Oil and Sea Turtles

BIOLOGY, PLANNING, AND RESPONSE

reprinted July 2010

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration • National Ocean Service • Office of Response and Restoration

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Cover photograph courtesy of Ursula Keuper-Bennett

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Table of Contents

Introduction

Chapters

Tables

Figures

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NOAA - National Oceanic and Atmospheric Administration. (U.S. Department of Commerce).

NMFS - National Marine Fisheries Service (NOAA).

Brian Voss and Maureen Wood of the NOAA Seattle Regional Library sought out and found even the most obscure of the sea turtle references we requested, and thus were largely responsible for the foundation of information on which this document is built.

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Introduction

Few animals in the world's oceans evoke the kind of wonder inspired by sea turtles. Ancient in their origins, sea turtles are bestowed with a mystical quality that in part derives from their longevity as inhabitants of the world's oceans and in part from their uncanny ability to navigate over vast expanses of water to return to their natal beaches.

However, few animals are at greater risk from an unfortunate confluence of global changes, widespread disease, and a host of problems of human origin. The latter category includes inevitable human population growth and the consequences of habitat destruction, impairment and entanglement in plastic trash, the persistent belief that turtle flesh and turtle eggs confer nearly supernatural health benefits, the inherent beauty and rarity of turtle shell jewelry, and even the indirect impacts of the breakdown of indigenous social mores within the populations of far-flung islands where turtles also dwell. Among these many risks to the continued existence of turtles is that from oil spills.

An oiled green turtle recovered by the Israeli Sea Turtle Rescue Center in August 1999. This and one other turtle were cleaned, rehabilitated, and released about two months later. Photo courtesy of Yaniv Levy, Israeli Sea Turtle Rescue Center, Hofit, Israel.

Admittedly, in the spectrum of threats facing sea turtles, oil spills do not rank very high. They are generally rare events, affecting a limited geographic area. Oil is not the most toxic material that could be spilled in a sensitive marine environment, which in places include turtle habitat. Oil may even be released naturally from seeps and vents. Yet in 1979 a massive oil spill resulting from a drilling platform blowout in the Gulf of Mexico threatened one of the only known nesting beaches of a particularly threatened sea turtle, the Kemp's ridley. The spill ultimately resulted in minor impacts to the Kemp's ridley population, but a major tragedy was averted.

Threatened - any species likely to become endangered in the foreseeable future (from the Endangered Species Act of 1973).

The 1979 Gulf of Mexico incident emphasized the tenuous nature of existence for threatened sea turtles in the world's oceans, and how a single catastrophic oil spill might serve as the synergistic "tipping point" that could prove devastating to externally stressed populations.

Those of us who work on environmental issues related to oil and chemical spill response often think about our job in the context of game theory and "minimum regret." We identify courses of action that do not eliminate risk, and in fact expand the area we consider at risk; but, ultimately, we minimize the regret we may feel about our course of action by explicitly considering the consequences of unlikely events. The probability of an incident affecting sea turtles may well be low—that is, mathematically negligible—but the result of such a low-probability event occurring at just the wrong time of year and at the wrong location could be catastrophic and unacceptable for a given popula-

NOAA - **National Oceanic and Atmospheric Administration. (U.S. Department of Commerce).**

RAR - **resources at risk.**

tion. Therefore, we plan for such an occurrence, while hoping we never need to invoke the plans we make.

The guidance document you hold is a part of that planning effort. It is the third in a series of publications prepared by NOAA's Office of Response and Restoration to provide response-relevant information on specific warm-water resources at risk. Previous publications include oil impacts to coral reef and mangrove ecosystems. Our intent is to present a basic overview of sea turtle biology, summarize what is known about the effects of oil on sea turtles, review potential response actions in the event of a release, and present case histories from previous spills that potentially could or actually have affected sea turtles. Our audience is intended to include spill responders and planners, resource managers, sea turtle rehabilitators, veterinarians—and anyone who is interested in the continued survival and health of one of the ocean's most intriguing inhabitants.

Gary Shigenaka, Technical Editor
National Oceanic and Atmospheric Administration
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Seattle, Washington

Chapter 1. Sea Turtle Taxonomy and Distribution

Sarah Milton and Peter Lutz

Key Points

- Sea turtles are long-lived, slow to mature, air-breathing, diving marine reptiles that have terrestrial life stages, primarily nesting and egg development, and hatchlings.
- There are seven living species of sea turtles; five are commonly found in continental U.S. waters: loggerhead, green, leatherback, hawksbill, and Kemp's ridley turtles. The olive ridley turtle is found in U.S. territorial waters in the Pacific.
- All five species found in coastal U.S. waters are listed as endangered or threatened under the Endangered Species Act; all species are on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix I list, which prohibits their traffic in international trade.
- Sea turtle species are identified by the numbers and pattern of plates (called scutes) on their shells and the scale pattern on their heads.
- While most sea turtles are tropical to subtropical, especially for nesting, some species range as far north as the waters off Newfoundland and Alaska and as far south as the coasts of Chile and Argentina.

