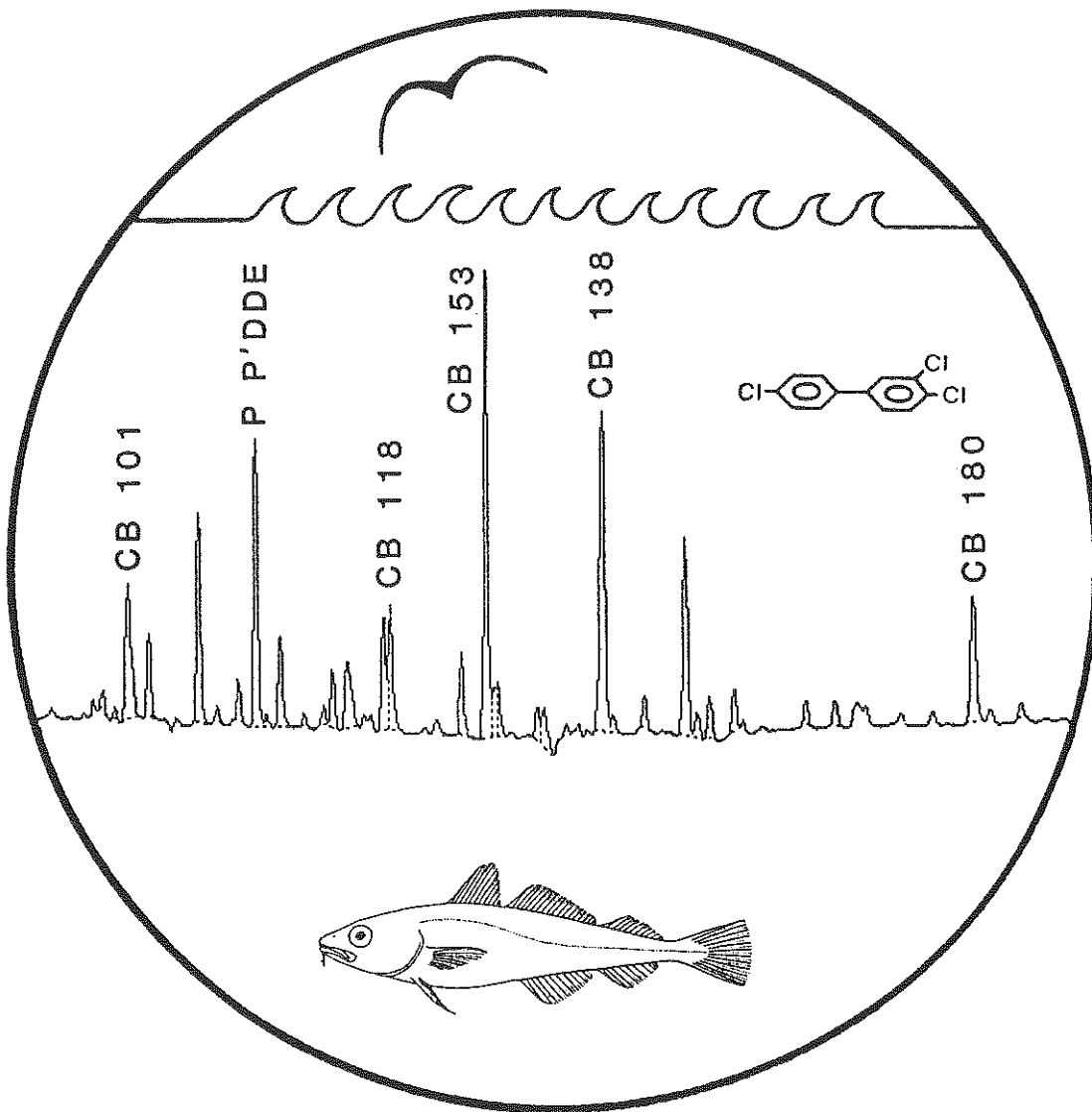


# Fisheries Bulletin No. 10 (1991)



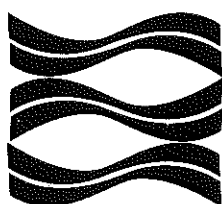
M.P. O'Sullivan, E.R. Nixon, D. McLaughlin, Ml. O'Sullivan and D. O'Sullivan

CHEMICAL CONTAMINANTS IN IRISH ESTUARINE AND  
COASTAL WATERS, 1978 TO 1988.



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**Roinn na Mara**  
**(Department of the Marine)**

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COASTAL WATERS 1978 TO 1988**

by

M.P. O'Sullivan, E.R. Nixon, D. McLaughlin,  
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Chemical contaminants in Irish estuarine and coastal waters,  
1978 to 1988.

by

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**ABSTRACT**

Observations on the concentrations of heavy metals (mercury, cadmium, copper, lead and zinc) and chlorinated hydrocarbons (PCBs and the pesticides, lindane, dieldrin, DDTs and chlordanes) are presented. Sources comprise mussels and oysters from twenty six estuarine and coastal locations and in fin fish landed from all coasts. Data on heavy metals and nutrients in sea water and heavy metals in sediments for nine estuaries are also reported.

Data were collected to comply with the Joint Monitoring Programme of the Oslo and Paris Commissions and with the Cooperative Monitoring Programme of the International Council for the Exploration of the Sea.

The locations sampled included Boyne estuary, Dublin Bay, Wexford Harbour, Barrow estuary, Waterford Harbour, Cork Harbour, Bandon estuary, Tralee Bay, Shannon estuary, Clarinbridge, Kilkieran Bay, Clew Bay, Killary Harbour and Mulroy Bay.

Four cases of elevated concentrations of cadmium, two each of copper, zinc and mercury and one of lead are reported. The general overall temporal trend in metal levels has been of stability or, in the case of more marked contamination, of reduction. The degree of organochlorine contamination was low in all the estuaries and shellfish growing areas monitored. No instances of contamination exceeding tolerance levels in shellfish and fin fish for human consumption were recorded. With very few exceptions, it was found that Irish coastal waters enjoyed exceptionally low levels of contamination.

**INTRODUCTION**

In 1975, the Department of Agriculture and Fisheries initiated a programme to monitor pollution with particular emphasis on the marine environment. The purpose of this programme has been to:

- i) ensure the quality of marine foodstuffs,
- ii) identify and monitor potential sources of pollution,
- iii) provide information on the state of the marine environment with a view to determining the spatial distribution and temporal trends of contaminants and to provide and renew baseline information for assessments of environmental quality including environmental impact studies, and
- iv) meet Ireland's international obligations under the Oslo and Paris Conventions, effective nationally under the Dumping at Sea Act, 1981 and the Water Pollution Act, 1977 respectively and to meet national obligations under fisheries legislation in the Fisheries (Consolidation) Act, 1959 and its amendments.

Between 1978 and 1988, various chemical parameters including heavy metals and chlorinated hydrocarbons were monitored in the fourteen estuarine and coastal areas shown in Figure 1 as part of the following programmes:

- A. Coastal and estuarine waters,
- B. Quality of marine fish,
- C. Quality of shellfish and shellfish-bearing waters,
- D. Marine waste disposal sites.

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## MONITORING PROGRAMMES

### Coastal and estuarine environment

Mussels are the most widely used indicator species for environmental contamination and were sampled here to provide a common basis to assess the geographical variation of contaminants within the area covered in this programme. Mussels and oysters were also monitored to ensure their suitability for human consumption.

Sediments are sinks for heavy metal and organic contaminants and are the preferred matrix with which to describe the spatial distribution of contaminants. Studies elsewhere (Anon, 1989a) have shown that, except for zinc and cadmium, contaminant levels in mussels appear to mirror the levels in sediments for most contaminants including chromium, copper, mercury, nickel, lead, PCBs, DDT, chlordane and dieldrin. Annual scale temporal trends are also much more readily described through bivalve analyses than with sediments.

Ambient concentrations of contaminants in water can be interpreted in terms of toxicity and water quality. However, these data are limited since a water sample can only represent the water body at a particular place and time. Seawater analyses are not appropriate for temporal trend monitoring although monitoring can be justified in areas with enhanced levels of contaminants and where changes can be expected as a result of known reduction of inputs.

In 1979 and 1980, surveys of one or two days' duration were undertaken in eight estuaries including the Boyne, Dublin Bay, and the Slaney (Wexford Harbour) on the east coast, the Barrow, Suir (Waterford Harbour) and Bandon on the south coast and Tralee Bay and the Shannon on the west coast. In these the three principal components of the coastal environment — biota, water, and sediments, were sampled to provide an indication of the prevailing levels of metals and nutrients.

Since 1980, five of Ireland's industrialised estuaries, Dublin Bay, Shannon, Cork Harbour, Boyne and Waterford Harbour have been monitored. These, together with the Cork marine industrial waste disposal site in the north Celtic Sea and the Dublin sewage sludge dumping site in the north-west Irish Sea have been designated as monitoring locations (Figure 1) under the Joint Monitoring Programme (JMP) of the Oslo and Paris Commissions. The JMP operates through national programmes, and enables the Commissions to examine the condition of Convention waters and the effectiveness of measures adopted to control marine pollution. The Irish programme focused primarily on contaminants in mussels which were sampled on an annual basis from the JMP areas between 1980 and 1986. Limited monitoring of sediments and seawater from these areas was undertaken in 1985.

Irish monitoring data for contaminants in mussels submitted to a major North Atlantic baseline study of contaminants in biota undertaken in 1985 under the auspices of the International Council for the Exploration of the Sea (ICES) (Anon, 1987) are also included here.

### Quality of marine fish

Cod, whiting, plaice, herring and mackerel have been analysed for mercury, cadmium and lead for national quality assurance purposes and to provide background information for certification purposes in keeping with the requirements of importing countries. Accordingly, contaminants were determined in fish muscle but fish liver was also analysed to give an indication of the degree of environmental contamination.

In 1979, a limited three year temporal trend monitoring programme for mercury and other heavy metals in fish from the Irish Sea was initiated using cod as the indicator species, as there were reports that fish from the Irish Sea were more contaminated with mercury than those from other coastal areas (Anon, 1977; Beggan, 1979). In 1985, two-year-old cod, herring and plaice were sampled from landings from five ICES areas — VIIa, VIIg, VIIj, VIIb and VIaS (Figure 1) to provide information on the quality of fish for human consumption generally and on the degree of contamination of the marine environment — although the sampling strategy used (Anon, 1990a) was designed to provide information on the geographical distribution of contaminants. Since then, additional sampling of various species of fish from landings has also been undertaken.

Mackerel were sampled from landings at Killybegs between 1982 and 1983 for the determination of mercury, cadmium and lead for trade purposes. More recently since 1987, dogfish have been sampled from Castletownbere and Howth and plaice from Dublin Bay.

### Quality of shellfish and shellfish-bearing waters

Four mariculture sites were designated in 1981 for shellfish culture for the purpose of Council Directive 79/923/EC (Anon, 1979a) as follows:

- Clarinbridge (oysters)
- Kilkieran Bay (oysters)
- Killary Harbour (mussels)
- Mulroy Bay (oysters, scallops and mussels).

In addition to the monitoring undertaken in designated sites, several other shellfish-growing areas were monitored on a regular basis. These comprised Wexford Harbour in the south-east, the Owennacurra Estuary and Tralee Bay in the south-west, and Clew Bay in the west. The Bandon estuary was also monitored in the late 1970s as being a potential shellfishery resource. In 1987, mussels were sampled from seventeen coastal locations (Figure 3) which were being monitored as part of the Department of the Marine's Shellfish Sanitation Programme (Griffith, 1987) and these results are also included.

