QUALITY STATUS REPORT OF THE NORTH SEA 1993

REPORT ON SUB-REGION 5

DENMARK AND GERMANY

Data Sheet

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Abstract:
Subregion 5 is situated in the south-eastern part of the North Sea. The area considered has an area of 32.000 km^2 and a volume of about 700 km^3. The region is strongly influenced by the discharge of the river Elbe. Pollution from other parts of the North Sea can be transported into subregion 5 by the currents. It is therefore obvious that elevated levels of nutrients and contaminants might occur in this area.
The area is an important spawning area for sole, herring and flatfish species. Blooms of different algae species such as Phaeocystis sp. are common. Occasionally since 1980 oxygen deficiency has been found in near-bottom water in summer in some areas of the subregion. During the eighties the benthos have been affected by both oxygen deficiency and increased food access. The most likely cause is eutrophication.

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PREFACE

In 1987, the Second Ministerial Conference on the protection of the North Sea requested the International Council for the Exploration of the Sea (ICES) and the Oslo and Paris Commissions (OSPARCOM) to establish a task force which should have the following objective:

"To carry out work leading, in a reasonable time-scale, to a dependable and comprehensive statement of circulation patterns, inputs and dispersion of contaminants, ecological conditions and effects of human activities in the North Sea."

An holistic assesment of the whole of the North Sea has been prepared based among others on 13 separate sub-regional assessments.

This report concerns the North Sea Task Force (NSTF) subregion 5, which represent the south-eastern part of the North Sea. The report is prepared in coorporation between Germany and Denmark with Denmark as lead country.

A large number of authors from various authorities and institutes in Germany and Denmark have contributed to the report.

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1. GENERAL DESCRIPTION OF THE NORTH SEA

1.1 PHYSICAL GEOGRAPHY

Subregion 5 is situated in the south-eastern part of the North Sea. The area considered in subregion 5 encompasses the area south of latitude 57°N, and east of 7°E and has an approximate area of 32,000 km^2 and a volume of about 700 km^3.

The region accordingly constitutes only a minor part of the North Sea (approximately 4 % by area, and less the 1 % by volume). The Wadden Sea is not included although it may comprise restricted sublittoral areas (Figure 1.1). The only coast line of subregion 5 is therefore the west coast of Jutland in Denmark.

A north going stream has built the straight coastline nearly closing the fiords and estuaries by transported materials. The coast is lowland exposed with high energy waves but to some degree protected by the sand banks. The coast is characterised by cliffs and dunes. Like the entire North Sea subregion 5 is resting on the shelf and has a widespread sandbottom, covering also the many elongated banks of moraine clay.

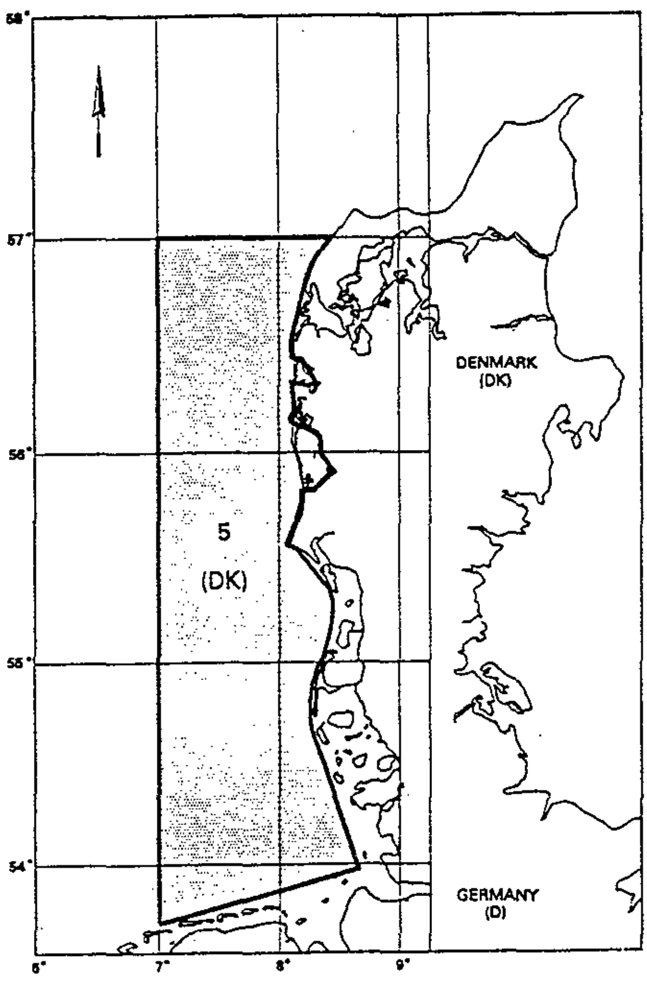

Figure 1.1. The geographical position of NSTF Subregion 5.

The area has a coastal climate with a January mid temperature of 0-4 °C, and a July mid temperature of 12-16 °C.

Four larger rivers are flowing into the North Sea in the southern part of sub-region 5: Elbe, Weser, Ems and Eider. The ratio between the discharge volumes of the Elbe, Weser, Ems and Eider is about 20:9:2½:1 (see Table 1.1).

The total discharge volume to subregion 5 from the Danish part of the catchment area has been estimated as an average for 1981-1990 to $5.36*10^9$ m^3 or about 2/3 of the discharge volume from the river Weser.

The river Elbe (Figure 1.2) is a major source of riverine inputs to the North Sea. The river drains highly industrialized regions in the Czech and Slovakian Republics and the eastern part of the Federal Republic of Germany. Sometimes some parameters are added in Hamburg and from industrial plants located downstream. Since the German unification the contaminant load of the Elbe has been reduced, mainly as a result of the closing down of factories. The recently signed Treaty for the sanitation of the Elbe will most probably have a further positive effect on the reduction of contaminant and nutrient loads.

The rivers Ems and Weser are also polluted by domestic sewage and industrial discharges and contribute to the input of harmful substances into the North Sea.

The river Eider, draining mainly agricultural areas, is only insignificantly subjected to industrial and municipal effluents for the whole length of its course.

The Danish part of the catchment area of subregion 5 (Figure 1.3) is situated to the west of the great moraine embankment border from the latest Glacial Age, which also created the 40 m Bovbjerg cliff at the coast. A number of small watercourses drains agriculture areas with only minor outlets from industry, municipalities and aquaculture.

1.2 DEMOGRAPHY

Subregion 5 is a centre of vigorous commercial activity involving the exploitation of biological and mineral resources, the transport of people and goods, infrastructures and the various means of recreation.

The Catchment area of the river Elbe has a very dense population with several million people. The catchment area includes large cities as Hamburg, Berlin, Dresden and Prague.

In Denmark, on the other hand, the catchment area of subregion 5 constitutes the most sparsely populated part of the country. The largest city is Esbjerg with an important harbour and almost 50,000 inhabitants. With the exception of 9-10 minor towns the rest of the area is rural country. However, during the summertime, this part of Denmark is invaded by tourists thus multiplying the population several times.

Table 1.1. Length, catchment area and water volume of the rivers Eider, Ems, Weser, Elbe and the Danish area.

	Length km	Catchment area km^2	Water volume 10^9 m^3/year
Eider*	110	2075	0,83
Ems	370	12672	2,10
Weser	432	46136	7,50
Elbe	1100**	148268**	16,40
DK-area	-	10888	5,36***

* oral communication from Wasser- u. Schiffahrtsamt, Tönning (Waterways and Shipping Office). ** oral communication from the Arbeitsgemeinschaft für die Reinhaltung der Elbe (ARGE ELBE) (Commission for Pollution Control in the river Elbe). *** 1981-1990 data (Danish Environmental Research Institute, 1992).

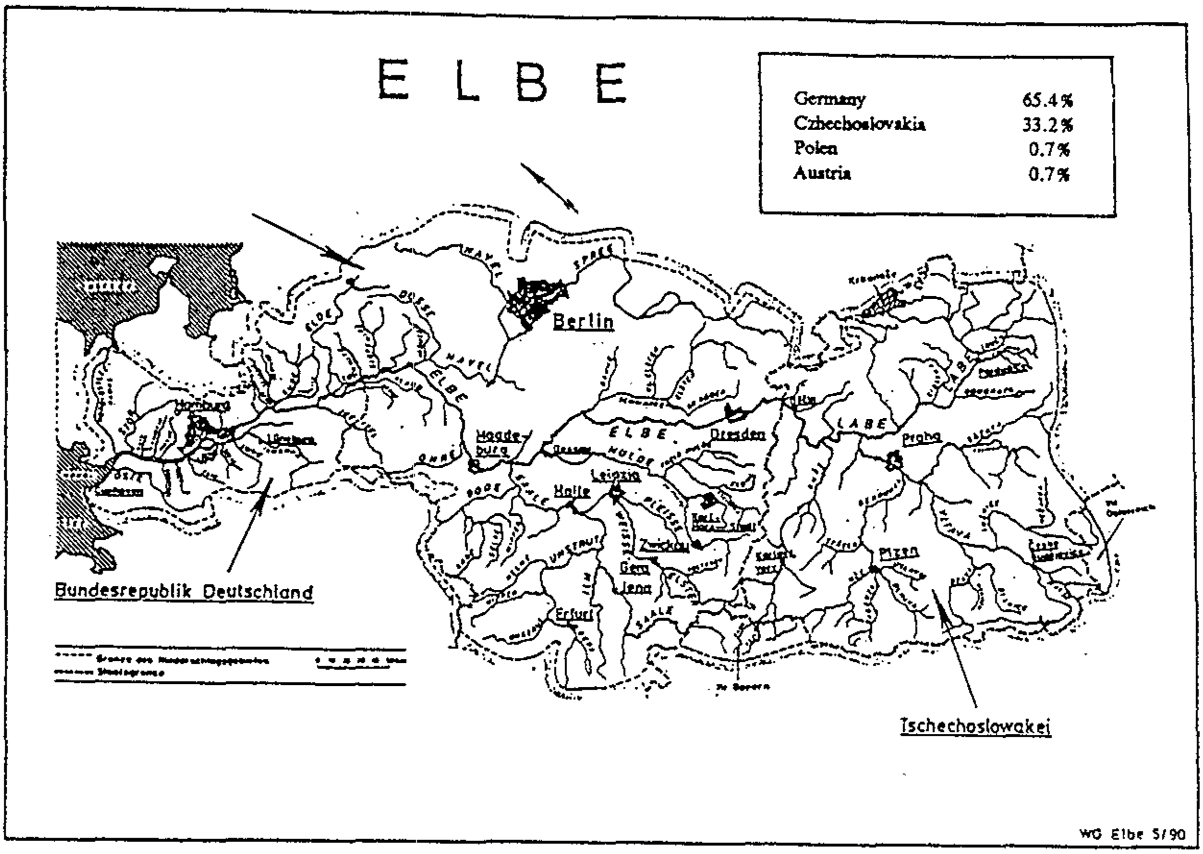

Figure 1.2. The river Elbe catchment area (148 268 km^2)

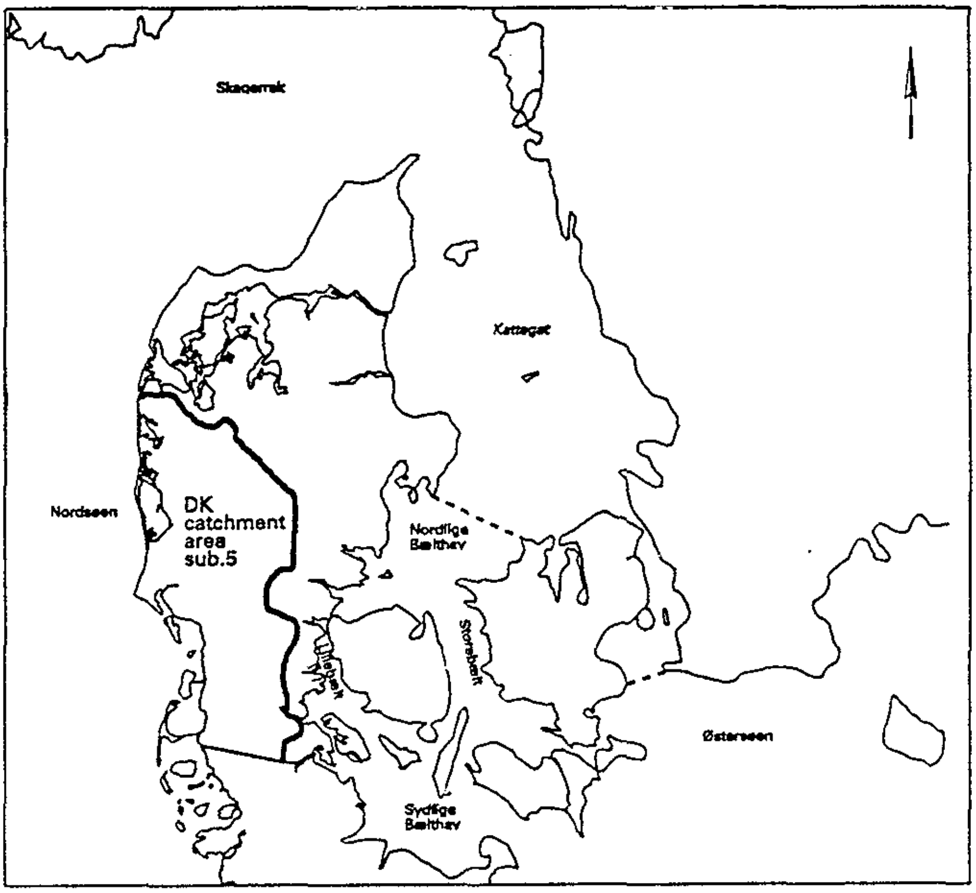

Figure 1.3. Danish catchment area of subregion 5.

1.3 USES AND FUNCTIONS OF THE NORTH SEA

1.3.1 Fishery

NSTF subregion 5 is highly productive. It is not surprising, therefore, that fishing is an important feature of the region providing a significant and renewable economic resource.

Five of the major Danish fishing ports are situated along the west coast of Jutland, in NSTF subregion 5. These harbours serve as home bases for a large number of fishing vessels. Ranging from some of the biggest trawlers in Denmark, typically fishing outside NSTF subregion 5, to the small boats less than 5 GRT. These small boats are not registreted and are therefore not included in the official statistics. The harbours may also serve as operating ports for a large number of vessels from other regions of Denmark. This is the case during the sole-fishing season from April to June.

The 783 fishing vessels registered in the harbours along the west coast of Jutland, do therefore not as such give any realistic figure for the fishing effort in the region.

A more precise indication on the fishing effort and catches from NSTF subregion 5, might be provided from the logbooks. The logbook is a formula to be completed by the fisherman during the fishing journey. It holds information on the vessel, the fishing operations and the amount of fish landed by species. Vessels with an overall length less than 12 meter are exempted from the logbook obligation. Meaning that neither the logbooks will give a complete coverage of the effort and catches in this coastal area.

Table 1.2 and 1.3 gives the aggregated logbook information from registered vessels fishing in the NSTF subregion 5, 1992. Mussels, cockles and common prawns are not included as they are mainly taken in the Wadden Sea (NSTF subregion 10).

Table 1.2 indicates that the majority of the vessels are between 12 and 20 meter, and that the largest part of the catches are taken by industrial trawlers (20-25 meter). The industrial fishery is mainly a fishery targeted for sand eel and sprat. The latter is known to have an important by-catch of herring. The sprat fishery takes place in july, august and september in the southern part of subregion 5. There are some very important fishing grounds for sand eel along the west coast of Jutland. The sand eel season is from April to August, with the major part of the catches taken in May.

Table 1.3 gives the catches in tons for some of the major species by gear type and by vessel group greater than or less than 20 meter in overall length. It can be seen that Cod, plaice and sole are mainly taken by gill-net. Though there's also an important fishery for plaice with Danish-seine and trawls in the northern part of subregion 5.

Table 1.2. Logbook informations from Danish fishing vessels fishing east of 7° N and south of 57° E, 1992. Vessel length group by overall length in meter. Catch in tons.

Length group by overall length in meter	(**) Number of vessels	Total Catch t	Cod t	European Hake t	Other Cod fishes t	Plaice t	Sole t	Turbot t	Other Flatfish t	Herring t	Industrial fish t	(*) Other t
- 12,00	32	636	75	8	3	150	16	6	1	0	373	4
12,01 - 16,00	256	19017	1705	291	76	2599	352	99	55	44	13629	167
16,01 - 20,00	213	25302	985	165	103	1724	134	67	53	17	21926	129
20,01 - 24,00	82	45788	316	64	30	530	53	9	15	57	44658	57
24,01 - 28,00	36	20116	91	22	16	324	12	10	11	105	19514	11
28,00 - 32,00	40	17335	14	7	7	170	0	2	1	190	16922	23
32,01 - 36,00	42	20332	17	7	15	193	0	3	3	15	20051	28
36,01 -	35	14161	29	0	4	392	0	8	4	40	13667	17
All	736	162687	3231	563	253	6081	568	204	143	469	150740	436

(*) Not including mussels and common prawn as they are mainly taken in the Wadden Sea.

(**) Registrated in the area during the year.
These vessels will also be fishing in other areas.

Table 1.3. Logbook information from Danish Fishing vessels fishing east of 7° N and south of 57° E, 1992. Gear type used by vessels ≥ or < than 20 meter in overall length. Catch in tons.

Gear + length group	Number of vessels + geartype	Total catch t	Cod t	European Hake t	Other Cod fishes t	Plaice t	Sole t	Turbot t	Other flat fish t	Herring t	Industrial fish t	(*) other t
Trawl lgt < 20	152	36965	360	8	29	803	18	3	26	60	35594	64
Trawl lgt >=20	201	115504	193	17	61	1078	5	17	23	407	113602	101
Danish lgt < 20	122	1996	446	16	25	1346	5	0	63	0	15	78
- Seine lgt >= 20	7	141	19	4	2	101	0	0	6	0	0	9
Gill net lgt < 20	262	5518	1894	438	123	2188	467	170	17	1	70	150
Gill net lgt > 20	28	705	246	78	7	276	60	12	5	0	1	20
Other	118	1858	72	1	5	289	13	3	3	0	1458	14
Total	(1) 890	162687	3231	563	253	6081	568	204	143	469	150740	436

(*) Not including mussels and common prawn as they are mainly taken in the Wadden Sea.

(1) Some vessels use two or more different types of gear.

The gill-net fishery for plaice and sole is a very seasonal fishery, the fish is caught from April to October by small vessels (less than 20 meters) that are operating in the near coastal region. This pattern is defined by the spawning season of the sole.

The total Danish catches from NSTF subregion 5, 1992 were according to the logbook information approximately 163 thousand t (12% of the total Danish catches from the North Sea).

In the period 1988-1992 only 12-17% of the total landings were representing fish for consummation (table 1.4.)

In Denmark the 3 main commercial target species for consummation are cod, plaice and herring. Calculated in total catch mackerel is being caught to the same extent as plaice but represents only about one fourth of its value.

The importance of NSTF subregion 5 for the German cutter fleet is shown in table 1.5, giving the landing of the 3 main commercial target species Cod, Plaice and Sole.

1.3.2 Tourism

The tourists in the western part of Jutland give their top priority to a clean beach and sea. In this area tourism has taken over from commercial fishing the position as the economically most important industry, and the amount of tourists per year seems to be still growing.

The number of overnight stays in the catchment area (roughly) of the Danish part of Subregion 5 was in 1989, 1990 and 1991 respectively 6.557.076, 7.435.790 and 9.617.007 (Danmarks Turistråd, unpublished data).

Table 1.4. *Danish cutter fleet landings from the North Sea in the period 1988-1992 (Danish Ministry of Fishery 1992).*

	1988 (t)	1989 (t)	1990 (t)	1991 (t)	1992 (t)
Cod	24.678	18.416	16.521	15.341	14.656
Plaice	18.433	21.699	24.310	22.569	18.610
Herring	60.620	69.863	62.049	68.357	66.622
Sole	400	724	1.022	1.042	1.295
Consummation (total)	151.890	151.306	147.784	155.111	152.072
Industry * (total)	1.151.832	1.236.824	833.474	1.063.202	1.186.427
Consummation and Industry	1.303.722	1.388.130	981.258	1.218.313	1.338.499

*Includes small amounts of rejected fish for consummation.

Table 1.5. *German cutter fleet landings from the North Sea in 1989 and 1990. (Ehrich, 1992)*

Species	Landings from the North Sea 1989 (Total) t	Landings from Subregion 5, 1989 t	Landings from Subregion 5, 1989 % of total	Landings from the North Sea 1990 (Total) t	Landings from Subregion 5 1990 t	Landings from Subregion 5 1990 %
Cod	10.548	7.097	67	8.359	4.869	58
Plaice	5.137	1.514	29	7.235	2.692	37
Sole	612	385	63	1.326	1.003	76

1.3.3 *Shipping*

At the west coast of Jutland Esbjerg is the dominating port in respect to commercial as well as a fishery harbour. Rømø, Hvide Sande, Thorsminde, and Thyborøn each has a fishery harbour. 3,3 mill. tons of goods are shipped and 3000 vessels of 8,9 mill. gross register tonnage in total call at the commercial harbour of Esbjerg annually (1990).

The transport of oil and hazardous substances is in the German Bight and through the Wadden Sea is intense. About 70-80 million tons of cargo, mainly crude oil are transported annually in the shipping lane Terschellingen-Elbe and the Deep Water Route. The Terschellingen-Elbe route passes north of the islands at a distance of about 6 miles. The Deep Water Route passes at a minimum distance of 32 miles with an average shipment of about 200,000 tons per day. This route is one of the largest shipping routes in the world in terms of ship movements and transport quantities.

1.3.4 *Offshore industries*

One oil and one gas pipeline transport the combined production from all Danish oil and gas fields to Denmark, across subregion 5. In 1990, 6 millions tons of oil and 5.1 millions m^3 of gas was transported by pipelines. Main pipelines had a total length of 450 km (Danish Statistical Office, 1992). The number of platforms in production was 30.

Pipelines in the German Bight yearly transport 270.000 t of oil from Mittelplate and 80 mill. m^3 of gas from the Emshörn field. Totally 3 platforms were in production and the length of major pipelines was estimated to be around 300 km.

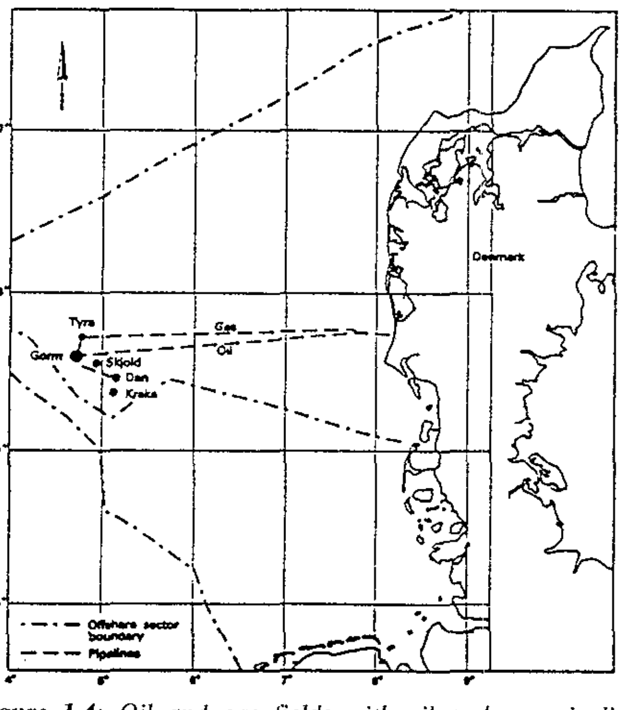

Figure 1.4: Oil and gas fields with oil and gas pipelines across subregion 5 to Denmark.

1.3.5 *Harbours and riparian industries*

The Danish part of the region 5 coastline has two main industrial centres, one big chemical plant (Cheminova) at Harboøre Tange by the mouth of the Limfjord producing esp. pesticides, and the industry located in Esbjerg. The industries of Esbjerg are small or medium sized and encompass the production of fish pulp and -oil, food, pesticides, and medicine.

As a result of the activities of the Danish off-shore industry, service factories have been established regarding surface treatment and metal construction. Chemicals for the off-shore industry are stored in Esbjerg as well. An additional boiler will be working from 1992 at the coal fired power plant.

The coast line of northern Germany is bordering to the Wadden Sea (sub region 10) and as a consequence the riparian industries of northern Germany is included in the report on the Wadden Sea.

1.3.6 *Dredging, sand and gravel extraction*

Dredging takes place at several localities along the west coast of Jutland. The dredging has increased during the eighties, and this increase is expected to continue for the next years. In addition to the proper dredging, sand is produced by the maintenance dredging in the fairways to the harbours Thorsminde and Hvide Sande. The dredging is carried out for the Danish Coast Authority, and Table 1.6 is based on information collected by this authority. The production of sand, gravel and aggregates for building- and construction takes place at Horns Rev located west off Blåvands Huk. The dredged material is transported to Esbjerg (and to minor extent to Hamburg). Table 1.7 is based on reports from Denmark's Geological Survey for the years 1981-1989 while information on dredged materials in 1990 and 1991 is based on information collected by the Danish Forest- and Nature Agency.

Table 1.6. Sand produced by maintenance dredging. All amounts are sand and are given as 1000 m^3 (Danish Coast Authority).

Year	1983	1984	1985	1986	1987	1988	1989	1990	1991
North Sea	204	32	121	228	295	539	473	661	1390
Thorsminde Harbour	1	38	56	32	111	90	130	195	97
Hvidesande Harbour	53	65	75	45	107	120	243	286	128
Total	258	135	252	305	513	749	846	1342	1615

Table 1.7. Dredged material for construction etc. Amounts are given as 1000 m^3. (Geological Survey of Denmark and Danish Forest and Nature Agency, 1991).

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
sand	8	19	9	10	7	17	15	20	21	34	1
gravel	56	103	148	126	114	163	181	150	152	23	2
aggregates	168	84	66	73	55	33	90	26	27	225	222
other	47	30	0	0	0	0	0	0	0	138	0
total	279	236	223	209	176	213	286	196	200	420	225

1.3.7 Military use

The Danish part of the region encompasses 4 military firing areas (at Nymindegab, Oksbøl, Rømø east, and Rømø west) and 4 firing ranges (in Måde, Darum, Hjerpsted and Fanø) all frequently in use. Military practice flights over the Sea take place daily at an altitude above 600 m and most frequently between 3000 and 6000 m, while flights over coastal land normally take place at an altitude of less than 600 m. Land flights especially concern the firing grounds (areas) of Oksbøl and Rømø, and the area between Blåvandshuk and Nymindegab. Naval practice takes place all over the North Sea.

1.3.8 Land reclamation and coastal protection

In subregion 5 land reclamation including establishment of dykes has been undertaken along the South West Coast of Jutland and in Nothern Germany. Dyke protected areas belonging to the Wadden Sea are not encompassed by this report.

Along the rest of the Danish West Coast groynes at many locations represent the only tool for coastal and harbour protection. Groynes are built with the purpose primarily to prevent erosion of the coast.

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2. PHYSICAL CHARACTERISTICS AND CONDITIONS

2.1 INTRODUCTION

The hydrographical characteristics of NSTF subregion 5 are a small depth and large tidal velocities especially in the southern part. There are large gradients perpendicular to the coast in both salinity and temperature caused by the dilution of the the North Sea water with water from continental rivers. The flow field in the area is mainly northgoing in accordance with the predominant anti-clockwise circulation pattern in the North Sea. This is highly determined by the meteorological conditions in connection with the geometry of the region (Kristensen K.B. 1991).

2.2 BOTTOM TOPOGRAPHY

The topography of the German Bight is a result of the retreat of glacial ice cover and rising sea level during the last 10 000 years, and is characterized by the extensive Wadden Seas off the Frisian Coast (about 7% of the total surface area of ICES Box 5 = Subregion 5) and a post-glacial valley formed by the river Elbe. The valley is running from the Elbe estuary through the German Bight in northwesterly direction and passes the Dogger Bank on the eastern side of Tail End. Figure 2.1 shows the depth contours of the German Bight.

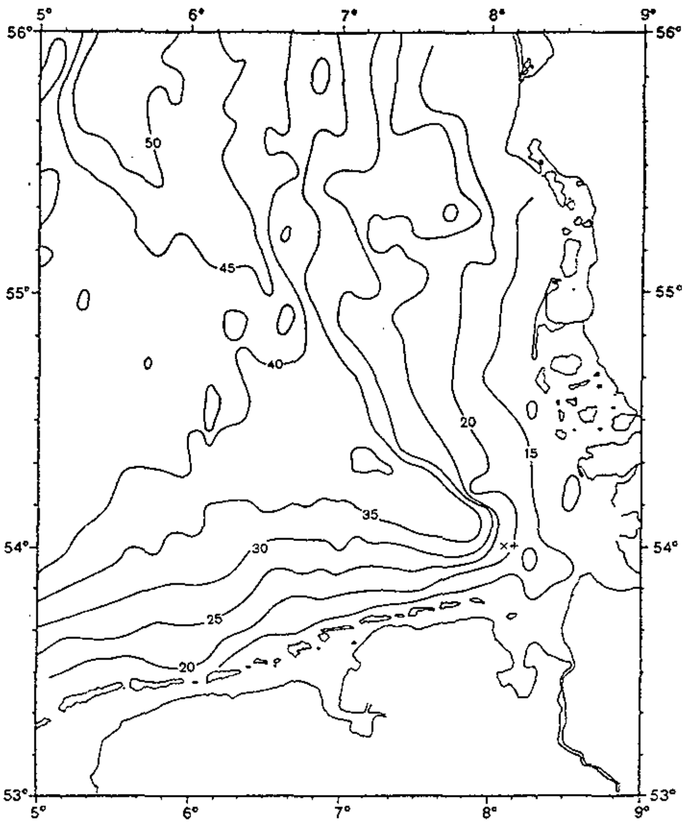

Figure 2.1. The German Bight with bottom topography (depth in meters). (Frey H., 1990).

Blaavandshuk north of Esbjerg and Horns Rev with Vestlugen - a deep - lying between them terminate the German Bight towards the north and are a transition to the relatively (undisturbed) uniform topography off the coast of Jutland.

Small topographic irregularities off the East Frisian islands are an important cause of upwelling. The "Helgoland Deep" is the deepest part in the inner German Bight; stronger sedimentation and resuspension of fine material occur here.

The surface sediment contains a higher share of silt and clay (smaller than 63 µm), starting with a share greater than 50% in the Helgoland Deep, and with the fine material content generally decreasing towards the Dogger Bank. The surface sediment in the German Bight is quite mobile. This means that turbulence generated by wave or current action can cause resuspension, and the tidal or residual current then transports the suspended matter. Measurements show how wave action in particular increases suspended matter (SPM). Figure 2.2 shows the high correlation between wave energy and SPM content at the Research Platform station in the northern part of the German Bight. The surface sediment in the German Bight and the benthic communities are also affected by heavy bottom trawling which causes resuspension of material into the water column, increases the turbidity and causes changes in the composition of benthic organisms.

2.3 PHYSICAL OCEANOGRAPHY AND GENERAL CIRCULATION

2.3.1 *Structural features*

Two main water masses are found in the German Bight: Continental Coastal Water and Central North Sea Water. Continental Coastal Water is a mixture of water from the Atlantic and water from the English Channel as well as run off from the rivers Rhine, Meuse and Ems. It has been attempted to differentiate between as many as six different water masses in the German Bight but the high variability in the area, and the strong yearly signals of temperature (amplitude of the yearly wave: about 8°C) and salinity (amplitude of the yearly wave off the estuaries: 1-2 PSU) are arguments against this differentiation.

The thermohaline stratification (Figure 2.3 a-c) in the German Bight is triggered by the run-off from the rivers Weser and Elbe on the one hand, and by the development of a seasonal thermocline in the outer part of the area on the other. Off the Weser and Elbe estuaries, there is a persistent haline stratification which triggers a thermal stratification. The run-off water from the rivers Rhine and Meuse as well as the river Elbe (due to the wind/circulation conditions) can occasionally cause some haline stratification north of the East Frisian islands.

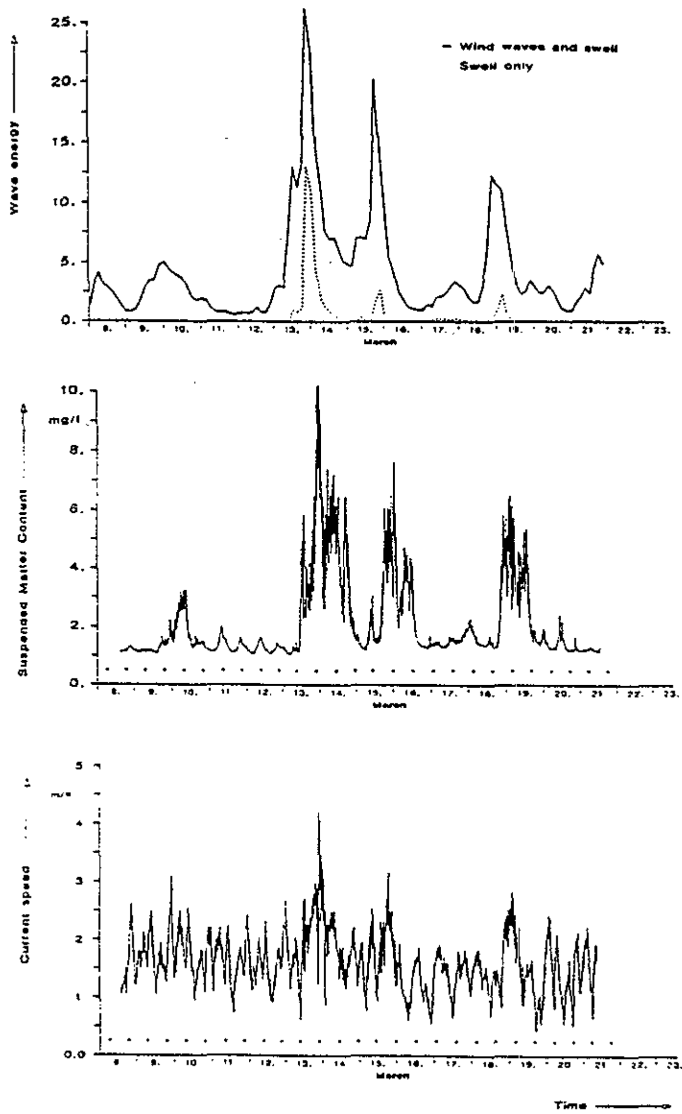

Figure 2.2. Time-series of wave energy, SPM concentration and current velocity near the bottom (near FPN) (König et al, 1991).

Krause et al. 1986 describes three different types of fronts in the German Bight. Figure 2.4 shows the areas where river plume, thermal and upwelling fronts are observed in the German Bight. Pronounced small scale and mesoscale variability, both in space and time, are found in the German Bight.

Off the East Frisian islands there is a "cold belt". The width of this upwelling belt is in the order of 3 to 7 km and its east-west extension can cover the whole southern German Bight. Anticyclonic vorticity production is Dippner's explanation for the cold belt (1991).

The North Sea waters have, in general, salinities between 34 and 35 PSU. Occasionally Atlantic water of salinity above 35 PSU is found in a tonguelike area to the south of a line from Scotland to the west coast of Norway and in another tonguelike area extending northwest from the English Channel even into the Western German Bight (BSH: Überwachung des Meeres 1990)

2.3.2 *Circulation*

The tides in the area are quite strong and cause turbulent horizontal and vertical exchanges. The dissipation of the tidal energy is proportional to the cube of the tidal current amplitude. Benthic communities are affected by the strong tidal bottom stress.

The semi-diurnal tidal wave takes about 6 hours to traverse subregion 5 from south to north along the open coast. The associated tidal currents decrease in the same direction. Maximum tidal current speeds range between >80 cm/s in the German Bight and about 20 cm/s in the very north of the subregion. The strong tidal mixing in the south (German Bight) prevent intense vertical stratification of the water column in the shallow coastal waters at depths not greater then 15 m.

The long term mean circulation within subregion 5 is characterized by a coastal alongshore flow towards north (Miljøstyrelsen, 1991) with velocities in the surface layer of a few centimetres/seconds (3 ± 2 cm/s). A water particle moving with the ambient mean circulation entering subregion 5 at its southern boundary would, thus, need between 2 months and almost one year to reach the northern end of the subregion at 57°N. The particle's actual path, however, will be no straight line from south to north, but rather complicated to and from motions due to the local tidal currents super-imposed and changing wind conditions during the transport time. At depth the longterm mean flow runs also towards north but with reduced velocities (1 to 2 cm/s).

The main long term mean inflow from offshore into the subregion takes place in the south and in the north. The main outflow occurs across the northern boundary of the subregion. In between the mean circulation basically runs parallel to the western boundary. This means, the inflowing waters mainly are coming from the English Channel and the Southern Bight carrying, among others, the diluted discharges of the rivers from the coasts there.

The proportion of coastal waters coming from the British coast is, on average, of secondary significance at the southern entrance of the subregion (Hainbucher et al. 1987). In the north, however, traces of these waters coming with the mean circulation may enter the subregion, but would leave it shortly thereafter again towards northerly directions.

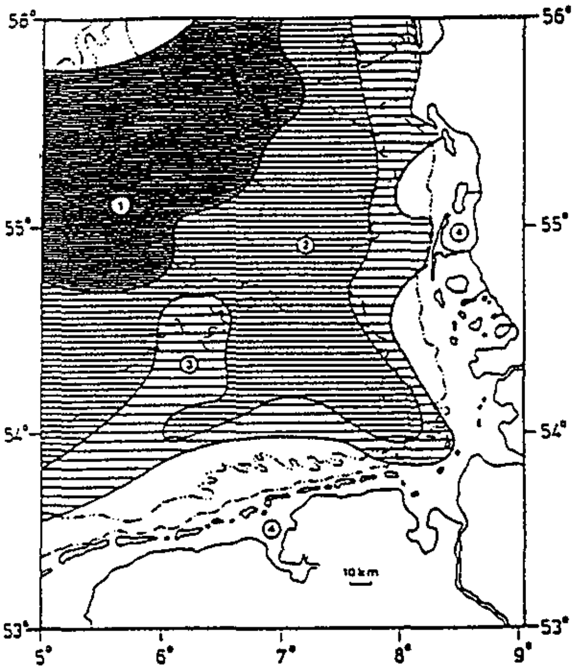

Figure 2.3 a:
1) Thermocline from may to September
2) Thermocline in July (includes then also Zone 1)
3) Thermocline in June (includes then also Zone 1-2)
4) Homogeneous the whole of the year

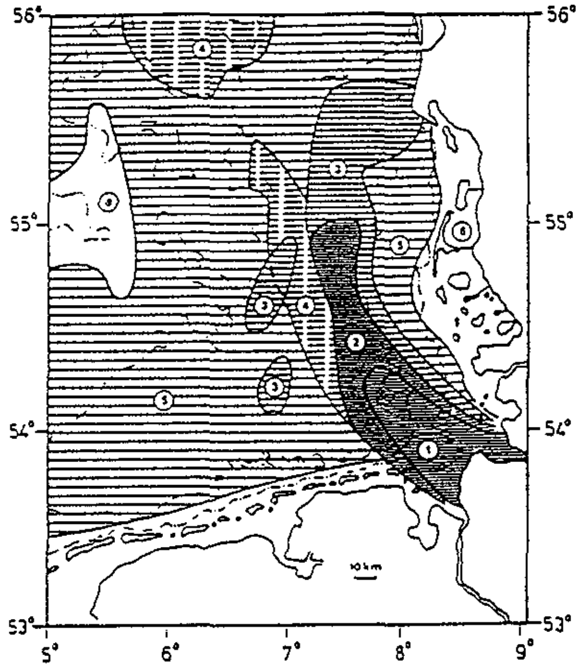

Figure 2.3 b:
1) Halocline throughout the year
2) Halocline from March to august (includes then also zone 1)
3) Halocline from March to May (includes then also zone 1-2)
4) Halocline from June to August (includes then also zone 1-2)
5) Halocline from time to time
6) Homogeneous the whole of the year

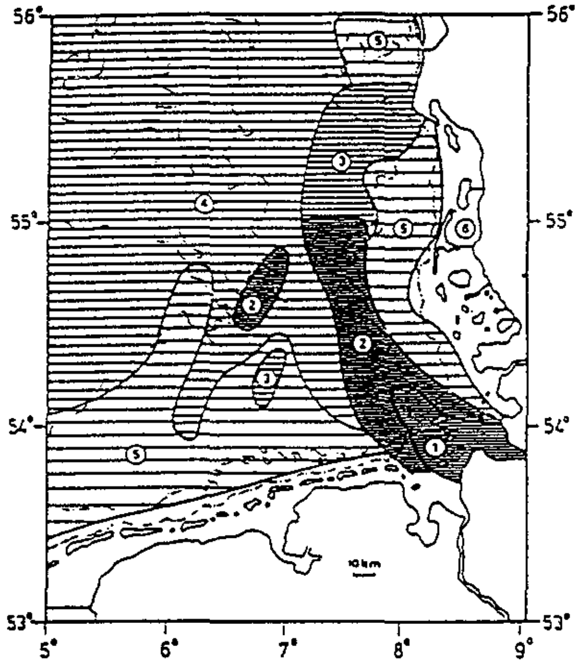

Figure 2.3 c:
1) Stratified the whole of the year
2) Stratified from march to August (includes then also zone 1)
3) Stratified from March to May (includes then also zone 1-2)
4) Stratified from June to august (includes then also zone 1-2)
5) Stratified temporarily
6) Homogeneous the whole of the year

***Figure 2.3 a-c.** Thermal, haline and density stratification in the German Bight (Frey & Becker 1986).*

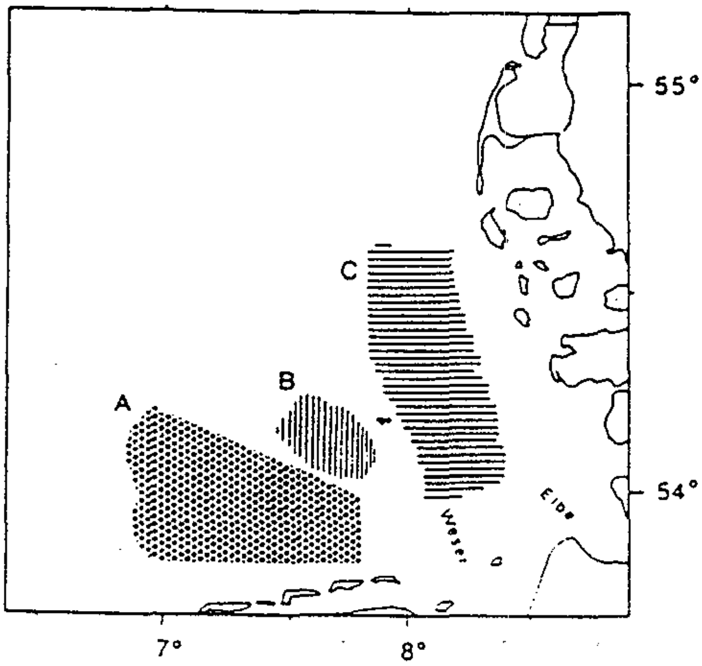

Figure 2.4. Frontal areas in the German Bight (Krause et al. 1988).

The outflow in the north influences the waters of the Skagerrak/Kattegat area (subregion 8) and may be traced in the area offshore the southern and southwestern Norwegian coast (subregion 6).

The rivers Weser and Elbe discharge their waters into the German Bight. Estimates of the discharges are 815 m^3/s (Elbe) and 360 m^3/s (Weser) (Rat von Sachverständigen für Umweltfragen 1980). Admixtures of these waters are carried with the longterm circulation towards north and may occasionally be traced eventually up to the northern boundary at 57°N after 2 to 12 months (within the surface layer).

A peculiarity of subregion 5 (and subregion 4 along the Dutch coast) is the existence of the Wadden Sea inshore and the foreland (Frisian isles). There is a significant exchange between the waters off- and inshore the islands perpendicular to the general northward circulation depending on the tides and the winds. An effect of this interaction is the retardation of near-coastal water transports towards north with the mean circulation offshore the isles. The Wadden Sea responds like a "sponge, which releases its water only reluctantly".

The rather short term winds may entirely change the mean current velocities and the circulation pattern.

Because of the proximity of the coast currents respond sensitively to onshore/offshore winds leading to considerable vertical current shears of the wind-induced flow. In the German Bight, for example, currents in the surface layer and in the bottom layer may be opposite during winds from southeast (offshore) or northwest (onshore).

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3. MARINE CHEMISTRY

NSTF region 5 is strongly influenced by the discharge of the river Elbe, and to a less extend by the rivers Weser and Ems. Pollution from other parts of the North Sea can be transported into subregion 5 by the currents. It is therefore obvious that elevated levels of nutrients and contaminants might occur in this area.

Among the contaminants the main concern relates to those harmful substances that are both toxic and persistent. Alarming observations were e.g. made after the worldwide application of the insecticide DDT which - as a result of its persistence over years - was accumulated to surprising concentrations in the final links of the marine food web. Pesticides applied today, however, have short environmental half lives, often in order of days and are therefore not expected to give contamination problems far away from their place of application. The low persistence also counteracts potential bio-accumulation to a relevant extent.

The spatial distributions in water, sediments and biota in area 5 of some of the most toxic contaminants are described in this chapter, together with other available important information in relation to these contaminants, e.g. background levels, input, and temporal trends.

A great deal of the reported data is collected in the frame-work of the Joint Monitoring Programme and the NSTF-MMP or other sub-groups of the Oslo-and Paris Commission. There are also many data from other sources such as national monitoring programmes like the German sediment data set, and from some German research programmes as the "Optimum", "Zisch" and "Tuvas" conducted by the German Bundesamt für Seeschiffahrt und Hydrographie. If data are from other sources, a reference is given.

In the 1987 status report (QSR, 1987) for area 5 the concentrations of heavy metals in sea-water, were reported to be generally low. Attention was drawn to a fairly constant (1979-83) gradient in the cadmium concentrations, which declined from levels around 45 ng/l at the southern end of the Danish North Sea, to around 25 ng/l at the northern end.

The heavy metal levels in the Danish Wadden Sea, which is a deposition area, indicated a moderate contamination, with 60-90 % of the heavy metals originating from the North Sea rather than from local inputs.

One of the main results presented in the 1987 report, was that the concentrations of Hg, Cd, Pb, and Zn decreased in the mussels upwards from the German Bight along the Danish North Sea coast. Similar relations were not found for Cu, Ni, Cr and As.

It was also stated, that the concentrations were generally low, although the influence of the former chemical waste site at Harboøre could be seen in an increased concentration of Hg and Cd in mussels at this site.

Only very few Danish data concerning organic contaminants were presented in the 1987 report. They were all very low (e.g. 10-20 µg PCB/kg wet fish muscle) and there was a weakly deceasing tendency in the concentrations found when going north along the Jutland coast.

3.1 DISTRIBUTION

3.1.1. Spatial distribution of chemical compounds in sea-water

Trace metals concentrations

German Bight (area latitude < 55.00 °N)

The trace metal concentrations in sea water have regularly been measured in the outer Elbe estuary and the German Bight, both as contributions to the Joint Monitoring Programme (JMP) of the Oslo-and Paris Commission and as a part of different national monitoring- and research programmes, e.g. the previously mentioned ZISCH and TUVAS programmes.

As the monitoring of the German Bight for trace metals in sea water started in DHI/BSH in 1971, a very large body of data has been obtained through these two decades. A large part of the data has been published in a number of scientific papers; (see list of references). Data for trace metals in sea water have also regularly been published in a series of official reports of BLMP and in annual reports (DHI, 1982 ff.).

The German Bight is influenced by the residual current system that transports dissolved and particulate heavy metals (as well as organic contaminants) from the southwest along the shores through the German Bight and then heads north flowing along the Danish coast as the Jutland Current. Input of metals from the southwest mainly originates from the outflow of the river Rhine. The German Bight itself is mainly influenced by the large rivers Elbe and Weser and the river Elbe is still the main contributor of some heavy metals to the German Bight. The smaller rivers Ems and Eider do not transport appreciable amounts of heavy metals that can be found some distance from the shore. A very high variability of concentrations is found in the water body when going from the purely riverine section through the brackish water area to the open sea areas of the German Bight. Concentration of certain pollutants decrease of more than three orders of magnitude have been measured from the port of Hamburg to the sea area northwest of Helgoland Island. Substantial chemical reactions occur within the turbidity maximum in the brackish water zone. This turbidity zone has a highly variably geographical location because it moves with the tides.

Very generally speaking, a gradient of trace metal concentrations in the water column can be seen that goes from the coasts to the open sea. Part of the metals then moves north along the

Danish Coast in dissolved form or in finely dispersed particulate. Some of the metal load of the German Bight is adsorbed and at least stabilized for some time in muddy sediments.

The German Bight is an extremely complex marine environment, however. Data from monitoring of metals in the water phase show a very high variability of concentrations. A range of probable residence times have been estimated to go from a few hours to several days, depending largely on the hydrodynamic parameters (Mart 1986).

The German Bight is relatively shallow. Thermal stratification occurs at least during the summer months. Frequent storms and accompanying severe weather conditions tend to stir up the freshly deposited sediments causing some remobilization of trace metals and a heavy particulate load of the water column. Strong tidal currents work to the same effects. Chemical and biological processes have a large impact especially in the Wadden Sea areas. This is described in more detail in the QSR covering the Wadden Sea (NSTF Area No. 10).

Atmospheric input of trace metals does occur to a substantial degree; however, this contribution is still not fully understood. Anoxic conditions prevail in some parts of the estuaries of the rivers and the Wadden Sea; also low oxygen concentrations occur sometimes during the summer months in the deeper layers of the German Bight. Redox reactions including changes in the chemical speciation of a number of trace metals tend to influence largely the concentrations of these metals under anoxic conditions.

Dumping of waste acid solutions from the titanium dioxide production industry in an area 14 nautical miles northwest of the island of Helgoland has finally been discontinued in 1989. Before that point, a regular input of the metal iron could easily be monitored in the dumping area and north of it. Additionally, manganese could be found that originated from the dumping. Although analyses for titanium, chromium and vanadium have not been obtained during the monitoring of the dumping, inputs of these metals can be assumed judging from the concentrations of metals analyzed in the acid waste solutions.

The concentrations of heavy metals are at most sites higher than those found for the open North Sea, (Cd (10-20 ng/l), Pb (10-60 ng/l), Hg (1-9 ng/l) (ICES, 1991a).

The Elbe is still the major contributor of **mercury** to the German Bight; it can be considered as a "point source" of mercury. Concentrations of mercury ***(Figure 3.1 a)*** less than 0.5 ng/l are typical for the outer German Bight whereas more than 1000 ng/l have been measured in the port of Hamburg. Most of the mercury in the marine environment is transported in the particulate phase.

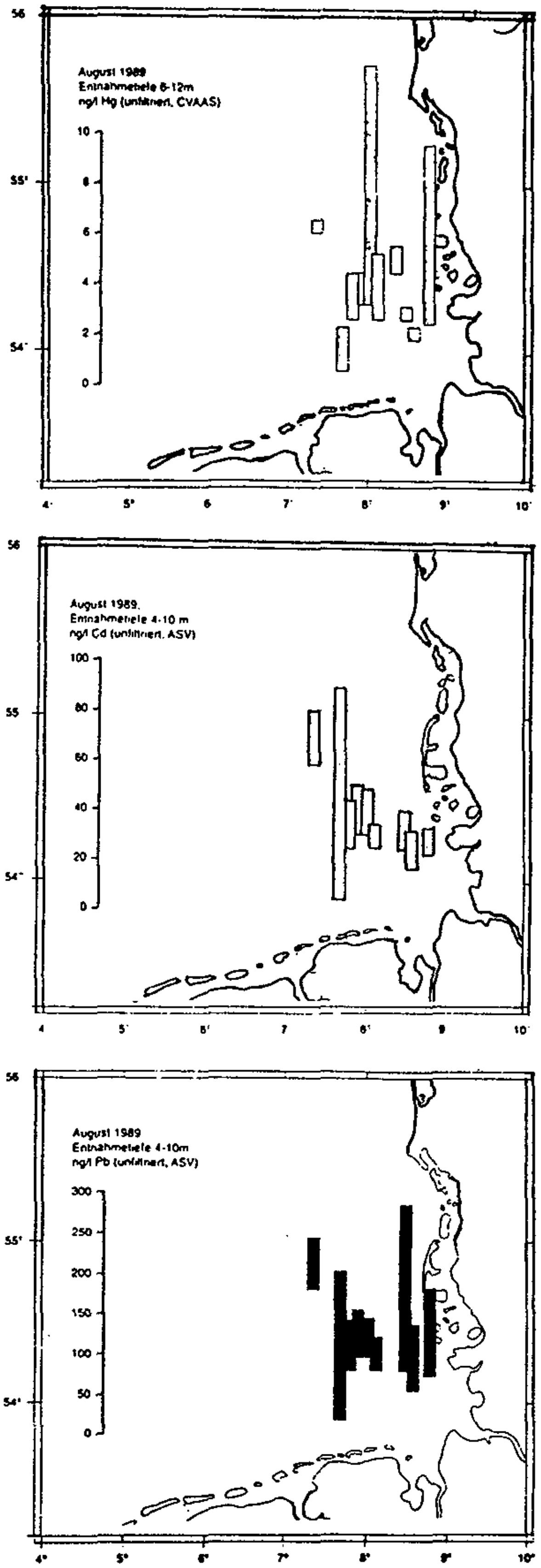


Figure 3.1 a-c: a) Mercury, b) Cadmium c) Lead concentration in seawater in the German Bight. (Figure from Jahresbericht 1990, BSH, data collected for the JMP programme).