Endangered - **Any species of animal or plant that is in danger of extinction throughout all or a significant part of its range (from the Endangered Species Act of 1973).**

CITES - **Convention on International Trade in Endangered Species of Wild Fauna and Flora.**

Scute - **plates of the sea turtle shell.**

What Is a Sea Turtle?

The modern sea turtle is a large (35 to 500 kilograms [kg]), long-lived, air-breathing reptile highly adapted and modified for a marine lifestyle. While the most obvious adaptation is the flattened, streamlined shell, or carapace (dorsal shell), sea turtles also have highly modified limbs, with the forelimb bones, called phalanges, extended to thin, flattened, oarlike flippers for swimming. The paddlelike forelimbs are relatively non-retractable, however, so they make the turtles awkward and vulnerable on land. Other adaptations to marine life include anatomical and physiological means of breathhold diving and excreting excess salt.

Carapace - **dorsal (top) shell of a turtle.**

Phalanges - **long "finger" bones of a turtle flipper.**

Although they are predominantly marine, sea turtles return to land to nest, and after the eggs develop and hatch, the hatchlings return directly to the sea. In some locations (Hawaii and Australia, for example), juveniles, subadults, and adults also come ashore to bask. In addition, sea turtles migrate great distances, traveling hundreds or even thousands of kilometers between foraging and nesting grounds, thus they are excellent navigators as well. Hatchlings orient in part by the earth's magnetic fields, as do migrating adults.

Sea Turtle Species and Their Geographic Distribution

Five species of sea turtles—loggerhead, green, leatherback, Kemp's ridley, and hawksbill—are commonly found in U.S. coastal waters. A sixth, the olive ridley, is found in U.S. territorial waters. All five species are listed as endangered or threatened under the U.S. Endangered Species Act. Spill response personnel should be aware that only trained and authorized personnel designated under a federal Endangered Species Act permit or cooperative agreement can be involved in handling sea turtles and their nests. Table 1.1 summarizes the current status of sea turtle species under the act, as well as critical habitat areas: Table 1.2 summarizes their habitats and diets.

Table 1.1 Status of turtle species found in U.S. waters.

Common and Species Names	Status in the United States	Date of Listing	Critical habitat
Loggerhead *Caretta caretta*	Threatened throughout its range.	7/28/78	None designated in the United States.
Green *Chelonia mydas*	Breeding colony populations in Florida and on the Pacific coast of Mexico are listed as endangered; all others are listed as threatened.	7/28/78	50 CFR 226.208 Culebra Island, Puerto Rico – Waters surrounding the island of Culebra from the mean high water line seaward to 3 nautical miles (5.6 km). These waters include Culebra's outlying Keys including Cayo Norte, Cayo Ballena, Cayos Geniquí, Isla Culebrita, Arrecife Culebrita, Cayo de Luis Peña, Las Hermanas, El Mono, Cayo Lobo, Cayo Lobito, Cayo Botijuela, Alcarraza, Los Gemelos, and Piedra Steven.
Leatherback *Dermochelys coriacea*	Endangered throughout its range.	6/2/70	50 CFR 17.95 U.S. Virgin Islands – A strip of land 0.2 miles wide (from mean high tide inland) at Sandy Point Beach on the western end of the island of St. Croix beginning at the southwest cape to the south and running 1.2 miles northwest and then northeast along the western and northern shoreline, and from the southwest cape 0.7 miles east along the southern shoreline. 50 CFR 226.207 The waters adjacent to Sandy Point, St. Croix, U.S. Virgin Islands, up to and inclusive of the waters from the hundred fathom curve shoreward to the level of mean high tide with boundaries at 17°42'12" North and 64°50'00" West.
Kemp's ridley *Lepidochelys kempii*	Endangered throughout its range.	12/2/70	None designated in the United States.

Table 1.1 ***Cont.***

Common and Species Names	Status in the United States	Date of Listing	Critical habitat
Hawksbill *Eretmochelys imbricata*	Endangered throughout its range.	6/2/70	50 CFR 17.95 Puerto Rico: (1) Isla Mona. All areas of beachfront on the west, south, and east sides of the island from mean high tide inland to a point 150 m from shore. This includes all 7.2 km of beaches on Isla Mona. (2) Culebra Island. The following areas of beachfront on the north shore of the island from mean high tide to a point 150 m from shore: Playa Resaca, Playa Brava, and Playa Larga. (3) Cayo Norte. South beach, from mean high tide inland to a point 150 m from shore. (4) Island Culebrita. All beachfront areas on the southwest facing shore, east facing shore, and northwest facing shore of the island from mean high tide inland to a point 150 m from shore. 50 CFR 226.209 Mona and Monito Islands, Puerto Rico – Waters surrounding the islands of Mona and Monito, from the mean high water line seaward to 3 nautical miles (5.6 km).
Olive ridley *Lepidochelys olivacea*	Breeding colony populations on the Pacific coast of Mexico are listed as endangered; all others are listed as threatened	7/28/78	None designated in the United States.

