Northern Ireland

Regional Report of the National Monitoring Programme

Marine Pollution Monitoring Management Group

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Northern Ireland

Regional Report of the National Monitoring Programme

Marine Pollution Monitoring Management Group

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Contents

1 Introduction

The Marine Pollution Monitoring Management Group (MPMMG) has representation from all Government organisations with statutory marine environmental protection monitoring obligations. The Group is chaired by a representative from the Ministry of Agriculture, Fisheries and Food.

In 1987/88 the MPMMG reviewed the monitoring carried out in UK estuaries and coastal waters (DOE, 1991a) and concluded that there would be considerable merit in the regular sampling of a network of coastal monitoring stations. It was agreed that these should include both nearshore stations which may be significantly contaminated and offshore stations thought to be free from anthropogenic inputs. It was envisaged that the uncontaminated sites would serve as a reference and would also provide information on the extent of natural variability in the marine environment.

In its formal response to the MPMMG review (DOE, 1991b), the Government accepted the need for a core programme of marine monitoring to national standards for all UK waters. As a consequence a network of 87 coastal monitoring stations in estuarine, intermediate and offshore locations around the UK was established. The competent monitoring authorities for the Programme are listed in Appendix I including details of reorganisation of authorities due to Government reform initiatives. Station locations and competent monitoring authorities for all stations are detailed in the UK National Monitoring Plan (HMIP, 1994), referred to as “the Plan” throughout the remainder of this document. Station locations are also shown in Figure 1.1.

The objectives of the National Monitoring Programme (NMP) are:

A. To establish as precisely as practicable, the spatial distribution of contaminants in different areas of the UK waters and to define their current biological status thus identifying any areas of specific concern e.g. areas where the concentrations of one or more contaminants might affect biological processes or render fish and shellfish unfit for human consumption.

B. To detect with appropriate accuracy trends in both contaminant concentrations and biological well-being in those areas identified as being of concern.

C. To measure long-term natural trends in physical, biological and chemical parameters at selected areas.

In achieving these objectives, it was necessary to establish a central computerised database for contaminants in all media and for biological effects in the UK marine environment. This was established in 1996 by the Environment Agency and is funded by the Department of the Environment, Transport and the Regions (DETR).

In addition to the UK NMP Report on the Spatial Survey 1993-95, MPMMG decided that regional reports for Northern Ireland, Scotland and England and Wales would be prepared. This report fulfills that obligation covering the Northern Ireland Spatial Survey. The Northern Ireland station locations are shown in Figure 1.2 and accurate site locations are given in Appendix II. The Northern Ireland ‘Estuarine Stations’ cover a limited salinity gradient since Belfast Lough is a marine embayment rather than a true estuary. Only very slight salinity differences (2-3ppt) are observed within the main body of the Lough. However, the three stations sampled lie on a known nutrient gradient. Whilst it has some estuarine characteristics and receives anthropogenic inputs, the freshwater input to Belfast Lough is relatively small. Belfast Lough was selected for the NMP because it was most likely to show elevated levels of contaminants since Belfast is the most densely industrialised part of Northern Ireland.

The station at the mouth of Belfast Lough (IS1) is an Intermediate site and the remaining three stations are Offshore sites.

FIGURE 1.1. Location of UK National Monitoring Programme Stations

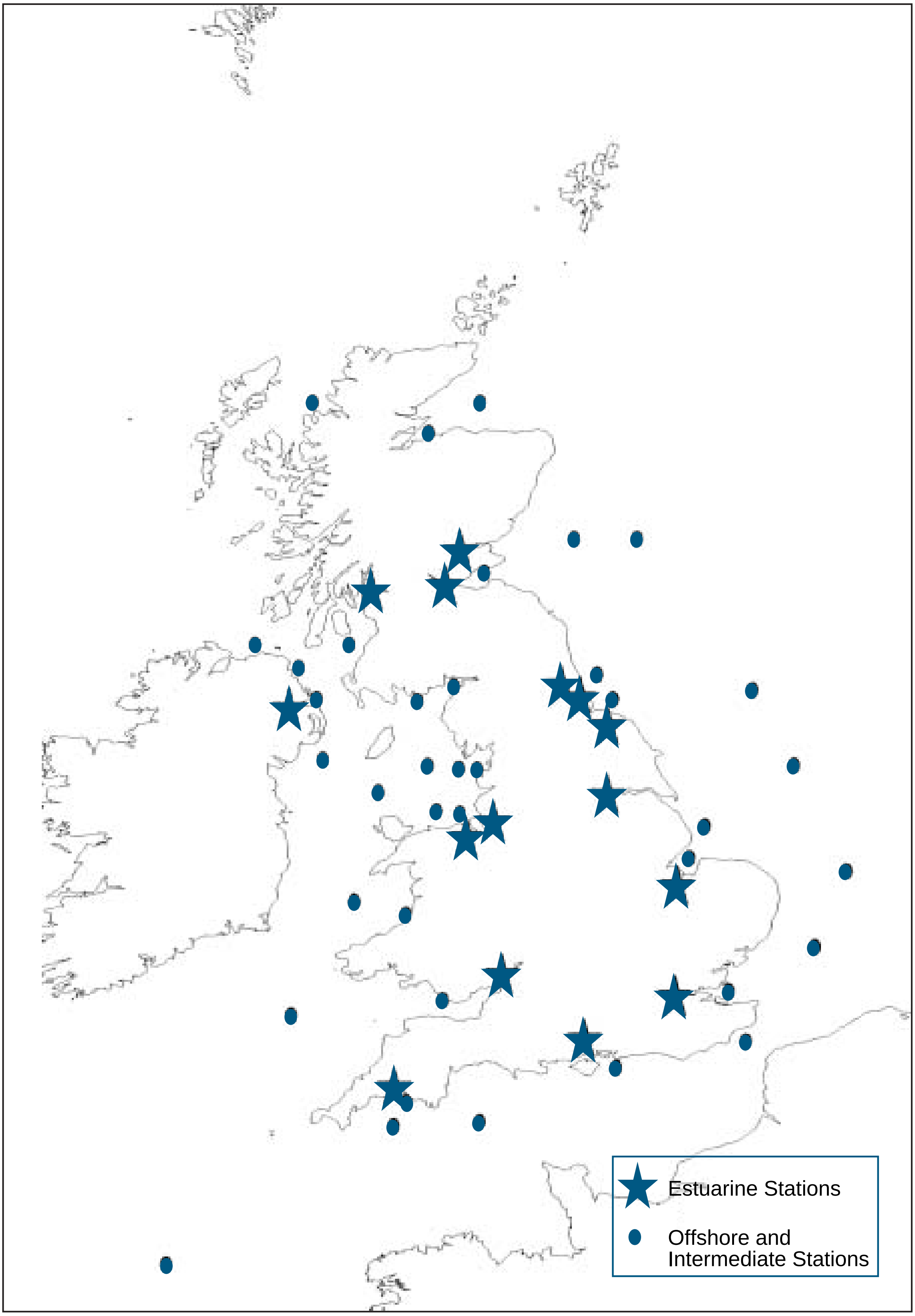
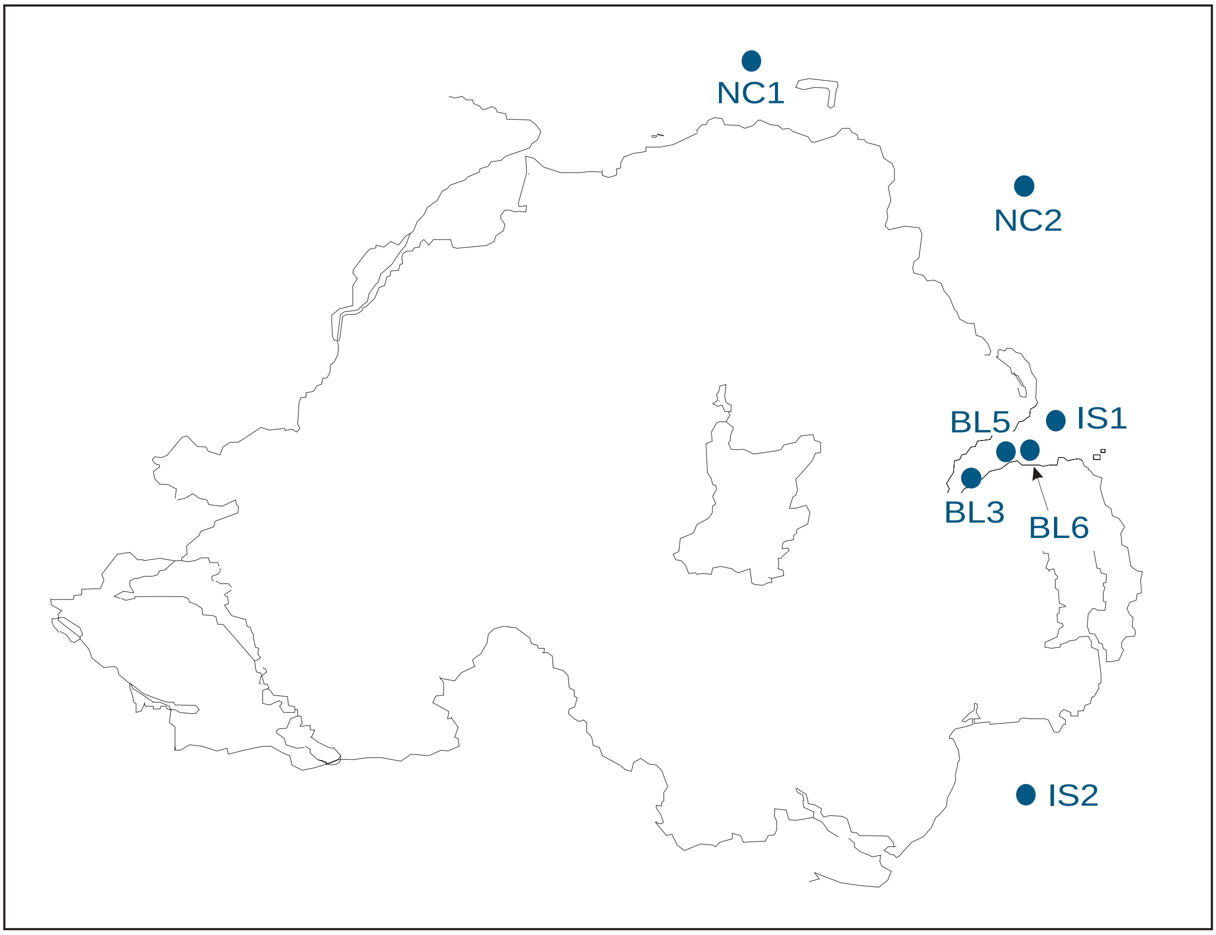


FIGURE 1.2. Locations of Northern Ireland NMP Stations.



2 Methods

The National Monitoring Programme was initiated by a spatial survey which was conducted from 1993 to 1995. In Northern Ireland the first NMP samples were taken in March/April 1993. The objectives of the spatial survey were:

A. To permit statistical comparison of the concentration of contaminants between sites (spatial distribution) and highlight areas with high concentrations of contaminants that are of concern and merit further study on a temporal basis (trends observed against time).

B. To estimate the inherent variability in the recorded data in those areas where concentrations of contaminants cause concern, arising from the natural variability of the determinands and from methods used for sampling and analysis.

C. To compare biological effects between the areas in the UK.

2.1. Sample Plan

In meeting the first objective, the determinands were measured in a variety of media including water, total surficial sediment, shellfish, fish liver and fish muscle. These are detailed in Table 1 from the Plan (HMIP, 1994). Different media were examined to reflect the way contaminants such as metals and organic compounds behave in the environment. The metals and organic compounds listed in Table 1 are all conservative contaminants; that is, they do not degrade over a short time scale and may therefore be considered as permanent additions to the marine environment.

2.1.1. Seawater Analysis

The determinands were analysed in filtered or unfiltered seawater as appropriate. The measurement of parameters in seawater provides a 'snap-shot' of environmental quality which will be dependant on tidal movements, rate of supply, rate of removal and other variables. To develop a true picture of environmental quality, a number of samples may have to be collected over a period of time. Many of the Environmental Quality Standards detailed in EC Directives are for seawater samples.

2.1.2. Sediment Analysis

Estuaries act as a sedimentation zone between freshwater and saline conditions. As particulate matter carried by rivers encounters saline conditions it undergoes a change in surface charge. Particles flocculate and are deposited out of the water column and into the sediments. It is for this reason that estuarine sediments act as sinks for conservative contaminants and generally this is more marked in heavily industrialised estuaries. Sediments were examined at all NMP sites. The preferred methodology for metals was a total digest of the samples which enable normalisation to aluminium or another surrogate for the mineral background. This method involves the sample being totally dissolved in hydrofluoric acid and *aqua regia*. This was a useful approach when trying to compare metal contents from samples of differing geochemical composition as was the case in the NMP spatial survey. Organic contaminants were extracted by solvents and analysed by gas chromatography.

2.1.3. Biota Analysis

Marine organisms vary widely in their ability to regulate their metal content. Metals and organic compounds which cannot be excreted remain in the body and are therefore accumulated. This is known as bioaccumulation. When this effect is seen through trophic levels it is known as biomagnification. An animal ingesting another organism with a body load of a particular contaminant may be unable to excrete the contaminant and will therefore increase its own body load. It was considered essential that the National Monitoring Programme should examine contaminants in a variety of media to meet its objectives.

TABLE 1 – National Monitoring Plan (after HMIP, 1994)

Analytical Requirements

DETERMINAND		Code	MATRIX & UNITS					
		Code	**UW**	**FW**	**SS**	**SF**	**FM**	**FL**
Metals								
Al	(Aluminium)	AL	-	-	mg/kg	-	-	-
Hg	(Mercury)	HG	-	ng/l	µg/kg	mg/kg	mg/kg	-
Cd	(Cadmium)	CD	-	ng/l	µg/kg	mg/kg	-	mg/kg
Cu	(Copper)	CU	-	µg/l	mg/kg	-	-	-
Pb	(Lead)	PB	-	µg/l	mg/kg	mg/kg	-	mg/kg
Ni	(Nickel)	NI	-	µg/l	mg/kg	-	-	-
Zn	(Zinc)	ZN	-	µg/l	mg/kg	mg/kg	-	-
As	(Arsenic)	AS	-	-	mg/kg	-	mg/kg	-
Cr	(Chromium)	CR	-	µg/l	mg/kg	-	-	-
TBT	(Tributyl tin)	TBTIN	ng/l	-	µg/kg	mg/kg	-	-
[in conjunction with Dogwhelk survey - See paragraph 8]								
Organic Compounds								
PCB	(Polychlorinated biphenyls) *[congeners: 28,52, 101, 105, 118, 128, 138, 153, 156, 170, 180][1]*	CB28, CB52, etc	-	-	µg/kg	µg/kg	-	µg/kg
a-HCH	(Alpha-hexachlorocyclohexane)	HCHA	ng/l	-	-	µg/kg	-	-
ß-HCH	(Beta-hexachlorocyclohexane) *[estuarine sites only]*	HCHB	ng/l	-	-	-	-	-
γ-HCH	(Gamma-hexachlorocyclohexane: Lindane)	HCHG	ng/l	-	-	µg/kg	-	-
Dieldrin	*[Unfiltered Water: estuarine sites only]*	DIELD	ng/l	-	µg/kg	µg/kg	-	µg/kg
Aldrin	*[estuarine sites only]*	ALD	ng/l	-	µg/kg	µg/kg	-	µg/kg
Endrin	*[estuarine sites only]*	END	ng/l	-	µg/kg	µg/kg	-	µg/kg
Isodrin	*[estuarine sites only]*	ISOD	ng/l	-	-	-	-	-
HCB	(Hexachlorobenzene)	HCB	ng/l	-	µg/kg	µg/kg	-	-
PCP	(Pentachlorophenol)	PCP	ng/l	-	-	µg/kg	-	-
DDT	(Dichlorodiphenyltrichloroethane) *[pp TDE, pp DDE, ppDDT]*	TDEPP, DDEPP, DDTPP	-	-	µg/kg	µg/kg	-	µg/kg
	op DDT *[estuarine sites only]*	DDTOP	ng/l					
HCBD	(Hexachlorobutadiene) *[estuarine sites only]*	HCBD	ng/l	-	-	µg/kg	-	-
[Priority Hazardous Substances to be analysed on Unfiltered Water samples at estuarine sites only - [See Table 1a]			µg/l	-	-	-	-	-
PAH's	(Polycyclic aromatic hydrocarbons) *[See Table 1b]* *[Part of Special Survey of Additional Determinands]*		-	-	µg/kg	µg/kg	µg/kg	-
Nutrients etc								
NH_4 - N	(Ammonium)	AMON	-	mg/l*	-	-	-	-
NO_3 - N	(Nitrate)	NTRA	-	mg/l*	-	-	-	-
NO_2 - N	(Nitrite)	NTRI	-	mg/l*	-	-	-	-
PO_4 - P	(Orthophosphate)	PHOS	-	mg/l*	-	-	-	-
SiO_4 - Si	(Silicate)	SLCA	-	mg/l*	-	-	-	-
Dissolved Oxygen		DOXY	mg/l†	-	-	-	-	-
Suspended solids		SUSP	mg/l	-	-	-	-	-
Chlorophyll-a		CPHL	µg/l	-	-	-	-	-
Physical Measurements								
Secchi depth or other appropriate measurement		SECCI	m	-	-	-	-	-
Salinity			‰	-	-	-	-	-
Temperature		TEMP	ºC	-	-	-	-	-
Oyster Embryo Bioassay								
Percent net response[2]		PNR	%	-	%	-	-	-

1. Also Congeners 77, 126 and 169 if possible.
2. $PNR = \frac{\%\ test\ abnormality - \%\ control\ abnormality}{100 - \%\ control} \times 100$

Alternative units: Chemical measurements can alternatively be given as required by ICES, ie as g/l (* = moles/l: † = l/l) or g/g in scientific notation expressed in the form: .xxxxxExxx. (See Appendix 3, p16).

Code: ICES Parameter/Contaminant Code, to be used as determined identifier when recording data.
UW: Unfiltered water
FW: Filtered water - pore size 0.45 microns
SS: Total Surficial Sediment - Total analysis of <2mm fraction of sediment; dry weight
SF: Shellfish - wet weight (plus % solid and % lipid)
FM: Fish Muscle - wet weight (plus % solid and % lipid)
FL: Fish Liver - wet weight (plus % solid and % lipid).

TABLE 1A - National Monitoring Plan (after HMIP, 1994)

Determinand Codes for Priority Hazardous Substances* to be analysed on Unfiltered Water samples.	
Carbon Tetrachloride	CCL4
Chloroform	CHCL3
Trifluralin	TRF
Endosulfan	ENDOS
Simazine	SIMZ
Atrazine	ATRZ
Azinphos - Ethyl	AZE
Azinphos - Methyl	AZM
Dichlorvos	DCV
Fenitrothion	FENT
Fenthion	FEN
Malathion	MAL
Parathion	PAR
Parathion - Methyl	PARM
Trichloroethylene	TRCE
Tetrachloroethylene	TECE
Trichorobenzene	TRCB
1,2 Dichloroethane	DCE
Trichloroethane	TCE

These determinands should normally be measured at estuarine sites only. However, if they are detected in unacceptable concentrations in an estuary, they should also be measured at the appropriate intermediate and offshore sites.

* Annex 1A to the Ministerial Declaration, Third Conference on the Protection of the North Sea.

TABLE 1B - National Monitoring Plan (after HMIP, 1994)

Determinand Codes for PAH's			
Category A		Category B	
Naphthalene	NAP	C1 napthalenes	NAPC1
Phenanthrene	PA	C2 napthalenes	NAPC2
Anthracene	ANT`	C1 phenanthrenes	PAC1
Fluoranthene	FLU	C2 phenanthrenes	PAC2
Pyrene	PYR	Dibenzothiophene	DBT
Benz[a]anthracene	BAA	C1 dibenzothiophenes	DBTC1
Chrysene/Triphenylene	CHRTR	C2 dibenzothiophenes	DBTC2
Benzo[a]pyrene	BAP		
Benzo[e]pyrene	BEP		
Perylene	PER		
Benzo[ghi]perylene	BGHIP		
Indeno[1,2,3-cd]pyrene	ICDP		

Category A provides a basic list which covers inputs from combustion sources, and, in the absence of oil-derived PAH, can be determined using HPLC techniques. The addition of determinands from Category B will allow PAH from both oil and combustion sources to be detected and the relative importance of these sources to be estimated, but would require the use of GC/MS to provide sufficient resolution.

PAHs should be determined in sediments at all sites, in shellfish at estuarine stations and in fish muscle at intermediate and offshore stations, as AQC methods become available. Units µg/kg.

2.1.4. Shellfish

The target species for the bioaccumulation studies were the common mussel, *Mytilus edulis* (L.) or the horse mussel, *Modiolus modiolus* (L.). These are sedentary organisms which filter seawater with their gills to collect particles of food. Since these organisms are immobile in their adult state, they act as good indicators of the surrounding water quality. Because they accumulate body burdens of contaminants they are a more reliable indicator than measurements of water quality alone.

The value of these organisms has long been recognised through the Global Mussel Watch which was first put forward by Goldberg (1975). Smaller regional programmes were already progressing in a number of areas, e.g. Topping (1973). Mussels and oysters have been used world-wide to monitor chemical contamination and there have been more than 400 papers published dealing specifically with the species *M. edulis* (Cantillo, 1991). This allows comparison of inter-regional variations in body burdens of metals. However, such comparisons need to be treated with caution as mussel body burdens will reflect different geochemical background levels as well as anthropogenic inputs.

