Section IV

THURSDAY, MARCH 11, 1999

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FISHING AND HARVESTING BANS IN OIL SPILL RESPONSE

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ABSTRACT: *Fishing and aquaculture harvesting bans are increasingly used as an oil spill management tool, with the intention of protecting public health and consumer markets. Such bans are easily imposed, but a rational basis is needed for maintaining and lifting them. Scientific criteria offer the best prospect for administering fishery bans in a consistent way, but recent marine pollution incidents reveal contradictions in their application. Inconsistencies can be found when comparing oil spills in different countries, and also when the response to different types of pollutant are compared. This paper explores the approaches for managing activity bans in the fisheries sector following oil spills. Examples are drawn from recent oil spills attended in North America, Europe, and Asia. Recommendations are made for caution to be exercised in the application of fishing and harvesting bans and for the adoption of sound criteria for monitoring their effectiveness.*

Introduction

Although there has been a downward trend in the incidence of major oil spills in the last decade, the risk of oil spill impact on commercial fisheries and aquaculture is increasing as coastal resources become more heavily exploited. The spread of aquaculture practices in European and American coastal waters as well as heightened food quality standards has also meant that even small oil spills can cause disproportionate damage. Subsistence fishing and recreational fishing can also be at risk. The impact of oil pollution on fisheries has been reviewed by Dipper and Chua (1997).

Tainting. Whilst commercially important marine animals and plants seldom suffer long-term harm from oil spill exposure, the contamination of seafood can be readily detectable as a petroleum taste, or taint. Public confidence in seafood products can quickly erode as a result of suspect, or actually contaminated, products reaching the market (Goodlad, 1996). A taint is commonly defined as an odour or flavour that is foreign to a food product (ISO, 1992). Tainting of living tissue is reversible but, whereas the uptake of oil taint is frequently rapid, the depuration process whereby contaminants are metabolised and eliminated from the organism is slower. The presence and persistence of taint will depend *inter alia* on type and fate of oil, species, extent of exposure, hydrographic conditions, and temperature.

Some, but by no means all, of the chemical components in crude oils and derivatives with the potential to cause tainting have been identified (PARCOM, 1996). Reliable threshold concentrations for petroleum-derived tainting agents are largely unknown. Hence it is not possible to determine by chemical analysis alone whether a product is tainted or not. However, the presence or absence of taint can be determined quickly and reliably by sensory testing, particularly if a trained panel and sound testing protocols are employed. The tainting of seafood and sensory testing procedures using trained taste panellists to assess taint by odour (and taste if necessary) have been studied extensively and the methodologies have been described in detail (Botta, 1994; Davis *et al.*, 1992; Howgate, 1987; MPCU, 1997), and recently reviewed by Howgate (in press).

Drastic measures are sometimes called for to limit the indirect effects of oil spills on fisheries and aquaculture. This paper focuses on the use of temporary fisheries closures and harvesting activity bans during oil spills as a means of protecting consumers from unpalatable and potentially unsafe seafood, and explores the repercussions of such measures on the operation of insurance and compensation schemes.

Economic loss and compensation. Economic loss occurring as a result of restrictions being imposed on fishing and aquaculture takes many forms. Traditional fishermen will be deprived of their livelihood unless they are able to exploit alternative uncontaminated stocks or pursue other sources of income. Aquaculture operators tend to sell their produce intermittently and so the timing and duration of harvesting bans in relation to the normal farming cycle will largely determine the extent of economic loss.

The payment of compensation for damage to fisheries and aquaculture resources caused by oil spills from tankers is governed primarily by international conventions. The Civil Liability Conventions, ratified by 110 countries, impose strict legal liability on tanker owners and, indirectly, their insurers. The Fund Conventions, ratified by 84 countries provide for supplementary compensation from the International Oil Pollution Compensation Funds (IOPCF) when claims exceed the tanker owner's limit of liability. Claims under the Conventions are assessed and paid in accordance with uniform admissibility criteria which stipulate *inter alia* that claims for losses incurred as a result of fisheries closures should be reasonable (IOPCF, 1998). In the context of the Conventions, fishery closures are expected to minimise or prevent economic damage which might otherwise occur. By implication, fishery closures should be lifted once marketing and public health considerations have been satisfied and the costs of the closure outweigh the economic benefits.