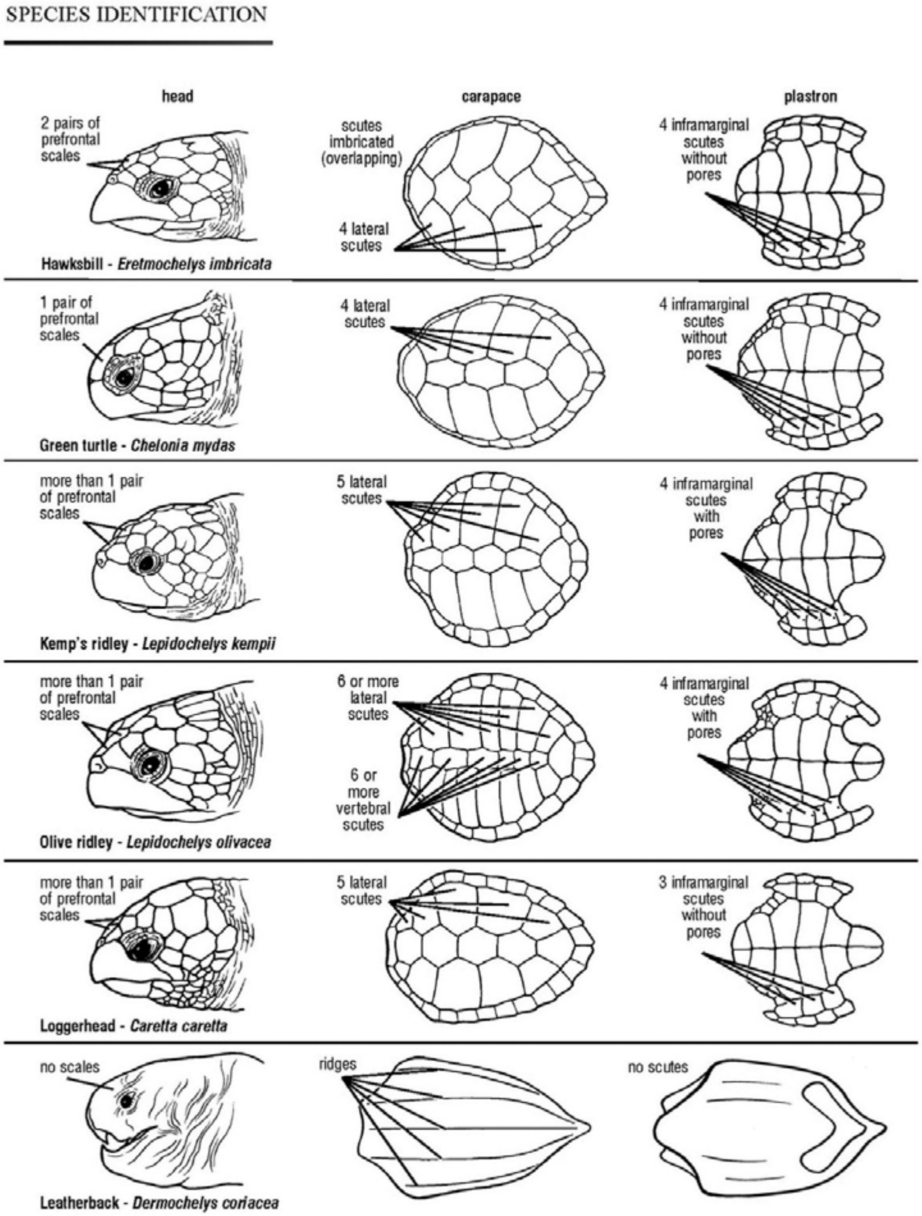
Source: http://northflorida.fws.gov/SeaTurtles/turtle-facts-index.htm, Code of Federal Regulations.

Table 1.2 Summary of adult habitat and diets for the six sea turtle species found in U.S. waters.

Species	Habitat	Diet
Loggerhead	Shallow continental shelf, coastal bays	Benthic invertebrates—mollusks and crustaceans
Green	Nearshore, coastal bays	Herbivorous—seagrasses and macroalgae
Leatherback	Pelagic	Jellyfish
Kemp's ridley	Coastal bays, shallow continental shelf	Fish and benthic invertebrates—crustaceans, squid, sea urchins
Hawksbill	Reefs, coastal areas, lagoons	Primarily sponges, also shrimp, squid, anemones
Olive ridley	Coastal bays, shallow continental shelf	Fish and benthic invertebrates—crustaceans, squid, sea urchins

All sea turtle species are on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix I list, which prohibits their traffic in international trade. In addition to coloring, range, and size, sea turtle species are positively identified by the number and pattern of carapace scutes (plates of the shell) and scales on the head (Figure 1.1).

Figure 1.1 Species identification guide to sea turtles found in U.S. territorial waters. Prefrontal scales are those located between the eyes. Lateral scutes lie on each side of the vertebral (center) scutes. Drawing courtesy of Dawn Witherington and Jeanette Wyneken.



