IPIECA REPORT SERIES

VOLUME TEN

CHOOSING SPILL RESPONSE OPTIONS TO MINIMIZE DAMAGE

Net Environmental Benefit Analysis

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PREFACE

This report is one of a series commissioned by the International Petroleum Industry Environmental Conservation Association (IPIECA), representing the IPIECA members' collective contribution to the global discussion on oil spill preparedness and response. The report series forms one of the key elements of IPIECA's global education programme, which is aimed at both industry and governments.

In preparing these reports—which represent a consensus of membership views—IPIECA has been guided by a set of principles that it would encourage every organization associated with the transportation, handling and storage of oil to consider:

- it is of paramount importance to concentrate on preventing spills;
- despite the best efforts of individual organizations, spills will continue to occur and will affect the local environment;
- response to spills should seek to minimize the severity of the environmental damage and to hasten the recovery of any damaged ecosystem;
- the response should always seek to complement and make use of natural forces to the fullest extent practicable.

Recognizing the inevitability of future spills, management should also give high priority to developing well-rehearsed contingency plans that will ensure prompt response to mitigate potential adverse effects. These plans should be sufficiently flexible to provide a response appropriate to the nature of the operation, the size of the spill, local geography and climate.

Close cooperation between industry and national administrations in contingency planning will ensure the maximum degree of coordination and understanding. When all involved parties work together there will be the greatest likelihood of achieving the key objective of mitigating potential damage.

INTRODUCTION

Once oil has been spilled, urgent decisions need to be made about the options available for clean-up, so that environmental and socioeconomic impacts are kept to the minimum. Getting the correct balance is always a difficult process and conflicts inevitably arise which need to be resolved in the best practicable manner. The advantages and disadvantages of different responses need to be weighed up and compared both with each other and with the advantages and disadvantages of natural clean-up, a process sometimes known as Net Environmental Benefit Analysis (NEBA).

The process will require taking into account the circumstances of the spill, the practicalities of clean-up response, scientific understanding of the relative impacts of oil and clean-up options, and some kind of value judgement of the relative importance of social, economic and environmental factors. Common sense and consensus-forming are just as important in this decision making as quantifiable scientific information. Decisions are best and most rapidly made if contingency planning has included reviews of environmental and socioeconomic information, consultations and agreements by all the appropriate organizations.

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AIMS OF OIL SPILL RESPONSE

The aims of oil spill response are to minimize damage to environmental and socioeconomic resources, and to reduce the time for recovery of affected resources by achieving an acceptable standard of cleanliness. This can involve:

- guiding or re-distributing the oil into less sensitive environmental components (e.g. deflecting oil away from mangroves onto a sandy beach, or dispersing oil into the water column);
- removing oil from the area of concern and disposing of it responsibly.

Initiation of a response, or decision to stop cleaning or leave an area for natural clean-up, is based ideally on an evaluation which has taken place both before the spill (as part of the contingency planning process) and after the spill.

Further clean-up is not necessary on this shore from an ecological point of view because the weathered residue is not inhibiting recovery of plants and animals. The question is: are there any socioeconomic considerations which should override the ecological considerations?

THE EVALUATION PROCESS

Evaluation typically involves the following steps:

- Collect information on physical characteristics, ecology and human use of environmental and other resources of the area of interest.
- Review previous spill case histories and experimental results which are relevant to the area and to response methods which could possibly be used.
- On the basis of previous experience, predict the likely environmental outcomes if the proposed response is used, and if the area is left for natural clean-up.
- Compare and weigh the advantages and disadvantages of possible responses with those of natural clean-up.

Much of this evaluation can be done at the contingency planning stage. However, a review of the collected information and limitations of the response options under the conditions of the actual incident is needed before a response is initiated.

All parties must accept that whatever the response, it is usually not possible to avoid all disadvantages. When making decisions in the face of conflicts of interest, wildlife (e.g. seabirds, turtles) typically merits higher priority than shore organisms (e.g. seaweeds, barnacles, marsh grass) because recovery or replacement of wildlife populations is likely to be comparatively slow and difficult. Protection of fish and shellfish resources merits higher priority than amenity sand beaches, jetties and slipways—oily taint may take many months to clear from fish, whereas surfaces of concrete or firm sand can be cleaned and restored to usefulness relatively quickly. Wildlife species may sometimes merit a higher priority than fisheries, notably in cases where dispersant spraying reduces the threat to seabirds at the expense of increasing the tainting of fish. The viability of most fish populations is less threatened by tainting than seabird populations are threatened by surface slicks.

