PROSJEKTRAPPORT

ISSN 0071-5638

HAVFORSKNINGSINSTITUTTET
MILJØ - RESSURS - HAVBRUK

Nordnesparken 2 Postboks 1870 5024 Bergen
Tlf.: 55 23 85 00 Faks: 55 23 85 31

Forskningsstasjonen	Austevoll	Matre
Flødevigen	Havbruksstasjon	Havbruksstasjon
4817 His	5392 Storebø	5198 Matredal
Tlf.: 37 05 90 00	Tlf.: 56 18 03 42	Tlf.: 56 36 60 40
Faks: 37 05 90 01	Faks: 56 18 03 98	Faks: 56 36 61 43

Distribusjon: ÅPEN

HI-prosjektnr.: 10.031

Oppdragsgiver(e): Amoco, BP, Conoco, Elf, Statoil

Oppdragsgivers referanse:

Rapport: FISKEN OG HAVET NR. 17 - 1997

Tittel:
OIL HYDROCARBONS IN FISH FROM NORWEGIAN WATERS 1993-95

Senter: Miljø

Seksjon: Marin kjemi

Forfatter(e):
Jarle Klungsøyr[1] and Ståle Johnsen[2]
[1]Institute of Marine Research, PO Box. 1870 Nordnes, N-5024 Bergen, Norway
[2]Statoil Research Centre, N-7005 Trondheim, Norway

Antall sider, vedlegg inkl.: 52

Dato: 06.03.98

Sammendrag:

This report presents the results of a study of oil hydrocarbons in fish (haddoc, cod, saithe) collected 1993-95 from the Barents Sea, Haltenbanken, Egersundbanken, northern and central North Sea. Total hydrocarbon concentrations (THC) in liver varied, but were not significantly higher in fish from petroleum installation areas. Concentrations of aromatic hydrocarbons were low and differences between geographic areas were not found. Generally higher levels of alkylated decalines were found in fish liver from the North Sea compared to the fish from more northern areas.

Rapporten presenterer resultatene av en undersøkelse på innhold av oljehydrokarboner i fisk (hyse, torsk, sei) som ble innsamlet 1993-95 i Barentshavet, Haltenbanken, Egersundbanken, nordlige og sentrale Nordsjø. Totalt innhold av hydrokarboner (THC) i lever varierte, men var ikke signifikant høyere i fisk fra områder med petroleumsinstallasjoner. Innholdet av aromatiske hydrokarboner var lave og uten geografiske forskjeller. Generelt ble det funnet høyere nivåer av alkylerte dekaliner i fiskelever fra Nordsjøen enn i fisken innsamlet lenger nord.

Emneord - norsk:
1. Fisk
2. Oljehydrokarboner

Emneord - engelsk:
1. Fish
2. Oil hydrocarbons

Prosjektleder

Seksjonsleder

le 5353

TABLE OF CONTENTS

SAMMENDRAG

Rapporten presenterer resultatene av en undersøkelse på innhold av hydrokarboner i fisk fra norske havområder. Prosjektet er finansiert av oljeselskapene Amoco, BP, Conoco, Elf og Statoil. Arbeidet ble utført av Statoils forskningssenter i Trondheim (SRD), Havforskningsinstituttet i Bergen (IMR), og Battelle Ocean Sciences, Duxbury, U.S.A.

Hovedmålsetningen var å undersøke i hvilken grad fisk innsamlet i nærheten av to utvalgte områder med olje og gassproduksjon i nordlige og sentrale deler av norsk sektor i Nordsjøen inneholdt forhøyete nivåer av petroleumshydrokarboner sammenlignet med referanselokaliteter på Egersundbanken, Haltenbanken og Barentshavet. Prosjektet skulle også gi informasjon om dagens bakgrunnsnivåer av hydrokarboner i fisk fra norske havområder, og om mulig identifisere områder med olje- og gassproduksjon som virker som kilder til økt hydrokarboninnhold i fisk

Innsamling av torsk (*Gadus morhua*), hyse (*Melanogrammus aeglefinus*) og sei (*Pollachius virens*) ble gjennomført i Barentshavet, Haltenbanken, nordlige Nordsjø, sentrale Nordsjø og Egersundbanken i tidsperioden 1993-1995. Torsk ble innsamlet fra alle områdene, hyse fra alle områdene bortsett fra Barentshavet, mens sei kun ble innsamlet fra den sentrale Nordsjø. Lever og muskel ble analysert vha. gasskromatografi (GC) for totalt hydrokarboninnhold (THC), og vha. gasskromatografi-massespektrometri (GC/MS) for innhold av utvalgte 2- til 6-ring aromatiske hydrokarboner og C_0-C_5 alkyldekaliner.

De kjemiske analysene ble gjennomført ved to laboratorier. Sammenlignende analyser viste at det var betydelige forskjeller i resultatene mellom laboratoriene på identiske prøver. Dette indikerer at det fremdeles er mulig med forbedringer i metodikken som ble benyttet i analysene av oljehydrokarboner. Hovedkonklusjonene fra undersøkelsen ble ikke i vesentlig grad påvirket av analyseproblemene.

Det ble ikke funnet signifikante forskjeller i THC i lever av torsk og hyse fra referanselokalitetene og områdene med oljeinstallasjoner. Nivåene av THC i muskel var under målegrensen (<22 µg/g våtvekt) i alle de analyserte prøvene. Resultatene fra SRD på torskelever viste at de gjennomsnittlige konsentrasjonene varierte mellom 63-135 µg/g våtvekt, med et høyt standard avvik innen hvert datasett (RSD 67-107 %). Torskelever analysert av IMR viste verdier som varierte mellom 41-64 µg/g våtvekt (RSD 27-56 %). Hyselever analysert av SRD inneholdt gjennomsnittlige THC konsentrasjoner som varierte mellom 35-139 µg/g våtvekt (RSD 66-250 %), mens IMR sine resultater for hyse varierte mellom 51-81 µg/g våtvekt (RSD 19-36 %). Seilever fra den sentrale Nordsjø inneholdt en gjennomsnittlig konsentrasjon på 66 µg/g våtvekt (RSD 68 %). Resultatene fra undersøkelsen viser at analyser av THC ikke er en spesielt følsom metode for å finne spor av oljehydrokarboner i fisk. Naturlig og analytisk variasjon var for høy til at det var mulig å måle signifikante forskjeller mellom grupper av fisk. Noe av THC-signalet skyldes sannsynligvis biogene komponenter i fisken.

IMR sine analyser av utvalgte aromatiske hydrokarboner i fiskelever viste svært lave verdier, og signifikante forskjeller mellom fisk fra ulike områder ble ikke funnet. Nivåene av sum

naftalen, antracen/fenantren, dibenzotiofen og C_1-C_3 alkylhomologer av disse (NPD), varierte mellom 33-110 ng/g våtvekt (gjennomsnittlig konsentrasjon), og de alkylerte naftalenene bidro mest til disse verdiene. Konsentrasjonene var i hovedsak lavere enn 1ng/g våtvekt av 3- til 6-ring polysyklisk aromatiske hydrokarboner, enkeltkomponenter (PAH). Det er kjent at fisk er i stand til ganske hurtig å metabolisere og skille ut aromatiske hydrokarboner. Dette medfører at nivåene i fisk ikke nødvendigvis gir et godt bilde på eksponeringen de har vært utsatt for. Analyser av aromatiske hydrokarboner i fisk gjennomføres derfor i hovedsak for å dokumentere fiskens ernæringsmessige kvalitet.

Analysene av C_0-C_5 alkyldekaliner i fiskelever fra de ulike områdene viste kvalitative og kvantitative forskjeller. På grunn av mangel på kommersielle standarder er verdiene for alkyldekaliner kun semikvantitative. Torsk og hyse fra Nordsjøen inneholdt i gjennomsnitt høyere verdier av dekaliner enn fisken fra referanselokalitetene på Haltenbanken og i Barentshavet. Resultatene fra SRD viste gjennomsnittsnivåer av C_0-C_5 alkyldekaliner i fisk fra Nordsjøen i området 686-1225 ng/g våtvekt for torskelever (RSD 32-58 %) og 806-3192 ng/g våtvekt for hyselever (RSD 49-109%). Hyselever fra den nordlige Nordsjø inneholdt de høyeste mengdene. Torskelever fra Barentshavet og Haltenbanken hadde gjennomsnittsverdier på henholdsvis 487 og 214 ng/g våtvekt (RSD 29-41 %). Hyselever fra Haltenbanken inneholdt gjennomsnittlig 349 ng/g våtvekt (RSD 109 %).

Resultatene fra IMR viste det samme bilde for C_0-C_5 alkyldekaliner som dataene fra SRD. Gjennomsnittsnivåene for torskelever fra Nordsjøen var 1468-1513 ng/g våtvekt (RSD 30-43 %). For hyselever var verdiene 1144-2485 ng/g våtvekt (RSD 17-95 %). De høyeste verdiene ble funnet i hyselever fra den nordlige og sentrale Nordsjø, men også fisk fra referanselokaliteten på Egersundbanken inneholdt et økt nivå i forhold til fisken fra Haltenbanken (271 ng/g våtvekt, RSD 67 %). Seilever fra den sentrale Nordsjø inneholdt en gjennomsnittlig konsentrasjon på 1154 ng/g våtvekt (RSD 52 %). Torskelever fra Barentshavet og Haltenbanken inneholdt gjennomsnittlig henholdsvis 683 ng/g (RSD 36%) and 376 ng/g våtvekt (RSD 73 %).

Dekaliner ble funnet i fisken fra alle de undersøkte områdene. Prinsipalkomponentanalyse (PCA) viste at det var forskjeller i den kvalitative sammensetningen av dekaliner i enkeltfisk, noe som kan indikere eksponering til ulike kilder. Når det gjelder fisken fra den sentrale og nordlige Nordsjø er det nærliggende å tro at petroleumsaktivitetene i området spiller en rolle. Betydningen av andre kilder er foreløpig ikke kjent. Forhøyete nivåer av dekalier i fisk fra Egersundbanken sammenlignet med de nordlige referanselokalitetene antyder et høyere generelt bakgrunnsnivå i fisk fra Nordsjøen. Virkninger av dekaliner i fisk er ikke kjent og studier må eventuelt igangsettes for å øke kunnskapen på dette området.

1 SUMMARY

This report presents the results of a study of oil hydrocarbons in fish from Norwegian sea areas. The project was financed by the oil companies Amoco, BP, Conoco, Elf and Statoil. The scientific activities were undertaken by Statoil Research and Development Centre in Trondheim (SRD), Institute of Marine Research in Bergen (IMR), and Battelle Ocean Sciences, Duxbury, USA.

The major aim was to determine to what degree fish from the vicinity of two selected offshore oil and gas production areas in the northern and central part of the Norwegian Sector of the North Sea contained elevated levels of petroleum hydrocarbons compared to reference sites at the Egersundbanken, Haltenbanken and Barents Sea. The project would also give information on present background concentration of hydrocarbons in fish from Norwegian waters and, if possible, identify source(s) of hydrocarbons in fish from the sampling areas affected by oil and gas production.

Sampling of cod (*Gadus morhua*), haddoc (*Melanogrammus aeglefinus*) and saithe (*Pollachius virens*) took place during 1993-1995 from the Barents Sea, Haltenbanken, Northern North Sea, Central North Sea and Egersundbanken. Cod was sampled from all areas, haddoc from all areas exept the Barents Sea, while saithe was sampled from the Central North Sea only. Liver and muscle was analysed by gas chromatography (GC) for total hydrocarbons (THC) and by gas chromatography - mass spectrometry (GC/MS) for selected 2- to 6-ring aromatic hydrocarbons and C_0-C_5 alkyl decalines.

The chemical analysis was carried out by two independent laboratories. Intercomparison of results showed considerable differences between the laboratories. This indicate that there still is room for improvement of methodology for the analysis of oil hydrocarbons in fish. However, this did not seriously affect the main conclusions from the study.

No significant difference in THC levels were found in cod and haddoc liver from reference areas compared to oil installation areas. Levels of THC in muscle was below the detection limit (<22 µg/g ww) in all samples analysed. Results from SRD showed that for cod liver the average concentration ranged between 63-135 µg/g ww, with high standard deviation within each data set (RSD 67-107 %). Cod liver analysed by IMR showed values ranging between 41-64 µg/g ww (RSD 27-56 %). Haddoc liver analysed by SRD contained average THC concentrations ranging between 35-139 µg/g ww (RSD 66-250 %), while IMR results for this species ranged between 51-81 µg/g ww (RSD 19-36 %). Saithe liver from the Central North Sea contained an average THC concentration of 66 µg/g ww (RSD 68 %). The results indicated that at present the analysis of THC is not a very sensitive method for detection of traces of oil hydrocarbons in fish. Natural and analytical variability were to high to detect differences between the different groups. Part of the THC signal is probably caused by natural biogenic compounds in the fish.

Analysis by IMR of selected aromatic hydrocarbons in fish liver showed very low values and no significant difference between fish from different sea areas were found. Levels for sum of naphthalene, anthracene/phenanthrene, dibenzothiophene and their C_1-C_3 alkyl homologs

(NPD) ranged between 33- 110 ng/g ww (average concentrations), alkylated naphthalenes contributing most to these numbers. Selected 3- to 6-ring polycyclic aromatic hydrocarbons (PAH) generally showed concentration < 1ng/g for single compounds. It is known that fish are able to quite effectively biotransform aromatic hydrocarbons. Due to the rapid metabolism, analysis of fish do therefore not necessarily provide a good indication of exposure. Analysis of aromatic hydrocarbons in fish are therefore carried out mainly for food quality assurance purposes.

Analysis of C_0-C_5 alkyl decalines in fish liver showed distinct qualitative and quantitative differences between areas. Values for decalines must at present only be considered semiquantitative due to lack of commercially available pure standards. Cod and haddoc from the North Sea contained higher average levels of decalines than fish from northern reference areas at the Haltenbanken and Barents Sea. Results by SRD showed that average values of C_0-C_5 alkyl decalines in fish from the North Sea were in the range 686-1225 ng/g ww for cod liver (RSD 32-58 %) and 806-3192 ng/g ww for haddoc liver (RSD 49-109%). Highest values were found in haddoc liver from the Northern North Sea. Cod liver from the Barents Sea and Haltenbanken contained average values of 487 and 214 ng/g ww respectively (RSD 29-41 %). Haddoc from the Haltenbanken contained an average value 349 ng/g ww (RSD 109 %).

Results from IMR showed the same picture for C_0-C_5 alkyl decalines as the SRD data. Average values for cod liver from the North Sea were in the range 1468-1513 ng/g ww (RSD 30-43 %) For haddoc values were 1144-2485 ng/g ww (RSD 17-95 %). Highest concentrations were found in haddoc liver from the Northern and Central North Sea, but also fish from the reference area at the Egersundbanken contained elevated levels of decalines compared to the Haltenbanken (271 ng/g ww, RSD 67 %). Saithe from the Cental North Sea contained an average concentration of 1154 ng/g ww (RSD 52 %). Cod liver from the Barents Sea and Haltenbanken contained average values of 683 ng/g ww (RSD 36%) and 376 ng/g ww (RSD 73 %) respectively.

Decalines were found in fish liver from all investigated areas. Principal component analysis (PCA) showed differences in decaline pattern beween individual fish, which may indicate exposure to different sources. For samples collected in the Central and Northern North Sea, it is likely to assume that the petroleum related activity in the sampling area is of importance. The importance of other sources are at present not known. Elevated levels of decalines in fish from the Egersundbanken compared to the northern reference locations may indicate a general higher background concentration of decalines in the North Sea. Effects of decalines on fish is not well known and studies should be initiated to fill gaps in knowledge.

2 INTRODUCTION

2.1 Background

Determination of total hydrocarbons (THC) and selected di- and polyaromatic hydrocarbons (PAH) in fish tissue was originally included in the regular environmental monitoring programme for offshore petroleum installations in the Norwegian sector of the North Sea. In a workshop hosted by Norwegian State Pollution Control Authority (SFT) at Mastemyr in 1988, these analyses were left out of the monitoring guidelines. This decision was made as a result of the lack of available standardised analytical methods for determining such compounds in a biological matrix, and the fact that the results presented in the annual reports were of relatively poor quality. The lack of good reference material for the monitoring surveys was also an important factor in this decision.

In 1989 Institute of Marine Research (IMR) in Bergen performed a study where fish caught in the vicinity of the Statfjord field was analysed for hydrocarbon content and potential tainting (Palmork *et al.* 1989). The conclusion of this work was that the fish was contaminated by oil from drill cuttings discharged in the area. These results have later on been disputed because of the low number of reference fish included. As a consequence a number of oil companies issued their own studies in the years to follow. In a joint project carried out by Norsk Hydro, BP and Conoco, the levels of hydrocarbons in fish from the Oseberg field were compared to levels in fish from the Egersundbanken and Haltenbanken (Aabel *et al.* 1990). At the same time Statoil performed a study where hydrocarbon levels in fish at the Statfjord field was compared to fish from the Egersundbanken and Faeroe Islands.

In the study performed by Aabel *et al.* (1990) it was concluded that fish caught in the vicinity of the Oseberg field generally contained increased hydrocarbon levels compared to fish from reference sites. Moe *et al.* (1994) found increased hydrocarbon levels in fish from the Statfjord field, and observed in addition that fish from the Egersundbanken contained increased levels of alkylated decalines compared to fish from the Faeroe Islands. Grahl-Nielsen (1992) went one step further and found by principal component analysis (PCA) patterns of decalines in fish from the Haltenbanken similar to base oil qualities used in the Northern North Sea. These observations were based on a very limited number of data, however.

The results from the studies described above led to the suspicion that base oil containing cuttings discharged in the North Sea may be the source of increased hydrocarbon levels found in fish from some of the mentioned oil field areas. This anticipation is based on the presence of decalines in the fish, compounds which also have been used as base oil tracers in sediment monitoring surveys. However, decalines are present in all oil qualities of a certain boiling range, and can be accumulated in organisms exposed to other oil contamination than drilling base oils. Little is known about the bioaccumulation of alkylated decalines in fish, and the potential of metabolism and excretion of these compounds. It is thus not necessarily correct, based on the data available from previous studies, to conclude that base oil contaminated sediments is the only source of hydrocarbon contamination in the actual areas.

In general, it was the opinion of the oil companies operating in the Norwegian sector that although these studies had shown contamination of fish in the vicinity of production fields, no unambigous conclusions could be drawn on whether the oil cuttings in sediments were the true source of the observed contamination. When SFT in 1994 again proposed to include the determination of hydrocarbons in fish in the regular monitoring programme, an alternative project including a comprehensive study of hydrocarbon levels in fish from the North Sea, Haltenbanken and Barents Sea was proposed by a joint group of oil companies. Upon SFT's acceptance of this alternative, the present project was initiated.

2.2 Objectives

The objectives of the present study can be summarised as follows:

- To determine to what degree fish from the vicinity of two selected offshore oil and gas production areas in the North Sea contained elevated levels of petroleum hydrocarbons compared to a North Sea reference site.

- To find whether fish from the Haltenbanken area are contaminated with oil derived hydrocarbons prior to the initiation of oil and gas production in the area.

- Establish the background concentration of hydrocarbons in fish from Norwegian waters.

- If possible, identify the source(s) of hydrocarbons in fish from the sampling areas affected by oil and gas production.

2.3 Project organisation and participants

The project was financed by the operating oil companies Statoil, Conoco, Elf, BP and Amoco. The scientific activities were undertaken by Statoil Research and Development Centre in Trondheim (SRD), Institute of Marine Research in Bergen (IMR) and Battelle Ocean Sciences, Duxbury, USA.

Project organisation:
Statoil Research and Development Centre (SRD): Project management, analyses of samples from the Barents Sea, Haltenbanken, Northern North Sea and Egersundbanken. Statistical evaluation (fingerprinting) and reporting.