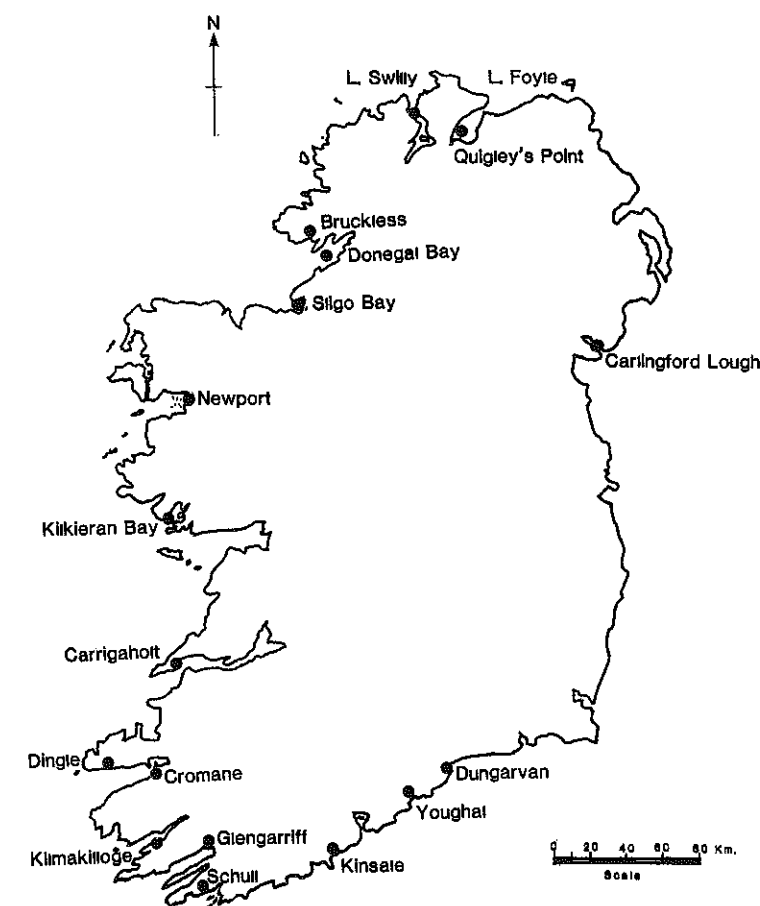


Figure 3 Shellfish growing areas.

### Marine waste disposal site monitoring

Only a brief outline of this programme is given here as the results of this work have already been published (Dinneen et al, 1988a, 1988b; Anon, 1989b, 1989c, 1989d). Dumping of industrial wastes and sewage sludge is licensed under the Dumping-at-Sea Act, 1981. The changes in benthic fauna, sediments and water column have been monitored at the major industrial waste, dredge spoil and sewage sludge dumpsites.

In 1982, a major survey of benthic fauna and sediments in the industrial waste disposal site, 20 km south of Cork Harbour was undertaken (Dinneen et al, 1988a). At this site, in the period 1983-1985, nutrients and chlorophyll were monitored during spring, summer and autumn. (O Sullivan et al, 1986). More recently, a REMOTS (Remote Ecological Monitoring of the Sea-floor) reconnaissance survey of Cork industrial and dredge spoil disposal grounds was carried out in 1988 (Anon, 1989b). A review of the studies carried out to assess the effect of licenced dumping in the vicinity of these dumpsites revealed no

adverse environmental impacts (Anon, 1989c).

In 1983, a major survey of sediment quality and benthic fauna was carried out in the vicinity of the sewage sludge dumping area off Howth Head in outer Dublin Bay. The investigation included a biological survey of the benthic fauna distribution, as well as the determination of potentially bioavailable (weakly bound) metals in the sediments (Dinneen et al, 1988b). In 1988, a REMOTS reconnaissance survey of the Dublin sewage sludge and dredge spoil disposal grounds was undertaken (Anon, 1989d) and a synthesis report on the results of all the investigations undertaken up to 1988 has now been published (Anon, 1989e). This review confirmed that the Bay is a highly dynamic environment and that the effects of dumping are localised and of little significance to the ecology or marine life of the Dublin Bay area.

## METHODS

### General sampling strategies

In surveys carried out in 1979 and 1980, water and sediments were sampled from at least six stations along each estuary and, if possible, during a neap tide regime. Water column measurements on location included salinity, temperature and dissolved oxygen while measurements of BOD, suspended solids, nutrients, chlorophyll and heavy metals were carried out subsequently in the laboratory. Salinity, temperature, dissolved oxygen and nutrients were then recorded for one station for a period of eight hours, representing the greater part of a tidal cycle. Granulometric fractionation of sediments was followed by the determination of organic carbon and heavy metals in the mud (<63 $\mu$ ) fraction.

A modified regime was followed in 1985 when water was sampled at three stations along each estuary for heavy metal (dissolved fraction) analysis on a quarterly basis and sediments were sampled for heavy metal and organic carbon analysis of the mud.

From 1979 onwards, mussels were sampled from a suitable location in each estuary for heavy metal analysis and, from 1985, for chlorinated hydrocarbon analysis. Since 1982, sampling of biota has followed JMP guidelines (Anon, 1990a) facilitating the comparison of monitoring data from year to year. Mussels in the size range 40-60mm (50 individuals except in 1981 and 1982 when a sample consisted of 30 individuals) were sampled from the intertidal zone. Shellfish were depurated for at least 24 hours prior to homogenisation. Analyses were carried out on sub-samples of a homogenate of 50 individuals. Fish tissue (muscle, liver) was either analysed on an individual basis for trend monitoring, or as in recent work, as a homogenate of between 10 and 25 individual samples.

In areas designated under the EC shellfish directive (Anon, 1979a), physicochemical profiles (temperature, salinity, dissolved oxygen, suspended solids) were recorded on a quarterly basis and shellfish (mussels and/or oysters) were analysed twice yearly for heavy metals and chlorinated hydrocarbons. Other areas were monitored less frequently.

### Analytical methods

After dry ashing or wet digestion using nitric acid and hydrogen peroxide (Borg et al, 1981), cadmium, copper, lead, chromium and nickel in biota were determined by electrothermal atomic absorption spectrophotometry. Zinc was determined by flame atomic absorption spectrophotometry. With the exception of mercury, metals in sediments were determined by flame/electrothermal atomic absorption spectrophotometry after nitric acid digestion of the dried material. Mercury (total) in biota and sediments was determined as elemental mercury after digestion by flameless (cold vapour) atomic absorption spectrophotometry (Hatch and Ott, 1968).

After filtration through 0.45 $\mu$  Whatman GF/C acid washed filters, dissolved heavy metals including cadmium, copper and lead were extracted, concentrated and determined in sea water using electrothermal atomic absorption spectrophotometry (Campbell et al, 1985). Total dissolved mercury was determined in sea water by flameless atomic absorption spectrophotometry after concentration on silver wool (Dogan and Haerdi, 1978).

Polychlorinated biphenyls (PCBs) and organochlorine pesticides in fish and shellfish tissue were determined by electron capture capillary column chromatography, after hexane-acetone extraction and clean-up using alumina-silica column chromatography (Wells and Johnstone, 1977). The PCB(7cb) results are reported as the sum of seven individual chlorobiphenyl (CB) congeners (CB-28, CB-52, CB-101, CB-118, CB-138, CB-153 and CB-180) identified for priority analysis by international agreement (Anon, 1986a). Likewise, the DDTs (tDDT) are expressed as the sum of four DDT isomers and metabolites (ppDDT, ppDDD, ppDDE and opDDT) and chlordanes (sChld) are reported as the sum of oxychlordanes, cis-chlordane, trans-chlordane and trans-nonachlor.

Ammonium, nitrate, nitrite, phosphate and silicate were determined in estuarine waters using the appropriate automated wet chemistries in a dual-channel Technicon 11 autoanalyser. Chlorophyll a was determined spectrophotometrically (Anon, 1980).

The FRC laboratory has participated in international and national intercalibration exercises to assure the quality of its analyses. Most recently, it took part in the 7th ICES intercalibration for trace metals in biological tissue in 1984 (Berman and Boyko, 1986), the 1984 ICES Marine Chemistry Working Group intercalibration for organochlorines in biological tissue (Reutergadh and Litzén, 1985), the 6th ICES intercalibration for trace metals in sea water (Berman and Boyko, 1988) and the first ICES intercalibration for trace metals in marine sediments (Loring, 1987). From 1984 to 1987, the laboratory participated in the BCR (Community Bureau of Reference) certification programme for chlorobiphenyls in mackerel and cod liver oils (Griepink et al, 1988; Wells et al, 1989).

All data for contaminants in biota are reported in mg/kg on a wet weight basis and contaminants in sediments on a dry weight basis. Data for trace metals in sea water are expressed in  $\mu$ g/l but nutrient data for seawater are expressed as  $\mu$ moles/l ( $\mu$ M).

## RESULTS

### INTRODUCTION

The results are presented in two groups, based on the expected level of environmental contamination at the sites concerned:

*Group A.* Estuaries which are or which potentially could be subject to environmental stress through inputs of contaminants from such sources as riverine loadings, industrial effluents and sewage. These areas include the five JMP areas: Boyne Estuary, Dublin Bay, Waterford Harbour, Cork Harbour and the Shannon Estuary together with Wexford Harbour.

*Group B.* Estuaries and coastal waters which are not subject to significant discharges and which are, generally speaking, regarded as "clean", unpolluted areas. These include the following shellfish growing locations: Clarinbridge, Killary Harbour, Mulroy Bay, Clew Bay, Tralee Bay.

For convenience, Group A areas are loosely referred to as 'contaminated' and Group B as 'clean'. However, some Group B areas could be contaminated for specific substances, for example, Tralee Bay has been contaminated with copper and zinc (O'Sullivan, 1977) and Mulroy Bay with the anti-fouling agent, tri-butyl tin oxide (Minchin et al, 1987). Monitoring data have also been included in the tables for Cromane, Carlingford Lough and Lough Foyle at Quigley's Point.

### VARIATIONS IN ENVIRONMENTAL LEVELS OF HEAVY METALS

In comparing levels of metals in environmental samples from different locations, it must be recognised that metals are natural constituents of soils and rocks and that concentrations may vary considerably depending on local geochemistry. Thus, higher concentrations, particularly in sediments and biota, do not necessarily reflect man-made contamination but could easily reflect differences in sediment provenance (Anon, 1989a). While, in general, areas affected by pollution display elevated concentrations of metals, studies have also shown that some areas not greatly influenced by man's activities also show elevated concentrations of a single metal (Davies and Pirie, 1980). Indeed, metal concentrations in natural mussel populations vary widely even in uncontaminated environments (Cossa, 1989). It is well known that metal concentrations in organisms are not only the result of their bioavailability in the environment. Environmental factors, such as temperature and salinity, and biotic ones, such as age and physiological condition, are important influencing factors. Therefore, data for biota should be interpreted with caution as other factors including size, body condition and date of sampling are all important in the interpretation of metal concentrations (Borchardt et al, 1988). Strictly speaking, in order to compare contamination levels on a geographical basis, normalization techniques are needed, for example, for both shell length and soft tissue weight in the case of shellfish and for grain size, organic carbon and carbonate content and Al or Li content in the case of sediments. However, this rigorous approach has not been feasible in this assessment.

For the purpose of assessment, the data for mercury and cadmium are described as being in the "lower", "medium" or "upper" ranges of contamination according to currently agreed, although arbitrary, JMP guidelines (Appendix 1). These guidelines, which are based on the monitoring data submitted by the countries participating in the Programme, refer to the ranges of contaminant concentrations which in general may be expected to occur in coastal waters of the North-east Atlantic region. Upper levels do not necessarily imply risk to human health or to the environment but indicate the possible need for action and the level of priority that should be assigned to different areas.