Loggerhead Turtle, *Caretta caretta*

The loggerhead turtle (Figure 1.2) is the most common nesting turtle found in coastal U.S. waters, where it is listed as threatened under the Endangered Species Act. The southeastern coast of the United States hosts the second largest breeding aggregate of loggerhead turtles in the world, 30 percent of the world's breeding population (the largest breeding population is in Oman). Ninety percent of U.S. nesting occurs along the central and southeast Florida coast, though regular nesting also occurs in Georgia, the Carolinas, and Florida's Gulf coast.

Figure 1.2 Male loggerhead turtle swimming in Argostoli harbor, Kefalonia, Greece. Photo courtesy of Michael White.

Identification

Adults and subadults have reddish-brown carapaces and dull brown to yellowish bottom shells, called plastrons. Juveniles are also reddish brown, while hatchlings have a yellowish margin on the carapace and flippers. Loggerhead turtles have more than one pair of prefrontal scales (between the eyes) and five lateral scutes on the carapace (Figure 1.2). Hatchlings and juveniles have sharp keels on the vertebral scutes, which recede with age. Adults in the southeastern United State are approximately 92 centimeters (cm) in straight carapace length (SCL), with a mean mass of 113 kg; adults elsewhere are generally somewhat smaller.

Plastron - ventral (bottom) shell of a turtle.

SCL - straight carapace length.

Range

Loggerheads range along the east coast of the United States, in the Gulf of Mexico, off southern Brazil, in the northern and southwestern Indian Ocean, near eastern Australia, in Japan, and in the Mediterranean. In the Western Hemisphere, loggerheads may range as far north as Newfoundland (rare) to as far south as Argentina. Along the Pacific coast, loggerheads range from the Gulf of Alaska southward, but are most frequently seen off the western Baja Peninsula. Nesting occurs in the northern and southern temperate zones and subtropics (they generally avoid nesting on tropical beaches).

Habitat

Adult and subadult loggerhead turtles are found primarily in subtropical (occasionally tropical) waters along the continental shelves and estuaries of the Atlantic, Pacific, and Indian Oceans. They are a nearshore species, but may be found in a variety of habitats from turbid, muddy-bottomed bays and bayous to sandy bottom habitats, reefs, and shoals. Juveniles swim directly offshore after hatching and eventually associate with the sargassum and pelagic drift lines of convergence zones. Juveniles from the southeastern United States may circumnavigate the entire northern Atlantic gyre before moving to nearshore habitats, when they have grown to 40 to 50 cm SCL.

Sargassum - genus of brown algae, also known as gulfweed. There are 15 species in the genus, and each has air bladders. Some species are free floating. Off the U.S. coast, south of Bermuda, is the Sargasso Sea, a large (two-thirds the size of the United States), loosely-defined portion of the Atlantic Ocean where an estimated 7 million tons of live sargassum may be found.

Diet

Adults and subadults feed primarily on benthic mollusks and crustaceans. Hatchlings and juveniles consume coelenterates and cephalopod mollusks associated with pelagic drift lines.

Cheloniid - **hard-shelled sea turtles composed of the genera Chelonia, Caretta, Lepidochelys, Eretmochelys, and Natator; contrast to dermochelyid.**

Green Turtle, *Chelonia mydas*

The green turtle (Figure 1.3) is the largest hard-shelled sea turtle (cheloniid), and the second most common nesting turtle, in U.S. waters. While considered threatened in most parts of the world, the breeding populations in Florida and on Mexico's Pacific coast are considered endangered.

Figure 1.3 Green turtle. Photo courtesy of Douglas Shea.

Identification

The adult green turtle has a black to gray to greenish or brown carapace, often with streaks or spots, and a yellowish-white plastron. Hatchlings have a dark brown to black carapace and white plastron, with a white margin along the carapace and rear edges. Greens have one pair of prefrontal scales, four lateral scutes, a small rounded head, and a single visible claw on each flipper. Worldwide, green turtles vary in size and weight among different populations. In Florida, green turtles average 101 to 102 cm in carapace length (SCL) and weigh about 136 kg.

Range

Adult green turtles, rare in temperate waters, are found in tropical and subtropical waters worldwide. In the United States they range from Texas to the U.S. Virgin Islands, near Puerto Rico, and north to Massachusetts. Major nesting areas are located in Costa Rica, Australia, Ascension Island, and Surinam. In the United States, small numbers nest in Florida, the U.S. Virgin Islands, and Hawaii. Culebra Island, Puerto Rico, is an important foraging area for juveniles.

A subspecies (possibly a distinct species), the black turtle (*Chelonia agassizii*) is confined to the eastern Pacific, with important nesting grounds in Mexico. The black turtle ranges from southern Alaska to southern Chile, but is usually found between Baja California and Peru.

