EFFECTS OF OIL POLLUTION ON FISHERIES AND MARICULTURE

TECHNICAL INFORMATION PAPER

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Introduction

Oil spills can cause serious damage to fishery and mariculture resources through physical contamination, toxic effects on stock and by disrupting business activities. The nature and extent of the impact on seafood production depends on the characteristics of the spilled oil, the circumstances of the incident and the type of fishing activity or business affected. In some cases, effective protective measures and clean-up can prevent or minimise damage.

This paper describes the effects of ship-source oil pollution on fishing and mariculture and provides guidance on response measures and management strategies which may help to reduce the severity of oil spill impacts. Damage to other economic resources is considered in a separate Technical Information Paper.

Damage and loss mechanisms

Fishing (the capture of wild species) and mariculture (the cultivation of captive species) are important industries which can be seriously affected by oil spills in various ways (*Figures 1, 2*). Commercially exploited animals and plants may be harmed as a result of oil toxicity and smothering. Seafood may become physically contaminated or may become tainted, acquiring an objectionable oil-derived taste. Fishing gear and cultivation equipment may be oiled, leading to the risk of catches or stock becoming contaminated or activities being halted until gear is cleaned or replaced. In addition to the losses of individual operators, the interruption of subsistence (*Figure 3*), recreational and commercial fishing activity and the disruption of seafood cultivation cycles can also have important economic consequences. Consumers may become reluctant to purchase seafood products from an affected region and the loss of market confidence can result in economic loss even if there is no actual contamination of the produce.

Figure 1: Fishing fleets can be affected by spilled oil, either as a result of contamination of vessels and gear or by fishing bans, both of which may force them to remain in port.

The impact of the spilled oil is determined by its physical and chemical characteristics, in particular the density, viscosity and chemical composition of the oil, and the way these characteristics change with time, or 'weather'. The changes brought about by weathering are themselves largely dependent on the prevailing climatic and sea conditions.

Adult free-swimming fish and wild stocks of commercially important marine animals in the open sea seldom suffer long-term damage from oil spills. This is because oil concentrations in the water column rapidly decline after a spill, only rarely reaching levels sufficient to cause mortality or significant harm, and are usually confined to an area near the source of the spill. In contrast, caged animals and seafood products that are cultivated in fixed locations are potentially at greater risk because they are unable to avoid exposure to oil contaminants on or in the surrounding water.

The greatest impact is likely to be found near-shore, where animals and plants may be physically coated and smothered by oil or directly exposed to toxic components over extended periods of time. For this reason, sedentary species, such as edible seaweeds and shellfish, are particularly sensitive to both smothering and oil toxicity. In addition to mortality, oil may cause more subtle damage to behaviour, feeding, growth or reproductive functions. However, because populations of many marine species normally exhibit significant natural fluctuations, the sub-lethal effects due to an accidental spill of oil can be difficult to isolate.

Damage to seafood may also be caused as a result of measures taken to combat an oil spill. For example, animals and plants that might otherwise be unaffected by floating oil may become tainted through exposure to oil droplets suspended in the water column, particularly if dispersants are used nearby. Aggressive or inappropriate clean-up techniques, such as indiscriminate washing with high pressure and/or hot water, can also adversely affect commercially exploited species and delay natural recovery.

The seasonal cycles of fishing and mariculture vary throughout the year, according to the type of species fished or reared.

▲ *Figure 2: A seaweed farm – fisheries and mariculture are often susceptible to oil spills.*

▲ *Figure 3: Small coastal communities often rely on fishing for income and subsistence and can be severely affected as a result of an oil spill.*

As a consequence, the sensitivity of a species or activity to spilled oil is also seasonally dependent. For example, some of the larger seaweeds grown in Asia are harvested in the spring or early summer and the next generation is not planted out until early autumn. Other faster growing species may have several plantings and harvests throughout the year. The rearing of larvae in onshore tanks supplied with water piped from the sea is similarly seasonal and does not generally extend beyond a few months in any year.

As a consequence, the precise extent and nature of the damage to fisheries or mariculture will depend on a combination of a variety of factors that may arise during a particular oil spill. Neither the spill volume alone, nor any other single factor, provides a reliable indication of the likely damage. Instead, the time of year, the type of oil and how much of the oil reaches these sensitive resources should all be taken into account. One of the most difficult challenges is to distinguish the effects of an oil spill from changes arising from other events, especially natural fluctuations in species levels, variation in fishing effort, including overfishing, climatic effects, for example El Niño, or contamination from industrial or urban sources. In many instances the absence of reliable data to describe the conditions existing prior to the spill, or the levels of productivity previously achieved, serve to compound the difficulty.