Cadmium *(Figure 3.1 b)* typically shows a relatively even distribution across the entire German Bight without any discernable "hot spots". Some higher cadmium concentrations have been measured by riverine monitoring programmes for the river Weser; however, an input of cadmium from the Weser cannot be found in monitoring programmes of the coastal waters and the open German Bight. Cadmium mainly occurs in the dissolved phase in sea water.

Lead *(Figure 3.1 c)* is occurring mainly in the particulate phase (comparable to mercury). Monitoring of the German Bight started some years later than for cadmium and other metals; during the monitoring some "hot spots" of increased particulate lead concentrations have been found.

Iron is a major constituent of the earth crust. High concentrations are found in the particulate form and to a much smaller extent in the dissolved form in coastal sea water. The behaviour of iron generally follows that of manganese. The concentrations in the German Bight are, however, much higher. Iron can act as a scavenger for other metals. Several trace metals can easily be adsorbed on freshly precipitating iron oxide and hydroxide particles. This behaviour was very typical for the regular dumping operations of the TiO_2 waste solutions northwest of Helgoland.

Nickel displays in general a relatively uniform distribution pattern throughout the German Bight, comparable to cadmium. No specific areas or points of increased concentration have been found for nickel; no substantial inputs through rivers or dumping could be discriminated.

No specific areas of increased concentrations of **copper** in the water phase of the German Bight have been found, although a general gradient from the estuaries of the rivers and the coastal zones to the open sea can be seen.

Zinc is not among the rare trace metals in the environment. It is known that substantial loads of this metal are transported from the terrestrial environment through the rivers to the sea. Concentrations in the German Bight show a relatively high variance; a general gradient from the coast to the sea can be inferred. A typical structure of the distribution pattern is not yet obvious from the present data set.

Trace metal concentrations
Westcoast of Jutland (Area latitude >55.00 °N)

Sea-water samples from 6 stations in area 5 along the West coast of Jutland have been analyzed in 1986, 1987 and 1990, as a part of the JMP-programme. The 1986-87 results are included in a recently published report (ICES, 1991a).

The samples have usually been collected at the same positions from north to south each year. All samples were non-filtered samples and the Cd, Cu, Hg, Ni, and Pb concentrations were analyzed. All samples were triplicate samples and were always collected in the middle of February.

The results are illustrated in ***Figures 3.2 a-c***, where some of the different metal concentrations are plotted against the salinity.

The salinity and not the sampling positions have been used to characterize and compare the water masses from year to year, along the Jutland coast, as this area is heavily influenced by the Jutland Current.

The Jutland Current has a salinity of less than 34 PSU, and transports water from the German and other European rivers along the Danish west coast as discussed earlier. The current is not stationary, but varies, mainly by the wind field.

The concentrations of **cadmium** are found to vary between 12 ng/l and 40 ng/l along the salinity gradient ***(Figure 3.2 a)***. There is a significant relationship between the Cd-concentration and the salinity, and hence also a concentration gradient upwards the Danish west coast, implying that dilution of the freshwater is the main process responsible for the distribution of Cd in this area.

The concentrations found are slightly lower, than those reported in the 1987 status report. It is not possible, however, to detect any regular trend in the 87-90 data.

The concentrations found are comparable to those reported earlier for the central part of the North Sea (10-20 ng/l)(ICES, (1991a)), but lower than those earlier reported for the outer Elbe estuary, 18-51 ng/l (Mart,1986). The concentrations are all higher than those reported for Cd in oceanic water, 5-10 ng/l (Fowler, 1990).

The concentrations of **copper** are found to vary between 0.16 µg/l and 1.10 µg/l along the salinity gradient, ***(Figure 3.2 b)***. The Cu concentrations are also closely related to the salinity, giving the same distribution pattern as for Cd. No obvious time trend can be detected during the period. No Cu data were reported in the 1987 QSR for the Danish area.

The concentrations found in 1987-1990 are in the same range as those reported in ICES (1991a) for comparable areas. The average values of the Cu-concentration for samples with salinities > 30 range from 0.1-0.2 µg/l in the off-shore waters of the North Sea. The concentration in coastal waters in general varies between 0.5 and 1.0 µg/l (ICES (1991a)) and in the outer Elbe estuary, values between 0.4 µg/l and 2.3 µg/l have been reported earlier (Mart,1986).

The concentrations of **nickel** are found to vary between 0.24 µg/l and 1.4 µg/l along the salinity gradient, ***(Figure 3.2 c)***. No time trend can be detected and the concentration pattern follows that of Cd and Cu.

No Ni data were discussed in the ICES report (ICES, (1991a)), but the Ni concentrations in the Northern Kattegat and Skagerak have earlier been reported to be between 0.2-0.5 µg/l (Salomons, 1988).

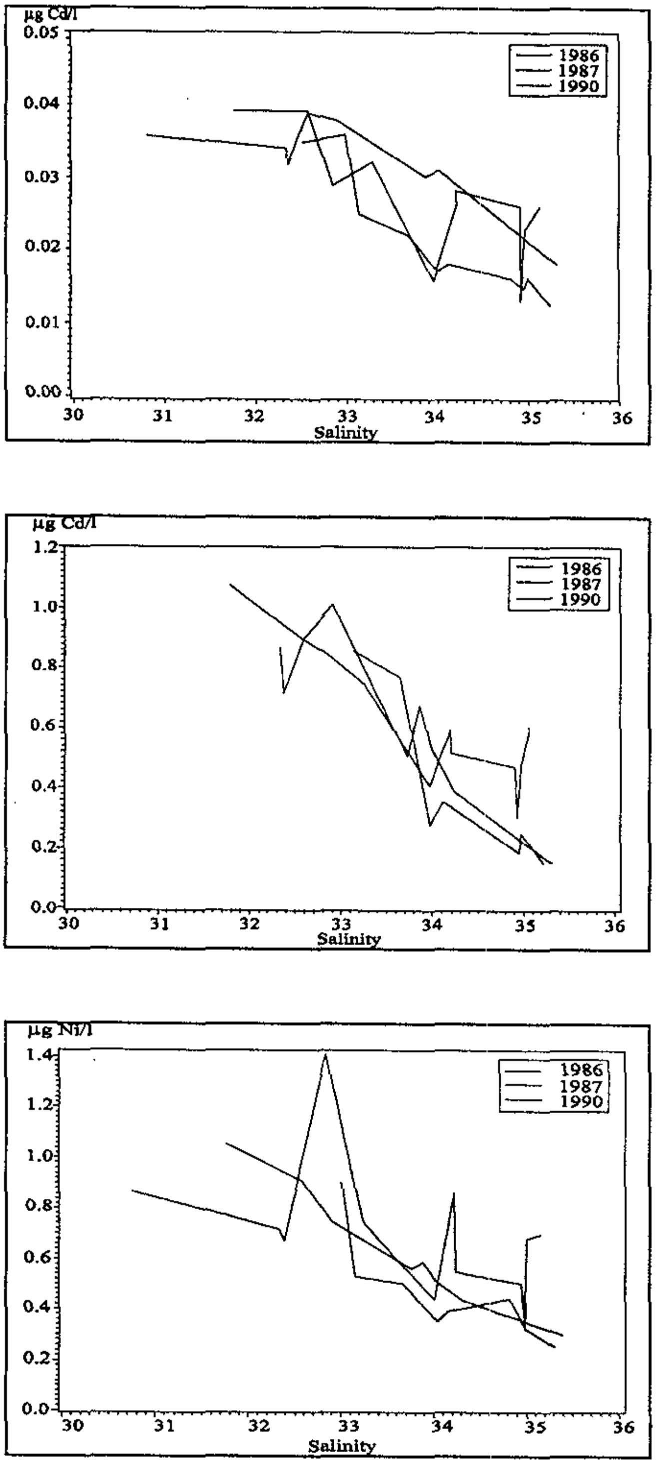


Figure 3.2 a-c: a) Cadmium b) Copper c) Nickel concentrations in seawater versus salinity along the west coast of Jutland. Data from 1986, 1987 and 1990.

The concentrations of **lead** are found to vary between 0.04 µg/l and 1.4 µg/l. Even though there is a slight but scattered correlation between the salinity and the Pb-concentration, this is not so pronounced as for the other metals.

The reasons for this can be manifold. It can be more difficult to obtain reliable measurements of lead in seawater due to contamination problems. The influence of air input is usually more pronounced for lead compared to the other metals. In addition, as non-filtered samples were analyzed, the influence of particulate material in the sea-water would be especially important for lead, as also would be the case for mercury and zinc, as these metals are more easily scavenged by suspended particulate material than the earlier mentioned metals which behave more conservatively (Harper, 1991).

Most lead data reported in ICES, (1991a) for areas with a salinity >34 were less than 0.05 µg/l, and the concentration in ocean waters has been reported to be 0.030 µg/l (Fowler, 1990).

There are not so many data available for **mercury** as for the other metals. The concentrations vary between < 3 ng/l and 14 ng/l. No relationship between mercury and salinity can be identified. All concentrations found are higher than the median values given in ICES, (1991a) for the salinity range >30, which vary from 0.6-2.5 ng/l.

Not many reliable data of **zinc** for this area are available due to problems caused by contamination during sampling and/or analysis.

Preliminary results suggest, however, that the concentrations are in the range 1-5 µg/l, increasing with a decreasing salinity. This might be an effect of the increasing amount of suspended particulate material, SPM, with decreasing salinity found in this area, as SPM in average contains > 200 mg/kg Zn, (ICES, (1991a).

Trace metals - temporal trend studies

A plot of the Cd concentration in the German Bight during 1973-1988 is given in ***Figure 3.3*** (from Schmidt and Dicke, 1990). Even though there might have been some analytical problems with the most early results, the results indicate a clear downward trend, although the endpoint concentration is still elevated compared to the concentrations in the open North Sea (10-20 ng/l)(ICES, 1991a).

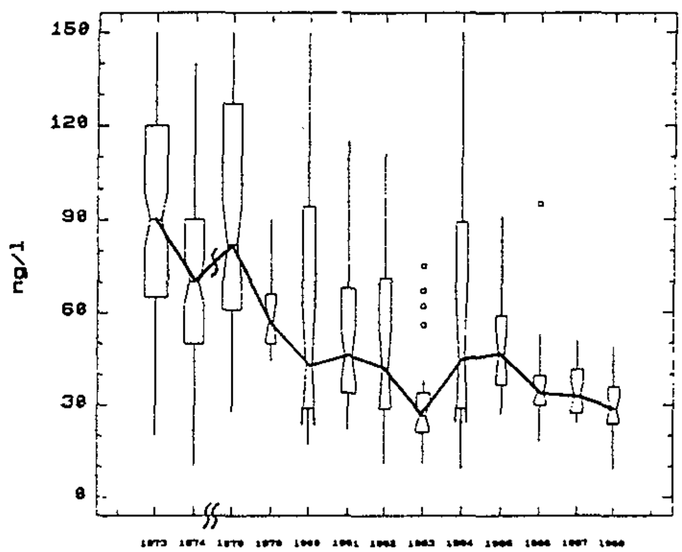


Figure 3.3: Time series of the cadmium concentration in the German Bight. Data from 1973-1988.

Organic contaminants concentrations.

The pesticides (i.e.toxic compounds) lindane (y-HCH), HCB, PCP, parathionmethyl and atrazine are traceable in the water phase in some parts of the Elbe estuary and the German Bight.

Contaminants with less known toxicity have also been found, like e.g. phthalic esters and organic phosphates used as plasticisers.

Compounds, that never intentionally have been produced but arise as by-products in chemical reactions (e.g. α-HCH) or are stable degradation products (e.g. DDD, DDE) were also found.

The majority of the detected organic compounds are known to be degraded rapidly and do therefore not pose a long-lasting or widespread threat.

Concentrations of organic contaminants found in 1989 in the German Bigth in the frame of the OPTINOM research project is presented in ***Table 3.1***. Stations no. refers to the map in ***Figure 3.4***.

Organic contaminants concentrations - Trend studies

Some temporal trend data are available from the German Bight. Samples from station E19, near Elbe light vessel have at least been analyzed annually. There is a considerable variability in the results (***Figure 3.5***), due to at least three independent reasons:

- the variation in the amount of input of pollutants from Elbe and Weser,
- the variable position of the plume of the rivers relative to the station,
- the variable flushing conditions of the sea.

In spite of this, some conclusions can be made drawn:

- Owing to the ban on technical HCH as insecticide (with 60% α-HCH as main ingredient) the concentrations of HCH have fallen to near back-ground values.
- No trend can be seen for the lindane data.
- HCB concentrations were higher in the early 1980' ies. Due to improved emission controls they are close to the limit of detection now.

Petroleum hydrocarbons and PAHs

In addition to the pollution load from the rivers, the German Bight is a region with a high shipping traffic, which contributes to the oil pollution to considerable extent. There is probably an input of PAHs by atmospheric input, but the amount is unknown because of lack of direct measurements. There are no offshore platforms in region 5; pollution by floating oil films or tar balls from the oil production fields in the central North Sea are observed in unusual weather situations with long lasting stable north westerly winds only.

"Total Hydrocarbon Concentration" (THC)

Most hydrocarbon concentration measurements reported in the literature are determined by the IGOSS method, yielding a summary parameter for total hydrocarbon concentrations. This method uses fluorescence spectroscopic data of lipophilic water extracts as a summary parameter, which can be used as a relative value only to detect "hot spots" of elevated concentrations. These values can at most be considered as an upper value, which would represent the true concentration, if the composition of the water extract would correspond to that of the calibration oil. As this is almost never the case and as the extracted fluorescence is not specific to hydrocarbons, it is likely that the actual hydrocarbon concentration (i.e. the sum of all hydrocarbons) is only 10 to 50% of the fluorescence value. ***Table 3.2*** presents a summary of recent values observed in the German Bight in 1990 and 1991. The spatial distribution of the relative concentrations of THC in Oct 1991 is shown in ***Figure 3.6***. Most values range between 0.2 and 2.5 µg/l (crude oil equivalents).

In the Elbe estuary the values increase up to 30 µg/l at Cuxhaven and up to 112 µg/l at Stade (about 70 km upstram), demonstrating that the river Elbe is one of the major input sources. Towards the outer German Bight and the open North Sea there is a steep concentration gradient observed which is caused by mixing with less contaminated North Sea and Atlantic ocean water. The THC-distribution is strongly influenced by the freshwater.

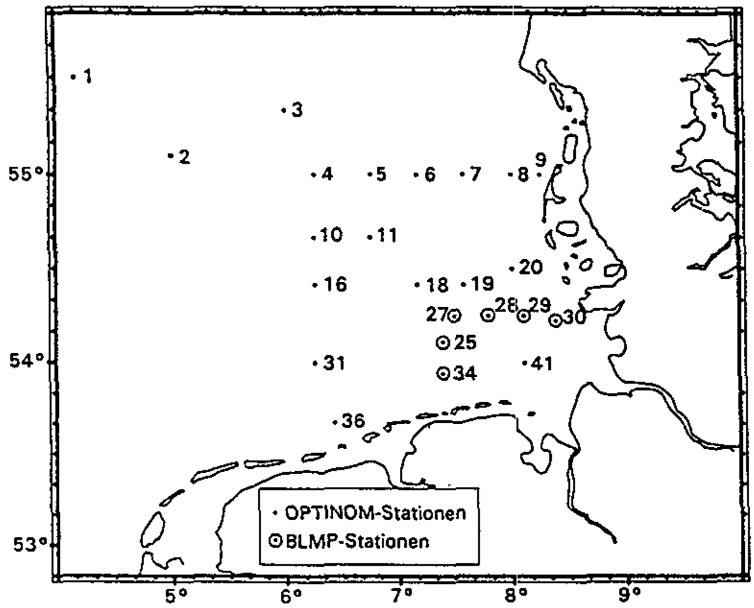


Figure 3.4.: Stations in the frame of the OPTINOM research project 1989.

Table 3.1.: Organic contaminants concentrations in the German Bight. OPTINOM, November 1989 (ng/l at 5 m depth). PBC's were all below the detection limit.

Station no.	α-HCH	β-HCH	γ-HCH	HCB	p,p'-DDD	p,p'-DDT
1	1,40	< 0,05	1,30	< 0,02	< 0,05	< 0,05
2	1,30	< 0,05	1,70	< 0,02	< 0,05	< 0,05
3	1,30	< 0,05	1,80	< 0,02	< 0,05	< 0,05
4	1,00	< 0,05	1,40	< 0,02	< 0,05	< 0,05
5	1,00	< 0,05	1,70	< 0,02	< 0,05	0,08
6	0,90	< 0,05	1,70	< 0,02	< 0,05	< 0,05
7	1,10	< 0,05	2,00	< 0,02	< 0,05	0,09
8	1,50	0,22	2,00	0,03	< 0,05	< 0,05
9	1,80	0,36	2,50	0,04	< 0,05	< 0,05
10	1,00	< 0,05	1,60	< 0,02	< 0,05	< 0,05
11	1,00	< 0,05	1,90	< 0,02	< 0,05	< 0,05
16	1,10	< 0,05	1,60	< 0,02	< 0,05	< 0,05
18	1,10	0,11	2,00	0,03	< 0,05	0,07
25	1,20	0,13	2,10	0,03	< 0,05	< 0,05
27	1,60	0,10	2,10	0,03	< 0,05	< 0,05
28	1,20	0,10	2,10	0,03	< 0,05	0,08
29	1,50	0,21	2,30	0,06	0,08	< 0,05
30	1,60	0,18	2,50	0,07	0,09	0,08
31	1,10	0,10	2,30	0,03	< 0,05	< 0,05
34	1,50	0,13	2,30	0,05	< 0,05	0,08
36	1,10	0,14	2,30	0,03	< 0,05	0,20
41	1,30	0,12	2,10	0,04	< 0,05	< 0,05

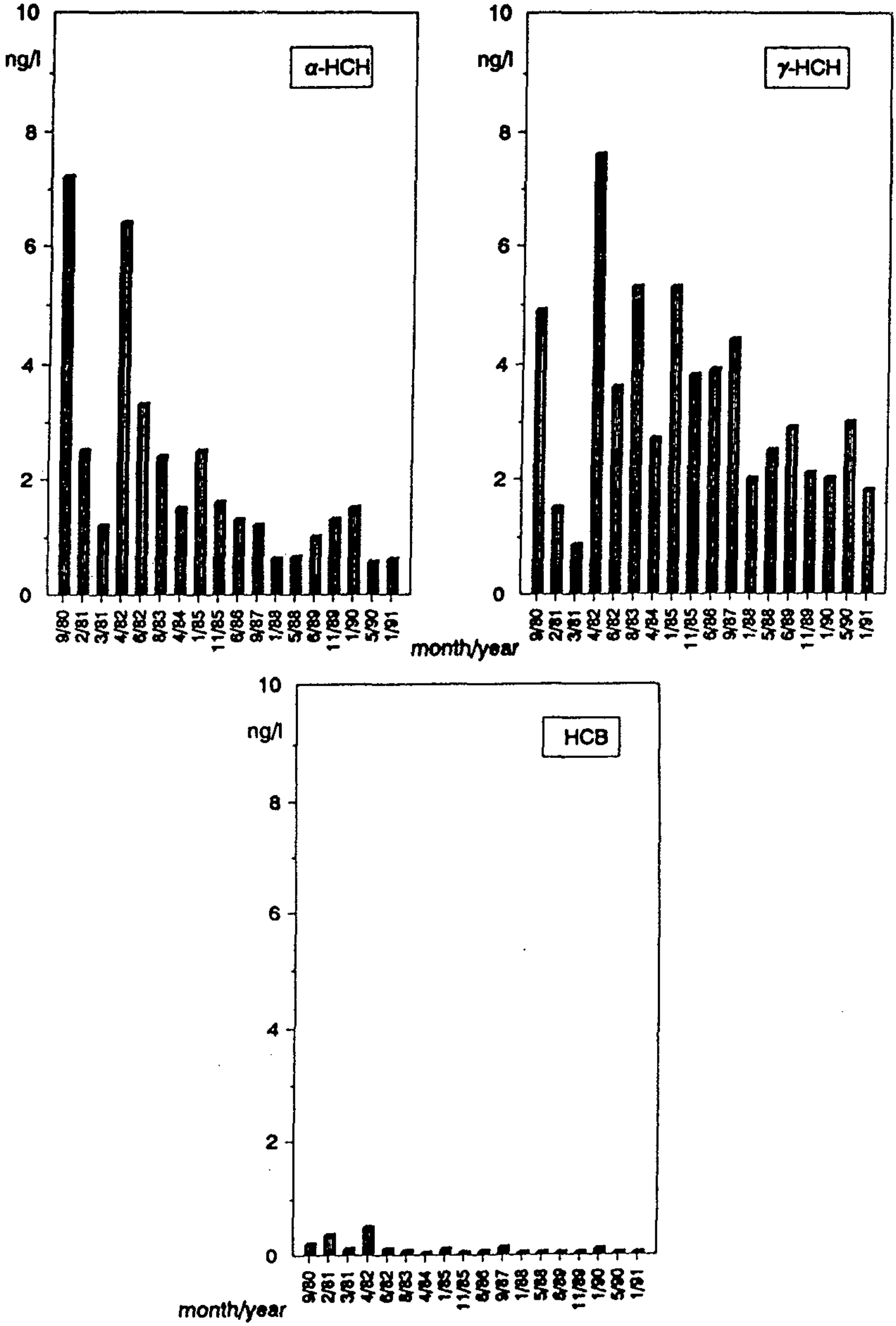


Figure 3.5.: Temporal trend of organic micropollutants at station El 9 (54°00'N, 08°05'E).

content and the current in the German Bight, which are dependent to a considerable part by the wind. Therefore in the inner German Bight the spatial distribution can vary from month to month. In addition to the quantitative differences of the THC, there are considerable qualitative differences in the composition of the estuarine samples and of those from the open sea. These differences in the hydrocarbon composition are discussed in the paragraph on single hydrocarbon concentrations in more detail.

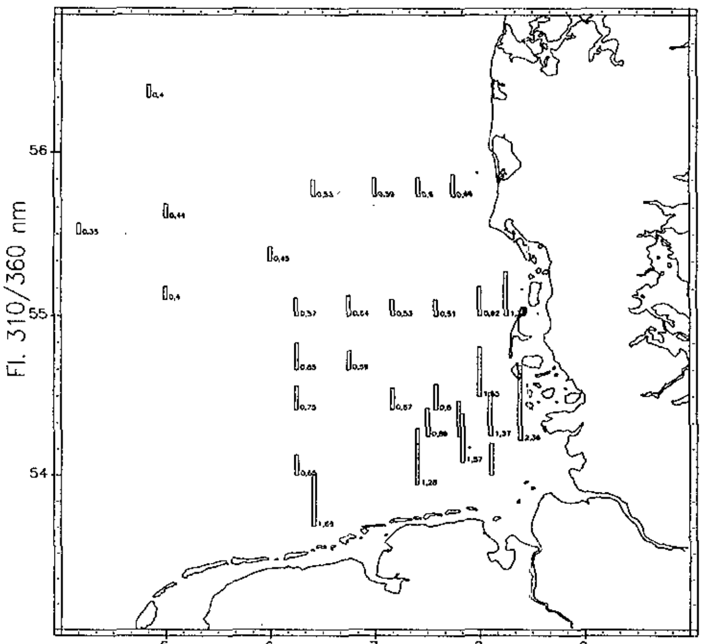


Figure 3.6: *Spatial distribution of "Total Hydrocarbon Concentrations" in Oct. 1991.*

Time dependence and temporal trends

The time dependence of the THC for the years 1990 and 1991 for several stations are depicted in ***Figure 3.7***. As can be seen, there is a great variation of the values during the year with a max to min relation of generally more than 5. There is no simple seasonal trend to be observed as might be expected from the temperature dependence of the chemical and biological degradation processes, although in general the values in winter are higher than in summer. In addition to the water temperatures the concentrations are strongly influenced by changing hydrographic situations (riverine inputs) and weather conditions. As most hydrocarbons are enriched at particles, the hydrocarbon concentrations in unfiltered water samples are considerably influenced by the amount of suspended matter. Because of the relatively low water depth in the GB the amount of suspended matter can be increased by storms within a short period. Thus the hydrocarbon concentrations are strongly influenced by the weather conditions and concentrations on a stormy summer day can be similar as those on a calm winter day. Because of the very high variance of the values it is not possible to make a statement on temporal trends of the last years.

Concentrations of single hydrocarbons

Aromatic Hydrocarbons: The mean concentrations of some PAHs in 1990 for selected stations in the German Bight are listed in ***Table 3.3***. The variance during the year is as high as for the THC-values. There are great differences between the concentrations of the individual hydrocarbons and even more, there are remarkable differences in the gradients of them from the coast to the open sea. For an overview, in ***Figure 3.8*** the values for an estuarine (Station 42) and the open sea (Station 2) are presented. While the 2- and 3-ring aromatics show only little differences between St.42 and St.2 with concentrations between 0.5 and 5 ng/l, the 4- to 6-ring PAH vary between 4 and 0.04 ng/l. The reason for this behaviour is due to the decreasing water solubility for the higher condensed aromatics and going along with this the increasing adsorption to particles.

There is a clear dependence between structure and adsorption to particles. This adsorption is more important for 4- to 6-ring aromatics than for 2 ring aromatics.

Alkanes

The concentrations of single aliphatic hydrocarbons (n-C_{19} to n-C_{30}) generally range in the German Bight between 1 and 5 ng/l and can reach up to 10 ng/l ***(Table 3.4)***. In coastal areas the values can reach up to 25 ng/l and in the Elbe estuary up to 100 ng/l. Mostly, there is observed an alternative distribution in the concentrations with a preference for the odd numbered alkanes indicating a biogenic origin by plants. In the months with a strong primary production (May to July) n-C_{17} shows an overwhelming abundance (up to 300 ng/l), sometimes n-C_{15} and n-C_{19} show elevated level too (15 to 75 ng/l). These three alkanes are known metabolites of algae.

Floating Oil Films

Because of their hydrophobic nature petroleum hydrocarbons float on the water surface as oil films or tar balls when large amounts of oil enter the aquatic environment. Therefore, for acute oil inputs (e.g. by accidents or illegal discharges of oil) the observation of oil films describes the pollution situation much better than concentration measurements in the water phase. In ***Figure 3.9*** the oil films detected in 1990 in the German Bight are shown. Most oil slicks were observed along the main shipping routes. Chemical analysis of oil films, stranded tar balls and oiled seabirds showed that more than 90% of the oil in the German Bight originated from illegal discharges of bilge or sludge tank residues. At the Danish coast slightly different results were observed: a larger fraction of crude oil residues was found, which originate in part from tanker washings and possibly in part from North Sea offshore installations (see special section "Oiled Seabirds").

Table 3.2. Total hydrocarbon concentrations in water samples in 1990-1991.

Location	Mean Conc. µg/l	Min. µg/l	Max. µg/l
Outer German Bight	0.5	0.18	1.42
North Frisian Coast	1.5	0.5	4.2
East Frisian Coast	1.5	0.27	4.08
Prox. Elbe plume	3.0	0.51	12.0
Cuxhaven	16.7	3.7	30.0
Stade (Elbe)	41.4	12.0	112.0

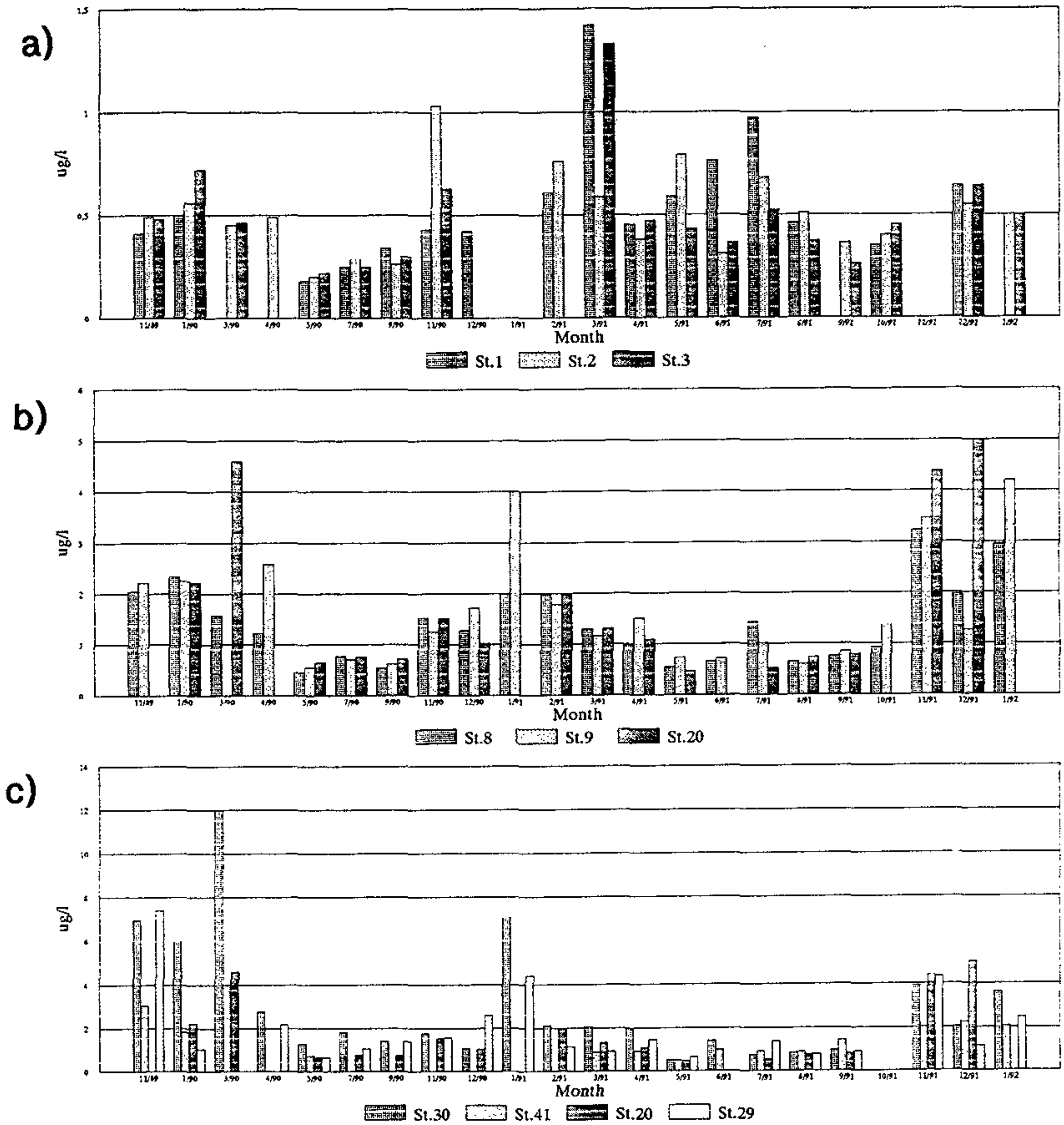


Figure 3.7.: *Temporal variation of THC in 1990 - 1991; a) outer German Bight, b) near shore, c) Elbe plume.*

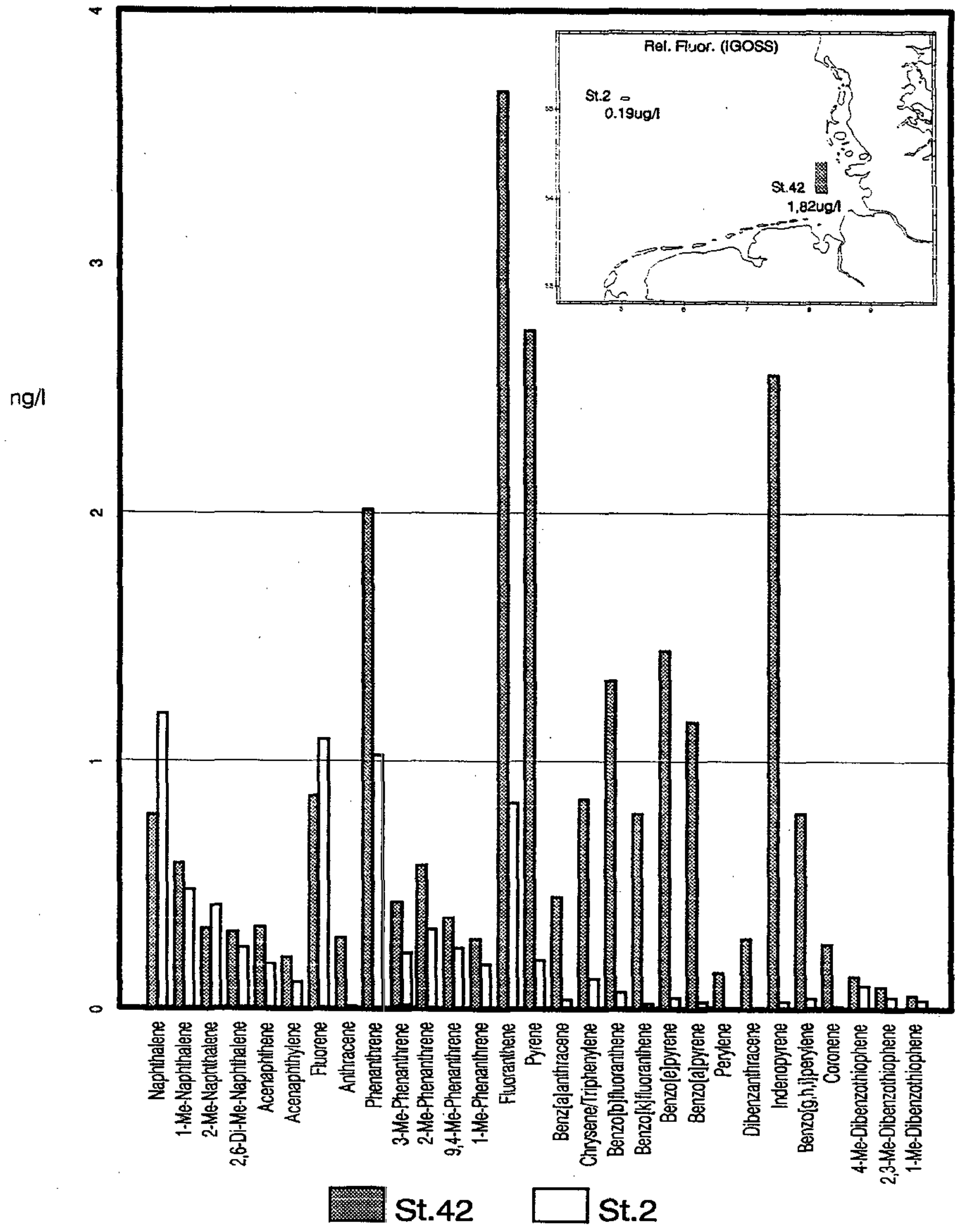


Figure 3.8.: *Concentrations of selected aromatic hydrocarbons in the water of St.42 (near shore) and St.2 (outer German Bight).*

Table 3.3. Mean Concentrations of PAHs in 1990 [ng/l].

	St. 1 Outer German Bight	St. 9 North Frisian Coast	St. 36 East Frisian Coast	St. 30 Prox. Elbe plume	Cuxhaven
Naphthalene	3.420	2.258	2.465	2.233	1.231
2-Me-Napthalene	1.034	0.928	1.130	0.925	0.817
1-Me-Napthalene	0.769	0.615	0.823	0.555	0.429
Acenaphthene	0.231	0.308	0.799	0.496	0.904
Acenaphtylene	0.128	0.276	0.564	0.429	0.290
Fluorene	1.584	1.303	2.204	1.330	1.834
Anthracene	0.041	0.152	0.140	0.295	1.452
Phenanthrene	1.199	1.453	2.202	2.076	5.731
Fluoranthene	0.948	2.696	2.220	4.601	15.460
Pyrene	0.371	1.772	1.271	3.364	13.156
Benz(a)Anthracene	0.141	0.656	0.336	1.312	6.603
Chrysene/Trophe.	0.279	1.281	0.664	2.782	9.843
Benzo(b)Fluoranthene	0.200	1.484	0.631	2.668	10.721
Benzo(k)Fluorenthene	0.139	1.128	0.487	2.136	8.537
Benzo(e)Pyrene	0.102	0.912	0.378	1.840	7.919
Benzo(a)Pyrene	0.105	1.020	0.446	2.104	9.831
Perylene	0.033	0.307	0.120	0.773	4.331
Dibenz(a,c)Anthracene	0.103	0.108	0.044	0.197	0.956
Indeno(123-c.d)Pyrene	0.046	0.463	0.205	0.908	3.600
Benzo(ghi)Perylene	0.044	0.373	0.172	0.818	3.660
Coronene	0.026	0.136	0.065	0.295	1.144
Dibenzothiophene	0.193	0.194	0.310	0.238	0.556

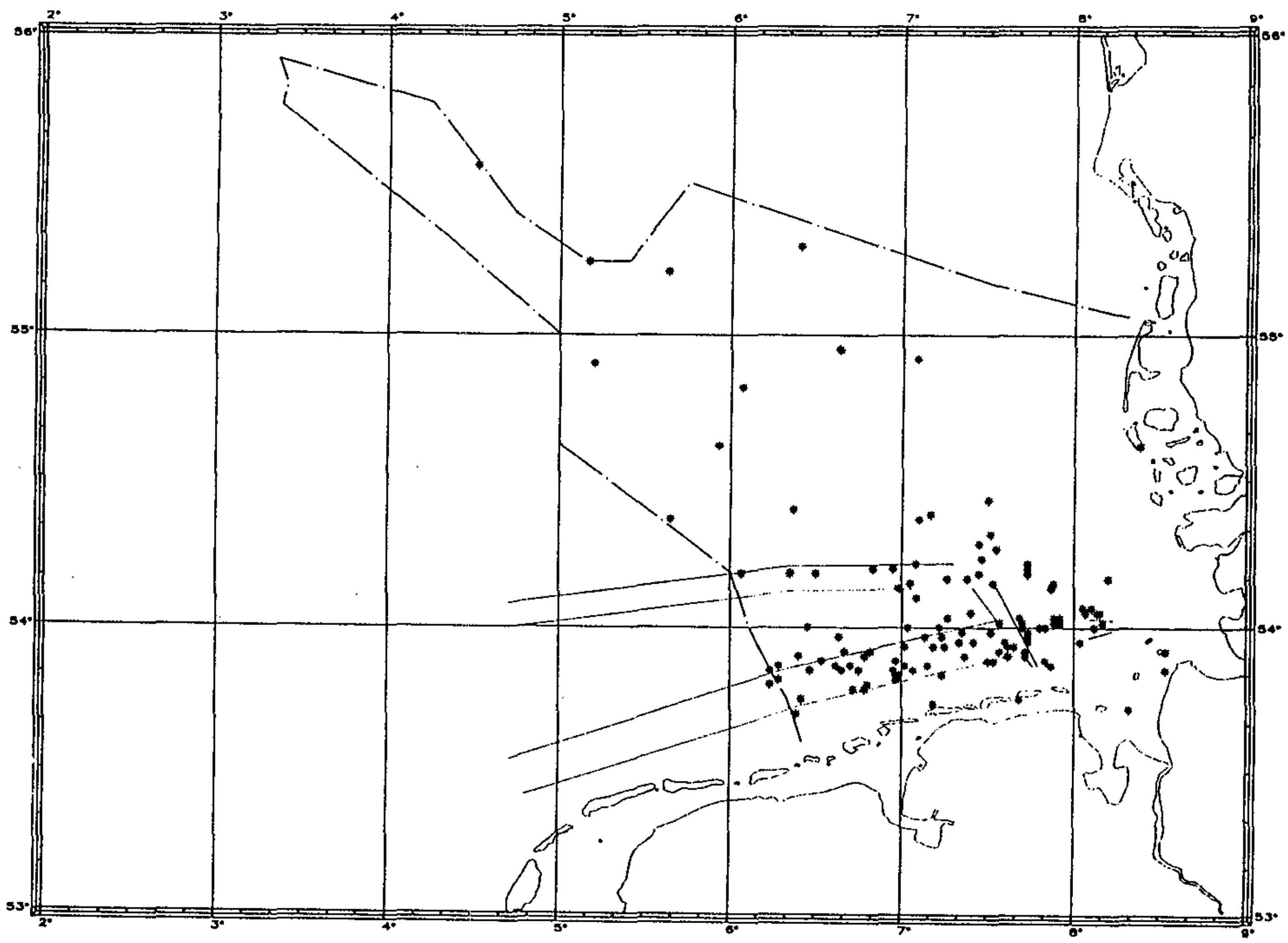


Figure 3.9.: Oil spills detected in 1990.

Table 3.4. Mean Concentrations of Aliphatic Hydrocarbons in 1990 [ng/l].

	St. 1 Outer German Bight	St. 9 North Frisian Coast	St. 36 East Frisian Coast	St. 30 Prox. Elbe plume	Cuxhaven
C_13	1.534	1.563	1.337	1.319	2.915
C_14	3.359	3.184	3.581	3.480	5.390
C_15	8.875	5.373	9.961	5.811	7.092
C_16	1.997	2.484	2.733	4.137	7.271
C_17	4.007	40.462	17.900	18.442	20.220
PRI	3.709	2.227	8.329	4.908	7.016
C_18	2.007	7.638	5.418	6.139	7.115
PHY	0.941	0.941	0.955	1.885	6.192
C_19	1.842	13.635	9.602	10.146	6.391
C_20	1.825	2.019	1.873	2.476	6.296
C_21	2.085	2.716	2.351	3.418	8.015
C_22	3.079	3.392	2.745	3.670	7.827
C_23	3.534	4.718	3.281	5.378	12.095
C_24	3.726	5.000	2.909	4.725	12.370
C_25	4.705	7.414	3.905	8.366	23.810
C_26	3.757	5.700	2.458	5.746	21.905
C_27	4.801	8.554	4.497	10.826	36.170
C_28	4.017	6.099	2.585	6.264	21.500
C_29	6.036	11.102	7.197	15.454	44.205
C_30	4.296	5.492	2.675	5.852	19.980

Nutrients

In January/February of the years 1985, 1987, 1989, 1990 and 1992 nutrient concentrations were measured in the German Bight and compared with a data set from January 1978 (Körner and Weichart, 1992). For the surface layer phosphorus and silicate data can also be compared with data from 1936.

In this mixing area of fresh water with North Sea water, the nutrient distribution during winter time shows a good linear nutrient-salinity relation ***(Figure 3.10)***. By using regression lines the nutrient concentrations of different years can be compared in spite of variations due to the actual hydrographic situation and fresh water run off.

The measurements of 1978, 1985, 1987, 1989, 1990 and 1992 show different concentration distributions but comparatively small variations in the nutrient-salinity relation. The concentrations of phosphate, silicate and nitrate + nitrite measured from 1985 to 1990 are on a slightly lower level than 1978. Nevertheless, a decreasing trend of the elevated nutrient concentrations in the coastal waters of the German Bight can not yet be stated.

In the trend graph ***(Figure 3.11)*** for a salinity of 30 the mean values of January and February 1991 and 1992 shows that in both years the phosphate concentrations in the coastal water of the German Bight were 20 % lower then in the years before. (Körner & Weichart, 1992).

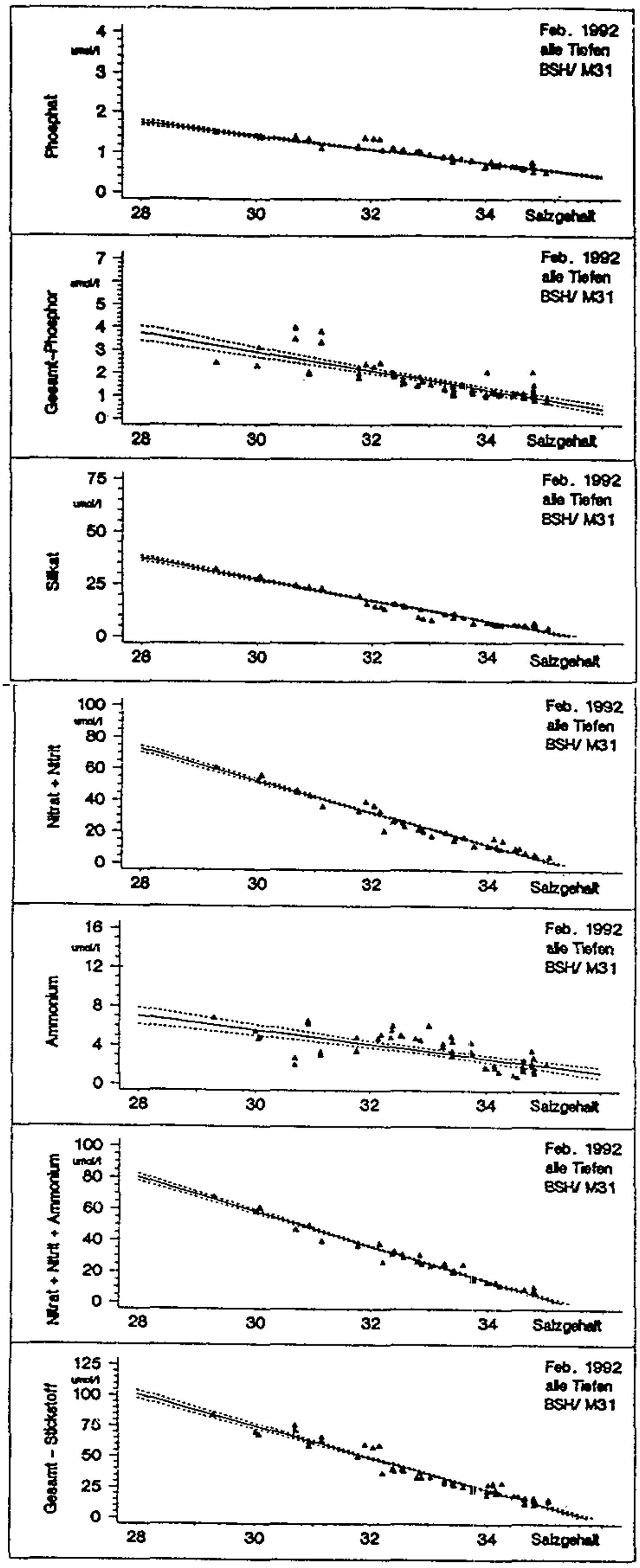


Figure 3.10.: Nutrient-salinity relation. All depth, February 1992

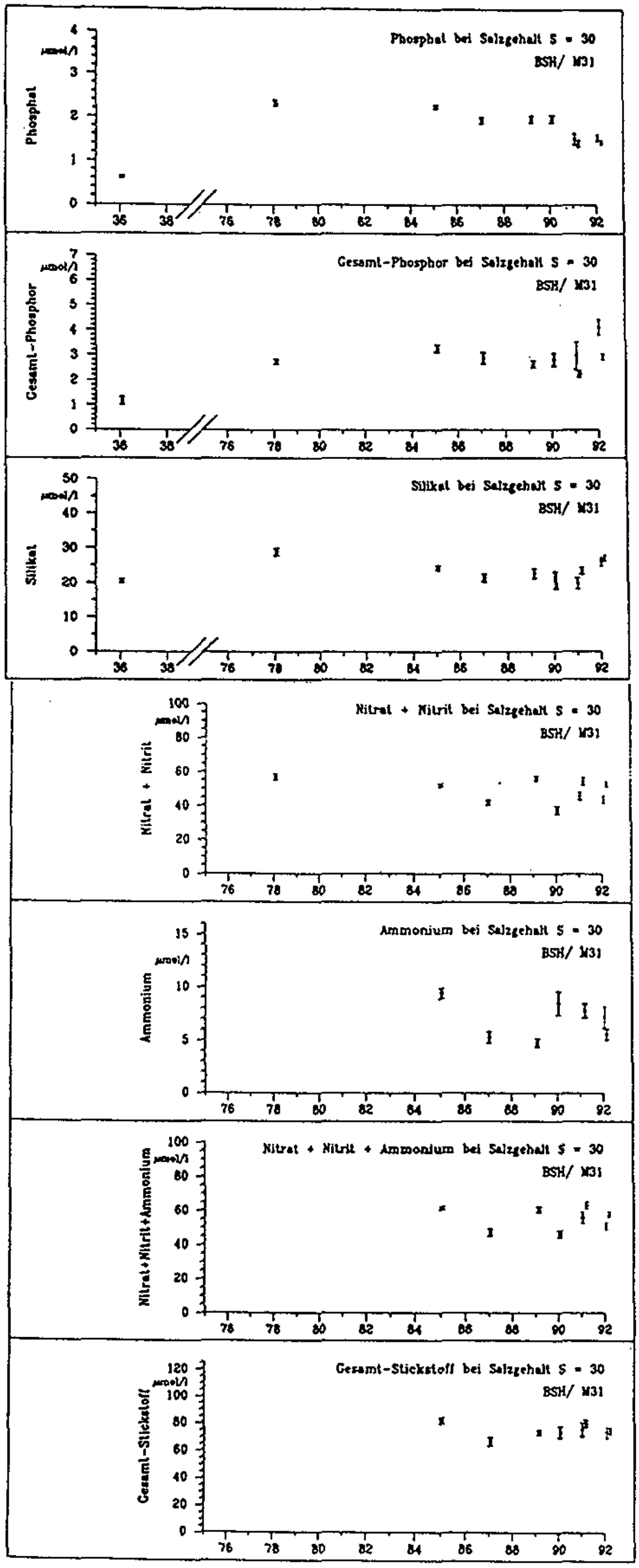


Figure 3.11.: Mean nutrient concentrations at a salinity of 30 in the winter water of the German Bight.

The Biologische Anstalt Helgoland determined inorganic nutrients at Helgoland Roads since 1962. These measurements were carried out daily and included many more parameters; they are among the longest and the most comprehensive time-series measurements in the North Sea. After three decades, they are now adequate to show the progress of eutrophication in this transition area between the coastal water and the North Sea water, about 50 km north west from the Elbe river mouth as the main source of eutrophication.

The **phosphate** concentrations increased in the sixties and early seventies levelling off to about twice the former concentrations, and then decreasing since 1982. The nitrate concentrations only increased since 1980/81 (Hickel et al. 1993). Phosphorus and nitrogen eutrophication hence did not occur simultaneously. Phosphate increased mainly as a consequence of phosphate-containing detergents, and comes from point sources, whereas nitrate comes mainly from non-point (diffuse) sources such as fertilized agricultural land. The wash-out of inorganic nitrogen from such areas can be demonstrated by its correlation with rainfall and river water discharge.

Nitrate concentrations are documented in **Figures 3.12 and 3.13** by the y-offset and the regression coefficients of the regressions between nitrate and salinity. From this it is clear that nitrate concentrations are still increasing, in contrary to phosphate concentrations. This leads to an increasing surplus of nitrogen over phosphorus as plant nutrients in the coastal water of the North Sea (Hickel et al., 1992 and 1993).In

February 1992, the Danish Environmental Research Institute found a general nutrient distribution following the salinity with the highest nutrient concentrations at the lowest salinity values in the German Bight and along the coast of Jutland. It was most conspicuous for nitrate and silicate but also clearly seen for phosphate and total phosphorus. Ammonium in measurable amounts was in general not found in the subregion (Ærtebjerg G. et. al 1992)

Very high concentrations of nitrite (max. 3,5 µmol/l) was found in the German Bight in an area up to Northwest of Horns Rev The high nitrite concentrations were not found along the coast like the other nutrients. The high nitrite concentrations were found more to the west at the edge of or outside the Jutland current. Nitrite concentrations values of more then 2 µmol/l was found at salinities of 33,7-34,75 ‰ with the highest concentrations at 34,3 ‰.

The origin of these unusual high nitrite concentrations is unknown, but they have been observed in a higher or lower extent in the eastern part of the North Sea at all cruises conducted by the Danish Environmental Research Institute in wintertime in the years 1986 to 1992. The nitrite probably does not come from discharges or by reduction of the nitrate carried out by the great rivers on the continent (Ærtebjerg et al. 1992).