Following some major incidents involving heavy contamination of cultivated fish and shellfish, the stock has been destroyed as a result of directives issued by public health authorities. The policy of the IOPCF is to admit claims only if the destruction of the stock is reasonable on the basis of scientific and other evidence available. Pertinent considerations include proven oil contamination of the cultivated stock; depuration rates in relation to the normal harvesting time; and the marketability of depurated stock (IOPCF, 1998).

Public health concerns

The occurrence of tainting in seafood organisms or products has damaging implications for marketing and, as shown by recent experience in Europe and North America, reports of tainting following a major spill can quickly lead to public health directives being invoked. The incentive for government intervention comes as much from political and social considerations as from a science-based concern for consumer welfare.

The aromatic fractions of oil contain the most toxic compounds, and amongst these it is the 3- to 7-ring polycyclic aromatic hydrocarbons (PAHs) that command most attention on account of their known carcinogenicity. The full suite of potential carcinogens comprises numerous PAH compounds and derivatives with varying potency. For convenience, concentrations of known carcinogens are expressed in terms of BaP equivalents, whereby potencies, if they are known, are normalised to that of the most studied compound, benzo[*a*]pyrene (BaP) (EPA, 1997).

There is no evidence for oil-induced cancers following spills or that oil spills significantly increase the overall human exposure to carcinogens, even though PAH levels in commercial species may temporarily be increased a hundred-fold or more following an oil spill. However, in common with other potentially carcinogenic pollutants, it is not possible to define a concentration threshold of carcinogens that represents a risk-free intake for humans. Potentially carcinogenic PAHs are largely from pyrogenic and petrogenic sources and, for the general population, exposure to PAH (often measured as about a dozen 4- and 5-ring compounds and designated ΣPAH) is primarily from food. The detailed composition of the diet determines which food items are major contributors. The background level of ΣPAH in most seafood from non-industrialised areas is in the range of 5–50 ppb (SEEEC, 1998). Leafy vegetables, shellfish and grilled, smoked and barbecued foods can contain concentrations of PAH in excess of 100 ppb (see Table 1). Grilling or smoking food commonly results in a two- to six-fold increase in PAH levels (Bolger *et al.*, 1996). Generally, PAH levels in foods are not subject to legislative limits, although limits are set for some compounds in drinking water.

The risk to an individual or community from oil spill-derived carcinogens should logically be assessed in the context of the overall exposure, which is subject to many variables. From a general risk evaluation of the amount, frequency and duration of PAH exposure following oil spills, most studies have led to the conclusion that oil spill-derived PAH contamination of seafood is not a significant threat to public health (EPA, 1997; GESAMP, 1993; Mearns and Yender, 1997). Specific data for free-swimming fish reveal relatively rapid PAH depuration rates and indicate that there is little or no justification for concern. Also for subsistence consumers of fish the risk is negligible (Collier *et al.*, 1993). Following the grounding of the tanker *Braer* in 1993 over 80,000 tonnes of crude oil were spilled and naturally dispersed into the water column within a few days. As shown in Table 2, most of the fish species examined were found to be tainted and to contain elevated

Table 1. PAH concentrations in shellfish after an oil spill compared with uncontaminated shellfish and some other foods.