Collect information on the area

When preparing a contingency plan, it is important to identify the sensitive resources of the particular area, and to summarize the information on a sensitivity map. Guidelines for sensitivity mapping are available (IMO/IPIECA 1996). Maps should include information on:

Shoreline sensitivity assessment in Ghana (above, left) and Tanzania (above, right). In these cases the assessments were carried out during sensitivity mapping workshops supported by IMO/IPIECA and managed by the Environmental Protection Agency (Ghana) and the National Environment Management Council (Tanzania) respectively.

- Shoreline sensitivity—different types of shorelines may be ranked using the basic principles that sensitivity to oil increases with: increasing shelter of the shore from wave action; penetration of oil into the sediments; natural oil retention times on the shore; and biological productivity of shore organisms. Typically, the least sensitive shorelines are exposed rocky headlands, and the most sensitive are marshes and mangroves.
- Other ecological resources such as coral reefs, seagrass and kelp beds, and wildlife such as turtles, birds and mammals.
- Socioeconomic resources, for example fishing areas, shellfish beds, fish and crustacean nursery areas, fish traps and aquaculture facilities. Other features include boat facilities such as harbours and slipways, industrial water intakes, recreational resources such as amenity beaches, and sites of cultural or historical significance.

  Sensitivities are influenced by many factors including ease of protection and clean-up, recovery times, importance for subsistence, economic value and seasonal changes in use.

Once a spill has occurred, the response options will need to be reviewed and fine-tuned throughout the response period, in the light of information being received about distribution and degree of oiling and resources affected. This process can be lengthy for some cases of shoreline response. It is useful to establish spill-specific criteria for termination of response to assist field teams and operations managers.

Shoreline Inspection Guidelines (Humboldt Bay Oil Spill, 1997)

The shoreline inspection team will determine when each shoreline segment has been cleaned to a reasonable degree, based on minimizing risk of impact to the environment and preventing human contact with the spilled oil. The following guidelines provide criteria for assessing shoreline status:

Water surface
No recoverable floating oil should remain on the water surface.

Sand beaches
The shoreline should be free of liquid oil. Tarballs, tar patties, oiled stranded eelgrass wrack and oiled debris that could contaminate wildlife should be removed—to the extent removal using reasonable clean-up techniques is feasible. Oil stain on sand that does not produce rainbow sheen may be allowed to weather and degrade naturally.

Marshes
Marsh vegetation should be free of oil that could contact and contaminate wildlife. Oil that is not likely to affect wildlife may be allowed to weather and degrade naturally.

Riprap and seawalls
Oiled riprap and seawalls should be free of bulk oil except for oil stain (defined as a thin layer that cannot be scraped off using a fingernail), which may be allowed to weather and degrade naturally.

An example of criteria for completion of shoreline treatment

Review previous experience

Previous experience from spills or experiments is a great help in predicting possible outcomes in a new situation. A considerable amount of information is available from different environments—the open sea, nearshore, and a variety of shorelines. There is experience of:

- natural cleaning timescales (in the absence of any spill response);
- ecological and socioeconomic effects of oil; and
- effects and efficiency of different response methods in dealing with oil.

The IPIECA report series (see page 19) summarizes a wide variety of such experience and provides suggestions for further reading.

Mangrove swamps, such as this one in Nigeria, are typically important both ecologically and socioeconomically (e.g. for shellfish production). They are also vulnerable to damage by oil.

Predict outcomes

The following are general predictions based on the case histories summarized in past volumes of the IPIECA report series. It may sometimes be possible to make more detailed predictions if there is a close match between well-documented case histories and new situations with similar ecological and socioeconomic considerations.

Natural cleaning timescales

For open water sites, timescales can be expressed in 'half-lives' (the time taken for natural removal of 50 per cent of the oil from the water surface). These typically range from about half a day for the lightest (Group I) oils such as kerosene to seven days or more for the heaviest (Group IV) oils such as heavy fuel oil (ITOPF 1987). However, for large spills near coastlines, some oil typically is stranded on the shore within a few days; once oil is stranded, the natural cleaning timescale may be prolonged. Observed timescales range from a few days (some case histories for very wave-exposed rocky shores) to more than 25 years (some case histories for very sheltered marshes). Given that in extreme cases thick deposits of oil may remain after 25 years, it is reasonable to extrapolate that natural cleaning may take several decades on some very sheltered shorelines.

