9. THE FATE AND EFFECTS OF OIL IN THE MARINE ENVIRONMENT

This section considers the patterns of movement and decay of oil slicks, the effects of oil on west coast marine life, including salmon, herring, groundfish, shellfish, birds and mammals, and the socio-economic effects of a blowout.

THE BEHAVIOUR OF OIL RELEASED BY BLOWOUTS

The behaviour of oil in the marine environment affects the nature of biological impacts resulting from an oil blowout. It also affects the success of countermeasure strategies and contingency plans.

When oil is released to the sea it undergoes complex physical and chemical changes such as spreading, evaporation, dissolution, dispersion, degradation and emulsion formation. The rate at which these processes occur depends on the type of oil and on the environment in which the blowout occurs.

TYPES OF OIL

Crude oil is composed of numerous complex hydrocarbon compounds of differing molecular weights and structures ranging from a light gas (methane) to heavy solids. Each crude oil varies in physical and chemical properties such as specific gravity, surface tension, viscosity, pour point, flash point and solubility.

Consequently, slicks of different oil types vary in their tendency to spread, move about, evaporate, dissolve, emulsify, oxidize and biodegrade. These characteristics determine the biological effects of the oil slick and influence the planning of countermeasures.

Chevron stated it is impossible to predict what type of oil might be found on the west coast in advance of a discovery. Therefore, the behaviour and fate of oil from a blowout occurring in the north coast region would be unpredictable.

INFLUENCES OF THE MARINE ENVIRONMENT

The spreading and movement of oil slicks is strongly influenced by surface water movement. On the west coast, surface water movement is affected by weather systems and storms from the north Pacific, which have a high incidence of gale force winds and high seastates. It is also affected by large tidal ranges, strong tidal currents and irregular coastlines.

Air and water temperatures, water salinity and sediment loads also determine the physical and chemical behaviour of oil. For example, crude oil becomes more viscous and evaporates more slowly in colder water. This will affect its spreading and toxicity as well as the penetration of oil into shoreline sediments.

CONCENTRATIONS OF OIL IN THE WATER COLUMN

The effects of crude oil on fish, birds, marine mammals and other marine species depend on the concentrations of the oil in the water column after a blowout. Concentration depends on the type of oil and the chemical and physical processes that weather and degrade it.

Chevron stated that a blowout would produce a flow of hydrocarbons that would break into patches and become weathered within a few hours. The light hydrocarbon fractions would quickly evaporate or dissolve in the water column, rapidly reducing the toxicity of the oil. Chevron stated that slicks formed by a blowout would be very thin, averaging about 0.1 mm at 1 km from the blowout site, depending on the viscosity of the oil and confining shorelines.

Chevron cited experiments where concentrations of oil in the water column were measured before and after application of dispersants. Concentrations of one to two parts per million were measured in the water column. When dispersants were applied to disperse oil from the surface into the water column, the highest concentrations measured in the water column were 40 parts per million.

Chevron's position was disputed by other participants. The Department of Fisheries and Oceans argued that turbulent mixing and dispersion of oil could result in high concentrations in the water column of minute hydrocarbon globules consisting of mostly unweathered hydrocarbons. The Department also questioned Chevron's information about observed slick thicknesses and oil concentrations in water after a blowout.

From the information presented to the Panel, there is clearly little agreement on slick thicknesses or on the concentrations of oil in the water column that would result from a blowout.

"Depending on the type of oil and the ambient conditions, 25 to 75 percent of the crude oil typically evaporates within the first 12 to 48 hours." (Ted Spearing, Chevron, Victoria, October 1985)
SINKING AND SEDIMENTATION

Unweathered crude oil is less dense than water and will float. However, as the lighter fractions evaporate and the oil is weathered, its density increases. After considerable weathering, some residual oils may sink below the sea surface. This is more likely to occur if the weathered oil adsorbs heavy particulate material in the water such as silt or clay, or if the slick spreads from denser sea water to less dense fresh water. Concern was expressed that sunken oil may poison, smother or displace seabottom and intertidal organisms.

