

Uptake of Hydrocarbon Pollution by Fish Eggs and Larvae

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ABSTRACT. The current study took place in the middle and northern parts of the Firth of Forth, Western North Sea. The main objective of this study is to determine the concentrations of total hydrocarbons (mg/l) in seawater (0.0 m and 1.0 m depths), fish eggs and larvae during the period March-May, 1988. Different concentrations of crude oil (0.124-2.480 mg/l) were used as standards. The intensities of each water sample were measured by an Ultra-Violet Fluorescence (UVF). Selected samples were then examined by gas chromatography.

The highest mean values taken from surface water samples were found in March (0.34 mg/l), followed by May and April, with mean concentrations of 0.19 mg/l and 0.09 mg/l being recorded respectively. Similar patterns of distribution were found at 1.0 m depth. The mean values recorded were 0.28 mg/l, 0.14 mg/l and 0.07 mg/l for March, May and April respectively. All values of hydrocarbons in March and May were higher at the surface than at 1.0 m. In April, higher concentrations were recorded at 1.0 m than at the surface. The results also show higher values of hydrocarbons in March than any other period.

While the highest concentrations of hydrocarbons detected in fish eggs during March were 26.43 $\mu\text{g/g}$, the lowest concentrations of hydrocarbons were 19.82 $\mu\text{g/g}$. The highest concentrations of hydrocarbons recorded in April were 33.61 $\mu\text{g/g}$, while the lowest values were 20.46 $\mu\text{g/g}$. In May, the highest and lowest concentrations found in fish eggs were recorded as 30.82 $\mu\text{g/g}$ and 4.08 $\mu\text{g/g}$ respectively.

The concentrations of hydrocarbons in fish eggs may reflect those found in surface seawaters. Hydrocarbon concentrations in fish larvae could not be detected in all samples analysed during either March or May. The highest concentrations of total hydrocarbons were found in fish larvae collected during the month of April.

The overall results show that the concentrations in general decreased significantly away from the source of contamination. This shows that concentrations of hydrocarbons decreased with increasing time and distance from the discharge point.

Introduction

Petroleum oils are important pollutants of the marine environment. Their importance, as stated by Hardy *et al.* (1977), stems from the damage they can cause to the marine environment and also to the high cost of their clean up. Their presence on the water surface can reduce the transmission of light and the diffusion of oxygen (Lacaze 1974). Crude oils can affect the ecosystem only at relatively high concentrations (Gordon and Prouse 1973; Anderson *et al.*, 1974; Pulich *et al.*, 1974).

Crude petroleum, as stated by Neff *et al.* (1976), is generally less toxic to marine organisms than refined products. The toxicity, which is directly correlated with the content of soluble aromatic derivatives, increases with increasing molecular size. Exposure of marine fish to petroleum aromatic hydrocarbons may result in induction of mixed-function oxygenase activity (Payne 1976; Gruger *et al.*, 1977; Kurelac *et al.*, 1977; Stegeman 1978; Walton *et al.*, 1978). Short-term exposure of fish to petroleum hydrocarbons showed significant effects, even at the lowest exposure concentration of 0.45 ppm WSF (Heras *et al.*, 1992).

Petroleum is not the only source of hydrocarbons in the marine environment, a considerable amount comes from biochemical synthesis (Koons and Monaghan 1976). According to Neff and Anderson (1981), alkanes, n-alkanes and branched alkanes are the predominant constituents of biogenic hydrocarbons. Grossling (1976) found that certain alkylated aromatic, naphtheno-aromatic, and naphthenic hydrocarbons appear to distinguish petroleum from biogenic hydrocarbons. These components are relatively abundant in most crude and seepage oils. However, they are not known to have been synthesized by marine organisms, besides they are restricted to biodegradation.

A large number of published papers concerning the acute toxicity of different crude and refined petroleum products to marine organisms are available. While Neff *et al.* (1976) reported the sensitivity of several representatives of marine organisms to specific hydrocarbons, Anderson *et al.* (1974) and Rice *et al.* (1977) studied their sensitivity to extracts of fuel and crude oils.

The effects of petroleum on planktonic eggs and larvae vary differently with different species. While Corner *et al.* (1976) indicated that some species show high mortality at low concentrations, others were able to withstand certain higher concentrations. Similar findings were reported by von Westernhagen *et al.* (1987). The toxicity of hydrocarbons on eggs and larvae, as stated by Kuhnhold (1977), depends largely on how long these organisms have been in the contaminated water layer, strength of wind force, and their specific buoyancy.

There is no simple method of accurately estimating the concentrations of petroleum in the open sea where the concentrations are low. However, the concentrations of petroleum in the environment appear to exceed the estimated annual inputs. This may stem from the reflection of the size of other non-petroleum inputs, erroneous calculations of the size of petroleum inputs, and/or a greater stability of the petroleum-like compounds in the ecosystem (Hardy *et al.*, 1977). The different estimates of petroleum concentrations introduced into the marine environment vary considerably (Zobell 1963; Blumer 1970). Although Kuhnhold (1977) emphasised that there is hardly any evidence of lethal toxicity of hydrocarbons to fish eggs and larvae in the sea, recent studies showed that pelagic fish eggs and larvae can be significantly affected when they come in contact with the sea surface-microlayer (Kocan *et al.*, 1987; von Westernhagen *et al.*, 1987).

The current study took place in the middle and northern parts of the Firth of Forth since all the earlier studies (Whittle *et al.*, 1973, 1974, 1982; Mackie *et al.*, 1976; Masie *et al.*, 1985, 1987) were carried out along the southern shore. The main objective of this study is to determine the concentrations of total hydrocarbons (mg/l) in seawater (0.0 m and 1.0 m depths), fish eggs and larvae.

Materials and Methods

a) Study Area

The Forth is considered to be a very important area for navigation, domestic and industrial activities. It lies between latitude 55°55'-56°15'N and longitude 2°50'-3°50'W and extends from Alloa to the Isle of May, a distance of some 100 km (McLusky 1987). It is divided into the Fourth estuary, west of the road and rail bridges at Queensferry and the more saline outer firth east of the bridges (Fig. 1).

The Firth of Forth is essentially a marine embayment of the North Sea with large sedimentary homogeneous areas which is approximately 50.0 km long and up to 60.0 m deep in the outer saline areas (Dyke 1987; Elliot and Kingston 1987). It widens from less than 2.0 km at the Forth bridges, the narrowest point, to 9.0 km between Pettycur and Leith, then it widens to its maximum extent of 26.0 km between Largo Bay and Aberlady Bay (Fulton 1896; Thomson 1978). The total area of the Firth of Forth is approximately $1.3 \times 10^3 \text{ km}^2$ and the volume of water ranges between $1.8 \times 10^{10} \text{ m}^3$ at low water and $2.2 \times 10^{10} \text{ m}^3$ at high water.

The main source of hydrocarbons in the Forth are those of the British Petroleum Company (BP) at Grangemouth, along with other anthropogenic sources from industrial and urban sites around the Forth, such as The South of Scotland Electricity Board (SSEB), as Europe's largest coal-fired electricity generation plant at Longanet. The Forth also receives petrogenic hydrocarbons from water from oil field (Kinneil BP Development outfall), treated tanker ballast water, ethane/ethylene cracking plant effluent (Braefoot Bay), along with occasional spillages, storm-water runoff and municipal discharges (Elliott and Griffiths 1987).