Ecological effects of oil

The initial ecological impact can vary from minimal (e.g. following some open ocean spills where the oil has dispersed naturally), to the significant and widespread mortality of a range of different species (e.g. in a mangrove swamp affected by large quantities of crude oil). Recovery times can vary from a few days to more than 25 years though are not necessarily directly correlated with cleaning timescales—in some cases recovery can progress well in the presence of oil residues. Conversely, an area may be left clean but bereft of organisms because a light product spill has caused rapid, severe toxic effects before evaporating. In such a case the recovery time will be determined by the rate of migration from unaffected areas, natural recruitment, settlement and growth.

Factors which are important in influencing degree of ecological damage are described in IPIECA (1991a) and include:

- Oil type. Lighter oils are more likely to cause severe localized toxic effects. Heavy oils are generally less toxic but can contaminate surfaces over wide areas due to their greater persistence.
- Oil loading. Thick oil deposits on shores are likely to smother plants and animals, and in some cases may form persistent asphalt pavements.
- Geographical factors. Damage is likely to be greatest in shallow enclosed waters and on sheltered shorelines, because these areas typically have high biological productivity and long natural cleaning timescales.
- Weather. Wind speed and water temperatures affect evaporation and viscosity of oil, and in turn its dispersibility and toxicity.
- Biological factors. Different species have different sensitivities, for example many algae are quite tolerant of oil whilst mangroves and seabirds are particularly sensitive.
- Seasonal factors. In general, the sensitivity of plants and animals varies seasonally. For example marsh plants are particularly sensitive at the seedling stage in the Spring.

Socioeconomic effects of oil

Socioeconomic problems may include the following:

- A spill can result in lost fishing opportunities if fishermen are unable to fish because of the risk of fouling boats and gear, or tainting the catch. Finfish and shellfish may become tainted and unfit for sale if oil-derived substances absorbed by the tissues impart unpleasant odours and flavours. Exclusion zones where fishermen are banned from fishing for particular species may be imposed until the species are free from contamination or taint (removal of taint by natural cleansing can take place quite rapidly provided the surrounding environment is clean). Farmed fish and shellfish may have to be destroyed if they cannot reach the market at the right time because of tainting.
- Coastal amenities and tourist facilities include beaches and park areas. Marinas and jetties provide facilities for pleasure boat use, and some fishing and angling activities serve the tourist trade. Oil may temporarily render such resources unusable. Moreover, the reputation of affected areas may suffer, such that tourist bookings are lost even for periods after the oil has been cleaned up. The sensitivity of parks is high because these areas are likely to contain sensitive resources such as birds and mammals; and some parks are an attraction for 'ecotourists'.
- Some industries abstract sea water for cooling or other purposes, and some countries rely on desalination plants for drinking water. Oil entering the industrial or desalination plant with the abstracted water can have serious effects, though the risk of this is reduced if the intakes are in deep water or they can be protected with floating booms.

Effects and efficiency of response options

The main response options while oil is on the water are containment and recovery, dispersant spraying, shoreline protection, or reliance on natural processes. *In-situ* burning may be an option in some cases (particularly in ice-infested waters). The physical removal of oil from the water surface reduces the threat to birds, mammals, nearshore waters and shorelines. Dispersants, by helping to break up a surface slick, do the same but the dispersed oil enters the water column. In deep offshore waters it is rapidly diluted, but there is often concern about the potential effects in nearshore waters where it may increase the threat to organisms such as fish larvae (IPIECA 1993b), or the risk of tainting of shellfish and fish held in cages.

In terms of efficiency, containment and recovery are limited by strong waves and currents. Recovering 10 per cent of the oil at a large spill in the open sea is considered good for these mechanisms. Dispersants can be used under sea conditions where mechanical collection is impossible and have been effective on some spills (IPIECA 1993b, Lunel and Elliott 1998). However, they need to be used quickly (typically within one or two days) before the oil becomes too weathered, emulsified or fragmented.