In Northern Ireland, monitoring of trace contaminants in mussels began in the mid-1970s. Early results from Strangford Lough and Lough Foyle were reported by Parker (DANI, internal report to the Fisheries Commodity Research Committee) who concluded there was no evidence that trace metals in mussels from these areas had reached concentrations which were harmful to human health.

Other studies during this period were conducted in Belfast Lough (Manga, 1980) and Carlingford Lough (Manga and Hughes, 1981). These studies demonstrated the existence of a gradient of concentrations of zinc (Zn), lead (Pb), cadmium (Cd) and mercury (Hg) decreasing in a seaward direction with the highest concentrations occurring in inner Belfast Lough.

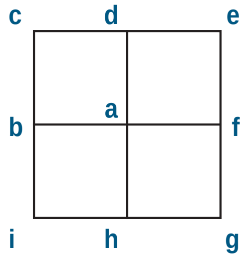
Leading on from the early studies, the first comprehensive surveys, temporal and spatial, of trace contaminants in mussels were undertaken by DANI during 1980 and 1981 (Gault, Tolland and Parker, 1983) with the intention of establishing a baseline from which routine monitoring could be established.

2.1.5. Fish

The target fish species in the National Monitoring Programme were the dab, *Limanda limanda* (L.) or the flounder, *Platichthys flesus* (L.). In contrast to the shellfish species, the fish species are mobile throughout their life. Throughout the larval stages, dab and flounder are part of the zooplankton feeding on smaller members of the zooplankton. As adults, dab and flounder are demersal species staying on the sea bed and feeding mainly on benthic organisms. These species were selected as they are believed to be widely available around the UK coast. They have also been selected as target species for other monitoring programmes such as the North Sea Quality Status Report.

2.2. Sample Design

The second objective of the Spatial Survey was to assess variability whether from natural sources or sampling techniques. This was achieved by sampling design. To obtain a meaningful spatial distribution of contaminant concentrations, the samples taken must be truly representative of the locality. This requires replicate sampling within a representative field as opposed to replicate point sampling. For this reason sediment sampling for the spatial survey was conducted on a nine point grid wherever possible in the format shown below:



The size of this grid was varied according to the station type. All Northern Ireland grids were 500 metres square. Estuarine sites were to lie on a salinity gradient where practicable and should represent the salinity regimes 0-10, 10-20 and 20-30 parts per thousand at high water. As noted earlier, Belfast Lough does not have a typical estuarine regime. This sampling design enabled an assessment of sampling and natural variability.

The Northern Ireland Offshore stations were sampled on a 500 metre, nine point grid for sediments with the exception of NC2 which was sampled on the minimum five point grid due to operational difficulties. Station NC2 has been relocated since the 1993 sampling round as detailed in Appendix II because of the unsuitability of the seabed substrate for remote sampling.

In 1993 the Northern Ireland water samples were collected at the four corners of the grid to provide four replicates. Single samples have been collected since 1994.

2.3. Biological Effects

The third of the objectives of the Spatial Survey was to compare biological effects across the UK. An essential part of the programme was to attempt to measure biological effects and if possible, to relate these effects to contaminant concentrations. A number of biological effects methods were used as appropriate:

- benthic macrofaunal monitoring
- oyster embryo bioassay
- fish disease studies
- dogwhelk imposex bioassay and
- the mixed function oxidase test (EROD).

2.3.1. Benthic Macrofauna

Benthic macrofauna are the animals living within the soft sediments. Since most benthic organisms are effectively sessile (remain in the same locality), they act as integrators of the effects of environmental stresses whether the stresses are natural, like salinity changes, or due to pollutants. Benthic organisms ultimately rely on the overlying water column for food and oxygen and are therefore useful indicators of the overlying water quality. Benthic communities have long been studied as a measure of environmental quality (Holme and McIntyre, 1971).

2.3.2. Oyster Embryo

The oyster embryo bioassay is another recognised indicator of environmental quality. Young oysters undergo intense cellular activity during the early stages of development. They develop from the 16-32 cell stage to the protective ‘D’ shaped shell whereupon the paired hinged shells are visible. The presence of contaminants in the surrounding environment adversely effects the normal development to the characteristic ‘D’ shape. The bioassay method involves exposing a number of embryos to a test solution and comparing them to a clean water control sample. This provides an estimate of overall water quality.

2.3.3. Fish Disease Studies

All of the competent monitoring authorities involved with the National Monitoring Programme have monitoring programmes to examine fish populations. These may be for environmental protection or fisheries purposes. Incidental surveys of the extent of fish diseases such as lesions, ulcers, lymphocystis and papillomas are made where appropriate as part of these surveys. These have been reported as part of the NMP.

2.3.4. Dogwhelk Imposex Studies

Imposex is an abnormality in gastropod molluscs in which male sexual characteristics are imposed on the genital systems of females. The female develops a penis and a *vas deferens* which may block the genital opening so that egg capsules cannot be laid. Since dogwhelks do not have a planktonic larval stage, affected populations gradually decline and may become eliminated. The imposex condition has been conclusively linked with the presence of organotins in the environment (Gibbs *et al.,* 1987). These were widely used as the active ingredient in antifouling paints which are used to discourage the settlement of marine organisms on marine structures and boats. Organotins are also extremely toxic to planktonic organisms and therefore to the larval stages of many molluscs.

Measurement of the degree of the imposex phenomenon in a dogwhelk population is probably the best documented form of biological effects monitoring. The technique is cheaper and more sensitive than measuring the associated chemical determinands and as such, was selected for biological effect monitoring for the National Monitoring Programme.

2.3.5. The Mixed Function Oxidase Test (EROD)

EROD or Ethoxyresorufin-O-deethylase activity is a measure of biochemical activity which may be determined in fish liver. It provides an early warning mechanism for the presence of contaminants such as polycyclic aromatic hydrocarbons (PAHs), the planar polychlorinated biphenyls (PCBs), the dibenzo-p-furans and the dioxins. These compounds are hydrophobic and tend to become associated with fine sediments. It is for this reason that benthic flatfish experience higher exposure rates.

3 Quality Control

Two Analytical Quality Control (AQC) schemes were established to run in parallel with the NMP. These were the National Marine Analytical Quality Control Scheme (NMAQC) for chemistry and the National Marine Biological Analytical Quality Control Scheme (NMBAQC) for benthic analysis. The purpose of these schemes is to ensure that all data used in the NMP are of an agreed quality standard. Participation in the AQC Schemes is a prerequisite to submitting NMP data. The two quality control schemes underpin the NMP field programme.

Both schemes involve the regular circulation of standard samples for proficiency testing of all participating laboratories. The co-ordinating committees of the two schemes also organise workshops for training in unfamiliar techniques or species identification. Links have been established with other International Quality Control programmes such as the Quality Assurance of Information for Marine Environmental Monitoring in Europe (QUASIMEME) to ensure minimum duplication between schemes.

3.1. Chemical Data

The participating laboratories in Northern Ireland are DANI Agricultural and Environmental Science Division (water, nutrients), DANI Food Science Division (biota, water and sediments) and the Department of Economic Development laboratory, Industrial Research and Technology Unit, IRTU (water and sediments). Chemical data from all laboratories have been assessed for all the determinands in the AQC scheme (Balls, 1996), and the assessment criteria presented in this document have been agreed. This assessment has been used to qualify all material included in the Northern Ireland Regional Report.

3.1.1. Seawater Analysis

Few problems have been experienced in sea/estuarine water analyses except for chromium and mercury determinations. The NMAQC scheme conducted special exercises to test the performance in the analysis of these determinands. The determination of chromium was highlighted as an area where improvement is required. All the Northern Ireland samples were analysed by a laboratory which had complied with the assessment criteria.

3.1.2. Sediment Analysis

All sediments analysed during the spatial survey were completed by one laboratory which satisfied the criteria for all determinands except for dieldrin, aldrin, isodrin and op-DDT. op-DDT is a minor component of total DDT compounds and isodrin was not a mandatory determinand.

3.1.3. Biota Analysis

All biota analyses were completed by one laboratory. For organics, the assessment criteria were satisfied for all but the following determinands; HCBD, op-DDT, PCBs 28, 31 and 52. As with the sediments, none of these is a critical determinand.

For the metals analysis, the assessment criteria were met for lead, cadmium and mercury but not for zinc and arsenic. Less than half the laboratories which participated met the criteria for arsenic which perhaps points to the need for a workshop in this area. Many of the problems associated with this group were related to the low detection limits required by the NMP.

3.2. Biological Data

The two laboratories participating in the NMBAQC scheme in Northern Ireland are IRTU and DANI Agricultural and Environmental Science Division. Both have been full participants of the scheme since it was established in 1993.

Assessing the performance of individual laboratories proved particularly difficult when all were provided with the same samples, since expertise tends to be closely linked with the types of samples that are routinely monitored. These observations led the NMBAQC committee to assess laboratory performance by the ‘own sample’ exercise where each laboratory was asked to analyse a benthic grab sample from a specific NMP station in its own area. The sorted and analysed sample was then returned to the co-ordinating laboratory for the National Committee which reanalysed the sample to assess the performance of each laboratory.

4 Benthos

Benthic sampling was conducted during March and April of 1993. All stations were sampled using a 0.1m^2 stainless steel Day Grab. Nine samples from each station were collected using the 500m 9 point grid with the exception of NC2 where five samples were collected. All samples were sieved through 1.0mm sieves, fixed in 8% seawater buffered formaldehyde solution and then preserved in 70% Industrial Methylated Spirit. All samples were subsequently sorted and identified by laboratories participating in the National Marine Biology Analytical Quality Control Scheme. Taxa were identified to species level where possible. The seven Northern Ireland stations yielded 300 taxa, and a total of 33991 individuals were counted. The full species list is presented in Appendix III and is in taxonomic order according to Howson *et al.,* (1981).

Biomass was determined for each sample using the wet-weight blotted technique (Rees *et al.,* 1990). Taxa for each station were bulked to give biomass per replicate rather than biomass per individual.

4.1. Number of Individuals

A plot of mean abundances at each station (Figure 4.1) shows that the greatest numbers of individuals occured at the stations within Belfast Lough.

BL5 was the richest station with a mean number of 2468 individuals per 0.1m^2. The dominant species present was the small ubiquitous bivalve *Mysella bidentata* (Montagu, 1803) with an average abundance of 451 per 0.1m^2. A total of 9 species accounted for 50% of the abundance. The most impoverished station was IS2 with a mean number of 16 individuals per 0.1m^2. Station BL3 is dominated by oligochaetes, namely *Tubificoides benedeii* (Udekem, 1855). IS2 supports an important commercial Dublin Bay Prawn *Nephrops norvegicus* (L.) fishery despite the low diversity (Hensley, 1996). In contrast to the soft muds of IS2 and Belfast Lough, the substrate at NC1 consists of coarse mobile sands and the dominant taxa are the small bivalve species typical of this habitat.

4.2. Number of Species

A plot of the mean number of taxa or species present at each station is similar to Figure 4.1. BL5 has a mean number of 76 different species while IS2 is represented by six species and NC1 by seven species. The sorting and identification of the samples from Belfast Lough was particularly labour intensive. The Belfast Lough fauna tend to be small in comparison with the Intermediate and Offshore stations; for example, the vast majority of the Nephtyd species are less than 10mm long making identification difficult. The Polychaete fauna are small but fully mature compared with the larger individuals found at North Sea sites. The reasons for this observation are unclear but may reflect an adaptive change to a stressed environment and merit further monitoring. This premise is reinforced by examination of the biomass plot (see Figure 4.3).

4.3. Biomass

Despite the fact that the Offshore and Intermediate stations have very few individuals, it is evident that IS2 and NC2 have biomass values comparable to the Belfast Lough stations which have far more individuals (Figure 4.3). This is mainly due to the presence of large individual echinoids (sea urchins and heart urchins). The values range from 0.33 g/0.1m^2 (IS1) to 21.8 g/0.1m^2 (BL5). The size of the standard error shows how biomass is a crude variable index which should be treated with caution.

4.4. Univariate Analysis

A full range of additional indices were calculated for each station and are presented in Figure 4.4.

FIGURE 4.1. Total Number of Individuals displaying Mean with Standard Error Bars.

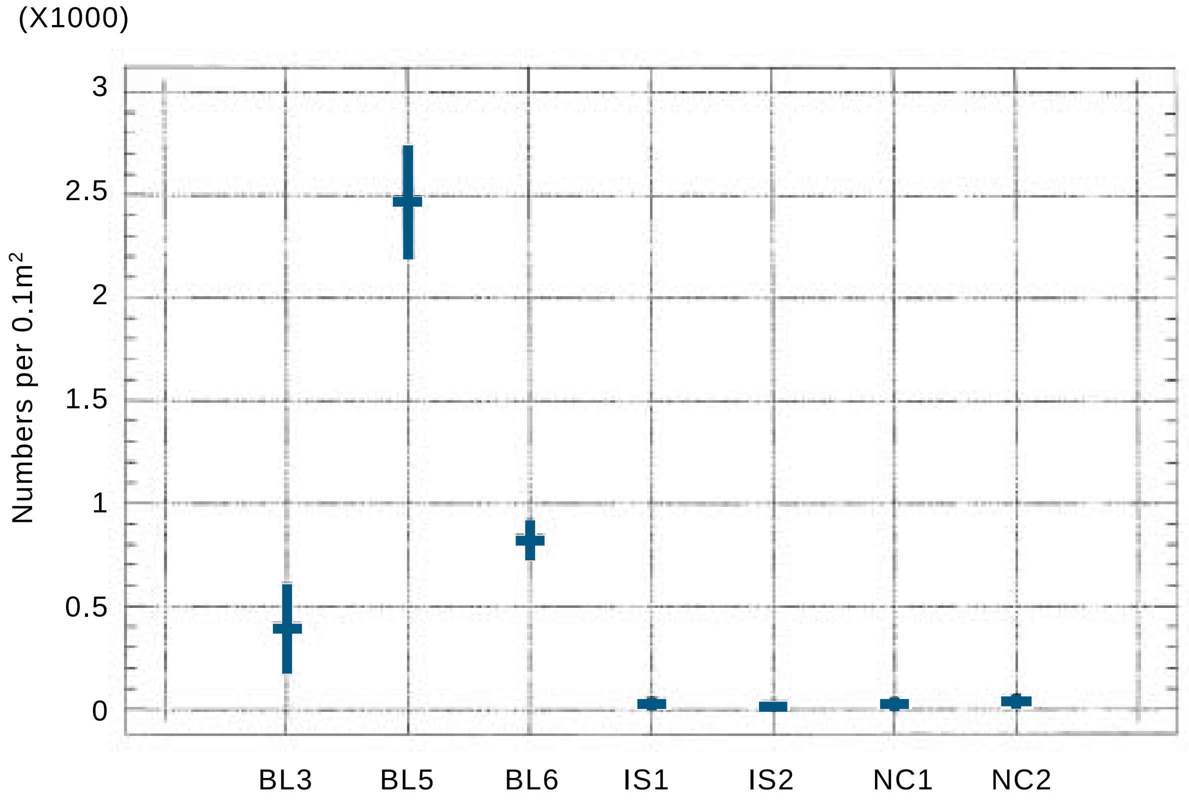


FIGURE 4.2. Total Number of Species (Taxonomic Units) displaying Mean with Standard Error Bars.

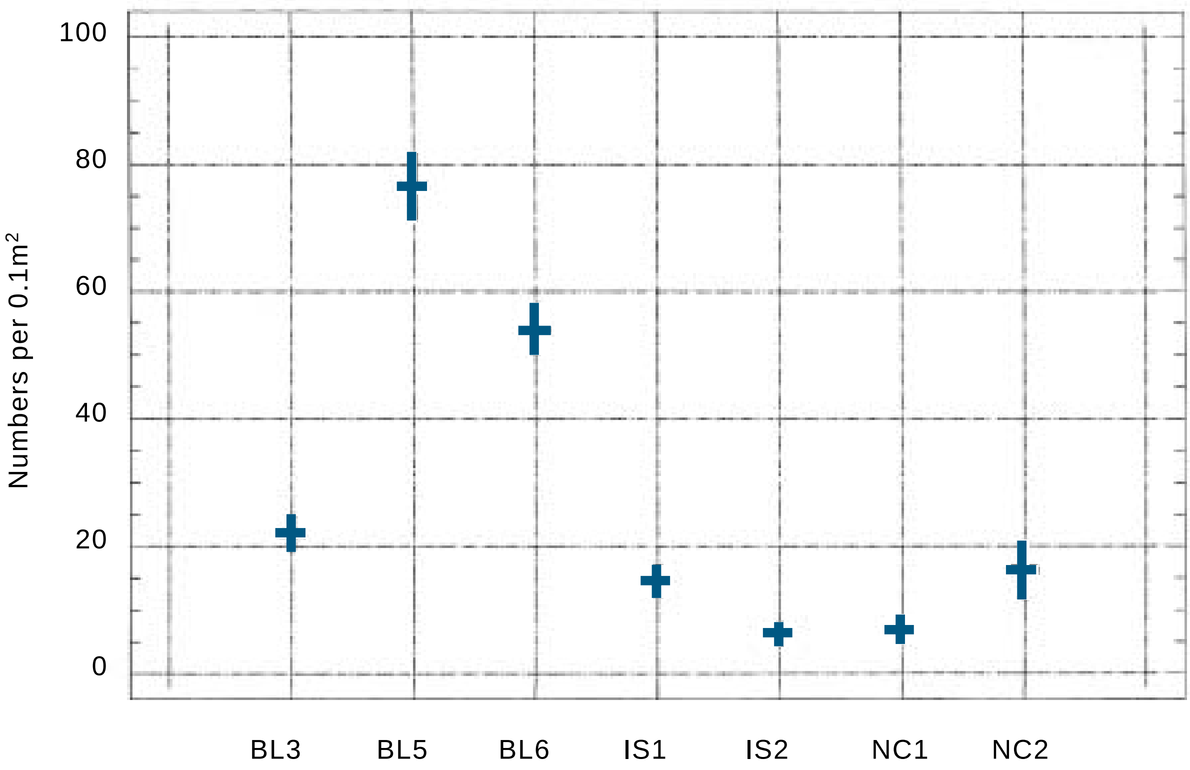


FIGURE 4.3. Biomass. Means with Standard Error Bars.

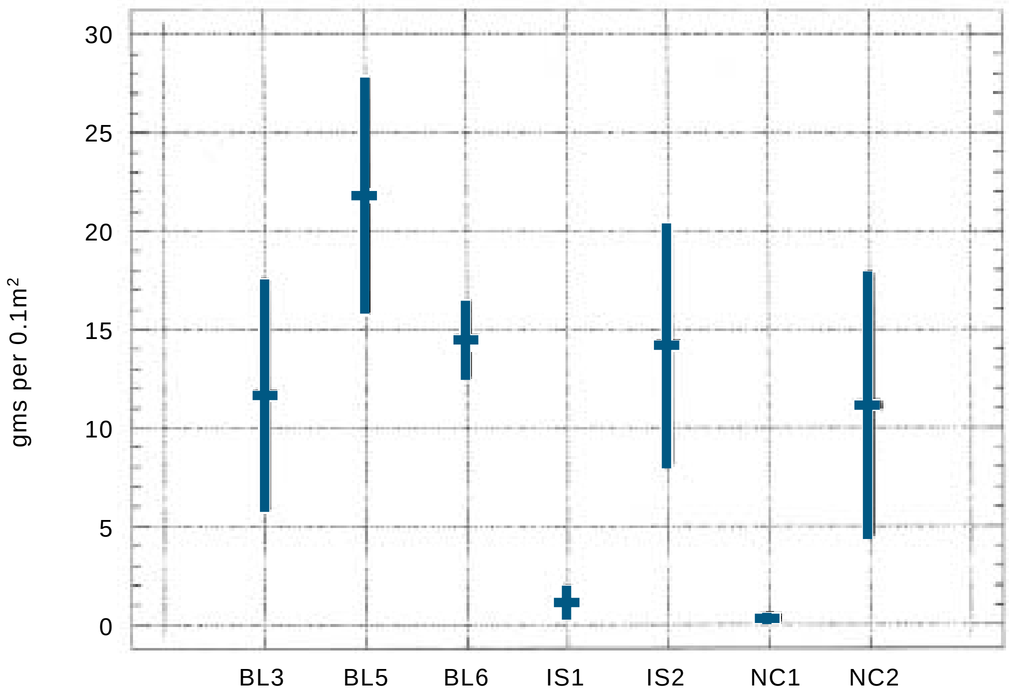
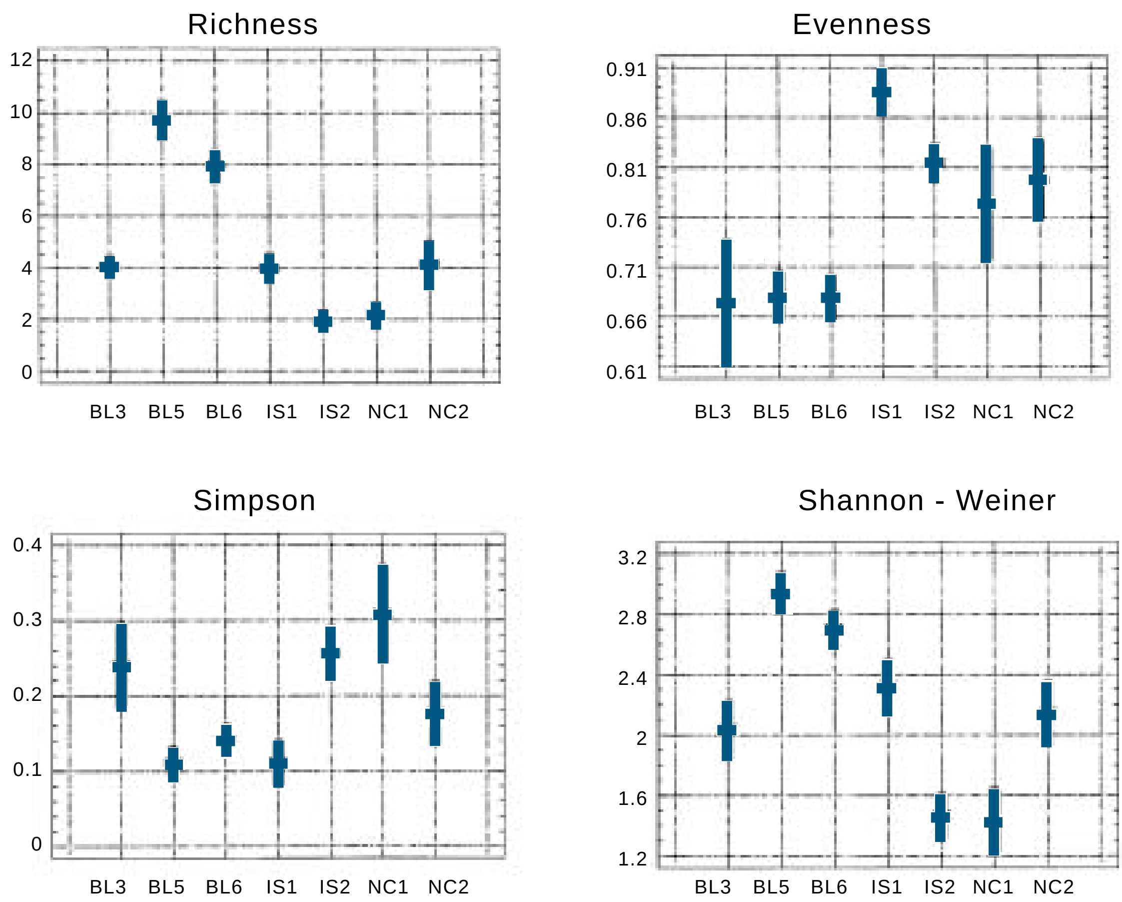


FIGURE 4.4 . Univariate Statistics Displaying Means with Standard Error Bars.



