	12	54	290	2.4	13
Newlyn	54	122	14-36	5.8.78	0.05	0.28	0.3	1.7	3.7	21	70	400	1.5	8.5
St Ives	50	111	22-40	5.8.78	0.03	0.14	0.4	1.9	1.6	7.7	57	280	1.4	6.7
Lelant - River Hayle	32	51	8-41	5.8.78	0.03	0.16	0.3	1.6	1.5	7.9	75	390	3.2	17
Newquay -	52	110	22-38	6.8.78	0.03	0.15	0.2	1.0	1.3	6.5	46	230	1.3	6.6
Camel	33	26	6-24	6.8.78	0.06	0.28	0.4	1.9	1.5	7.1	75	350	2.8	13
Bude - Widemouth Bay	50	83	17-41	7.8.78	0.05	0.29	0.3	1.7	0.6	3.5	60	350	1.1	6.4
Westward Ho	49	140	22-38	7.8.78	0.03	0.18	0.9	5.3	1.1	6.4	29	170	0.9	5.3
Barnstaple - River Taw	51	437	57-81	7.8.78	0.03	0.12	0.4	1.5	0.8	3.1	14	54	1.3	3.9
Lynmouth	52	99	34-53	8.8.78	0.11	0.62	0.9	5.1	1.4	8.0	22	130	1.1	6.3
Minehead	50	38	26-39	8.8.78	0.11	0.63	6.2	36	3.2	19	40	230	1.5	8.7
Witches Point	50	33	25-36	9.8.78	0.20	1.2	1.4	8.3	2.5	15	38	230	2.5	15
Porthcawl	50	90	45-60	29.8.78	0.13	0.87	3.0	20	3.1	21	40	270	1.4	9.5

Table 5. Continued

Location	No. analysed	Total weight (g)	Size range (mm)	Date	Hg		Cd		Pb		Zn		Cu	
					Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Aberavon	50	110	48-61	29.8.78	0.44	2.3	2.4	13	35	190	60	330	6.9	38
Oystermouth	53	112	42-60	15.8.78	0.13	0.86	4.5	30	4.1	27	47	310	1.8	12
Mumbles	50	63	35-52	15.8.78	0.16	0.96	1.6	9.6	2.6	16	40	240	1.8	11
Oxwich	50	136	48-58	27.8.78	0.08	0.32	1.2	4.8	2.0	11	23	92	1.4	5.6
Rhossili	50	50	34-45	27.8.78	0.03	0.17	0.6	3.4	0.7	4.0	20	110	1.3	7.4
Burry Inlet	50	202	50-60	30.8.78	0.03	0.13	1.0	4.4	1.1	4.8	21	93	1.8	7.9
Amroth	50	153	46-55	26.8.78	<0.02		0.3	1.2	1.1	7.2	14	56	1.7	6.8
Angle Bay	56	236	49-60	25.8.78	0.04	0.19	<0.2		1.3	6.4	30	150	1.3	6.4
Nolton Haven	50	85	36-48	25.8.78	0.02	0.09	0.2	0.9	0.6	2.8	14	66	1.2	5.7
Cardigan	50	183	48-58	25.8.78	0.02	0.09	0.2	0.9	0.9	4.2	15	71	1.6	7.5
Aberporth	55	62	37-44	26.8.78	0.03	0.17	0.3	1.7	1.5	7.6	18	100	1.4	7.9
Aberaeron	56	55	37-46	26.8.78	<0.02		0.4	2.6	0.8	5.1	12	76	1.0	6.4
Aberdovy	48	237	50-66	7.8.78	0.03	0.19	<0.2		9.3	61	16	110	0.7	4.6
Portmadog	56	652	48-73	5.8.78	0.09	0.62	0.2	1.4	2.3	16	15	100	0.7	4.9
Tal-y-Foel	56	341	52-67	13.9.78	0.10	0.42	0.5	2.1	1.8	7.6	22	93	1.9	8.1
Bangor	69	389	56-71	15.9.78	0.12	0.61	0.7	3.5	2.5	13	23	120	1.6	8.2
Conwy	50	448	55-77	12.9.78	0.06	0.27	0.4	1.8	1.2	5.3	17	75	1.7	7.5
Liverpool	72	74	24-37	22.8.78	0.12	0.87	0.5	3.6	4.3	31	62	450	2.2	16
Lytham St Annes	50	370	49-72	23.8.78	0.04	0.19	<0.2		1.7	8.0	36	170	2.3	11
Blackpool	70	422	43-66	22.8.78	0.05	0.22	<0.2		1.6	7.1	29	130	1.9	8.5
Fleetwood	50	150	32-65	15.8.78	0.07	0.49	0.3	2.1	2.0	14	27	190	1.5	10
Heysham	50	160	30-50	15.8.78	0.07	0.47	0.4	2.7	1.6	11	28	190	1.8	12
Morecambe	50	118	35-50	15.8.78	0.06	0.34	0.3	1.7	1.9	11	25	140	1.8	10
Barrow in Furness	49	172	48-60	7.8.78	0.10	0.51	0.6	3.1	2.6	13	25	130	1.1	5.7
Ravenglass	50	170	35-50	14.8.78	0.06	0.42	0.5	3.5	1.0	6.9	24	170	1.4	9.7
Whitehaven	54	140	30-50	14.8.78	0.05	0.38	2.0	15	2.0	15	20	150	1.5	12
Maryport	48	104	24-55	14.8.78	0.06	0.42	0.6	4.2	1.5	11	17	120	1.0	7.1
Silloth -	50	89	30-47	15.8.78	0.04	0.17	0.5	2.2	1.2	5.3	15	66	1.7	7.5
Bowness	55	221	34-57	15.8.78	0.03	0.13	0.3	1.3	1.0	4.3	13	55	1.8	7.7