▲ *Figure 4: Lobsters, starfish and shellfish affected by a spill of diesel, which dispersed naturally in shallow water during a storm.*

Toxicity

The toxic effects of oil depend on the concentrations of the light aromatic components in the oil and the duration of exposure to these components. Toxicity effects can range from subtle sub-lethal behavioural effects to localised mass mortalities of marine life.

As a generalisation, light crude oils and light refined products, for example petrol or kerosene, contain relatively high proportions of the low molecular weight aromatic compounds that can cause acute toxic effects. Wild stocks occasionally suffer toxic effects following large spills of lighter oils close to the shore, especially in storm conditions or in heavy surf (*Figure 4*). In these circumstances, rather than evaporating rapidly from the sea surface, a relatively large proportion of the lighter toxic components can disperse into the water column and become confined in shallow waters, resulting in sufficiently elevated concentrations to cause narcosis or mortality of marine organisms. Intertidal and shallow sub-tidal benthic fauna, such as bivalve molluscs and crustacea, are particularly vulnerable, but on rare occasions free swimming fish have also been observed to succumb under these conditions.

▲ *Figure 5: Oiled fishing nets and pots may be cleaned, provided they are not too heavily fouled. However, in some instances, replacement may be more economically viable.*

▲ *Figure 6: Fish traps are susceptible to contamination by floating oil.*

▲ *Figure 7: Onshore fish hatcheries require large volumes of clean sea water. Water intakes are usually located below the water surface and may be affected by dispersed oil.*

At lower concentrations, laboratory studies have demonstrated that exposure of test species to the more toxic components of oil can result in impairment of various physiological functions, such as respiration, movement and reproduction, and can increase the likelihood of genetic mutations in eggs and larvae. However, not only is it difficult to detect such sub-lethal effects in the field but the widespread impact on stocks, which might be predicted by extrapolation of the laboratory results to the field, has not been observed. Similarly, despite mortality of eggs and larvae which may occur following a spill, subsequent depletion of adult wild stocks is very rarely recorded. In part, this can be explained by the considerable natural resilience of marine ecosystems to a variety of acute impacts. Marine organisms readily adapt to naturally high mortalities, *inter alia* by the production of vast surpluses of eggs and larvae and recruitment from stock reservoirs outside the affected area.

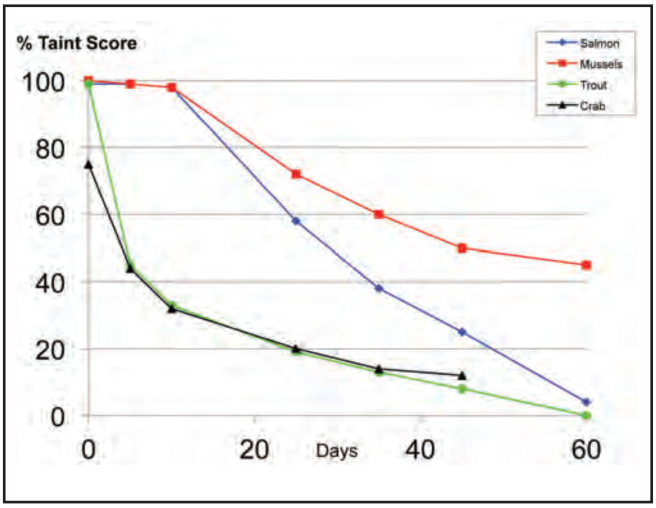
Physical contamination

Oil can foul boats, fishing gear and mariculture facilities and can then be transferred to the catch or produce (*Figure 5*). The rearing and handling of many seafood products in bulk means that it is seldom practical to locate, isolate and remove just the oiled specimens. Flotation equipment, such as buoys and floats, lift nets, cast nets, and fixed traps (*Figure 6*) extending above the sea surface are particularly at risk of contamination by floating oil. Lines, dredges, bottom trawls and the submerged parts of cultivation facilities are usually protected, provided they are not lifted through an oily sea surface or affected by sunken or dispersed oil. Shoreline cultivation facilities, such as intertidal oyster racks (*Figures 16 and 19*) are especially vulnerable. They are usually located in the middle or lower shore, where the natural rise and fall of the tide exposes a band of the shoreline to oil pollution. When fish farming facilities become physically impacted by floating oil, the oiled surfaces may themselves be a source of secondary contamination until they are cleaned.