For the assessment of risk to human health through human consumption, figures for the strictest health standards and guidevalues currently being applied by the Oslo and Paris Commissions (OSPARCOM) countries are detailed in Appendix 2.

The national limit and guide values which are used to assess compliance with the EC directive on the quality of shellfish-bearing waters are given in Anon, 1979a.

### HEAVY METALS IN SHELLFISH

Monitoring data for heavy metals for Groups A and B locations are summarised for mussels in Table 1 and oysters in Table 2. Maximum and minimum values are pertaining to the complete dataset for each location while the median values were calculated for comparable data for shellfish sampled prior to spawning during the spring. Overall summary statistics are reported for this latter dataset. With at least six years' data for most areas, the geographical variation of chemical contaminants in shellfish is well described and an indication of the general trend is given. The results, though historical in nature, of an earlier Mussel Watch survey carried out in 1976 by Crowley and Murphy (1976) are included as background information.

#### Mercury

Apart from chloro-alkali plants, of which there are none in Ireland, mercury contamination results from laboratories (including dental laboratories), its use as a fungicide and the burning of fossil fuel. The discharge of mercury to the aquatic environment is controlled under environmental legislation including the Water Pollution Act, 1977 and its 1989 update and the Dumping-at-Sea Act, 1981. It also has been the subject of two EC directives, one for the chloro-alkali industry (Anon, 1982) and another (Anon, 1984) covering discharges from other sources, both of which have been incorporated into national legislation. In particular, mercury discharges from two major industrial operations, aluminium smelting in the Shannon Estuary and mining in the vicinity of R. Boyne, are controlled by licence. The 900MW coal-fired power station in the Shannon Estuary could potentially contribute to local and distant mercury contamination but this has been discounted by Cabot (1979). The Paris Commission's Environmental Quality Standard for mercury in fish flesh of 0.3mg/kg wet weight has been adopted as an 'early warning' concentration for both fish flesh and shellfish.

Concentrations in mussels sampled from Group A areas were all less than 0.2mg/kg wet weight with an overall median concentration of <0.1mg/kg wet weight. With one exception (Waterford Harbour, 1983) the data for contaminated areas were in the medium and lower JMP ranges. Values in the medium range were identified for the Boyne Estuary (1984), Cork Harbour — Ringaskiddy (1983) and the Shannon Estuary (1982, 1983). In 1983, an unusually high mercury concentration in the upper range was recorded in mussels from Duncannon, Waterford Harbour. The source or reason for this contamination could not be traced but the level did not persist. Indeed, where elevated levels of contamination have been identified from time to time, contamination has tended to decline in the subsequent years. In 1985 and 1986, all the Group A areas were classified in the lower JMP range. In contrast, the data for Cork Harbour and Waterford Harbour were in the upper quartile of the ICES North Atlantic 1985 Baseline Study (Anon, 1987). Mercury concentrations in mussels from 'clean' Group B areas were less than 0.1mg/kg, consistently lower than those reported for the major estuaries in Group A and median concentrations for both mussels and oysters were 0.05 mg/kg wet weight. With the exception of L. Swilly, mercury levels in mussels sampled in the 1987 Mussel Watch programme were also all less than 0.1 mg/kg wet weight. The level of 0.12mg/kg mercury in mussels from L. Swilly was unexpected given that the location sampled was not subject to any known polluting discharges and therefore, this result should be regarded with caution. The overall median for the complete dataset for mercury in shellfish was 0.05mg/kg wet weight.

All data from both Group A and Group B areas readily met the Paris Commission's Environmental Quality Standard in fish flesh of 0.3mg/kg wet weight mercury. Among the JMP countries, the strictest guidevalue (0.3mg/kg mercury in molluscs) is applied by Germany. The concentrations reported did not give any reason for concern with regard to risk to human health through consumption of shellfish (Murray and Portmann, 1984, Anon, 1989h).

Overall, the level of mercury contamination was low as might be expected where inputs are localised from small-scale activities. The temporal trend has been consistent except for short term episodes of elevated levels of contamination in the Boyne estuary, Shannon estuary and Cork Harbour. The incident of significant contamination in mussels from Waterford Harbour has remained unexplained.

Mercury contamination of sediments in upper Cork Harbour was detected in 1987 (Anon, 1988; Anon, 1989i; Anon, 1990b). Earlier measurements of mercury in sea water provide tentative evidence for local, perhaps historical and probably diffuse, mercury sources in the area.

#### Cadmium

Cadmium inputs into the aquatic environment are associated with base metal mining operations, the electroplating industry, and fertiliser manufacture. Like mercury, it is a List 1 substance and as such discharges are controlled by EC legislation (Anon, 1983a) which has been given effect in national legislation. There are no generally agreed European standards for cadmium in fish or shellfish at the present time but the strictest guidevalue of 0.5 mg/kg wet weight is applied by Germany and Norway.

Cadmium concentrations in mussels for Group A locations were less than 0.5mg/kg wet weight with some exceptions. Using JMP criteria, mussels from two locations, the Shannon Estuary and Dublin Bay, were described as being in the upper range of contamination in 1980 and, likewise mussels from the Boyne estuary in 1984. Subsequent monitoring indicated levels in mussels from the Shannon Estuary in the medium range in 1985 and 1986 whereas levels for Dublin Bay were in the lower or background range. With the exceptions of Waterford Harbour (1981, 1984, 1987) and the Boyne Estuary (1981) when levels were in the medium range of contamination, the degree of contamination has been low. The general temporal trend in cadmium concentrations has been constant at most locations.

The Boyne estuary, Waterford Harbour and the Shannon Estuary have been subject to higher contamination compared to other estuaries. Since these levels have not persisted, it is likely that they were associated with transitory anthropogenic inputs though these have never been identified. Relatively higher levels of contamination were also identified in the Shannon estuary by Stapleton et al (1987).

Levels in mussels from uncontaminated Group B locations were also generally less than 0.5mg/kg cadmium, somewhat lower than levels for potentially contaminated areas but within the lower category of contamination according to JMP guidevalues. A high value of 0.74 mg/kg was reported in mussels from Tralee Bay in 1980, but levels have declined since then. No hotspots or unsuspected areas of pollution were identified in areas included in the 1987 Mussel Watch survey and all these data were low, less than 0.5 mg/kg. Median levels for Group A and B locations were 0.3 and 0.25 mg/kg, with an overall median value of 0.25 mg/kg wet weight for cadmium in mussels.

Earlier monitoring results (Crowley and Murphy, 1976) in 1976 for cadmium in mussels ranged from 0.03 to 0.97, with a median value of 0.2 mg/kg, the highest concentration being reported for Carlingford Lough.

Oysters accumulate metals more readily and to higher concentrations than mussels and separate criteria have therefore been set by JMP for oysters. Cadmium concentrations in oysters (on a wet weight basis) from Group A and B areas shown in Table 2, were similar to or higher than those for Group A 'contaminated areas'. However, using JMP criteria, all the data with the exception of Mulroy Bay in 1983 were in the lower range of contamination. Higher concentrations than normal were identified in oysters from Mulroy Bay between 1983 and 1985, with the data reported for 1983 being identified in the medium JMP category. Recent data for mussels and oysters indicate much lower concentrations, at a low level of contamination similar to other shellfish growing areas.

#### Lead

Sources of lead are varied and, apart from industrial inputs and inputs from mining activities, include diffuse sources such as paints, piping, lead in petrol and the burning of fossil fuels. Because of the low solubility of lead compounds in sea water, much of the particulate lead in runoff and discharge from industrial plants is deposited in coastal sediments (Anon, 1983b). Health regulations regarding lead vary between countries, with the strictest tolerance or guidevalues of 0.8 mg/kg and 0.5 mg/kg wet weight being applied by Germany and Spain respectively (Anon, 1991).

Contamination of mussels and oysters with lead was higher in the Group A, populated estuarine locations as compared with the remote coastal areas of Group B. The area of greatest contamination was Dublin Bay, with concentration of 2.6 mg/kg wet weight. Mussels from Dublin Bay were used only as environmental indicators and are not marketed. Though concentrations greater than 1 mg/kg were noted for the Boyne estuary, Cork Harbour and Waterford Harbour, a median concentration of 0.71 mg/kg was calculated for the Group A set of data. Median concentrations for lead in mussels and oysters from the Group B areas were consistently lower, less than 0.5 mg/kg, than the Group A areas monitored. In the 1987 Mussel Watch survey, lead concentrations greater than 1.0 mg/kg were determined for Dungarvan and Sligo Bay and concentrations greater than 0.5 mg/kg were recorded for Schull, Youghal and Kinsale. Overall median figures of 0.47 mg/kg and 0.17 mg/kg were calculated for the available comparable data for lead in mussels and oysters, respectively. Earlier concentrations reported by Crowley and Murphy (1976) ranged up to 3.0 mg/kg with the highest figure being recorded for Dundalk Bay.

*Copper and zinc*

These metals are present in discharges from mining operations and the electroplating industry as well as in paints, including antifoulants. High concentrations of zinc in shellfish are not generally considered a risk to human health as our diet is often deficient in zinc (Anon, 1984). Human health guidance values for molluscs of 10 mg/kg copper wet weight in Norway and 50 mg/kg zinc wet weight in Great Britain are the strictest currently applied. In contrast to mussels which are not suitable indicators for copper (Phillips, 1980), copper and zinc are both readily accumulated by oysters.

All the results for copper in mussels were less than 10 mg/kg. Levels in oysters from uncontaminated areas — Clew Bay, Clarinbridge and Kilkieran Bay, were less than 5 mg/kg. In contaminated areas such as Tralee Bay, the levels were higher, up to 112 mg/kg in Tralee oysters. Relatively higher concentrations of up to 50 mg/kg copper were also recorded for oysters from Carlingford Lough and Lough Foyle at Quigley's Point. These are likely to be indicative of local, though not serious, contamination and the levels reported for Mulroy Bay and Cork Harbour are also perhaps indicative of local copper contamination. Mussels from Dungarvan sampled as part of the 1987 Mussel Watch survey, showed elevated levels of copper (c. 4 mg/kg wet weight) compared to concentrations less than 2 mg/kg for all the other locations monitored.

Zinc concentrations, as expected, were lower in mussels than in oysters with an overall median value for zinc of less than 20 mg/kg in mussels compared to an overall median value of 330 mg/kg in oysters. Highest values of zinc (c. 50 mg/kg) were identified for mussels in the Boyne estuary and Cork Harbour and in oysters (c. 500 mg/kg) from Tralee Bay, Mulroy Bay and L. Foyle at Quigley's Point.

In the 1970s, Tralee Bay was contaminated with copper and zinc from electroplating effluent. This resulted in high bioaccumulation of these metals by the oyster population there. This contamination has declined since 1978, though not as rapidly as might be expected, following the cessation of the metal containing discharge. While elevated levels of copper and zinc have been recorded in a number of locations, these are not considered detrimental to the environment or human health.

*Chromium and nickel*

Some limited monitoring data for chromium and nickel determined between 1980 and 1982 in mussels and oysters are included in Tables 1 and 2 with median values for chromium of 1.2 mg/kg in mussels and 0.77 mg/kg in oysters and corresponding median values for nickel of 3.91 mg/kg in mussels and 1.51 mg/kg in oysters.

**HEAVY METALS IN FISH**

Heavy metals were monitored in the demersal species cod, plaice, dogfish and whiting, the pelagic species mackerel and herring and in by-catch (inadvertently netted) species such as shark and scabbard fish. The resulting data are summarised in Tables 3 and 4.

It is clear that the levels of mercury, cadmium, lead, copper and zinc in the flesh of the following commercially important species: cod, whiting, herring, mackerel and plaice comply with the strictest standards and guidevalues currently being applied by OSPARCOM countries (Appendix 2) and as such do not pose a threat to human health. The Paris Commission standard of 0.3mg/kg fish flesh for mercury was met for all the commercial species monitored. Higher concentrations of mercury (greater than 0.3 mg/kg) were determined for the by-catch species, porbeagle shark and scabbard fish. This is to be expected on account of their physiology.

