NRA Water Quality Series 12

THE QUALITY OF THE HUMBER ESTUARY

1980 - 1990

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Report of the National Rivers Authority

July 1993

NRA

National Rivers Authority

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THE QUALITY OF THE HUMBER ESTUARY

(1980 - 1990)

NRA WATER QUALITY SERIES 12

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PREFACE

The Humber Estuary is the largest estuary within the NRA's jurisdiction. Three Regions of the NRA - Anglian, Severn-Trent and Northumbria & Yorkshire - share management responsibility for water quality within the estuary. These three Regions carry out extensive monitoring in the Humber, as did their predecessor organisations in the years before the NRA was formed. This report, arising from the Humber Estuary Committee, summarises the results of that monitoring during the 1980 to 1990 decade.

The report covers the quality of the Humber and its tidal tributaries. Over the years much work has been undertaken to reduce the impact of the conurbations and discharges of trade effluent in the catchment. More schemes are still in hand and will come to fruition in the years ahead.

The NRA is fully committed to maintaining within the Humber Estuary and its tidal tributaries and adjacent coastal waters, a healthy, diverse and prolific biological life. Water quality will continue to be managed to ensure that this objective is met.

R. J. Pentreath

DR R J PENTREATH
Chief Scientist

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This report was prepared by Geoff Woodward, formerly Environmental Quality Manager, Severn Trent Water and Rosie Fair, formerly Biologist to the Humber Estuary Committee.

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Mr D Sayers (Chairman) - Regional Marine Officer, Anglian Region, National Rivers Authority.

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CONTENTS

		Page
Executive Summary		**9**
Introduction		9
Physical Characteristics		9
Water Quality Management		10
Pollution Inputs to the Humber Estuary		10
Chemical Quality		11
Biological Quality		12
Fish Populations		13
Conclusions		13
1.	**INTRODUCTION**	**15**
1.1	General description of the Humber Estuary and its environs	15
1.2	Water quality management in the Humber Estuary	18
1.3	Monitoring	19
2.	**PHYSICAL CHARACTERISTICS OF THE ESTUARY**	**21**
2.1	Freshwater inputs	21
2.2	Tides and currents	21
2.3	Sediments	21
2.4	Salinity	22
3.	**OBJECTIVES AND STANDARDS RELEVANT TO THE HUMBER ESTUARY**	**24**
3.1	Humber environmental quality objectives	24
3.2	Freshwater river quality objectives and estuary classification	24
3.3	European Community controls	26
3.4	United Kingdom controls	26
3.5	The derivation of Environmental Quality Standards for discharges to the Humber Estuary	27

			Page
4.	**INPUTS TO THE HUMBER ESTUARY SYSTEM**		**28**
4.1	Inputs from freshwater rivers		28
	a.	Biochemical oxygen demand and ammoniacal nitrogen	28
	b.	Temperature and dissolved oxygen	28
	c.	Metals	32
	d.	Pesticides and other synthetic organic compounds	33
4.2	Direct discharges of significant biochemical oxygen demand and ammoniacal nitrogen loads		34
4.3	Direct discharges of metals		38
5.	**CHEMICAL QUALITY OF THE HUMBER ESTUARY SYSTEM**		**42**
5.1	Dissolved oxygen		42
5.2	Biochemical oxygen demand and ammoniacal nitrogen		46
5.3	Metal concentrations in the estuary		46
	a.	Tidal rivers	46
	b.	Estuary downstream of Trent Falls	47
	c.	Metals in sediments	48
5.4	Pesticides, hydrocarbons and other organic micropollutants		50
5.5	Nutrients		52
6.	**BIOLOGICAL SURVEYS**		**55**
6.1	Tidal rivers		55
6.2	Intertidal monitoring		57
	a.	South shore	57
	b.	North shore	61
	c.	Upper estuary mudflats	62
6.3	Subtidal fauna		62
	a.	Distribution patterns	64

			Page
	b.	Faunal associations	66
6.4	Discussion		67
7.	**BIOACCUMULATION**		**69**
7.1	Heavy metal levels in seaweed *(Fucus vesiculosus)*		69
	a.	South shore	69
	b.	North shore	71
7.2	Heavy metal levels in ragworms *(Nereis diversicolor)*		73
	a.	South shore	73
	b.	North shore	75
7.3	Heavy metal levels in fish and shrimp		77
	a.	Brown shrimp *(Crangon crangon)*	77
	b.	Flounder *(Platichthys flesus)*	78
	c.	Dover sole *(Solea solea)*	79
7.4	Discussion		80
8.	**FISH POPULATIONS**		**81**
8.1	Fish community structure		81
8.2	Trent salmon fishery		82
8.3	Spatial distribution of fish		82
8.4	Long term variations in individual species		83
	a.	Plaice	83
	b.	Dab	85
	c.	Sand goby	85
8.5	Fish and water quality interactions		85

		Page
9.	**FUTURE DEVELOPMENTS**	**87**
9.1	Statutory Water Quality Objectives	87
9.2	Environmental Agency	88
9.3	The Paris Convention	88
9.4	The North Sea Conferences	89
9.5	Input of nutrients	89
9.6	Improved effluent treatment and other developments	90
9.7	Humber Barrage	91
9.8	Conclusion	92
10.	**REFERENCES**	**93**
11.	**GLOSSARY**	**96**
12.	**APPENDICES**	**98**
	Appendix A — Terms of reference and objectives of the Humber Estuary Committee	98
	Appendix B — River Quality Classification	99
	Appendix C — Scheme for classifying estuaries	101
	Appendix D — EC Dangerous Substances Directive, List 1 and List 2	102
	Appendix E — Environmental Protection Act 1990 Red List	103
	Appendix F — Fish species recorded from the Humber tidal system	104

EXECUTIVE SUMMARY

1. INTRODUCTION

The Humber Estuary is the largest estuary in the United Kingdom, with a catchment draining one fifth of the area of England. It is a valuable resource for the community, for fisheries and for wildlife. In the wider context, as the major United Kingdom freshwater input to the North Sea, the Humber has a special importance with regard to its quality.

In 1982 the Humber Estuary Committee published a review of the quality of the estuary during the period 1961 to 1981. This report continues by reviewing the results of the monitoring and management of water quality carried out during the period 1980 to 1990 by the National Rivers Authority and its predecessor Water Authorities. Bearing in mind that any consideration of estuarine water quality must take into account the rivers draining to the estuary, this report also considers the whole of the tidal waters associated with the Humber.

Much of the country's coal output, electricity generating capacity and manufacturing industry is located within the Humber catchment and some 11 million people live within the area. Most of the population live in the large inland cities within the catchment, the largest being Birmingham, Leeds, Sheffield, Bradford, Leicester and Nottingham, all of which have populations greater than 250,000. This contrasts with the population distribution around most other major UK estuaries, where the principal centres of population are located in the immediate environs.

2. PHYSICAL CHARACTERISTICS

The average freshwater flow generated by the Humber catchment is 250 cubic metres per second, which is more than three times that of the River Thames. This freshwater flow is derived from two major river catchments, the Trent and the Yorkshire Ouse. The freshwater flow from the Trent catchment to the estuary is composed principally of the main nontidal Trent, whereas the freshwater input from the Ouse catchment consists of significant contributions from the rivers Don, Aire, Derwent and Wharfe, with only around 25% of the total freshwater flow being derived directly from the Ouse upstream of these tributaries.

The Humber is a highly energetic estuary and has a tidal range of seven metres, which is extremely high on a world scale and is only exceeded in Britain by the Bristol Channel. The average tidal excursion in the Humber is around fifteen kilometres, which is several times greater than the sea water displacement due to the freshwater input during the tidal cycle. Thus effluents which are discharged to the estuary are contained within it for a considerable length of time, being progressively diluted and edging gradually into the North Sea.

The Humber has a characteristic turbid swirling appearance and contains very high concentrations of suspended sediments. These sediments are derived mainly from the North Sea rather than the freshwater rivers.

The highest suspended solids concentrations are found in the vicinity of Trent Falls, where the rivers Trent and Ouse meet, and concentrations are much greater in the Ouse than in the Trent. The bottom deposits within the estuary become finer towards the banks of the estuary, with coarser sands and gravel deposits in the central channels, where the strongest currents are found.

The range of salinity in the Humber system varies from the low salinity of the freshwater rivers to practically 100% sea water at the estuary mouth. Within the estuary the salinity can change rapidly during a tidal cycle, providing a harsh biological environment in which only specialised species can exist.

3. WATER QUALITY MANAGEMENT

There is now over 30 years experience of co-ordinated chemical and biological monitoring within the Humber Estuary. In the past this was carried out by the appropriate Water Authorities and their predecessors. Since its formation in 1989, the National Rivers Authority has been responsible for water quality management in the Humber Estuary and has continued to exercise this responsibility through a revised Humber Estuary Committee.

Three general environmental quality objectives have been recognised for the Humber system:

i. the protection of all existing defined uses of the estuary;

ii. the ability to support on the mud bottom the biota necessary to sustain sea fisheries; and

iii. the ability to allow the passage of migratory fish at all states of the tide.

These objectives will be achieved by the control of new discharges and by the progressive improvement of existing discharges in order to meet international environmental quality standards which have been set for the estuary. These have been set in two zones. Freshwater standards are applicable landwards from Trent Falls and estuarine water standards apply seawards from Trent Falls to the mouth of the estuary. A co-ordinated chemical monitoring programme is carried out throughout the estuary seven times per year and this is complemented by an extensive biological monitoring programme of bioaccumulation and community analysis. From time to time, these routine surveys are supplemented by special intensive surveys and a network of continuously recording dissolved oxygen monitors is maintained in the estuary at strategic locations.

The full control of estuarine pollution was made possible in 1984 by the implementation of the Control of Pollution Act, 1974. Since then, the environmental policies of the European Community have become increasingly important in water quality management. Several EC Directives now control the input of specific pollutants to the estuary and in particular the Dangerous Substances Directive (76/464/EEC) progressively tightens control as new substances are classified under List 1 and List 2 of the Directive, which are commonly known as the 'Black' and 'Grey' lists respectively.

Other EC Directives applicable to the estuary control the microbiological quality of the bathing beach at Cleethorpes and the heavy metals content of the titanium dioxide discharges located on the south bank of the Humber. More generally, the recently introduced EC Directive on Urban Waste Water Treatment (91/271/EEC) will set standards for the treatment of all municipal sewage discharged to fresh, estuarine and coastal waters. This Directive will be particularly significant in the Humber Estuary and several large municipal discharges will require substantial improvement.

International concern for the quality of the North Sea has been discussed at three North Sea Conferences; following the third there was agreement by the UK and other relevant governments to reduce by 50% or more the discharge of a wide range of dangerous substances to the North Sea between the years 1985 and 1995.

The control of nutrients, that is, nitrogen and phosphorus, is necessary in parts of the North Sea but no such controls are required in the Humber Estuary at present.

4. POLLUTION INPUTS TO THE HUMBER ESTUARY

The main inputs of polluting load to the Humber Estuary are from the freshwater rivers and the direct discharges of sewage and industrial effluents. The direct sewage discharges contribute about half of the total Biochemical Oxygen Demand (BOD) load discharged to the estuary with the vast majority of it originating from the Hull and Grimsby sewage discharges. The remaining BOD load is divided equally between the freshwater river systems and the direct industrial discharges.

Sewage discharges also contribute around one quarter of the total ammoniacal nitrogen load discharged, but the Ouse river system is the source of nearly half of the total load.

The concentrations of all metals except copper are generally below the Environmental Quality Standards (EQS) in the freshwater section of the estuary. However, the copper present in the river system, and within the estuary, has been shown to be non-toxic as it is complexed with organic matter. Significant metal concentrations are added to the estuary via the direct sewage discharges and, more importantly, from the direct industrial discharges which are the major sources of metal loads to the estuary.

It is commonly the case that a single industrial discharge provides the majority of the load of an individual metal discharged. Thus the non-ferrous metals smelter situated on the north bank of the Humber discharged practically all of the arsenic and cadmium load to the estuary during the decade under consideration. This particular industrial concern has now closed and any discharges from the site will end completely in 1993. The two titanium dioxide discharges on the south bank of the Humber discharge the bulk of the chromium to the estuary and the discharge from the synthetic fibre manufacturer in the Grimsby area is responsible for the bulk of the zinc discharged.

The lack of reliable effluent flow data renders it difficult to compute accurate metal load values but, generally, there does appear to have been a reduction in the metal load discharged from industry during the decade whilst the load from the river system and sewage effluents has not varied significantly.

5. CHEMICAL QUALITY

The overall quality of the Humber Estuary is determined largely by the quality of the rivers draining via the Yorkshire Ouse and Trent systems. Thus the quality of these freshwater inputs is of crucial importance to the estuary. The Trent river input is of reasonable quality and meets its non-statutory river quality objectives standards, but the input from the Ouse system requires considerable improvement.

The most serious pollution problem is the severe depletion of dissolved oxygen in the area around Trent Falls. This is a long standing problem and is caused by discharges of inadequately treated sewage and industrial effluents into the lower reaches of the Ouse system where there is minimal dilution available. Complete de-oxygenation occurs in this region during low flow periods in the summer months. The tidal Ouse fails to satisfy the EQS for dissolved oxygen for some 40 km from Selby to Blacktoft and the rivers Aire and Don also fail in their lower reaches. However, a steady improvement in dissolved oxygen concentration has occurred during the past thirty years although substantial further improvement is necessary. Major improvements to sewage discharges are currently being undertaken particularly at Bradford, Huddersfield, Leeds and Chesterfield, and by the mid 1990s it is expected that the dissolved oxygen regime should be substantially improved.

The EQS for dissolved oxygen is achieved elsewhere in the estuary and dissolved oxygen concentration generally improves towards its mouth as increasing dilution with well oxygenated sea water becomes available.

The large volumes of cooling water discharged from the electricity generating stations in both the Ouse and Trent catchments have caused some thermal pollution in the past, particularly in the Trent system. However, the progressive closure of direct cooled power stations and the closure of older stations has led to a steady reduction in water temperature.

The EQS for unionised ammonia is exceeded in the rivers Aire and Don by a large margin, due to the sewage discharges, but elsewhere throughout the estuary system this standard is satisfied.

Despite the substantial discharges of metal load to the estuary, the dilution available ensures that the concentrations for all metals (except copper), are well below the appropriate EQSs throughout the estuary system.

Sediments within the estuary have been analysed for metals on a regular basis and although there are no EQS values set for sediments, the variation in metal concentrations does provide useful evidence of any local contamination.

The general tendency appears to be for sediments obtained from the tidal rivers to contain lower concentrations of metal than those from the estuarine waters, although there is considerable variability within the data. The sediments in the estuary appear to be well mixed although local elevation of the arsenic and chromium levels is observed around the major industrial inputs of these metals.

The concentrations of pesticides and other organic compounds monitored in the estuary are all at very low levels and well below the relevant EQS. The only exception to this was hexachlorocyclohexane (HCH) which contaminated the River Aire in the early 1980s. This contamination was derived from the textile industry in West Yorkshire but the use of HCH has steadily declined and the river now meets its EQS for this substance.

There is a high level of nutrients - nitrogen and phosphorus - within the Humber system derived from both sewage and industrial sources. However, no problems associated with eutrophication have been identified and there are presently no EQS values stipulated for nutrients within the estuary.

6. BIOLOGICAL QUALITY

Biological monitoring forms an integral part of the Humber monitoring programme and is based on an assessment of environmental quality by the examination of invertebrate populations in the intertidal and subtidal habitats. These organisms do not move far and are continually exposed to the surrounding water and can thus provide an integrated assessment of water quality.

The tidal rivers of the Humber system are a harsh environment for invertebrates, with fluctuating salinities and tidal scouring effects prohibiting the development of rich benthic faunas. Consequently the invertebrate community of the tidal rivers is generally poor in species composition. The poor chemical quality of the rivers Don and Aire is confirmed by their biological quality, with an abundance of pollution tolerant species indicating severe organic pollution.

Approximately one third of the estuary is exposed at low water and many discharges are made at or above mean low water and effluents are dispersed over the intertidal flats. Monitoring is carried out at specific sites on both the north and south shores. An assessment of temporal trends is undertaken by the examination of abundance and species variety. The fauna of the lower estuary on the south bank have been modified by polluting discharges with the presence of large densities of pollution tolerant species indicative of organic enrichment. Following improvements to the disposal of sewage from Grimsby, implemented over the decade, there has been a dramatic decline in the densities of these indicator species and the invertebrate fauna are now showing evidence of improvements. On the north shore of the estuary there is no regime of heavy industrialisation which parallels the industrial zone on the south bank and the majority of discharges are of a domestic origin. There have been relatively few changes in effluent disposal over the decade and consequently the community structure of the north shore fauna has not varied appreciably.

Monitoring of the subtidal habitat comprises both routine annual sampling and extensive grid surveys conducted on a five-yearly basis. The assessment of changes in environmental quality over the decade was undertaken by examining the information provided from these detailed grid surveys. In general there were no major changes observed over the monitoring period. The enhanced population of the indicator species, the polychaete worm *Capitella capitata*, in the middle estuary was still apparent in 1990 and may be linked to the discharge of crude sewage from Hull. The consistency of this pattern would suggest that organic enrichment has been a persistent problem in this area.

The use of biological material to assess metal contamination provides an integrated assessment of conditions over a period of time and may be considered as an estimate of biologically available levels of contaminants. In the Humber, the seaweed *Fucus vesiculosus* has been used to study bioaccumulation. Additionally, the ragworm *Nereis diversicolor* has been used effectively, as has the monitoring of metals in fish caught within the estuary.

Iron concentrations in *Fucus vesiculosus* have fallen dramatically since the two titanium dioxide outfalls were relocated to deeper water. Reductions in the discharge from the non-ferrous metal smelter on the north bank have been found to be accompanied by significant reductions in the levels of arsenic and cadmium in *Nereis diversicolor*. Copper and zinc discharges in the lower estuary have been reflected in the monitoring results of *Fucus vesiculosus* in that area.

7. FISH POPULATIONS

Fish populations within the Humber Estuary have been studied but the identification of trends is difficult given the relatively short data series available and the fact that stocks will be influenced by events outside the estuary in the North Sea.

The fish community of the Humber is similar to other North Sea estuaries and juvenile populations of marine species utilise parts of the estuary as nursery areas providing food and shelter. The passage of migratory fish is restricted by the severe dissolved oxygen depletion of the estuary in the vicinity of Trent Falls, although occasional salmon are still caught in the Trent on rod and line.

Commercial fisheries within the estuary are on a relatively small scale in the United Kingdom context and the main fisheries currently operating are for sole and cod. Of the shellfish, shrimp are now fished commercially following an earlier decline and the cockle populations are increasing.

As with other estuaries, the Humber plays an important role as a nursery and over-wintering area for species of marine fish. The sand flats of the outer estuary serve as a significant nursery area for flatfish, with an estimated 3% of North Sea plaice utilising the outer estuary for this purpose.

The annual surveys carried out to date do not indicate any trends in fish community which would indicate a change in environmental quality.

8. CONCLUSIONS

The Humber Estuary is a valuable resource and as the major UK input of freshwater to the North Sea it is important to maintain a thorough monitoring programme to quantify the extent of any pollution problems and to monitor any significant trends in quality.

Although the bulk of the estuary is relatively clean, a serious problem of dissolved oxygen depletion exists in the area around Trent Falls. This long standing problem is improving, but much remains to be done. The problem is largely due to inadequate sewage treatment in the tidal Ouse system and several major schemes are in hand to secure improvement by the mid 1990s.

The range of substances recognised as being potentially harmful to the aquatic environment is increasing and EC directives are becoming ever more demanding. It may thus be necessary to expand the range of monitoring undertaken within the estuary to cover the newly identified dangerous substances.

The background of data accumulated over the past thirty years will be invaluable in enabling significant trends within the estuary to be recognised so that appropriate remedial work can be instigated as required.

Substantial loads of metals are discharged to the estuary from rivers and effluents. However, although generally the Environmental Quality Standards (EQS) are met, further reductions in inputs are planned to meet targets for the environmental protection of the North Sea. Further investigation of the significance of metals in sediments is required because of the effects of discharges over many decades, when for much of the period a number of high impact discharges were outside of pollution control.

The National Rivers Authority has a comprehensive programme of water quality monitoring and management for the Humber system; it is committed to improving the poor quality waters and protecting all the uses of the estuary.

1. INTRODUCTION

This chapter provides background information on the extent and uses of the Humber Estuary and the monitoring which has been undertaken to assess its quality.

1.1 General description of the Humber Estuary and its environs

The Humber Estuary receives runoff from the Trent and Yorkshire Ouse river systems, a fifth of the area of England. This is the largest catchment of any UK estuary. The Humber itself is a valuable resource for the community, fisheries and wildlife, and is of international importance for a number of species of birds. Its location and the size of its input of freshwater makes the Humber of great significance in relation to the environmental management of the North Sea.

This report reviews the results of the monitoring and management of water quality undertaken in the period 1980 to 1990 by the National Rivers Authority (since 1989) and its predecessor regional Water Authorities (1980 to 1989). It thus builds on the report "The Quality of the Humber Estuary: A review of the results of monitoring 1961 - 1981", published by the Humber Estuary Committee in 1982.

The term "Humber Estuary" is used in this report to denote the whole of tidal waters associated with the Humber (Figure 1). The Humber itself is the estuarine part of the system from the confluence of the Ouse and Trent at Trent Falls to the mouth of the estuary between Spurn Head on the north bank and Donna Nook on the south. The centre line of the Humber has a length of 62 km. The details of the tidal rivers of the system are given in Table 1.

TABLE 1: THE MAJOR TIDAL RIVERS FLOWING TO THE HUMBER

River	Upstream Limit	Downstream Limit	Length km
Ouse	Naburn Weir	Humber at Trent Falls	62
Wharfe	Tadcaster Weir	Ouse	15
Aire	Chapel Haddlesley Weir	Ouse	25
Don	Doncaster	Ouse	32
Trent	Cromwell Weir	Humber at Trent Falls	85
Hull	Hempholme Weir	Humber at Hull	32

The total length of tidal waters is 313 km and the longest tidal run is 147 km from Spurn Head to Cromwell Weir on the Trent.

The lowest 24 km of the Derwent were also tidal until 1975 when a barrier was constructed across the river at its confluence with the Ouse. The tide is also excluded from the other smaller rivers flowing to the tideway by tidal doors or sluices. These waters include the River Idle, Bottesford Beck, and the River Ancholme.

The Humber catchment has an area of 24,240 km^2. Within this catchment much of the country's coal output, electricity generating capacity and manufacturing industry is concentrated. Within it and on the banks of the Humber live some 11 million people. The major centres of population are given in Table 2 and it should be noted that, unlike many other UK estuaries, most of the population lives in inland cities.

FIGURE 1: THE HUMBER ESTUARY AND ITS CATCHMENT

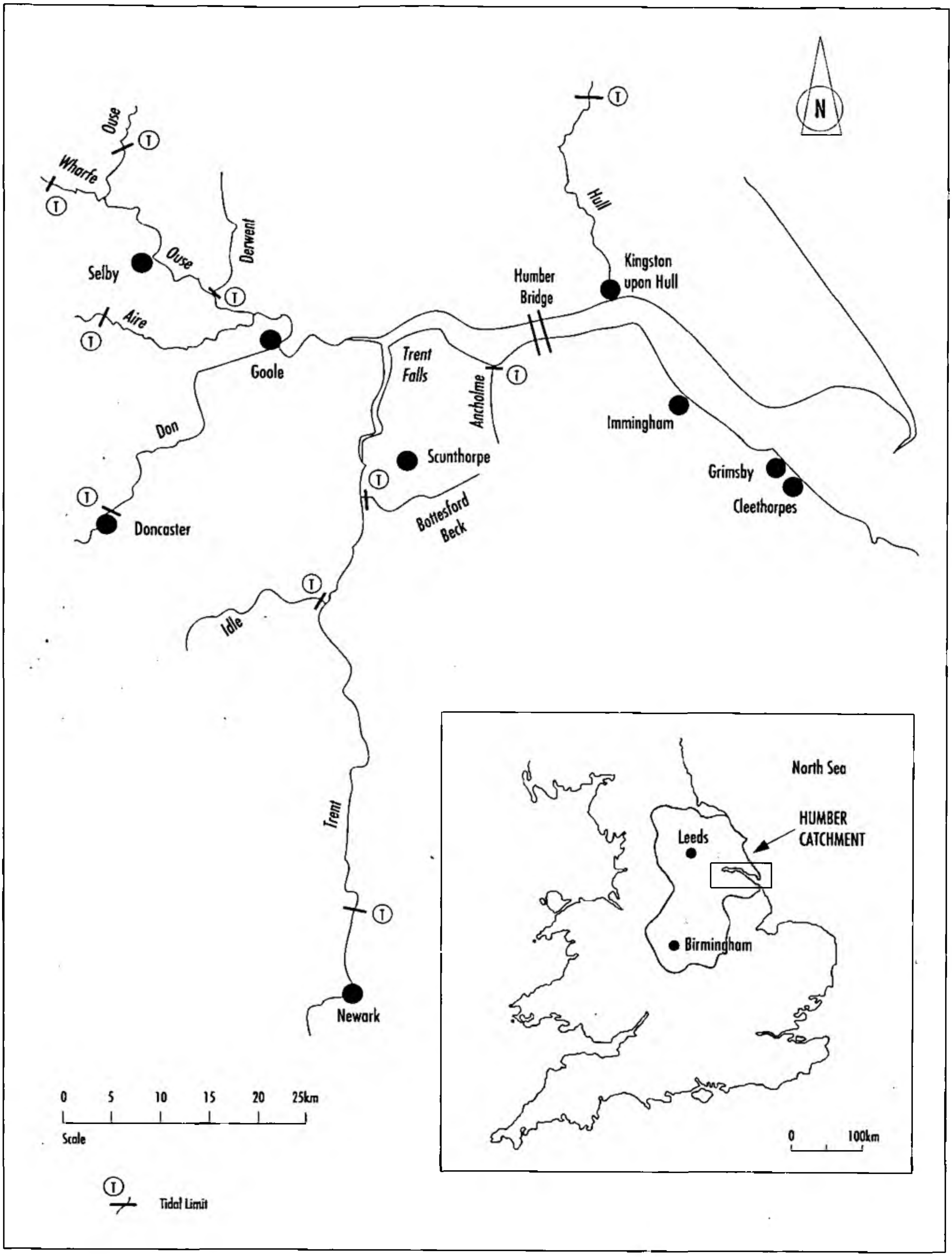


TABLE 2: PRINCIPAL CENTRES OF POPULATION IN THE HUMBER CATCHMENT, 1990

Administrative District	Population
Birmingham	993,000
Leeds	712,000
Sheffield	526,000
Bradford	469,000
Leicester	278,000
Nottingham	275,000
Stoke upon Trent	247,000
Kingston upon Hull	245,000

(Source: Office of Population Censuses and Surveys, 1990, Key Population and Vital Statistics, HMSO.)

The major inputs of industrial and municipal effluent thus arise in the nontidal catchments of the Ouse and Trent river systems. However, the polluting inputs which originate directly from Humberside industry are not inconsiderable and the direct discharges of sewage in various stages of treatment from Hull, Grimsby and other Humberside towns have appreciable, albeit relatively local, significance.

The visual aspect of the Humber Estuary and its immediate environs is not unattractive, being predominantly rural with localised industrial areas. Agriculture dominates the areas immediately adjacent to the estuary and the vast mud-flats create an open level landscape with wide skies and a characteristic lonely and desolate landscape which has a strong appeal to many people. The area contains many wildlife conservation areas and designated Sites of Special Scientific Interest (SSSIs); these are detailed in later chapters. In particular, the Humber is internationally renowned for its bird life.

The recreational use of the Humber Estuary is relatively underdeveloped in comparison with other British estuaries. Cleethorpes provides the only traditional seaside holiday resort within the Humber area with a sandy bathing beach and associated tourist amenities.

Sailing in the estuary is becoming increasingly popular although conditions are not ideal. There has been a considerable growth in marinas, particularly in the old docks of Hull. Sea angling and wildfowling are buoyant local pastimes but the relatively difficult access to the estuary and restricted provision of basic facilities, such as car parking, has tended to inhibit the substantial growth of informal outdoor recreation. Salmon catches in the estuary have declined dramatically over the past century from around 60 tonnes per annum 100 years ago to the present day occasional salmon caught by rod and line.

The most dramatic industrial change on Humberside in recent years has been the decline in the distant water fishing industry which resulted from changes in fishing policy. Somewhat surprisingly, the associated food processing industries have survived, mainly by the use of imported fish. Despite the decline in the fishing industry, the Humber Estuary is not without significance to the North Sea fisheries, having a particular importance as a nursery ground.

In the 1960s and early 1970s a major expansion of Humberside's industrial activity was envisaged. This has failed to materialise despite improved infrastructure, typified by the opening of the Humber Bridge in 1981, and new motorways. Nevertheless, the potential of the area for industrial expansion remains, with large areas of flat, cheap land available close to a deep water channel.

Additionally, the strategic situation of the Humber to the European Community and to Northern Europe must continue to keep alive the possibility of major industrial expansion in the locality. The quality of the Humber Estuary may itself be a factor in any future growth as it is becoming increasingly recognised that environmental considerations play an important part in attracting new major industries to an area.

1.2 Water quality management in the Humber Estuary

Historically, the management and control of water quality in estuaries in England and Wales has commanded a lower priority than river pollution control. The reasons for this may be debated but one factor of significance was undoubtedly the widely held view that any pollution within an estuary situation was generally diluted to insignificance by the practically infinite capacity of the adjacent coastal waters to dilute and disperse. This general misconception, particularly in the case of the shallow North Sea, has now been replaced by a general and widespread concern for the wider environmental impact of the pollution of rivers, estuaries and coastal waters. The early legislation on pollution control in estuaries prior to the Control of Pollution Act 1974 was deficient in several respects, and it was only after the eventual implementation of this Act that the complete control of pollution discharges to the Humber Estuary became possible. The Yorkshire, Anglian and Severn Trent Water Authorities and their predecessor River Authorities and River Boards had, fortunately, a long history of co-ordinated scientific monitoring of water quality in the Humber Estuary.

There is now some thirty years experience of co-ordinated chemical and biological monitoring which forms an invaluable database with which to detect genuine trends in water quality and on which to base future water quality management decisions and policies. Prior to 1989, the responsibility for the control of water quality in the Humber Estuary rested jointly with the three local Water Authorities and the Humber Estuary Committee was established to administer this responsibility. As well as having representatives from the Water Authorities, the committee was assisted by additional expert representatives from the Water Research Centre, the Natural Environmental Research Council, British Transports Docks Board, Hull University, the Institute of Estuarine and Coastal Studies, Government Departments and other specialists from time to time.

A major achievement of this committee was the development of a mathematical model of water quality for the Humber Estuary. The development of this model was carried out primarily by the Water Research Centre using data provided by the Water Authorities (Mollowney, 1962); it has proved to be invaluable for understanding and predicting changes in water quality within the estuary and is an essential management tool for policy decisions. The model was developed primarily to predict the concentration of dissolved oxygen within the estuary, but has since been further developed for applications involving other parameters and is now used to study the causes of existing pollution, the most effective means of achieving Environmental Quality Standards (EQSs), consent conditions for new discharges and the effect of abstraction from the nontidal rivers.

The Water Act, 1989, privatised the water supply and sewage treatment functions of the water industry and created the National Rivers Authority (NRA) as the body responsible for water pollution control throughout England and Wales. Thus, for the first time, the management of water quality in the Humber Estuary became the responsibility of a single organisation. This management function is currently carried out by the Northumbria & Yorkshire, Anglian and Severn Trent Regions of the National Rivers Authority through a revised Humber Estuary Committee, which now consists only of technical officers. The Humber Estuary Committee continues to be supported by additional representatives from other expert bodies, as required, and continues the water quality management of the estuary as before. However, with the NRA as the single authority responsible for the quality management of all the estuaries in England and Wales there will be a consistent policy for all estuaries and this should provide data which may be used for the valid comparison of their quality throughout the country.

The terms of reference of the revised Humber Estuary Committee and its objectives are listed in Appendix A. It should be noted that the objectives will need to be reviewed when Statutory Water Quality Objectives (SWQOs) are set under the Water Resources Act 1991.

1.3 Monitoring

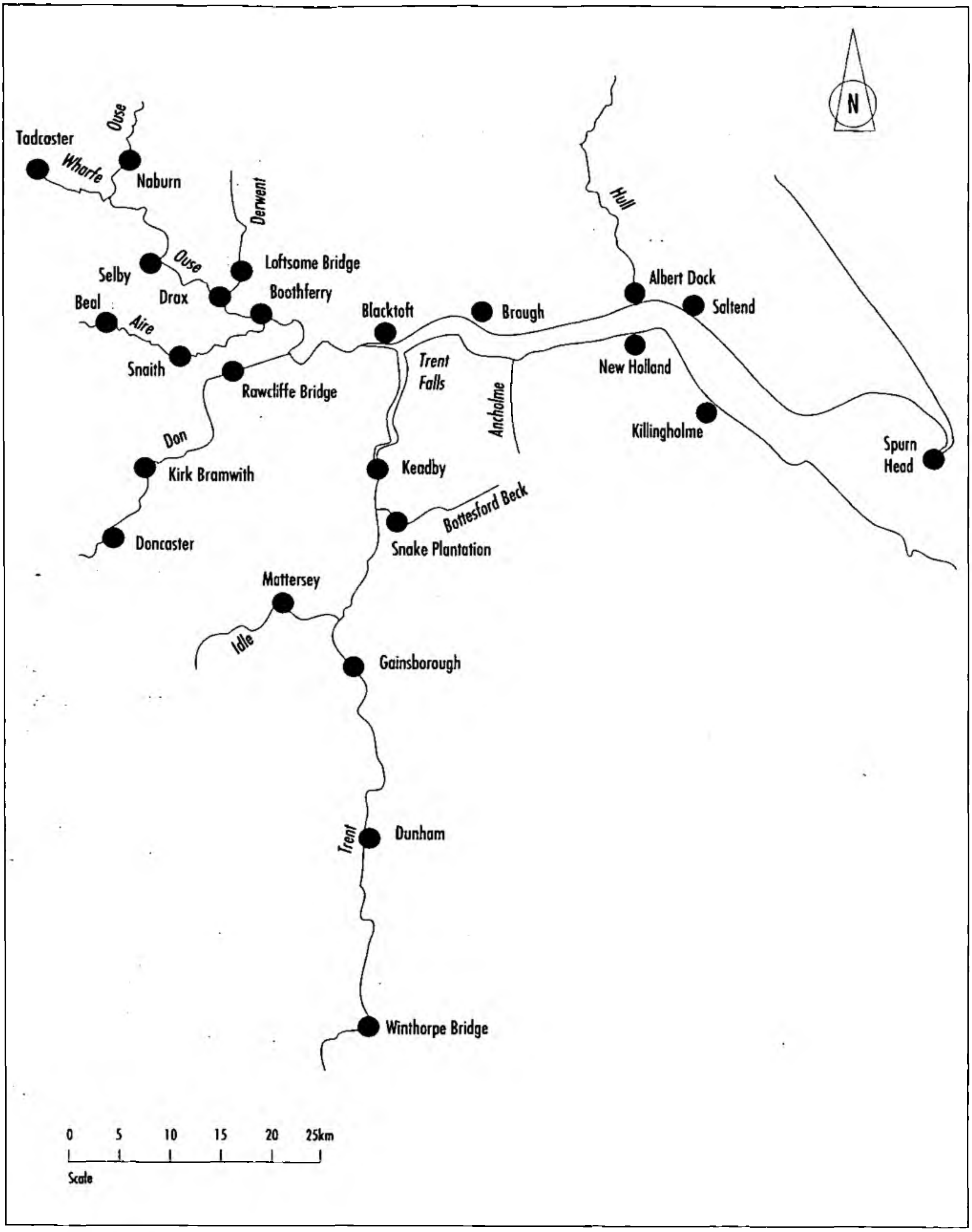
The joint monitoring programme which was started in the early 1960s was initially based on monitoring surveys which were carried out at 26 day intervals. This was amended to the present frequency of 7 surveys per year in 1982.

Samples of water from the Humber Estuary are taken for chemical analysis by NRA staff at 18 shore stations at slack high and slack low water. These are supplemented by samples from the tidal rivers at their tidal limits. The locations of these sampling points are shown in Figure 2. The importance of the dissolved oxygen concentration within the estuary was recognised by the introduction of a programme of continuous monitoring at a number of locations. The continuous monitoring of dissolved oxygen in an estuary situation is very valuable as the concentration can change very rapidly. However, such monitoring presents a number of technical problems with rapidly changing currents and salinities, varying water levels, and high levels of suspended matter. In these circumstances, it is therefore not surprising that there has been considerable "down-time" at some of the stations. Nevertheless, the data provided have proved to be extremely useful.

Information on the year-to-year variation in pollution input load to the estuary is obtained by monitoring all the significant effluent discharges on a co-ordinated basis during the week before the routine chemical surveys are carried out. Shore sediments are also analysed twice per year for metals and mid-estuary sediments are analysed on an annual basis. The chemical sampling programme is complemented by an extensive biological monitoring programme consisting of bioaccumulation studies for metals and toxic substances on ragworms and seaweed, and community analysis of the intertidal and subtidal fauna. In addition, quarterly samples are taken mid-estuary at three stations for the purposes of the United Kingdom baseline monitoring programme.

In order to obtain detailed information on water quality changes during a tidal cycle, a series of special intensive chemical and biological surveys has also been carried out. Additionally, a specially commissioned survey of hydrocarbon levels in the Humber Estuary was undertaken by the Oil Pollution Research Unit (OPRU) in 1987. This was commissioned after the monitoring of the extent of an oil pollution in the estuary following a major oil spillage in 1983. It was realised after this survey that the interpretation of the data produced required a more detailed knowledge of background hydrocarbon residues and the OPRU report has proved invaluable in that respect.