The cultivation of seaweed, fin fish and many marine animals, such as crustaceans, molluscs, and echinoderms, frequently involves the use of onshore tanks to rear the young to marketable size or to a size and age suitable for transfer to the sea (*Figure 7*). Such facilities are usually supplied with clean sea water drawn through intakes located below the low water mark. These intakes may occasionally be under threat from sunken oil or dispersed oil droplets, which may lead to contamination of pipework and tanks, and the loss of cultivated stock. The presence of oil may significantly add to the stresses already imposed on stock kept in the artificial environment of cages or tanks. If, for example, the stocking density or the water temperature in a fish farm is unusually high, there is a greater risk of mortality, disease or growth retardation, although these may occur irrespective of oil contamination.

Tainting

Taint is commonly defined as an odour or flavour that is foreign to a food product. Oil contamination of seafood can usually be readily detected as a petroleum taste or smell. Bivalve



▲ *Figure 8: Depuration rates (loss of taint) for fish and shellfish after experimental exposure to Forties crude oil (Source: Davis, H.K., Moffat, C.F. & Shepherd, N.J. (2002). Experimental tainting of marine fish by three chemically dispersed petroleum products, with comparisons to the Braer oil spill. Spill Science & Technology Bulletin, Vol 7, Nos.5-6, pp.257-278.)*

molluscs and other filter-feeding, sedentary animals are particularly vulnerable to tainting, since they filter substantial quantities of water and so risk ingesting dispersed oil droplets and oiled particles suspended in the water column. Caged fish, and in particular those with a high fat content, such as salmon, have a greater tendency to accumulate and retain petroleum hydrocarbons in their tissue.

Other factors that influence the presence and persistence of taint include the type of oil, the species affected, the extent and duration of exposure, the hydrographical conditions and the water temperature. Tainting of living tissue is reversible but, whereas the uptake of oil taint is frequently rapid (minutes or hours), the depuration process, whereby contaminants are metabolised and eliminated from the organism, is much slower (weeks) (*Figure 8*). At low ambient temperatures, metabolism, and therefore depuration, may be very slow.

Some of the chemical components in crude oils and oil products which have the potential to cause tainting have been identified, but many remain unknown. Furthermore, although no reliable threshold concentrations have been established, the hydrocarbon concentrations at which tainting can occur are very low. Consequently, 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 (also known as organoleptic testing), particularly if a trained panel and well-established testing protocols are employed. Since the levels of contamination that lead to an unpalatable oil taint are very low, it is widely considered, as far as oil contaminants are concerned, that if seafood is judged to be taint-free, it is safe to eat.

Public health concerns

The occurrence of contamination in seafood organisms or products following a major spill can lead to public health

▲ *Figure 9: Seafood is an important protein source for many communities.*

concerns and may give rise to the imposition of fishing restrictions. These concerns stem primarily from the presence of polycyclic aromatic hydrocarbons (PAHs) in the oil. Not all PAHs are of the same potency because of differences in molecular structure that affect their metabolism. Crude oil spills give rise primarily to contamination by low molecular weight PAHs which usually exhibit little or no carcinogenic potential, but are of concern due to their acute toxicity or tainting properties. On the other hand, heavy fuel oils generally contain a greater proportion of high molecular weight PAHs, including those that can be actively carcinogenic. A key factor in PAH mutagenic potency is the formation of reactive metabolites that attach to DNA and can lead to genetic mutations, a particular concern of PAHs of between 3 and 7 benzene rings. Importantly though, because of the physical characteristics of fuel oils and associated emulsions, including their high viscosity and low dispersability, they are less readily incorporated into living tissue, being less bio-available.

Background PAH concentrations in water, sediment and tissues are highly variable and arise from a variety of inputs, including pyrogenic (combustion related), chronic anthropogenic (from human activities) and natural sources. Normal PAH intake through eating seafood varies greatly between individuals and communities according to typical portion size, the frequency with which seafood is eaten and individual body weights. The risk to an individual or community from oil spill-derived carcinogens is therefore dependent on the pattern of consumption of fishery products in any one location (*Figure 9*). Although it is not possible to define a risk-free intake for humans, 'acceptable' levels of PAH in seafood can be developed for specific geographic areas according to the typical level and patterns of consumption. As a consequence, a number of authorities have now adopted Maximum Permitted Levels (MPL) of PAH in marine products. For example, in the European Union the MPL for the PAH Benzo[a]pyrene (BaP) in fish is <2 µg/kg and for bivalve molluscs is <10 µg/kg (*Table 1*).

The US Environmental Protection Agency (US EPA) has identified 16 PAH compounds as 'priority' pollutants which are often targeted for measurement in environmental samples.