Food item	PAH ng/g Product wt.		% 4– to 6–ring PAH	Total CPAH	Reference
Exclusion Zone post–*Braer* oil spill sampled in January 1993					
Lobster Meat	11.2–1,060	*	2.6		Topping *et al.*, 1997
Crab White Meat	18.9–281	*	1.1		
Scallop Muscle	223–3,580	*	10.9		
Scallop Gonad	90.2–20,800	*	6.8		
Reference samples outside Zone					
Lobster meat	2.7–24.9	*			Topping *et al.*, 1997
Crab white meat	1.8–13.0	*			
Scallop muscle	12.8–289	*			
Scallop gonad	25.7–2,030	*			
Food products					
Margarines	40.5–91.3	*		9.8	Moffat and Whittle, in press
Vegetable oils	71.7–209	*		22.4	
Fish oils	60.6–2,048	*		14.4	
Dietary supplements/health foods	0.2–8,000	*		0.0–263	
Chocolate	10.5	**		2.2	Lodovici *et al.*, 1995
Beet greens	11.2	**		5.1	
Barbecued and smoked food					
Barbecued beef	42.1	**		30.0	
Barbecued pork	13.6	**		6.5	
Pizza in wood–burning oven	13.1	**		12.3	
Smoked mackerel, modern kilns	54.2	***		1.5	Karl, 1997

Note: PAH, polycyclic aromatic hydrocarbon; CPAH, sum of six or seven potentially carcinogenic PAH
* Sum of 2– to 6–ring PAH
** Sum of nine 4– to 6–ring PAH
*** Sum of thirteen 3– to 5–ring PAH

Table 2. Total measured PAH* (ng/g) wet wt) in reference samples of wild commercial fish and farmed salmon form outside the Exclusion Zone after the *Braer* oil spill in Shetland, January 1993, compared with sample inside the Zone (Whittle *et al.*, 1997).

	Reference samples		January samples			March samples			July samples	
Fish	Range	Mean	Range	Mean		Range	Mean		Range	Mean
Cod	2.2–5.1	3.2	1.3–74.4	21.9						
Haddock	0.8–11.2	3.8	7.8–262	60.8	T	5.3–6.4	5.8			
Plaice	1.6–37.0	11.1	15.4–184	78.7	T	5.6–6.1	5.8			
Whiting	0.3–10.2	4.5	8.8–2,650	384	T	3.5–5.9	4.4			
Lemon sole	2.4–13.0	7.1	6.0–1,240	453		7.5–16.1	11.8			
Dab	4.9–42.1	19.5	24.8–2,160	794	T	11.4	11.4			
Farmed salmon**	9.3–83.4	29.1	6,650–14,145	10,396	TT	98.2–273	197	TT	7.7–13.2	10.5

Note: Individual results are the PAH concentrations of a composite sample of fish muscle derived from up to 25 individual wild fish or from 10 farmed fish. T, some samples tainted; TT, all samples tainted.
* Naphthalenes, phenanthrenes, and dibenzothiophenes.
** The results for each month for the farmed salmon are from samples taken from the worst-affected site.

concentrations of mostly 2- and 3-ring PAHs but the levels rapidly diminished to background levels, by which time the fish were also taint-free (Topping *et al.*, 1997; Whittle *et al.*, 1997). This experience from a major incident indicated that reliable sensory testing was an adequate fisheries screening and monitoring technique. In other words, in terms of oil contamination, if a seafood product is found to be taint-free, it is likely to be fit for consumption.

Crustaceans, although generally more sedentary than fish, also lose their tissue burden of hydrocarbons relatively quickly. In the *North Cape* incident off Rhode Island, lobsters became contaminated and tainted by a spill of No. 2 fuel oil. An extensive programme of sensory testing and PAH monitoring of lobster tissues showed that tainting was detected for several months, but human health criteria applied at the time were not exceeded. Thus, also in this case, sensory testing proved to be a sufficiently sensitive monitoring technique for managing a fishery closure.

For other sessile, non-swimming species the situation is more complex with many filter-feeding molluscs, such as mussels, cockles, and oysters, tending to concentrate PAH and other potentially harmful oil components in their hepatopancreas, gonads, and other fatty tissues as a result of slower depuration. As such shellfish are commonly consumed whole, these elevated concentrations may be perceived to be an unacceptable health risk for the consumer. Shellfish predominantly inhabit the benthic and intertidal environments, of which the former is rarely affected by oil spills. However, in the *Braer* incident the increased PAH levels in certain mollusc and crustacean species persisted for several years, largely because of severe sediment contamination (Topping *et al.*, 1997). As of August 1998, a closure on the burrowing crustacean *Nephrops norvegicus* remains in force. Although the animals are able to tolerate the presence of the oil without apparent harm, the body burden of PAH has persisted as a result of continuous contact with contaminated sediment particles.