EMULSIONS

Some participants were concerned about the possible formation of water-in-oil emulsions, or "mousses." Mousses form as a result of the turbulent mixing of certain types of relatively high viscosity and high specific gravity oil into the water column. The turbulence can result from heavy wave action or from the gas flowing in the blowout plume, especially in shallow water.

Mousses can be very stable and may persist for months or years after a spill. The light ends of oil trapped within mousses do not evaporate readily. Mousses resist weathering and can drift long distances while retaining their toxicity. The Department of Fisheries and Oceans reported that mousses in layers up to one metre thick formed during the Ixtoc I blowout in the Gulf of Mexico, and drifted for several weeks before stranding on beaches over 500 miles away in south Texas.

On reaching the shore, mousses tend to pick up sand and debris and, once the water in them evaporates, they form lumps of tar which resist further weathering. Concern was raised that these tar lumps could result in the slow release of toxic oil over several years.

STRANDING ON SHORES

The biological importance of shorelines and nearshore waters is particularly high because of the concentrations of juvenile salmon, herring roe, shellfish, birds and marine mammals. At the same time, oil tends to collect in higher concentrations on shorelines than open water because further movement and dispersion is impeded by the shore itself.

The effects of oil on the nearshore ecosystem depends on the type of oil and the degree of weathering it has undergone. Generally, a slick is less damaging the longer it has been at sea. Highly weathered oil may come ashore as individual tar balls, whereas fresh oil may coat the entire intertidal zone.

The effects of oil on shorelines also depend on the type of shoreline. Shores exposed to high wave energy usually do not retain oil for long. Wave and tidal action disperse the oil, allowing it to weather and biodegrade faster. On the other hand, sheltered areas such as bays, inlets, lagoons, marshes and pocket beaches retain oil longer due to the lower wave energy. In these cases, oil may be retained for years.

If the shores are steep, intertidal zones are relatively narrow. A broad intertidal zone with tidal pools may retain oil longer. If oil comes in on a high tide, it may be deposited where it can only be reached by the next high tide.

The material making up the shore also affects oil retention. Oil penetrates some materials more quickly than others, influenced by the viscosity of the oil, temperature, the permeability of the beach material and other factors. On exposed sandy beaches, for example, oil may be mixed into the substrate where it retains its toxicity and resists further weathering.
BIOPHYSICAL EFFECTS OF A BLOWOUT

In considering the effects of oil on fish, shellfish, birds and marine mammals, the Panel recognizes that research on these effects is incomplete. Oil in sea water has different effects on different species. Not all of these effects have been identified. In addition, individual species are often related to each other within the marine ecosystem in complex, poorly understood ways. As a result, an effect on one species usually has effects on other species. These effects can occur, for example, through the food web and predator-prey relationships. Therefore, while studies of the biophysical effects of oil tend to focus on individual species or groups of species, care must be used in applying these studies to the total marine environment.

EFFECTS OF OIL ON FISH AND INVERTEBRATES

The west coast supports large populations of salmon, herring, groundfish, shellfish and invertebrates. Effects of oil vary with species, type of oil and environmental conditions. Effects can include fish kills and sublethal effects such as reduced growth, developmental abnormalities, behavioural changes, and changes in reproductive potential. In the competitive natural environment, sublethal effects can affect the size and health of fish populations.

