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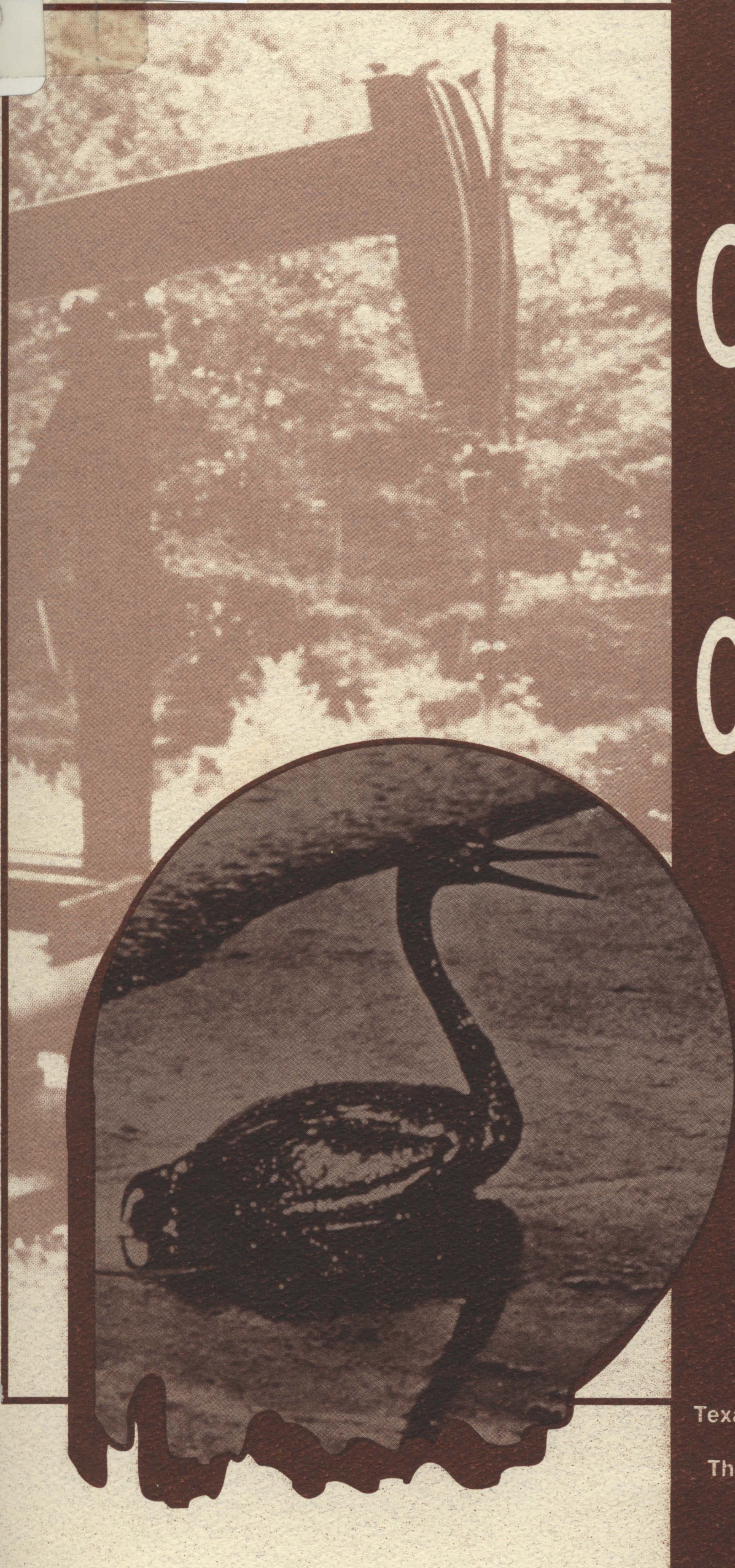

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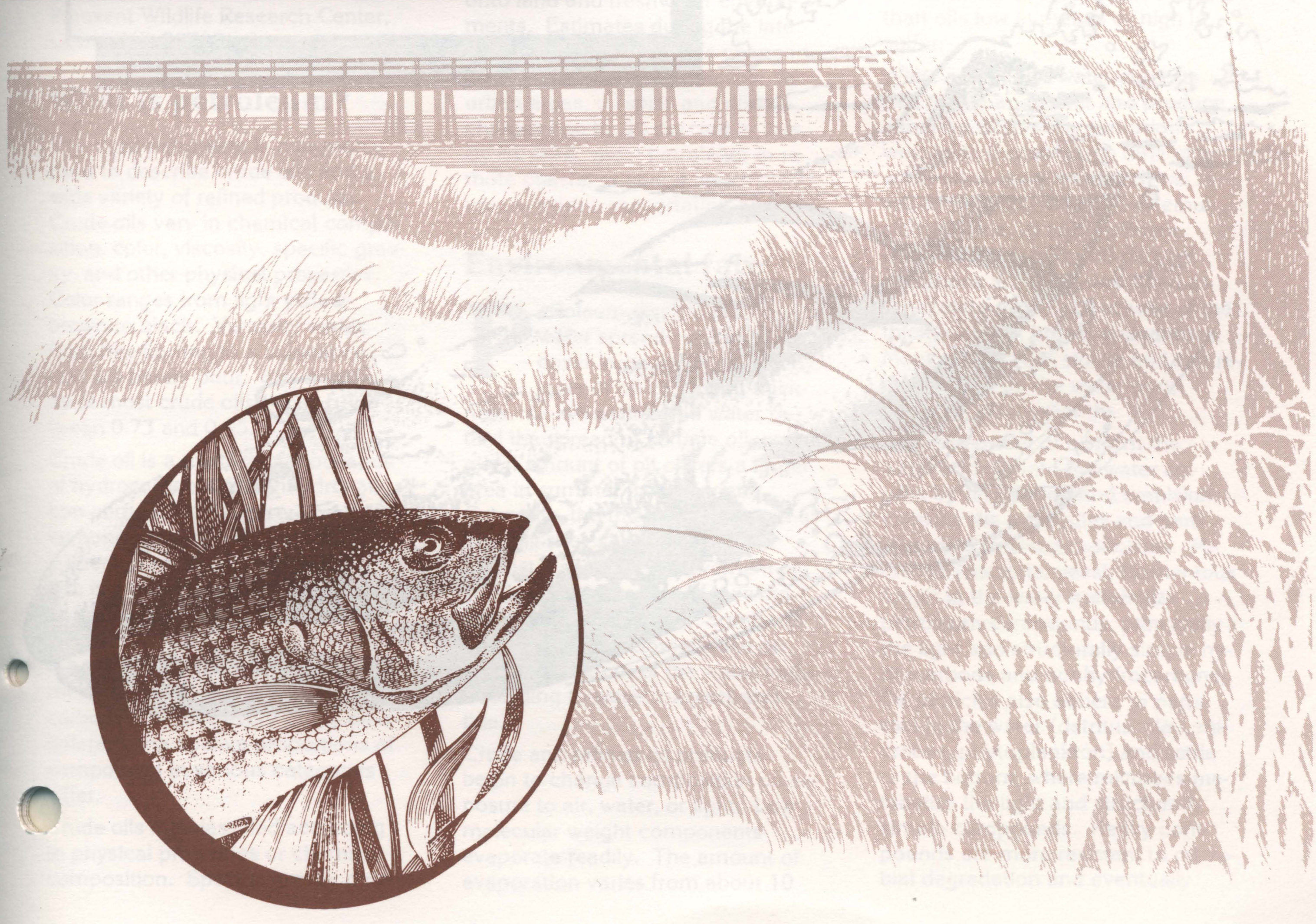

