Chapter 4 Oil Toxicity and Impacts on Sea Turtles

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Key Points

- Although surprisingly robust when faced with physical damage (shark attacks, boat strikes), sea turtles are highly sensitive to chemical insults such as oil.
- Areas of oil and gas exploration, transportation, and processing often overlap with important sea turtle habitats.
- Sea turtles are vulnerable to the effects of oil at all life stages—eggs, post-hatchlings, juveniles, and adults in nearshore waters.
- Several aspects of sea turtle biology and behavior place them at particular risk, including a lack of avoidance behavior, indiscriminate feeding in convergence zones, and large predive inhalations.
- Oil effects on turtles include increased egg mortality and developmental defects, direct mortality due to oiling in hatchlings, juveniles, and adults; and negative impacts to the skin, blood, digestive and immune systems, and salt glands.

Although oil spills are the focus of this book, it would be misleading to portray them as the most significant danger to the continued survival of sea turtles, either in U.S. waters or worldwide. In 1990, the National Research Council qualitatively ranked sources of sea turtle mortality by life stage. The highest mortalities on juvenile and adult turtles were caused by commercial fisheries, on hatchlings it was nonhuman predation and beach lighting, and on eggs, nonhuman predators. While "toxins" appeared as a listed source, their impact to all three turtle life stages was unknown. Oil spills were not considered as a specific potential impact, but their absence should not be construed as lack of a spill-related threat. Spills that have harmed sea turtles have been documented and case studies of those spills are described in Chapter 6. Moreover, it is not difficult to imagine a large spill washing ashore on a known nesting beach for an endangered sea turtle species when females are converging to nest or eggs are hatching.

Oil spills are rare events, but they have the potential to be spectacularly devastating to resources at risk. In addition, it is not simply infrequent or episodic spills that threaten sea turtles. Continuous low-level exposure to oil in the form of tarballs, slicks, or elevated background concentrations also challenge animals facing other natural and anthropogenic stresses. Chronic exposure may not be lethal by itself, but it may impair a turtle's overall fitness so that it is less able to withstand other stressors.

What do we know about the toxicity of oil to sea turtles? Unfortunately, not much. Direct experimental evidence is difficult to obtain, because all sea turtle species are listed as threatened or endangered under the 1973 U.S. Endangered Species Act (Table 1.1). The tenuous status of sea turtles worldwide has significantly influenced research activities and is a key reason that basic information about the toxicity of oil to turtles is scarce. According to Lutz (1989), "Studies on sea turtles must take fully into account that all species are at risk and have either threatened or endangered species status. Investigation must be confined to sublethal effects that are fully reversible once the treatment is halted. This restricts the scope of toxicity studies that can be carried out, especially the study of internal effects, and investigations of natural defense mechanisms … would be very difficult."

Notwithstanding ethical or legal arguments over exposing organisms to potentially harmful materials in order to document effects, from a response and operational perspective the lack of data impairs decision-making on trade-offs during oil spills. Fritts et al. (1983) concluded two decades ago that the dearth of basic scientific information about sea turtles complicates the detection of oil-related problems and non-oil-related problems. While much has been learned since then, it is still true that determining the source of stress to sea turtles is complicated and difficult.

Most reports of oil impact are anecdotal or based on small sample sizes, but there is no question that contact with oil negatively impacts sea turtles. Because they are highly migratory—spending different life-history stages in different habitats—sea turtles are vulnerable to oil at all life stages: eggs on the beach, post-hatchlings and juveniles in the open ocean gyres, subadults in nearshore habitats, and adults migrating between nesting and foraging grounds. Severity, rate, and effects of exposure will thus vary by life stage. Unfortunately, areas of oil and gas exploration, transportation, and processing often overlap with important sea turtle habitats, including U.S. waters off the Florida and Texas coasts and throughout the Gulf of Mexico and the Caribbean.

In this chapter, research on the toxicity of oil to sea turtles is summarized, along with indirect impacts that might occur during an oil spill and subsequent cleanup methods.