Institute of Marine Research (IMR): Sampling, sample coding and distribution. Analysis of samples from the Central North Sea, control checks of samples analysed by Statoil and reporting.

Battelle Ocean Sciences: Statistical evaluation of data, fingerprinting and reporting.

The project was managed by a steering group with representatives from the participating oil companies and IMR.

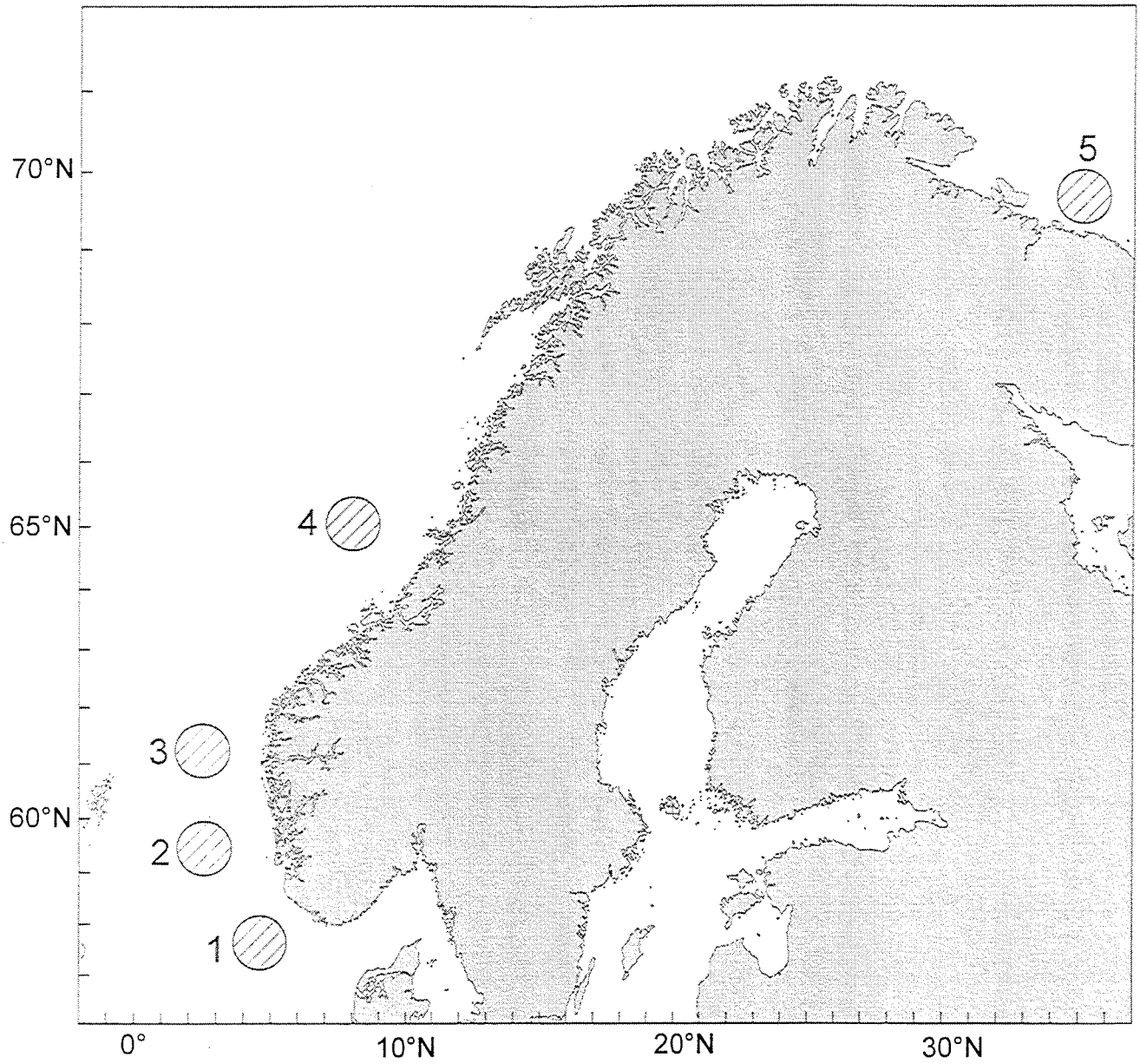

Figure 1. Overview of sampling areas: 1. Egersundbanken, 2. Central North Sea (Norwegian sector), 3. Northern North Sea, 4. Haltenbanken, 5. Barents Sea
Figur 1. Oversikt over innsamlingsområder: 1. Egersundbanken, 2. sentrale Nordsjø (Norsk sektor), 3. nordlige Nordsjø, 4. Haltenbanken, 5. Barentshavet

3 SAMPLING

Five geographical regions were sampled (Figure 1). Two of these were located in areas with several oil and gas production fields, in the northern and the central part of the Norwegian Sector of the North Sea, for convenience called the Northern North Sea and Central North Sea. The other three locations represented areas with no local oil and gas production, the Barents Sea, Haltenbanken and Egersundbanken. The aim of the sampling design was to collect species

representing the pelagic and the seabed ecosystem. Cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) were selected, and in addition saithe (*Pollachius virens*) from the Central North Sea.

Cod is one of the commercially most important fish species in the Northeast Atlantic. It is found in coastal areas in the North Atlantic Ocean, including the North Sea and Barents Sea. Cod is an opportunistic feeder, and the diet can vary considerably from year to year based on availability of prey species. For cod smaller than 40 cm length, euphauciides and amphipodes often contribute significantly to the diet. Cod of more than 70 cm length often feed on shrimp or fish like herring (*Clupea harengus*), capelin (*Mallotus villosus*) or sandeel (*Ammodytes* sp.).

Haddoc and saithe are found in the North Sea, the Norwegian Sea and the Barents Sea. Both species are of commercial interest. Haddoc is a bottom living fish feeding on fish row, smaller fishes, octopus and benthic organisms like brittle stars, snails and crustaceans. Saithe is a pelagic fish feeding on organisms like euphauciides, amphipodes and smaller fish like sprat and herring.

The samples of cod and haddock were collected during six cruises carried out by IMR. An effort was made to collect 25±10% individuals of each species at each location, in accordance with the recommendations by the International Council for Exploration of the sea (ICES) for monitoring of fish for spatial or temporal trends (ICES, 1987). However, even after this comprehensive field work, the number of cod collected from the Haltenbanken and Northern North Sea was incomplete. Cod from the Northern North Sea and saithe from the Central North Sea eventually had to be collected through commercial catches. Table 1 is a summary table giving fish sample information. Individual fish parameters are given in Appendix 1.

Total fresh weight, length and sex were recorded for all fish. Fish livers were weighed and packed in pre-cleaned glass jars with screw caps, while samples of fish muscle tissue were wrapped in clean aluminium foil inside polyethene plastic bags. All samples were frozen immediately after sampling to -20°C, and kept in darkness at this temperature until work up and analysis. The fish from the commercial fishing boats (*Svanodd, Kvernsund*) were frozen whole in polyethene plastic bags to avoid secondary contamination due to untrained handling. Total fresh weight, length and sex were recorded in the laboratory.

4 EXPERIMENTAL APPROACH

4.1 Chemical analyses - materials and methods

All samples of fish from the Barents Sea, Haltenbanken, Northern North Sea and Egersundbanken were analysed by SRD. Samples from the Central North Sea were analysed by IMR. In addition, the two laboratories involved performed an interlaboratory quality control programme described in 4.2.

Table 1. Fish sample information

Region	Species	Date	Boat	Station id	Latitude N	Longitude E	N	Length (cm)	Weight (g)
Barents Sea	Cod	31.03.93	J. Hjort	269	69°24′	35°49′	24	39-51	600-1090
Haltenbanken	Cod	24.10.94	J. Hjort	675	64°44′	08°59′	2	40-103	860-8750
		24.10.94	J. Hjort	676	65°03′	08°23′	1		
		24.10.94	J. Hjort	677	64°52′	08°22′	1		
		24.10.94	J. Hjort	678	64°46′	08°43′	2		
		26.06.94	G.O.Sars	330	67°06′	08°31′	14		
	Haddoc	24.10.94	J. Hjort	675	64°44′	08°59′	20	30-57	300-1985
Northern North Sea	Cod	06.05.95	Svanodd	1	60°55′	02°35′	7	40-65	661-3132
		06.05.95	Svanodd	2	61°00′	02°36′	15		
	Haddoc	11.10.94	G.O.Sars	607	60°38′	02°41′	21	30-54	325-930
Central North Sea	Cod	13.12.94	G.O.Sars	725	59°35′	02°15′	13	31-48	291-1328
		18.10.94	G.O.Sars	628	59°45′	01°17′	5		
		18.10.94	G.O.Sars	629	59°46′	02°25′	7		
	Haddoc	13.12.94	G.O.Sars	725	59°35′	02°15′	10	30-44	270-1041
		18.10.94	G.O.Sars	629	59°46′	02°25′	14		
	Saithe	09.05.95	Kvernsund	3	59°20′	03°20′	25	40-54	542-1404
Egersundbanken	Cod	29.10.94	G.O.Sars	659	58°04′	04°42′	25	25-35	135-415
	Haddoc	29.10.94	G.O.Sars	660	57°52′	04°35′	22	30-39	280-770

As mentioned in chapter 2.1, previous studies have focused on PAH and decalines in fish liver and muscle tissue. The same compounds were included in the present study, together with determination of total hydrocarbon content (THC) as an indicator of total oil contamination of the fish.

Extraction and clean-up
Approximately 5g of the sample was saponified (100ml of 0.5N KOH in methanol, reflux boiling for 1.5 hours) together with a mixture of fully deuterated internal standards (naphthalene, phenanthrene, pyrene, perylene, and decaline). IMR replaced naphthalene and phenanthrene as internal standards with deuterated biphenyl and anthracene respectively. After saponification, water (25ml) was added to the sample and the mixture extracted by n-pentane (2 x 30ml). The volume of the combined extracts was reduced to approximately 1ml (Turbovap system), and the solvent exchanged to n-hexane (add 2 x 3ml, Turbovap reduction to 1ml). Each sample was then eluted through a gravity fed adsorbtion column (1.0 g alumina on top of 11.0 g silica in a 50 x 1.1cm column). An aliphatic (18ml n-hexane) and an aromatic (21ml 1:1 methylenechloride:n-hexane) fraction were collected, and combined to reduce the number of analyses. SRD concentrated the sample to 1ml and used an 0.5 ml aliquot for gel permeation chromatography (GPC). IMR continued with the whole sample (0.5 ml) due to less sensitive GC/MS instrumentation.

The extracts (0.5ml) was injected on a HPLC gel permeation column (Bio-beads SX-3, approximately 2.5 g swelled overnight in methylenechloride and packed in a 50 x 1.0 cm glass HPLC column) with a molecular weight cut-off at approximately 1000 dalton. The high molecular weight fraction (>1000 dalton) was eluted and discarded, and the low molecular weight fraction collected; i.e. the hydrocarbon fraction (flow: 1.0 ml/min, collection range 13-25min). The sample volume was reduced to approximately 0.5ml for GC analysis, and further concentrated to 50µl (only IMR) for GC/MS analysis.

Sample analysis - total hydrocarbon content
The levels of THC in the samples were determined by GC-FID analysis, using a drilling base oil as external standard (HDF baseoil from the Statfjord field). A calibration curve covering the concentration range of the real samples was obtained prior to analysis. The THC of the samples was determined by comparing the area of the chromatographic retention window C_8-C_{24} n-alkane with the corresponding area of the calibration curve.

Sample analysis - aromatic compounds and decalines
The content of PAH and decalines in the samples was determined by selected ion monitoring (SIM) GC/MS analysis, using the internal standards in the samples and response factors for the different target compounds for quantitative correction. Peak areas were used for calculating the sample concentrations of the target compounds. Since no authentic standards were available for the alkylated decalines, a response factor of 1.0 relative to deuterated decaline was used. The analysis of the decalines must thus be regarded only as semi-quantitative.

4.2 Chemical analyses - quality control programme

The quality control programme for the chemical analysis was organised as a two-level system, interlaboratory QC and intralaboratory QC.

All samples were collected and registered by IMR, and the samples coded before shipping to SRD. The codes were not broken until all quantitative results were presented to IMR by SRD. The extraction, clean-up and analytical procedures were drilled by technical staff from the two laboratories while working together at Statoil's facilities during the start of the project. Fifteen % of the samples were analysed at both laboratories. These samples served as the major basis for a comparison of results from the two laboratories.

SRD internal QC
For every fifth real sample, blanks were included in the extraction, clean-up and analysis. The blank samples were analysed together with the real samples, and the analytical signals corresponding to peaks (compounds) were used to determine the limits of detection (LOD) for different compounds.

Accuracy and precision of the analysis were controlled by spiking some of the material from the reference locations with known amounts of the target compounds. These samples were extracted, cleaned and analysed after the same procedures as the real samples.

The performance of the GC and GC/MS instruments were controlled by analysing a standard sample containing the external standard oil and the target PAH compounds, respectively. The control samples were analysed for every ninth real sample on the instruments.

IMR internal QC
Complete procedural blanks were analysed for every fifth sample and recovery tests of spiked samples carried out to check the analytical procedures. IMR has participated in a number of intercomparison exercises for the validation of analytical methods for PAH. 1992-93: International Sediment Exchange for Tests on Organic Contaminants, SETOC. PAHs in sediments. 1993-present: Quality Assurance of Information for Marine Environmental Monitoring in Europe, QUASIMEME. PAH in standard solutions and sediment extracts.

4.3 Data evaluation - source identification

In the present study, an attempt was made to use the large amount of information hidden in the qualitative data from the GC and GC/MS analysis to identify possible sources of hydrocarbons in the fish. This was achieved by Principal Component Analysis (PCA) of the compounds analysed, and by comparing groups of fish from each of the sampling locations. This technique is frequently referred to as "fingerprinting". PCA is a multivariate data analysis tool for creating data matrices that distinguish similarities/differences in patterns (analytic distributions) between individual samples, and which determine the influence each variable or set of variables has on that pattern. PCA is especially useful for looking at underlying patterns that may not be seen from a visual analysis of the data only. This technique helps

determine how samples may be related and which characteristics of the samples define their relationship.

The traditional way of performing PCA on a sample set like the present is to employ the quantitative results for single compounds in the multivariate matrix. There are some disadvantages linked to this method however. In a comprehensive data set, like the present, integration and quantification of all components in all samples is a time consuming operation. Integration may also introduce additional variation to the results.

The data set was treated by two different approaches of fingerprinting. PCA was performed on the quantitative data and on raw data files imported directly from the GC and GC/MS systems. For the purpose of the latter, a special computer programme was developed. The programme imports non integrated raw data files from the analytical system into a sample list where all samples of interest for the fingerprinting can be included. From this list, a reference sample is selected, and all other samples are shift corrected until the chromatographic retention times for each of the common peaks in all samples gives a perfect match. Each sample is then exposed to a noise reduction algorithm to remove insignificant signals from the chromatograms. The resulting chromatogram is presented as a string of responses for each sample, each response figure related to a specific retention time and representing one variable in the PCA matrix. For every single sample the GC/MS SIM data are organised as a coupled string of the actual ion chromatograms included in the analysis. A typical number of variables for a sample may fall within the rang 400 - 1000, depending on the number of peaks in the chromatogram.

The samples included in the present study were divided into two groups, cod and haddock liver. Fingerprinting based on integrated data was performed for fish from all sampling sites, while samples from the Central North Sea area were excluded for the fingerprinting based on raw data. The reason is that all samples have to be analysed on the same instruments under the same conditions to be able to perform this interpretation. Since the Central North Sea samples were analysed only by IMR, these data were unavailable for this part of the evaluation.

5 RESULTS

SRD had the responsibility for analysis of cod and haddoc from the Barents Sea, Haltenbanken, Northern North Sea and Egersundbanken. IMR carried out analysis on 15 % of the same material for control purposes, and had in addition the responsibility for analysis of cod, haddoc and saithe from the Central North Sea. Appendix 2 presents the results of the analysis by the to laboratories on identical samples. Unfortunately the comparability of results between the two laboratories was poor for PAH, with more than a factor 10x difference between the laboratories. Extensive checks of the analytical procedures at the two laboratories revealed that SRD had added internal standards to the samples a factor 10 lower than intended. In addition, high blank values and low absolute recoveries of the deuterated PAH standards were noted. It was therefore decided to exclude the quantitative results on PAH analysed by SRD. Discussion on PAH will be based on the results obtained by IMR. This will not have any serious implications for the conclusions to be made from the study, as will be shown from presentation of results.

Table 2. Summary statistics for THC in liver (µg/g ww)
Tabell 2. Oppsummerende statistikk for THC i lever (µg/g våtvekt)

Sample id.	Lab.	N	Mean	St. dev.	Median	Min	Max
Cod Barents Sea	SRD	24	92	107	64	-	437
	IMR	5	63	17	66	45	87
Cod Haltenbanken	SRD	19	63	66	43	-	220
	IMR	6	41	23	32	13	72
Cod Northern North Sea	SRD	22	64	43	59	-	159
	IMR	5	61	23	68	38	93
Cod Central North Sea	IMR	27	64	29	57	17	118
Cod Egersundbanken	SRD	25	135	92	137	-	432
	IMR	4	56	20	57	35	73
Haddoc Haltenbanken	SRD	20	139	348	44	-	1570
	IMR	5	53	19	50	25	74
Haddoc Northern North Sea	SRD	20	82	54	83	-	162
	IMR	5	81	15	83	60	99
Haddoc Central North Sea	IMR	26	54	18	51	27	92
Haddoc Egersundbanken	SRD	20	35	32	21	-	133
	IMR	5	51	16	49	33	73
Saithe Central North Sea	IMR	24	66	45	60	5.6	233

-: below limit of detection

For sum parameters like THC and sum of C_0-C_5 alkyl decalines the comparability between SRD and IMR was better than for PAH (Appendix 2). However looking at details for single groups of decalines, considerable difference can be found in the decaline patterns. Lack of commercially available pure standards can explain much of this between laboratory differences. Numbers for concentrations of decalines in fish must therefore be handled with caution and considered indicative only. Results from within laboratory analysis is comparable and can be discussed, however, as long as the samples are analysed under control with identical analytical conditions. Due to the between laboratory differences, further presentation of results from the two laboratories will be kept partly separate.

5.1 Quantitative results

SRD data
In general, the content of the target compounds for the analysis was relatively high in the procedural blank samples. This was found to be related to contamination of the blank samples during the volume reduction step on the Turbovap system. As a result, limit of detection (LOD) were relatively high for the analysed compounds.

Table 2 gives the summary statistics for THC in fish liver. Detailed information on results for individual fish are found in Appendix 3. The average concentration of THC in cod liver ranged between 63 and 135 µg/g ww, with high relative standard deviation within each sample set (67-107 %). Haddoc liver contained average values ranging from 35 to 139 µg/g ww, with a standard deviation of 66-250 %. Due to this high variability, there was no significant difference between the sampling areas included in this study. Haddoc from the Haltenbanken and cod from the Egersundbanken and Barents Sea contained the highest average levels of THC, areas considered reference sites. Much of the THC probably represents a natural background level of partly biogenic compounds in liver from these two species. THC in muscle was below detection in all samples analysed (< 22 µg/g ww).

The average concentrations for C_0-C_5 alkyl decalines in cod liver from the Haltenbanken, Barents Sea, Northern North Sea and Egersundbanken were 214, 487, 686 and 1225 ng/g ww respectively (Table 3). Standard deviation for each sample set was 29-58 %. Cod liver from the North Sea, contained higher levels of decalines than cod from the Haltenbanken, particularly cod from the Egersundbanken. Haddoc liver contained 349 to 3192 ng/g ww average values for sum of decalines with areas ranged: Northern North Sea > Egersundbanken > Haltenbanken. Elevated levels of decalines was statistically significant for haddoc livers from the Northern North Sea compared to the reference sites ($p>0.95$, t-test, assuming unequal variance). In cod and haddoc muscle the levels of C_0-C_5 alkyl decalines was below detection in all samples analysed (LOD: 20-380 ng/g ww).