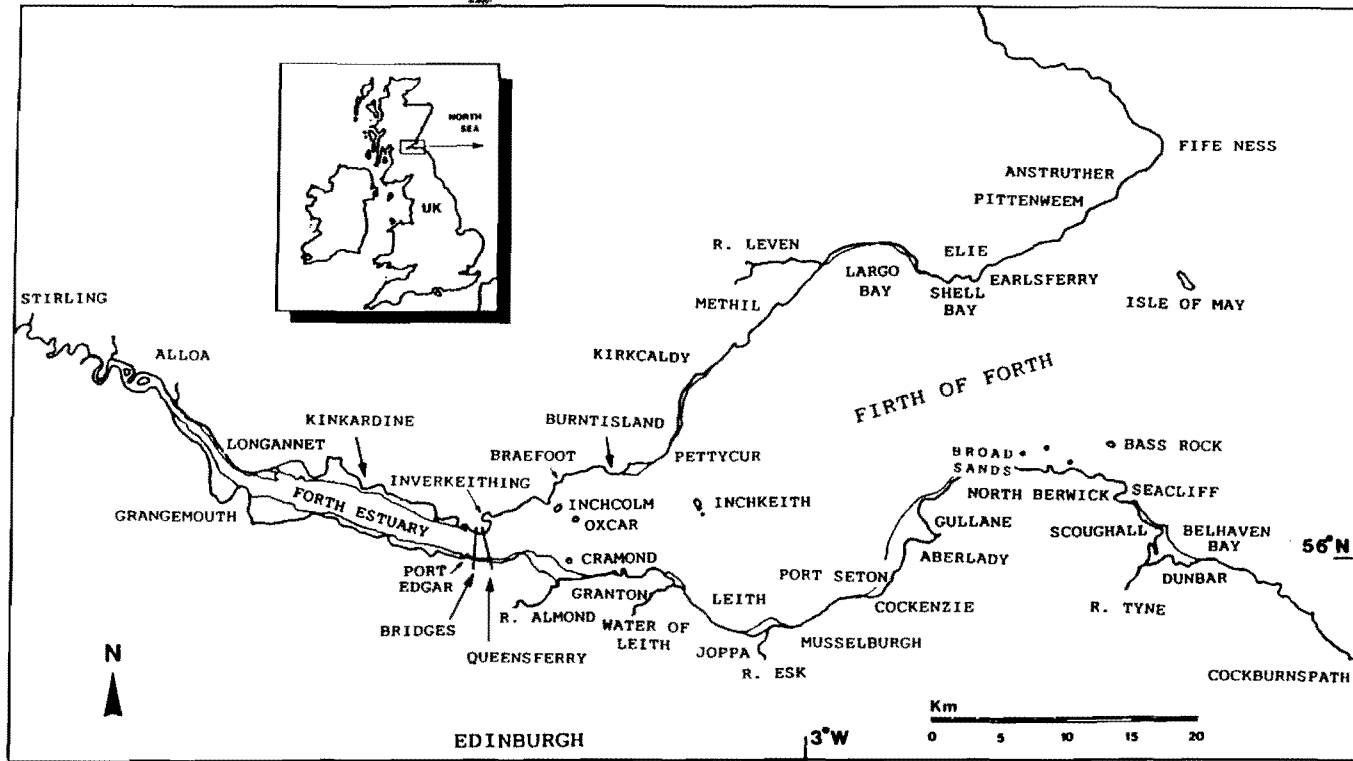


FIG. 1. Location of the Firth of Forth on the east coast of Scotland.

b) Collection and Analysis

Surface and 1.0 m water samples were taken from five stations (1, 2, 3, 4, 5) during the period March-May, 1988 (Fig. 2). A special device (frame) made of "Dexion" aluminium was especially designed for this study to hold two (2.8 l) Winchester bottles (Plates 1 & 2). This device was similar to those described by Gordon and Keizer (1974). A long handle of the same material was attached to the frame to help immerse the bottles to the desired depth. A string was attached to the foil cap of the bottle that collected water from the 1.0 m depth.

Fish eggs and larvae were taken by Bongo nets, with 0.250 mm and 0.500 mm mesh nets (Fig. 3, Plates 3 & 4), from the same stations in order to determine the total hydrocarbon concentrations in these organisms. This gear is considered as the standard gear for the collection of fish eggs and larvae (UNESCO 1975). The nets were towed with a depressor weight of about 54 kg (100 lb), suspended beneath the net. This particular weight was considered by the UNESCO (1975) as sufficient to maintain stability of the gear at towing speeds of about 3 knots. The nets were towed from the FRPB survey vessel, Forth Ranger (Plate 5), at towing speed of 2.5-3.0 knots for a mean time of 9 minutes.

The stations were chosen according to their nearness and/or remoteness from the sources of contamination in the Forth. They were orientated in a west-east direction. All water samplers were acidified with 10.0 ml concentrated hydrochloric acid (conc. HCl) prior to sampling. A piece of aluminium foil, previously cleaned with methanol and dichloromethane (DCM), was used to cover each bottle in order to help prevent any sort of contamination.

All glassware and equipment was thoroughly cleaned and rinsed three times with 50:50 DCM/methanol before use. Water samples were extracted following the methods employed by Grahl-Nielsen *et al.* (1976, 1977) and Grahl-Nielsen (1987). Each water sample was extracted with 3×25.0 ml DCM in a 5.0 litre separating funnel. The extracts were then collected in a 100.0 ml flask and reduced to about 5.0 ml under a gentle stream of nitrogen. Each extract was then transferred by a clean pipette into a 10.0 ml volumetric flask. The 100.0 ml flask was washed three times with a few volumes of DCM and added to the volumetric flask. Each extract was then reduced to just dryness and hexane was immediately added to the 10.0 ml mark. A blank of the same solvent (75.0 ml DCM) was also prepared and treated as any other water sample. Different concentrations of crude oil (0.124-2.480 mg/l) were used as standards.

The intensities of each water sample were measured by an Ultra-Violet Fluorescence meter (UVF) and then plotted against the intensities and concentrations of the crude oil standards. Selected samples were then examined by gas chromatography.

The contents of the 0.500 mm net from each station were collected in jars, previously cleaned with methanol and DCM, and were preserved in methanol. Fish eggs and larvae from each jar were sorted, counted and transferred separately into a clean vial and covered with a foil cap. The contents of each vial were weighed to determine