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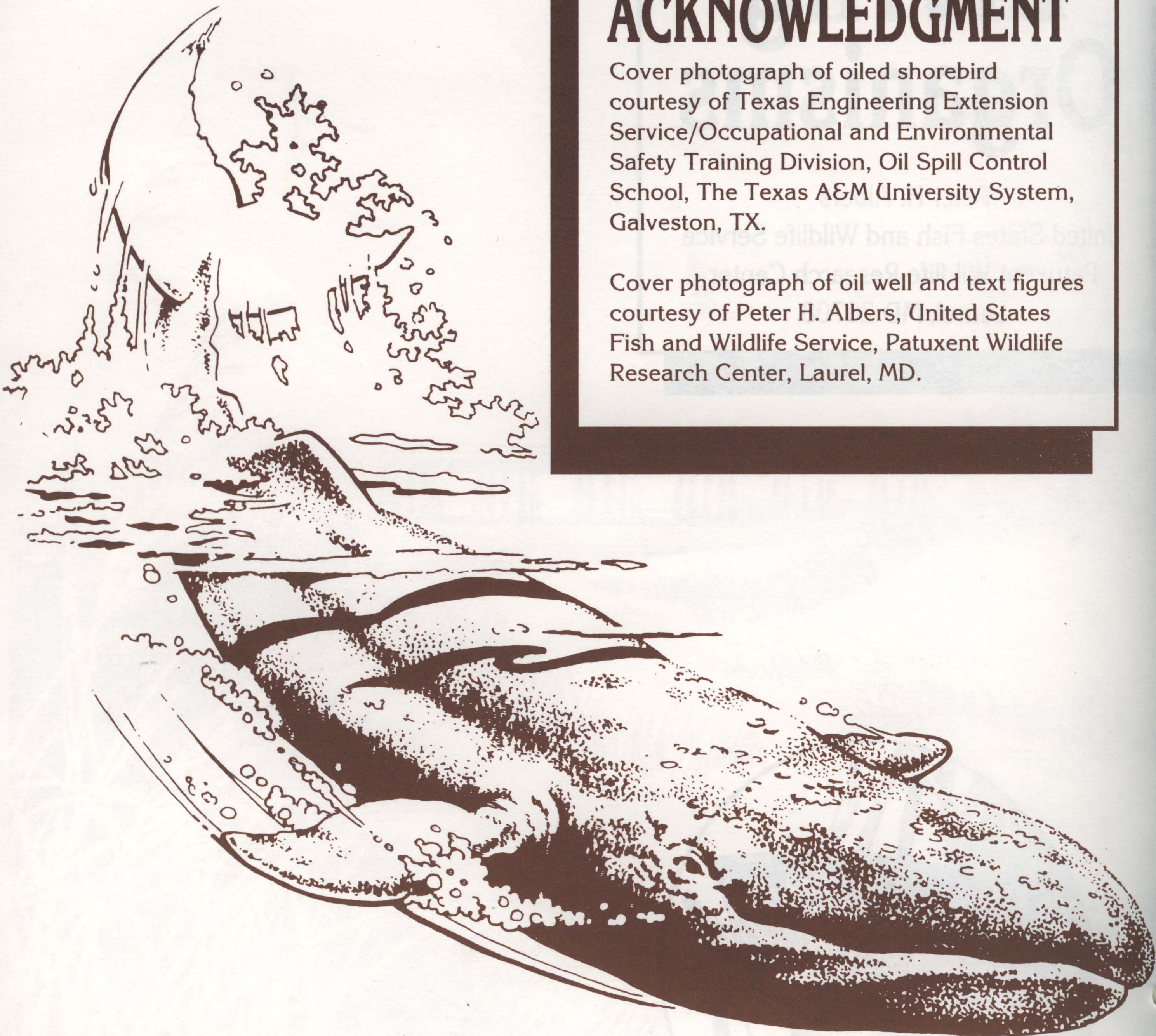


Oil Spills and Living Organisms

Peter H. Albers

Oil spills can and do occur almost anywhere. Minor spills usually receive very little attention and are cleaned up quickly or allowed to dissipate. Large spills attract public comment and usually require government agencies to act rapidly. Serious oil spills are unpredictable but on occurring, biologists and administrators must respond. This fact sheet is intended to provide general information. For more detailed information refer to *Oil Spills and the Environment: A Review of Chemical Fate and Biological Effects of Petroleum* from Oil Symposium 1990 by Peter H. Albers. It is available from the United States Fish and Wildlife Service at Patuxent Wildlife Research Center, Laurel, MD 20708.

What is petroleum?

The word petroleum is commonly used to describe crude oils and a wide variety of refined products. Crude oils vary in chemical composition, color, viscosity, specific gravity, and other physical properties. Color ranges from light yellow-brown to black. Viscosity varies from free-flowing to a substance that will barely pour. Specific gravity of most crude oils varies between 0.73 and 0.95.

Crude oil is a mixture of thousands of hydrocarbon and nonhydrocarbon compounds (Figure 1). Hydrocarbons constitute more than 75 percent of most oils. A hydrocarbon is a molecule consisting solely of hydrogen and carbon. Nonhydrocarbons are compounds containing oxygen, sulfur, nitrogen, or metals in addition to hydrogen and carbon. Because every crude oil is different, the relative proportions of compounds in various categories differ.