FIGURE 2: THE HUMBER ESTUARY SYSTEM CHEMICAL MONITORING POINTS



2. PHYSICAL CHARACTERISTICS OF THE ESTUARY

2.1 Freshwater inputs

The catchment area of the Humber Estuary is 24,240 km^2 and this generates an average freshwater flow of 250 m^3/s, which is more than three times that of the River Thames. Strictly speaking, the name Humber applies only to the estuary downstream of Trent Falls, which is the point where the Rivers Trent and Yorkshire Ouse meet, but for the purposes of this report the Humber Estuary is considered to be the entire Humber tidal system. The average annual freshwater run-offs from the Ouse and Trent catchments are of similar magnitudes. The Trent's flow to the estuary is composed primarily of the main nontidal River Trent with the addition of only a relatively small contribution from a number of tidal tributaries. This contrasts with the freshwater input from the Ouse which consists mainly of contributions from the tidal rivers Don, Aire, Derwent and Wharfe with only around 25% of the total freshwater flow being derived directly from the Ouse upstream of these tributaries. The largest contributions to the Ouse are made from the Rivers Aire and Don which drain industrial areas of Yorkshire and which consequently carry a high pollution load. Downstream of Trent Falls, a further small contribution to the estuary is made by the River Ancholme which enters the estuary from the south bank of the Humber and the River Hull discharging from the north bank.

2.2 Tides and currents

The Humber has the classic shape of major estuaries with a mouth width of 8 km narrowing to less than 0.5 km in the Ouse and Trent. It has a maximum tidal range of 7 m which is extremely large on a world scale and is only exceeded in Britain by the Bristol Channel.

The tides of the North Sea are powered primarily by the tides of the Atlantic Ocean which send a tidal pulse into the northern North Sea. This tidal pulse generates a secondary pulse into the Humber Estuary as it passes the mouth of the Humber. The extent of the tidal waters in the estuary illustrates the great importance of the tidal effect, which causes water to be carried upstream throughout most of the estuary. The average tidal excursion in the Humber is around 15 km. This is several times greater than the seaward displacement due to the freshwater input during the tidal cycle. Thus effluents which discharge to the estuary are held there for a considerable length of time, being progressively diluted as they edge their way gradually into the North Sea. This residence period allows the full polluting effect of discharges to be exerted within the estuary.

Current velocities can be very high in the Humber, peaking to 11 km/h at spring tides. The speed of the tidal wave is important and, although the water within the wave moves relatively slowly, the tidal wave moves very quickly, at around 50 km/h at the mouth. Thus high tide is achieved throughout the estuary in rapid sequence; for example, high water at Spurn Point may be followed by high water at Hessle one hour later, a distance of 40 km. As the tidal wave moves upstream into shallower water the tidal crest overtakes the trough and the wave becomes steeper. A tidal bore known as the Eagre sometimes occurs in the lower Trent and occasionally in the Ouse above Selby. Although not to be compared with the Severn Bore, the Eagre does attract local attention.

2.3 Sediments

The Humber has a characteristic turbid swirling appearance caused by very high concentrations of suspended sediments known locally as "warp". Over the past 300 years the natural accretion of sediments in the estuary and consequential reduction in mouth width has been accelerated by land reclamation works. In past years this has been carried out by the "warping" process whereby high tide water is temporarily confined by bunds. This allows the suspended sediment in the water to settle out before the clear water is drained off. Such reclaimed land provides valuable and fertile agricultural land.

The sediments of the Humber are derived mainly from the North Sea, rather than the freshwater rivers, and it has been estimated that over 60,000 tonnes of sediment are deposited in the Humber each year. Some 200,000 tonnes per year of sediment are carried into the Estuary by the river system, but most of this load passes into the North Sea (Pethick, 1988). The Holderness cliffs are eroding rapidly but it is thought that most of the sediment produced moves directly into the North Sea rather than into the Humber Estuary. The asymmetry of tidal flow within the estuary is considered to be mainly responsible for the dominance of sea derived sediments together with a tendency for the less dense freshwater to float on the surface of the flow so that its sediments are carried out to sea.

The concentration of suspended solids at any particular point in the Humber is determined largely by current velocities. High velocity currents re-suspend solid material which has deposited on the bed of the estuary at slack water and concentrations may vary at a particular point by an order of magnitude during a single tidal cycle. The highest suspended solids concentrations are found in the vicinity of Trent Falls with concentrations being much greater in the Ouse than the Trent. As might be expected, there is a vertical stratification of suspended matter in the estuary and the concentration of suspended solids at one point has been shown to increase considerably with depth.

The types of bottom sediments have a complex distribution and this is shown in Figure 3. Generally, the bottom deposits become finer towards the banks of the estuary, with coarser sands and gravel deposits in the central channels, where the strongest currents are found. At high water, when very slow currents exist, only the finest material can be transported and this creates the large areas of mud flats which characterise the Humber Estuary. This is particularly evident in the notable feature known as Spurn Bight, an area some 12 km long and 4 km wide. This is reached only by the top metre of the flooding tide and is therefore not affected by strong tidal currents or waves.

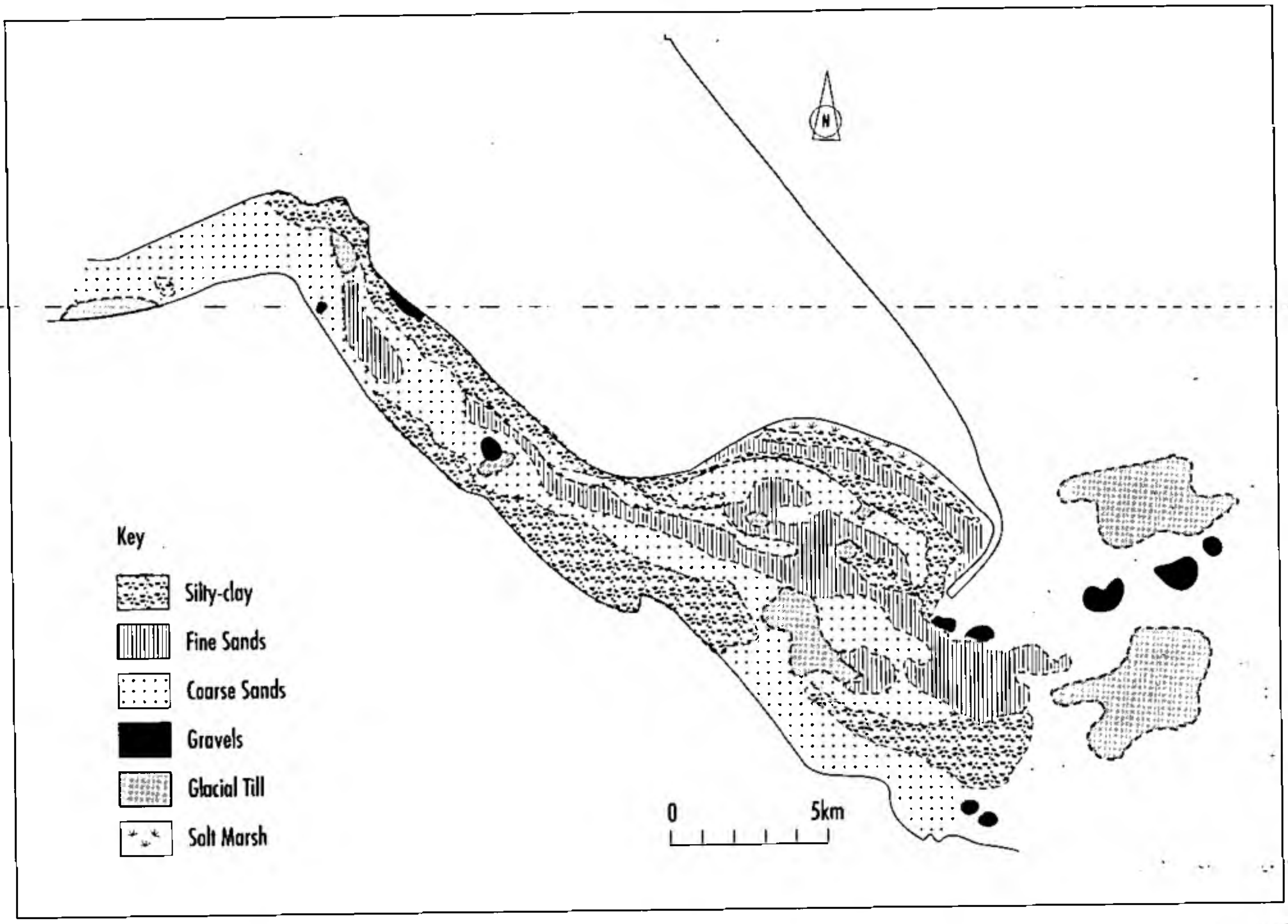
2.4 Salinity

The range of salinity experienced at a particular point on the estuary is of special importance because, to a large extent, it determines the types of flora and fauna which can survive. A detailed account of the salinity distribution is given by Gameson in the earlier report on the quality of the estuary (Humber Estuary Committee, 1982).

The range of salinities which exist varies from the low salinity of the freshwater rivers to practically 100% sea water at the mouth of the estuary. It is in the rapidly changing salinity regions where the biological conditions are at their most restrictive.

The Humber does not exhibit a marked vertical saline stratification, being relatively well mixed at the interface of fresh and saline water. A maximum salinity range of approximately 5 parts per thousand is observed at high water at Spurn, falling to zero at Brough. This zero gradient may be taken to be the normal limit of salt intrusion into the Humber, although significantly elevated chloride concentrations are occasionally found as far inland as 30 km above Trent Falls, especially during low river flows. The current established by the movement of saline water along the bed of the estuary to replenish the freshwater flow on the surface is responsible for the movement of considerable amounts of sediment up to the salt intrusion limit. Another salinity gradient is observed in the Humber along the width of the outer estuary where slightly higher salinities occur at the north bank due to the tendency for incoming sea water to enter the estuary via the northern bank and for freshwater to keep to the southern bank as it discharges towards the North Sea.

FIGURE 3: SEDIMENT MAP OF THE HUMBER ESTUARY



3. OBJECTIVES AND STANDARDS RELEVANT TO THE HUMBER ESTUARY

3.1 Humber environmental quality objectives

A generalised set of environmental quality objectives for the Humber Estuary was set by the Humber Estuary Committee in 1983, based on the need to protect the existing uses of the estuary and on the recommendations of the third report of the Royal Commission on Environmental Pollution (1972). These objectives were as follows:

1. the protection of all the existing defined uses of the estuary system;

2. the ability to support on the mud bottom the biota necessary for sustaining sea fisheries; and

3. the ability to allow the passage of migratory fish at all stages of the tide.

It will be necessary to review these objectives when statutory water quality objectives are introduced under the Water Resources Act 1991.

The existing uses of the Humber Estuary which should be protected are as follows: nature conservation; commercial fishing and angling; tourism and amenity; bathing; boating and water skiing; navigation; and abstraction for industrial and agricultural use. The Humber Estuary Committee also resolved that the year 1995 should be the target date for the achievement of the declared objectives, relative to a comprehensive list of EQSs as shown in Table 3.

These standards are based on the best scientific information available or, where applicable, on mandatory limits specified by either the European Community or UK Legislation. Thus the limits set for mercury, cadmium and the organic compounds are based on SWQOs laid down in 1989 Regulations and the list for the remaining metals are those set by the EC Dangerous Substances Directive. It should be noted that in the case of copper, a higher value may be acceptable where acclimation is expected or the copper is present as an organic complex.

3.2 Freshwater river quality objectives and estuary classification

The overall quality of the Humber Estuary is largely determined by the quality of the rivers draining via the Ouse and Trent river systems. The relevant rivers are currently classified according to the scheme of the former National Water Council (see Appendix B) and Table 4 shows the current (1990) river water quality together with the quality objective set for each river.

The major improvements necessary to achieve the EQSs in the estuary are in the Yorkshire Rivers Aire and Don, which require upgrading from Class 3 to Class 2. The remaining significant tidal rivers have already achieved their river quality objectives as originally set, except for the Ouse, the quality of which deteriorated to Class 2 in 1990. The restoration of the river to Class 1B is a high priority.

The Humber Estuary has been classified according to the national scheme shown in Appendix C. In 1990 the tidal sections of the Ouse and Don were found to be Class C (poor quality). The tidal Trent and the estuary downstream of Trent Falls to Hull is Class B (fair quality) as is the southern half of the Humber to Grimsby. The north section of the Humber from Hull seawards and the remaining parts of the estuary are Class A (good).

TABLE 3: HUMBER ENVIRONMENTAL QUALITY STANDARDS
(All values are annual averages in $\mu g/l$ except where indicated)

Determinands	Tidal Rivers	Estuary
Temperature	25°C (95%ile)	25°C (95%ile)
Dissolved Oxygen	40% saturation	55% saturation
pH range	5.5 - 9.0	6.0 - 8.5
Unionised Ammonia	0.021 mg/l (95%ile)	0.021 mg/l (95%ile)
Mercury	1 (total)	0.3 (dissolved)
Cadmium	5 (total)	2.5 (dissolved)
Arsenic	50 (dissolved)	25 (dissolved)
Chromium (III & VI)	250 (dissolved)	15 (dissolved)
Copper (II)	28 (dissolved)	5 (dissolved)
Lead	250 (dissolved)	25 (dissolved)
Nickel	200 (dissolved)	30 (dissolved)
Zinc	500 (total)	40 (dissolved)
Iron	1000 (dissolved)	1000 (dissolved)
HCH	0.1 (total)	0.02 (total)
DDT (all isomers)	0.025 (total)	0.025 (total)
DDT (pp isomers)	0.01 (total)	0.01 (total)
Carbon Tetrachloride	12 (total)	12 (total)
PCP	2 (total)	2 (total)

TABLE 4: RIVER WATER QUALITIES AND OBJECTIVE QUALITIES AT TIDAL LIMITS

River	1990 Quality Class	Objective Class
Wharfe	1B	1B
Ouse	2	1B
Derwent	1B	1B
Aire	3	2
Don	3	2
Trent	2	2
Idle	2	2
Bottesford Beck	3	3

3.3 European Community controls

There is particular concern in the European Community about the control of substances in the aquatic environment which are considered to be toxic, persistent and which accumulate in biological organisms. The principle EC Directive which controls these substances is the Dangerous Substances Directive (76/464/EEC) which applies to estuarine as well as to other bodies of water. This Directive classifies dangerous substances into two types. List 1 (commonly known as the Black List) contains substances which must be controlled by the adoption of community-wide limit values or by EQSs. The legislation for each specific substance is introduced by a separate 'daughter' directive and to date such directives have been introduced for cadmium, mercury, HCH, DDT, PCP and carbon tetrachloride; all are therefore subject to control in the Humber Estuary. List 2 substances (the Grey List) may be controlled by United Kingdom EQSs and this list, together with the Black List, is shown in Appendix D.

The EC Bathing Water Directive (76/160/EEC) is relevant to standards in the Humber Estuary, at Cleethorpes near to Grimsby. This Directive lays down microbiological standards for bathing waters, principally in terms of total and faecal coliform levels. The waters at Cleethorpes do not comply with the necessary standard, but full compliance is expected to be achieved by 1995 as a result of major improvements to the sewerage system and the provision of secondary sewage treatment, carried out by Anglian Water Services plc.

The EC Directive relating to waste from the titanium dioxide industry (78/176/EEC) is particularly relevant to the Humber Estuary because two of the three UK factories manufacturing titanium dioxide are located on the south bank of the Humber. The discharges from these two factories have been studied in depth by the former Anglian Water Authority and this has been well documented in a separate report by the National Rivers Authority.

The recently introduced EC Directive on Urban Waste Water Treatment (91/271/EEC) will set standards for the treatment of all municipal sewage discharging to fresh, estuarine and coastal waters. The effect of this Directive in the Humber Estuary will be significant in future years and will require several discharges to be substantially improved.

3.4 United Kingdom controls

In 1989, following the second North Sea Conference, the United Kingdom Government issued its "Red List" of dangerous substances which must be controlled in order to protect UK estuaries and the North Sea. The Government proposed an integration of the United Kingdom's Environmental Quality Objectives (EQOs)/EQSs approach to discharge control with the uniform emission standards approach which is adopted in most other EC countries. This new procedure requires the progressive application of technology-based emission standards, using the "best available techniques not entailing excessive cost" (BATNEEC) with respect to prescribed industrial point sources. Diffuse sources are to be controlled by restrictions on the supply, use and disposal of dangerous materials. Under this approach any prescribed discharge containing a Red List substance must meet either a BATNEEC based standard or an EQS, whichever is the more stringent.

The UK priority Red List has now been largely overtaken by the controls introduced under Part 1 of the Environmental Protection Act 1990 (EPA '90). The EPA '90 list is very similar to the Red List but contains a number of subtle differences which substantially enlarge the number of substances which must be controlled. Thus it includes "all isomers of hexachlorocyclohexane" whereas the Red List specified only the gamma isomers, and specifies all the isomers of DDT, specific compounds of pentachlorophenol and the isomers of trichlorobenzene, whereas the Red List does not. The list of EPA '90 prescribed substances for release into water is shown in Appendix E.

The BATNEEC controls were introduced as part of a system of Integrated Pollution Control (IPC), designed to develop an approach to pollution control which considers discharges to all media - air, water and land - in the context of the effect on the environment as a whole; this is known as the "Best Practicable Environmental Option" (BPEO). Under the EPA '90, Her Majesty's Inspectorate of Pollution (HMIP) are the authority responsible for enforcing IPC; however, the NRA is a statutory consultee with respect to all processes which involve releases into controlled waters, including the Humber Estuary.

Following the third North Sea Conference, a further list of some 36 substances, including those on the Red List, were designated as priority hazardous substances. The conference included an agreement to reduce by 50% or more the discharge of these substances to the North Sea via rivers and estuaries between the years 1985 and 1995.

For dioxins, lead, cadmium and mercury, reductions of the order of 70% were agreed where available by BATNEEC. The third North Sea Conference also agreed common action to reduce specific groups of substances; thus specific pesticides and PCBs must be strictly controlled or phased out altogether. Nutrients (nitrogen and phosphorus) are also required to be controlled where they are discharged into areas where they are likely to cause pollution. This is not considered to be the case in the Humber Estuary and therefore no controls on nutrients are considered necessary at present.

3.5 The derivation of Environmental Quality Standards for discharges to the Humber Estuary

The application of the EQO approach to tidal waters is more complex than its application to nontidal freshwater rivers having uni-directional flow. Thus an important consideration when determining a particular environmental standard for a specific discharge is the shape, extent and dilution afforded by the effluent plume, bearing in mind the ebb and flow of the tidal waters into which the discharge is made. In this context, the concept of a "mixing zone" becomes important. A mixing zone may be considered to be the location around the point of discharge in which the discharge is diluted and in which the standard does not apply. The size of such a mixing zone is of obvious environmental importance, but the techniques necessary to define mixing zones require further development. In general, they should reflect the local prevailing conditions at the point of discharge. In particular, the tidal energy and turbulence of the estuary is a vital factor and this will, in turn, depend on the freshwater flow, the tidal range, and the tidal excursion within the estuary.

A number of possible methods of defining a mixing zone have been suggested (Sayers, 1986), as follows.

i. The length of the mixing zone may be defined as a fraction of the average tidal excursion at the point of discharge; in this case it is assumed that the generally elliptical shape of the plume would normally vary in size in proportion to its length, if the discharge is made from an open pipe.

ii. Where a discharge is made via a diffuser type system, the length of the plume is not the most appropriate parameter and the dimensions of the pool formed around the diffuser at low slack water is the most significant criterion; in these circumstances the depth of water available at slack low water is more relevant.

iii. The more direct method of defining a mixing zone is to base it on local biological effects; such effects may be the life on the bed of the estuary around the discharge point or on caged biological organisms, such as mussels, located at strategic points around the discharge point. Whilst this direct method has much appeal the resources required to detect accurately the effects of pollution on biological organisms are very substantial and must be deployed for a considerable length of time.

Having considered the relevant factors affecting the mixing zone, its most practical application is often the determination of the design of the outfall for a given discharge.

4. INPUTS TO THE HUMBER ESTUARY SYSTEM

The main inputs of polluting loads which are discharged to the Humber Estuary system may be classified by their three principal sources:

1. the freshwater rivers discharging into the system, the loads from which are measured at the relevant rivers' tidal limits;

2. the direct discharges of sewage from population centres, which may be untreated crude sewage, settled sewage or biologically treated sewage effluent; and

3. the direct discharges of industrial effluents.

4.1 Inputs from freshwater rivers

a. Biochemical oxygen demand and ammoniacal nitrogen

The rivers which contribute significant input loads are the Ouse, Derwent, Aire and Don (The Ouse system) and the Trent, Idle and Bottesford Beck (The Trent system). The main inputs from the Ouse system consist of three clean rivers (Class 1), the Ouse, Wharfe and Derwent, and two dirty rivers (Class 3) the Aire and Don. The Trent system is heavily dominated by the River Trent itself which is of fair quality (Class 2) at its tidal limit, with a relatively small contribution from the Rivers Idle (Class 2) and Bottesford Beck (Class 3). Although the latter is of poor quality, its relatively small flow generates only a small polluting load to the Trent system. During the decade 1981 to 1990 there was little significant change in the organic quality of the rivers at their tidal limits and Figures 4 and 5 show typical variations in annual mean values of biochemical oxygen demand (BOD) and ammoniacal nitrogen, respectively.

The most serious pollution problem in the Humber Estuary has long been recognised as the severe dissolved oxygen depletion in the system around Trent Falls, particularly at times of low freshwater flow. The loads of biodegradable matter responsible for this oxygen depletion in the non-tidal rivers, measured as BOD and ammoniacal nitrogen, are shown in Table 5.

The River Trent at its tidal limit has the largest flow of the contributing rivers and adds the greatest load of BOD to the system, despite its fair quality. However the rivers Aire and Don, with much lower flow rates, add significant BOD loads and the Ouse system in total adds appreciably more BOD load than the Trent system. Both the Rivers Don and Aire individually discharge more ammoniacal nitrogen to the Humber system than the whole of the River Trent and its tributaries. Three-quarters of the total ammoniacal nitrogen load discharged by the rivers originates in the Ouse system. The relative contributions of the individual rivers to the BOD and ammoniacal nitrogen loads are clearly shown in Figures 6 and 7; the qualities of the Rivers Aire and Don offer the most potential for significant reductions in organic pollution loads discharged to the estuary. It should also be noted that the Rivers Aire and Don discharge close to the most vulnerable zone of the Humber where there are long residence times in dry weather.

b. Temperature and dissolved oxygen

The water temperature in the Humber Estuary is important for two reasons: the rates of biodegradation of organic matter and the rate of nitrification - with the associated depletion of dissolved oxygen concentration - increase with increasing temperature, whilst at the same time the solubility of the oxygen decreases.

FIGURE 4: BOD (AVERAGES 1981-1990) AT THE TIDAL LIMITS

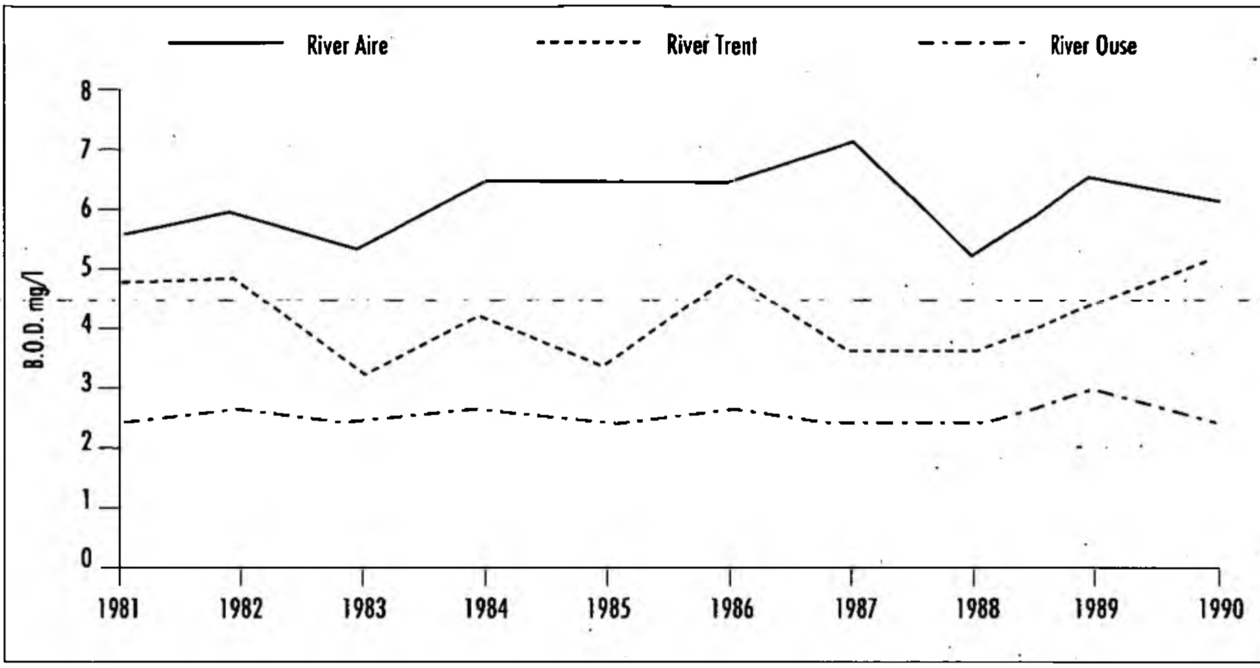


FIGURE 5: AMMONIACAL NITROGEN (AVERAGES 1981-1990) AT THE TIDAL LIMITS

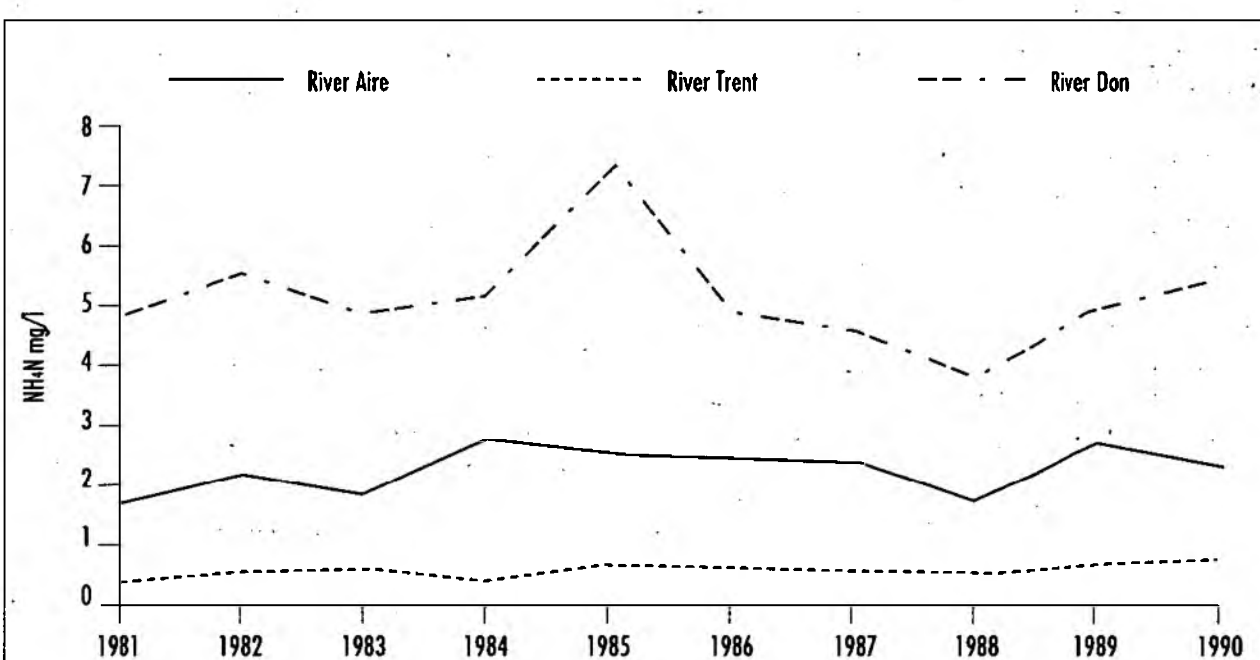


FIGURE 6: COMPARISON OF BOD LOAD DISCHARGED FROM FRESHWATER RIVERS INTO HUMBER ESTUARY SYSTEM (1980 - 1990)

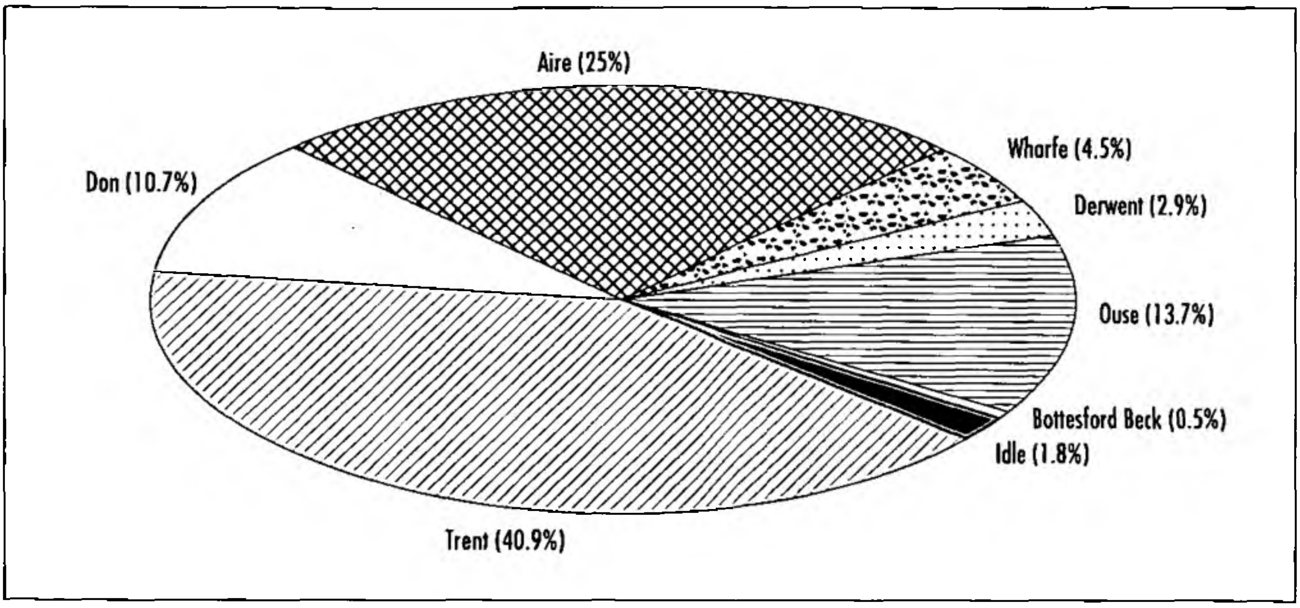


FIGURE 7: COMPARISON OF AMMONIACAL NITROGEN DISCHARGED FROM FRESHWATER RIVERS INTO HUMBER ESTUARY SYSTEM (1980 - 1990)

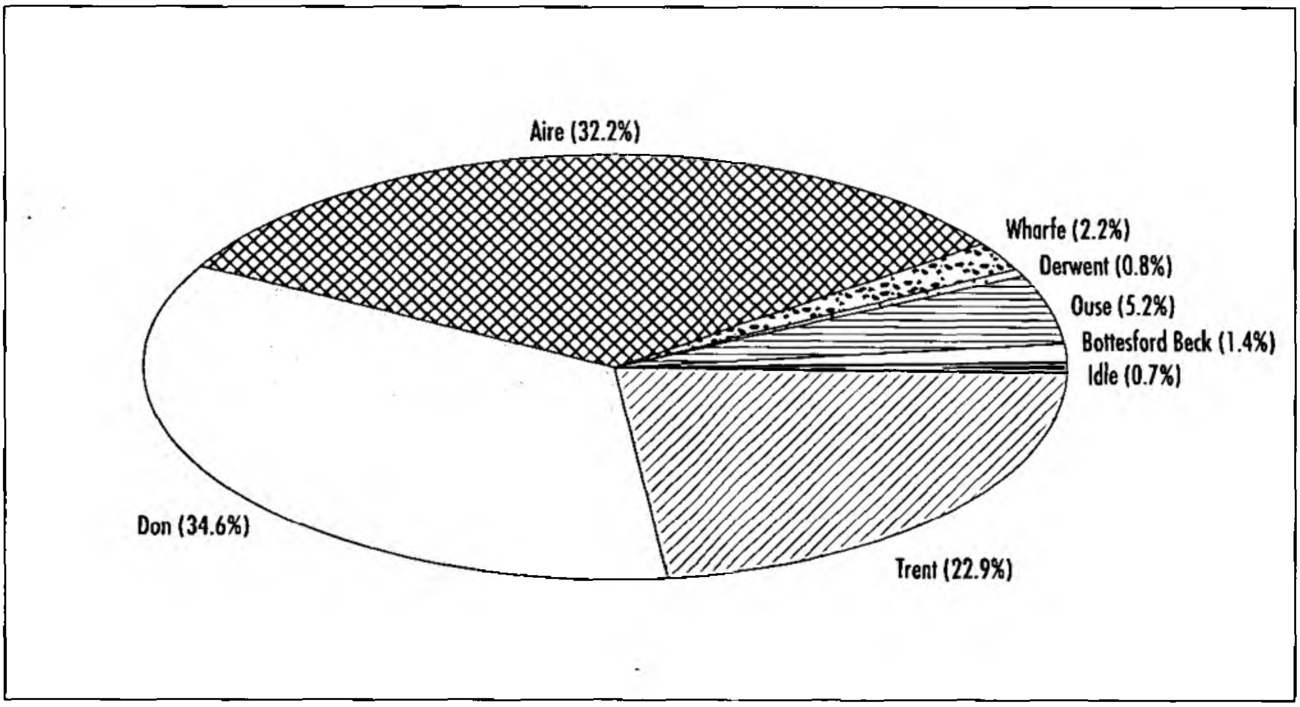


TABLE 5: AVERAGE FRESHWATER LOAD OF BOD AND AMMONIACAL NITROGEN DISCHARGED TO THE HUMBER ESTUARY (1981 - 1990)

River (at tidal limit)	Class	Flow (m3/s)	BOD Concentration (mg/l)	BOD Load (kg/d)	Ammoniacal Nitrogen Concentration (mg/l)	Ammoniacal Nitrogen Load (kg/d)
Ouse	1B	49.8	2.4	10,320	0.26	1,120
Wharfe	1B	18.1	2.2	3,430	0.14	220
Derwent	1B	4.7	1.7	690	0.14	60
Aire	3	36.9	5.9	18,820	2.17	6,920
Don	3	16.9	5.5	8,030	5.09	7,430
Ouse System		126.4		41,290		15,750
Trent	2	89.2	4.0	30,840	0.64	4,930
Idle	2	4.7	3.4	1,390	0.38	160
Bottesford Beck	3	0.6	7.6	400	5.84	300
Trent system		94.5		32,630		5,390
Totals		220.9		73,920		21,140

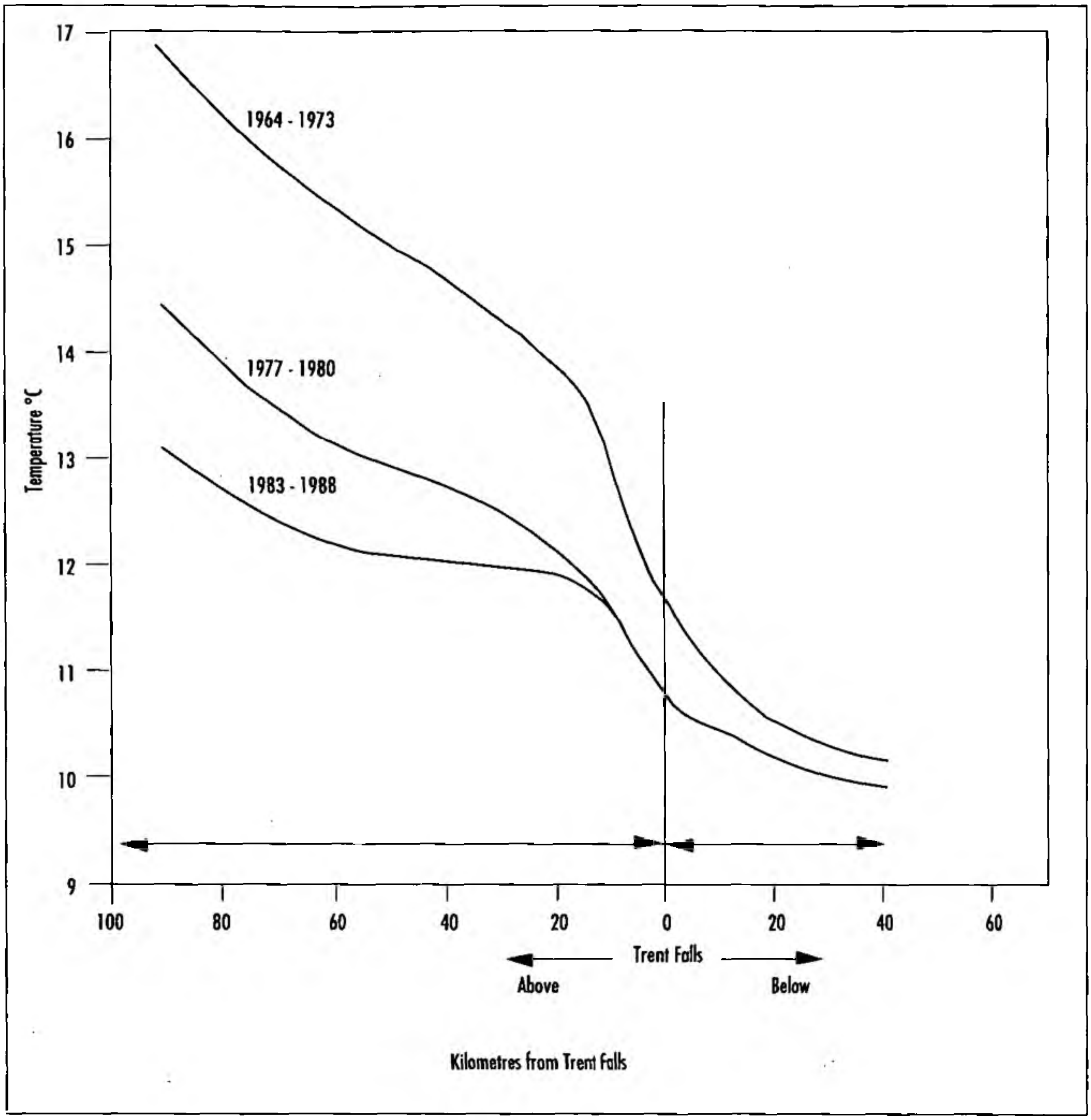
Additionally, migratory fish are known to be sensitive to water temperatures and it is possible that a temperature barrier could be at least partly responsible for the virtual disappearance of the salmon runs up the river Trent which were such a feature in the early part of the century. Although there are virtually no data to test this theory, the fact that a very high proportion of the UK's electricity generating stations are located in the Humber catchment, with their high potential for thermal pollution, makes an examination of it a worthwhile exercise.