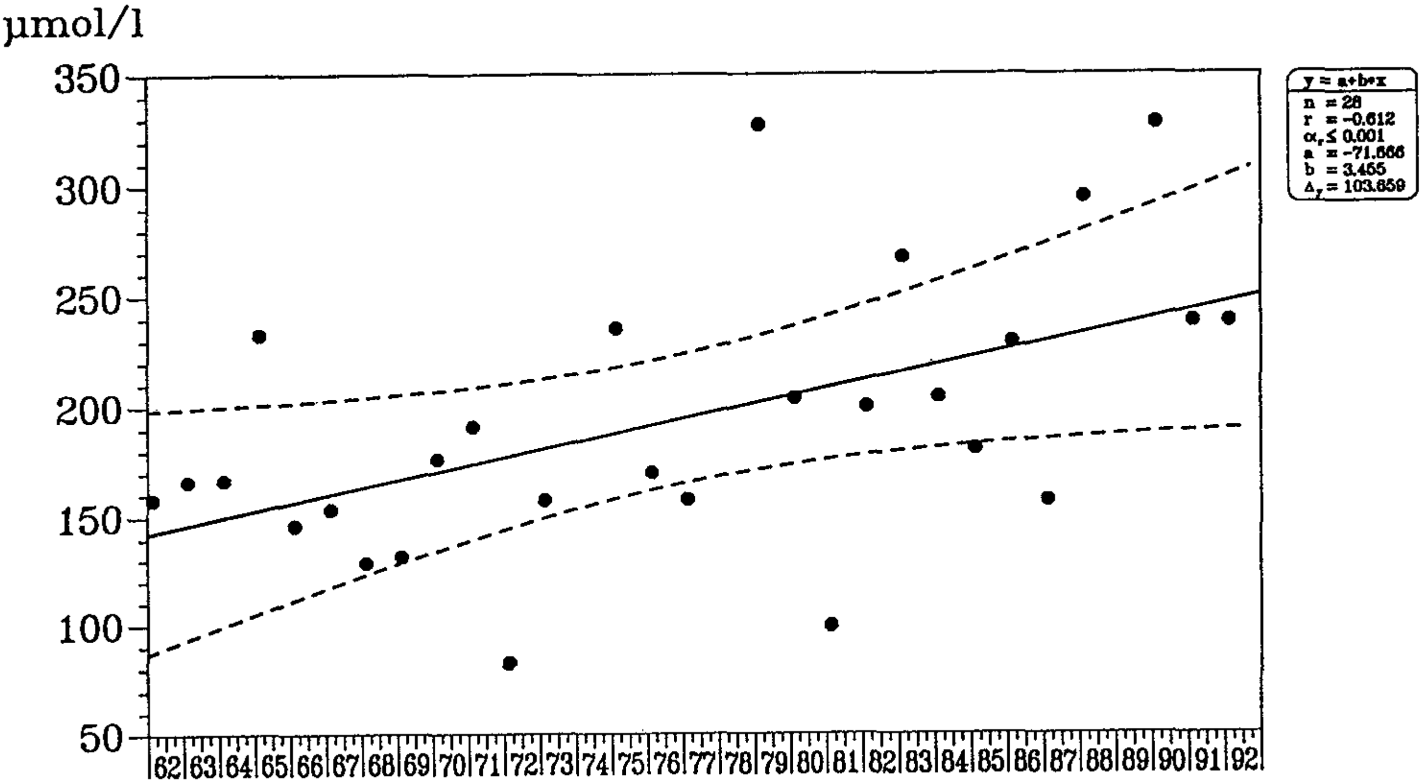


Figure 3.12.: Nitrate-N, Helgoland Roads, month January to March during the period 1962-1992. Y-offsets (calculated nitrate concentrations at a salinity of 0) from regressions of nitrate on salinity, for the pooled values, January to March, from each year.

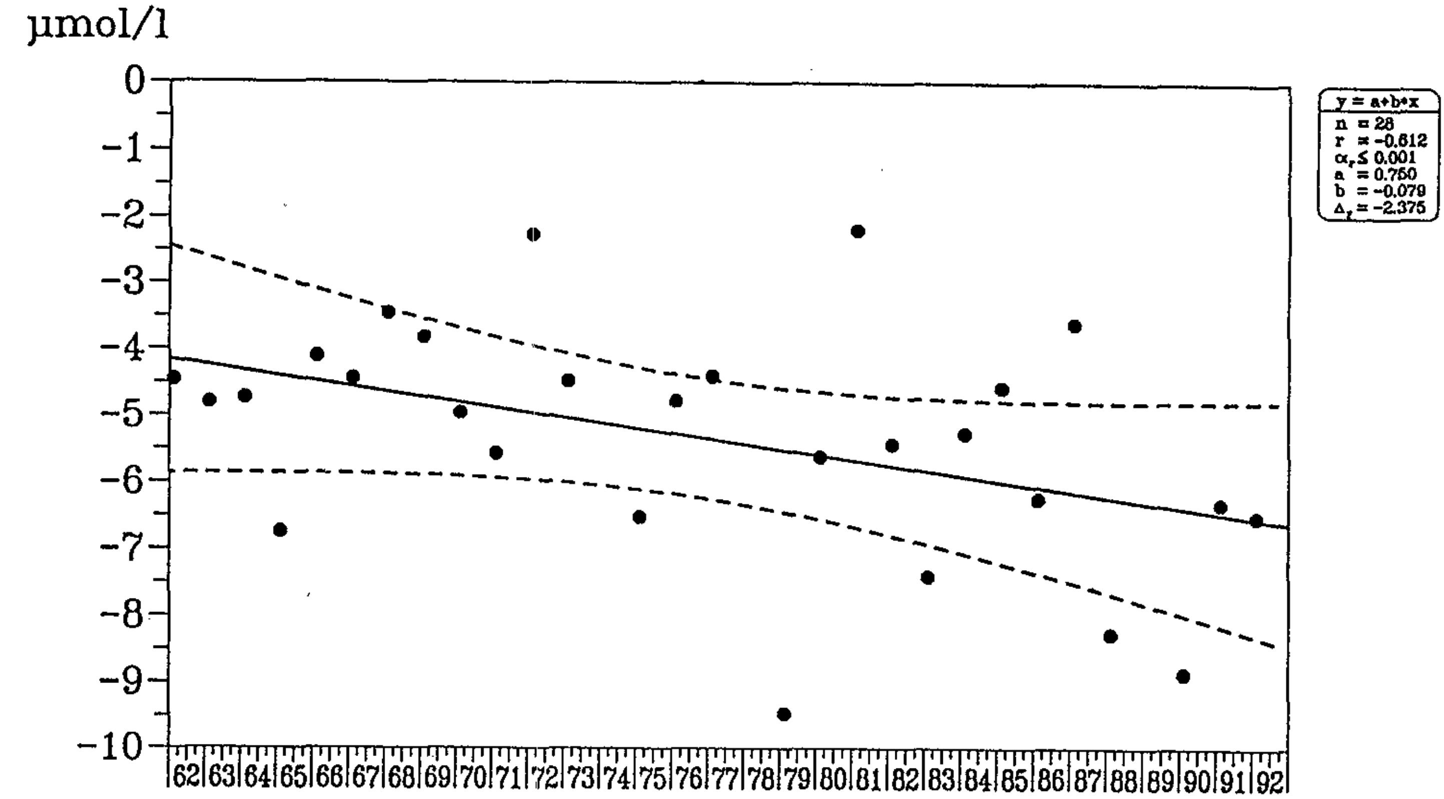


Figure 3.13: Nitrate-N, Helgoland roads, month January to march during the period 1962-1992. Slopes (regressions coefficients) from the (negative) regressions of nitrate on salinity for pooled values, January to March, from each year.

Radioactive substances

Artificial radioactivity of the North Sea originates primarily from the following sources:

- global fallout from atmospheric nuclear weapon tests
- liquid discharges from the nuclear reprocessing plants at Sellafield, La Hague, and Dounreay
- the fallout from the nuclear reactor accident at Chernobyl end of April 1986
- releases from nuclear power plants surrounding the North Sea or located on rivers discharging into the North Sea.

By far, the discharges from the reprocessing plants at Sellafield into the Irish Sea were the dominant source of artificial radioactivity in the North Sea during recent years. However, a significant decrease of liquid discharges at Sellafield induced the drop of concentration in the North Sea after a time delay of 2 to 4 years after the discharge, respectively (Nies, 1990a). The other sources are of minor importance concerning the inventory of artificial radioactivity in the North Sea. Liquid discharges from nuclear power stations are negligible in the North Sea (MARINA 1989, Nies 1990b).

Discharges from La Hague were much lower in activity, but, according to the water mass transport through the North Sea, the La Hague contamination is primarily detected in seawater on a parallel route to the southern and eastern margin of the North Sea (Nies, 1989).

Subregion 5 is located within the area of the La Hague contamination, but at its northern part, it represents the mixing zone between the Sellafield and La Hague contamination (Nies, 1989).

During recent years it has been possible to distinguish the source of contamination of a given water mass by its characteristic activity ratio Sr 90/Cs 137. The Sellafield signal showed a higher Cs 137 activity, while the La Hague plume revealed a pronounced Sr 90 activity. The Chernobyl contribution could be identified by means of the characteristic Cs 134 nuclide which was released during the accident with a fairly constant activity ratio Cs 134/Cs137 of about 0.54. Area 5 was a region which received a higher deposition from the Chernobyl accident compared to other areas of the North Sea except area 6. It was calculated that about 4 kBq/m^2 Cs 137 were deposited on area 5 at beginning of May 1986 (DHI, 1987; Nies und Wedekind, 1987; Mitchell and Steele, 1988).

Figure 3.14 shows the long-term observation of the Cs 137 and Sr 90 activity concentration at two positions of the inner German Bight since 1961. The input from the Chernobyl accident are well elucidated by sharp signals in 1986. However, the concentrations decreased rapidly due to removal of the contaminated water mass from the German Bight along the Jutland coast current and by dilution with less contaminated water from the Channel.

Figure 3.15 and 3.16 exhibit the spatial distribution of Cs 137 in february 1991 and Sr 90 in February 1991 in and around area 5, respectively. The somewhat higher concentration of Cs 137 in the north-western box of area 5 are still due to Sellafield discharges in previous years, whereas the slightly higher values of the Sr 90 concentration are located closer to the shore line according to higher Sr 90 discharges at La Hague.

Tc 99 (T = 210000 a) concentrations were found to vary between 1 and 3 Bq/m^3 in area 5. The concentration of the *transuranic nuclides* Pu 239/240, Pu 238, and Am 241 are close to global fallout levels. Pu 239/240 in area 5 was determined at levels between 2.8 and 7.5 mBq/m^3, Pu 238 between 0.5 and 2.0 mBq/m^3, and Am 241 between 0.4 and 2.9 mBq/m^3.

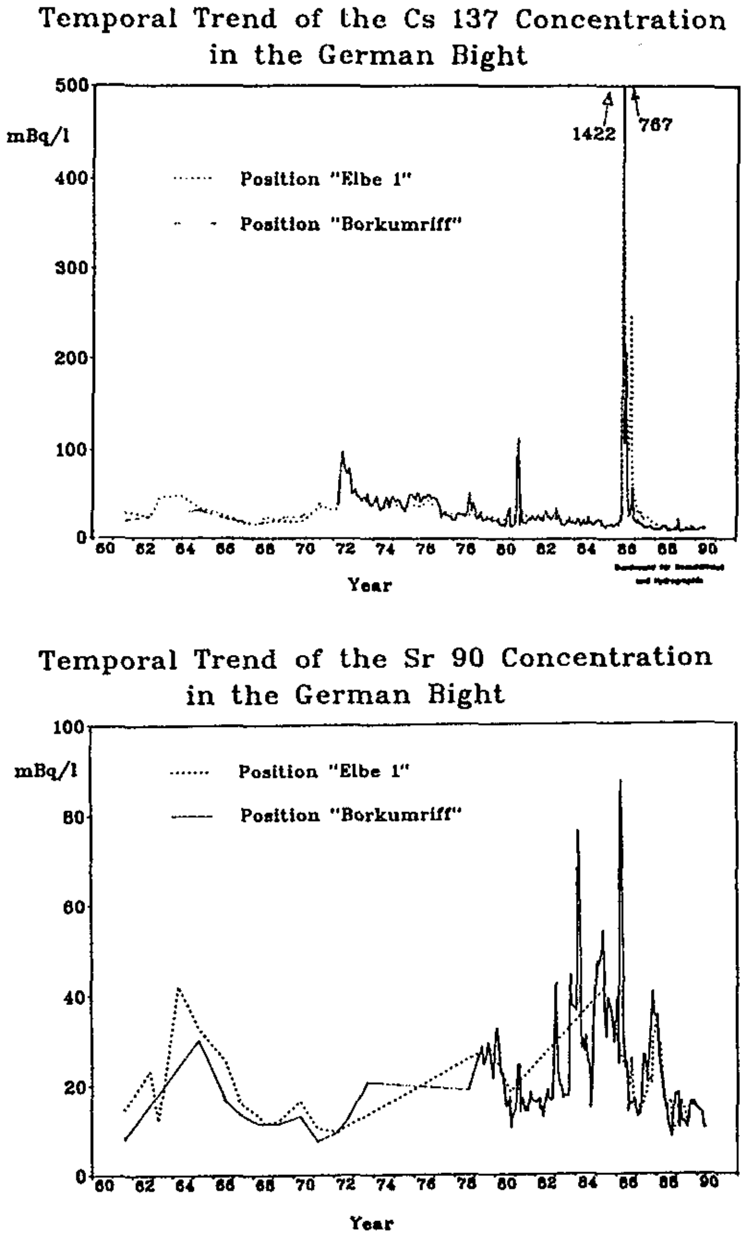


Figure 3.14.: The long-term observation from 1961 to 1990 of the Cs 137 and Sr 90 activity concentration (Bq/m^3) at the two positions of the former light vessels "Borkumriff" and "Elbe 1" located in subregion 5.

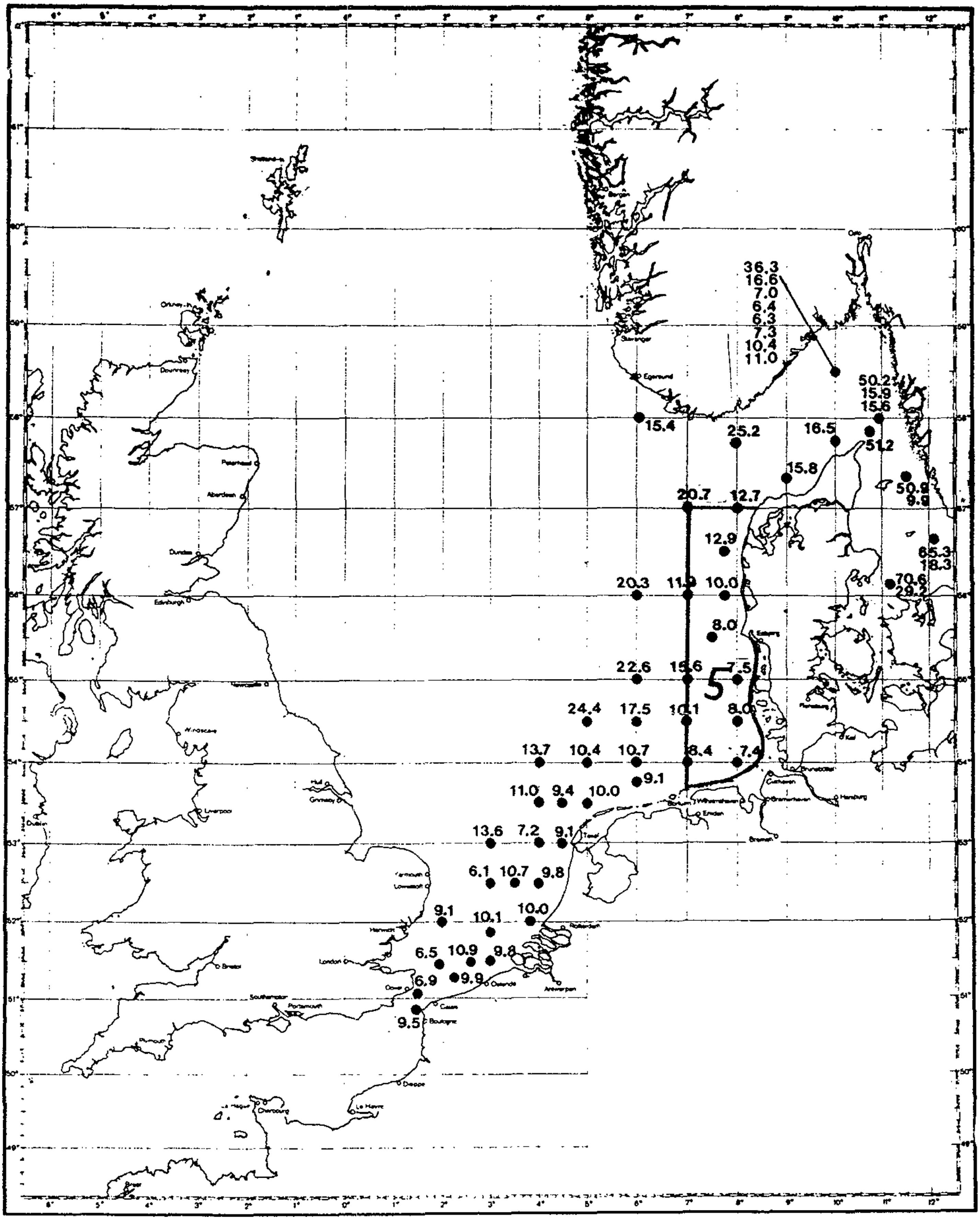


Figure 3.15.: The spatial distribution of Cs 137 (Bq/m³) in the water of the North sea in February 1991. Subregion 5 is indicated.

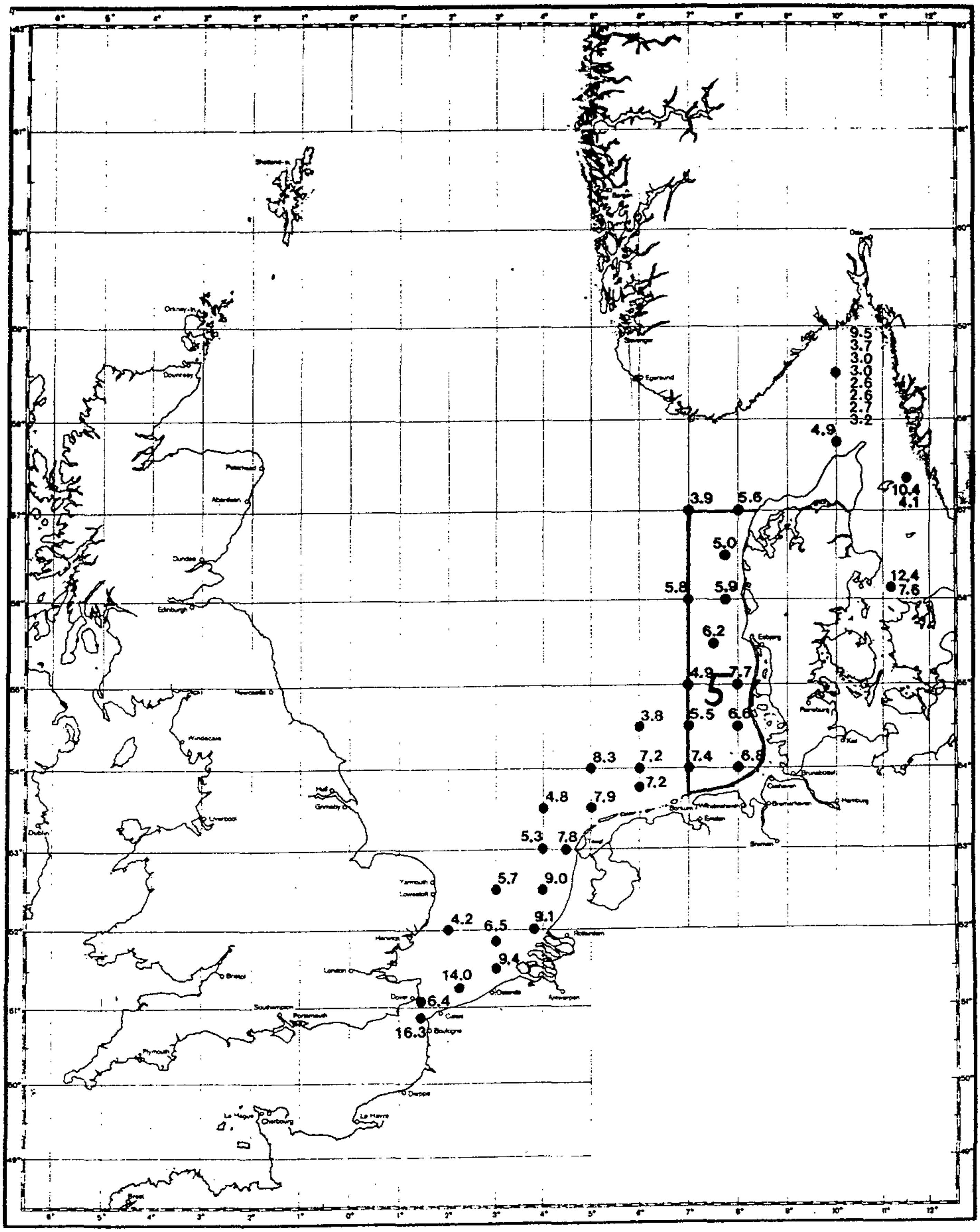


Figure 3.16.: The spatial distribution of Sr 90 (Bq/m³) in the water of the North sea in February 1991. Subregion 5 is indicated.

3.1.2 Spatial distribution of chemicals in sediments

Wide areas of the North Sea floor are covered by sandy sediments. There are few mud areas only. High values of mud are mainly found in NSTF-area 5, especially in the area south east of Helgoland, and in parts of NSTF-area 6 and 8.

Particulate metals from natural and anthropogenic sources accumulate together. A normalization procedure of the concentrations found is therefore necessary to compensate for the natural variability of trace metals in the sediments in order to be able to differentiate between the natural and the anthropogenic input. Several normalisation procedures have been suggested but grain size is an important parameter which is necessary to compensate for in any normalisation procedure (Loring, 1991).

In area 5 the amount of fines (grain size fraction < 20 µm) varies between less than 0.1% and more than 70%. A relevant normalisation procedure is therefore highly demanded to get comparable data for the whole area 5. ***Figure 3.17*** shows a "south north transect" of the content of fines in area 5.

High levels of fines are only found in the southern part of area 5. The sediment along the Jutland west coast is sandy and there is in general no net sedimentation in this area, although there is always the possibility of a temporary deposition. No regular monitoring of contaminants in the sediment has therefore been performed in this part of area 5. This has been done, however, for certain areas in the German Bight. Therefore are e.g. time-trend series only available for the German area.

Most trace metal data of surficial sediment are from one German laboratory, (BSH) They have analyzed 630 samples from the whole NSTF-area. 240 of these are from area 5 and mainly from the German part (224). Sediment samples collected along the Jutland west coast, were also analyzed by a Danish laboratory as a part of the JMP/NSTF programme 1990/91. The metal concentrations in the <63 µm fraction as well as in the total fraction were analyzed.

In order to be able to compare new data with their older sediment data, e.g. for trend analysis Germany has mainly analyzed the fines(< 20 µm) of the sediments and not the <63 µm fraction or the total fraction, <2000 µm, which was the method agreed upon by NSTF/JMG. They have also used nitric acid under pressure for the extraction of most metals, in stead of a total dissolution method. It is often stated, that nitric acid extraction dissolves certain metals, especially chromium, incompletely in coarse sediment. In the case of fraction <20 µm, however, the nitric acid extraction yields almost the same results as total digestion using HF according to the German experience (Albrech, 1992). However, in addition, a series of samples were also analyzed according to the guidelines. This set of data is, however, much smaller than the <20 µm data set.

The German data set of fines (<20 µm) is without exception the largest directly comparable data set from area 5, as mentioned earlier. These results are therefore mainly used below to describe the geographical distribution and time trends of metals in the sediment in area 5. The Danish data sets as well as the other German data are only used as a supplement and in comparison with the <20 µm data.

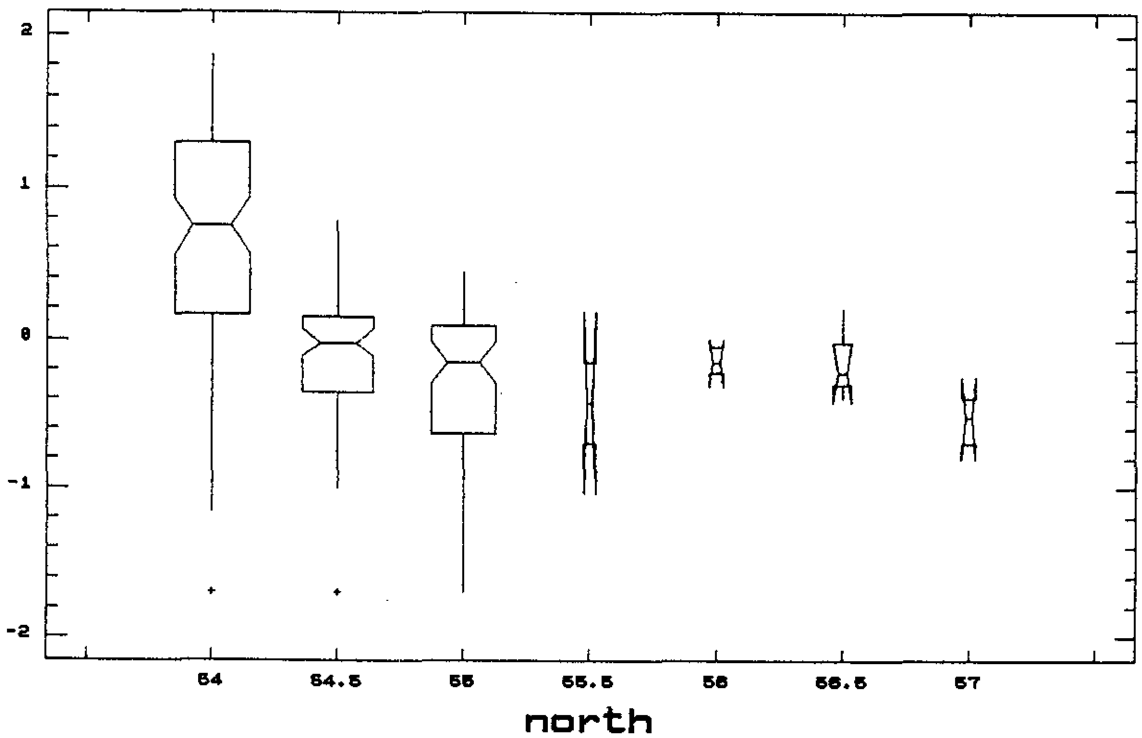


Figure 3.17.: *South-north transect of fines (particles < 20 µm) in subregion 5. Log10 of % of fines.*

North Sea

Some data for the whole North Sea are first presented to give some relevant background information before the trace metal distribution in area 5 is discussed.

In order to understand the pattern of the trace metal distribution and also for a relevant assessment of the pollution, *information concerning the main components distribution is* necessary. These parameters are also often used for the normalisation procedures.

Figure 3.18 shows the content of TOC in the fines of surficial sediments in different NSTF-areas, and ***Figure 3.19*** shows a "south north transect" of TOC through area 5. TOC levels in area 5 are in the same range as in most other NSTF areas. The highest levels are found around 55°N.

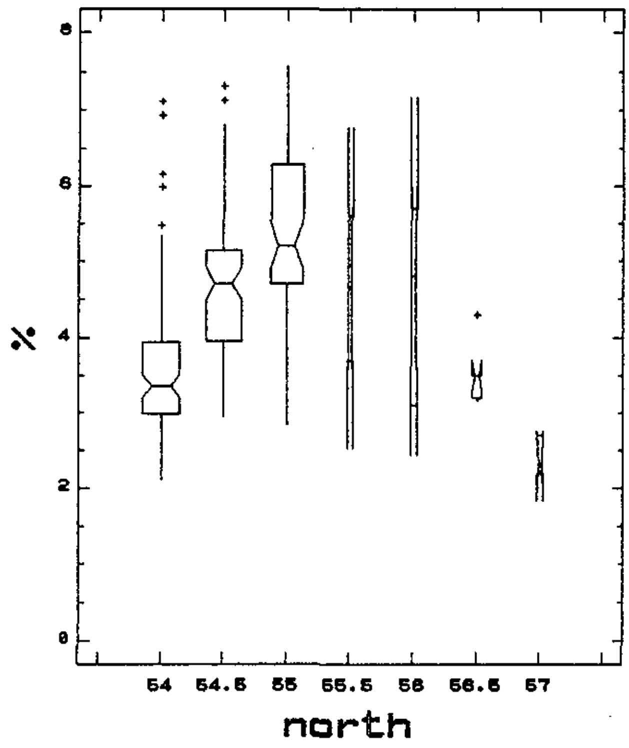


Figure 3.19.: *TOC in the fine fraction (particles < 20 µm) of NSTF area 5, south-north transect.*

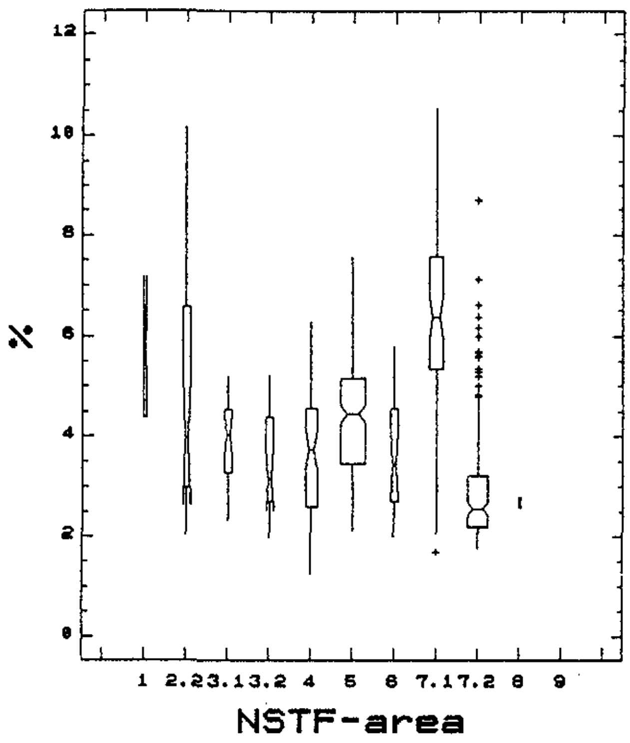


Figure 3.18.: *TOC in the fine fraction (particles < 20 µm) of suficial sediments.*

The content of organic carbon in a sediment depends both on the rate of supply and the rate of degradation. It is therefore not possible to give any background level for organic carbon.

In ***Figure 3.20*** the level of **aluminum** in the fines of surficial sediments is given. The levels are relatively uniform. Some low values in areas 2b, 3a, 3b and 4 correspond to high levels of carbonates in these areas.

The concentration of **titanium** is shown in ***Figure 3.21.*** Titanium is generally not enriched in the fines, but are usually found in the fraction of fine sands (60 to 90 µm), as titanium is a component of heavy minerals like ilmenite and rutile. Titanium has however been dumped into the German Bight, as acid iron wastes originating from titanium dioxide industry. The titanium dumped was in the form of fine grains. Some high levels have also been found in the German Bight within NSTF-area 5. In most areas titanium is rather uniform, showing again - as expected- some lower levels in areas of high carbonate content.

The content of **iron** and **manganese** in the fines of surficial sediments in different NSTF-areas. In most areas some high values do occur *(**Figures 3.22 and 3.23**).*

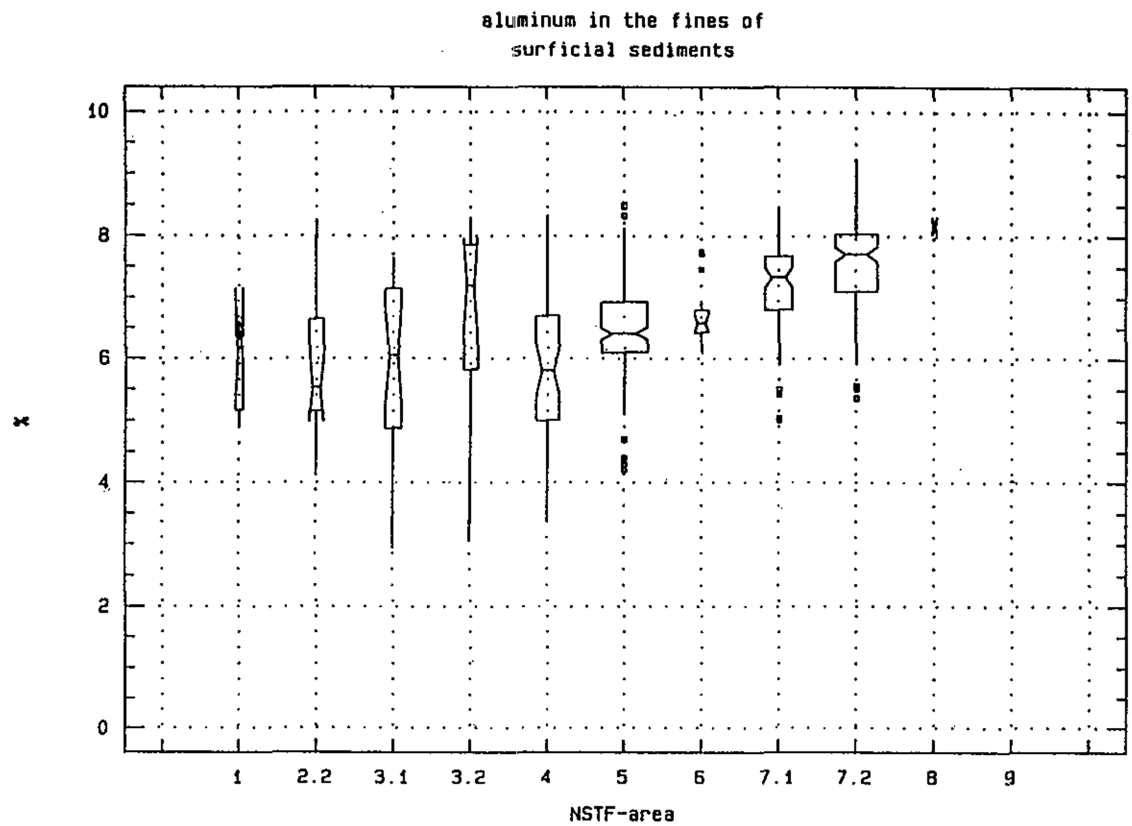


Figure 3.20.: Aluminum in the fine fraction (particles < 20 µm), NSTF-areas

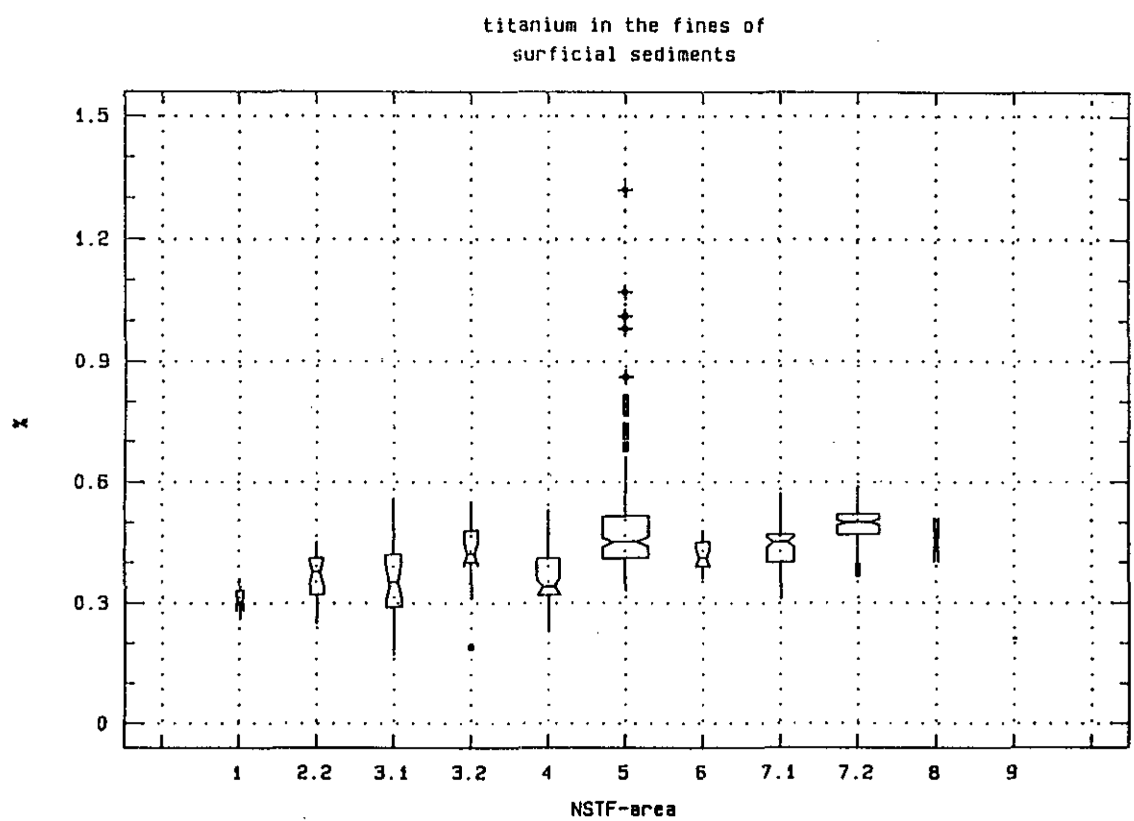


Figure 3.21.: Titanium in the fine fraction (particles < 20 µm), NSTF-areas

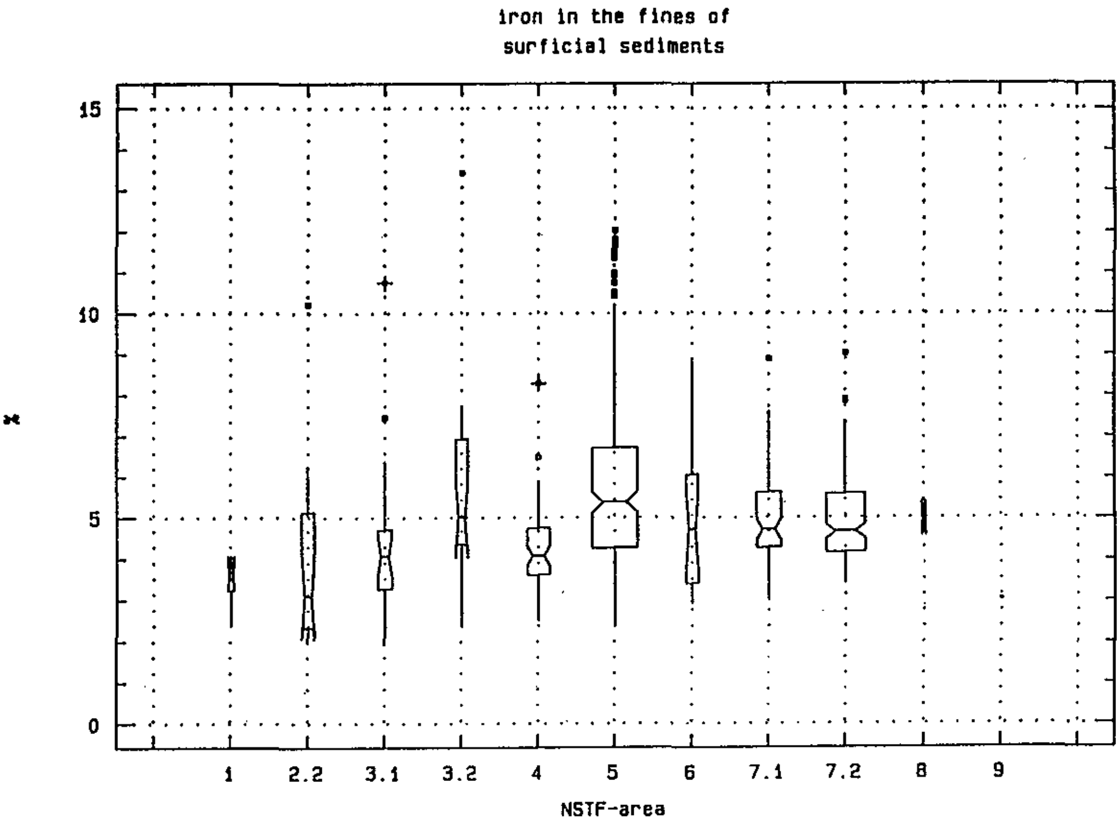


Figure 3.22.: Iron in the fine fraction (particles < 20 µm), NSTF-areas

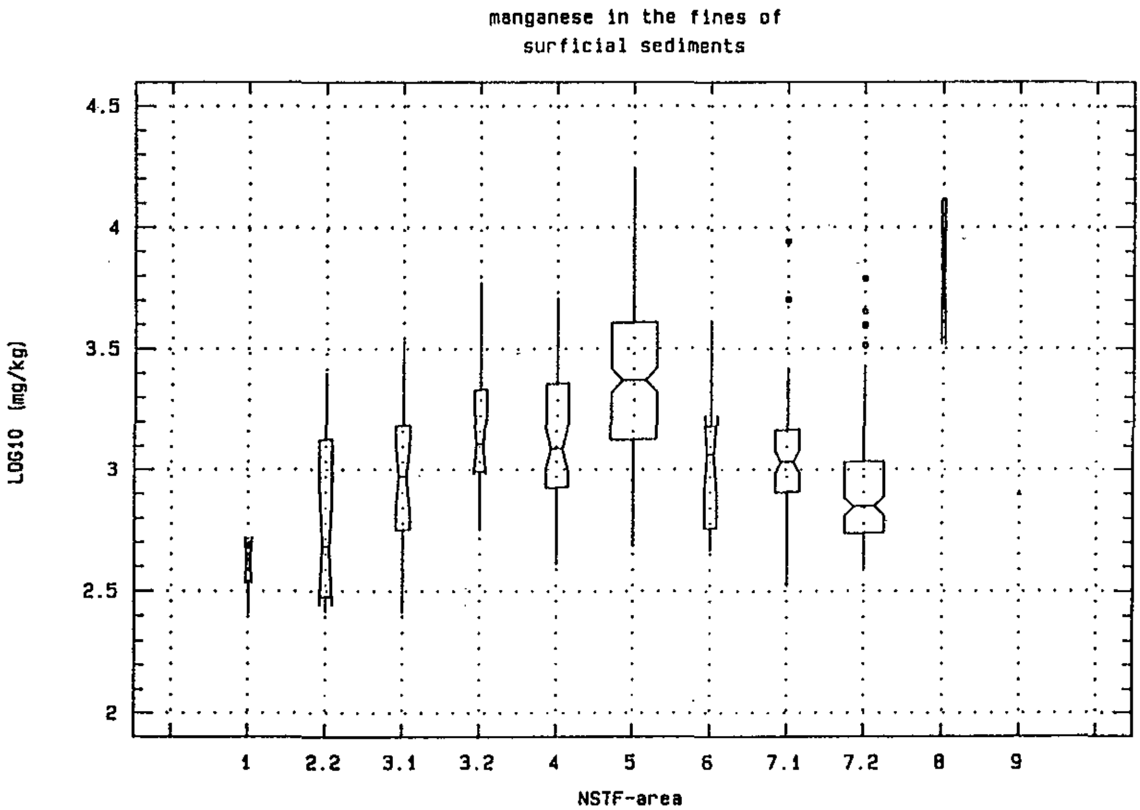


Figure 3.23.: Manganese in the fine fraction (particles < 20 µm), NSTF-areas

Iron and **manganese** are mobile elements, involved in the redox cycles of the sediments. They are partly dissolved in suboxic sediments, diffusing upward and downward from that zone, being oxidized and precipitated in the (surface) oxic zone in the form of oxide-hydrates and being precipitated in the downcore sulphitic zone as sulphide. The amount of fines in the sediment have an influence on these reactions.

The precipitation of iron in surface oxic sediments strongly influences the distribution of a series of elements, in particular those elements, which occur in the form of oxo-anions like arsenic, vanadium and (inorganic) phosphorus. But also some other elements like lead and zinc may be affected.

The distribution of **cadmium** *(Figure 3.24)*, **lead** *(Figure 3.25)*, **zinc** *(Figure 3.26)*, **copper** *(Figure 3.27)*, **chromium** *(Figure 3.28)*, **nickel** *(Figure 3.29)*, and **mercury** *(Figure 3.30)* in the fines of surficial sediments in different NSTF-areas have been measured by Albrecth (1992)

The results may be summarised as follows: High levels of mercury, cadmium and zinc in the fines occur mainly in area 5. Levels of lead and chromium higher than those found in area 5 occur in area 7a. The lead-TOC ratio and the chromium-TOC ratio in area 7a, however, are not higher than in area 5. Only minor differences appear in the distribution of nickel and copper between different NSTF-areas.

Very high levels of arsenic could be seen in some areas. These high levels are however associated with high levels of iron. Any possible anthropogenic input of arsenic and vanadium might be difficult to detect, due to the scavenging by iron oxide-hydrates.