Crude oils are classified according to physical properties or chemical composition. Specific gravity determines whether an oil is classified as light, medium, or heavy. The relative amounts of hydrocarbons in various categories are sometimes used to classify oil. Sulfur content is also used as a basis for classification.

Sources of contamination

About 35 percent of the petroleum hydrocarbons in the marine environment during the early 1970s were caused by spills and discharges from marine transportation. Transportation spills and discharges probably accounted for less than 35 percent of the total oil discharged onto land and freshwater environments. Estimates during the late 1970s indicated that this changed to 45 percent in marine areas. In urban areas, oil spills and discharges can be 10 percent or less. By contrast, most petroleum in remote coastal or inland areas comes from transportation activity.

Environmental fate

Petroleum discharged on water spreads quickly to cover large areas with a layer of oil varying in thickness. Cold weather and water retard the spread of surface oil, and a given amount of oil covers a larger area in summer than in winter. Generally, the thickest oil layer is at the spill site, where oil collects against a shoreline. Movement of surface oil is determined by wind, water current, and tide. Some oils sink and move below surface or along the bottom of the water body according to water currents and tide.

Crude and refined oil products begin to change composition on exposure to air, water, or light. Low molecular weight components evaporate readily. The amount of evaporation varies from about 10 percent of the spilled oil for very heavy crudes and refined products (No. 6 fuel oil) to as much as 75 percent for light crudes and refined products (No. 2 fuel oil, gasoline). Some of the low molecular weight compounds that readily evaporate will dissolve in water. Less than 5 percent of a crude oil or refined product will dissolve. This process of "weathering" causes the remaining oil to become denser and less likely to float on the water surface. Petroleum exposed to sunlight changes to polar, oxidized compounds. Thin films of oil and oil emulsified in water are more likely to be oxidized than are large masses of oil. Oils high in metals or low in sulfur oxidize more readily than oils low in metals or high in sulfur.

Wave action and water currents mix the oil and water and produce either an oil-in-water emulsion which will disperse with time or a water-in-oil emulsion which will resist dispersion. Water-in-oil emulsions have a 10 to 80 percent water content; 50 to 80 percent emulsions are often described as "chocolate mousse" because of the thick, viscous, brown appearance. Mousse degrades slowly and can remain intact on the water or on shore for many months.

The movement of oil from the water surface into the water column by dissolution and emulsion exposes the molecules and particles of oil to living organisms. Microbes (bacteria, yeast, filamentous fungi) in the water metabolize petroleum compounds, principally the light and structurally simple hydrocarbons and nonhydrocarbons. Oil particles also adhere to particles in the water (detritus, clay, microbes, phytoplankton) and settle to the bottom, where microbes metabolize the light and structurally simple compounds. Heavy compounds are more resistant to microbial degradation and eventually

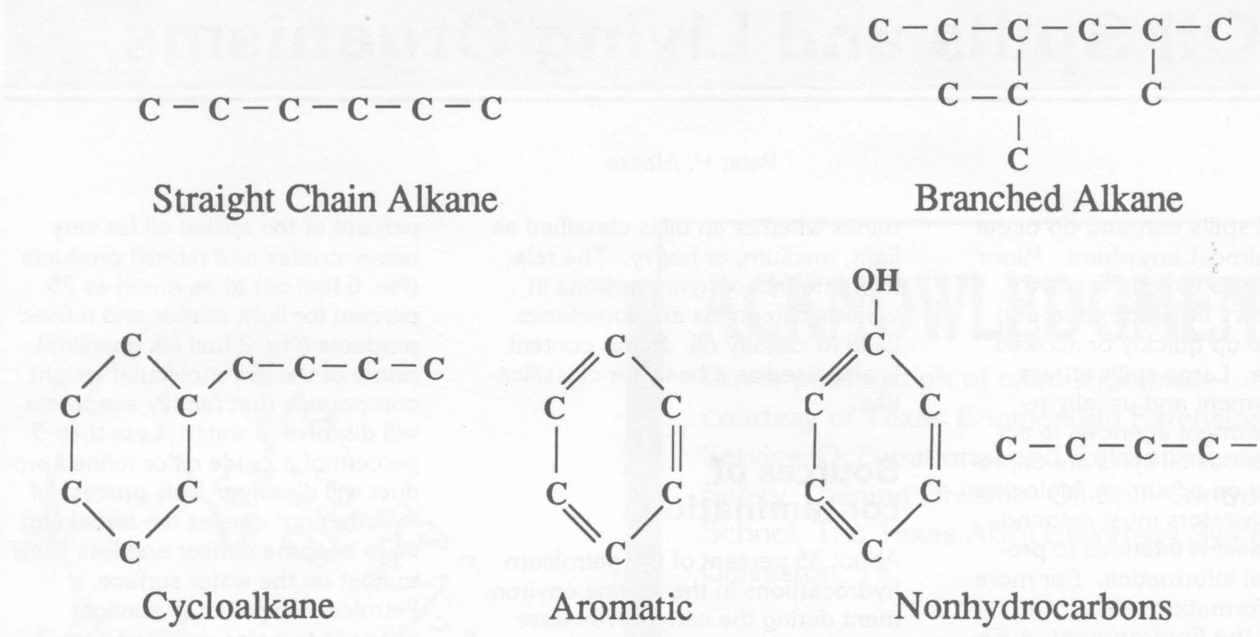


Figure 1. Examples of the molecular structures found in petroleum. Hydrogen atoms bonded to carbon atoms are omitted.

settle into the bottom sediments. The effectiveness of microbial degradation depends on water temperature, pH, salinity, oxygen availability, oil composition, nutrients in the water, and microbes available. In general, microbial degradation is most rapid when dissolved oxygen, nutrients, and water temperature are elevated. Oil-degrading microbes proliferate in water bodies subject to chronic oil input and rapidly respond to a major oil discharge. About 40 to 80 percent of a crude oil spill can be degraded by microbial action.

A variety of other organisms take up oil. Filter-feeding zooplankton and bivalve mollusks ingest oil particles during feeding. Although mollusks and many zooplankton are incapable of metabolizing the oil, they can transport and temporarily store it. Fish, mammals, birds, and some large invertebrates (crustaceans, polychaete worms) metabolize some of the petroleum hydrocarbons ingested during feeding, grooming, and respiration.

Residence time for petroleum in the water column is typically less than 6 months unless the oil is spilled during or just before winter at a high latitude. Oil can remain trapped under ice until the following spring, when it is exposed to air, wind, sunlight, and the increased microbial activity that accompanies increased water temperature.

