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Oil Pollution and Fisheries [and Discussion]

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Phil. Trans. R. Soc. Lond. B 1982 **297**, 401-411
doi: 10.1098/rstb.1982.0050

Phil. Trans. R. Soc. Lond. B **297**, 401–411 (1982)
Printed in Great Britain

Oil pollution and fisheries

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The term 'pollution' is taken in its broadest sense and effects are recognized to be due to interference, tainting and toxicity. Each of these types of impact is discussed and assessed. It is concluded that no long-term adverse effects on fish stocks can be attributed to oil but that local impacts can be extremely damaging in the short term and that produce from specific localities can be tainted and unmarketable for long periods. In some coastal areas oil can be one among several contributors to reduced water quality, and the implications of this are discussed.

Introduction

To obtain an adequate overall view of the impact of oil pollution on fisheries, it is necessary to accept the broad Gesamp definition of pollution, which includes 'hindrance to marine activities including fishing'. Given this definition, three main points can be made: first, that oil, and in particular oil-related operations, can interfere with fisheries; second, that tainting can be a significant problem, and third, that oil, largely through its toxicity, can kill or cause adverse sublethal effects on marine species of commercial importance. The points are ranked for attention in that sequence because that is the order in which most practical fishermen would probably voice their concern with the oil industry.

Before expanding on these three points and considering fisheries as a target for oil pollution, it may be useful briefly to define the target. The global yield of fisheries from the sea in 1980 was estimated by F.A.O. at some 64.3 Mt of fish, crustaceans and molluscs, with a cash value, extrapolated from 1978 prices, of the order of $\$30 \times 10^9$. Apart from a slight decrease last year (attributed partly to the state of certain stocks but also probably to the establishment of relatively new exclusive economic zones) the trend in landings has been almost continuously upward for many years (F.A.O. 1981 *a*), and the most recent F.A.O. forecast expects a further expansion of the volume of trade in fishery products, sustained by reinforcement of the use of traditional food species, by the introduction of new, non-traditional species, and by a continuing increase in aquaculture (F.A.O. 1981 *b*). These figures testify to the importance of fisheries. They constitute a renewable resource, which quite apart from its cash and employment value, represents a significant food source for mankind. This emphasizes the need not only for proper management of the resource, but also for its protection from pollution and for the maintenance of global water quality.

The distribution of fishing effort varies according to the type of resource. The large pelagic species like tuna are exploited mainly in the upper waters of the open ocean, and many of the non-traditional species at present under consideration (for example, krill and small meso-pelagic fish) are also open-ocean-pelagic. However, the bulk of the world's marine fish yield (over 90%) is taken either near the edge of the continental shelf at a small number of upwelling areas, or on the shelf itself where many small pelagic species are located and the total demersal fishery is carried on. The shelf also carries the highest concentrations of molluscs (except squids) and crustaceans, these shellfish being mainly confined to coastal regions and in some cases even to intertidal zones. Finally, aquaculture is mostly associated with shallow coastal waters. The fisheries target for pollution is thus in the water and on the seabed of the relatively restricted areas of the world's continental shelves, and to a lesser extent in the upper waters of the open ocean.

Interference

In regions of oil exploitation, interference with fishing operations by oil-related activities can be a more or less continuous feature, and this interface between the two industries is a permanent area of potential conflict. Such conflict crystallizes round a number of specific types of situation (I.C.E.S. 1980).

One of these situations occurs at an early stage in the development of oil fields, when seismic investigations are under way. The use of explosives in such work can cause ecological disturbance and in the worst cases can kill fish. However, during the past decade in the North Sea less harmful techniques have been introduced, and this, together with consultations between the oil industry and fishermen on the timing and location of seismic surveys, can eliminate the problem.

A second aspect of interference, and one that probably creates the greatest frustration, is the existence of oil-related debris. A great variety of items has been found, but the bulk consists of ropes, cables, chains, anchors, fenders, drums and buoys. Some of these can float and endanger navigation, while others sink and damage fishing gear on the bottom.

