OIL SPILL EFFECTS ON FISHERIES

Introduction

Oil spills can cause damage to fishing and aquaculture resources by physical contamination, toxic effects and by disrupting business activity. The nature and extent of the impact of an oil spill on seafood production depends on the characteristics of the spilled oil, the circumstances of the incident and the type of fishing activity or businesses affected. In some cases effective clean-up and protective measures can prevent or minimise damage. This Technical Information Paper describes the effects of oil pollution on fishing and aquaculture, and provides guidance on remedial measures.

Effects of Oil on Fisheries and Aquaculture

Fishing and aquaculture are important industries which may be affected by oil spills in various ways. Commercially exploited animals and plants may be killed as a result of oil smothering and toxicity. Catches and cultivated stock may become physically contaminated or may acquire an objectionable oil-derived taste known as 'tainting'. Fishing and cultivation gear may be oiled, leading to the risk of catches or stock becoming contaminated or fishing being halted until gear is cleaned or replaced. The interruption of subsistence, recreational and commercial fishing activity and the disruption of seafood cultivation cycles can have important economic consequences. The reluctance of consumers to purchase seafood products from an affected region can also result in a loss of market confidence.

The impact of an oil spill on marine life depends largely on the physical and chemical characteristics of the particular oil and the way these change with time, a process known as 'weathering'. Important physical processes which act on the oil during the course of a spill are evaporation, natural dispersion and, to a lesser extent, dissolution and sedimentation. The prevailing weather and sea currents will determine the movement of spilled oil. Specific gravity, viscosity, chemical composition and toxicity of the pollutant are the main properties which determine the likely impact of oil on seafood organisms. The type of environment oiled is also important, e.g. sandy, rocky, saltmarsh or mangrove.

Thus, a variety of factors combine to define the character of a particular oil spill and the possible effects on sensitive resources in its path. Some incidents may lead to considerable impact on seafood resources whilst others may be of little or no consequence. Neither spill volume nor any other single factor is a reliable yardstick for predicting or measuring damage and a careful examination of many facets of an incident is necessary in order to reach correct conclusions. Precise prediction of recovery is equally difficult.

As a generalisation, the toxic effects of oil on marine life depend on the duration of exposure and oil concentration in the environment. Adult free-swimming fish, squid, shrimp and wild stocks of other commercially important marine animals and plants seldom suffer long-term damage from oil spill exposure. This is because oil concentrations in the water will only rarely reach sufficient levels to cause harm. In such circumstances, the effects of oil are usually temporary and localised, especially when compared with the impacts of commercial exploitation and natural processes like unusual weather patterns, predation, disease and harmful algal blooms which include Red Tides.

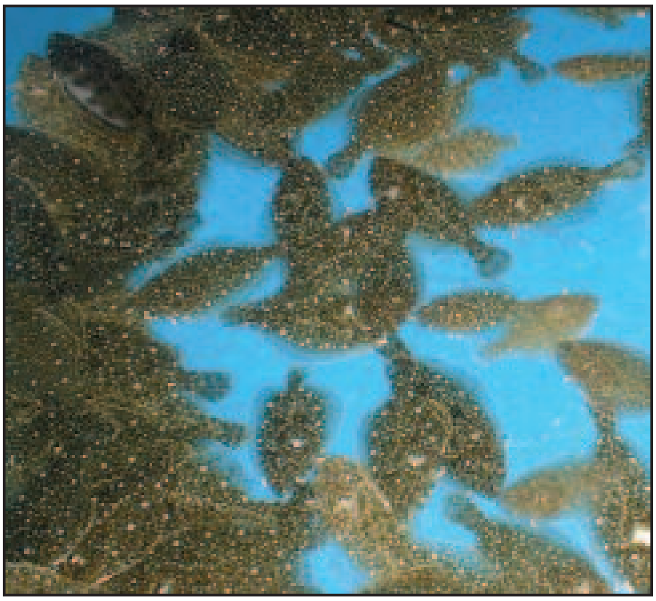
The greatest impact is likely to be found on shorelines where animals and plants may be physically coated and smothered by oil or exposed directly to toxic components in the oil. The tidal rise and fall exposes a band of the shoreline environment to oil pollution. Edible seaweeds and sea urchins are examples of shoreline species that are especially sensitive to smothering and oil toxicity. In addition to mortality, oil may cause more subtle longer-term damage to behaviour, feeding, growth, or reproductive functions. It is a complex task to isolate such sublethal pollution effects from the influence of numerous other factors.