Residence time of petroleum deposited in nearshore sediments, or coming ashore as weathered oil or as a water-in-oil emulsion, is determined by the characteristics of the sediment and shoreline. Oil retention times for coastal environments (Table 1) range from a few days on rock cliffs to more than 10 years in sheltered tidal flats and wetlands. Oil retained in sediments and shorelines can be a source of chronic discharge to nearshore waters. Periodic storms often uncover large amounts of buried oil and recycle it into the water. In cold climates, because of ice, low wave energy, and decreased chemical and biological activity, oil remains in sediments or on the shore longer than in temperate or tropical climates. In cold climates, sheltered tidal flats and wetlands can retain oil indefinitely. Some sediments or moist soils contain insufficient oxygen for aerobic microbial degradation; petroleum degrades under anaerobic conditions but at a much slower rate.

Oil spilled on land has little time to weather before it penetrates into the soil. Oil spilled on smaller water bodies such as lakes and streams typically weathers less before coming ashore than does oil spilled on the ocean. Variations in stream velocity, soil porosity, vegetation, and exposure to wind and waves affect retention time of petroleum on shorelines.

Petroleum spilled directly on land is degraded by evaporation, photo-oxidation, and microbial action. Oil spilled on land can contaminate groundwater if the soil is porous and the water table shallow.

Oil spill response

Responses to petroleum spills can be complex and confusing, particularly for large spills. The degree of response is determined by the size of the spill and where it occurs. A 1,000 gallon oil spill in a city harbor or a wildlife refuge will draw more attention than the same amount of oil 200 miles offshore in the Atlantic Ocean. Hazardous materials spills on the oceans, adjacent coastal areas, and major inland waterways of the United States are the responsibility of the U.S. Coast Guard (CG). All other inland spills are the responsibility of the U.S. Environmental Protection Agency (EPA). National and Regional Response Teams representing federal and state agencies coordinate activities on major oil spills.

Table 1. Oil spill vulnerability index of marine coastal environments (Gundlach and Hayes 1978). Environments are presented in order of increasing persistence of spilled oil within each environment and consideration of initial biological impact.

1. Exposed, steeply dipping or cliffed rock headlands
2. Eroding wave-cut platforms
3. Flat, fine-grained sand beaches
4. Steeper, medium- to coarse-grained sand beaches
5. Exposed, compacted tidal flats
6. Mixed sand and gravel beaches
7. Gravel beaches
8. Sheltered rocky coasts
9. Sheltered estuarine tidal flats
10. Sheltered salt marshes and mangrove coasts

The party responsible for the oil spill can accept responsibility for cleanup or request that the CG or EPA assume responsibility. The CG and EPA can assume control of the cleanup if the efforts of the spiller are inadequate. The actual cleanup of spilled oil can be performed by the spiller, private contractors, or oil spill cooperatives sponsored by private industry. Small inland oil spills often involve local fire departments.

The actual methods used to protect or clean habitats after an oil spill are quite variable. The type of habitat and the circumstances of the spill determine methods for removing oil and minimizing adverse ecological effects. The American Petroleum Institute offers an excellent reference for evaluating oil spill cleanup methods and the unique characteristics of marine habitats (API Publication No. 4435). Most methods used to combat oil spills in marine environments are also used for freshwater environments. Exceptions would be methods involving chemical products (dispersants, herding agents, gelling agents) developed for use on salt water. Only chemical products approved by EPA can be used to combat oil spills.

Contingency plans for oil spills should be prepared at the state and local level. These plans establish high-priority areas for protection and cleanup. They describe how objectives are to be met and who is responsible for the cleanup. State and federal biologists, natural resource managers, law enforcement personnel, cleanup contractors, trained animal rehabilitators, and local public officials are usually involved. In addition, major spills attract large numbers of volunteers, media representatives, and curious onlookers.

Although no two spills are alike, case histories familiarize the reader with typical problems encountered and their biological impact. The primary emphasis of each case history is generally a function of the profession of the authors (i.e., case histories reported by biologists have more biological detail).

Effects of petroleum on animals and plants

Birds

Petroleum affects birds through external oiling, ingestion, egg oiling, and habitat changes. External oiling disrupts feather structure, causes matting of feathers, and eye irritation. Death often results from exposure to cold water and drowning. Bird losses greater than 5,000 are common for moderate to large petroleum spills. Birds that spend much of their time in the water are the most vulnerable to surface oil.

Petroleum can be ingested through feather preening, drinking, eating contaminated food, and inhalation of fumes. Ingestion of oil seldom kills directly but promotes death from starvation, disease, and predators.

Bird eggs are very sensitive to petroleum. Contaminated nest material and oiled plumage transfer oil to the shell surface. Small quantities of some types of oil are sufficient to cause death, particularly during the early stages of incubation.

Petroleum spilled in bird habitats can have immediate and long-term impacts on the birds. Fumes from evaporating oil, a shortage of food, and cleanup activities can reduce utilization of an affected area. Severely oiled wetlands and tidal mud flats are likely to have altered plant and animal communities for years after a major spill.

Direct and indirect impacts of oil spills on bird populations have been estimated. The recovery of a species depends on the reproductive potential of the survivors and the immigration potential for the species at the spill site. Death and reduced reproduction caused by oil spills are more easily detected at the local or colony level than at the regional or species level. Death from natural causes, human activities, weather, food availability, and movement of birds within the region can obscure the effects of a single or periodic catastrophic event. For example, seabird populations of western Europe continued until recently to increase despite many years of accidental and intentional oil discharges that resulted in numerous local losses of birds.

Mammals

The effects of petroleum on mammals are less known than for birds, and less is known about nonmarine mammals than marine mammals. Marine mammals that rely primarily on fur for insulation (i.e., sea otters, polar bears, fur seals, newborn hair seals) are the most likely to be killed by contact with spilled oil. Oiled fur becomes matted and loses its ability to trap air or water. Adult sea lions, seals, and cetaceans (whales, porpoises, dolphins) depend primarily on layers of fat for insulation so oiling causes much less heat loss. However, oil can cause skin and eye irritation and interference with normal swimming. Skin absorption of oil is known to occur in seals and polar bears. The skin of whales and dolphins sometimes suffers minor, temporary damage from petroleum exposure.