4.4.1. Species Richness

This is a measure related to the total number of species present. The more species a sample contains, the more diverse it is. As would be expected, this plot is similar to the plot of species number (Figure 4.2).

4.4.2. Pielou's Evenness

Evenness expresses how evenly distributed the individuals are among the different species and is often referred to as equitability. For example, if two samples each comprising 100 individuals and four species had abundances of 25, 25, 25, 25 and 97, 1, 1, 1, the first would intuitively be considered to be more diverse although the species richness is the same. The former exhibits high evenness, but low dominance while the latter has high dominance and low evenness. Samples dominated by one species are indicative of a stressed community. In contrast, highly diverse communities with high evenness usually imply unstressed communities. The Belfast Lough stations which exhibit low evenness values are indicative of a stressed environment. The causes of this stress are numerous and may be physical (shipping, dredging, wave action) as well as anthropogenic (organic enrichment, higher inputs of contaminants). The Intermediate/Offshore stations are more stable and less stressed as evidenced by high evenness.

4.4.3. Simpson's Index

Often quoted in older literature, the values obtained should not be misread since the higher the value, the lower the diversity. These values would indicate that BL5, BL6 and IS1 are more diverse than the remaining stations.

4.4.4. Shannon-Weiner

Incorporates both species richness and evenness components and is widely quoted in benthic ecology literature. When comparing with other data sets it is important to check from which logarithmic base the values have been calculated. Rees *et al.* (1990) recommend use of log to the base 2. As with the other indices, BL5 and BL6 are the most diverse stations even though they show low evenness.

4.5. Multivariate Analysis

Multivariate methods of data analysis are believed to be more sensitive in detecting community change than univariate measures (Warwick and Clarke, 1991). The process reduces large complex data matrices to simple pictorial representations such as dendrograms and Multidimension Scaling Plots which visually represent how one site relates to another based on similarity. Various classification and ordination techniques are available, each with its own advantages and disadvantages.

4.5.1. Multidimensional Scaling

Multidimensional Scaling (MDS) was the chosen method of ordination for the whole data set. The stress value of 0.12 indicates that the plot is useful although examination of the ordination shows a classic 'horseshoe' effect which indicates that MDS may not be the most suitable ordination for this data set.

It is interesting to note that it was only after the addition of the Offshore stations that this effect became apparent. The application of the MDS is shown in the dendrogram (Figure 4.6). This shows the effect of replicate sampling in that the replicates group together with similarity values ranging from 36.79 (IS2) to 71.75 (BL6). The degree of similarity shown between replicates demonstrates that fewer replicates may be sufficient for future surveys of these sites.

FIGURE 4.5. MDS Plot for 1993 Benthos Data at Northern Ireland NMP Stations - Stress Value 0.12.

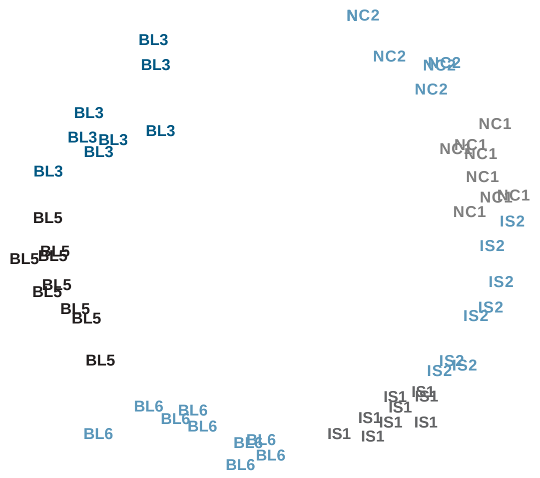


FIGURE 4.6. Bray-Curtis Similarity Dendrogram - Northern Ireland NMP Stations 1993.

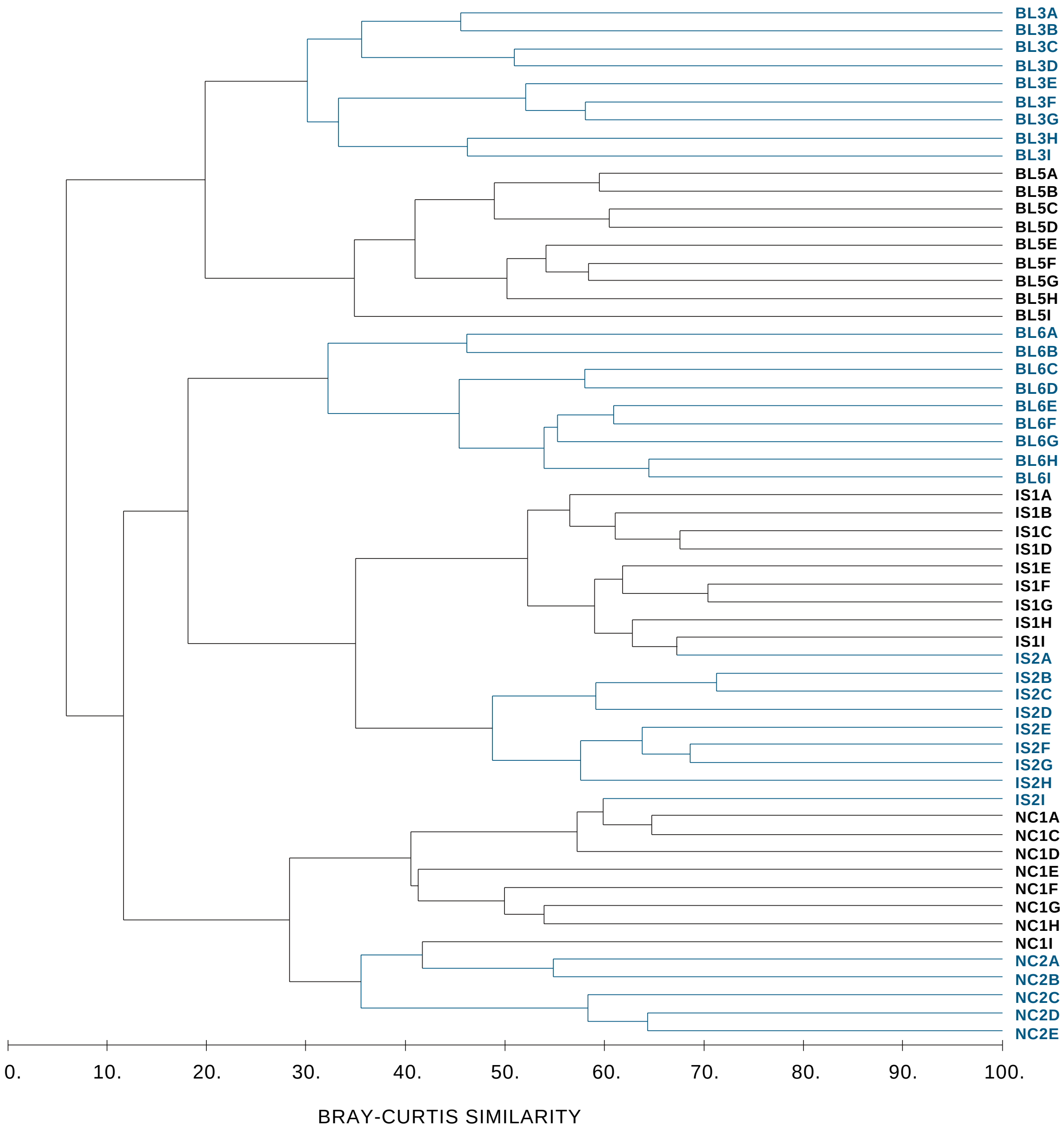


FIGURE 4.7. Bray-Curtis Similarity Dendrogram and MDS Plot for Estuarine Stations (BL3, BL5 and BL6) with Intermediate Station, IS1. STRESS 0.09

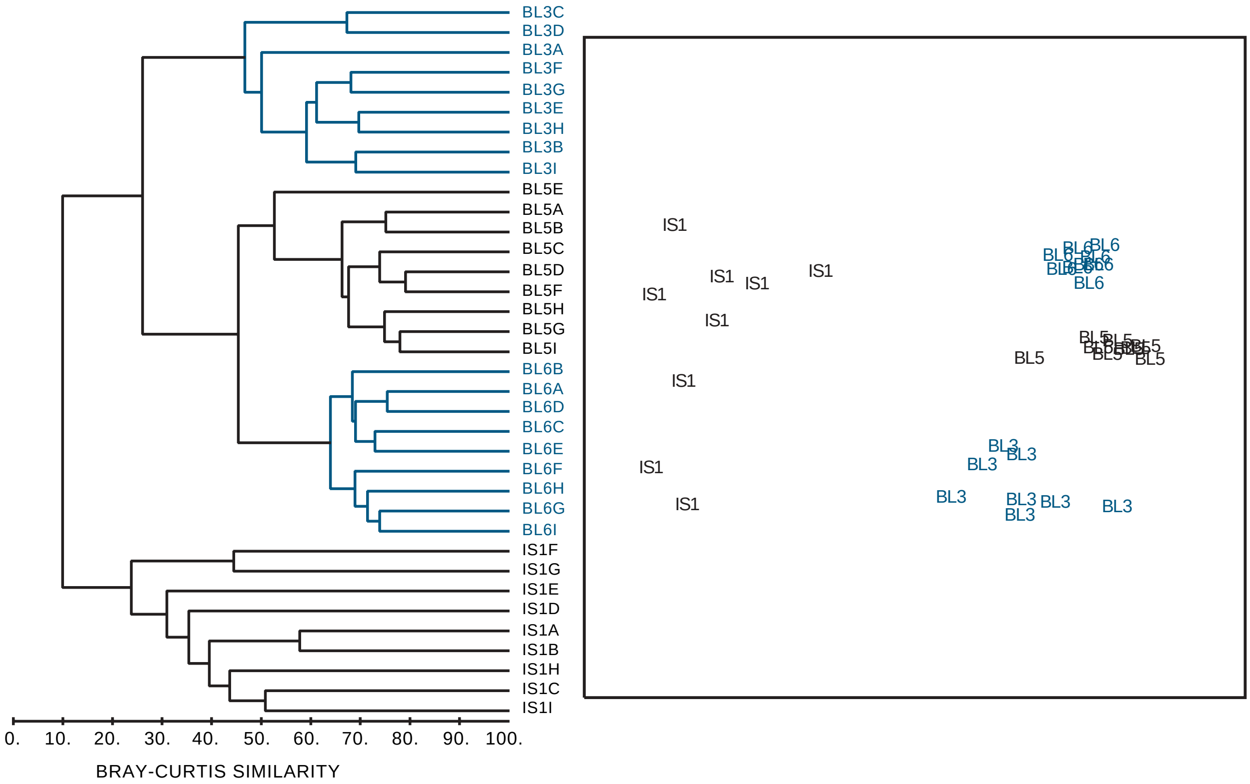
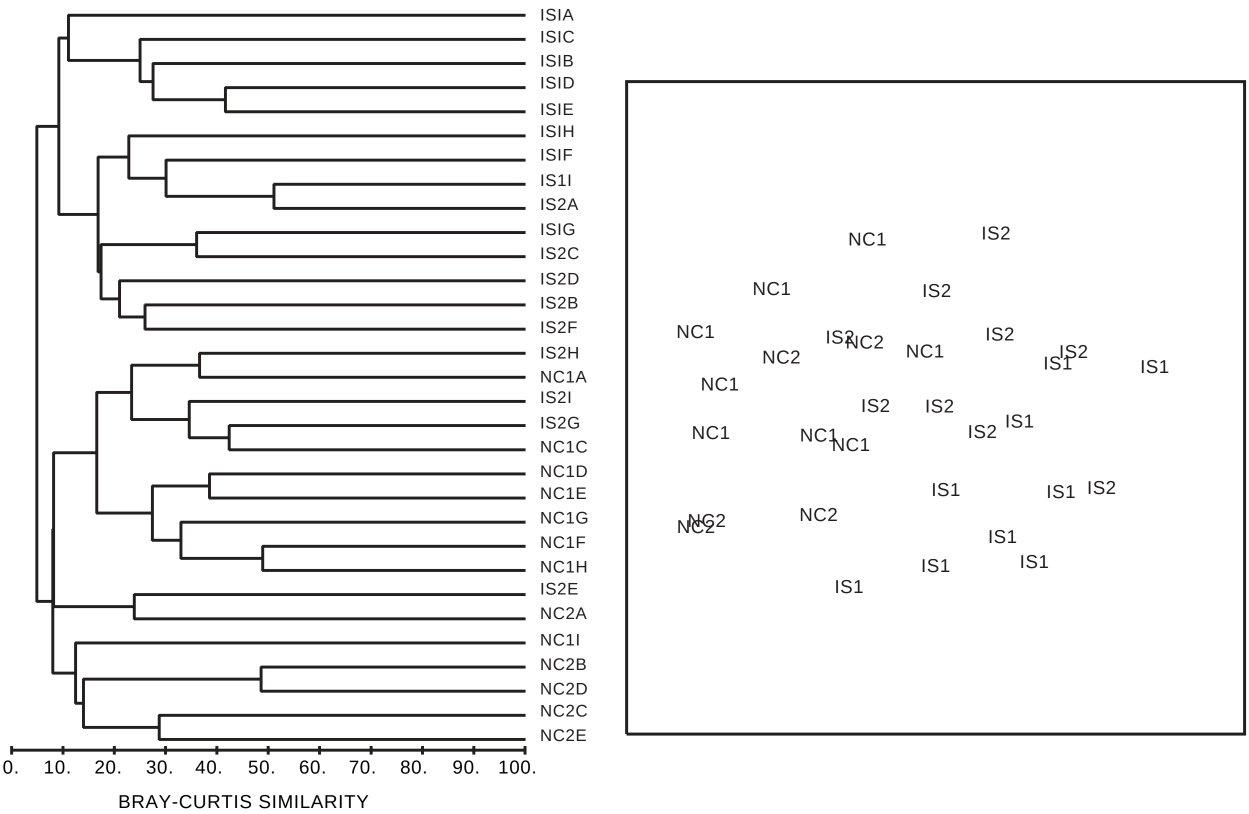


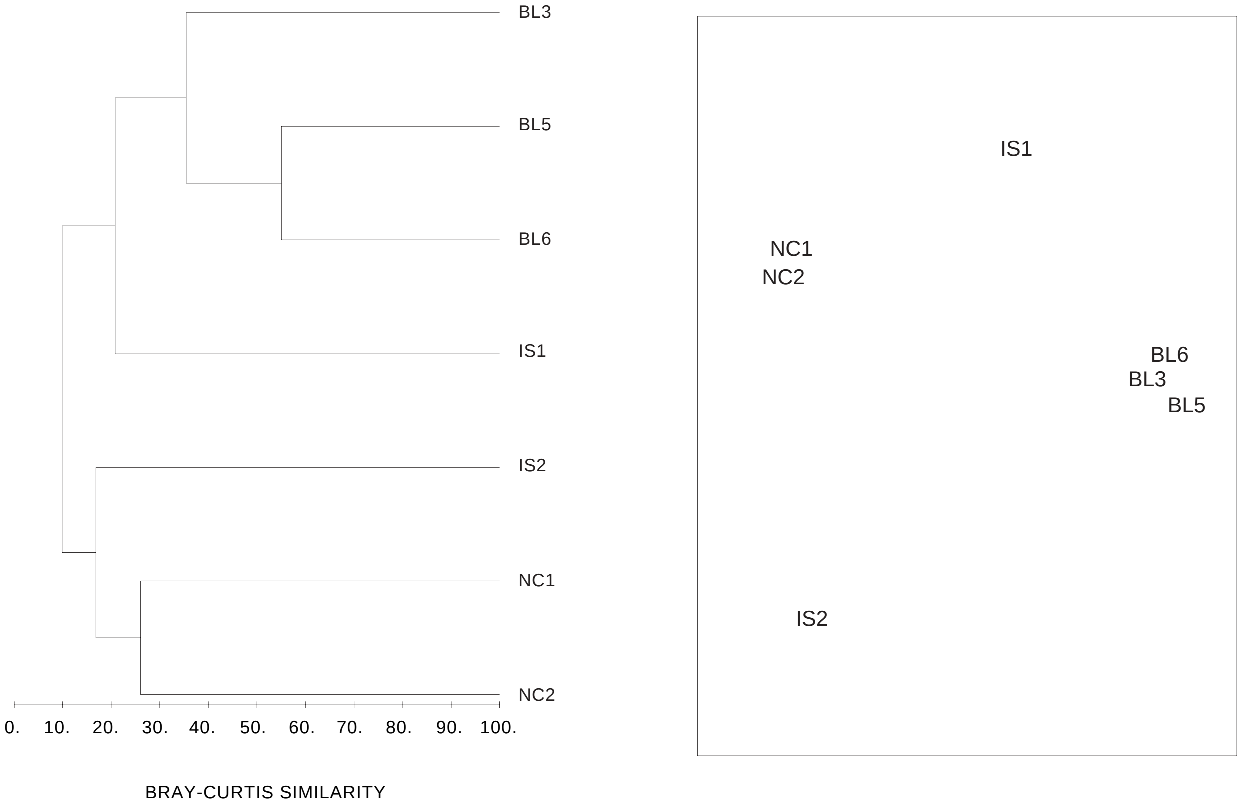
FIGURE 4.8. Bray-Curtis Similarity Dendrogram and MDS Plot for Offshore Stations (IS2, NC1 and NC2) with Intermediate Station, IS1. STRESS 0.19



Splitting the Estuarine stations from the Intermediate and Offshore stations (leaving IS1 as a common link to both) has the effect of reducing data stress levels (improved graphical representation) and hence producing a clearer picture. Figure 4.7 shows that the four Belfast Lough stations (BL3, BL5, BL6 and IS1) are distinct, with the Estuarine stations tending to be different from the Intermediate station (IS1). The picture for the Intermediate/Offshore stations (IS1, IS2, NC1 and NC2) is not so clear with a higher stress, increased heterogeneity and lower similarity between both replicates and sites (Figure 4.8).

In order to reduce the variability induced by replication, all replicates for each site were pooled and averaged, producing a much simplified and clearer picture of the relationship of the Northern Ireland sites (Figure 4.9). The Estuarine sites (BL3, BL5 and BL6) clump together with an average similarity of 35%. The Offshore sites NC1 and NC2 clump together at 26% and bring in the remaining Offshore site IS2 at 18%. The Intermediate station is more similar to the Estuarine stations with an overall similarity of 20%.