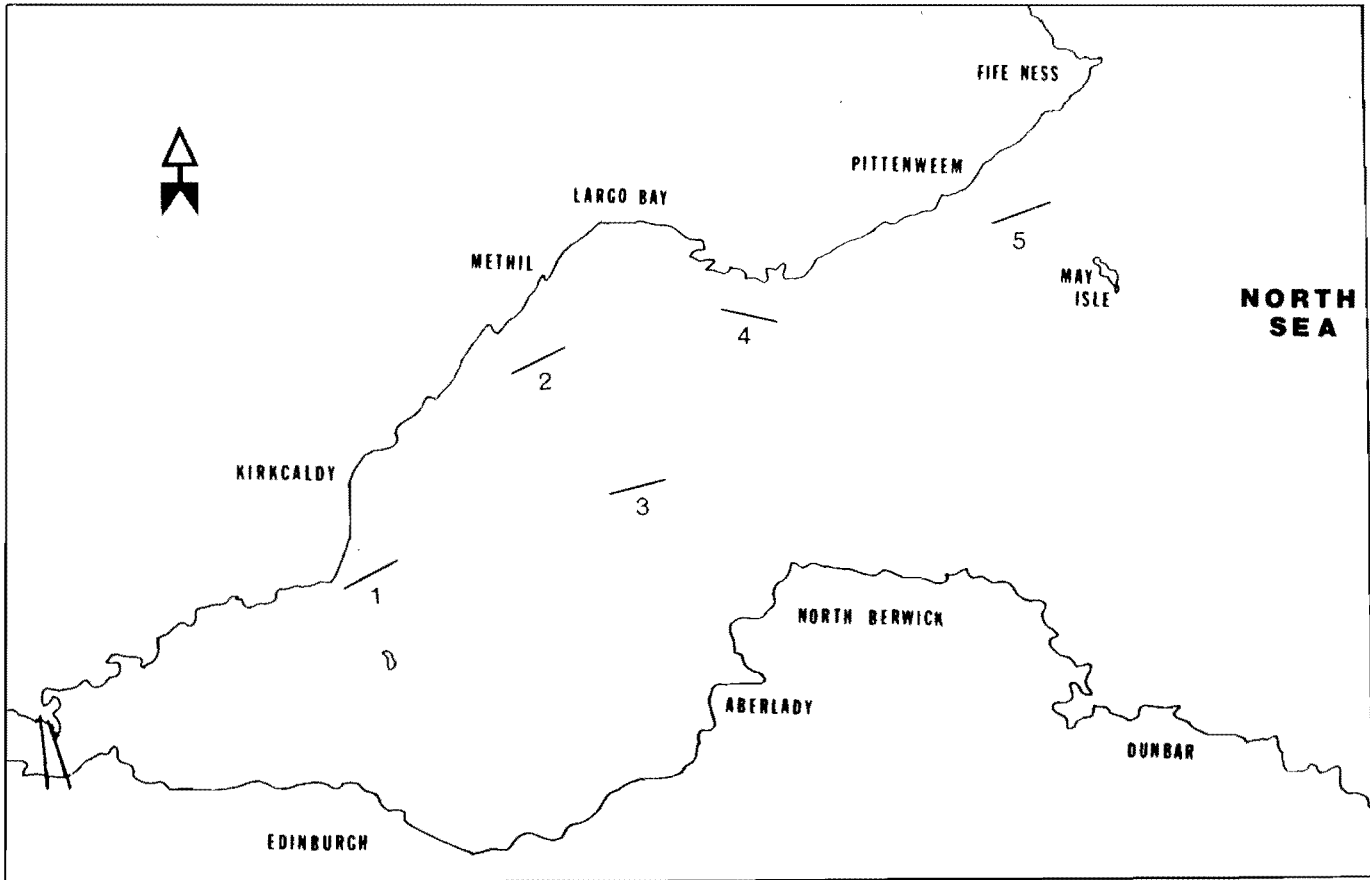


FIG. 2. Sampling site locations in the Firth of Forth.

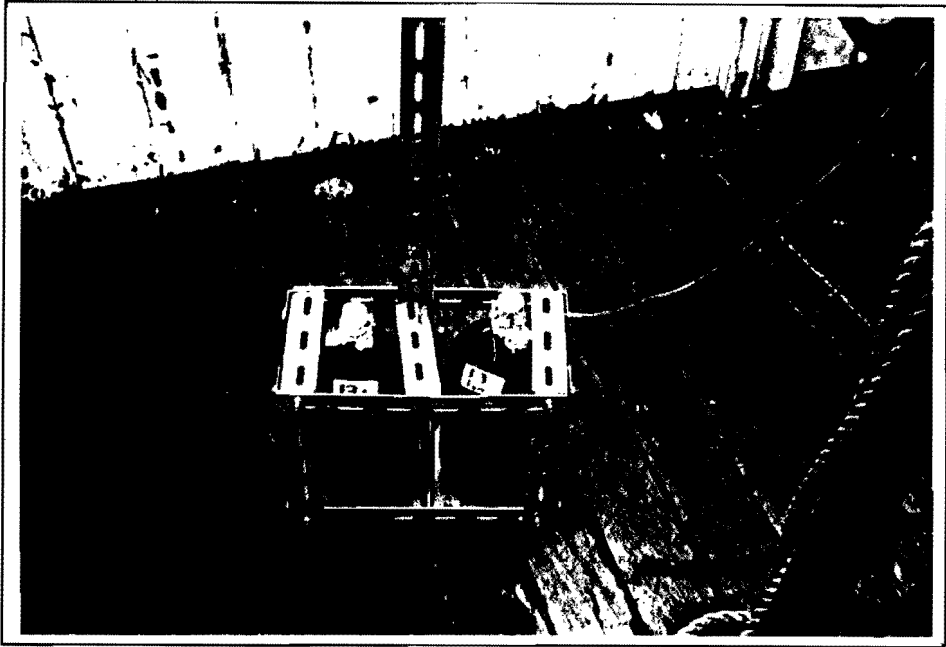


PLATE .1. The frame of the water sampler is made of "dexion" aluminium to hold two winchester bottles.

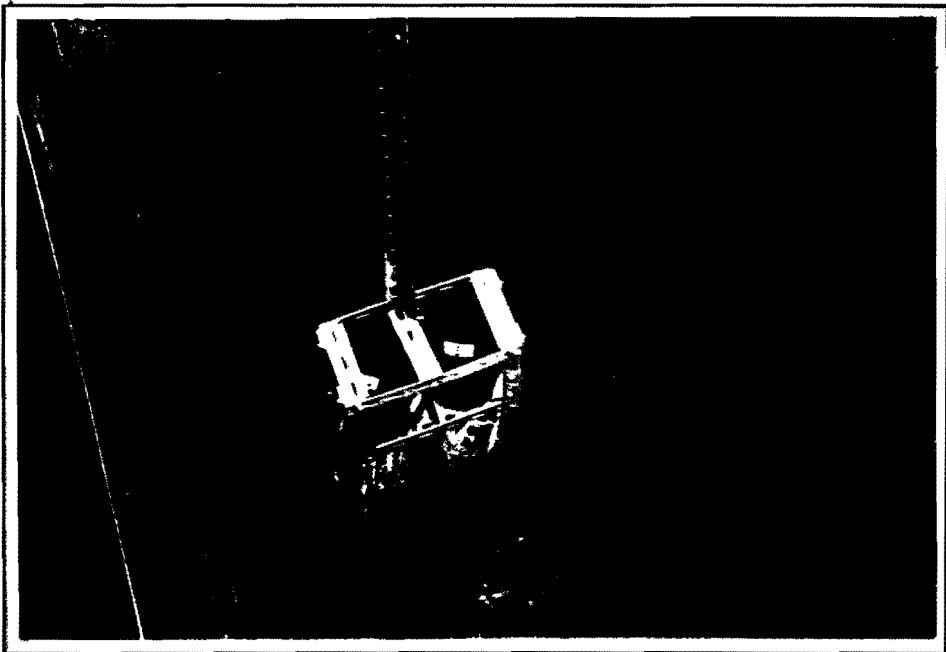
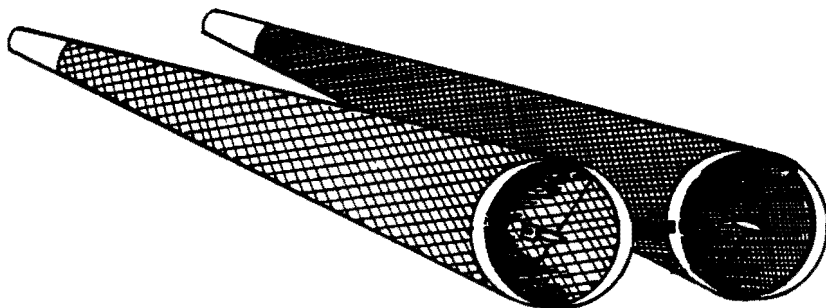


PLATE. 2. The water sampler during collection of water samples from the surface and 1.0 m.



BONGO NETS

FIG.3. The Bongo nets as the standard gear for sampling ichthyoplankton. The nets used (0.250 mm and 0.500 mm) were 0.4 m diameter.

the wet weight and then ground in a mortar and pestle with methanol.