Most of the electricity generating stations are located well inland on the nontidal River Trent, but several large power stations are situated directly on the tidal system itself, and in the Aire valley. However, it is the River Trent system rather than the Ouse system which has, in the main, been responsible for raising the temperature of the Humber. During the past 30 years there has been a steady reduction in the temperature of the nontidal Trent due to the progressive closure of the direct-cooled power stations and a reduction in the use of older stations along the Trent valley. Thus the annual average temperature of the River Trent at its tidal limit has fallen by 5°C, from around 18°C to 13°C between 1960 and 1980. Since then there has been little further change in average temperature of the nontidal Trent other than that due to normal year to year variations, although the average temperature in the Trent system is still slightly higher than that in the River Ouse system.

Figure 8 shows average temperature profiles of the Trent-Humber system for periods since 1964 and the significantly lower river temperatures in recent years can be clearly seen, although the temperature of the nontidal Trent is still several degrees higher than that of the Humber downstream of Trent Falls.

The nontidal rivers entering the Humber Estuary are generally reasonably well oxygenated, and during low flow summer periods their dissolved oxygen concentration may be supersaturated due to photosynthetic algal activity. This is particularly marked, at times, in the River Trent.

FIGURE 8: AVERAGE TEMPERATURE PROFILES OF THE TRENT - HUMBER SYSTEM



c. **Metals**

The accurate determination of the concentration of metals in samples from the Humber Estuary has presented analytical problems and the results obtained in the early part of the decade should be treated with a degree of caution. Many were at, or below, the limits of detection of the analytical methods employed and hence results could often only be reported as "less than" values. Additionally, the limits of detection were often not sufficiently sensitive and in some cases higher than the EQSs for the waters under examination. In these cases it was not possible to use the results to assess compliance with the relevant standards.

Problems were also encountered in connection with sample filtration and the time lapse between sampling and laboratory analysis. These problems have now been largely resolved and better techniques developed, but it is only towards the end of the decade that reliable metal data have been available.

The average concentration of metals in the freshwater rivers is shown in Table 6 and is generally lower than the relevant EQS. However, occasional samples have given higher values for dissolved copper concentration. In this case the standard for copper is based on the concentration of free copper ions and any complexation of copper by organic ligands is known to reduce the toxicity to aquatic life. In these circumstances the value specifically excludes any copper present as a complex. Recent work carried out by the Water Research Centre, using cathodic stripping voltammetry, has shown that dissolved copper in the Humber Estuary system is present almost totally in the form of organic complexes and therefore the copper may not be regarded as having a detrimental effect.

TABLE 6 - AVERAGE METAL CONCENTRATIONS IN THE FRESHWATER RIVERS DISCHARGING TO THE HUMBER ESTUARY (1990) (ALL RESULTS IN μg/l)

River at Tidal Limit	Mercury (filtered)	Cadmium (total)	Chromium (total)	Copper (total)	Zinc (total)	Arsenic (total)	Lead (total)
Ouse	LT	LT	LT	30		LT	39
Wharfe	LT	LT	LT	4	133	LT	6
Aire	LT	LT	30	34	97		15
Don	LT	LT	8	11	39	LT	9
Derwent	LT	LT	LT	3	7	LT	1
Trent	0.6	0.3	33	120	367	14	80
Idle	LT	LT	0.8	5	18	1	2
Bottesford Beck	LT	LT	0.2	1	6	0.1	0.6

L.T. indicates that in a high proportion of the samples analysed the metal concentrations were less than the limit of detection of the analytical method employed.

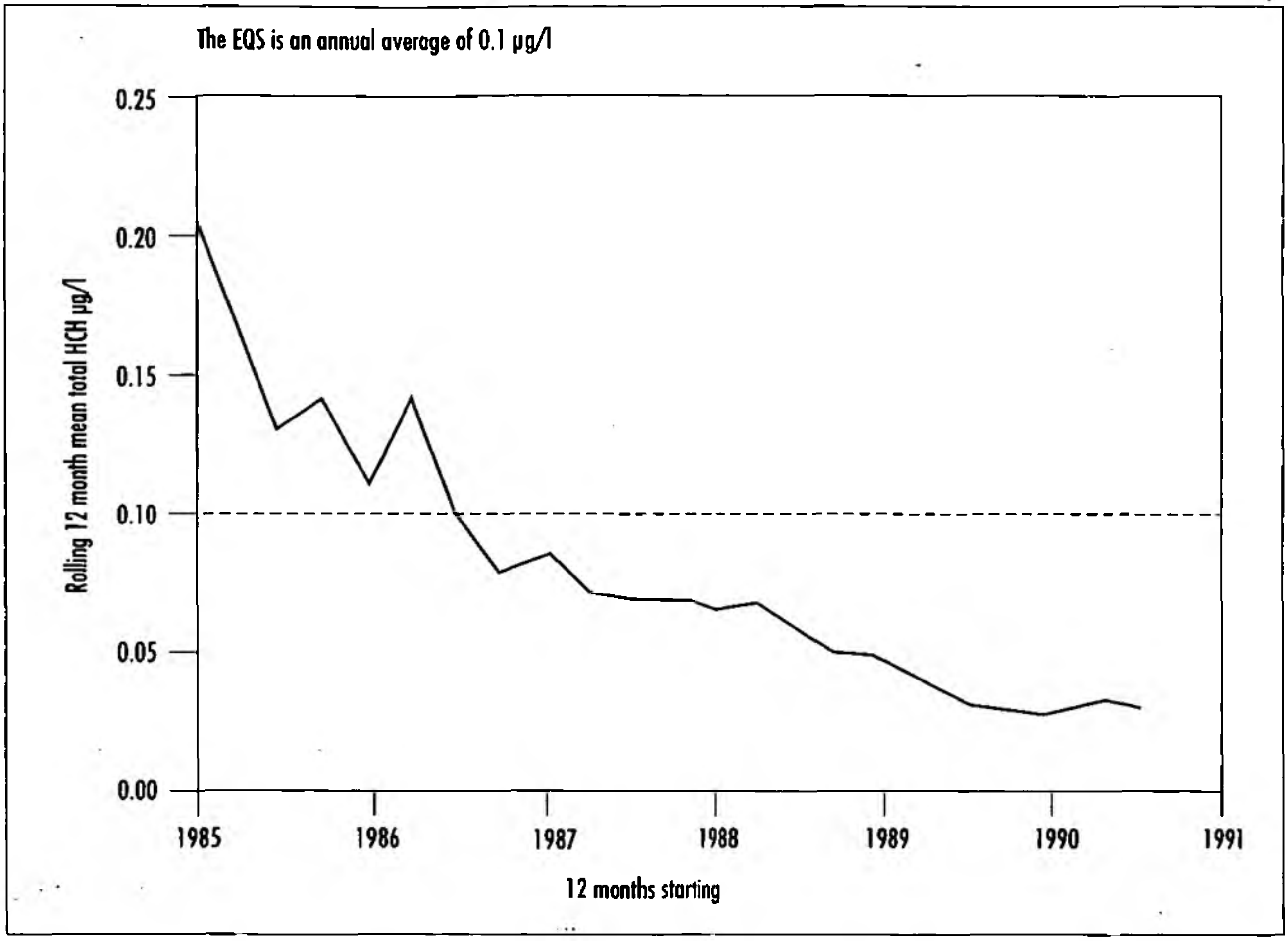
The black list metals, mercury and cadmium, are practically absent from these rivers but because of their large flows, the freshwater rivers are a significant, albeit dilute, source of other metals.

d) Pesticides and other synthetic organic compounds

In the early 1980s' the River Aire was found to contain relatively high levels of the pesticide gamma hexachlorocyclohexane (HCH) and this, in turn, caused elevated levels in the section of the Humber system immediately downstream of the River Aire. The source of this compound was traced to discharges from the textile industry in West Yorkshire. Between 1983 and 1985 it was found that the level of HCH in the River Aire rose as it was used in industry to replace the banned pesticide dieldrin. Since then there has been a steady decline in the HCH concentration as this, in turn, has been replaced by less persistent organo-phosphorus compounds. Figure 9 shows a downward trend in concentration of HCH in the Aire at Beal and it is seen that the river Aire now complies with its EQS for HCH.

As further synthetic organic compounds are added to the list of substances to be controlled under the EC Dangerous Substances Directive, these are included in the monitoring programme for the Humber Estuary system. Thus analyses are now carried out for DDT, dieldrin, aldrin and endrin, carbon tetrachloride and pentachlorophenol (PCP), as well as HCH. Apart from HCH, which is widespread in trace concentrations, all these compounds are present at barely detectable levels in the freshwater rivers.

FIGURE 9: HCH IN THE RIVER AIRE AT BEAL (1985 - 1989)



4.2 Direct discharges of significant biochemical oxygen demand and ammoniacal nitrogen loads

The locations of the main sources of effluent loads of BOD and ammoniacal nitrogen discharged directly to the Humber Estuary system are shown in Figure 10, and Table 7 gives the individual loads for each significant discharge. For the purpose of this report, only discharges which contribute more than 0.1 tonnes per day of BOD or ammoniacal nitrogen are considered to be significant. The loads shown must be regarded as approximate, as in many instances the information available on the rate of discharge is very limited and the resultant calculation of load necessarily imprecise.

There are twenty one major discharges of BOD and ammoniacal nitrogen, nine sewage discharges and twelve industrial effluents. It is seen from Figure 10 that there are no significant BOD or ammoniacal nitrogen discharges made directly to the River Trent, as all the major organic effluents discharge further inland into the nontidal Trent system a long distance upstream of the estuary. These discharges are thus included in the contribution of the freshwater Trent.

The principal organic discharges to the estuary are concentrated into three zones: the tidal Ouse and its tributaries, the north Humber bank around Hull, and the south bank in the Killingholme/ Grimsby area.

Six of the sewage discharges are made directly to the tidal Ouse and its tributaries, but the total organic load discharged in this zone is much less from these effluents than that discharged from the other two zones. However, the lack of clean dilution and long retention times in the tidal Ouse at times of low freshwater flow result in the severe depletion of dissolved oxygen. The discharge of untreated sewage from Hull, combined with a large organic load from an industrial organic effluent in the same zone, contributes around 60% of the total BOD load discharged directly to the estuary.

TABLE 7 - MAJOR EFFLUENT LOADS OF BOD AND AMMONIACAL NITROGEN DISCHARGED TO THE HUMBER ESTUARY (1980 - 1990)
ALL LOADS IN TONNES PER DAY

Sewage Discharges			Industrial Discharges		
	BOD	Ammonia N		BOD	Ammonia N
1. Selby	0.6	1.1	1. Animal Feeds	0.5	
2. Barlby	0.6	-	2. Paper	1.0	
3. Goole	1.7	0.1	3. Citric Acid	8.9	0.5
4. Hull	84.3	4.2	4. Chemical	0.6	
5. Doncaster	0.4	0.2	5. Chemical	0.3	0.1
6. Thorne	2.6	0.3	6. Organic Chemicals	36.4	
7. Grimsby	37.1	2.6	7. Fertilizer	0.1	4.9
8. Cleethorpes	4.7	0.5	8. Latex	0.8	0.3
9. Immingham	0.3	0.1	9. Synthetic Fibres	5.1	0.1
			10. Chemical	2.3	0.1
			11. Titanium dioxide	0.7	0.2
			12. Sugar	10.9	-
Total	132.3	9.1		67.6	6.2

The discharge of crude sewage from Hull also contributes over one quarter of the total ammonia load discharged to the estuary. Despite this, the high dilution available with well oxygenated sea water avoids any significant local deoxygenation in the estuary.

It should be appreciated that the BOD test is not a suitable one for the estimation of the oxygen demand of effluents which contain high levels of inhibitory substances such as metals, or which are very acidic. Several such discharges are among those arising from the industrial zone in the Killingholme/Grimsby area and thus the oxygen demand from these effluents is underestimated by use of the BOD test. In these circumstances, the chemical oxygen demand (COD) is a better test; around 125 tonnes of COD is discharged per day from these effluents.

On the south bank, in the Immingham/Grimsby area, there is a large concentration of industry discharging both organic matter and a variety of metals. This is combined with sewage discharges from Grimsby and Cleethorpes in the same zone and represents a significant BOD load; around one third of the total ammoniacal nitrogen discharged to the estuary comes from this source. It is noteworthy that a single industrial effluent in this zone contributes most of the ammoniacal nitrogen.

During the last decade several significant improvements have been made to a number of sewage and industrial discharges. For example, Tadcaster Breweries installed a new treatment plant in late 1982, removing a very significant BOD load from the River Wharfe. Similarly several large industrial discharges to the Ouse system and to the outer estuary have been significantly reduced by either the installation of effluent treatment plant or reduction in industrial output. In some cases a reduced level of industrial production, or a change in manufacturing trades, has caused an appreciable reduction in pollution load discharged; in particular, a much reduced BOD load from a citric acid plant has made a significant difference.

FIGURE 10: LOCATION OF MAJOR DISCHARGES OF BOD AND AMMONIACAL NITROGEN LOAD TO THE HUMBER ESTUARY SYSTEM (1989 - 1990)

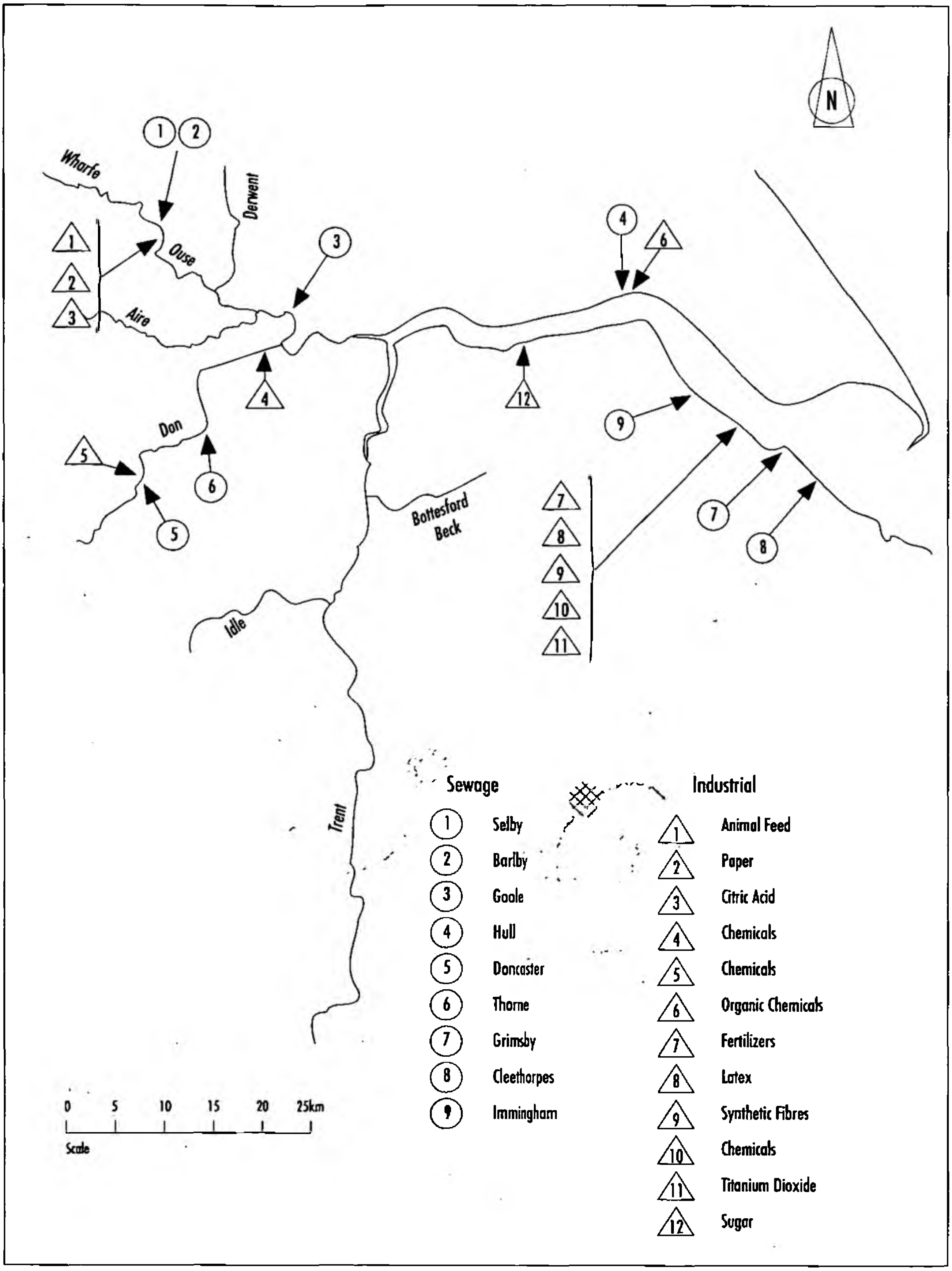


FIGURE 11: SOURCES OF BOD LOAD DISCHARGED TO THE HUMBER ESTUARY SYSTEM (1980 - 1990)

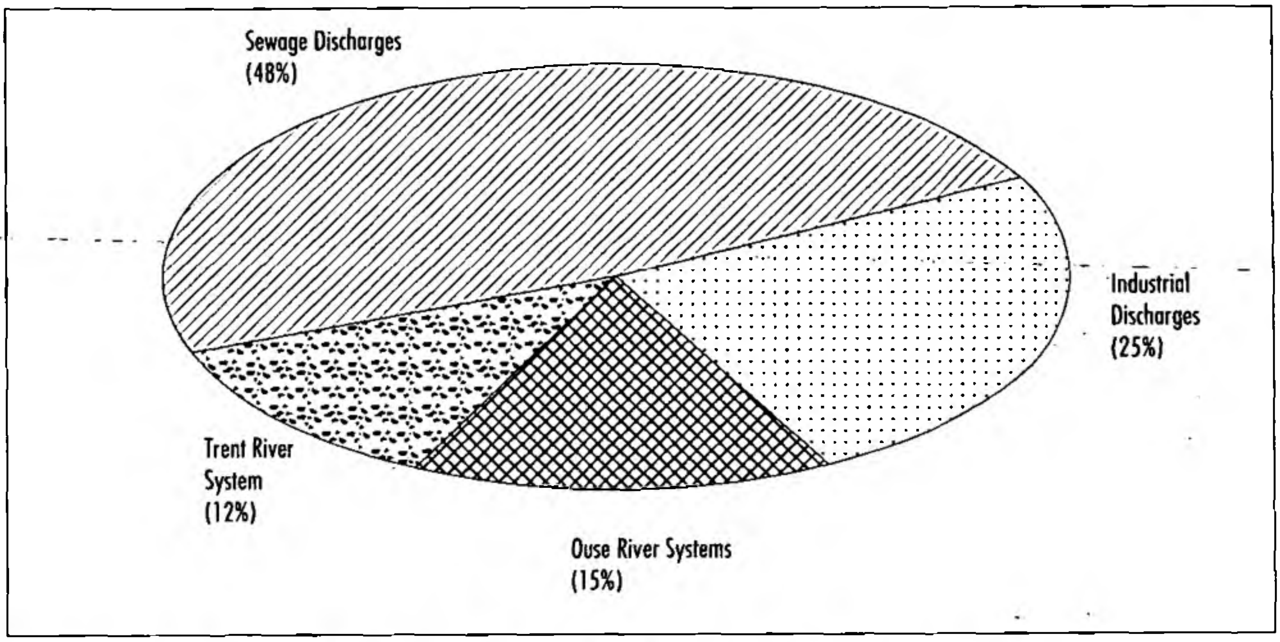
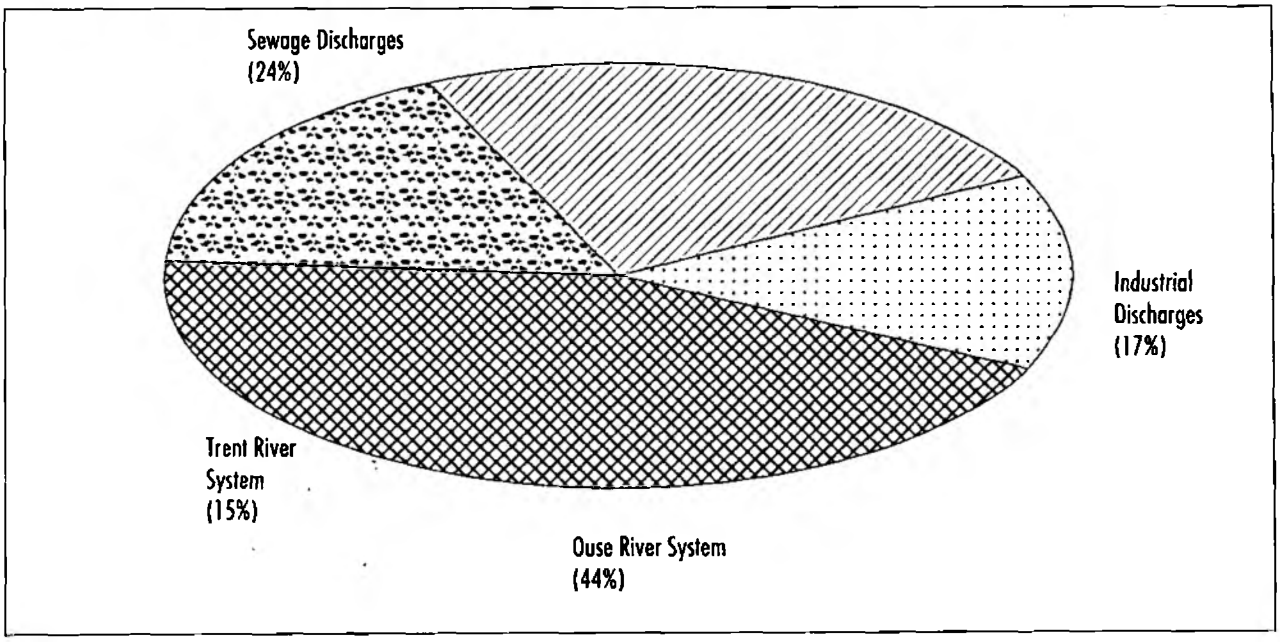


FIGURE 12: SOURCES OF AMMONIACAL NITROGEN LOAD DISCHARGED TO THE HUMBER ESTUARY SYSTEM (1980 - 1990)



If the total BOD load discharged to the entire Humber system in the period 1980 to 1990 is compared with that discharged in the previous twenty years, it would appear that there has been an increase in organic pollution. Thus the sewage derived BOD load had risen from 78 tonnes per day to 132 tonnes per day, whilst the industrial BOD load has fallen from 97 tonnes per day to 68 tonnes per day. These comparisons must, however, be treated with caution due to the imprecision associated with poor flow data. Figures 11 and 12 show a comparison of the sources of BOD and ammoniacal nitrogen loads discharged to the estuary.

4.3 Direct discharges of metals

The locations of the significant effluent discharges of metal load to the estuary are shown in Figure 13 and the metal loads discharged by individual effluents are given in Table 8. The same nine sewage discharges which are regarded as significant in the context of organic pollution also contribute significant metal loads to the estuary. In this context the discharge of 0.1 kg per day of metal is considered to be significant. It is seen that the load of metals discharged is much greater from the industrial effluents than from the sewage effluents and the combined industrial metal load is substantially greater than that from sewage discharges for all the individual metals under consideration.

It is usually the case that, when considering the metal load discharged by effluents, a single industrial discharge is responsible for a high percentage of any particular metal. For example the discharge from a non-ferrous smelter on the north bank of the Humber contributes practically all the arsenic load to the estuary, discharging 375 kg per day and most of the cadmium load, 2.6 kg per day. This particular effluent also contains significant loads of all the other metals under consideration. This process ceased operation in 1991 and restoration of the site should be completed in 1993, resulting in a marked lowering of arsenic and cadmium concentrations in the estuary. The copper load discharged is largely dominated by those of Hull sewage and the industrial discharges from a fine chemicals manufacturer and a titanium dioxide plant on the south bank of the Humber. The chromium load originates predominantly from the two titanium dioxide plants together with a significant contribution from Hull sewage. The lead load is mainly derived from Hull sewage and one of the titanium dioxide plants. A single discharge of chemical effluent on the south bank is responsible for nearly 80% of all the zinc discharged into the estuary.

Figure 14 shows a comparison of the metal loads discharged from industry, sewage and freshwater rivers for the year 1990 with the 1985 to 1989 average. There has been a reduction for all metals, the most significant being industrial arsenic and cadmium. The other apparent changes should be treated with caution due to the lack of precision of the metal load data due to poor flow data.

FIGURE 13: LOCATION OF MAJOR DISCHARGES OF METALS TO THE HUMBER ESTUARY SYSTEM (1980 - 1990)

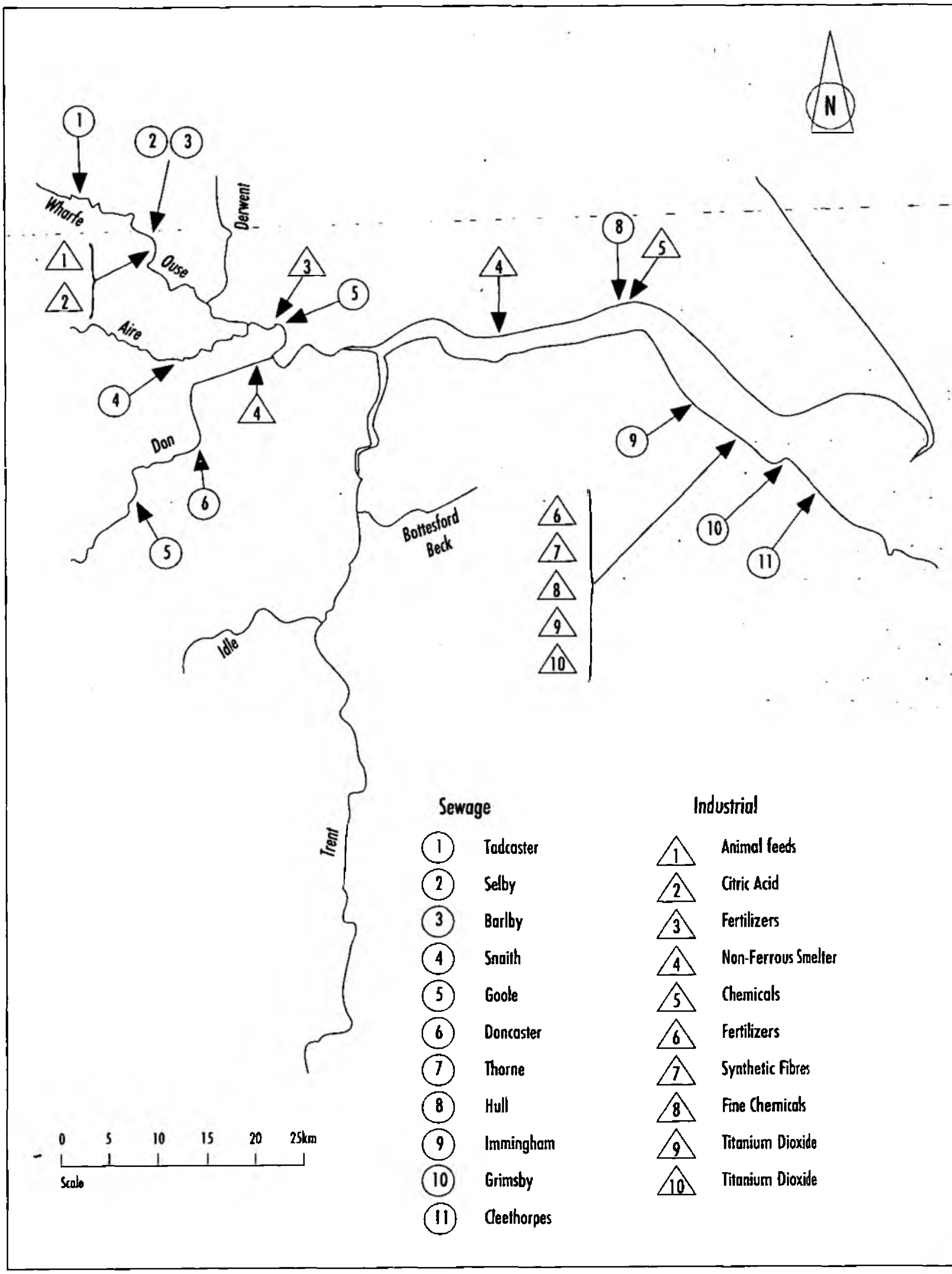
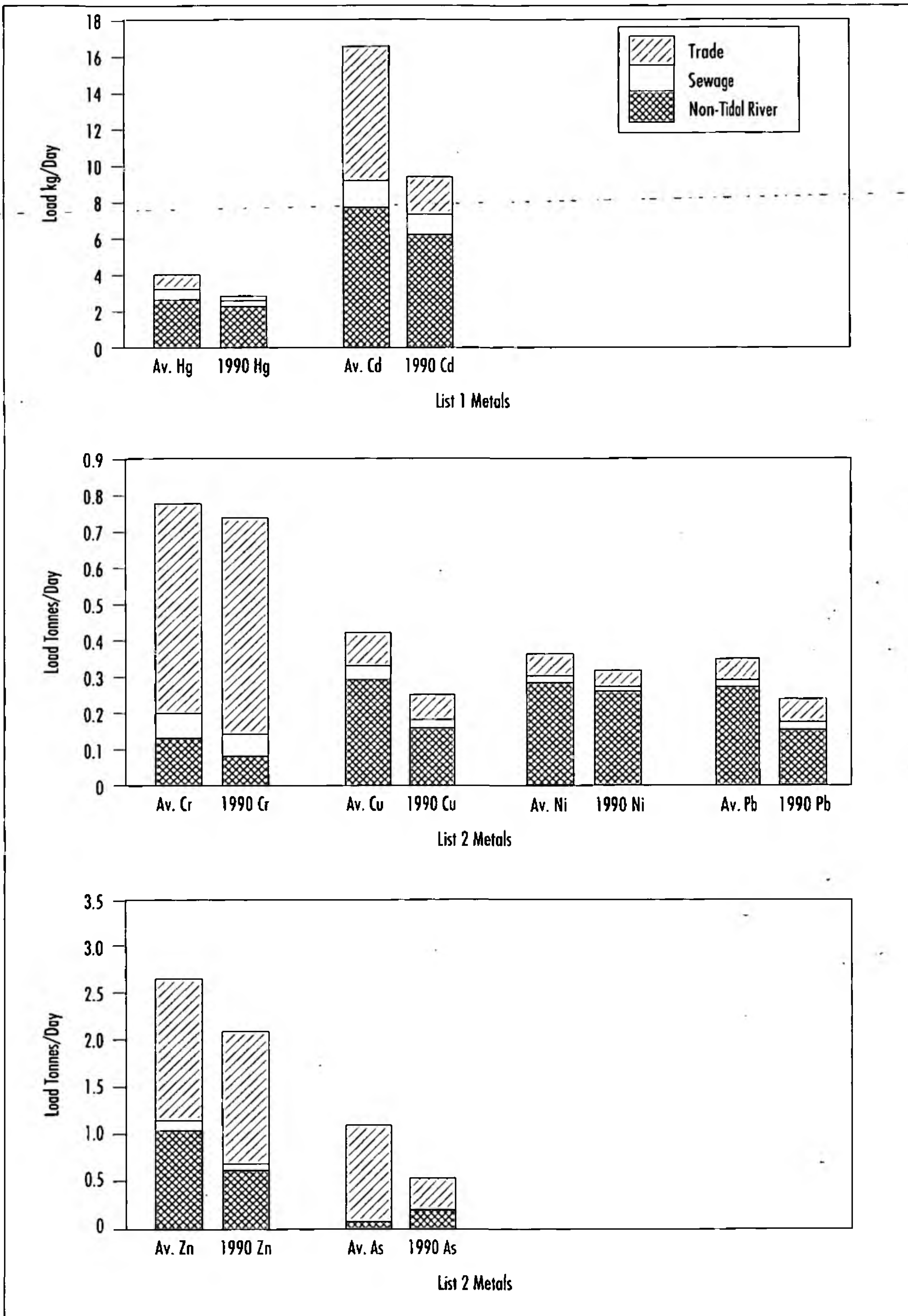


TABLE 8 - MAJOR EFFLUENT METAL LOADS TO THE HUMBER ESTUARY (1990)
ALL LOADS IN KG PER DAY

	Arsenic	Copper	Chromium	Cadmium	Nickel	Lead	Zinc
Sewage Discharges							
1 Tadcaster		0.1	0.1	-	0.1	0.1	0.2
2. Selby		0.2	0.8	-	0.1	0.3	0.2
3. Barlby		0.2	-	-	-	0.1	0.3
4. Snaith		0.3	0.1	-	0.1	0.2	0.3
5. Goole		2.2	-	-	3.0		-
6. Doncaster		-	0.1	-	0.1	-	0.1
7. Thorne		0.4	0.1	-	0.1	0.3	0.6
8. Hull	2.4	20.6	90.3	-	3.8	29.6	111.7
9. Immingham		0.1	0.1	-	0.1	-	1.4
10. Grimsby	1.0	10.1	2.7	-	0.9	9.8	35.5
11. Cleethorpes		0.6	0.6	-	0.2	0.4	1.9
Total	3.4	34.8	94.9	-	8.5	40.8	152.2
Industrial Discharges							
1. Animal Feeds	0.2	0.1	0.1	-	0.1	0.1	0.2
2. Citric Acid	-	-	0.6	-	0.3	0.7	7.5
3. Fertilizers	0.1	0.3	1.1	0.1	0.4	-	1.3
4. Non Ferr Smelter	365.6	6.4	0.8	2.6	3.1	2.7	8.1
5. Organic Chemicals	0.2	4.3	8.7	-	1.8	0.5	16.7
6. Fertilizer	0.2	0.5	0.9	-	0.5	0.2	6.6
7. Synthetic Fibres	-	1.1	7.8	-	2.4	0.3	1234.0
8. Fine Chemicals	-	31.6	0.1	-	8.3	-	2.1
9. Titanium dioxide	7.9	24.2	137.2	0.1	10.9	58.1	143.3
10. Titanium dioxide	1.2	1.4	444.5	0.2	13.7	0.5	2.5
Total	375.4	69.9	601.8	3.0	41.5	63.1	1422.3
Grand Total	378.8	104.7	696.7	3.0	50.0	103.9	1574.5

FIGURE 14: COMPARISON OF METAL LOADS DISCHARGED TO THE HUMBER ESTUARY IN 1990 WITH THE 1985-89 AVERAGE



5. CHEMICAL QUALITY OF THE HUMBER ESTUARY SYSTEM

This chapter summarises and interprets the extensive chemical monitoring data obtained during the period 1980 to 1990 and assesses the compliance of the freshwater and saline sections of the estuary with the relevant environmental quality standards.

5.1 Dissolved oxygen

It is known that organic pollution has caused a serious depletion of dissolved oxygen in the Humber Estuary around Trent Falls and that this is the most serious pollution problem in the Humber. The problem is caused mainly by the continuing seriously polluted conditions which exist in the tributaries of the Ouse which drain industrial Yorkshire, exacerbated by the discharges of inadequately treated sewage and industrial waste which go directly to the estuary system. However, there have been substantial improvements in estuarial quality since the last century and these have been discussed in earlier reports. Nevertheless the problem of severe oxygen depletion still remains, and its solution is probably the single most important quality objective to be achieved. Table 9 summarises the dissolved oxygen, BOD and ammoniacal nitrogen concentrations in the estuary during 1980 to 1990.

It is seen that the tidal Ouse from Selby to Blacktoft, a distance of 40 km, failed to comply with the requirements of the dissolved oxygen standard ie that the tidal rivers should contain at least 40% saturation of dissolved oxygen for 95% of the time. The Aire at Snaith and the Don at Rawcliffe also failed to comply with the standard. The annual average dissolved oxygen values at particular points on the estuary system also show erratic variations during the decade, being affected by several factors, the most important in any one year being the river flows, summer temperature and tidal states.

During any particular year there is a very marked seasonal variation in dissolved oxygen concentration, particularly at the most polluted sampling points on the River Ouse and its tributaries, where very low dissolved oxygen concentrations are observed during the summer months. These appear to be generally associated with high temperatures, low river flows and high concentrations of suspended matter. At certain points on the system however, particularly on the lower Trent, supersaturated dissolved oxygen values are sometimes measured during the summer, indicating active photosynthesis.

The margin of failure to comply with the dissolved oxygen standard is substantial throughout the Ouse from Selby to Blacktoft, and it is obvious that a major reduction in the input of biodegradable polluting loads to the Ouse, Aire and Don will be required to achieve the desired oxygen levels. Major improvements to sewage works are currently being undertaken in the Don and Aire catchments at Bradford, Leeds, Sheffield and Chesterfield and by the mid 1990s the pollution load from these rivers should be substantially reduced.

The dissolved oxygen concentration in the estuary below Trent Falls is more satisfactory and a summary of the relevant dissolved oxygen data is given in Table 9. In these estuarine waters a more demanding standard is applicable whereby the dissolved oxygen concentration should be greater than 55% saturation for 95% of the time. Despite this tighter standard, all points on this part of the estuary system comply. The dissolved oxygen concentration generally improves towards the mouth of the estuary as the dilution available from well oxygenated sea water becomes greater. Although the estuary complied with the dissolved oxygen standard at all points during the decade as a whole, during any particular year there were occasional failures at particular points. However, the frequency of sampling and analysis of the estuary on a co-ordinated basis is only 7 times per year and any 5 percentile values computed from such sparse data for any one year are subject to considerable error.