Onshore, methods can be classified into non-aggressive and aggressive. Non-aggressive shore cleaning (methods which have been shown to have minimal impact on shore structure and shore organisms) include:

- vacuum removal of pooled oil;
- physical removal of surface oil from firm sandy beaches using machinery such as front-end loaders (avoiding the vehicles mixing the oil into the sand, and the removal of underlying sediment);
- manual removal of oil, asphalt patches, tar balls etc., by small, trained crews;
- collection of oil using sorbent materials (followed by safe disposal);
- low-pressure flushing with ambient temperature seawater; and
- bioremediation using fertilizers to stimulate indigenous oil-degrading bacteria.

In appropriate circumstances these methods can be effective, but they also may be labour-intensive and clean-up crews must be careful to minimize damage by the wheels of heavy vehicles, trampling by many human feet, and secondary damage off-site. The methods do not work well in all circumstances. For example, low pressure flushing is ineffective on weathered, firmly-adhering oil on rocks; and bioremediation is ineffective for sub-surface oil in poorly aerated sediments.

Aggressive methods of shore cleaning (those that are likely to damage shore structure and/or shore organisms at least in the short term) include:

- sediment relocation, i.e. moving sand or coarser sediments down the beach where they receive greater natural cleaning by wave action;

- removal of shore material such as sand, stones, or oily vegetation together with underlying roots and mud. (In some cases the material may be washed and returned to the shore);
- water flushing at high pressure and/or high temperature;
- sand blasting; and
- chemical cleaning.

Weigh the advantages and disadvantages

The first option to consider should be natural clean-up. Case history evidence shows that in many cases there is good natural cleaning and recovery. As clean-up operations may be damaging, the natural clean-up option is often the best. Intervention may be considered necessary in cases where:

- Oil on the sea surface or the shore is a threat to birds or mammals. Some response methods predicted to be effective (e.g. dispersant spraying at sea or hot water flushing on intertidal rocks) reduce the threat to the birds or mammals, but are likely to increase the threat to water column organisms (e.g. fish) and shore organisms. It will be necessary to consider the relative importance and recovery rates of the birds or mammals on the one hand and the fish or shore organisms on the other.
- ‘Free’ or ‘bulk’ oil is present on the shore, such that it may spread with tidal action and contaminate a wider area, or smother plants and animals. In such a case decision making is straightforward because it is usually obvious that rapid removal of the oil (e.g. using vacuum pumping) will reduce the area or extent of damage.
- The predicted length of the natural cleaning time is unacceptably long to the main stakeholders. For example, six weeks natural cleaning time for an amenity sand beach may be unacceptably long if a spill occurs just a few days before the main tourist season. Disruption caused by clean-up (e.g. removal of shore material and associated organisms) may be justified if this will restore an important human use of the shore. Conversely, longer natural cleaning times may be acceptable if the main interest is, for example, plants and animals on a remote shore in a conservation area.

CONSIDERATIONS AND EXAMPLES

Oil on the water

When a large spill occurs many miles offshore and it is not clear where the oil will move, a wide-ranging preliminary evaluation is an appropriate precaution, taking into account the most important resources in all the possible directions that the slicks may travel. If monitoring of the slick indicates that it is likely to move into a sensitive area, it has to be decided if and how it can be treated while it is still well offshore (at the same time taking action to protect sensitive shorelines). If the oil is approaching the shore and trajectories have been predicted, evaluation should focus on a particular area in more detail, for example using information from local sensitivity maps. Rapid decision making is particularly important for nearshore situations, where there may be only a few hours available for at-sea response before the oil reaches the shore.

If sea conditions preclude containment and recovery, dispersant spraying may be the only possible option if there is to be any at-sea response. Modern low-toxicity dispersants can help to minimize damage in some cases, for example when seabirds or sensitive shorelines are under imminent threat from floating oil slicks and when it is agreed that fisheries interests are at low risk from dispersant spraying. Scenarios involving beneficial use of low-toxicity dispersants are described in IPIECA (1993b).

Oil on the shore

If large volumes of mobile oil are present on the shore surface, a rapid response is necessary before the oil spreads over a wider area. For some shores, ecological

1. *Dispersant spraying, in deep open water such as this or even in some nearshore waters, can sometimes help to minimize damage.*
2. *Nearshore evaluation should include comparison of shoreline and nearshore sensitivities in an assessment of at-sea response compared with shoreline protection and clean-up. Logistical feasibility of response options also needs to be considered.*
3. *If there is an extensive shoreline of firm, easily cleaned sand (not very productive biologically) the optimum response in some cases may be to deal with oil on the shore.*

1


2


3


After the Sea Empress *spill in southwest Wales it was important to clean this rocky shore quickly because there was free oil which might have moved elsewhere, the bay is an important area for tourists, and the shore is an area of outstanding ecological interest.*

recovery times may be reduced by rapid action to remove smothering or particularly toxic oil. In contrast, more time can be given to decisions involving small amounts of weathered oil firmly stuck to the shore or retained beneath the surface.