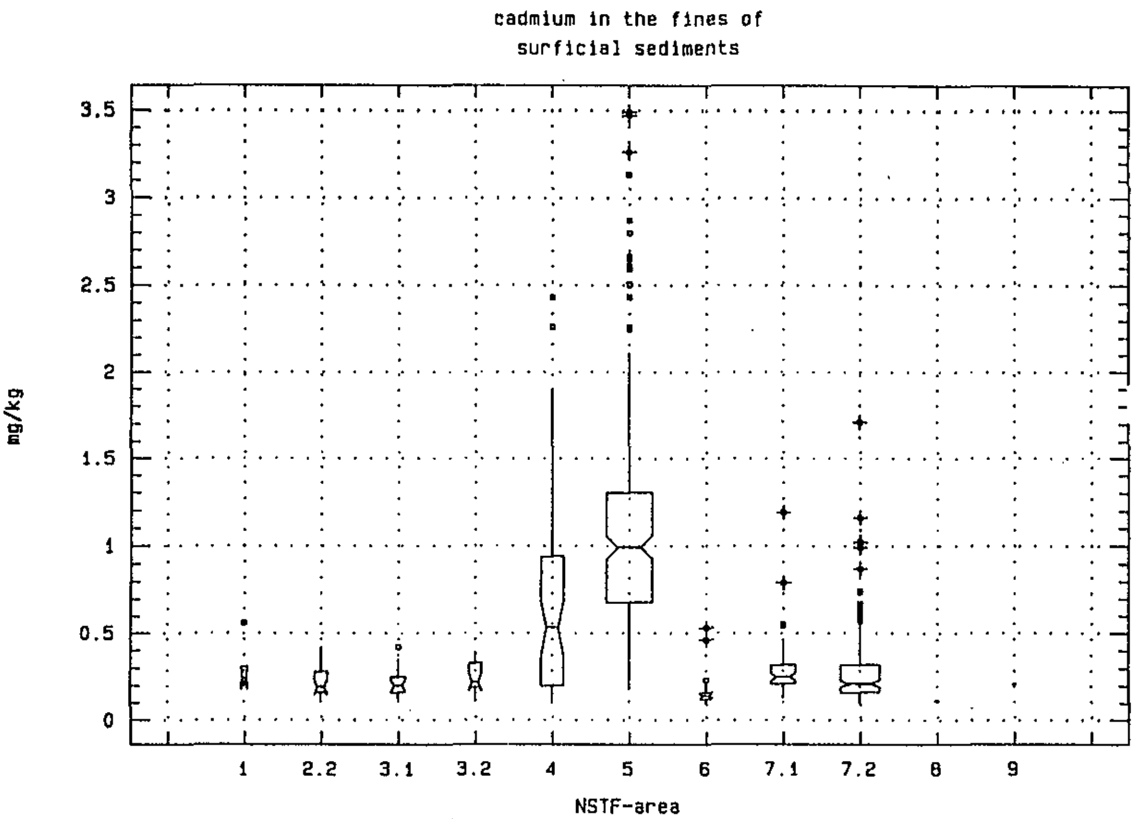


Figure 3.24.: Cadmium in the fine fraction (particles < 20 μm), NSTF-areas

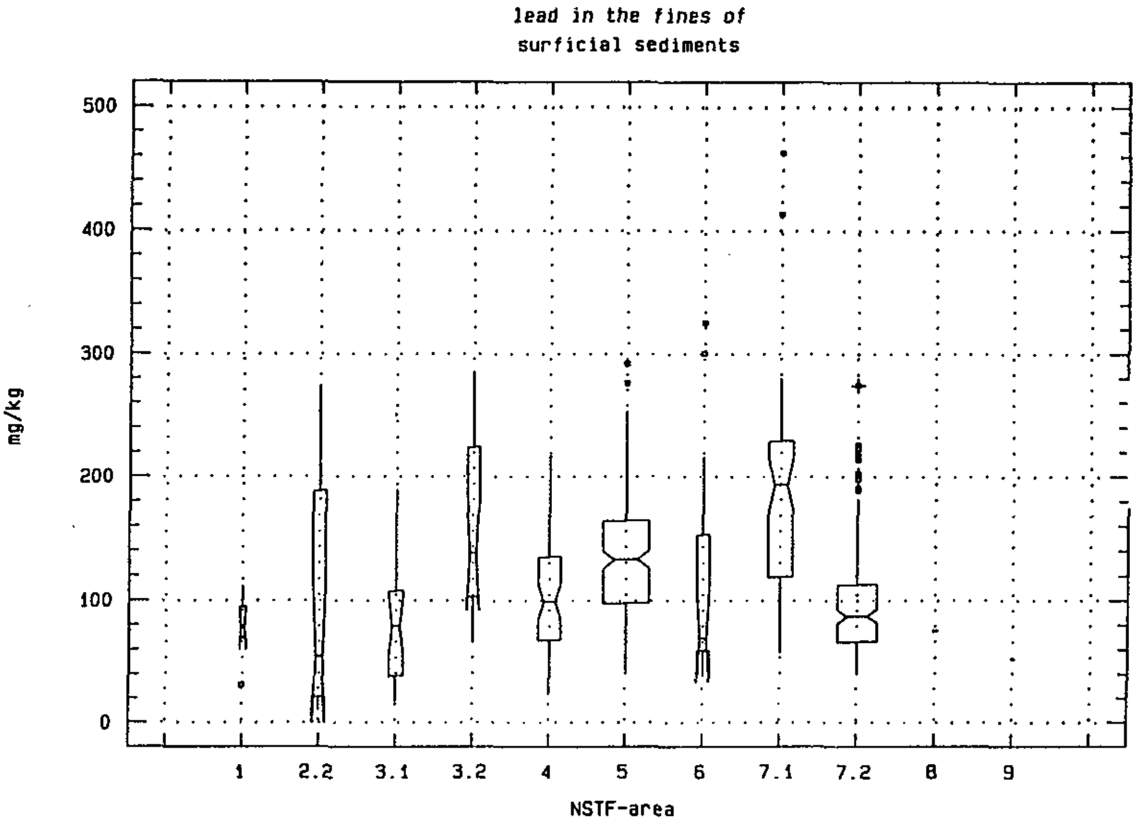


Figure 3.25.: *Lead in the fine fraction (particles < 20 μm), NSTF-areas*

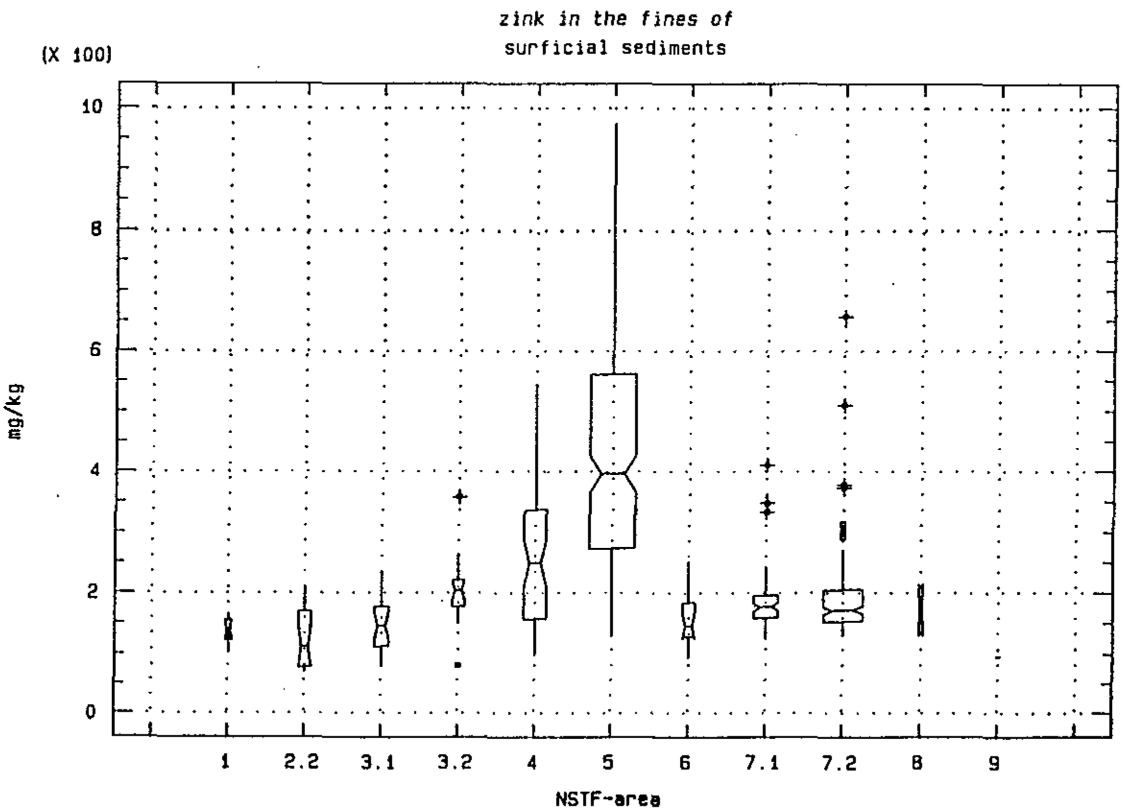


Figure 3.26.: *Zink in the fine fraction (particles < 20 μm), NSTF-areas*

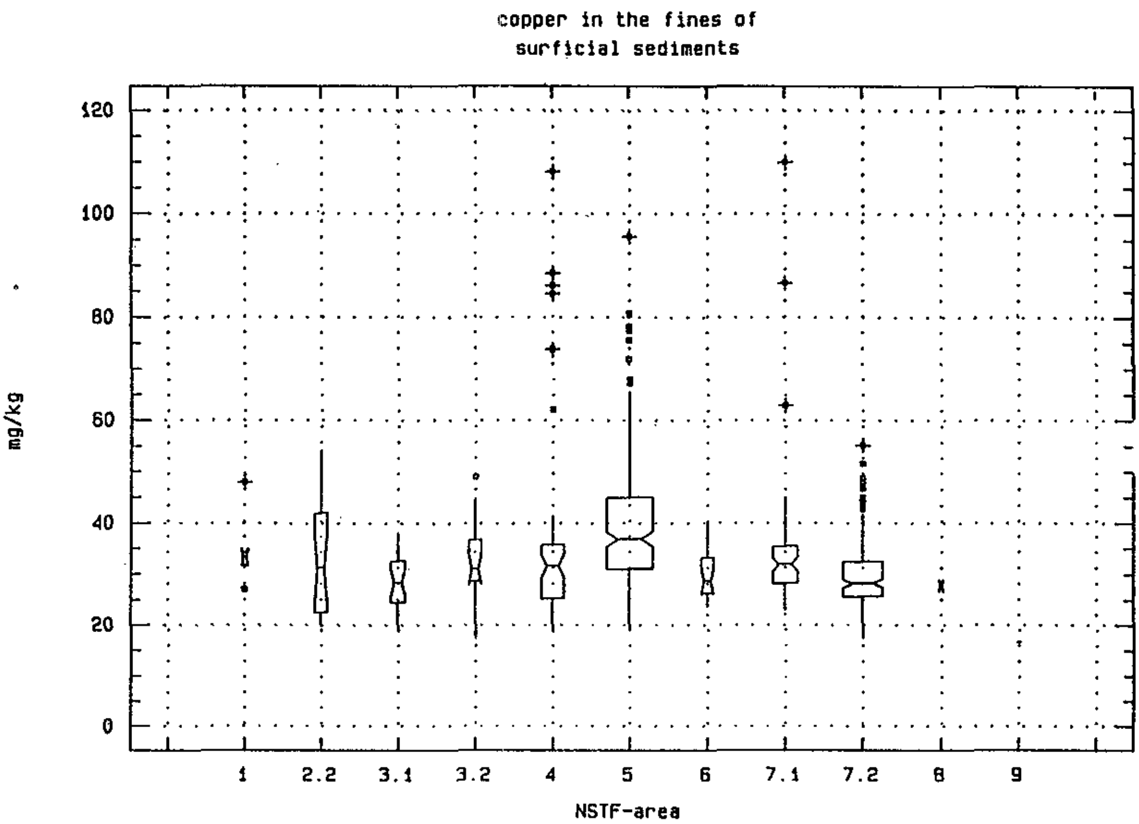


Figure 3.27.: Copper in the fine fraction (particles < 20 µm), NSTF-areas

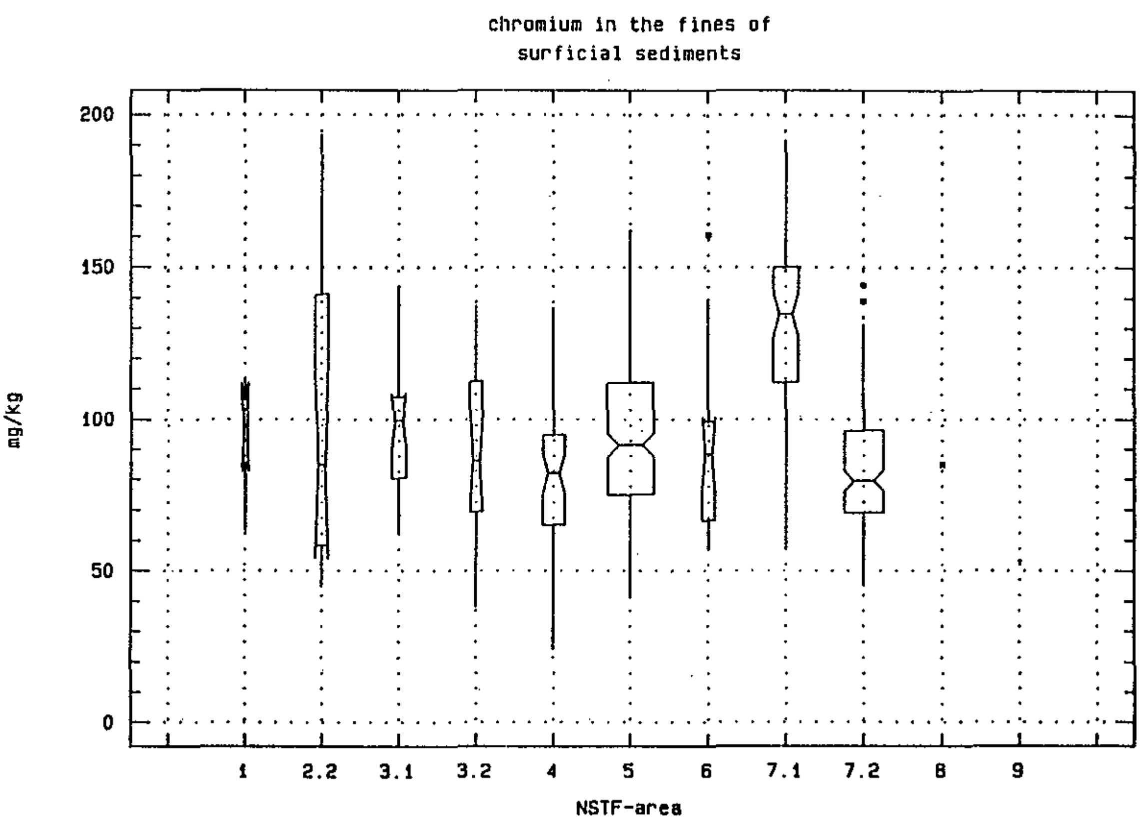


Figure 3.28.: Chromium in the fine fraction (particles < 20 µm), NSTF-areas

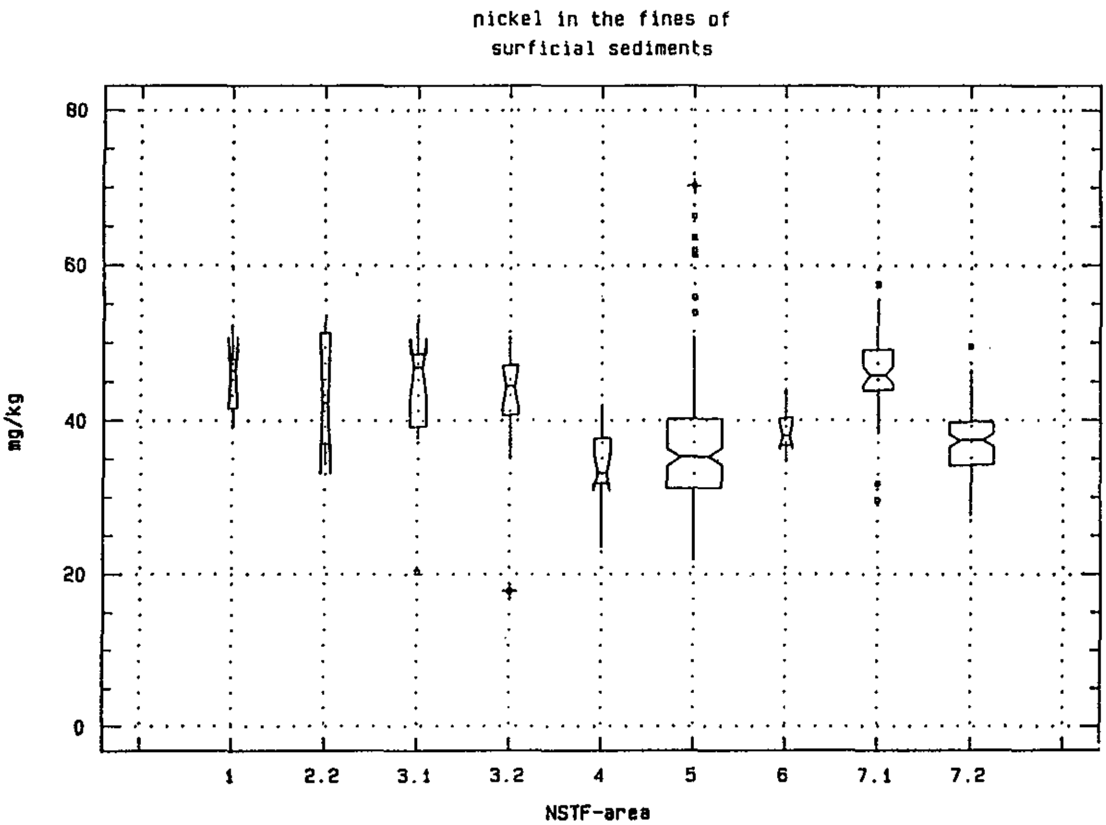


Figure 3.29.: *Nickel in the fine fraction (particles < 20 μm), NSTF-areas*

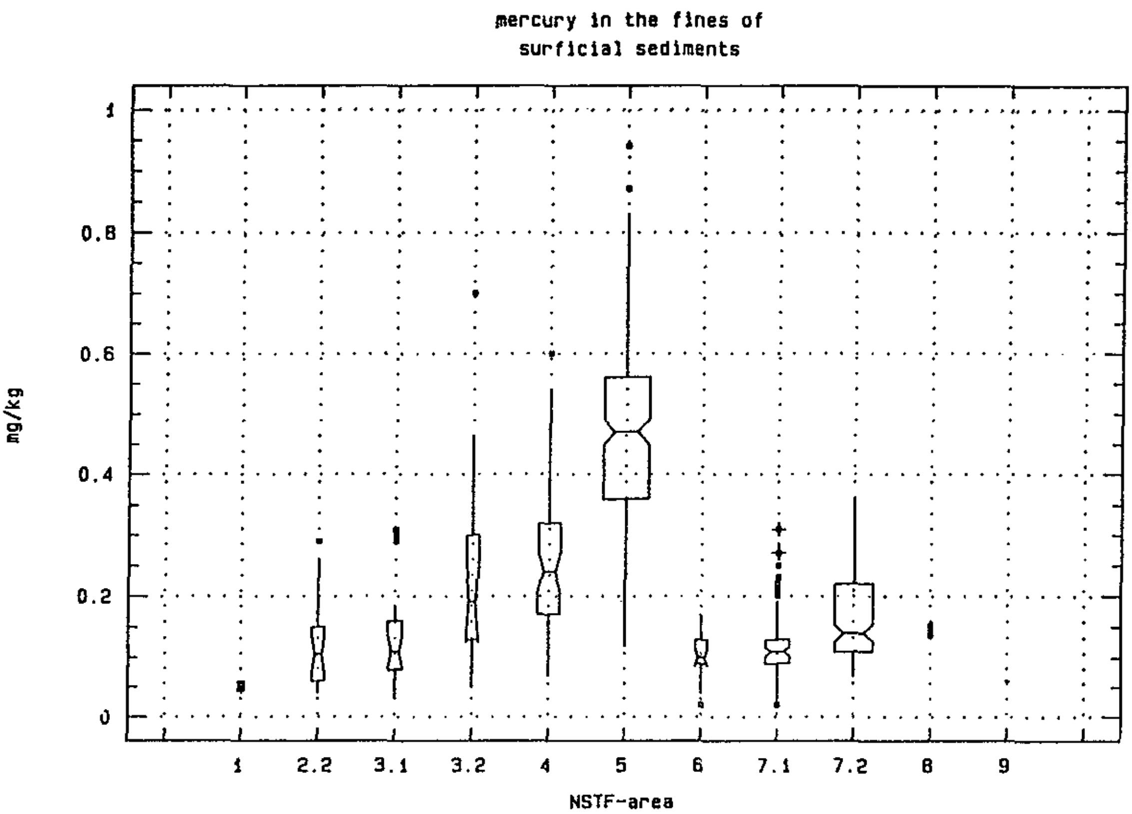


Figure 3.30.: *Mercury in the fine fraction (particles < 20 μm), NSTF-areas*

Sub-region 5

High levels of metals occur mainly in the southern part of area 5. The high levels of **copper** and **cadmium** at 55°N are accompanied by high levels of TOC. High levels of **lead, zinc,** and **chromium** at 54.5°N are accompanied by high levels of **iron**.

Iron level itself is, in addition to digenetic enrichment, affected by former dumping of acid iron wastes in that area. This view is supported by high levels of titanium at 54.5°N.

Figures 3.31-3.37 show "south north transects" of heavy metals (Hg, Cd, Pb, Zn, Cu, Cr, Ni) in the fines, metal-TOC ratios, metal-iron ratios, and metal-aluminum ratios within area 5. ***Figure 3.38*** shows corresponding plots for TOC, iron, aluminum, and titanium in the fines of NSTF-area 5.

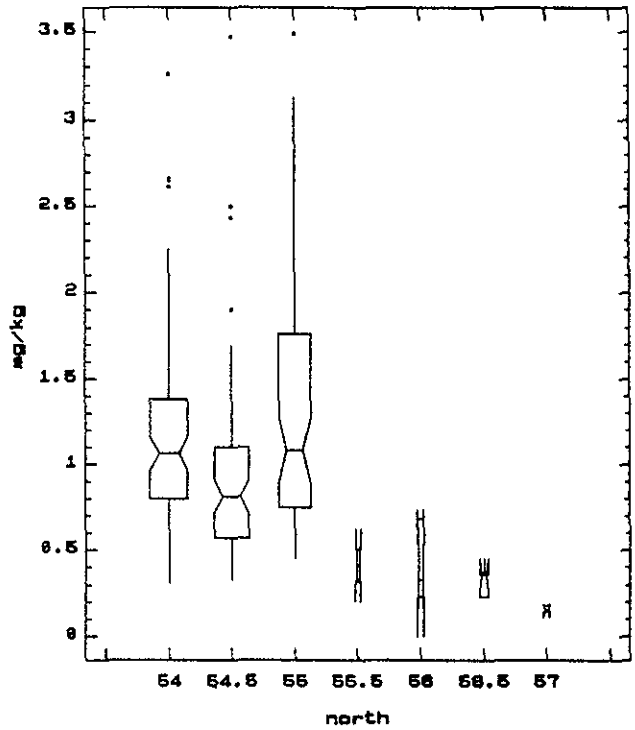


Figure 3.32.: *Cadmium in the fine fraction (particles < 20 µm), subregion 5 vs latitude*

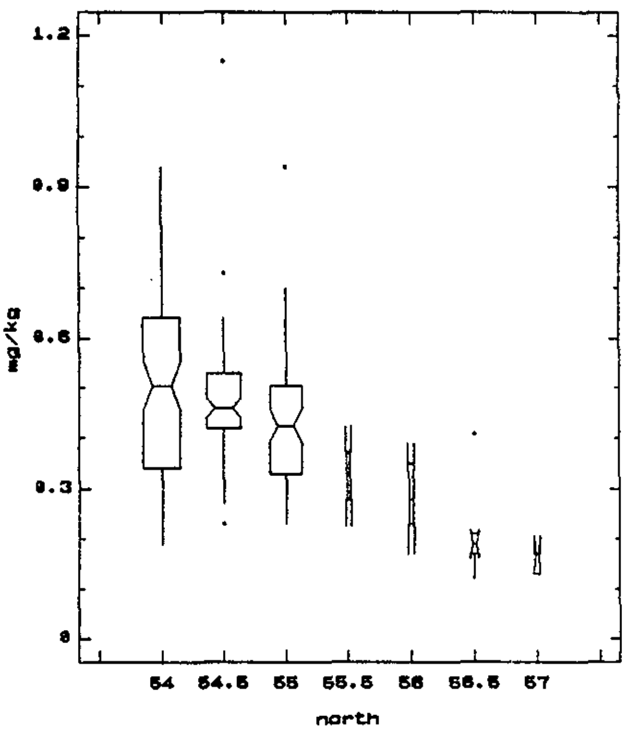


Figure 3.31.: *Mercury in the fine fraction (particles < 20 µm), subregion 5 vs latitude*

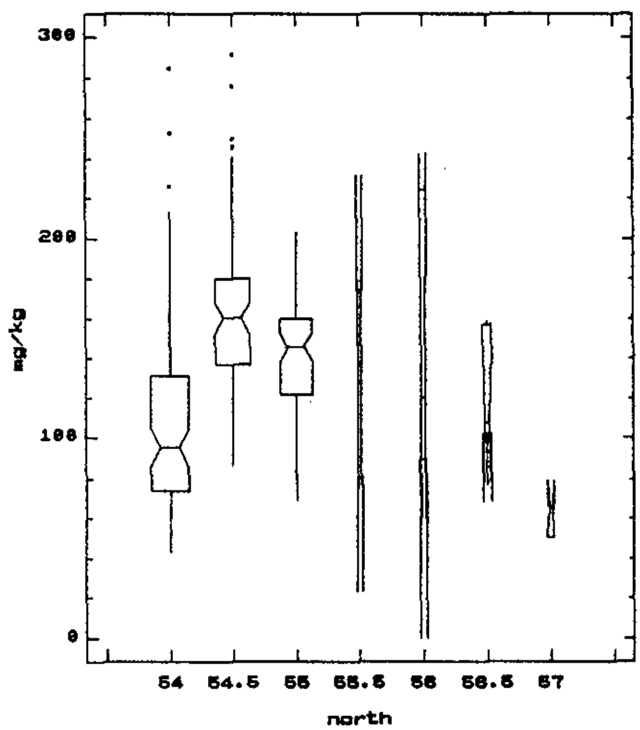


Figure 3.33.: *Lead in the fine fraction (particles < 20 µm), subregion 5 vs latitude*

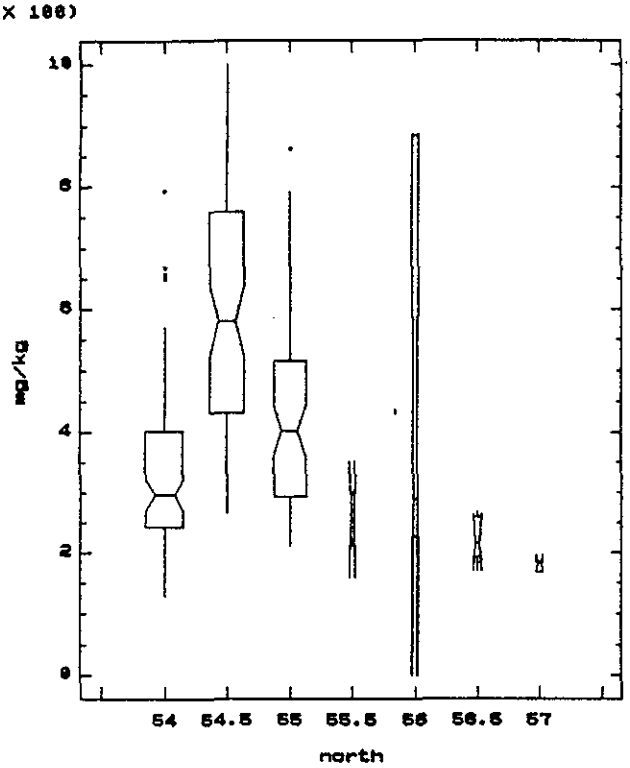


Figure 3.34.: Zink in the fines fraction (particles < 20 μm), subregion 5

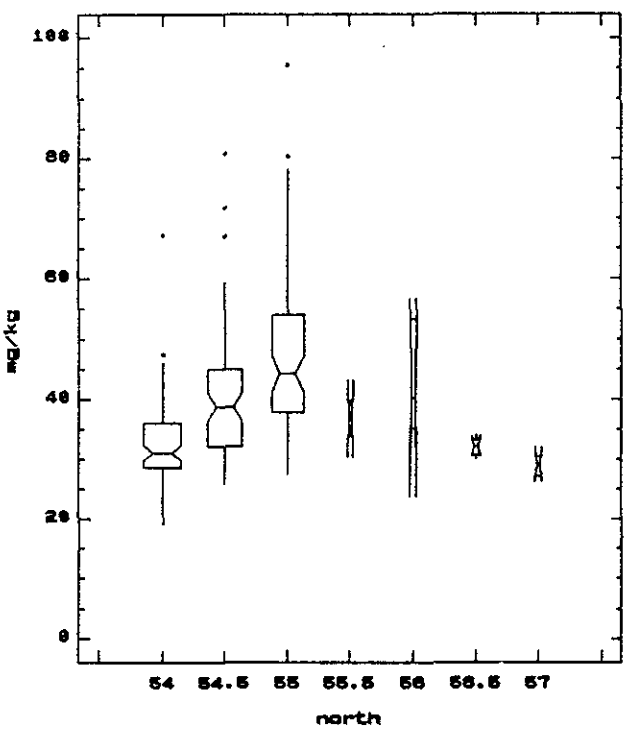


Figure 3.35.: Copper in the fine fraction (particles < 20 μm), subregion 5 vs latitude.

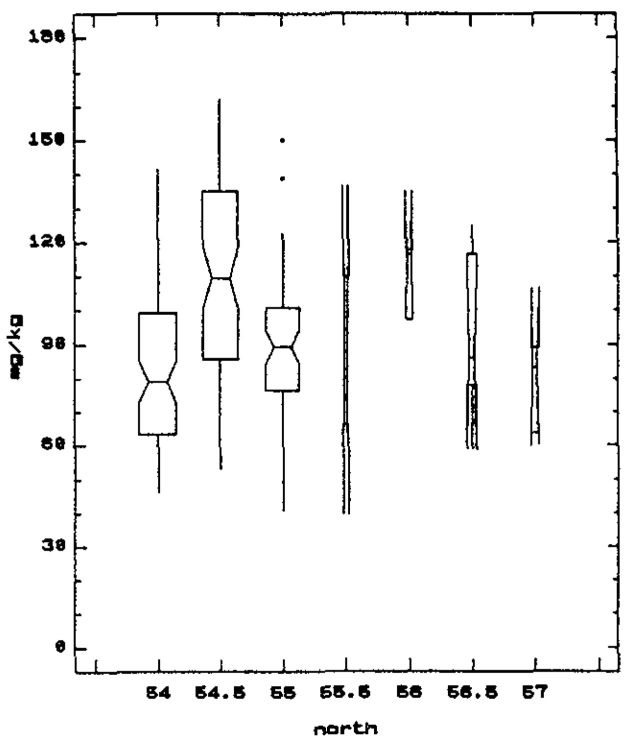


Figure 3.36.: Chromium in the fine fraction (particles < 20 μm), subregion 5 vs latitude

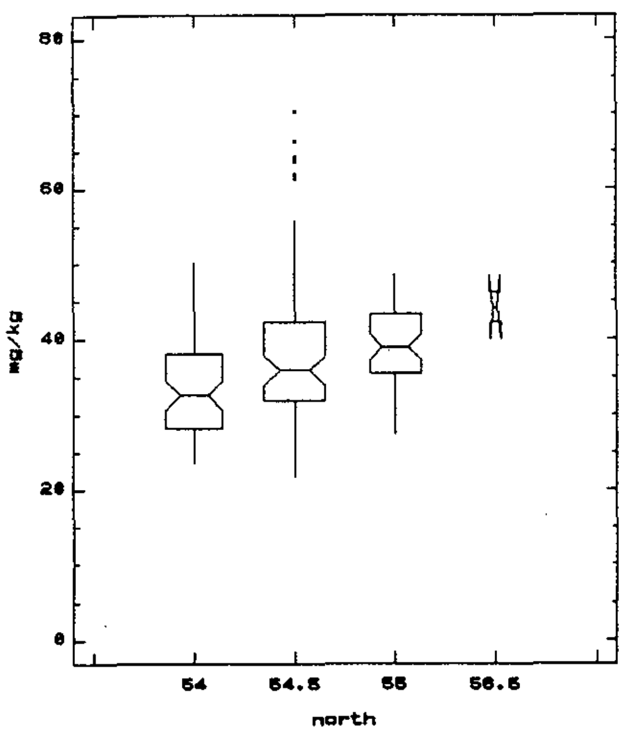


Figure 3.37.: Nickel in the fine fraction (particles < 20 μm), subregion 5 vs latitude.

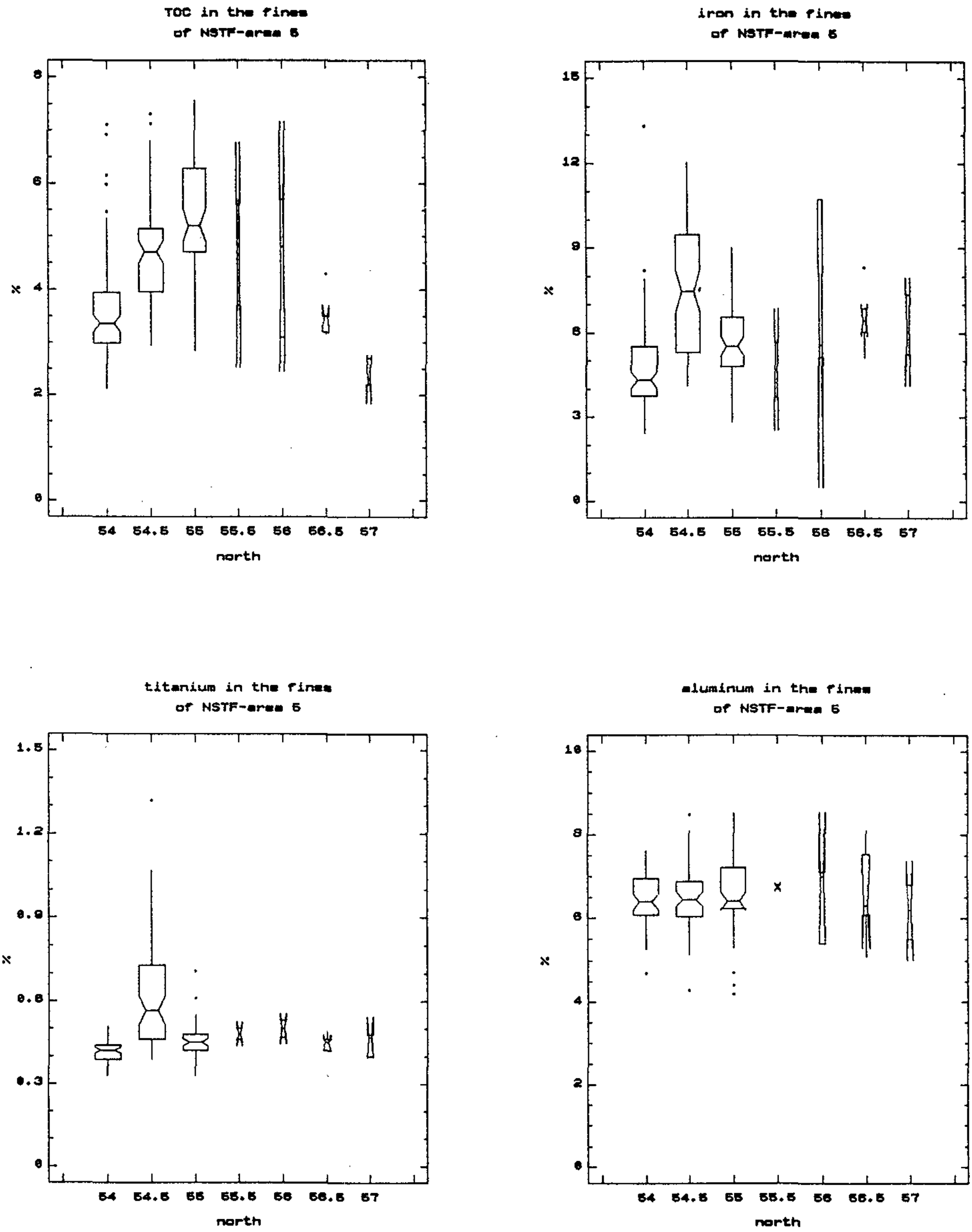


Figure 3.38.: TOC, iron, titanium, aluminum in the fine fraction (particles < 20 μm), subregion 5 vs latitude.

Frequently "background levels" are estimated from down core profiles penetrating to "preindustrial" layers (Pb-210 age more than 150 years). Although, this is not a straight forward procedure, it might, nonetheless, be useful to compare data from surficial sediments to data from deeper layers.

For these cores the average and the range for some trace metals are as follows in the fines < 20 µm (Data from Bundesamt für Seeschiffart, Hamburg):

Hg:	0.04 mg/kg	(0.02 - 0.08)
Pb:	24 mg/kg	(10 - 34)
Zn:	90 mg/kg	(80 - 110)
Cu:	19 mg/kg	(15 - 25)
Cr:	58 mg/kg	(50 - 70)
Ni:	34 mg/kg	(30 - 40)

No value has been given for cadmium. The detected range for cadmium is 0.1 to 0.7 mg/kg DW. In some areas cadmium is increasing with depth, even within "preindustrial" layers. This is probably due to precipitation of cadmium as sulphide or coprecipitation with sulphides.

A comparison of the concentrations found in the whole NSTF area and the background values given above shows, that in the northwestern part of the North Sea, i.e. in parts of areas 1, 2b and 3a, values not too far from "preindustrial" values are detected. The results also shows, that there is a large scale contamination of North Sea sediments with lead.

The Danish data set support the conclusions drawn from the large German data set.

The concentration of Zn, Cu, Ni, and Pb in the <63 µm fraction are given in ***Figure 3.39***, as a function of sampling site, given as the latitude of the position.

The **Zn-concentration** varies between 110-300 mg/kg DW. There is a clear tendency of a decreasing concentration when going north along the Jutland coast. A similar trend is not found for iron, neither for the other metals illustrated in the ***Figure 3.39***.

The concentrations of **Cu** and **Ni** are almost constant and approximately the same, 20-45 mg/kg DW. The Pb concentration vary between 45-85 mg/kg DW.

These concentrations are general except for Pb in the lower end of the ranges of the metal concentrations in general in the <63 µm fractions reported by Everaarts, et al. in 1992. The ranges for the North Sea were:

- Cu, 10-100 mg/kg DW, with even higher concentrations in the Southern Bight (144 and 242 mg/kg DW).

- Zn, 100-1000 mg/kg DW, with exceptional high concentrations between 1300 and 4000 mg/kg DW in the Southern Bight and one west of the Dogger Bank.

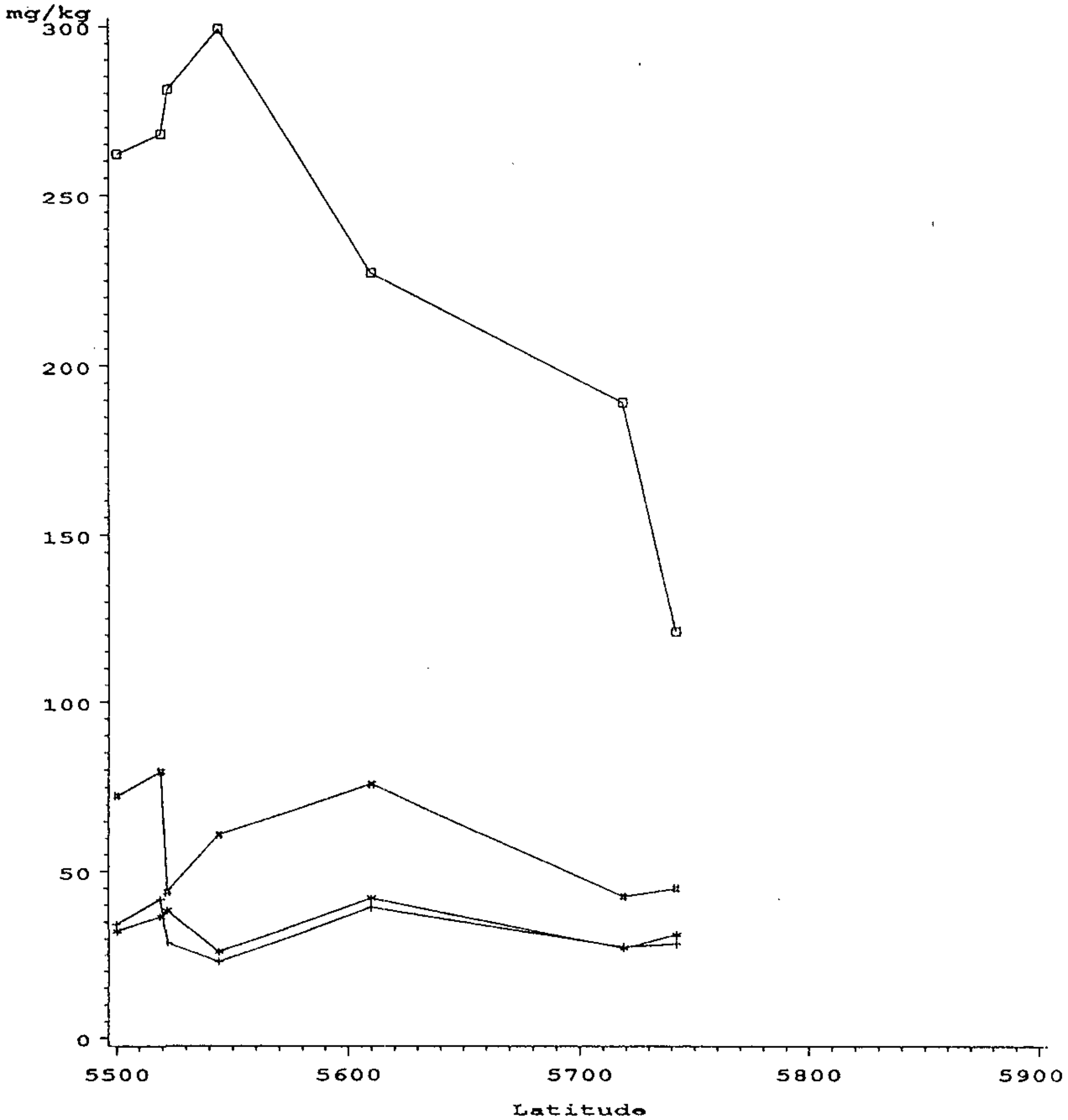
- Pb, 30-120 mg/kg DW, also here with exceptional concentrations in the Southern bank and north of the Dogger Bank, 150-255 mg/kg DW.

The concentration range of mercury is 0.05-0.25 mg/kg DW. There is a clear decease in the concentration going north. The range of the Hg concentration in the fines, <20 µm, in whole area 5 is 0.1-0.9 mg/kg DW (Albrecht, 1992). The <63 µm fraction and <20 µm fraction are not directly comparable however, due to a dilution effect of sand in the <63 µm fraction.

There is reason to believe that the very high concentrations known to be found in the inner German Bight are the main source of the increased Hg-concentrations found in the sediments along the Jutland west coast.

The concentration range of cadmium is 0.1-0.95 mg/kg. There is no regular geographical trend in the concentrations found, although the Cd-concentration at the most northern station is significantly lower than those in the southern part.

Everraarts (1992) reported cadmium levels varying between 0.2-6 µg/kg DW, although very high cadmium contents (10-31 mg/kg D.W.) were measured in the surface layer of sediments from a number of sampling stations in the Southern Bight.
The range of the Cd concentration in the fines, <20 µm, in whole area 5 is 0.2-3.5 mg/kg DW (Albrecht, 1992).



□ = Zn, += Cu, *= Ni, and ⌗=Pb

Figure 3.39.: Zn, Cu, Ni, and Pb in sediment (< 63 μm fraction) along the west coast of Jutland.

Temporal trends

Sediment samples for the analysis of the fines have been collected regularly for temporal trend monitoring in different subareas of the German section of area 5 and at some adjacent positions. The centre positions are given in ***Figure 3.40***, together with the area codes. Only subareas from which there are results from at least three different years are shown. There exist no temporal trend data for the Danish section of area 5. Although the German investigations of the fines began already in 1981 and in more detail in 1983, it is still difficult to detect any temporal trends.

Repeated surveys have shown very similar regional distributions. At a single station, however, the trace metal content usually fluctuates strongly.

Sediment redistribution by wave-current action is presumably the main reason for such fluctuations, in particular for those elements who show large regional variations like mercury. Fluctuations are particular large in areas of mobile sands.

Variations in the depth of the redoxcline in relation to sampling depth could be another reason, at least for those elements which are associated with iron oxide-hydrates cycle.

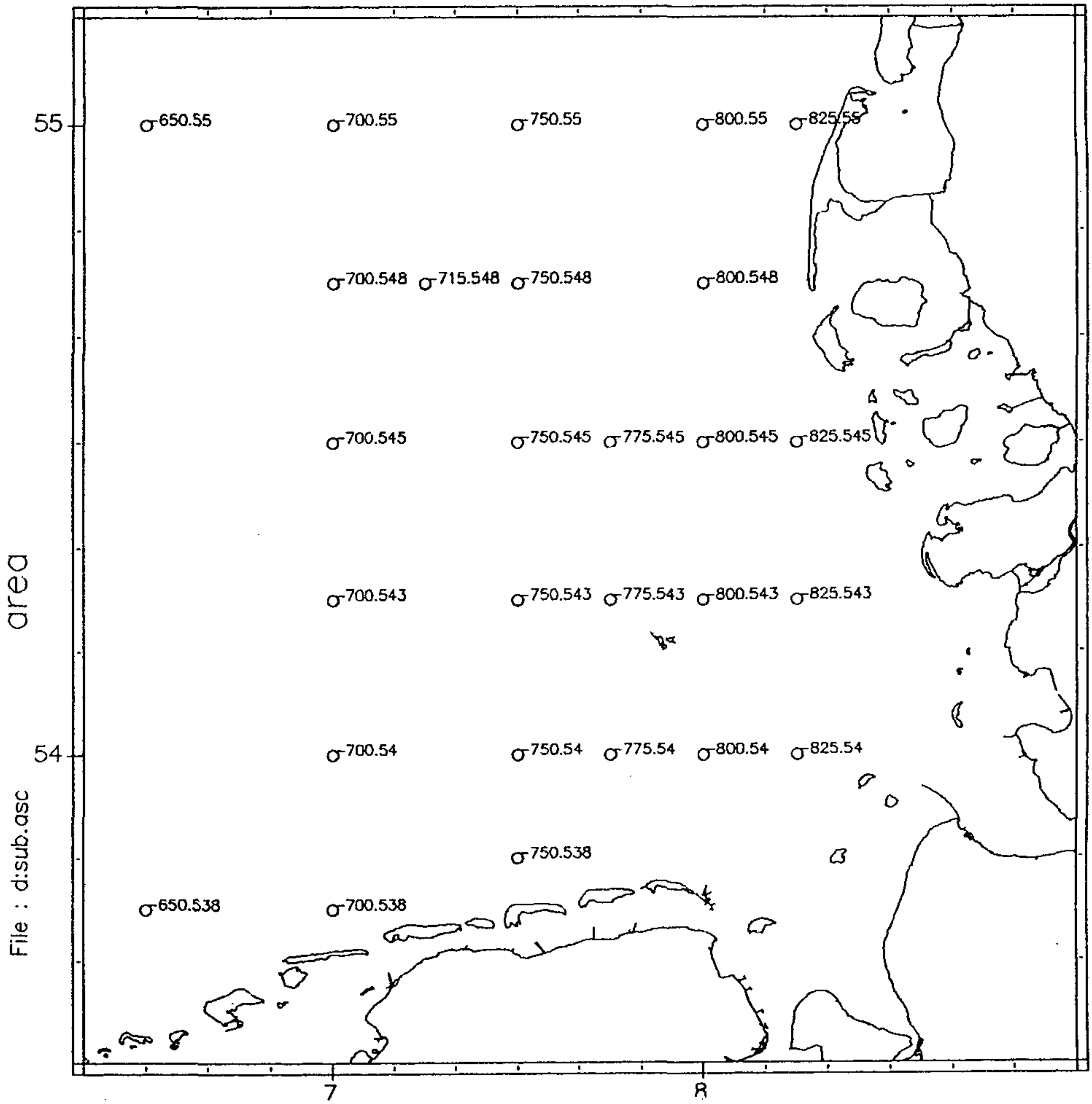


Figure 3.40.: Center sampling posistions in subareas of the German section of subregion 5.

In ***Figures 3.41-3.44*** some of the main conclusions are illustrated.

These are as follows:

In several subareas the **mercury** concentration decreased, as illustrated for subarea 825.54 in ***Figure 3.41***. In the many areas, mercury fluctuates at relatively high levels (e.g. subarea 825.5425, ***Figure 3.41***) or it is more stable at relatively low levels (subarea 650.55, ***Figure 3.41***) .

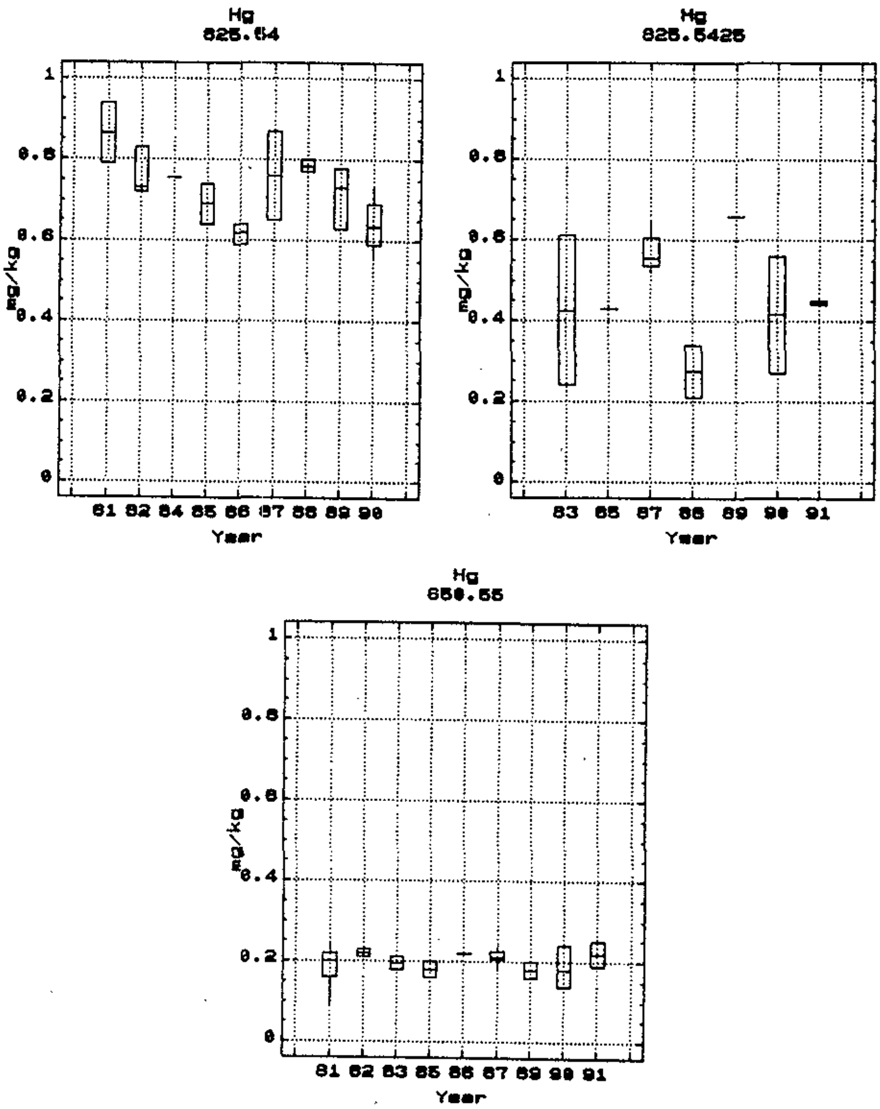


Figure 3.41.: Mercury concentration of surficial sediment (areas 825.54, 825.5425 and 650.55), 1983-91.

In some subareas the concentrations of **lead** and **zinc** increased, being accompanied, however, by increasing levels of iron. In few areas (e.g. subarea 750.55, ***Figure 3.42***) the concentration of lead decreased, and there was not a parallel decrease in iron.

In several areas the **copper** concentration decreased (e.g. subarea 755.545, ***Figure 3.43***).

A slight increase of **nickel** was found in many subareas. In general, however, the nickel concentrations are rather low.

Fluctuations of **cadmium** are particularily large. They are not followed by any variations of any of the main components.

Subareas 825.55 (***Figure 3.43***) may serve as examples of this variation. In this area cadmium almost doubled from 1987 to 1990, being already at high level in 1987. In 1991 levels were close to levels in 1990. The same pattern was seen in many other areas too.

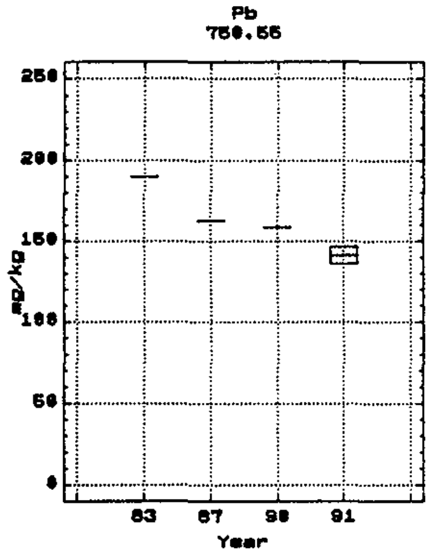


Figure 3.42.: Lead concentration of surficial sediment, area 750.55, 1983-91

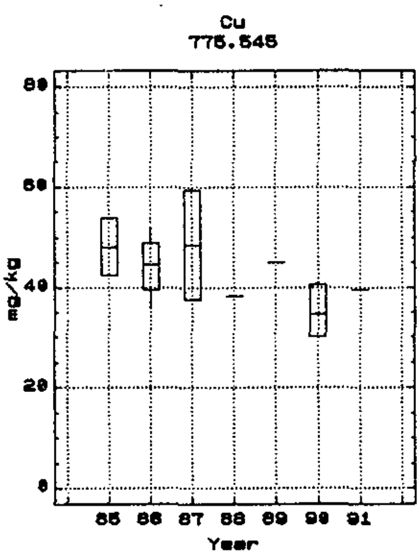


Figure 3.43.: Copper concentration of surficial sediment, area 775.545, 1983-91

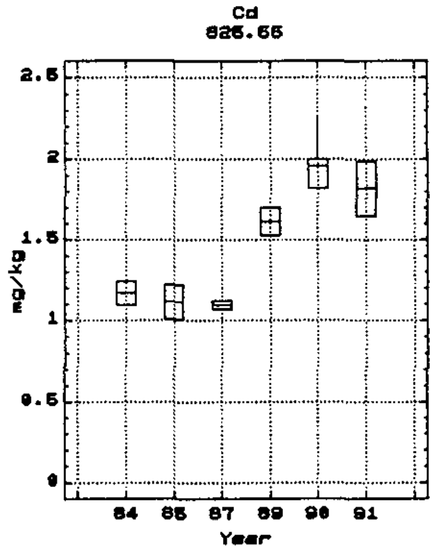


Figure 3.44.: Cadmium concentration of surficial sediment, area 825.55, 1983-91

Oxygen/EH in the sediments

Oxygen enters the sediment via diffusion, irrigation, or by (interstitial water) bioturbation. Within the sediment, oxygen is consumed rapidly. Shelf sediments in temperate areas underlying oxygenated waters contain oxygen, in general, only within the top millimetre to some few centimetres or within the borrow tubes of borrowing organisms.

In area 5 very different sediments do occur. In the centre of the mud area south east of Helgoland sediments are highly anoxic showing, at least in late summer, no signs of bioturbation. In these sediments sulphate is exhausted sometimes already at a depth of 20 cm. No such strong anoxic sediments were detected in other areas of the North Sea.

At the western boundary of the mud area sediments are heavily bioturbated showing oxygenated borrow tube walls up to 30 to 40 cm depth. North of Helgoland gravely sands occur. These sands, at some few locations, appear to be flushed by seawater down to several cm depth. Further north, at some locations, black sands containing only 1% or less of fines are found. These sands are sulphitic already at some few cm depth below the surface. Such sulphitic sands, being sulphitic though they contain so small amounts of fines, do also occur at some locations of the south western German Bight. It appears, however, that they are rare in other areas of the North Sea.

Petroleum hydrocarbons and PAHs in sediments

The concentrations of PAH and some organochlorine compounds in sediments have been measured in 1991 at two of the NSTF stations in subregion 5 (55°54'1 N , 7°03'3 E and 55°03'8 N , 8°05'7 E).

The sum of the concentrations of 12 PCB cogener were 0.25 ± 0.08 ng/g DW and 0,12 ng/g DW respectively at the two stations.

The concentrations of pesticides like HCB, Lindane, Aldrine, Dieldrine, pp-DDE, op-TDE, op-DDT, pp-DDT and some other chlorinated compounds were all less then 0.05 ng/g DW at both stations.

The concentrations of selected aromatic hydrocarbons were all les than 5 ng/g DW and usually less than the detection limit (1 ng/g DW) at both stations.

Radioactive substances in sediments

As earlier mentioned the radioactivity of the North Sea originates primarily from global fallout from atmospheric nuclear weapon tests, liquid discharges from the nuclear reprocessing plants at Sellafield, La Hague, and Dounreay, the fallout from the nuclear reactor accident at Chernobyl end of April 1986, and releases from nuclear power plants surrounding the North Sea or located on rivers discharging into the North Sea.

Sediments in area 5 consist of partly muddy sand material which may adsorb radionuclides to a certain extent. A number of artificial radionuclides could be detected in sediment surface layer, such as Cs 137, Cs 134, Ru 106, Sb 125, Co 60, Pu 239/240, Pu 238, and Am 241. The Chernobyl fallout can be identified by the Cs 134 contribution in surface layer. The nuclides Co 60, Ru 106 and Sb 125 are typical nuclides from the La Hague discharge. In July 1989 at the sedimentation area on the position 54°04'N 08°08'E, where muddy sediment is located, the specific activity of Cs 137 ranged from 16 to 26 Bq/kg DW; the Cs 134 activity is only detected in top 3 cm layer amounting to 1.5 Bq/kg DW (BSH, 1991). Co 60 was determined with 4.2, Ru 106 with 19.3, and Sb 125 with 7.5 Bq/kg DW. The specific activity of the natural radionuclide K 40 was measured with 520 Bq/kg DW. Calculating the Cs 137 specific activity to areal deposition one comes to about 200 to 300 Bq/m^2 in layers of 3 cm thickness. At a depth of 21 cm in the sediment the pre-contamination level could not yet be reached. This can also be a result of heavy reworking of surface sediments. The Cs 137 inventory down to a depth of 21 cm would amount to about 1.8 kBq/m^2.

In June 1990 sediment from the same location was taken (BSH, 1992). The results were very similar, however, the core taken to a depth of 45 cm indicated an intensive vertical mixing. At a depth of 42 to 45 cm the specific activity for Cs 137 drops from about 25 Bq/kg DW in the layers above to only 7 Bq/kg DW. This horizon seems to indicate the pre-contamination layer. Calculating the total inventory of Cs 137 along the whole core of 45 cm one comes to an inventory of about 3.9 kBq/m^2. The sedimentation rate at this location is in the order of about 1.2 cm/y.