IMR data
Table 2 and Appendix 4 presents the IMR results on THC in fish liver. No significant difference was found in average THC levels for cod, haddoc and saithe from the different sea areas. In cod liver THC ranged between 41 and 64 µg/g ww, with a relative standard deviation for each sample set varying between 27-56 %. Cod from the reference sites in the Barents Sea and Haltenbanken contained approximately the same concentration of THC as found in fish from the oil installation areas of the North Sea. Haddoc liver contained average THC concentrations ranging from 51 to 81 µg/g ww. For saithe liver this number was 66 µg/g ww, approximately the same as for cod and haddoc. The analysis of THC by IMR showed slightly lower average values than the analysis by SRD, the only exeption is for haddoc liver from the Egersundbanken (Table 2).

Table 3 and Appendix 4 shows the results of the analysis of C_0-C_5 alkyl decalines. The highest levels for sum of C_0-C_5 alkyl decalines for cod liver were found in the North Sea. Average levels at the Egersundbanken, Central North Sea and Northern North Sea ranged from 1468 to 1513 ng/g ww, with a relative standard deviation varying between 30-62%. Cod liver

Table 3. Summary statistics for $\sum C_0$-C_5 alkyl decalines in liver (ng/g ww)
Tabell 3. Oppsummerende statistikk for $\sum C_0$-C_5 alkyldekaliner i lever (ng/g våtvekt)

Sample id.	Lab.	N	Mean	St. dev.	Median	Min	Max
Cod Barents Sea	SRD	24	487	202	456	210	1108
	IMR	5	683	248	656	429	1066
Cod Haltenbanken	SRD	19	214	61	205	94	328
	IMR	6	376	276	355	121	884
Cod Northern North Sea	SRD	22	686	398	620	21	2010
	IMR	5	1513	654	1237	983	2534
Cod Central North Sea	IMR	27	1509	940	1130	369	3351
Cod Egersundbanken	SRD	25	1225	395	1149	747	2310
	IMR	4	1468	444	1443	1016	1972
Haddoc Haltenbanken	SRD	20	349	381	159	30	1135
	IMR	5	271	181	219	97	573
Haddoc Northern North Sea	SRD	20	3192	1984	2881	494	7827
	IMR	5	2485	418	2392	1910	2909
Haddoc Central North Sea	HI	26	2304	1148	2037	101	4656
Haddoc Egersundbanken	SRD	20	806	396	689	433	1912
	IMR	5	1144	1088	553	443	3027
Saithe Central North Sea	HI	24	1154	596	1161	178	2264

from the Haltenbanken and Barents Sea contained average levels of 376 to 683 ng/g ww respectively, which is significantly lower than for the North Sea. Haddoc from the North Sea showed higher average levels of sum of C_0-C_5 alkyl decalines in liver (1144 -2485 ng/g ww) than at the Haltenbanken (271 ng/g ww). Areas were ranged Northern North Sea > Central North Sea > Egersundbanken > Haltenbanken. Saithe from the Central North Sea contained slightly lower average levels of decalines than cod and haddoc from the same area. Big variations between individual saithe livers was found (178-2263 ng/g ww). This was also seen in cod and haddoc from most areas (Table 3).

Table 4. Summary statistics for NPD in fish liver (ng/g ww)
Tabell 4. Oppsummerende statistikk for NPD i fiskelever (ng/g våtvekt)

Sample id.	N	Mean	St. dev.	Median	Min	Max
Cod Barents Sea	5	110	33	108	64	146
Cod Haltenbanken	6	77	59	51	20	161
Cod Northern North Sea	5	89	18	87	72	114
Cod Central North Sea	27	72	45	68	2	193
Cod Egersundbanken	4	102	55	82	63	180
Haddoc Haltenbanken	5	33	12	32	20	47
Haddoc Northern North Sea	5	66	17	70	40	84
Haddoc Central North Sea	26	62	27	55	27	157
Haddoc Egersundbanken	5	59	24	49	43	102
Saithe Central North Sea	23	55	46	43	6	195

[1]NPD: See Appendix 5

Table 5. Summary statistics for PAH in fish liver (ng/g ww)
Tabell 5. Oppsummerende statistikk for PAH i fiskelever (ng/g våtvekt)

Sample id.	N	Mean	St. dev.	Median	Min	Max
Cod Barents Sea	5	4.6	2	4.4	2.7	7.2
Cod Haltenbanken	6	7	5.8	4.1	1.3	15.2
Cod Northern North Sea	5	8.4	1.4	8.5	6.6	10
Cod Central North Sea	27	4.3	1.8	4.1	1.4	7.5
Cod Egersundbanken	4	7.2	2.7	7.1	4.1	10.6
Haddoc Haltenbanken	5	11.4	10.8	4.4	3.4	26.8
Haddoc Northern North Sea	5	3.8	2.1	3.6	1.3	7
Haddoc Central North Sea	26	3.6	2.1	3	1	10.6
Haddoc Egersundbanken	5	4.6	2.9	3.9	1.8	9.5
Saithe Central North Sea	23	3.2	1.9	2.7	1	7.9

[1]PAH: See Appendix 6

Table 4 and Appendix 5 shows the results of the analysis of selected 2- and 3-ring aromatic hydrocarbons, often termed NPD (naphthalene, phenanthrene, dibenzothiophene and their alkyl homologs). The sum of 2- and 3-ring aromatic hydrocarbons were generally low in all samples analysed (33-110 ng/g ww), and alkylated naphthalenes contributed most to these numbers. No significant difference between areas were found for cod and haddoc. The same was the situation for 4- to 6- ring aromatic hydrocarbons (PAH) in fish liver where individual compounds were found at levels close to or below detection limit (Table 5, Appendix 6).

5.2 Qualitative evaluation

The qualitative evaluation of the data was first performed on a combined set of SRD and IMR data, including all variables. Combining the data for multivariate PCA showed that the most dominant variable was the origin of the data, i.e. which laboratory had performed the analysis.

A qualitative evaluation could therefore only be performed on data produced within one laboratory. In addition, experience with the present methods of fingerprinting showed that all samples had to be analysed within the same calibration tuning period of the GC/MS in order to be directly comparable. This is especially important when semiquantitative methods are involved, as for decalines in this study. Indeed, even though the quantitative results of total C_0-C_5 alkyl decalines from the two laboratories were in reasonable agreement, the profile and relative composition of the alkylated decalines were clearly different (Appendix 2). However, as will be demonstrated in the following discussion, when the data sets from the two laboratories are treated separately with regard to qualitative interpretation, the results are in good agreement.

SRD data
Figure 2 and 3 shows PCA score plots for aromatic hydrocarbons and decalines in haddock and cod livers respectively. In these analyses, the quantitative data have been normalised, so that concentration of the different compounds would not appear as a variable. As can be seen from Figure 2, there is a clear and significant clustering tendency for the haddock samples. This shows that the chromatographic pattern or fingerprint of the samples are different for the three sampling areas. Especially samples from the Northern North Sea seem to have a composition different from the others. For cod liver samples (Figure 3) the tendency is less obvious, but a majority of the Northern North Sea samples tend to fall outside the major group. This observation was confirmed by performing PCA on the non-integrated decaline data by the on-line fingerprinting system.

The same tendency, however less significant, was observed for the THC chromatographic fingerprints of haddock liver samples when exposed to PCA evaluation by the on-line method. All samples from the Northern North Sea clustered outside the main group consisting of the reference areas. The loading plot showed that the source of this difference originated from the typical "base oil window" of the chromatogram. This observation indicate sediments contaminated with base oil as a possible source of the hydrocarbon content in haddoc. The cod liver samples showed no such trends.

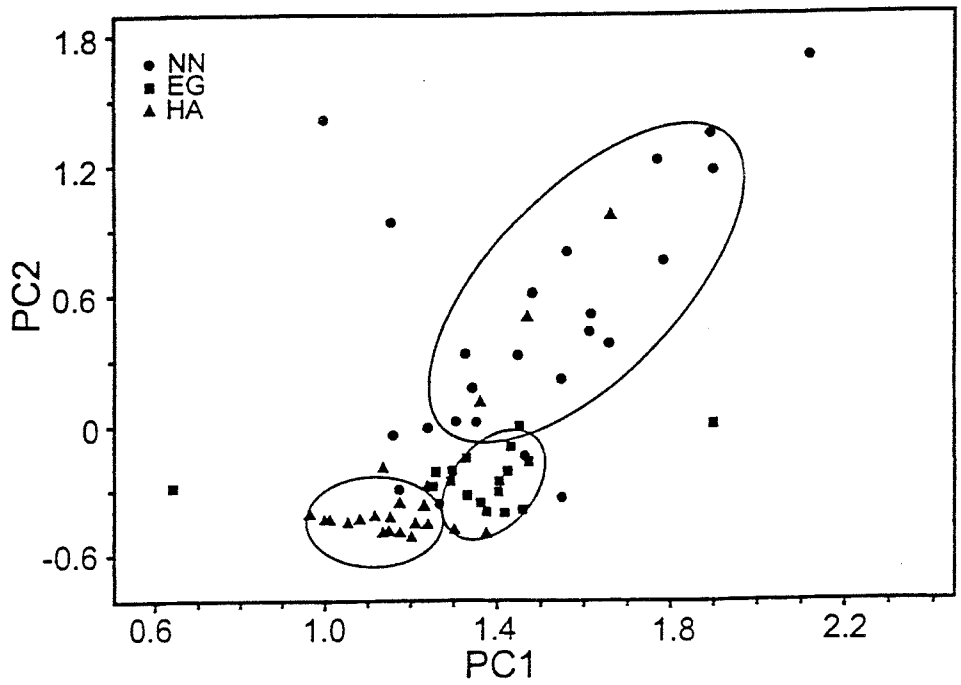

Figure 2. PCA score plot of haddoc liver, aromatic hydrocarbons and decalines as variables (SRD data)
Figur 2. PCA score plot av hyselever, aromatiske hydrokarboner og dekaliner som variable (SRD data)

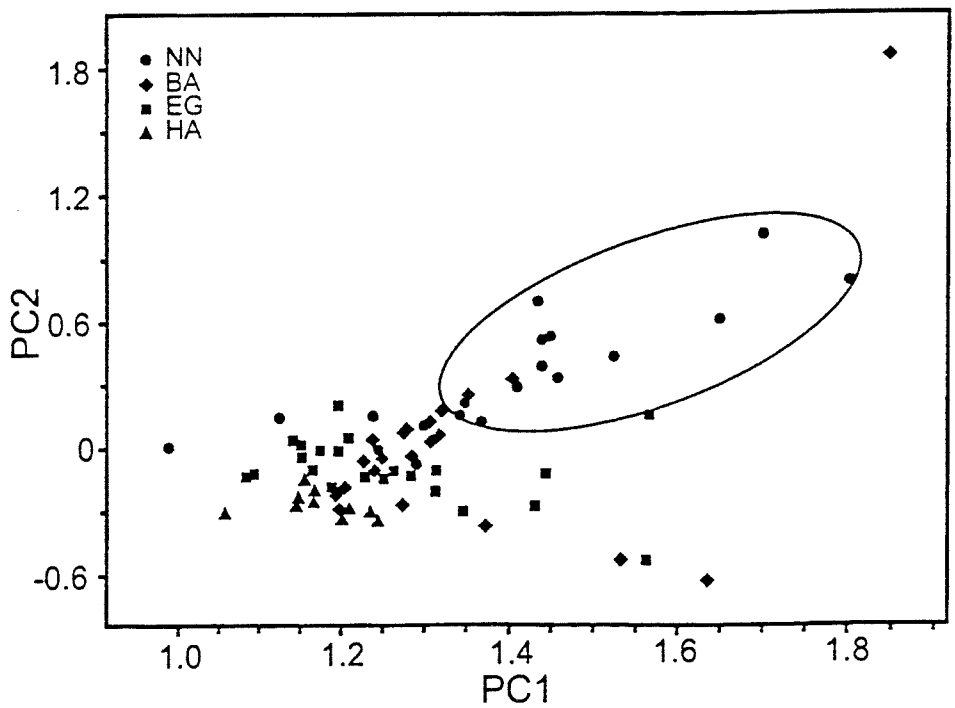

Figure 3. PCA score plot of cod liver, aromatic hydrocarbons and decalines as variables (SRD data)
Figur 3. PCA score plot av torskelever, aromatiske hydrokarboner og dekaliner som variable (SRD data)

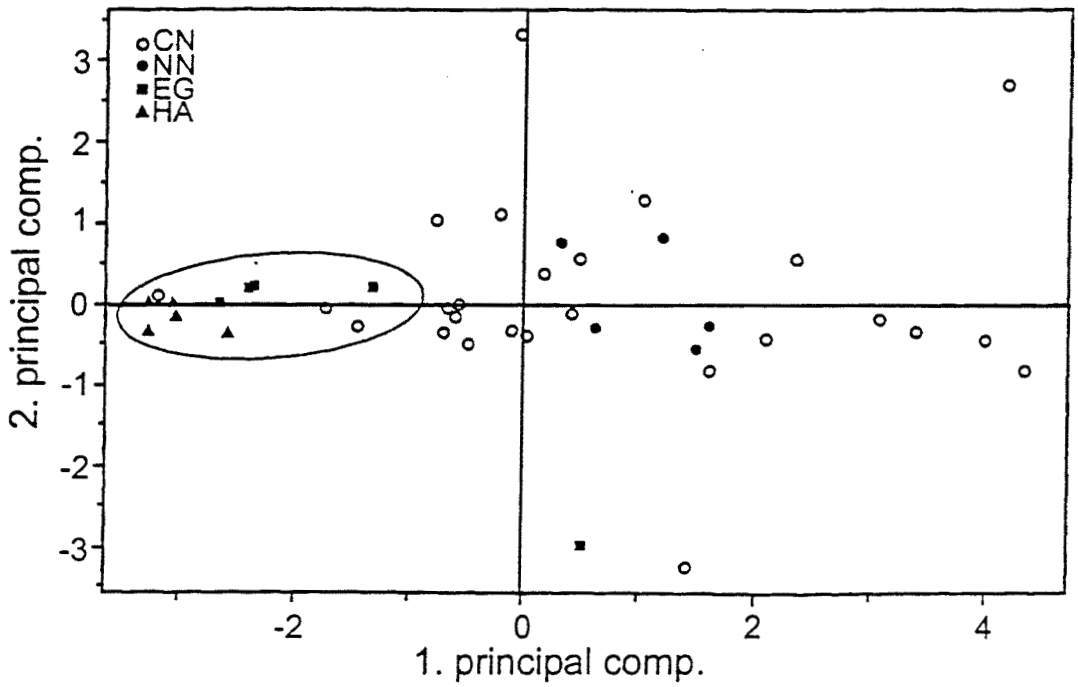

Figure 4. PCA score plot of haddoc liver, aromatic hydrocarbons and decalines as variables (IMR data)
Figur 4. PCA score plot av hyselever, aromatiske hydrokarboner og dekaliner som variable (IMR data)

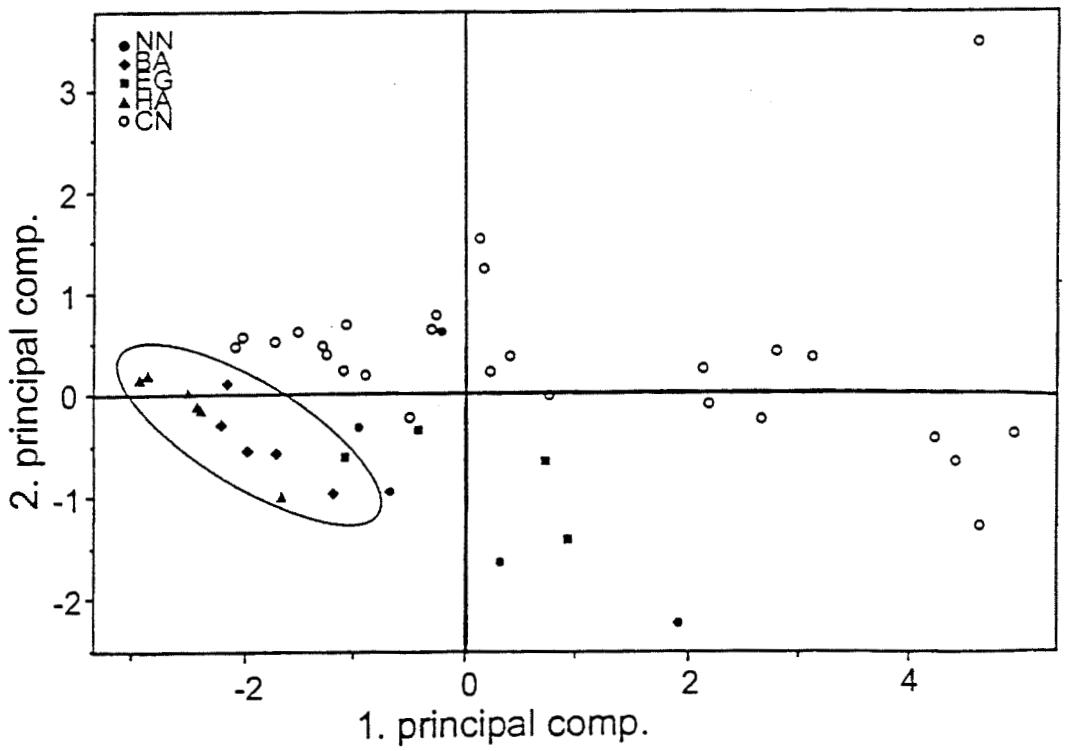

Figure 5. PCA score plot of cod liver, aromatic hydrocarbons and decalines as variables (IMR data)
Figur 5. PCA score plot av torskelever, aromatiske hydrokarboner og dekaliner som variable (IMR data)

IMR data

PCA was performed for the IMR data by applying quantitative results for aromatic hydrocarbons and decalines. For these data sets the number of replicates from most sampling areas is limited to 5, except for the Central North Sea. This limits the weight of the conclusions that can be made. Figures 4 and 5 show the PCA score plots for haddock and cod livers respectively. In both cases, PCA models describing more than 95% of the total variation in the data sets were obtained. The results clearly show the same trend for the IMR data as for the SRD data. The samples from the Northern North Sea and the Central North Sea are different in composition compared to the reference sites. This difference is caused mostly by the decalines, while the variation of aromatic hydrocarbons in the samples is of less importance.

6 DISCUSSION

From the quantitative results alone, no clear significant variation in THC levels between areas could be identified within the total data set. Average levels in fish liver ranged between 35-135 µg/g ww (Table 2). Analysis of THC is less specific than the analysis of individual hydrocarbons, and the contribution of natural biogenic compounds in the fish to the numbers obtained is probably quite high. This can mask weak signals of contamination by petroleum hydrocarbons in the fish. Variability between individual fish from the same area were also noted. The reason for this is not known, it may probably be caused by natural variablity between fish. Analytical problems with the preparation of "pure" THC fractions may also be part of this picture. However, the clean up procedure used in this study was more comprehensive than in previous studies on fish from the same areas (Aabel *et al.*, 1990; Moe *et al.*, 1994). The results for THC indicate that this type of method is not sensitive enough for detection of traces of oil hydrocarbons in fish.