Habitat

Like other sea turtle species, green turtles use three distinct habitats: nesting beaches, convergence zones in the open sea (hatchlings/juveniles), and benthic foraging grounds (adults/subadults). Juveniles move into benthic feeding grounds in relatively shallow, protected waters when they reach about 20 to 25 cm SCL. Foraging areas consist primarily of seagrass and algae beds, though they are also found over coral and worm reefs and rocky bottoms. In the United States, important foraging areas include Florida estuaries, such as Indian River Lagoon, and the French Frigate Shoals in Hawaii. Green turtles prefer nesting on high-energy beaches, often on islands.

Diet

Post-hatchling, pelagic-stage green turtles are believed to be omnivorous. Adults and subadults feed primarily on seagrasses and kelp.

Leatherback turtle, *Dermochelys coriacea*

Dermochelyid - **leathery-shelled sea turtles (i.e., leather-back).**

The leatherback turtle (Figure 1.4), the largest and most pelagic sea turtle, is easily identified by its lack of scutes (hence the name). The leatherback is listed as endangered.

Identification

This large sea turtle has seven ridges running from front to rear along its back instead of the usual scutes, with a continuous thin, black layer of skin, often with white spots. Leatherbacks have no scales on their heads and no claws on their flippers. They range in size from 150 to 170 cm SCL, and may grow to 500 kg (rarely, even to 900 kg). Hatchlings also have carapace ridges and lack scutes; they are two to three times larger than other sea turtle hatchlings.

Range

Adult leatherbacks may range as far north as the coastal waters off Newfoundland or the Gulf of Alaska: this is the species most frequently found stranded on beaches of northern California. Nesting is entirely tropical, however, occurring in Mexico, the eastern Pacific, Guyana, the South Pacific (Malaysia), coastal Africa, and the Caribbean (Costa Rica, Surinam, French Guiana, and Trinidad). Very small numbers (20 to 30) nest along the Florida coast each year, with larger numbers nesting in the U.S. Virgin Islands (St. Croix in particular) and Puerto Rico (mainland and Culebra Island).

Figure 1.4 A leatherback turtle covers her nest in French Guiana. Photo courtesy of Matthew Godfrey.

Habitat

Leatherbacks are primarily pelagic, deep-diving animals. They are occasionally seen in coastal waters, more frequently when nesting.

Diet

Leatherbacks primarily eat jellyfish and other coelenterates that inhabit the water column in the open ocean and pelagic colonial tunicates (pyrosomas).

Pyrosoma - **pelagic colonial tunicate; most species inhabit tropical waters, with some up to 4 m in length.**

Kemp's Ridley Turtle, *Lepidochelys kempii*

The Kemp's ridley (Figure 1.5), along with the olive ridley, is the smallest of all sea turtles. Listed as an endangered species, this is the rarest sea turtle in the world, and it has the most restricted range of all U.S. sea turtle species.

Figure 1.5 A Kemp's ridley turtle. Photo courtesy of Dr. Jeanette Wyneken, Florida Atlantic University.

Identification

The small adult Kemp's ridley sea turtle has a light gray to olive or gray-green carapace and a creamy white or yellowish plastron. Hatchlings are gray-black on both carapace and plastron. Kemp's ridleys have more than one pair of prefrontal scales and five lateral scutes. Adults usually weigh less than 45 kg, with an SCL averaging 65 cm (nesting females range from 52 to 75 cm), and they are almost as wide as they are long.

Range

Except for the Australian flatback turtle, the Kemp's ridley has the most restricted range of all sea turtles, occurring primarily in the coastal areas of the Gulf of Mexico and the northwestern Atlantic Ocean. The primary nesting beach is near Rancho Nuevo, on Mexico's northeast coast. While adults are confined almost exclusively to the Gulf of Mexico, the northeastern coast of the United States appears to be an important habitat for juveniles, which are often found in waters off New York and New England.

Habitat

As with other sea turtles, little is known of the Kemp's ridleys' post-hatchling, planktonic life stage. Young animals presumably feed on sargassum and associated infauna in the Gulf of Mexico. As juveniles, they frequent bays, coastal lagoons, and river mouths, then as adults move into crab-rich areas of the Gulf of Mexico over sandy or muddy bottoms.

Diet

Juvenile and adult Kemp's ridleys are primarily crab-eaters. They also consume fish and a variety of invertebrates such as sea urchins and squid.

Hawksbill Turtle, *Eretmochelys imbricata*

The hawksbill turtle (Figure 1.6) is the most tropical sea turtle, and it is one of the most heavily poached, both as juveniles and adults, to obtain "tortoiseshell." Hawksbills are endangered throughout their range.

Identification

The hawksbill turtle has thick carapace scutes, with streaks of brown and black on an amber background. The rear edge of the carapace is deeply serrated. Hawksbills have two pairs of prefrontal scales and four overlapping lateral scutes; a small, narrow head that tapers to a distinct hooked beak; and two claws on the front of its flippers. The second smallest sea turtle, nesting females vary in size from 27 to 86 kg, with an SCL of 53 to 114 cm (the average is 95 cm).