The extracts of each vial were then dried under a gentle stream of nitrogen and weighed again to estimate the extracted (dry) weight. A few volumes of DCM were added to each vial, the extracts then being filtered through a Whatman GFC filter into a 10.0 ml volumetric flask and dried then hexane was added to the 10.0 ml mark. The intensities and concentrations were measured as previously stated. The concentrations (mg/l) were then interpreted as $\mu\text{g/g}$ as follows :

$$\frac{\text{concentration of extracts} \times 0.01 (\mu\text{g})}{\text{sample dry weight (g)}} = \mu\text{g/g dry weight}$$

The concentrations of total hydrocarbons were obtained by plotting the intensity values of the samples against those of the standards. The values of the regression line, estimated for the intensities of crude oil standards, were calculated as 18.8 and 98.1 at concentrations of 0.00 and 2.48 mg/l respectively.

Results

1 - Seawater

1 - March

The highest concentrations of hydrocarbons in seawater taken from the surface in March were observed in station 1 (0.40 mg/l). Relatively lower values (0.32-0.36 mg/l) were recorded in stations 2, 3 and 4. The lowest concentrations (0.27 mg/l), as seen in Table 1, were found in the outer station (5). At 1.0 m depth, the highest values were also recorded in station 1 (0.39 mg/l), followed by stations 2 and 3 with similar

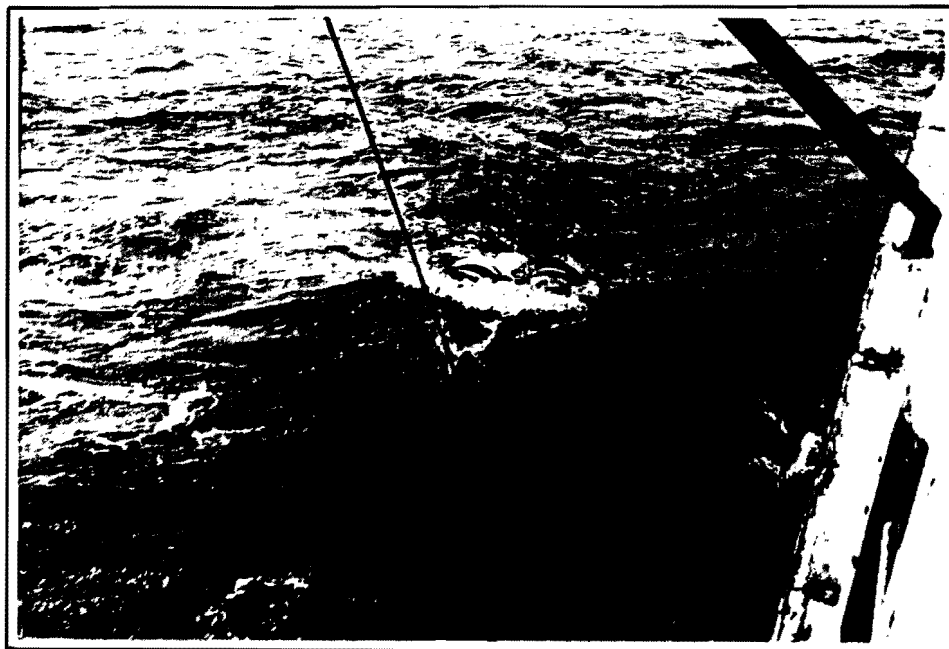


PLATE. 3. The ichthyoplankton sampling gear during shooting.

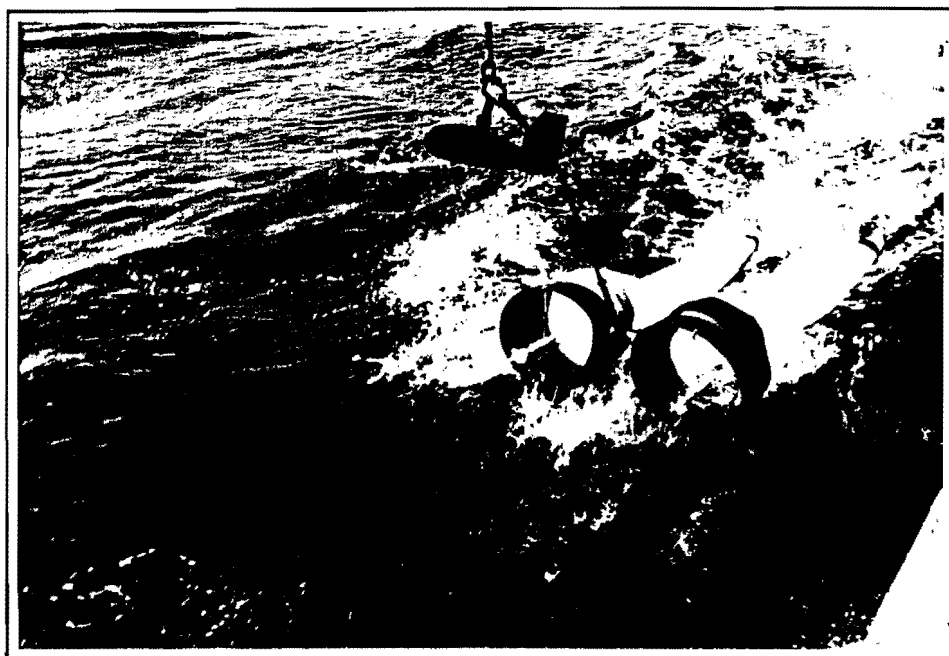


PLATE. 4. The ichthyoplankton sampling gear during hauling.

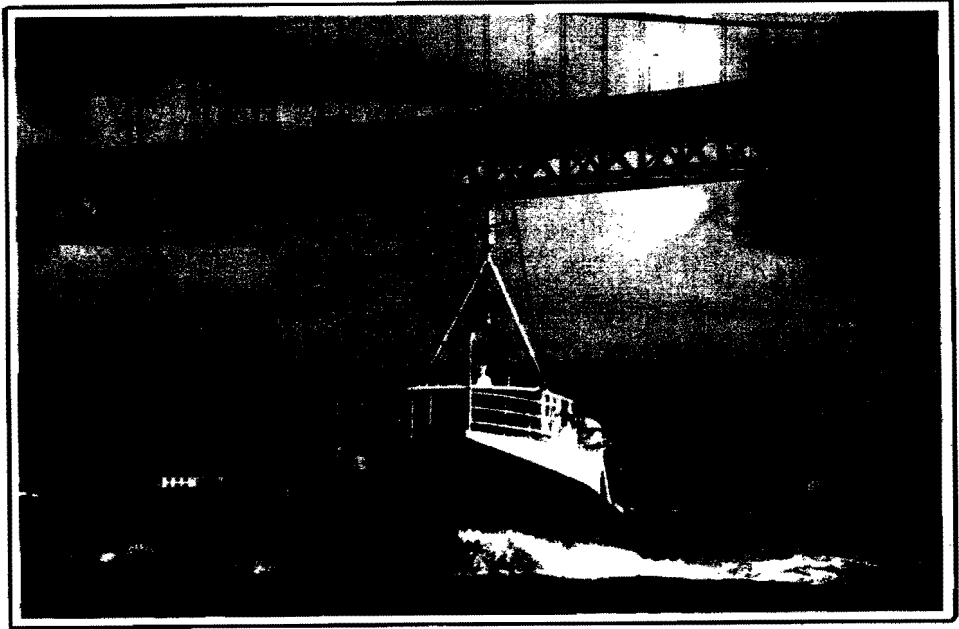


PLATE. 5. The Forth Ranger, an 18 m inshore research vessel.

TABLE 1. The concentrations of total hydrocarbons (mg/l) detected in water samples collected from the Firth of Forth (March-May 1988).