No different levels of 2- to 6- ring aromatic hydrocarbons in fish were observed for any of the sampling areas. These observations are based on a number of samples collected in areas known to be exposed to various offshore petroleum activity and areas expected to be clean. Based on the large geographical scale in the sampling locations and general knowledge of hydrocarbon discharges, one might expect differences in background levels. This does not appear to be the situation. It is known that fish are able to quite effectively biotransform aromatic hydrocarbons like PAH due to the activity of the mixed-function oxygenase (MFO) enzymatic system, to more polar, water-soluble metabolites which can be excreted (Varanasi *et al.*, 1989). In experimental studies up to 99% of parent PAH have been converted to metabolites within 24h (Meador *et al.*, 1995; Varanasi *et al.*, 1989). Law *et al.* (1997) showed that concentrations of PAH in fish remained low even following a large spill of oil as in the case of *Sea Empress*. Due to the rapid metabolism, analysis of fish do therefore not necessarily provide a good indication of exposure. Analysis of aromatic hydrocarbons in fish should therefore be carried out mainly for food quality assurance purposes, and not for studies of geographical or temporal trends.

Analysis of C_0-C_5 alkyl decalines in fish liver showed distinct qualitative and quantitative differences between areas. Both results by the SRD and IMR laboratory showed that cod and

haddoc from the North Sea contained higher levels of decalines than fish from northern reference areas, the Haltenbanken and Barents Sea. This picture was more clear for haddoc than for cod liver. Big individual differences in levels beween fish from the same sampling areas partly masked the picture of the semiquantitative analysis of decalines. The results are in accordance with results from previous invstigations in the Norwegian sector of the North Sea and at Haltenbanken (Aabel *et al.*, 1990, Moe *et al.*, 1994).

The results from the PCA analysis of haddock livers clearly indicate that the content of C_0-C_5 alkyl decalines in the fish from the different sampling areas originates from different sources. For the samples collected in the Central and Northern North Sea, it is likely to assume that the petroleum related activity in the sampling area is the dominant source of the hydrocarbon composition in fish from that area. The elevated levels of decalines for both cod and haddoc at Egersundbanken compared to the northern reference locations may be caused by a general higher background concentration in the North Sea, an area yearly receiving high contaminant inputs from different sources.

There are basically two major sources of decalines in an area with high petroleum activity, oil containing cuttings and produced water. Accidental spills are regarded as less important. Since 1993 discharges of oil containing cuttings have been banned in the Norwegian sector of the North Sea. However, considerable amounts of hydrocarbons from previous discharges are trapped in the sediments close to older production fields, and this may serve as a contamination source. It is known that some of the base oils used as drilling fluid contain relatively high amounts of decalines, and these components have been regarded as tracer compounds for base oil contamination. However, decalines are also present in all crude oils and several refined oils, and the decaline patterns spotted in the present samples may very well originate from such sources. The observed composition of decalines may therefore be a result of both water and sediment exposure from different sources.

Further monitoring and studies of alkyl decalines is justified because of their ubiquity in fish from norwegian waters, to be able to document to what extent the quality of fish are influenced by such compounds compared to fish from other areas. However, before routine monitoring can be started there is a clear need for improvement of analytical procedures. One particularly important point is to produce new standards and standard reference materials which is essential to obtain reliable quantitative results. It is important to get a better understanding of the sources of decalines in fish, bioaccumulation and excretion of decalines and their potency for toxic effects.

7 ACKNOWLEDGEMENTS

A large number of people have devoted their time and expertise to this project. The authors wish to thank: The crew on board R/V Johan Hjort, R/V G.O. Sars, MV. Svanodd and MV. Kvernsund for help with the collection of samples. Liv Guri Faksnes, Janne Myrhaug, Rick Restucci and Bodil Torvaldsen for hydrocarbon analyses at Statoil Reseach Centre. Torunn Eide, Merete Fonn and Kjell Westrheim for hydrocarbons analyses at Institute of Marine Research. Carol Peven, Battelle Ocean Sciences for data handling and statistical treatment.

8 REFERENCES

Aabel, J.P., Rasmussen, t., Uppstad, B., Endresen, U., Grahl-Nielsen, O and Solheim, E (1990). Tissue hydrocarbon Analyses and Taste Assessment in Cod Caught Near the Field Centre. Rogaland Research Institute, Stavanger, Norway, report no.113/90, 53 pp.

Grahl-Nielsen, O. (1992). Dekaliner i Lever av Torsk fra Osebergfeltet, Egersundbanken og Haltenbanken. Project Memo from University of Bergen/Rogaland Research Institute, 2 pp.

ICES (1987). Guidelines for Temporal Trend Analysis of Data on Contaminants in Fish. In; Report of the ICES Advisory Committee on Marine Pollution. ICES Coop. Res. Report 142, pp. 15-17, 115-128.

Law, R.J., Kelly, C.A., Graham, K.L., Woodhead, R.J., Dyrunda, P.E.J., and Dyrunda, E.A. (1997). Hydrocarbons and PAH in fish and shellfish from southwest Wales following the Sea Empress oilspill in 1996. Proceedings of the 1997 Oilspill Conference, Fort Lauderdale, Florida 7-10 April 1997. American Petroleum Institute, Washington DC. Publication no. 4651. ISSN 75-4161, pp. 205-211

Meador, J.P, Stein, J.E., Reichert, W.L., and Varanasi, U. (1995). Bioaccumulation of polycyclic aromatic hydrocarbons by marine organisms. Rev. Environ. Contam. Toxicol., 143, 79-165

Moe, K.E., Skeie, G.M., Futseter, G., Reiertsen, L.O. and Tjessem, K. (1994). Accumulation of Hydrocarbons (Base oil, Crude oil and Fuel oil) in Fish from the North Sea (Statfjord and Oseberg Field Centre, Bank of Egersund), Bank of Halten, and Northwest of the Faroe Islands. SPE paper No. 27165, HSE Conference in Jakarta, Indonesia, pp. 583-592

Palmork, K. and Westrheim, K. (1988). Kjemisk Analyse av Fisk fra Statfjordområdet. Institute of Marine Research, Bergen, Norway, report No. BKO 8801, 27 pp.

Varanasi, U., Stein, J.E. and Nishimoto, M. (1989). Biotransformation and disposition of polycyclic aromatic hydrocarbons (PAH) in fish. In: Metabolism of Polycyclic Aromatic Hydrocarbons in the Aquatic Environment. Varanasi, U. (ed.), CRC Press, Boca Raton, pp. 94-149

APPENDIX 1: Fish sample information

Sample id.	Sex f=1/m=2	Lenght (cm)	Weight (g)
Cod Barents Sea-1774	2	44	890
Cod Barents Sea-1775	2	48	1075
Cod Barents Sea-1776	1	50	1085
Cod Barents Sea-1777	2	44	840
Cod Barents Sea-1778	2	51	1038
Cod Barents Sea-1779	1	48	1090
Cod Barents Sea-1780	2	45	800
Cod Barents Sea-1781	1	47	865
Cod Barents Sea-1782	2	45	900
Cod Barents Sea-1783	1	44	850
Cod Barents Sea-1784	1	50	1025
Cod Barents Sea-1785	-	44	850
Cod Barents Sea-1786	2	41	680
Cod Barents Sea-1787	1	46	890
Cod Barents Sea-1788	1	48	1015
Cod Barents Sea-1789	2	44	715
Cod Barents Sea-1790	2	47	905
Cod Barents Sea-1791	1	47	995
Cod Barents Sea-1792	1	47	980
Cod Barents Sea-1793	2	39	600
Cod Barents Sea-1795	-	44	955
Cod Barents Sea-1796	2	43	865
Cod Barents Sea-1797	1	46	830
Cod Barents Sea-1798	1	44	800
Cod Haltenbanken-1321	1	65	2650
Cod Haltenbanken-1687	2	74	4145
Cod Haltenbanken-1688	1	49	985
Cod Haltenbanken-1690	2	45	905
Cod Haltenbanken-1692	1	57	1595
Cod Haltenbanken-1693	2	48	1125
Cod Haltenbanken-1696	1	74	3910
Cod Haltenbanken-1697	2	50	860
Cod Haltenbanken-1698	1	72	3530
Cod Haltenbanken-1699	1	92	6790
Cod Haltenbanken-1700	1	99	7750
Cod Haltenbanken-1701	2	67	2820
Cod Haltenbanken-1702	1	91	6950
Cod Haltenbanken-1703	1	103	8750
Cod Haltenbanken-1704	1	65	2490
Cod Haltenbanken-1705	1	83	5840
Cod Haltenbanken-1706	2	74	3620
Cod Haltenbanken-1707	2	74	4100
Cod Haltenbanken-1708	1	75	3730

APPENDIX 1: Fish sample information

Sample id.	Sex f=1/m=2	Lenght (cm)	Weight (g)
Cod Haltenbanken-1709	1	82	5370
Cod Northern North Sea-1724	1	50	1255
Cod Northern North Sea-1725	1	50	1294
Cod Northern North Sea-1726	2	40	682
Cod Northern North Sea-1728	1	47	1237
Cod Northern North Sea-1731	2	47	1244
Cod Northern North Sea-1732	1	45	939
Cod Northern North Sea-1733	1	65	3132
Cod Northern North Sea-1744	1	41	714
Cod Northern North Sea-1745	1	42	771
Cod Northern North Sea-1746	1	42	699
Cod Northern North Sea-1747	2	40	661
Cod Northern North Sea-1748	2	41	738
Cod Northern North Sea-1749	2	41	663
Cod Northern North Sea-1750	2	45	1059
Cod Northern North Sea-1751	2	46	1007
Cod Northern North Sea-1752	2	48	1270
Cod Northern North Sea-1753	1	41	773
Cod Northern North Sea-1754	1	47	1137
Cod Northern North Sea-1755	2	46	1040
Cod Northern North Sea-1756	1	44	905
Cod Northern North Sea-1757	2	45	1007
Cod Northern North Sea-1758	1	48	1218
Cod Central North Sea-2256	1	48	1328
Cod Central North Sea-2257	2	44	836
Cod Central North Sea-2258	2	44	814
Cod Central North Sea-2259	1	48	1141
Cod Central North Sea-2260	2	37	550
Cod Central North Sea-2261	2	36	526
Cod Central North Sea-2262	2	37	468
Cod Central North Sea-2263	1	36	458
Cod Central North Sea-2264	2	35	416
Cod Central North Sea-2265	2	34	386
Cod Central North Sea-2266	2	33	360
Cod Central North Sea-2267	1	31	314
Cod Central North Sea-2268	2	32	291
Cod Central North Sea-2240	2	34	445
Cod Central North Sea-2241	2	34	445
Cod Central North Sea-2244	2	39	610
Cod Central North Sea-2245	1	34	445
Cod Central North Sea-2246	1	32	340
Cod Central North Sea-2215	1	44	900
Cod Central North Sea-2216	1	33	420

APPENDIX 1: Fish sample information

Sample id.	Sex f=1/m=2	Lenght (cm)	Weight (g)
Cod Central North Sea-2220	1	35	470
Cod Central North Sea-2221	1	33	460
Cod Central North Sea-2222	2	32	370
Cod Central North Sea-2223	1	35	520
Cod Central North Sea-2225	1	37	535
Cod Egersundbanken-1448	2	32	390
Cod Egersundbanken-1500	1	30	285
Cod Egersundbanken-1501	2	32	325
Cod Egersundbanken-1502	1	29	280
Cod Egersundbanken-1503	1	29	280
Cod Egersundbanken-1504	1	30	245
Cod Egersundbanken-1505	1	35	415
Cod Egersundbanken-1506	1	28	220
Cod Egersundbanken-1507	1	30	295
Cod Egersundbanken-1508	2	28	230
Cod Egersundbanken-1509	1	32	325
Cod Egersundbanken-1510	2	28	225
Cod Egersundbanken-1511	1	28	245
Cod Egersundbanken-1512	2	29	260
Cod Egersundbanken-1513	2	27	195
Cod Egersundbanken-1514	1	28	245
Cod Egersundbanken-1515	2	28	195
Cod Egersundbanken-1516	2	25	150
Cod Egersundbanken-1517	2	27	195
Cod Egersundbanken-1518	2	27	185
Cod Egersundbanken-1519	2	25	155
Cod Egersundbanken-1520	2	27	175
Cod Egersundbanken-1521	2	29	225
Cod Egersundbanken-1522	1	28	175
Cod Egersundbanken-1523	2	25	135
Haddoc Haltenbanken-1222	2	31	370
Haddoc Haltenbanken-1223	2	32	325
Haddoc Haltenbanken-1224	2	30	300
Haddoc Haltenbanken-1225	2	32	350
Haddoc Haltenbanken-1226	2	32	335
Haddoc Haltenbanken-1227	1	32	310
Haddoc Haltenbanken-1228	2	31	315
Haddoc Haltenbanken-1231	1	34	365
Haddoc Haltenbanken-1232	2	47	1095
Haddoc Haltenbanken-1233	2	32	335
Haddoc Haltenbanken-1234	2	57	1985
Haddoc Haltenbanken-1235	2	49	1375
Haddoc Haltenbanken-1236	1	50	1155

APPENDIX 1: Fish sample information

Sample id.	Sex f=1/m=2	Lenght (cm)	Weight (g)
Haddoc Haltenbanken-1237	1	33	340
Haddoc Haltenbanken-1239	2	33	330
Haddoc Haltenbanken-1240	2	36	515
Haddoc Haltenbanken-1241	2	36	510
Haddoc Haltenbanken-1242	1	34	390
Haddoc Haltenbanken-1243	1	31	320
Haddoc Haltenbanken-1245	2	31	300
Haddoc Northern North Sea-1397	2	36	555
Haddoc Northern North Sea-1400	1	39	605
Haddoc Northern North Sea-1401	1	41	825
Haddoc Northern North Sea-1403	1	36	500
Haddoc Northern North Sea-1404	1	33	450
Haddoc Northern North Sea-1405	2	38	650
Haddoc Northern North Sea-1406	2	42	930
Haddoc Northern North Sea-1407	2	40	825
Haddoc Northern North Sea-1408	1	41	750
Haddoc Northern North Sea-1409	1	35	545
Haddoc Northern North Sea-1410	2	37	645
Haddoc Northern North Sea-1411	1	37	620
Haddoc Northern North Sea-1412	2	37	500
Haddoc Northern North Sea-1413	1	32	390
Haddoc Northern North Sea-1414	2	37	555
Haddoc Northern North Sea-1415	2	30	350
Haddoc Northern North Sea-1416	1	33	405
Haddoc Northern North Sea-1417	2	54	420
Haddoc Northern North Sea-1419	1	31	325
Haddoc Northern North Sea-1420	1	32	325
Haddoc Northern North Sea-1421	2	34	425
Haddoc Central North Sea-2357	1	42	1041
Haddoc Central North Sea-2358	2	44	971
Haddoc Central North Sea-2359	2	43	860
Haddoc Central North Sea-2360	1	40	826
Haddoc Central North Sea-2361	2	37	551
Haddoc Central North Sea-2362	1	39	638
Haddoc Central North Sea-2363	1	38	679
Haddoc Central North Sea-2364	2	36	542
Haddoc Central North Sea-2365	2	37	520
Haddoc Central North Sea-2366	2	34	525
Haddoc Central North Sea-2286	2	35	465
Haddoc Central North Sea-2328	1	38	645
Haddoc Central North Sea-2329	2	31	330
Haddoc Central North Sea-2330	1	40	660
Haddoc Central North Sea-2331	1	35	460

APPENDIX 1: Fish sample information

Sample id.	Sex f=1/m=2	Lenght (cm)	Weight (g)
Haddoc Central North Sea-2332	2	40	755
Haddoc Central North Sea-2333	2	35	450
Haddoc Central North Sea-2334	1	31	270
Haddoc Central North Sea-2335	2	38	605
Haddoc Central North Sea-2336	2	35	410
Haddoc Central North Sea-2337	2	33	390
Haddoc Central North Sea-2338	1	35	480
Haddoc Central North Sea-2339	2	32	350
Haddoc Central North Sea-2340	2	30	305
Haddoc Egersundbanken-1246	1	35	425
Haddoc Egersundbanken-1248	1	31	305
Haddoc Egersundbanken-1249	1	32	310
Haddoc Egersundbanken-1251	2	31	290
Haddoc Egersundbanken-1252	1	36	445
Haddoc Egersundbanken-1253	1	34	425
Haddoc Egersundbanken-1254	2	32	330
Haddoc Egersundbanken-1255	1	37	590
Haddoc Egersundbanken-1256	2	31	310
Haddoc Egersundbanken-1257	1	35	405
Haddoc Egersundbanken-1258	1	34	385
Haddoc Egersundbanken-1260	1	39	770
Haddoc Egersundbanken-1261	1	38	595
Haddoc Egersundbanken-1262	1	34	410
Haddoc Egersundbanken-1263	2	32	370
Haddoc Egersundbanken-1264	2	33	345
Haddoc Egersundbanken-1265	2	30	280
Haddoc Egersundbanken-1266	2	35	415
Haddoc Egersundbanken-1267	1	36	500
Haddoc Egersundbanken-1268	2	35	425
Haddoc Egersundbanken-1269	1	35	510
Haddoc Egersundbanken-1270	2	37	580
Saithe Central North Sea-3830	1	45	825
Saithe Central North Sea-3831	2	53	1404
Saithe Central North Sea-3832	1	40	542
Saithe Central North Sea-3833	2	48	996
Saithe Central North Sea-3834	1	46	1055
Saithe Central North Sea-3835	2	44	791
Saithe Central North Sea-3836	2	43	707
Saithe Central North Sea-3837	1	46	885
Saithe Central North Sea-3838	2	43	618
Saithe Central North Sea-3839	1	46	908
Saithe Central North Sea-3840	1	45	903
Saithe Central North Sea-3841	1	45	805

APPENDIX 1: Fish sample information

Sample id.	Sex f=1/m=2	Lenght (cm)	Weight (g)
Saithe Central North Sea-3842	1	52	1339
Saithe Central North Sea-3843	1	47	1004
Saithe Central North Sea-3844	2	43	664
Saithe Central North Sea-3845	1	43	743
Saithe Central North Sea-3846	1	52	1214
Saithe Central North Sea-3847	1	51	1235
Saithe Central North Sea-3848	2	49	1098
Saithe Central North Sea-3849	2	43	853
Saithe Central North Sea-3850	2	44	920
Saithe Central North Sea-3851	2	46	982
Saithe Central North Sea-3852	2	48	1002
Saithe Central North Sea-3853	1	44	725
Saithe Central North Sea-3854	1	54	1378

APPENDIX 2: Intercomparison of results for selected 2- and 3-ring aromatic hydrocarbons analysed by SRD and IMR. Concentrations in ng/g ww.