Damage may also result from measures taken to combat an oil spill. Animals and plants which might normally be unaffected by floating oil can become tainted through exposure to oil droplets suspended in the water column if chemical dispersants are used unwisely. For this reason dispersants should not be used close to aquaculture facilities or spawning grounds and nursery areas. Stripping oiled seaweed from rocks and indiscriminate hot water washing are further examples of aggressive techniques that can affect commercially exploited species and delay natural recovery.

One of the most difficult challenges is to identify spill effects from changes caused by other factors, especially over-fishing or contamination from industrial or urban sources.

Physical contamination

Oil can foul the boats and gear used for catching and cultivating commercial species. Such oil contamination is then easily transferred to the catch. The handling of many seafood products in bulk means that it is seldom practical to locate and remove the oiled specimens. Flotation equipment, lift nets, cast nets, and fixed traps extending above the sea surface are more likely to become contaminated by floating oil, whereas lines, dredges, bottom trawls and the submerged parts of cultivation facilities are usually well protected, provided they are not lifted through an oily sea surface, or affected by sunken oil.



High stock densities are common in turbot farms, and water quality needs to be monitored carefully for metabolic wastes if sea water intakes are closed and water is recirculated.

Oiled nets can be cleaned provided they are not too heavily fouled and the oil is not highly weathered and persistent.

Especially vulnerable are shoreline cultivation facilities, such as racks used for the cultivation of oysters. They are usually located in the middle or lower shore, where oil often strands. Shellfish and cultivated animals kept in cages or tanks are usually unable to avoid exposure to oil contaminants in the water, and so effects such as tainting and mortality may be worsened. The presence of oil pollutants may significantly add to the stresses already imposed by keeping animals in artificial conditions. 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 occurring as a result of oil contamination. When fish farming facilities become physically coated by floating oil, their polluted surfaces may act as a source of stock re-contamination until they are cleaned.

The cultivation of seaweed, fish, crustaceans, molluscs, echinoderms and sea squirts 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. Such facilities are usually supplied with clean sea water drawn through intakes located below the low water mark. The 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.

Economic impact

The most serious threat of oil spills to fisheries and aquaculture activity is the economic loss arising from business interruption. Oil on the water and the application of temporary fishing and harvesting bans may prevent normal production, or a loss of market confidence may occur leading to price reductions or outright rejection of seafood products by commercial buyers and consumers. In extreme cases the mere hint of oil contamination can affect the marketing of high-price luxury seafood even if the produce is proven to be taint-free after testing by trained sensory panels and contaminants are at background levels after exhaustive chemical analysis.

Fishing and seafood cultivation are not always pursued throughout the year and seasonal differences in sensitivity to oil spills can therefore occur. 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 also often a seasonal activity that does not generally extend beyond a few months.

Protection and Clean-up Techniques

Booms and other physical barriers can sometimes be used to protect fixed fishing gear and aquaculture facilities, although in most cases it is impossible to prevent damage altogether. Fishing and cultivation equipment is often purposely sited to benefit from migration routes or efficient water exchange. Such locations are characterised by fast water flow, which is where booms will not perform well.

Plastic sheeting from a local supplier of building material is weighted and suspended around a fish cage.

Oil in the vicinity of fishing ports or in fishing grounds can result in interruption of business.

In calm conditions fish farms 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. 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 weak currents or light wave action.

Dispersants must be used with care so as not to cause tainting of shellfish and captured or cultivated stock. As a general guide, it is not prudent to use dispersant in shallow waters where fishing or aquaculture are important. However, if used at a safe distance, dispersants can reduce or prevent contamination of equipment by floating oil. It is difficult to define in general terms what represents a safe distance since this will depend on dilution rates and the strength and direction of prevailing currents.

Sorbent materials are often useful for removing oil sheens from water and tank surfaces. Sorbent booms are easy to deploy and move, and serve to control sheens in floating cultivation pens. However, oil-saturated sorbents should be replaced regularly to avoid them becoming a source of secondary pollution.

The remedial methods employed should be chosen with care, so as not to make matters worse. Almost all clean-up techniques have the potential to cause additional damage, which should be taken into account when considering the merits of dealing with oil pollution in the vicinity of fisheries resources. For example, attempts at cleaning intertidal mud flats are likely to cause long-term disruption and damage to shellfish habitats.

Lobsters, starfish and shellfish were killed by a diesel spill which dispersed naturally in shallow water during a storm.

When mariculture facilities and nets become contaminated, they can sometimes be cleaned *in situ*. When contamination is more severe, they may have to be dismantled for cleaning, and when impossible to clean they may have to be replaced.