A third type of interference is exclusion from fishing grounds by platforms, pipelines and suspended wellheads. These structures are of course clearly charted, but they define 'no-go' areas for fishing. A 500 m zone round platforms is internationally recognized and enforceable as a safety zone, and the area where trawlers can manoeuvre may be further reduced if a number of platforms cluster together. Pipelines present a comparable problem, and even though they may be trenched by jetting, this can produce large mounds of sediment which may be a greater hazard to fishing gear than the pipelines themselves. Although the loss of access is real, the area involved is relatively small. It has been calculated (F.A.O. 1977) that for nearly 7600 offshore wells in the Gulf of Mexico only a few thousandths of one per cent of the total trawlable ground was lost, and for the North Sea a comparable figure has been estimated at around 0.3%, possibly rising to a maximum of 1.0% depending on the assumptions made (Johnston 1976). However, effects may not be all adverse, since some platforms may function as artificial reefs, and significant enhancement of sport fisheries have been reported around rigs (F.A.O. 1977).

The problems discussed so far are associated with the operations of extracting oil. In addition, oil itself can cause interference. The presence of an oil slick will inhibit fishermen from shooting, and if a slick drifts over an area where fishing is in progress, the gear may have to be hauled through it, resulting in contamination. Gear contamination is perhaps most damaging in the case of fixed equipment, and the increasing aquaculture interests are highly conscious of the dangers of oil slicks, although some positive actions are possible in the provision of booms and the transfer of floating cages to uncontaminated areas.

Finally, it should perhaps be noted that intereference is not entirely one-sided, since vessels passing or anchoring too close to rigs or pipelines can cause damage which could be extremely expensive to the oil industry (I.C.E.S. 1980).

Tainting

The second main consideration, which is of very great concern to fishermen, is tainting: a change in the characteristic smell or flavour. Tainting may be due to oil taken up by the tissues or contaminating the surface of the catch, and can be caused by crude oil, petroleum products, refinery effluents and waste from petrochemical complexes. Light oils and the middle boiling range of crude oil distillates are the most potent sources of taint, but all oil fractions from petrol to heavy boiler fuels can be implicated (Whittle 1978). There is evidence to suggest that 0.01 $\mu l\, l^{-1}$ is the minimum concentration of oil in sea water necessary to taint fish (Nitta 1972) but such generalizations are not particularly helpful because the effect will vary greatly depending on the type of oil involved, the length of time it is present, and various other circumstances surrounding the exposure. Thus the threshold concentration of Louisiana crude oil necessary to taint the crab *Callinectes sapidus* after cooking was as high as 620–1120 $\mu l\, l^{-1}$ (Knieper & Culley 1975).

A recent experiment with salmon and saithe illustrates well the difficulties of generalizing about taint even in relatively simple situations (Brandal *et al.* 1976). The two species of fish were exposed in a tank to oil concentrations in water of 6–13 $nl\, l^{-1}$, derived from a slick of Ekofisk oil floating on the surface. The total exposure time was 10 weeks, and during this period samples of fish were removed at intervals for chemical analyses and organoleptic tests. The chemical analyses showed that both species took up aromatic hydrocarbons into liver and muscle tissues, but their tainting reactions were totally different. In the salmon, taint was detected within 6 days but in the saithe the only effect was slight and barely detectable after 22 days, which disappeared 5 days later. Even in the salmon the taint was not stable, and disappeared after the fourth week. During the whole period the oil concentrations in the water were about the same, but there was a reduction in volatile components with time.

These results demonstrate the differences in reaction between a fatty and a non-fatty fish and show the sort of variability that may be expected in the field. The important point is that tainting is not necessarily a permanent condition. It will persist if organisms are continuously exposed to renewable sources, but if exposure is terminated, depuration quickly takes place. Thus, for example, it is possible to cleanse shellfish that have been tainted by a spill or that have been taken from a habitat exposed to chronic low-level contamination.