Sample i.d.	Laboratory	NAP	C1-NAP	C2-NAP	C3-NAP	FLE	ANT	PHE	C1-PHE	C2-PHE	DBT	C1-DBT	C2-DBT	C3-DBT
Haddoc Haltenbanken-1232	SRD	405.8	490.0	996.5	2131.9	40.6	393.5	194.8	225.8	1814.8	13.9	61.9	115.5	235.5
	IMR	-	8.3	13.1	16.3	-	-	-	-	3.4	-	-	-	3.4
	SRD/IMR		59.3	75.9	130.5					527.7				69.8
Haddoc Haltenbanken-1234	SRD	553.5	514.5	931.0	1871.3	20.3	8.1	56.1	65.2	61.9	21.6	58.1	74.5	75.8
	IMR	-	-	9.3	11.0	-	-	-	-	-	-	-	-	-
	SRD/IMR			100.5	170.5									
Haddoc Haltenbanken-1235	SRD	390.6	501.6	736.5	1319.7	45.8	6.1	82.3	58.1	46.5	21.6	50.0	51.6	44.2
	IMR	-	8.5	-	14.5	-	-	-	-	-	-	-	-	-
	SRD/IMR		58.9		91.2									
Haddoc Haltenbanken-1236	SRD	307.9	300.7	431.4	718.6	34.5	7.2	73.8	55.9	47.6	11.4	30.0	33.1	34.1
	IMR	-	-	9.1	10.7	-	-	-	-	-	-	-	-	2.5
	SRD/IMR			47.3	67.4						-			13.8
Haddoc Haltenbanken-1240	SRD	350.8	447.6	844.8	1880.4	34.4	8.8	69.6	80.0	94.4	15.6	41.2	44.8	64.4
	IMR	-	-	15.6	21.6	-	-	3.5	-	3.3	-	1.3	1.9	-
	SRD/IMR			54.3	87.1			19.8		29.0		31.7	24.1	
Haddoc Egersundbanken-1267	SRD	334.4	418.8	596.8	1055.6	49.6	7.2	84.8	76.0	82.8	30.0	67.2	79.2	84.8
	IMR	-	9.2	13.9	16.2	-	-	-	-	2.5	-	-	-	4.2
	SRD/IMR		45.4	42.8	65.2					33.8				20.4
Haddoc Egersundbanken-1269	SRD	360.8	428.4	570.8	934.4	42.4	7.2	69.6	64.8	64.4	24.0	58.0	76.0	56.0
	IMR	-	7.4	12.4	18.3	-	-	-	2.9	4.7	-	-	2.4	8.1
	SRD/IMR		57.8	46.2	51.1				22.4	13.8			31.0	6.9
Haddoc Egersundbanken-1270	SRD	260.8	347.2	535.6	811.6	38.0	5.2	56.4	52.4	44.0	15.6	36.8	49.6	38.0
	IMR	-	-	24.3	18.4	-	-	-	3.8	2.7	-	-	-	-
	SRD/IMR			22.1	44.0				13.6	16.3				
Haddoc Northern North Sea-1401	SRD	483.8	636.6	1078.3	1654.5	52.8	6.9	102.4	60.3	45.5	23.8	39.3	51.4	52.8
	IMR	-	10.7	18.4	13.2	-	-	-	-	7.3	1.8	2.7	3.9	11.8
	SRD/IMR		59.6	58.7	125.7					6.2	13.3	14.7	13.3	4.5
Haddoc Northern North Sea-1407	SRD	366.8	166.0	193.5	183.8	15.3	2.0	85.0	26.5	14.0	5.0	6.0	7.3	5.0
	IMR	-	10.8	24.5	14.3	3.2	-	4.1	-	6.9	1.6	-	3.3	6.8
	SRD/IMR		15.3	7.9	12.9	4.7		21.0		2.0	3.1		2.2	0.7

APPENDIX 2: Intercomparison of results for selected 2- and 3-ring aromatic hydrocarbons analysed by SRD and IMR. Concentrations in ng/g ww.

Sample i.d.	Laboratory	NAP	C1-NAP	C2-NAP	C3-NAP	FLE	ANT	PHE	C1-PHE	C2-PHE	DBT	C1-DBT	C2-DBT	C3-DBT
Haddoc Northern North Sea-1410	SRD	707.7	737.7	1525.0	3417.7	40.4	8.1	98.1	54.6	51.5	24.2	35.0	[illegible]	48.5
	IMR	-	7.6	14.5	13.6	-	-	-	-	-	1.4	-	-	-
	SRD/IMR		96.9	104.9	251.7						17.9			
Cod Egersundbanken-1501	SRD	766.0	754.7	1059.3	1932.0	151.3	125.3	89.3	14.7	22.0	26.7	65.3	83.3	46.7
	IMR	20.8	12.8	26.1	23.6	4.2	-	-	-	4.2	-	1.7	2.0	4.0
	SRD/IMR	36.8	59.2	40.6	81.8	36.1				5.3		37.7	40.8	11.6
Cod Egersundbanken-1503	SRD	1182.0	1142.0	1404.0	2267.0	297.0	303.0	173.0	28.0	36.0	51.0	119.0	146.0	112.0
	IMR	35.6	17.1	48.2	45.7	6.9	-	5.5	4.3	4.3	2.7	2.7	2.9	3.9
	SRD/IMR	33.2	66.8	29.1	49.6	42.8		31.5	6.6	8.3	19.1	44.0	50.9	28.6
Cod Egersundbanken-1505	SRD	454.3	532.4	963.8	1938.6	101.9	98.6	86.7	16.7	29.5	25.7	101.0	118.1	108.6
	IMR	-	8.8	21.5	21.5	3.1	-	-	-	3.2	-	1.4	-	4.9
	SRD/IMR		60.3	44.8	90.1	32.4				9.3		69.7		22.0
Cod Egersundbanken-1509	SRD	226.1	300.9	830.4	2077.4	46.5	53.9	40.9	4.8	13.5	19.1	37.4	38.3	34.3
	IMR	-	7.7	9.6	22.1	3.5	-	4.2	-	4.6	1.7	-	3.3	6.7
	SRD/IMR		39.0	86.2	94.0	13.3		9.8		2.9	11.0		11.7	5.2
Cod Haltenbanken-1696	SRD	176.7	194.0	380.0	781.3	33.0	30.3	46.0	-	28.0	30.0	36.0	51.7	38.0
	IMR	-	-	9.0	11.0	-	1.3	7.3	-	-	-	-	-	-
	SRD/IMR			42.3	70.9		23.1	6.3						
Cod Haltenbanken-1698	SRD	125.8	152.9	283.9	621.3	21.0	18.1	39.4	-	17.1	25.2	26.8	51.3	12.9
	IMR	-	13.0	13.3	-	4.1	1.4	7.4	-	-	-	-	-	-
	SRD/IMR		11.8	21.3		5.1	12.8	5.3						
Cod Haltenbanken-1699	SRD	86.6	105.5	176.8	294.7	12.6	10.5	29.5	-	10.8	12.6	14.2	23.4	15.0
	IMR	-	14.0	19.2	13.0	4.8	-	-	-	-	-	-	-	-
	SRD/IMR		7.5	9.2	22.6	2.6								
Cod Haltenbanken-1709	SRD	134.7	147.4	273.2	527.9	19.7	17.9	38.8	-	15.0	21.8	27.9	40.6	32.6
	IMR	-	33.3	47.7	48.6	13.4	3.2	6.6	-	-	-	2.2	-	5.9
	SRD/IMR		4.4	5.7	10.9	1.5	5.7	5.8		-		12.9		5.6
Cod Northern North Sea-1725	SRD	131.2	166.5	330.0	669.7	20.6	21.2	28.2	-	11.8	15.6	22.1	35.3	28.2
	IMR	25.2	8.6	20.8	12.9	3.2	-	-	-	-	1.5	-	-	-
	SRD/IMR	5.2	19.4	15.8	52.0	6.5					10.4			

APPENDIX 2: Intercomparison of results for selected 2- and 3-ring aromatic hydrocarbons analysed by SRD and IMR. Concentrations in ng/g ww.

Sample i.d.	Laboratory	NAP	C1-NAP	C2-NAP	C3-NAP	FLE	ANT	PHE	C1-PHE	C2-PHE	DBT	C1-DBT	C2-DBT	C3-DBT
Cod Northern North Sea-1733	SRD	81.9	99.4	99.7	97.8	22.2	16.9	21.3	-	17.5	131.3	132.2	252.8	306.3
	IMR	-	29.3	18.4	-	10.9	1.1	-	4.0	3.1	1.8	-	1.0	3.4
	SRD/IMR		3.4	5.4		2.0	15.8			5.6	73.7		260.6	90.1
Cod Barents Sea-1775	SRD	161.6	155.3	346.9	678.4	16.3	19.1	36.6	3.8	12.8	12.5	16.9	37.2	37.2
	IMR	31.6	14.3	36.7	16.1	23.7	1.2	-	-	2.8	-	-	4.0	6.5
	SRD/IMR	5.1	10.9	9.5	42.3	0.7	16.5			4.6			9.4	5.7
Cod Barents Sea-1779	SRD	186.6	230.6	498.4	950.3	29.1	38.4	64.4	-	15.3	9.7	20.0	45.6	44.1
	IMR	26.8	10.5	25.6	14.6	4.9	1.0	-	-	-	-	-	2.6	7.7
	SRD/IMR	7.0	21.9	19.4	65.3	5.9	39.8						17.3	5.7
Cod Barents Sea-1784	SRD	134.4	150.6	281.9	563.1	27.5	32.8	39.7	-	18.4	22.8	31.9	44.4	30.9
	IMR	34.9	10.4	16.7	12.7	3.9	-	3.6	18.7	4.3	-	-	1.1	2.6
	SRD/IMR	3.8	14.5	16.8	44.3	7.1		10.9		4.3			38.9	11.7
Cod Barents Sea-1787	SRD	127.3	127.3	248.0	485.4	15.9	17.3	35.9	-	12.0	12.7	17.3	30.2	31.0
	IMR	29.2	12.2	25.6	18.8	5.1	-	-	32.3	19.1	-	-	3.7	-
	SRD/IMR	4.4	10.5	9.7	25.8	3.1				0.6			8.2	-
Cod Barents Sea-1791	SRD	137.4	150.0	321.5	690.9	19.1	20.9	35.3	-	7.1	11.8	16.5	25.6	25.9
	IMR	-	10.3	19.3	15.8	3.8	1.0	-	-	5.3	-	3.6	-	4.3
	SRD/IMR		14.5	16.7	43.7	5.0	20.9			1.3		4.5	-	6.0

-: below detection limit (LOD)
SRD/IMR: Between laboratory ratio

NAP: Naphthalene; C1-NAP: C1-Naphthalenes; C2-NAP: C2-Naphthalenes; C3-NAP: C3-Naphthalenes
FLE: Fluorene; ANT: Anthracene; PHE: Phenanthrene; C1-PHE: C1-Phenanthrenes; C2-PHE: C2-Phenanthrenes
DBT: Dibenzothiophene; C1-DBT: C1-Dibenzothiophenes; C2-DBT: C2-Dibenzothiophenes; C3-DBT: C3-Dibenzothiophenes

APPENDIX 2: Intercomparison of results for selected 3- to 6-ring aromatic hydrocarbons analysed by SRD and IMR. Concentrations in ng/g ww.

Sample i.d.	Laboratory	Ace-naphten	Ace-naphtyl	FLU	PYR	BAA	CHR	BAP	DBAH ACA	BGHIP	ICDP
Haddoc Haltenbanken-1232	SRD	4.84	11.61	80.32	29.35	23.23	107.10	46.13	-	-	-
	IMR	2.37	1.05	1.63	-	-	-	-	-	-	-
	SRD/IMR	2.05	11.08	49.19							
Haddoc Haltenbanken-1234	SRD	1.29	6.13	12.90	15.81	33.23	227.42	25.16	47.10	28.06	14.19
	IMR	3.44	0.95	1.26	-	-	-	-	-	-	-
	SRD/IMR	0.38	6.47	10.21							
Haddoc Haltenbanken-1235	SRD	3.23	14.52	14.19	15.81	16.45	55.81	17.10	50.32	65.81	6.45
	IMR	2.43	1.23	1.58	-	-	-	-	-	-	-
	SRD/IMR	1.33	11.82	8.99							
Haddoc Haltenbanken-1236	SRD	1.03	10.69	12.76	15.86	4.14	20.34	2.41	2.07	1.38	1.03
	IMR	1.59	25.25	1.21	-	-	-	-	-	-	-
	SRD/IMR	0.65	0.42	10.58							
Haddoc Haltenbanken-1240	SRD	2.40	22.00	11.20	12.40	14.40	52.40	10.40	38.80	46.00	3.60
	IMR	2.00	16.61	1.55	-	-	-	-	-	-	-
	SRD/IMR	1.20	1.32	7.22							
Haddoc Egersundbanken-1267	SRD	20.40	26.80	12.40	29.20	16.80	43.60	20.80	-	-	6.40
	IMR	2.28	1.60	1.15	-	-	-	-	-	-	-
	SRD/IMR	8.95	16.75	10.83							
Haddoc Egersundbanken-1269	SRD	14.40	16.40	12.40	15.60	16.80	70.00	-	-	-	-
	IMR	1.80	1.42	1.13	-	-	-	-	-	-	-
	SRD/IMR	8.00	11.57	10.98							
Haddoc Egersundbanken-1270	SRD	12.40	16.40	12.40	26.00	10.80	49.60	4.00	-	-	-
	IMR	1.79	-	1.04	-	-	-	-	-	-	-
	SRD/IMR	6.93		11.91							
Haddoc Northern North Sea-1401	SRD	14.48	14.83	15.17	13.79	9.31	37.24	3.45	-	-	-
	IMR	2.42	1.95	1.20	-	-	-	-	-	-	-
	SRD/IMR	5.98	7.60	12.61							
Haddoc Northern North Sea-1407	SRD	4.50	6.00	8.75	12.25	4.00	15.00	3.00	-	-	-
	IMR	3.62	-	1.56	1.43	-	-	-	-	-	-
	SRD/IMR	1.24		5.62	8.56						

APPENDIX 2: Intercomparison of results for selected 3- to 6-ring aromatic hydrocarbons analysed by SRD and IMR. Concentrations in ng/g ww.

Sample i.d.	Laboratory	Ace-naphten	Ace-naphtyl	FLU	PYR	BAA	CHR	BAP	DBAH ACA	BGHIP	ICDP
Haddoc Northern North Sea-1410	SRD	6.92	11.15	15.38	13.85	6.15	33.46	-	1.15	-	-
	IMR	2.88	-	-	-	-	-	-	-	-	-
	SRD/IMR	2.40									
Cod Egersundbanken-1501	SRD	174.00	11.33	26.67	22.67	-	4.00	-	-	-	-
	IMR	4.16	2.17	1.53	-	-	-	-	-	-	-
	SRD/IMR	41.85	5.22	17.42							
Cod Egersundbanken-1503	SRD	331.00	53.00	49.00	42.00	2.00	8.00	1.00	-	-	-
	IMR	4.52	6.05	1.50	-	-	-	-	-	-	-
	SRD/IMR	73.18	8.76	32.62							
Cod Egersundbanken-1505	SRD	111.90	8.57	15.24	24.29	-	2.38	-	-	-	-
	IMR	2.55	1.57	-	-	-	-	-	-	-	-
	SRD/IMR	43.83	5.47								
Cod Egersundbanken-1509	SRD	67.83	5.22	6.52	7.83	-	-	-	-	-	-
	IMR	5.05	2.77	1.12	-	-	-	-	-	-	-
	SRD/IMR	13.44	1.89	5.82							
Cod Haltenbanken-1696	SRD	71.67	5.00	6.00	5.33	1.00	2.33	1.33	2.00	4.33	-
	IMR	-	1.28	-	-	-	-	-	-	-	-
	SRD/IMR		3.91								
Cod Haltenbanken-1698	SRD	45.48	2.58	4.52	3.87	-	-	-	5.81	11.94	-
	IMR	1.34	2.39	1.40	-	-	-	-	-	-	-
	SRD/IMR	33.89	1.08	3.24							
Cod Haltenbanken-1699	SRD	26.05	1.84	2.63	2.37	-	-	-	-	-	-
	IMR	1.19	2.87	-	-	-	-	-	-	-	-
	SRD/IMR	21.99	0.64								
Cod Haltenbanken-1709	SRD	38.82	2.94	10.88	4.41	-	1.18	-	2.06	5.59	-
	IMR	7.52	5.66	1.63	-	-	1.04	-	-	-	-
	SRD/IMR	5.16	0.52	6.68			1.13				
Cod Northern North Sea-1725	SRD	36.18	2.65	2.65	2.94	-	-	-	1.18	1.47	-
	IMR	2.44	-	-	2.12	1.70	2.15	1.05	-	-	-
	SRD/IMR	14.82			1.39						

APPENDIX 2: Intercomparison of results for selected 3- to 6-ring aromatic hydrocarbons analysed by SRD and IMR. Concentrations in ng/g ww.

Sample i.d.	Laboratory	Ace-naphten	Ace-naphtyl	FLU	PYR	BAA	CHR	BAP	DBAH ACA	BGHIP	ICDP
Cod Northern North Sea-1733	SRD	57.19	4.38	70.63	60.00	1.88	13.75	-	-	-	-
	IMR	2.21	1.91	-	-	-	-	-		-	-
	SRD/IMR	25.90	2.29								
Cod Barents Sea-1775	SRD	27.50	3.44	1.56	1.88	-	-	-	0.94	2.19	-
	IMR	3.95	2.09	-	-	-	-	-	-	-	-
	SRD/IMR	6.96	1.64								
Cod Barents Sea-1779	SRD	44.38	5.31	3.44	3.75	-	1.88	-	2.19	4.69	-
	IMR	2.11	2.27	-	-	-	-	-	-	-	-
	SRD/IMR	21.04	2.34								
Cod Barents Sea-1784	SRD	46.56	3.13	2.50	3.75	-	-	-	1.56	4.06	-
	IMR	1.52	1.23	-	-	-	-	-	-	-	-
	SRD/IMR	30.71	2.55								
Cod Barents Sea-1787	SRD	27.80	2.93	1.95	1.95	-	-	-	1.22	2.68	-
	IMR	1.77	1.01	-	-	-	-	-	-	-	-
	SRD/IMR	15.73	2.90								
Cod Barents Sea-1791	SRD	29.71	2.65	2.35	2.35	-	-	-	-	2.06	-
	IMR	1.88	-	2.91	2.46	-	-	-	-	-	-
	SRD/IMR	15.82		0.81	0.96						

-: below detection limit (LOD)
SRD/IMR: Between laboratory ratio

FLU: Fluoranthene; PYR: Pyrene; BAA: Benz(a)anthracene; CHR: Chrysene; BAP: Benz(a)pyrene
DBAHACA: Dibenz(a,c+a,h)anthracenes; BGHIP: Benzo(ghi)perylene; ICDP: Indeno(1,2,3-cd)pyrene

APPENDIX 2: Intercomparison of results for THC and decalines analysed by SRD and IMR

Sample i.d.	Laboratory	Decalin ng/g ww	C1-Decalines ng/g ww	C2-Decalines ng/g ww	C3-Decalines ng/g ww	C4-Decalines ng/g ww	C5-Decalines ng/g ww	THC ug/g ww
Haddoc Haltenbanken-1232	SRD	4.52	8.39	10.00	-	-	363.55	45.5
	IMR	-	13.40	92.46	113.13	168.00	185.94	47.3
	SRD/IMR		0.63	0.11			1.96	0.96
Haddoc Haltenbanken-1234	SRD	12.58	15.16	11.29	8.39	13.23	19.68	-
	IMR	-	-	18.06	43.84	65.77	60.49	25.4
	SRD/IMR			0.63	0.19	0.20	0.33	
Haddoc Haltenbanken-1235	SRD	21.61	36.45	25.81	18.39	28.39	28.71	84.1
	IMR	2.41	5.83	23.53	17.51	23.10	24.39	50.3
	SRD/IMR	8.98	6.26	1.10	1.05	1.23	1.18	1.67
Haddoc Haltenbanken-1236	SRD	5.86	8.28	5.17	3.10	3.45	3.79	53.2
	IMR	3.21	7.14	39.60	56.48	55.16	57.76	74.3
	SRD/IMR	1.83	1.16	0.13	0.05	0.06	0.07	0.72
Haddoc Haltenbanken-1240	SRD	74.80	108.80	72.00	78.80	248.40	184.40	84.7
	IMR	-	4.12	55.06	111.27	53.31	54.88	68.1
	SRD/IMR		26.41	1.31	0.71	4.66	3.36	1.24
Haddoc Egersundbanken-1267	SRD	98.80	190.00	125.20	72.40	93.20	110.80	13.5
	IMR	4.42	14.66	82.07	94.68	118.56	128.11	32.6
	SRD/IMR	22.36	12.96	1.53	0.76	0.79	0.86	0.41
Haddoc Egersundbanken-1269	SRD	105.20	200.40	152.80	98.40	89.20	100.00	44.9
	IMR	6.43	22.94	110.79	113.77	143.25	155.96	48.9
	SRD/IMR	16.36	8.74	1.38	0.86	0.62	0.64	0.92
Haddoc Egersundbanken-1270	SRD	94.00	194.00	182.00	164.00	179.60	196.00	32.0
	IMR	8.86	40.92	228.90	259.62	301.24	305.96	59.2
	SRD/IMR	10.61	4.74	0.80	0.63	0.60	0.64	0.54
Haddoc Northern North Sea-1401	SRD	107.24	249.66	433.45	720.69	851.38	1031.72	-
	IMR	9.31	94.11	545.82	673.92	767.49	818.43	82.5
	SRD/IMR	11.51	2.65	0.79	1.07	1.11	1.26	