▲ *Figure 10: Fish for sale – the interruption of commercial fishing activity can have important economic consequences throughout the sales chain, from landing ports to retailers, such as this market stall.*

Guidance values have been established based on the sum of these 16 priority PAHs following spills. However, since PAHs form a complex mixture of thousands of compounds, 'total PAH' is often used as a measure of contamination. Total PAH is, however, often difficult to interpret, since it will depend on the nature of the particular components that have been added together to obtain the global figure. For this reason, the identities of the actual PAHs analysed should be specified to allow an evaluation of contamination levels based on a comparison of like-with-like.

The range of relative potency of various PAHs extends over many orders of magnitude. In this respect, BaP is considered a key compound and, because of its presence in cigarette smoke, is the PAH most studied. As a result, a range of guidelines have been developed around the use of BaP as an indicator. As a further step, in order to compare samples from different origins and apply guidelines, Toxic Equivalency Factors (TEF) have been developed whereby the concentrations of individual PAHs are expressed as equivalents of BaP, based upon their relative carcinogenic potency. These values are summed to obtain a Benzo[a] pyrene equivalent figure (BaPE).

Overall human exposure to PAHs from all potential sources is subject to many variables. For example, a wide variety of smoked or barbecued foods also contain the same or similar PAH compounds as might be derived from spilled oil. Leafy vegetables grown close to urban centres may become contaminated by airborne PAHs deposited on the leaves. A further complication for food quality controllers is the fact that seafood quality is also affected by other forms of contamination, such as heavy metals, algal toxins, pathogenic bacteria and viruses. The potential impact of an oil spill on public health therefore has to be viewed in its overall context in order to identify and implement appropriate remedies. Taking into account the amount, frequency and duration of PAH exposure following oil spills, most risk assessment studies have led to the conclusion that there is usually a sufficient safety margin between the levels of PAHs in seafood following an oil spill and those that would lead to a significant threat to public health, even for subsistence consumers.

	Indicator	Guidelines[1]	Target
France - AFSSA[2] (ERIKA 1999)	16 PAH analysed by National Network of Observations (RNO)	∑ < 500 µg/kg DW Sale exclusion>1,000 µg/kg DW	Shellfish
UK FSA[3] (2002)	Benzo[a]anthracene Benzo[a]pyrene Dibenz[a,h]anthracene	∑ < 15 µg/kg WW	All seafood
European Union (2005)	Benzo[a]pyrene (BaP)	< 2 µg/kg WW < 5 µg/kg WW < 10 µg/kg WW	Fish Crustaceans & Cephalopods Shellfish
South Korea (MIFAFF)[4] (HEBEI SPIRIT 2007)	Benzo[a]pyrene equivalent (BaPE)	< 3.35 µg/kg WW	All seafood
US EPA[5] (NEW CARISSA 1999)	BaPE	'Safe' < 10 µg/kg WW 'Unsafe' > 45 µg/kg WW	Shellfish Shellfish
US EPA[5] (KURE 1997)	BaPE	'Safe' < 5 µg/kg WW 'Unsafe' > 34 µg/kg WW	Shellfish Shellfish
US EPA[5] (JULIE N 1996)	BaPE	'Safe' < 16 µg/kg WW 'Unsafe' > 50 µg/kg WW	Lobster Lobster

[1] DW – Dry weight; WW – Wet weight. As a rule of thumb DW = ca. 15% x WW; µg/kg ≡ ppb.
[2] AFSSA: Agence de Sécurité Sanitaire des Aliments.
[3] FSA: Food Standards Agency. This guideline has now been superseded by European Union standards.
[4] MIFAFF: Ministry of Food, Agriculture, Forestry and Fisheries
[5] EPA: Environment Protection Agency. Variation in guidelines limits are primarily due to differing regional diets.

▲ *Table 1: Examples of guideline PAH levels used by different authorities to manage seafood safety following oil spills.*

Loss of market confidence and business disruption

The disruption of fisheries and mariculture activities and the potential for substantial economic loss are often among the most serious consequences of an oil spill (Figure 10). Public health concerns and the detection of taint are likely to lead to produce being withdrawn from the market. A loss of market confidence may also occur leading to price reductions or outright rejection of seafood products by commercial buyers and consumers. Media coverage of oil contamination, or word-of-mouth, can have implications for the marketability of seafood. However, quantifying financial loss due to loss in market confidence can be difficult, because it depends on reliable data being available to demonstrate both that sales have been lost and that prices have fallen as a direct consequence of the spill.