It should be noted that mercury levels generally increase with increasing size and age (Clarke and Topping, 1989). This can be seen in close examination of the trend monitoring data for cod and also is a feature of the mercury levels in the shark family. The average age at which dogfish are caught exceeds 15 years (Fahy and Gleeson, 1990) which would account for the relatively higher levels reported for dogfish. Mercury levels in the north-east Irish Sea which has been subject to mercury inputs, were found to be five to ten times higher in the lesser-spotted dogfish compared to dab and plaice (Leah et al, 1991).

Overall, the heavy metal data reported here for fish flesh are within the ranges reported in the 1985 ICES baseline study (Anon, 1987). As expected, metal levels were higher in fish liver as compared to fish flesh with concentrations similar to those reported in the 1985 ICES baseline study. With the exception of one result for cadmium in dogfish liver, the metal levels in liver from commercial species of fish met the strictest standards applied among OSPARCOM countries.

**CHLORINATED HYDROCARBONS**

Polychlorinated biphenyls (PCBs) are technical mixtures of chlorinated biphenyls which on account of their thermal and chemical stability have been used in a wide range of industrial products. Since PCBs are now known to be extremely persistent, to have high toxicity and to accumulate readily in biological tissues, their production and use has been discontinued. These substances are List 1 or black list substances as described in the Council directive 76/464/EC (Anon, 1976). Of 209 possible congeners, 120 have been identified as being present as contaminants in the environment (Kerkhoff, 1985). Apart from direct input, atmospheric deposition is an important route to the marine environment.

Likewise, organochlorine pesticides are readily soluble in natural oils and fats and are bioaccumulated by marine biota. They are also transported to the marine environment through atmospheric deposition and agricultural run-off.

Monitoring data for polychlorinated biphenyls (PCBs, expressed as the sum of seven individual chlorobiphenyl congeners), dieldrin, DDTs, chlordanes, hexachlorocyclohexanes ( $\alpha$ HCH,  $\gamma$ HCH) and hexachlorobenzene (HCB) in mussels, oysters and fish from Group A and B locations are summarised in Tables 5, 6 and 7 respectively.

*Shellfish*

PCBs and organochlorine pesticides were determined annually between 1984 and 1987 in mussels and oysters sampled from a number of estuarine and shellfish growing areas. In 1987, these data were supplemented with a coast-wide "Mussel Watch" programme in which mussels were sampled from seventeen intertidal locations. Results are given in Tables 5 and 6.

PCBs concentrations in the principal estuaries monitored (Group A) ranged between 0.002 and 0.030 mg/kg with the highest concentrations being recorded for Cork Harbour in 1985. Concentrations were less than 0.010 mg/kg in all the other areas monitored during the four year period from 1984 to 1987. It is important to emphasise that these concentrations are low and are indicative of a relatively unpolluted environment, with contamination due to long-range atmospheric transport. A similar range of concentrations (0.004 to 0.021 mg/kg) was reported by Granby (1987) for Danish coastal waters. The Irish data which were assessed as part of the ICES 1985 Baseline Study were described as being the lowest reported in that study with Irish data being significantly less than 0.050 mg/kg compared to concentrations in excess of 0.150 mg/kg reported for mussels from the Firth of Clyde, west Scotland and the Scheldt estuary in the Netherlands (Anon, 1987).

PCB levels in mussels from the 'clean' shellfish growing areas (Group B) monitored between 1984 and 1987 ranged from 0.001 to 0.004 mg/kg, consistently lower than the concentrations reported for the estuarine locations. Similar results (0.001 to 0.005 mg/kg) were obtained in the 1987 Mussel Watch programme with the highest concentration being detected in intertidal mussels from Bantry Bay. As expected, PCBs were not present in oysters from Clarinbridge and Mulroy Bay. The highest CB concentration for oysters was 0.004 mg/kg reported for Carlingford Lough. It must be emphasised these concentrations are very low and are unlikely to pose any threat to human health.

Again, trace levels (<0.001 mg/kg) of HCB, HCHs and chlordanes were recorded in mussels and oysters. Some apparently elevated values were noted for chlordanes at 0.015 mg/kg in Shannon Estuary (1984) and lindane at 0.036 mg/kg in Boyne Estuary (1985). Dieldrin and DDT were common contaminants in mussels and, to a lesser extent, in oysters. Geographically, the higher concentrations were found in urban estuarine locations as compared to the more remote and less populated shellfish growing areas. The most contaminated areas were Dublin Bay (dieldrin), Cork Harbour (dieldrin, DDTs) and Wexford Harbour (DDTs). However, the level of contamination did not have any significance for human health.

Comparison with earlier data (Eades and Crowley, 1970), indicates a ten-fold decrease in dieldrin and DDT concentrations in mussels since 1970 though this reduction has not been as marked in some areas, notably Wexford Harbour. HCH and HCB contamination was very low, amongst the lowest in Europe in comparison with the 1985 Baseline Study with these organochlorine compounds not being detected at all in most of the samples analysed. The level of dieldrin and DDT contamination was similar to other estuaries monitored in the 1985 ICES Baseline Study and to the levels reported for Danish coastal waters (Granby, 1987). Contamination was even less in the 'clean unpolluted' shellfish growing areas which were monitored.

In summary, contamination by organochlorine pesticides was generally very low. Relatively higher levels of contamination by dieldrins and DDTs were associated with urban industrialised estuaries, though these levels were lower than in 1970 — most likely due to their discontinued usage. No point sources of pollution were identified. PCB contamination was greatest in urban estuarine locations but again the degree of contamination was low and local pollution problems attributable to these substances have not been observed nor indeed, are they to be expected.

*Fin fish*

PCBs and organochlorine pesticides were determined in cod, plaice and herring muscle and in cod and plaice livers and the results are given in Table 7. Data from the analysis of porbeagle muscle are also given. Chlorinated hydrocarbons are preferentially accumulated in fish liver which is a lipid-rich detoxifying organ and is monitored for temporal trend analysis (de Boer, 1988).

The concentrations of PCBs in cod and plaice muscle were very low especially when compared with the levels in herring muscle which is lipid-rich. The highest concentration in muscle (0.018 mg/kg) was recorded in herring landed on the east coast. Though the data set is small, it would seem that highest PCB concentrations are present in herring landed from the Irish Sea. The fat content of the herring sampled was relatively low and did not reflect the content normally present in this species during the fishing season (Molloy and Cullen, 1981).

Data (de Boer et al, 1983) have been tabulated for herring from the Celtic Sea, and to the west of Scotland, together with data for the central North Sea for comparison. The PCB data for herring muscle from ICES areas 7a and 6as are lower than the levels reported by de Boer et al (1983) for the North Sea and the Celtic Sea, and are comparable with the levels reported in herring from the west coast of Scotland. As expected, PCB concentrations were significantly higher in fish liver than in fish muscle with up to 0.41 mg/kg PCBs being determined in cod liver, the highest concentration detected in fish from the south-west coast. This compares favourably with mean PCB concentrations (expressed as the sum of 7 congeners) for the North Sea ranging from 0.422 to 3.300 mg/kg wet weight (de Boer, 1988).

The remaining organochlorine pesticides (HCB,  $\alpha$ HCH,  $\gamma$ HCH, Dieldrin, DDTs and chlordanes) were either not detected in cod and plaice muscle or were present in negligible quantities. Dieldrin and DDTs were determined at low concentrations at less than 0.100 mg/kg in cod and plaice liver except for one result of 0.432 mg DDTs/kg wet weight reported for cod liver sampled from a landing off the south-west coast. This result together with a chlordane concentration of 0.112 mg/kg for the same sample is similar to values reported for cod liver from the southern North Sea and for hake liver from the Atlantic Ocean by Kerkhoff et al (1982). An overall mean value of 0.084 mg/kg was reported for dieldrin in cod liver in the 1985 ICES baseline study with slightly elevated values (0.12-0.14 mg/kg) being reported for the Irish Sea. Compared to cod and plaice, lindane and  $\alpha$ HCH, together with dieldrin, DDTs and chlordanes were present in relatively higher quantities in herring muscle. HCB was not detected in any of the herring muscle samples analysed. The level of chlordanes was lower by a factor of five than that of 0.01 mg/kg reported by Kerkhoff et al (1982) for herring from the North Sea and Atlantic Ocean. Again, comparison of these data with the results of the ICES 1985 baseline study indicates that the degree of contamination is low.

In spite of the small dataset examined here, the indications are that the levels of chlorinated hydrocarbon contamination in demersal and pelagic species landed at Irish ports are low, though higher levels are found in fish livers. Based on present knowledge, there are no reasons to conclude that the consumption of fish containing existing levels of chlorinated hydrocarbons presents a hazard to human health.

Similar concentrations have been reported for organochlorine pesticides in fish muscle sampled around the UK coast between 1984 and 1987. Levels of organochlorine contamination generally were greatest in the NE Irish Sea with high levels of DDT and PCBs being determined in fish liver from Liverpool Bay and Morecambe Bay (Franklin, 1990).

Concerns are now focused on the implications of the relatively high body burden of organochlorines which can be accumulated by marine mammals and high concentrations of chlorinated hydrocarbons have been reported in marine mammals from the Irish Sea including seals and small cetaceans such as dolphins and porpoises (Law et al, 1989, Morris et al, 1989, Nixon, 1989) which may affect the well-being of these species. The levels of organochlorines in fish, a major component of their diet, would contribute significantly to the high body burdens reported.

The Irish Sea should be a focus for future temporal trend studies of chlorinated hydrocarbons in fish, given the potential for inputs of chlorinated wastes and the concerns for the well-being of the marine mammal populations. While there are indications that organochlorine concentrations are declining within the area, it has been reported that the levels are still high relative to other UK coastal waters (Anon, 1990c).

**HEAVY METALS IN SEA WATER**

Heavy metals in sea water were monitored in several major estuaries in 1979, 1980 and 1985, focusing on those industrialised populated areas most likely to be affected by pollution. The results are summarised in Table 8. This work followed earlier investigations in 1975 by Crowley and Murphy (1976). Short one-day surveys were carried out in 1979 and 1980. A more detailed quarterly sampling programme was undertaken in 1985 in the Boyne estuary, Dublin Bay, Waterford Harbour, Cork Harbour and Shannon estuary.

The analytical determination of trace metals in sea water is difficult, requiring clean air technology with particular attention being given to potential contamination problems associated with sampling and storage as well as the analytical procedure itself. These surveys and the analytical determinations undertaken were carried out with limited facilities. Improvements in analytical methodology, made in 1985, were reflected in an acceptable performance for mercury and cadmium determinations in sea water in the 6th ICES/JMG intercalibration exercise for metals in sea water (Berman and Boyko, 1988). Nevertheless, problems with contamination due to sampling and storage were still encountered and, therefore, the data can be used only to obtain an approximate indication of geographical variation in Irish coastal waters. Actual levels are almost certainly lower than measured levels. With the exception of the data for copper and zinc for Tralee Bay, discussion of the monitoring results is limited to those data for 1985. It should be noted that all these results relate to surface water samples taken at a depth of one metre and that only the dissolved fraction was determined and reported for each metal analysed.

*Mercury*

The highest concentrations of dissolved mercury were found in Cork Harbour with a maximum value of 82 ng/l in March 1985. Concentrations in the remaining areas decreased in the order Dublin Bay, Waterford Harbour, Shannon estuary, Boyne estuary. These data were similar to the earlier figures reported for 1979 and 1980 but appear to be relatively high for estuaries which have no significant inputs of mercury compared to other estuaries in Europe.