3.1.3 Spatial distribution of chemical contaminants in biota

Concentrations of metals in plaice (*Pleuronectes platessa*) collected along the Jutland west coast as well as dab (*Limanda limanda*), flounder (*Platichys flesus*) and mussels (*Mytilus edulis*) in the German Bight and the Elbe estuary are monitored regularly for temporal trend investigations. Organic contaminants are analyzed as well at some stations. The results are reported to the Oslo and Paris Commission as a part of the JMP-programme. These results have been evaluated recently (ICES, 1991b).

Denmark and Germany have also participated in two base-line studies covering area 5, organised by the Commission and ICES, one in 1985 (ICES, 1987), and one supplementary, in 1990 (AHWG, (1992). Some supplementary monitoring concerning the geographical distribution of metals and organic compounds has also been performed in the framework of the North Sea Task Force monitoring programme.

There are also many data available from different research investigations as the German "Biogeochemistry and Distribution of Suspended matter in the North Sea and Implications to Fisheries Biology. The main conclusions in the above mentioned reports will be given here, together with some supplementary data available from the area.

The results of the 1990 baseline study will however, be discussed in more details.

Trace metals.

Geographical distribution

In spring and autumn 1990, a survey was made by Denmark (National Environmental Research Institute) in cooperation with Germany, (Bundesforschungsanstalt für Fischerei, Hamburg) of the heavy metal concentrations in common mussels (*Mytilus edulis*) from the German Bight and up along the Jutland West coast. See also ref. Harms (1991).

Samples were collected at 14 stations from the German Bight to Skagen in North Jutland, see ***Figure 3.45***. Stations marked with a X was visited both in 1983 and 1990, the others only in 1983. Sites were chosen to reflect a possible gradient of contaminant concentrations. The survey was to some extent a repetition of a survey made in 1983, (QSR, 1987). The mussels were analyzed for mercury, cadmium, lead, zinc and copper. PCB and some pesticides were also measured in samples from some stations. These results discussed in the section, organic contaminants below.

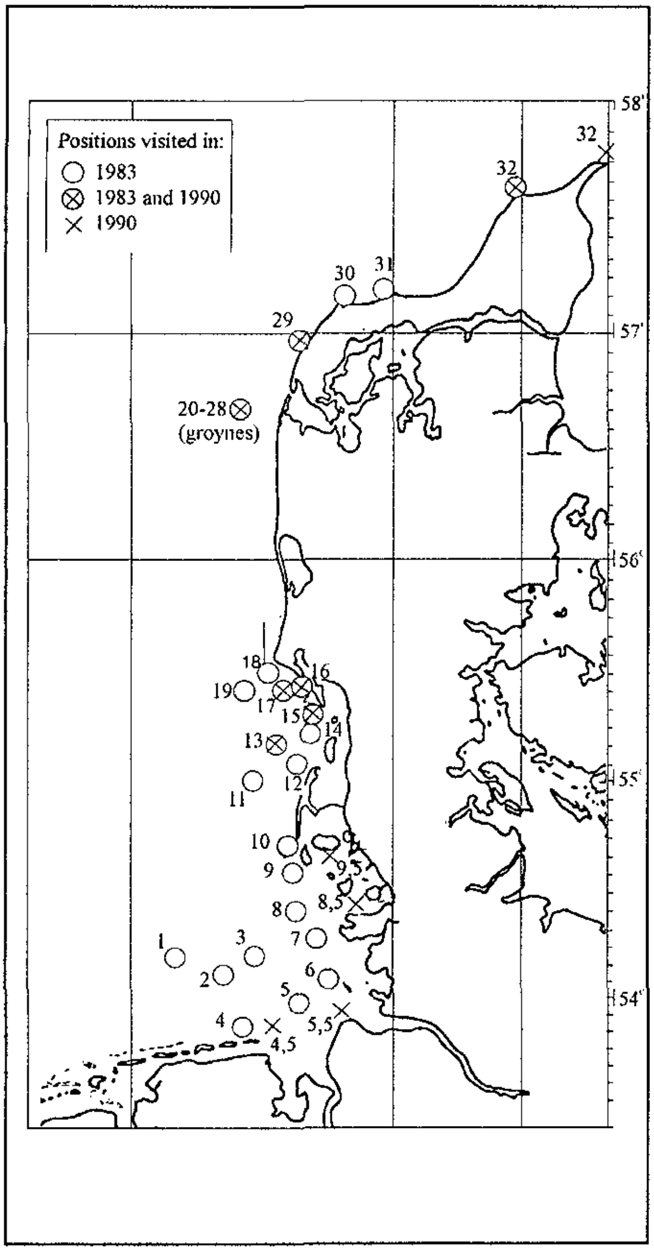


Figure 3.45.: Sampling position for common mussels (Mytilus edulis)

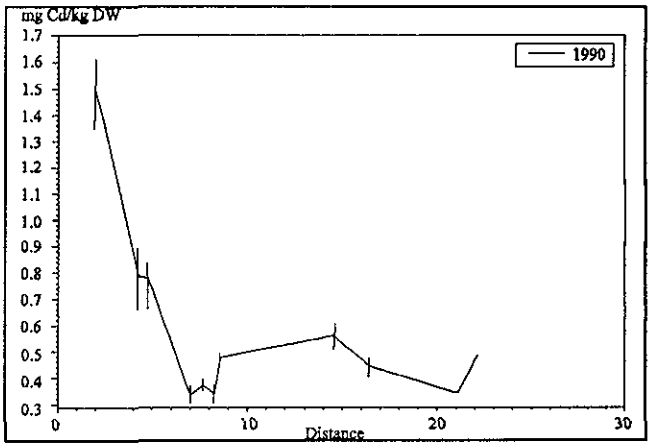


Figure 3.46.: Cadmium concentrations (mg/kg DW) in common mussel. Mussel baseline study 1990

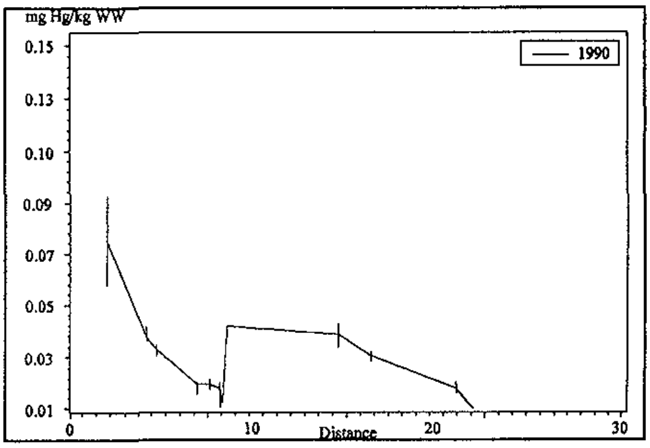


Figure 3.47.: Mercury concentrations (mg/kg DW) in common mussel. Mussel baseline study 1990.

Most stations were only visited once, in the autumn, according to the guidelines (Oslo-and Paris Commission, 1990). A few stations were also visited in the spring, to be able to compare the 1990- results with the 1983-survey, where all samples were collected in the spring.

The results demonstrated that the concentrations of cadmium and mercury decrease going north from the German Bight, see ***Figure 3.46 and 3.47***, respectively, where the cadmium and mercury concentrations are plotted against the distance (arbitrary unit), and where distance =0 is placed at station 4.5 in ***Figure 3.45***.

Similar geographical trends were also found in the 1983 survey. The influence of the former chemical waste site on the Hg concentration, can still be seen around distance 14.5, corresponding to stations 20-28 in ***Figure 3.45***.

The trends could also be seen for Cd and Hg in the spring samples (***Figures 3.48 and 3.49***).

The significant downward trends were not found for lead, zinc, and copper. A trend was reported for lead and zinc in 1983.

Beside the regional structure, higher concentrations for all metals were generally detected in the samples collected in spring.

The higher values in the spring compared to the values in the autumn, is presumably due to different conditions of the mussels at the different times of the year, but also dependent on the site, as the food supply can be very different along the Jutland coast at different times of the year.

Most concentrations were slightly higher in the spring 1990 survey, compared to those found in 1983. This is illustrated for Cd, Hg, and Cu in ***Figures 3.48 to 3.50.***

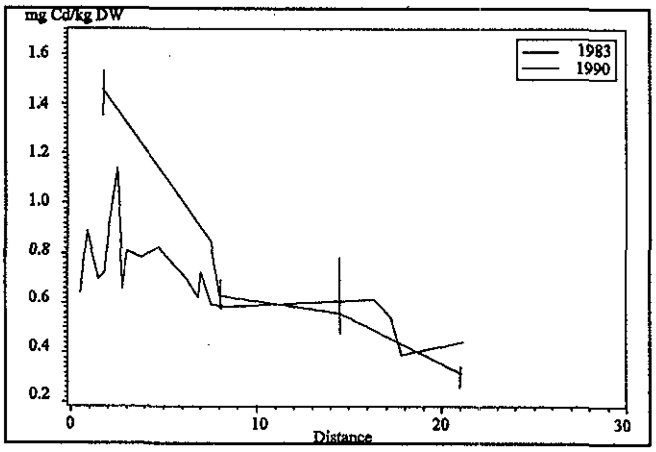


Figure 3.48.: *Cadmium concentrations (mg/kg DW) in common mussel. Mussel baseline study, 1983, compared with baseline study 1990.*

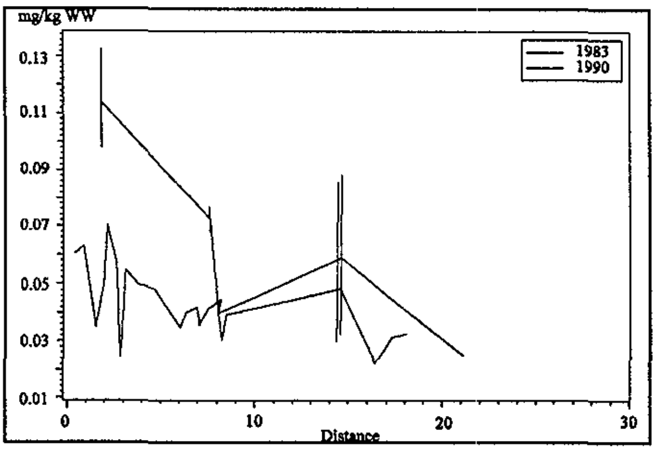


Figure 3.49.: *Mercury concentrations (mg/kg DW) in common mussel. Mussel baseline study 1983 compared with base line study 1990.*

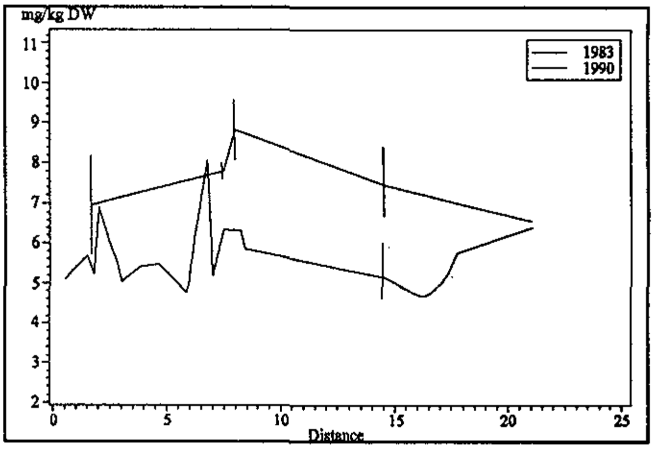


Figure 3.50.: *Copper concentrations (mg/kg DW) in common mussel. Mussel baseline study 1983 compared with base line study 1990.*

The concentrations in both years were, however, at most stations lower than the 75 % quartiles of metal concentrations in mussels reported for the 1990 baseline study (AHWG, 1992), except for the highest concentrations of **mercury** and **cadmium**, see ***Table 3.5*** below. All concentrations were also lower, than the upper limits of what can be regarded as normal concentrations in Norwegian marine area, not affected by any known point source (Knutzen, 1992). These limits are also given in ***Table 3.5***.

In the 1985 Baseline study (ICES, 1988), plaice (*Pleutonectes platessa*) was caught at different position along the Jutland west coast, as well as further down in area 5, covering altogether eleven ICES coordinates.

The concentration of **Cu, Cd, Zn, and Pb** was determined in the fish liver, and **Hg** in the muscle.

The concentrations found were generally low. All concentrations of **Cd, Cu** (except in one area), **Pb** (except in 4 areas), **Zn** (except in one area) and **Hg** (except in the area outside the former waste site) were lower than the respectively 75 % quartiles found in that base-line.

The spatial distribution of trace metals in liver tissue of dab (*Limanda limanda*) round in the German Bight has been measured by Claussen (1988) and is shown in ***Figures 3.51, 3.52 and 3.53***. Statistical evaluation of the data obtained, allowed division of the Inner German Bight in two or three subareas respectively as given in the ***Figures 3.51-3.53.***

Table 3.5.: Maximum values in the 1990 mussel survey (autumn data) together with the 75 % quartile of the 1990 Baseline (AHWG, 1992), and Norwegian water quality criteria data, (Knutzen, 1992), all in mg/kg DW except Hg, which is in mg/kg WW.

	75 % quartile	Maximum	Norwegian data
Cu	8.7	8.1	< 10
Pb	3.6	3.2	< 5
Zn	149	120	< 200
Hg	0.04	0.07	< 0.2
Cd	1.54	1.5	< 2

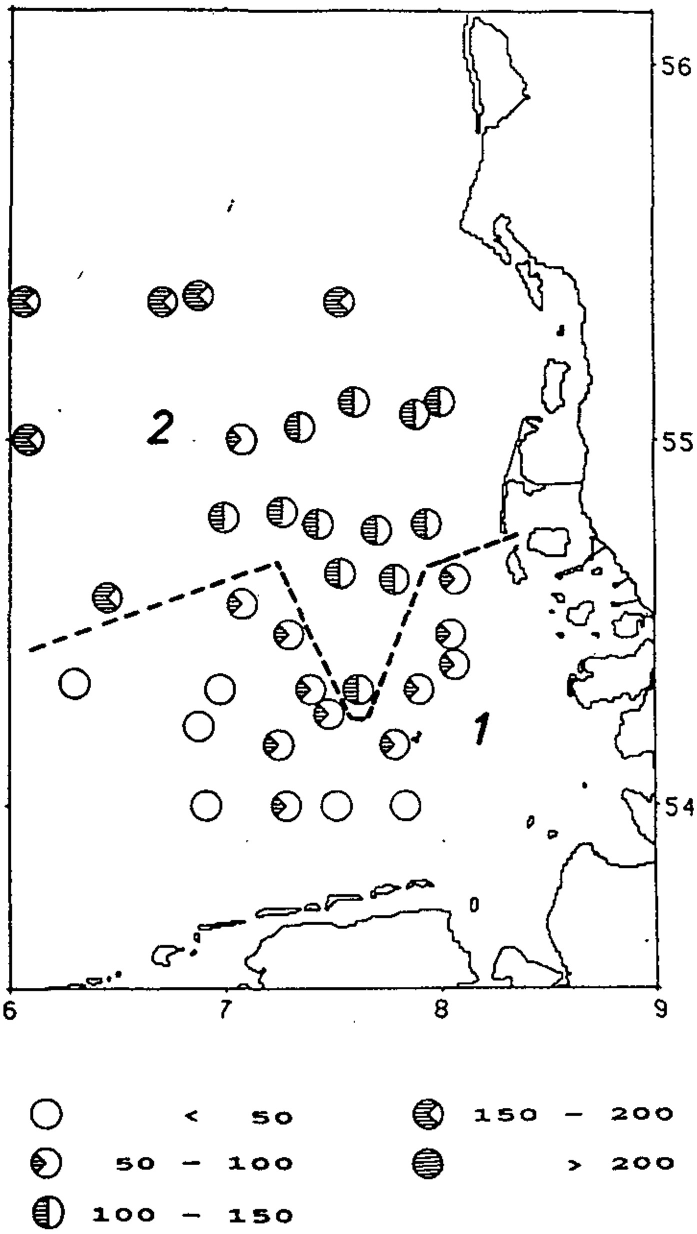


Figure 3.51.: *Distribution of cadmium concentrations in livers of dab (Limanda limanda) from sampling sites in the German Bight (December 1984). Ranges of concentration in µg/kg WW.*

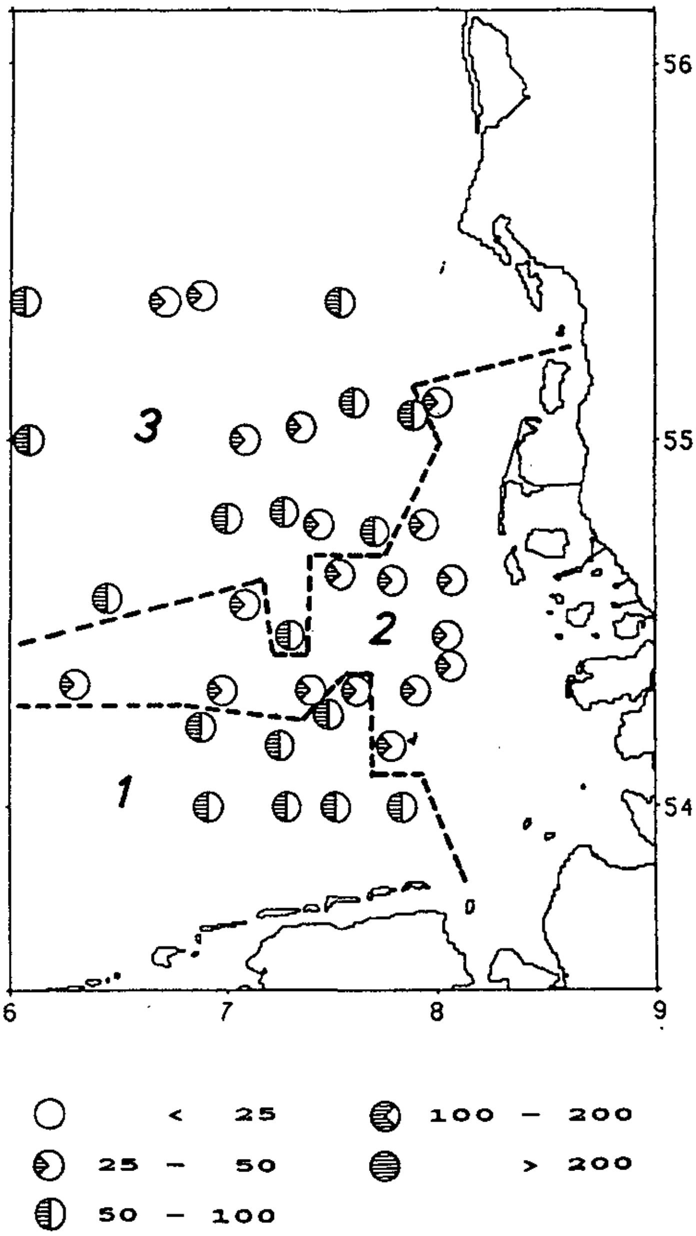


Figure 3.52.: *Distribution of lead concentrations in livers of dabs (Limanda limanda) from sampling sites in the German Bight (December 1984). Ranges of concentration in µg/kg WW.*

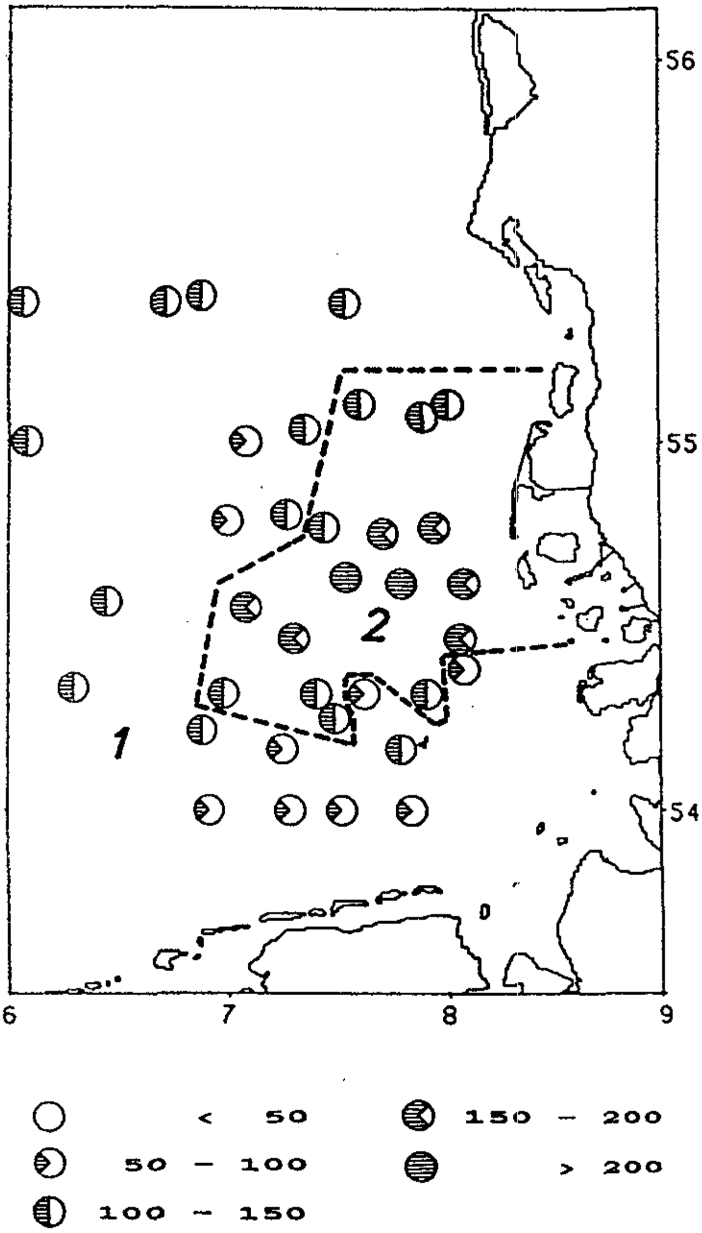


Figure 3.53.: Distribution of mercury concentrations in livers of dabs (Limanda limanda) from sampling sites in the German Bight (December 1984). Ranges of concentration in µg/kg WW.

Concentrations of cadmium in the German Bight ranged from the lower quartile with a value of 55 to the upper quartile with a value of up to nearly 200 µg/kg. Remarkably low levels occurred only in samples taken near the East Frisian Isles. Values off the Danish south coast were twice as high as those in the Inner German Bight (*Figure 3.51*).

The average lead concentrations in dab livers were below 100 µg/kg. Lowest values were found in a small region in the Inner German Bight (*Figure 3.52*). Compared to cadmium, lead concentrations varied within a smaller range.

Similar to the cadmium results, mercury concentrations showed rather large variations between 50 and 252 µg/kg. Samples collected off the East Frisian Isles exhibited the lowest mercury contents, while clearly enhanced concentrations occurred off the German North Frisian Isles (*Figure 3.53*). A clear decrease of mercury levels in dab liver tissue in a north-westerly direction was recognized.

In 1991, whiting (*Merlangius merlangus*) and dab (*Limanda limanda*) were caught at two Danish NSTF-stations in area 5, station 1 (55 54'1, 7 50'3), and station 2 (55 03'8 8 05'7), as a part of the NSTF Monitoring Master Plan. They were analyzed according to guidelines, (Oslo-and Paris Commission, 1990).

The results are given in *Table 3.6* below, where also the concentrations of the 75 % quartiles of whiting and dab in the 1990 base-line are given (AHWG, 1992) as a comparison. The concentrations of Hg at the more southern position (station 2) were higher than at station 1 for both dab and whiting, and they were also relatively high compared to the 75 % quartile. The concentrations of the other metals were almost the same at the two stations, and either lower or comparable to the 75 % quartiles.

Table 3.6.: Metals in cod and dab in area 5. (Cd, Cu, Zn, and Pb are analyses in liver, and Hg is analyses in muscle, all in mg/kg WW

Metal	Whiting			Dab		
	Station 1	Station 2	75 %	Station 1	Station 2	75 %
Cd	0.093	0.089	0.090	0.297	0.282	0.400
Pb	< d.l.	0.098	no value	0.043	0.062	no value
Cu	4.20	-	5.05	8.82	13.64	8.35
Zn	19.5	22.8	19.0	35.0	30.4	35.0
Hg	0.062	0.093	0.067	0.120	0.180	0.120

Organic contaminants

Bücher (1988) has measured the distribution of chlorinated organic compounds in livers of dab (*Limanda limanda*) in the central and southern parts of the North Sea.

He found that dabs in the inner part of the German Bight have the highest PCB concentrations related to fat content of the livers ***(Figure 3.54)***. The lowest concentration found were mainly in the northwestern part of the study area. ***Figures 3.55-3.57*** depict the distributions of DDT and derivatives, HCB, x-HCH and of lindane in the German Bight. As with the PCBs, the highest concentrations found were in the inner part of the German Bight.

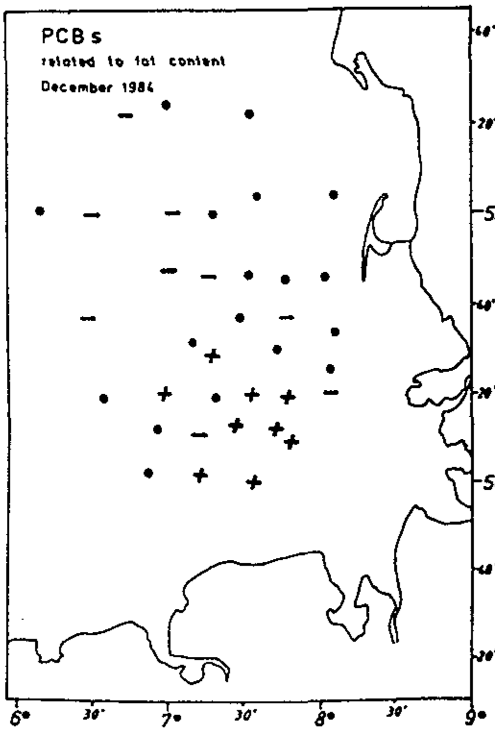


Figure 3.54.: *Distribution of polychlorinated biphenyls (PCBs) in livers of dab (Limanda limanda) in the German Bight in December 1984. PCBs = (CB 153 + CB 138 + CB 180)/0,3. Result given in relation to the technical PCB-mixture Clophen A 60 containing the three congeners to an amount of 30 %.*
- : 1480-2620 µg/kg liver fat
o : 2620-4200 µg/kg liver fat
+ : 4200-8300 µg/kg liver fat

The lowest values of DDT, its derivatives and HCB are more dispersed than those of the PCBs. For x-HCB and lindane, the lowest values are clearly distributed between the northern and western stations. This distribution gives an indication of the influence of the rivers Elbe and Weser on the contamination level of organisms of the German Bight.

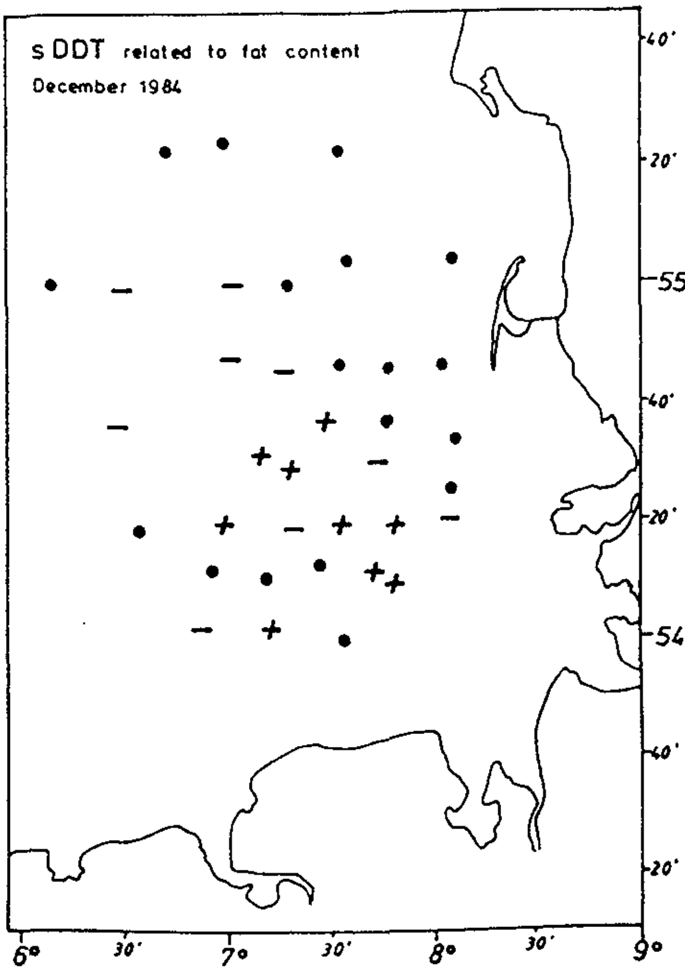


Figure 3.55.: *Distribution of the sum of DDT and derivates (∑DDTp = DDEPP + TDEPP + DDTPP) in livers of dab (Limanda limanda) in the German Bight i December 1984.*
- : 240-310 µg/kg liver fat
o : 310-430 µg/kg liver fat
+ : 430-820 µg/kg liver fat

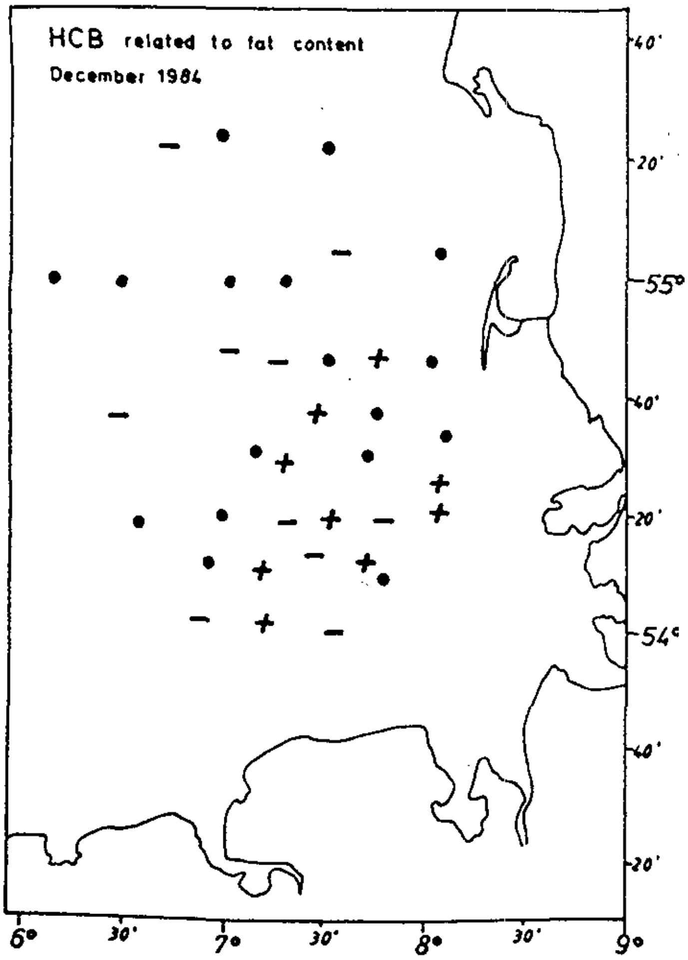


Figure 3.56.: Distribution of hexachlorobenzene (HCB) in livers of dab (Limanda limanda) in the German Bight in December 1984.
- : 8-28 µg/kg liver fat
o : 28-47 µg/kg
+ : 47-94 µg/kg.

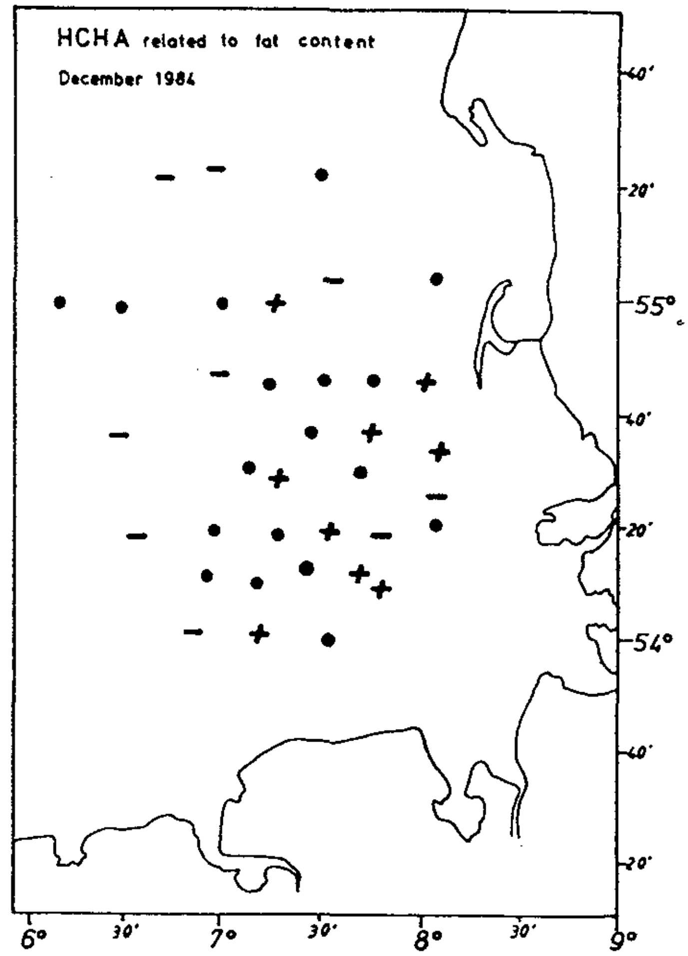


Figure 3.57.: *Distribution of a-HCH in livers of dab (Limanda limanda) in the German Bight in December 1984.*
- : 33- 53 µg/kg liver fat
o : 53-100 µg/kg liver fat
+ : 100-194 µg/kg liver fat

As compared with a first pilot study in 1979 a drastic decrease of DDT and derivatives within six years was found which can be explained by the ban of DDT in the early seventies.

Enhanced concentrations of organochlorine in fish and shellfish has also been found in other species taken from the German Bight. (Kruse & Krüger, 1989). High concentrations were found in fat fish like mackerel (Scomber scombrus). In young cod (*Gadus morhua*), however, low concentration was encountered like in samples taken far away from the coast.

The spatial distribution of the concentrations of PCB and some chlorinated pesticides in the biota were also studied in the 1985 baseline study (ICES, 1988). The German Bight was among the areas where the highest CB concentrations were recorded in flounder liver. The residue levels in plaice liver, measured as the sum of five CBs was also somewhat enhanced in areas to the west of Denmark, as compared to the areas east of Denmark.

Danish data for organochlorines in blue mussels from the 1990 base-line study (Stations map in ***Figure 3.45***) is given in ***Table 3.7***. The higeste concentrations are found at the most southern stations (south of 55° N) while the concentrations at the stations north of this lattitude are in the same order.

At two Danish NSTF-stations in area 5, station 1 (55 54'1, 7 50'3), and station 2 (55 03'8 8 05'7) the PCB content in fish liver from whiting (*Merlangius merlangus*) and dab (*Limanda limanda*) was analyzed in 1991. The result are shown i ***Figures 3.58 a-b.***

Time-trends

In the report ICES, 1991b, are the results of the Joint Monitoring Programme, of the Oslo and Paris Commission for trend analysis, evaluated statistically.

Four stations discussed in the report are placed along the Jutland west coast and four stations in the German Bight and/or the Elbe estuary. Most of the data cover the period

1978-1988. The main results are summarized below.

A statistical significant downward trend with fluctuations can be seen for **lead** and **zinc** at all Danish stations. The trend at the German stations varied.

A statistical significant downward trend could be detected for **copper** and **cadmium** at three of the four Danish stations, even though there were large fluctuations, and there were generally an increase in the cadmium concentrations during the last two-three years.

muscle from the Danish samples discussed above (Jørgensen, 1992), a significant downward trend could be detected at one of the stations.

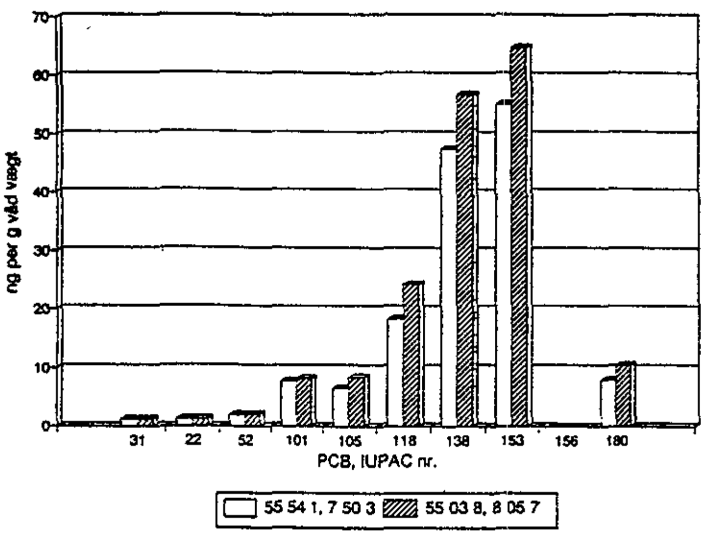
No trend for Cu could be detected at the German stations, and one showed a downward trend and two un upward trend for Cd.

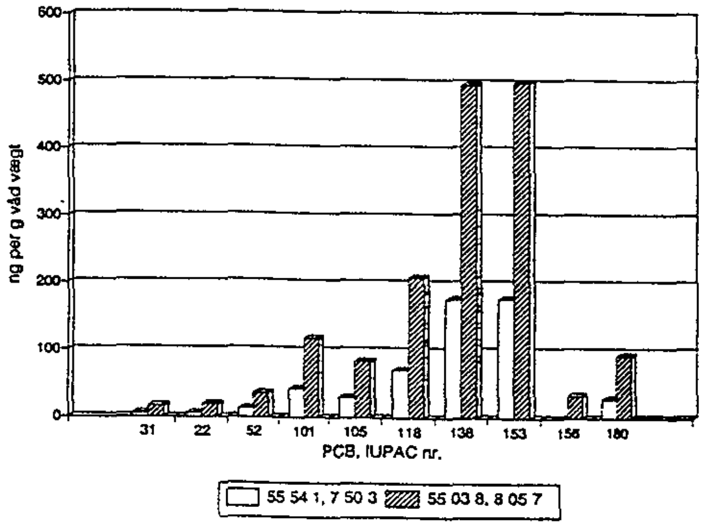
The concentrations in fish muscle of **mercury** were not evaluated in the ICES report.

In a recent evaluation of three of the Hg data sets of fish

Table 3.7.: *Organochlorines in blue mussels from the 1990 base-line study, related to wet weight µg/kg. (The relative standard deviations for the different compounds have been measured at same position and the average value ± standard deviation are 13 ± 5 %).*

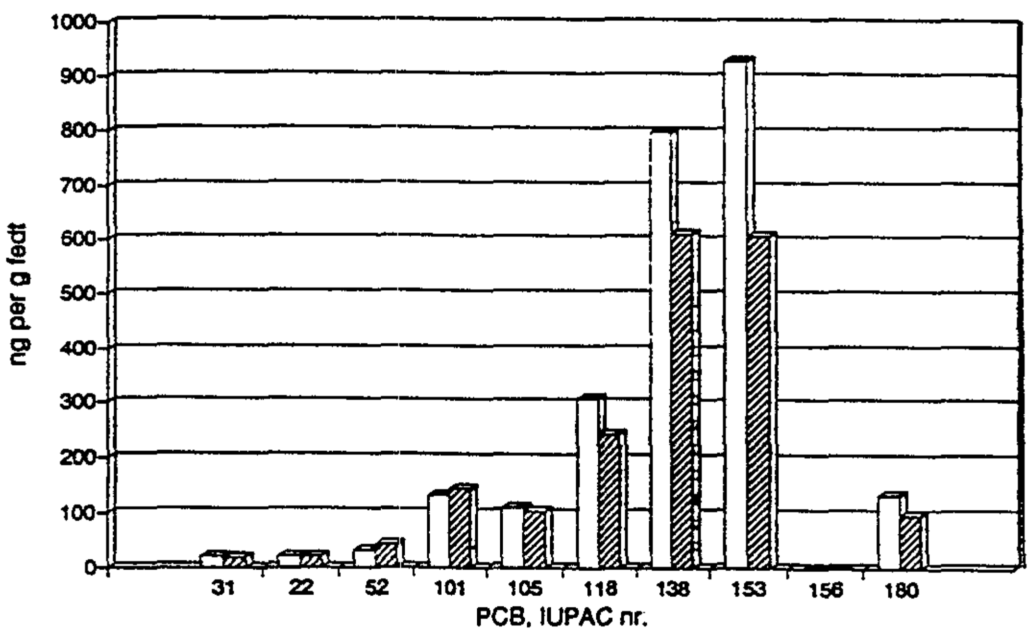
Station	HCH α	HCH γ	HCB	PCB 28	PCB 52	PCB 101	PCB 118	PCB 138	PCB 153	PCB 180
53° 42' 13" N,- 08° 04' 06" E	1.03	7.05	b.l.q.	1.73	1.63	4.06	2.51	8.03	8.20	0.63
53° 53' 40" N,- 08° 41' 50" E	b.l.q.	2.03	b.l.q.	0.57	0.83	3.49	3.13	8.55	8.63	1.04
54° 26' 05" N,- 08° 45' 05" E 54° 39' 40" N,- 08° 31' 54" E	0.61	3.46	b.l.q.	0.75	0.88	1.54	1.04	4.35	4.60	0.48
55° 05' 04" N,- 08° 16' 06" E	0.42	1.87	0.09	b.l.q.	0.29	0.90	1.02	2.48	2.67	0.25
55° 18' 66" N,- 08° 20' 42" E	0.57	2.28	0.10	0.30	0.36	1.08	1.26	3.04	3.14	0.28
55° 25' 04" N,- 08° 09' 06" E	0.40	1.77	0.06	b.l.q.	0.29	0.90	1.02	2.36	2.37	0.19
55° 26' 0" N,- 08° 14' 06" E	0.41	2.24	0.07	0.37	0.35	1.09	1.16	2.99	3.04	0.28
55° 30' 05" N,- 08° 01' 04" E	0.40	1.34	0.06	0.53	0.32	0.73	1.26	2.50	2.38	b.l.q.
56° 43' 0" N,- 08° 14' 0" E	0.31	2.65	0.06	0.24	0.27	0.65	0.82	2.26	2.17	0.22
56° 58' 0" N,- 08° 29' 0" E	0.40	2.00	0.09	b.l.q.	0.41	0.94	1.66	2.95	2.92	0.17
57° 36' 04" N,- 09° 58' 0" E	0.42	0.85	0.17	b.l.q.	0.29	0.78	1.00	2.67	2.50	0.27
57° 46' 02" N,- 16° 33' 0" E	0.56	1.44	0.12	0.23	0.24	0.57	0.65	1.53	1.40	0.10





Dab (Limanda limanda) **Whiting (Merlangius merlangus)**

Figure 3.58.a: PCB in liver from Dab (Limanda limanda) and Whiting (Merlangius merlangus) at two Danish NSTF stations in subregion 5, 1991, (ng/g WW).



White bar: Dab (Limanda limanda)
Hatched bar: Whiting (Merlangius merlangus)

Figure 3.58.b: PCB in liver from Dab (Limanda limanda) and Whiting (Merlangius merlangus) at station 1 (55 54'1, 7 50'3) in subregion 5, 1991, (ng/g fat).

3.2 ANTHROPOGENIC INFLUENCES

3.2.1 Inputs

Atmospheric inputs

Information concerning atmospheric inputs into sub-region 5 was compiled by the Institute of Inorganic and Applied Chemistry of Hamburg University. Extensive series of measurements are available for estimates of the atmospheric input into the inner German Bight. The data from the German Bight allow a projection of pollutant inputs into sub-region 5 only.

Inputs can be calculated using measurements of ground air concentrations of the components under investigation with a knowledge of the appropriate transfer processes and rough deposition parameterizations.

Where input mainly occurs through precipitation, it can be calculated using measurement series of precipitation amounts and the concentrations of substances present in precipitation as the sum of all depositions.

One objective of this long-term investigation was to investigate and quantify the flux of atmospheric pollutants in the North Sea area. Two processes are mainly responsible for the removal from the atmosphere of aerosol and the pollutants attached to it. They are wet and dry deposition. Based on the sampling strategies used in this project, input was determined by calculating dry deposition using calculated deposition velocities according to the calculation scheme given by (Slinn and Slinn, 1980). The share of pollutants deposited wet was calculated using precipitation amounts as recorded on Helgoland and scavenging factors. The scavenging factors describe how effectively precipitation washes aerosols from the atmosphere. They are based on experimental data taken from comparisons of air and precipitation concentrations of various elements. The scavenging factors used here are taken from the 1989 GESAMP report and, where data were not available, were supplemented by our own estimated values based on measurements of the distribution of atmospheric substances, (Kriews, 1992).

In ***Table 3.8*** recorded yearly mean concentrations of selected anthropogenic elements in the period 1986-1990 from Helgoland are shown. It can be seen that for Pb, input into the North Sea is falling as a result of a reduction in Pb concentrations in the atmosphere unlike concentrations of the other investigated elements which tend to remain the same.

Table 3.8.: *Yearly mean concentrations of selected anthropogenic elements in weekly samples from Helgoland. All values or concentrations given in ng/m³*

	1986	1987	1987[1]	1988	1989	1990
Arsenic (As)	1.3	2.7	2.0	1.1	1.7	1.4
Copper (Cu)	3.1	4.7	3.9	3.3	3.0	2.5
Nickel (Ni)	1.7	3.0	2.7	2.2	3.0	3.4
Lead (Pb)	23.8	26.9	21.8	16.0	15.6	12.8
Antimony (Sb)	0.98	1.0	0.88	0.85	1.0	0.94
Selenium (Se)	0.79	0.94	0.79	0.96	1.1	1.2
Vanadium (V)	4.6	7.1	6.7	5.0	5.9	5.9
Zinc (Zn)	26.6	40.6	32.5	30.9	49.5	46.3

1987[1]: Yearly mean value excluding the extreme values of February and October 1987

Total input into the North Sea water body consists of the sum of both wet and dry deposition. The mean yearly input calculated on the basis of the weekly Helgoland samples is given in ***Table 3.9*** it is compared with the measured deposition rates. For the calculation of deposition fluxes 161 samples representing the period 22.04.1988-25.09.91 from Westerhever and a research platform in German Bight were included.

Table 3.9. Median rain concentrations, the deposition flux inferred from them (Westerhever and a research platform "Nordsee") and yearly atmospheric inputs derived from aerosol measurements at Helgoland.

Element	Median Concentration in deposition (µg/l)	Deposition Flux At 430 mm $mg\ m^{-2}y^{-1}$	Deposition Flux Helgoland $mg\ m^{-2}y^{-1}$
Lead (Pb)	12.2	5.25	6.7
Cadmium (Cd)	0.32	0.14	-
Nickel (Ni)	2.70	1.16	0.96
Copper (Cu)	19.5	8.35	1.3
Arsenic (As)	0.60	0.26	0.3
Chromium (Cr)	2.0	0.87	0.77
Zinc (Zn)			8.0
Antimony (Sb)			0.15
Selenium (Se)			0.14
Ammonium (NH_4-N)	1170	510	-
Nitrate (NO_3-N)	2350	1010	-

German investigations into the atmospheric pollutant fluxes in sub-region 5 can be summarized as follows:

- concentrations of inorganic, toxicologically relevant trace elements in the atmosphere above the German Bight have been determined with an accuracy of 10-15%.
- since 1986, Pb concentrations in the atmosphere have shown a fall of 40-50% while the immission concentrations of other anthropogenic elements have remained almost constant.
- because of prevailing meteorological distribution conditions, pollution loads in the atmosphere above the German Bight are dominated by continental sources.
- the estimations of inputs represent the lower limit, as considerable uncertainties exist about deposition sampling and the parameterization of deposition processes.
- short-term loads with monthly inputs, which can make up more than 30% of total yearly input, occur annually but irregularly.
- atmospheric inputs of lead and ammonium in particular are important for the marine ecosystem.
- as much as 30 % of the total nitrogen consists of ammonium
- atmospheric inputs of organic components are largely unknown.
- estimates do not take account of fluvial inputs (an indirect input path for atmospheric pollution). It must be assumed that a large degree of the nitrates deposited on land is washed into the sea and that they could be prevented through measures to reduce emissions of nitrogen oxides.

From 1991 atmospheric wet deposition has been measured at a number of danish stations. Two of them are situated at the Danish West Coast, (Hovmand et al., 1992). One station at the island Rømø is situated close to Helgoland. Husby is found in the northern part of the danish sub-region 5, south of Limfjorden.

In ***Table 3.10*** measurements of rainfall and deposition of NH_4-N and NO_3-N in 1991 at Rømø and Husby at the Danish North Sea Coast is shown.

Table 3.10. Measurements of rainfall and wet deposition of nitrogen at the Danish West Coast in 1991.

Location	Rainfall (mm $year^{-1}$)	NH_4-N mg $m^{-2}y^{-1}$	NO_3-N mg $m^{-2}y^{-1}$	N-sum mg $m^{-2}y^{-1}$
Husby	634	421	447	868
Rømø	566	392	383	775

Compared to actual Danish measurements in ***Table 3.10***, the German calculated wet deposition of NO_3-N in ***Table 3.9*** are relatively high. However, ammonium and nitrate deposition in German and Danish investigations are of the same order of magnitude.

The wet deposition of NH_4-N and NO_3-N in sub-region 5 can as an rough estimate be calculated as simple means from German and Danish numbers as shown below:

NH_4-N: 0.458 g $m^{-2}y^{-1}$
NO_3-N: 0.708 g $m^{-2}y^{-1}$

This input must be considered as maximum values as all measurements and calculations are referring to coastal areas. It is assumed that input deminishes with distance from the coast.

Riverine inputs

The main German rivers draining into sub-region 5 are the Elbe, Weser, Ems and Eider. ***Table 3.11*** summarizes loads in 1990.

It contains data about various heavy metals and organochlorine compounds as well as the nutrients nitrogen and phosphorous. The data were compiled by the Paris Commission using the German annual reports. ***Table 3.11*** clearly shows the river Elbe to be the major source of inputs. The Elbe is the largest German river system flowing into the North Sea. In the case of the River Elbe it has to be taken into account that not only Germany but also Czechoslovakia, situated upstream, contaminate the river with organic and inorganic substances.

Table 3.12 summarizes German data on direct inputs as compiled by the Paris Commission. Sewage and industrial effluent are included in the table. ***Table 3.13*** summarizes total riverine and direct inputs in 1990 by Germany.

Table 3.11.: *Riverine inputs in 1990 by Germany. "NI" indicates: no information.*

Discharge area	Heavy metals (t)					Organochlorine compounds (kg)		Nutrients (Total) (t)	
	Cd	Hg	Cu	Pb	Zn	1)	2)	N	P
Ems (Herbrum)	0.6	0.16	5.6	9	32	6	20	17000	400
Weser (Intschede)	2	0.7	90	26	250	120	60	45000	2400
Weser (Bremen)	0.01	0.006	0.4	0.1	6.8	NI	0.4	NI	NI
Elbe (Estuary)	5.8	9.5	181	170	1400	210	66	120000	7900
Elbe (Tributaries)	0.2	0.1	0.4	6	32	3	2	4600	300
Eider	0.03	0.006	1.1	0.3	4.6	3.9	NI	4300	200
Total	8.6	10.5	280	210	1700	340	150	190000	11000

1) refers to *r*-HCH. 2) refers to PCBs

Table 3.12.: Direct discharges in 1990 by Germany. "NI" indicates: no information. The "<" character indicates that the detection limit was used for calculation. The values for Elbe indicates upper estimates.

Discharge area	Heavy metals (t)					Org. chlor. compounds (kg)		Nutrients (Total) (t)	
	Cd	Hg	Cu	Pb	Zn	1)	2)	N	P
Jade	0.001	0.002	0.03	0.0003	0.3	NI	Ni	NI	NI
Weser (Estuary)	0.03	0.02	0.9	0.5	0.4	NI	0	NI	NI
Elbe (Estuary)	<0.04	<0.03	<1	<0.5	<0.5	NI	<1	400	50
Total	<0.07	<0.05	<1.9	<1.0	<5.7	NI	<1	400	50

1) refers to *r*-HCH. 2) refers to PCBs

Table 3.13.: Total riverine and direct inputs in 1990 by Germany. "NI" indicates: no information. The "<" character indicates that the detection limit was used for calculation. The values for Elbe indicates upper estimates.