In order to examine the general trend in dissolved oxygen concentration in the estuary system as a whole, data has been compared over different periods. Figures 15 and 16 show a comparison of

TABLE 9 - DISSOLVED OXYGEN, BOD AND AMMONIACAL NITROGEN DATA FOR THE HUMBER ESTUARY SYSTEM 1980 - 1990

	Dissovled oxygen (% saturation)		BOD (mg/l)	Ammoniacal nitrogen (mg/l)	Unionised ammonia (mg/l)	
Sampling Point	**Mean**	**5%ile**	**Mean**	**Mean**	**Mean**	**95%ile**
Tidal Rivers:						
Ouse - Cawood	84	55	4.1	0.24	0.003	0.007
Ouse- Selby	67	30*	5.5	0.28	0.002	0.007
Ouse - Drax	59	22*	5.1	0.44	0.003	0.008
Ouse - Boothferry	49	17*	5.0	0.69	0.004	0.012
Ouse - Blacktoft	57	28*	2.9	0.50	0.005	0.015
Ouse - Snaith	64	38*	5.9	1.95	0.012	0.030*
Don - Rawcliffe	50	21*	5.4	2.68	0.020	0.058*
Don - Kirk Bramwith	73	47	6.0	4.51	0.039	0.098*
Trent - Dunham	99	70	3.5	0.44	0.007	0.020
Trent - Gainsborough	89	67	3.5	0.34	0.004	0.010
Trent - Keadby	80	53	3.6	0.31	0.003	0.008
Humber:						
Brough	76	58	2.3	0.26	0.002	0.007
Albert Dock	75	58	2.7	0.21	0.001	0.005
New Holland	76	62	2.1	0.15	0.001	0.004
Saltend	79	63	2.5	0.16	0.001	0.003
Immingham	82	65	1.6	0.18	0.001	0.004
Spurn Head	93	80	1.5	0.12	0.001	0.005

* *Values do not comply with the required EQS. Note however that EQSs are defined over a twelve month period and the comparison with 10-yearly figures is for illustration only.*

dissolved oxygen profiles for the periods 1964 to 1968, 1977 to 1981 and 1980 to 1990 in the Ouse-Humber and Trent-Humber systems respectively. There have been substantial improvements in both systems since 1964 to 1968, and this is particularly marked in the Trent Humber system where the lower Trent was more severely deoxygenated than the Ouse in the period 1964 to 1968, but by 1980 to 1990 the lower Trent had higher oxygen levels than the Ouse. This reflects the general improvement in the freshwater section of the Trent and the removal of the substantial pollution load from the local steel manufacturing industry in Scunthorpe.

The outer estuary has remained well oxygenated during the period under consideration.

The dissolved oxygen concentrations at any particular point in the middle and upper estuary may be liable to rapid fluctuation throughout the day. To provide more detailed information about this variation, continuously recording dissolved oxygen monitors have been installed at a number of points; however, these monitors have all been inoperative for significant periods since their installation. Thus it is not possible to give any long term detailed statistical information, but the data has been very useful in understanding the short-term variability of dissolved oxygen at specific locations. The installation of new instrumentation in the 1990s has resulted in the production of a more reliable data record.

Figure 17 shows an example of the information produced from the continuous monitors at three stations in the estuary - the River Trent at Burton Stather, and the Humber at Upper Whitton and at Saltend. The data shown were obtained during a special intensive survey of the estuary in June 1986. It is during such summer periods that the minimum dissolved oxygen levels are often reached, when river flows are normally at their lowest and temperatures at a maximum, and both nitrification and carbonaceous oxidation proceed at their highest rates.

FIGURE 15: COMPARISON OF DISSOLVED OXYGEN PROFILES IN THE OUSE - HUMBER SYSTEM 1964-68, 1977-81 AND 1980-1990

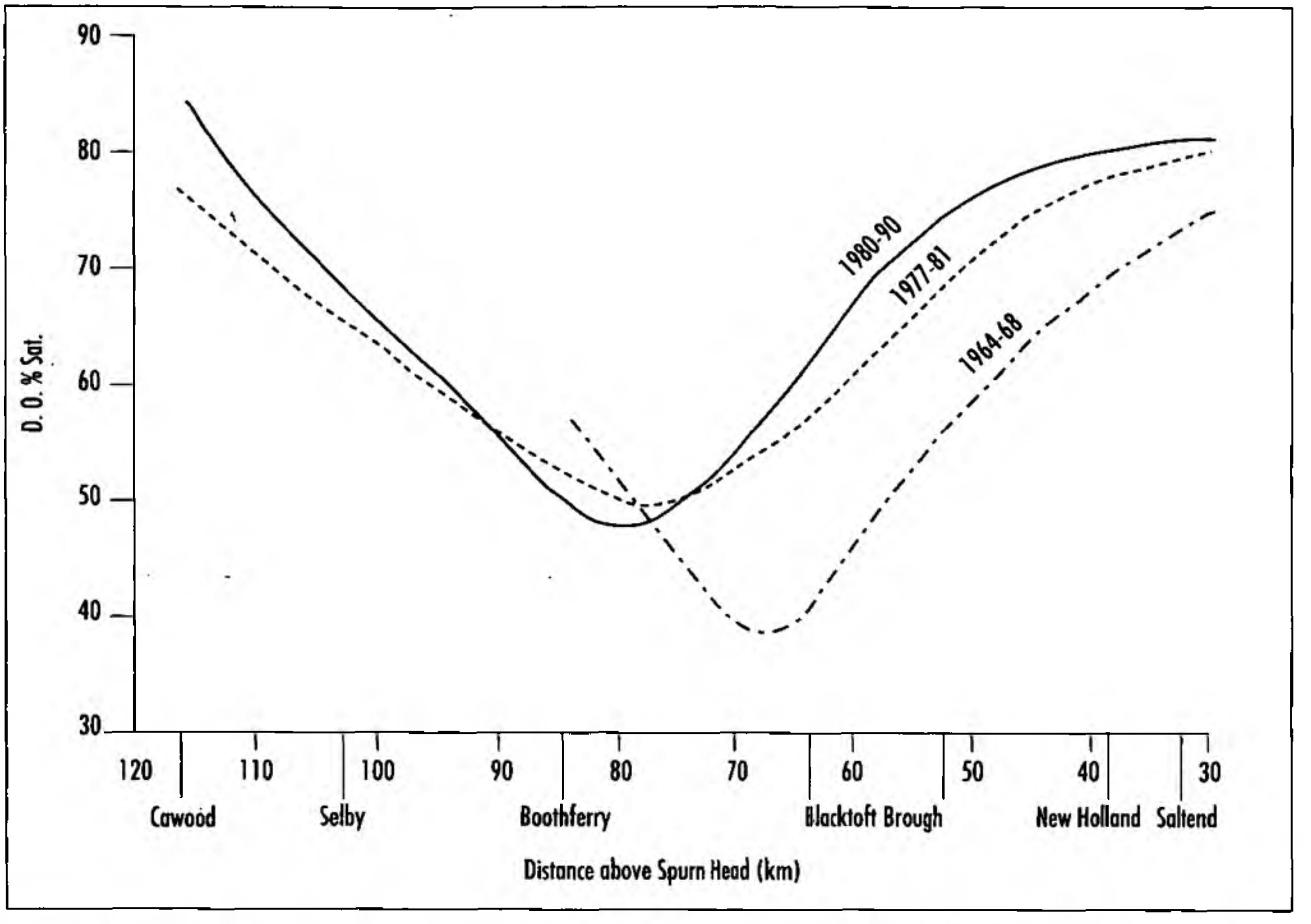


FIGURE 16: COMPARISON OF DISSOLVED OXYGEN PROFILES IN THE TRENT-HUMBER SYSTEM 1964-68, 1977-81 AND 1980-1990

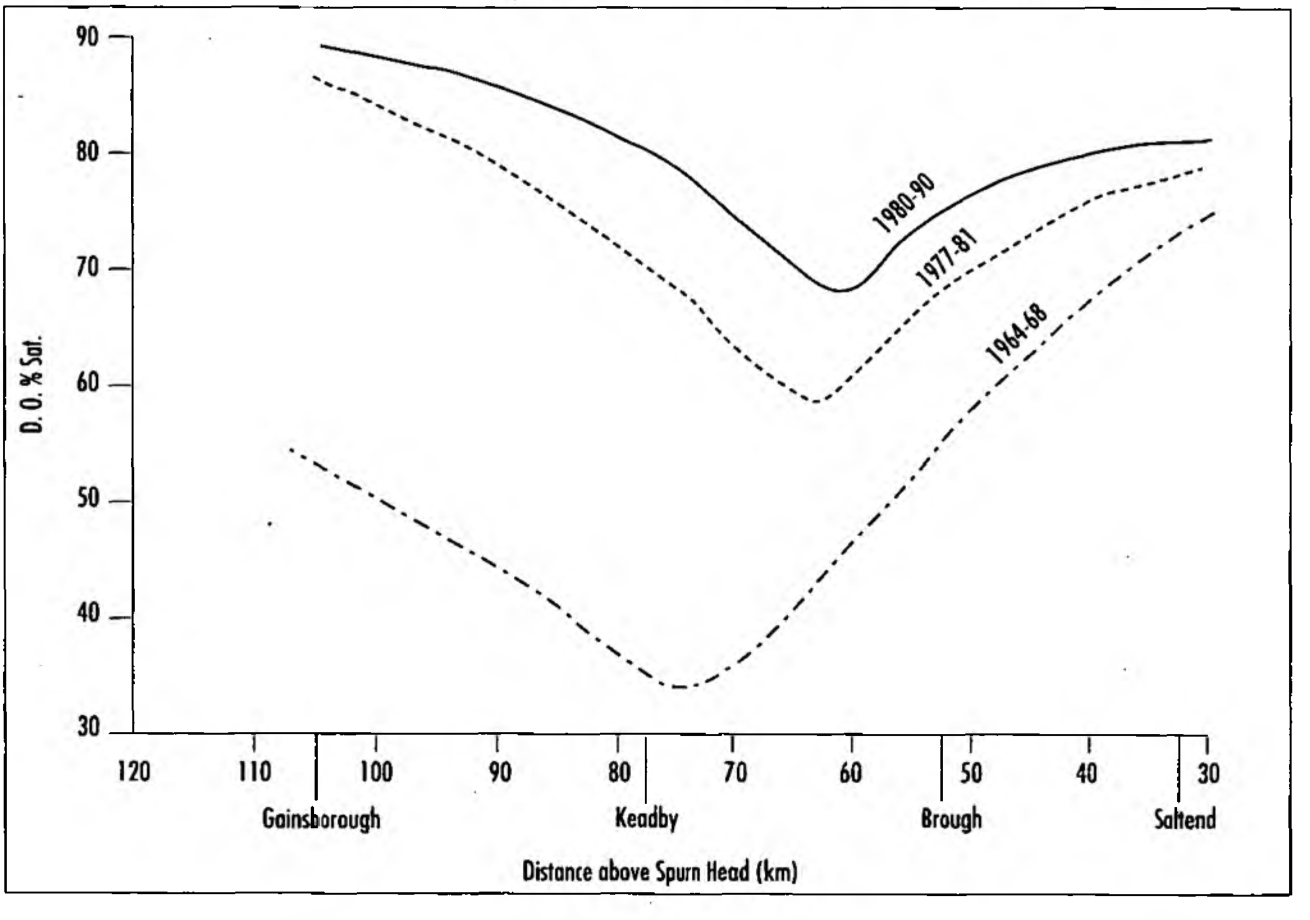
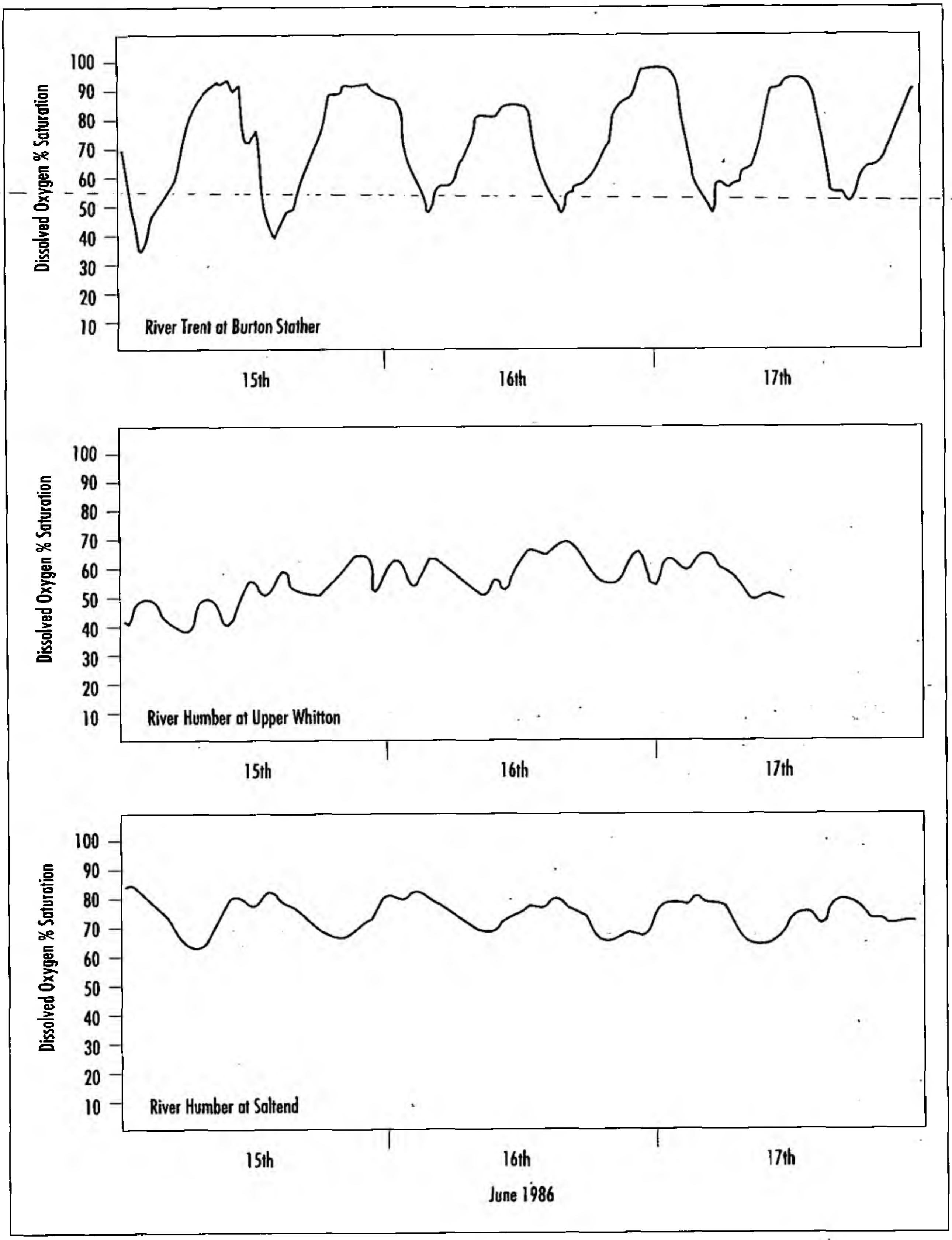


FIGURE 17: DISSOLVED OXYGEN LEVELS AT SELECTED CONTINUOUS MONITORING STATIONS OVER THE PERIOD 15TH TO 17TH JUNE 1986



The continuous dissolved oxygen data for the River Trent at Burton Stather show a regular pattern of peaks and troughs twice per day which correlate with the state of tide at that point. The dissolved oxygen is seen to vary during every tidal cycle between a minimum of 40 to 50% saturation at high tides to 90 to 100% at low tides. This regular variation is caused by the polluted low dissolved oxygen water of the lower Ouse being pushed back up the River Trent on the incoming tide after mixing with the Trent below Trent Falls. The dissolved oxygen then rises to a new peak on each tidal cycle as the freshwater component of the water increases to a maximum at low tide. Further downstream at Upper Whitton a similar, although less marked, variation is seen. At Saltend, a smaller and more irregular variation in dissolved oxygen is observed. This variation pattern is probably caused by the sewage and industrial discharges from Hull and the varying dilution factors applicable during the tidal cycle.

5.2 Biochemical oxygen demand and ammoniacal nitrogen

The BODs recorded in Table 9 are nitrification - suppressed values obtained by the addition of allyl thiourea. They are generally similar to those reported in earlier years at most points, but do indicate a slight improvement in quality in the tidal Ouse system. However, the BOD values for the tidal Ouse and its tributaries the Aire and Don still indicate an unsatisfactory level of organic pollution. The BOD concentration decreases progressively towards the mouth of the estuary with increasing dilution by clean sea water. The slightly elevated mean BOD at Albert Dock on the north Humber bank is probably due to the localised streaming effect of sewage and industrial organic waste discharged from Hull. This may be compared with the rather lower value at New Holland on the south bank, where no such discharges exist.

The severely polluted state of the Aire and Don, caused mainly by sewage discharges, is confirmed by the very high recorded average ammoniacal nitrogen concentrations in these rivers. The effect, at times, of the nitrification of this level of ammonia on the dissolved oxygen concentration in these rivers and the lower Ouse is thought to be considerable, particularly during the low flow warm summer periods. Surveys by the Water Research Centre have confirmed that active nitrification does take place in the lower Ouse during the summer, and it is thought that the high levels of suspended solids which exist there help to provide the conditions in which nitrifying bacteria thrive and the nitrification process proceeds.

In addition to its potential detrimental effect on dissolved oxygen levels, ammonia exerts a direct toxic effect on aquatic life when in the unionised state. The concentration defined by the EQS for unionised ammonia is exceeded in the Rivers Aire and Don by a large margin, but not elsewhere. However, during the decade, individual years at a particular point may have complied. The River Trent at Dunham has a concentration of unionised ammonia very close to the standard and in 1990 it was actually exceeded. This implies the need for tighter ammonia standards at selected discharges in the freshwater River Trent. As with the BOD values, the concentration of ammoniacal nitrogen declines towards the estuary mouth to relatively insignificant levels.

5.3 Metal concentrations in the estuary

(a) Tidal rivers

Metal concentrations have been monitored in the estuary for many years, but it is only since the setting of the EQSs for the List 1 and List 2 metals included in the EC Dangerous Substances Directive that they have been determined with the accuracy required to assess compliance. Particular difficulties were experienced initially, but the adoption of improved modern instrumental techniques such as ICPMS (Inductively Coupled Plasma Mass Spectrometry) has largely resolved the early difficulties. Thus, prior to 1980 there were no systematic routine analyses of the Humber estuary for metals and this report contains the first comprehensive data for such surveys. Table 10 shows the results of analysis for metals in the non-saline tidal rivers, and Table 11 indicates the results for the estuary downstream of Trent Falls, which is predominantly saline.

TABLE 10 - AVERAGE METALS CONCENTRATIONS IN THE HUMBER TIDAL RIVERS (1980-1990)
(ALL RESULTS IN µg/l)

Sampling Point	Arsenic (f)	Cadmium (t)	Mercury (t)	Copper (f)	Zinc (f)	Chromium (f)	Iron (f)	Nickel (f)
EQS	50	5	1	28	500	250	1000	200
Ouse - Cawood	2	0.7	0.4	6	9	1	130	7
Ouse - Selby	4	0.6	0.3	9	10	3	205	8
Ouse - Drax	4	0.8	0.2	12	14	2	112	10
Ouse - Boothferry	5	1.0	0.3	22	20	2	106	47
Ouse - Blacktoft	8	2.2	0.4	18	14	26	48	19
Aire - Snaith	5	0.5	0.2	9	23	4	150	13
Don - Rawcliffe	4	0.7	0.3	19	20	3	78	13
Don - Kirk Bramwith	0.4	0.4	0.2	15	24	3	84	30
Trent - Dunham	3	0.6	0.2	18	50	3		29
Trent - Gainsborough	5	0.6	0.1	18	59	3		21
Trent - Keadby	7	0.7	0.2	20	77	3		16

f = filtered sample *t = total sample*

Table 10 shows that the long-term average metals concentrations are all below the level of the EQS in the tidal rivers; for all except copper, the measured levels are well below, and in the case of copper, where the standard is approached but not exceeded, complexation reduces the free metal ion to insignificant levels. Note that the figures quoted in Table 10 are meant only as an indication of the long-term patterns of metals concentrations. The EQSs, however, are annual averages and information on actual compliance with the EQSs in any particular year can be found in previous reports of the Humber Estuary Committee (see References section).

(b) Estuary downstream of Trent Falls

Table 11 gives the long-term average metal concentrations in the estuary downstream of Trent Falls, where the standards are much tighter. As with Table 10 the intention is to give a picture of the long-term pattern in metals concentrations. Strictly, these figures are not directly comparable with the EQSs, which are annual averages. However, the EQS gives a useful indication of the long-term metals concentrations which are acceptable in this part of the estuary. Information on compliance with EQSs in any particular year can be found in the previous reports of the Humber Estuary Committee (see References section).

The value for copper of 5 µg/l is ostensibly breached, or equalled, at all the estuarine points but, as discussed earlier, complexation reduced the toxicity to insignificance. The standards for all the other metals monitored are met at all points downstream of Trent Falls.

The dissolved arsenic concentration in the estuary is highest at Brough and is also elevated at Saltend.

TABLE 11 - AVERAGE DISSOLVED METAL CONCENTRATIONS IN THE HUMBER ESTUARY (1980 TO 1990)
(ALL RESULTS IN µg/l)

Sampling Point	Arsenic	Cadmium	Mercury	Copper	Zinc	Chromium	Iron	Nickel
EQS	25	2.5	0.3	5	40	15	1000	30
Brough	12	LT	0.1	22	14	2	27	15
Albert Dock	7	LT	0.1	13	12	1	24	10
New Holland	4	0.3	0.03	7	11	0.5	19	7
Saltend	11	LT	0.1	14	14	1	35	14
Immingham	2	0.3	0.3	5	14	0.5	47	8
Spurn Head	3	LT	0.1	9	9	1	29	3

All analyses were carried out on filtered samples. In cases where a high proportion of the determinations showed the cadmium concentration to be less than the detection limit, this is shown as LT and no reliable mean values can be produced.

These points are close to the major discharge of arsenic from Capper Pass and indicate its effect on the estuary. As expected, the concentration of arsenic declines seawards with progressive dilution. The arsenic content of the estuary should diminish significantly as a result of this discharge ceasing in 1991.

Cadmium levels in the estuary were often below the limits of detection, but long-term average values of 0.3 µg/l were recorded at New Holland and Immingham, well below the standard of 2.5 µg/l. There were significant decreases in cadmium input during the 1980's with progressive reductions from Capper Pass before the closure of the works.

There have been significant reductions in the input of mercury from the Rother catchment (a tributary of the Don) where the annual amount discharged fell from some 1100kg per year in the 1980s to 7kg per year in 1986 after the provision of an industrial treatment plant. The cessation of the use of sulphuric acid contaminated with mercury by some factories on the South Bank further reduced the mercury input.

Nickel tends to remain in solution in the estuary and quite high values are observed in the tidal rivers Ouse, Don and Trent. The levels of this relatively non-toxic metal are, however, well within the required standard. Much lower levels of nickel are seen in the saline parts of the estuary, consistent with the progressive dilution of a conservative substance by sea water.

Zinc is widespread and found in significant levels in both the freshwater and saline sections of the estuary, but always within the relevant standard. Similarly, dissolved iron is as high as 250 µg/l in the Ouse, with much lower values in the estuary section. The iron concentrations are well within the required standard at all points.

(c) Metals in sediments

No environmental quality standards for metals in sediments have been set by the Humber Estuary Committee, but the monitoring of metals in sediments in the estuary is a useful complimentary technique to the monitoring of metals within the water column. Although sediments do move within the estuarine environment they are much less mobile than the water column, and thus the analysis of sediments should provide a better historical record. However, the direct biological availability of

TABLE 12 - SEDIMENT ANALYSIS FOR METALS. HUMBER TIDAL RIVERS (1980 - 1990)
(ALL RESULTS EXCEPT IRON REPORTED AS MG/KG DRY WEIGHT. IRON IS REPORTED AS PERCENTAGE BY WEIGHT
SEDIMENT TYPE <90µM FRACTION)

Location	Chromium	Lead	Zinc	Cadmium	Copper	Nickel	Arsenic	Mercury	Iron %
Aire - Snaith	53	64	195	1.0	48	28	21	0.3	2.6
Don - Thorne	42	59	180	0.9	40	33	18	0.3	2.5
Ouse - Cowood	59	117	258	1.1	50	34	30	0.3	3.0
Wharfe - Ryther	77	74	199	0.7	37	33	51	0.4	3.3
Trent - Gainsborough	47	66	185	0.8	42	30	23	0.3	2.6
	81	106	333	1.7	76	49	-	-	3.3
Average	60	81	225	1.0	49	35	29	0.3	2.9

metals in sediments is largely limited to those who ingest them, although there is always the potential for their transfer into solution, particularly under anaerobic conditions.

The concentration of metals in sediments is much greater than that in water, the results obtained thus tend to be analytically more reliable. However, results expressed in terms of concentration (µg/g) are very dependent on the size fraction of sediment analysed and variations in sample type may introduce considerable variations.

Organic muddy sediments generally contain the highest concentration of metals and sandy sediments the lowest. It is important, therefore, to compare samples of similar particle size if any valid conclusions are to be drawn.

Generally the observed tendency is for sediments obtained from the tidal rivers to contain lower concentrations of metals than those taken from the estuarine waters, although there is considerable variability. The only exception to this is cadmium where the average concentration of the tidal river sediments is higher than that of the estuary downstream of Trent Falls. In both sections of the estuary system, however, the concentrations are very low. Apart from lead, the concentrations of heavy metals in the sediments taken from the Trent are slightly higher than those from the Ouse system.

No general geographical trend can be observed for the metal content of sediments within the estuary, which could indicate that the sediments are relatively well mixed. The only exception to this is chromium, which is generally higher towards the mouth of the estuary. This is not surprising, as the major discharges of chromium are from the titanium dioxide plants in the South Humberside industrial complex. As expected, some local elevation of the arsenic concentration is evident around its major industrial discharge - a non-ferrous metal smelter.

Sediment samples have been collected from the Humber estuary routinely during the decade 1980 to 1990 and the results of analysis from a representative selection of sites are summarised in Tables 12 and 13.

Considerable reductions in metal loads discharged in effluents were made during the decade but it may be some time before this is reflected in sediment analysis. The mercury concentrations in the tidal river sediments are fairly constant around 0.3 mg/kg, whereas the levels in the estuary samples are generally around twice this value.

The concentrations of iron in the sediment samples are generally higher in samples taken from the south bank of the Humber, than from the north bank. This is consistent with the known input of industrial ferruginous discharges in the area. The major industrial source of iron on the south bank

TABLE 13 - SEDIMENT ANALYSIS FOR METALS. HUMBER ESTUARY (1980 TO 1990) (ALL RESULTS REPORTED AS MG/KG (DRY) EXCEPT IRON WHICH IS REPORTED AS A PERCENTAGE BY WEIGHT <90 μM).

Location	Chromium	Lead	Zinc	Cadmium	Copper	Nickel	Arsenic	Mercury	Iron %
Brough	99	116	287	0.6	49	43	62	0.5	4.2
Hessle	59	75	203	0.5	38	31	31	0.5	3.3
Hull	94	117	290	0.5	53	43	62	1.0	4.4
Paull	81	108	266	0.5	49	42	53	1.7	4.2
Thorngonbald	64	66	199	0.3	33	30	33	0.3	3.3
Barton	105	99	256	0.8	54	41	-	0.5	4.6
Barrow	163	150	348	0.5	71	58	-	0.7	5.9
New Holland	142	146	337	0.4	68	54	-	0.7	5.6
S Killingholme	171	158	352	0.9	71	59	-	0.9	6.3
Grimsby	123	108	256	0.2	53	44	-	0.6	5.2
Average	110	114	279	0.5	54	45	48	0.7	4.7

was relocated to the outer estuary via a long sea outfall in 1988 and this resulted in a remarkable improvement in the appearance of the local stretch of coastline. The unsightly iron staining of the coastline which has dominated the area for many years has now disappeared. However, it could be some time yet before the elevated iron levels in the local sediment samples return to the average levels found in the rest of the estuary.

There is evidence that a considerable proportion of the metals discharged to the Humber are retained in the sediments which are accumulating within the system. A proportion will, however, be transported either in solution or adsorbed onto suspended sediment into the North Sea. The significance of metals in the plume of Humber water dispersed into the sea is one of the topics currently being investigated by the Natural Environment Research Council (NERC).

5.4 Pesticides, hydrocarbons and other organic micropollutants

The list of EQSs for the Humber estuary includes those for HCH, pp DDT, "drins", carbon tetrachloride, and pentachlorophenol.

Table 14 compares the average individual organic pollutant concentrations. In all cases they comply, although at Snaith on the River Aire and at Brough, the concentrations of HCH are close to the standard applicable to the estuary downstream of Trent Falls. Note that the comments made in Section 5.3a and b on the comparability of long-term average values with EQSs also apply here.

Although aldrin and endrin were generally absent, dieldrin was present in measurable quantities in the tidal rivers, although well below the standard value. Pentachlorophenol, carbon tetrachloride and DDT were usually undetectable or only present at concentrations close to the detection limits.

In 1983 there was a major oil spill when 6,000 tonnes of crude oil entered the estuary following a collision between the "Sivand" and a jetty. The data produced after the subsequent investigation appeared to indicate a high level of background oil pollution throughout the estuary. To obtain more information, the Humber Estuary Committee commissioned the Oil Pollution Research Unit to carry out a detailed study of hydrocarbon residues in sediments. Samples were taken in August and

September 1987 from a range of intertidal and subtidal sites, and these were analysed by capillary gas liquid chromatography. It was found that there was a wide range of total hydrocarbon content, ranging from 6 to 885 parts per million, with a clear correlation between hydrocarbon concentration and the mud content of the samples. Hydrocarbon contamination was thus found to be widespread throughout the estuary, probably from a variety of causes including spillages, effluents and road run-off. It was concluded that the 1983 oil spill was unlikely to have contributed significantly to the relatively small hydrocarbon loading in the estuary when compared with other UK estuaries. Table 15 indicates that the Humber is more contaminated than Milford Haven and the Dart Estuary, but much less contaminated than the Firth of Forth or Southampton Water.

TABLE - 14 COMPARISON OF ORGANO-CHLORINE CONCENTRATIONS WITH EQS VALUES (1980 - 1990)
(ALL FIGURES AS TOTAL μg/l)

Location	HCH	PP-DDT	DRINS	PCP	CCl_4
Tidal Rivers EQS	0.10	0.01	0.03	2.0	12
Ouse - Cawood	0.01	LT	0.004	LT	LT
Ouse - Selby	0.01	LT	0.006	LT	LT
Ouse - Drax	0.02	LT	0.01	LT	LT
Ouse - Boothferry	0.02	LT	0.006	LT	LT
Ouse - Blacktoft	0.02	LT	0.01	LT	LT
Aire - Snaith	0.09	LT	0.02	LT	LT
Don - Rawcliffe	0.02	LT	0.006	LT	LT
Don - Kirk Bramwith	0.02	LT	0.003	LT	LT
Trent - Gainsborough	0.03	LT	0.005	-	
Trent - Keadby	0.002	LT	0.004	-	-
Estuary EQS	0.002	0.001	0.003	2.0	12
Brough	0.018	LT	LT	LT	LT
New Holland	0.01	LT	LT	LT	
Albert Dock	LT	LT	LT	LT	LT
Saltend	LT	LT	LT	LT	LT
Killingholme	LT	LT	LT	LT	LT
Spurn	LT	LT	LT	LT	LT

LT indicates that in a high proportion of the samples analysed the concentrations were less than the detection limit. In all these cases the detection limits were well below the EQS values.

TABLE 15 - COMPARISON OF HYDROCARBON CONCENTRATIONS IN SEDIMENTS FROM THE HUMBER WITH OTHER UK ESTUARIES (OPRU 1988)

Location	Total hydrocarbon concentrations (mg/kg) dry weight		
	Min	Max	Mean
Humber Estuary	6	885	343
Southampton Water	222	23,500	6,716
Firth of Forth	41	1,645	835
Milford Haven	1	615	144
Sullom Voe	13	1,405	289
Dart Estuary	83	346	156

5.5 Nutrients

The nutrients considered are limited to nitrogen and phosphorus. The ammoniacal nitrogen, nitrate nitrogen and orthophosphate concentrations have been routinely monitored in the estuary system during the decade and the average results are shown for the estuary in Table 16. The average chloride concentrations are also shown at each point and this indicates the average sea water concentrations corresponding to the nutrient levels.

The rivers discharging to the estuary carry a high sewage effluent load from the industrial Midlands and from Yorkshire. Consequently they contain relatively high levels of sewage - derived nitrogen and phosphorus. Nutrients are also leached from the large agricultural areas within the Humber catchment, and the natural nutrient load from land drainage is increased by the leaching of agricultural fertilisers within the catchment. The major sewage discharges from Hull and Grimsby and several smaller discharges add significant quantities to the estuary, as does the discharge of industrial effluent from a fertiliser manufacturer situated on the south bank of the Humber. Table 17 gives the estimated loads of inorganic nitrogen and phosphorus which are added to the Humber Estuary system via the freshwater rivers, the two major sewage discharges from Hull and Grimsby, and the fertiliser discharge in the Grimsby area. From this table it can be seen that the Trent river system is the largest source of both nitrogen and phosphorus, reflecting the sewage input from the large population and major industry located within the Trent catchment. It is also of interest to note that 94% of the nitrogen derived from the Trent system is as nitrate, compared with 74% from the Ouse system. This may be attributed to the fuller overall oxidation of sewage within the Trent catchment, but there may also be a larger contribution of nitrate from non-point sources such as agricultural run-off, although this is difficult to quantify.

The two major sewage discharges to the estuary, from Hull and Grimsby, are responsible for around one quarter of the ammoniacal nitrogen load added to the estuary and they also contribute 9% of the orthophosphate load. Phosphorus is not removed at any of the sewage treatment plants discharging effluent to the Humber system. Indeed, there are currently no plans to reduce the nutrient input from sewage within the Humber catchment, because no significant eutrophication problems have, so far, been identified. However, the input of nitrogen and phosphorus to the North Sea from the Humber Estuary is a significant proportion of the total nutrients discharged from UK waters, contributing around 30% of both the UK nitrogen and phosphorus input.

Both nitrogen and phosphorus concentrations fall with progressive sea water dilution towards the mouth of the estuary. However, the nitrogen and phosphorus levels are both sufficiently high to support photosynthetic organisms throughout the estuary. Algal blooms are observed from time to time, particularly in the tidal rivers sections of the estuary, but no adverse conditions have so far been associated with these blooms and there are no standards for nutrient levels in the Humber estuary.

TABLE 16 - AMMONIACAL NITROGEN, NITRATE NITROGEN, ORTHOPHOSPHATE AND CHLORIDE CONCENTRATIONS IN THE HUMBER ESTUARY SYSTEM AVERAGES 1980 - 1990.
(ALL RESULTS IN mg/l FILTRATE)

Location	Ammoniacal N	Nitrate N	Ortho Phosphate P	Chloride
Tidal Rivers:				
Ouse - Cawood	0.2	3.4	0.2	29
Ouse - Selby	0.3	3.8	0.2	36
Ouse - Drax	0.4	4.8	0.3	57
Ouse - Boothferry	0.7	4.8	0.3	133
Ouse - Blacktoft	0.5	5.7	0.3	1,229
Aire - Snaith	1.9	6.1	1.0	108
Don - Rawcliffe	2.7	6.2	0.7	300
Don - Kirk Bramwith	4.5	6.2	1.3	202
Trent - Gainsborough	0.3	9.8	1.0	102
Trent - Keadby	0.3	8.8	1.0	103
Estuary:				
Brough	0.3	5.9	0.2	3,260
New Holland	0.1	5.1	0.2	6,858
Albert Dock	0.2	5.0	0.2	7,057
Saltend	0.2	4.7	0.2	7,985
Killingholme	0.2	3.7	0.09	10,340
Spurn	0.1	1.7	0.06	15,828

Studies by the NERC in the North Sea around the Humber estuary have identified a nutrient plume extending well out into the North Sea. This plume contains relatively high concentrations of nitrate and phosphorus compared with background sea water levels. Nitrate appears to be transferred conservatively throughout the outer estuary into the plume zone where it is actively removed.

TABLE 17 - INORGANIC NITROGEN AND PHOSPHORUS INPUTS FROM FRESHWATER RIVERS, MAJOR SEWAGE AND FERTILISER DISCHARGES

Source	Ammoniacal N Load (tonnes/day)	Nitrate N Load (tonnes/day)	Orthophosphate P Load (tonnes/day)
Ouse System:			
Aire	7.3	16.3	3.5
Wharfe	0.3	3.0	0.3
Ouse	1.3	15.0	1.7
Derwent	0.1	5.6	0.4
Don	7.9	7.7	1.2
Total (Ouse)	16.9	47.6	7.1
Trent System:			
Trent	4.6	73.2	12.3
Idel	0.2	5.0	0.6
Bottesford Beck	0.2	0.4	0.4
Total (Trent)	5.0	78.6	13.3
Total Rivers	21.9	126.2	20.4
Hull Sewage	4.2	0.1	1.4
Grimsby Sewage	2.6	0.2	0.6
Total Sewage	6.8	0.3	2.0
Fertiliser Discharge	4.9	1.5	0.1
Grand Total	33.6	128.0	22.5

6. BIOLOGICAL SURVEYS

Biological surveillance of the Humber estuary and tidal rivers commenced in the early seventies and now forms an integral part of the Humber monitoring programme. Assessment of the environmental quality of the estuary is based primarily on the examination of invertebrate populations in the intertidal and subtidal habitats. Many of these organisms are relatively sedentary and can therefore provide an integrated assessment of all aspects of water quality. Initial observations on the invertebrate fauna were provided by the previous water quality report (Humber Estuary Committee 1992). Because little historical data were available, information was confined to a description of the characteristic fauna and an examination of spatial distributions in relation to physical parameters and polluting inputs. In the late seventies and early eighties, with the development and establishment of a routine monitoring strategy, annual information on environmental quality has become available. The biological programme comprises a variety of surveys which monitor different habitats and areas within the estuarine system; details of these are summarised in Table 18.

TABLE 18 - SUMMARY OF HUMBER BIOLOGICAL SURVEYS

	No of Sites	Sampling Frequencies	Sampling Method
Routine Surveys:			
Tidal Rivers	8	Annual	Kick, Sweep, Airlift
Intertidal North Shore	8	Annual	Core
Intertidal South Shore	10	Annual	Core
Subtidal	14	Annual	Day Grab
Special Surveys:			
Subtidal Grid	75	5 yearly	Day Grab
Intertidal Upper Estuary	44	1990 only	Core

The existence of a time series of data (1981 to 1990) on benthic communities has allowed a comparison of annual changes in populations to be made. By examining variations over the monitoring period, long-term trends may be established which can be related to anthropogenic or natural events. The following account summarises the findings of these surveys and examines changes in invertebrate populations in relation to environmental quality.