Aquaculture Management

In addition to standard spill response measures, there are management strategies which may help to minimise contamination and financial losses to seafood cultivators. Options include moving 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 are likely to be rare for a range of technical, logistical and financial reasons, but in the right circumstances and with planning they may be practicable.

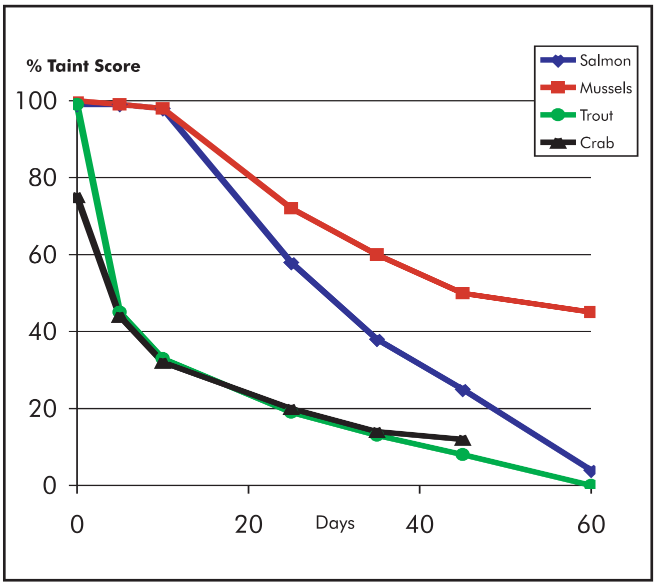
For shore tanks, ponds or hatcheries, temporary suspension of water intake and re-circulation of the water already within the system may be an effective method of isolating stock from the threat of oil contamination. Closing sluice gates to prawn ponds, for example, can also afford short-term protection, but care must be taken to ensure that the build-up of noxious waste products in stagnant or re-circulating water over time does not cause mortalities. Suspension of feeding is another way of reducing the risk to farmed fish and other cultivated stock from coming into contact with floating oil or feed which has been contaminated by floating oil traces. In land-based facilities the reduction or suspension of feeding has the advantage that the loading of waste products in the re-circulated water is reduced.

For such measures to be effective it is vital that sensitive fishing and aquaculture facilities are identified in contingency plans and that operators are notified promptly in the event of a significant oil spill. The plans can also identify optimal response options and the sources of necessary materials and equipment.

In some cases aquaculture operators may face the risk of ultimately losing all the stock due to oil spill damage. Harvesting before the stock becomes oiled might be possible, albeit at a lower price, and thereby salvaging some of its value. Conversely, normal harvesting could be delayed to allow contaminated stock to become taint-free by natural metabolic processes, but given that depuration rates are likely to vary somewhat depending on local conditions, it may prove difficult to set a reliable timetable for this process to be completed.

Tainting

The contamination of seafood can usually be detected as a petroleum taste, or taint. Filter-feeding animals such as bivalve molluscs are particularly vulnerable to tainting since they may easily ingest dispersed oil droplets and oiled particles suspended in the water column. Animals with a high fat content in the flesh e.g. salmon, have a greater tendency to accumulate and retain petroleum hydrocarbons in their tissues.



Depuration rates (loss of taint) for fish and shellfish after experimental exposure to Forties crude oil.

Taint is commonly defined as an odour or flavour that is foreign to a food product. Background concentrations of oil in water, sediment and tissues are highly variable. Both the degree of taint which may result and consumer tolerance levels for taint are different for different seafood products, communities and markets. Public confidence in seafood products can quickly erode as a result of suspect, or actually contaminated, products reaching the market.

The presence and persistence of taint will depend mainly on the type and fate of oil, the species affected, the extent of exposure, hydrographic conditions and 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 slower (weeks or months). At low ambient temperatures metabolism and depuration rates may be very slow.

The concentrations of hydrocarbons at which tainting can occur are very low. Some of the chemical components in crude oils and oil derivatives with the potential to cause tainting have been identified, and the concentrations causing taint vary widely, but many are unknown and no reliable threshold concentrations for petroleum-derived tainting agents have been established. 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 (also known as organoleptic testing), particularly if a trained panel and sound testing protocols are employed.

Sensory Testing

Oil-tainted food is unpalatable even at very low levels of contamination, which provides a safety margin in terms of public health. As a generalisation, in the context of oil contamination, if seafood is taint-free, it is safe to eat. Properly conducted sensory testing is the most efficient and appropriate method for establishing the presence and disappearance of tainting, and for indicating whether seafood is fit for human consumption. Trained taste panellists and valid control samples are essential elements in a sensory test protocol. Tests should be conducted 'blind' (so that the testers do not know the identity of either control or potentially tainted samples) in order to obtain reproducible results and eliminate any personal bias on the part of the testers.