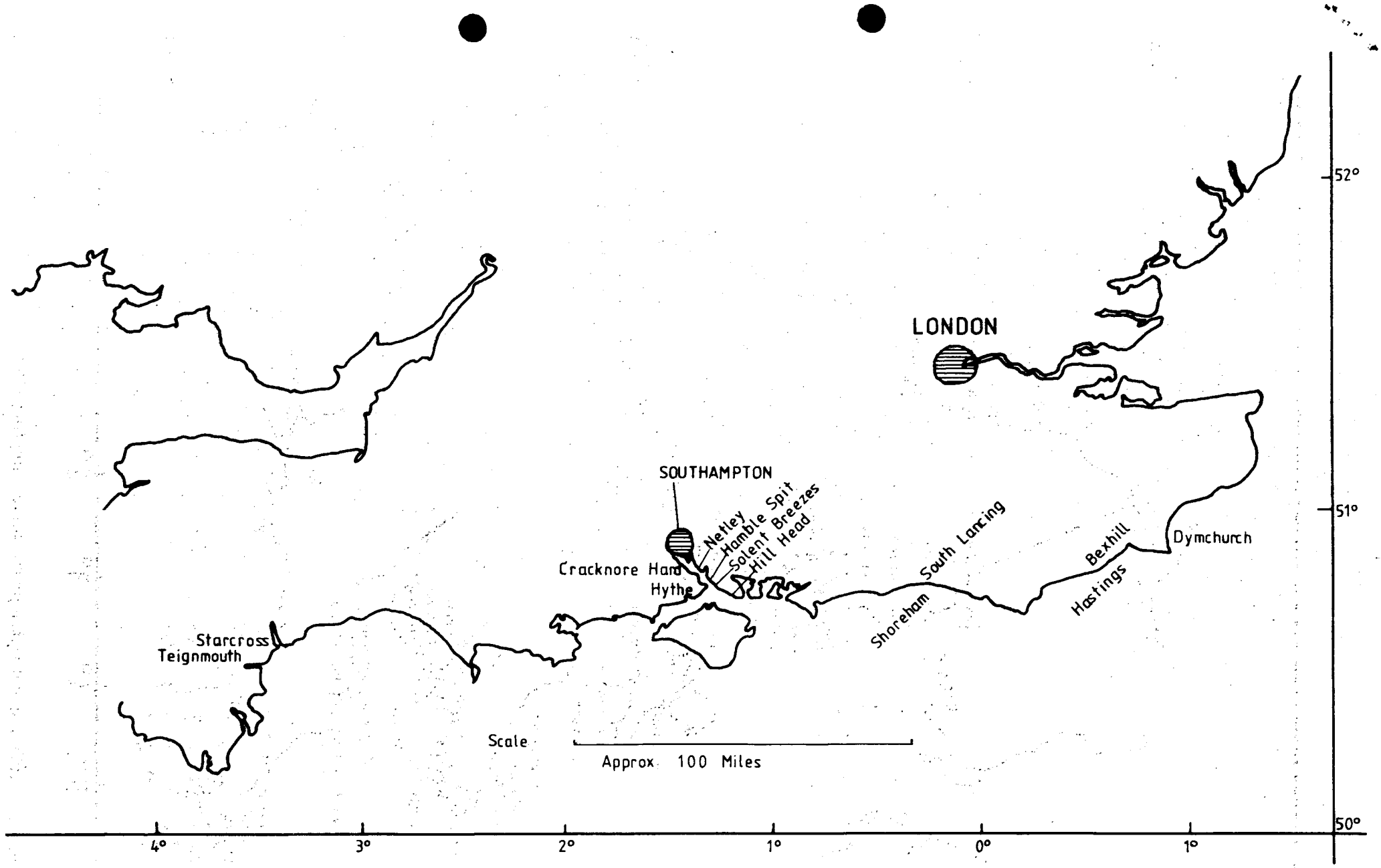

Figure 1 1977 mussel watch programme sampling sites.