6.1 Tidal rivers

The tidal rivers of the Humber system represent an environment with fluctuating salinities and tidal scouring effects which prohibit the development of rich benthic faunas. Most of the invertebrate communities of the tidal rivers were generally poor in species composition, although in certain cases the effects of pollution were undoubtedly a contributing factor.

Sampling of the tidal reaches of the rivers Don, Aire, Ouse, Wharfe and Hull for invertebrates is carried out annually. The disparate nature of the localities, in conjunction with the topography of the muddy banks and deep fast running flows, requires that a variety of sampling techniques be utilised. Historical data are available since the early eighties although in most cases there has been little change in invertebrate communities over the decade. For the purposes of this report therefore, the summarised results of the 1990 survey are examined (Table 19) in order to assess the current biological quality of the rivers, and reference to previous results is made only if appropriate. The data presented in Table 19 is semi-quantitative and the abundance scale only provides a guide to whether the fauna of a particular site is sparse or abundant.

Biological quality of the rivers Don and Aire has remained poor over the decade, with the species present indicative of organic pollution. The river Don in particular supported large densities of tubificid worms including the pollution - tolerant species *Limnodrilus hoffmeisteri* and *Tubifex tubifex*. In most other years the only other species present was the shrimp *Gammarus zaddachi*.

The fauna of the tidal Ouse is typically sparse and the species recorded are tolerant of organic pollution. A deterioration in biological quality was recently observed at Cawood with the presence of large densities of oligochaetes - indicative of gross organic pollution. This is probably related to low flows in both the Ouse and Wharfe which has allowed the tidal influence to push water of a high BOD, and suspended solids load, upstream from the Selby area.

The river Wharfe is tidal for 16km before flowing into the Ouse; prior to 1982 the most serious and long-standing pollution problem was the discharge of brewery waste upstream at Tadcaster. The introduction of a new treatment plant and improved sewage treatment has resulted in improvements in biological quality and the establishment of a diverse fauna in the tidal river.

The fauna of the tidal river Hull was also richer (especially at Beverley) than that of the Ouse, although it was still dominated by animals tolerant of organic pollution. In recent years the Sutton site has become more 'estuarine' in character with the dominance of the brackish-water oligochaete *Tubifex costatus* and the presence of two estuarine species of crustaceans, *Sphaeroma rugicauda* and *Corophium volutator*. Although relatively diverse, the fauna at Beverley has recently declined in biological quality and is now classed as moderately polluted. Low freshwater flows in the Hull in 1989 and subsequent years is probably a significant factor and may have contributed to this situation.

TABLE 19 - SUMMARY RESULTS OF SURVEYS OF HUMBER TIDAL RIVERS FAUNA, 1990

	Taxa	Ouse					Wharfe	Hull	
		Don	Aire	Cawood	Drax	Saltmarshe		SRB	Beverley
Worms	Oligochaeta	C	D	D	A	B	C	C	C
Leeches	Erpobdellidae	A					A		A
	Glossiphoniidae						B		
Molluscs	Hydrobiidae						A		A
	Neritidae						A		
	Sphaeriidae								B
Crustaceans	Aslllidae		A					A	A
	Janiridae							A	
	Sphaeromatidae							A	
	Corophiidae							B	C
	Gammaridae	C	A			A	C		
Springtails	Collembola							A	
Mayflies	Caeniidae						A		
	Heptageniidae						A		
Beetles	Elmidae						A		
	Haliplidae						A		
Waterbugs	Corixidae								A
Caddisflies	Brachycentridae						A		
Flies/Midges	Tipulidae						A		
	Chironomidae						B	A	B

(SRB = Sutton Road Bridge)

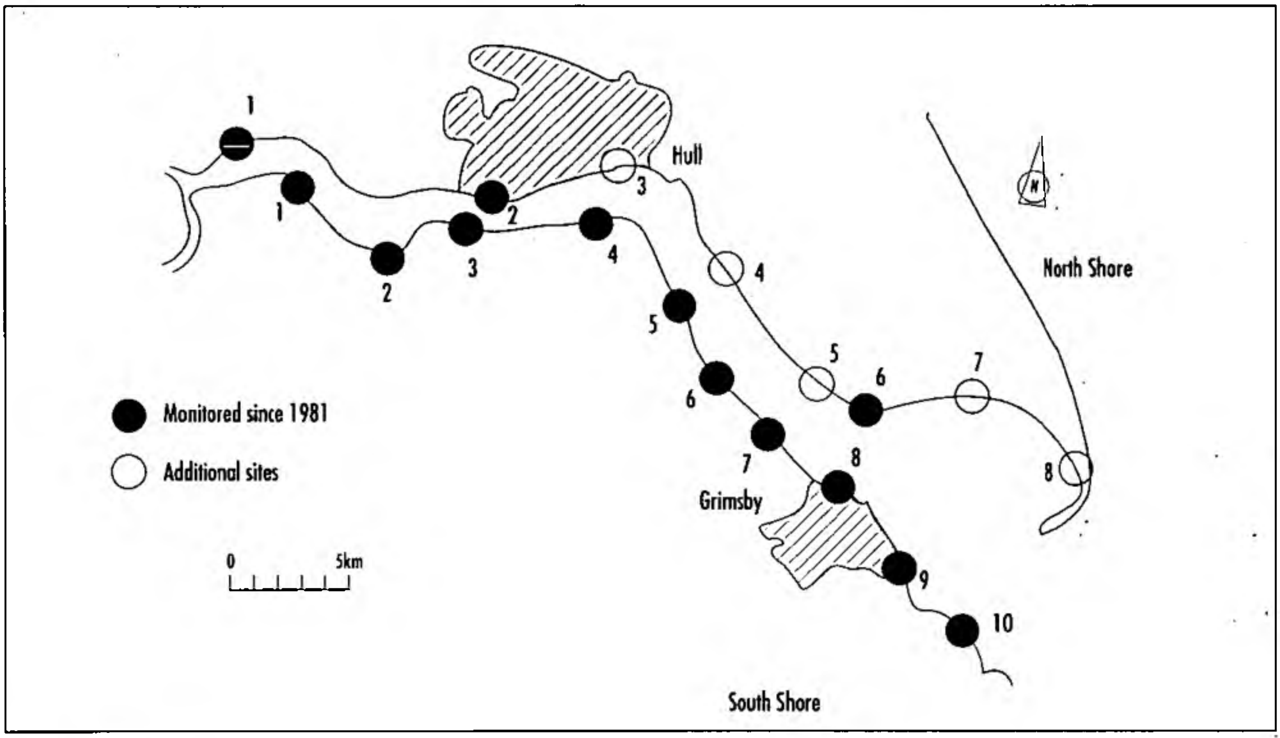
ABUNDANCE SCALE = A 1 - 9 B 10 - 99 C 100 - 999 D 1000 - 9999 (see text for explanation)

6.2 Intertidal monitoring

Approximately one-third of the estuary is exposed at low water providing extensive intertidal habitats which are very important for birds. This is of particular interest in terms of environmental quality, as many major discharges have been located at or above low water with effluents dispersed over the intertidal flats.

In order to assess the changes in invertebrate populations over the decade, the basic community parameters of abundance and species variety are examined for mid shore locations only. Low shore data are only included for specific sites if appropriate. Data from all historical sites (Fig. 18) is pooled for each year to provide an 'overall' view of temporal changes in the estuary. Results from the north and south shores are presented and discussed separately due to differences in the sampling and processing techniques employed.

FIGURE 18: LOCATION OF INTERTIDAL SAMPLING SITES IN THE HUMBER ESTUARY

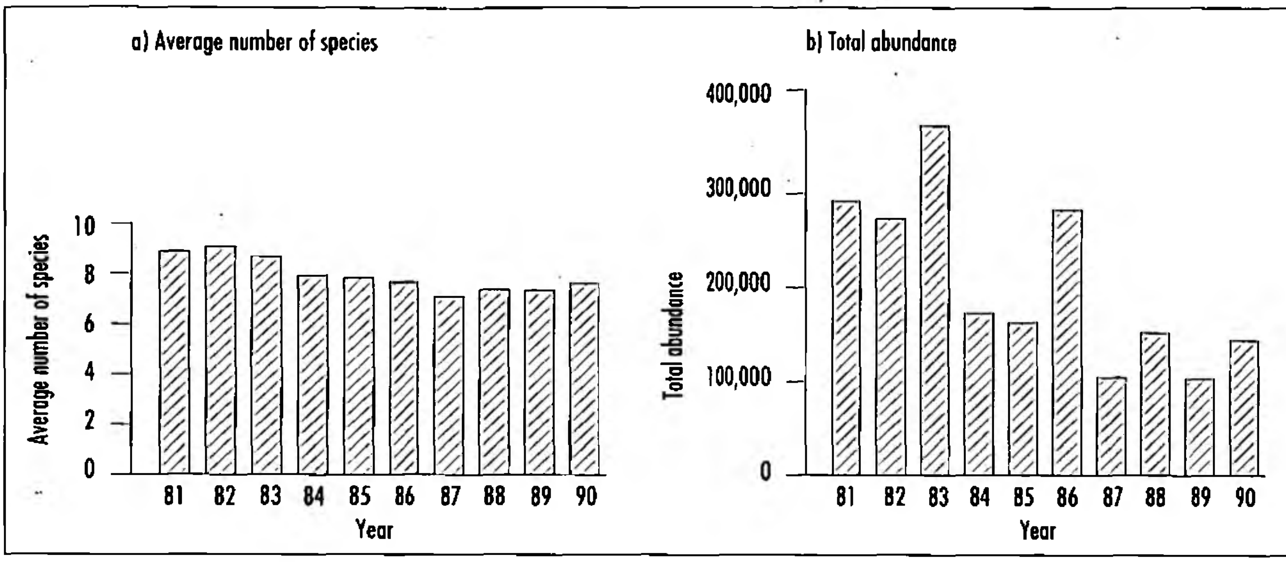


a) **South shore**

The basic community data are portrayed graphically in Figures 19a and 19b. Total abundance represents the combined number of individuals per square metre from the ten sites. The average number of species has been relatively stable with a comparable species variety recorded each year. This is in contrast to the large differences in abundance levels over the monitoring period. High abundances were apparent between 1981 and 1983, but since then the total number of individuals has declined and consistently lower levels (with the exception only of 1986) have been recorded.

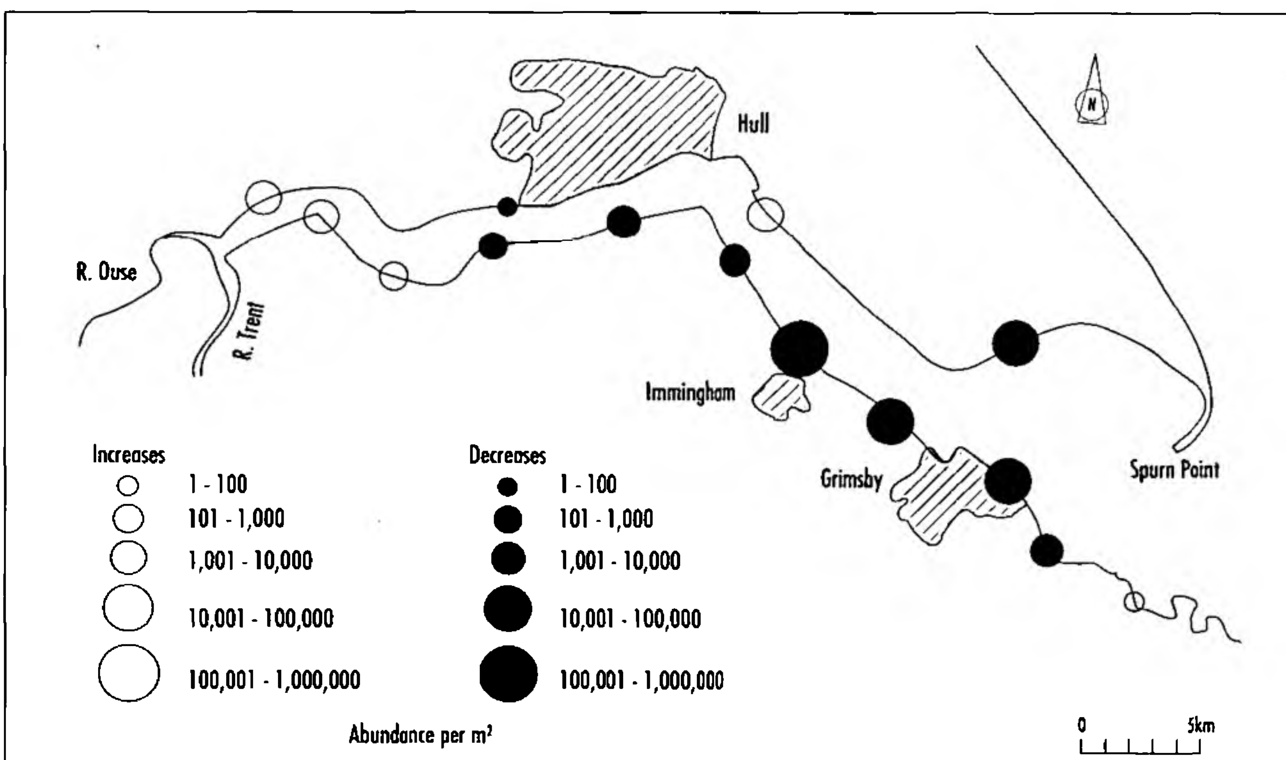
The initial decline in abundance in 1984 may have been related to the effects of the Sivand oil spill in September 1983, when 6,000 tonnes of crude oil were released into the Humber at Immingham resulting in substantial oiling of the intertidal habitat. A comparison of pre and post oil spill surveys, including north bank data, (Figure 20), shows that dramatic reductions in invertebrate populations were observed in areas close to the incident. Changes were greatest at the site immediately adjacent to Immingham where, in addition to large decreases in faunal abundance, several major species disappeared.

FIGURE 19 (a) AND (b): SOUTH HUMBER SHORE INTERTIDAL FAUNA



However, an assessment of long-term trends at individual sites suggested that populations recovered quickly and apart from the site closest to Immingham, the changes observed elsewhere were within the scale of normal year-to-year variations. The lower abundances recorded in later years were mainly attributable to changes in community structure at sites in the lower estuary. This region is most affected by urbanisation with discharges of both industrial and domestic effluents at numerous points. Evidence from past intertidal surveys shows that the fauna of the lower estuary has been modified by these inputs, with the presence of large densities of pollution tolerant organisms indicative of organic enrichment (Barnett, 1984). During the decade there have been several improvements in effluent disposal in this area, including the relocation and diversion of discharges to

FIGURE 20: CHANGES IN TOTAL ABUNDANCE AT INTERTIDAL SITES IN THE HUMBER ESTUARY FOLLOWING THE SIVAND OIL SPILL



the deep water channel via long-sea outfalls. The differences in invertebrate populations observed over the monitoring period at nearby sites may reflect the reduction in polluting load to the intertidal zone. In particular, the site adjacent to Grimsby represents an area which is most likely to have benefited from improvements to the Grimsby sewerage scheme following closure of the nearby intertidal outfall in November 1986. Concomitant with the diversion of sewage to the long sea outfall, the total number of individuals declined dramatically at this site. A close inspection of population changes in individual species, (*Capitella capitata, Tubificoides benedeni* and *Nereis diversicolor*) at both mid and low shore locations illustrates the changes which have occurred (Figure 21). All three species have been described as pollution tolerant (Pearson and Rosenberg, 1978 and Barnett, 1983) and prior to 1987 were present in considerable densities. Their decline in recent years and in some cases their actual disappearance, is consistent with a decrease in organic enrichment following the closure of the sewage outfall. Indeed it would appear that most of the lower estuary is benefiting from a decrease in sewage pollution following improvements to the disposal of Grimsby sewage. As noted previously, the presence of high densities of *C. capitata* at lower estuary sites (6 to 8) since 1981 has been linked to organic inputs from local sewage discharges. In recent surveys the abundance and distribution of *C. capitata* has considerably reduced (Figure 22) suggesting a general reduction in organic enrichment throughout the area.

The re-occurrence of the amphipod *Corophium volutator* on south (and north) shores is of particular interest. This common estuarine invertebrate is an important component of the food chain, in particular as a prey species for wading birds such as redshank. Prior to 1981, *Corphium volutator* was distributed throughout the estuary attaining maximum densities in the middle reaches. Its subsequent disappearance in 1982 initially caused concern, but population crashes have been observed elsewhere in non-industrialised estuaries for example Conway, and were considered natural phenomena related to severe winter conditions (P Allen, personal communications). It therefore seems unlikely that the population crash can be attributed to pollution, particularly because *Corophium volutator* reappeared in the Humber in 1988. Observations from recent surveys would indicate that populations have recovered rapidly and are achieving previous densities.

The major change over the decade on the south shore is the decline in pollution tolerant organisms in the Grimsby area, which previously supported large populations. The fauna of other areas has changed relatively little and most differences can be attributed to natural variation. Generally, differences have been greatest in the lower estuary where the invertebrate fauna are now showing improvements as a result of a reduction in organic enrichment due to changes in effluent disposal.

FIGURE 21: CHANGES IN THE ABUNDANCE OF THREE POLLUTION TOLERANT SPECIES AT A SITE ADJACENT TO GRIMSBY IN THE HUMBER ESTUARY

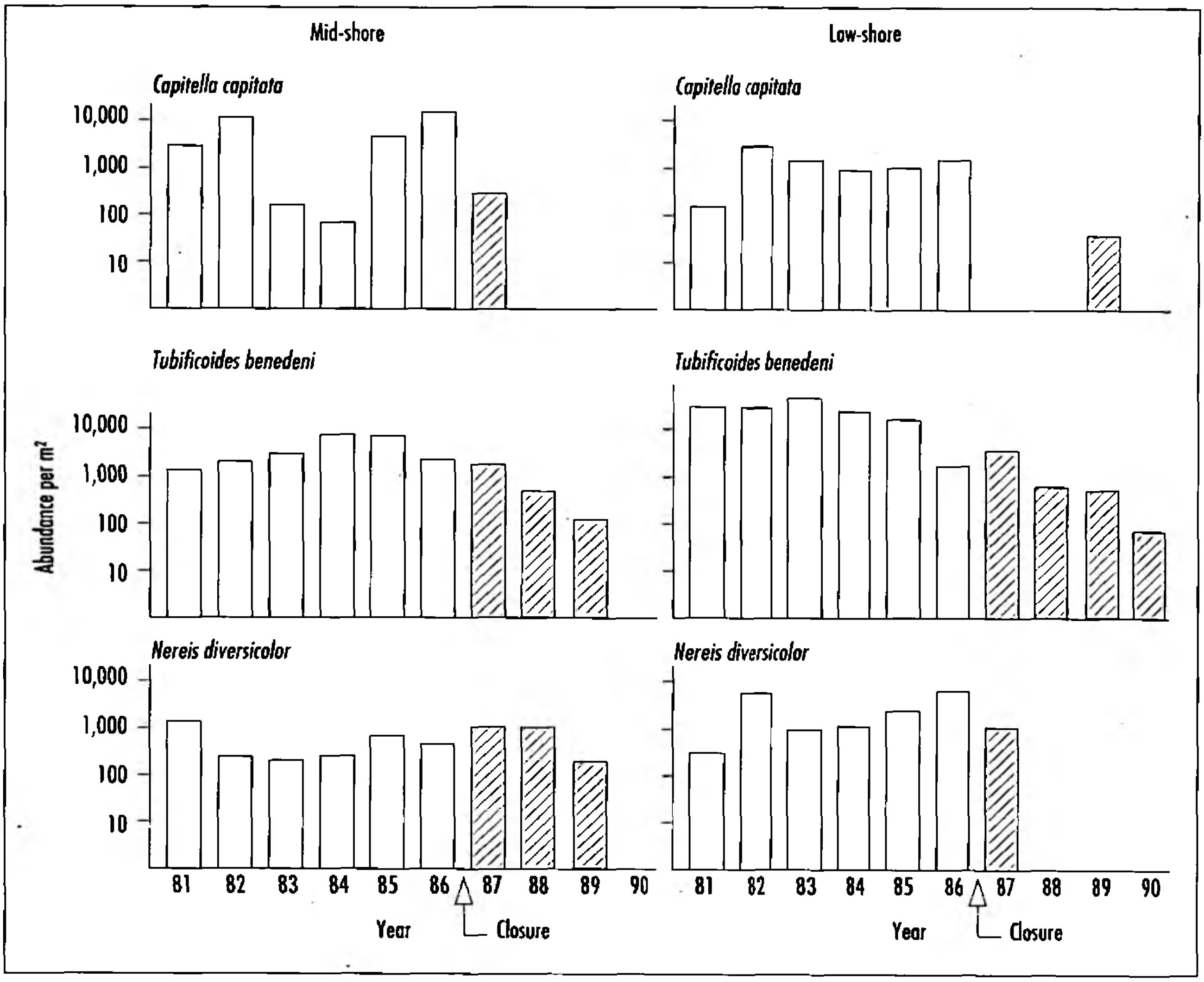
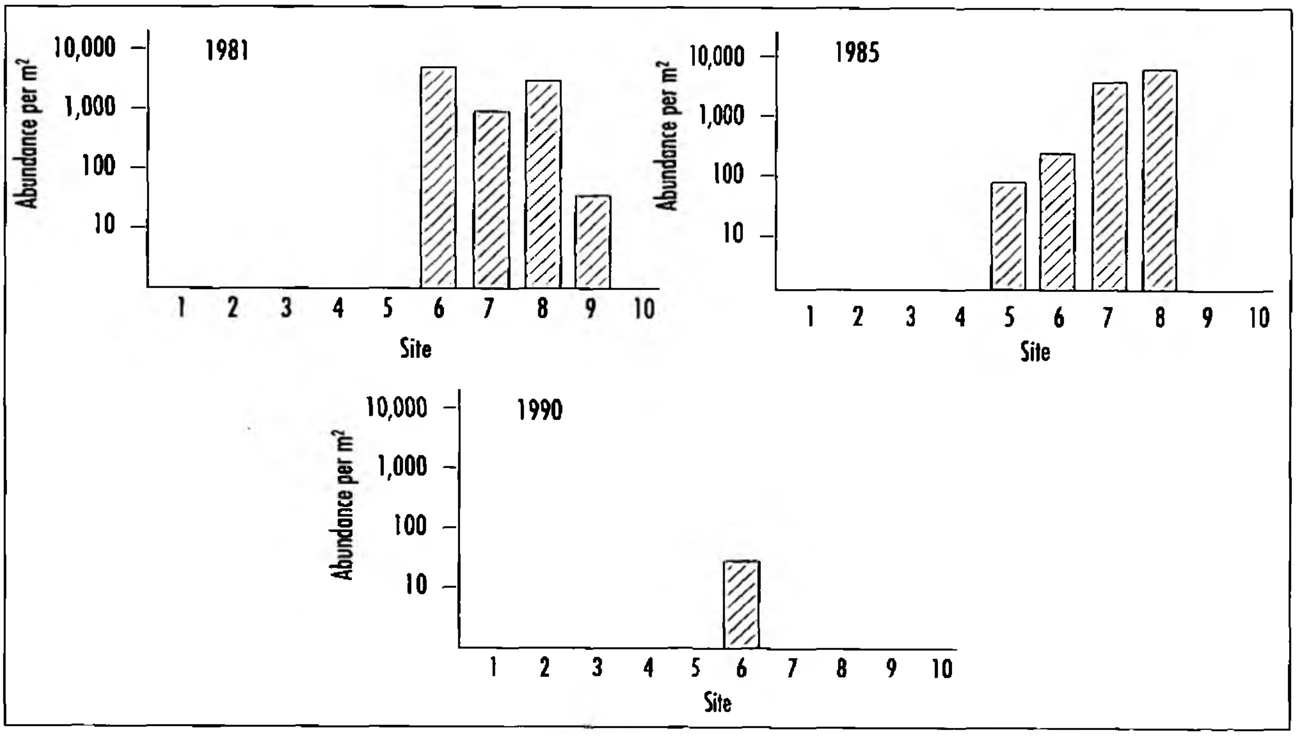


FIGURE 22: DISTRIBUTION AND ABUNDANCE OF *Capitella capitata* ON THE SOUTH SHORE OF THE HUMBER ESTUARY



b) **North shore**

Historical data for the north bank are limited and only available for three sites, but the addition of five sites in recent years has considerably improved coverage and provides useful information on sensitive areas in the estuary. However, in order to assess temporal changes, species variety and abundance were examined at those sites which have been monitored throughout the decade. Total abundance figures were derived by combining the abundance per square metre at the three historical sites. As on the south shore, species variety has not altered appreciably, as can be seen in Figure 23a, (the relatively low numbers recorded reflect the small number of sample points). In contrast abundance levels (Figure 23b) have fluctuated more widely over the decade with a decline in recent years, but this variation can be attributed solely to population changes at one site, which characteristically supports large densities of animals and is not an indication of trends at other sites in the estuary.

FIGURE 23: NORTH HUMBER SHORE INTERTIDAL FAUNA

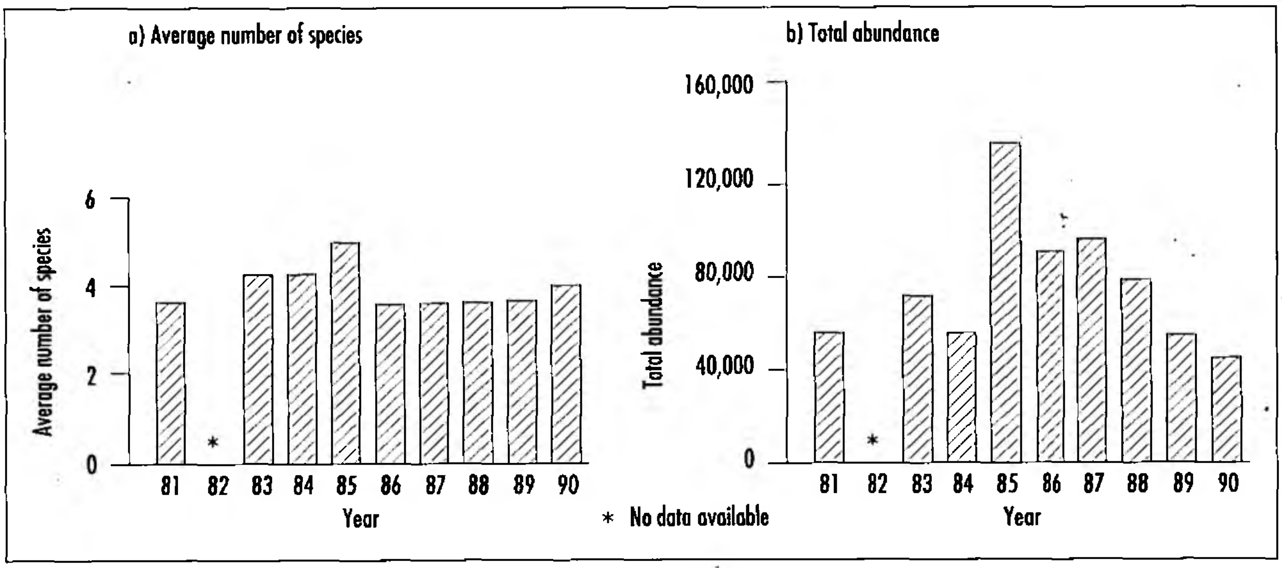
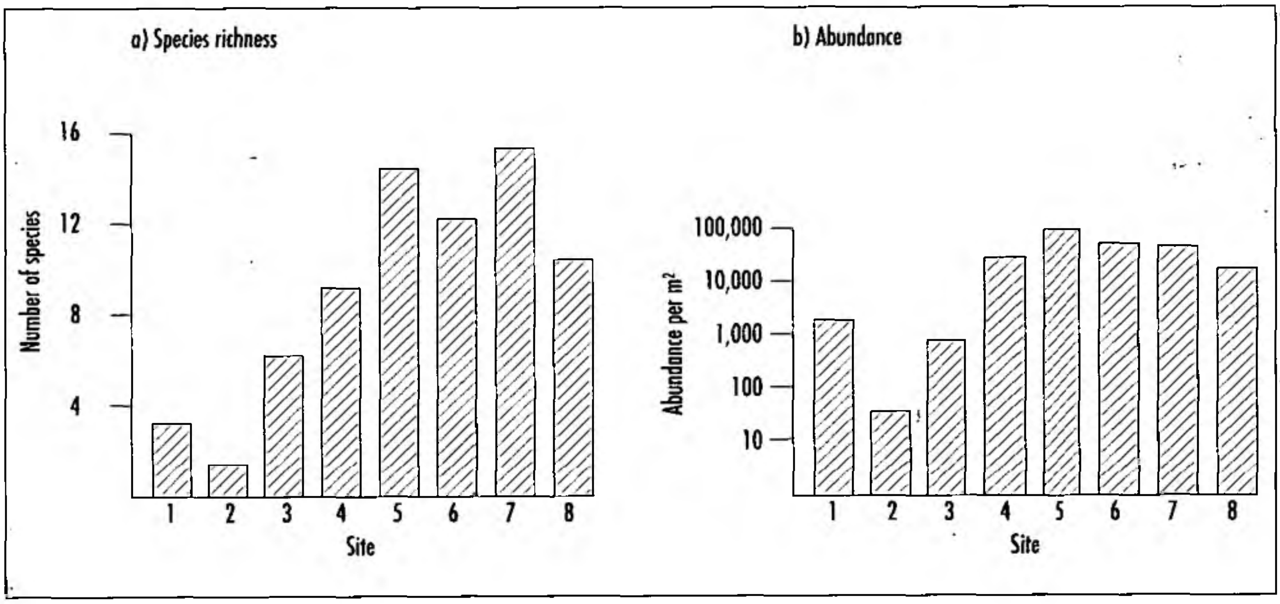


FIGURE 24: 1990 NORTH HUMBER BANK SURVEY RESULTS



In contrast to the south shore there are no regions of heavy industrialisation on the north side and the majority of discharges are of domestic origin. The highly productive sites of the middle estuary (4, 5 and 6) (Figure 24), probably exhibit the effects of slight organic enrichment from these sewage discharges. The dominant organism at all of the sites in 1990 was the pollution-tolerant species *Tubificoides benedeni*. However, the absence of the opportunist polychaete *Capitella capitata*, associated with organic enrichment elsewhere in the estuary, is surprising; the reason for this is unclear. A decrease in *Tubificoides benedeni* populations in recent years, and the absence of *Capitella capitata* would indicate that the middle estuary is only subject to slight organic enrichment.

In general, the community structure was similar throughout the monitoring period. The lack of any noticeable change would suggest that environmental conditions along the north shore have remained relatively stable. This consistency, in contrast to the south shore, probably reflects the differences in industrialisation and the fact that several major discharges to the south bank have undergone significant changes within the decade. The overall pattern on the north bank of species-poor inner estuary sites and good quality outer estuary fauna has not altered appreciably over the years.

c) Upper estuary mudflats

Over two-thirds of the upper estuary (Humber Bridge to Trent Falls) consists of extensive intertidal areas exposed at low water. This area has been designated as a Site of Special Scientific Interest (SSSI) because it supports large populations of over-wintering wildfowl and waders such as shelduck, teal, dunlin, redshank and curlew. In addition to the conservation interest there are water quality problems with concern over the depletion of dissolved oxygen in the vicinity of Trent Falls during the summer months.

Few studies have been carried out on this part of the estuary due to problems of accessibility; information on the resident invertebrates which support these large densities of birds is thus sparse. A special survey of the area was undertaken in 1990 in conjunction with the Nature Conservancy Council (now English Nature) which concentrated on previously identified bird feeding areas. Samples were collected from within the eight major feeding areas (Figure 25). Species variety was, as anticipated, relatively low; this region represents a harsh environment with low and fluctuating salinities, which only a few brackish-water species can tolerate.

The fauna principally consisted of oligochaetes, the naidid *Paranais litoralis* and the tubificid *Tubifex costatus,* both species commonly found in the upper reaches of estuaries. Other major species included two polychaetes *Nereis diversicolor* and *Streblospio shrubsolii* and the amphiphod *Corophium volutator* which has only recently recolonised areas of the estuary.

Invertebrate populations were generally greatest in the mid to upper tidal zone, which in the upper estuary constitutes a more stable habitat than the low shore which is affected by scouring and erosion from strong tidal currents. Highest invertebrate densities were recorded from Brough and South Ferriby flats, with average densities of 22,000 per m^2 and 17,000 per m^2 respectively, (Figure 26). Both of these mudflats are important feeding grounds for birds, with Brough in particular supporting large numbers of shelduck. Despite water quality problems during summer months, it would appear that the upper estuary clearly supports substantial invertebrate populations. Indeed these intertidal mudflats are productive areas providing important feeding grounds for wildfowl and waders.