Many authorities take the view that the known bioconcentration capacity of some shellfish cannot be ignored and that some form of chemical analysis to monitor PAH levels and depuration rates is necessary (EPA, 1997). In contrast to this position are the conclusions drawn from studies of the potential threat posed by oil spilled in the *Exxon Valdez* incident. No significant risk was found to be associated even with regular consumption of shellfish from oil-contaminated subsistence fishing grounds when extrapolated over an average human lifespan. Levels of PAH in mussels from oil contaminated areas (30 ppb BaP equivalents) were found to be lower than those in samples of smoked salmon (112 ppb BaP equivalents) (Bolger *et al.*, 1996).

In any event, since no standards exist for determining precisely what level of oil contamination represents an acceptable risk in terms of carcinogenicity, it is difficult to operate a fisheries closure in a consistent manner. Data on background (baseline) levels of PAHs are sparse, and chronic marine inputs of PAHs from many populated areas can be of a similar order of magnitude to spill-generated levels. An additional complication is the fact that there are conflicting interests between the parties involved in a fisheries closure:

- Governments have a desire to protect public health but politicians may seek to capitalise on opportunities offered by a high-profile oil spill event.
- Fishermen and aquaculture operators with access to compensation may be content to benefit from the clear-cut loss situation created by a government-imposed ban.
- The spiller, insurers, and the IOPCF will contest any unjustified closures leading to unnecessary economic loss.
- Consumers may or may not be reassured by closures, depending on their perceptions.

When faced with conflicting economic, social, and political interests, the recourse for decision makers is to rely on objective scientific evidence. All interested parties will be united in their wish to prevent tainted (unpalatable) seafood from reaching the market and reasonable measures to achieve that aim should not be controversial. The question is whether sensory testing is sufficiently sensitive to prevent unsafe seafood from reaching the market.

Oil-tainted food is unpalatable even at very low levels of contamination, which provides a safety margin in terms of public health. The fact that oil-contaminated seafood contains carcinogenic substances is undeniable, but it does not follow that consumers must be protected from eating such food since all human beings consume the same substances in similar or greater quantities in other freely available food. Every safety standard for PAH levels in oil-contaminated seafood devised in the wake of recent oil spills is exceeded in many freely available food items and as a result of normal cooking practice (Table 1). From a strictly medical standpoint, there is no historic oil spill-related incident that can be held up as justification for regulating public seafood consumption.

The control of fishing activity as a management tool

Government restrictions on fishing activity are often imposed as a means of stock conservation or to ensure fair competition amongst fishermen. Fishing may be restricted to certain periods and locations, with closures often coinciding with breeding seasons and sites so as to encourage natural stock replenishment.

Catches may be restricted to certain quantities in a given period (quotas). Temporary closures of fisheries are imposed to protect consumers from health hazards when water quality or a seafood resource has become degraded by pollutants, natural toxicants, or micro-organisms. It is instructive to compare oil spill response measures with the remedies applied for non-oil-generated problems, in different countries.

Industrial effluents, plankton blooms, and sewage discharges are examples of agents other than oil causing the degradation of water and seafood quality. Public health may be severely threatened and in some cases consumers have died from eating shellfish contaminated by heavy metals, algal toxins, and pathogenic bacteria and viruses. For this reason government health authorities in many countries routinely monitor seafood hygiene and quality parameters and impose safety measures to help reduce the risk of food poisoning. In France, for example, all shellfish-growing waters are tested twice a week for bacteria, phytoplankton, and, in some areas, heavy metals. Fisheries and aquaculture facilities may be temporarily or permanently closed in cases where contaminants and toxins in shellfish exceed agreed action limits. Other examples of non-oil spill incidents include the 1998 closure on lobster fishing in an area adjacent to a nuclear power station in Scotland because of levels of radioactivity.