When it proves impossible to protect fishing gear and cultivation facilities from oil, economic losses are typically suffered until facilities are cleaned and become operational again. Quantifying economic loss due to mortalities of cultivated organisms is often a relatively straightforward process of counting and weighing the affected produce. Lost profit is then calculated from projected harvest weights and the expected market price at the first point of sale, less any saved production costs such as staff wages, feed and fuel. Account also has to be taken of the degree of natural mortality which routinely occurs during cultivation.

Response options and mitigation of pollution damage

When mariculture facilities, structures or nets become contaminated, they can sometimes be cleaned *in situ*, for example, with high pressure washing equipment (*Figure 11*). For more severe contamination, the facilities may have to be dismantled for cleaning. When it is impossible to clean, or cleaning costs are likely to exceed the costs of purchasing new equipment, replacement may be the preferred option (*Figure 12*).

To protect fixed fishing gear and mariculture facilities from contamination, booms and other physical barriers can sometimes be used. However, fishing and cultivation equipment are frequently purposely sited to benefit from migration routes or efficient water exchange and such locations are usually characterised by moderately fast flowing water in which booms are largely ineffective. Fish farms located in calm waters can sometimes be protected with heavy-duty plastic sheeting wrapped around the perimeter of the cages, thereby preventing floating oil from entering the nets or contaminating the floats (*Figure 13*). The sheeting should not extend too far below the water surface and should be weighted at the bottom edge to prevent it from riding up as a result of currents or wave action. In certain situations, sorbent booms can also be deployed around cages.

Although sorbents are not appropriate for the removal of

Figure 11: Mariculture facilities can be cleaned in-situ by pressure washing.

Figure 12: Seaweed cultivation racks heavily contaminated with oil. These could not be cleaned to a satisfactory standard and were therefore dismantled and replaced with new structures.

Figure 13: With sufficient notice, weighted plastic sheeting can be suspended around fish cages in an attempt to prevent contamination by floating oil.

▲ *Figure 14: An oiled abalone farm. Sorbent pads, though inappropriate for bulk oil removal, are often useful for removing sheen from inside fish cages.*

▲ *Figure 15: Fishing restrictions may be imposed to protect public health and to prevent contaminated produce reaching markets after an oil spill.*

bulk oil, they are often useful for removing thin oil films from water surfaces in tanks and cages (*Figure 14*). Sorbent materials have also been used successfully to filter sea water for onshore facilities. In all cases, it is important to replace oiled sorbents to avoid them becoming a source of secondary pollution. Loose particulate sorbent should not be used, as this can be mistaken for feed.

Contamination of equipment by floating oil can sometimes be reduced or prevented by the application of dispersants to slicks at a sufficient distance from facilities and inshore fisheries. The distance necessary to avoid contamination of stock by dispersed oil is dependent upon the strength and direction of prevailing currents and the time required for the dispersed oil to be sufficiently diluted in the water column. As a consequence, dispersant use in the vicinity or up current of mariculture facilities, spawning grounds, nursery areas or water intakes should be undertaken only after consideration of the potential effects.

In addition to standard spill response measures, alternative mitigation strategies include towing floating facilities out of the path of slicks, temporary sinking of specially designed cages to allow oil to pass over, and the transfer of stock to areas unlikely to be affected. The opportunities to use these approaches may be rare for a range of technical, logistical and financial reasons but, in the right circumstances and with sufficient planning, opportunities to avoid contamination and financial loss should not be overlooked.

For shore tanks, ponds or hatcheries, temporary suspension of water intake and re-circulation of the water already within the system may be effective to isolate stock from the threat of oil contamination. Closing sluice gates to prawn ponds, for example, can also afford short-term protection. Suspension of feeding may offer an option to avoid farmed fish and other cultivated stock coming into contact with contaminated feed if food would otherwise be distributed through a surface film of oil. The reduction or suspension of feeding has the additional advantage that the loading of waste products in the re-circulated water is reduced, but care must be taken to ensure that the build-up of noxious waste products in stagnant or re-circulating water does not result in excessive mortality of stock. A balance will be required between the potential damage to stock caused by these mitigating actions and from the oil.

For such mitigation strategies to be effective, it is vital that sensitive fishing and mariculture facilities are identified in contingency plans. Operators should be included in drills and exercises to test their readiness to respond and should be notified promptly in the event of a spill that poses a threat to their facilities, to allow sufficient time for strategies to be put into effect.