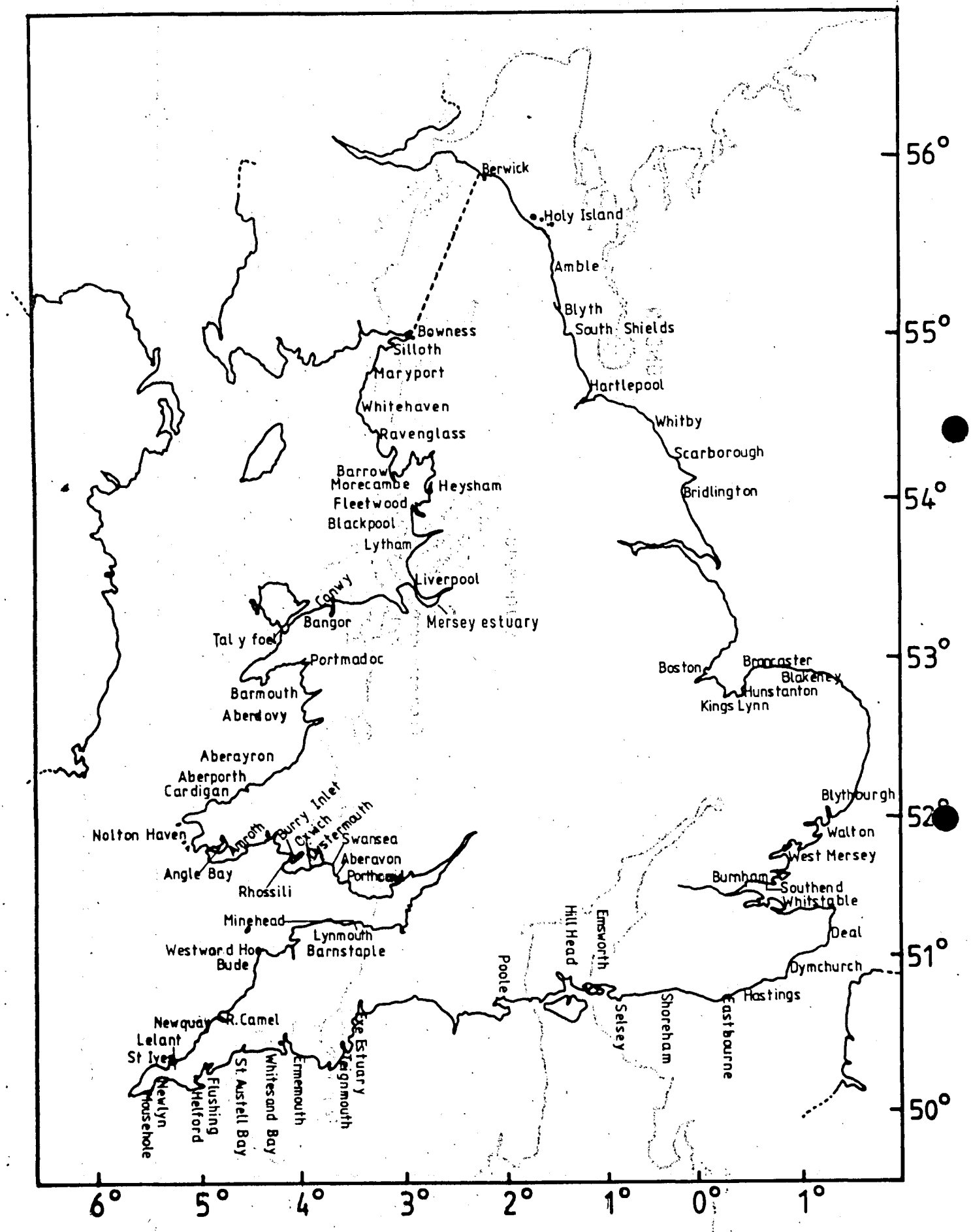

Figure 2 1978 mussel watch programme sampling sites.