Figure 1.6 A hawksbill turtle. Photo of "Ake" courtesy of Ursula Keuper-Bennett.

Range

Hawksbills are found throughout the tropical oceans, with larger populations in Malaysia, Australia, the Western Atlantic from Brazil to South Florida, throughout the Caribbean, and in the southwestern Gulf of Mexico. In U.S. waters, hawksbills are found in the U.S. Virgin Islands (nesting beaches are in Buck Island National Monument, St. Croix), Puerto Rico (nesting beaches are on Mona Island, Figure 1.7), South Florida, along the Pacific coast from southern California southward, and in Hawaii.

Habitat

Hawksbills forage near rock or reef habitats in clear, shallow tropical waters. They are most common near a variety of reefs, from vertical underwater cliffs to gorgonian (soft coral) flats, and are found over seagrass or algae meadows. Adults are not usually found in waters less than 20 m deep, while juveniles rarely leave shallow coral reefs. Pelagic-stage hawksbills presumably are associated with sargassum rafts, moving into shallow reefs when they reach 15 to 25 cm SCL, then into deeper waters as their size and diving capabilities increase.

Figure 1.7 Hawksbill hatchlings emerge from a nest on Pajaros Beach, Isla de la Mona, in the Mona Channel west of Puerto Rico. Photo courtesty of Michelle Schärer, Department of Marine Sciences, University of Puerto Rico-RUM.

Diet

Hawksbill turtles feed primarily on sponges (in the Caribbean, on only a few distinct species), but may also forage on corals, tunicates, and algae.

Olive Ridley Turtle, *Lepidochelys olivacea*

Figure 1.8 An olive ridley turtle. Photo courtesy of Janos Csernoch, Programa Restauración de Tortugas Marinas, Costa Rica

The olive ridley (Figure 1.8), while probably the most numerous sea turtle worldwide, is rare in U.S. waters.

Identification

The olive ridley, like its close relative the Kemp's ridley, is a small turtle. The adult carapace is dark gray and nearly round; hatchlings are gray-brown. Olive ridleys have two claws on each limb, more than one pair of prefrontal scales, and six or more lateral scutes.

Figure 1.9 Olive ridley turtles leave the beach at Ostional, Costa Rica. Photo courtesy of Janos Csernoch, Programa Restauración de Tortugas Marinas, Costa Rica.

Range

The olive ridley is found in Pacific and South Atlantic waters, but may occasionally be found in the tropical North Atlantic. Along the Pacific coast, the olive ridley ranges from the Gulf of Alaska to Central America, but is most common in the southern portion of this range. Enormous nesting aggregations, called arribadas, occur at two sites on Costa Rica's Pacific coast (Figure 1.9), one site on Mexico's Pacific coast, and two or three in northeastern India. Smaller nesting sites are found in Nicaragua and scattered along other tropical mainland shores.

Arribada - mass nesting aggregation; Spanish, meaning literally, "arrived."

Habitat

Olive ridleys are associated with relatively deep, soft-bottomed habitats inhabited by crabs and other crustaceans. They are common in pelagic habitats but also feed in shallower benthic habitats, sometimes near estuaries.

Diet

Carnivorous to omnivorous, olive ridley stomach contents have included crabs, mollusks, gastropods, fish, fish eggs, and algae.

Flatback Turtle, *Natator depressus*

Figure 1.10 A flatback turtle on Abutlion Island, Lownedal Island group, Western Australia. Photo courtesy of Kellie Pendoley, Murdoch University, Australia.

The flatback turtle (Figure 1.10) is confined to the waters along the northeast to northwest coast of Australia. The adult carapace is a dull olive-gray edged with pale brownish-yellow, and the plastron is creamy white. The flatback inhabits inshore turbid waters in coastal areas along the main coral reefs and continental islands, where it feeds on a varied diet that includes algae, squid, invertebrates, and mollusks.

For Further Reading

Bjorndal, K. A. 1982. *Biology and Conservation of Sea Turtles*, Smithsonian Institution Press, Washington, D.C.

Gulf of the Farallones National Marine Sanctuary. 1994. *Beached Marine Birds and Mammals of the North American West Coast*, NOAA Sanctuaries and Reserves Division, U.S. Dept. of Commerce, 1443-CX-8140-93-011, 1994.

Lutz, P. L., and J. A. Musick, eds. 1997. *The Biology of Sea Turtles*, Vol. I. CRC Press, Boca Raton, Fla.

Lutz, P. L., J. A. Musick, and J. Wyneken, eds. 2002. *The Biology of Sea Turtles*, Vol. II. CRC Press, Boca Raton, Fla.

National Research Council. 1990. *Decline of the Sea Turtles*, National Academy Press, Washington, D.C.

Pritchard, P. C. H. 1997. Evolution, phylogeny, and current status. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. A. Musick, eds. CRC Press, Boca Raton, Fla. pp. 1–28

Pritchard, P. C. H. 1982. Nesting of the leatherback turtle *Dermochelys coriacea* in Pacific Mexico, with a new estimate of world population status. *Copeia* 3: 741.