Overall, these data indicated that the water quality objective of 100 ng/l for mercury specified in Department of the Environment (DOE) Technical Water Quality Guidelines (Anon, 1979c) was being met.

The higher values reported for Cork Harbour for 1985 seemed to indicate contamination with mercury, an observation which was also supported by the levels observed in shellfish at that time and subsequently in sediments from upper Cork Harbour. Total unfiltered mercury levels have been reported for Cork Harbour by the Environmental Research Unit (Anon, 1989f) with outlying values of up to 125 ng/L being recorded.

*Cadmium*

Median values were lower than the minimum concentrations reported in earlier monitoring surveys and were highest for the Shannon estuary closely followed by the Boyne estuary. These data satisfy the DOE water quality objective of 10  $\mu$ g/L (Anon, 1979c). However, the cadmium status of the estuaries monitored remains unclear with wide variations being recorded.

*Lead*

In 1985, the highest maximum concentrations were recorded for Dublin Bay and Boyne Estuary, followed by Waterford Harbour. Overall, the concentrations were similar to those reported in 1987 (Clancy et al, 1987) for Irish coastal waters though a lower analytical limit of determination was achieved. Although, these data are similar to those reported in 1979 and 1980 they are very variable and are high compared to data reported for UK waters (Franklin, 1990). Nevertheless, the DOE water quality objective of 100  $\mu$ g/l has been satisfied.

*Copper and zinc*

The monitoring results for copper would indicate that the DOE water quality objective of 50  $\mu$ g/l is being satisfied. Copper levels (30  $\mu$ g/l maximum) in Tralee Bay recorded in 1979 were significantly higher than in other estuaries monitored due to the copper inputs at that time. This is supported by the monitoring data for biota and sediment included in other sections in this report. Zinc data for 1979 and 1980 are also summarised in Table 8. The levels of zinc determined for Tralee Bay were similar to the levels determined for the other estuaries monitored and the DOE water quality objective of 100  $\mu$ g/l was met.

**HEAVY METALS IN SEDIMENTS**

Monitoring data for trace metals in sediments are summarised in Table 9 for 1979, 1980 and 1985. This database is limited as only three sites were monitored in each area in 1985 compared to seven stations in 1979 and 1980. Most contaminants (metals, pesticides, chlorinated hydrocarbons) show high affinity to particulate matter and are consequently enriched in the bottom sediments of estuaries and coastal areas.

In this dataset, normalisation was achieved by the analysis of the silt-clay fraction (<63 $\mu$ ) of the sediments sampled. This facilitates the direct comparison of contaminant levels between different areas. Metals, in particular lead and copper, are naturally scavenged by organic sediments, and higher concentrations are expected. Sediments are normally enriched with zinc so relatively high concentrations were also expected and this is evident in the magnitude of the concentrations reported here.

The results indicate that levels of contamination in the mud were low in general. Levels of cadmium less than 5 mg/kg were determined in most of the areas monitored with the highest concentration being reported in Cork Harbour for 1985. Likewise, copper contamination was generally less than 50 mg/kg. The highest copper concentrations were reported for Tralee Bay where 342 mg/kg copper was reported in 1979 due to known inputs. While levels have decreased in the sediments, the 1985 data still indicated higher copper concentrations than elsewhere. Some limited data for the Boyne estuary for 1980 also suggested relatively higher concentrations.

High lead levels, greater than 100 mg/kg were also identified in Tralee Bay in 1979 but these subsequently declined. Levels did not exceed 55 mg/kg except in Tralee Bay (1979), Boyne estuary (1980) and Dublin Bay (1980).

High concentrations of zinc (c. 400 mg/kg) were identified in Tralee Bay in 1979. These have since declined to 146 mg/kg in 1985 though this was still the highest concentration determined overall in 1985. Relatively higher concentrations were also determined in the Boyne and Slaney estuaries in 1980 and 1979 respectively.

The distribution of the trace metals in the sediments from the sewage disposal site in Dublin Bay showed that heavy metal concentrations in the sediments surrounding the dumpsite were elevated in relation to the general levels in outer Dublin Bay. Lead, copper, zinc and nickel are present in greater concentrations close to the dumpsite while, in contrast to Liverpool Bay, cadmium and mercury were only slightly elevated (Dickson and Boelens, 1988).

In a recent investigation into the geochemistry of sediments in eleven locations around the Irish coast, elevated zinc levels in the inner Tolka estuary and copper levels in Arklow Harbour (Brennan, 1988) were confirmed. Elevated levels of copper and cadmium were reported by Jones and Jordan (1979) in their investigation of the distribution of heavy metals in the inner Liffey Estuary.

In particular, metal contamination is a feature of port and docks areas. Recent work in Dublin Port has identified port sediments contaminated with lead and zinc and contamination of sediments with mercury has also been detected in the upper Lee estuary close to Cork city (Anon, 1988; Anon, 1989; Anon, 1990b).

Few areas of gross heavy metal contamination of sediments have been identified. However, more intensive spatial and temporal trend investigations of contamination in sediments are required to enable the use of this monitoring tool to be fully realised.

## NUTRIENTS

The data from nutrient monitoring carried out during 1979 and 1980 in nine estuaries and bays are summarised in Table 10 together with summary data for nutrients at the Dublin Bay sewage disposal site and industrial waste disposal site off Cork. Summary details of nutrients monitored during 1982 and 1983 in the vicinity of fish farms in Mulroy Bay are also included. These datasets are limited as the estuarine surveys (except for Mulroy Bay) were one-day surveys carried out in spring and early summer, a period of high biological activity in which nutrient concentrations tend to be unstable. Winter surveys carried out when biological activity is at its minimum are essential to determine baseline levels of nutrients and to monitor temporal trends in nutrient levels. Recently, more comprehensive investigations have been carried out on riverine inputs of nutrients along the east coast and also in Dublin Bay (Anon, 1989g).

In all the estuarine areas monitored, nutrient levels decreased seawards from the tidal limits as would be expected. The nitrogen figures showed a wide variation compared with the phosphate data. Relatively high nitrogen levels were noted in estuaries with sewage inputs in the Boyne estuary, Dublin Bay and Wexford Harbour. High nutrient levels were also reported for the Barrow estuary into which there is a high riverine loading of nutrients. Greatest productivity indicated by chlorophyll *a* levels was reported for the Bandon estuary. This could be explained by the occurrence of an algal bloom at the time of sampling. The generally unsatisfactory condition of estuaries including the Boyne estuary, upper Liffey estuary and inner Tralee Bay have been highlighted (Toner et al, 1986). However, our knowledge of the nutrient loadings and regime in Irish estuaries remains limited and much work is needed, especially during the winter period, to obtain accurate baseline information.

## CONCLUSIONS

### Estuarine and coastal waters

A greater degree of contamination with heavy metals and chlorinated hydrocarbons was found to be associated with populated, industrialised estuaries as compared with remoter, less populated locations such as those used for mariculture activities.

Elevated metal contamination was identified in the following estuaries:

Boyne	cadmium
Dublin Bay	lead
Waterford Harbour	cadmium and mercury
Cork harbour	copper, mercury and zinc
Tralee Bay	copper and zinc
Shannon	cadmium
Mulroy Bay	cadmium

It must be emphasized that, with shellfish being used as a monitoring tool, in no case were areas identified as being subject to ongoing stress due to heavy metals. The general overall temporal trend in metal levels has been of levels remaining stable or, in the case of more marked contamination, declining. Decreasing levels have been observed in Cork Harbour, Tralee Bay and Mulroy Bay. The overall level of heavy metal contamination is relatively low in the European context. The degree of organochlorine contamination is low in all the estuaries and shellfish growing areas monitored and is very low in European terms. In this context, our coastal environment can be regarded as being unpolluted.

### Marine foodstuffs

Based on presently available scientific knowledge, the levels recorded for heavy metals and chlorinated hydrocarbons in fin fish and shellfish do not pose a risk to human health.

### Quality of shellfish-bearing waters

Monitoring between 1981 and 1986 of the two areas designated under the EC Shellfish Directive (1979), Clarinbridge and Killary Harbour, were deemed to have complied with the directive. Mulroy bay and Kilkieran bay designations were revised on review in 1988.

## OVERVIEW

Monitoring programmes from 1978 to 1988 focused on the quality of the coastal and estuarine environment primarily through heavy metals and chlorinated hydrocarbons in shellfish. These data confirm the generally unpolluted nature of the Irish estuarine and coastal environment with regard to heavy metals and chlorinated hydrocarbons. Localised contamination has occurred, resulting in elevated metal levels in shellfish, especially in areas with industrial activities. While these episodes have not persisted, it is clear there is a likelihood of elevated levels of contamination from point source inputs, although these are mostly small-scale operations.

In terms of temporal and spatial coverage, shellfish were intensively monitored, while the monitoring of contaminants in fish, sediments and seawater was limited. Confidence in describing the degree of contamination in monitored areas can only be achieved when data for contamination in one environmental compartment, such as biota, are supported by data for other compartments such as sediments and seawater. More detailed monitoring of indigenous fish species and other environmental compartments including sediments in estuarine locations is needed to characterise further the quality of the environment, to extend baseline information and to establish firmly the contamination status of each location.

There are concerns about adverse effects from waste disposal practices in the Irish Sea (Anon, 1990c). In the past, these practices led to significant mercury contamination of the sediments in Liverpool Bay which, in turn, resulted in mercury accumulation in fish with implications for human health. However, with improvements in technology and with tighter emission controls, mercury levels in fish have been declining in the last decade. More recently, elevated chlorinated hydrocarbon levels in marine mammals including cetaceans and seals have aroused concern as these may have serious health implications for these populations.

There is a need for more intensive trend monitoring of organochlorines and heavy metals in fish to include a wider range of species and a wider geographical area including major fishing grounds, coastal areas and especially, the Irish Sea. This would help to assess the well-being of the marine environment generally and to evaluate the effectiveness of emission controls.

New pollutants, such as organotin compounds used in antifouling paints, pose threats to the marine environment. Hydrocarbon compounds as in fuel oils, diesel oils and petroleum and their combustion products are also a potential threat to the quality of marine produce. These and other hitherto unanalysed contaminants need to be addressed on an ongoing basis. Research also needs to be directed towards an improved interpretation of contaminant monitoring data in terms of biological effects.

Nutrients are possibly the most significant anthropogenic inputs to the Irish aquatic environment through domestic sewage, industrial activities, agricultural sources, land runoff, and fin fish farming. The increased incidence of algal blooms in recent years has resulted in greater attention to the trends and behaviour of nutrients in the coastal areas. A co-ordinated research programme has been initiated to monitor trends in nitrate and phosphate in the Irish Sea. However, much work remains to be carried out in monitoring nutrient trends in estuaries.

While this report confirms the non-polluted nature of most of Ireland's coastal waters, it also highlights the limited nature of the monitoring which has been undertaken. The importance of continuing this programme, and expanding it to provide a database which can be used for the effective protection of the marine environment, cannot be understated. Regular monitoring is the only means by which early warning of potential disastrous situations can be given.

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Table 1. Heavy metals (mg/kg wet weight) in mussels, 1980-1988. %D = percentage dry weight.