Oil ingested in large quantities can kill polar bears, but seals and cetaceans are more resistant and rapidly metabolize petroleum. Ingested oil can cause gastrointestinal tract hemorrhaging, renal failure, liver toxicity, and blood disorders. Inhalation of evaporating oil is a potential respiratory problem for mammals near or in contact with large quantities of fresh oil.

Documentation of the impact of oil spills on nonmarine mammals is limited. Large numbers of muskrats were killed by a spill of bunker C fuel oil in the St. Lawrence River. Giant kangaroo rats in California have been found dead after being oiled. Beaver and muskrats were killed by an aviation kerosene spill in a Virginia river. Rice rats, in a laboratory experiment, died after swimming through oil-covered water.

The impact of major oil spills on mammals could include food reduction or a change of prey species. These effects could be short- or long-term and could be serious during the breeding season when movement of females and young is restricted.

Sea otters and fur seals are particularly vulnerable to oil spills because of dense population concentrations, constant presence in the water, and dependence on fur for insulation. One effort to simulate the effect of oil spills on the fur seal population of Alaska indicated that a relatively small percentage (4 percent) of the total population was likely to be killed by an "extreme case" oil spill. Annual natural mortality (16 percent females, 29 percent males) plus mortality from entanglement in fishing nets (2 percent females, 3 percent males) was much greater than projected losses from the oil spill scenarios, but recovery time from the "extreme case" oil spill was estimated at 25 years.

Reptiles and amphibians

The response of reptiles and amphibians to petroleum exposure is not well known. Marine turtles eat plastic objects and tar balls. Oil ingestion has been reported for green, loggerhead, and Atlantic Ridley turtles. Petroleum could have caused deaths of sea turtles off the coast of Florida and in the Gulf of Mexico following the Ixtoc I oil spill. Turtle embryos died or developed abnormally when the eggs were exposed to oiled sand. Weathered oil is less harmful to the embryos than is fresh oil. Recently oiled beaches could pose a problem for newly hatched turtles that must cross the beach to enter the ocean. Various species of reptiles and amphibians were killed by a spill of bunker C fuel oil in the St. Lawrence River.

Bullfrog larvae were exposed to amounts of No. 6 fuel oil that could be expected in shallow waters following oil spills; mortality was most severe in larvae that were in the late stages of development. Larvae from all exposure groups and all ages exhibited abnormal behavior. Larvae of the wood frog, the spotted salamander, and two species of fish were exposed to several fuel oils and crude oils in static and flow-through tests. Sensitivity of the amphibian larvae to oil was similar to that exhibited by the two species of fish.

Fish

Fish are exposed to spilled oil in the water column, by eating contaminated food and water, and through contact by floating egg masses with surface oil.

Death of fish beyond the early juvenile stages usually requires a heavy exposure to petroleum. Consequently, it is unlikely that large numbers of adult fish in large bodies of water would be killed by petroleum. However, crude oils and petroleum products vary considerably in their toxicity to different kinds of fish. Concentrations of 0.5 ppm or less of oil in water can kill cutthroat trout. Sub-lethal effects of oil on fish include changes in heart and respiratory rate, enlarged livers, reduced growth, fin erosion, a variety of biochemical and cellular changes, and behavioral responses.

The larval and early juvenile stages of fish are the most sensitive to oil. Oil spills are likely to kill fish eggs and larvae that are in the surface water and early juveniles that are in shallow water.

The potential effects of oil spills on fish populations has been evaluated with an extensive modeling effort of the Georges Bank fishery off the northeast coast of the United States. Major factors in determining oil spill effects are toxicity of the oil, percentage of spilled oil dispersed into the water column, location of the spill, time of year of the spill, and the species involved. Normal variation in natural mortality of eggs and larvae for such pelagic species as Atlantic cod, haddock, and Atlantic herring is often larger than mortality estimates for even the largest of spills.

A Baltic Sea oil spill in 1969 killed "numerous" fish that inhabit shallow nearshore waters. A survey of several of the oiled sites and a control site in 1971 found that fish populations, age structure, growth, and body condition were not significantly different among sites. Because a similar assessment had not been conducted before the spill, the authors could not determine whether fish populations at individual sites had changed during the preceding 2 years. As with birds, it appears that immediate effects of oil on local fish populations are more likely to be detected than are regional or long-term effects.

Invertebrates

Invertebrates are good indicators of pollutant stress because of their limited mobility. Published reports of the effects of oil spills often indicate the death or temporary effects on organisms in the littoral zone, in or on sediments, and in the water column. Effects of oil spills on invertebrates can last for as little as a week to as much as 10 years. This depends on the type of oil, circumstances of the spill, and organisms affected. Invertebrate communities in the water column (zooplankton) of large bodies of water return to prespill condition much faster than those in small bodies of water. This is because of greater pollutant dilution and greater availability of colonizing zooplankton in nearby waters.

Much work on marine invertebrates has been done with petroleum in laboratory bioassays, experimental ecosystems, enclosed ecosystems, and field experiments and surveys. Less work has been conducted on freshwater invertebrates with laboratory bioassays and field experiments. Results of this research document long- and short-term effects of various types of crude and refined oils on invertebrate survival, physiological function, reproduction, behavior, species population, and community composition.

Plants

Plants are also good organisms to observe for pollutant effects because of their limited mobility. Published reports on the effects of oil spills contain accounts of the death of mangroves, seagrasses, and large intertidal algae; severe and long lasting destruction of salt marsh vegetation and freshwater wetland vegetation; enhanced or reduced biomass and photosynthetic activity of phytoplankton communities; and microbial community changes and increases in numbers of microbes. The effects of oil spills on most local plant populations can last from a few weeks up to 5 years, depending on the type of oil, circumstances of the spill, and species affected. Mechanical cleanup activities in wetlands can increase the recovery time 25 to 50 percent. Complete recovery of mangrove forests could require 10 to 15 years. Plants in the water column of large water bodies return to prespill conditions much faster than do those in small water bodies.

The importance of microbes in petroleum degradation has prompted a considerable amount of research on these organisms. Studies using assays, experimental ecosystems, and field experiments and surveys have been performed to determine responses of microbes to petroleum hydrocarbons and various exposure conditions. In general, petroleum can initially stimulate or inhibit microbial activity, depending on the quantity and type of oil present and the composition of the microbial community. The presence of oil favors resistant species that can use the oil as a food source. The species composition of the microbe community will adjust to the oil, and an increase in overall numbers and activity can occur.