Wyneken, J. 2002. The anatomy of sea turtles. NOAA Tech. Memo. NMFS-SEFSC-470, Miami, Fla.

Chapter 2 Life History and Physiology

Sarah Milton and Peter Lutz

Key Points

- The life history of all sea turtle species is similar; they are almost entirely marine.
- Females return to the beaches primarily to nest, emerging at night to dig an egg chamber and lay eggs. No further parental care is provided.
- Hatchlings of most sea turtles live for several years in the open ocean gyres, returning as juveniles to nearshore habitats.
- Some turtles migrate great distances between feeding and nesting areas.
- Sea turtles routinely dive for long periods. They have anatomical and physiological adaptations that permit a rapid exchange of air at the surface and the ability to carry oxygen "on board" for diving.
- Sea turtles excrete excess salt loads through modified tear, or lachrymal, glands located behind the eyes.

Lachrymal gland - tear glands highly modified to excrete excess salt.

Life History

The life history of all sea turtle species is similar. Mature, breeding females migrate from foraging grounds to nesting beaches, which may be nearby (tropical hawksbill, for example) or a significant distance away (one population of green turtles migrates some 2,000 kilometers (km) from feeding grounds off Brazil to nesting beaches on Ascension Island in the mid-Atlantic). The turtles mate some time during the migration, usually in the spring, when mature males and females congregate off nesting beaches.

Female turtles must return to land to nest, generally crawling up a dark beach to above the high-tide line at night, although female Kemp's ridley turtles nest predominantly during the day, as do olive ridleys, which nest in a large mass, or arribada. The general requirements for a nesting beach are that it is high enough to not be inundated at high tide, has a substrate that permits oxygen and carbon dioxide to diffuse into and out of the nest, and is moist and fine enough that it won't collapse during excavation. The female uses her front flippers to toss loose surface sand aside to excavate a large body pit, then uses her hind flippers as "scoops" to dig a flask-shaped egg chamber, into which she deposits approximately 100 parchment-shelled eggs, about the size of Ping-Pong balls (larger for leatherbacks). Once the eggs are deposited, she covers the eggs with moist sand and again uses her flippers to broadcast sand around the nesting area to disguise the exact location of the egg chamber. She then returns to the sea, providing no further parental care. Photographs of sea turtle nests and the typical tracks left by different turtle species are in Appendix B.

Females generally deposit from 1 to 10 egg clutches per season, laying at regularly spaced intervals of 10 to 20 days. Most turtle species nest only every two to four years. The exceptions to this general schedule are the Kemp's and olive ridley turtles, which commonly nest each year, with no intervening nonbreeding seasons, unlike other turtle species. Both ridleys nest in arribadas, at three- to four-week intervals. Individual olive ridleys may nest one, two, or three times per season, typically producing 100 to 110 eggs each time.

After an incubation period of about two months, hatchlings of all species dig their way up to the surface all together. Thus the majority of hatchlings emerge from the nest on a single night in a group numbering between 20 and 120, with only a few stragglers hatching on successive nights. High surface-sand temperatures can inhibit hatchling movement, so most emergences occur at night, after the sand has cooled, although daytime emergences on cloudy days or after a rain are not uncommon.

Upon emerging from the nest, the hatchlings scramble across the beach to the ocean, orienting away from the darkness of the duneline and moving toward the shine of the surf. Once in the water, hatchlings then orient into the waves, engaging in frenzied swimming that transports them to offshore waters within the first 24 to 48 hours. There they will spend the next several years, feeding in sargassum beds, upwellings, and convergence zones of the open sea (Figure 2.1).

Sea turtles spend their early years caught up in the open ocean gyres. Thus turtles born on the U.S. Atlantic coast circle past Europe and the Mediterranean Sea before returning as juveniles to the U.S. eastern seaboard. Young turtles found off the California coast generally originate from beaches of the western Pacific.

Figure 2.1 A loggerhead hatchling in sargassum. Photo courtesy of Dr. Blair Witherington, Florida Fish and Wildlife Conservation Commission.

As juveniles, most species enter the coastal zone, moving into bays and estuaries, where they spend more years feeding and growing to maturity. Estimates of age at sexual maturity vary not only among species, but also among different populations of the same species: as early as three years in hawksbills, 12 to 30 years in loggerheads, and 20 to 50 years in green turtles. Mature sea turtles then join the adult populations in the nesting and foraging grounds.

Leatherbacks are the exception to this life-history pattern. Upon hatching, leatherbacks do not move passively with the open ocean gyres; instead they become active foragers in convergence zones and upwellings. Leatherbacks are the most pelagic of the sea turtle species; they remain in deeper waters as both juveniles and adults, bypassing the nearshore stage common to other marine turtle species.