However, it is clearly better to prevent taint in the first place. In this context, the situation of the ballast water treatment plant outfall at Sullom Voe in the Shetlands is relevant. A survey of the projected location revealed the presence nearby of a habitat for scallops. However, given the expected concentration of oil in the effluent, and in view of the dilution provided by the site and the diffuser, it was clear that the impact that could not be ruled out was the possibility of taint. Laboratory experiments were therefore set up in which scallops were exposed to a range of dilutions of the effluent, and it was determined that a dilution of tenfold did not taint scallops after 15 h exposure. Since this dilution was going to be substantially exceeded at the site, protection of the scallops seemed assured. This was tested when the plant was fully operational by suspending scallops in cages round the discharge point for several weeks. The specimens were later presented to a taste panel, which pronounced them free of taint. Thus, by setting appropriate discharge standards, and by proper design and siting of the outfall, resource protection can be achieved.

Unfortunately, even the demonstration of lack of taint may not be enough. There are records of situations where clean produce has been rejected on the market because it had been associated

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with a spill, or even where it was erroneously thought to have been oiled. Thus merely the suspicion of taint can be as damaging as taint itself, and it is clear why fishermen take this matter so seriously.

Tainting from oily water effluents is likely to be highly localized, but the effects of a large spill can be more widespread. We know well the effects of an incident on the scale of the *Amoco Cadiz*, and we also know that much smaller spills can have effects for years if the oil becomes incorporated in sediments, and that in such circumstances local shellfisheries may be closed down for a long time.

Finally, the question of carcinogenic effects must be raised, since this tends to be linked in the public mind with oil tainting. Crude oil, and in particular refined oils, do contain polynuclear aromatic hydrocarbons (PNAHs), some of which are known to be associated with mammalian cancer. When exposed to oil, marine fish and shellfish can concentrate PNAHs in their tissues, particularly in lipid-rich tissues, but depuration of most of the intake is rapid when the source of taint is removed. Molluscs are the most efficient accumulators of PNAHs, but these shellfish form only a small part of the human diet so that, compared with the intake of PNAHs through consumption of fresh vegetables and smoked foods, the contribution from unsmoked sea food is negligible (King 1977).

Effects of oil on fish and shellfish

The third main category of impact is the direct effect of oil on marine organisms themselves, and recalling the distribution of resources already discussed we may begin by considering open sea fisheries. These are conducted away from coasts, mostly well clear of many of the hazards that cause shipping accidents, and usually remote from sites of oil exploitation. The main sources of oil to the open ocean are discharges from ships, oil carried by ocean currents, and input from the atmosphere. The first of these sources, discharges from ships, is the most direct and significant, while input from the other two is difficult to quantify and evaluate. It is clear that in the open ocean the main concentrations of oil are on the surface, but such contamination is not extensive. An international study group has recently estimated that 0.015 % of the world's oceans are covered by an oil film at any given time, and agreed that this is the upper limit, probably exaggerating the real situation (GESAMP 1980). In general, particulate oil residues of varying size and density are distributed throughout the oceans, mostly on the sea surface. Some are formed soon after oil is discharged by tanker washings; others materialize over a longer period from weathering of spilled crude or heavy oil products. One recent estimate of the particulate oil residues on the surface of the North Atlantic is between 15 and 20 kt, a level of contamination that is closely related to routes of tankers and other shipping (Kohnke 1978). Quantitative data are now becoming available to show that these oil particles can be enriched by organochlorines and heavy metals (Sunay *et al.* 1978), but at present there is no indication that they pose any threat to marine life. Below the surface film, in the general water column of the open ocean, concentrations of oil are very low indeed, less than 1 nl l^{-1} – levels at which no effects on populations would be expected, or even detected against the natural variation. Indeed, there is no record of adverse effects on ocean fisheries from oil.