In some cases mariculture operators may face the risk of ultimately losing all the stock due to oil spill damage. With sufficient notice it might be possible for operators to harvest stock early, before it becomes oiled. Although the stock may not have reached full marketable size, some of its value could be salvaged. Conversely, normal harvesting might be delayed to allow contaminated stock to become taint-free by natural metabolic processes. However, it may prove difficult to predict a reliable timetable for this process to be completed satisfactorily since depuration rates depend on local conditions and the species involved. In addition, given that depuration rates are likely to be slow, stock may have grown beyond optimal market size, so that alternative and perhaps less lucrative markets may need to be found.

Management strategies

A number of management strategies are available to prevent or minimise the impact of oil pollution. The simplest involves no intervention beyond monitoring the evolution of an oil spill and any threat to seafood quality. Low-key intervention can take the form of guidelines to the seafood industry, for example measures that could be taken to mitigate losses. Where fish are caught by anglers for sport, sufficient protection can sometimes be provided simply by issuing advice against consuming the catch and the temporary adoption of a catch-and-release policy. Stricter measures include retail controls, impoundment of catches and seafood products, activity restrictions and fishery closures (*Figure 15*). Each measure has potential drawbacks and a careful review of the options available is advisable before action is taken. The following four strategies may allow authorities to manage the situation and to confidently allow controls and restrictions to be revoked.

Sampling, monitoring and analysis

The objectives of a well-defined monitoring programme should be to determine the degree, duration and the spatial extent of the oil contamination (*Figure 16*). In principle, in order to introduce a restriction on fishing or sale of products, the sampling and analysis of a relatively small number of samples is often sufficient to confirm the initial presence of contamination or taint and to define the affected area. The minimum number of samples required to obtain reliable results is determined on a case-by-case basis. Monitoring the progressive loss of contamination by sampling at appropriate intervals thereafter allows the point at which levels return to background to be ascertained with some confidence.

The frequency and geographic extent of sampling and testing should be determined by the severity of contamination and the rate at which depuration is observed to occur. One practical approach is to ensure that samples should be taint-free and that levels of PAH are no higher than reference samples collected just outside the affected zone or than found in marine produce freely marketed elsewhere in the country. When two successive sample sets, taken over a short period of time, produce results at acceptable levels, restrictions can be removed or the scope of the ban adjusted as contamination within a distinct area or species is shown to have reduced sufficiently.

It may not be necessary to analyse all the samples taken and some may be retained for later analysis should initial results prove inconclusive or unreliable. Target species will be those of commercial, recreational or subsistence value and which are actually consumed. Carefully selected control samples from nearby areas unaffected by oil pollution are important for reference purposes and to help eliminate the interference from background contamination. In some cases, samples from local seafood markets can provide a benchmark for comparison with samples from oil-polluted areas.

Samples of animal and plant tissue are perishable and must be collected and stored appropriately to preserve their integrity. Clean storage containers should be used (preferably glass) to avoid spoilage and cross-contamination of samples. Chilling or freezing is the most convenient conservation method for counteracting the microbial decomposition of samples in the short term. Collected samples should be sealed, labelled and quickly placed in an insulated container with a suitable refrigerant pack ready for transport to the analytical laboratory or to a freezer facility for longer term storage. It should be recognised that under some analytical protocols even frozen samples become invalid after long periods of storage.

▲ *Figure 16: Collecting oyster samples for analysis – the minimum number of samples to obtain reliable results needs to be determined on a case-by-case basis.*

▲ *Figure 17: Fish and shellfish are usually steamed prior to sensory testing. After cooking, these lobsters have been opened and the white meat will be tested for taint by smell and taste.*

Sensory testing

Sensory testing is often the most appropriate method for establishing the presence or lack of tainting and for indicating whether seafood is fit for human consumption (*Figure 17*). Trained taste panels and valid control samples are essential elements in a sensory test protocol. In order to obtain reproducible results and minimise bias, tests should be conducted ‘blind’, that is, the tasters should not know the identity of either control or potentially tainted samples.

Figure 18: Collection of water samples in an enclosed onshore farm. Analysis may indicate the potential for contamination of stock.

Figure 19: Procedures for monitoring the levels of contamination, as with these oysters, should be included in contingency plans to avoid unnecessary fishery closures.

The taint-free threshold can be defined as the point at which a representative number of samples from the polluted area are found to be no more tainted than an equal number of samples from a nearby control area or commercial outlet outside the spill zone. This approach takes account of the fact that there may be variation between individual testers and consumers and that in any population tainted samples may occur for reasons other than an oil spill. The confidence in accepting that the fish or shellfish are clean and safe comes from an adequate time-series of monitoring data showing the progressive reduction in taint following a spill (*Figure 8*).