Stn.	March		April		May	
	0.0 m	1.0 m	0.0 m	1.0 m	0.0 m	1.0 m
1	0.40	0.39	0.24	0.07	0.09	0.08
2	0.32	0.31	0.02	0.08	0.74	0.60
3	0.36	0.31	0.07	0.03	0.07	ND
4	0.36	0.20	0.06	0.11	0.06	ND
5	0.27	0.19	0.07	0.05	ND	ND
Mean	0.34	0.28	0.09	0.07	0.19	0.14

ND : Not Detected.

values (0.31 mg/l) being recorded. The lowest concentrations were recorded in stations 4 (0.20 mg/l) and 5 (0.19 mg/l).

ii - April

In April, the highest concentrations of hydrocarbons were also recorded at the surface of station 1 (0.24 mg/l). Lower concentrations were found in water samples taken from stations 3, 4 and 5 (range 0.06-0.07 mg/l). The lowest concentrations were found at station 2, with only 0.02 mg/l being recorded. Unlike surface water samples,

the highest concentrations recorded in water samples taken from 1.0 m depth were found at station 4 (0.11 mg/l). Nearly similar values were recorded in stations 1 (0.07 mg/l) and 2 (0.08 mg/l). The lowest concentrations were taken from stations 3 and 5, with hydrocarbon concentrations of 0.03 and 0.05 mg/l being recorded respectively.

iii - May

Unusually high values were observed in surface water samples taken from station 2 in May (0.74 mg/l). This was followed by stations 1, 3 and 4, which contained 0.09, 0.07 and 0.06 mg/l respectively. No trace of hydrocarbons was detected in the outer station (5). At 1.0 m depth, hydrocarbon concentrations from only two stations could be detected. The highest and the lowest concentrations were recorded in stations 2 and 1, where hydrocarbon concentrations of 0.60 mg/l and 0.08 mg/l were detected respectively.

The highest mean values taken from surface water samples were found in March (0.34 mg/l), followed by May and April, with mean concentrations of 0.19 mg/l and 0.09 mg/l being recorded respectively. Similar patterns of distribution were found at 1.0 m depth. The mean values recorded were 0.28 mg/l, 0.14 mg/l and 0.07 mg/l for March, May and April respectively.

2 - Eggs and Larvae

i - March

The highest concentrations of hydrocarbons detected in fish eggs during March were found in station 1 (26.43 µg/g). The highest numbers of fish eggs (62) were also collected from this station (Table 2). About the same concentrations were recorded in eggs taken from stations 2 (19.82 µg/g) and 4 (19.96 µg/g). No traces of hydrocarbons were detected in eggs taken in stations 3 and 5. The lowest numbers of eggs were also occurred in these stations. Although all fish larvae taken from stations 1, 2, 3 and 5 were analysed for hydrocarbons, none were detected.

TABLE 2. The concentrations of total hydrocarbons (µg/g dry wt) detected in fish eggs and larvae collected from the Firth of Forth (March-May 1988).

Stn.	March				April				May			
	Eggs		Larvae		Eggs		Larvae		Eggs		Larvae	
	No.	µg/g	No.	µg/g	No.	µg/g	No.	µg/g	No.	µg/g	No.	µg/g
1	62	26.43	11	ND	729	28.93	1	-	497	30.82	16	ND
2	12	19.82	4	ND	97	33.61	3	-	117	ND	1	-
3	51	ND	2	ND	1013	22.88	239	16.41	3812	4.08	13	ND
4	47	19.96	0	-	112	23.59	55	36.82	101	ND	11	ND
5	13	ND	7	ND	957	20.46	44	11.60	161	ND	3	-

ND : Not detected.

- : Not analysed.

ii - April

The highest concentrations of total hydrocarbons recorded in April were found in eggs taken from station 2 (33.61 $\mu\text{g/g}$), followed by station 1 (28.93 $\mu\text{g/g}$). Relatively lower values were recorded in eggs taken from stations 5, 3 and 4 respectively. Only larvae from stations 3, 4 and 5 had been analysed, since there were only 4 larvae taken from the other two stations and therefore they were neglected. Higher concentrations of hydrocarbons were recorded in larvae taken from station 4 (36.82 $\mu\text{g/g}$). Slightly higher values were found in station 3 (16.41 $\mu\text{g/g}$) than station 5 (11.60 $\mu\text{g/g}$).

iii - May

In May, the highest and lowest concentrations found in fish eggs were recorded in stations 1 (30.82 $\mu\text{g/g}$) and 3 (4.08 $\mu\text{g/g}$) respectively. No hydrocarbons were detected in fish eggs collected from stations 2, 4 and 5. Very few fish larvae were taken in stations 2 and 5, and therefore they have not been analysed. However, no hydrocarbons were detected in fish larvae collected from stations 1, 3 and 4.

Discussion

The mean values of hydrocarbons in March, April and May were higher at the surface than at 1.0 m, which indicated that most of the oil present had not yet reached the 1.0 m level. Monaghan *et al.* (1973) and Corner (1975) also reported higher concentrations of hydrocarbons at the surface. Since most anthropogenic hydrocarbons, petroleum and chlorinated hydrocarbons enter the marine environment through the surface layer, higher concentrations are usually found in the surface-microlayer of the sea than at any other depths (Swinerton and Linnenbom 1967; Duce *et al.*, 1972; Gordon and Keizer 1974; Whittle *et al.*, 1974; Marty and Saliot, 1976; Kattner *et al.*, 1983; Hardy and Apts 1984; Hardy *et al.*, 1987; Kocan *et al.*, 1987; von Westernhagen *et al.*, 1987). The content of hydrocarbons, according to Mackie *et al.* (1974), is considerably lower in middle depths than that of the surface water. Gordon *et al.* (1974) reported higher concentrations of hydrocarbons at the surface (20.4 $\mu\text{g/l}$) than at 1.0 m depth (0.8 $\mu\text{g/l}$) in water from the northwestern Atlantic Ocean.

In April, higher concentrations were recorded at 1.0 m than at the surface only in stations 2 and 4. Similar results were recorded by Iliff and Calder (1974), where they observed higher concentrations of hydrocarbons at 1.0 m depth than at any depth in the Yucatan Strait. However, Cormack and Nichols (1977) indicated that the highest concentrations of oil are usually found when oil spills occur. They reported concentrations of 0.79-3.95 mg/l at 2.0 depth beneath a small slick of Ekofish oil.

Unusual high values were observed at all depths (0.0 and 1.0 m) in station 2 during May. Chromatographic analysis of the 1.0 m water sample indicated a definite hydrocarbon contamination at that particular station. The chromatograph (Fig. 4) clearly shows an homologous series of n-alkanes, which is characteristic of many petroleum products (Gundlach *et al.*, 1983), ranging from C12-C30, no odd carbon preference and the presence of an unresolved complex mixture (UCM). Hites and