On the continental shelf, however, where the bulk of the fishing effort is deployed, it might be expected that fisheries would be at greater risk. Shipping concentration is greater on the shelf, exploitation of oil is increasingly carried on, and shelf areas are nearer to influence from

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land-based sources of contamination. In general, we might expect a higher concentration of oil in shelf waters, and a corresponding enrichment of the sediments. It may be useful to consider this under three headings: impact of operational inputs on the outer continental shelf; oil spills, and effects from multiple inputs in coastal waters.

Impact of operational inputs on the outer shelf

Oil originates from platforms and other such installations, so a number of point sources can be identified, and a distinction should be made between effects of oil and those of other inputs. One frequent input around platforms is drilling muds and cuttings, and this is well documented in American waters. At one platform off the Californian coast, several years of cuttings disposal produced a conical pile of silt about 37 m in diameter and 8 m high; it initially did not attract fish but after some years developed a flourishing fauna (Reid & Steimle 1978). In the Gulf of Mexico it was observed that fish did not avoid mud plumes and browsed on cuttings piles. Such piles in the Gulf were typically about 1 m high and some 0.2 ha in area. After 10–15 years the piles were not detectable, having been dissipated by storms and mixed with the surrounding sediments. In such cases there is clearly little impact on the environment, but in the deeper North Sea, where deviational drilling requires the use of oil-based muds, the levels found in sediments of 'clean' stations (9–53 $\mu g\ g^{-1}$ dry mass) are greatly exceeded. These enhanced concentrations occur within a radius of several miles round some platforms, the highest level recorded being 257 $\mu g\ g^{-1}$ total oil half a mile from a platform where oil-based drilling muds are being used. Armstrong *et al.* (1979), studying the outfall of effluent water from a separator platform, reported detrimental effects on the benthos, where napthalenes occurred at a persistent level above 2 $\mu g\ g^{-1}$ wet mass. If this threshold is applied to the North Sea data, adverse effects on the benthos might be expected within a 1 km radius round at least one platform (Massie *et al.* 1981).

Apart from the specific issue of muds and cuttings, it must be recognized that platforms are operational centres at sea and that they would be expected to be hot spots of oil contamination. This was demonstrated by surveys in 1975–7 (before the largest North Sea fields were on stream) by Gunkel *et al.* (1980), who showed that oil degrading bacteria were greatly enhanced in both water and sediments in the vicinity of the Ekofisk and Forties fields; more recent work has confirmed the existence of such hot spots (Ward *et al.* 1980; Law & Blackman 1981; Massie *et al.* 1981). However, the total oil input from production platforms in the U.K. sector of the North Sea in 1980 was less than 1 kt, and although this will increase as the volume of production water increases, the corresponding estimate for 1985 is just short of 2.5 kt (Read & Blackman 1980). Thus over the greater part of the North Sea the levels of hydrocarbons from operational inputs are not such as to cause lethal or sublethal effects on marine organisms.