6.3 Subtidal fauna

The subtidal habitat is characterised by mobile channel systems and fringing shoals. In addition to salinity stress, tidal effects are substantial. Strong tidal currents associated with the channel regime produce a scouring effect that has significant implications for the benthos. These effects are less severe in the relatively sheltered marginal habitats. As noted previously, most effluents are discharged to the

FIGURE 25: INTERTIDAL FEEDING AREAS FOR WILDFOWL AND WADERS, IN THE UPPER HUMBER ESTUARY

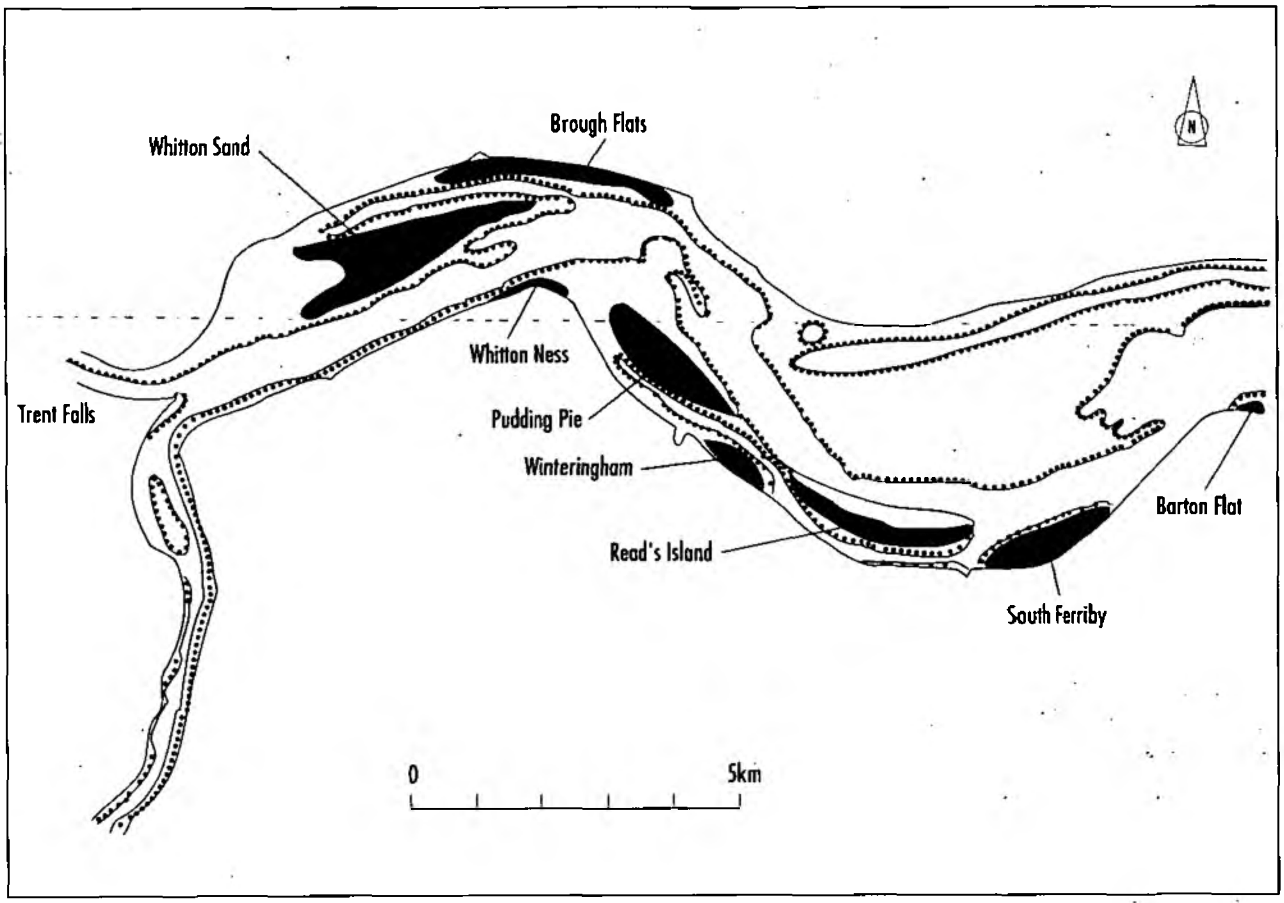
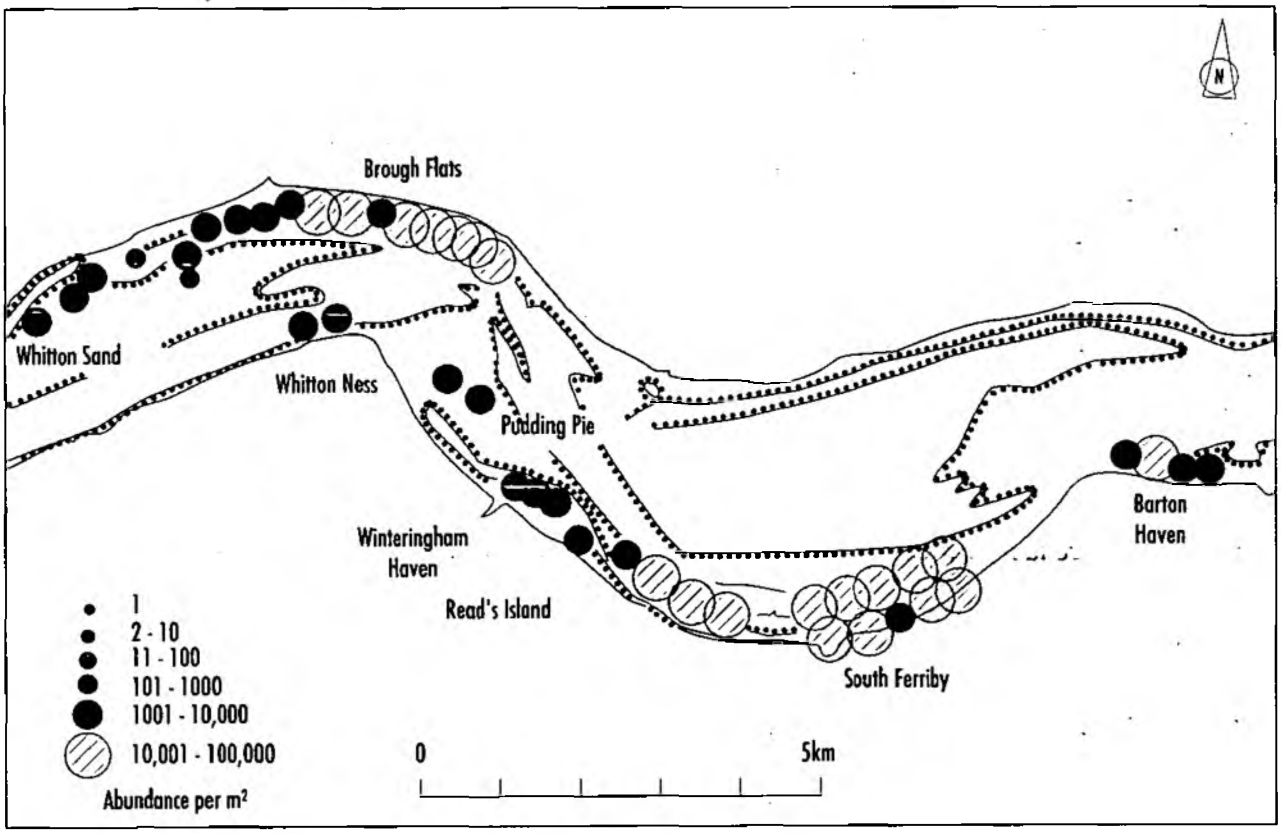


FIGURE 26: TOTAL NUMBER OF INDIVIDUALS IN THE UPPER HUMBER ESTUARY



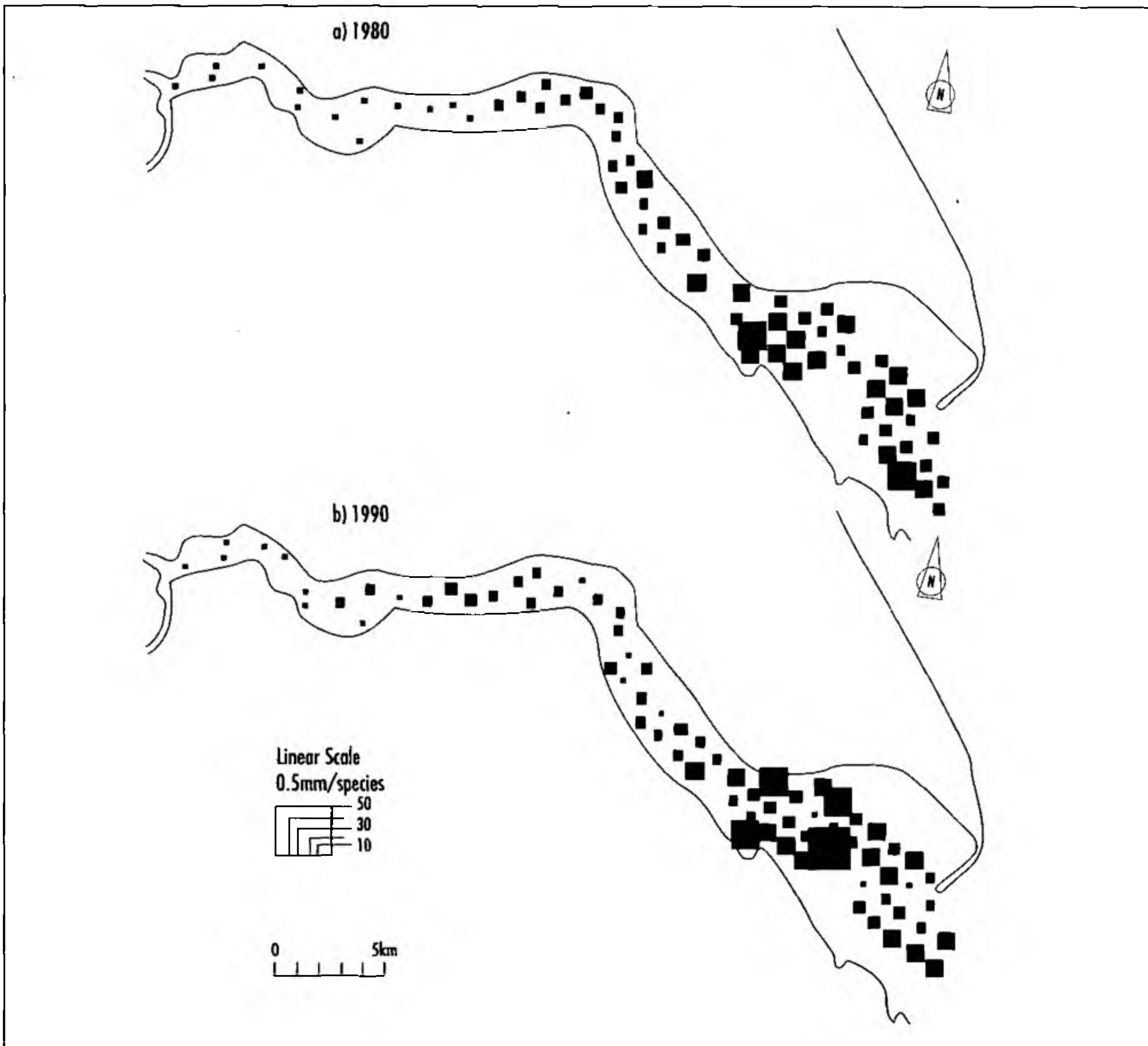
intertidal zone - although in recent years alterations to various sewerage schemes, and the relocation of some industrial outfalls, has resulted in an increase in the number of discharges beyond the low water mark.

Monitoring of the subtidal habitat comprises both routine annual sampling and more extensive investigations (grid surveys) conducted on a five-yearly basis; the most recent survey was undertaken in 1990. These examinations have proved extremely useful as a supplement to the annual monitoring programme, by providing increased geographical coverage, such that general areas of impact from industrial and domestic discharges can be identified. In order to assess current environmental conditions the results from the most recent grid survey (1990) are compared with the 1980 grid survey. Attention is focused on general changes in community structure and the implications of these changes on water quality assessments.

a) Distribution patterns

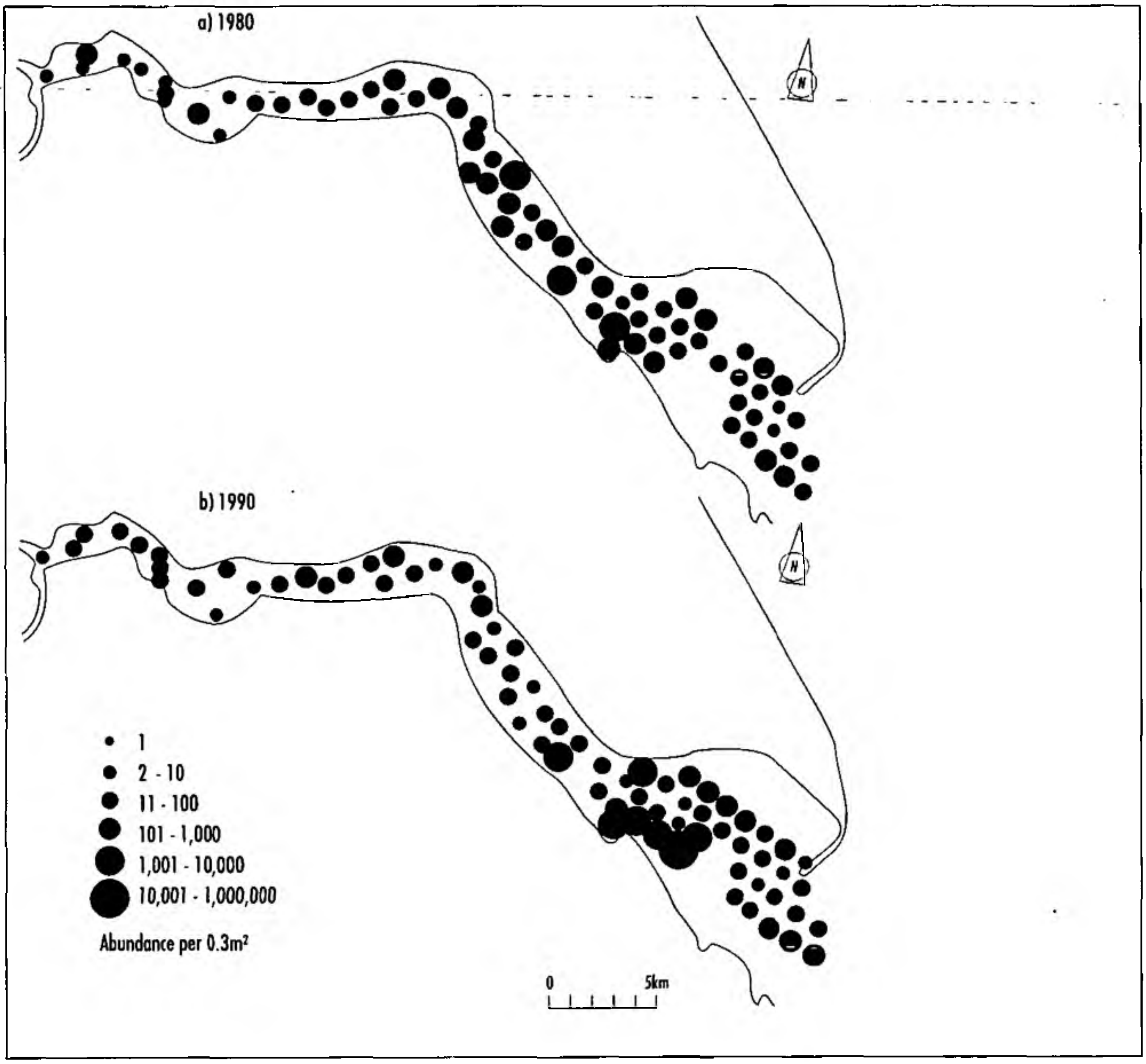
Patterns were broadly comparable over the decade with species variety conforming to the expected pattern and increasing along the salinity gradient of the estuary (Figure 27).

FIGURE 27: SPECIES VARIETY IN THE HUMBER ESTUARY



A small increase in the number of species was evident at certain sites in the lower and outer estuary, an area that historically supports the greatest variety of species. Similar areas of high abundance (Figure 28) were found around Hull, Grimsby and within Spurn Bight, although the number of individuals has increased substantially along the peripheral margins of the lower estuary adjacent to Grimsby.

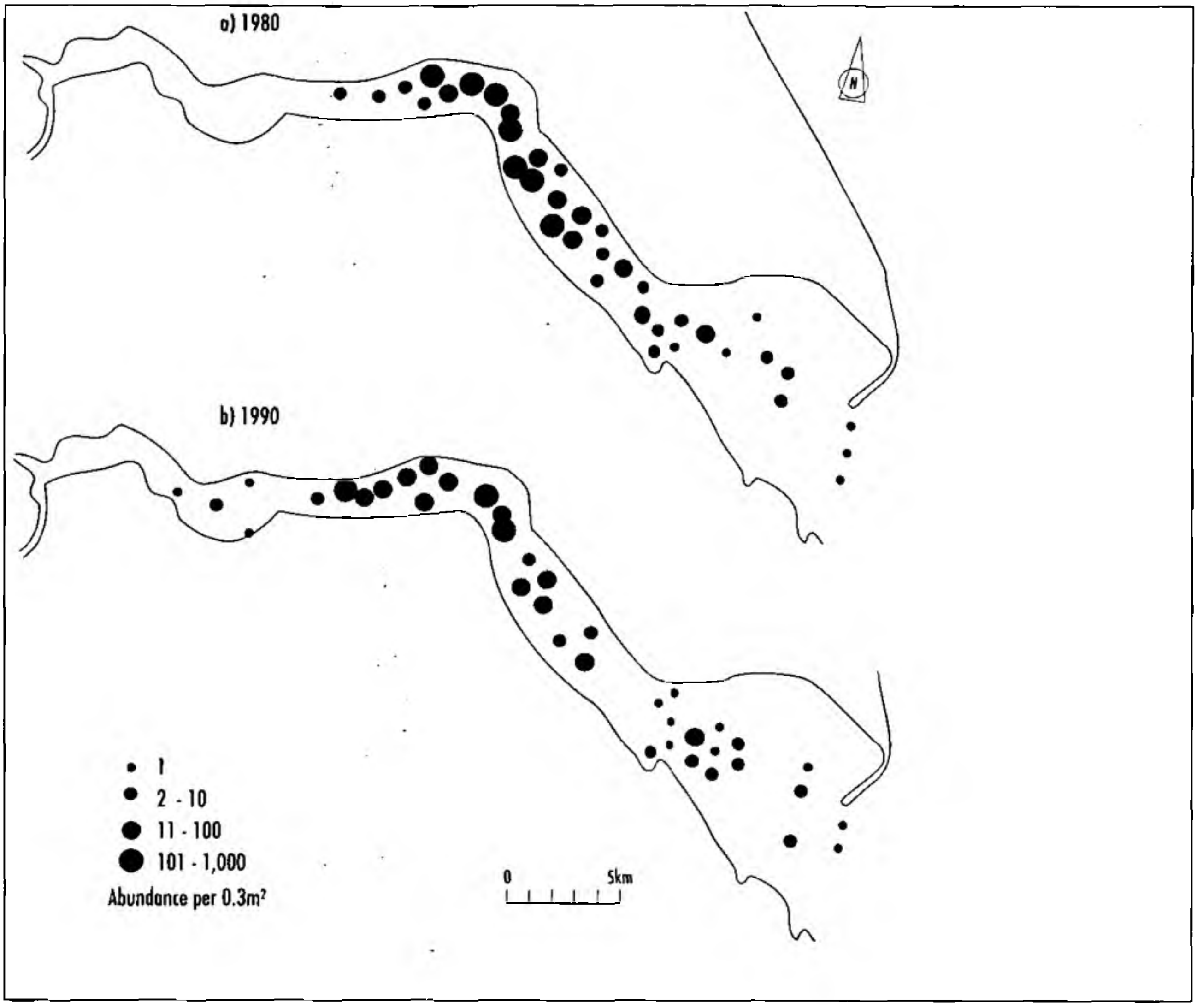
FIGURE 28: TOTAL NUMBER OF INDIVIDUALS IN THE HUMBER ESTUARY



This area is colonised by a certain species of the polychaete *Polydora*. Some species belonging to this genus are known to exhibit dramatic natural population changes from year to year. The enhanced populations of the middle estuary (observed both in 1980 and 1990) were due to the dominance of the opportunistic polychaete *Capitella capitata*. The distribution of this species in 1990 was similar to the pattern identified in the 1980 survey (Figure 29) and closely relates to channel configurations.

Because the channel system provides the likely transport pathway for Hull sewage, it is probable that the proliferation of *Capitella capitata* in the middle estuary is the result of organic enrichment. The distribution patterns of faecal bacteria in 1990 indicated that there was extensive sewage contamination in the vicinity of Hull. Indeed the consistency of the capitellid distribution would indicate that enrichment has been a persistent problem in the middle estuary. The distribution of *Capitella capitata* was more widespread in 1990, extending upstream of Hull towards Read's Island.

FIGURE 29: DISTRIBUTION OF *Capitella capitata* IN THE HUMBER ESTUARY



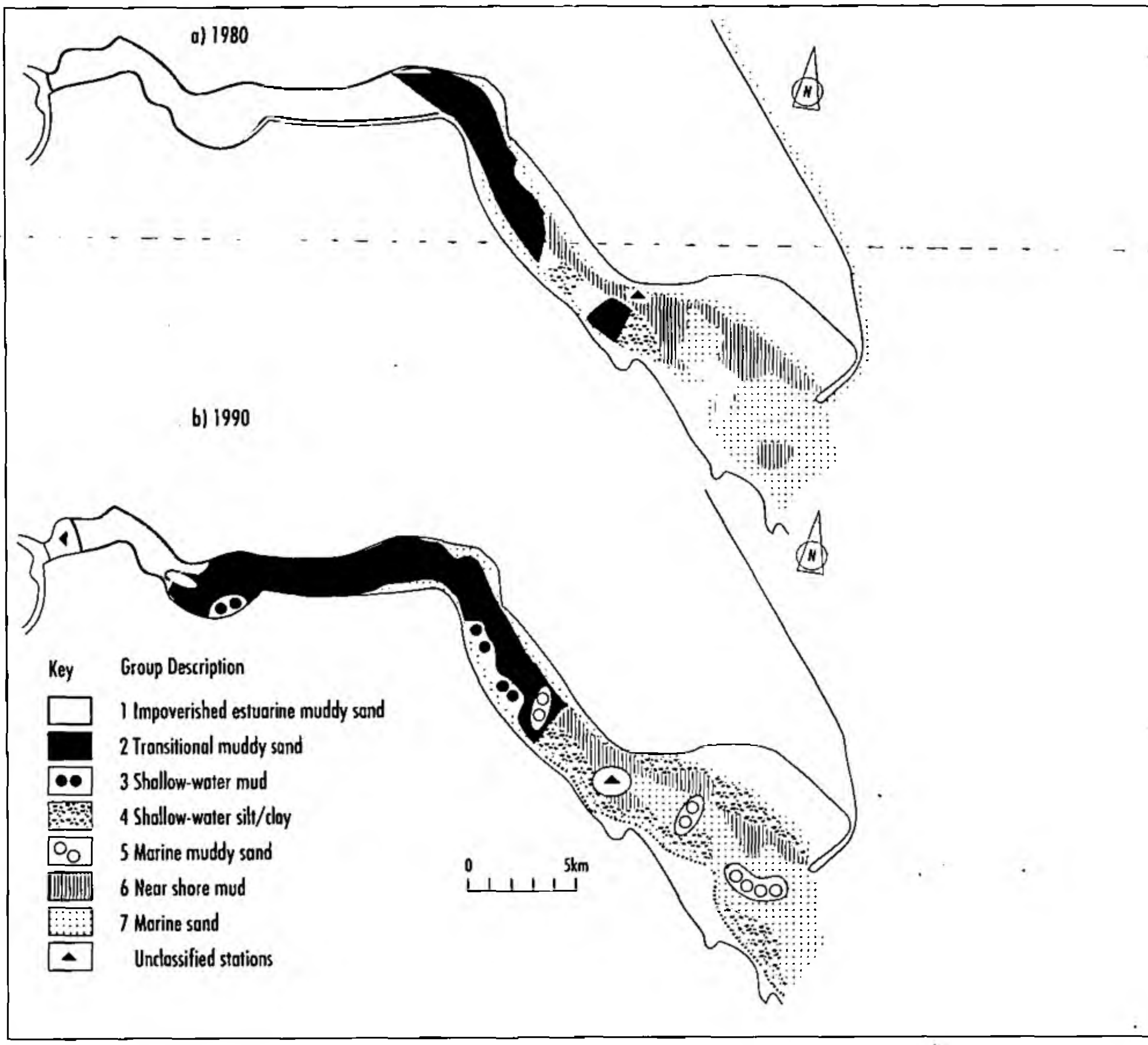
Although this may therefore suggest an increase in the influence of Hull sewage, it may also be related to an increase in salinity in the upper estuary due to reduced freshwater flows.

b) Faunal associations

A comparison of the major faunal communities identified in the estuary is shown in Figure 30. The fauna of the 1990 survey were classified into the same five major associations identified in 1980 and details of these are summarised in the insert table accompanying the diagram. Patterns were broadly comparable, with only small differences being noted in the extent of the communities and the identification of two additional small associations in 1990.

The upper estuary association (group 1) has reduced noticeably in size and now only encompasses the area between Trent Falls and Read's Island. The fauna of this area remain typically impoverished probably due to the physical rigours of low and fluctuating salinities and strong tidal currents. In both 1980 and 1990, mobile epibenthic species predominated, including the mysid *Neomysis integer* and species of the amphipod *Gammarus*. Most of the sites of the middle estuary fell within group 2. The high abundance and dominance of *Capitella capitata*, coupled with reduced species variety, indicated the continued response of the fauna to organic inputs. This association extended into the upper estuary in 1990, perhaps reflecting an increase in faecal contamination from Hull sewage - although increased salinity linked to reduced freshwater flows may also have been a factor. The

FIGURE 30: FAUNAL ASSOCIATIONS IN THE HUMBER ESTUARY



marginal habitats of the lower estuary represent some of the most productive areas of the Humber. These regions are generally more sheltered and are characterised by a rich mud fauna.

Two communities were identified (groups 4 and 6) in both 1980 and 1990 and the differences between the associations may relate to sediment characteristics. Increased populations and slightly elevated numbers of species in 1990 within association 4 may indicate beneficial enrichment due to local sewage discharges. In contrast, the fauna of the outer estuary (group 7) continue to consist of low numbers of species and individuals, probably as a consequence of the effects of tidal scour.

6.4 Discussion

The 1991 report on the Quality of Rivers, Canals and Estuaries in England and Wales by the National Rivers Authority has shown that environmental conditions over the decade have changed relatively little, with the Humber remaining a 'fair' to 'good' category of estuary. The stretch corresponding to fair quality is the upper estuary where low dissolved oxygen levels can be a problem in summer months, and along the industrialised south bank as far as Grimsby. The most significant pollution is found in the tidal tributaries, with most maintaining a poor water quality status. Improvements in trade and sewage discharges from Tadcaster have produced a corresponding improvement in the biological quality of the Wharfe. Of the remaining tidal rivers the fauna of the Don and Aire are still severely affected by polluted waters entering the system further upstream. Schemes for effluent and sewage treatment works are now in progress which will benefit the quality of these rivers. The Ouse and Hull tidal tributaries also receive sewage discharges, although the River Hull is able to support a reasonably diverse fauna and is classed in the fair category.

Within the estuary, even though there is no evidence of serious pollution, there are localised areas of concern. The effects of pollution were still apparent in the middle estuary where subtidal sediments continued to exhibit organic enrichment associated with crude sewage discharges from Hull. The presence of large densities of pollution-tolerant species on the south Humber bank have in the past been linked to local sewage discharges. Changes in the disposal of Grimsby sewage have resulted in a reduction in organic enrichment and the invertebrate fauna are now showing evidence of improvements.

Biological monitoring over the decade has provided a useful means of assessing changes with respect to environmental quality. Although there is evidence of improvements within the system in general, conditions have remained relatively stable. The Humber continues to be a very productive estuary supporting substantial invertebrate populations, and its international importance is recognised by the designation of large areas as Sites of Special Scientific Interest. Future scheduled changes in effluent control in both the Humber and tidal tributaries will substantially improve the quality within the next two or three years.

7. BIOACCUMULATION

The use of biological material to assess metal contamination has several advantages over the traditional methods of water and sediment analysis because it can provide an integrated assessment of conditions over a period of time. Different organisms absorb metals, by various pathways. Most monitoring programmes therefore utilise a combination of indicator species which also helps to ensure adequate coverage of an area because it is unlikely that all species will be present at all sites.

In the Humber, the seaweed *Fucus vesiculosus* has been used as part of a programme on both north and south shores to monitor heavy metals since 1981. Sampling is conducted in February/March and August/September. Fucoid algae have proved very effective as indicators and integrators of contamination of estuarine waters, and are monitors of nickel, cadmium, zinc and copper. In addition, the ragworm, (*Nereis diversicolor*) has also been included in the programme as an indicator of sediment-available metals. It is particularly useful due to its wider distribution and occurrence in the low salinity regions of the estuary, an area from which most other potential indicators are excluded. The metals accumulated by *Nereis diversicolor* include copper and mercury.

Subtidally there are few species present in sufficient numbers to be suitable as indicator organisms. Some fish tissues are of limited suitability, because the concentrations in them are maintained relatively constant irrespective of ambient concentrations. However, since 1984, two species of flatfish, the flounder (*Platichthys flesus*) and dover sole (*Solea solea*), have been used, and the inclusion of the brown shrimp (*Crangon crangon*) in 1985 provide additional important information on the likely availability of contaminants to human consumers.

In the case of *Fucus vesiculosus* and *Nereis diversicolor*, long-term 'site-averaged' trends were examined for north and south shores separately and where appropriate temporal trends at individual sites were considered. Neither the *Fucus vesiculosus* nor *Nereis diversicolor* monitoring programmes were designed for statistical analysis and in most cases there was insufficient data to allow a proper statistical examination. A comparison of heavy metal levels in *Fucus vesiculosus* from the different shores is not appropriate, due to methodological and analytical differences. Fish data were pooled to provide an estuarine average for each year, and metal levels were then compared with data from other UK areas.

7.1 Heavy metal levels in seaweed (*Fucus vesiculosus*)

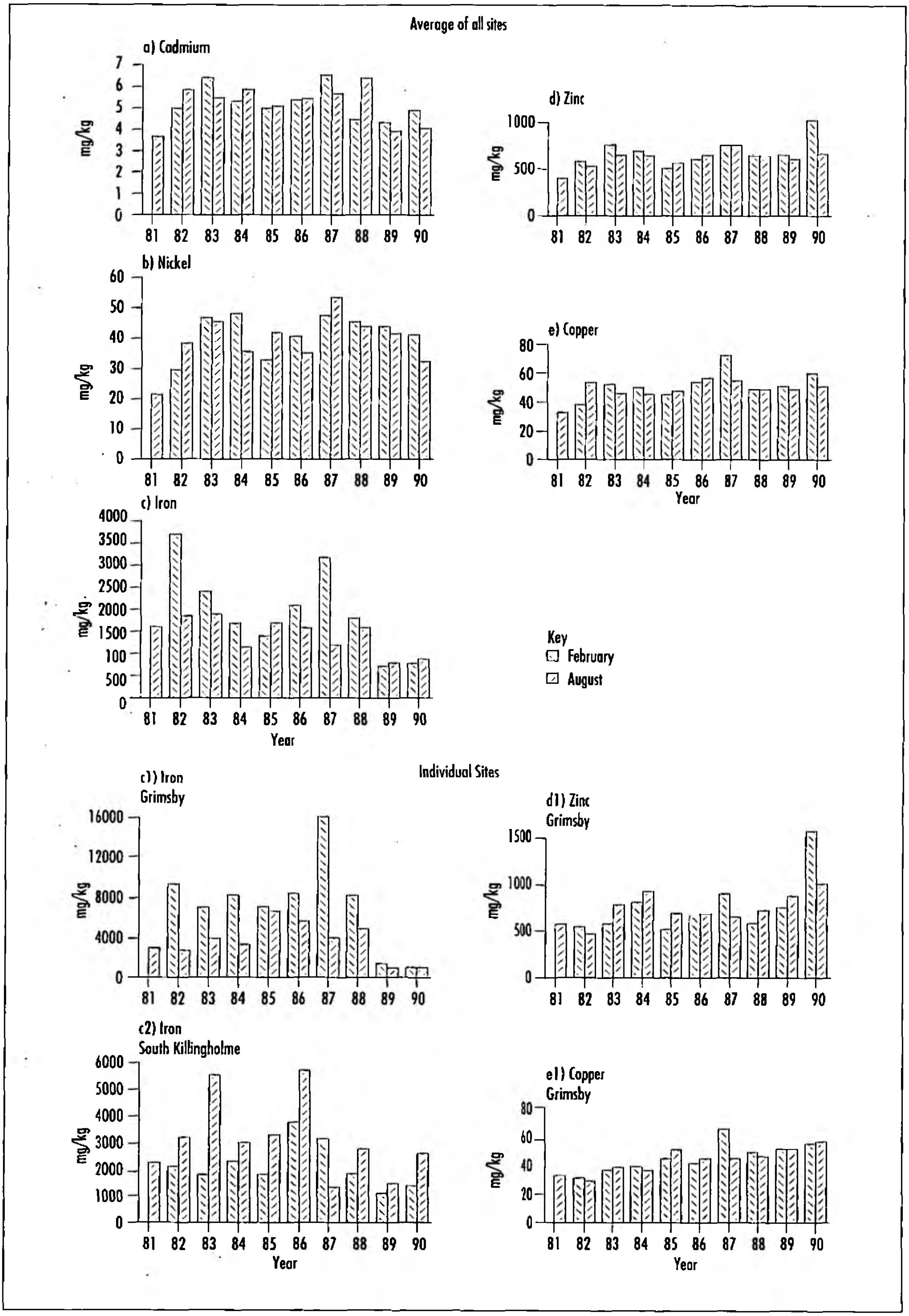
a) South shore

There is no clear pattern in cadmium levels (Figure 31a); but, although a clear downwards trend cannot yet be confirmed, recent results are encouraging.

Examination of the site-averaged long-term trend for nickel (Figure 31b) suggests that levels have been relatively stable in recent years. There are no known major inputs of nickel to the estuary and the main source is thought to be the tidal rivers. The low value recorded in 1990 may reflect lower freshwater flows with correspondingly reduced input of nickel from the tidal rivers. However, this would not necessarily result in a reduction in the total load entering the estuary.

The major input of dissolved iron to the estuary is from the two titanium dioxide factories situated at Grimsby and Immingham. The average concentration of iron (Figure 31c) has been consistently lower since August 1988 when the two new outfalls were commissioned. Inspection of the trends at the two most contaminated sites (Figures 31c, 1 and 2) provides a good explanation for the overall trends. Levels of iron have been dramatically reduced at the Grimsby site, reflecting the relocation of one of the discharges to a position well offshore of the old outfall. Visual examination of the foreshore at Grimsby, which previously was heavily stained by ferric deposits, shows a reduction in iron-

FIGURE 31: LEVELS OF HEAVY METAL IN SEAWEED *(Fucus vesiculosus)* - SOUTH HUMBER SHORE



staining concomitant with the commissioning of the new outfall. Iron levels have also decreased at the other contaminated site (South Killingholme) although the reduction in iron concentration is much less evident, presumably because the outfall was only moved a relatively short distance offshore. The most recent results indicate a return to iron levels broadly comparable with historical values. It is not known whether this relates to ineffective effluent dispersion from the new outfall or from an increase in manufacturing output. The peak in iron concentrations now occurs at this site whereas previously it occurred at Grimsby.

Levels of zinc (Figure 31d) have generally remained stable since 1988 apart from a very marked increase throughout the estuary in February 1990 which cannot be readily explained. The highest levels are consistently recorded at Grimsby.

Copper levels - particularly in recent surveys - have also generally been reasonably consistent, although as with zinc the February 1990 concentration was discernibly higher (Figure 31e). Examination of trends at a lower estuary site, however, shows that levels of copper have risen gradually there over the last 5 or 6 surveys (Figure 31e, 1).

b) **North shore**

As for the south shore, site-averaged trends for cadmium, copper, zinc and nickel have been examined (Figure 32), plus arsenic because of the significant discharge of this metal to the upper estuary from the Capper Pass smelting works at North Ferriby. This smelter was the major industrial discharge on the north bank.

No clear pattern is evident from an examination of the temporal trend for cadmium (Figure 32a) although levels in most recent surveys have declined. The major input of cadmium on the north bank was from the non-ferrous smelter at Capper Pass and this decline in concentration may reflect the cutback in production prior to closure. Decreases in the cadmium load to the estuary resulting from changed processes have been implemented since 1988 and further reductions in cadmium concentrations are expected following the installation of cadmium recovery plants in 1989. There is no *Fucus vesiculosus* sampling point close to the outfall (due to salinity restriction of the seaweed's distribution) but the nearest site to the discharge has historically yielded the highest cadmium concentrations. Particularly low levels were observed at this site in 1990.

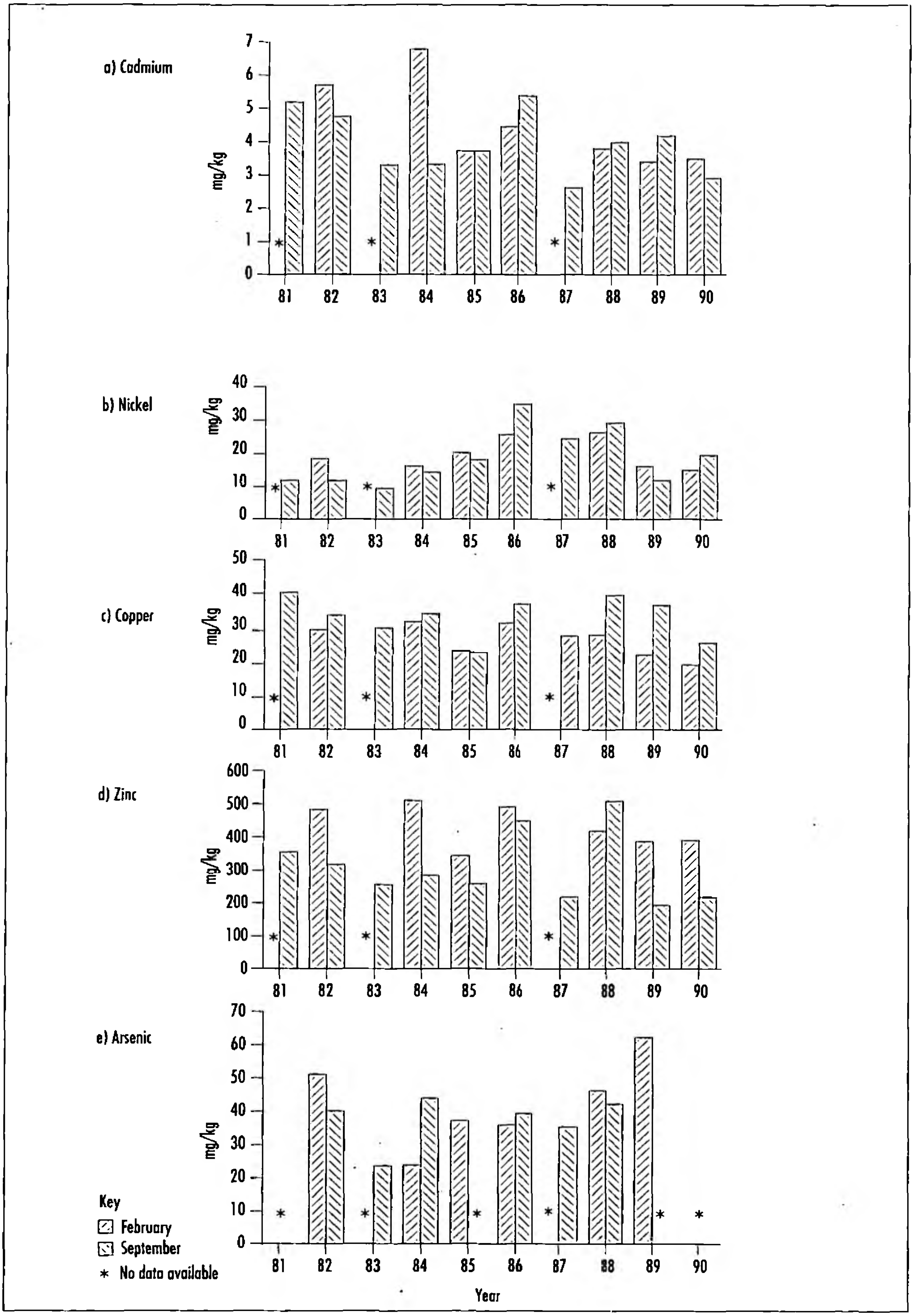
A general rise in average nickel levels was apparent during the middle of the decade (Figure 32b), and although concentrations subsequently declined, a slight rise was observed in the most recent surveys. As noted previously the major input of nickel to the estuary is via the tidal rivers. The lower levels in recent years may thus reflect reduced freshwater flows although this would not necessarily result in a reduction in the total load entering the system.

No clear temporal trend was identified from the averaged copper results (Figure 32c) with levels fluctuating over the years; however, in the last two years both of the February values were the lowest recorded throughout the monitoring period.

The site-averaged trends in zinc concentrations are shown in Figure 32d. Levels have fluctuated widely between surveys and there is no evidence of any temporal trend. Unlike the south shore there are no major discharges and in general zinc concentrations were highest at upper estuary sites with levels decreasing in a seawards direction.

The temporal trends in arsenic concentrations are illustrated in Figure 32e. The particularly large value recorded in February 1989 enhances the impression of a general increase in arsenic concentrations since 1987. Prior to this, levels of arsenic were relatively consistent apart from the particularly low concentrations in 1983 and 1984. The arsenic load to the estuary has been mainly derived from Capper Pass, which has undergone various production changes in recent years. Since

FIGURE 32: LEVELS OF HEAVY METAL IN SEAWEED *(Fucus vesiculosus)* - NORTH HUMBER SHORE

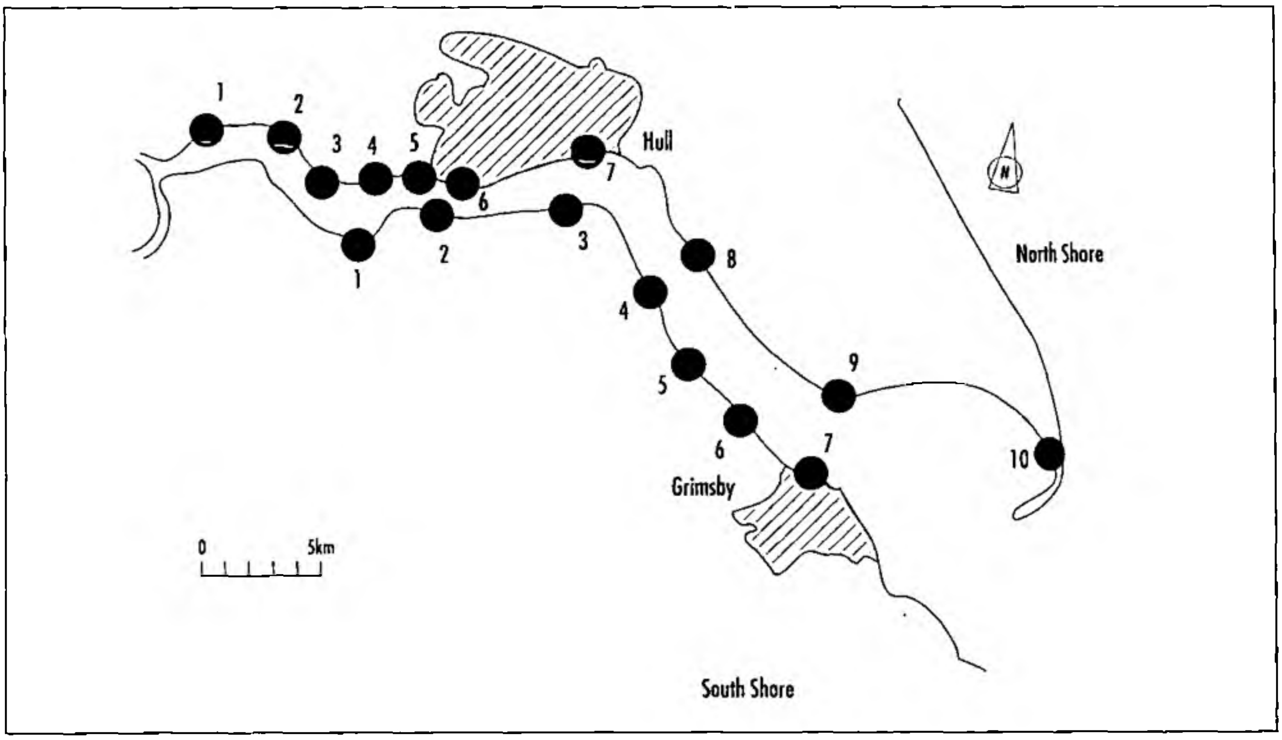


1989 reductions in the arsenic load have been implemented but unfortunately the only data available are for the uppermost site in September 1990 where levels were markedly reduced and lower than any concentrations previously recorded at that site. Results from future surveys will be examined with interest to see if this trend is continued.