APPENDIX 2: Intercomparison of results for THC and decalines analysed by SRD and IMR

Sample i.d.	Laboratory	Decalin	C1-Decalines	C2-Decalines	C3-Decalines	C4-Decalines	C5-Decalines	THC
		ng/g ww	ng/g ww	ng/g ww	ng/g ww	ng/g ww	ng/g ww	ug/g ww
Haddoc Northern North Sea-1407	SRD	257.50	106.00	59.25	31.50	21.50	17.75	-
	IMR	10.88	108.00	534.71	669.50	771.71	785.19	60.1
	SRD/IMR	23.67	0.98	0.11	0.05	0.03	0.02	
Haddoc Northern North Sea-1410	SRD	238.08	323.08	723.85	1408.46	1446.15	1750.38	-
	IMR	17.05	105.61	520.16	575.34	582.54	591.00	76.1
	SRD/IMR	13.96	3.06	1.39	2.45	2.48	2.96	
Cod Egersundbanken-1501	SRD	176.67	357.33	267.33	122.00	155.33	220.67	21.9
	IMR	3.34	13.42	95.46	162.91	322.60	417.88	35.3
	SRD/IMR	52.91	26.63	2.80	0.75	0.48	0.53	0.62
Cod Egersundbanken-1503	SRD	286.00	550.00	350.00	169.00	249.00	320.00	137
	IMR	4.74	33.73	222.18	298.17	610.40	802.99	73.3
	SRD/IMR	60.40	16.31	1.58	0.57	0.41	0.40	1.87
Cod Egersundbanken-1505	SRD	120.48	229.05	153.33	85.24	104.29	169.05	-
	IMR	4.61	29.45	152.16	158.43	539.00	303.22	41.8
	SRD/IMR	26.16	7.78	1.01	0.54	0.19	0.56	
Cod Egersundbanken-1509	SRD	93.91	125.65	161.74	156.09	240.00	351.74	62.5
	IMR	5.54	42.90	265.51	291.34	478.06	616.71	72.4
	SRD/IMR	16.95	2.93	0.61	0.54	0.50	0.57	0.86
Cod Haltenbanken-1696	SRD	36.00	49.67	30.33	26.00	34.67	53.67	168
	IMR	-	-	16.02	25.99	35.95	65.46	64.4
	SRD/IMR			1.89	1.00	0.96	0.82	2.61
Cod Haltenbanken-1698	SRD	21.29	27.74	19.03	15.16	31.29	48.71	181
	IMR	-	3.47	27.01	46.87	112.35	202.88	72.2
	SRD/IMR		8.00	0.70	0.32	0.28	0.24	2.51
Cod Haltenbanken-1699	SRD	14.21	19.21	16.32	12.63	13.68	17.89	5.07
	IMR	-	3.54	17.58	41.91	101.60	152.74	34.3
	SRD/IMR		5.42	0.93	0.30	0.13	0.12	0.15

APPENDIX 2: Intercomparison of results for THC and decalines analysed by SRD and IMR

Sample i.d.	Laboratory	Decalin	C1-Decalines	C2-Decalines	C3-Decalines	C4-Decalines	C5-Decalines	THC
		ng/g ww	ng/g ww	ng/g ww	ng/g ww	ng/g ww	ng/g ww	ug/g ww
Cod Haltenbanken-1709	SRD	28.53	39.71	29.12	25.00	35.29	48.24	46.6
	IMR	-	4.92	30.88	49.18	208.20	105.45	29.8
	SRD/IMR		8.07	0.94	0.51	0.17	0.46	1.57
Cod Northern North Sea-1725	SRD	36.47	57.35	55.29	48.53	88.24	143.82	54.2
	IMR	-	18.01	159.87	145.97	448.43	464.91	68.1
	SRD/IMR		3.18	0.35	0.33	0.20	0.31	0.80
Cod Northern North Sea-1733	SRD	5.00	-	2.81	3.44	3.44	4.38	60.7
	IMR	8.25	51.45	194.04	163.67	236.42	371.24	93.3
	SRD/IMR	0.61		0.01	0.02	0.01	0.01	0.65
Cod Barents Sea-1775	SRD	30.63	44.38	56.88	75.00	98.75	171.88	85.1
	IMR	2.19	9.34	76.18	147.62	266.37	564.54	65.5
	SRD/IMR	14.02	4.75	0.75	0.51	0.37	0.30	1.30
Cod Barents Sea-1779	SRD	39.38	61.56	75.63	87.50	114.38	182.19	-
	IMR	-	8.23	59.68	108.21	191.40	384.41	68.2
	SRD/IMR		7.48	1.27	0.81	0.60	0.47	
Cod Barents Sea-1784	SRD	29.69	41.25	77.81	55.31	39.38	55.00	29.5
	IMR	-	11.61	95.31	99.89	98.03	123.86	51.2
	SRD/IMR		3.55	0.82	0.55	0.40	0.44	0.58
Cod Barents Sea-1787	SRD	28.78	37.32	50.24	52.68	53.66	87.56	65.6
	IMR	-	5.53	57.51	105.01	166.67	321.69	87.3
	SRD/IMR		6.74	0.87	0.50	0.32	0.27	0.75
Cod Barents Sea-1791	SRD	42.94	40.88	43.53	48.82	65.29	109.41	39.8
	IMR	-	5.91	43.10	71.20	149.47	240.51	44.9
	SRD/IMR		6.92	1.01	0.69	0.44	0.45	0.89

-: below detection limit (LOD)
SRD/IMR: Between laboratory ratio

APPENDIX 3: THC and C_0-C_5 decalines in fish liver (SRD data)

Sample id.	THC	Decalin	C1-Decalines	C2-Decalines	C3-Decalines	C4-Decalines	C5-Decalines	C0-C5 Decalines
	ug/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Cod Barents Sea-1774	67	47	70	71	92	108	164	553
Cod Barents Sea-1775	85	31	44	57	75	99	172	478
Cod Barents Sea-1776	228	147	196	147	128	139	197	952
Cod Barents Sea-1777	86	38	57	68	79	78	107	428
Cod Barents Sea-1778	105	32	48	65	63	59	84	351
Cod Barents Sea-1779	-	39	62	76	88	114	182	561
Cod Barents Sea-1780	42	33	43	44	37	40	13	210
Cod Barents Sea-1781	50	38	55	96	96	111	182	578
Cod Barents Sea-1782	66	36	51	61	78	86	134	446
Cod Barents Sea-1783	37	25	34	47	36	29	42	213
Cod Barents Sea-1784	29	30	41	78	55	39	55	298
Cod Barents Sea-1785	62	87	55	45	46	61	102	396
Cod Barents Sea-1786	437	210	258	170	130	142	198	1108
Cod Barents Sea-1787	66	29	37	50	53	54	88	310
Cod Barents Sea-1788	224	99	121	87	80	98	156	640
Cod Barents Sea-1789	-	50	77	229	57	60	72	544
Cod Barents Sea-1790	-	54	64	77	57	75	108	435
Cod Barents Sea-1791	40	43	41	44	49	65	109	351
Cod Barents Sea-1792	-	37	52	110	62	66	101	428
Cod Barents Sea-1793	13	53	71	110	61	76	95	466
Cod Barents Sea-1795	12	36	48	47	66	131	249	578
Cod Barents Sea-1796	-	36	52	67	81	96	139	471
Cod Barents Sea-1797	-	51	68	58	64	71	112	422
Cod Barents Sea-1798	-	34	53	64	80	88	147	466
Cod Haltenbanken-1321	-	44	61	35	26	42	61	269
Cod Haltenbanken-1688	28	59	78	41	31	47	69	323
Cod Haltenbanken-1690	18	49	69	41	30	43	52	284
Cod Haltenbanken-1692	44	31	42	25	19	43	45	205
Cod Haltenbanken-1693	43	33	43	27	19	33	50	205
Cod Haltenbanken-1696	168	36	50	30	26	35	54	230
Cod Haltenbanken-1697	3	38	52	41	24	16	19	190
Cod Haltenbanken-1698	181	21	28	19	15	31	49	163
Cod Haltenbanken-1699	5	14	19	16	13	14	18	94
Cod Haltenbanken-1700	-	64	79	45	34	44	63	328
Cod Haltenbanken-1701	26	56	77	21	30	37	48	269
Cod Haltenbanken-1702	8	47	62	35	24	34	48	249
Cod Haltenbanken-1703	220	32	42	25	20	28	38	185
Cod Haltenbanken-1704	57	30	40	23	18	25	37	173
Cod Haltenbanken-1705	53	29	40	23	17	24	33	167
Cod Haltenbanken-1706	106	30	39	25	17	23	32	167
Cod Haltenbanken-1707	31	26	37	22	18	22	29	155
Cod Haltenbanken-1708	38	37	45	27	20	30	40	200
Cod Haltenbanken-1709	47	29	40	29	25	35	48	206
Cod Northern North Sea-1724	57	39	71	81	79	142	189	601
Cod Northern North Sea-1725	54	36	57	55	49	88	144	430
Cod Northern North Sea-1726	147	54	81	92	88	158	242	716

APPENDIX 3: THC and C_0-C_5 decalines in fish liver (SRD data)

Sample id.	THC	Decalin	C1-Decalines	C2-Decalines	C3-Decalines	C4-Decalines	C5-Decalines	C0-C5 Decalines
	ug/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Cod Northern North Sea-1731	72	40	82	101	83	141	249	696
Cod Northern North Sea-1732	42	37	55	47	39	95	165	438
Cod Northern North Sea-1733	61	5	2	3	3	3	4	21
Cod Northern North Sea-1743	-	35	56	58	46	53	79	327
Cod Northern North Sea-1744	88	41	68	90	82	129	237	646
Cod Northern North Sea-1745	159	39	117	302	283	269	190	1200
Cod Northern North Sea-1746	92	30	75	126	99	152	222	704
Cod Northern North Sea-1747	44	33	62	102	94	119	169	580
Cod Northern North Sea-1748	-	43	80	106	115	264	559	1167
Cod Northern North Sea-1749	60	39	99	277	395	455	746	2010
Cod Northern North Sea-1750	35	43	91	140	141	217	364	995
Cod Northern North Sea-1751	4	39	60	54	53	117	218	541
Cod Northern North Sea-1752	20	37	63	62	46	74	119	401
Cod Northern North Sea-1753	76	44	71	93	96	187	352	843
Cod Northern North Sea-1754	120	41	74	95	80	128	220	638
Cod Northern North Sea-1755	54	38	74	123	108	120	181	644
Cod Northern North Sea-1756	67	66	89	64	45	80	158	502
Cod Northern North Sea-1757	12	35	58	54	40	78	129	394
Cod Northern North Sea-1758	-	53	80	60	63	136	211	603
Cod Egersundbanken-1448	84	128	279	259	195	167	243	1270
Cod Egersundbanken-1500	59	165	331	248	123	122	159	1149
Cod Egersundbanken-1501	22	177	357	267	122	155	221	1299
Cod Egersundbanken-1502	-	328	305	78	25	28	39	804
Cod Egersundbanken-1503	137	286	550	350	169	249	320	1924
Cod Egersundbanken-1504	156	264	509	359	197	189	241	1759
Cod Egersundbanken-1505	4	120	229	153	85	104	169	861
Cod Egersundbanken-1506	138	231	452	357	199	213	331	1783
Cod Egersundbanken-1507	43	169	321	236	128	147	228	1229
Cod Egersundbanken-1508	166	81	109	119	107	129	202	747
Cod Egersundbanken-1509	63	94	126	162	156	240	352	1129
Cod Egersundbanken-1510	233	199	263	243	210	234	336	1484
Cod Egersundbanken-1511	98	107	149	155	141	205	320	1077
Cod Egersundbanken-1512	64	117	190	227	189	341	515	1579
Cod Egersundbanken-1513	-	230	188	118	62	68	93	758
Cod Egersundbanken-1514	150	97	163	206	198	213	282	1159
Cod Egersundbanken-1515	251	133	185	237	236	264	350	1404
Cod Egersundbanken-1516	432	298	417	393	308	357	537	2310
Cod Egersundbanken-1517	176	131	168	127	95	133	205	859
Cod Egersundbanken-1518	192	126	183	173	133	163	247	1024
Cod Egersundbanken-1519	105	110	163	201	173	165	224	1036
Cod Egersundbanken-1520	155	161	211	204	153	179	257	1166
Cod Egersundbanken-1521	197	115	157	151	127	145	213	908
Cod Egersundbanken-1522	72	89	137	175	153	178	253	985
Cod Egersundbanken-1523	118	147	190	179	141	13	261	931
Haddoc Haltenbanken-1222	73	14	8	14	24	32	35	129
Haddoc Haltenbanken-1223	11	9	7	10	17	18	18	78

APPENDIX 3: THC and C_0-C_5 decalines in fish liver (SRD data)

Sample id.	THC	Decalin	C1-Decalines	C2-Decalines	C3-Decalines	C4-Decalines	C5-Decalines	C0-C5 Decalines
	ug/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Haddoc Haltenbanken-1224	81	15	8	19	22	36	42	140
Haddoc Haltenbanken-1225	21	12	12	32	36	54	56	201
Haddoc Haltenbanken-1226	11	-	-	-	-	-	-	-
Haddoc Haltenbanken-1227	8	18	14	22	23	39	46	162
Haddoc Haltenbanken-1228	23	-	-	-	-	-	-	-
Haddoc Haltenbanken-1231	42	30	23	36	52	74	82	297
Haddoc Haltenbanken-1232	46	5	8	10	0	0	364	386
Haddoc Haltenbanken-1233	26	13	19	12	6	8	10	68
Haddoc Haltenbanken-1234	3	13	15	11	8	13	20	80
Haddoc Haltenbanken-1235	84	22	36	26	18	28	29	159
Haddoc Haltenbanken-1236	53	6	8	5	3	3	4	30
Haddoc Haltenbanken-1237	51	26	36	22	13	21	23	141
Haddoc Haltenbanken-1239	1570	-	-	-	-	-	-	-
Haddoc Haltenbanken-1240	85	75	109	72	79	248	184	767
Haddoc Haltenbanken-1241	404	76	122	82	70	213	542	1104
Haddoc Haltenbanken-1242	135	120	-	-	-	-	-	120
Haddoc Haltenbanken-1243	16	185	287	171	75	169	249	1135
Haddoc Haltenbanken-1245	33	209	345	394	-	-	-	947
Haddoc Northern North Sea-1397	27	102	263	522	747	851	590	3074
Haddoc Northern North Sea-1400	144	119	178	236	284	271	292	1380
Haddoc Northern North Sea-1401	-	107	250	433	721	851	1032	3394
Haddoc Northern North Sea-1403	136	171	380	361	279	256	328	1775
Haddoc Northern North Sea-1404	101	130	455	1286	2088	2013	1856	7827
Haddoc Northern North Sea-1405	127	98	345	841	1220	1099	1141	4744
Haddoc Northern North Sea-1407	-	258	106	59	32	22	18	494
Haddoc Northern North Sea-1408	-	225	249	440	651	689	842	3096
Haddoc Northern North Sea-1409	-	298	497	971	1031	785	771	4353
Haddoc Northern North Sea-1410	-	238	323	724	1408	1446	1750	5890
Haddoc Northern North Sea-1411	-	436	429	886	1224	1009	1304	5289
Haddoc Northern North Sea-1412	-	262	288	544	556	449	588	2688
Haddoc Northern North Sea-1413	-	712	452	282	206	223	301	2175
Haddoc Northern North Sea-1414	17	302	253	294	322	348	497	2015
Haddoc Northern North Sea-1415	162	252	206	160	191	250	344	1404
Haddoc Northern North Sea-1416	33	230	212	196	14	190	256	1098
Haddoc Northern North Sea-1417	-	1380	914	475	312	327	414	3823
Haddoc Northern North Sea-1419	33	206	345	293	206	211	287	1548
Haddoc Northern North Sea-1420	37	1569	1159	921	846	838	889	6221
Haddoc Northern North Sea-1421	83	185	329	274	235	219	308	1551
Haddoc Egersundbanken-1246	18	70	148	113	72	75	90	568
Haddoc Egersundbanken-1248	64	75	130	110	63	71	72	521
Haddoc Egersundbanken-1249	21	67	126	87	45	49	59	433
Haddoc Egersundbanken-1251	39	97	178	147	87	70	85	663
Haddoc Egersundbanken-1252	39	100	188	133	66	66	77	630
Haddoc Egersundbanken-1253	133	75	157	165	180	185	245	1008
Haddoc Egersundbanken-1254	57	116	212	160	104	101	121	812
Haddoc Egersundbanken-1255	9	96	165	112	66	27	71	536

APPENDIX 3: THC and C_0-C_5 decalines in fish liver (SRD data)

Sample id.	THC	Decalin	C1-Decalines	C2-Decalines	C3-Decalines	C4-Decalines	C5-Decalines	C0-C5 Decalines
	ug/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Haddoc Egersundbanken-1257	8	100	179	142	74	84	107	687
Haddoc Egersundbanken-1258	-	92	160	108	49	48	72	529
Haddoc Egersundbanken-1262	7	93	185	155	100	89	143	766
Haddoc Egersundbanken-1263	49	94	186	140	84	94	87	684
Haddoc Egersundbanken-1264	12	324	640	365	126	173	206	1834
Haddoc Egersundbanken-1265	5	111	194	147	148	495	818	1912
Haddoc Egersundbanken-1266	20	142	251	134	53	74	68	722
Haddoc Egersundbanken-1267	14	99	190	125	72	93	111	690
Haddoc Egersundbanken-1268	16	91	163	108	49	51	66	530
Haddoc Egersundbanken-1269	45	105	200	153	98	89	100	746
Haddoc Egersundbanken-1270	32	94	194	182	164	180	196	1010

-: below limit of detection (LOD)

APPENDIX 4: THC and C_0-C_5 decalines in fish liver (IMR data)