Location		n	Hg	Cd	Pb	Cu	Zn	Cr	Ni	%D
GROUP A:										
Boyne Estuary	min	12	.03	.17	.24	.39	13.20	.26	1.53	15.76
	max		.26	1.33	1.25	3.64	42.57	3.33	4.56	25.80
	median		.06	.32	.65	1.64	17.00			18.12
	interquartile		.04	.14	.23	.73	8.84			5.94
Dublin Bay	min	6	.04	.21	.98	.75	14.40			17.29
	max		.10	2.70	2.60	2.00	37.20	1.03	6.24	23.11
	median		.05	.35	2.01	1.66	21.70			20.70
	interquartile		.05	.23	1.38	.07	19.88			5.51
Waterford Harbour	min	10	.02	.20	.32	1.32	12.78	.35	1.68	15.26
	max		.66	.64	1.07	5.59	18.78	1.33	4.75	26.33
	median		.07	.47	.71	1.40	16.60			16.85
	interquartile		.03	.28	.15	.25	3.21			1.81
Cork Harbour Ringaskiddy	min	5	.05	.16	.48	1.12	9.93			18.97
	max		.12	.40	1.03	2.06	51.23			21.98
	median		.07	.25	.76	1.50	24.83			19.26
	interquartile		.03	.11	.55	.66	28.03			1.64
Owennacurra estuary	min	6	.04	.09	.11	1.04	16.91			20.23
	max		.10	.37	1.60	1.57	22.03			24.45
	median		.07	.22	.76	1.43	21.52			23.55
	interquartile		.03	.04	.48	.36	5.12			2.16
Shannon estuary	min	7	.04	.16	.13	1.00	11.43			16.90
	max		.18	2.51	.60	1.73	27.00			26.27
	median		.05	.36	.23	1.19	12.00			19.20
	interquartile		.02	.07	.28	.48	1.36			4.25
Wexford Harbour	min	8	.02	.13	.38	.70	12.73	.13	1.22	19.44
	max		.10	.25	.90	5.13	22.03	2.31	5.36	26.15
	median		.05	.19	.67	1.51	18.11			21.14
	interquartile		.04	.11	.37	.25	3.90			2.55
Summary of Group A data for pre-spawning samples	min	39	.02	.09	.13	.49	9.93	.26	1.22	15.26
	max		.17	2.51	2.60	5.59	51.23	3.33	5.36	24.45
	median		.06	.30	.71	1.51	17.32	1.20	3.91	19.44
	interquartile		.03	.18	.35	.46	8.33	2.03	2.07	4.85
GROUP B:										
Killary harbour	min	10	.01	.13	.10	1.09	11.43			16.30
	max		.08	.42	.24	3.60	31.06			25.60
	median		.05	.33	.22	2.60	19.20			21.33
	interquartile		.03	.12	.04	1.27	12.28			2.36
Mulroy Bay	min	4	.03	.16	.08	1.27	13.16			18.15
	max		.05	.23	.18	1.63	21.50			25.52
Clew Bay	min	4	.03	.17	.19	1.65	22.00			14.90
	max		.06	.26	.30	1.85	22.80			22.10
Tralee Bay	min	5	.03	.21	.26	1.51	16.43			15.44
	max		.09	.74	.47	2.37	36.14			20.60
	median		.06	.30	.38	1.77	19.05			18.85
	interquartile		.04	.33	.15	.20	10.31			2.83
Lough Foyle (Quigley's Point)	1985	17	.04	.38	.15	1.32	13.00			21.30
	1987		.06	.22	.34	1.12	12.30			14.10
	1988		.04	.33	.32	1.78	12.80			18.90
Summary of Group B data for pre-spawning samples	min	17	.02	.16	.08	1.28	16.43			14.90
	max		.09	.74	.47	2.91	36.14			22.78
	median		.05	.25	.26	1.77	19.50			19.66
	interquartile		.03	.17	.10	.79	4.20			3.18
MUSSEL WATCH										
1976	min	26		.03	0.00	.08	1.22	0.00		
	max		.97	3.12	4.00	29.00	6.40			
	median		.26	.05	.60	9.96	.03			
	interquartile		.13	.30	.56	7.90	.32			
1987	min	14	.04	.12	.19	.81				12.90
	max		.12	.36	1.55	4.02				23.00
	median		.06	.20	.37	1.11				15.90
	interquartile		.01	.08	.34	.30				5.70
Overall summary of data for pre-spawning samples	min	74	.02	.09	.08	.49	9.93	.26	1.22	12.90
	max		.17	2.51	2.60	5.59	51.23	3.33	5.36	24.45
	median		.05	.25	.47	1.51	17.48	1.20	3.91	19.10
	interquartile		.03	.16	.45	.54	7.38	2.03	2.07	4.40

**Table 2. Heavy metals (mg/kg wet weight) in oysters, 1980-1988. *Ostrea edulis* except where stated. With the exception of the Shannon estuary, all the areas sampled are Group B.**

Location		n	Hg	Cd	Pb	Cu	Zn	Cr	Ni	% dry weight
Owennacurra estuary C. gigas 1981-1987	min	10	.03	.13	.17	2.50	134.69	.23	1.51	21.80
	max		.22	.63	.81	25.78	431.69	.56	1.75	23.34
	median		.05	.37	.27	15.95	322.37			22.98
	interquartile		.03	.08	.36	8.01	151.87			1.06
Tralee Bay 1980-1988	min	10	.03	.29	.10	5.56	159.37	.77	.97	20.26
	max		.13	.66	.86	112.47	618.10	1.64	4.46	22.02
	median		.06	.49	.15	43.79	397.12			21.68
	interquartile		.04	.12	.09	2.59	62.83			.54
Clarinbridge 1981-1988	min	14	.02	.23	.04	1.36	114.68	.20	1.04	15.41
	max		.13	.54	.33	5.18	255.70	.90	1.91	24.33
	median		.05	.45	.15	2.44	175.56			21.36
	interquartile		.03	.18	.09	.26	61.77			6.38
Clew Bay 1983-1988	min	6	.04	.40	.12	4.23	190.90			18.50
	max		.13	.73	.17	6.90	426.96			27.57
	median		.12	.68	.16	5.21	320.13			20.77
	interquartile		.05	.05	.05	.80	156.30			4.12
Mulroy Bay 1983-1989	min	8	.01	.39	.06	4.12	219.89	8.37		16.00
	max		.04	1.64	.24	31.51	572.00			22.10
	median		.03	1.34	.20	7.22	332.95			20.07
	interquartile		.03	.74	.10	10.21	144.95			.66
Kilkieran Bay	1983		.08	.72	.24	1.14	362.44	2.74		22.73
	1987		.06	.42	.13					14.50
Shannon-Aughinish	1987		.06	.64	.18					16.20
Carlingford Lough	1987		.06	.54	.34					16.10
	1988		.04	.72	.35	52.60	332.00			19.00
Lough Foyle (Quigley's Point)	1988		.03	.57	.10	45.30	471.90			21.70
Overall summary of data for pre-spawning samples	min	31	.01	.29	.10	1.14	114.68	.20	.97	14.50
	max		.13	1.64	.56	60.35	471.90	8.37	4.46	27.57
	median		.05	.54	.17	5.57	332.48	.77	1.51	21.60
	interquartile		.03	.24	.10	22.78	190.57	1.25	.87	2.84

**Table 3. Heavy metals (mg/kg wet weight) in fish, 1978-1988. Each sample except those indicated by an asterisk consisted of an homogenate of 10 to 25 individuals.**

Location	ICES area	Date	Species	Tissue	n	Mean length (cm)	Cd	Cu	Hg	Pb	Zn	% dry weight		
EAST COAST Irish Sea	VIIa	1978-81	Cod	liver	min	4	48.8	.024	3.09	.03	.10	15.78		
					max			.280	5.55	.04	.37	17.22		
					median			.049	4.13	.04	.13	17.16		
		1978-85	Cod	flesh	min	6	49.0	.001	.02	.08	.02	3.01	19.93	
					max			.031	.31	.20	.3	4.67		
					median			.010	.18	.10	.06	3.71		
		1988	Dogfish	liver	min	1	74.5	.620	6.38	.03	.10	11.80		
					max			.031	.31	.20	.3	4.67		
					median			.010	.18	.10	.06	3.71		
		1978-88	Herring	flesh	min	5	22.8	.002	.05	.06	.04	3.91	24.05	
					max			.010	.82	.15	.07	7.00		
					median			.005	.33	.11	.06	5.34		
		1978	Plaice	liver	min	1	30.5	.108	2.14		.45	27.74		
					max			.020	.63		.03	4.88		
median	.003				.11			.08	.03	18.14				
1987	Porbeagle shark	flesh	min	1*	30.6	.002	.44	3.53	.9	29.26				
			max											
			median											
1978	Whiting	liver	min	1	32.4	.026	1.39		.17	7.64				
			max			.050	3.51	.06	.08	15.25				
			median			.009	.23		.16	3.93				
1988	Whiting	flesh	min	1	31.3	.030	.15	.06	.14	2.51	20.00			
			max											
			median											
Dublin Bay	VIIa	1986	Plaice	liver	min	1	26.5	.050	2.35	.09	.38	21.50	27.13	
					max									
					median									
1988	Plaice	flesh	min	1	22.1	.004	.22	.04	.03	5.13	19.74			
			max											
			median											
1988	Plaice	liver	min	1	22.1	.061	1.81	.07	.25	28.10	25.90			
			max											
			median											
SOUTH-EAST COAST	VIIa	1979	Cod	flesh	min	1	22.0	.004	.2	.07	.06	3.50		
					max									
					median									
SOUTH-WEST COAST	VIIg	1979	Plaice	flesh	min	1	22.0	.003	.54	.10	.01	27.81		
					max									
					median									
SOUTH-EAST COAST	VIIg	1985	Cod	flesh	mean	2	43.6	.009	.28	.14	.02	18.35		
					mean			49.5	.045	8.60	.11	.01	34.87	
		1985	Plaice	flesh	mean	1	26.7	.002	.16	.13	.06	18.65		
					mean			30.5	.002	.16	.15	.07	20.08	
		1987	Dogfish	flesh	mean	3	60.8	.013	.64	.09	.03	2.14	26.45	
					mean			60.8	.280	1.83	.16	.06	7.05	71.54
		1987	Scabbard fish	flesh	mean	1*	60.8	.020	.39	.47	.06	22.23		
					mean									
		WEST COAST	VIIb	1985	Cod	flesh	min	1	51.5	.100	.10	.09	.01	19.33
							max			.020	2.25	.05	.03	63.93
1986	Shark			flesh	min	1	30.5	.002	.10	.09	.02	21.58		
					max			.010	.51	.9	.05	27.25		
NORTH-WEST COAST	VIaS	1985	Herring	flesh	min	1	19.6	.004	.47	.07	.02	23.66		
					max			.011	.56	.06	.25			
						mean (88)								