Effects of oil spills

A consideration of oil spills suggests that they may be divided into two groups. The first consists of those like the Ekofisk blowout and the *Argo Merchant* spill, which occur in relatively open sea areas so that oil is quickly dispersed before it reaches the coast, and environmental effects are transient and confined to the vicinity of the spill, where elevated concentrations of oil occur only in the surface waters. In such situations, most mobile species probably avoid the spill area, and adverse effects are not usually recorded for adult fish. It might be expected that the most vulnerable commercial components would be the eggs and larvae, which occur in the upper waters, and there is an increasing accumulation of experimental data on the effects of water-soluble fractions of oil on these young stages. For example, Johannessen (1976) showed that a water-soluble extract of Ekofisk crude oil reduced the hatching success of fertilized capelin eggs at concentrations of 10–25 nl l^{-1}, while Tilseth *et al.* (1981), working with the same oil, found reduction in growth and a change in buoyancy in cod eggs and larvae after 14 days at 50 nl l^{-1}. Larvae exposed to the higher concentration of 250 nl l^{-1} developed malformations of the head and jaws that reduced their feeding efficiency. Unfortunately, direct extrapolation of such experimental information to the sea cannot be made. Oil concentrations of up to 250 nl l^{-1} were measured in the upper waters in the immediate vicinity of the *Argo Merchant* wreck, but it is difficult to judge how long individual plankters would be exposed to such concentrations, and to estimate the extent to which other features of the field situation might confound experimental forecasts. The most numerous fish eggs in the *Argo Merchant* spill zone were those of pollack, and a high proportion of those collected were superficially contaminated with oil and were found to be dead or moribund (Sherman (ed.) 1977). It is unlikely that this would have a detectable effect on fish stocks, and indeed the biological impact of such offshore spills on fish stocks appears to be negligible.

The second type of spill is that which occurs in shallow water, when wind can bring the oil inshore, mixing it throughout the water column and into the sediments. Even in these situations, effects on fish are difficult to detect. After the *Tsesis* spill in the Baltic, herring continued to migrate through the area, and contamination was not detected in their tissues. There was apparently some reduction in spawning the following spring, but investigators did not attribute this to the spill (Lindén *et al.* 1979). After the *Betelgeuse* incident in Bantry Bay, oil leaked out of the wreck for 18 months and dispersants were frequently used. During the spring, spawning of sprats and whiting took place, and there seemed to be no effects on the eggs and larvae (Grainger *et al.* 1980). In the *Amoco Cadiz* incident there was an immediate kill of several tons of rock-living fish at the site of the wreck, enhanced proportions of diseased fish were reported some time after the spill, and one year-class of flatfish was thought to have been reduced (CNEXO 1981). It is of interest that this is probably the one well-documented spill in which such effects on fish are recorded.

Indeed, most of the quantified effects on fisheries refer to shellfish, and mostly relate to the oiling of sediments either intertidally or in shallow water. The West Falmouth spill in 1969 of 700 t of no. 2 fuel oil contaminated shellfish beds, salt marshes and beaches, and 8 months later the polluted area covered 20 km^2. Effects on the crab populations were still obvious 7 years after the incident (Burns & Teal 1979). The grounding of the *Arrow* in Chedabucto Bay, Nova Scotia, in 1970 released 8 kt of bunker C fuel oil and contaminated about 240 km of shoreline. Populations of the clam *Mya arenaria* were still adversely affected 6 years later (Thomas 1978). These and other comparable spills are by now too well documented to need further comment here, but one point that must be emphasized is that the nature of the damage need not relate to the size of the spill. Even a few hundred tonnes of oil can devastate a local habitat and damage shellfish for tens of years. Further, the view has been expressed that after the *Amoco Cadiz* incident, the medium and long-term damage may turn out to be more alarming than the immediate destruction (CNEXO 1981).

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Effects from multiple inputs in coastal waters

Effects on biota in the area of a large oil spill or in the immediate vicinity of an oily discharge at sea can, with appropriate concomitant observation, usually be attributed to the one obvious source. In coastal waters, particularly in estuaries, oil may be contributed to a relatively small, perhaps partly enclosed, sea area from several sources including refinery outfalls, shipping, rivers and land drainage. It may then mingle with a wide range of other contaminants (metals, sewage, organochlorines, pharmaceuticals). In such areas, the biota are subjected to a general reduction in water quality, but even if advese effects can be detected, it is usually impossible to attribute them to one or other of the contaminants. Indeed, even the attempt to make such an attribution may not be justified, since the effect could be a reaction to non-specific stress. Obvious effects in this context are poor condition, and increased incidence of parasitism and disease, as discussed in detail by Sindermann (this symposium). It is, however, difficult to determine with confidence the effects of reduced water quality and general stress on populations of commercial species.