Chemical analysis

Sensory testing may serve as a useful screening tool. However, the lack of trained taste panels, the greater accessibility and reduced cost of analytical techniques, and the adoption of chemical seafood safety standards by many authorities, means chemical analysis is used more frequently to manage fisheries and mariculture following an oil spill. Most commonly, chemical analysis of PAHs is undertaken using Gas Chromatography linked to Mass Spectrometry (GC/MS). PAH concentrations are then compared with nationally or internationally accepted standards or with levels found in reference samples taken from a local control area.

The selection of samples of seafood organisms for analysis is usually preferable to samples of water and sediment as the organisms effectively 'monitor' the condition of the surrounding water and/or sediment by the processes of accumulating and then depurating contaminants. The water and/or sediment serve as the pathway by which the contaminants reach and become accessible to the organism. As a consequence, in cases where the water column is known to be impacted (for example by visual observation), it is generally preferable to analyse the seafood in order to determine whether or not the contamination has transferred to the organism. Primarily, it is the condition of the seafood, rather than the water or sediment, that is of interest and importance to regulators and consumers. Where the presence of contaminants cannot be ascertained by obvious means, testing of water column samples, particularly from enclosed onshore facilities (*Figure 18*), or of individual indicator species (e.g. mussels) may be necessary to allay fears of contamination to stock.

Managing fishery closures

Fishing and harvesting restrictions can be imposed after an oil spill in order to prevent or minimise contamination of fishing gear and to protect or reassure seafood consumers. Fishermen can agree to a voluntary suspension of fishing activity as a precautionary measure during a period when oil is drifting in their normal fishing area, and thereby avoid repeatedly contaminating fishing gear. Where a voluntary suspension is inappropriate, formal closures or marketing restrictions may be applicable, but it is essential that criteria for reopening and lifting such bans are also considered when restrictions are imposed.

Fishery closures imposed to protect equipment and catches can generally be lifted once the sea surface is visually free of oil and sheen and provided that there is no evidence of sunken oil. Restrictions imposed on the basis of proven tainting or contamination are likely to be more prolonged and require careful monitoring. In most oil spill scenarios, a fisheries and mariculture management protocol will consist of measures such as surveys to confirm the absence of floating sheens or sunken oil, sensory testing to determine the lack of taint and chemical analysis to demonstrate that contamination levels have returned to background or to below Maximum Permitted Levels (MPL). Separately, or more often in combination, these strategies offer scientific credibility and meet the demand to provide adequate safeguards against unpalatable or unsafe seafood reaching consumers.