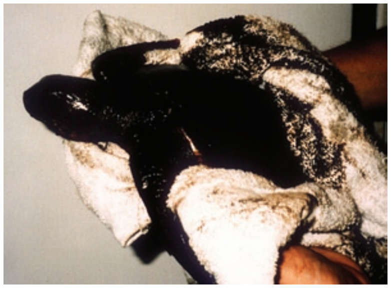

Figure 4.1 A juvenile green turtle oiled during a spill in Tampa Bay, Florida, in 1993. The turtle was rehabilitated by the Clearwater Aquarium and eventually released. Photo courtesy of Dr. Anne Meylan, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute.

Toxicity Basics

It is necessary to begin the discussion of oil toxicity by defining what we mean by "oil." One universal challenge facing resource managers and spill responders when dealing with oil spills is that oil is a complex mixture of many chemicals. The oil spilled in one incident is almost certainly different from that spilled in another. In addition, broad categories such as crude oil or diesel oil contain vastly different ingredients, depending on the geologic source, refining processes, and additives incorporated for transportation. Even if we could somehow stipulate that all spilled oil was to be of a single fixed chemical formulation, petroleum products released into the environment are subjected to biological, physical, and chemical processes—called weathering— that immediately begin altering the oil's original characteristics. As a result, samples of oil from exactly the same source can be very different in composition after exposure to a differing mix of environmental influences. Thus, while we generalize about oil toxicity to sea turtles in this book, the reader should be aware of the limitations in doing so.

Oil affects different turtle life stages in different ways. Unlike many other organisms, however, each turtle life stage frequents a habitat with notable potential to be impacted during an oil spill. Thus, information on oil toxicity is organized by life stage.

The earlier life stages of living marine resources are usually at greater risk from an oil spill than adults. The reasons for this are many, but include simple effects of scale: for example, a given amount of oil may overwhelm a smaller immature organism relative to the larger adult. The metabolic machinery an animal uses to detoxify or cleanse itself of a contaminant may not be fully developed in younger life stages. Also, in early life stages animals may contain a proportionally higher concentration of lipids, to which many contaminants such as petroleum hydrocarbons bind.

Weathering - **the alteration of the physical and chemical properties of spilled oil through a series of natural biological, physical, and chemical processes beginning when a spill occurs and continuing as long as the oil remains in the environment. Contributing processes include spreading, evaporation, dissolution, dispersion, photochemical oxidation, emulsification, microbial degradation, adsorption to suspended particulate material, stranding, or sedimentation.**

Eggs and Nesting

While eggs, embryos, and hatchlings are likely to be more vulnerable to volatile and water-soluble contaminants than adults, only one study has directly examined the effects of oil compounds on sea turtle eggs. Following the 1979 Ixtoc 1 blowout in the Bay of Campeche, Mexico, Fritts and McGehee (1981) collected both field and laboratory data on the spill's effects on sea turtle nests from an impacted beach. In laboratory experiments where fresh oil was poured on nests of eggs during the last half to last quarter of the incubation period, the researchers found a significant decrease in survival to hatching. Eggs oiled at the beginning of incubation survived to hatching, but the hatchlings had developmental deformities in the form of significant deviations in the number of scutes. Weathered oil, however, appeared to lose its toxic effect on eggs: oiled sand taken from the beach the year following the spill did not produce measurable impacts on hatchling survival or morphology. The data thus suggest that oil contamination of turtle nesting sites would be most harmful if fresh oil spilled during the nesting season.

On the other hand, Fritts and McGehee also concluded that oil spilled even a few weeks prior to the nesting season would have little effect on egg development and hatchling fitness. A threshold level of oiling to produce measurable effects on survival of loggerhead embryos was not determined; however, a mixture of 7.5 ml of oil per kg of sand did not significantly reduce survival. The way oil was introduced into a nest did affect toxicity. Oil poured on top of a clutch of eggs, versus that mixed thoroughly into the sand, had greater impact. That is, 30 ml of oil poured onto the sand over eggs lowered survival in embryos, whereas 30 ml of oil mixed into the sand around the eggs did not. The authors speculated oil on the sand surface created an exposure gradient in which lethal concentrations were experienced by individual eggs, but not all of them.

The effects of beach oiling on nesting females' behavior and physiology were not investigated. Females may refuse to nest on an oiled beach, and crossing it could cause external oiling of the skin and carapace. Fritts and McGehee noted that the oil behaved like any other flotsam; not all beach areas received equal amounts, and most of it was deposited just above the high-tide line. The latter point is significant for planning and response because most turtles nest well above the high-tide level. One implication of nesting behavior is that under normal circumstances, nest sites are less likely to be directly affected by stranding oil. Spills, however, are often associated with storms or exceptional tides, which may deposit oil at higher than normal levels. In addition, beached oil would lie between nests and the water, thus females coming ashore to lay eggs or emerging hatchlings would risk exposure as they traversed the beach.