Input	Heavy metals (t)					Org.chlor. compounds (kg)		Nutrients Total (t) x 1000	
	Cd	Hg	Cu	Pb	Zn	1)	2)	N	P
Riverine	8.6	10.5	280	210	1700	340	150	190	11
Direct	<0.07	<0.05	<1.9	<1.0	<5.7	NI	<1	0.4	0.05
Total	8.7	11.0	280	210	1700	340	151	190	11

1) refers to *r*-HCH. 2) refers to PCBs

In Denmark a similar distinction between riverine and direct input has been undertaken as in Germany, with the exception that river inputs refer to loads into lakes and watercourses which mainly passes brackish areas in western fjords before entering the North Sea. ***Table 3.14*** summarizes Danish data on riverine and direct inputs as compiled by the Paris Commission. Sewage and industrial effluent are included in the table.

In ***Table 3.15*** the sum of all inputs into subregion 5 is shown. It is evident that the main load of sub-region 5 originates from the German part of the coast.

Table 3.14.: Total riverine and direct inputs in 1990 by Denmark.

Input	Heavy metals (t)					Org. chlor. compounds (kg)		Nutrients (Total) (t) x 1000	
	Cd	Hg	Cu	Pb	Zn	*r*-HCH	PCBs	N	P
Riverine	0.3	0.02	5.8	2.6	49	0 - 11	0 - 13	23	0.6
Direct	0.02	0.02	0.6	0.4	1.6	0 - 11	0 - 13	1.8	0.4
Total	0.3	0.04	6.4	3.0	51	0 - 22	0 - 26	25	1.0

Table 3.15.: Total inputs into sub-region 5 in 1990 by Denmark and Germany.

Inputs	Heavy metals (t)					Org. chlor. compounds (kg)		Nutrients (Total) (t) x 1000	
	Cd	Hg	Cu	Pb	Zn	γ-HCH	PCBs	N	P
Germany	8.7	11.0	280	210	1700	340	151	190	11
Denmark	0.3	0.04	6.4	3.0	51	22*	26*	25	1
Sub-reg. 5	9.0	11.0	286.4	213.0	1751	362	177	215	12

* refers to maximum-values.

It should, with respect to the Danish industrial phosphorous input, be mentioned that the pesticide factory, Cheminova, at Harboøre Tange, which represents the main source of direct phosphorous discharge into subregion 5, has reduced the yearly outlets with more than 30% since 1990.

Dumping of waste from production of titanium oxide

Between 1969 and the end of 1989, German waste from titanium dioxide production (so-called waste acid) was dumped in sub-region 5. The dumping ground was situated about 10 nautical miles north west of Helgoland.

The waste is obtained in the production of titanium dioxide using the sulphate process. Titanium dioxide is used, for example, in gloss paint, paper and textiles. In the sulphate process, the titaniferous raw materials are digested using sulfuric acid. A waste product of this process is waste acid comprising approx. 20% sulfuric acid which itself contains various heavy metals. In addition, mineral residues (gangue) and, depending on the raw materials used, so-called copperas (iron sulphate) are obtained.

The amounts of waste dumped and their metal loads for the period 1978 to 1989 is given in ***Table 3.16***. The effects from dumping of titanium dioxide is considered in section 5.5.

Sewage Sludge

Digested sewage sludge from the City of Hamburg was dumped in sub-region 5 between 1961 and 1981. The mean annual amount dumped was approx. 250 000 tons (wet weight). The effects from dumping of sewage sludge will further be considered in section 5.5.

Dredged Material

With the exception of 44,000 tons of dredged material from the approach channel to Norddeich harbour, no dredged material has been dumped in sub-region 5 in recent years. The dredged material from Norddeich harbour was dumped to the northwest of the island of Norderney. Otherwise, dumping was carried out in internal waters.

Pollution by alkylated phenols in 1991

In June 1991 wide areas of the German North Sea coast were polluted, heavily in places, by a mixture of alkylated phenols. ***(Figure 3.59)***. Its main component (about 90%) was identified as 4,4'-methylene-bis (2,6-di-tert.butylphenol). This compound is used, for example, as an additive in lubricating oil (oxidation inhibitor).

The remainder consisted mainly of tert.butylphenols (2,6-di-tert.butylphenol; 4-methyl-2,6-di-tert.butylphenol; 2,4,6-tri-tert.butylphenol).

Small pebble-size pieces of the product were found as well as football-size lumps.

Especially affected were the islands of Borkum, Juist, and Wangerooge, where about a ton of the product was removed from the beaches by authorized personnel.

These phenols are classified as "weakly toxic". As a precaution, any contact with the skin should be avoided as should oral uptake.

The appearance of this kind of pollution at the beginning of the holliday season was a serious problem: particularly children playing on the beaches were at risk. Adults, too, were at risk as the lumps were mistaken for amber.

The same kind of pollution was found earlier in the year on Danish beaches (findings of the "Oiled Seabirds" project, funded by the European Community). In April wide stretches of the coast around Hanstholm were affected. Smaller quantities were found on 16 May in Ringkøbing Fjord and on 5 June around Agger Tange.

It is suspected, that this mixture has been disposed of illegally in the North Sea by a ship.

Moreover, the suspicion exists that similar incidents occur more often but go undetected: these cases came to our attention only, because strong northerly winds forced the pollution ashore.

Table 3.16.: Dumping of waste from the production of titanium dioxide in subregion 5, 1978-1989

Year	Total quantity	Sulphuric acid	Cd	Hg	As	Cr	Cu	Ni	Pb	Zn	V	Fe	Ti
1978	727506	82831	<0.058	<0.006	<0.06	110.2	0.80	8.3	1.1	22.0	60.6	35806	1654
1979	740331	88840	<0.059	<0.006	<0.06	117.3	0.90	8.8	1.2	23.5	64.5	38121	1774
1980	591846	71022	<0.047	<0.005	<0.05	93.8	0.71	7.1	0.95	18.9	51.6	30478	1420
1981	672967	80756	<0.054	<0.005	<0.05	106.7	0.81	8.08	1.08	21.5	56.7	34677	1612
1982	489923	74232	<0.036	0.007	0.04	74.9	0.22	9.73	0.216	7.91	196.0	27018	1765
1983	419439	75499	<0.031	0.006	0.34	64.1	0.19	8.33	0.19	6.8	167.8	23131	1511
1984	412696	75170	<0.009	<0.003	0.17	66.0	<0.12	8.38	0.10	7.14	148.0	19875	1192
1985	385080	72575	<0.004	<0.001	0.08	62.0	0.13	6.25	0.15	5.61	135.8	13104	882
1986	366685	72492	<0.003	<0.001	0.09	65.8	<0.16	7.11	0.14	4.68	143.4	13185	851
1987	369771	72308	<0.006	<0.001	<0.03	58.5	<0.16	6.51	0.18	4.34	136.7	12811	882
1988	233909	43950	0.004	<0.000	0.02	44.2	0.09	4.50	0.11	2.9	92.3	7407	480
1989	149966	28290	<0.001	<0.000	0.01	28.3	0.07	2.80	0.05	1.7	58.7	4700	300

Permits were issued by the Deutsches Hydrographisches Institut since 1978
"<" : the character "less than" indicates that the value of the detection limit was partly used to calculate the metal loads
The total quantity contains coppera (e.g. in 1978 about 150 000 t; in 1984 about 30 000 t) as well as approxiately 16.000 t of gangue (dry weight)
From 1978 - 1983 load calculations were based on dumping applications; since 1984 they were based on weakly waste analyses

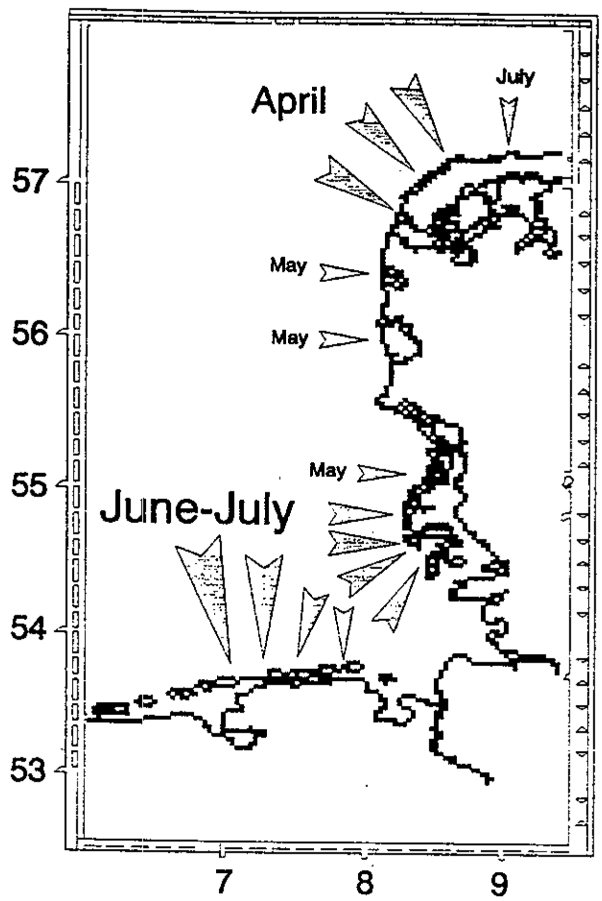


Figure 3.59.: Areas of the coast in subregion 5 which were polluted by a mixture of alkylated phenols in June 1991.

3.2.2 *Identification of influences of anthropogenic inputs on environmental levels*

Dumping of waste acid

Numerous investigations into water, suspended matter, sediment and biota were carried out in the waste acid dumping area. Some important results are given below.

In 1985, the dumping area was not found to differ greatly from control areas with regard to the parameters temperature, salinity, pH and dissolved oxygen. Measurements in 1985 confirmed results between 1969 and 1974 and 1980 results (Commission of the European Communities, 1990).

Data from heavy metal monitoring (copper, nickel, iron, manganese, zinc, cadmium and mercury) in 1987,1988 and 1989 confirm earlier results: the dumping of waste acid in the German Bight has no great prejudicial effect on the inorganic chemistry of the water in that area (Oslo Commission, 1991).

The iron content of suspended matter in the waste acid dumping area is considerably higher than elsewhere in the eastern North Sea. The iron content of suspended matter increased between 1985 and 1989 although the annual quantity of waste dumped had already been greatly reduced. Lower values were again found in February 1990, two months after dumping ceased (Oslo Commission, 1991).

Compared with other regions of the North Sea, elevated levels of various heavy metals were found in the surface sediments of the dumping area and its vicinity (Commission of the European Communities, 1990 and Deutshes Hydrographisches Institut, 1984, 1987, 1989).

In 1985, high concentrations of iron, vanadium, arsenic phosphorus, chromium and, less so, zinc and lead, detected in certain parts of the German Bight starting from the dumping area north-west of Helgoland, would appear to indicate that the area is affected by the waste (Commission of the European Communities, 1990 and Deutshes Hydrographisches Institut, 1987).

In 1987, high levels of zinc, iron, titanium, arsenic and vanadium were measured in the fine grain fraction of the surface sediments in the dumping area and adjacent areas influenced by dumping (Deutsches Hydrographisches Institut, 1989).

Dumping of sewage sludge

In 1989, the Oslo Commission published a review of sewage sludge disposal at sea (Oslo Commission, 1989). The review contains amongst other things a summary of monitoring activities in the dumping area in the Inner German Bight. A supplementary review is given in (Oslo Commission, 1990). The most important findings are given here.

Investigations in the dumping area in the Inner German Bight and its vicinity were carried out regularly since the beginning of the 1970'ies to ascertain if the ecosystem was influenced by the dumping of digested sewage sludge.

Although sediment investigations in the dumping area revealed that levels of certain heavy metals were generally high, it was not possible to decide to what extent the elevated levels were due to the dumping of sewage sludge, as the area has always been strongly influenced by the River Elbe in particular.

The Deutsches Hydrographisches Institut evaluated monitoring data for copper, zinc and lead from 1975 to 1988 and additionally for cadmium from 1981. It was found that the decrease in lead values in sediments coincided with the termination of the dumping of sewage sludge. No explanation has yet been found, however, as to whether a causal relationship existed. For the other metals the changes were less distinct.

Investigations into heavy metals in the water of the dumping area for sewage sludge revealed no elevated levels compared with other monitoring areas.

It can be stated that there are indications that the marine environment is negatively influenced by the dumping of sewage sludge. Negative influences are, however, obscured by environmental factors such as natural biological variations, stratification, tidal currents and the influence of River Elbe run-off, so that no definite relationship can be said to exist between sewage sludge dumping and the above findings; at the same time, the possibility cannot be excluded.

Because of the findings detailed above, the dumping area in the inner German Bight was abandoned in favour of an offshore area. This area lay about 20 to 30 nautical miles to the west - northwest of Helgoland. Sewage sludge dumping in the North Sea ceased in spring 1981. After the dumping area was again transferred, this time to the North Atlantic, the dumping of German sewage sludge at sea was phased out altogether in April 1983. Since then, sewage sludge has been deposited on land.

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4. MARINE BIOLOGY

4.1 GENERAL DESCRIPTION OF MARINE BIOTA

4.1.1 Microbiology

Almost no systematic investigations into bacteriology in the North Sea exist. There is thus hardly any information available about historical changes in bacterial populations in the North sea. Only the long term investigations carried out at Helgoland Roads give some indication about the development of bacterial populations in this sea area.

Since 1962 bacteriological investigations have been carried out on Helgoland in addition to hydrographic and hydrochemical measurements. During the first decade, samples were taken three times a week; since 1973 samples have been taken once a week.

Figure 4.1 shows the annual mean values of marine and fresh water bacteria. No explanation has yet been given for the large increase in marine water bacteria between 1971 and 1974 despite the availability of a good number of hydrochemical measurements and plankton investigations. The reason for this is our limited knowledge of the actual processes in water bodies. Annual mean values of bacteria densities vary greatly. In general, however, a clear upward trend can be recognized and this suggests increased pollution in the form of organic substances.

The influence of the Elbe estuary on the spread of bacteria in the German Bight is shown in ***Figure 4.2***. A section from the Elbe estuary to the open sea reveals that the values near Helgoland were determined by the gradient of water from the Elbe mixing with relatively germ-free water from the central North Sea.

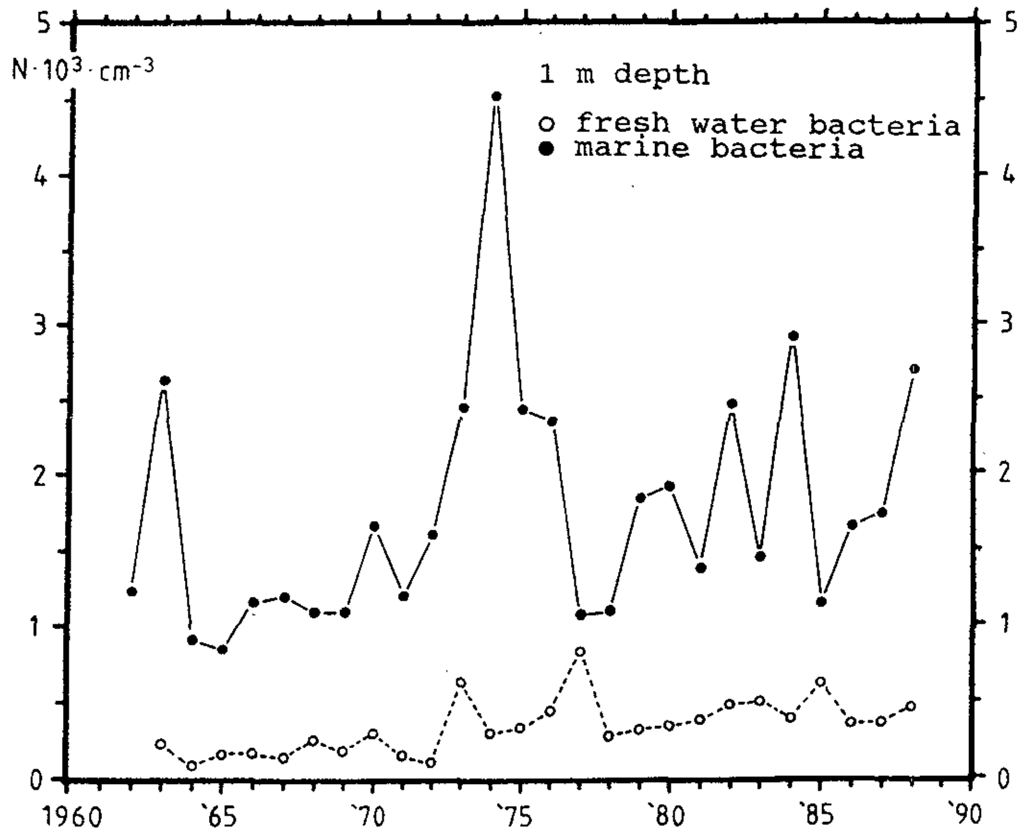

Figure 4.1.: *Annual mean values of marine bacteria (colony-forming units using a marine water agar) and freshwater bacteria (colony-forming units using a fresh water agar) in water samples from The Helgoland Roads station.*

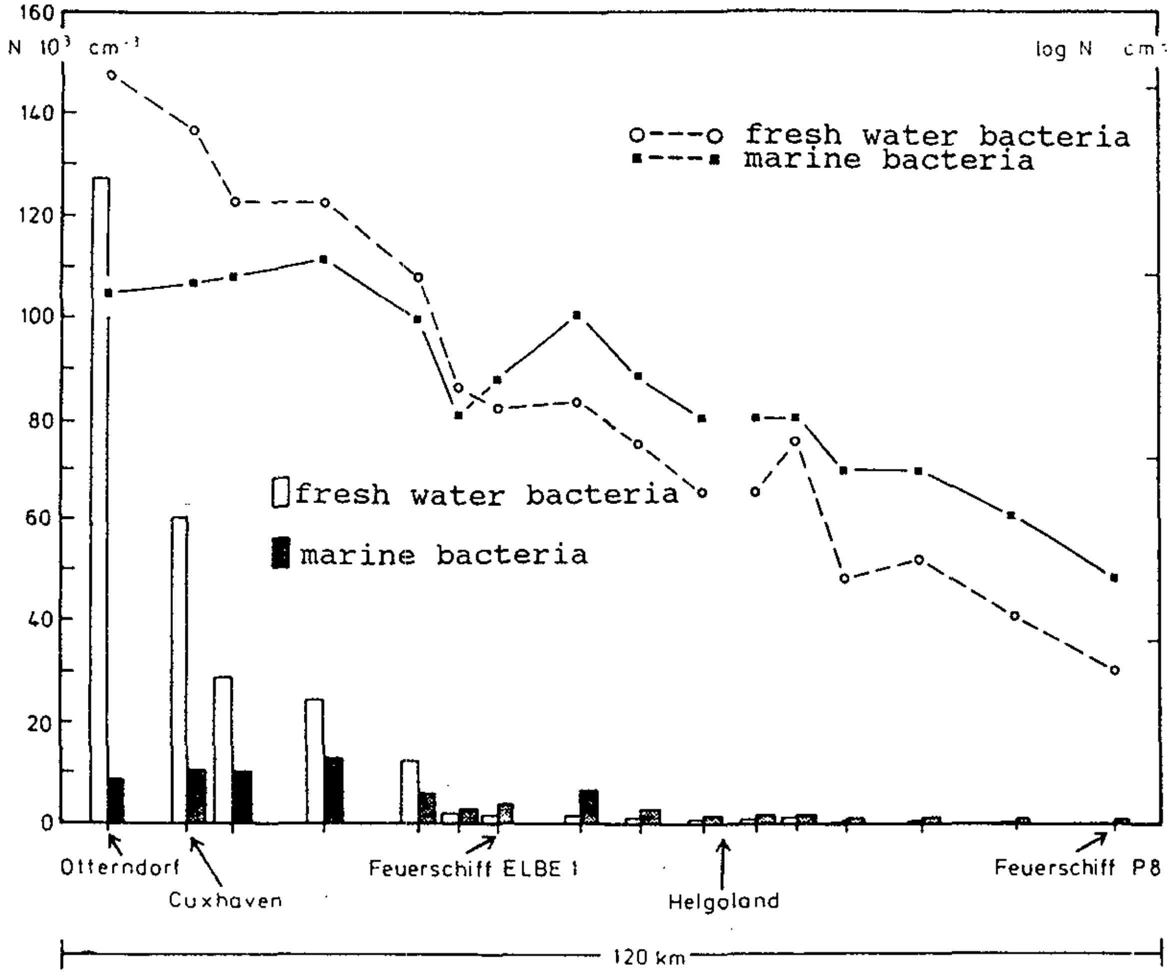

Figure 4.2.: Distribution of marine and fresh water bacteria on a section from the Elbe estuary to the open sea in 1966 (agar plate culture method). Bars refer to the left-hand scale, curves refer to the right-hand logarithmic scale.
Salinity values were as follows:

- *off Ottendorf*	*1.3 ‰*
- *Cuxhaven*	*4.79 ‰*
- *Elbe light vessel*	*29.99 ‰*
- *Helgoland*	*30.70/30.42 ‰*
- *P8 light vessel*	*32.40 ‰*

4.1.2 Phytoplankton

In the German Bight a grid of 17 stations was sampled monthly from January to May 1989. Emphasis was laid on the examination of species composition, primary productivity and biomass of the phytoplankton in order to understand the seasonal development of the planktonic biocoenose in this polluted and eutrophicated part of the North Sea. This investigation reflects the general pattern of phytoplankton of the subregion.

Figures 4.3, 4.4 and ***Table 4.1*** display the temporal development of the phytoplankton biomass and the primary productivity. In ***Figure 4.5*** the production rates of the nanoplankton (< 20µm) are described as percentage of the total primary production.

Table 4.1. *Seasonal development of phytoplankton biomass and primary production in the German Bight including the nanoplankton. Minimum and maximum values are given in addition.*

Month	Biomass (mg C m^{-2})	Total Primary Production (mg C m^{-2} d^{-1})	Primary Production 20 µm-fraction (% of total production)
January 1989	35 (2-170)	610 (300-930)	63 (50-80)
February	70 (1-470)	460 (230-980)	54 (23-67)
March	340 (4-1440)	800 (350-1620)	48 (18-75)
April	122 (11-250)	1520 (479-4390)	60 (38-81)
May	840 (140-2230)	9690 (2700-36100)	37 (11-91)

Following a winter period of stagnating growth till February new phytoplankton stocks developed up to March and in May a really rapid growth of the phytoplankton was observed. Due to stormy weather situations in March only the stations in the south-western part of the research area were sampled. Therefore the values given in ***Table 4.1*** can not be applied for the whole German Bight.

The very high biomass in March were the result of a bloom of the allochthonous *Coscinodiscus wailesii*, a big centric diatom which dominated in the species composition at most stations. It was observed in high densities since spring 1984 (Hesse, 1988), often associated with *Thalassiosira punctigera*, an other allochthonous species. In April the bloom of *Coscinodiscus wailesii* collapsed and was replaced by atypical early spring diatom development. The extremely high biomass in May were caused by a nearly stationary bloom of diatoms (*T. nordenskiöldii, T. punctigera, T. rotula, Thalassionema nitzschioides, Guinardia flaccida, Odontella sinensis* etc.), mainly in the area of influence of the Elbe river. In the southwestern part of the German Bight the prymnesiophyte *Phaeocystis globosa* was stock forming. Maximum numbers of 90 x 10 6 cells l^{-1} were determined.

In the southern part of the North Sea blooms of this species are very common (e.g. Bätje & Michaelis, 1986, Cadee & Hegemann, 1986; Veldhuis et al., 1986; Rick & Aletsee, 1989; Rick, 1990; Baumann et al., 1992). A possible explanation could be the capability of *Phaeocystis globosa* to use shares of phosphorous and nitrogen not assimilated by diatoms due to an incipient silicate depletion.

On the other hand *Phaeocystis* tolerates high levels of heavy metal pollution, especially of copper, while the same metals show toxic effects on autochthonous diatoms even in low doses. Interestingly enough the aforementioned immigrated diatoms (*C. wailesii, T. punctigera*) are also very tolerant to increased heavy metal levels, this may possibly be an additional advantage in natural selection (Rick, 1990).

The values of primary production (***Table 4.1***) correspond well with available literature data of the German Bight (***Table 4.2***). Only in May 1989 extremely high values were determined. The significance of enhanced eutrophication in this event compared to the influence of different methods applied by the authors, can not be judged up to now.

Due to the eutrophication (e. g. Radach & Berg, 1986; Hickel et al., 1986) the high amounts of produced biomass (***Table 4.1***) will probably be sufficient to cause a more or less distinctive oxygen deficit in the bottom waters during unfavourable weather conditions (Rachor, 1985, 1990; Hickel et al., 1989; Dethlefsen & v. Westernhagen, 1983; Gerlach, 1984) connected with the well known hardships of benthic organisms (e.g. Niermann et al., 1990).

Table 4.3 gives the most common species blooming in the Danish part of subregion 5 in 1980 to 1989. *Phaeocystis pouchetii* and *Noctiluca scintillans* bloom nearly every year while *Gyrodinium areolum* only blooms some years. In September 1990 there was a bloom of a hitherto unknown flagellate. It was properly *Leptodinium viridis* which at the same time was observed by the Germans in the German Bight.

Table 4.2. Primary production values of phytoplankton in the southern North Sea (from Coljin et al., 1990, modified).

Month	Total Primary Production (mg C m^{-2} d^{-1})	Reference
May; July; September	1240; 1057; 1013	Gieskes & Kraay 1984 (* reference is missing in list)
May - September	400 - 740	Tijessen & Wetsteyn 1984
March; April	600; 3200	Tijssen & Eygenraam 1982
March; April 9; April 24	300; 900; 3360	Veldhuis et al. 1986
May 5; May 15	4440; 900	
May - June	420 - 9520	Rick 1990
January - February	160 - 330	
May - June	53 - 6000	Colijn et al. 1990

Tabel 4.3: *Common dominating species at blooms of phytoplankton along the west coast of Jutland (NERI report no 8, 1990)*

Dominating species:	**Distribution:**	**Time of the year:**	**Year with blooms:**
Gyrodinium areolum	North Sea and Kattegat	August - September	1968, 1981, 1988, 1990
Noctiluca scintillans	North Sea and Limfjord	July - August	1983 - 1990
Leptodinium viridis	North Sea	September	1990
Phaeocystis pouchetii	North Sea	April - June	Every Year (except 1989)

ZISCH4 bis ZISCH8 --- VAL77, GAUSS127, VAL79, VH89, VAL81

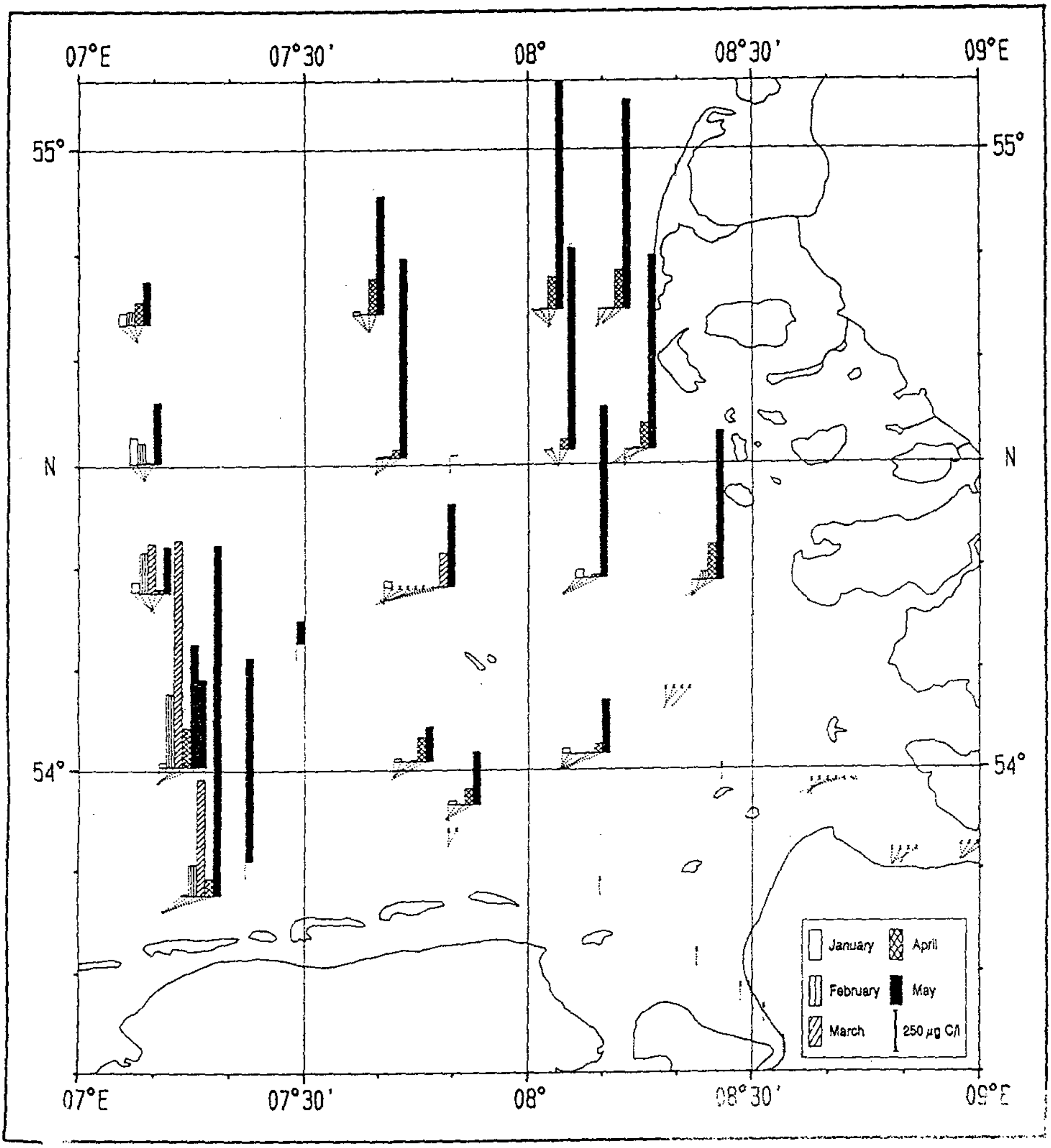

Figure 4.3.: Variation of phytoplankton biomass in German Bight from January to May 1989 (integrated values in depth-interval 0-20 m (µg C/l).

ZISCH4 bis ZISCH8 --- VAL77, GAUSS127, VAL79, VH89, VAL81

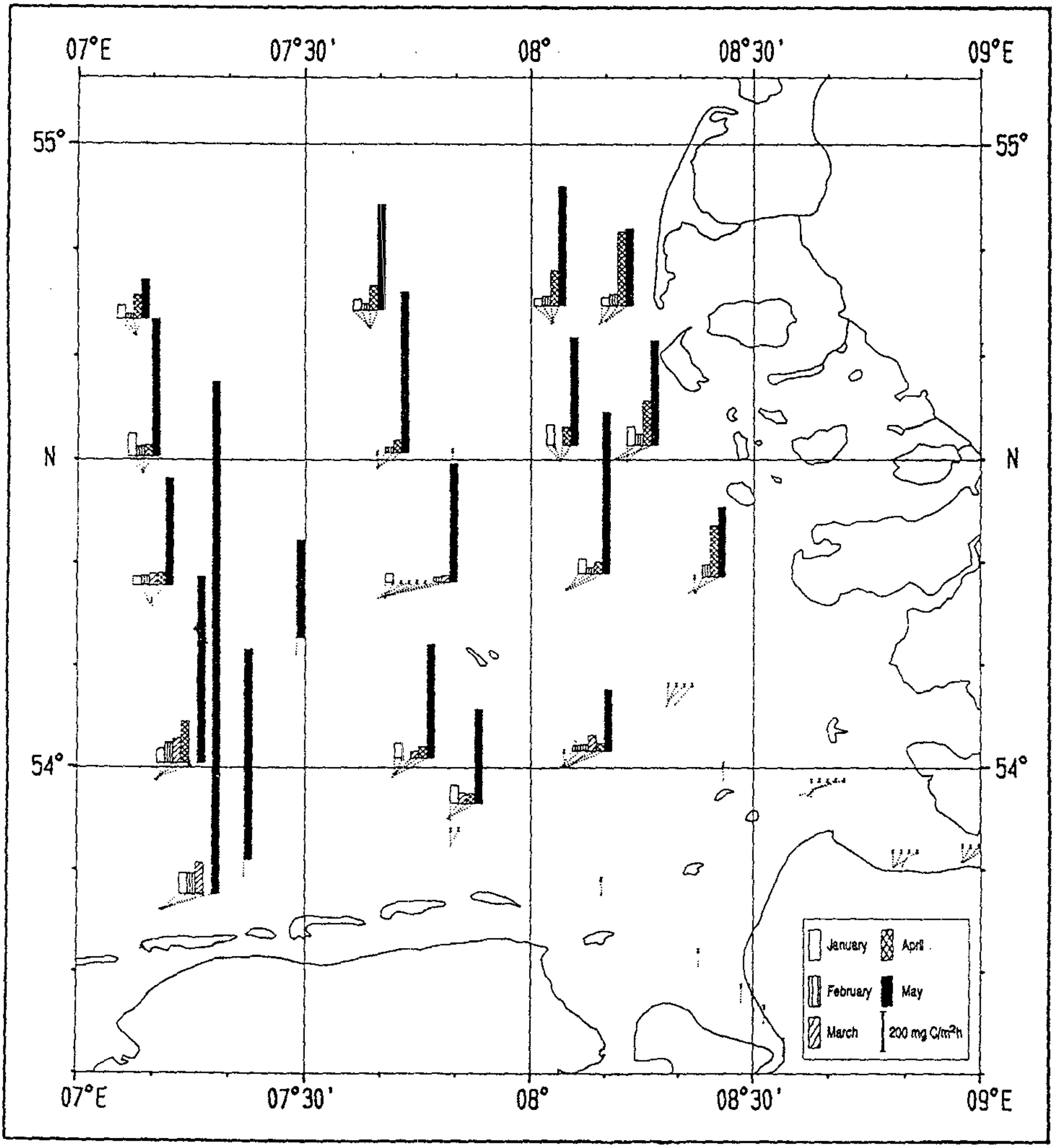

*Figure 4.4.: Variation of total primary production in German Bight from January to May 1989 (un fractionated mg C/m²*h).*

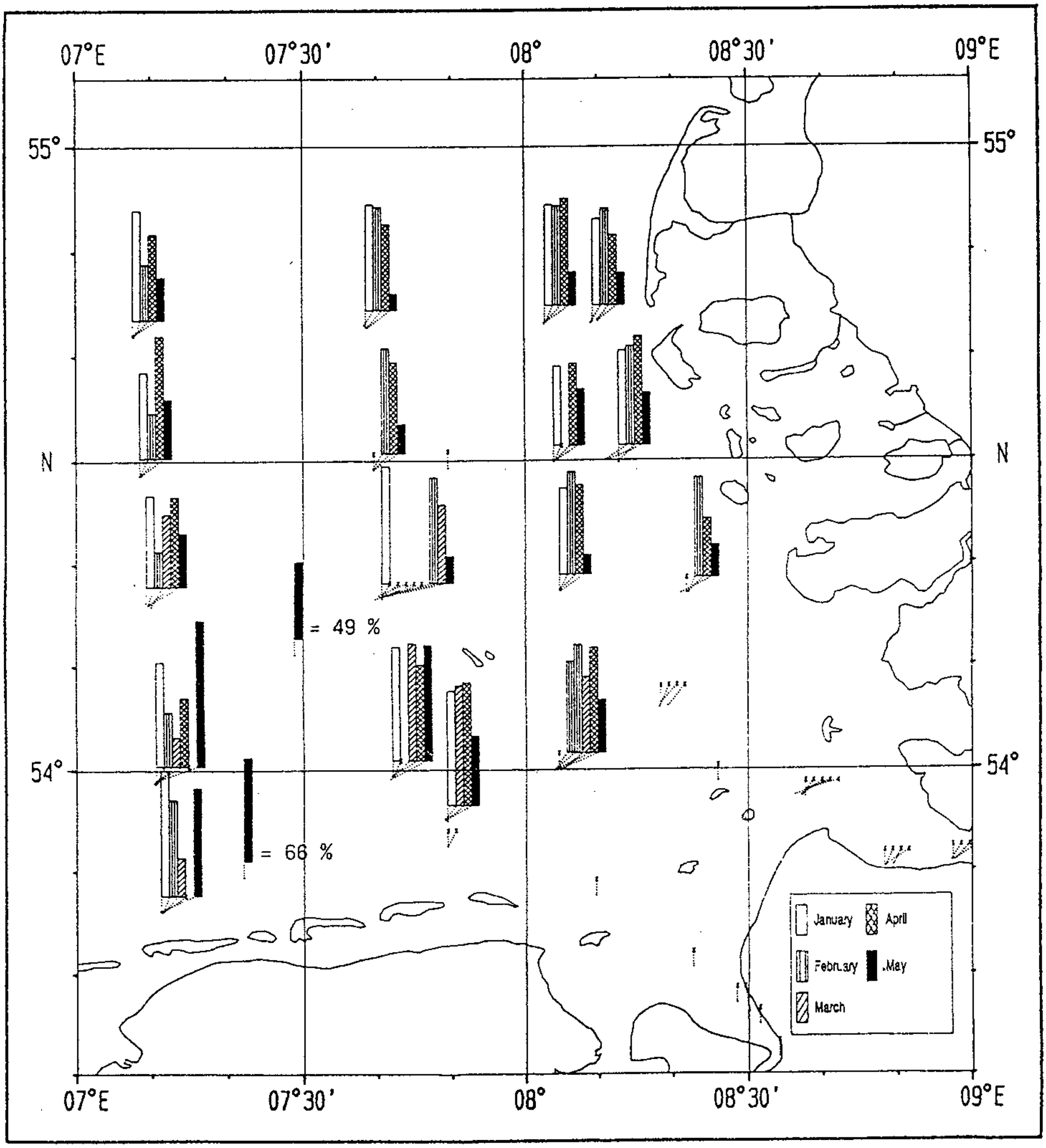

Figure 4.5.: Variation of nanoplankton (< 20 μm) primary production in German Bight from January to May 1989 (percent of total primary production).

4.1.3 Zooplankton

German Bight is a highly productive ecosystem, typically containing populations of tertiary consumers such as *Beroe gracilis* and *Chrysaora hysoscella*. They characterize the biocoenoses of the fully maturated ecosystem in summer. The lower consumer and producer levels are well established accordingly (Greve, 1992).

Since 1974 all plankton components are permanently surveyed. From these measurements four major changes have been deduced (Greve, 1992):
- an increased secondary production
- lack of zooplankton winter-deficiency
- the appearance of warm water species
- shifts in species composition including key species

The population dynamics of calanoid copepods at the station "Helgoland Roads" indicates a threefold increase of the standing stock from 1975 to 1986 with succeeding decline until 1990 still on a high level. Winter - populations of calanoid copepods increasingly maintain an abundance-level of at least 1000 individuals m^{-3}. This modifies the regeneration conditions of the ecosystems which depend on the starvation of predators and parasites in winter. Further changes in the timing of the annual succession of populations are to be expected (Greve, 1992).

The appearance of warm water species in German Bight could be registered in the last couple of years. These were the siphonophores *Muggiaea atlantica* and *Nanomia cara*, The tunicate *Dolidum nationalis*, the decapod *Caridion steveni*, the polychaete *Mystides limbata* and the cladocera *Penilia avirostris*. These populations indicate the possibility of changes in the bicoenotic composition. Whether this already relates to the registered rise of the sea - temperature in the last decades or the warm winters in the last years cannot be decided. In each case species as *Muggiaea atalntica* obviously can successfully reproduce in German Bight. They would not be controlled by e.g. *Beroe gracilis*, the population which is regulating *Pleurobrachia pileus*, the local resident in the ecological niche which might be occupied by the siphonophore. Drastic modifications of fish larval survival, phytoplankton blooms in summer (including bottom oxygen consumption) and other changes have to be anticipated (Greve, 1992).

Shifts in the species composition of ecological systems are part of the natural regeneration and stability of ecosystems. The state of our knowledge of these processes does not permit to characterize certain changes as risk-indicators, even if they might be just that. Still it is surprising to register the increase of e.g. *Alaurina composita*, a pelagic flatworm, in the eighties to an abundance level at which relatives of this species in lakes are seen as dominant carnivores (Greve, 1992).

4.1.4 Benthos

Zoobenthos, including shellfish

The by far greatest part of the area is sandy sediments which are inhabited by primarily a suspension-feeding bottom macrofauna. The dominant type of faunal community is the *Tellina fabula* association, characterized by a small bivalve with the same name (v. Westernhagen et al. 1987). Other conspicuous species in this community are the filtering bivalves *Venus striatula* and the Ocean qua-hog (*Arctica islandica*), the burrowing sea-urchin *Echinocardium cordatum* and the brittle star *Ophiura alpida*.

In the postglacial River Elbe Valley in the southern part of the area, and along the western margin sediments are softer and here the *Amphiura filiformis* association dominates (Westernhagen et al. 1987, Nierman 1990). This community contains a high number of different bristle worms and mollusca. The sea-urchin *Echinocardium* and the bivalve Ocean qua-hog also occur in this community.

Phytobenthos and other macroflora

The centre of highly diversified phytobenthos within subregion 5 is the rocky island of Helgoland, where major seaweed species characteristic of the European North Atlantic coasts are present, with a total of around 200 algal species. Regular observations of the Helgoland seaweed flora since 1958, when the Biologische Anstalt Helgoland (BAH) came back to the island after the destructions of the Second World War, do not reveal qualitatively or quantitatively substantial changes of the seaweed flora. The main components are three kelp species (*Laminaria digitata*, *L. saccharina* and *L. hyperborea*) in the sublittoral zone, and the usual fucacean species (*Fucus serratus*, *F. vesiculosus*, *F. spiralis*) in the intertidal. The lower limit of the sublittoral *Laminaria hyperborea* forest is still at 4 m and the deepest situated individuals of this characteristic European kelp species occur at 8 m water depth below mean low water of spring tides, with the deepest coralline crusts at around 12-15 m depth. This was determined in an extensive diving survey conducted from 1965 to 1972, and was revealed again by numerous dives of the Marine Botany group of the BAH until 1992.

A few species have been added to the Helgoland marine phytobenthos:

- The red alga *Porphyra ochotensis*, probably as a foreign introduced species, maybe originating from the French coast as a contaminant of oyster imports from Japan,

- The brown alga *Sargasssum muticum*, which was established as an Asiatic introduced species on the coasts of France, United Kingdom, The Netherlands, Denmark and Norway before,

- The red alga *Mastocarpus stellatus*, a typical lower intertidal species of European Atlantic coasts, planted in the seventies at Helgoland by a foreign algologist, using material from Iceland. This alga is now abundantly distributed along the west coast of Helgoland, without apparent damage or competition to or with other conspicuous algae, e.g. in regard to the similarly shaped red alga *Chondrus crispus* which grows somewhat deeper in the intertidal so that the newly arrived perennial *Mastocarpus stellatus* seems to occupy its normal niche like on other shores, which was before occupied by annual opportunist such as the green alga *Ulva* spp..

There are quantitative increases of two species with a southern and Mediterranean distribution:

- The brown alga *Dictyota dichotoma*, which was abundant in the somewhat warmer thirties of our century in the lower intertidal of Helgoland, and was very rare and only occurring as small individuals from 1958 to the ils, has now been found more often as up to 10 cm long thalli. This may indicate somewhat warmer conditions around Helgoland waters.

- Similarly, the red alga *Phyllophora crispa (=rubens)*, again with a more southern distribution than many other seaweeds occurring near Helgoland, has now been found with a size of up to 10 cm.

A general eutrophication effect on the Helgoland seaweed flora is not apparent. The main reason may be that the main benthic marine primary producers in the Helgoland sublittoral, i.e. the brown kelp species, reduce their growth rate in summer due to increasing day length and would thus not be good indicators e.g. of the human-caused ample supply with nitrate in the seawater in summer anyhow. As to annual and fast-growing seaweed species such as *Ulva* spp. which have become a nuisance along the Wadden Sea coasts, the perennial brown seaweeds in the Helgoland intertidal and sublittoral zones leave little room for these opportunistic r-strategists. As a single observation it should be noted, however, that in 1991 a 5 m (five meter) long individual of an *Ulva* sp. (probably *U. pseudocurvata*) was found on the rocky North coast of Helgoland. This may be an organismic answer to the high nitrate levels available in summer in these years.

4.1.5 Fish and shellfish

Catch data of a biological monitoring program of the Bundesforschungsanstalt für Fischerei in Hamburg are used to show the variation of the species composition in summer from 1987 to 1991. Twenty to thirty hauls are carried out each year in July in a small and fixed area (Box a) of 10 to 10 nautical miles using the GOV-standard trawl ***(Figure 4.6)***. In ***Figure 4.7*** the mean catch in weight per 30 min. for the 7 main species is given. The high proportions in some years for whiting (*Gadus merlangus*) and scad (*Caranx trachurus*) of together nearly 90% are conspicuous.

Figure 4.8 shows the difference in the species composition between winter and summer. During the cold seasons the more southerly distributed scad has left the German Bight and starts to reenter in this area in June. Against the occurrence of herring (*Clupea harengus*) in that area decreases in summer and the catch of whiting seems to be independent of the time of the year.

There's a broad variety of fish species present in the very productive area along the west coast of Jutland. Present are flatfish species such as: plaice (Pleuronectes platessa), sole (Solea solea), brill (Scophthalmus rhombus), dab (Limanda limanda), lemon sole (Microstomus kitt) and turbot (Scophthalmus maximus). Pelagic species like herring (Clupea harengus), sprat (Sprattus sprattus) and mackerel (Scomber scombrus). Cod (Gadus morhua), haddock (Melanogrammus aeglefinus), sandeel (Ammodytes sp.), and a number of less commercialy interesting species are also present.

The area is a very important spawning area for sole (Solea solea). The sole spawns in June near the coast line. After spawning the soles migrate southwest to their winter quarter along the German and Dutch coast.

NSTF subregion 5 is also a major nursery area for many of the flatfish species and herring (Clupea harengus). The North Sea herring has it's spawning grounds along the British east coast. The herring spawns from August to December depending on the spawning ground. After the hatching the small larvae are brought to their nursery grounds on the British east coast and the Danish west coast by the sea currents.

To protect the large number of juvenile fish within this region so called boxes have been established. Boxes are areas where fishing is prohibited for certain periods of the year, with certain types of gear and for certain species.

Examples are the sprat-box and the plaice-box. (See ***Figure 4.9***).

In the sprat-box fishery for herring and sprat is prohibited from 1. July to 31. October. The purpose of the box is to reduce the catch of juvenile herring. The plaice-box encompass the 12 miles zone, corresponding to the major nursery area for plaice and sole. In the plaice-box it is forbidden to use beam and/or otter trawl from 1. April to 30. September.

There are no separate assessments for the stocks in NSTF subregion 5, as most of the stocks in the southern part of the North Sea (ICES IV b) are treated as a whole. Meaning that the stock trends that are observed in the Southern North Sea would also be true for subregion 5. Generally speaking this means that the cod stock is declining, the plaice stock is stable, and so is the herring stock, the sole stock is increasing and the sprat stock is still low compared to the early eighties.

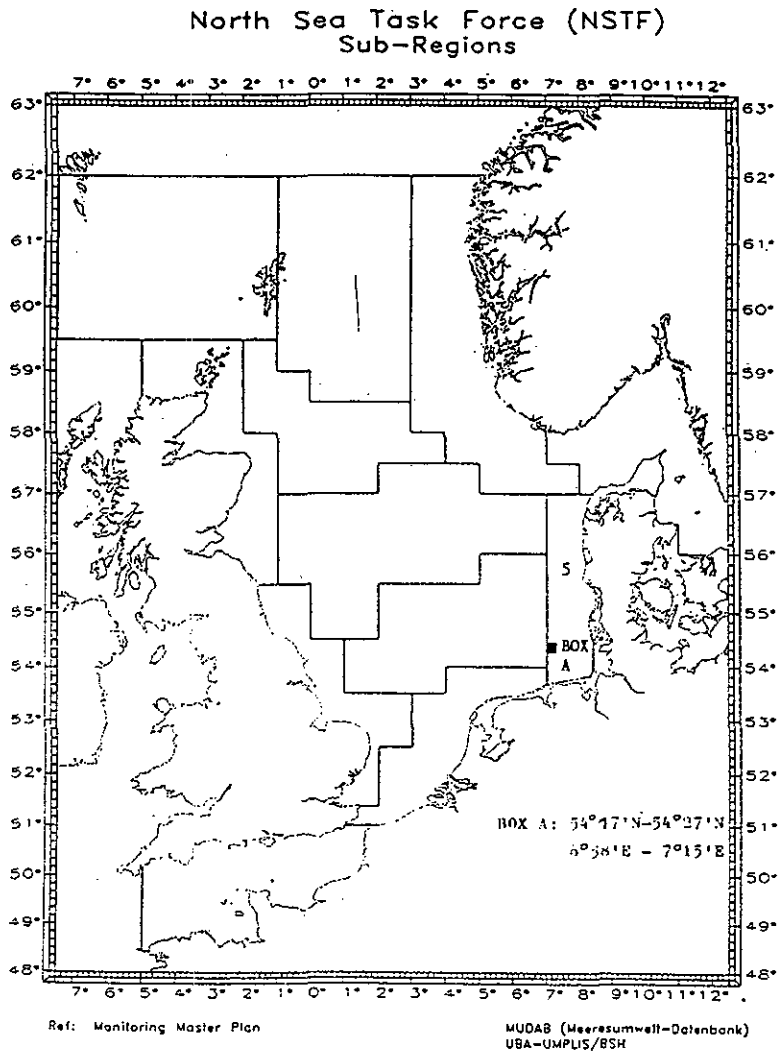

Figure 4.6.: Position of Box A in subregion 5

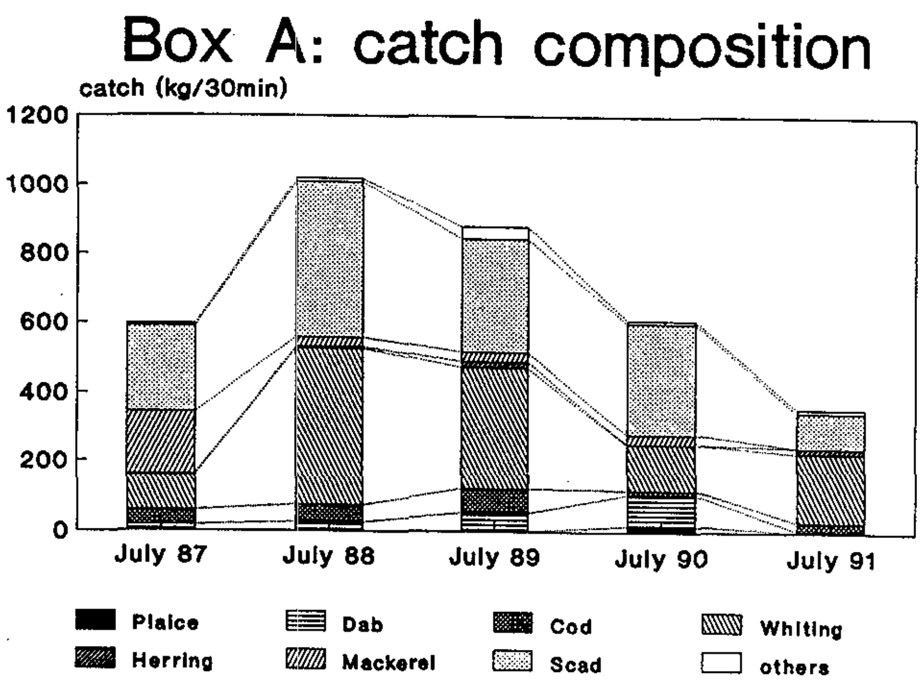

Figure 4.7.: Catch composition of the main species in July in Box A from 1987 to 1991

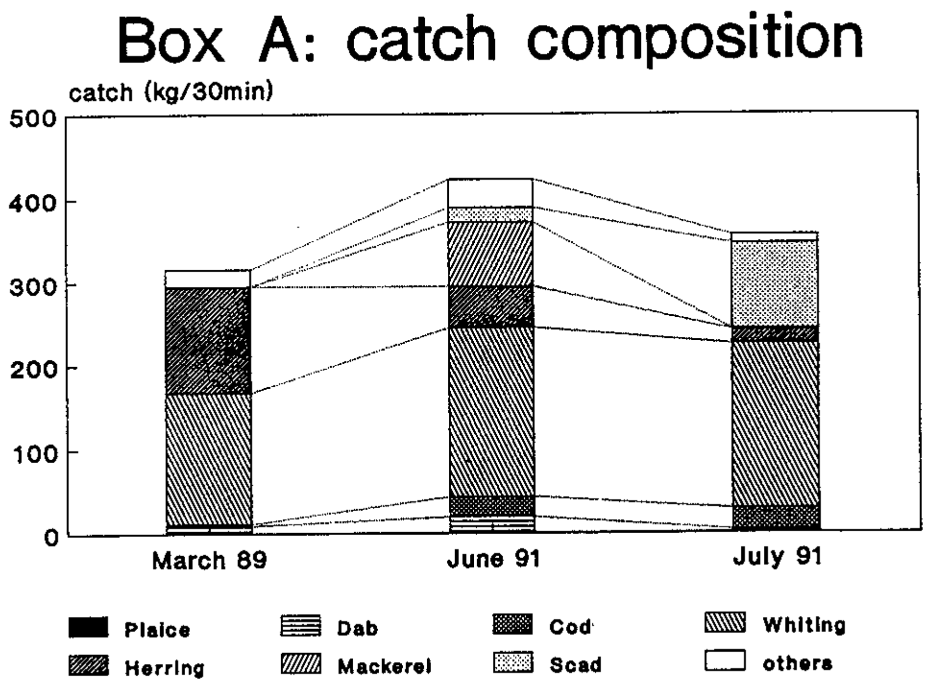

Figure 4.8.: Seasonal differences in the catch composition of species in Box A.