Assessment

Finally, we may attempt to make a general assessment of the impact of oil on fisheries.

From the foregoing, it will be clear that the interference issue is a source of irritation and of some financial loss to fishermen, but looked at in the overall context of shelf-seas fisheries it cannot be regarded as a global problem, and any effect on the commercial stocks is on balance negligible. In the North Sea, at least, the various aspects of interference are tackled by formal consultations between the two industries. Complaints are examined, and, where appropriate, compensation is paid.

The tainting problem is serious and must not be underplayed. At its worst it can bring severe financial hardship to individual fishermen and can close grounds for years. But there does not appear to be a public health problem and the impact of tainting must be regarded as local rather than even regional, and recognized as one that can be corrected with time.

Thus, if we are looking for significant effects on commercial fisheries, it is to the toxic effects of oil that we should turn, and we should be concerned not with effects on individual specimens but rather with long-term impact on stocks. In the open sea there is no record of adverse effects on commercial species, and indeed the concentrations of petroleum in ocean waters are so low that a threat could not be expected.

On the shelf, in the more open waters, we have seen that large spills may cause egg and larval mortalities, but again effects at the population level are not evident, while any impact from point sources such as oil platforms is very localized. It is possible to hypothesize about the effects of a major spill, by using information on the movement and toxicity of oil. Johnston (1977) postulated a major oil spill at the time and place of the main fish spawning in the North Sea and, using 'worst case' assumptions at each stage in the exercise, he calculated that the maximum effect would be a slight reduction in the overall yield for 1 year, a reduction that would be difficult to detect against the background of normal variability. It does seem that the commercial stocks in the open parts of the shelf are not at risk from oil.

This leaves the shallow coastal and intertidal area. It is recognized that the major impact of spills is here, and that it may last for years. It must be added, however, that the impact is

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not on whole stocks of fish or shellfish, but rather is localized, tied to specific bays or beaches that have been grossly contaminated.

Apart from major spills, the overall effects of diverse small oil inputs must be considered. We know (Bayne *et al.*, this symposium) that oil concentrations in some coastal waters are high enough to affect animals like the common mussel, reducing the feeding rate and producing other sublethal effects, including possible genetic changes. Oil must thus add to the general contaminant mixture, especially in estuaries, and we know that significant changes in commercial stocks do take place in these inshore areas although attempts are not usually made to link them with any single pollutant. There is, for example, no satisfactory explanation for the disappearance of oysters from the Firth of Forth. Again, since drilling started in the Gulf of Mexico in the 1920s there has been a major redistribution of the oyster fishery, and the valuable white shrimp has declined in relation to the brown shrimp – changes that some investigators claim to be attributable to the impact of man (F.A.O. 1977).

It is difficult to assess such claims and identify unequivocally the causes of the changes, as several papers in this volume demonstrate. However, it may be wise to end on a note of caution, recognizing the vulnerability of inshore areas and the fact that they require control and surveillance, and recognizing also that if hot spots are allowed to grow and multiply, what starts as a series of local problems could become of regional significance.

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Discussion

J. M. Baker (*Field Studies Council, Orielton Field Centre, Pembroke, U.K.*). Most oil pollution meetings are inevitably concerned with the temperate zones and the Western world. In global terms, however, mangrove swamps are (1) important for coastal fisheries (often unquantified subsistence fisheries) as they provide breeding and feeding grounds and fallen leaves for detritus-based food chains, and (2) known to be particularly sensitive to oil spills. Large trees may be killed, and as we have some evidence that these may be at least 60 years old, it follows that complete recovery of a damaged swamp may take at least 60 years.

A. D. McIntyre. I too am conscious of the damage that can be done by oil to mangroves and other tropical habitats such as coral reefs. It is relevant that the United Nations Environmental Programme is aware of this and is stimulating appropriate work in various parts of the world. A number of other international agencies are also considering the problems of mangroves.