Fishery closures can be imposed after an oil spill in order to prevent or minimise fishing gear contamination and to protect or reassure seafood consumers. Fishermen can agree to a voluntary suspension of fishing activity during a period when oil is drifting in their normal fishing area, and thereby avoid repeatedly contaminating fishing gear. Alternatively, a fishery may be protected by extending existing closures or imposing additional bans, but there are likely to be secondary consequences from all these measures, both positive and negative. Oil spill fishery closures may result in beneficial stock conservation, particularly if the exploited species are non-migratory, and this can serve to offset fishermen's losses. Coates (1998) has documented improved lobster catches when the fishing ban was lifted 6 months after the *Sea Empress* incident in Wales. However, a closure generally leads to an economic loss for fishermen unable to pursue their business and may generate substantial compensation claims (Mauseth *et al.*, 1997). Aquaculture enterprises may also suffer large losses as a result of taint-induced closures, as shown by the impact of the *Braer* spill on Shetland salmon farms (Goodlad, 1996).

Occasionally, it is possible to extend fishing periods or to increase quotas ahead of a spreading oil spill and thereby reduce the anticipated loss of production. In the *Aegean Sea* oil spill in La Coruña, Spain, the Galician Fisheries Council deliberately authorised and encouraged fishermen to exceed published daily quotas of shellfish in an area under threat from spreading oil, but as yet unaffected. By this prompt action, the economic loss of the fishermen was reduced. A harvesting ban was imposed lasting 8 months, but fishermen were still able to obtain their full annual quota in the remaining 4 months of the year because the shellfish stocks were non-migratory and available for collection in larger numbers of bigger specimens when the ban was lifted.

The *Braer*, *Aegean Sea*, and *Sea Empress* incidents demonstrate the European trend towards instituting fishery closures following major oil spills. Public health concerns are invoked as the primary reason for introducing controls, but marketing issues related to fears of adverse public perception are clearly important factors, as discussed by Goodlad (1996). In the *Braer* spill 5,500 tonnes of farmed salmon worth US$32 million were condemned because the marketing of depurated salmon was deemed to be at odds with the high quality image of Shetland seafood products. Those involved in assessing compensation for oil spills questioned whether government regulators should be the arbiters of whether depurated seafood products are marketed, since this is essentially a commercial judgement.

The *Aegean Sea* incident provides an opportunity to contrast a spill related closure with a non-spill closure. Following the incident in December 1992, a ban was imposed by the Galician Fisheries Council for over a year on all aquaculture activity in a defined zone, leading to mussel farming losses estimated at over US$6 million. Mussels were strongly tainted and depuration was slow. The effect of the ban on all cultivation and maintenance activity was to remove any possibility of depurated mussels ever reaching the market. Some 8,000 tonnes of mussels were condemned and destroyed at a municipal waste site. When the activity ban was lifted in May 1994 the mussel cultivation resumed with the collection of fresh seedlings. The drastic intervention was justified by the Fisheries Council as a means of protecting seafood product image more than public health.

The same mussel farms are also regularly afflicted by blooms of toxic plankton, often referred to as "red tides." Seawater quality is monitored each week at a centre established by the Fisheries Council and harvesting bans are introduced when toxic plankton species exceed specified abundance. Despite the fact that red tide toxins in shellfish are potentially lethal to consumers, compared with the threat of an unpleasant taste from oil contamination, the authorities do not require the mussels to be destroyed and depurated mussels are later allowed to reach the market. A notable difference between the two different scenarios is that full compensation is not available for losses caused by algal blooms and so all parties are anxious to resume normal operations as soon as possible.

In the *Sea Empress* spill an oyster farm in a sheltered estuary within the closure zone was found to be severely affected by PAH contamination (ΣPAH> 3,000 ppb), but high pre-spill levels were also revealed (900 ppb) indicating chronic pollution of the intertidal mud flats. Even if the oysters were to become taint-free through natural depuration it was predicted that they would fail other, non-oil spill related public health criteria. Fortunately the oyster farmer was in the process of closing his business and retiring, thereby saving public health administrators from having to reach a decision on closing the farm. The farmer received full compensation under the terms of the Civil Liability and Fund Conventions for the progressive destruction of 65 tonnes of oil-tainted oyster stock, carried out in step with his pre-spill harvesting plans.