Phillott and Parmenter (2001) determined that oil covering different portions and different proportions of the surface of sea turtle eggs affects hatching success. For example, an egg's upper hemisphere is the primary gas exchange surface during early incubation. If oil covers enough of the upper surface to impede gaseous exchange, higher mortality in embryos will occur. Larger eggs are more likely to survive than smaller eggs. Physical smothering effects of oil therefore represent a threat to nest viability, even if the oil has low inherent toxicity.

Three important factors—nest temperature, gas exchange, and moisture—affect hatching success. Oil can potentially impact a nesting beach by interfering with gas exchange within the nest (oil-filled interstitial spaces, for example, would prevent oxygen from diffusing through the sand into the nest); altering the hydric environment (sea turtle nests need sand that is not too wet or too dry); and altering nest temperature by changing the color or thermal conductivity of the sand.

Hatchlings

Once hatchling turtles successfully reach the water, they are subject to the same kinds of oil spill exposure hazards as adults (see page 39). However, relative size, lack of motility, and swimming and feeding habits increase the risk to recently hatched turtles. The increased risks can be linked to the following factors, among others:

- Size. A hatchling encountering the same tar patty or oil slick as an adult has a greater probability of being physically impaired or overwhelmed.
- Motility. Most reports of oiled hatchlings originate from convergence zones, ocean areas where currents meet to form collection points for material at or near the surface of the water. These zones aggregate oil slicks as well as smaller, weaker sea turtles. For a weakly motile organism such as a young turtle, a Langmuir cell, where

Langmuir cell - **individual counter-rotating vortices (i.e., one rotates clockwise, the next counter clockwise, the next clockwise, etc.), resulting in the commonly observed "windrows" in which flotsam is arranged in rows paralleling the wind direction. At boundaries between the cells, water is moving either up or down. Where it is moving down, the surface water is converging (being pulled together), and any surface objects will be pulled into the boundary line between the cells; where the water is moving up between the cells, the water diverges, and no material collects.**

surface currents collide before pushing down and around, represents a virtually closed system where the turtle can easily become trapped.

- Surface swimming. Because hatchlings spend a greater proportion of their time at the sea surface than adults, their risk of exposure to floating oil slicks is increased.

The physical processes and behaviors that place sea turtles at risk during spills also pose threats from non-spill-related petroleum sources. Tarballs, for example, are a byproduct of normal and accepted ship operations (e.g., bilge tank flushing), are illegally discharged from tank washings and other shipboard operations, and are even released naturally from coastal oil seeps. They are found in every ocean and on every beach; features such as convergence zones and Langmuir cells can aggregate even widely dispersed tarballs into an area where sea turtles concentrate. Oil exposure is therefore a threat to sea turtles both in the presence and in the absence of an identified spill.

Non-spill-associated tarballs are likely to be more weathered than those derived from a spill, mostly due to differences in time spent on the water. While less toxic to eggs and embryos than freshly spilled oil, weathered oil can have significant impacts on hatchlings. Hatchlings that contact oil residues while crossing a beach can exhibit a range of effects, from acute toxicity to impaired movement and normal bodily functions. In convergence zones off the east coast of Florida, tar was found in the mouths, esophagi, or stomachs of 65 out of 103 post-hatchling loggerheads (Loehefener et al. 1989). In another study (Witherington 1994), 34 percent of post-hatchlings at "weed lines" off the Florida coast had tar in their mouths or esophagi, and over half had tar caked in their jaws. Lutz (1989) reported that hatchlings have been found apparently starved to death, their beaks and esophagi blocked with tarballs. Hatchlings sticky with oil residue may have a more difficult time crawling and swimming, rendering them more vulnerable to predation.

Whether hatchlings, juveniles, or adults, tarballs in a turtle's gut are likely to have a variety of effects—starvation from gut blockage, decreased absorption efficiency, absorption of toxins, effects of general intestinal blockage (such as local necrosis or ulceration), interference with fat metabolism, and buoyancy problems caused by the buildup of fermentation gases (floating prevents turtles from feeding and increases their vulnerability to predators and boats), among others.