For many spills which do not involve thick or particularly toxic oil deposits, moderate shore cleaning has little effect on longer-term recovery rates of shore organisms, i.e. organisms such as molluscs and algae which live on the shore (Sell *et al.* 1995). This is an important finding for shoreline response, because it raises the following key issues for decision making about clean-up.

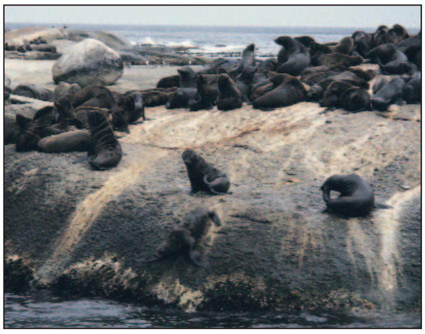
Severity of oiling

Should the shore be classified as a case of severe oiling which justifies clean-up because otherwise the ecological recovery time is likely to be prolonged well beyond the normal timescale? In a minority of cases, the oiling may be so severe that, on the basis of previous case history evidence, the predicted recovery times may be many years. For example, following the 1974 *Metula* spill in Chile, one very sheltered marsh received thick deposits of mousse which were still present and inhibiting recovery 25 years later. If the decision is taken to clean the shore,

This reedbed by the Caspian sea in Kazakhstan is an example of a wetland habitat particularly susceptible to damage from over-cleaning. Natural clean-up may be the best option (even though this may take months or years).

it needs to be borne in mind that aggressive clean-up can also prolong recovery times. For example, following the 1978 *Amoco Cadiz* spill in Brittany, some areas of marsh were cleaned using heavy equipment. As much as 50 cm of sediment was removed and subsequently it was realized that some of the marsh surface was lowered to the extent that it was at the wrong intertidal height for plant growth, and this delayed recovery (IPIECA 1994).

What would happen if it was necessary to deal with a new case of very thick oil deposits on a shore? On the basis of the above evidence, it seems that in some cases neither natural clean-up nor intense treatment will be the best option. It seems likely that the least environmental harm would result from a moderate level of clean-up—sufficient to remove most of the bulk oil, but gentle enough to leave the surface of the shore intact and to avoid churning oil into underlying sediments. In support of the above conclusion, field observations during the clean-up of the Kolva Basin oil spills in the Komi Republic (Owens and Sergy 1997) showed that as much as 90 per cent of the oil that could be easily dislodged came off in the first four to five passes with a low pressure hose. After this initial series of passes, further time spent in attempts to dislodge the remaining oil was inefficient, in terms of effort and reward, and caused a high level of intrusion by



If this rocky shore was oiled, there would be a need for effective clean-up with minimum disturbance of the seals. Experience such as the San Jorge *spill in Uruguay (1997) shows that young seals are particularly vulnerable to oil.*

eroding surface soil and vegetation. Considerable training time was spent with field teams to ensure that the response did not cause unnecessary harm through going on too long.

Interacting systems

Are there any interacting systems (wildlife species or nearshore ecosystems) which might be damaged if the shore is not cleaned?

Examples of interacting systems are:

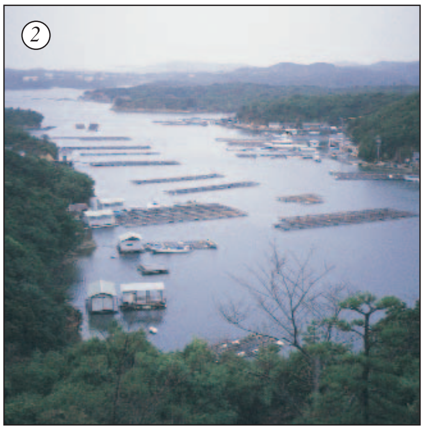
- bird colonies, with birds nesting above the intertidal zone but sometimes visiting the intertidal zone; or feeding in nearshore water which may receive oily run-off from a polluted shore;
- marine mammals, for example seals using the shore as a haulout and breeding area; and
- nearshore habitats such as coral reefs, seagrass beds, and kelp beds, which may receive oily run-off or oil and sediment mixtures from a polluted shore.