The effects of petroleum on marine plants, such as mangroves, seagrasses, saltmarsh grasses, and algae, have been studied in laboratory bioassays, experimental ecosystems, and field experiments and surveys. Petroleum caused death, reduced growth, and impaired reproduction in the large plants. Microalgae were either stimulated or inhibited, depending on the type and amount of oil present and the species of algae. Response was expressed as changes in biomass, photosynthetic activity, and community structure.

The effects of petroleum on freshwater phytoplankton and periphyton have been studied with laboratory bioassays and field experiments. Petroleum induced effects similar to those described for marine microalgae.

Considerations for Specific Habitats

Open ocean, offshore

The offshore ocean environment is characterized by deep water, remoteness from land, and a limited array of organisms vulnerable to spilled oil. Surface oil is broken up and dispersed in the water column by wind and wave action.

Densities of seabirds, mammals, and reptiles are low, and these species usually are not seriously exposed to surface oil in the offshore ocean. Adult fish are unlikely victims of oil spills. Phytoplankton, zooplankton, and fish larvae inhabiting surface water will be affected by the oil, and local declines of these organisms are probable.

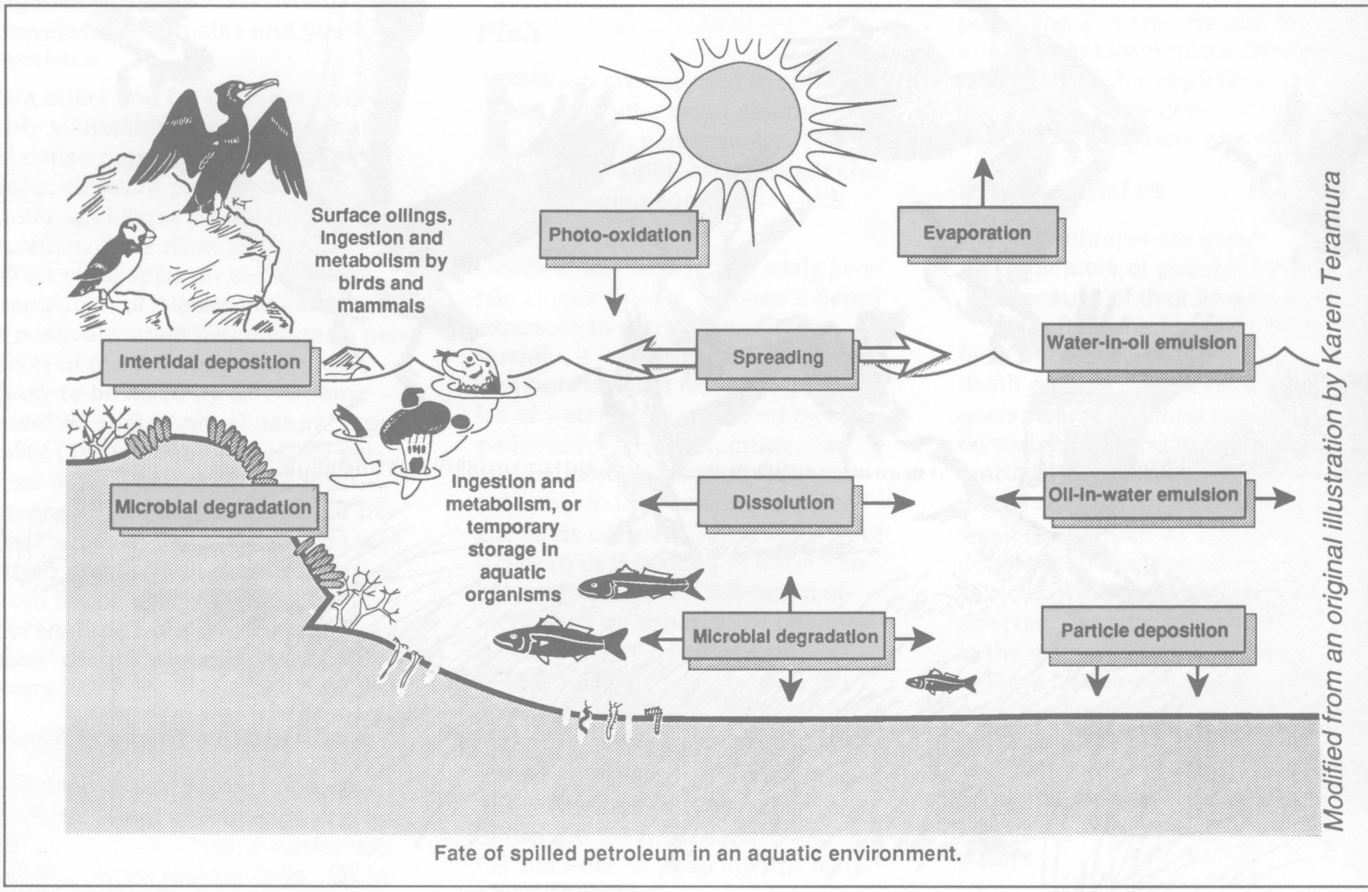
The offshore ocean is a low priority for cleanup. Usually nothing is done to the oil unless it threatens offshore islands. A detailed assessment of marine habitats and cleanup options can be found in American Petroleum Institute Publication 4435.

Open ocean, nearshore

The nearshore ocean environment extends from the deep water of the offshore region to the low-tide line and is more complex and biologically productive than the offshore environment. Nearshore areas can contain peninsulas, isolated islands, barrier islands, harbors, lagoons, and estuaries. Water movement is determined by tides, complex water currents, and wind patterns. The shallow portions of the nearshore area may contain kelp and seagrass beds or coral reefs. Oil will accumulate around islands and against coastlines, especially at sheltered sites. A large amount of surface oil on water only a few meters deep will produce high oil concentrations in the water column and a high rate of deposition on the sediments. Oil moving below the surface in shallow waters will probably make direct contact with the ocean bottom.

Concentrations of birds vary greatly depending on the site and time of year. Many bird species found in this habitat are very vulnerable to surface oil. Oil spills pose the greatest threat to birds breeding at colonial breeding sites, overwintering sites, and at major resting areas during migration.

Sea otters are very likely to be affected by surface oil. Sea lions and fur seals, walrus, and hair seals are most vulnerable during breeding season. Breeding adults and young will be exposed to oil in the nearshore waters when they surface or attempt to move onto offshore rocks and islands. Polar bears could become oiled if spilled oil accumulates along or under the edge of the coastal ice. Whales,



Fate of spilled petroleum in an aquatic environment.

porpoises, dolphins, and sea turtles are unlikely to be seriously affected.