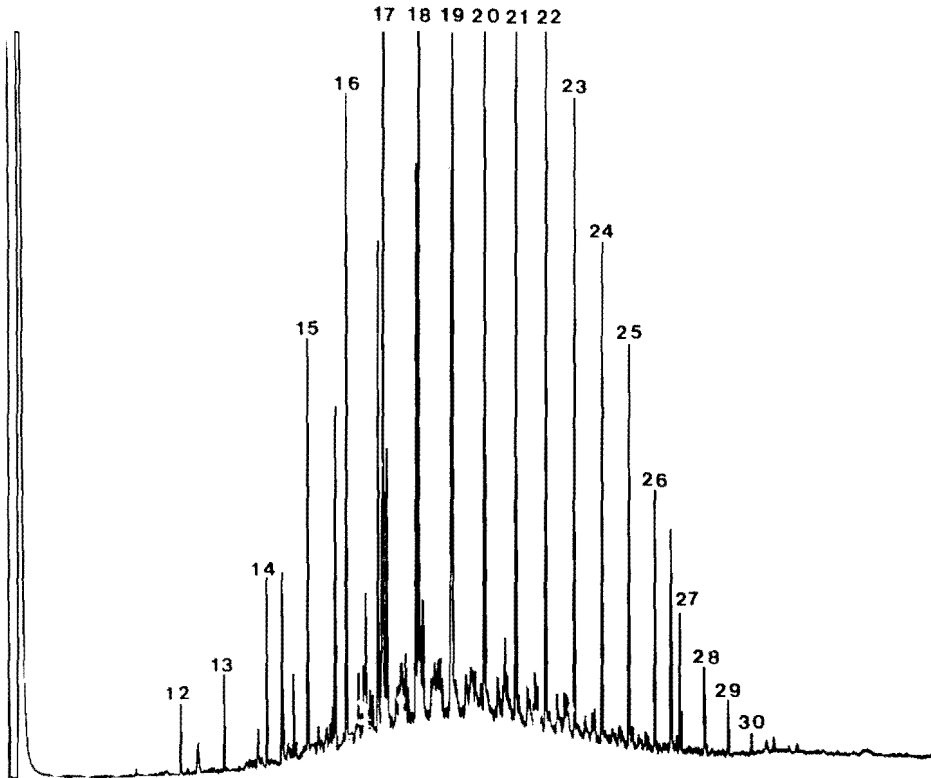


FIG. 4. Gas chromatogram of total hydrocarbons from a surface water sample obtained in May 1988 from station 2 in the Firth of Forth.

Biemann (1972) detected much higher values (3.4 mg/l) of aromatic hydrocarbons after an oil spill in the Charles River, Boston. Therefore, the source of pollution detected in this study may be oil released from ships operating or passing through.

The results also show higher values of hydrocarbons in March than at any other period. This may be due to either low microdegradation which coincides with the low temperatures observed during that time (Table 3) or presence of large concentrations of phytoplankton at that particular time. Zsolnay (1973) and Mackie *et al.* (1974) concluded that when phytoplankton is present in large concentrations, a very large increase in hydrocarbon content occurred in the seawater.

The overall results show that the highest concentrations of hydrocarbons in seawater were almost always found in station 1, as the nearest location to the oil and petroleum-related product industries located in the Forth estuary. The lowest values were mostly recorded in the outer station (5). Ajayi and Poxton (1987) concluded that the Forth estuary was heavily polluted. This occurs partly as a result of the resuspension and redistribution of polluted sediments by the action of currents and

through constant dredging and dumping. Therefore, the concentrations in general decreased significantly away from the source of contamination. Similar findings have been reported by Whittle *et al.* (1973), Mackie *et al.* (1978), Massie *et al.* (1985) and Mohd-Long (1985). While Whittle *et al.* (1982) indicated that the concentrations of hydrocarbons in the Forth decreased towards the open sea, Anon (1985) concluded that concentrations of hydrocarbons decreased with increasing time and distance from the discharge point, primarily due to evaporation and dispersions.

It is expected, as stated by Hardy *et al.* (1977), that the actual values obtained by different groups vary widely. While Law and Blackman (1981) reported the highest concentrations of hydrocarbons in the North Sea as 6.6 µg/l, Massie *et al.* (1985) reported values of 11.4 and 33.1 µg/l. Hardy *et al.* (1977), on the other hand, detected hydrocarbon concentrations of 4.5 µg/l. The variability between the results of the current study and those of many others are probably due to the effects of tides, currents and the time of sampling. Such values also vary with different areas. Marty and Saliot (1976) reported concentrations of 15.0-114.0 µg/l and 3.3-7.2 µg/l in the surface waters of the eastern North Atlantic and western Mediterranean respectively. While Carlberg (1973) reported concentrations of 0.2 µg/l in Swedish coastal waters, Levy and Walton (1973) recorded values of 1.0-10.0 µg/l in the coastal waters of the western Atlantic.

TABLE 3. The temperature (°C) and salinity (S‰) measurements taken from the Firth of Fourth during the period March-May 1988.

Stn.	March		April		May	
	Temp. (°C)	Sal. (S‰)	Temp. (°C)	Sal. (S‰)	Temp. (°C)	Sal. (S‰)
1	6.0	33.2	6.5	32.5	8.0	33.0
2	6.5	33.5	6.5	33.0	8.0	33.5
3	6.0	33.5	6.5	33.5	8.0	33.5
4	6.5	33.5	6.5	33.6	8.5	33.5
5	6.0	33.7	7.0	33.7	8.0	33.7

Higher concentrations of hydrocarbons in fish eggs were found in station 1 during March and May. However, slightly higher concentrations were found in station 2 in April. This may also be due to the nearness of station 1 from the different sources of oil companies. Although high numbers of fish eggs taken from station 3 in March were analysed, the hydrocarbon concentrations could not be detected probably due to the fact that this station, along with station 5, was distant from the sources of contamination.

The concentrations of hydrocarbons in fish eggs may reflect those found in surface seawaters, because fish eggs can be affected only when they contact the surface micro-layer (von Westernhagen *et al.*, 1987). One of the difficulties in this experiment is the lack of any information with which one can compare the results. How-

ever, Anderson *et al.* (1977) reported concentrations of 12.0 µg/l crude oil in cod eggs.

Hydrocarbon concentrations in fish larvae could not be detected in all samples analysed during either March or May. It may be due to the low numbers of larvae analysed. Higher values of hydrocarbons in fish eggs and larvae during the month of April than any other time indicates the presence of higher concentrations of hydrocarbons in water deeper than 1.0 m and therefore fish eggs and larvae were contaminated. The highest concentrations of total hydrocarbons were found in fish larvae collected from station 3 during April. This may come from their food (phytoplankton). Many studies confirmed that phytoplankton organisms are capable of producing hydrocarbons (Clark and Blumer 1967; Blumer *et al.*, 1971; Youngblood *et al.*, 1971; Zsolnay 1973).

References

- Ajayi, O.D. and Poxton, M.G. (1987) Sediment aliphatic hydrocarbons in the Forth estuary, *Estuarine, Coastal and Shelf Science*, **25**: 227-244.
- Anderson, J.W., Dixit, D.B., Ward, G.S. and Foster, R.S. (1977) Effects of petroleum hydrocarbons on the rate of heart beat and hatching success of estuarine fish embryos, *In: Vernberg, F., Calabrese, A., Thurberg, F. and Vernberg, W.* (eds.) *Physiological Responses of Marine Biota to Pollutants*, pp. 241-258. Acad. Press, New York.
- Anderson, J.W., Neff, J.M., Cox, B.A., Tatem, H.E. and Hightower, G.M. (1974) Characteristics of dispersion and water-soluble extracts of crude and refined oils and their toxicity to estuarine crustaceans and fish, *Mar. Biol.*, **27**: 75-88.
- Anon. (1985) *Oil in the Sea: Inputs, Fates and Effects*, Nat. Acad. Press, Washington D.C., 601 p.
- Blumer, M. (1970) Dissolved organic compounds in seawater: saturated and olefinic hydrocarbons and singly branched fatty acids. *In: Symp. of Organic Matter in Natural Waters*, pp. 153-167, Alaska Univ., Inst. Mar. Sci., U.S.A.
- Blumer, M., Guillard, R.R.L. and Chase, T. (1971) Hydrocarbons of marine phytoplankton, *Mar. Biol.*, **8**: 183-189.
- Carlberg, S.R. (1973) A three year study of the occurrence of non-polar hydrocarbons (oil) in Baltic waters 1970-1973, *ICES, CM 1973/E: 28* (mimeo).
- Clark, R.C. and Blumer, M. (1967) Distribution of n-paraffins in marine organisms and sediment, *Limnol. Oceanogr.*, **12**: 79-87.
- Cormack, D. and Nichols, J.A. (1977) The natural and chemical dispersions of oil in the sea, *Rapp. P.-v. Reun. Cons. Int. Explor. Mer.*, **171**: 97-100.
- Corner, E.D.S. (1975) The fate of fossil fuel hydrocarbons in marine animals, *Proc. Roy. Soc. London*, **189B**: 391-413.
- Corner, E.D.S., Harris, R.P., Klivington, C.C. and O'Hara, S.C.M. (1976) Petroleum compounds in the marine food webs. Short-term experiments on the fate of naphthalene in Calanus, *J. Mar. Biol. Ass., U.K.*, **56**: 121-133.
- Dyke, P.P.G. (1987) Water circulation in the Firth of Forth, Scotland, *Proc. Roy. Soc. Edinburgh*, **93B**: 273-284.
- Duce, R.A., Quinn, J.G., Olney, C.E., Piotrowicz, S.R., Ray, B.J. and Wade, T.L. (1972) Enrichment of heavy metals and organic components in the surface microlayer of Narragansett Bay, Rhode Island, *Science, New York*, **176**: 161-163.
- Elliott, M. and Griffiths, A.H. (1987) Contamination and effects of hydrocarbons on the Forth ecosystem, Scotland, *Proc. Roy. Soc. Edinburgh*, **93B**: 327-342.
- Elliott, M. and Kingston, P. (1987) The sublittoral benthic fauna of the estuary and Firth of Forth, Scotland, *Proc. Roy. Soc. Edinburgh*, **93B**: 449-465.