"But it is apparent that hydrocarbons can greatly reduce the individual's chances of survival; individuals make up populations, and accordingly, reductions in population size are of concern... It cannot be assumed that fish will avoid contaminated waters, and studies have demonstrated that fish do not necessarily avoid harmful conditions in their environment. Motivated fish, competing for food, avoiding predators or migrating in the natural environment may react quite differently to less stimulated and less motivated fish held under laboratory conditions." (I. Birtwell, D.F.O., Vancouver, October 1985)

"...there seems to me to be a lot of data missing on the behaviour of oil and how it affects estuaries, how it affects migrating fish, how it affects fingerlings, the small fish fry that are in estuaries, and what do you do if this information isn't forthcoming." (Kevin O'Neil, Central Coast Fishermen's Protective Association, Bella Coola, November 1984)

Salmon

The effects of oil on juvenile and adult salmon would depend on the concentrations of oil in the water column. Chevron stated that concentrations from a blowout would be unlikely to reach lethal levels. Many intervenors disputed this statement, arguing that likely concentrations of oil in the water would be lethal to salmon. The Department of Fisheries and Oceans argued that not all toxic components of the oil would evaporate, and that some of the remaining heavier fractions would still be toxic.

At present, much of the data on lethal concentration levels for salmon is based on a few experiments and limited field information. Given the wide divergence of opinion between Chevron and other participants, it is prudent to assume that oil could be toxic to fish at low concentrations. Since it is not known what those concentrations would be, the possibility that lethal concentrations of hydrocarbons would be present in the water column in the event of an oil blowout, and that fish would be affected, cannot be ruled out.

The Department of Fisheries and Oceans and other participants were also concerned about the potential for sublethal effects of oil on salmon. The presence of oil contamination when juvenile salmon enter the sea could affect their ability to make the adjustment from fresh to salt water. Exposure to oil might also affect the growth of juvenile salmon, rendering the fish more susceptible to predation and less able to compete for food.

There is reason to be concerned about the lack of knowledge concerning the lethal and sublethal effects of various concentrations of oil on juvenile and adult salmon. More information is required for contingency planning and fisheries management in the event of an offshore oil blowout.

The Panel recommends that the Department of Fisheries and Oceans conduct research to determine the lethal and sublethal effects of naturally and artificially dispersed crude oil on critical life stages of migrating salmonid species.

Herring

Herring are at risk from a blowout because their spawning, incubation and nursery stages take place in nearshore waters where the risk of exposure to toxic concentrations of oil is high. Herring eggs are deposited on kelp, algae and rocks in shallow nearshore areas. The greatest threat would occur during their spawning and larval stages, particularly March and April. Exposure to oil at this time could cause mortality or abnormal development. The effects on the early life stages of a year-class of herring could have long-term recurring consequences on herring stocks.
Groundfish

Concerns were raised that the groundfish eggs and larvae could be affected by spilled oil. The eggs and larvae of several groundfish species float at or near the surface and drift with the current. As a result, they are vulnerable to oil floating on the surface or dispersed in the water column. The most sensitive period is during the reproductive months from January to September.

Sinking oil may also affect adult and juvenile groundfish that inhabit seafloor environments. Impacts could vary from lethal to sublethal effects such as reduced growth and other physiological changes. Food sources could be reduced or contaminated by oil. However, since groundfish inhabit seafloor environments, they would be less likely to be affected by oil drifting on the surface or in near-surface waters.

Shellfish and Invertebrates

Several species of shellfish and invertebrates are important to commercial fishing, the native food fishery and potential mariculture operations. These include shrimps, crabs, clams, abalone, scallops, mussels, oysters and sea urchins. At one or more stages in their life cycle, most invertebrates form part of the marine food web upon which other species, including commercial species of fish, depend. Many invertebrates live in surface waters early in their life. At this stage they are extremely sensitive to oil and could be exposed to oil slicks. Invertebrates also occupy nearshore areas where they are vulnerable to oil. If these were contaminated, invertebrates may be killed, lose habitat or experience reduced food availability, contamination or tainting. Crab, shrimp, amphipods and other crustaceans are particularly sensitive to oil, especially during larval stages and molting periods. A decline in crab populations has been noted in oil polluted waters. Clams, oysters and other bivalves exposed to oil have remained contaminated for up to a year.