**Table 4. Heavy metals (mg/kg wet weight) in fish — summary statistics, 1978-88.**

Species		n	Mean length (cm)	Cd	Cu	Hg	Pb	Zn	% dry weight
Cod flesh	min	10	37.6	.001	.02	.07	.01	3.01	17.80
	max		53.0	.031	.31	.20	.30	4.67	21.08
	median		49.8	.008	.19	.10	.04	3.50	18.99
	interquartile		6.2	.007	.14	.05	.06	1.26	.55
Cod liver	min	6	43.5	.020	2.25	.03	.01	15.78	34.87
	max		51.5	.280	8.60	.11	.37	17.22	63.93
	median			.040	4.13	.05	.10	17.16	
	interquartile			.040	2.46	.05	.10	1.44	
Plaice flesh	min	8	22.1	.002	.10	.04	.02	4.88	18.14
	max		30.6	.020	.63	.15	.09	5.13	21.58
	median		30.5	.003	.16	.09	.03		19.74
	interquartile		3.8	.002	.11	.07	.03		1.43
Plaice liver	mean	3		.073	2.10	.08	.36	25.78	26.52
Herring flesh	min	7	18.4	.002	.05	.06	.01	3.91	23.50
	max		24.9	.010	.82	.15	.07	7.00	27.81
	median		20.8	.004	.40	.1	.05	5.34	24.08
	interquartile		2.4	.001	.46	.05	.04	3.09	.84
Dogfish flesh	mean	4		.013	.49	.16	.04	2.14	25.62
Dogfish liver	mean	4		.363	2.97	.13	.07	8.24	71.54
Whiting flesh	mean	2		.020	.19	.06	.15	3.22	
Whiting liver	mean	2		.040	2.45	.06	.13	11.45	
Mackerel flesh	min	88		.001		0.01	.03		
	max		.050		0.16	.47			
	median		.008		.05	.25			
	interquartile		.007		.05	.14			
Summary of all data for fish flesh	min	31	18.4	.001	.02	.04	.01	1.49	17.80
	max		53.0	.031	1.25	.30	.30	7.00	29.48
	median		30.6	.005	.22	.09	.04	3.71	21.33
	interquartile		24.9	.007	.27	.07	.04	2.02	5.13
Summary of all data for fish liver	min	15	26.5	.020	1.39	.03	.01	6.73	25.90
	max		51.5	.620	8.60	.38	.45	28.10	71.65
	median			.060	2.35	.06	.10	15.52	49.40
	interquartile			.180	2.32	.05	.19	11.84	41.57
ICES baseline study (Anon, 1987)									
Cod	flesh			.005	.30	.05		3.56	
	liver	median		.034	6.70	.02	.05	18.40	
Plaice	flesh	median		.004	.27	.05		4.76	
	liver	median		.078	2.30	.06	.07	26.90	
Herring	flesh	median		.006	.81	.02	.02	7.82	
OSPARCOM human health tolerance values (Anon, 1991)									
	fish flesh			.05		.3	.5		
	fish liver			.5		1	2		

**Table 5. Chlorinated hydrocarbons (mg/kg wet weight) in mussels.**

PCBs = sum of cb28 + cb52 + cb101 + cb118 + cb138 + cb153 + cb180.  
 tDDT = sum of ppDDT + ppDDD + ppDDE + opDDT.  
 sChld = sum of cis-chlordane + trans-chlordane + trans-nonachlor + oxychlordane.

Location	Year	n	PCBs	HCB	αHCH	γHCH	Dieldrin	tDDT	sChld	%lipid weight	
GROUP A											
Boyne estuary	84-87	min	4	.005	nd	<.001	nd	.002	.005	nd	1.62
		max		.009	<.001	.001	.036	.007	.013	.001	3.58
		mean		.007				.004	.008		2.34
	1969						.060	.130		0.70	
	1970						.010	.040		1.30	
Dublin Bay	84-86	min	3	.005	nd	<.001	nd	.001	.008	.001	1.72
		max		.008	<.001	<.001	.001	.010	.014	.011	1.99
		mean		.007				.007	.010		1.86
Waterford Harbour	84-87	min	4	.005	nd	nd	<.001	<.001	.004	nd	1.24
		max		.009	<.001	.001	.001	.002	.009	.001	2.08
		mean		.007				.001	.006		1.66
	1969				t	t		.060		2.00	
	1970				t	t	.010	.030		0.30	
Cork Harbour	84-87	min	5	.007	nd	nd	nd	.001	.007	<.001	.84
		max		.030	.001	.001	.001	.011	.031	.006	3.78
		mean		.015				.005	.017		2.03
	1967					.150	.050			1.90	
	1967				.010	t	.040	.050		0.80	
	1969				t	t	.020	.050		1.10	
Shannon estuary	84-86	min	3	.002	nd	nd	<.001	.001	.003	nd	1.09
		max		.007	<.001	.001	.001	.004	.008	.015	2.22
		mean		.004				.002	.006		1.59
Wexford Harbour	85-87	min	3	.002	<.001	nd	nd	.002	.004	<.001	1.22
		max		.003	<.001	.002	<.001	.007	.027	.001	2.74
		mean		.003				.004	.013		1.85
	1969				t	0.010	.010	.020		0.40	
Summary of Group A data		min	22	.002	nd	nd	nd	.002	.003	nd	.84
		max		.030	.001	.002	.036	.011	.031	.015	3.78
		median		.007	nd	nd	nd	.002	.008	.001	1.81
	interquartile			.003			.004	.008	.001	.80	
GROUP B											
Killary Harbour	1985		.001	<.001	.001	<.001	.001	.002	.001	1.85	
	1985		.003	<.001	.001	.004	.003	.003	nd	3.23	
Mulroy Bay	1987		.003	<.001	<.001	<.001	.001	.002	.001	1.75	
	1987		.004	<.001	<.001	<.001	.002	.004	nd	2.39	
Tralee Bay	1985		.004	<.001	.002	.002	.005	.019	nd	2.27	
	1986		.002	nd	nd	.001	.001	.003	nd	1.51	
	1987		.001	nd	nd	<.001	.001	.002	nd	1.55	
Clew Bay	1987		.001	<.001	nd	.001	.002	.001	<.001	1.33	
	1987		.001	<.001	nd	.001	.003	.001	nd	1.37	
Cromane	1985		.002	<.001	<.001	<.001	.002	.003	.001	1.62	
	1986		.002	<.001	<.001	nd	.001	.003	.001	1.58	
	1987		.001	<.001	<.001	<.001	.001	.002	<.001	1.28	
Lough Foyle	1985		.008	<.001	.001	.001	.002	.017	.002	2.05	
	1987		.003	<.001	nd	.001	.001	.006	nd	1.58	
Summary of Group B data	85-87	min	12	.001	nd	nd	nd	.001	.001	nd	1.28
		max		.004	.001	.002	.004	.005	.019	.001	3.23
		median		.002	nd	nd	nd	.002	.003	nd	1.60
	interquartile			.002			.002	.001		.62	
Mussel watch	1987	min	14	.001	nd	nd	nd	.001	nd	nd	1.11
		max		.005	nd	.001	.001	.001	.006	.001	2.20
		median		.002	nd	nd	nd	.001	.002	nd	1.54
	interquartile			.002			.002	.003		.41	
Overall summary of entire dataset: Statistical characteristics of the 1984-1987 database for chlorinated hydrocarbons in mussels.											
		min	50	.001	nd	nd	nd	nd	nd	.84	
		max		.030	.001	.002	.036	.011	.031	.015	3.78
		mean		.005	<.001	<.001	.001	.002	.006	<.001	1.78
		median		.003	nd	nd	nd	.001	.004	nd	1.62
		interquartile		.005				.002	.006		.59
OSPARCOM human health tolerance values (Anon, 1991).											
Molluscs				.52	.05		.1	.2	.5		

Table 6. Chlorinated hydrocarbons (mg/kg wet weight) in oysters.

Location	Species	Year	PCBs	HCB	αHCH	γHCH	Dieldrin	sDDT	sChd	%lipid weight
Carlingford Lough	pacific	1987	.004	<.001	.001	.001	.002	.005	.001	2.15
Owennacurra estuary	native	1985	.005	nd	.001	.001	.008	.018	.001	1.78
		1986	.006	nd	nd	<.001	.002	.004	.001	1.24
		1987	.006	nd	nd	nd	.003	.010	nd	2.68
Shannon estuary	native	1987	.001	<.001	<.001	<.001	.001	nd	<.001	1.23
Clarinbridge	native	1985	.001	<.001	.001	.001	.002	.005	.001	1.27
		1986	.001	<.001	<.001	nd	nd	.001	<.001	1.26
		1987	.001	<.001	<.001	<.001	.001	.002	nd	1.23
Kilkeran Bay Clew Bay	native	1987	.001	<.001	.001	<.001	nd	<.001	nd	1.37
	native	1985	.002	<.001	.001	<.001	<.001	.004	.001	1.53
Mulroy Bay	native	1984	.002	nd	nd	nd	nd	.001	nd	2.28
		1985	.001	nd	.001	.001	.001	.005	.001	1.24
Summary of entire dataset n = 12	min		.001	nd	nd	nd	nd	nd	nd	1.23
	max		.006	nd	.001	.001	.008	.018	.001	2.68
	mean		.003	nd	<.001	<.001	.001	.005	<.001	1.61
	median		.002	nd	<.001	nd	.001	.004	<.001	1.32
	interquartile		.004	nd	.001	.001	.002	.004	.001	.73

Table 7. Chlorinated hydrocarbons (mg/kg wet weight) in fish.

Location	ICES area	Year	Species	Number	Mean length (cm)	HCB	αHCH	γHCH	Dieldrin	sDDT	sChd	PCBs	%lipid weight
EAST COAST													
Irish Sea	VIIa	1985	Cod Muscle	2	49.4	nd	nd	<.001	<.001	<.001	>.001	.001	0.27
	VIIa	1985	Plaice Muscle	1	30.6	nd	nd	nd	>.001	nd	nd	nd	0.10
	VIIa	1985	Herring Muscle	3	20.1	nd	.001	.001	.008	.013	.002	.018	4.97
Dublin Bay	VIIa	1986	Plaice Liver	1	26.5	.002	.005	.005	.036	.051	.003	.032	12.02
SOUTH-EAST COAST													
	VIIa	1985	Herring Muscle	1	22.0	nd	.002	.001	.01	.017	.005	.017	6.12
SOUTH-WEST COAST													
	VIIj	1985	Cod Muscle	2	43.6	nd	nd	nd	>.001	.002	>.001	.003	.26
	VIIj	1985	Cod Liver	1	49.5	.002	.007	nd	.056	.432	.112	.410	19.70
	VIIj	1985	Plaice Muscle	1	26.7	nd	nd	>.001	>.001	>.001	nd	>.001	0.30
	VIIg	1985	Plaice Muscle	2	30.5	nd	>.001	>.001	>.001	.001	>.001	.002	0.34
WEST COAST													
	VIIb	1985	Cod Muscle	1	51.5	nd	nd	>.001	>.001	>.001	>.001	.001	0.37
	VIIb	1985	Cod Liver	1	51.5	nd	.016	.004	.042	.087	.061	.075	48.70
	VIIb	1985	Plaice Muscle	1	30.5	nd	nd	nd	>.001	>.001	nd	>.001	0.83
	VIIb	1986	Shark Muscle	1		nd	nd	nd	>.001	.015	.002	.014	.34
NORTH-WEST COAST													
	VIIaS	1985	Herring Muscle	1	19.6	<.001	.001	<.001	.003	.007	.002	.004	2.30
de Boer et al. (1983)													
Celtic Sea		1981	Herring Muscle			.002	.005	.002	.007	.024	.009	.032	10.4
West Scotland		1982	Herring Muscle			.001	.001	.001	.005	.008	.007	.017	7.0
Central North Sea		1981	Herring Muscle			.004	nd	.005	.013	.023	.010	.054	8.2
OSPARCOM human health tolerance values (Anon, 1991)			Fish Muscle			.05		.05	.1	.5	.1	.56	
			Fish Viscera			.05		.2	.2	.5		2.8	

Table 8. Heavy metals (µg/l) in seawater.