A sampling programme with defined objectives will often be necessary to determine the degree, spatial extent and duration of the oil contamination problem. The aim is to take and analyse the minimum number of samples consistent with obtaining statistically reliable results. Control samples from a nearby area unaffected by oil pollution are important for reference purposes and to eliminate the interference of background contamination. Samples from local seafood markets can provide a benchmark for comparison with samples from oil-polluted areas. Target species are those of commercial, recreational or subsistence fishing value and which are commonly consumed.

Samples of animal and plant tissue are perishable and must be collected and stored so as to preserve their integrity. Clean storage materials must be used to avoid spoilage and cross-contamination of samples. Chilling 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 (bags of frozen vegetables can be used instead), ready for transport to the analytical laboratory, or to a freezer facility for long-term storage.

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 on fishing or sale of products. Monitoring the progressive loss of taint by sampling at appropriate intervals thereafter, allows the point at which taint disappears to be predicted with some confidence. The frequency of sampling and testing should be determined by the severity of taint and the rate at which depuration is observed to occur. 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 taint-free threshold can be defined as the point where 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. This

Fish and shellfish are usually steamed prior to sensory testing. Once cooked, these lobsters have been opened, and the digestive gland and white meat are tested for taint by smell and taste.

approach takes account of the fact that there may be variation between individuals and that tainted samples, not necessarily due to oil spills, can occur in any population. 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.

Public Health Concerns

Government authorities have a duty to ensure that seafood products reaching the consumer are safe and palatable. The occurrence of contamination in seafood organisms or products following a major spill has potentially damaging implications for marketing and can lead to public health directives being invoked because of the presence of known carcinogenic compounds in petroleum products. The aromatic fractions of oil contain the most toxic compounds, and amongst these it is the 3- to 7-ring polycyclic aromatic hydrocarbons (PAH) that command particular attention.

The uptake of potentially carcinogenic PAH stems largely from combustion sources and petroleum and, for the human population, exposure to PAH is primarily from food. However, in common with other potentially carcinogenic pollutants, it is not possible to define a concentration threshold of potential carcinogens in seafood products that represents a risk-free intake for humans. Furthermore, a wide variety of smoked food, leafy vegetables and other dietary components also contain the same or similar PAH compounds. The detailed composition of the diet determines which food items are major contributors of PAHs for individual consumers.

Generally, PAH levels in foods are not subject to legislative limits, although limits exist for some compounds in drinking water. The US EPA issues guidance for assessing contaminant data for use in managing fishing advisories. The risk to an individual or community from oil spill-derived carcinogens should be assessed in the context of the overall exposure from all potential sources, 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, even for subsistence consumers.

A further complication for food quality controllers is the fact that a seafood diet is inherently nutritious and rich in protein and vitamins. Restrictions on seafood intake can cause consumption patterns to shift towards less healthy diets. 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 must be viewed in a wider context in order to identify and implement appropriate remedies.

Fish are often the main food protein source for coastal communities, and clean produce is vital.

Chemical Analysis

In some cases, the chemical composition of the spilled oil, widespread subsistence fishing, or the presence of commercial shellfish resources in the path of the oil may argue for chemical analysis for PAH to be undertaken. Since detailed chemical analysis is invariably costly, it is sensible to screen samples using simple methods in order to determine roughly the extent of any contamination and rates of depuration. Sensory testing may serve as a screening tool, as there would be little point in undertaking costly PAH analyses on samples that have already failed a taint test.

It is widely recognised that to impose a single fixed standard for PAH levels in seafood by reference to baseline data is unworkable 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. One viable approach is to ensure that samples should be taint-free and contain no more PAHs than control/reference samples collected just outside the affected zone or which are freely marketed elsewhere in the country.

Analysis of water and sediment is usually not necessary in relation to the management of fishery impacts since the condition of seafood organisms inhabiting water and sediment environments is of primary interest. In any case, the organisms effectively 'monitor' the condition of their surrounding environment by the process of accumulating/depurating contaminants, and if they remain healthy then there is little need to monitor other components.

Management of Fishing and Harvesting Bans

A number of management strategies are available to prevent or minimise oil pollution impact on the fisheries sector. 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 advisory information or the issuing of guidelines to the seafood industry. Where fish are caught by anglers for sport, sufficient protection can sometimes be provided simply by issuing advice against consuming the catch and the adoption of a catch-and-release policy. Stricter measures include retail controls, impoundment of catches and seafood products, activity bans and fishery closures. All have potential drawbacks and a careful review of available options is advisable before any actions are taken.