FIGURE 4.9. Bray Curtis Similarity Dendrogram and MDS Plot for all NMP 1993 replicates pooled to station. STRESS 0.01



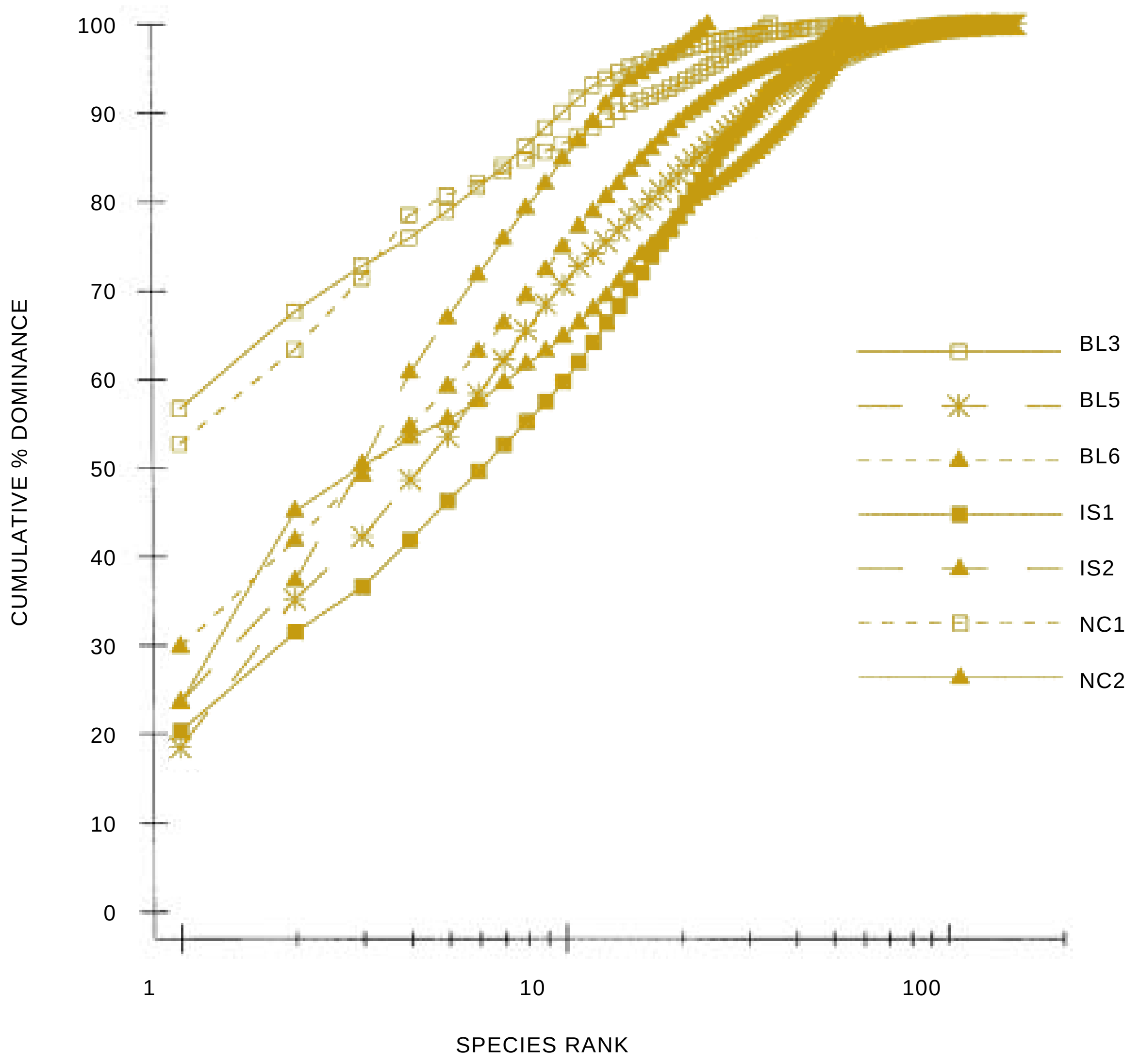
4.5.2. SIMPER Analysis

Following on from the MDS it is important to know which species are responsible for the similarity or dissimilarity of one site against another. This data set was subjected to 'Similarity Percentage Analysis' (SIMPER). Due to software constraints, prior to performing SIMPER analysis, the data set had to be reduced to the top 160 species based on abundance. The results are presented in Appendix IV and show the top 10 rank ordered species found at each site. SIMPER can also be used to assess overall similarity between sites based on both presence and absence of species and relative abundance.

4.5.3. K-Dominance Plot

Figure 4.10 shows the K-dominance curves for the seven Northern Ireland NMP stations. As pollution impact becomes more severe, communities tend to become numerically dominated by one or a few very small opportunistic species. This is indicated by the plot being skewed to the top left of the graph. While this premise may sucessfully explain the position of BL3 it does not explain the similar location of NC1. Biologically, BL3 is dominated by Nephtyd and Tubificid species which are indicative of organically enriched sediments; while NC1 is dominated by bivalve molluscs which tend to prefer sandy substrates. NC1 is a highly scoured, high energy site and the K-dominance plot probably reflects a physically stressed community.

FIGURE 4.10. K-dominance curves for Northern Ireland NMP sites. The x axis shows the species rank order on a log scale and the y axis shows cumulative percentage abundance.



5 Biological Effects

The Imposex survey was conducted during 1994 for intertidal stations adjacent to the NMP stations.

An Oyster Embryo Bioassay is performed on a yearly basis at Offshore and Intermediate stations and twice yearly at Estuarine stations.

The Fish Disease survey is ongoing at monthly intervals, carried out in association with other statutory work.

The optional EROD survey of Northern Ireland coastal waters was not conducted during this NMP survey.

5.1. Imposex

A total of 1799 dogwhelks, *Nucella lapillus* (L.) from 18 stations adjacent to the Northern Ireland NMP Stations were dissected and examined for Imposex. A control was selected from an exposed Atlantic site thought to be remote from anthropogenic influence. Since dogwhelks are an intertidal species, three sites were selected at the closest onshore locations to each NMP station. Five replicates each of 20 individuals were collected at each of these sites.

The Mean Relative Penis Size Index (RPSI) is a measure of Imposex. The values for the Northern Ireland stations are given in Table 5.1. A full listing of site locations is given in Appendix V.

FIGURE 5.1. 1994 Northern Ireland NMP Imposex Survey Sites.

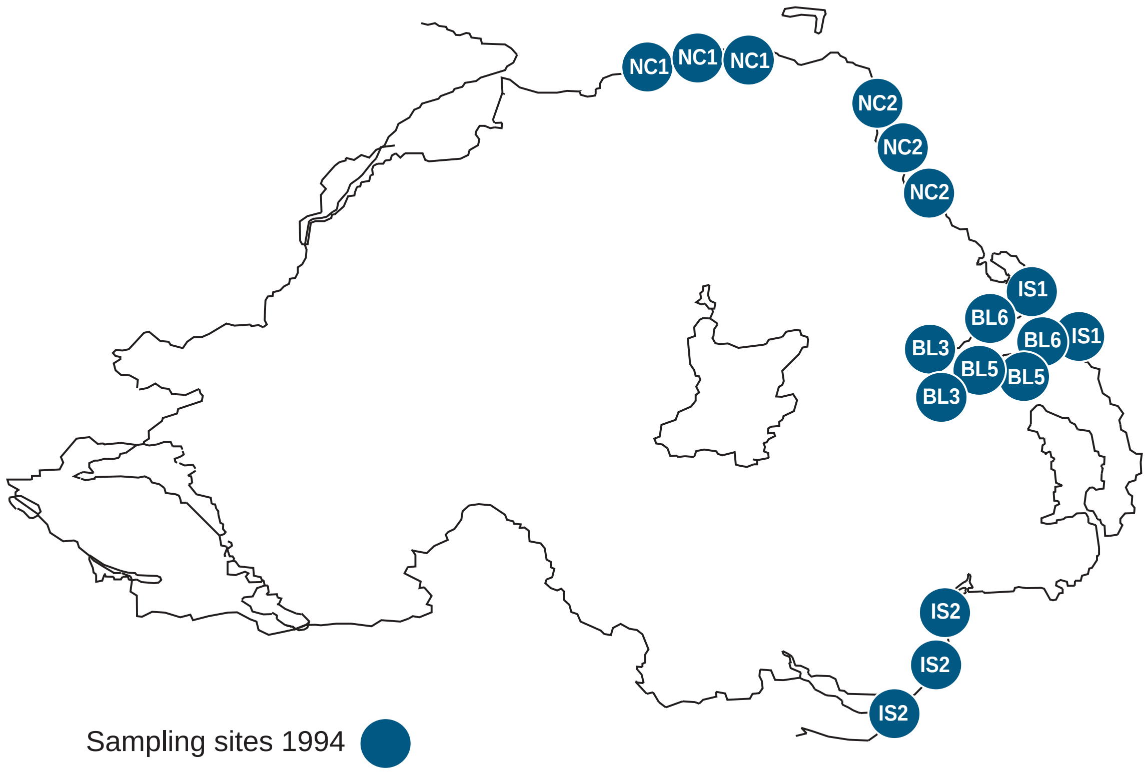
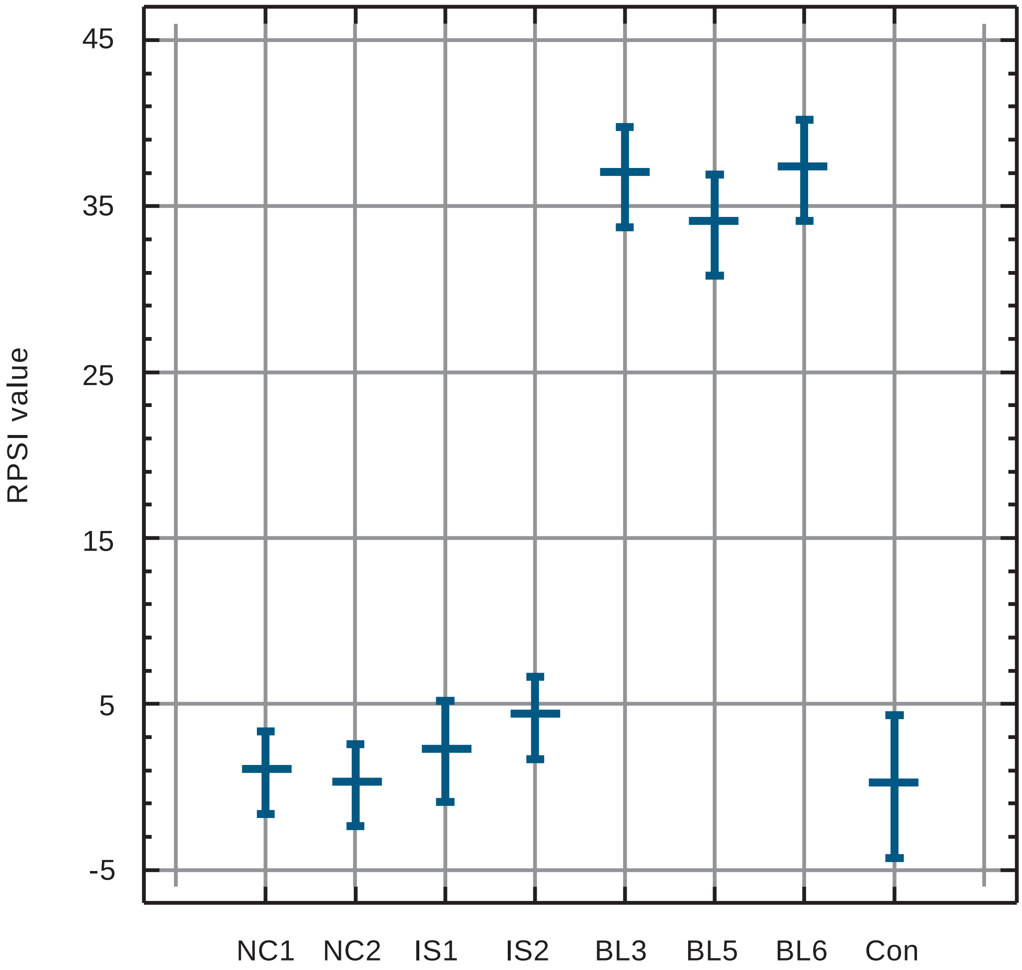


TABLE 5.1. Mean RPSI for 1994 Northern Ireland NMP Imposex Survey Sites.

NMP Station	Number of replicates	Mean RPSI	Standard error
BL3	10	36.74	2.66
BL5	10	34.69	2.43
BL6	10	40.20	3.75
IS1	10	2.14	1.01
IS2	15	4.17	0.08
NC1	15	0.85	0.28
NC2	15	0.11	0.03
Control	5	0.01	0.01

An RPSI of 0 indicates no Imposex detected while a value of 100 would indicate that all females had acquired full male characteristics. An analysis of variance (ANOVAR) was carried out on the data collected during 1994. Figure 5.2 shows the results of this and demonstrates that the dogwhelks at sites within Belfast Lough are significantly different from all other sites ($p<0.0001$). It also shows that the Intermediate and Offshore sites are not significantly different from the control site. The sites in Belfast Lough clearly show the Imposex phenomenon. This survey represents the first published Imposex data pertaining to Northern Ireland.

FIGURE 5.2. ANOVAR of Imposex Data. Mean Values with 95% confidence intervals.



5.2. Oyster Embryo Bioassay

Oyster Embryo Bioassays were conducted at the Northern Ireland NMP stations during 1994 and 1995. Further development of the application of the Oyster Embryo Bioassay is required before there is total confidence in its suitability for testing Northern Ireland coastal waters. The main problem is geographical in that both conditioned oysters and control water had to be flown to Northern Ireland from Guernsey and this adds additional stress to an already sensitive test system.

5.3. Fish Disease Studies

The severity of fish diseases is recorded according to categories recommended in the International Council for the Exploration of the Seas (ICES) Training Guide for the Identification of Common Diseases and Parasites of Fish in the North Atlantic (Buckie *et al.,* in press). During the period 1993-1995, as part of an ongoing inshore fish population study within Belfast Lough, a survey of the presence of fish diseases was conducted (i.e. lesions, ulcers, lymphocystis (nodules occuring on the body surface of the fish) and papillomas). The numbers of fish examined are detailed in Table 5.3. The number of species has remained constant from year to year and the reduction in numbers in 1995 can be explained as a consequence of low numbers of two species, herring, *Clupea harengus* (L.) and sprat, *Sprattus sprattus* (L.). On no occasion was any disease observed or diagnosed. This survey covers stations BL3, BL5, BL6 and IS1.

TABLE 5.3. Number of Fish/Species Examined from NMP Stations, 1993-1995.

	1993	1994	1995
No. of fish	11428	15466	1723
No. of species	35	31	34

6 Bioaccumulation

6.1. Fish

To obtain fish from the Offshore and Intermediate stations, the DANI wide-scale ground fish surveys which are carried out every spring were utilised. In the event, the distribution of dab proved variable and specimens were obtained only from IS1 and IS2. Flounder were obtained by beam trawl from Belfast Lough at BL3 and BL5.

Dab and flounder were deep frozen to -20°C immediately upon capture and returned to the laboratory where they were thawed. The liver and left fillet were dissected out within one month of capture. Between 5 and 10 fish were typically pooled to obtain enough tissue for analysis.

Results for the dab tissues are presented in Table 6.1.1. 'Less than' values were considered as equal to the detection limit when calculating means. Organic contaminants tend to accumulate in the lipid fraction of the liver and hence lipid concentrations are used as a co-factor in the normalisation of organic contaminants. Normalisation to lipid concentrations should:

- reduce the variability of data within stations
- allow more accurate comparisons between stations and
- allow comparison between different species.

It is difficult to draw conclusions about the levels of trace contaminants in the Intermediate and Offshore waters of Northern Ireland with results from two stations only and a limited sample size. For most of the contaminants measured, concentrations are greater at IS2 than at IS1. However, after normalisation against the lipid concentration is carried out, these differences are minimal for the organic compounds.

TABLE 6.1.1. Mean Concentrations of Organochlorines in Dab Liver 1994-1996 (µg/kg wet weight).

Station	No. of Samples	Aldrin	Dieldrin	Endrin	ppTDE	pp'DDE	ppDDT	%Lipid	%Dry Weight
IS1	2	<5.0	11.0	<5.0	14.0	9.5	8.0	5.4	22.0
IS2	8	<5.0	15.5	9.0	11.5	15.5	11.5	7.9	20.1

TABLE 6.1.2. Mean Concentrations of PCB Congeners in Dab Liver 1994-1996 (µg/kg wet weight).

Station	No. of Samples	28	52	101	118	138	153	180	%Lipid	%Dry Weight
IS1	2	<5.0	<5.0	<5.0	<5.0	7.0	8.0	<5.0	5.4	22.0
IS2	8	7.0	<5.0	<5.0	9.0	11.3	11.0	9.3	7.9	20.1

**TABLE 6.1.3. Mean Concentrations of Metals in Dab 1994-1996.
(mg/kg wet weight, number of replicates in brackets).**

Station	Matrix	As	Hg	Cd	Pb	%Lipid	%Dry Weight
IS1	Dab Muscle	1.60(1)	0.03(2)				
	Dab Liver			0.20(2)	0.30(2)	5.4	22.0
IS2	Dab Muscle	2.40(11)	0.02(11)				
	Dab Liver			0.09(7)	0.40(7)	7.9	20.1

The flounder results for Belfast Lough are shown in Tables 6.1.4-6.1.6 together with results for dab from IS1. Most organochlorine compounds were present above the limits of detection and were higher in the inner station (BL3). The highest concentrations of PCB congeners 138 and 153 were observed at BL3 and decreased moving seawards out of Belfast Lough. PCB 180 was detected at BL5. However, as with the dab data, once normalisation against the percentage lipid is carried out, these differences are less striking. The metal concentrations in the fish are a limited data set and less than values were considered to be equal to the limit of detection when calculating means.

The Environmental Quality Standard for mercury in fish flesh is 0.3mg/kg wet weight (EC Dangerous Substances Directive, 76/464/EEC. Community Decision 93/351 EEC (European Communities, 1993) applies to samples of fishery products. This states that the total mean mercury content of fisheries products must not exceed 0.5 mg/kg fresh weight. There are no standards or guidelines in the UK for cadmium or arsenic in fish flesh. From the Lead in Food Regulations (HMSO, 1979): lead in fish should not exceed 2mg/kg wet weight.

None of the samples taken exceeded these concentrations.

TABLE 6.1.4. Mean Concentrations of Organics in Flounder Liver from Belfast Lough, 1994 (μg/kg wet weight).

Station	No. of samples	Aldrin	Dieldrin	Endrin	ppTDE	ppDDE	ppDDT	% Lipid	% Dry Weight
BL3	2	<5.0	10.0	7.0	7.5	12.0	<5.0	5.3	21.0
BL5	2	<5.0	6.0	<5.0	<5.0	8.5	<5.0	3.2	20.0

TABLE 6.1.5. Mean Concentrations of PCB Congeners in Flounder Liver from Belfast Lough, 1994 (μg/kg wet weight).

Station	No. of Samples	28	52	101	118	138	153	180	% Lipid	% Dry Weight
BL3	2	12.0	24.5	6.5	<5.0	19.0	24.0	<5.0	5.3	21.0
BL5	2	14.0	14.0	9.0	<5.0	17.0	36.0	21.0	3.2	20.0

TABLE 6.1.6. Mean Metal Concentrations in Flounder Liver from Belfast Lough, 1994 (mg/kg wet weight).

Station	No. of Samples	Cd	Pb	% Lipid	% Dry Weight
BL3	2	<0.01	<0.01	5.3	21.0
BL5	2	0.02	<0.01	3.2	20.0

There are no standards for pesticides in fish in the UK. However, all concentrations are lower than the European Commission's *Codex Alimentarius* guidelines for organic compounds in fish liver.

6.2. Shellfish

Specimens of horse mussel were collected using a Naturalist's Dredge at a station adjacent to IS1. The common mussel is collected at a number of locations within Belfast Lough for monitoring compliance with the EC Shellfish Directives (79/923/EEC and 91/492/EEC) and the Dangerous Substances Directive (76/464/EEC). It was agreed that specimens collected from these programmes would be used to fulfill the requirements of the NMP.

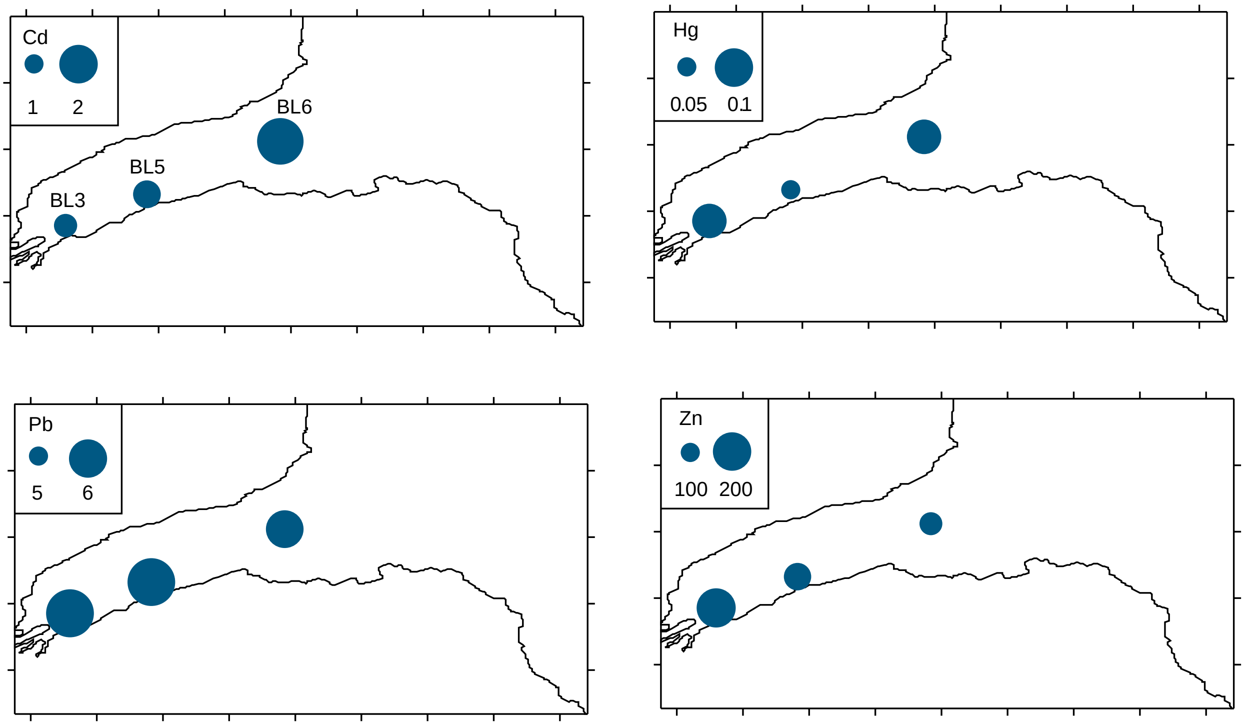
All shellfish collected were returned to the laboratory and placed in "clean" seawater at 8° C for 24 hours to undergo depuration. A minimum of 25 common mussels, or five of the larger horse mussel, were pooled for analysis. Results from the metal analysis in Belfast Lough are presented in summary form in Table 6.2.1 and the mean values plotted in Figure 6.1. Perhaps surprisingly, gradients are weak with only zinc showing a clear pattern decreasing seawards. This appears to be a general confirmation of current trends observed in local long term data sets.