Research on the Effects of Oil on Fish and Shellfish

There is considerable controversy about the effects of oil on fish and shellfish. In view of the economic and social importance of the west coast fishery, however, it is prudent to assume that an oil blowout could seriously damage the fishery and significantly reduce fish and shellfish stocks.

Because of the inherent limitations of laboratory experimental research in determining the effects of oil on marine species, knowledge to aid in assessing the effects of oil can best be obtained in actual field conditions. Unfortunately, the documentation of the biophysical effects of actual marine oil spills has often been poor, and the interpretation of case studies controversial.

Although further research on the lethal and sublethal effects of oil on salmon and other fish species at various life stages is useful, the Panel believes that concentrating on this particular data gap would be misleading because it is only one element of a range of data which is needed to develop comprehensive models of the potential effects of an oil spill on important fish species.

The Panel recommends that the Department of Fisheries and Oceans, in cooperation with other agencies, develop a comprehensive research program designed to reduce data gaps necessary to develop a credible model of the impact of an oil blowout on important fish species at their various life stages.

The Panel recommends that, in the event of a blowout, the Department of Fisheries and Oceans be prepared to immediately initiate a major research and monitoring program to gather information on the actual concentrations of dispersed oil in the water column and the lethal and sublethal effects on important west coast species, particularly salmon and herring, at critical life stages, in order to assess more accurately the effects of oil on these species.

At the same time, government and industry should continue to pursue present research programs on the effects of oil on fish and shellfish and to improve basic information on the fisheries resources of the west coast.

EFFECTS OF OIL ON BIRDS

Birds are the most conspicuous victims of oil slicks. When a large oil slick reaches an area with many seabirds, significant losses occur. The plight of oiled birds, and the inability to do much to clean them, is a source of strong public concern.

The most important factor leading to bird deaths is the oiling of feathers. Birds attempt to remove oil by preening their feathers. However, it is not prudent to assume that an oil blowout could seriously damage the fishery and significantly reduce fish and shellfish stocks.

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alcids and sea ducks, are likely to encounter oil if they are in the vicinity of a slick. By far the greatest proportion of Canada's west coast seabirds are continuous swimmers, except during the breeding season. Some species go through flightless periods on the water or migrate by swimming. These birds are poorly adapted to function out of the water and would not be able to forage or look after their young.

In addition to the effects of oil on waterproofing, oil may be ingested as birds preen their feathers. The effects of ingesting oil have been studied, but there is some controversy about its effect on survival. If incubating birds get oiled they may oil their eggs, reducing hatching success.

While there are concentrations of seabirds in offshore areas such as over upwellings and offshore banks, birds are most concentrated in nearshore waters. Although many seabirds spend most of their life at sea, several species concentrate in colonies during breeding season to produce their young, while continuing to forage at sea. A large proportion of the breeding population of several species may be found in certain colonies. These colonies are usually on exposed and isolated islands and shores, which are vulnerable to oil. Little is known about the offshore distribution of these birds outside the breeding season.

Many migratory birds use coastal migration routes in their spring and fall migrations, and use certain coastal areas as stopovers or staging areas. At these sites, thousands of birds may congregate to feed and rest. Some species spend the winter in the region. Birds in these nearshore locations are highly vulnerable to oil slicks.

Intervenors and government agencies argued that more information is required on bird populations in the region. While the information base on coastal bird populations is expanding, information on certain species is lacking and many areas have not been adequately surveyed. Certain information is vital to contingency planning, such as which shore areas are used by birds during various stages in their life cycle. The Panel believes that, prior to drilling, improved inventories of coastal bird populations are necessary for contingency planning purposes.

The Panel recommends that, before exploratory drilling begins, Environment Canada (Canadian Wildlife Service), assisted by appropriate provincial agencies, undertake inventory surveys of the coastline of the region as well as adjacent shelf waters, to establish baseline information on the population, location and behaviour of coastal bird species for contingency planning purposes.