Adult fish probably will not be killed in large numbers but eggs, larvae, and in the case of anadromous species, juveniles moving to sea are more susceptible to the effects of oil than are adults. Surface water organisms (phytoplankton, zooplankton, invertebrate larvae) will be affected by surface oil. Mollusks, crustaceans, polychaete worms, and other benthic organisms can be seriously affected in shallow waters.

Protection and cleanup efforts usually are initiated on ocean oil spills when contact with land or important natural resources seems probable. The intensity of the cleanup effort is determined by the circumstances of the spill. Proximity of densely populated areas, harbors, public beaches, fishing grounds, concentrations of wildlife, important natural areas, endangered species, and vulnerable shoreline habitats (e.g., sheltered tidal flats, marshes) will influence protection and cleanup actions. Although high winds and storm conditions interfere with most protection and cleanup methods, these conditions also promote the dispersion of oil before it reaches land.

Ocean coastline

The coastline consists of the area between high and low tides and adjacent land areas used by animals and plants associated with the marine environment. This habitat consists of rocky cliffs; beaches of sand, gravel, or rocks; mud flats; marshes; mangrove forests; and portions of adjacent upland. The vulnerability to oil of coastal habitats increases as substrate porosity increases and wave energy decreases (Table 1).

Dense concentrations of nesting birds during the breeding season and large numbers of shorebirds during migration can be found in some locations. Wintering sites can harbor fish-eating raptors and large numbers of shorebirds. Oil on the coastline poses the greatest threat at these times.

Onshore oil is most hazardous to seals and walruses during the breeding season, when young pups move around at the waters' edge. Oiled beaches can be hazardous for sea turtles if eggs are laid in recently oiled sand or if beaches are oiled during hatching when young move to the ocean. Intertidal benthic organisms can be severely affected by shoreline oil.

Coastal lands consisting of nonporous (rocky) or poorly porous (hard, fine sand) material and subject to intense wave action usually are not subjected to cleanup, because natural cleaning is rapid. Coarse sand and gravel beaches are often cleaned with heavy earth-moving equipment. Cleanup of rocky beaches is difficult and typically labor intensive. Tidal mud flats, mangrove forests, and marshes are very difficult to clean because of unstable substrates, vegetation, and limited effectiveness of acceptable cleanup methods. These areas are usually subjected to methods that minimize disruption of substrate and enhance natural cleaning. Limited accessibility of coastlines often seriously hinders cleanup efforts.

Lakes and rivers

Lakes are landlocked water bodies with salinities ranging from freshwater (< 0.5 ppt) to highly saline (40+ ppt). Lakes vary tremendously in size, shape, and water characteristics; consequently, the fate of spilled oil and its biological consequences are difficult to predict. Fates and effects of petroleum in freshwater ecosystems are not well known; a recently published review addresses the subject. Some important generalities about lakes are:

- The chemical and physical fate of oil should be similar to that of oceans. Rates of change and relative importance of each mechanism of change could differ.
- The influence of wind and currents decreases with decreases in lake size.
- The small size of most lakes (compared to oceans) increases the chance that spilled oil will reach shore in a relatively unweathered state.

Rivers are moving bodies of freshwater that vary in length, width, volume of flow, and water characteristics. Some important generalities about rivers are:

- Because of water movement, a small quantity of spilled oil can affect a large amount of stream.
- Spilled oil is almost certain to contact riverbanks.
- Rivers can remove oil rapidly during high water flow; the inland equivalent of a high energy marine coastline.
- The shallow water and high energy of some rivers promote mixing of oil into the entire water column.

Birds most likely to be affected by surface oil on lakes and rivers are ducks, geese, swans, loons, grebes, rails, coots, cormorants, pelicans, and kingfishers. Concentrations of these species in northern latitudes are highest during premigration staging and migration. In southern latitudes concentrations are highest during winter. The double-crested cormorants and pelicans are also colonial nesters. Muskrat, river otter, beaver, and nutria will be the most commonly affected mammals. Reptiles and amphibians become victims of oil spills when they encounter oil in shallow water. Amphibian eggs near the water surface or in shallow water will probably be affected by spilled oil.

Adult fish will be killed in shallow waters of streams where the oil mixes into the water. Species that inhabit nearshore shallows of lakes and rivers will probably sustain losses. Fish mortality in rivers is hard to verify because dead and disabled fish are carried downstream. Phytoplankton, zooplankton, and fish eggs/larvae near the lake surface will be affected by the oil. Aquatic insects, mollusks, crustaceans, and other benthic organisms will probably be seriously affected in shallow waters of lakes and in shallow rivers. Many dead and disabled invertebrates will be transported downstream.

Oil spill protection and cleanup on large lakes involve methods similar to those used on oceans. Oil spill protection and cleanup on rivers are often limited to deflection booms and associated oil removal methods (suction pumping, absorbents). Rapid movement of oil downstream requires speedy response, uncomplicated methods, and cooperation among local governments along the banks of the affected river. Winter oil spills at high latitudes will be difficult to clean up if oil becomes incorporated in or trapped under the ice.

Wetlands

Marine coastal wetlands occur in sheltered areas of coastlines where wave action is minimal and water carries a high sediment load. Characterized by gently sloping surfaces, saltwater-tolerant grasses and woody plants, and unvegetated tidal channels, these areas vary in size from isolated pockets of a few hectares to vast expanses of coastal lowland covering many square kilometers. Coastal wetlands receiving input from streams often have a salinity gradient ranging from saltwater to freshwater. Coastal wetlands vary from being underwater most of the time to being dry except for high spring tides.

Nonmarine wetlands occur on borders of lakes (freshwater and saltwater), along streams, or as isolated habitats dependent on rainfall and groundwater seepage. Vegetation varies from aquatic plants to shrubs and trees.

Bird use of wetlands from the temperate zone northward is greatest during ice-free months. Reproductive activity is great in some wetlands but limited in others. Some wetlands receive heavy use during migration and over winter. Wetland species most vulnerable to spilled oil include ducks, geese, swans, grebes, rails, and coots. Muskrat, river otter, beaver, nutria, and some small mammals that inhabit wetlands are the mammals most likely to be affected. Reptiles and amphibians will be affected by spilled oil if it contacts eggs or if adults and larvae are exposed in shallow water.

Adult fish will suffer heavy mortality in wetlands if they do not have access to deep water. Fish eggs and larvae, phytoplankton, zooplankton, aquatic insects, mollusks, crustaceans, and other benthic organisms in shallow water or near the surface will be greatly affected by oil.