TABLE 6.2.1. Metal Concentrations in mussels from Belfast Lough, 1994-1995 (mg/kg dry matter basis).

	Station	No. of Samples	Cd	Hg	Pb	Zn	% Dry Weight
Common mussel	BL3	7	1.31	0.13	8.83	195.35	19.7
	BL5	8	1.44	0.09	6.71	136.16	19.5
	BL6	8	2.42	0.03	6.11	117.35	19.9
Horse mussel	IS1	2	1.42	0.07	6.90	56.13	20.6

There are no exceedences of the Guideline and Imperative values given in the Shellfish Waters Directive outlined in Appendix VI.

FIGURE 6.1. Metal concentrations in the common mussel, Belfast Lough (mg/kg dry matter basis).



The only organochlorines which were above the limit of detection in 1994 and 1995 were ppDDE in the horse mussels IS1(1994) and in the common mussel at all Belfast Lough stations. Dieldrin was detected at BL3. In all cases concentrations were very close to the limit of detection.

A summary of the PCB results is given in Table 6.2.2.

TABLE 6.2.2. PCB Concentrations in Mussels from Belfast Lough, 1994-1995 (µg/kg wet weight).

	Station	No. of Samples	%HEL AVE	28	52	101	118	138	153	180	% Dry Weight
Common mussel	BL3	8	5.4	8	6	<5	<5	11	11	<5	19.7
	BL5	8	3.7	<5	6	<5	<5	9	12	<5	19.5
	BL6	8	5.5	<5	<5	<5	<5	<5	7	<5	19.9
Horse mussel	IS1	2	<5.0	<5	<5	<5	<5	6	9	11	20.6

These results are consistent with those from other monitoring programmes in Belfast Lough and it would appear from the limited data set that PCB concentrations decrease seawards. Comments made previously about normalisation to lipid (section 6.1) are also applicable here. Again, there are no breaches of the Guideline and Mandatory standards in the Shellfish Waters Directive as outlined in Appendix VI, or the *Codex Alimentarius*.

7 Water

7.1. Dissolved Nutrients and Physico-chemical Parameters in Water

All stations were sampled for dissolved nutrients and associated water quality parameters according to NMP protocol since 1993. For the purposes of the following discussion, the data gathered since 1994 is used as this has been subject to the full rigours of the National Analytical Quality Control Scheme.

The three Offshore stations lie in water bodies with quite different characteristics (MAFF, 1981). NC1 lies in the North Atlantic waters whereas IS2 lies in the Western Irish Sea Basin, an area which stratifies in summer (Gowen *et al.,* 1995). In contrast NC2 lies in the tidally dynamic North Channel, an area which maintains strong vertical mixing throughout the year. This station may be subjected to differing influences from both the outflow from the Firth of Clyde and water exiting the Irish Sea. The Intermediate station IS1 at the mouth of Belfast Lough also lies within the North Channel but is also subjected to the local influences of Belfast Lough.

Belfast Lough does not show a consistent salinity gradient and the maximum gradient does not exceed 2-3ppt (Parker, 1981) but the 3 stations sampled lie on a known nutrient gradient.

A summary of the winter (ie late February to early March) nutrient and chlorophyll concentrations obtained for all stations is shown in Table 7.1.1. Data from 1994 are plotted graphically on Figures 7.1.1 and 7.1.2. In general, the concentrations of nutrients at NC1 were the lowest with those at the Intermediate station, IS1 the highest. The higher salinity at NC1 demonstrates the influence of the North Atlantic.

FIGURE 7.1.1. Winter Nutrients at Offshore and Intermediate NMP Stations 1994.

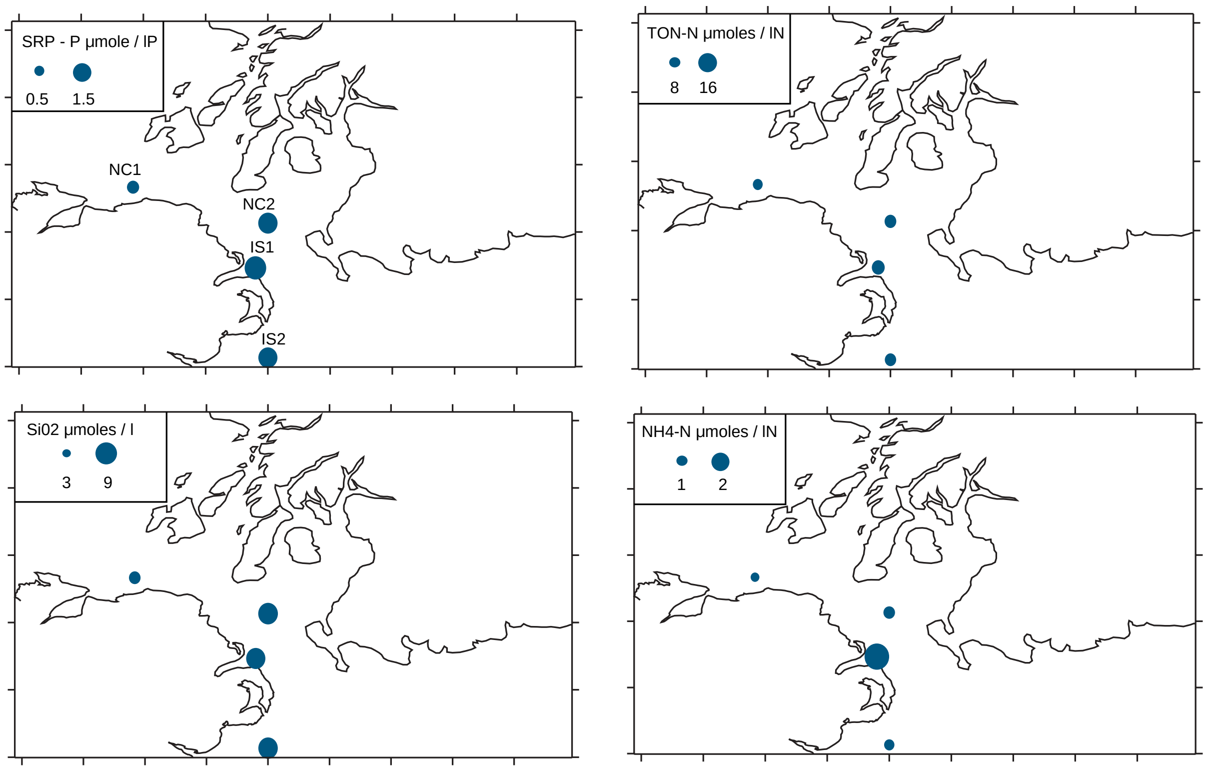
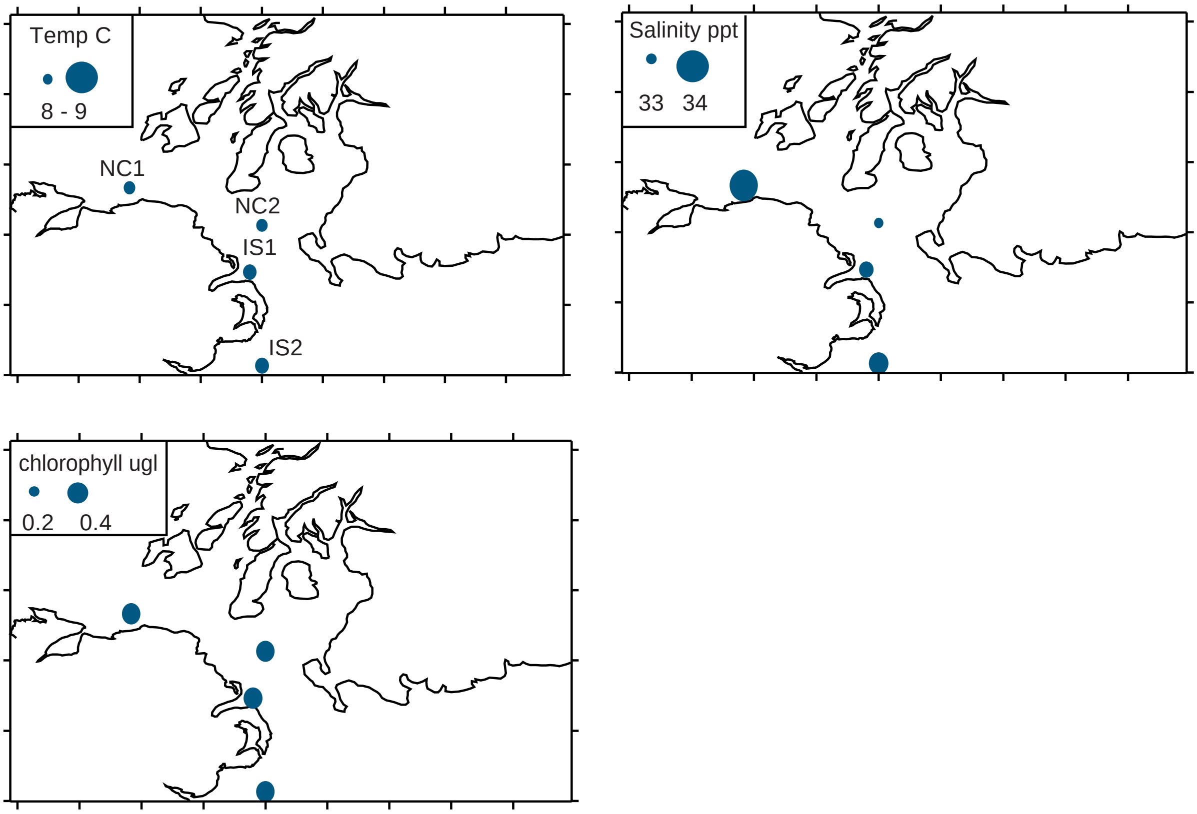


FIGURE 7.1.2 Winter Physico-chemical Parameters at Offshore and Intermediate Stations 1994.



Higher chlorophyll-a concentrations at IS2 than at the other Offshore stations suggests that there may be an earlier start to the spring algal growth at this location.

Summary data for the three Belfast Lough stations are plotted on Figures 7.1.3 and 7.1.4. Although the salinity range is narrow, a clear gradient in salinity and temperature does exist and a corresponding gradient in all the nutrients is also evident. Sources of all the nutrients to Belfast Lough are documented in Service *et al.,* (1996) which points out the existence of a major point industrial source of dissolved nitrogen and soluble reactive phosphate in the inner Lough. There are also two major sewage treatment works which treat a high proportion of the sewage from Belfast and also imported sewage sludge from other sewage treatment works in Northern Ireland. Belfast Lough is never nitrogen limited and, with chlorophyll-a concentrations at times exceeding 50µg/l, is exhibiting symptoms of eutrophication. It is likely that part of Belfast Lough will be designated as a sensitive area under the Urban Waste Water Treatment Directive (91/271/EEC).

The rapid reduction in the nutrient gradients moving out to the Intermediate station is evidence of the tidal flushing taking place with the waters of the North Channel.

Chlorophyll-a at the inner station is in excess of 2.2 µg/l, about four times the value at the Intermediate station. This suggests that algal growth had already started at the time of sampling and that nutrient concentrations recorded may therefore be below the winter maximum.

TABLE 7.1.1 Winter Nutrient and Chlorophyll Data 1994-96 (µmoles / l).

Station		TON	SRP-P	SiO2	NH3N	Chla(µg/l)
BL3	replicates	4	4	4	4	4
	mean	45.08	3.52	17.12	60.32	2.17
	max	65.22	4.15	21.50	92.10	6.50
	min	31.50	2.40	14.12	30.10	0.10
BL5	replicates	4	4	4	4	4
	mean	27.81	2.81	14.10	31.81	1.47
	max	32.60	4.64	15.77	50.44	2.90
	min	22.90	2.00	11.71	17.00	0.60
BL6	replicates	4	4	4	4	4
	mean	12.81	0.91	8.18	3.32	0.78
	max	15.65	1.12	9.10	5.53	1.20
	min	8.98	0.63	6.44	0.25	0.20
IS1	replicates	7	7	7	7	7
	mean	10.53	1.03	7.50	2.01	0.41
	max	11.47	1.18	8.13	3.55	0.86
	min	10.11	0.92	7.04	1.52	0.19
IS2	replicates	8	8	8	8	6
	mean	9.21	0.92	6.65	0.94	0.83
	max	9.91	1.02	8.12	1.83	1.37
	min	8.12	0.65	4.89	0.17	0.42
NC1	replicates	8	8	8	8	6
	mean	8.80	0.78	4.77	0.89	0.41
	max	9.25	0.88	5.46	1.13	0.49
	min	7.62	0.64	4.19	0.78	0.20
NC2	replicates	7	7	7	7	6
	mean	9.46	0.99	7.27	1.12	0.36
	max	10.19	1.08	9.07	1.83	0.85
	min	9.05	0.93	6.38	0.61	0.17

FIGURE 7.1.3. Nutrient Concentrations in Belfast Lough 1995.

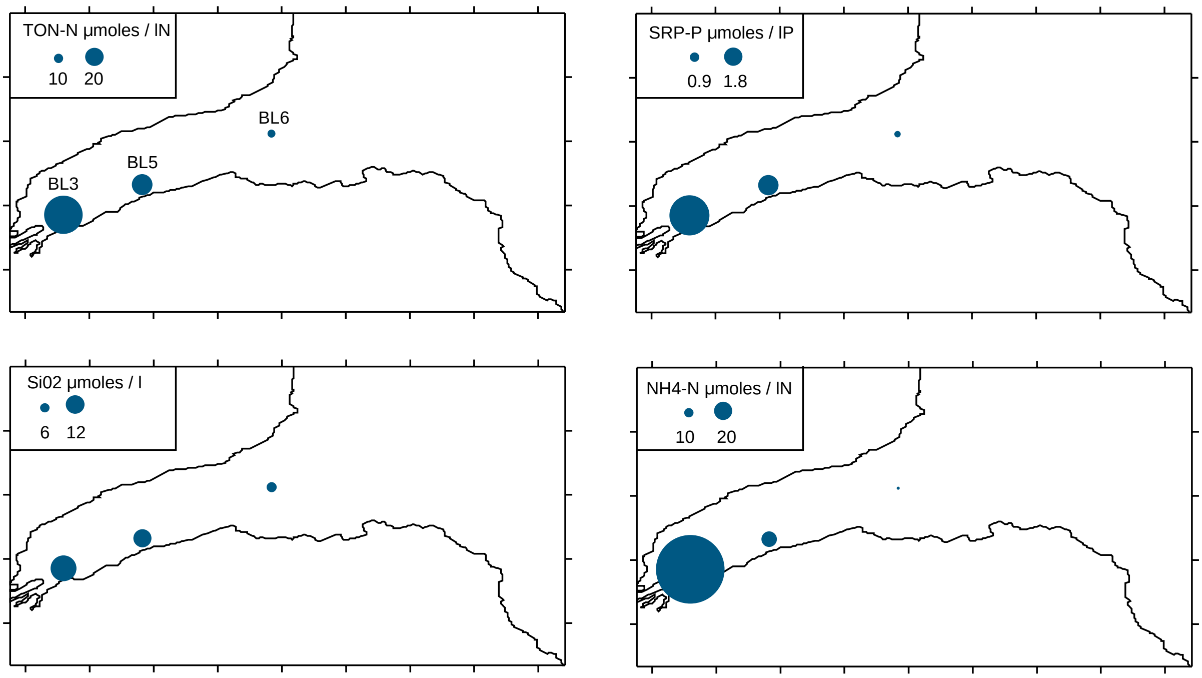
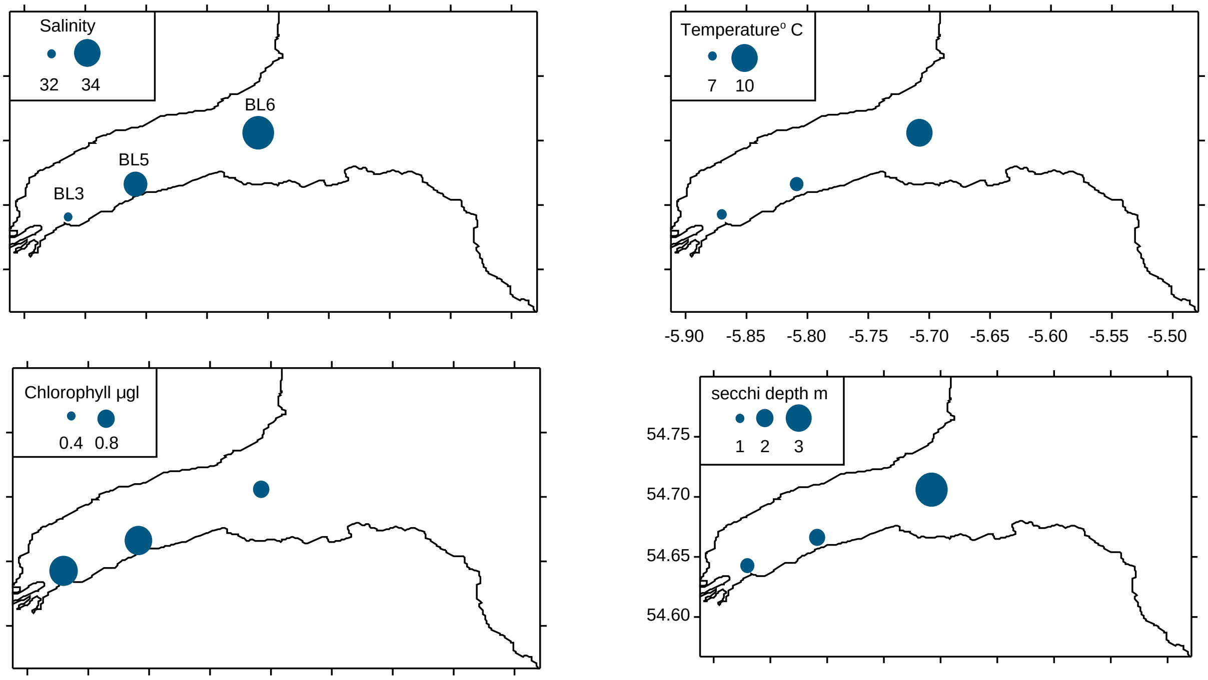


FIGURE 7.1.4. Physico-chemical Data from Belfast Lough 1995.



Overall, there is no evidence of elevated nutrient levels at the three Offshore stations and differences between the stations can be attributed to the different water masses involved. Nutrient concentrations are clearly elevated in Belfast Lough. This is being investigated further at present.

7.2. Metals in Water

All three stations in Belfast Lough lie in the high salinity (>30ppt) band due to the relatively minor freshwater input to Belfast Lough.

In 1993 the water samples were collected at one metre depth from four grid positions at each station. The metals analysed were cadmium, copper, lead, nickel and zinc. Chromium and mercury were not routinely analysed and therefore there was no participation in quality control for these two determinands. Mercury was included from late 1995.

The summary of salinity, suspended solids (SS), and trace metals data using median values is given in Table 7.2.1. below.

TABLE 7.2.1. Metals in Seawater at Northern Ireland NMP Stations and Associated Data.

Location	Station	Mean salinity ppt	Mean SS mg/l	Cd	Cu	Pb	Ni	Zn
Belfast Lough	BL3	32.3	5.2	<0.035	0.80	<0.75	0.75	2.53
Belfast Lough	BL5	32.8	3.7	<0.035	0.66	<0.75	0.56	<2.50
Belfast Lough	BL6	33.7	2.6	<0.035	0.68	<0.75	<0.50	<2.50
Belfast Lough	IS1	33.9	2.7	0.030	0.70	<0.75	0.55	3.70
Dundrum Bay	IS2	33.8	<2.0	0.046	1.80	3.60	0.62	6.60
N. Channel	NC2	33.5	<2.0	0.035	0.85	<0.75	0.65	2.90
N. Coast	NC1	34.0	<2.0	<0.035	<0.65	<0.75	<0.50	<2.50

Metals are expressed as µg/l (median values).
ppt - parts per thousand

The median values reported for the Belfast Lough sites (BL3, BL5, and BL6) are based on four results for each of the years 1993-95 inclusive, giving 12 results for each site. The median values for the Intermediate station (IS1) are derived from four results for 1993 and one for each of 1994 and 1995, giving a total of six results.

The possibility of contamination during sampling was recognised and some samples yielding suspect results were re-analysed to confirm the original results. The use of median values in this data set is considered more appropriate since anomalous results can significantly skew a mean value. Such problems do not arise for salinity and suspended solids measurements and as results show little variation, the mean and median values are virtually the same.