Whenever spills occur, efforts are made by concerned individuals to help clean oiled birds. Although this is done for humanitarian reasons, bird survival rates are usually low. In some cases, birds may actually suffer considerably from the cleaning effort, especially if skilled staff are not available to advise on the best methods, and to decide which birds should be treated.

The Panel recommends that the operator, as part of its oil blowout contingency plan, identify experts on bird cleaning who will be available on call to direct local efforts to clean oiled birds.

EFFECTS OF OIL ON MARINE MAMMALS

Pinnipeds and Otters

Oil can affect pinnipeds (seals and sea lions) and otters in various ways. Physical contact with oil can irritate or damage sensitive tissues such as eyes. Evidence suggests that these effects, if not too severe, may clear up after exposure to clean water. Oil can also block noses and mouths and immobilize flippers, thus interfering with swimming ability.

Species that depend on fur for warmth and buoyancy such as otters, northern fur seals, young sea lions and harbour seals, may be the most sensitive to oiling. Experimental evidence suggests that fur bearing marine mammals may experience drastic losses of warmth and buoyancy due to oiling and these effects can last for several days. Oil causes matting and loss of insulation, which may result in hypothermia and death.

Oil can also be ingested directly during grooming or by feeding on oiled prey, or indirectly through the food chain. Ingestion may result in effects on nervous and reproductive systems.
Because otters feed on seabottom organisms, some of their food supplies may be affected by oil settling on bottom sediments.

Based on existing information, the major concern regarding seals, sea lions and otters is the potential for oil reaching a haulout or rookery site. If this should occur, some animals could be killed or suffer sublethal effects.

Inventories of major seal and sea lion rookery and haulout sites are available. These sites are located in nearshore areas, underscoring the vulnerability of the nearshore areas to oil.

**Cetaceans**

Oil can also affect cetaceans, which include whales, dolphins and porpoises. It can damage sensitive tissues such as eyes, foul blowholes, and have minor, short-lived effects on skin.

There is evidence that whales and dolphins will avoid oil slicks but they may not be able to detect thin surface sheens. Some species of dolphins and baleen whales have been observed swimming and apparently feeding in oil slicks. This could result in the ingestion of oil especially through feeding on contaminated prey. In addition, baleen whales such as the grey whale, which feed on seabottom organisms in nearshore areas, might have their baleen fouled by oil while feeding in contaminated waters.

Grey whales are known to migrate along the coast within a few kilometres of shore. However, there have been no systematic surveys of the seasonal distribution and abundance of whales and dolphins on the west coast.

**SOCIO-ECONOMIC EFFECTS OF A BLOWOUT**

A major oil blowout could have significant socio-economic effects on the British Columbia north coast and the residents of its communities.

Some communities would be affected more severely than others should a blowout occur. Depending on winds and surface currents, oil could come ashore in relatively higher concentrations in certain areas. More severe effects would occur on the communities which depend on those areas for resource harvesting. Diet, income, social structure and culture could be affected and the continued viability of some communities threatened.

Although the socio-economic effects of a blowout would be felt most strongly at the community level, significant regional effects could also occur. The most serious of these would be damage to the salmon fishery, which provides the majority of the income from commercial fishing. The damage to fish and shellfish stocks could reappear at intervals long after the actual event. For example, damage to a year-class of salmon or herring would be evident at regular intervals for decades. Repopulation of an area where shellfish and invertebrates were harvested for food could take years.

If fish and shellfish stocks were damaged, fishing and harvesting closures would follow. These closures could seriously affect the commercial fishing industry and, in the case of shellfish, could last a year or longer.

Previous sections of this report have described the socio-economic dependency of coastal native peoples on the marine resources of the region. It is also clear that very little information exists to document these resource uses. This could present a considerable problem in the design of contingency plans to deal with the possibility of an offshore blowout, or in the administration of compensation programs dealing with the effects of a blowout.

The Panel recommends that programs be undertaken to improve the quality and quantity of information related to native food fisheries in the region.