- Fulton, T.W.** (1896) Review of the trawling experiments of the (Garland) in the Firth of Forth and St. Andrews Bay in the years 1886-1896. *Sci. Invest. Rep. Fish. Bd. Scotl.*, **14**: 128-149.
- Gordon, D.S. and Keizer, D.D.** (1974) Estimation of petroleum hydrocarbons in seawater by fluorescence spectroscopy: improved sampling and analytical methods, *Fish. Res. Bd. Can. Tech. Rep.* **481**: 1-24.
- Gordon, D.C. and Prouse, N.J.** (1973) The effects of three oils on marine phytoplankton photosynthesis, *Mar. Biol.*, **22**: 329-333.
- Gordon, D.C., Keizer, P.D. and Dale, J.** (1974) Estimates using fluorescence spectroscopy of the present state of petroleum hydrocarbon contamination in the water column of the Northwest Atlantic Ocean, *Mar. Chem.*, **2**: 251-261.
- Grahl-Nielsen, O.** (1987) Hydrocarbons and phenols in discharge water from offshore operations. Fate of hydrocarbons in the recipient, *Sarsia*, **72**: 375-382.
- Grahl-Nielsen, O., Westrheim, K. and Wilhelmsen, S.** (1977) The Ekofish Bruvo blow-out. Part 3: determination of petroleum hydrocarbons in the water, *ICES, CM 1977/E*: **55**, 13 p. (mimeo).
- Grahl-Nielsen, O., Neppelberg, T., Palmork, K., Westrheim, K. and Wilhelmsen, S.** (1976) The Drupa oil spill, investigation concerning oil, water and fish, *ICES, CM 1976/E*: **34**, 18 p.
- Grossling, B.F.** (1976) An estimate of the amounts of oil entering the oceans. In: *Sources, Effects and Sinks of Hydrocarbons in the Aquatic Environment*, pp. 5-36, Am. Inst. Biol. Sci., Washington, D.C.
- Gruger, E.H., Wekell, M.M., Numoto, P.T. and Craddock, D.R.** (1977) Induction of hepatic aryl hydrocarbon hydroxylase salmon exposed to petroleum and polychlorinated biphenyls, separate and together, in food, *Bull. Environ. Contam. Toxicol.*, **17**: 512-520.
- Gundlach, E.R., Boehm, P.D., Marchands, M., Atlas, D.M., Ward, D.M. and Wolfe, D.A.** (1983) The fate of the Amoco Cadiz oil, *Science (New York)*, **221**: 122-129.
- Hardy, J.T. and Apts, C.W.** (1984) The sea-surface microlayer: Phytoneuston productivity and effects of atmospheric particulate matter, *Mar. Biol.*, **82**: 293-300.
- Hardy, J.T., Kiesser, S., Antrim, L., Stubin, A., Kocan, R. and Strand, J.** (1987) The sea-surface microlayer of Puget Sound. Part I. Toxic effects on fish eggs and larvae, *Mar. Environ. Res.*, **23**: 227-249.
- Hardy, R., Mackie, P.R., Whittle, K.J., McIntyre, A.D. and Blackman, R.A.A.** (1977) Occurrence of hydrocarbons in the surface film, sub-surface water and sediment in the waters around the United Kingdom, *Rapp. P.-v. Reun. Cons. Int. Explor. Mer*, **171**: 61-65.
- Harper, D.J., Ridgeway, I.M. and Leatherland, T.M.** (1992) Concentrations of Hexachlorobenzene, Trichlorobenzenes and Chloroform in the Waters of the Forth Estuary, Scotland, *Marine Pollution Bulletin*, **24**(5): 244-249.
- Heras, H., Ackman, R.G. and Macpherson, E.J.** (1992) Tainting of Atlantic Salmon (*Salmo salar*) by petroleum hydrocarbons during a short-term exposure, *Marine Pollution Bulletin*, **24**(6): 310-315.
- Hites, R.A. and Biemanh, K.** (1972) Water pollution: organic compounds in the Charles River, Boston, *Science (New York)* **178**: 158-160.
- Iilfe, T.M. and Calder, J.A.** (1974) Dissolved hydrocarbons in the Eastern Gulf of Mexico and the Caribbean Sea, *Deep Sea Res.*, **21**: 481-488.
- Kattner, G., Nagel, K. and Bockman, U.H.** (1983) Composition of natural surface films in the North Sea. In: *Sundermann, J. and Lenz, W.* (eds.) *North Sea Dynamics*, Berlin, pp. 662-670.
- Kocan, R.M., von Westernhagen, H., Landolt, M.L. and Frustenberg, G.** (1987) Toxicity of sea-surface microlayer: effects of hexane extract on Baltic herring (*Clupea harengus*) and Atlantic cod (*Gadus morhua*) embryos, *Mar. Environ. Res.*, **23**: 291-305.
- Koons, C.B. and Monaghan, P.H.** (1976) Input of hydrocarbons from seeps and recent biogenic sources. In: *Sources, Effects and Sinks of Hydrocarbons in the Aquatic Environment*, pp. 84-107. Am. Inst. Biol. Sci., Washington, D.C.
- Kuhnhold, W.W.** (1977) The effect of mineral oils on the development of eggs and larvae of marine species. A review and comparison of experimental data in regard to possible damage at sea, *Rapp. P.-v. Reun. Cons. Int. Explor. Mer*, **171**: 175-183.
- Kurelec, B., Britvic, S., Rijavec, M., Muller, W.E.G. and Zahn, R.K.** (1977) Benzo(a)pyrene

monoxygenase induction in marine fish-molecular response to oil pollution, *Mar. Biol.*, **44**: 211-216.