In the United States the *North Cape* oil spill in Rhode Island in 1996 has acted as a catalyst for reviewing fisheries management procedures. Subsequent oil spills in other states have also highlighted differences in response strategies. In Maine, California, and Washington fishery closures are introduced, maintained and removed by reference to monitoring programmes for tainting and PAH contamination, but an interesting contrast is provided by Texas. There have been no fishery closures in Texas for 20 years and public health officials prefer advisory declarations and other, less drastic, controls on harvesting and retailing. Controls are removed when gross contamination has disappeared and public health officials utilise tissue analysis purely to verify ongoing depuration. If there is a clear downward trend in contaminant levels it is argued that any public exposure to the contaminant will be of short duration and restrictions can be safely removed (Mearns and Yender, 1997).

In Asia there are many examples of oil spills affecting fisheries and aquaculture enterprises. In China, Korea, and Japan aquaculture facilities are very common in coastal waters and shoreline types are classified according to the different seafood species available for licensed collectors (Moller *et al.*, 1989). Despite such a heavy concentration of living marine resources at risk from oil spills, there are few reported instances of tainting or seafood contamination. Formal closures or activity bans are seldom, if ever, introduced. Instead voluntary suspension of fishing in oil-polluted areas is the norm. The voluntary suspension typically lasts 2–4 weeks until the gross oil contamination of shorelines has disappeared or has been removed. Fishermen usually participate in the shoreline clean-up operation and receive compensation for lost fishing income during the non-fishing period. In most cases, fishing and harvesting is resumed without any ill effects in terms of tainting, public health, or market confidence. An exception is provided by *nori* seaweed farms, which are particularly sensitive to oil contamination, and the stock is sometimes destroyed in order to maintain market confidence.

The recent trend in both Europe and in North America for imposing more stringent opening criteria for fishing and harvesting bans, based on perceived cancer risks, can send conflicting signals to the public. Some consumers may be reassured by firm government action restricting the availability of taint-free seafood on the grounds of PAH contamination. Others may become alarmed and sensitised by a heightened awareness of carcinogens in food generally and set about changing dietary habits even in the absence of compelling reasons. This is at the very least unnecessary and may be actively detrimental if inherently beneficial dietary components like fish and shellfish (and vegetables), rich in protein and vitamins, are replaced by less wholesome food.

A further danger of focusing public attention on a flawed perception of the PAH threat comes from the fact that many fisheries and aquaculture enterprises operate in environmental conditions degraded by chronic PAH pollution. Singling out oil spills for special treatment could lead to demands for the same standards to be applied more widely. Permanent closures, loss of employment, and adverse public opinion are the likely consequences of taking the PAH issue to its extreme.

Criteria for re-opening fishery closures

Experience from recent major oil spills affecting fishing and aquaculture suggests that there is sufficient time for a quick screening programme to establish whether commercially important species are affected by oil contamination (Law *et al.*, 1997). The alternative of imposing an automatic ban pending analytical results is less satisfactory in view of the problems associated with selecting re-opening criteria that are appropriate to the circumstances of the oil spill.

Fishery closures imposed to prevent oil contamination of fishing gear and catches can generally be lifted once the sea surface is visually free of oil and sheen, and there is no problem with sunken oil. Aerial surveillance is the most reliable way of checking sea surface conditions. Restrictions imposed on the basis of proven tainting are likely to be more prolonged and require careful monitoring. A sampling programme with defined objectives will be necessary to determine the degree, spatial extent and duration of the problem.