Juveniles/Adults

Studies of oil effects on loggerheads in a controlled setting (Lutcavage et al. 1995) suggest that all post-hatch life stages are vulnerable to oil effects and tar ingestion because sea turtles show no avoidance behavior when they encounter an oil slick. Turtles also indiscriminately eat anything that registers as being an appropriate size for food, including tarballs. Such was the case with a juvenile loggerhead stranded in Gran

Canaria, Spain, which had an esophageal defect that trapped tarballs, plastics, and fishing line in its digestive system. The large esophageal swelling displaced the liver and intestines, causing severe tissue swelling near the stomach. The turtle was nearly starved, and it had buoyancy problems and a bacterial infection (most likely secondary to its poor physical condition).

Sea turtles' diving behavior also puts them at risk. They rapidly inhale a large volume of air before diving and continually resurface over time. Adults doing this in an oil spill would experience both extended physical exposure to the oil and prolonged exposure to petroleum vapors, the most acutely harmful phase of a spill. Compared to hatchlings, however, juveniles and adults spend less time at the sea surface, which potentially reduces their chances of exposure from a smaller oil slick.

Oil ingested by a turtle does not pass rapidly through its digestive tract. It may be retained for several days, increasing internal contact and the likelihood that toxic compounds will be absorbed. The risk of gut impaction also increases for turtles that have ingested oil.

Anecdotal accounts of dead or impaired green turtles found with tarballs in their mouths were summarized by Witham (1978). Three turtles found dead after the Ixtoc 1 blowout showed evidence of oil externally and in the mouth, esophagus, and small intestine, although there was no evidence of lesions in the gastrointestinal tract, trachea, or lungs (Hall et al. 1983). However, chemical analysis of tissue showed a chronic exposure to and selective accumulation of hydrocarbons. Some were concentrated 15 times higher than reference levels. Hall et al. believed prolonged exposure to oil may have caused the poor body condition of the animals by disrupting feeding.

Laboratory Studies

The only laboratory work investigating the direct impacts of oil on sea turtle health and physiology performed to date was part of comprehensive, multi-facility study conducted for the U.S. Minerals Management Service (MMS) in 1986 (Lutcavage et al. 1995). A conceptual framework for considering behavioral and physiological oil impacts was summarized by Lutz (1989) in a series of diagrams, two of which are reproduced here as Figures 4.2 and 4.3.

MMS - U.S. Minerals Management Service (U.S. Department of the Interior).

The Lutcavage et al. experiments on physiological and clinicopathological effects of oil on loggerhead sea turtles approximately 15 to 18 months old showed that the turtles' major physiological systems are adversely affected by both chronic and acute exposures (96-hour exposure to a 0.05-cm layer of South Louisiana crude oil versus 0.5 cm for 48 hours). The skin of exposed turtles, particularly the soft pliable areas of the neck and flippers, sloughed off in layers. This continued for one to two weeks into the recovery period. Histological examination of the damaged skin showed proliferation of inflamed,

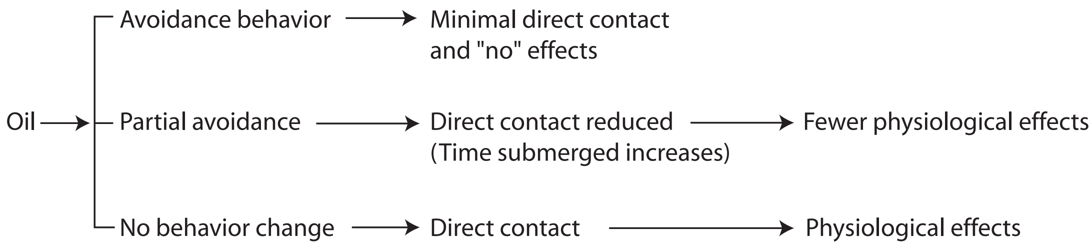

Figure 4.2 Conceptual framework of sea turtle behavioral responses to oil exposure (adapted from Lutz 1989).