Sample id.	THC µg/g	Decalin ng/g	C1-Decalines ng/g	C2-Decalines ng/g	C3-Decalines ng/g	C4-Decalines ng/g	C5-Decalines ng/g	C0-C5 Decalines ng/g
Cod Barents Sea-1775	65	2	9	76	148	266	565	1066
Cod Barents Sea-1779	68	-	8	60	108	191	384	752
Cod Barents Sea-1784	51	-	12	95	100	98	124	429
Cod Barents Sea-1787	87	-	6	58	105	167	322	656
Cod Barents Sea-1791	45	-	6	43	71	149	241	510
Cod Haltenbanken-1321	30	-	-	31	57	250	546	884
Cod Haltenbanken-1687	13	-	-	12	19	31	59	121
Cod Haltenbanken-1696	64	-	-	16	26	36	65	143
Cod Haltenbanken-1698	72	-	3	27	47	112	203	393
Cod Haltenbanken-1699	34	-	4	18	42	102	153	317
Cod Haltenbanken-1709	30	-	5	31	49	208	105	399
Cod Northern North Sea-1725	68	-	18	160	146	448	465	1237
Cod Northern North Sea-1728	68	6	43	232	296	722	1236	2534
Cod Northern North Sea-1731	39	3	31	156	187	483	926	1786
Cod Northern North Sea-1733	93	8	51	194	164	236	371	1025
Cod Northern North Sea-4396	38	4	24	122	141	278	414	984
Cod Central North Sea-2215	48	9	43	280	303	464	476	1575
Cod Central North Sea-2216	51	14	51	209	189	275	313	1050
Cod Central North Sea-2220	118	14	54	218	198	235	248	967
Cod Central North Sea-2221	77	13	87	512	451	625	671	2359
Cod Central North Sea-2222	82	10	40	183	192	264	308	998
Cod Central North Sea-2223	29	11	66	360	425	600	654	2117
Cod Central North Sea-2225	98	5	30	130	118	199	317	798
Cod Central North Sea-2240	93	11	61	401	571	650	643	2337
Cod Central North Sea-2241	94	13	82	577	667	852	925	3116
Cod Central North Sea-2244	99	37	125	453	479	572	575	2240
Cod Central North Sea-2245	97	17	92	564	690	915	980	3258
Cod Central North Sea-2246	106	11	78	550	771	925	1018	3352
Cod Central North Sea-2256	23	4	25	102	77	116	157	482
Cod Central North Sea-2257	50	6	24	111	88	137	186	552
Cod Central North Sea-2258	30	5	32	124	103	165	253	682
Cod Central North Sea-2259	20	4	16	80	45	90	140	374
Cod Central North Sea-2260	47	7	31	153	120	172	215	699
Cod Central North Sea-2261	54	6	29	153	138	240	329	895
Cod Central North Sea-2262	60	4	33	179	176	307	430	1130
Cod Central North Sea-2263	32	6	31	107	97	162	264	667
Cod Central North Sea-2264	54	6	48	273	260	337	367	1291
Cod Central North Sea-2265	87	10	83	393	381	531	596	1993
Cod Central North Sea-2266	41	6	57	239	172	231	265	970
Cod Central North Sea-2267	57	8	59	250	197	337	474	1325
Cod Central North Sea-2268	83	10	108	468	345	554	696	2182
Cod Central North Sea-4397	79	13	87	553	667	788	870	2979
Cod Central North Sea-4398	17	4	21	84	46	79	136	369
Cod Egersundbanken-1451	35	3	13	95	163	323	418	1016
Cod Egersundbanken-1453	73	5	34	222	298	610	803	1972
Cod Egersundbanken-1455	42	5	29	152	158	539	303	1187
Cod Egersundbanken-1459	72	6	43	266	291	478	617	1700
Haddoc Haltenbanken-1232	47	-	13	92	113	168	186	573
Haddoc Haltenbanken-1234	25	-	-	18	44	66	60	188

APPENDIX 4: THC and C_0-C_5 decalines in fish liver (IMR data)

Sample id.	THC	Decalin	C1-Decalines	C2-Decalines	C3-Decalines	C4-Decalines	C5-Decalines	C0-C5 Decalines
	µg/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Haddoc Haltenbanken-1235	50	2	6	24	18	23	24	97
Haddoc Haltenbanken-1236	74	3	7	40	56	55	58	219
Haddoc Haltenbanken-1240	68	-	4	55	111	53	55	279
Haddoc Northern North Sea-1401	82	9	94	546	674	767	818	2909
Haddoc Northern North Sea-1406	90	14	92	471	406	485	443	1910
Haddoc Northern North Sea-1407	60	11	108	535	669	772	785	2880
Haddoc Northern North Sea-1410	76	17	106	520	575	583	591	2392
Haddoc Northern North Sea-4395	99	8	91	441	517	613	665	2335
Haddoc Central North Sea-2286	54	2	15	21	26	17	19	101
Haddoc Central North Sea-2328	81	10	75	545	808	857	796	3090
Haddoc Central North Sea-2329	32	9	48	299	344	441	454	1596
Haddoc Central North Sea-2330	51	10	71	414	580	598	547	2219
Haddoc Central North Sea-2331	44	13	85	489	538	487	455	2069
Haddoc Central North Sea-2332	71	14	128	895	1225	1266	1126	4656
Haddoc Central North Sea-2333	65	18	125	645	779	801	751	3118
Haddoc Central North Sea-2334	33	34	92	290	247	230	193	1086
Haddoc Central North Sea-2335	60	7	63	394	538	573	494	2069
Haddoc Central North Sea-2336	50	29	224	978	869	780	655	3535
Haddoc Central North Sea-2337	92	16	82	362	365	371	328	1524
Haddoc Central North Sea-2338	27	14	68	301	279	296	276	1233
Haddoc Central North Sea-2339	54	9	49	352	487	556	553	2006
Haddoc Central North Sea-2340	38	8	49	307	361	487	439	1651
Haddoc Central North Sea-2341	52	12	138	849	1008	1020	910	3936
Haddoc Central North Sea-2357	48	6	53	315	397	497	516	1784
Haddoc Central North Sea-2358	67	-	50	181	749	1258	1290	3527
Haddoc Central North Sea-2359	52	9	156	875	900	913	827	3681
Haddoc Central North Sea-2360	27	4	45	219	244	338	325	1175
Haddoc Central North Sea-2361	75	9	119	652	801	831	794	3207
Haddoc Central North Sea-2362	41	6	44	344	397	439	434	1663
Haddoc Central North Sea-2363	32	4	35	245	246	249	211	991
Haddoc Central North Sea-2364	50	15	147	531	469	478	457	2096
Haddoc Central North Sea-2365	46	7	58	384	395	429	353	1625
Haddoc Central North Sea-2366	65	7	102	538	460	431	368	1907
Haddoc Central North Sea-4399	90	15	129	855	1195	1143	1018	4355
Haddoc Egersundbanken-1260	73	4	-	90	566	1144	1223	3027
Haddoc Egersundbanken-1261	39	7	16	105	88	173	163	552
Haddoc Egersundbanken-1267	33	4	15	82	95	119	128	443
Haddoc Egersundbanken-1269	49	6	23	111	114	143	156	553
Haddoc Egersundbanken-1270	59	9	41	229	260	301	306	1145
Saithe Central North Sea-3832	6	4	14	88	119	163	194	582
Saithe Central North Sea-3833	57	9	41	290	356	410	478	1584
Saithe Central North Sea-3835	233	-	14	101	166	193	224	698
Saithe Central North Sea-3836	61	-	9	75	127	179	222	611
Saithe Central North Sea-3837	60	4	21	114	140	151	174	604
Saithe Central North Sea-3838	24	5	20	89	105	131	154	504
Saithe Central North Sea-3839	69	5	25	164	195	235	286	910
Saithe Central North Sea-3840	85	6	40	306	345	365	404	1465
Saithe Central North Sea-3841	71	6	31	155	175	194	229	790
Saithe Central North Sea-3842	43	4	19	97	116	131	148	515

APPENDIX 4: THC and C_0-C_5 decalines in fish liver (IMR data)

Sample id.	THC	Decalin	C1-Decalines	C2-Decalines	C3-Decalines	C4-Decalines	C5-Decalines	C0-C5 Decalines
	µg/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Saithe Central North Sea-3843	67	6	37	243	335	413	507	1542
Saithe Central North Sea-3844	25	3	16	99	138	151	188	594
Saithe Central North Sea-3845	23	-	3	24	38	56	57	178
Saithe Central North Sea-3846	104	3	30	241	302	366	437	1378
Saithe Central North Sea-3847	42	4	51	446	568	597	596	2264
Saithe Central North Sea-3848	44	n.i.	30	214	277	298	341	1161
Saithe Central North Sea-3849	58	6	39	304	373	376	427	1525
Saithe Central North Sea-3850	71	2	44	257	281	309	324	1217
Saithe Central North Sea-3851	52	11	62	351	323	354	367	1467
Saithe Central North Sea-3852	109	-	16	366	545	611	696	2235
Saithe Central North Sea-3854	98	-	5	142	273	325	349	1094
Saithe Central North Sea-3400	54	11	75	443	528	583	617	2258
Saithe Central North Sea-3401	61	8	49	303	339	322	343	1363
LOD	4	2	3	10	10	19	13	57

-:below limit of detection (LOD)

APPENDIX 5: Concentrations (ng/g ww) of selected 2- and 3-ring aromatic hydrocarbons (NPD) in fish liver (IMR data)

Sample id.	NAP	C1-NAP	C2-NAP	C3-NAP	FLE	ANT	PHE	C1-PHE	C2-PHE	DBT	C1-DBT	C2-DBT	C3-DBT	Sum NPD
Cod Barents Sea-1775	31.6	14.3	36.7	16.1	23.7	1.2	-	-	2.8	-	-	4.0	6.5	136.9
Cod Barents Sea-1779	26.8	10.5	25.6	14.6	4.9	1.0	-	-	-	-	-	2.6	7.7	93.7
Cod Barents Sea-1784	34.9	10.4	16.7	12.7	3.9	-	3.6	18.7	4.3	-	-	-	2.6	107.9
Cod Barents Sea-1787	29.2	12.2	25.6	18.8	5.1	-	-	32.3	19.1	-	-	3.7	n.i.	145.9
Cod Barents Sea-1791	-	10.3	19.3	15.8	3.8	1.0	-	-	5.3	-	3.6	n.i.	4.3	63.5
Cod Haltenbanken-1321	-	19.5	80.4		10.9	-	-	-	3.0	-	-	1.9	-	115.6
Cod Haltenbanken-1687	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cod Haltenbanken-1696	-	-	-	11.0	-	1.3	7.3	-	-	-	-	-	-	19.6
Cod Haltenbanken-1698	-	13.0	13.3	-	4.1	1.4	7.4	-	-	n.i.	-	-	-	39.3
Cod Haltenbanken-1699	-	14.0	19.2	13.0	4.8	-	-	-	-	-	-	-	-	51.1
Cod Haltenbanken-1709	-	33.3	47.7	48.6	13.4	3.2	6.6	n.i.	n.i.	-	2.2	-	5.9	160.8
Cod Northern North Sea-1725	25.2	8.6	20.8	12.9	3.2	-	-	n.i.	-	1.5	-	-	-	72.1
Cod Northern North Sea-1728	30.3	9.1	26.9	14.7	3.8	1.7	-	7.8	3.4	1.3	-	4.1	11.2	114.3
Cod Northern North Sea-1731	-	9.8	27.7	18.3	6.2	1.8	-	10.1	3.1	2.2	3.7	3.5	-	86.5
Cod Northern North Sea-1733	-	29.3	18.4	-	10.9	1.1	-	4.0	3.1	1.8	-	-	3.4	71.9
Cod Northern North Sea-4396	21.8	12.0	18.1	13.7	3.5	2.8	4.5	11.8	5.5	2.8	-	-	3.3	99.8
Cod Central North Sea-2215	-	9.4	16.8	11.8	2.9	-	-	-	3.1	2.5	-	-	6.0	52.5
Cod Central North Sea-2216	-	11.1	13.6	-	-	-	-	24.6	10.6	1.2	-	2.3	4.3	67.7
Cod Central North Sea-2220	-	8.7	13.7	9.6	8.8	-	3.9	n.i.	n.i.	2.8	1.3	14.8	9.5	73.2
Cod Central North Sea-2221	24.6	15.2	23.6	9.4	-	-	3.8	21.1	11.5	11.3	-	-	4.0	124.4
Cod Central North Sea-2222	25.8	19.7	19.5	12.7	-	-	4.4	77.8	25.2	1.8	-	-	6.3	193.2
Cod Central North Sea-2223	-	14.2	21.9	-	-	-	-	-	3.6	2.9	-	-	n.i.	42.6
Cod Central North Sea-2225	-	-	12.7	9.3	4.9	-	-	51.2	26.0	1.7	-	5.7	8.8	120.2
Cod Central North Sea-2240	-	14.6	31.4	23.6	-	-	-	3.4	3.0	1.1	1.4	2.2	6.6	87.3
Cod Central North Sea-2241	-	27.4	25.3	33.4	-	1.0	3.8	4.5	3.7	6.6	-	2.0	5.2	113.0
Cod Central North Sea-2244	44.5	42.5	38.4	11.7	-	-	-	5.2	2.5	1.7	-	-	4.1	150.4
Cod Central North Sea-2245	22.4	15.9	42.1	15.6	4.0	-	4.8	3.4	3.8	1.4	1.3	3.5	7.5	125.7
Cod Central North Sea-2246	-	13.6	26.7	13.4	3.2	-	3.5	-	2.7	2.8	-	-	11.9	77.8
Cod Central North Sea-2256	-	-	-	-	-	-	-	3.8	3.3	-	-	1.8	5.8	14.7
Cod Central North Sea-2257	-	15.7	11.8	30.7	-	-	-	5.6	4.3	-	1.3	-	3.2	72.6
Cod Central North Sea-2258	-	-	13.2	11.8	-	-	-	3.3	2.7	1.9	-	2.1	-	35.1
Cod Central North Sea-2259	-	-	-	-	-	-	-	-	2.2	-	-	-	-	2.2
Cod Central North Sea-2260	-	12.3	11.5	-	-	-	-	3.5	3.3	1.3	-	-	-	32.0
Cod Central North Sea-2261	-	14.2	14.0	23.4	-	-	-	2.9	-	2.8	-	-	4.6	61.9
Cod Central North Sea-2262	-	8.7	16.5	14.2	-	-	-	3.1	2.5	3.1	-	-	3.6	51.7

APPENDIX 5: Concentrations (ng/g ww) of selected 2- and 3-ring aromatic hydrocarbons (NPD) in fish liver (IMR data)

Sample id.	NAP	C1-NAP	C2-NAP	C3-NAP	FLE	ANT	PHE	C1-PHE	C2-PHE	DBT	C1-DBT	C2-DBT	C3-DBT	Sum NPD
Cod Central North Sea-2265	-	10.4	30.0	19.4	3.2	-	-	25.3	11.3	-	-	-	7.7	107.2
Cod Central North Sea-2266	-	-	12.9	11.7	-	-	-	4.8	3.5	-	-	-	2.3	35.3
Cod Central North Sea-2267	21.1	8.9	19.2	16.6	3.0	-	5.6	6.0	4.9	1.7	-	2.2	6.3	95.5
Cod Central North Sea-2268	-	-	15.6	14.2	-	-	-	5.6	3.6	2.6	-	2.7	4.9	49.1
Cod Central North Sea-4397	-	16.9	24.9	25.6	-	-	-	4.3	-	5.7	-	-	7.4	84.7
Cod Central North Sea-4398	-	-	9.2	10.1	-	-	-	-	2.5	-	-	-	4.6	26.4
Cod Egersundbanken-1451	20.8	12.8	26.1	23.6	4.2	0.9	-	-	4.2	-	1.7	2.0	4.0	100.3
Cod Egersundbanken-1453	35.6	17.1	48.2	45.7	6.9	-	5.5	4.3	4.3	2.7	2.7	2.9	3.9	179.7
Cod Egersundbanken-1455	-	8.8	21.5	21.5	3.1	-	-	-	3.2	-	1.4	-	4.9	64.6
Cod Egersundbanken-1459	-	7.7	9.6	22.1	3.5	-	4.2	-	4.6	1.7	-	3.3	6.7	63.4
Haddoc Haltenbanken-1232	-	8.3	13.1	16.3	-	-	-	-	3.4	-	-	-	3.4	44.5
Haddoc Haltenbanken-1234	-	-	9.3	11.0	-	-	-	-	-	-	-	-	-	20.2
Haddoc Haltenbanken-1235	-	8.5	9.0	14.5	-	-	-	-	-	-	-	-	-	31.9
Haddoc Haltenbanken-1236	-	-	9.1	10.7	-	-	-	-	-	-	-	-	2.5	22.3
Haddoc Haltenbanken-1240	-	-	15.6	21.6	-	-	3.5	-	3.3	-	1.3	1.9	-	47.1
Haddoc Northern North Sea-1401	-	10.7	18.4	13.2	-	-	-	-	7.3	1.8	2.7	3.9	11.8	69.7
Haddoc Northern North Sea-1406	-	7.8	20.0	26.9	-	1.1	-	5.6	8.8	11.8	-	n.i.	2.5	84.3
Haddoc Northern North Sea-1407	-	10.8	24.5	14.3	3.2	-	4.1	-	6.9	1.6	-	3.3	6.8	75.6
Haddoc Northern North Sea-1410	-	7.6	14.5	13.6	-	-	-	-	2.4	1.4	-	-	-	39.5
Haddoc Northern North Sea-4395	-	-	29.6	14.2	-	-	-	-	2.8	1.8	-	3.2	8.9	60.5
Haddoc Central North Sea-2286	-	-	11.4	10.4	-	-	-	-	5.1	1.1	1.2	1.9	7.2	38.2
Haddoc Central North Sea-2328	-	8.5	22.5	15.3	-	-	-	-	5.2	-	1.3	2.4	4.8	60.0
Haddoc Central North Sea-2329	-	-	13.6	12.9	-	-	-	4.1	5.7	1.0	-	4.2	5.1	46.6
Haddoc Central North Sea-2330	-	-	19.2	14.0	-	-	-	8.2	4.1	-	-	2.3	3.2	50.9
Haddoc Central North Sea-2331	-	-	13.7	11.1	-	-	-	-	5.8	-	-	4.4	6.4	41.4
Haddoc Central North Sea-2332	-	10.7	27.8	21.4	-	-	-	3.2	4.8	-	-	3.5	7.2	78.5
Haddoc Central North Sea-2333	-	9.7	31.8	10.9	3.6	-	-	-	8.2	-	-	5.5	2.8	72.4
Haddoc Central North Sea-2334	54.7	47.3	25.1	11.7	-	-	5.1	4.2	3.4	-	-	2.0	3.7	157.2
Haddoc Central North Sea-2335	-	8.0	18.9	10.4	-	-	-	-	4.0	-	-	n.i.	2.7	44.0
Haddoc Central North Sea-2336	-	13.0	19.7	15.4	-	-	-	-	3.1	1.0	-	-	5.6	57.9
Haddoc Central North Sea-2337	-	-	16.6	13.3	-	-	3.6	4.6	5.1	1.5	-	-	5.5	50.3
Haddoc Central North Sea-2338	-	8.9	16.1	14.0	-	-	3.5	4.6	8.4	1.5	-	-	4.8	61.7
Haddoc Central North Sea-2339	-	8.4	18.5	12.4	-	-	-	-	3.8	5.6	-	2.3	3.4	54.3
Haddoc Central North Sea-2340	-	-	14.5	-	-	-	-	3.1	2.9	1.8	-	-	5.2	27.4
Haddoc Central North Sea-2341	-	-	18.6	17.8	-	-	-	-	4.8	2.2	-	5.1	10.4	58.8

APPENDIX 5: Concentrations (ng/g ww) of selected 2- and 3-ring aromatic hydrocarbons (NPD) in fish liver (IMR data)