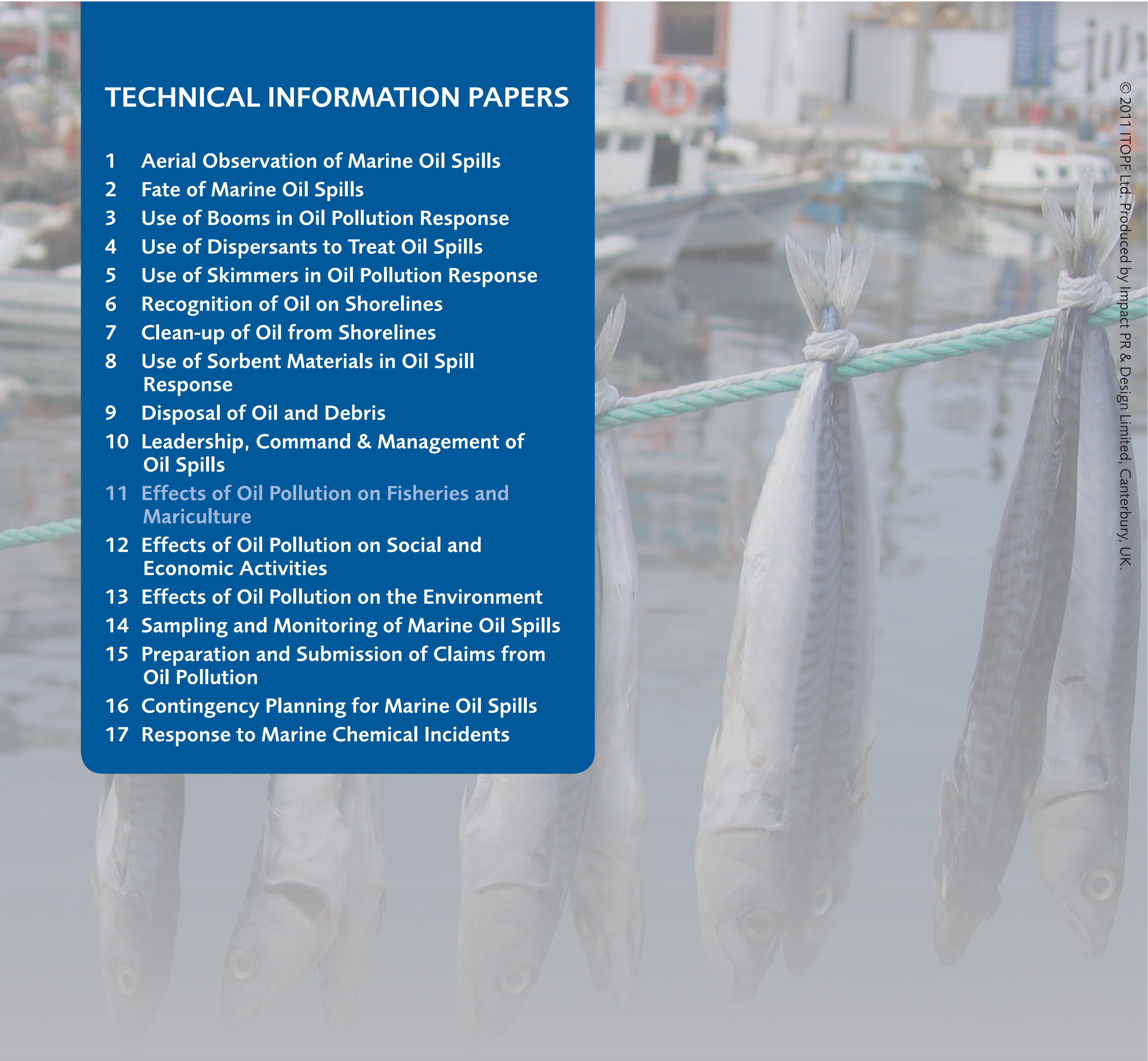
The criteria for reopening a fishery must be realistic and achievable in terms of the normal seafood quality in the area. Credible decision-making calls for a knowledge of fishery resource management and reliable data on background levels of contamination, both locally and nationally. A good understanding of the physical and chemical characteristics of oil pollutants and how these affect marine plants and animals is also helpful. Seafood consumption patterns and seasonal variations in availability will further help to define the risk to public health and allow regulators to form a considered opinion on risk management.

Seafood quality regulators will have to strike a balance between the need to inform, reassure and protect the public while addressing the risk of raising unnecessary fears. The strategies adopted will reflect the cultural and administrative practices of the country affected and will therefore vary globally. The media can play a valuable role in promoting a rational reaction to temporary restrictions by relaying the results of properly conducted sampling and testing regimes.

Both closure and reopening criteria should form an important part of contingency plans (*Figure 19*). Ultimately, the benefits of a closure need to be balanced against the economic losses that arise from a prolonged disruption of normal fishing and cultivation activity. Paradoxically, oil spill fishery closures can sometimes result in beneficial stock conservation, particularly if the exploited species are non-migratory and the impacts from the oil are minimal.

Key points

- The effects of oil pollution most commonly suffered by the fisheries and mariculture sector are the physical oiling of equipment and contamination of seafood leading to tainting.
- The effects of an oil spill on natural fishery resources and fish populations are extremely difficult to isolate from other factors, such as natural fluctuations in stock, climatic effects, contamination by industrial or urban sources and from over-fishing.
- The effects on commercial and subsistence fisheries can lead to substantial losses.
- The repercussions of contaminated seafood on public perception can be serious unless the issues of market confidence and public health are well managed.
- Arrangements to advise operators as early as possible of the threat of an oil spill to their facilities offers the best opportunity for the use of effective mitigation techniques.
- To maintain confidence in the fisheries sector, management strategies adopted following an oil spill should rely on scientific methods and data to ensure seafood safety and quality.
- In the context of oil pollution, if seafood is taint-free it is widely considered safe to eat because contaminant levels at which humans detect oil taint are so low.
- Effective contingency plans that address fisheries' closures and reopening, as well as oil spill response measures, can prevent or reduce the impact of oil spills on fishing and mariculture.



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16 Contingency Planning for Marine Oil Spills
17 Response to Marine Chemical Incidents

ITOPF is a not-for-profit organisation established on behalf of the world's shipowners and their insurers to promote effective response to marine spills of oil, chemicals and other hazardous substances. Technical services include emergency response, advice on clean-up techniques, pollution damage assessment, assistance with spill response planning and the provision of training. ITOPF is a source of comprehensive information on marine oil pollution and this paper is one of a series based on the experience of ITOPF's technical staff. Information in this paper may be reproduced with the prior express permission of ITOPF. For further information please contact:

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