Location	Year	Depth (m)	Salinity (ppt)		Suspended solids (mg/l)		Cadmium			Mercury			Copper			Lead			Zinc		
			Min	Max	Min	Max	Min	Max	median	Min	Max	median	Min	Max	median	Min	Max	median	Min	Max	
Barrow estuary	1979	1	0.24	13.87			0.007	0.320		0.006	0.025		1.56	6.14		0.500	0.100		8.16	15.36	
Bandon estuary	1980	1	18.47	34.21			0.480	5.200		0.005	0.024		2.05	3.63		<0.174	1.150		20.90	68.64	
Boyne estuary	1980	1	0.20	32.77	2	10	0.330	0.600		0.002	0.040		2.06	3.30		0.276	0.060		8.95	25.97	
	1985	1	0.10	26.00	7	44	0.047	0.089	0.070	0.008	0.025	0.014	1.81	5.31	3.06	0.230	0.910	0.530			
Dublin Bay	1979	1	30.59	32.64			0.320	1.720					1.50	3.10		0.308	1.230		20.00	31.00	
	1980	1	29.47	33.32	2	38	0.250	0.415		0.009	0.059		1.79	4.81		0.400	1.720		15.20	38.00	
	1985	1	26.00	33.00	2	16	0.038	0.083	0.051	0.010	0.059	0.025	1.03	4.42	1.86	0.130	0.940	0.350			
Waterford Harbour	1979	1	13.27	31.35			0.110	1.180		0.006	0.044		0.79	3.04		0.400	2.080		18.50	72.85	
	1980	1	3.96	32.94	14	59	0.133	0.557		0.003	0.018		1.38	2.53		0.247	1.700		18.66	27.80	
	1985	1	5.00	30.00	12	47	0.034	0.096	0.060	0.013	0.033	0.024	1.07	5.47	2.56	0.110	0.670	0.510			
Cork Harbour	1985	1	15.50	34.00	5	26	0.047	0.075	0.059	0.014	0.082	0.031	1.55	8.40	2.36	0.170	0.570	0.490			
Shannon estuary	1979	1	0.16	29.05			0.020	0.310		<0.003	0.024		1.72	5.56		0.050	3.840		10.40	51.68	
	1980	1	0.17	27.97	16	28	0.434	0.930		0.001	0.031		1.33	2.96		<0.171	1.207		13.93	36.18	
	1985	1	3.00	24.00	55	780	0.044	0.096	0.079	0.012	0.053	0.015	1.36	9.76	3.68	0.300	0.610	0.460			
Wexford Harbour	1979	1	11.58	33.08			3.800	1.620		0.004	0.027		0.80	4.10		0.200	1.500		13.00	42.00	
	1980	1	34.21	15.49	8	16	0.138	0.480		0.009	0.023		0.88	2.31		<0.180			12.36	34.42	
Tralee Bay	1979	1	28.75	31.80			0.140	3.800					1.90	30.00		0.128	0.768		1.30	27.00	
	1980	1	4.10	33.40	10	84	0.440	1.840		0.005	0.028		1.13	5.60		0.310	0.930		12.54	52.13	
DOE Tech. Memo. no 1																					
Water quality objectives (Anon, 1979c)								10.0			0.10			50.0			100			100	

Table 9. Heavy metals (mg/kg dry weight in <63µ fraction) in sediments, 1979-1985.

Location	Year	n	Organic carbon (%)		Cadmium		Copper		Lead		Zinc		Chromium		Nickel	
			min	max	min	max	min	max	min	max	min	max	min	max	min	max
Bandon estuary	1979		5.5	12.0	.12	.75	7.26	18.78	7.67	50.81	43.53	94.62				
	1980		4.5	14.8	<0.31	.16	8.30	16.34	7.56	25.70	39.14	67.56				
	median	16		10.2		.12		9.92		15.79		63.95				
	interquartile			5.6		.26		5.19		7.94		27.17				
Barrow estuary	1979		12.7	15.5	0.24	.52	7.35	36.65	15.98	40.16	71.53	107.50				
	median	6		13.8		.31		15.01		21.90		80.45				
	interquartile			1.5		.02		9.24		8.20		20.43				
Boyne estuary	1980		12.1	14.1	<0.04	1.67	7.74	50.37	14.45	93.21	43.96	151.70				
	median	6		12.2		.04		30.07		26.47		86.13				
	interquartile			2		.08		32.76		24.58		27.45				
Cork Harbour	1985	2		4.4		2.79		19.85		34.02		50.81				
Dublin Bay	1980		11.4	20.1	<0.05	.41	7.61	33.41	16.71	91.89	41.47	106.70				
	1985		7.2	8.2	.14	.31	2.55	10.46	16.00	28.50	34.14	88.52				
	median	9		12.9		.11		14.50		25.29		77.98				
	interquartile			7.1		.17		10.30		9.34		46.35				
Dublin Bay sewage sludge dump site	1983		.2	4.5	.04	.58	.81	28.32	1.41	50.36	20.98	215.50	2.05	16.39	1.79	27.62
	median	44		2.3		.20		3.78		14.00		39.78		4.07		3.88
	interquartile			1.0		.16		5.46		8.65		33.12		3.07		6.75
Shannon estuary	1979		6.1	15.0	0.53	.86	5.27	8.06	15.59	22.24	49.23	85.00	10.75	17.50		
	1980		12.0	19.5	<0.02	<0.04	4.88	10.57	12.03	23.95	32.92	81.60				
	1985		7.2	11.6	0.36	.62	12.00	13.88	11.11	25.66	78.68	118.03				
	median	19		12.9		.52		6.85		18.65		72.26		13.23		
interquartile				5.3		.59		1.94		5.23		25.81		4.25		
	1979		8.2	12.6	0.29	.84	15.90	41.67	18.30	36.21	<0.01	338.38				
	1980		9.5	12.4	0.13	.62	8.48	61.04	7.22	28.88	38.38	128.85				
median		12		10.2		.43		18.34		22.60		83.36				
	interquartile			2.8		.26		8.26		8.80		64.12				
	1979		10.6	15.4	0.16	.49	7.82	13.77	11.12	25.68	38.00	79.22				
1980		10.9	15.0	<0.04	.26	8.47	21.65	11.37	24.57	60.16	95.54					
	1985		5.2	10.2	0.53	.76	10.52	19.66	6.35	58.15	65.57	93.44				
	median	17		12.9		.32		11.55		20.52		73.00				
interquartile				2.5		.25		3.25		8.77		15.43				
	1979		15.9	23.1	0.43	1.03	4.05	342.00	3.12	187.50	24.20	404.00				
	1980		.9	6.9	<0.03	.16	18.34	59.55	<0.61	18.44	26.94	131.07				
1985		13		15.9	1.82	1.97	51.71	63.78	221.80	25.20	108.19	145.90				
	median			15.9		.46		24.02		5.08		38.20				
	interquartile			12.2		.76		41.20		15.83		93.20				
Summary statistics	mean	100		11.6		.38		22.07		22.39		78.22				
	median			12.1		.29		12.96		19.27		72.78				
	interquartile			4.8		.50		11.00		10.47		32.46				

Table 10. Nutrients ( $\mu\text{M}$ ) in estuarine and coastal waters, 1979-83.

Location	Year	Salinity (ppt)		Nitrate ( $\text{NO}_2 + \text{NO}_3\text{-N}$ )		Phosphate ( $\text{PO}_4\text{-P}$ )		Ammonia ( $\text{NH}_4\text{-N}$ )		Silica ( $\text{SiO}_2\text{-Si}$ )		Chlorophyll a ( $\text{mg/m}^3$ )	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Bandon estuary	1978	7.5	34.2	.8	52.8	.6	1.2	.3	1.2				
	1979	6.7	31.6	8.8	152.0	.3	2.7	.3	2.6				
	1980	18.5	34.2	1.4	55.5	1.6	4.4	1.2	10.6	2.0	4.3	.7	25.0
Barrow estuary	1979	.2	13.9	108.2	156.8	6.1	9.0	5.0	13.0		0.2		
Boyne estuary	1980	.2	33.3	1.0	147.0	1.0	3.3	1.7	6.4	1.8	64.6	1.4	3.7
Dublin Bay	1979	30.6	33.6	3.6	31.5	1.2	4.3	1.5	30.1				
	1980	29.5	33.3	10.3	23.8	1.1	3.6	3.1	7.6	8.0	12.8		
Waterford Harbour	1979	13.3	34.5	5.6	108.0	.8	2.8	1.3	9.7			1.0	5.9
	1980	4.0	35.6	11.1	137.0	4.1	1.3	2.7	7.2	3.1	23.3	1.9	9.2
Shannon estuary	1979	.2	29.6	15.8	73.5	.7	1.7	10.2	4.4	5.0	48.8	.2	6.4
	1980	.2	28.0	49.3	94.2	.5	1.5	2.1	3.3	6.2	14.1	1.9	5.1
Wexford Harbour	1979	11.6	33.4	3.2	230.0	.5	2.8	.5	10.1			1.4	7.6
	1980	15.5	34.5	1.0	142.0	1.0	5.2	.8	5.2	.1	42.8	2.8	4.6
Tralee Bay	1979	28.8	32.6	.8	1.3	.2	.5	.5	.9			4.0	8.1
	1980	4.0	34.1	1.2	91.2	1.3	6.8	1.2	27.2	1.5	33.3	.7	11.3
Mulroy Bay	1980			.1	3.4	.3	4.4	.6	21.8	1.1	4.5	.1	1.4
	1982	29.8	35.2	.1	1.5	.3	1.2	.6	6.9	.8	9.0	>.1	3.1
	1983	29.0	34.8	.3	1.4	.3	1.6	<.4	3.8	>.9	5.4	.3	2.6
Dublin Bay sewage sludge dumping ground	1983	29.0	32.5	.6	33.3	.4	1.6	.8	3.4	1.0	10.6	.9	5.9
Cork sea disposal site 1983-85		29.9	34.5	.2	21.9	.1	1.2	.5	2.6	1.4	12.3	.2	16.7

Appendix 1  
 Joint Monitoring Programme guide values for the assessment of monitoring data for mercury and cadmium in biota  
 Concentrations in  $\text{mg/kg}$  dry and wet weights (Aron 1990a)

	lower	medium	upper	wet/dry weight
<b>CADMIUM</b>				
in mussels	<2	2-5	>5	dry
in oysters	<8	8-20	>20	dry
<b>MERCURY</b>				
in fish muscle	<0.1	0.1-0.3	>0.3	wet
in molluscs	<0.1	0.1-0.3	>0.3	wet
	0.6	0.6-1.0	1.0	dry
in crustacea	<0.1	0.1-0.3	>0.3	wet
	0.5	0.5-1.0	1.0	dry

**Appendix 2**  
**Summary of the strictest human health values applied by OSPARCOM countries (Anon, 1991). Concentrations in mg/kg wet weight.**

Cadmium	Fish	0.05	standard
	– viscera	0.5	standard
	Crustaceans	0.1	guidance
	Molluscs	0.5	guidance
Copper	Fish	10	guidance
	– viscera	10	guidance
	Crustaceans	10	guidance
	Molluscs	10	guidance
Lead	Fish	0.5	standard
	– viscera	2	guidance
	Crustaceans	0.5	standard
	Molluscs	0.8	guidance
Mercury	Fish	0.3	standard
	– viscera	1	guidance
	Crustaceans	0.5	standard
	Molluscs	0.5	standard
Zinc	Fish	50	guidance
	– viscera	–	
	Crustaceans	50	guidance
	Molluscs	50	guidance
DDT and its transformation products	Fish	0.5	standard
	– viscera	5	standard
	Crustaceans	0.5	standard
	Molluscs	0.5	standard
HCB	Fish	0.05	guidance
	– viscera	0.05	guidance
	Crustaceans	0.05	guidance
	Molluscs	0.05	guidance
γ HCH	Fish	0.1	standard
	– viscera	0.2	guidance
	Crustaceans	0.1	standard
	Molluscs	0.1	standard
CB 28	Fish	0.08	standard
CB 52		0.04	standard
CB 101		0.08	standard
CB 118		0.08	standard
CB 138		0.1	standard
CB 153		0.1	standard
CB 180		0.08	standard
Sum 7CBs		0.56	
CB 28	Fish	0.4	standard
CB 52	– viscera	0.4	standard
CB 101		0.4	standard
CB 118		–	
CB 138		0.6	standard
CB 153		0.6	standard
CB 180		0.4	standard
Sum 7CBs		2.8	
CB 28	Crustaceans	0.08	standard
CB 52	Molluscs	0.08	standard
CB 101		0.08	standard
CB 118		–	
CB 138		0.1	standard
CB 153		0.1	standard
CB 180		0.08	standard
Sum 7CBs		0.52	