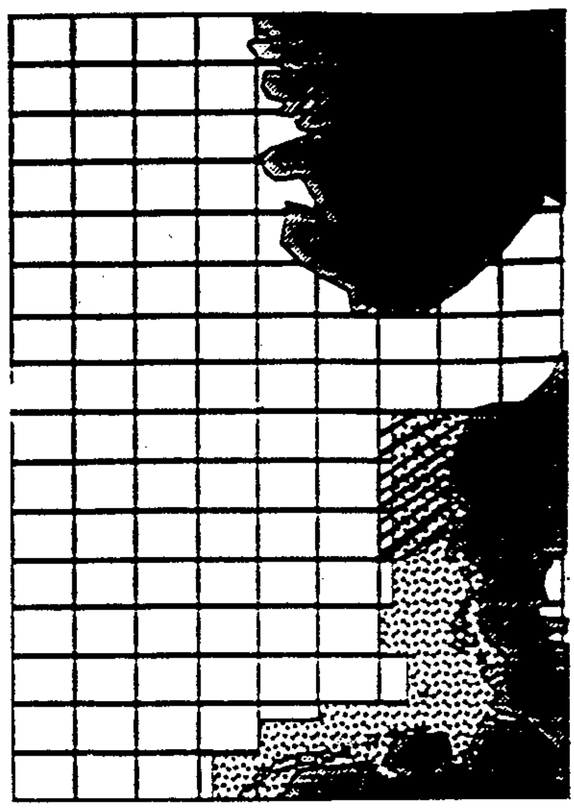

Figure 4.9.: Sprat and plaice-box in subregion 5. Dotted area = Plaice box, hatched area = Sprat box.

4.1.6 *Birds*

Sub-region 5 south of 55°N contains the only offshore breeding ground in the southeastern North Sea - Helgoland. Like on many other islands, the birds on Helgoland were used intensively for hunting and egg culling by the islanders well into this century. As a result, the kittiwake *Rissa tridactyla* became extinct at the beginning of last century; the puffin *Fratercula arctica* was wiped out around 1840. The number of guillemots *Uria aalge* was reduced from "thousands" to about a thousand pairs around 1910. Only when it was realized that sea birds should be protected did numbers begin to recover. Now, more than 4,000 pairs of kittiwakes breed on Helgoland after they began colonizing the island around 1950. The number of guillemot pairs has also risen from 1,000 or so after the war to 2,500 now. Following a general increase in numbers and an extension of the breeding area, the fulmar *Fulmarus glacialis* has bred on Helgoland at least since 1972; now 81 pairs are found there. Other breeding seabirds are the gannet *Sula bassana* (first recorded in 1991, 1 pair), the herring gull *Larus argentatus* (approx. 80 pairs) and the razorbill *Alca torda* (7 pairs).

The most important source of food for birds breeding on Helgoland are small fish, discards and offal from fisheries: sand eels *Ammodytes* spec., sprats *Sprattus sprattus* and herrings *Clupea harengus* in greatly varying degrees for the guillemot; whiting *Gadidae*, probably mostly unwanted catch, for the kittiwake and the herring gull. The feeding ground of these three species during the breeding season is restricted to the near vicinity of the island (< 10 miles). This means the birds would be particularly affected by changes in the food supply caused by different fishing practices in the waters around the island, or by a severe oil spill. In 1989 there were mass deaths of kittiwakes as a result of a sudden shortage of food. It is not known what the fulmars feed on at Helgoland, but it can be assumed that they forage far to the north west of the island.

The importance of fisheries as a source of food for sea birds in this area has obviously been underestimated. Charts drawn up by the Institut für Vogelforschung show herring, lesser and greater black-backed gulls *Larus argentatus, L. fuscus* and *L. marinus* and probably kittiwakes and common and black-headed gulls *Rissa tridactyla, Larus canus, and L. ridibundus* to be the most important escorts of fishing vessels; all these are species found in large numbers near shore and which usually use up to more than 80% of any unwanted catch and almost 100% of the offal from the gutting when whitings are being fished for. The birds' distribution at sea mainly depends on fishing activities, so food shortages occur when the weather is poor and fishing reduced. In areas further away from the coast, e.g. the area to the west of the 32‰ isohaline, the numbers of gulls fall steeply. There, the fulmar, gannet and kittiwake benefit most from fisheries.

The coastal areas of sub-region 5 are used as a feeding ground by Wadden Sea birds such as gulls and terns, by sea-ducks, in particular the eider and common scoter *Somateria mollissima* and *Melanitta nigra*, as well as divers, mainly the red-throated diver *Gavia stellata*. For divers, this area is perhaps as important a wintering ground as the Moray Firth. More than 400 cormorants (*Phalacrocorax carbo*) spend the winter on Helgoland and their numbers are increasing.

Because of the large numbers of individual birds and the proximity to the Elbe shipping lanes, the southern part of sub-region 5 reacts particularly sensitively to pollution by oil and garbage. Countings on gannets (*Morus bassanus*) at Helgoland showed that 2.6% were entangled in nets and other filaments.

4.1.7 *Mammals*

Seals

The occurrence of seals (Pinnipedia): To the east, sub-region 5 borders on the Wadden Sea where common seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) are regularly seen on the sandbanks. In the area, the only resting places for seals are available on the Helgoland dune and on a nearby rocky island that is only sometimes emerged. In rare cases, seals are also known to lie in the Wadden area of Helgoland island itself. The Helgoland dune, however, can only be used as a resting place through the night and in the early hours of the morning until the first tourists arrive. The seals on the dune can number up to 110 in the autumn and winter. At this time of the year, seal-count flights across the Wadden Sea show numbers to be greatly reduced. As yet, no information is available as to the seals' whereabouts in the winter, but observations lead scientists to assume that seals leave the Wadden Sea towards the open North Sea and pass nearby Helgoland.

Ringed seals (*Pusa hispida*) and harp seals (*Phoca groenlandica*) should occasionally be expected from the North Atlantic.

Seal births have not yet been observed on Helgoland. There are no reports of dead seals found on Helgoland in 1991. During the seal epidemic in 1988/89, 16 dead animals were found on the island (1990: 1). Only a small number of grey seals has been observed on Helgoland (1990: 4). Little reliable information is available about sightings of seals in the open sea. It can be assumed, however, that the whole of sub-region 5 is the habitat of common and grey seals from the Wadden Sea. This is suggested by initial results from the Danish-German-Dutch telemetric study of seals: a seal captured in the Wadden Sea could thus be traced in the open sea near Helgoland. It can therefore be assumed that the growth of the seal population in sub-region 5 runs parallel to that of seals in the Wadden Sea. Nothing can be said about regional differences in the occurrence of seals.

Whales

Whales (Cetacea) in this area have not yet been counted. In 1990 and 1991, a few chance sightings were reported ***(Tabel 4.4)***; they are being assessed at the University of Kiel's Institut für Haustierkunde. The whales sighted were mostly harbour porpoises (*Phocoena phocoena*); one white beaked dolphin (*L-agenorhynchus albirostris*) and one fin-whale (*Balaenoptera physalus*) was sighted.

Whales trapped in fishing nets

In 1991, 4 harbour porpoises which had obviously drowned in fishing nets were found on the North Sea coast of Schleswig-Holstein. All whales found beached or caught in nets were examined by veterinary surgeons. Samples were taken from the animals for other investigations into virology, parasitology, toxicology, histology, food analyses and reproductive biology. Initial results have been published in the last interim report about the BMU R&D project.

Eighteen species of Cetacea have been recorded for Danish waters up to 1976 (Bondensen, 1977 and Kinze et al.,1987). From 1977 to 1985 a total of 22 stranding (excluding *P. phocoena*) and 20 sightings (excluding *P. phocoena*) have been recorded (Kinze et al., 1987).

The harbour porpoise (*Phocoena phocoena)* is by far the most common cetacean in all Danish waters. Along the north-western coast of Jutland, also white-beaked dolphins *Lageno-rhynchus albirostris,* killer whales *Orcinus orca*, pilot whales *Globicephalea melaena*, and mink whales *Balaenoptera acutorostrata* occur rather frequently. All other species appears to be stragglers, however during the last years common dolphin *Delphinus delphis* and white whale *Delphinapterus leucas* have been observed on several occasions.

During the summer and autumn 1991 (from about the 10th of July 1991), 200 dead harbour porpoises (*Phocoena phocoena*) and some individuals of white-beaked dolphins (*Lagenorhyn-chus albirostris*) were found on Danish coasts (***Figure 4.10***). Most of the animals were strongly decomposed, after several weeks in the water.

In order to co-ordinate the effort by The Danish National Forest and Nature Agency in the best possible way, the State Forest Districts in 1991 were asked to help by collecting information about stranded Cetaceans and to make sure that as many fresh animals as possible were sent for examination at the National Verterinarian Serum Laboratory in Århus. The main tasks of the Districts, were done in co-operation with, among others, municipalities and the Fisheries Inspections.

In July 1991, 13 dead Porpoises were examined by the National Environmental Research Institute (Denmark) and the Fisheries and Maritime Museum in Esbjerg. The research did not show significant signs of diseases, but indicated that the animals probably were drowned as incidental by-catch in fishing tackles.

During July and August 1991, 16 dead Porpoises were examined by veterinarians. There is a autopsy report from the 9th. of August made on the first 9 animals. The autopsy report did conclude that it was not possible to prove the cause of death of 5 out of the 9 examined Porpoises, but it can't be precluded that 3 of them are drowned. Two adult males were dead because of a solid attack of lungworm and two juvenile Porpoises were dead from a rare kind of pneumonia, which often can be seen at virus diseases. However, it was not possible to isolate virus from the organs.

In 1991, 92 porpoise were landed of which 66 were examined by the Danish National Veterinarian Serum Laboratory.

Table 4.4. *In 1990, the following whales were found dead on beaches along the German North Sea coast. Numbers of dead harbour porpoise (91) were differentiated into "strandings" (87 individuals) and "by-catch" (4 individuals)*

	1990	1991
Harbour porpoise (*Phocoena phocoena*)	62	91
Common dolphin (*Delphinus delphis*)	1	-
White beaked dolphin (*Lagenorhynchus albirostris*)	2	2
White sided dolphin (*Lagenorhynchus acutus*)	2	-
Mink whale (*Balaenoptera actutorostrata*)	1	-
Fin whale (*Balaenoptera physalus*)	1	-
Bottlenose dolphin (*Tursiops truncatus*)	-	1
Humpback whale (*Megapetra novaeangliae*)	-	1
Total	69	95

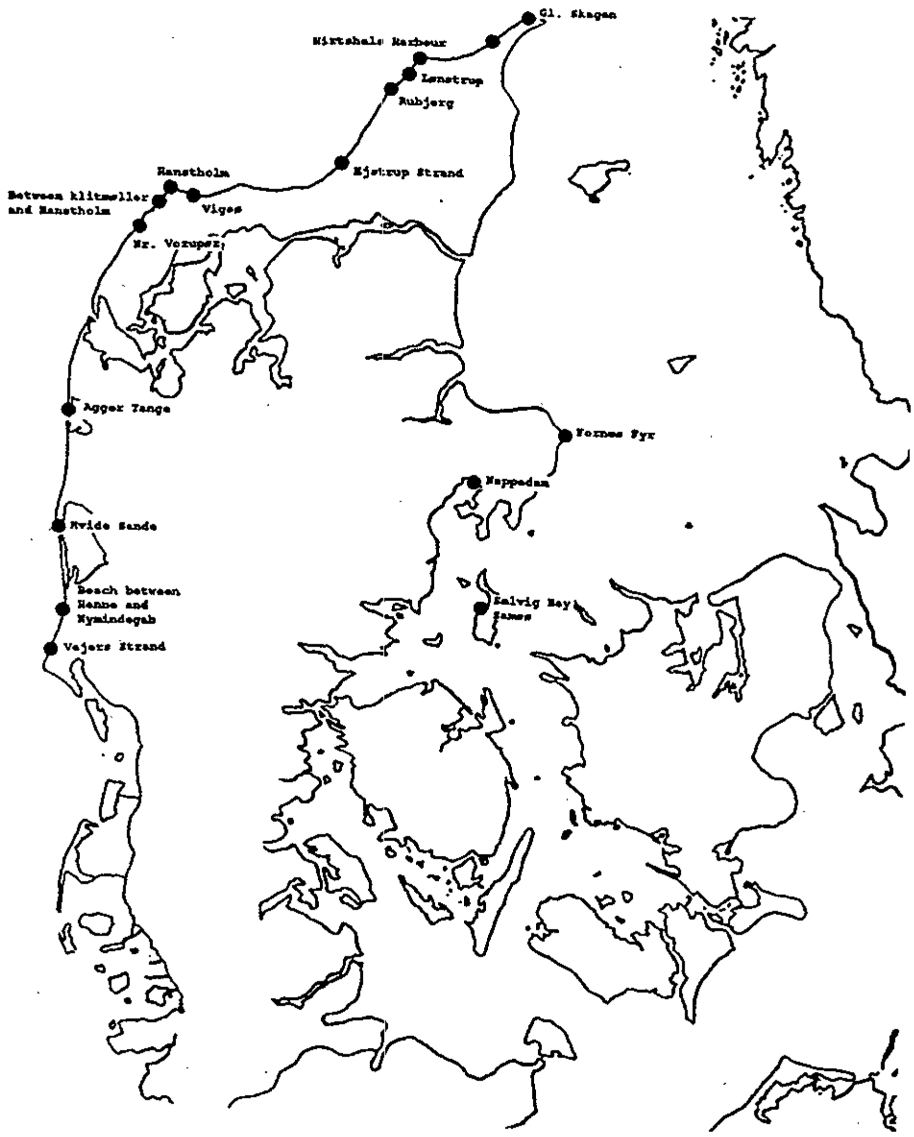

Figure 4.10.: *Location along the Danish coast where stranded cetaceans where found in 1991.*

Since august 1991, a minor economic compensation has been given to the fishery for the landing of porpoise. The number of landed porpoises from August to December 1991 is shown in ***Figure 4.11.***

64.1 % of registered and landed harbour porpoise have been recorded to be caught in gillnets (often referred to as cod nets). For the major part of the remainder of the caught animals (31.5%) the type of fishing gear has not been recorded ***(Figure 4.12).***

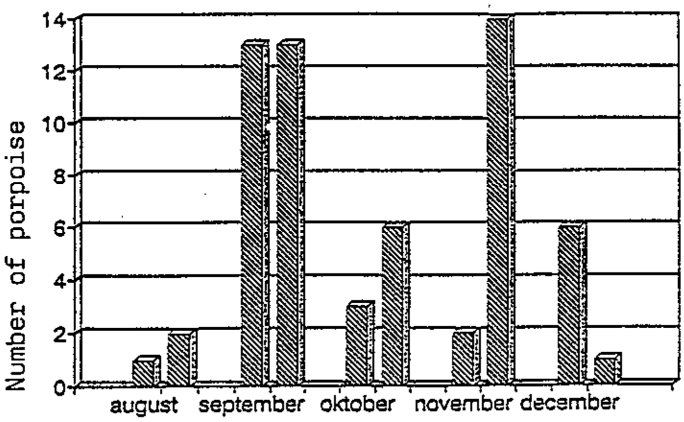

Figure 4.11.: *Number of porpoise in by catch during the period August to December 1991 (1/2 month interval, N=92).*

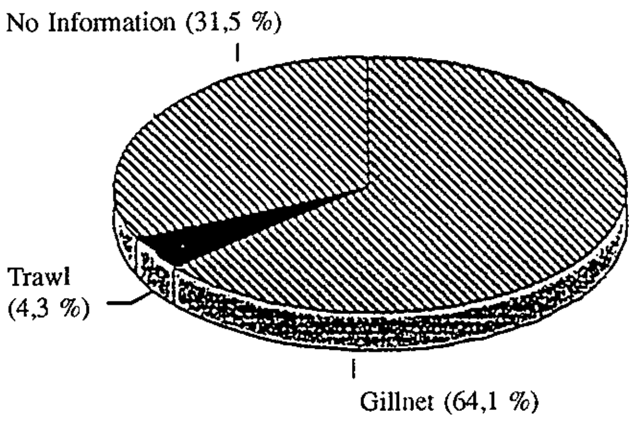

Figure 4.12: *Landed porpoises in 1991. Distribution on different types of fishing tackle (N=92).*

4.2 INTER-RELATIONSHIPS

4.2.1 Description of main communities

Plankton populations differ in principle from benthic, nectonic and coastal communities. Plankton populations in general are r-strategic or opportunistic. Sudden changes in the species compositions and abundances are characteristic for these pelagic biocoenoses. These sudden shifts, though, are geared by highly sensitive ecological functional relationships, determining regional differences in ecological equilibria formation. Such structurization supports a multitude of ontogenetically German Bight-oriented populations, many of which are, commercial fish (Greve, 1992).

Holoplanktonic organisms such as diatoms, copepods and ctenophores exclusively live on the r-strategy. In shallow seas meroplanktonic organisms such as most zoobenthos, fish and others get increasingly more important. There, the nutritional state of the adults determines the abundance of the planktonic larvae. In German Bight these larvae at times contribute the majority of the zooplankton. Little is known on the budgetary impact of these important over annual ecological relationships (Greve, 1992).

4.2.2 Foodwebs and energy pathways

The pelagian ecosystem is not a food chain. According to the production/biomass ratio the dynamics of this system exceed most other ecosystems. In the temperate zone each trophic level has to be established to functional significance each year. Thus the ecosystem - maturation process is repeated annually. That includes the structurization of successive or alternative ecological equilibria, which provide variance, regional inhomogenuities and thereby diverse living conditions for plankton feeders. These inhomogenuities may depend on (Greve, 1992)

- endemic ecosystem regulation
- epidemic population processes
- advective or turbulent external influences

4.2.3 Productivity of systems

The majority of zooplankton populations is omnivorous or carnivorous. It is not permitted therefore to assume all zooplankton to be herbivorous and to relate zooplankton as a unit solely to phytoplankton (Greve, 1992).

Total productivity estimates have to include either continuous productivity profile measurements including the impact of wave action or to budget on the basis of standing stock, sedimentation and other losses from the system. Standing stock is the phytoplankton present and the phytoplankton incorporated in the trophic levels with an increasingly level of aggregation. The inaccuracy in the definition of many zooplankton populations impedes this calculation so far (Greve, 1992).

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5. MAN'S IMPACT ON ECOSYSTEMS

5.1 NUTRIENTS (relation with eutrophication effects)

The German Bight is particulary vulnerable to eutrophication and pollution effects, as is evident alone from its shallow depth and, hence, small volume relative to the discharge volume of the rivers running into it. In addition, flushing times are reduced in the German Bight, and trapping of river borne substances within the coastal water body may enhance its eutrophication (Hickel W. 1992).

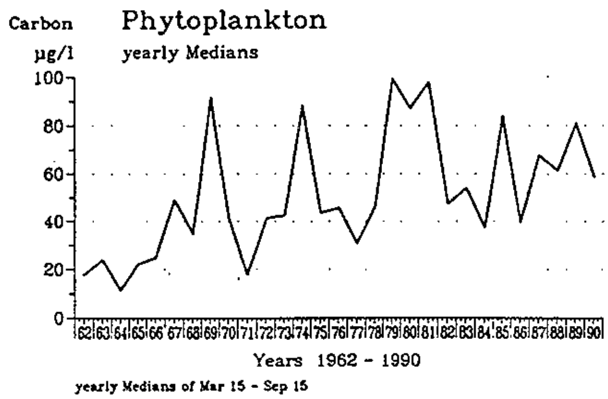
The Helgoland data of phytoplankton from every working day since 1962 shows an increase (***Figure 5.1***) in the phytoplankton stocks probably as a response to eutrophication, but the increase was less pronounced, and large interannual variations make an interpretation difficult. These variations can be understood from the fact that main growing areas of phytoplankton are situated farther north or northwest of Helgoland; some plankton blooms are only occasionally found near Helgoland, when the residual current reverses its direction. Even if the phytoplankton stocks increased in the whole German Bight as an average due to eutrophication, this must not necessarily show up in the inner German Bight, where nutrient supply is best, but light climate, as a main factor for phytoplankton growths, is not.

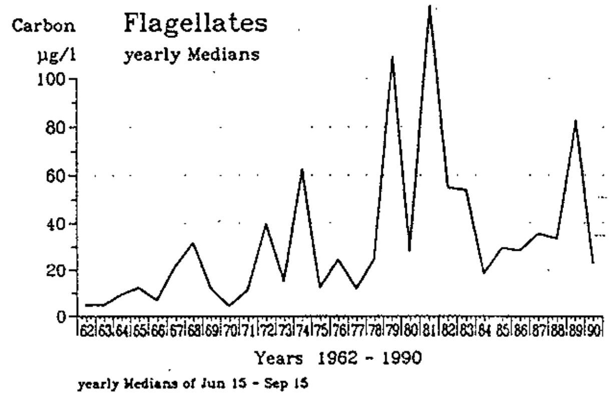
The much later nitrogen eutrophication as compared with the phosphate eutrophication must be understood as the consequence of the nearby riverine nutrient sources and the different behaviour of these elements in agricultural soils. These differences became evident most clearly by investigating the influence of large Elbe river floods.

The River Elbe discharges an average yearly load of 25 km³ of freshwater, 190.000 tons of total nitrogen and 1.000 tons of total phosphorus into the inner German Bight. Two years with exceptionally large Elbe flood periods, 1987 and 1988, provided particularly good evidence for the eutrophication effects by this river. In these years, the Elbe river discharge volume was twice as large as normal.

Compared with the long-term average of the decade before (***Figure 5.2***), the nitrate concentrations at Helgoland where twice as high, whereas the phosphate concentration did not rise but rather declined because of a dilution effect. This resulted in a large nitrogen surplus in the German Bight coastal water even during the summer, when normally the contrary situation occurs due to phosphate remineralisation. Furthermore, an unexpected large increase of dissolved inorganic silicate was measured at Helgoland as associated with Elbe river water, or reduced salinity.

The Elbe river floods in the years 1987 and 1988 confirmed an increasing trend towards a specific nitrogen eutrophication of the German Bight coastal water. The marked and short time injection of large river water quantities in April of both years (*Figure 5.3*) allowed to trace the response in the waters of Helgoland, situated some 60 km off the Elbe river mouth, after a lag time of about one month (which is the transportation time for Elbe river water from the monitoring station at Neu Darchau above the tidal influence in the lower Elbe river system, to Helgoland).





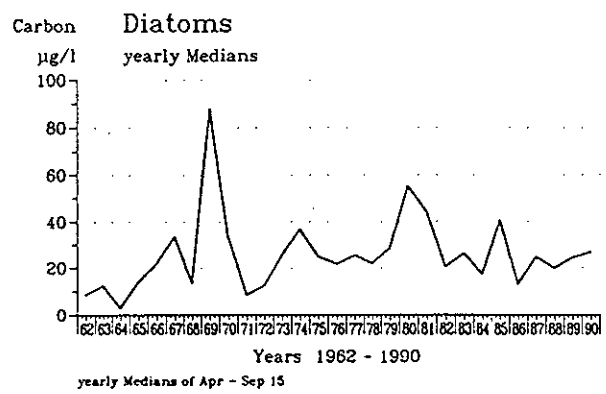


Figure 5.1.: *Phytoplankton,flagellate and diatom biomass at Helgoland Roads, 1962-1990. Yearly medians of the respective main growing season as indicated in the graph: Mid of March through mid of September for total phytoplankton, mid of June through mid of September for flagellates and April through mid of September for diatoms.*

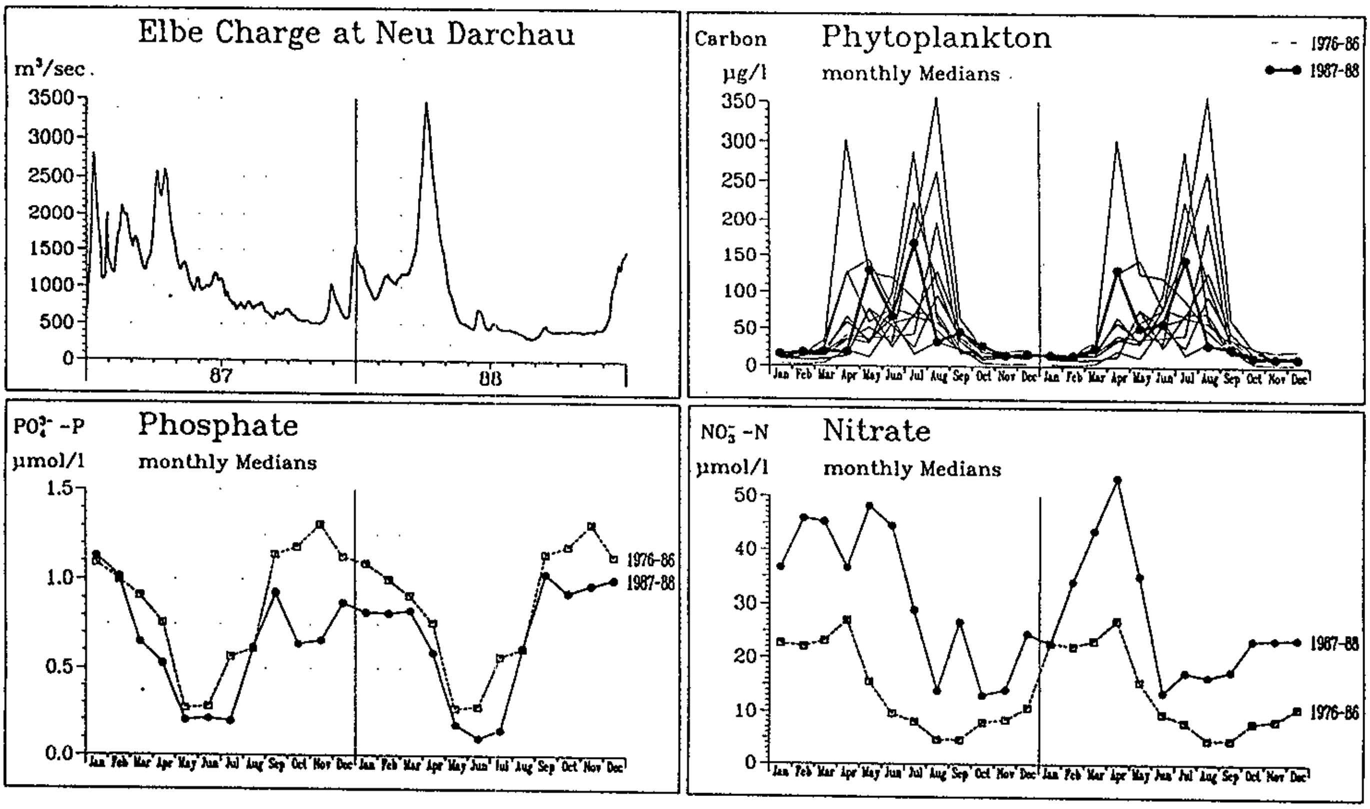


Figure 5.2.: *Elbe river water charge at Neu Darchau, nutrients and phytoplankton at Helgoland in 1987 and 1988, as compared with the decade before.*

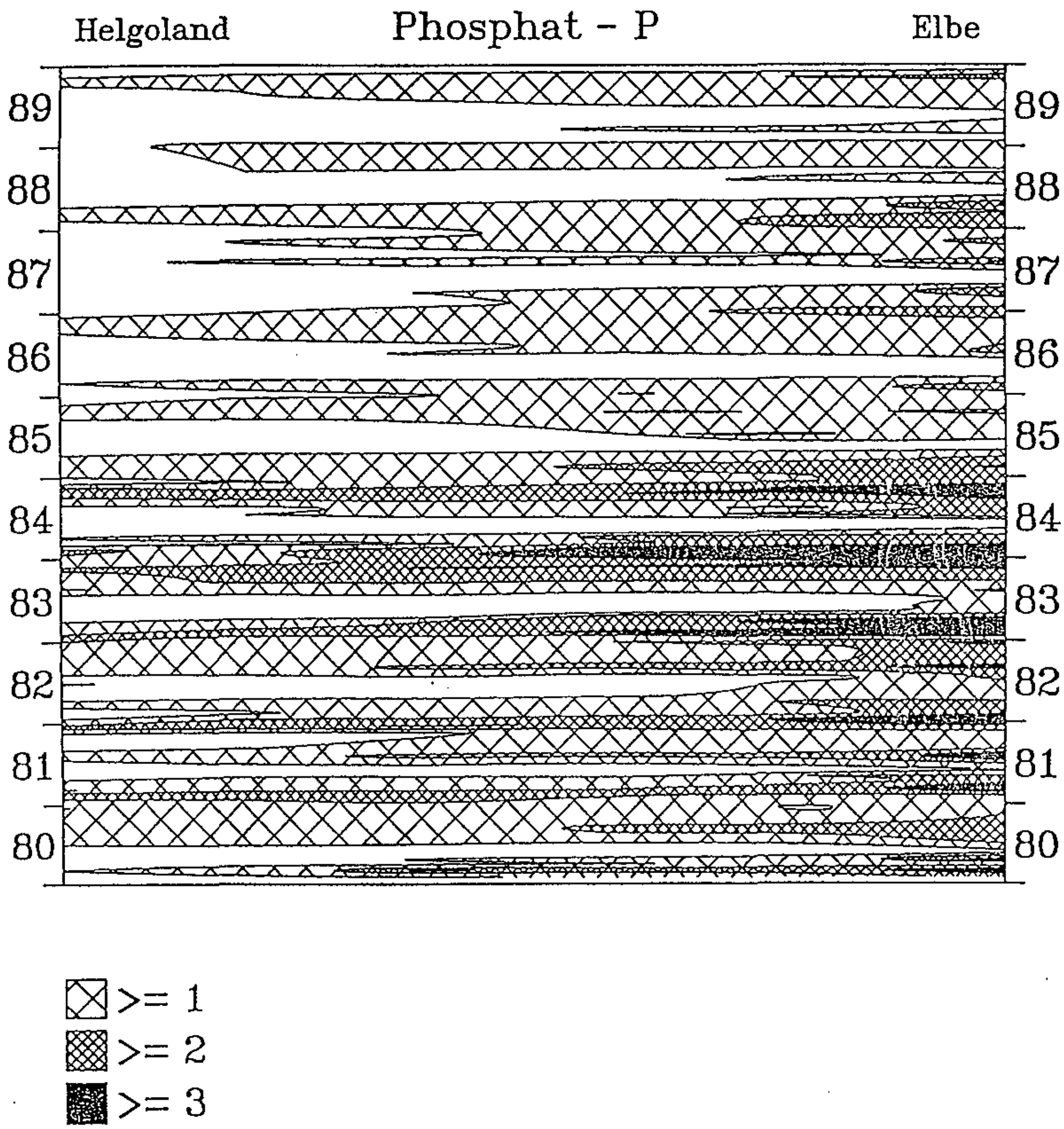


Figure 5.3.: Horizontal gradients of phosphate concentrations (µmol/l) in surface water, on monthly transects from Helgoland to the Elbe estuary. The smoothed isopleths show the changing phosphate concentrations with time and with distance from the estuary.

It is known, that the inorganic nitrogen loads increase in the river water after heavy rainfall, indicating a diffuse source. This is different with phosphate, which is much less water soluble and mainly originates from constant point sources. Therefore, phosphate concentrations decline with rising river water volume due to dilution effects. Inorganic nitrogen salts, being highly water soluble, are easily washed into the rivers after heavy rainfall, and increasing nitrogen loads reach the sea. This results in higher concentrations of nitrate at least in the coastal water, were a marked increase of the nitrogen/phosphorus ratio has been found in the last decade.

Additional information about the eutrophication from rivers can be expected from transects from Helgoland to the estuaries of the Weser, Elbe and Eider rivers. These transects were visited in monthly intervals. On 6 stations per transect, vertical series of water samples were taken in order to measure horizontal gradients and vertical stratification of nutrients.

An example from January, 1986 shows the close relationship between inorganic nutrients and salinity, demonstrating river water as the nutrient source (***Figure 5.4***). This relationship gets weaker with the distance from the estuaries and with the ongoing vegetation period of the phytoplankton taking up the nutrients. In the case of phosphate, decreasing concentration in river water leads to lower costal concentration of phosphorus. Even the large Elbe river floods in 1987 and 1988 did not results in an increase of phosphate concentration, unlike the situation with inorganic nitrogen.

As a result of the increasing surplus of nitrogen over phosphorus as plant nutrients in the coastal water of the North Sea (Hickel 1990) phosphorus decreases to limiting concentrations in spring earlier than nitrogen, and thus became limiting for growth in spring in some areas (Somer 1991).

Several studies have shown that the bloom of Phaeocystis coincides with periods, when phosphorus limitation was expected. ***Figure 5.5*** shows a time series of inorganic phosphorus and nitrate + nitrite concentrations at a station on the Danish North Sea Coast (Ringkøbing Amtskommune 1990). The graph indicates the periods of phaeocystis blooms which have occurred every year over the last decade, but not in 1989. It is seen that there was no period of phosphorus limitation in 1989 (Somer 1991).

This can be explained by particular climatic and hydrographic conditions of that year. The preceeding winter was extremely dry. The run-off from land was unusually low and accordingly also the nitrate input which depends on run-off. Phosphorus on the other side is rather independent on run-off. Thus, the ratio between nitrate and phosphate run-off has been corresponding to the situation more then ten years ago, before the regular occurrence of phaeocystis blooms in this area (Somer 1991)

The graph in ***Figure 5.5*** (Ringkøbing Amtskommune 1990) shows that the nitrate winter peak in 1988/1989 has been larger then usual in spite of the low run-off. This is due to the fact that the Jutland current, which carries water from the German Bight (and particulary from river Elbe) up along the Danish North Sea coast, was exceptionally strong and concentrated in 1989. This is evidenced by the exceptional quantities of the Jutland current water which were transported into Kattegat. Thus, river Elbe water was less mixed up with North Sea water than usual on its way up the Danish North Sea coast and this is the reason for the higher than usual nitrate peak.

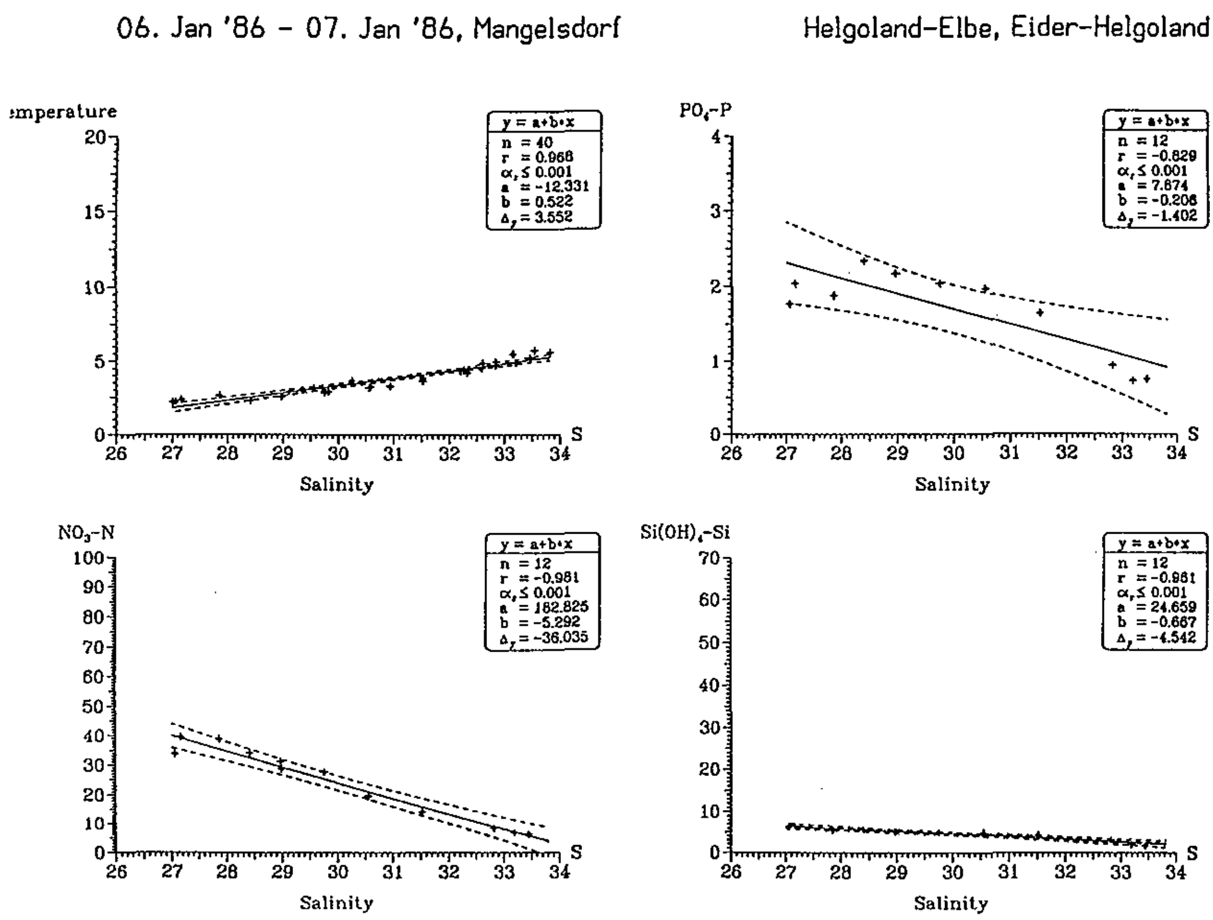


Figure 5.4.: relationship between inorganic nutrients and salinity on transects from Helgoland to the Elbe and Eider estuaries, (linear regression with 95% confidence range).

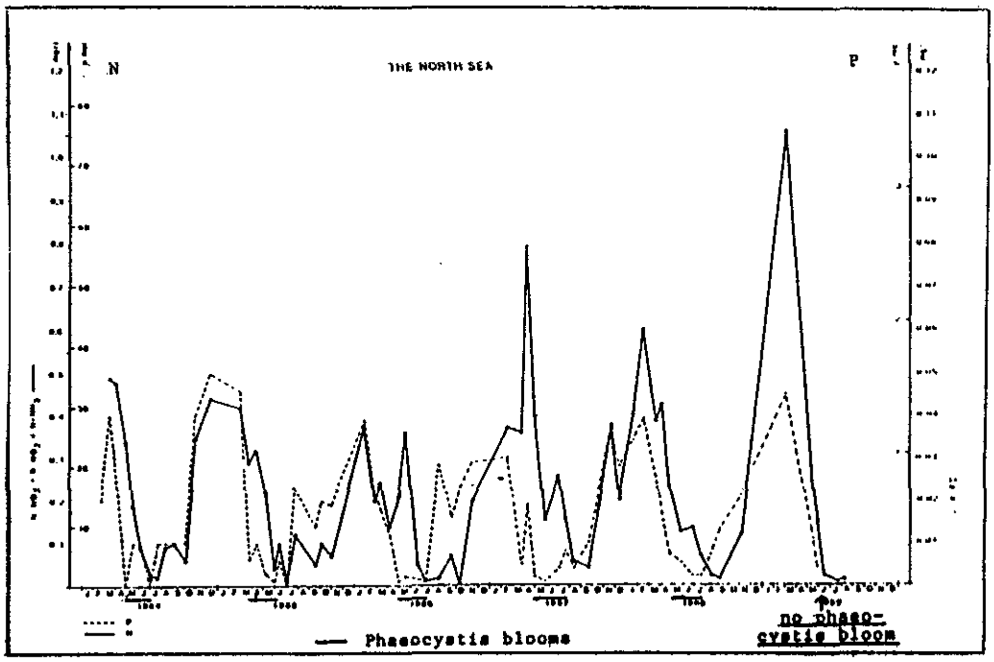


Figure 5.5.: Concentrations of inorganic phosphorus and nitrogen compounds in the North Sea at Ringkøbing County's station 42 situated north-west of Ringkøbing Fjord.

Areas with oxygen deficiency

Occasionally since 1980, the areas shown in ***Figure 5.6*** (German Bight, eastern North Sea) have been found to suffer from oxygen deficiency in near-bottom water in the summer (less than 50% saturation; in some areas less than 20%).

Such conditions usually develop as a result of vertically stratified water bodies as found in the open southeast North Sea only in summer and mostly in deeper water. In certain weather conditions, e.g. periods of high air temperatures weather with winds from the east, shallow water can also be affected. In inshore water 20 - 25 m deep, oxygen deficiency in the water column would be the exception, however (e.g. immediately after a severe plankton bloom or in the outer estuary of the Elbe). The areas with a lack of oxygen towards the central North Sea have not yet been sufficiently described. It is assumed that they extend as far as the 40m isobath southeast of the Dogger Bank Tail.

Earlier this century, autumn oxygen concentrations of just below 50% saturation were only measured in the very stable strata of the central North Sea (not the German Bight, however); this is why conditions measured on repeated occasions in the southeastern North Sea, especially saturation values far below 40% even in summer, cannot be regarded as normal. These findings would seem to indicate an increased eutrophication process in the south-eastern North Sea and that the ecosystem's decomposition capacity in this area is overloaded (Dethlefsen & v. Westernhagen 1983, Hickel et al. 1989, Rachor & Albrecht 1983, v. Westernhagen et al. 1986).

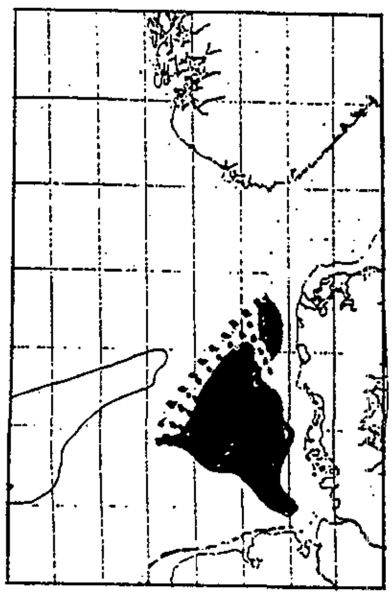


Figure 5.6.: *Areas in the Eastern North Sea where oxygen-deficiency has occurred in bottom-near water during summer since 1980 (less than 50% of saturation, partly less than 20%). (according to Dethlefsen & v. Westernhagen 1983, Hickel et al. 1989, Rachor & Albrecht 1983, v. Westernhagen et al. 1986).*

Distribution of eelgrass

The depth range of eelgrass is a well-suited expression of effects of nutrient concentration of the coastal waters. In non-affected areas the highest depth range is 6-8 meters. In the major part of the Danish inlets, this potential depth limit is considerably reduced and areas covered by eelgrass have been more than halved. In some areas, bottom vegetation has completely disappeared, as e.g. in the inlet Ringkøbing Fjord, where in 1972 there was a dense stand of bottom vegetation and where today such is not found in depths of more then 80 cm. ***Figure 5.7*** shows a picture of the decline of the eelgrass in the inlet Nissum Fjord since 1966.

In the inlets changes are observed of the vegetation in through the inlets with reduced number of strains, less cover degree and depth range and a higher dominance of annual algae. all signifying an increasing deterioration of the biological state in through the inlets (Danish EPA, 1991).

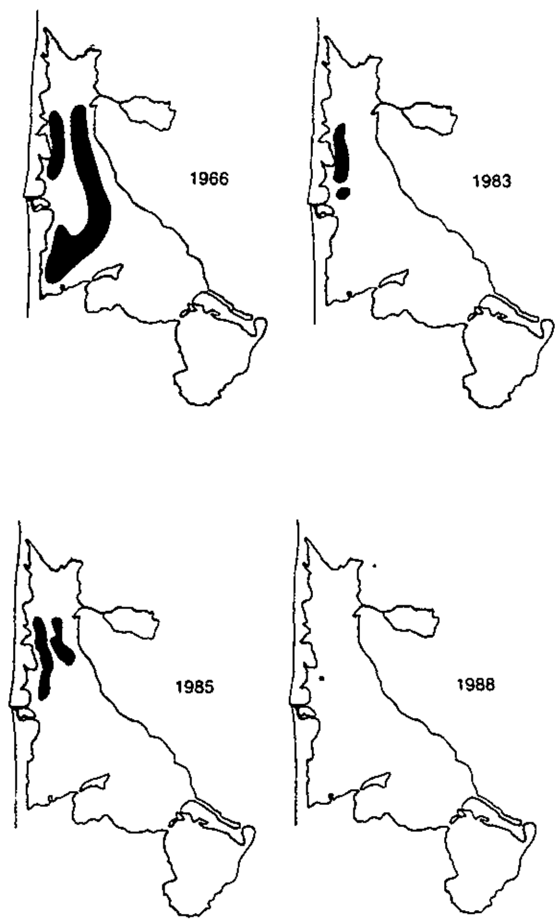


Figure 5.7.: *Development of range of bottom vegetation in Nissum fjord from 1966 to 1988 (Ringkøbing County 1990)*

5.2 IMPACT OF OIL SPILLS

Latest results of the "Oiled Seabirds project", supported by the European Community, confirm that "normal" shipping operations are the main source of oil pollution on our beaches, see ***Figure 5.8.*** Illegal discharges of oil sludge, i.e. mainly residues from the separation process of heavy fuel oil on board of the ships, lead to a wide-spread distribution of oil pollution on the coasts. In the Netherlands and Germany, this kind of pollution was superimposed by two severe cases of crude oil pollution accompanied by high accumulations of dead oiled seabirds: in November 1990 nearly the whole Dutch coast was polluted by Venezuelan (Bachaquero) crude oil and in June 1991 about 70 tons of two different types of North Sea crude were found on German Beaches. One major new finding of the "Oiled Seabirds" project, however, is that the Danish coast is also continuously affected by crude oil pollution. Illegal discharges from crude oil tankers at the outlet of the Skagerak might be the main source of this kind of pollution. The great number of cases of severe crude oil pollution in this area indicates that illegal discharges of crude oil from the tankers leaving the Baltic Sea is common practise.

The detection of other products than mineral oil, such as dodecylphenol, bis-phenol, vegetable oil, different kinds of paraffin wax or coal tar in the feathers of birds and on beaches is a second striking feature.

"Normal" shipping operations are the main source of oil pollution. Engine room residues, i.e. bunker and lubricating oil, were in 1990 mainly found. There is a relatively high proportion of crude oil residues, however, which ranges from 2.6% in Germany to 18.1% in Denmark and up to 33.5% in the Netherlands.

These results must be interpreted with great care: differences could be the result of the dissimilar sampling strategies used. Besides, even a single, more severe case of oil pollution could have significantly influenced these proportions.

Dodecylphenols were in November 1990 found to have caused the deaths of about 50 seabirds on the German islands of Juist and Norderney - an incident which was investigated in cooperation with the water police.

A considerable amount of crude oil pollution is detected on the Danish coast. There are only two possible sources: oil platforms in the North Sea or tank-washing by crude oil tankers. The crude oils have in 1990 been identified as Libyan, Nigerian and Middle East ones, so oil tankers can be the only source of pollution. This pollution might originate from the tanker shuttle service with the Baltic Sea states: tankers which have unloaded these types of crude oil at a Baltic port could start tank-washing on their return journey and discharge residues immediately on leaving the Baltic Sea which is a Special Area under the MARPOL Convention. Another explanation could be that these residues reach the Danish coast from the shipping lanes in the German Bight although in this case, a greater incidence of crude oil pollution on the west coast of Schleswig-Holstein would be expected.

From August 1983 until April 1988 1901 oiled birds of 50 species were found at the coast of Helgoland (Vauck et al., 1989). The main number of the dead externally oiled birds found was made up of guillemots (*Uria aalge*) (41.9%), kittiwakes (*Rissa tridactyla*) (19%); razorbill (*Alca torda*)-(4.3%) eider ducks (*Somateria mollissima*)(4%), common scoter (*Melanitta nigra*) (1.6%) and seagulls (*Larus*) (14.6%).

The oiling rate (number of oiled birds expressed as a percentage of the total number of birds found dead) averaged 34.8%. Besides some of the externally oiled birds were oiled internal.

2484 oiled plumage samples (from Helgoland and the German North Sea Coast) had been analyzed by the Bundesamt für Seeschiffahrt und Hydrographie. 94.4% of all feather-soilings by oil can be attributed to fuel residues from ships; it had been affected mainly by heavy-fuel-oil.

On Helgoland the number of oil victims was much higher in the 80ies than in the 60'ies and early 70'ies.

Records of ship's waste washed up at the coast of Helgoland showed high burden from the main shipping routes. Rough estimates of drifting litter between the island of Helgoland and the Elbe-estuary came to 8.5 million items with a weight of 1,300 t annually. Also trawl-net counting showed the most widespread pollution of sunken ship's waste.

On Helgoland 33 birds were found dead mainly entangled in plastic packaging. 53 victims were found alive.

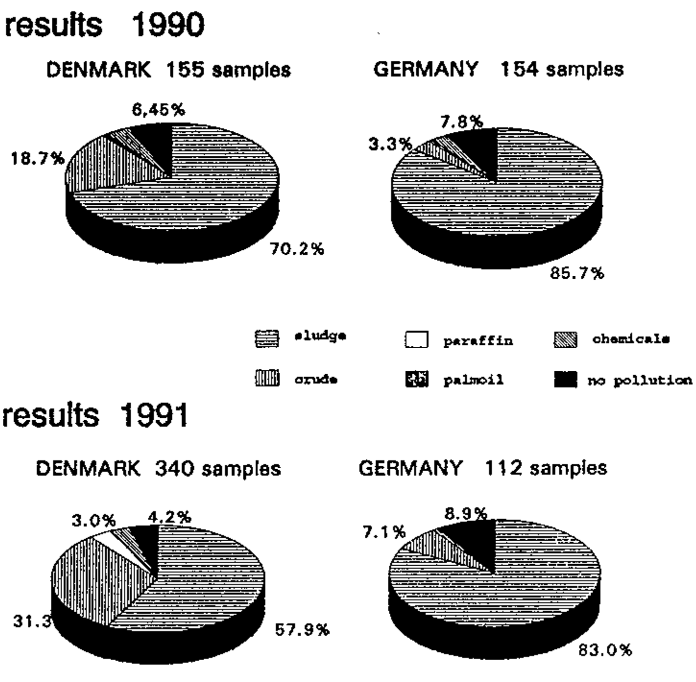


Figure 5.8.: The results from the "Oiled Seabirds" project

5.3 IMPACT OF FISHING ACTIVITIES

The most obvious impacts of fishery activities is the mortality generated by fishing, when biomass of commercially exploited fish, non-target fish and other organisms are removed from the sea. An other direct effect of fishing is the physical disturbance of the seabed by active gears, such as bottom and beam-trawl. Thirdly there's the generation of litter, in the form of lost gear and debris as comparable to that produced by shipping in general.

Some indirect effects of fishing can be the modification of prey-predator relationships, modification of habitats and possibly some longterm evolutionary changes on the affected species.

The level of fishing mortality is not assessed for NSTF-subregion 5 alone, but for the North Sea as a hole. Generally for relatively long-lived species cod, plaice and sole fishing mortality is by far the most important factor, whereas for relatively short-lived species e.g. sand eel and juveniles in general other causes of mortality are predominant.

As a general trend in the North Sea, fishing mortality for cod, plaice, sole and sand eel has been increasing. There are also some indications that fishing has altered the live history characteristics of some of the North Sea stocks, in regard to growth, maturation and fecundity. For the heavily exploited stocks there has been a shift in the age composition as older and larger individuals are removed.