Sensory testing. Properly conducted sensory testing is the most efficient and appropriate method for establishing the presence and disappearance of tainting. Blind testing, trained taste panellists and valid control samples are essential elements in a sensory test protocol in order to obtain reproducible results and eliminate any personal bias on the part of the testers (Howgate, 1987). In principle, a relatively small number of samples is sufficient to confirm the initial presence of taint and define the affected area in order to introduce a restriction. Monitoring the progressive loss of taint by sampling at appropriate intervals thereafter, allows the point at which taint disappears to be determined with some confidence. Once two successive sample sets over a short period of time remain clear, restrictions can be removed or the scope of the ban adjusted as a distinct area or species is shown to be free of taint. The confidence in accepting that the fish or shellfish are clean and safe following a particular spill comes from an adequate time-series of monitoring data showing the progressive reduction in taint.

There are some fundamental points to be considered when examining the statistical basis for lifting a fishing or harvesting restriction. As numbers of contaminated and tainted organisms decrease, they are encountered progressively less often in samples. A small sample from a large population will, in statistical terms, give a lesser degree of certainty that fish are clean than a larger sample. Another issue concerns what proportion of individual sensory testing verdicts should determine the overall panel pass/fail mark. Criteria that are set in absolute terms of a pre-set pass rate may be rendered unworkable by an overly sensitive test protocol. This situation can arise in urban and industrial areas with high background or pre-spill levels of contamination. There are several reported examples of investigations in which significant oil contamination has proved to be non-spill-related (Mauseth *et al.*, 1997).

One justifiable approach, which addresses both problems, is to establish at what point a representative number of samples from the polluted area are no more tainted than an equal number of samples from a nearby area or commercial outlet outside the spill zone (IOPCF, 1998). This approach is inherently fair and recognises that tainted samples (not necessarily due to oil spills) can occur in any population but, if applied rigorously, attention may well be drawn to high, unregulated pre-spill levels of contamination in seafood from urban and industrial areas.

Chemical analysis. In some cases, the chemical composition and the fate of the spilled oil, or the presence of commercial shellfish resources in the path of the oil, may argue for chemical analysis to be undertaken. Since detailed chemical analysis is invariably expensive, it is sensible to screen samples using quick and cheap methods in order to determine roughly the extent of any contamination. Alternatively, sensory testing can be used as a screening tool so that only those samples that are taint-free are selected for further analysis. However, in selecting sampling frequency, a desire to save on analytical costs must be balanced against the very substantial financial implications of a closure, with costs potentially running to many thousands of dollars per day.

It is widely recognised that to impose a single fixed standard for PAH levels in seafood by reference to baseline data is impracticable for several reasons. Baseline data are rarely available and unlikely ever to be applicable to the conditions prevailing during a particular oil spill. Background levels of hydrocarbons, where they are known, vary greatly and are subject to both pyrogenic and chronic anthropogenic input. PAH intakes in seafood meals also vary greatly between different communities, as do the perceived sensitivities of individual consumers.

In recent U.S. spills, threshold concentrations of PAHs have been selected on a case by case basis, partly reflecting differences in State regulations (Mauseth *et al.*, 1997). For example, the criteria imposed by Rhode Island state authorities for opening a lobster fishery in the *North Cape* incident included: the absence of floating sheen in the closure area; less than 1 ppb [PAH] in water samples; tissue samples to be free of taint; and carcinogenic PAH levels in lobster tissue to be less than 20 ppb BaP equivalents. These criteria were derived from a risk-based assessment and an assumed maximum acceptable cancer risk level of 1 in 100,000 (10^{-5}) during a 5-year exposure. A similar approach has been adopted in Maine, California, and Washington, but there is a trend towards more stringent PAH and sensory criteria being applied in successive U.S. spills (Challenger and Mauseth, 1998).

Other strategies have been devised to overcome the disadvantages of a fixed standard. The basic criteria for re-opening fisheries set by U.K. government authorities in the wake of the *Braer* oil spill in 1992 provided that sampled species should be taint-free and contain no more PAHs than control/reference samples collected just outside the restricted zone (Topping *et al.*, 1997). This strategy promotes a solution that is consistent in the local context of individual spills, but there is also the likelihood that markedly different criteria are applied openly or tacitly within a country depending on background pollution levels. Public health authorities can then be accused of operating double standards.