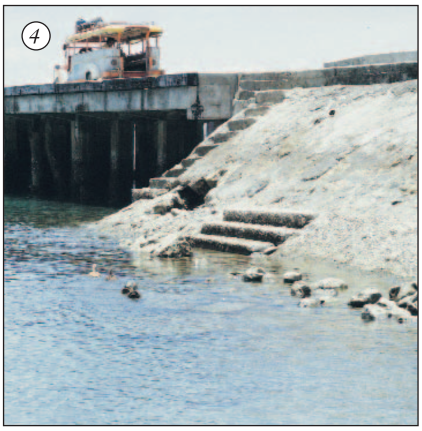
If moderate clean-up of the shore is carried out for the sake of interacting systems, this can be done in most cases without prolonging the ecological recovery time of the shore. Aggressive clean-up may be considered justifiable in some cases, for example if sticky viscous fuel oil is adhering to rocks which are soon to be used by seals during the breeding season. If effective removal of oil can only be achieved by high-pressure hot-water washing or sand blasting, prolonged recovery times of shore organisms might be accepted because the seals are given a higher priority. A consideration here and in similar cases is that populations of wildlife species (mammals and birds) are likely to be smaller, more localized, and slower to recover if affected by oil than populations of abundant and widespread shore organisms such as algae, barnacles and mussels.

Socioeconomic issues

Will socioeconomic issues dictate clean-up, even though it is not necessary from an ecological point of view? Resources such as amenity beaches, marinas, or fisheries may be of such importance to the local economy that this (rather than ecological factors) determines the nature of the spill response.
For example, consider a cobble shore with sub-surface oil which is gradually

leaching into the nearshore waters. Near the shore on the shallow sea bed are abundant shellfish which are collected for food by local people. Ecological recovery on the shore has started without any clean-up but the shellfish are tainted. It is predicted that some tainting will continue for several years because of chronic leaching from the shore, making the shellfish inedible for this period of time. Does this justify aggressive removal of the oil? From an ecological point of view, there is no justification, because the recovery of the shore would be set back. Moreover, it is doubtful that there would be any ecological benefit to the shellfish populations, which can survive even though they are tainted. There might, however, be local consensus that compelling economic benefits of clean-up take precedence over the ecological point of view.





1. *Aggressive clean-up of an oil soaked stony shore, south Korea. In this case, there were economically important fish cages and shellfish aquaculture near the oiled shore.*

2. *Nearshore oyster culture, Japan—an example of a resource which can be economically damaged (through tainting) by relatively small amounts of oil.*

3. *This beach near Madras, India, is an example of an area which is so important for amenity and tourism that restoration of human use after oil pollution would take precedence over ecological considerations (such as protecting any crabs that survived the oil).*

4. *Jetties, such as this one in the Philippines, need to be cleaned quickly in order to minimize loss of human use. Such structures are not usually of great importance from an ecological point of view, so aggressive clean-up may be justifiable.*

CONCLUSIONS

Some damage caused by specific response options may be justifiable if the response has been chosen for the greatest environmental and socioeconomic benefit overall.

Groundwork for evaluation of response options is best done before a spill as part of contingency planning, and involves collecting a variety of information on environmental and socioeconomic resources in the area of interest, likely response methods, and outcomes of previous case histories.

The advantages and disadvantages of different responses should be weighed up and compared both with each other and with the advantages and disadvantages of natural clean-up.

Response options need to be reviewed when a spill occurs, and such review should be an ongoing process in cases of large scale lengthy clean-up operations.

Offshore and nearshore dispersant spraying can in some cases lead to an outcome of least environmental harm.

For onshore evaluation, it is necessary to consider both the shore in itself, and systems which interact with the shore in some way (e.g. bird and mammal colonies).

In many cases of oiling there is no long-term ecological justification for clean-up, provided that the only concern is for the shore itself (i.e. habitats with associated plants and invertebrates).

For extremely oiled shores, moderate clean-up can facilitate ecological recovery, but aggressive clean-up may delay it.

In most cases of shore oiling where moderate clean-up is considered likely to reduce the damage to socioeconomic resources, wildlife or near-shore habitats, the evidence is that this will not make a significant difference to the shore ecological recovery times.

ACKNOWLEDGMENTS AND FURTHER READING

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