Cadmium
For all stations, the median concentrations were less than 0.05µg/l, and most were less than 0.035µg/l. For one station (IS2), and based on four 1993 results only, the median concentration was 0.046µg/l.

Copper
Copper concentrations within Belfast Lough ranged from 0.6 to 0.8µg/l. Some copper was detected in the Offshore stations where the median concentrations ranged from <0.65 to 1.8µg/l. These latter values are based on 1993 results only.

Lead
The median concentration at all stations except one (IS2) was <0.75µg/l.

Nickel
Dissolved nickel concentrations at all locations had median values ranging from <0.5 to 0.75µg/l.

Zinc
The median concentrations in Belfast Lough and the North Coast were 2.5µg/l or less; those for the offshore stations ranged from 2.9 to 6.6µg/l.

The following general conclusions can be drawn:

- There was little variation in the concentrations measured over the years 1993-95 and all sites were in the high salinity range of 32 to 34 ppt.
- The results for IS2 are relatively high and may indicate contamination at the sampling stage. These results are based on only four samples taken in 1993.
- The results are generally consistent with previously published data (Law *et al.,* 1994; Balls *et al.,* 1993; Kremling and Hydes, 1988). Law *et al.,* (1994) observed that the concentrations of dissolved copper and cadmium in the Irish Sea were higher than in any other area around England and Wales.
- Detection limits for the analysis of lead in seawater should be lowered.
- The concentrations found during the survey did not exceed the UK Environmental Quality Standards (EQS) for Dangerous Substances of 0.5µg/l for cadmium in marine waters; 5 µg/l for copper; 25 µg/l for lead; 30µg/l for nickel and 40 µg/l for zinc. Nor did they exceed the revised and tighter EQS proposed by the DOE(UK); 10µg/l for lead; 15µg/l for nickel; 10µg/l for zinc.

7.3. Organic Compounds in Water

The range of determinands analysed increased between 1993 and 1995. The priority hazardous substances carbon tetrachloride, chloroform, trifluralin, endosulphan, tri- and tetrachloroethylene were added in 1994 and in 1995 the triazines and organophosphorus compounds were included.

The detection limits were generally 1 to 2 ng/l for the organochlorine compounds with higher levels for pentachlorophenol and the volatiles. The only substance consistently detected at, or slightly above, the detection limit was lindane, γHCH. This was detected at the 3 stations in Belfast Lough and in 1994 at the Intermediate station. At the innermost station in Belfast Lough (BL3) it was detected on each of the 12 sampling occasions and on 11 out of 12 occasions at station BL5, the next seaward station.

The main conclusions are:

- The concentration range for all Belfast Lough samples was <1.0-4.0 ng/l.
- There was a downward gradation in concentrations seawards apparent in 1994, ranging from 4 to 1.3ng/l.
- The absence of organic contaminants other than lindane, is consistent with the results of local freshwater monitoring. Total concentrations of lindane and the other isomers do not exceed the UK Environmental Quality Standard for total HCH of 20 ng/l.

8 Sediments

8.1. Metals in Sediments

At six of the seven Northern Ireland stations nine sediment samples were taken on a grid system. At the station in the North Channel (NC2) it was possible to sample only five points of the grid due to the hard substrate.

Total analysis of the less than 2mm fraction was carried out using a hydrofluoric/*aqua regia* strong acid digestion in a microwave oven. Organic carbon (OC) content and particle size were also assessed. The results related to dry weight are summarized in Table 8.1.1.

TABLE 8.1.1. Metals in Sediments and Associated Parameters.

Site ID	Al %	OC %	< 2 mm %	< 63µm %	As mg/kg	Cu mg/kg	Cr mg/kg	Cd mg/kg	Hg mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg
Belfast Lough BL3												
Mean	2.68	0.63	89.60	8.20	5.10	16.20	85.00	0.59	0.13	18.40	38.30	130.00
RSD%	25.40	68.90	18.70	73.50	43.30	82.10	35.60	100.00	102.20	44.60	53.50	81.80
Belfast Lough BL5												
Mean	3.64	1.27	91.40	21.90	7.50	24.20	102.00	0.52	0.220	32.50	49.70	165.00
RSD%	17.30	32.90	5.30	44.10	14.70	23.10	12.50	19.20	31.80	11.70	21.50	18.70
Belfast Lough BL6												
Mean	3.85	1.43	94.00	37.00	7.90	27.10	84.00	0.18	0.14	28.50	52.00	113.00
RSD%	7.80	27.90	2.80	20.50	8.50	17.30	7.20	16.70	28.60	12.30	10.80	17.00
Belfast Lough IS1												
Mean	1.81	1.49	99.20	1.30	8.80	9.10	26.00	<0.06	<0.05	10.40	16.30	34.20
RSD%	14.90	29.50	1.20	103.80	28.50	16.80	17.50	-	-	7.80	13.50	18.10
Dundrum Bay IS2												
Mean	6.00	1.62	100.00	88.00	9.30	18.00	91.00	<0.06	0.10	30.30	51.50	139.00
RSD%	1.20	5.50	-	-	5.30	9.10	9.70	-	10.00	4.50	3.50	1.80
N. Channel NC2												
Mean	1.92	1.69	96.00	0.30	11.30	4.50	31.00	<0.06	<0.05	11.50	11.20	27.10
RSD%	24.00	34.90	-	-	7.60	12.70	16.10	-	-	17.40	5.40	25.10
N. Coast NC1												
Mean	0.76	1.24	99.00	0.30	7.90	2.20	14.00	<0.06	<0.05	3.50	8.60	9.00
RSD%	14.50	46.20	-		8.40	7.50	30.00	-	-	28.60	17.40	36.70

Particle size analysis was completed using the dry sieve technique (Holme and McIntyre, 1994). The modal (most common) particle size for the innermost station in Belfast Lough and the IS1 is that of fine sand. The outermost station (BL6) had a modal size corresponding to silt and station BL5 has characteristics of silt and medium sand.

The Relative Standard Deviations (RSD) are generally greater at the innermost station in Belfast Lough (BL3). When the grid for this station was plotted on an Admiralty Chart it was apparent that one corner point was on a mud bank near an old spoil ground with 21% fines less than 63µm while the opposite corner was close to the shipping channel, which is subject to periodic dredging.

This location had 3.9% fines less than 63µm. This area is consequently a poor choice for the National Monitoring Programme. The organic carbon content for all stations ranged from 0.23 to 2.4% with a mean value of 1.3%.

The particle size distribution of the sediments at the three Offshore stations and the Intermediate station reflects the local tidal regimes of each area. IS2 is an area of slack tides at the edge of a major circulatory "gyre" system and as such is an area of poorly sorted very fine sands with a high silt/clay content. The other sites range from clean fine sands at IS1 to coarse sand/gravel at NC2 the latter reflecting the strong tides in the North Channel. The particle size data suggests that IS2 may be a depositional area whereas the other stations generally have an erosional substrate to a greater or lesser extent.

Organic carbon at the Offshore stations shows little variation although the mean values at NC1 tend to be lower, but all lie within the range normally associated with offshore marine sediments (Degens and Mopper, 1976).

Trace metals in marine sediments are associated with the fine grained aluminosilicates, a major constituent of which is aluminium. For this reason aluminium is often used as a normaliser, and the metal to aluminium ratios are examined. Uncontaminated sediments show low ratios, while unusually high metal to aluminium ratios indicate anthropogenic inputs.

Reference metal to aluminium ratios for uncontaminated sediments were taken from Kersten *et al.*, (1994) and enrichment factors (EF) were calculated using the expression:

$$EF = \frac{[M/Al]\ obs}{[M/Al]\ ref}$$

where [M/Al] obs and [M/Al] ref. are the observed and reference values of the metal (mg/kg) to aluminium (%) ratio respectively. The reference values used for As, Cu, Cr, Cd, Hg, Ni, Pb and Zn were 2.33, 3.87, 13.9, 0.021, 0.0105, 6.73, 4.47 and 17.8 respectively.

The results of the EF calculations are presented in Figure 8.1.1 as area proportional symbols giving an assessment of the degree of contamination at each site.

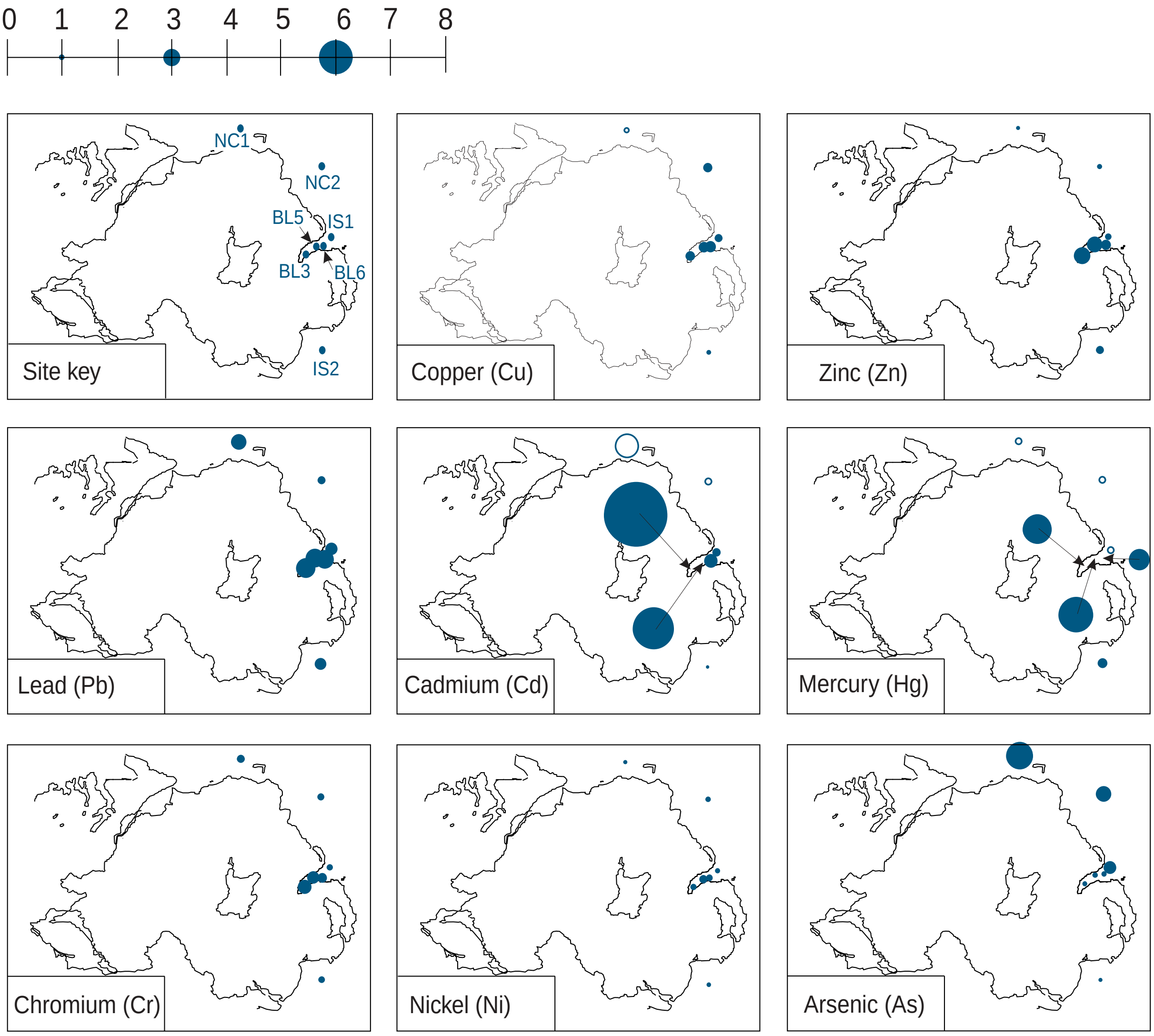
'Less than' values were taken as being equal to the limit of detection. The symbol representing the EF was then left open to indicate the assumption made.

With the exceptions of cadmium and mercury at the two innermost stations in Belfast Lough, the metal enrichment factors are less than 3. The cadmium and mercury inputs have probably arisen from historical industrial sources. Phosphate rock from Senegal which was known to contain both cadmium and mercury was historically imported into Belfast for an industrial process within the harbour area.

The apparently high enrichment factors for the North Coast station (NC1) for cadmium and arsenic may be attributable to the very low aluminium content of the sediments at that location.

The relatively high aluminium content at the Dundrum Bay station (IS2) indicates that it is an area where sedimentation occurs. The metal concentrations found are generally higher than at the other Offshore stations, and also higher for some metals than at the outermost station in Belfast Lough (BL6).

FIGURE 8.1.1. NMP 1993 - Metal enrichment factors.



Note: Open circles indicate that a maximimum concentration (rather than an actual concentration) of a particular metal was recorded (e.g. <0.25 rather than 0.25).

8.2. Organic Compounds in Sediments

Most of the determinands were at low concentrations and close to the detection limits.

Generally, the positive results were at the two innermost stations in Belfast Lough.

No detections were made at the Intermediate or Offshore stations except for two of the DDT isomers which were just above the detection limits at station IS2. This is perhaps more evidence that this is an area of sedimentation.

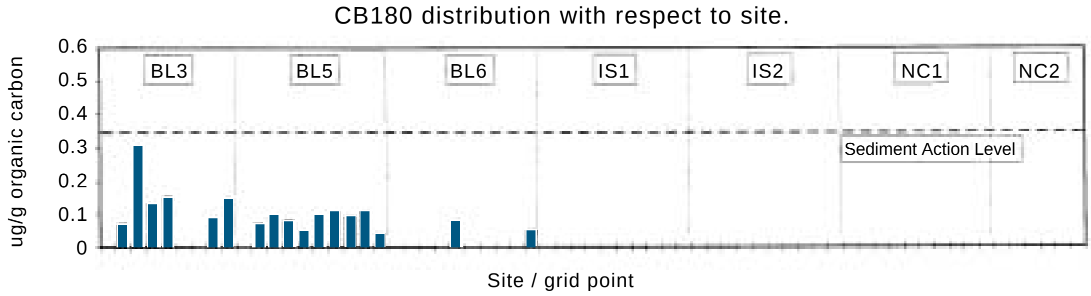
In Belfast Lough, the three major PCB congeners detected were 138, 153 and 180. These have been normalised to organic carbon and compared to the proposed Sediment Action Levels of the Group Co-ordinating Sea Disposal Monitoring by the Task Team on Organics which studied monitoring nationally during the period 1989-1994 (CEFAS,1997). The Task Team endeavoured to devise environmental quality standards based on the equilibrium partitioning (EP) approach. The term "Sediment Action Level" was considered more appropriate because of the limitations of the EP approach. If sediment actions levels are exceeded, the restriction of further inputs may be required accompanied by more detailed investigations.

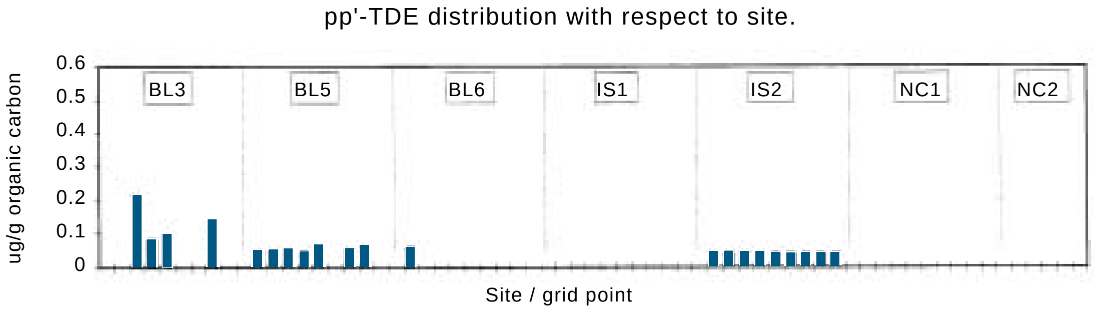
An advantage of the EP approach is that it takes account of organic carbon levels. If the determinands are expressed as µg/g of organic carbon the Sediment Action Levels are:

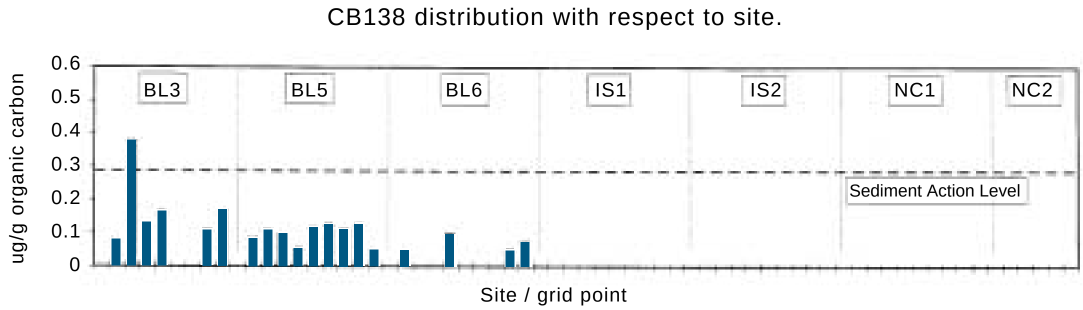
- PCB 138 0.292,
- PCB 153 0.474 and
- PCB 180 0.348.

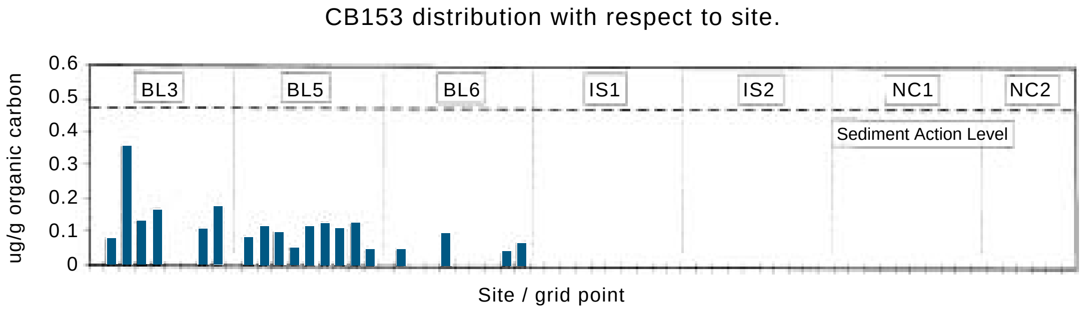
There was considerable variation around the grid at the innermost Belfast Lough station BL3. This reflects the stations proximity to the dredged channel.

FIGURE 8.2.1 The distribution of PCB congeners normalised to organic carbon at NMP stations.









8.3. Variability within the sampling grids for individual sites

The variability of a determinand within a grid for an individual site can be assessed using Table 8.1.1 and Figures 8.3.1 and 8.3.2. The variability was particularly apparent for the two innermost stations in Belfast Lough (BL3 and BL5). This can be seen by the high relative standard deviations (RSD%) for copper, cadmium, mercury and zinc for BL3 in Table 8.1.1. The variability generally decreases from BL5 to BL6. The Box and Whisker plots (Figure 8.3.1) show the variability at and between the Belfast Lough stations for three selected metals and the silt/clay components.

At sites other than BL3 and BL5 uniformity is generally good with some randomness where the metal concentrations are low. This information shows which sites are reasonably uniform and suitable for use in future studies. It also shows whether sampling on a 9 point grid at selected sites can be discontinued with the consequent increase in cost effectiveness.

The site at Dundrum Bay appears quite uniform and would be a suitable site for future work. The innermost site in Belfast Lough (BL3), however, straddles a mud bank and the dredged shipping channel and hence is very variable. To be more useful it should be re-located within the inner Lough or combined with BL5 as both sites reflect the input of contaminants.

FIGURE 8.3.1. Multiple Box-and-Whisker Plot for % silt/clay component.