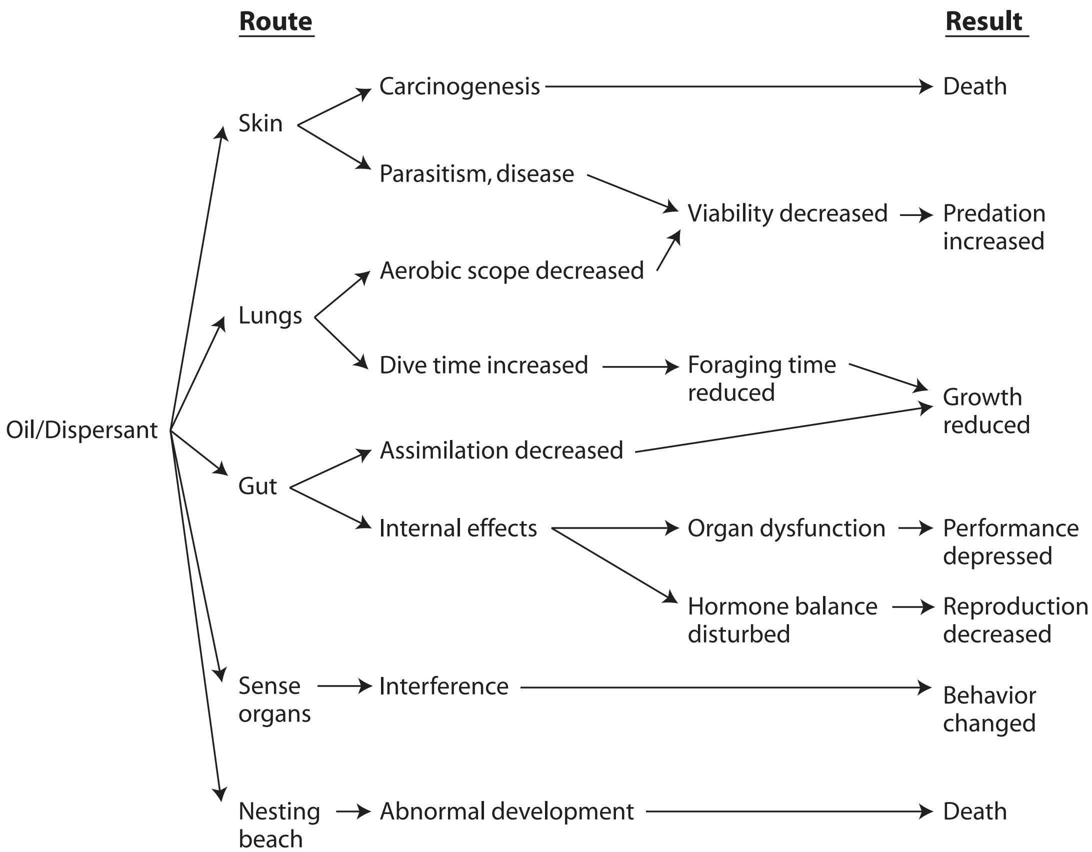

Figure 4.3 Conceptual framework for the effects of oil exposure to sea turtles (adapted from Lutz 1989).

abnormal, and dead cells. Recovery from the sloughing skin and mucosa took up to 21 days, increasing the turtle's susceptibility to infection.

Oil was also detected in the nares, eyes, upper esophagus, and feces, indicating that turtles were ingesting oil, though apparently not enough to cause intestinal bleeding and anemia. Ingestion would almost certainly have been greater if the turtles had been fed during the experimental period.

Hematocrit - red blood cell volume.

Internal effects of oil exposure include significant changes in blood and blood chemistry. Hematocrits (red blood cell volume) decreased nearly 50 percent in oiled turtles and did not increase again during the recovery period, though the presumed decrease in oxygen carrying capacity was not reflected in changes in blood oxygen or respiration. In mammals, changes in red blood cells and their production are associated with regenerative anemic conditions. Similar effects have been observed in oiled seabirds, indicating that red blood cells may be a primary target of oil toxicity. An immune response was also indicated by significant increases in white blood cells, which by day 3 of oil exposure were four times higher in oiled turtles than control animals. This increase persisted for more than a week.

While vapor inhalation changes the behavior and pathology of marine mammals—as evidenced, for example, by an increase in time spent submerged—such behavior was not evident with turtles. The experimental animals showed no overall avoidance behavior, though some were clearly disturbed by the fumes. Some turtles surfaced away from the oil in behavioral tests, but they appeared to be avoiding the dark surface, not the oil per se.