A. J. Southward (*Marine Biological Association, Plymouth, U.K.*). Could I question the use of the word 'legitimate' in referring to fishing activities in comparison with exploitation of North Sea oil? This may have been true 100 years ago, but today's high-technology fishing operations would better be regarded as a serious assault. Pollution and overfishing both have a tendency to drive the ecosystem into a simpler state and reduce diversity. Surely what we need now is a policy to reduce or mitigate both forms of stress, rather than allow each side to attribute ecological changes to the excesses of the other? Would it not be better to admit this and to channel more scientific activity into prevention rather than encourage the well known delaying

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tactic that has been practised by both the fishing industry and the oil industry, of asking for more research to quantify the after-effects?

A. D. McIntyre. Dr Southward may question it! The phrase 'or interference with other legitimate uses of the sea' occurs in Article 1 of the Convention for the Prevention of Marine Pollution from Land-Based Sources (the Paris Convention). Without entering the interesting but possibly irrelevant discussion on the relative merits of various uses of the sea, I may say that I would be unwilling to equate exactly the effects of overfishing and pollution. However, I do agree with Dr Southward that adequate surveillance must involve consideration of all forms of stress. This is the policy of the Fishery Departments.

W. R. P. Bourne (*Zoology Department, Aberdeen University, U.K.*). There are also other interactions between fishing and the oil industry. Fishing rapidly became a major recreation on some of the oil platforms, until at the point where it was being developed on a commercial scale it had to be banned because the lost lines and hooks became a hazard to divers. A large part of the British fishing industry thrown out of work by the closure of foreign fishing grounds has now also found employment as standby vessels for oil installations.

S. J. Hawkins (*Department of Zoology, Manchester University, U.K.*). A recent circular from the S.E.R.C.-funded North West Universities Consortium for Marine Technology suggested that know aggregations of fish around offshore structures could be commercially exploitable, and were a subject worthy of research. This did not seem very sensible to me. Please could the speaker comment on this suggestion especially with regard to localized tainting, and the practical problems of catching the fish.

A. D. McIntyre. If this refers specifically to the North Sea, then the safety regulations round platforms would prohibit use of the normal fishing gear, and even if they were caught, fish would need to be examined for taint, at least initially, before being accepted as fit for the market. There is no doubt, however, that platforms do attract fish, and when they are close enough to the shore to allow access by small sport-fishing boats, as in the Gulf of Mexico, then this is a useful spin-off.

J. S. Gray (*Department of Marine Biology and Limnology, University of Oslo, Norway*). My impression from the meeting is that no long-term effects of oil have been shown on fisheries, and recovery of benthic communities occurs in 3–4 years on exposed coasts or 10–15 years on sheltered coasts. The latter may seem important but no mention has been made of the spatial extent of effects. The *Florida* spill, the most intensively studied to date, covers areas of a few hundred square metres, which compared even with the coastline of Massachusetts, far less the eastern seaboard of the U.S., is very small. Even areas affected by *Amoco Cadiz* oil are today confined to a few small embayments covering a very small percentage of the coast line of Brittany. With this knowledge, if there is a spill tomorrow, is it worth it, except for political reasons, for us to stop our current research to indulge in yet another descriptive follow-up of a spill when we know what will happen within fairly tolerable limits? Surely science has progressed further and is able to ask more specific and meaningful question today than mere descriptive work. What I miss at this meeting is a consensus of opinion of the way forward, and in particular the important questions that we should be asking in the event of future spills, and what should and should not be done.

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A. D. McINTYRE. I think that after a spill there will frequently be a need for descriptive follow-up if only for purposes of damage assessment, which may be required for several practical reasons. However, I agree that the more interesting problems lie elsewhere. For example, detailed comparisons of organisms in polluted sites with those that flourish in areas contaminated naturally by oil and metals could lead to basic studies on adaptation.