Wetlands merit a high priority for oil spill protection because of their high productivity, unstable substrate, and extensive emergent vegetation. Once spilled oil enters a wetland, it is difficult to remove. Tidal action circulates oil through coastal wetlands, and vegetation in both saltwater and freshwater wetlands retains much oil. Oil spill protection and cleanup methods usually consist of nondisruptive measures (booms, absorbents, low pressure flushing, management of natural drainage). Natural cleansing is often favored when oil contamination is not severe. The presence of ice, snow, and low temperatures hinders natural and human cleaning of wetlands.

Assessment of injury to natural resources

The organization that causes an oil spill is responsible for the consequences of that spill. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended (1986), provides for recovery of costs associated with response and cleanup actions and for "damages" to natural resources belonging to, held in trust, managed by, or otherwise controlled by federal, state, local, or foreign governments, or Indian tribes. Natural resources are defined as land, air, water, ground water, drinking water, fish, wildlife, and other biota. Final rules on the procedures for natural resources damage assessments are published as Federal Register (FR) publications 51 FR 27673 (Type B Rule) and 52 FR 9042 (Type A Rule) and codified at 43 CFR Part 11. Amendments and corrections to these procedures are issued as 53 FR 5166 and 53 FR 9769. The Type A Rule is primarily a modeling approach using standard physical, biological, and economic relationships for simplified assessments. Minimum field observation is necessary. The Type B Rule describes alternative protocols for more complex cases where environmental damage is uncertain, potentially extensive, or long-term in nature. Extensive field observation is necessary. The *Exxon Valdez* oil spill qualified for a Type B assessment.

The Type B assessment requires major data collection by the government agency responsible for the affected resources. The major steps are:

1. Establish a link between resource injury and the oil spill. This step requires documentation of the movement of the oil from spill site to the affected resources.
2. Determine the extent of the injury. This step requires measurement of severity and geographic extent of injury.
3. Determine the 'before spill' condition. This step requires knowledge of baseline or normal conditions for the affected resource.
4. Determine the amount of time needed to recover to the 'before spill' condition. This step requires extensive knowledge of the natural history of the resource and the environmental fate of the oil.

The term "injury" is defined as a change in biological viability. The Type B Rule specifies six categories of injury (death, disease, behavioral abnormalities, cancer, physiological malfunctions, physical deformation) and various approved biological responses that can be used to demonstrate injury. Non-approved responses can be used if they meet a set of four criteria that were used to identify the approved responses. Injury determination is based on a statistical difference between the "after spill" and "before spill" conditions or between the affected area and a control area.

The CERCLA procedures ensure that a thorough and legally defensible evaluation is made of the impact of an oil spill on natural resources. However, the CERCLA process is complex and very time consuming, particularly for the Type B assessment. For example, after the injury assessments are made, the actual "damage" assessments have to be made either through the Type A computer model or the detailed monetary and restoration determinations for the Type B approach.

A court decision in July, 1989, held that 'restoration' costs are to be the minimum costs sought from the responsible party. Lost use costs are no longer an optional alternative to the normally more costly and complex restoration option, but must be added to the restoration cost.

The National Oceanic and Atmospheric Administration, in accordance with the requirements of the Oil Pollution Act of 1990, is developing a natural resource damage assessment Rule specifically for oil. When finalized, this new Rule will be used for oil spills in lieu of the current damage assessment Rules.

The best approach for a field biologist or supervisor is to insure that as much evidence as possible is properly collected to document the effects of the spill. Appropriate evidence includes animal carcasses, surveys of afflicted live animals, tissue samples or carcasses for chemical confirmation of the presence of oil, population surveys, surveys of reproductive performance, photographic documentation of spill events, and detailed records of all correspondence, spill activities, sample inventories, and field notes.

Wildlife rehabilitation

The sight of oiled and obviously distressed animals triggers strong human emotional responses. This feeling of empathy for the plight of suffering animals guarantees extensive media coverage, which in turn evokes emotional responses from people who are not at the spill site. Consequently, one element of every organized oil spill response is the provision for animal rehabilitation.

Public pressure to help oiled animals has resulted in the establishment, in many parts of the world, of volunteer organizations capable of rehabilitating oiled vertebrates. Improvements in treatment procedures and in the professionalism of rehabilitation personnel during the last 15 years has markedly improved the success of rehabilitation efforts.

The importance of oiled animal rehabilitation to wildlife populations is minor for most situations. The numbers of oiled animals in major oil spills are so large and the task of collecting them so great that only a small portion of birds and mammals that could benefit from rehabilitation actually receive it. Uncertainties about the fate of rehabilitated and released animals further reduce the potential significance of those that are released. However, rehabilitation efforts can be important for endangered or rare species. Helping adult long-lived animals with low reproductive potential has a greater population impact than does helping shorter-lived animals with high reproductive potential. Rehabilitation of oiled animals is costly and is usually not biologically significant, but it is a sincere expression of human concern.

Public relations

Petroleum is an easily visible substance that can cause highly visible problems for wildlife and man. People do not like oil on their beaches, boats, docks, fishing nets, seafood, and pristine shorelines. It smells bad, soils clothing and carpets, is visually offensive, and can kill or disable large numbers of aquatic and terrestrial animals. Newspaper and television coverage can be extensive because it is an easily covered and photogenic topic. Organizations participating in oil spill response and damage assessment activities should be prepared to devote considerable time to dealing with media inquiries, concerned citizens of local communities, and representatives of all sorts of organizations.

Examples of issues likely to produce public relations challenges are:

- The magnitude of the spill is often unclear. This results in periodic revisions (usually up) of the seriousness of the spill and subsequent changes in the response effort.
- The first days of an oil spill are often confusing because of the crisis environment. Delays with cleanup activities are common.
- Despite the best efforts of the Coast Guard and Environmental Protection Agency, spilled oil and weather often do unpredictable things. Plans for dealing with spilled oil and estimates of anticipated damage can change.
- Representatives of government, industry, academia, or conservation groups are often interviewed by news reporters. Statements sometimes are contradictory, misleading, or erroneous. Misquotes complicate even the best efforts to keep the public informed.
- Animal rehabilitation activities are closely watched because of the emotional attachment of people to the stricken animals. Shortcomings will become well known.
- Results of the damage assessment process are not made available to the public until the spiller agrees to an out-of-court settlement or the determination of damages is argued in court. The lengthy nature of injury assessment and the subsequent legal process could produce discontent among organizations and individuals that desire access to the findings.

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