7.2 Heavy metal levels in ragworms (*Nereis diversicolor*)

The location of the *Nereis diversicolor* monitoring sites for both shores are shown in Figure 33. All samples were analysed for copper and mercury, those from the south bank were also analysed for iron, and those from the north bank were also analysed for arsenic and cadmium.

FIGURE 33: LOCATION OF *Nereis diversicolor* SAMPLING SITES IN THE HUMBER ESTUARY



a) South shore

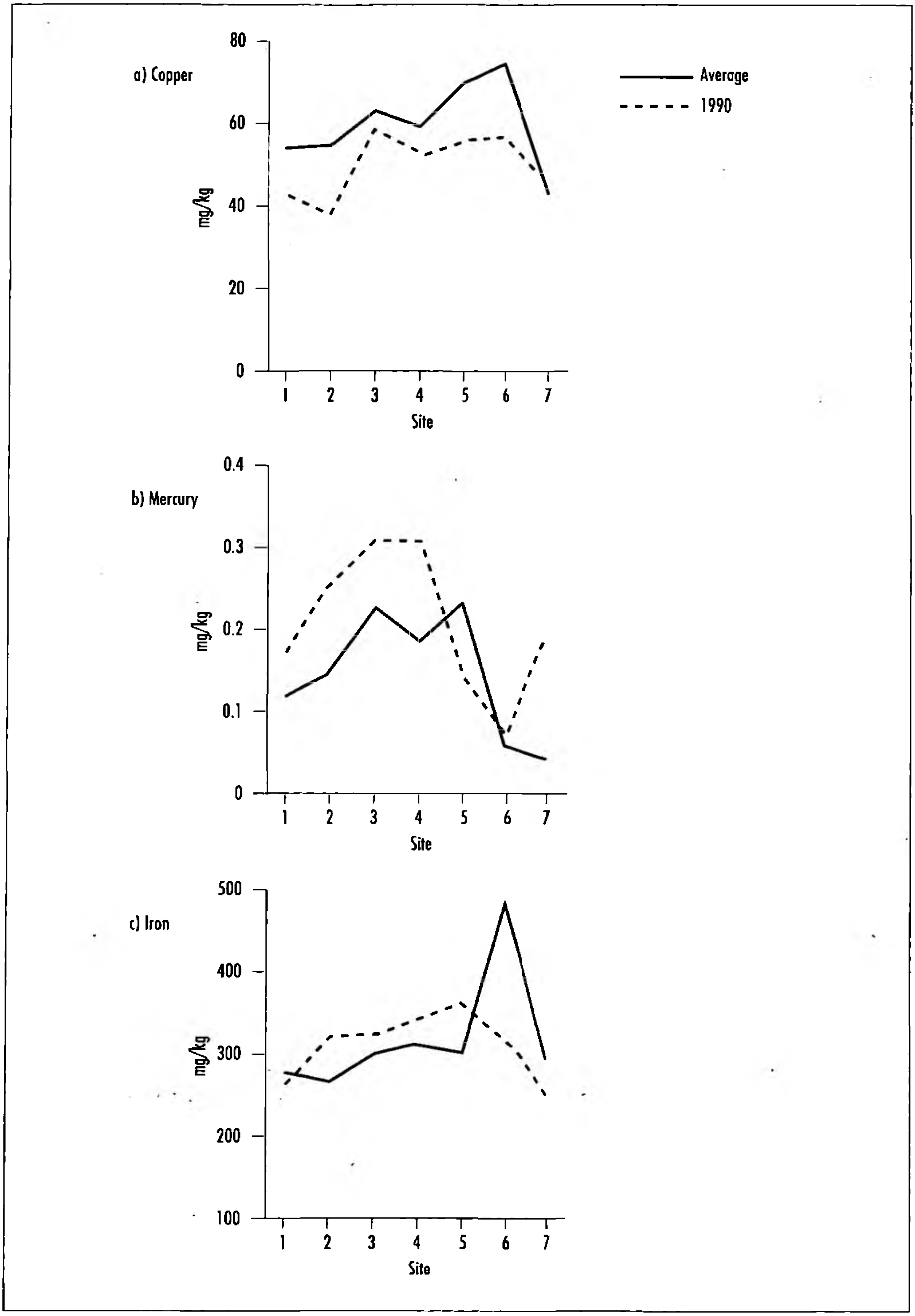
Nereis diversicolor was only included in the south bank sampling programme in 1988. Only the spatial distribution of the different metals are therefore considered, with a comparison of the 1990 data set to average values compiled from the 1988 and 1989 results (Figure 34).

Levels of copper were generally lower in 1990 compared with the average values (Figure 34a) and the noticeable peak in concentration at sites 5 and 6 was not apparent in 1990. The elevated levels of copper in the lower estuary coincide with observations from the *Fucus vesiculosus* work, although the reason for the decline in levels in 1990 is unclear.

In general the distribution pattern of mercury in 1990 was similar to previous years with a rise in levels towards the middle estuary and a subsequent decline moving seawards (Figure 34b). The 1990 concentrations were higher than in the previous two years and an increase was apparent at the outermost site. This erratic distribution pattern is difficult to interpret and the reason for elevated levels in the middle estuary is not known.

The peak in average iron levels (Figure 34c) corresponds to the point between the two titanium dioxide discharges. The persistence of the peak following the closure of the old outfalls probably

FIGURE 34: SPATIAL PATTERNS OF HEAVY METAL IN RAGWORMS *(Nereis diversicolor)* - SOUTH HUMBER SHORE

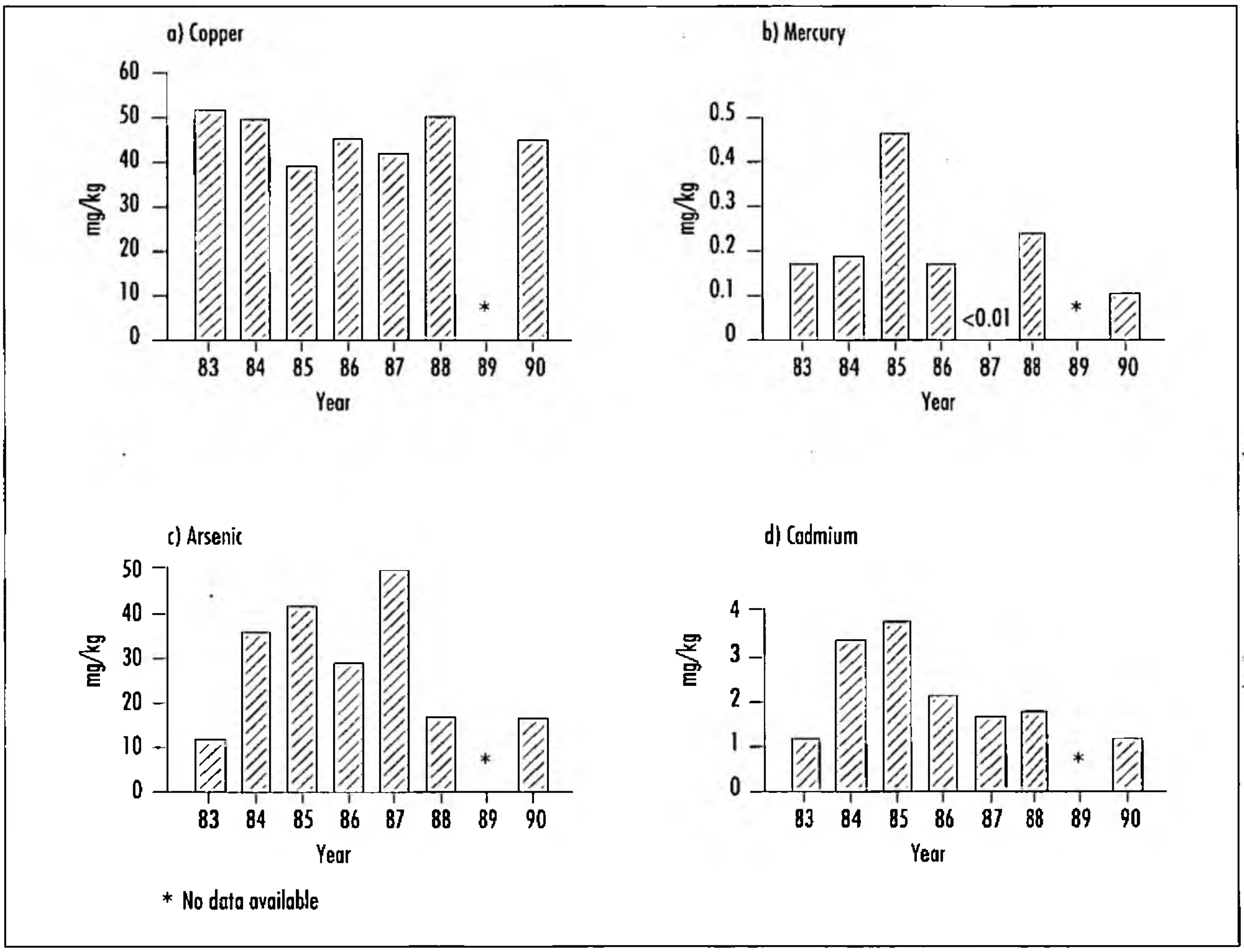


reflects the residue of the historical sources of iron rather than present inputs. Given that enhanced levels of iron in sediments persisted at some sites following closure of the old outfalls (National Rivers Authority, 1989) the elevated 1988 and 1989 concentrations are perhaps not surprising. The 1990 distribution pattern has altered, however, with the peak in levels much reduced and now occurring at South Killingholme (Site 6) which again coincides with the peak iron value for *Fucus vesiculosus*.

b) **North shore**

In contrast to the south shore, a more extensive data set exists for sites on the north bank, allowing an examination of temporal trends based on site-averaged results for copper, mercury, arsenic and cadmium (Figure 35). Spatial patterns of arsenic and cadmium concentrations are also examined.

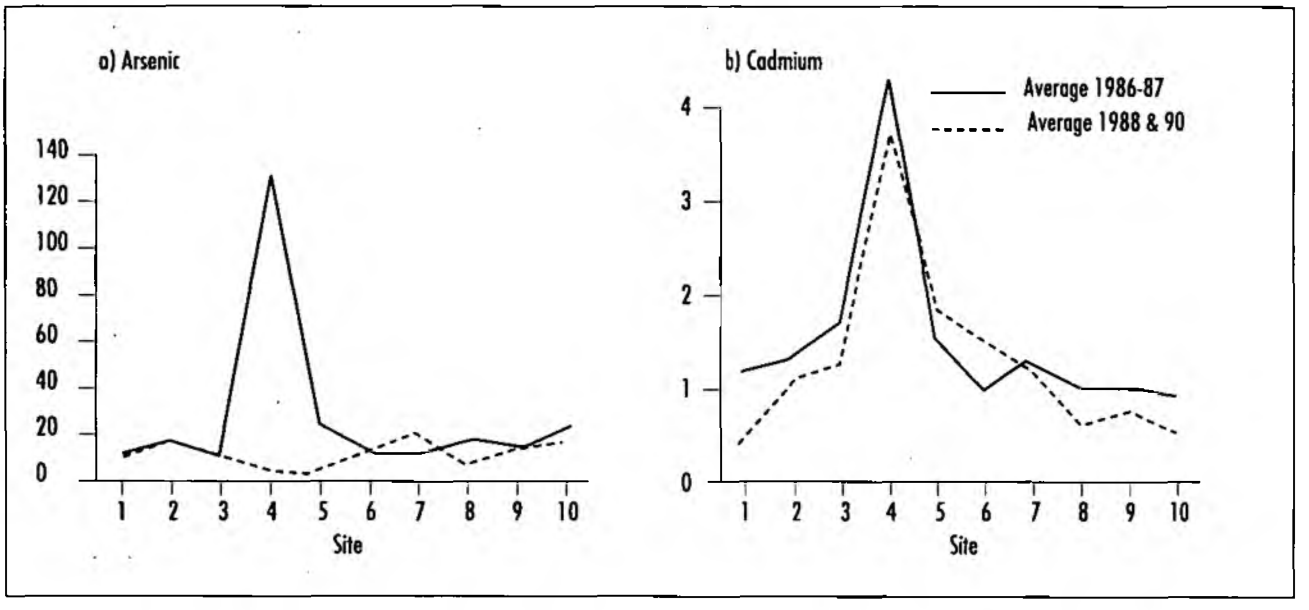
FIGURE 35: LEVELS OF HEAVY METAL IN RAGWORMS *(Nereis diversicolor)* - NORTH HUMBER SHORE



There is no clear trend in copper levels throughout the decade (Figure 35a). Mercury levels have also remained relatively stable (Figure 35b) with the exception of 1985 when a particularly high value was recorded, and in 1987 when concentrations were below the limit of detection.

In contrast, both arsenic and cadmium levels (Figures 35c and d) have undergone pronounced changes with the concentrations of both metals declining in recent years. The reduction in arsenic levels in 1988 coincided with the relocation of the discharge from Capper Pass to below the low water mark. Prior to this, concentrations were discernibly higher with the site adjacent to the discharge recording particularly high values. The 1990 levels of cadmium were the lowest recorded although a gradual decline in concentration has been observed since 1986. The reason for the distinctly low values for both arsenic and cadmium in 1983 is not known, and may relate to methodological and analytical problems during the initial stages of the programme. Inspection of the spatial distribution of arsenic and cadmium provides further details of overall trends, (Figures 36a and b). Average levels for the two years prior to the relocation of the outfall (1986 and 1987) are compared with the average value for 1988 and 1990 (no data are available for 1989). Prior to 1988 a pronounced peak in arsenic levels was observed at site 4 (closest to the outfall). The peak disappeared following the commissioning of the new outfall leaving relatively uniform levels throughout the estuary. Examination of the cadmium distribution reveals a similar peak concentration although there has not been a comparable reduction in values in recent years. Analysis of data from individual years, however, shows that 1990 levels at the most contaminated site have decreased markedly. It is expected that levels will continue to decline following the closure of the factory in 1991.

FIGURE 36: SPATIAL PATTERNS OF HEAVY METALS IN RAGWORMS *(Nereis diversicolor)* - NORTH HUMBER SHORE



7.3 Heavy metal levels in fish and shrimp

a) **Brown shrimp** (*Crangon crangon*)

The levels of heavy metals found in shrimp (whole tissue) from the Humber are summarised in Table 20. In order to assess the significance of these results the data are compared with information from other areas, Table 21.

Data were collected from the upper, middle and lower Humber and results were combined to provide an 'estuary average' for each year. Both copper and nickel levels appear to be slightly elevated in 1990 compared with results from previous years. Copper, however, is known to be regulated because it is the metal constituent of the respiratory pigment so caution should be exercised when assessing trends in this metal. Zinc and cadmium levels have been relatively consistent, although the highest cadmium values were recorded in 1989 and 1990. Average mercury levels have fluctuated throughout the period but recent results are comparable to data from earlier years.

TABLE 20 MEAN HEAVY METAL LEVELS IN THE BROWN SHRIMP (*Crangon crangon*) FROM THE HUMBER ESTUARY 1985-1990 (RESULTS EXPRESSED AS mg/kg WET WEIGHT)

METAL	YEAR					
	1985	1986	1987	1988	1989	1990
Cd	1.14	0.96	0.98	0.93	1.20	1.16
Cu	17.90	13.20	14.40	20.20	19.50	22.50
Hg	0.06	0.04	0.02	0.02	0.03	0.04
Ni	0.35	0.33	0.29	0.23	-	0.46
Zn	17.90	16.10	18.90	16.60	18.60	16.40

TABLE 21 CONCENTRATION OF HEAVY METALS IN BROWN SHRIMP (*Crangon crangon*) FROM DIFFERENT LOCATIONS (mg/kg WET WEIGHT)

LOCATION	Cadmium	Copper	Mercury	Zinc	Source
Humber	1.16	22.5	0.038	16.4	Present Study
Thames	0.5	20.0	0.12	23.3	)
Liverpool Bay	0.4	24.5	0.17	23.5	) MAFF, 1982
Bristol Channel	4.4	30.0	0.15	22.5	)
Humber (Dumping grnd)	<0.2-1.0	10-23	0.01-0.06	17-29	)
Medway	0.59	18.5	0.17	26.4	Wharfe & Van Den Broek, 1977
Northumberland Coast	3.5–2.1				Wright, 1976
Denmark (Limfjord)			0.56		Kiorboe et al, 1983

It would appear that there is a slight enhancement of cadmium levels in the Humber relative to other areas, although these are lower than values reported for the Bristol Channel where elevated levels are known to exist, and from the Northumberland coast. Mercury and zinc levels were particularly low and were within the range of values reported by MAFF at the mouth of the estuary.

Although there is little evidence to suggest a problem in heavy metal contamination, it should be recognised that crustaceans are far from ideal "sentinel" organisms. The mobility of the species and their ability to regulate certain metals (partcularly zinc and copper) against environmental change should be taken into consideration when assessing trends and comparing results.

b) Flounder (*Platichthys flesus*)

Metal contamination concentrations in fish tissue (muscle) are presented in Table 22 and represent the mean level of metals in fish collected from the lower estuary.

TABLE 22 MEAN LEVELS OF HEAVY METALS IN FLOUNDER (*Platichthys flesus*) FROM THE HUMBER ESTUARY 1984 TO 1989 RESULTS EXPRESSED AS mg/kg WET WEIGHT

	YEAR					
METAL	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**
Cu	0.33	0.48 (0.26)	0.35 (0.07)	0.31 (0.05)	0.26 (0.04)	0.40 (0.07)
Hg	0.01	0.03 (0.038)	0.03 (0.013)	0.02 (0.009)	0.03 (0.039)	0.03 (0.023)
Zn	15.1	11.10 (2.19)	8.16 (1.40)	8.03 (1.67)	8.43 (1.91)	8.44 (1.79)
Number	9	25	12	37	36	9
Mean Size (cms)	15.9	21.7	19.6	21.2	23.5	25.2

Figures in brackets denote standard deviation .

Fish muscle tissue was analysed for copper, zinc and mercury because most other metals (lead, nickel, chromium and cadmium) occur at very low concentrations. No data are available for 1990. There are no obvious trends in any metal levels except zinc. The results can be further evaluated by comparison of the most recent results (1989) with data from other areas, Table 23. It would appear that zinc levels may be slightly elevated in the Humber; also the copper value appears to be within the higher category of levels reported.

TABLE 23 HEAVY METAL CONCENTRATIONS IN FLOUNDER FROM AROUND THE BRITISH COAST (mg/kg WET WEIGHT)

LOCATION	Copper	Zinc	Mercury	
Humber	0.40	8.4	0.03	Present Study
Humber	0.16	6.8	0.13	)
Tyne	0.40	5.6	0.04	)
Swansea Bay	0.40	8.0	0.10	) MAFF, 1990
Liverpool Bay	0.47	4.9	0.28	)
Morecambe Bay	0.23	5.8	0.29	)
Thames (outer estuary)	0.29	7.2	0.12	)
Thames	0.56	9.6	0.37	Rickard & Dulley, 1983
Medway	0.30	14.5	0.64	Wharfe & Van Den Broek 1977

Mercury concentrations, in contrast, were particularly low and consistent with the findings of the shrimp and dover sole results. Flounder are considered to be especially useful monitors of mercury contamination (Bryan et al, 1985) and the low values recorded in the Humber would suggest that there is no problem with respect to mercury levels in the estuary. However there have been problems associated with the analysis of mercury in biota and these results may represent an underestimation of mercury concentrations in fish tissue.

c) Dover sole (*Solea solea*)

The trends in metal levels in dover sole (muscle) are given in Table 24. The 1990 results were provided by MAFF and are based on the duplicate analysis of pooled tissue rather than the analysis of individual specimens as in previous years. Any comparison therefore must also take into account the possibility of analytical differences between laboratories. (No analytical quality control comparisons have yet been carried out between laboratories.)

TABLE 24 MEAN LEVELS OF HEAVY METALS IN DOVER SOLE (*Solea solea*) FROM THE HUMBER ESTUARY 1984 - 1990
RESULTS EXPRESSED AS mg/kg WET WEIGHT

METAL	YEAR						
	1984	1985	1986	1987	1988	1989	1990
Copper	0.23	0.26 (0.060)	0.27 (0.078)	0.34 (0.126)	0.24 (0.058)	0.53 (0.060)	0.47 (0.48; 0.45)
Mercury	0.07	0.04 (0.030)	0.04 (0.038)	0.02 (0.0158)	0.01 (0.0136)	0.05 (0.013)	0.03 (0.03; 0.03)
Zinc	6.40	3.68 (0.282)	4.20 (0.41)	4.37 (0.413)	4.15 (0.618)	5.33 (0.76)	4.65 (4.7; 4.6)
No. of fish	15	30	28	63	29	7	25
Mean size (cms)	24.5	24	20	21	23	16	22.7

Figures in brackets (1985 to 1989) denote standard deviation or range of duplicate analysis (1990).

The only metal exhibiting an increase in levels was copper, with elevated concentrations noted in both 1989 and 1990. This may not however represent a 'real' trend since the high 1989 value may relate to the small number and size of fish analysed and analytical and methodological differences may account for the elevated 1990 value. Concentrations of the other two metals have fluctuated from year to year and no clear pattern can be established. Zinc levels however, apart from 1989, have been relatively stable since 1986.

A comparison of the 1990 results with data from other areas (Table 25) is based on the results of MAFF surveys around the UK. The data suggest a possible enhancement of both zinc and copper levels in the Humber, an observation in keeping with the results of the flounder analysis. Mercury levels were typically low, consistent with the findings from both the shrimp and flounder data.

TABLE 25 COMPARISON OF METAL LEVELS IN DOVER SOLE FROM DIFFERENT UK LOCATIONS (mg/kg WET WEIGHT)

LOCATION	Copper	Zinc	Mercury	
Humber	0.47	4.7	0.03	Present Study
Tees	0.14	4	0.13	)
Thames	0.21	4.5	0.08	)
Bristol Channel	<0.1	3.7	0.08	) MAFF, 1990
Liverpool Bay	0.35	4.1	0.14	)
Morecambe Bay	0.22	4.3	0.18	)

7.4 Discussion

The analysis of biological material from the Humber has proved to be an interesting and effective means of assessing and monitoring metal levels. In particular *Fucus vesiculosus* has provided valuable information on trends and the use of *Nereis diversicolor* in recent years has highlighted the potential of this indicator species.

Improvements in effluent disposal to the estuary have been implemented over the decade. On the south bank the principal change has been the relocation of the two titanium dioxide outfalls to deeper water where dilution and dispersion are significantly greater. Iron concentrations in *Fucus vesiculosus* have fallen since the closure of the old outfalls, indicating a very large improvement in terms of dissolved iron in the inshore areas. The reduction in iron-staining on the Grimsby foreshore and the colonisation of the area by *Fucus vesiculosus* and invertebrates provides further evidence of the general improvement in environmental quality (NRA (Anglian) 1989).

The closure of Capper Pass metal smelter in 1991 will have major implications for metal inputs to the north bank. Recent results have already shown reductions in both arsenic and cadmium levels in *Nereis diversicolor*, reflecting the previously enforced reduction in loads and decline in operations prior to closure. Although this provides evidence of improving water quality, there are still areas of the estuary where problems exist. Inputs of copper and zinc to the lower estuary from the south Humber bank have been identified by the *Fucus vesiculosus* monitoring programme and the possible elevation of these metals in fish tissue may be a further indication of metal contamination in this area.

The scheduled 50% reduction of UK inputs to the sea by 1995 will have an important influence on water quality. Targets were set at ministerial conferences on the North Sea and recent estimates on percentage reductions between 1985 and 1990, based on information supplied by the NRA to the Paris Commission, show that both cadmium and mercury inputs have declined by 61% and 51% respectively, copper by 28%, with only zinc so far showing little change. Significant reductions in metal inputs to the Humber are expected by 1993 and evidence of improvements will be sought from future monitoring of biological tissues.

8. FISH POPULATIONS

Water quality management of an estuary usually involves biological criteria relating to the state of fish and invertebrate populations. One of the objectives of the Humber Committee is "to maintain, improve and develop the indigenous fisheries in the estuary and to allow the passage of migratory fish by improving water quality conditions in the estuary". Specific studies on fish populations of the Humber have in the past been limited and mainly confined to the status of commercial fisheries (Rees, 1982). Little information exists on the nature of the resident fish community, although the Institute of Estuarine and Coastal studies at Hull has recently embarked on a project to study fish populations in the Humber in relation to water quality.

In the early seventies the Ministry of Agriculture, Fisheries and Food (MAFF) instigated annual surveys to map the distribution and abundance of small demersal fish in relation to North Sea stock management (Riley et al, 1986; Millner et al, 1988) Part of the programme included collecting data from the Humber and information on catches is available from 1973 to 1984 until the surveys were discontinued. In 1988, the Humber Committee in collaboration with MAFF reinstated these surveys and they now constitute a regular component of the Humber Monitoring Programme.

The following account is mainly based on the information provided by these surveys (data supplied by Fisheries Laboratory, Lowestoft) and examines community structure in relation to environmental variables and water quality.

8.1 Fish community structure

The species of fish recorded from the Humber tidal system since 1970 are tabulated in Appendix F. The list was compiled from a variety of sources and the current total for the entire system is 76. Of the fish recorded from the tidal rivers, most (36) inhabit the upper reaches towards the inland tidal limits. On the lower parts of these rivers the effects of strong tidal currents, high levels of suspended solids, and pollution combine to restrict permanent breeding populations. Good coarse fisheries obtain in the inland areas of the rivers Hull, Ouse, Wharfe and Trent whereas few fish are caught in the Aire and Don. A total of 58 fish species were recorded from the estuary, 35 of which were collected during the MAFF annual surveys. The species of coarse fish listed for the Humber were mainly collected by eel fishermen in the upper estuary. These will originate from fresh water sources and their longevity in estuarine conditions is unknown. The estuarine fish have been classified into 6 ecological types (McHugh, 1987) as follows: freshwater residents that occasionally enter brackish conditions; catadromous/anadromous migrants; estuarine residents which spend their entire lives in the estuary; marine seasonal; marine juvenile which use the estuary primarily as a nursery ground; and marine adventitious migrants that have no apparent estuarine requirement and occur irregularly. Some species have been assigned to more than one category. For example, the flounder has previously been regarded as an estuarine resident reflecting the situation pertaining for most of its life. As it is known to migrate to coastal regions to reproduce (Wheeler, 1963) and to use the fresh water brackish water interface as a nursery area, it can also be included in the anadromous migrant category.

Of the 58 species recorded in the estuary, 14 were estuarine residents and most of the remainder were marine species. It is likely that the catadromous/anadromous and freshwater species will only be collected sporadically due to their limited residence time within the estuary. The marine species comprise mainly marine adventitious migrants (dragonet, weever, rays etc), although at certain times of the year (ie post recruitment) it is the marine juveniles (plaice, dab and whiting) which will be most important in terms of abundance.

Most UK estuaries support a similar species complement of approximately 30 species, typical of the inshore fish community proposed by Henderson, (1989). Amongst east coast estuaries the fish community of the Humber was found to be very similar to that of the Forth and Tyne. In particular, the Humber and the Forth have a similar diversity of habitats, in contrast to the Tyne which is canalised in certain parts. Both the Humber and the Forth have sandy areas suitable for species such as the sand eel, weever and rays, and the presence of hard substrata provides suitable habitats for father-lashers and sea snails, neither of which species is common in the Tyne.

8.2 Trent salmon fishery

Salmon have continued to be caught and sighted in the River Trent since they first came back into the river over 20 years ago. Numbers have remained low with a total of 21 catches and sightings over the five year period from 1987 to 1991. There are many physical barriers to the migration of salmon which include the Holme Sluices downstream of Nottingham and weirs built for navigation purposes. These prevent the salmon reaching suitable spawning grounds in the Dove and Derwent catchments.

Past policy was to take an opportunistic approach to developing the river as a salmon fishery. Where the opportunity arose to build a fish pass as part of a weir improvement scheme then this was taken. The building of the canoe slalom at Holme Pierrepont now allows salmon to pass upstream of the Holme Sluices. However, there was no active development of the fishery.

Future policy has recently been discussed by the NRA's Regional Fisheries Advisory Committee and it was agreed that a more proactive approach should be adopted. It was decided that there should be a full feasibility study on the reinstatement of salmon, including a full analysis of those aspects of water quality and resources likely to affect the fishery. Over the next few years major water supply abstractions are planned for the Trent, leading to the export of water to Lincolnshire and the South East of England. Subject to favourable results from the feasibility study, there will then be a progressive implementation of a programme to improve access to the upstream tributaries. This will eventually open up the River Dove to support a home run of at least 1000 fish.

8.3 Spatial distribution of fish

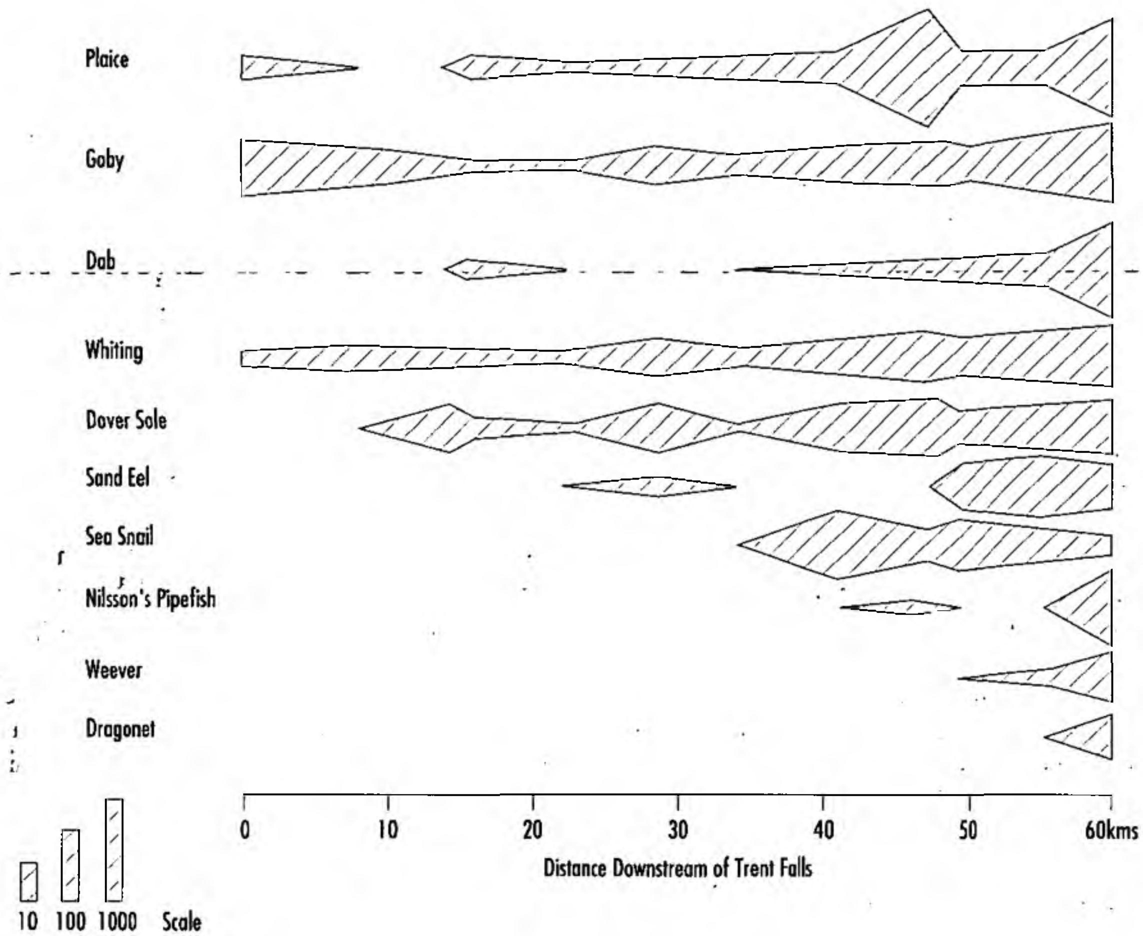
The distribution of the ten top catch abundance ranked species in the estuary is illustrated in Figure 37. Abundance is expressed as the total catch from all years, although for the upper estuary (0 - 20 kms) data were available for only a limited number of years. The intention is not to compare 'absolute catches' but to examine the geographical distribution of the different fish species in the estuary.

The increase in species variety with distance seawards is as expected with the marine adventitious species (weever and dragonet) restricted to the seawards end of the system. Of the indigenous species, the sand goby was the most ubiquitous occurring throughout the estuary.

The preference of both the sand eel and Nilsson's pipefish for sandy areas restricted their distribution to the sand flats of the outer Humber, with the remaining estuarine resident, the sea snail, common on the rough, stony ground in the lower estuary. The distribution of sole, categorised as both an estuarine resident and marine adventitious species, penetrated the upper reaches of the estuary. Riley et al (1981) observed that sole mainly occur in salinities between 10 and 30 g/l and in the Humber, peak numbers were obtained in this region.

The contribution of the marine juvenile species to the overall abundance was high with plaice, dab and whiting ranked 1, 3 and 4 respectively. This is perhaps not surprising since sampling conducted in September is post recruitment, when the young flatfish have moved into the nursery areas. Such a pattern is consistent with studies on the Forth Estuary which found that plaice move into estuaries as juveniles in July, slightly later than whiting which move inshore from May onwards (Elliot et al, 1990). Dab were also found to have a well defined seasonal occurrence from September to December. Of the 3 species, plaice and whiting were the most ubiquitous with distributions extending in to the low salinity regions of the upper estuary, in contrast to dab which was restricted to more saline areas.

FIGURE 37: GEOGRAPHICAL DISTRIBUTION OF FISH IN THE HUMBER ESTUARY



The distribution of fish within the Humber is largely controlled by physico-chemical factors including salinity (extent of freshwater flow) and tidal scour. Relatively small catches are obtained from channel areas, whilst the shallow marginal habitats generally support the greatest diversity and abundance of fish.

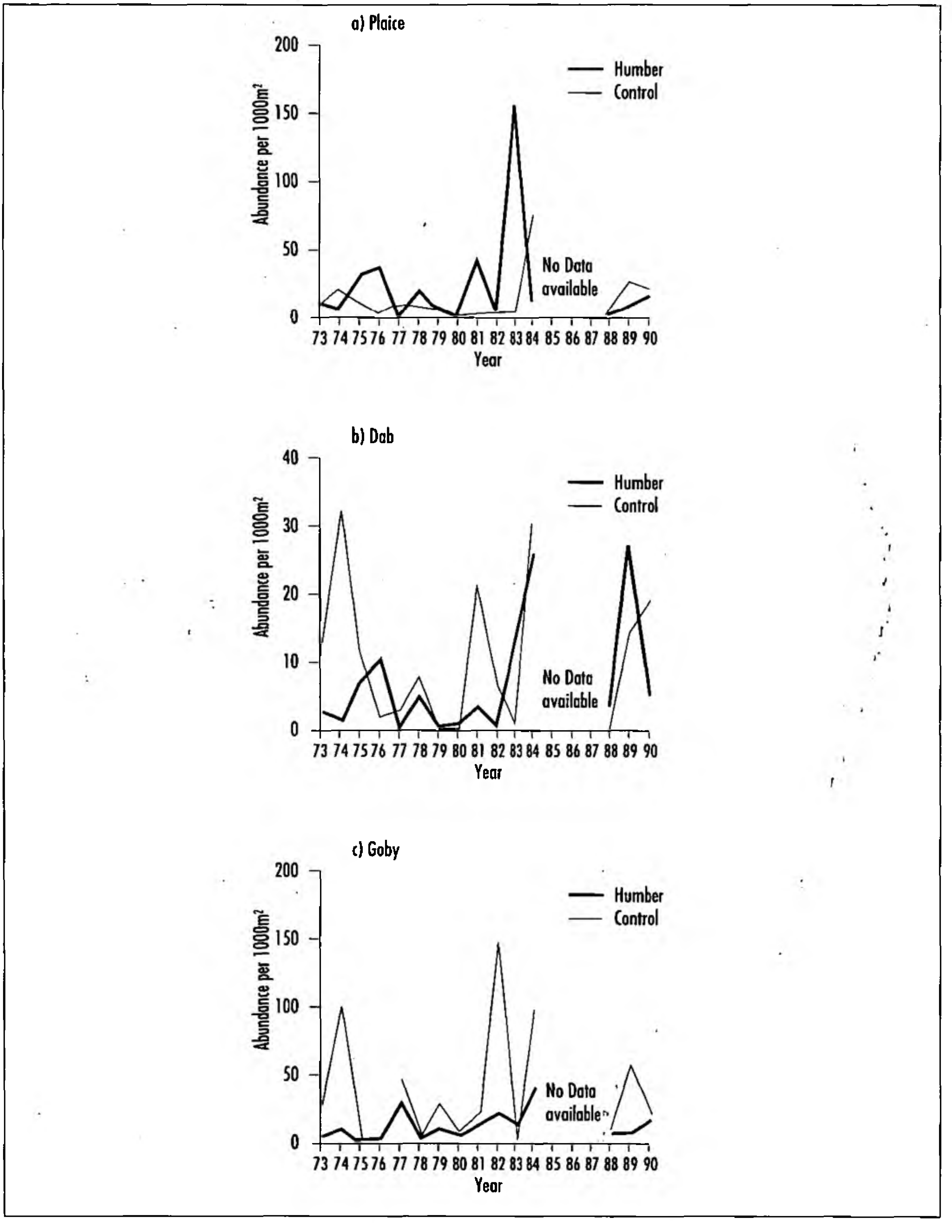
8.4 Long term variations in individual species

A comparison of the catches of the three most abundant species - plaice, dab and sand goby - in the Humber and at a control site off the Lincolnshire coast is presented in Figure 38. Catches are standardised as abundance per $1000m^2$.

a) Plaice

In general, plaice populations appear to be higher in the Humber than on the Lincolnshire coast, although this pattern was reversed recently, (Figure 38a). The Humber data exhibits a 2 - yearly cycle of high and low catches with a particularly large abundance in 1983.