The *Sea Empress* oil spill in 1996 off Milford Haven, Wales, reinforced the importance of transparent decision-making based on scientific principles and sound data. Following the spill of 72,000 tonnes of crude oil, a government ban on fishing and marketing activity was imposed by the Welsh Office Agriculture Department under the 1985 Food and Environment Protection Act (FEPA), with respect to all commercial and recreational species in a defined marine exclusion zone and the adjoining terrestrial freshwater catchment area. The closure was maintained and progressively lifted by reference to a monitoring programme involving a range of species tested for taint, total hydrocarbon contamination, and ΣPAH levels (Law *et al.*, 1997). Sensory tests revealed all samples to be taint-free, and concentrations of hydrocarbons and PAH declined to accepted levels within weeks (free-swimming fish), months (crustaceans), and over a year (bivalve molluscs). However, no public information on re-opening criteria was ever issued and some people were under the mistaken impression that seafood was severely contaminated and very unsafe to eat (SEEEC, 1998). Similar experiences are described by Challenger and Mauseth (1998) in their account of the *Kure* oil spill in California in 1997 and the difficulties encountered in agreeing upon re-opening criteria several weeks after the harvesting ban on oyster harvesting was imposed.

Conclusions

Credible decision making with respect to fishing and harvesting bans should be based on sound scientific principles and common sense. Knowledge of fishery resource management is essential, as is an understanding of oil pollutants, their physical and chemical characteristics, and background levels of contamination, both locally and nationally. Seafood consumption patterns and seasonal variations in availability will further help define a public health risk profile and allow regulators to form a considered opinion on risk management. Other important oil spill contingency considerations include the need to determine re-opening criteria before deciding on whether to impose fishing and harvesting bans; the consistent application of management restrictions; and a full cost-benefit appraisal of the impact of control measures. The media will inevitably expose the shortcomings in the response to a spill, but can also play a valuable role in promoting a rational reaction to temporary disruptions. The needs of the media are best served by providing factual information and by clearly justified decisions.

Consumer reaction to seafood quality during oil spills is unpredictable since public perception is not entirely governed by fact or informed opinion. Government regulators need to strike a balance between the need to inform the public and the risk of raising unnecessary fears. Seafood retailers and those responsible for paying compensation for oil spill damage have a legitimate interest in the marketing of taint-free and safe produce. The concept of "due diligence" on the part of the food industry is enshrined in U.K. food safety law, which requires that food must not be injurious to health, unfit, or so contaminated that it would be unreasonable to expect it to be eaten.

The need for international guidelines on managing fishery resources during oil spills has been recognised by the International Maritime Organisation, and GESAMP (1993) recommend the development of standard procedures for measuring taint. In most oil spill scenarios a fisheries and aquaculture management protocol consisting of a visible-sheen test and sensory tests will satisfy the demand for scientific credibility and provide adequate safeguards for the twin concerns about unpalatable and unsafe seafood. Interestingly, the absence of sheen and taint is also the oil pollution standard adopted by the European Union for determining the fitness of coastal waters for shellfish cultivation.

As shown by recent food scares in Europe, government authorities are in an unenviable position and face accusations of cover-up or scaremongering whichever response is chosen in an incident. By taking a wider view of oil spill impact on fishing and harvesting, regulators have a better opportunity of identifying appropriate methods of intervention, applying controls and restrictions in a consistent manner, and thereby retaining credibility in the eyes of all affected parties.

Biography

A marine biologist by training, Dr. T.H. Moller is a Technical Team Manager at The International Tanker Owners Pollution Federation. In the course of his 20 years at ITOPF he has attended some 70 oil pollution incidents in 30 countries. Although living and working in the United Kingdom, Dr. Moller is a citizen of Sweden and studied at Gothenburg University before completing his national service in Sweden and continuing his postgraduate studies in fisheries biology at the University of Wales in Bangor, North Wales U.K. He was awarded a Ph.D. there in 1977 and held a postdoctoral research post at Liverpool University until 1979.

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