Another concern is the possibility of fish tainting and its impact on the commercial fishery. Tainting is the contamination of fish by hydrocarbons, giving them an oily odour and unpalatable taste and making them unmarketable. Because contamination cannot be detected in advance of consumption, tainting of only a very small proportion of a fish catch could threaten the market value of an entire catch. In addition, publicity about a blowout could create consumer perceptions that the whole British Columbia fishery was contaminated and affect overall marketability of the catch.

Effects on the fishing industry could also extend to southern-based fishermen, who harvest an estimated 60% of the commercial chinook in the region, and to the fish processing sector, which is a major employer in the region.

The Panel recommends that, before exploratory drilling begins, the Department of Fisheries and Oceans develop a contingency plan for managing the commercial fishery after a blowout, including monitoring of fish for tainting and administration of closures.

The effects of a blowout upon the developing mariculture industry in the region is another concern. Although commercial mariculture development is still in its early stages, there is potential for considerable growth of this activity in the future. Mariculture could become an important industry on the west coast, and could be especially important for small communities. Mariculture sites are vulnerable to oil.
The exploration area contains numerous sites with recreational, environmental and cultural attractiveness. Outdoor recreation is important to north coast residents, and the basis for a rapidly expanding tourist industry. Individual operators and communities have started to develop the region's tourism potential for wilderness recreation and sport fishing. Much of the appeal of the north coast is based on its pristine condition and natural attractions. Interveners argued that news reports of an oil blowout would create a perception that the waters of the region were polluted, affecting the region’s attractiveness as an outdoor recreation and tourism destination.

**PROTECTION OF NEARSHORE WATERS**

Nearshore environments and estuaries are particularly vulnerable to oil contamination. The intertidal zones in these areas often support highly productive ecosystems, because of abundant light, shelter and nutrients. Shallow nearshore waters and bays have a rich and varied plant life, including marsh grasses and seaweed, which provide food and shelter to a variety of animals. Estuaries, which are formed at the mouths of streams or rivers, are particularly important.

Nearshore environments, especially estuaries, provide habitat and food for migrating juvenile salmon as they make the transition to salt water. Nearshore areas also provide habitat for many species of shellfish and invertebrates, which are harvested for food and income. The growing mariculture industry is also located in these areas.

Seabird breeding colonies and stopovers for migrating birds of international significance are located in nearshore areas and large numbers of marine-associated birds feed and swim there. Seal and sea lion haulout sites, rookeries and feeding areas are located in these waters and certain whales migrate and feed close to shore. The scenic, unspoiled coastal areas of the north coast are the major attraction of a growing outdoor recreation and tourist industry.

Several shoreline and nearshore sites within the region have been set aside as ecological reserves where typical or unique species or ecosystems are protected for scientific study or conservation.

Certain offshore areas are also important for primary production of plankton and provide the habitat for numerous species of fish, birds and marine mammals. However, because the oil is not trapped by a shoreline blocking its drift, offshore areas are usually susceptible for shorter periods. Of most concern would be the waters close to a blowout where oil would not be weathered.

The west coast environment has a rich and varied ecosystem highly vulnerable to oil. A major oil blowout could have serious effects on that ecosystem. While offshore waters may be important to various species at certain times, nearshore waters are important all of the time. Exploration lease areas on the west coast are closer to these sensitive and vulnerable shores than those off the east coast of Canada, or those in northern North Sea fields. As a result, drifting oil would be fresher when it reached the shore.

The most important factor in judging the biological effect of oil is the time it will take for the oil to reach sensitive nearshore areas, given the seasonal wind and current patterns. The farther a blowout occurs from shore, the greater will be the weathering of the oil, and the more time will be available for response teams to implement countermeasures. This underscores the need to maintain a buffer zone between drill sites and the shore. The Panel, therefore, concludes that a 20 kilometre exclusion zone is an essential limitation on exploratory drilling.
Spill cleanup crew