In vertebrates, the liver is the primary site of chemical detoxification, so it is reasonable to expect toxic effects to be evident in changed serum levels of various liver enzymes. (Such diagnoses are used in veterinary and human medicine, though their significance in turtle health has not yet been ascertained). However, no changes were evident in the Lutcavage et al. study, which differed significantly from control animals. Changes in some enzyme levels were most likely the result of starvation during the experiment (animals were not fed during exposure), since changes were similar in both control and experimental animals. Enzyme levels in oiled turtles did not recover as quickly once feeding commenced, however.

Hemorrhagic enteritis - bleeding inflammation of the intestine.

Since no animals were sacrificed during this study, it was not possible to examine the turtles for internal damage, except through indirect methods such as measuring serum enzyme levels. Potential effects, however, may be extrapolated from investigations of dead oiled birds, because reptiles and birds share a common lineage. Following the Gulf War, postmortem examinations of 300 birds revealed a variety of damage: gizzard impaction due to tarballs, enteritis, starvation, fluid and hemorrhaging in the lungs, damage to the absorptive surface of the intestines, liver degeneration, kidney damage, and degeneration of adrenal gland cells (which in turn affects salt gland function in seabirds and possibly turtles). Other studies found high incidences of hemorrhagic enteritis in oil-killed birds. Sea turtles may be at particular risk from such problems due to their habit of eating anything that floats; post-hatchlings, in particular, feed in convergence zones, which collect a variety of anthropogenic materials such as tarballs.

Although they found little experimental evidence in the MMS studies to indicate bioaccumulation of hydrocarbons by sea turtles, Lutcavage et al. (1995) cited a report by Greenpeace from the Gulf War in which high concentrations of petroleum hydrocarbons were found in the liver (4,050 mg/kg) and stomach (310 mg/kg) of an oiled green turtle. The Lutcavage et al. studies provided qualitative evidence that oil exposure affects the balancing of salt and water. Extended salt gland dysfunction would have significant negative impacts on turtle health, altering internal salt and water homeostasis. In two experimentally oiled turtles, the salt glands effectively shut down for several days, although the turtles eventually recovered after the exposure was discontinued. The salt glands did not appear to be physically blocked (though this could not be ruled out), so it appeared that the impact was toxic, rather than physical.

Indirect Effects of Oil on Sea Turtles

Studies summarized thus far show that oil has a number of direct effects on sea turtles. Like any living resource at risk, turtles are susceptible to a number of potential indirect impacts, which would generally be less obvious than short-term direct impacts such as mortality, but may ultimately cause more harm to populations.

A number of potential indirect impacts can be attributed to the unique biological attributes or behaviors of marine turtles. Frazier (1980) suggested that olfactory impairment from chemical contamination could represent a substantial indirect effect in sea turtles, since a keen sense of smell apparently plays an important role in navigation and orientation. Frazier noted that masking olfactory cues may not harm a turtle outright, but impairing its ability to properly orient itself can result in a population impact as significant as direct toxicity—perhaps even greater. A related problem is the possibility that an oil spill impacting nesting beaches may affect the locational imprinting of hatchlings, and thus impair their ability to return to their natal beaches to breed and nest.

Even if sea turtles avoid direct contact with oil slicks, eating contaminated food is a direct exposure path, and reduced food availability is an indirect exposure route. A 1986 oil spill off Panama, for example, trapped oil in sediments of intertidal beds of turtle grass (*Thalassia testudinum*), killing the seagrass, a significant component of green turtle diets. Sediments below the damaged seagrasses subsequently eroded, exposing the coralline rock bed. Decreases in invertebrates and sponge populations affect other sea turtle species as well, including hawksbills, loggerheads, and ridleys. In this instance, after long-term contact with oil many invertebrates were killed and many others declined in numbers. A variety of petroleum compounds are toxic to fish and invertebrates, although the effect is not uniform; different species have different sensitivities to different compounds. Some compounds are more toxic than others or are more toxic in different combinations (National Research Council 2003).

Dietary differences can potentially increase or decrease risk from hydrocarbon ingestion. Kemp's ridley and loggerhead turtles, for example, feed primarily on crustaceans and mollusks, which bioaccumulate petroleum hydrocarbons because they cannot efficiently clear contaminants from their bodies. Thus Kemp's ridleys and loggerheads may be at greater risk of exposure by ingesting food than leatherback turtles, which feed primarily on coelenterates.