Sample id.	NAP	C1-NAP	C2-NAP	C3-NAP	FLE	ANT	PHE	C1-PHE	C2-PHE	DBT	C1-DBT	C2-DBT	C3-DBT	Sum NPD
Haddoc Central North Sea-2357	-	9.4	23.8	18.8	-	-	3.6	3.4	2.5	1.3	-	2.3	2.7	67.8
Haddoc Central North Sea-2358	-	7.7	40.7	36.4	4.8	1.6	6.5	6.1	3.7	3.7	-	1.9	3.9	117.2
Haddoc Central North Sea-2359	-	8.3	14.5	15.2	3.1	-	-	-	-	-	-	1.9	5.3	48.4
Haddoc Central North Sea-2360	-	9.3	17.2	13.7	-	-	-	3.1	3.4	1.6	-	-	n.i.	48.2
Haddoc Central North Sea-2361	-	13.0	24.9	36.3	4.6	-	-	4.1	4.5	1.6	1.4	4.3	3.3	98.1
Haddoc Central North Sea-2362	-	7.6	13.4	12.0	-	-	-	3.9	3.9	-	-	2.7	4.2	47.7
Haddoc Central North Sea-2363	-	8.6	15.1	22.0	-	-	-	4.1	3.3	-	-	-	-	53.2
Haddoc Central North Sea-2364	-	7.5	15.6	14.4	-	-	-	-	6.5	-	1.2	3.0	6.9	55.0
Haddoc Central North Sea-2365	-	-	12.2	14.7	-	-	-	4.5	4.0	-	-	2.2	3.4	41.0
Haddoc Central North Sea-2366	-	8.6	15.1	19.1	3.4	-	-	6.0	4.4	1.0	-	2.1	4.4	64.1
Haddoc Central North Sea-4399	-	9.4	23.2	20.4	-	-	-	6.4	3.4	-	1.4	4.1	12.1	80.3
Haddoc Egersundbanken-1260	-	12.5	43.7	33.0	5.7	-	-	3.3	-	-	-	-	3.9	102.2
Haddoc Egersundbanken-1261	-	-	14.9	14.8	-	-	-	2.9	3.1	-	1.4	2.0	4.1	43.2
Haddoc Egersundbanken-1267	-	9.2	13.9	16.2	-	-	-	-	2.5	n.i.	-	-	4.2	46.0
Haddoc Egersundbanken-1269	-	7.4	12.4	18.3	-	-	-	2.9	4.7	-	-	2.4	8.1	56.2
Haddoc Egersundbanken-1270	-	-	24.3	18.4	-	-	-	3.8	2.7	-	-	-	-	49.2
Saithe Central North Sea-3832	-	-	-	-	-	1.2	-	6.0	4.6	-	-	1.9	6.6	20.3
Saithe Central North Sea-3833	-	-	10.3	10.1	-	1.4	-	5.2	4.3	1.3	7.0	4.4	5.5	49.5
Saithe Central North Sea-3835	-	-	9.4	-	-	1.7	-	4.5	3.9	1.2	-	2.4	3.4	26.5
Saithe Central North Sea-3836	-	-	-	-	-	2.0	3.5	5.8	2.8	-	-	4.0	-	18.0
Saithe Central North Sea-3837	-	-	-	-	-	-	4.5	22.4	12.3	-	-	4.4	7.8	51.4
Saithe Central North Sea-3838	-	-	-	-	-	-	-	-	2.6	-	-	-	4.2	6.7
Saithe Central North Sea-3839	-	-	-	-	-	1.3	-	23.3	8.3	-	-	2.9	5.1	40.9
Saithe Central North Sea-3840	-	-	11.1	11.0	-	1.7	6.8	47.9	14.8	1.6	-	4.0	8.9	107.7
Saithe Central North Sea-3841	-	-	-	-	-	1.0	-	21.6	7.2	-	-	2.5	6.6	38.9
Saithe Central North Sea-3842	-	-	-	-	-	-	-	21.8	8.6	-	-	5.6	6.4	42.5
Saithe Central North Sea-3843	-	-	11.3	9.6	3.0	1.9	3.8	70.4	16.2	1.1	1.2	n.i.	11.0	129.4
Saithe Central North Sea-3844	-	-	-	-	-	-	-	-	3.5	-	-	n.i.	2.7	6.1
Saithe Central North Sea-3845	-	-	-	-	-	1.2	8.2	7.0	5.7	-	-	2.0	2.9	27.0
Saithe Central North Sea-3846	-	-	10.5	-	3.0	1.5	4.4	27.0	13.0	3.0	-	n.i.	6.3	68.6
Saithe Central North Sea-3847	-	-	-	-	-	1.0	-	10.5	6.9	-	-	4.6	7.6	30.7
Saithe Central North Sea-3848	-	-	-	-	-	1.4	-	5.1	4.6	1.3	-	2.0	2.2	16.5
Saithe Central North Sea-3849	-	-	10.1	-	-	1.7	-	n.i.	n.i.	1.3	n.i.	60.4	121.5	195.1
Saithe Central North Sea-3850	-	-	-	-	3.2	1.2	-	56.8	29.1	-	-	21.8	26.0	138.0
Saithe Central North Sea-3851	-	-	10.7	10.8	-	1.0	-	3.4	3.9	-	-	-	3.4	33.3

APPENDIX 5: Concentrations (ng/g ww) of selected 2- and 3-ring aromatic hydrocarbons (NPD) in fish liver (IMR data)

Sample id.	NAP	C1-NAP	C2-NAP	C3-NAP	FLE	ANT	PHE	C1-PHE	C2-PHE	DBT	C1-DBT	C2-DBT	C3-DBT	Sum NPD
Saithe Central North Sea-3852	-	-	9.2	-	-	1.3	-	17.4	10.2	1.0	-	n.i.	6.1	45.2
Saithe Central North Sea-3854	-	-	-	-	-	1.6	-	26.5	8.9	-	-	11.8	4.7	53.4
Saithe Central North Sea-3400	-	-	15.2	17.9	-	1.1	-	4.2	5.1	2.5	-	7.2	12.0	65.1
Saithe Central North Sea-3401	-	-	10.5	15.1	-	1.2	4.0	7.7	4.6	-	-	-	5.0	47.9
LOD	20.0	7.4	9.1	8.9	2.9	1.0	3.5	2.9	2.5	1.0	1.2	1.8	2.2	64.4

n.i.: not identified

-: below limit of detection (LOD)

NAP: Naphthalene; C1-NAP: C1-Naphthalenes; C2-NAP: C2-Naphthalenes; C3-NAP: C3-Naphthalenes

FLE: Fluorene; ANT: Anthracene; PHE: Phenanthrene; C1-PHE: C1-Phenanthrenes; C2-PHE: C2-Phenanthrenes

DBT: Dibenzothiophene; C1-DBT: C1-Dibenzothiophenes; C2-DBT: C2-Dibenzothiophenes; C3-DBT: C3-Dibenzothiophenes

APPENDIX 6: Concentrations (ng/g ww) of selected 3- to 6. ring aromatic hydrocarbons (PAH) in fish liver (IMR data)

Sample id.	Ace-naphten	Ace-naphtyl	FLU	PYR	BAA	CHR	BBKJF	BEP	BAP	PER	ICDP	BGHIP	DBAH ACA	Sum PAH
Cod Barents Sea-1775	4.0	2.1	-	-	-	-	-	-	-	-	-	-	-	6.0
Cod Barents Sea-1779	2.1	2.3	-	-	-	-	-	-	-	-	-	-	-	4.4
Cod Barents Sea-1784	1.5	1.2	-	-	-	-	-	-	-	-	-	-	-	2.7
Cod Barents Sea-1787	1.8	1.0	-	-	-	-	-	-	-	-	-	-	-	2.8
Cod Barents Sea-1791	1.9	-	2.9	2.5	-	-	-	-	-	-	-	-	-	7.2
Cod Haltenbanken-1321	6.3	4.6	-	-	-	-	-	-	-	-	-	-	-	10.9
Cod Haltenbanken-1687	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cod Haltenbanken-1696	-	1.3	-	-	-	-	-	-	-	-	-	-	-	1.3
Cod Haltenbanken-1698	1.3	2.4	-	-	-	-	-	-	-	-	-	-	-	3.7
Cod Haltenbanken-1699	1.2	2.9	-	-	-	-	-	-	-	-	-	-	-	4.1
Cod Haltenbanken-1709	7.5	5.7	-	-	-	1.0	1.0	-	-	-	-	-	-	15.2
Cod Northern North Sea-1725	2.4	-	-	2.1	1.7	2.1	-	-	1.1	-	-	-	-	9.5
Cod Northern North Sea-1728	5.8	2.7	-	-	-	-	-	-	-	-	-	-	-	8.5
Cod Northern North Sea-1731	6.1	2.5	-	-	-	-	1.4	-	-	-	-	-	-	10.0
Cod Northern North Sea-1733	2.2	1.9	-	-	-	-	1.5	-	-	-	-	-	1.0	6.6
Cod Northern North Sea-4396	3.1	2.0	-	-	-	-	1.5	-	-	-	-	-	1.0	7.7
Cod Central North Sea-2215	5.1	-	-	-	-	-	-	-	-	-	-	-	-	5.1
Cod Central North Sea-2216	1.2	2.4	-	-	-	-	-	-	-	-	-	-	-	3.6
Cod Central North Sea-2220	1.8	-	2.3	-	-	-	-	-	-	-	-	-	-	4.1
Cod Central North Sea-2221	4.7	1.2	-	-	-	-	-	-	-	-	-	-	-	5.9
Cod Central North Sea-2222	2.5	1.0	-	-	-	-	-	-	-	-	-	-	-	3.6
Cod Central North Sea-2223	4.4	1.2	-	-	-	-	-	-	-	-	-	-	-	5.7
Cod Central North Sea-2225	2.0	-	-	-	-	-	-	-	-	-	-	-	-	2.0
Cod Central North Sea-2240	3.4	1.5	-	-	-	-	-	-	-	-	-	-	-	5.0
Cod Central North Sea-2241	5.7	1.8	-	-	-	-	-	-	-	-	-	-	-	7.5
Cod Central North Sea-2244	4.5	-	-	-	-	-	-	-	-	-	-	-	-	4.5
Cod Central North Sea-2245	5.9	1.2	-	-	-	-	-	-	-	-	-	-	-	7.1
Cod Central North Sea-2246	5.2	1.3	-	-	-	-	-	-	-	-	-	-	-	6.5
Cod Central North Sea-2256	1.7	-	3.4	-	-	-	-	-	-	-	-	-	-	5.1
Cod Central North Sea-2257	1.2	1.0	-	-	-	-	-	-	-	-	-	-	-	2.2
Cod Central North Sea-2258	2.4	-	-	-	-	-	-	-	-	-	-	-	-	2.4
Cod Central North Sea-2259	1.9	-	-	-	-	-	-	-	-	-	-	-	-	1.9
Cod Central North Sea-2260	1.4	-	-	-	-	-	-	-	-	-	-	-	-	1.4
Cod Central North Sea-2261	2.2	1.5	-	-	-	-	-	-	-	-	-	-	-	3.7
Cod Central North Sea-2262	4.0	1.1	-	-	-	-	-	-	-	-	-	-	-	5.1

APPENDIX 6: Concentrations (ng/g ww) of selected 3- to 6. ring aromatic hydrocarbons (PAH) in fish liver (IMR data)

Sample id.	Ace-naphten	Ace-naphtyl	FLU	PYR	BAA	CHR	BBKJF	BEP	BAP	PER	ICDP	BGHIP	DBAH ACA	Sum PAH
Cod Central North Sea-2263	1.9	1.0	-	-	-	-	-	-	-	-	-	-	-	2.9
Cod Central North Sea-2264	2.6	1.2	-	-	-	-	-	-	-	-	-	-	-	3.8
Cod Central North Sea-2265	4.4	1.1	-	-	-	-	-	-	-	-	-	-	-	5.5
Cod Central North Sea-2266	2.3	-	-	-	-	-	-	-	-	-	-	-	-	2.3
Cod Central North Sea-2267	3.0	1.2	2.3	-	-	-	-	-	-	-	-	-	-	6.4
Cod Central North Sea-2268	2.9	-	-	-	-	-	-	-	-	-	-	-	-	2.9
Cod Central North Sea-4397	5.8	1.2	-	-	-	-	-	-	-	-	-	-	-	7.0
Cod Central North Sea-4398	1.9	-	-	-	-	-	-	-	-	-	-	-	-	1.9
Cod Egersundbanken-1451	4.2	2.2	-	-	-	-	-	-	-	-	-	-	-	6.3
Cod Egersundbanken-1453	4.5	6.1	-	-	-	-	-	-	-	-	-	-	-	10.6
Cod Egersundbanken-1455	2.6	1.6	-	-	-	-	-	-	-	-	-	-	-	4.1
Cod Egersundbanken-1459	5.0	2.8	-	-	-	-	-	-	-	-	-	-	-	7.8
Haddoc Haltenbanken-1232	2.4	1.0	-	-	-	-	-	-	-	-	-	-	-	3.4
Haddoc Haltenbanken-1234	3.4	1.0	-	-	-	-	-	-	-	-	-	-	-	4.4
Haddoc Haltenbanken-1235	2.4	1.2	-	-	-	-	-	-	-	-	-	-	-	3.7
Haddoc Haltenbanken-1236	1.6	25.2	-	-	-	-	-	-	-	-	-	-	-	26.8
Haddoc Haltenbanken-1240	2.0	16.6	-	-	-	-	-	-	-	-	-	-	-	18.6
Haddoc Northern North Sea-1401	2.4	2.0	-	-	-	-	-	-	-	-	-	-	-	4.4
Haddoc Northern North Sea-1406	2.9	1.8	-	-	-	-	-	1.0	1.3	-	-	-	-	7.0
Haddoc Northern North Sea-1407	3.6	-	-	-	-	-	-	-	-	-	-	-	-	3.6
Haddoc Northern North Sea-1410	2.9	-	-	-	-	-	-	-	-	-	-	-	-	2.9
Haddoc Northern North Sea-4395	1.3	-	-	-	-	-	-	-	-	-	-	-	-	1.3
Haddoc Central North Sea-2286	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Haddoc Central North Sea-2328	3.4	-	-	-	-	-	-	-	-	-	-	-	-	3.4
Haddoc Central North Sea-2329	3.0	-	-	-	-	-	-	-	-	-	-	-	-	3.0
Haddoc Central North Sea-2330	2.8	-	-	-	-	-	-	-	-	-	-	-	-	2.8
Haddoc Central North Sea-2331	1.7	-	-	-	-	-	-	-	-	-	-	-	-	1.7
Haddoc Central North Sea-2332	4.0	-	-	-	-	-	-	-	-	-	-	-	-	4.0
Haddoc Central North Sea-2333	1.9	1.1	-	-	-	-	-	-	-	-	-	-	-	3.0
Haddoc Central North Sea-2334	2.3	-	2.1	3.0	-	-	-	-	-	-	-	-	-	7.4
Haddoc Central North Sea-2335	2.6	-	-	-	-	-	-	-	-	-	-	-	-	2.6
Haddoc Central North Sea-2336	4.9	1.1	-	-	-	-	-	-	-	-	-	-	-	6.0
Haddoc Central North Sea-2337	3.0	-	-	-	-	-	-	-	-	-	-	-	-	3.0
Haddoc Central North Sea-2338	2.0	-	-	-	-	-	-	-	-	-	-	-	-	2.0
Haddoc Central North Sea-2339	3.1	-	-	-	-	-	-	-	-	-	-	-	-	3.1

APPENDIX 6: Concentrations (ng/g ww) of selected 3- to 6. ring aromatic hydrocarbons (PAH) in fish liver (IMR data)

Sample id.	Ace-naphten	Ace-naphtyl	FLU	PYR	BAA	CHR	BBKJF	BEP	BAP	PER	ICDP	BGHIP	DBAH ACA	Sum PAH
Haddoc Central North Sea-2340	3.3	-	-	-	-	-	1.1	-	-	-	-	-	-	4.4
Haddoc Central North Sea-2341	4.0	1.0	-	-	-	-	-	-	-	-	-	-	-	5.0
Haddoc Central North Sea-2357	2.9	1.1	-	-	-	-	-	-	-	-	-	-	-	4.0
Haddoc Central North Sea-2358	8.3	2.3	-	-	-	-	-	-	-	-	-	-	-	10.6
Haddoc Central North Sea-2359	4.1	-	-	-	-	-	-	-	-	-	-	-	-	4.1
Haddoc Central North Sea-2360	1.8	-	-	-	-	-	-	-	-	-	-	-	-	1.8
Haddoc Central North Sea-2361	4.1		-	-	-	-	-	-	-	-	-	-	-	4.1
Haddoc Central North Sea-2362	2.0	-	-	-	-	-	-	-	-	-	-	-	-	2.0
Haddoc Central North Sea-2363	1.0	-	-	-	-	-	-	-	-	-	-	-	-	1.0
Haddoc Central North Sea-2364	2.6	-	-	-	-	-	-	-	-	-	-	-	-	2.6
Haddoc Central North Sea-2365	1.5	-	-	-	-	-	-	-	-	-	-	-	-	1.5
Haddoc Central North Sea-2366	2.1	-	-	-	-	-	-	-	-	-	-	-	-	2.1
Haddoc Central North Sea-4399	3.8	-	-	-	-	-	-	-	-	-	-	-	-	3.8
Haddoc Egersundbanken-1260	7.1	2.4	-	-	-	-	-	-	-	-	-	-	-	9.5
Haddoc Egersundbanken-1261	1.7	2.9	-	-	-	-	-	-	-	-	-	-	-	4.6
Haddoc Egersundbanken-1267	2.3	1.6	-	-	-	-	-	-	-	-	-	-	-	3.9
Haddoc Egersundbanken-1269	1.8	1.4	-	-	-	-	-	-	-	-	-	-	-	3.2
Haddoc Egersundbanken-1270	1.8	-	-	-	-	-	-	-	-	-	-	-	-	1.8
Saithe Central North Sea-3832	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saithe Central North Sea-3833	1.6	-	-	-	-	-	-	-	-	-	-	-	-	1.6
Saithe Central North Sea-3835	1.5	1.4	-	-	-	-	1.1	-	-	-	-	-	-	4.1
Saithe Central North Sea-3836	-	1.2	-	-	-	-	-	1.5	-	-	-	-	-	2.7
Saithe Central North Sea-3837	-	1.1	3.2	-	-	-	-	-	-	-	-	-	-	4.3
Saithe Central North Sea-3838	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saithe Central North Sea-3839	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saithe Central North Sea-3840	1.0	1.2	3.4	2.3	-	-	-	-	-	-	-	-	-	7.9
Saithe Central North Sea-3841	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saithe Central North Sea-3842	-	1.0	-	-	-	-	-	-	-	-	-	-	-	1.0
Saithe Central North Sea-3843	-	2.0	-	-	-	-	-	-	-	-	-	-	-	2.0
Saithe Central North Sea-3844	-	1.1	-	-	-	-	-	-	-	-	-	-	-	1.1
Saithe Central North Sea-3845	-	1.2	2.6	-	-	-	-	-	-	-	-	-	-	3.8
Saithe Central North Sea-3846	1.3	2.5	-	-	-	-	-	-	-	-	-	-	-	3.8
Saithe Central North Sea-3847	1.0	1.2	-	-	-	-	-	-	-	-	-	-	-	2.2
Saithe Central North Sea-3848	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saithe Central North Sea-3849	1.0	-	n.i.	n.i.	1.8	3.8	-	-	-	-	-	-	-	6.6

APPENDIX 6: Concentrations (ng/g ww) of selected 3- to 6. ring aromatic hydrocarbons (PAH) in fish liver (IMR data)

Sample id.	Ace-naphten	Ace-naphtyl	FLU	PYR	BAA	CHR	BBKJF	BEP	BAP	PER	ICDP	BGHIP	DBAH ACA	Sum PAH
Saithe Central North Sea-3850	-	-	3.5	-	-	-	-	-	-	-	-	-	-	3.5
Saithe Central North Sea-3851	1.2	1.1	-	-	-	-	-	-	-	-	-	-	-	2.4
Saithe Central North Sea-3852	1.5	-	-	-	-	-	-	-	-	-	-	-	-	1.5
Saithe Central North Sea-3854	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saithe Central North Sea-3400	2.2	-	-	-	-	-	-	-	-	-	-	-	-	2.2
Saithe Central North Sea-3401	1.1	1.0	-	-	-	-	1.3	-	-	-	-	-	-	3.4

-: below limit of detection (1 ng/g ww)

FLU: Fluoranthene; PYR: Pyrene; BAA: Benz(a)anthracene; CHR: Chrysene; BBKJF: Benz(b+j+k)fluoranthenes; BEP: Benz(e)pyrene
BAP: Benz(a)pyrene; PER: Perylene; ICDP: Indeno(1,2,3-cd)pyrene; ; BGHIP: Benzo(ghi)perylene;DBAHACA: Dibenz(a,c+a,h)anthracenes