Fishing and harvesting bans 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 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 bans may be applicable, but there are likely to be secondary consequences from all such measures. Paradoxically, oil spill fishery closures may result in beneficial stock conservation, particularly if the exploited species are non-migratory.

Fishery closures imposed to protect equipment 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. In most oil spill scenarios a fisheries and aquaculture management protocol consisting of a visible-sheen test (absence of floating sheens) and sensory tests will satisfy the demand for scientific credibility and provide adequate safeguards against unpalatable and unsafe seafood reaching consumers.

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.

It is vital to determine the criteria which will be applied for reopening a fishery before a ban is put in place, and they need to be realistic in terms of the normal seafood quality in the area. It is unrealistic to set criteria which are unachievable, such as open ocean background PAH concentrations. Both closure and reopening criteria form an important part of contingency plans. Ultimately, the benefits accruing as a result of a closure need to be assessed against the economic losses which will ensue from unnecessarily prolonged disruption of normal fishing and cultivation activity.

Seafood quality managers need to strike a balance between the need to inform and protect the public and the risk of raising unnecessary fears. Preferred strategies will reflect cultural and administrative traits in different countries. The media can play a valuable role in promoting a rational reaction to temporary disruptions. For example, where a properly conducted sampling and testing regime provides clear evidence that seafood is safe, the media provides a means for getting this message to the consumer. The needs of the media are best served by providing factual information and clearly justified decisions.

Costs and Compensation

When it proves impossible to protect fishing gear and cultivation facilities from oil contamination, the choice becomes one of cleaning, repairing or replacing the affected item. In some situations compensation arrangements may exist allowing fishermen and aquaculture operators to be reimbursed for costs incurred and losses suffered. Claimants will be expected to provide evidence of the losses, such as receipts of payments made and records of income in previous years. However, in the case of subsistence fishing no financial transactions may be involved and catch records are unlikely to

Fishing communities are often involved with clean-up during fishing bans or whilst fishing areas are oiled. This can help offset short-term financial hardship.

be available. Nevertheless, an understanding of the fishery can be gained from interviews and general sources on a case by case basis.

Quantifying economic loss resulting from mortality of cultivated organisms is often simply a question of counting and weighing the casualties, followed by calculating financial losses from projected harvest weights and price at the first point of sale. Account has to be taken of normal losses during the course of cultivation or maintenance, which may include factors which are unrelated to a spill such as disease or Red Tides, as well as the saved expense of feed, staff costs and other items of deductible expenditure normally included in the market price.

Assessing losses in wild stocks of commercial species is frequently more difficult, since precise stock assessment is impossible and any evidence of mortalities is quickly removed by scavenging species. The complexities of biological systems and business interactions make it difficult to separate the actual impact of an oil spill from other influences. Reliable catch statistics are rarely available in sufficient detail to enable oil spill effects to be isolated from other influences such as variable fishing effort and natural fluctuations in the stock. Only with expert knowledge of local circumstances, careful investigation and comparisons with nearby unpolluted areas can the true causes of observed damage be determined.

Conclusion

Oil spills can pose a significant threat to fishing and aquaculture resources. The main oil pollution effects are physical contamination of equipment, tainting and contamination of seafood, and economic loss from business interruption. With effective contingency plans and spill response procedures, much can be done to prevent or reduce the impact of oil spills on fishing and aquaculture.

The repercussions of contaminated seafood on public perception can be serious unless the issues of market confidence and public health are properly managed. In most cases a management protocol consisting of a visible-sheen test coupled with sensory testing will provide adequate safeguards against unpalatable and unsafe seafood reaching consumers.

Contingency planning provides the best opportunity for managers to select an appropriate response strategy and implement the most effective measures for dealing with a threat to seafood safety and quality. To maintain confidence in the fisheries sector there should be a sound strategy for implementing any temporary restrictions on the industry, based on scientific methods and data. An important component of oil spill contingency considerations is the need for consistent criteria for applying and lifting such restrictions.

The International Tanker Owners Pollution Federation Limited (ITOPF) is a non-profit making organisation involved in all aspects of combating oil spills in the marine environment. Its highly experienced technical staff have responded to more than 500 ship-source spills in over 80 countries to give advice on clean-up measures, environmental and economic effects, and compensation. They also regularly undertake contingency planning and training assignments. ITOPF is a source of comprehensive information on marine oil pollution through its library, wide range of technical publications, videos and website.

ITOPF

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