Followup studies on the effects of an oil spill on San Cristóbal in the Galapagos Islands suggest an indirect and unanticipated food-related effect on another reptile, the marine iguana (*Amblyrhynchus cristatus*). Although the spill's short-term impacts were minimal, in the year that followed the iguana population of nearby Santa Fe Island suffered a significant mortality, 62 percent. Wikelski et al. (2002) reported that the probable cause of this substantial population decline was chronic, low-concentration oil exposure to the specialized fermentation bacteria that iguanas carry in their hindguts. The authors postulated that oil impacts on these bacteria impaired the iguanas' ability to process the algae they eat. Largely herbivorous sea turtles, like the green, also carry symbiotic bacteria to aid in digestion and are likely to be similarly vulnerable to effects on the bacteria observed in the marine iguanas.

Some authors (e.g., Hutchinson and Simmonds 1992) have suggested a link between low-level chronic exposure to contaminants such as oil, and the occurrence of cutaneous fibropapilloma disease (Chapter 3). The link was circumstantial; it was based on immune system responses to oil exposure observed by Lutcavage et al. (1995) and assertions by other pathologists that immune system weakness and aberrant wound responses may trigger fibropapilloma disease. However, the relationship is likely to be complex, thus it is unclear which is cause and which effect (L. Herbst 2002[1]).

albedo - **ratio of solar energy reflected from an object to solar energy received by it.**

Beach sand temperature influences sea turtle development and behavior, and Hays et al. (2001) determined that subtle differences in sand color or albedo can significantly affect underlying temperatures. Because sex determination in turtles is temperature-dependent, shifts in albedo could potentially change hatchling sex ratios. Even light surface oiling that does not penetrate directly to the eggs could therefore affect gender distribution in a population.

Exposure Risk

Much of the oil spilled in the oceans results in surface contamination along ocean tanker lanes and coastal areas, including along the coasts of California, Texas, and Florida; Cuba and northwest South America; northern Europe; the Gulf of Arabia and the Arabian Sea; and throughout the Indo-Pacific region along eastern Asia. Unfortunately, the risk of an oil spill affecting a significant nesting beach within U.S. territory is high. Of these higher risk areas, south Florida is particularly vulnerable due to the convergence of ocean currents and shipping lanes. Data on wind, loop current, and drifter studies led Geo-Marine, Inc. (1980) to predict that oil spilled in the eastern Gulf of Mexico would have the highest probability of washing ashore along the southeast coast of Florida between Key West and Fort Pierce, an area that also hosts a large percentage of the loggerhead sea turtle nests in the southeastern United States. The Sargasso Sea alone is estimated to entrap 70,000 metric tons of tar, while a two-year study by Van Vleet et al. (1984) indicated that, in general, pelagic tar concentrations in the eastern Gulf of Mexico were significantly higher than those reported for other parts of the world.

Because environmental problems do not respect human boundaries, it is not surprising that sea turtles found in U.S. waters are vulnerable to spills that occur both within and outside U.S. waters. Approximately 1 percent of annual U.S. sea turtle strandings are associated with oil; rates are higher in south Florida (3 percent) and Texas (3 to 6.3 percent) (stranding statistics are summarized by Lutcavage et al. 1997). Rates of contact with pollutants are likely to be much higher than those detected from strandings alone; during the 1986 fishing season off Malta, for example, 17 of 99 loggerhead turtles caught by Maltese fisherman suffered from crude oil contamination, compared to three contaminated with plastic or metal litter but not oil (Gramentz 1988).

The consequences of chronic exposure to oil in the form of ingested tarballs is not clear, but some evidence exists that this occurrence, alone or in combination with other foreign material, can seriously compromise sea turtle health. Torrent et al. (2002) examined a juvenile loggerhead captured barely alive off the coast of Gran Canaria, Spain. The turtle died in transport and was necropsied. A number of abnormal pathologies were found, including an esophageal diverticulum (an abnormal saclike pouch) and an infection by bacteria not normally found in sea turtles. The authors attributed the poor condition of the turtle, directly and indirectly, to ingested tarballs, plastic, and fishing line.

Diverticulum - **an abnormal saclike pouch projecting from a defect in the wall of a tube or cavity.**

For Further Reading

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