FIGURE 38: LONG-TERM VARIATION IN THREE INDIVIDUAL SPECIES OF FISH IN THE HUMBER ESTUARY



The Humber - Wash margin of the North Sea is an important nursery area for plaice containing 14% of the North Sea population. In the Humber itself, approximately 3% of plaice utilise the sand flats of the outer estuary for this purpose (Rees et al, 1988). Clearly, when examining trends in catch data for commercial migratory species, it is necessary to recognise the fact that stocks in the Humber will be influenced by events in the North Sea. The years corresponding to peaks in catches may relate to a particularly successful recruitment from stocks in the North Sea. Similarly, reduced abundance may be the result of a less successful or delayed recruitment due to factors outside the Humber.

b) **Dab**

Dab also utilise the sandflats of the outer Humber as nursery areas and the peak annual catches usually occur from September onwards when the young flatfish move inshore. Since populations will be subject to influences outside of the Humber, in the same way as plaice, caution must be exercised when interpreting variations in abundance. The annual pattern in the Humber, particularly since 1977, was very similar to that observed off the Lincolnshire coast (Figure 38b). A comparison of the dab and plaice populations in the Humber shows that a remarkably similar pattern exists with the years of peak catches (1976, 1978, 1981 and 1984) coinciding. It is therefore very likely that factors controlling or influencing plaice populations are also affecting the stocks of dab in the estuary.

c) **Sand goby**

It is perhaps more appropriate when examining fish populations in relation to water quality assessments to focus attention on species which are resident within the estuary than those species which spend their planktonic and perhaps adult life in the sea and are subject to outside influences. One estuarine species which is relatively abundant within the Humber is the sand goby. The population of gobies in the Humber was generally much smaller and less variable than at the control sites where large annual fluctuations in numbers were evident (Figure 38c). Patterns were however, broadly comparable, with peaks in numbers usually coinciding although differing by an order of magnitude. In the Humber, the population tended to increase between 1978 and 1984,although the most recent results indicate that the increase has not continued and abundance has returned to previous levels. Similarly at the control sites, numbers were lower between 1988 and 1990 with smaller annual fluctuations.

The assessment of trends in fish populations within the Humber is difficult given the relatively short data series that is available and the distortion in patterns produced by good and bad years. The similarity of patterns in most cases between the Humber and the Lincolnshire coast would indicate that fish populations within the estuary are probably controlled by natural variables. However, considerably more data are required in order to interpret trends in relation to water quality and the selection of a more remote control site for comparisons may also be appropriate.

8.5. Fish and water quality interactions

The fish community of the Humber is similar to other North Sea estuaries, supporting representatives of various ecological types. Juvenile populations of marine species utilise parts of the estuary as nursery areas providing food and shelter. Over-wintering species including cod and whiting move inshore for the increased availability of food such as the brown shrimp (*Crangon crangon*) and other epifaunal crustaceans. The Humber plays an important role not only for those species resident within the estuary but also in the life cycle of commercial marine species using the estuary.

Anthropogenic problems of poor water quality, habitat loss and exposure to contaminants will not only affect resident species but those marine species which are estuarine dependent.

In the Humber the most serious pollution problem is the depletion of dissolved oxygen in the tidal rivers in the vicinity of Trent Falls. One of the likely effects of reduced dissolved oxygen concentrations is the restriction of the passage of migratory fish. Observations in the upper reaches of other estuaries have found that migrations were affected by low dissolved oxygen levels (see for example Pomfret et al, 1991, Curran and Henderson, 1988).

Netting for salmon has been banned by bye-laws in the Humber and Lower Ouse since 1977 and in the Trent net licenses have not been issued since 1960. Recent records for the Trent indicate that limited numbers of salmon have been caught by rod and line (Rees, 1982, Newark Advertiser 29th March 1991). In addition salmon runs have also been observed in the Ouse and Wharfe catchments, which may be related to water quality improvements. Evidence of the presence of salmonids in the estuary has been provided by eel netsmen on the Humber bank who have recently reported catching young salmon and sea trout. Although these reports are generally encouraging there is no evidence to suggest that salmon stocks have improved.

Fish species other than salmonids are also known to exhibit avoidance behaviour when poor quality water is encountered. Prior to improvements in the Thames, the distributions of both sole and plaice were shown to be restricted by low dissolved oxygen levels (Andrews and Rickard, 1980). In the Humber, changes in the distribution of plaice also highlight the sensitivity of this species to a deterioration in water quality. Following the Sivand oil spill in 1983, the distribution of 0-group plaice altered, with significantly reduced catches recorded in an area where historically abundances had been highest (Rees et al, 1982). Other species did not exhibit any changes that could be linked to the incident and results from later surveys indicated a recovery in plaice populations in that area. The extent of water quality problems may well vary seasonally. In the Tyne estuary summer dissolved oxygen levels were found to have a significant effect on flounder populations (Pomfret et al, 1988) and the introduction of a seasonal component to the programme may therefore be desirable.

Commercial fisheries within the estuary, although of importance locally, have always been relatively small scale in the context of the UK. A decline in certain fisheries (oysters, mussels, salmon and migratory trout) occurred early this century and in certain cases this may partly be attributable to pollution, although a direct causal link is difficult to establish. The main fisheries currently operating include sole and cod, although the occurrence of cod in recent years has declined (North Eastern Sea Fisheries Committee, 1990). The decrease in cod numbers reflects more widespread changes relating to this species and is probably linked to the decline in North Sea stocks rather than local factors. Of the shellfish, after an earlier decline shrimp are now fished commercially from Immingham to South Ferriby (N.E.S.F.C, 1990) and an increase in cockle populations has also been observed (previous population collapse was related to climatic and topographical changes).

In common with other estuaries, the Humber plays an important role as a nursery and over-wintering area for species of marine fish. The sandflats of the outer estuary serve as a significant nursery area for flatfish with an estimated 3% of North Sea plaice utilising the outer estuary for this purpose (Rees et al, 1988). Stocks within the estuary will clearly be influenced by events in the North Sea as well as locally and this makes the interpretation of trends very difficult. However, changes in fish communities over the monitoring period do not indicate a deterioration in environmental quality.

9. FUTURE DEVELOPMENTS

There have been many changes affecting the Humber Estuary over the past ten years, and there will be more in the next ten years. Some will be imposed by central government or other external agencies; some will be initiated by the Humber Estuary Committee in order to improve the Humber; some, no doubt, will materialise which are unforeseen at present. The implications of the changes that can be foreseen are considered below.

9.1 Statutory Water Quality Objectives

Possibly the greatest change will be the move to a national system of water quality management. This will be imposed, by statute, as water quality objectives, on all controlled waters including the Humber. These objectives will set a framework for a national policy on water quality and it will be the duty of the NRA to ensure that the objectives are achieved. It is likely that the new objectives will have three main components:

i) the uses of any particular stretch of water will be categorised and a set of water quality standards, which will protect those uses, will be defined;

ii) where an EC Directive applies to a particular stretch of water, there will be a need to ensure compliance with the provisions of the Directive; and

iii) where a stretch of water receives a discharge containing a prescribed substance (as defined in the 1990 Environmental Protection Act) the standards set for that substance must be met.

There will be a new general quality assessment scheme which will measure the existing quality of a stretch of water, both chemically and biologically. This will not be part of the statutory scheme, but will be used for quinquennial assessment and reporting of water quality status.

The statutory objective itself will be set by the Secretary of State serving a notice on the NRA relating to a specific stretch of water. Each notice will:

i) define the stretch of water to which it applies;

ii) identify one or more appropriate use categories, referring to the corresponding quality standards;

iii) fix dates by which each of the relevant sets of standards is required to be met.

Once set, the SWQO will have to be taken into account by the NRA when determining any new application for consent for a discharge of trade or sewage effluent and when reviewing any such existing consents.

The use categories that are likely to be applied to the Humber estuary are:

i) fisheries ecosystem;

ii) commercial harvesting of marine fish and shellfish for human consumption;

iii) water sports; and

iv) special ecosystem.

The EC Directives that are relevant to the Humber estuary, or parts of it, are those relating to:

i) dangerous substances;

ii) bathing water quality (in the vicinity of Cleethorpes);

iii) titanium dioxide (for the two factories near Grimsby); and

iv) urban waste water treatment.

The NRA has issued a consultation document which sets out issues relevant to the setting of SWQOs. It is anticipated that they will be introduced as from 1993.

The Humber Estuary Committee has worked to a broadly similar system of water quality management as the proposed new Statutory Scheme and this has been reviewed in Chapter 3 of this report. The target date originally set by the Committee for its quality objectives to be met in the Humber was 1995. In practice this will not be fully achieved, although there will have been substantial progress towards them. This will give a solid base on which to go forward with SWQOs.

A new general classification system for estuaries has been proposed. Appropriate criteria are not yet available for the scheme but research is currently in progress.

9.2 Environmental Agency

In July 1992 the Government announced its intention to create a unified environmental agency by bringing together the NRA, HMIP and the waste regulating authorities.

For water quality management in the Humber Estuary the main implication would be that a single agency would then control all discharges to the estuary either directly or indirectly. For those industries who discharge effluents containing prescribed substances to the Humber (of which there are several) this would be a significant benefit. It will also make water quality management more straightforward. An additional advantage would be that the related topics of solid waste disposal and gaseous waste emission would be controlled by the same agency.

9.3 The Paris Convention

The SWQO scheme is a UK initiative. There are international initiatives which will also bring change to the Humber.

The Paris Convention is an international agreement dealing with pollution of the sea by the discharge of industrial wastes into rivers and estuaries. The UK is a signatory to the Convention. Recently there have been changes to the way the Convention is implemented.

The aim of the Convention is to control the discharge of dangerous substances to the aquatic environment in a broadly similar way to the Dangerous Substances Directive (See Section 3.3) . The Convention has two lists, a black list of particularly dangerous substances (eg; mercury, cadmium, organo-halogen compounds) and a grey list of less dangerous substances (eg; organo-phosphorus compounds, arsenic, chromium, copper, lead, nickel, zinc). The Convention requires the elimination of pollution by black list substances and the limitation of pollution by grey list substances.

The Paris Commission, who implement the Convention, have recently instituted a comprehensive annual study of inputs of selected pollutants to Convention waters. The first study was carried out in 1990. The Humber estuary is included. The parameters monitored are five metals (mercury, cadmium, copper, zinc and lead), three nutrients (nitrate, ortho-phosphate and total inorganic nitrogen), one pesticide (gamma HCH) and seven of the pentachlorobiphenol (PCB) congeners.

All the major sewage and trade effluent inputs made to the Humber estuary, and the more significant freshwater river inputs, have been monitored by the NRA monthly to provide data for the Paris Commission survey. The survey will continue on an annual basis for the foreseeable future.

As yet the Paris Commission have made no pronouncement on the results of the survey work but it is likely they will be looking particularly at nutrient levels and the risks of eutrophication.

The Paris Convention has recently been reviewed and combined with the Oslo Convention (which covers pollution of the marine environment by dumping from ships and aircraft) into a new Convention covering all forms of pollution of the marine environment. The new Convention is likely to have some impact on water quality management in the Humber estuary but it is too early to tell what that will be.

9.4 The North Sea Conferences

Over the past decade the quality status of the North Sea has been a topic with a high profile. This has resulted in a series of ministerial conferences on the North Sea: in Bremmen in 1984; London in 1987; and most recently at The Hague in 1990. The conferences have provided a powerful stimulus to marine pollution control and have prompted new policy developments. The initial UK response to the Declarations has been to carry out a major monitoring exercise for the 36 priority hazardous substances identified in Annex 1A of the Hague Declaration.

The North Sea Conference Declarations, and the UK response to them, will also have a significant effect on water quality management practice within the Humber catchment area. The Humber estuary is one of the UK's main freshwater inputs to the North Sea. One fifth of the UK population live within its catchment area and parts are highly industrialised.

The preliminary results of the Annex 1A monitoring suggest the Humber estuary is significant in national terms for inputs of 14 of the 36 substances: ie cadmium, organic tin, gamma HCH, aldrin, dieldrin, endrin, trifluralin, trichlorobenzene, hexachlorobenzene, dichlorvos, malathion, atrazine, simazine and PCP.

Many of these 14 substances have diffuse inputs to rivers and only appear as significant loads in the Humber due to the very high freshwater flows which are discharged via the estuary to the North Sea. The UK is committed to reducing inputs of Annex 1A substances by at least 50%. Where it is confirmed that the Humber is a major source for a particular Annex 1A substance, then further load reductions will need to follow.

Reductions in loads will be achieved via a range of measures. Where the load is the result of direct inputs (eg cadmium, organic tin, HCB) reductions will be obtained directly from the discharger or dischargers concerned. The closing of the Capper Pass smelter has already resulted in substantial reductions in input for cadmium and organic tin. For diffuse inputs, more information will be required about their origins.

9.5 Input of nutrients

There has been concern about the input of nutrients to the North Sea. Whilst nutrients are not dangerous because they are toxic, they can result in eutrophication. This is a particular problem on the eastern side of the North Sea but is of less significance on the UK side. The most obvious evidence of an algal bloom is the presence of large mats of foam or scum on beaches. On the eastern side of the

North Sea, blankets of foam of up to one metre in depth have been recorded on numerous occasions. No similar events have been reported on the UK side although there have been occasional algal scums reported in areas south of the Wash.

Whilst the controls the North Sea Conference Declaration proposes for nutrients are less stringent than for dangerous substances, they are still significant. The coastal zones of the North Sea have to be identified as whether they are at risk from eutrophication. All urban areas with a population of 5,000 or more, and industries with a comparable waste water load, have to be connected to sewage treatment plants equipped with secondary treatment unless it can be demonstrated that the discharge will not adversely affect the North Sea environment on a local or regional level. Even where this is the case, primary treatment at least should be provided. These proposed controls are mirrored in two other initiatives: one international and one national. The EC Urban Waste Water Treatment Directive, (UWWTD) which also sets minimum levels of sewage treatment for a particular size of discharge, is currently being implemented, and the UK Government has already announced broadly similar measures whereby all significant discharges of sewage to coastal waters will have a minimum of primary treatment and all significant discharges of sewage to estuaries will have a minimum of secondary treatment.

The Humber estuary is not regarded as being in any danger from eutrophication but restrictions on nutrient levels could have a significant impact given the volume of sewage effluent discharged either direct to the Humber or to its tributary rivers. The reduction of nutrient levels in sewage effluent, whilst technically feasible, is a costly process. There may well be higher priorities for investment in pollution control within the Humber catchment than removal of nutrients from sewage effluent. At present a number of discharges of sewage effluent to the Humber Estuary are not treated. As a result of these new initiatives two stage treatment (or its equivalent) will have to be provided. The UWWTD requires this level of treatment to be achieved by the year 2000.

Existing monitoring of nutrient levels in the Humber has not revealed any problem. However, steps are being taken by the NRA to enhance that monitoring in order to define more precisely its eutrophic status. In addition, there are two major national research projects being carried out, in part, on the Humber Estuary which will help determine the extent to which nutrients are having an impact.

The first is MAFF's JONUS (JOint NUtrient Study) project which is looking at the way nutrients brought into the Humber by the freshwater rivers are lost within the system and hence not discharged to the North Sea. The second is NERC's LOIS Project (Land Ocean Interaction Study) which will be examining the flux of many materials, including nutrients, from the Humber system and other load sources into the coastal zone.

9.6 Improved effluent treatment and other developments

A number of improvements are planned to sewage and trade effluent discharges made to the Humber and its tributaries. A major new effluent treatment facility takes many years to develop. The plant has to be designed, pilot scale plants may have to be run; capital has to be raised; and construction work has to take place. Only then can a new treatment plant come on stream. There is a continuing dialogue between the NRA and major dischargers about the level of treatment they should provide. Discussions which have already taken place have resulted in a number of plans for improved effluent treatment facilities. Some of the more major ones are as follows.

i) **Cleethorpes Sewage Works.** A new sewage works providing full secondary biological treatment and possibly some form of tertiary treatment will be built by 1997 to enable the provisions of the EC Bathing Water and UWWT Directives to be met. It is likely that the new works will discharge its effluent into the Tetney Haven, the tidal part of the Louth Canal, rather than direct to the Humber Estuary.

ii) **Tioxide UK Limited and SCM Chemicals Limited.** It is anticipated that there will be effluent treatment plants at both these two factories by 1995, to meet the provisions of EC Titanium Dioxide Directives. The new treatment plants will significantly decrease the acidity of these effluents and virtually eliminate the discharge of ferrous iron.

iii) **Ciba Geigy.** A new effluent treatment plant is being constructed at this factory which should be operational by 1994. The effect of this plant will be to reduce the organic chemical content of the effluent to a fraction of its present level.

iv) **Flue gas desulphurisation (FGD).** There are a number (five in Yorkshire plus 10 in Severn Trent) of large power stations in the Humber catchment and others are planned. Three of these power stations are either having FGD fitted or it is intended they will have FGD fitted. This process will remove large quantities of metal from the power stations' atmospheric emissions. Standards are being set for the stations' effluent discharges so that the Humber EQSs are not exceeded.

v) In the Yorkshire part of the system the UWWT Directive will require the provision of two stage sewage treatment or its equivalent at Goole and Hull. Secondary treatment will have to be added to the sewage works at Hedon, Selby and Thorne. There will be no nutrient removal at these works but the new treatment at Goole, Selby and Thorne and consequent reductions on BOD load will help alleviate the low dissolved oxygen problem at Trent Falls. The provision of treatment at Hull will have no significant effect on dissolved oxygen levels in the estuary.

vi) Consent conditions are being tightened to reduce the organic load discharged from industry to the Ouse at Selby. B P Chemicals Limited at Saltend also have a programme of work to reduce their aqueous discharges.

vii) Much work is programmed to restore the quality of the rivers Aire, Calder, Don and Rother and their tributaries, which will also benefit the Humber system. Major improvements are in progress in a phased manner for the sewage treatment works serving Bradford, Chesterfield, Huddersfield, Leeds and Sheffield. Much of this work will come to fruition with improved water quality in the mid 1990s after the investment of well over £100m.

9.7 Humber Barrage

A tidal barrage across the Humber in the vicinity of Hull has been discussed for a number of years. The main benefits of the scheme are claimed to be improved road communication between the north and south bank and the generation of hydro-electric power. The disadvantages would be the loss of inter-tidal mud flats and restricted navigation upstream of the barrage.

A Humber Barrage Group has been set up by the Local Authorities on Humberside. However, the initial conclusions of the group are that a barrage would only just be economically viable and that there are more cost effective tidal power schemes elsewhere. It is therefore unlikely that the Humber Barrage will be a priority in the near future. The maximum tidal range in the Humber (ie, the difference in level between high and low water) on spring tides is 7m. Whilst high for the North Sea this is less than half the tidal range of the Severn Estuary.

There is a tidal power generation scheme in the Rance Estuary on the North Brittany coast, but the tidal range there is similar to that of the Severn.

If a tidal barrage was constructed in the Humber there would be significant changes within the estuary. Upstream of the barrage the tidal range would be reduced leading to increased siltation in the main channels, some loss of inter-tidal mud flats (which are important feeding grounds for certain species of bird) and a less saline water quality regime, resulting in ecological changes. Downstream of the barrage there would be fewer changes, although there may be some minor changes to the tidal regime. The impact of any proposed barrage on the dilution, dispersion and assimilation of effluent discharges would have to be examined in detail so that water quality standards in the Humber would not be jeopardised.

9.8 Conclusion

The National Rivers Authority has inherited the basis of a comprehensive programme of water quality monitoring and management in the Humber and its tidal rivers. A strategy is being implemented to achieve the Humber Estuary Committee's quality standards throughout the system. Changes in legislation, including Statutory Water Quality Objectives and Integrated Pollution Control, plus resources to protect the environmental quality of the North Sea, will further underpin the work on the estuary. The National Rivers Authority is committed to protecting and enhancing the quality of the Humber and the uses made of its estuarine ecosystem.

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11. GLOSSARY

ADSORPTION
the process by which one substance is taken up and held on the surface of a material, for example, metals in seaweeds.

AMMONIACAL NITROGEN
ammonia is a compound commonly found in sewage effluents, and its concentration expressed as nitrogen, is widely used to characterise water quality.

AMPHIPOD
small shrimp-like crustacean

ANADROMOUS
migrating from salt to freshwater, as in the case of a fish moving from the sea into a river to spawn (for example, salmon).

ANAEROBIC
containing no oxygen.

BENTHIC
referring to life in or on the sea floor.

BIOACCUMULATION
mechanism whereby organisms concentrate substances present in dilute concentration in sea or freshwater.

BIOCHEMICAL OXYGEN DEMAND (BOD)
a standard test measuring the uptake of dissolved oxygen in water by the microbial decomposition of organic matter.

BIODEGRADABLE
capable of being broken down by bacteria into harmless substances such as carbon dioxide and water.

CARBONACEOUS OXIDATION
the bacterial decomposition of organic matter by the process of converting the carbon content into carbon dioxide; a process which uses up dissolved oxygen.

CATADROMOUS
migrating from fresh to sea water, as in the case of a fish moving from a river to the sea to spawn. (for example, eel).

CATCHMENT
the area of land which drains into a particular river system.

DEMERSAL
living at or near the sea bottom but having the ability to actively swim.

DEOXYGENATION
the removal of dissolved oxygen from water, often by the bacterial oxidation of organic matter such as sewage.

DISSOLVED OXYGEN
the amount of oxygen dissolved in water, which is an indication of the 'health' of the water and its ability to support a balanced aquatic system.

ENVIRONMENTAL QUALITY STANDARD (EQS)
a specific concentration limit for a particular substance which affects a particular water use or objective.

EPIBENTHIC
living near or on the sea bottom.

EUTROPHICATION
the increase in nutrients in a body of water, which may lead to extensive algal and weed growth, with undesirable consequences.

FAECAL BACTERIA
a group of bacteria found in faeces.

HYDROCARBONS
compounds of carbon and hydrogen such as those contained in petroleum products. (for example, oil)

INTERTIDAL
refers to the region of the shore that lies between the highest and lowest tides.

INVERTEBRATE
animal without a backbone.

MATHEMATICAL WATER QUALITY MODEL
the representation of the physical, chemical and sometimes biological processes influencing water quality by equations which, when solved by computer enable simulations to be made of the level of a particular quality parameter, for example, dissolved oxygen, in the estuary in response to relevant variables such as river flow, tidal state, effluent input and temperature.

MIGRATORY FISH
refers to certain species of fish which move from one habitat or location to another, seasonally.

MYSID
small free swimming crustacean of the order Mysidacea.

NITRIFICATION
the bacterial oxidation of ammonia to nitrate, a process which uses dissolved oxygen.

OLIGOCHAETE
segmented worms related to the common earthworm.

ORGANIC COMPLEX
a compound formed between, for example, a metal ion and an organic substance such as protein.

PHOTOSYNTHESIS
a process requiring sunlight, in which plants transform carbon dioxide and water into oxygen and plant material.

PLANKTON
microscopic drifting organisms in water, which can include the egg and larval stages of some species of fish.

POLYCHAETE
segmented bristle worms of the class Polychaeta.

RECRUITMENT
the influx of new members into a population by reproduction or immigration.

SALINITY
the extent to which salts are dissolved in water.

SHOAL
shallow stretch of water.

SUBTIDAL
the area which lies below the low water mark which is continuously covered by water.

SUPERSATURATED
the situation when the apparent concentration of oxygen dissolved in water exceeds the saturation value, due to the evolution of oxygen within the water by photosynthesis.

SUSPENDED SOLIDS
solid matter in a water sample which is retained by filtration under specified conditions.

TIDAL RANGE
the difference between high and low water levels.

APPENDIX A
TERMS OF REFERENCE AND OBJECTIVES OF THE HUMBER ESTUARY COMMITTEE

Humber Committee terms of reference

To advise the constituent National Rivers Authority Regions and other bodies on matters appertaining to their functions relating to the restoration and maintenance of the wholesomeness of the rivers and other waters in the Humber Estuary, and to act as a co-ordinating link between constituent Regions on matters relating to the management of the estuary with particular reference to the objectives laid down for the committee.

Humber Committee objectives

To consider matters concerned with the control, management and use of the Humber estuary of relevance to the constituent National Rivers Authority Regions, and in particular:-

(1) to restore and maintain the wholesomeness of water in the estuary and to reduce pollution. In particular to restore the wholesomeness of all tributaries and their tidal reaches and to control areas of local pollution east of the Humber Bridge;

(2) to consider the quality and quantity of the residual flows to the estuary which it is desirable to maintain at the various tidal limits under varying conditions and at different times of the year;

(3) to undertake a programme to survey and monitor flows and quality conditions in the estuary;

(4) to monitor and assess the effects of toxic materials carried from the Humber Estuary to the North Sea;

(5) to maintain, improve and develop the indigenous fisheries in the estuary and to allow the passage of migratory fish by improving the quality conditions in the estuary;

(6) to initiate, co-ordinate and undertake appropriate research on the Humber Tidal System;

(7) to further conservation, in accordance with section 8 of the Water Act 1989, of the flora and fauna, and the geographical physiographical and archaeological features of special interest in, and adjacent to, the estuary;

(8) to advise on matters in and adjacent to the estuary, such as flood defence, amenity and future development, where these impact on water quality management.

APPENDIX B
NWC RIVER QUALITY CLASSIFICATION SCHEME

RIVER CLASS	QUALITY CRITERIA	REMARKS	CURRENT POTENTIAL USES
1a Good Quality	1. 5 percentile Dissolved Oxygen Saturation greater than 80%. 2. 95 percentile Biochemical Oxygen Demand not greater than 3 mg/l. 3. 95 percentile Ammonia not greater than 0.4 mg/l. 4. Where the water is abstracted for drinking water, it complies with requirements for A2*. 5. Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures are unavailable).	1. Mean Biochemical Oxygen Demand probably not greater than 1.5 mg/l No visible evidence of pollution.	1. Water of high quality suitable for potable supply abstractions. 2. Game or other high quality fisheries. 3. High amenity value.
1b Good Quality	1. 5 percentile Dissolved Oxygen Saturation greater than 60%. 2. 95 percentile Biochemical Oxygen Demand not greater than 5 mg/l. 3. 95 percentile Ammonia not greater than 0.9 mg/l. 4. Where water is abstracted for drinking water it complies with the requirements for A2*. 5. Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures are unavailable).	1. Mean Biochemical Oxygen Demand probably not greater than 2 mg/l. 2. Mean Ammonia probably not greater than 0.5mg/l. 3. No visible evidence of pollution. 4. Water of high quality which cannot be placed in Class 1a because of the effect of physical factors such as canalisation, low gradient or eutrophication.	Water of less high quality than Class 1a but usable for substantially the same purposes.
2 Fair Quality	1. 5 percentile Dissolved Oxygen Saturation greater than 40%. 2. 95 percentile Biochemical Oxygen Demand not greater than 9 mg/l. 3. Where water is abstracted for drinking water it complies with the requirements for A3*. 4. Non toxic to fish in EIFAC terms (or best estimates if EIFAC figures are unavailable).	1. Mean Biochemical Oxygen Demand probably not greater than 5 mg/l. 2. Water showing no physical signs of pollution other than humic colouration and a little foaming below weirs.	1. Waters suitable for potable supply after advanced treatment. 2. Supporting reasonably good coarse fisheries. 3. Moderate amenity value.
3 Poor Quality	1. 5 percentile Dissolved Oxygen Saturation greater than 10%. 2. 95 percentile Biochemical Oxygen Demand not greater than 17 mg/l. This may not apply if there is a high degree of re-aeration.		Waters which are polluted to an extent that fish are absent or only sporadically present. May be used for a low grade abstraction for industry. Considerable potential for further use if cleaned up.
4 Bad Quality	Waters which are inferior to Class 3 in terms of Dissolved Oxygen and likely to be anaerobic at times.		Waters which are grossly polluted and are likely to cause nuisance.
X	DO greater than 10% saturation.		Insignificant watercourses and ditches which are not usable, where the object is simply to prevent nuisance.

* *see note (e) overleaf*

NOTES ON THE RIVER QUALITY CLASSIFICATION SCHEME

NOTES:

a) Under extreme weather conditions (eg, flood, drought, freeze-up), or when rivers are dominated by plant growth, or by the decay of aquatic plants, rivers usually in Class 1, 2 and 3 may have levels of Biochemical Oxygen Demand and Dissolved Oxygen, or Ammonia outside the stated levels for those classes. When this occurs the cause should be stated alongside the analytical results.

b) The Biochemical Oxygen Demand refers to the 5-day carbonaceous determination performed in the presence of Allylthiourea (ATU). Ammonia is expressed as the Ammonium Ion, $NH4^+$.

c) In most instances the chemical classification given above will be suitable. However, the basis of the classification is restricted to a finite number of chemical determinands and there may be a few cases where the presence of a chemical substance other than those used in the classification markedly reduces the quality of the water. In such cases, the quality classification of the water should be downgraded on the basis of biota actually present, and the reasons stated.

d) EIFAC, the standards set up to protect freshwater fisheries by the European Inland Fisheries Advisory Commission, should be expressed as 95-percentiles.

e) The definition and the requirements of A2 and A3 are those specified in the Directive on the Quality of Water Intended for Abstraction for Drinking Water.

APPENDIX C
NWC SCHEME FOR CLASSIFYING ESTUARIES

DESCRIPTION		Points Awarded if the estuary meets this description
Biological Quality (scores under a, b, c and d to be summed)		
a)	Allows the passage to and from freshwater of all relevant species of migratory fish, when this is not prevented by physical barriers.	2
b)	Supports a residential fish population which is broadly consistent with the physical and hydrographical conditions.	2
c)	Supports a benthic community which is broadly consistent with the physical and hydrographical conditions.	2
d)	Absence of substantially elevated levels in the biota of persistent toxic or tainting substances from whatever source.	4
Maximum number of points		10
Aesthetic Quality		
a)	Estuaries or zones of estuaries that either do not receive a significant polluting input or which receive inputs that do not cause significant aesthetic pollution.	10
b)	Estuaries or zones of estuaries which receive inputs which cause a certain amount of pollution but do not seriously interfere with estuary usage.	6
c)	Estuaries or zones of estuaries which receive inputs which result in aesthetic pollution sufficiently serious to affect estuary usage.	3
d)	Estuaries or zones of estuaries which receive inputs which cause widespread public nuisance.	0
Water Quality (Score according to quality)		
Dissolved Oxygen exceeds the following saturation values:		
	60%	10
	40%	6
	30%	5
	20%	4
	10%	3
	below 10%	0

The points awarded under each of the headings of biological, aesthetic and water quality are summed. Waters are classified on the following scales.

Class A	Good Quality	24 to 30 points
Class B	Fair Quality	16 to 23 points
Class C	Poor Quality	9 to 15 points
Class D	Bad Quality	0 to 8 points

APPENDIX D
EC DANGEROUS SUBSTANCES DIRECTIVE LIST 1 AND LIST 2

LIST 1 (BLACK LIST)

Mercury
Cadmium
Hexachlorocyclohexane (HCH)
DDT
Pentachlorophenol (PCP)
Carbon Tetrachloride
Aldrin
Dieldrin
Endrin
Isodrin
Hexachlorobenzene (HCB)
Chloroform
Trichloroethylene (TRI)
Tetrachloroethylene (PER)
Trichlorobenzene (TCB)

LIST 2 (GREY LIST)

1,2-Dichloroethane (EDC)
Lead
Chromium
Zinc
Copper
Nickel
Arsenic
Boron
Iron
pH
Vanadium
Tributyltin
Triphenyltin
PCSDs
Cyfluthrin
Sulcofuron
Flucofuron
Permethrin

APPENDIX E
List of EPA (1990) Prescribed Substances for release into water.

1. Mercury and its compounds.
2. Cadmium and its compounds.
3. Hexachlorocyclohexane (all isomers).
4. DDT (all isomers).
5. Pentachlorophenol and its compounds.
6. Hexachlorobenzene.
7. Hexachlorobutadiene
8. Aldrin.
9. Dieldrin.
10. Endrin.
11. PCBs.
12. Dichlorvos
13. 1,2 - Dichloroethane.
14. Trichlorobenzene (all isomers).
15. Atrazine.
16. Simazine.
17. Tributyl tin compounds.
18. Triphenyl tin compounds.
19. Trifluralin.
20. Fenitrothion.
21. Azinphos-methyl.
22. Malathion.
23. Endosulphan.

APPENDIX F
FISH SPECIES RECORDED FROM THE HUMBER TIDAL SYSTEM

COMMON NAME	SCIENTIFIC NAME	TYPE	OUSE	WHARFE	AIRE	DON	TRENT	HULL	HUMBER
Allis Shad	Alosa alosa	FW					+		
Barbel	Barbus barbus	FW	+	+			+		+
Bleak	Alburnus alburnus	FW	+				+		+
Bream	Abramis brama	FW	+	+			+	+	
Brown Trout	Salmo trutta fario	FW					+		
Bullhead	Cottus gobio	FW					+		
Carp	Cyrprinus carpio	FW					+		+
Chub	Leuciscus cephalus	FW	+	+			+		+
Crucian Carp	Carassius carassius	FW					+		
Dace	Leuciscus leuciscus	FW	+	+			+	+	
Gudgeon	Gobio gobio	FW	+	+			+	+	
Minnow	Phoxinus phoxinus	FW					+		
Perch	Perca fluviatilis	FW	+	+			+	+	
Pike	Esox lucius	FW	+	+		+	+	+	+
Rainbow Trout	Salmo gairdneri	FW					+		
Roach	Rutilus rutilus	FW	+	+	+	+	+	+	+
Rudd	Scardinius erythropthalmus	FW				+	+		
Ruffe	Gymnocephalus cernua	FW					+		
Silver Bream	Blicca bjoerkna	FW					+		+
Spined Loach	Cobitis taenia	FW					+		
Stickleback (3 spined)	Gasterosteus aculeatus	FW		+	+		+		
Stickleback (10 spined)	Pungitius pungitius	FW					+		
Stoneloach	Noemacheilus barbatulus	FW			+		+	+	
Tench	Tinca tinca	FW					+		+
Twaite Shad	Alosa fallux	FW					+		
Eel	Anguilla anguilla	CA	+	+		+	+	+	+
River Lamprey	Lampetra fluviatilis	CA					+		+
Salmon	Salmo salar	CA	+	+			+	+	+
Sea Lamprey	Petromyzon marinus	CA					+		+
Sea Trout	Salmo trutta	CA					+	+	
Smelt	Osmerus eperlanus	CA	+				+		+
Flounder	Platichthys flesus	ER/CA	+				+	+	+
Great Pipefish	Syngnathus acus	ER							+
Father Lasher	Myoxocephalus scorpius	ER							+
Nilsson's Pipefish	Syngnathus rostellatus	ER							+
Pogge	Agonus cataphractus	ER							+

COMMON NAME	SCIENTIFIC NAME	TYPE	OUSE	WHARFE	AIRE	DON	TRENT	HULL	HUMBER
Sand Eel	Ammondytes tobionus	ER							+
Sand Goby	Pomatochistus minutus	ER					+		+
Sea Snail	Liparis liparis	ER							+
Viviparous Blenny	Zoarces viviparus	ER							+
Five Bearded Rocking	Ciliata mustela	ER/MA							+
Long rough Dab	Hippoglossoides platessoides	ER/MA							+
Bufferfish	Pholis gunnellus	ER/MS							+
Common Goby	Pomatochistus microps	ER/MA							+
Dover Sole	Solea solea	ER/MA MJ							+
Bib	Trisopterus luscus	MJ							+
Dab	Limanda limanda	MJ							+
Plaice	Pleuronectes platessa	MJ							+
Tope	Galeorhinus galeus	MJ							+
Whiting	Merlangius merlangus	MJ					+		+
Brill	Scophtholmus rhombus	MJ/MA							+
Cod	Godus morhua	MJ/MA							+
Turbot	Scophthalmus maximus	MJ.MA							+
Conger Eel	Conger conger	MA							+
Dogfish	Scyliorhinus sp	MA							+
Dragonet	Callionymus lyra	MA							+
Haddock	Melanogrammus aeglefinus	MA							+
Halibut	Hippoglossus hippoglossus	MA							+
Lemon Sole	Microstomus kitt	MA							+
Lesser Weever	Echiichthys vipera	MA							+
Mackerel	Scomber scomber	MA							+
Painted goby	Pomatochistus pictus	MA							+
Pollack	Pollachius virens	MA							+
Roker	Raja clavata	MA							+
Sand Eel	Ammondytes marinus	MA							+
Scaldfish	Arnoglussus laterna	MA							+
Sea Scorpion	Taurulus bubalis	MA							+
Skipper	Scomberesox saurus	MA							+
Solenette	Buglossidium luteum	MA							+
Spotted Ray	Raja montagui	MA							+
Bass	Dicentrarchus labrax	MA/MS							+
Greater Sand Eel	Hyperoplus lanceolatus	MS							+
Grey Gurnard	Eutriglia gurnardus	MS							+

COMMON NAME	SCIENTIFIC NAME	TYPE	OUSE	WHARFE	AIRE	DON	TRENT	HULL	HUMBER
Herring	*Clupea harengus*	MS					+		+
Sprat	*Sprattus sprattus*	MS					+		+
Thick lipped Mullet	*Crenimugil labrosus*	MS							+
Total			13	13	2	4	36	10	58

Total number of species = 76

* Type refers to ecological category of fish ie

FW = Freshwater
CA = Diadromous migrant
ER = Estuarine resident
MJ = Marine juvenile
MA = Marine adventitous
MS = Marine seasonal

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