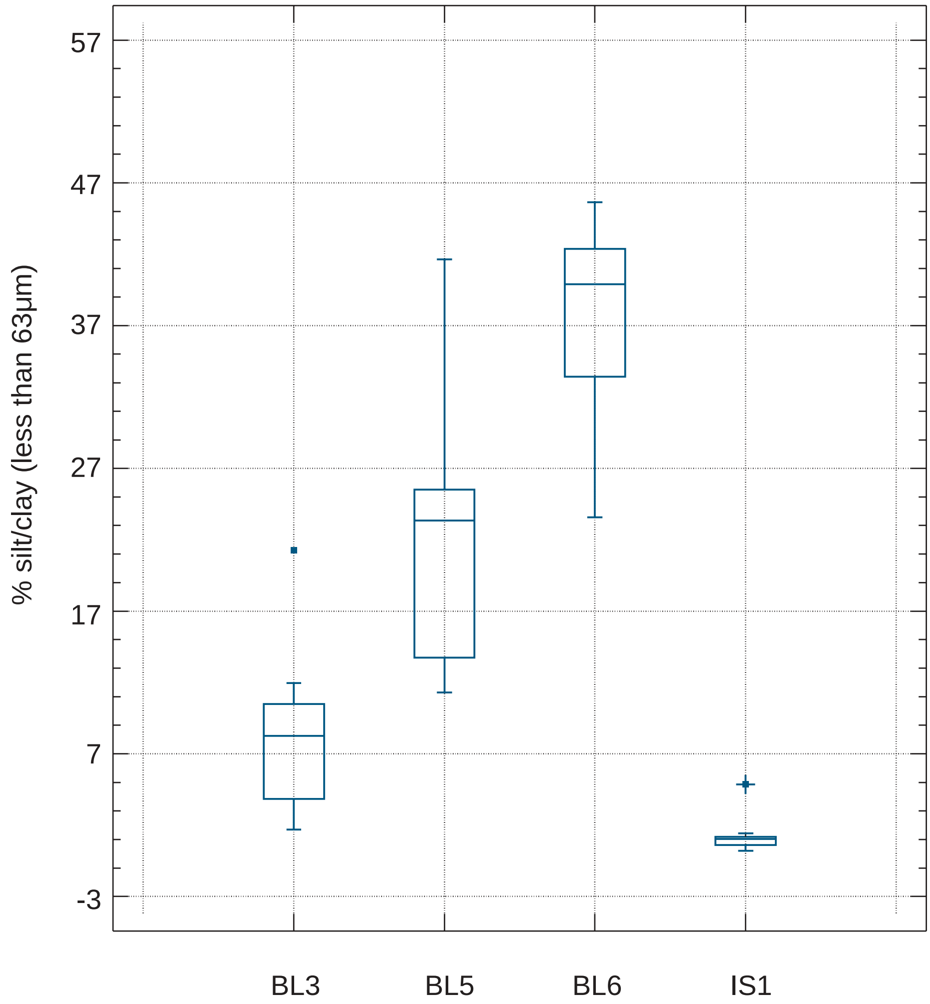
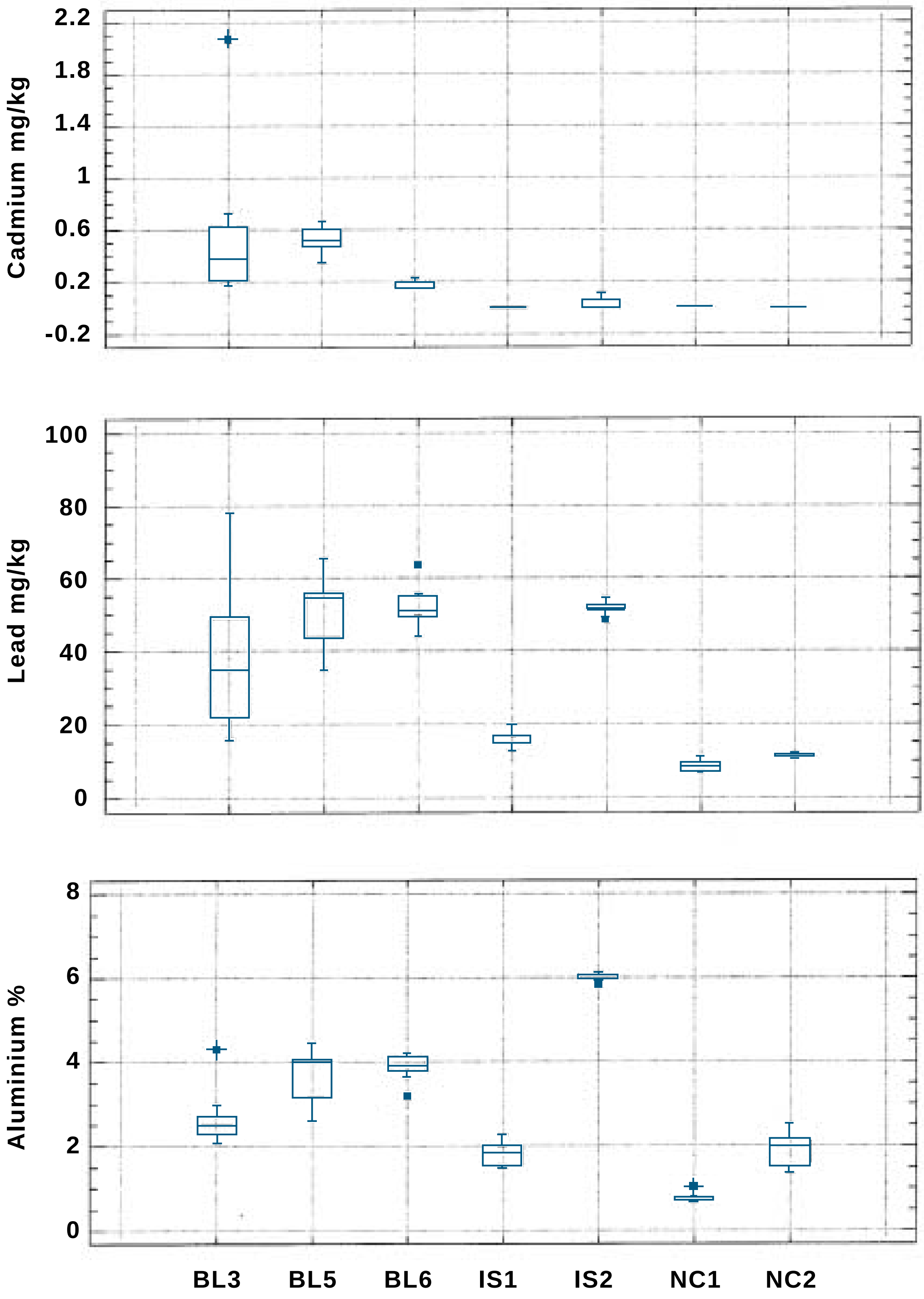


FIGURE 8.3.2. Multiple Box-and-Whisker Plot for Selected Metals.



9 Conclusions

The data set collected for this programme is large and varied and is especially valuable in that there is a full quality control programme associated with it. The following is not an attempt at a full analysis but is a synopsis of the main points.

9.1. Benthos

The two outer Belfast Lough stations exhibit the highest diversity with high numbers of taxa and individuals and high biomass. However, both of these stations have low evenness indicative of some stress. Organisms from these sites also tend to be small. The Intermediate and Offshore stations have a high evenness and are more stable. The lower diversity is primarily a function of the seabed substratum.

The degree of similarity between replicates observed in the dendrogram (Figure 4.6) would suggest that for this type of survey, some of the nine replicates are surplus to requirements.

Performing the Multi Dimensional Scaling on Estuarine stations as distinct from the Offshore stations with the Intermediate station as a link, has shown the weakness in performing the technique globally on all sites and replicates. Figure 4.9 shows that it is possible to compare directly the two differing station types after pooling the replicates. When certain environmental variables such as lead, copper, cadmium, chromium and nickel are overlaid on the biological groupings in Belfast Lough as determined by the MDS plot (Figure 9.1), a clear trend of decreasing contamination is evident moving seawards. The plot of mean particle size data shows that this trend is independent of sediment type. The figures also show the variability of the metal data at each site as evidenced by the differing size of circles at each cluster of replicates.

9.2. Biological Effects

The dogwhelk population of Belfast Lough clearly shows the Imposex phenomenon. This is not wholly surprising since Belfast Lough is one of the busiest shipping channels in the UK, and the ban on the sale of TBT-based paints only applies to vessels under 25m length at present. However, there are also ‘hot spots’ in the Lough which may be associated with small boat activities.

The occurrence of Imposex at intertidal sites adjacent to the Intermediate and Offshore stations did not appear to be significantly higher than at the control station with the exception of IS2. Here the number of dogwhelks showing Imposex was approximately twice that of any other Intermediate/ Offshore station. This may be related again to shipping/fishing vessel movements compounded by the low tidal range/dispersion in the area.

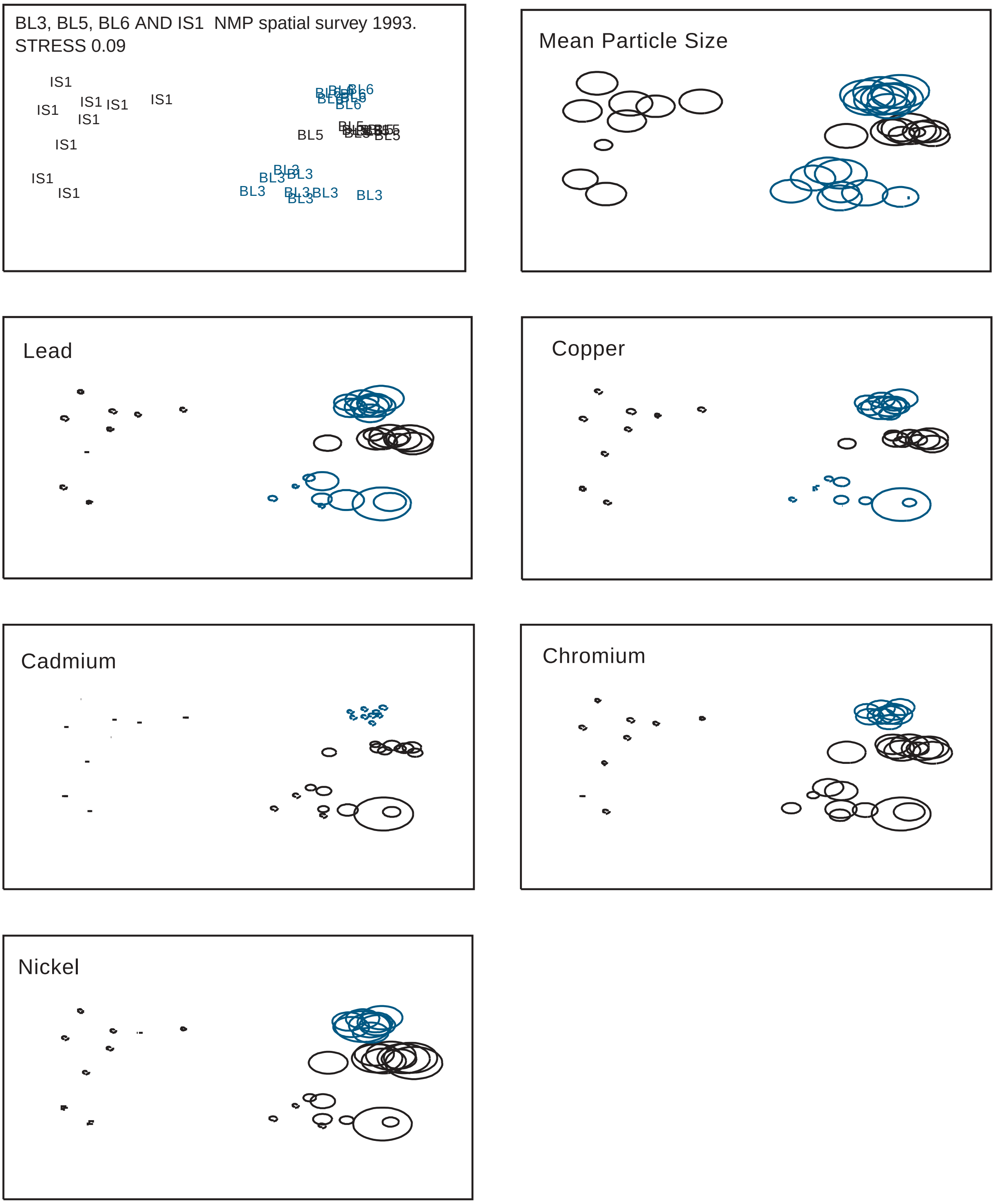
The Oyster Embryo Bioassay technique is currently applied only to NMP samples within the EHS and DANI marine monitoring programmes in Northern Ireland. The perfomance of the control embryos was poor during 1995 and there is little confidence in the results produced on this occasion. Further use of the technique may improve confidence in this test. Local production of embryos may reduce physical stresses on the organisms and improve confidence in the method.

9.3. Contaminants in Water, Sediments and Biota

Generally the concentrations found did not exceed UK EQSs for dangerous substances. For mercury, analytical quality control and interlaboratory studies have been progressing nationally in recent years, and the laboratory has participated in this since late 1995. However, the analytical methodology still fails to produce satisfactory results at low environmental concentrations, <1 to 10ng/l.

The fish species recommended in the Plan presented one of the main problems encountered when examining bioaccumulation of contaminants through the trophic levels. Dab were found regularly at only one station (IS2), intermittently at IS1 and were not found at the other Offshore stations. The

FIGURE 9.1. Environmental Data Superimposed on to the MDS Ordination of Estuarine Sites and the Intermediate Site. Elipses are proportional to concentration.



catches of flounder in Belfast Lough were also limited. The scarcity of these species in Northern Ireland waters poses a question as to their suitability as indicators for the Plan. However, these remain the accepted species in international monitoring programmes.

There is evidence that IS2 is an area of deposition and is acting as a sink for contaminants. This is consistent with the physical oceanography of the area which has weak tidal currents and stratifies during the summer (*Gowen et al.,* 1995). The existence of a circulatory gyre in this region has been demonstrated by Hill *et al.,* (1994).

9.3.1. Intermediate and Offshore Stations

Most metal concentrations were consistently higher in both water and sediments at IS2 than at other stations. The exceptions were nickel in seawater and arsenic and cadmium in sediments.

This is reflected in the biota where metal concentrations in dab were consistently higher at IS2 than at IS1, although this observation is based on a limited data set.

Concentrations of organochlorines and PCBs in sediments were always close to the limits of detection. However, ppTDE was detected at IS2. This was consistent with the biota results. Dieldrin, ppTDE, ppDDE, ppDDT, CB138 and CB153 were detected at both IS1and IS2. Concentrations observed were close to the limits of detection but were consistently higher at IS2. In addition, endrin, CB28, CB118 and CB180 were detected at IS2.

9.3.2. Belfast Lough Stations

At the Belfast Lough stations, the percentage of fine materials (<63µm) increases seawards. BL3 is on the edge of the shipping channel which is regularly dredged. Consequently metal concentrations in sediments are higher at BL5 and BL6 than at BL3. This may be due to the removal of material including fines by dredging through BL3, physically removing sediment which is richer in metal content. Generally the positive results for organic compounds in sediments were at the two innermost stations and the concentrations were low.

The gradients of metals in biota throughout the Lough are weak. However, on examining long term mussel data sets from Belfast Lough, it is evident that both cadmium and mercury concentrations have been decreasing over the last two decades.

The only organochlorine substance above the limit of dectection in seawater was γHCH (lindane) at the Belfast Lough stations. ppDDE was detected in the common mussels and flounder in Belfast Lough and the horse mussel at IS1. Dieldrin was detected in both the common mussel at BL3 and the flounder at BL3 and BL5.

10 Recommendations

- BL3 should be relocated outside the influence of the shipping channel.
- For seawater sampling of contaminants, one site in Belfast Lough is sufficient to represent the high salinity band.
- The monitoring of benthic populations in the outer Belfast Lough stations should be continued. Research into the possible stresses evident in this environment should be undertaken.
- Imposex data should be correlated with actual TBT/organotin concentrations in sediments and shellfish tissue. Temporal trends of imposex in dogwhelks should be assessed to ascertain whether the high RPSIs in Belfast Lough are due to an historical problem.
- Further development of the Oyster Embryo Bioassay needs to be undertaken locally before the technique may be used with confidence.
- Whole sediment toxicity testing should be considered for future monitoring.
- A statistical assessment of the number of samples required at each station type should be undertaken for the Northern Ireland data.
- The suitability of dab as an indicator at Intermediate and Offshore stations should be assessed once the UK NMP database is collated.
- IS2 should be adopted as a station for further work and should be included in future NMP studies.
- Monitoring of γHCH should be continued in seawater from Belfast Lough.
- The station on the North Coast (NC1) generally represents a different body of seawater from the Irish Sea being influenced by the North Atlantic, and as such should be maintained for future NMP studies as a remote station.
- Quality control systems for biological effects monitoring should be developed.

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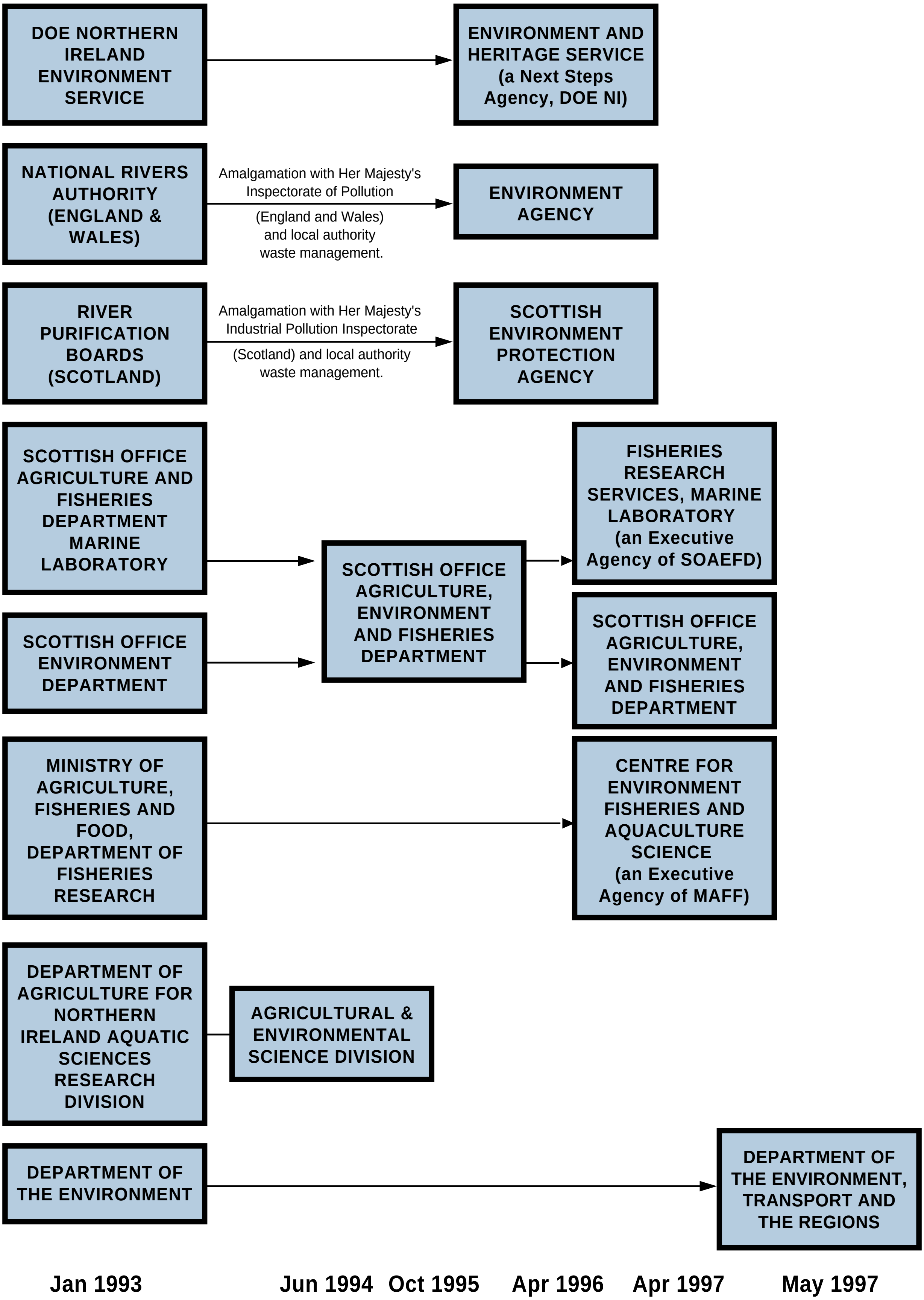
12 Appendices

12.1. APPENDIX I Organisation Chart.



12.2. APPENDIX II Locations of Northern Ireland NMP Stations.

Code	Location	NMP No.	Type	Monitoring Authority	Lat.	Long.
BL3	Belfast Lough	835	E	DOE(NI)	54° 38.69N	05° 52.10W
BL5	Belfast Lough	845	E	DOE(NI)	54° 40.10N	05° 48.40W
BL6	Belfast Lough	855	E	DOE(NI)	54° 42.35N	05° 42.50W
IS1	Belfast Lough	825	I	DOE(NI)	54° 44.00N	05° 36.00W
IS2	Dundrum Bay	815	O	DANI	54° 04.00N	05° 30.00W
NC1	North Coast	875	O	DANI	55° 20.00N	06° 35.00W
NC2 1993	North Channel	865	O	DANI	55° 04.99N	05° 53.12W
NC2 1994-	North Channel	865	O	DANI	54° 03.96N	05° 30.00W

Type E - Estuarine
I - Intermediate
O - Offshore

12.3. APPENDIX III Species List.

Phylum	Class	Species
CNIDARIA	HEXACORALLIA	EDWARSIIDAE spp. juv.
	HEXACORALLIA	HEXACORALLIA sp.
	HEXACORALLIA	ACTINIIDAE sp.
	HEXACORALLIA	Halcampa chrysanthellum
NEMERTEA	NEMERTEA	NEMERTEA sp.
	NEMERTEA	NEMERTEA sp. A
	NEMERTEA	NEMERTEA sp. B
	ANOPLA	Cerebratulus sp.
NEMATODA	ADENOPHOREA	Nematode sp.
PRIAPULIDA	PRIAPULIDAE	Priapulus spp. juv.
SIPUNCULA	SIPUNCULIDEA	Golfingia procera
ANNELIDA	POLYCHAETA	APHRODITIDAE spp. juv.
	POLYCHAETA	Aphrodita aculeata
	POLYCHAETA	Gattyana cirrosa
	POLYCHAETA	Harmothoe imbricata
	POLYCHAETA	Harmothoe impar
	POLYCHAETA	Harmothoe lunulata
	POLYCHAETA	Harmothoe marphysae
	POLYCHAETA	Lepidonotus squamatus
	POLYCHAETA	Panthalis oerstedi
	POLYCHAETA	Pholoe inornata
	POLYCHAETA	Sthenelais boa
	POLYCHAETA	Sthenelais limicola
	POLYCHAETA	Eteone foliosa
	POLYCHAETA	Eteone cf. longa
	POLYCHAETA	Eteone flava
	POLYCHAETA	Eteone picta
	POLYCHAETA	Anaitides groenlandica
	POLYCHAETA	Anaitides longipes
	POLYCHAETA	Anaitides mucosa
	POLYCHAETA	Anaitides subulifera
	POLYCHAETA	Eulalia viridis
	POLYCHAETA	Eilalia ornata
	POLYCHAETA	Eumida bahusiensis
	POLYCHAETA	Glycera sp.
	POLYCHAETA	Glycera rouxii
	POLYCHAETA	Glycera oxycephala
	POLYCHAETA	Glycera alba
	POLYCHAETA	Glycera lapidum
	POLYCHAETA	Goniada maculata
	POLYCHAETA	Sphaerodorum gracilis
	POLYCHAETA	Gyptis capensis
	POLYCHAETA	Kefersteinia cirrata
	POLYCHAETA	Nereimyra punctata
	POLYCHAETA	Ophiodromus flexuosus
	POLYCHAETA	Syllidia armata
	POLYCHAETA	Langerhansia cornuta
	POLYCHAETA	Typosyllis armillaris
	POLYCHAETA	Typosyllis sp.
	POLYCHAETA	Ancistrosyllis groenlandica
	POLYCHAETA	Exogone naidina
	POLYCHAETA	Exogone verugera
	POLYCHAETA	Sphaerosyllis tetralix
	POLYCHAETA	Sphaerosyllis taylori
	POLYCHAETA	Sphaerosyllis bulbosa
	POLYCHAETA	Autolytus spp.indet.
	POLYCHAETA	Neanthes virens
	POLYCHAETA	Aglaophamus rubella
	POLYCHAETA	Nephtys cirrosa
	POLYCHAETA	Nephtys hombergii
	POLYCHAETA	Nephtys kersivalensis
	POLYCHAETA	Nephtys incisa