- Lacaze, J.C.** (1974). Ecotoxicology of crude oils and the use of experimental marine ecosystems, *Mar. Poll. Bull.*, **5**: 153-156.
- Law, R.I. and Blackman, R.A.A.** (1981) Hydrocarbons in water and sediments from oil-producing areas of the North Sea, *ICES, CM 1981/E*: **16**.
- Levy, E.M. and Walton, A.** (1973) Dispersed and particulate petroleum residues in the Gulf of St. Lawrence, *J. Fish. Res. Bd. Can.*, **30**: 261-267.
- Mackie, P.R., Platt, T.S. and Hardy, R.** (1978) Hydrocarbons in the marine environment. II. Distribution of n-alkanes in the fauna and environment of the sub-antarctic island of south Georgia, *Est. Coastl. Mar. Sci.*, **6**: 301-313.
- Mackie, P.R., Whittle, K.J. and Hardy, R.** (1974) Hydrocarbons in the marine environment. I. n-Alkanes in the Firth of Clyde, *Est. Coastl. Mar. Sci.*, **2**: 359-374.
- Mackie, P.R., Hardy, R., Whittle, K.J., Conway, D.V.P. and McIntyre, A.D.** (1976) Relationship between hydrocarbons and chlorophyll, particulate carbon and plankton in the area between the Firth of Forth and the Forties oilfield, *ICES, CM1976/E*: **42**, 9 p.
- Marty, J.C. and Saliot, A.** (1976) Hydrocarbons (normal alkanes) in the surface microlayer of seawater, *Deep Sea Res.*, **23**: 863-873.
- Massie, L.C., McIntosh, A.D., Davies, J.M. and Mackie, P.R.** (1987) Hydrocarbons and their microbial degradation in the Firth of Forth, *Proc. Roy. Soc. Edinburgh*, **93B**: 566-567.
- Massie, L.C., Ward, A.P., Davies, J.M. and Mackie, P.R.** (1985) The effects of oil exploration and production in the northern North Sea: Part 1 – The levels of hydrocarbons in water and sediments in selected areas, 1978-1981, *Mar. Environ. Res.*, **15**: 165-213.
- McLusky, D.S.** (1987) Introduction. *Proc. Roy. Soc. Edinburgh*, **93B**: vii-x.
- Mohd-Long, S.** (1985) *The Impact of Pollution on the Meiofauna of an Estuarine Mudflat*, M.Sc. Thesis, Heriot-Watt Univ. Edinburgh, 239 p.
- Monaghan, P.H., Seefinger, J.H. and Brown, R.A.** (1973) Persistent hydrocarbon content of the sea along certain tanker routes. A preliminary report, *API Report of the 18th Annual Tanker Conference*, Hilton Head Island, South Carolina.
- Neff, J.M. and Anderson, J.W.** (1981) *Response of Marine Animals to Petroleum and Specific Petroleum Hydrocarbons*, Applied Science Publishers, London 177 p.
- Neff, J.M., Cox, B.A., Dixit, D. and Anderson, J.M.** (1976) Accumulation and release of petroleum-derived aromatic hydrocarbons by 4 species of marine animals, *Mar. Biol.*, **38**: 279-289.
- Payne, J.E.** (1976) Field evaluations of benzopyrene hydroxylase induction as a monitor for marine petroleum pollution, *Science, New York*, **191**: 945-946.
- Pulich, W.M., Winters, K. and van Baalen, C.** (1974) The effects of a No. 2 fuel oil and two crude oils on the growth and photosynthesis of microalgae, *Mar. Biol.*, **28**: 87-94.
- Rice, S.D., Shorty, J.W. and Karinen, J.F.** (1977) Comparative oil toxicity and comparative animal sensitivity. In: *Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms*, pp. 78-94, Pergamon Press, New York.
- Stegeman, J.J.** (1978) Influence of environmental contamination on cytochrome P-450 mixed function oxygenases in fish: implications for recovery in the Wild Harbor Marsh, *J. Fish. Res. Bd. Can.*, **35**: 668-674.
- Swinnerton, J.W. and Linnenbom, V.J.** (1967) Gaseous hydrocarbons in sea water: Determination, *Science, New York*, **156**: 1119-1120.
- Thomson, D.G.** (1978) Studies of the geology of the Firth of Forth and its approaches, *Inst. Geol. Sci. Rep. No. 77/17*, Edinburgh.
- UNESCO** (1975) Ichthyoplankton report of the CICAR ichthyoplankton workshop, *UNESCO Tech. Pap. Mar. Sci.* No. **20**, 46 p.
- von Westernhagen, H., Landolt, M., Kocan, R., Furstenberg, G., Janssen, D. and Kremling, K.** (1987) Toxicity of sea-surface microlayer: effects on herring and turbot embryos, *Mar. Environ. Res.*, **23**: 278-290.
- Walton, D.G., Penrose, W.R. and Green, J.M.** (1978) The petroleum-inducible mixed-function

- oxidase of cunner (*Tautoglabrus adspersus* Walbaum): some characteristics relevant to hydrocarbon monitoring, *J. Fish. Res. Bd. Can.*, **35**: 1547-1552.
- Whittle, K.J., Mackie, P.R. and Hardy, R.** (1974) Hydrocarbons in the marine ecosystem, *S. African J. Sci.*, **70**: 141-144.
- Whittle, K.J., Mackie, P.R., Hardy, R. and McIntyre, A.D.** (1973) A survey of hydrocarbons in Scottish coastal waters, *ICES, CM 1973/E*: **30**, 9 p.
- Whittle, K.J., Hardy, R., Mackie, P.R. and McGill, A.S.** (1982) A quantitative assessment of the sources and fate of petroleum compounds in the marine environment, *Phil. Trans. Roy. Soc. London*, **B297**: 193-218.
- Youngblood, W.W., Blumer, M., Guillard, R.R.L. and Fiore, F.** (1971) Saturated and unsaturated hydrocarbons in marine benthic algae, *Mar. Biol.*, **8**, 190.
- Zobell, C.E.** (1963) The occurrence, effects and fate of oil polluting the sea, *Int. J. Air-Water Poll.*, **7**: 173-198.
- Zsolnay, A.** (1973) Measurements made at sea of the saturated and aromatic hydrocarbons in the Baltic in April 1973, *ICES, CM 1973/E*: **22** (mimeo).

أثر التلوث البترولي على بيض ويرقات الأسماك

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المستخلص . تمت هذه الدراسة في منتصف وشمال الفيرث ، غرب بحر الشمال ، وأهم أهداف هذه الدراسة هو تعيين نسبة تركيزات مشتقات البترول في ماء البحر (عينات سطحية ومن عمق واحد متر) وكذلك الموجودة في بيض ويرقات الأسماك خلال الفترة (مارس - مايو ١٩٨٨م) ، فقد جمعت عينات بيض ويرقات الأسماك بواسطة شبك البونجو ، كما قيست التركيزات بواسطة الأشعة فوق البنفسجية واختبرت بعض العينات لقياسها بواسطة الغاز كروماتوجرافي .

كل نسب تركيزات الهيدروكربونات كانت أعلى في مارس ، ومايو في عينات الماء السطحية ، ولكن في ابريل كانت أعلى نسبة تركيزات في عينات الماء تحت السطحية (واحد متر) .

وجدت أعلى نسبة تركيزات الهيدروكربونات في عينة ماء البحر السطحية (٣٤,٠ مجم/لتر) وكذلك على عمق واحد متر (٢٨,٠ مجم/لتر) وفي شهر مارس .

في مارس وجدت أعلى نسبة تركيز للهيدروكربونات في بيض الأسماك ، وقدرت بـ ٢٦,٤٣ ميكروجرام/الجرام ، وأقل نسبة هي ١٩,٨٢ ميكروجرام/الجرام .

في ابريل كانت أعلى نسبة تركيزات هي ٣٣,٦١ ميكروجرام/الجرام . وكانت أقل نسبة تركيزات هي ٤٦,٢٠ ميكروجرام/الجرام .

في مايو كانت أعلى نسبة تركيزات هي ٣٠,٨٢ ميكروجرام/الجرام . وكانت أقل نسبة تركيزات هي ٤,٠٨ ميكروجرام/الجرام .

النتائج الكلية تدل على أن التركيزات تقل بشكل عام كلما ابتعدنا عن مصدر التلوث ، وهذا يعني أن تركيزات التلوث البترولي تقل بزيادة الوقت والمسافة من مصدر التلوث .