In the case of benthos, towed fishing gears in contact with the seabed cause mortalities on the infauna and the epifauna. The infauna is mostly affected by gears or gear parts that penetrates the seabed, such as beam-trawls or the otter boards of bottom trawls. Mortalities on animals left in the path of beam-trawls have been estimated for a limited number of species and ranged from 15% to 55%. For benthic animals caught in the beam trawl, mortalities ranges from 0% to nearly 100%.

NSTF-subregion 5 contains some very important fishing grounds, meaning that the level of fishing activities is high, but as mentioned above the quantity of this effect is only poorly assessed.

Apart from lost gears and other debris fishing also results in discards and offal from gutting the fish at sea. The offal resulting from gutting corresponds to approximately 12% of the landings. Both discards and offal provide a food source for scavenging bird and fish species. Lost gears might continue to fish some time after being lost, this phenomenon is called "ghost-fishing". The abundance and extent of this "fishing" activity is unknown for subregion 5, as for most other areas.

5.4 BIOLOGICAL EFFECTS

5.4.1 Benthos

Data that allow comparisons over time are most common from the southern part of the area and in particular the German Bight, where quantitative data exist as far back as from twenties (Hagmeier 1925). From the northern part of the area, north of Horns Rev, benthic data only exist from the twenties and onwards.

There have been made several studies of temporal variations in benthic communities in the German Bight since the twenties (e.g. Rachor & Salzwedel 1976, Rachor & Gerlach 1978, Ziegelmeier 1978) and some of them concluding that a deterioration of the environment has taken place (Rachor 1977, 1982) and pointing out the area as being ecologically sensitive (Rachor 1980). The immediate factor explaining some of the benthic changes was apparently oxygen deficiency (Rachor & Albrecht 1983). Niermann et al. (1990) studied the recovery of the benthos after the severe oxygen deficiencies in 1981-1983. A rapid recovery seemed to occur and biomass, species numbers and number of individuals increased in 1984-1987 to pre-oxygen deficiency levels. Rachor (1990) compared benthic biomass and faunal composition over the last 60 years in this area and concluded that both biomass and number of individuals had increased over this period, mainly due to mollusc and polychaete. The most likely cause to these changes was suggested to be eutrophication.

From papers of Duineveld et al. (1987) and of Kröncke (1990) one can conclude that organic enrichment (related to increased eutrophication) is expanding to more offshore waters up to the Dogger Bank.

The overall trend of the German Bight sublittoral bottom fauna - being impoverished in the mud area in front of the Elbe river mouth and becoming richer in more offshore waters - was demonstrated during the ICES/IOC Bremerhaven Workshop on Biological Effects of Contaminants in March 1990 (Kröncke & Rachor, in press). It has not been possible to discern along this natural and, in addition, eutrophication-related gradient, any other clear anthropogenic influence, e.g. by pollutants like heavy metals or chlorinated hydrocarbons, which show similar, but inverse trends in the sediment (Rachor E., 1992).

Unlike the situation in the German Bight, the benthic communities in the northern part of Area 5 have been the subject of much less attention from marine benthic ecologists, especially before 1980. In the eighties large parts also of this area was affected by oxygen depletion, especially in 1982-1983 (Kröncke 1985, v. Westernhagen et al. 1986). On the western border of the area Dyer et al. (1983) observed mass mortality of fish and benthos in autumn 1981. Niermann et al. (1990) presented benthos data from a large part of the area in the period 1984 - 1987. Different faunal variables showed lower values in 1984 than in other years, which was attributed to the hypoxic events the years before. In summer 1989 a restricted part of the area just north of 55 °N was affected by oxygen deficiency with kills of sensitive benthic species such as the sea urchin *Echinocardium cordatum* (Niermann 1990).

Although the areal coverage of benthic studies is uneven, there is a basis to conclude that the benthos in sector 5, during the eighties, has been affected by both oxygen deficiency and increased food access, the first factor possibly being related to the latter one, and that the most likely cause is eutrophication. The data published do not, however, permit conclusions concerning differential effects of eutrophication within the area.

Dumping of waste acid

Up until 1985, research was carried out in Germany with a view to detecting effects on benthic fauna which were due to the dumping of waste acid. Regular analyses of the fauna were made over 15 years but have shown no evidence of a modification of the fauna (CEC 1990).

Since 1985, the Biologische Anstalt Helgoland (BAH) has been in charge of the monitoring of benthic fauna in the dumping area. Between 1985 and 1989, comparative studies were carried out between macrobenthos in the dumping area and in reference areas. Samples of endobenthos were taken between 1985 and 1988 using box corers; between 1987 and 1989, dredge surveys were also done to collect samples of epibenthos (Oslo Commision 1990).

In summary, it can be stated that of the three epibenthic investigations, one (in 1987) showed no, one (in 1989) showed only little while one (in 1988) showed a strong indication that the survival or settling of epibenthos in the dumping area was affected by the dumping of waste. Of the four endobenthic investigations, only the 1985 investigation showed possible indications that endobenthos could have been adversely affected by the dumping.

According to the Oslo Commission 1990, these findings are sufficient to refuse the statement that the dumping of waste from the production of titanium dioxide in the North Sea is harmless to the ecosystem. However, these findings do not permit us to conclude that the diversity and abundance of the benthic fauna are not affected by dumping. In other words, it cannot be ruled out or disproved that the negative effects observed resulted from the dumping of waste acid.

Dumping of sewage sludge

Investigations into the benthic fauna in the dumping area showed species diversity, the number of individuals and biomass to be reduced. Investigations in 1989 - nine years after the termination of dumping in the area in the Inner German Bight - still showed a strong faunal gradient to surrounding areas. However, in the former dumping area itself, a slow but steady recovery of the fauna could be observed. Nevertheless, no clear indication of a successful regeneration of soft bottom endofauna was found.

5.4.2 *Fish diseases*

German data

In the southern North Sea, 17 NSTF stations along 2 transects (Danish coast - mouth of River Tyne and mouth of the River Humber - mouth of the River Eider) were sampled by Germany from 24 January to 4 February 1991 (Figure 5.9). Investigations focused on the liver of dab (*Limanda limanda*) and comprised histopathology, determination of lysosomal membrane stability (LYSY-Test), and measurements of MFO activities (EROD and ECOD) as well as of heavy metal (Cr, Pb, Cd, Hg, As) and organohalogenics (alpha-HCH, gamma-HCH, p,p'-DDE, p,p'-DDD, PCB no. 52, 118, 138, 153 and 170) contents.

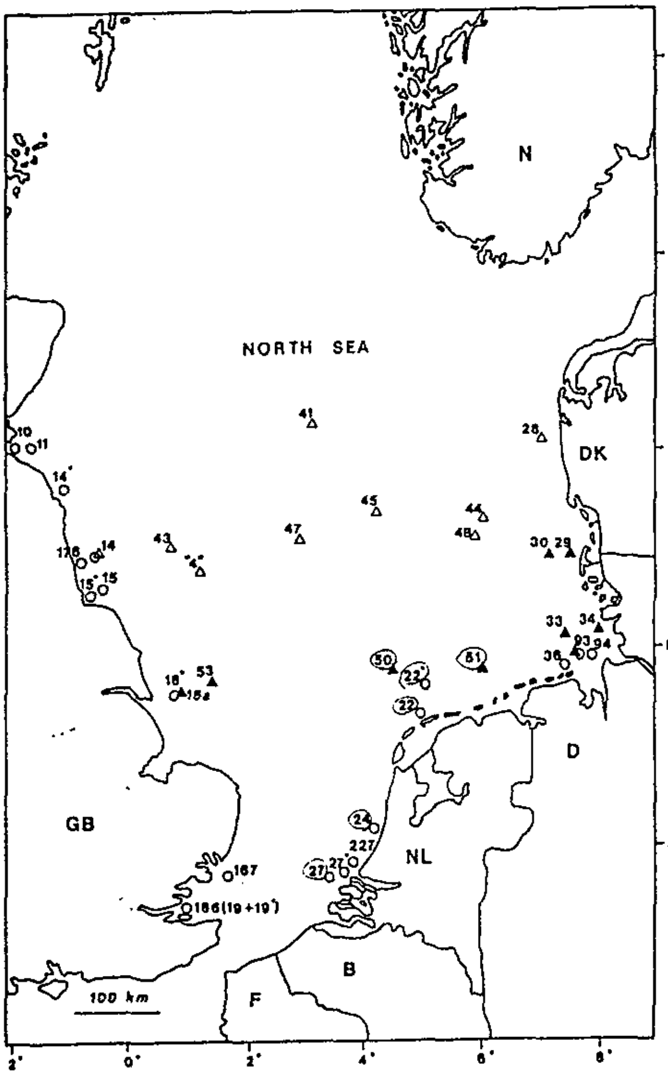


Figure 5.9.: Station map of northern transect (△), southern transect (▲) and coastal stations (o).

Additional investigations on malformation rates of pelagic fish embryos were carried out in spring and summer 1991.

In the following preliminary data related to the NSTF area 5 (Stations 28, 29, 30, 33 and 34) are presented.

Lysosomal membrane stability of dab liver was considerably lower on stations 28, 29 and 33 in comparison to stations 30 and 34. On station 29 the highest prevalence (28%) of macroscopically visible dab liver nodules (> 1mm up to 10 mm) was determined. This coincides with the fact that the highest MFO activities of all specimens examined were found in dab from the same station (29). Corresponding values for heavy metal/metaloides and organohalogenic contents are not yet available.

In the whole area 5, overall malformation rates of pelagic fish embryos were 33.0% (n=3375) in spring and 23.3% (n=4339) in summer. The highest values were recorded for horse mackerel (*Trachurus trachurus*) with 35.5% (n=152) in summer, followed by values of dab and flounder (*Platichthys flesus*) in spring.

Prevalence of dab afflicted with lymphocystis and epidermal papilloma south of station 28 were 15.7% and 8.2% and at station 33 11.4% and 5.4%. Low prevalence were encountered for acute and healing ulcers and x-cell-hyperplasia in gills of dab.

Dumping of waste acid

Twice a year since 1979, the Bundesanstalt für Fischerei has investigated the incidence of externally visible disease affecting the flatfish dab in the dumping area. Two cruises are undertaken, one in early summer, the other in winter.

The most common externally visible diseases are epidermal papillomas (possibly caused by viruses), lymphocystis (caused by viruses) as well as different types of ulcerations (due to a number of bacteria), (Oslo Commission, 1991).

Dethlefsen et al., 1987, summarizes how an increased incidence of disease in dab occurs in the dumping area for waste from titanium dioxide production and adjacent areas. The diseases in question are epidermal papillomas, lymphocystis and ulcerations. Because of the significant difference in results from the dumping area and adjacent areas, it seems reasonable to assume that there could be a causal relationship between disease in dab and the dumping of waste acid.

In addition, fish embryos were investigated in 1984 and 1985, (Dethlefsen et al. 1986). Regional comparisons showed that an increased frequency of malformations also occurred in the waste acid dumping area in the German Bight. This is in addition to two other areas off the Rhine estuary and in the shipping routes along the German and Dutch coasts.

Further investigations into the frequency of malformation in fish embryos were carried out in 1987. They confirmed the results of earlier investigations. The incidence of malformation in fish embryos was greatest in the centre of the German Bight and off the Dutch coast i.e. in the areas where waste from the production of titanium dioxide was dumped. Although embryonic malformation was classed as mild, it proved lethal for individual embryos (Oslo Commission 1991).

The dumping of waste from titanium dioxide production was phased out on schedule at the end of 1989 when waste acid recycling plants became fully operational. The waste acid now obtained in the sulphate process is concentrated, purified and returned to the production process.

Figure 5.10 - 5.12 shows the temporal changes (1979-1991) in the prevalence (%) of lymphocystis, hyperplasia/papilloma and acute/healing ulcerations in North Sea dab (*Limanda limanda*) at the dumping ground for wastes of the titaniumdioxide-production in the German Bight (subregion 5).

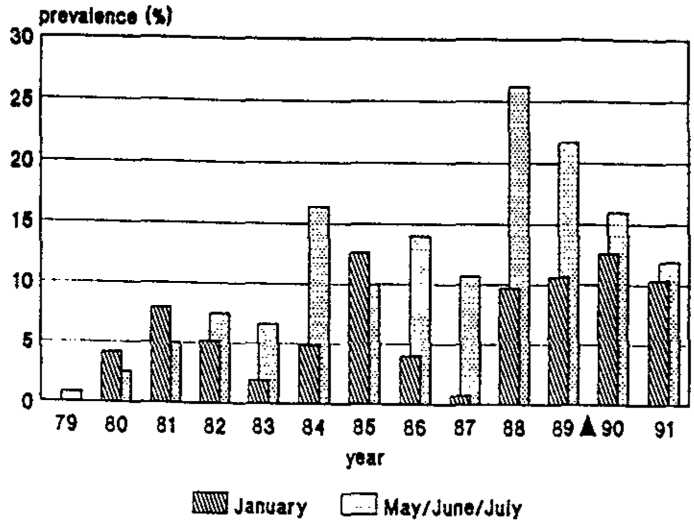


Figure 5.10.: The temporal changes (1979-1991) in the prevalence (%) of lymphocystis, in North Sea dab (Limanda) at the dumping ground for wastes of the titaniumdioxide-production in the German Bight. (Stop of dumping marked with an arrow).

Dumping of sewage sludge

In 1977 investigations started into the occurrence and abundance of fish diseases in the German Bight. It was shown that in the area between Helgoland and Cuxhaven certain diseases occurred quite frequently, especially those probably caused by bacteria. No causal relationship between the fish diseases and dumping of sewage sludge could however be proved.

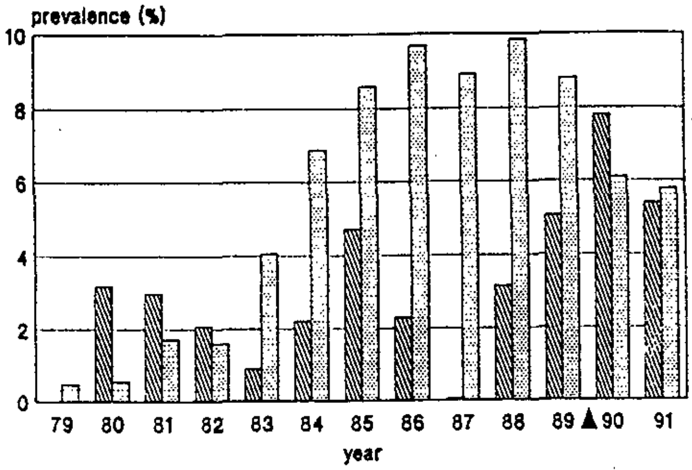


Figure 5.11: *The temporal changes (1979-1991) in the prevalence (%) of epidermal hyperplasia/papilloma in North Sea dab (Limanda limanda) at the dumping ground for wastes of the titaniumdioxide-production in the German Bight. (Stop of dumping marked with an arrow).*

Danish data

Based on Danish data the following fish disease status for subregion 5 can be summarized. The station pattern is illustrated in Figure 5.13. To illustrate the annual variations within the different areas the data are presented as bar charts ***(Figure 5.14-5.17)***, (Mellergaard, 1991).

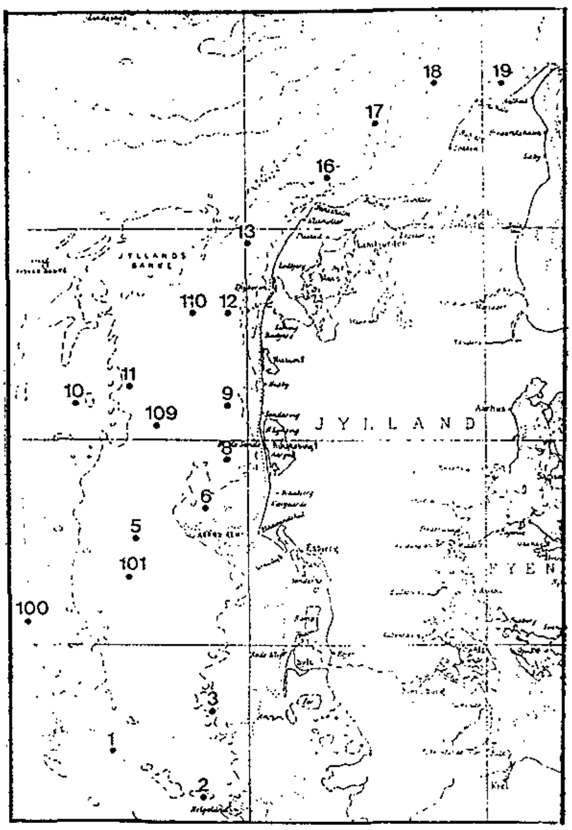


Figure 5.13: *The station pattern for the Danish fish disease monitoring*

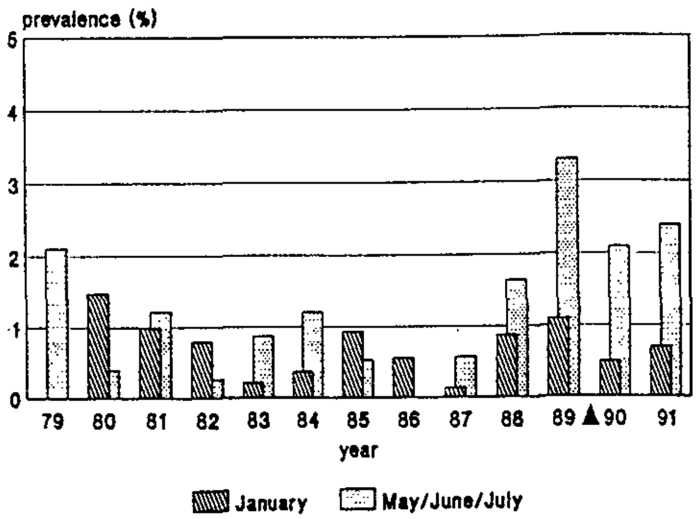


Figure 5.12: *The temporal changes (1979-1991) in the prevalence (%) of acute/healing ulcerations in North Sea dab (Limanda limanda) at the dumping ground for wastes of the titaniumdioxide-production in the German Bight. (Stop of dumping marked with an arrow).*

In the German Bight, (station 1, 2 & 3) the prevalence of lymphocystis increased in the period 1983-85, from 8.9 % - 12.3 %. In 1986-87, the prevalence was reduced to c. 8 %. However, in 1988, the prevalence increased to the highest level in the investigation period, 12.8 %. Since then, the prevalence has gradually decreased to 5.1 % in 1990 and 7.6 % in 1991. However, none of the changes in the prevalence of lymphocystis were statistically significant.

For epidermal papillomas, the prevalence increased from 1.6 % in 1983 to 8 % in 1986. A chi-square test of the prevalence of the 1986 against 1983 gives a chi-square value of 5.64 (p <

0.05). This indicates a significant change. After a decline in 1987, the prevalence increased to 9.7 % in 1988; the highest level registered in the whole investigation area during the time of investigation. In 1989, the prevalence fell to 2.9 % and remained at that level in 1990. The decrease of the prevalence from 1988-1989 was statistically significant, chi-square = 4.11 ($p < 0.05$). An increase to 4.7 % was observed in 1991.

From 1983-91, the prevalence of skin ulcers varied from 0.7 % - 1.9 %. The prevalence of ulcerations did not show the same peaks as observed for lymphocystis and epidermal papillomas.

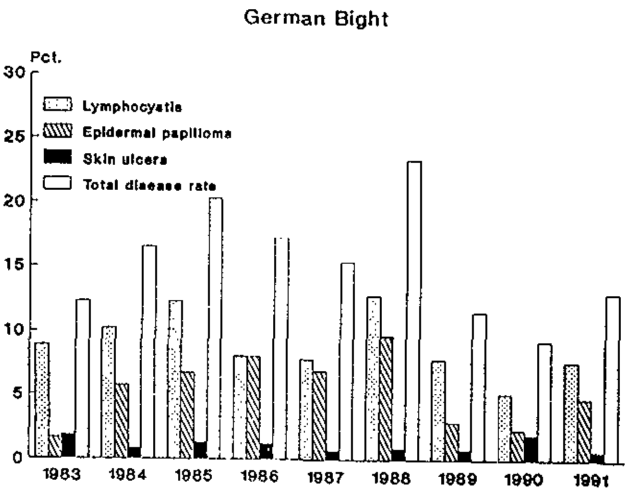


Figure 5.14: The prevalence of fish diseases in the German Bight. (Danish data 1983 - 1991)

At Horns Reef, (stations 5 & 101) the prevalence of lymphocystis showed only a minor increasing trend from 1983-85 from 8.2 % to 9.6 %. During the following two years, the lymphocystis rate dropped to c. 3 % - a statistically significant drop - chi-square = 4.12 ($p < 0.05$). In 1988, a statistically significant increase to 18.4 % was observed - chi-square = 13.05 ($p < 0.001$). However, this was followed by a decline to c. 14 % in 1990 and a further decline to 6 % in 1991.

The prevalence of epidermal papillomas increased in the first four years from zero to 3.1 %. A decline was observed in 1987 to 1.5 %. As for lymphocystis, the prevalence of epidermal papillomas increased significantly in 1988 and reached a level of 7.4 % - chi-square = 4.09 ($p < 0.05$). A reduction to c. 3 % has been observed during the last three years.

The prevalence of skin ulcers varied from zero to 1.3 % without reflecting the variations as observed for lymphocystis and epidermal papillomas.

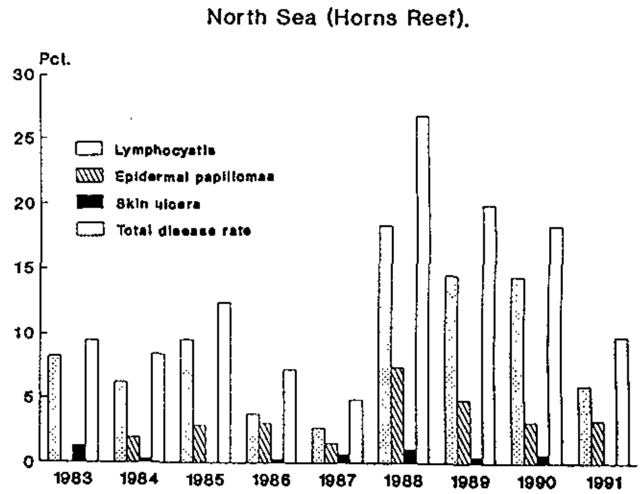


Figure 5.15: The prevalence of fish diseases in the North Sea (Horns Reef).(Danish data 1983 - 1991)

In the North Sea region called the ("Dead area"), (Station 10 & 11) an increase in lymphocystis prevalence was observed during the first three years of the investigation from 10 % to 14.5 %. During 1986-87, it dropped significantly to 2.9 % -chi-square = 8.47 ($p < 0.01$). However, this was followed by an increase to 12 % in 1988 - chi-square = 6.0 ($p < 0.05$). In the period 1989-91, the prevalence was reduced from 12 % to 8 %.

During the first four years, the epidermal papilloma rate increased from 0.7 % to 3 %. A drop to 1.6 % was observed in 1987 followed by an increase to 4.4 % in 1988. During 1989-90 the prevalence rate decreased to c. 2 %. The figure for 1991 was 3 %. None of these changes were statistically significant.

For skin Ulcers the prevalence rate was similar to the two previous stations varying from 0.5 % to 1.5 %.

In the coastal area, (station 6,8,9 & 12) the lymphocystis prevalence increased from 1983-85 from 4.2 % to 7.9 % and decreased in 1986-87 to 2.1 %. In 1988, the prevalence level reached 13.3 % but was reduced to c. 7 % during the period 1989-91. Only the change of prevalence from 1987-88 was statistically significant - chi-square = 8.82 ($p < 0.01$).

An increase in the prevalence of epidermal papillomas from 1.2 % to 4.3 % was observed from 1983-85. After a decline to 1.2 % during 1986-87, a significant increase to 7.5 % was observed in 1988 -chi-square = 5.35 ($p < 0.05$) followed by a decrease to c. 3 % the following three years.

In this region also, the skin ulcer rate fluctuated from 0.3 % - 1.9 % without reflecting the trends of the other registered diseases.

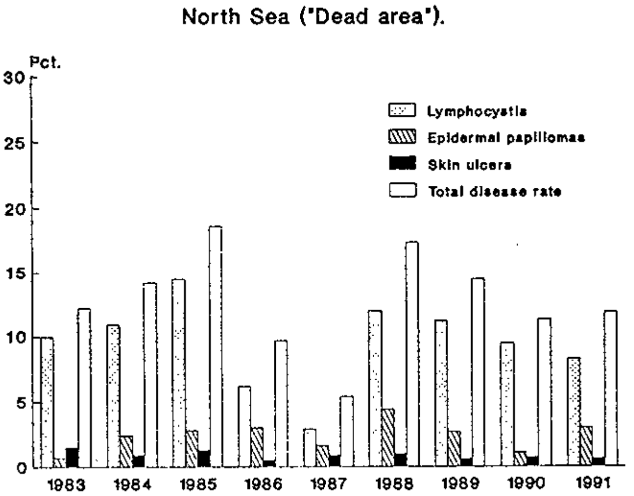


Figure 5.16: The prevalence of fish diseases in the North Sea ("Dead area").(Danish data 1983 - 1991)

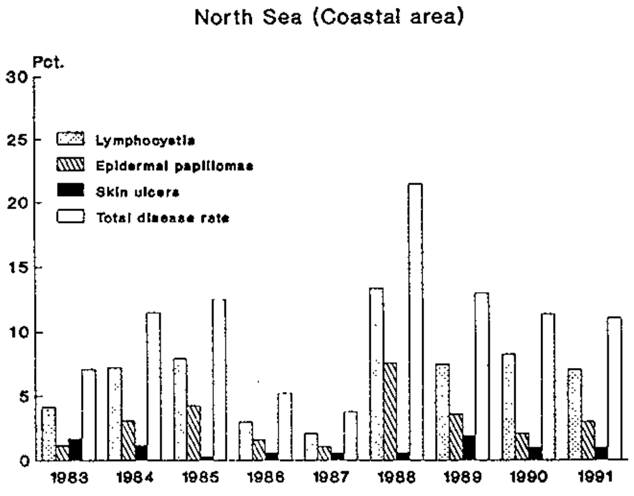


Figure 5.17: The prevalence of fish diseases in the Coastal area. (Danish data 1983 - 1991)

5.5 MICROBIOLOGY

5.5.1 *Bathing water Quality*

Subregion 5 only includes bathing water along the the Danish coastline. The German coastline is included in subregion 10 covering the Wadden Sea area.

In Denmark bathing water samples are to be taken in the period May 1 - October 1. Normally 10 samples are taken in one season, but in case of problems with the water quality the number of samples is doubled, (Danish Ministry of Environment, 1992).

The requirements for fine bathing water qualities first and foremost build on the number of colibacteria present in the water. The Danish limit for thermostable colibacteria in salt bathing water is 1000 bacteria per 100 ml water, which shall not be exceeded for more than 5 % of the samples during a bathing season. This means that when 20 samples are taken over the whole bathing season, only one sample may exceed the limit.

In 1991 the bathing water quality was fine along all the coastline of Jutland included in subregion 5 with the exception of three places where bathing was not allowed, and two places where the bathing water quality was doubtful. At two of the places where bathing was not allowed this was caused by pollution with chemicals and at one place in Ringkøbing fjord it was caused by possible illegal input and diffuse discharges from summerhouse area.

Both places with doubtful bathing water quality are located in Ringkøbing fjord and the doubtful quality has been caused by pollution from sewage.

5.5.2 *Oil-degrading bacteria*

As early as the sixties, investigations into the quantitative spread of oil-degrading bacteria were carried out between the Elbe estuary and Helgoland (Gunkel, 1990). Between 1975 and 1978, these investigations were extended across the whole of the North Sea as far as Lofoten. The proportion of oil-degrading bacteria in the German Bight seems relatively small. The reason for this is the very high number of saprophytes bacteria found there. Following oil spills, an increase in bacteria was found in oil lumps. Many of the bacteria that normally occur in water were able to reproduce greatly by feeding on the oil components (Gunkel 1990).

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6. OVERALL SCIENTIFIC ASSESMENT

6.1 INTRODUCTION

This section is derived from the content of the previous chapters. An overall assesment of the state in the region and its development will mainly be related to man's impact as described in chapter 5. Accordingly uses and functions of the region will constitute the framework for an evaluation of impacts in accordance with the activities outlined in chapter 1.

The Catchment area of subregion 5 has a very dense population with several million people. The inputs from the Danish part of the catchment area are small compared to the inputs from the much bigger catchment area of the German rivers entering the German Bight.

Transport mainly by the northgoing Jutland Coastal Current along the Danish coast has an important influence on the concentration levels of elements measured in the Danish part of Region 5.

6.2 HABITAT CHANGES AND PHYSICAL DISTURBANCES

The North Sea, including subregion 5 described in this context, provides a rich diversity of habitats. However these habitats are affected by physical human activities such as: harbour and industry installations, dredging, sand and gravel extraction, disposal of wastes, sewage and dredged material, coastal protection and land reclamation, oil and gas production, shipping, tourism, fishery and military uses. The physical activities directly influence habitats in the North Sea.

As the Wadden Sea is not encompassed by NSTF's subregion 5, the few harbours and coastal industries to be mentioned in this report are situated along the the Danish west coast of Jutland. The main harbour in subregion 5 is Esbjerg, but a number of smaller fishery harbours can be found along the Danish West Coast. Esbjerg also holds a number of small to medium sized industries, and chemicals for the off-shore activities are stored in the town as well. North of the town the chemical industrial enterprise Grindsted Products A/S can be found. At Harboøre Tange imidiately south of Limfjorden another chemical industry: Cheminova A/S is situated.

Land reclamation, including sand and gravel extraction associated with construction of harbours and continuous maintenance through later dredging may cause a direct habitat destruction and loss of biotopes. But along the Danish west coast the effects from harbours seem to be limited.

Maintenance dredging has increased during the eighties and for the Danish part of NSTF's subregion 5 the total amount of dredged sand in 1991 was estimated to be 1.615.000 m^3. Dredged material for constructions covering sand, gravel and aggregates was in 1990 and 1991 evaluated to 420.000 and 225.000 m^3 respectively.

Most material dredged for maintenance of sailing routes or harbours is sandy materials which are dumped at sea. A minor part of the dredged material is disposed of on land in coastal deposits.

Dumping of dredged material can alter the bottom communities. But as tidal movements and currents are strong in this area, the turbidity is also high, and the dumped material especially from the sailing route to Esbjerg will not settle in the area, but is reintroduced in the generel coastal material flow.

Landreclamation including building of dykes has the effect of smoothening the coastline while groynes has the opposite effect and hereby influence the near coastal currents and their impact on the coastal environment, which might include breeding areas for fish.

The physical impact of tourism along the western coast of Jutland is primarily influencing habitats of birds and probably seals, and habitats have dissapeared as a consequence of building of summer houses and hotels. On the other hand protected areas has been established and kept free of visitors especially during the breeding season. Recreational boating is not considered to be a problem at the Jutland West Coast as the coast most of the year is being exposed to heavy waves.

Military excersises first of all cause acoustic disturbances, occasionally being a nuisance to tourism from Skallingen to the German border. The disturbance may also represent a problem to bird and wildlife.

The total landings of fish which have been caugth in subregion 5 are approximately 170.000 tons per year. Most of the fish (about 95 %) are landed in Danish harbours. The Danish cutter fleet has also been allocated the main quotas on most species compared to the German fleet.

In 1992 only 7 - 8 % of the Danish fishing activities in subregion 5 were directed towards fishing for consumption. The rest of the landings were accounted for by fish for industrial purposes.

The Danish landings from subregion 5 are only 12% of the total Danish catches from the North Sea which are about 1.34 mill. tons.

Direct impact from fishing may be described under the folowing headings:

* Mortality and injury of target and non-target species
* Disturbance of the seabed by the action of some fishing gears.
* Generation of litter and loss of gear

Mortality and injury of target and non-target species

The current level of fishing mortality expressed as percent of the population present at the start of the year has shown to vary from 27.6 % (plaice) to 63.3 % (cod). Additional mortality is caused by injury as a consequence of damage when they escape through meshes of fishing nets. Specific information on these subjects are not known to exist with specific reference to subregion 5.

During the summer 1991 200 porpoises were found dead. Investigations indicated that the animals probably were drowned as incidental by-catch in fishing tackles. Further information is needed to evalute the impact of fishery on the porpoise population in the North Sea.

Infauna is affected by gears that penetrate the seabed, such as beam trawls. From other areas in the North Sea, but not in subregion 5, such information exist for a limited number of species and ranged between 15 % to 55 % of infauna affected out of the total number of individuals. In relation to this information on yearly numbers of sweepings over the most frequent visited fishing localities should be described.

Disturbance of seabed

Disturbance of the seabed causes mortality to the infauna as already described above. Depending on the gear and the nature of the seabed different kinds of gear have an physical influence on bottomvegetation and bottomfauna. The physical impact from fishing gear comprise displacement of boulders, as a primary substratum for benthic organisms, mobilization of sedimentparticles and modification of sediment chemistry comprising sediment-water exchange of nutrients and contaminants.

Generation of litter

Fishing activities generate litter through intended or accidental dumping and loss of fishing gear. Wastes and rubbish discarded from fishing boats may also contribute to generation of litter being a problem in marine areas. Seabirds, mammals and fish get entangled in discarded nets and lines. In the period 1979 - 1989 200 entangled birds were found along the Dutch coast which is 0.2 % of the total numbers of corpses washed ashore. It is unknown whether such similar information exist for subregion 5.

6.3 CONTAMINATION AND EFFECTS

6.3.1 Inputs

With the exception of atmospheric inputs and the general transport of contaminants from the North Atlantic Ocean, inputs are introduced at single geographical locations, where they affect concentrations in water, sediments and biota. Generally, effects noted are most conspicious close to the source. In subregion 5 the main point sources of contaminant input are located in Northern Germany, first of all represented by the Elbe. Accordingly effects from contaminant inputs are primarily found in the German Bight. Secondary transport of contaminants out of the Bight influences a substantial part of subregion 5.

Atmosphere and the North Atlantic

The atmosphere and the North Atlantic represent diffuse sources for contaminant input.

For subregion 5 atmospheric input has been estimated for heavy metals and nutrients by means of measurements at Helgoland, the research platform "Nordsee" and Westerhever for many years.

In ***Table 6.1*** the total input of heavy metals from atmospheric deposition in subregion 5 is shown. The estimates have been calculated by multiplying the subregion 5 area of 31.000 km^2 with the specific input values cited in chapter 3.

Values and ranges for lead, nickel, copper, arsenic, chromium and cadmium have been calculated assuming a yearly precipitation of 430 mm which is the mean value between Westerhever and the research platform "Nordsee". For Zinc, antimony and selenium the input is calculated from aerosol measurements at Helgoland.

The atmospheric input of lead, cadmium, copper and zinc can be compared with the data for riverine input. With the exception of zinc the input from both sources of the mentioned heavy metals are of the same order of magnitude. For zinc the amospheric input is about 7 times lower then the riverine input.

Table 6.1. Atmospheric input of heavy metals in subregion 5.

Heavy metal	Estimated atmospheric input $t\ y^{-1}$
Lead (Pb)	162.8 - 207.7
Cadmium (Cd)	4.3
Nickel (Ni)	29.8 - 36.0
Copper (Cu)	40.3 - 258.9
Arsenic (As)	8.1 - 9.3
Chromium (Cr)	23.9 - 27.0
Zinc (Zn)	248.0
Antimony (Sb)	4.7
Selenium (Se)	4.3

Riverine and direct input

According to data from 1990 (OSPARCOM 1992) the Danish and German riverine and direct inputs of heavy metals can be estimated to constitute 10 - 20 % of the total riverine and direct input to the North Sea except for mercury. The input of mercury from subregion 5 constitutes up to nearly 50 % of the total riverine and direct input to the North Sea ***(Table 6.2).***

For the organoclorine compounds subregion 5 contributes with more then one third of the γ-HCH input. The input of PCBs to the whole North Sea is very uncertain but with the calculated range the input from subregion 5 can be estimated to be between 10 - 40 % of the PCB input to the whole North Sea.

The riverine and direct inputs to subregion 5 are thus of great importance for the North Sea, and for mercury and HCH the inputs to subregion 5 constitutes the major input to the North Sea.

***Table 6.2** Total riverine and direct inputs to subregion 5 with respect to heavy metals and organochlorine compounds in 1990 compared with the total riverine and direct input to the North Sea including the Channel, Kattegat and Skagerrak (North Sea Quality Status Report 1993).*

Heavy metals	Riverine + direct input Subregion 5 $t\ y^{-1}$	Riverine + direct input total North Sea $t\ y^{-1}$	Riverine + direct input to subregion 5 in % of input to the whole North Sea
Cadmium (Cd)	9	49 - 59	15 - 18
Mercury (Hg)	11	23 - 27	41 - 48
Copper (Cu)	286	1500	19
Lead (Pb)	213	1100 - 1200	18 - 19
Zinc (Zn)	1751	7600 - 7700	10
Organochlorine compunds	**Riverine + direct input Subregion 5 $kg\ y^{-1}$**	**Riverine + direct input total North Sea $kg\ y^{-1}$**	**Riverine + direct input to subregion 5 in % of input to the whole North Sea**
γ-HCH	362*	870 - 1100	33 - 42
PCBs	177*	420 - 2300	8 - 42

* indicates maximum values

Industrial waste

For subregion 5 it can be stated that dumping of industrial waste and sewage sludge has taken place during earlier periods. The dumping of industrial waste from the production of titanium dioxide (waste acid) took place from 1969 to 1989. In the period 1978 to 1989 the total amounts of waste acids dumped varied between about 150.000 and 750.000 t y^{-1}. Digested sewage sludge from the City of Hamburg was dumped between 1961 and 1981 and amounted to approx. 250.000 t y^{-1} (mean wet weight).

Other sources

Occasionally other compounds are discharged or disposed of illegally, as for instance is indicated by the occurrrence of alkylated phenols on German and Danish beaches in 1991. The "Oiled Seabirds" project clearly indicates the same fact. As most oil slicks are observed along the main shipping routes, it is suspected that such sources of contaminants originates from ships in open sea.

6.3.2 Physical transport

The majority of contaminants entering subregion 5 do not remain dissolved in the water, but become adsorbed onto particulate material and at some stage sediment out. Consequently movement of most contaminants from the source of input is a complex process and is only loosely related to major water movement patterns.

For contaminants in true solutions, dispersion do depend on major water movement patterns whether they originate from external discharge or internal mineralization in the water column or mobilization from sediments.

Contaminants adsorbed onto fine particulates are progressively transported to areas of deposition, which might encompass estuaries coastal waters or more permanent deep depressions as Skagerak and the Norwegian Trench. There are indications that 50-70% of the particulate load of the North Sea ends up in Skagerak.

There are no major deposition fields in subregion 5 that represents the final sink for particle born contaminants in the North Sea and as such in the long term Subregion 5 must generally be considered as a transition zone.

For a number of heavy metals and nutrients represented with the highest concentrations in the German Bight in subregion 5, transport and dispersion can generally be described as negative correlations between salinity and a number of contaminant concentrations, indicating that the freshwater flow from the German Rivers carries a high load of contaminants and that dispersion and transport of contaminants depend on dilution.

Such correlations for specific contaminants must be considered as trends with a considerable variability, indicating that actual physical processes and probably immobilization and mineralization processes are superimposing simple dilution.

Heavy metals

As other contaminants heavy metals are often transported with particles they are adsorped or absorbed at. Especially organic particles have a high affinity for most heavy metals and generally fine grained material contains higher concentrations of heavy metals than more coarse grained material in the same area. But as described for other contaminants the stability of heavy metals bound to particles depends on chemical processes influencing the way by which metals are being transported.

Hydrocarbons

As for other elements the distribution of hydrocarbons in the German Bight is mainly influenced by the input of the river Elbe, the current by which its water is transported through the German Bight, the dilution by mixing with relatively unpolluted North Sea (Atlantic) water and by adsorption to and sedimentation of suspended material in the water column.

The hydrocarbon concentrations show a very high variance and are as described for other contaminants dependent of many physical parameters like water temperature, wind direction and strength, salinity and the amount of suspended matter. In addition, all processes are strongly dependent of the chemical structure of the individual hydrocarbons. The pattern of the hydrocarbons observed in the water phase indicate biogenic (alkanes) and combustion (PAH) processes as main sources.

Radioactive substances

With respect to input of artificial radioactive substances into the North Sea Sellafield located at the Irish Sea used to be the dominant source. Discharges of radioactivity from La Hague had a much lower activity. Subregion 5 is however located within the area of La Hague influenced contamination, but at its north part, it represents the mixing zone between Sellafield and La Hague derived contamination.

Biological transport of contaminants

Phytoplankton organisms can have a high affinity for surface absorption of particles, and transport of contaminants in this way is likely to occur. Zooplankton as well as higher trophic levels consequently will also contribute to the transport of particles and contaminants.

Benthic animals are known to mobilise contaminants from the sediment. On the other hand they are also known to immobilise contaminants either by transporting them to deeper sediment layers or improving the availability of oxygen and consequently immobilise them below the bottom surface.

6.3.3 *Concentrations and interpretation of their significance.*

Heavy metals

The large riverine input of heavy metals to the German Bight is also reflected in the spatial distribution of the subregion.

Cadmium mainly occurs in the dissolved phase of sea water and shows an even distribution across the German Bight. A decrease in cadmium concentrations during the period 1973-1988 in the German Bight indicates a trend for a decreasing metal input. The concentrations are still elevated compared to measurements reported earlier for the the central part of the North Sea (10 - 20 ng/l).

The highest concentrations of copper in seawater are found in the German Bight. A general gradient across the German Bight has been found. The concentrations are comparable to earlier reported measurements in coastal (0.5 - 1.0 µg/l) and off-shore waters of the North Sea with salinities > 30 (0.1 - 0.2 µg/l).

The concentration of nickel in seawater has a distribution similar to copper.

Lead in seawater is mainly occurring in the particulate phase, and has not regularily been measured as long as other metals. Most lead measurements in areas with salinities > 34 indicates concentrations of lead below 0.05 µg/l. In ocean water concentrations of about 0.030 µg/l are found.

Like lead mercury is mainly occuring in the particulate phase. All concentrations were higher than the mean values for off-shore waters of the North Sea with a salinity > 30 which have been reported to vary between 0.6 ng/l and 2.5 ng/l.

Data for zinc indicate that the concentrations found are in the range 1 - 5 µg/l increasing with decreasing salinity.

There is for many metals and also in different types of samples, a decrease in the concentrations, when going upwards along the Jutland west coast. This is especially pronounced for those metals, where the concentration is rather high in the German Bight. There are no known point sources of any importance, that seems to have an influence on the concentrations found along the Jutland coast, except the old waste site at Thyborøn, which still can be detected in the distribution of mercury.

Heavy metals in sediments and the biota.

Temporal trends analyses for heavy metals in sediments in the German Bight do not generally indicate that the load of the bight has been reduced, as shown for seawater with special reference to cadmium. Concentrations of metals in sediments fluctuates depending on the locality. Fluctuations of cadmium are particularily large. Variations of cadmium concentrations are not followed by variations of any other main component in seawater.

Measurements in the biota indicates that there has been a slight downward trend of the Pb, Zn, Cu, and Cd concentrations in fish liver in the Danish area in the period 1978-1988. No trend could be detected for Hg. The same consistent trends of Pb, Zn, Cu, and Cd in fish liver were not detected in samples from the German Bight.

Hydrocarbons

Measurements of hydrocarbons expressed as THC (Total Hydrocarbon Concentrations), based on fluorescence techniques have been performed in the German Bight for 1990 and 1991. In a transsect from the Elbe to the Outer German Bight mean concentrations varied between 0.5 - 41.4 µg/l, the minimum values between 0.18 - 12.0 µg/l while maximum values were recorded between 1.42 - 112.0 µg/l. The highest values were located at the Elbe plume.

With respect to PAHs (Polycyclic Aromatic Hydrocarbons) the general tendency is that the highly water insoluble 4-6-ring PAHs have a high affinity for particles and settle with increasing distance from the shore thereby concentrations decrease with a factor of 100 from approx. 4 to 0.04 ng/l. The better soluble 2-3-ring PAHs only varied with a factor of 10 from 5 to 0.5 ng/l.

Radioactive substances

The main sources of radioactivity are:

- global fallout from atmospheric nuclear weapon test, primarily during the sixties.
- liquid discharges from the nuclear reprocessing at Sellafield, La Hague and Dounrey
- the fallout from the nuclear reactor accident at Chernobyl in 1986
- releases from nuclear power plants surrounding the North Sea

It has been possible to distinguish between the radioactivity mainly originating from the reprocessing plant at Sellafield, La Hague and the Chernobyl accident. The Sellafield signal is mainly dominated by the Cs 137-activity and La Hague by the Sr 90-activity. The Chernobyl derived activity was characterised by the activity ratio between Cs 134 and Cs 137 of about 0.54 in April 1986.

In 1986 a significant signal from the Chernobyl accident was measured in the German Bight. Compared to other North Sea Regions, subregion 5 received a considerable amount of the radioactive fallout. However, due to the prevailing water transport pattern in the North Sea this contamination was moved northward and was diluted with less contaminated water from the Channel within about one year.

Dumping of sewage sludge and waste acid

Dumping of sewage sludge in the inner German Bight ceased in 1981. It can be stated that there were indications that the marine environment was negatively influenced by the dumping of sludge, but that the effects were obscured by natural biological variations, stratification, tidal currents and the influence of River Elbe run-off. Thus no definite relationship was established between dumping and effects.

Dumping of acid waste from titanium oxide production ceased in 1989. It was early stated from results in biological systems in the dumping area that detrimental effects might occur as a consequence of dumping of waste acid. Although there was no scientifically conclusive evidence of a causal relationship between dumping and the observed negative effects, measures were taken as early as 1980 as part of the licensing procedure. These were made possible by the German High Sea Dumping Act which requires action to be taken when damage to the marine environment as a result of waste dumping "is not improbable according to human discretion". The dumping permits required the waste producer to carry out research and development projects into the recycling of waste acid and dumping was finally stopped.

6.4 NUTRIENTS AND EUTROPHICATION

Background concentrations of nutrients in the North Sea are mainly determined by the inflow of North Atlantic water. Superimposed on these background levels of nutrients are the atmospheric, riverine and direct inputs of anthropogenic origin.

6.4.1 Nutrient inputs

Atmospheric input

Atmospheric input of nutrients to subregion 5 is closely discussed in chapter 3. With respect to the amounts of inorganic nitrogen components the atmospheric deposition differs in German and Danish investigations. Using a total area of subregion 5 and simple means for the area specific load in subregion 5 the following deposition can be estimated:

NH_4-N	: 14.200 t y^{-1}
NO_3-N	: 22.000 t y^{-1}
Total inorganic-N	: 36.200 t y^{-1}

This input must be considered as a maximum value as all measurements and calculations are referring to coastal areas.

Riverine and direct input

In table 6.3 direct and riverine inputs of total nitrogen and total phosphorus to subregion 5 are compared with the inputs to the whole North Sea. The data are based on information from the Paris Commision in 1990. Retention of nutrients in the Wadden Sea has not been estimated in the calculations.

The inputs to the subregion are dominated by the contributions from the rivers. Both nitrogen and phosphorus inputs are relatively high with more then 20 % of the total inputs to the North Sea. Compared to the atmospheric input of inorganic nitrogen, riverine and direct input together are about 6 times greater.

6.4.2 Nutrient concentrations

As shown in section 6.4.1 the main inputs of nutrients to subregion 5 are in the German Bight. Here also the highest concentrations of phosphorus, nitrogen and silicate components can be found. Decreasing nutrients concentrations are correlated with increasing salinity, indicating a dilution in the north going current.

With special reference to nutrients as phosphate and nitrate it has been measured at Helgoland, that concentration levels in periods can be measured at even high salinities (> 33) in the offshore waters of the outer German Bigth, beyond the direct influence of the Elbe river plume. The reason for this is probably that nitrogen and phosphorous in some years is being transported in organic form by plankton and detritus. Through several sedimentation and remineralization processes at an increasing distance from the river plume causes a delayed elevation in nutrient concentrations at even high salinities.

The measurements of 1978 and the period 1985-1992 show different concentration distributions, but rather small variations in the nutrient-salinity relation. Phosphate nitrate + nitrite and silicate concentrations in the period 1985-1992 are on a slightly lower level than in 1978 except for the coastal areas in the German Bight.

Since the beginning of the sixties up to 1991 inorganic nutrient measurements have been undertaken at Helgoland. For this time range of measurements it can be seen that the occurence of increasing inorganic nutrient concentrations appear in different periods. Phosphate concentrations increased in the sixties and seventies, whereas nitrate concentrations increased in the eighties only. Phosphate increased mainly as a consequence of phosphate containing detergents, and comes from point sources, whereas nitrate mainly comes from diffuse non point sources as fertilized agricultural land.

Nitrate concentrations are still increasing in contrary to phosphate concentrations. To day day there is an increasing surplus of nitrogen over phosphorus as a plant nutrient in subregion 5.

Table 6.3. Total riverine and direct nutrient input to subregion 5 compared with the total riverine and direct nutrient input to the whole North Sea. (All figures are maximum estimates)

Riverine and direct nutrients input	Total to the North Sea* kt	Total to Subregion 5 kt	Input to Subregion 5 in % of input to the whole North Sea
Total N:			
Direct input	120	2	1.7
Riverine input	912	213	23
Total	1000	215	22
Total P:			
Direct input	7.1	0.5	7
Riverine input	47.9	11.5	24
Total	55	12	22

* Data from 1990 (Norway 1991). Including the Channel, Kattegat and Skagerrak (North Sea Quality Report, 1993)

6.4.3 Eutrophication effects

Increasing concentrations of nutrients in the subregion 5 over some decades both for nitrogen and phosphorus components implies that eutrofication effects are generally expected to occur. Most pronounced eutrophication effects are envisaged in coastal areas of the German Bight.

Bacteria

With respect to marine and freshwater bacteria a decresing number is found with increasing distance from coastal areas in German Bight, indicating that the content of organic matter decreases with distance and that the mixing with cleaner, germ free water reduces the growth potential for bacteria.

At Helgoland a general trend towards increasing bacteria numbers since 1960 has been observed.

Algae biomass, algae blooms and oxygen deficiency

Time series on productivity of algae over decades are not available for a description of eutrophication effects in subregion 5, but algae blooms dominated be several different species has since 1968 up to now regularily been observed in the Danish part of the North Sea.

Four species have been observed as dominating during algae blooming. Only one seems to occur each year: *Phaeocystis pouchetii*, which both has a high tolerance towards heavy metals and seems to grow at very low phosphorus concentrations.

In the German Bight and eastern North Sea there has since 1980 been observed oxygen deficits in near bottom water and the oxygen depletion has occurred with an increasing frequency.

At the first decades of this century autumn oxygen concentrations of just below 50% saturation were only measured in the very stable strata of the central North Sea, but not in the German Bight where oxygen deficits are found today.

Zooplankton

With respect to zooplankton some major changes have been observed since 1974 at Helgoland. Shifts in species composition including key species and an increased secondary production is among the most obvious changes. These changes are happening in an ecosystem which already is highly productive and typically is containing populations of tertiary consumers. indicating that lower consumer and producer levels are well established accordingly.

Macroflora

Some minor changes in the species composition might indicate increasing temperatures in the North Sea, an indication which can also be observed in the species composition of macroalgae around Helgoland. Generally for the macroflora and its extension with respect to depth limits and species composition there are no indications of eutrofication effects. Observations back in 1958 are similar with other observations until today.

Benthos

Benthos investigations in the subregion with special reference to the German Bight have been undertaken since 1920. From the northern part of the subregion, north of Horns Rev, benthic data only exist from the 1980s onwards.

Some investigations over 60 years on have concluded that both biomass and number of individuals have increased during the period mainly due to molluscs and polychaetes. The most likely cause to these changes was suggested to be eutrophication. Other investigations have concluded that a detoriation of the environment in some areas has taken place. The immidiate factor explaining some of the benthic changes was apparently oxygen deficiencies. On the other hand it has been shown that the recovery capacity of benthos is high with respect to both biomasses, species numbers and number of individuals.

There are indications saying that benthos in the subregion during the 1980s has been affected by both oxygen deficiency and increased food acces, the first factor being related to the latter, and the most likely cause generally is eutrophication.

6.5 ISSUES OF CONCERN

The most serious issue of concern seems to be eutrophication.

Nitrate is the main problem. The main reason for this is that nitrate is still being washed out of the catchment area in immense amounts from arable land.

During the last decades the phosphorus load of the region has clearly been reduced as a consequence of large investments in sewage plants, and in some areas there is an indication of a falling phosphorous concentration in seawater.

Effects of eutrophication are algae blooms, increased biomass and depletion of oxygen in the bottom layers of the region with an increasing yearly frequency involving still larger areas.