Phylum	Class	Species
ANNELIDA	POLYCHAETA	Nephtys assimilis
	POLYCHAETA	Nephtys paradoxa
	POLYCHAETA	Nephtys ciliata
	POLYCHAETA	Nephtys spp. juv./indet.
	POLYCHAETA	Nematonereis unicornis
	POLYCHAETA	Lumbrineris gracilis
	POLYCHAETA	Lumbrineris scopa
	POLYCHAETA	Lumbrineris latreilli
	POLYCHAETA	Lumbrineris sp.
	POLYCHAETA	Arabella iricolor
	POLYCHAETA	Ophryotrocha sp. indet.
	POLYCHAETA	Parougia caeca
	POLYCHAETA	Protodorvillea kefersteini
	POLYCHAETA	Scoloplos armiger
	POLYCHAETA	Paraonis fulgens
	POLYCHAETA	Levinsenia gracilis
	POLYCHAETA	Paradoneis lyra
	POLYCHAETA	Aonides oxycephala
	POLYCHAETA	Aonides paucibranchiata
	POLYCHAETA	Malacoceros fuliginosus
	POLYCHAETA	Polydora caulleryi
	POLYCHAETA	Polydora ciliata
	POLYCHAETA	Polydora flava/caeca
	POLYCHAETA	Polydora quadrilobata
	POLYCHAETA	Prionospio multibranchiata
	POLYCHAETA	Scolelepis squamata
	POLYCHAETA	Spio spp. indet.
	POLYCHAETA	Spio armata
	POLYCHAETA	Spio decorata
	POLYCHAETA	Spio filicornis
	POLYCHAETA	Spiophanes bombyx
	POLYCHAETA	Magelona minuta
	POLYCHAETA	Magelona mirabilis
	POLYCHAETA	Caulleriella alata
	POLYCHAETA	Caulleriella killariensis
	POLYCHAETA	Caulleriella zetlandica
	POLYCHAETA	Chaetozone sp.
	POLYCHAETA	Chaetozone setosa
	POLYCHAETA	Cirratulus cirratus
	POLYCHAETA	Cirriformia tentaculata
	POLYCHAETA	Dodecaceria sp. indet.
	POLYCHAETA	Tharyx marioni
	POLYCHAETA	Monticellina
	POLYCHAETA	Cossura longocirrata
	POLYCHAETA	Diplocirrus glaucus
	POLYCHAETA	Pherusa plumosa
	POLYCHAETA	Capitella spp. indet.
	POLYCHAETA	Cappitellides giardi
	POLYCHAETA	Dasybranchus caducus
	POLYCHAETA	Mediomastus fragilis
	POLYCHAETA	Notomastus latericeus
	POLYCHAETA	Notomastus spp.
	POLYCHAETA	Clymenura borealis
	POLYCHAETA	Euclymene spp. indet.
	POLYCHAETA	Euclymene oerstedii
	POLYCHAETA	Nicomache personata
	POLYCHAETA	Praxillella spp. indet.
	POLYCHAETA	Ophelina modesta
	POLYCHAETA	Ophelina acuminata
	POLYCHAETA	Polyphysia crassa
	POLYCHAETA	Scalibregma inflatum
	POLYCHAETA	Myriochele oculata
	POLYCHAETA	Owenia fusiformis
	POLYCHAETA	Lagis koreni
	POLYCHAETA	AMPHARETIDAE spp.juv.
	POLYCHAETA	Melinna palmata

Phylum	Class	Species
ANNELIDA	POLYCHAETA	Ampharete lindstroemi
	POLYCHAETA	Terebellides stroemi
	POLYCHAETA	Terebellides sp.
	POLYCHAETA	Trichobranchus roseus
	POLYCHAETA	AMPHITRITINAE sp.juv.
	POLYCHAETA	Lanice conchilega
	POLYCHAETA	Neoamphitrite figulus
	POLYCHAETA	Pista cristata
	POLYCHAETA	Polycirrus norvegicus
	POLYCHAETA	Polycirrus sp. A
	POLYCHAETA	Amphicteis gunneri
	POLYCHAETA	SABELLIDAE sp. indet.
	POLYCHAETA	Sabellaria spinulosa
	POLYCHAETA	Branchiomma bombyx
	POLYCHAETA	Chone spp. juv.
	POLYCHAETA	Euchone rubrocincta
	POLYCHAETA	Euchone papillosa
	POLYCHAETA	Laonome kroyeri
	POLYCHAETA	Pomatoceros lamarcki
	POLYCHAETA	Serpula vermicularis
	POLYCHAETA	Thelepus cincinnatus
	OLIGOCHAETA	Tubificoides sp. indet.
	OLIGOCHAETA	Tubificoides amplivasatus
	OLIGOCHAETA	Tubificoides benedii
	OLIGOCHAETA	Tubificoides pseudogaster
	OLIGOCHAETA	Tubificoides swirencoides
	OLIGOCHAETA	Tubificoides insularis
		Limnodriloides winckelmanni
CHELICERATA	PYCNOGONIDA	Anoplodactylus petiolatus
		Mysid
CRUSTACEA	OSTRACODA	CYPRIDINIDAE sp. A
	OSTRACODA	CYPRIDINIDAE sp. B
	MALACOSTRACA	Nebalia herbstii
	EUMALACOSTRACA	AMPHIDPODA indet
	EUMALACOSTRACA	Perioculodes longimanus
	EUMALACOSTRACA	Synchelidium maculatum
	EUMALACOSTRACA	Amphilochus neapolitanus
	EUMALACOSTRACA	Gitana sarsi
	EUMALACOSTRACA	Leucothoe spinicarpa
	EUMALACOSTRACA	Leucothoe incisa
	EUMALACOSTRACA	Urothoe elegans
	EUMALACOSTRACA	Harpinia antennaria
	EUMALACOSTRACA	Harpinia crenulata
	EUMALACOSTRACA	Harpinia pectinata
	EUMALACOSTRACA	Orchomene nana
	EUMALACOSTRACA	Tryphosites longipes
	EUMALACOSTRACA	Argissa hamatipes
	EUMALACOSTRACA	Iphimedia obesa
	EUMALACOSTRACA	Atylus falcatus
	EUMALACOSTRACA	Atylus vedlomensis
	EUMALACOSTRACA	Dexamine thea
	EUMALACOSTRACA	AMPELISCIDAE spp. indet.
	EUMALACOSTRACA	Ampelisca brevicornis
	EUMALACOSTRACA	Ampelisca diadema
	EUMALACOSTRACA	Ampelisca spinipes
	EUMALACOSTRACA	Ampelisca tenuicornis
	EUMALACOSTRACA	Ampelisca typica
	EUMALACOSTRACA	Bathyporeia elegans
	EUMALACOSTRACA	Bathyporeia tenuipes
	EUMALACOSTRACA	Bathyporeia sarsi
	EUMALACOSTRACA	Abludomelita obtusata
	EUMALACOSTRACA	Cheirocratus sundevalli
	EUMALACOSTRACA	Gammaropsis maculata
	EUMALACOSTRACA	Gammaropsis palmata
	EUMALACOSTRACA	Gammoropsis spp.

Phylum	Class	Species
CRUSTACEA	EUMALACOSTRACA	Megamphopus cornutus
	EUMALACOSTRACA	Microprotopus maculatus
	EUMALACOSTRACA	Photis longicaudata
	EUMALACOSTRACA	Photis reinhardi
	EUMALACOSTRACA	Ericthonius sp.
	EUMALACOSTRACA	Microjassa cumbrensis
	EUMALACOSTRACA	Aora gracilis
	EUMALACOSTRACA	Corophium bonnellii
	EUMALACOSTRACA	Corophium crassicorne
	EUMALACOSTRACA	Pariambus typicus
	EUMALACOSTRACA	Phtisica marina
	EUMALACOSTRACA	Gnathia sp. juv.
	EUMALACOSTRACA	Gnathia oxyuraea
	EUMALACOSTRACA	Pleurogonium rubicundum
	EUMALACOSTRACA	Arcturella dilatata
	EUMALACOSTRACA	Tanaidae sp.
	EUMALACOSTRACA	Tanaopsis graciloides
	EUMALACOSTRACA	Bodotria scorpioides
	EUMALACOSTRACA	Eudorella truncatula
	EUMALACOSTRACA	Pseudocuma longicornis
	EUMALACOSTRACA	Diastylis bradyi
	EUMALACOSTRACA	Diastylis laevis
	EUMALACOSTRACA	Diastylis rugosa
	EUMALACOSTRACA	Crangon allmanni
	EUMALACOSTRACA	Crangon crangon
	EUMALACOSTRACA	Hyperiid sp.
	EUMALACOSTRACA	Anapagurus laevis
	EUMALACOSTRACA	Pisidia longicornis
	EUMALACOSTRACA	Hyas araneus
	EUMALACOSTRACA	Hyas sp.
	EUMALACOSTRACA	Liocarcinus arcuatus
	EUMALACOSTRACA	Liocarcinus depurator
	EUMALACOSTRACA	Monodaeus couchi
	EUMALACOSTRACA	Carcinus maenas
	EUMALACOSTRACA	Calocaris macandreae
MOLLUSCA	CAUDOFOVEATA	Chaetoderma nitidulum
		Chiton sp.
	POLYPLACOPHORA	GASTROPODA sp. indet.
	GASTROPODA	Emarginula fissura
	GASTROPODA	Tectura testudinalis
	GASTROPODA	TROCHIDAE spp. indet.
	GASTROPODA	?Onoba semicostata
	GASTROPODA	Odostomia sp. indet.
	GASTROPODA	Mangelia coarctata
		OPISTHOBRANCHIA sp.
	GASTROPODA	Cylichna cylindracea
	GASTROPODA	Philine sp.
	GASTROPODA	Retusa truncatula
	GASTROPODA	Cuthona sp.
	SCAPHAPODA	Antalis entalis
	PELECYPODA	Goodallia triangularis
	PELECYPODA	Tridonta elliptica
	PELECYPODA	Nucula nitidosa
	PELECYPODA	Nucula nucleus
	PELECYPODA	Nucula sulcata
	PELECYPODA	Nuculana minuta
	PELECYPODA	Nuculoma tenuis
	PELECYPODA	Mytilacea sp.
	PELECYPODA	Modiolus modiolus
	PELECYPODA	?Lucinoma borealis
	PELECYPODA	Thyasira flexuosa
	PELECYPODA	Timoclea ovata
	PELECYPODA	Mysella bidentata
	PELECYPODA	Moerella pygmaea
	PELECYPODA	Parvicardium ovale
	PELECYPODA	Parvicardium scabrum

Phylum	Class	Species
MOLLUSCA	PELECYPODA	Spisula elliptica
	PELECYPODA	Phaxus pellucidus
	PELECYPODA	Tellinidae indet.
	PELECYPODA	?Arcopagia crassa
	PELECYPODA	Fabulina fabula
	PELECYPODA	Abra alba
	PELECYPODA	Abra prismatica
	PELECYPODA	Abra nitida
	PELECYPODA	VENERIDAE spp. juv./indet.
	PELECYPODA	Circomphalus casina
	PELECYPODA	Dosinia lupinus
	PELECYPODA	Dosinia exoleta
	PELECYPODA	Venerupis senegalensis
	PELECYPODA	MYACEA sp. juv.
	PELECYPODA	Mya truncata
	PELECYPODA	Sphenia binghami
	PELECYPODA	Corbula gibba
	PELECYPODA	Cuspidaria cuspidata
PHORONIDA	PHORONIDA	Phoronis muelleri
ECHINODERMATA	ASTEROIDEA	Asterias rubens
	ASTEROIDEA	Crossaster papposus
	ECHINOIDEA	Echinocyamus pusillus
	ECHINOIDEA	Brissopsis lyrifera
	ECHINOIDEA	Echinocardium flavescens
	ECHINOIDEA	Strongylocentrotus droebachiensis
	OPHIUROIDEA	OPHIUROIDEA sp. juv.
	OPHIUROIDEA	Ophiothrix fragilis
	OPHIUROIDEA	Amphiura chiajei
	OPHIUROIDEA	Amphiura filiformis
	OPHIUROIDEA	Amphipholis squamata
	OPHIUROIDEA	Ophiura albida
	OPHIUROIDEA	Ophiura ophiura
	HOLOTHURIOIDEA	Leptopentacta elongata
	HOLOTHURIOIDEA	Labidoplax buskii
CHORDATA	PLEUROGONA	PLEUROGONA sp.

12.4. APPENDIX IV SIMPER Analysis.

NUMBER OF SPECIES (ROWS) IN DATA SET = 137
NUMBER OF COLUMNS IN DATA SET = 59
NO SPECIES REDUCTION
SPECIES NAME FILE : C:\TMP\NMPRED.TXT

GROUP	SIZE	COLUMN NUMBERS
BL3	9	1-9
BL5	9	10-18
BL6	9	19-27
IS1	9	28-36
IS2	9	37-45
NC1	9	46-54
NC2	5	55-59

DOUBLE SQUARE-ROOT TRANSFORMATION
BRAY-CURTIS SIMILARITY
Value for percentage cutoff = 100.0
Only the top 10 species printed

BL3 AVERAGE SIMILARITY = 56.00

SPECIES		AV.ABUNDANCE	AVERAGE	RATIO	PERCENT	CUM %
Nepht spp.	**26**	20.22	5.9	1.97	10.54	10.54
Tubif bene	**72**	223.56	5.8	2.56	10.31	20.86
Nepht homb	**22**	10.56	5.4	3.01	9.64	30.50
Abra alba	**127**	6.00	4.9	4.57	8.70	39.20
Mysel bide	**124**	9.44	4.8	5.38	8.51	47.71
Pholo inor	**7**	43.44	4.6	4.70	8.22	55.94
Sphen bing	**131**	2.78	4.0	2.90	7.15	63.09
Medio frag	**54**	12.00	3.7	1.73	6.59	69.67
Tubif pseu	**73**	6.67	3.3	1.70	5.94	75.61
Tubif swir	**74**	9.00	2.0	0.75	3.61	79.22

BL5 AVERAGE SIMILARITY = 69.27

SPECIES		AV.ABUNDANCE	AVERAGE	RATIO	PERCENT	CUM %
Mysel bide	**124**	451.89	3.3	10.94	4.82	4.82
Medio frag	**54**	175.22	2.6	7.08	3.69	8.51
Pholo inor	**7**	158.00	2.5	7.80	3.58	12.10
Cirri tent	**49**	414.78	2.3	2.21	3.31	15.41
Ampel tenu	**90**	117.56	2.3	6.48	3.30	18.71
Ampha lind	**64**	81.56	2.1	11.52	3.09	21.80
Vener sene	**130**	95.56	2.0	3.57	2.83	24.63
Abra alba	**127**	52.78	1.9	10.40	2.81	27.44
Parvi scab	**125**	53.89	1.9	8.19	2.80	30.23
Tubif swir	**74**	73.22	1.8	2.85	2.56	32.79

BL6 AVERAGE SIMILARITY = 71.75

SPECIES		AV.ABUNDANCE	AVERAGE	RATIO	PERCENT	CUM %
Ampha lind	64	244.22	5.1	8.89	7.06	7.06
Nucul niti	118	99.44	3.6	7.41	5.01	12.07
Melin palm	63	60.78	3.6	7.96	4.98	17.06
Photi long	99	37.78	3.0	8.92	4.23	21.29
Phoro muel	133	32.44	2.7	4.87	3.77	25.06
Ampel spin	89	26.00	2.7	7.01	3.76	28.81
Ampel diad	88	26.33	2.6	6.36	3.64	32.45
Levin grac	34	44.56	2.6	5.20	3.62	36.07
Mysel bide	124	20.44	2.5	7.23	3.50	39.57

IS1 AVERAGE SIMILARITY = 38.29

SPECIES		AV.ABUNDANCE	AVERAGE	RATIO	PERCENT	CUM %
Scolo armi	33	6.00	11.2	1.51	29.36	29.36
Abra pris	128	1.56	6.0	1.05	15.70	45.07
Amphi fili	134	3.33	3.6	0.82	9.40	54.47
Nepht spp.	26	1.00	3.2	0.79	8.45	62.91
Bathy eleg	92	1.56	2.6	0.60	6.86	69.78
Sthen limi	9	0.67	2.1	0.59	5.58	75.35
Prion malm	42	1.33	2.0	0.60	5.24	80.59
Magel mira	44	0.67	1.3	0.44	3.50	84.09
Nucul tenu	120	0.67	1.2	0.43	3.19	87.28
Chaet seto	47	0.89	1.2	0.44	3.07	90.35

IS2 AVERAGE SIMILARITY = 33.24

SPECIES		AV.ABUNDANCE	AVERAGE	RATIO	PERCENT	CUM %
Lumbr latr	28	3.78	11.4	0.80	34.29	34.29
Glycera sp	16	0.56	6.1	0.61	18.26	52.55
Nepht cili	25	2.11	4.1	0.42	12.32	64.87
Nepht spp.	26	1.67	3.1	0.30	9.41	74.28
Monticelli	52	0.78	2.9	0.44	8.81	83.09
Lumbr sp.	29	0.67	2.3	0.30	6.92	90.01
Abra alba	127	2.22	2.2	0.30	6.64	96.65
Nepht inci	24	1.00	0.6	0.17	1.93	98.58
AMPHI inde	79	0.33	0.5	0.17	1.42	100.00

NC1 AVERAGE SIMILARITY = 36.79

SPECIES		AV.ABUNDANCE	AVERAGE	RATIO	PERCENT	CUM %
Spisu elli	126	2.67	13.7	1.50	37.22	37.22
Gooda tria	117	13.11	13.2	1.05	35.85	73.06
Timoc ovat	123	2.00	4.1	0.60	11.19	84.25
Nucul nucl	119	1.78	4.0	0.59	10.99	95.25
Scolo armi	33	0.22	0.5	0.17	1.24	96.48
Ampel spin	89	0.22	0.3	0.17	0.94	97.43
AMPHA spp.	62	0.56	0.3	0.17	0.89	98.32
Scali infl	58	0.22	0.3	0.17	0.88	99.20

NC2 AVERAGE SIMILARITY = 37.19

SPECIES		AV.ABUNDANCE	AVERAGE	RATIO	PERCENT	CUM %
Chiton sp.	114	8.40	12.6	1.05	33.84	33.84
Nucul tenu	120	9.00	7.7	1.09	20.68	54.51
Glycera sp	16	1.20	7.4	1.05	19.84	74.35
Aonid pauc	36	2.00	7.0	1.06	18.94	93.29
AMPHI inde	79	0.80	0.8	0.32	2.24	95.53
Scali infl	58	0.60	0.8	0.32	2.24	97.76

12.5. APPENDIX V.

	IGR	NMP Station
Cultra	J413811	BL3
Ross's Rock	J357822	BL3
Swineley Point	J470825	BL5
Helen's Bay	J459832	BL5
Quay (Carrickfergus)	J421878	BL6
Smelt Mill Bay	J491823	BL6
Sandy Bay	J566829	IS1
Cloghfin Port	J486940	IS1
Dunseverick Harbour	C995445	NC1
Giants Causeway	C946447	NC1
Portballintrae	C925420	NC1
Red Arch (Waterfoot)	D244262	NC2
Port Obe (Cushendall)	D248289	NC2
Fallowvee (Waterfoot)	D280254	NC2
Cranfield Point	J268103	IS2
Bloody Bridge	J391272	IS2
Wreck Port (Annalong)	J369186	IS2

12.6. APPENDIX VI.

Limits for Certain Dangerous Substances to satisfy the Dangerous Substances Directive (76/464/EEC) and the Shellfish Waters Directive (79/923/EEC).

Metals	Guideline Value mg/kg dry flesh	Imperative Value mg/kg dry flesh
Cadmium	5	15
Mercury	1	3
Lead	15	50
Zinc	3,000	10,000
Organics	**Guideline Value ng/g wet flesh**	**Imperative Value ng/g wet flesh**
Dieldrin	15	50
DDE	30	100
total PCBs	300	1,000

Designed by DANI Media Services.

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