Physiology

Sea turtles exhibit a number of adaptations as air-breathing, marine reptiles. Besides the obvious physical adaptations—the flattened, streamlined carapace and elongated, paddlelike flippers (due to the space constraints of streamlining, neither head nor flippers are retractable)—the most important physical and physiological adaptations to the marine lifestyle are those that permit diving and excretion of excess salt. These adaptations are the focus of this section because they are the features that put sea turtles at particular risk when exposed to oil spills (discussed in Chapter 4).

Diving

Sea turtles are among the longest and deepest diving air-breathing vertebrates, spending as little as 3 to 6 percent of their time at the surface. While most sea turtle species routinely dive no deeper than 10 to 50 meters (m), the deepest recorded dives for leatherbacks are over 1,000 m! Routine dives may last anywhere from 15 to 20 minutes to nearly an hour. The primary adaptations that permit extended, repeated dives are efficient transport of oxygen and a tolerance for low-oxygen conditions, or hypoxia. As surface breathers but deep divers, all the oxygen required by a diving turtle must be carried "on board." Upon surfacing, a sea turtle exhales forcefully and rapidly, requiring only a few breaths, each less than 2 to 3 seconds, to empty and refill its lungs. Such high flow rates are possible because turtles have large, reinforced airways, and their lungs are extensively subdivided, which increases gas exchange between the them and the bloodstream. The blood will continue to pick up oxygen from the lungs even as oxygen stores are depleted to almost undetectable levels, stripping oxygen from the lungs to be used by the heart, brain, and muscles.

Unlike diving marine mammals, which have dark, iron-rich blood and muscle tissue that can store large amounts of oxygen, most sea turtles use the lungs as the primary oxygen store. (An exception to this is the leatherback, which is more like marine mammals in its ability to store oxygen in blood and tissues.) During routine dives, sea turtles will surface to breathe before they run out of oxygen, though when forced to remain submerged (for example, when caught in a trawl) their oxygen stores are rapidly consumed and instead they must convert glucose to lactic acid for energy, a process called anaerobic metabolism. Sea turtles can tolerate up to several hours without oxygen (due to their low metabolic rates and adaptations of the brain to survive without oxygen), but when they are forced to submerge, and thus expend much energy escaping, their survival time under water is greatly decreased. Lactic acid levels can rise rapidly, even to lethal levels. Turtles affected by sublethal levels of lactic acid may require up to 20 hours to recover, during which time they are vulnerable to capture or other stresses. Accidental drowning in shrimp trawls, drift nets, and long-line fisheries is a major cause of sea turtle mortality worldwide.

Salt Excretion

Nares - external nostrils.

A second important adaptation for a marine lifestyle is a way to excrete excess salt from seawater and food. Sea turtles, like all vertebrates, have a salt concentration in their body fluids only about one-third that of seawater. Marine grasses and invertebrates (such as crabs and sea urchins), however, have the same salt levels as seawater. The turtle must excrete the excess salt consumed eating these plants and animals, because high salt levels in vertebrates interfere with a variety of bodily functions and can be lethal. To lessen the possibility of accidentally ingesting salt water while feeding, a sea turtle's esophagus is lined with long, densely packed conical spines, or papillae, which are oriented downward, toward the stomach. Biologists believe that this defense against "incidental drinking" traps food, while contractions of the esophagus expel seawater out the mouth or nostrils, called nares. However, even with these features, most sea turtles still ingest high amounts of salt from their prey. Their kidneys are not powerful enough to excrete large salt loads, but highly modified tear glands behind their eyes, when stimulated by high salt levels in the blood, can excrete a salt solution that is nearly twice as concentrated as seawater. The practical effect is that ingesting 1 liter of seawater will result in the excretion of 500 milliliters (ml) of tears, providing a net gain of 500 ml of salt-free water.

For Further Reading

Ackerman, R. A. 1977. The respiratory gas exchange of sea turtle nests (*Chelonia, Caretta*), *Respir. Physiol*. 31: 19–38.

Ackerman, R. A. 1997. The nest environment and the embryonic development of sea turtles. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. A. Musick, eds. CRC Press, Boca Raton, Fla. 432 p.

Bjorndal, K. A. 1997. Foraging ecology and nutrition of sea turtles. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. A. Musick, eds. CRC Press, Boca Raton, Fla. pp. 199–231.

Crowder, L. B., S. R. Hopkins-Murphy, and J. A. Royle. 1995. Effect of turtle excluder devices (TEDS) on loggerhead sea turtle strandings with implications for conservation. *Copeia* 1995: 773.

Eckert, S. A. 2000. Global distribution of juvenile leatherback sea turtles. Hubbs Sea World Research Institute San Diego, Calif. pp. 99–294

Eckert, S. A., K. L. Eckert, P. Ponganis, and G. L. Kooyman. 1989. Diving and foraging behavior of leatherback sea turtles (*Dermochelys coriacea*). *Can. J. Zool.* 67: 2834.

Ehrhart, L. M. 1982. A review of sea turtle reproduction. In: *Biology and Conservation of Sea Turtles*, K. Bjorndal, ed. Smithsonian Institution Press, Washington, D.C. p. 29.

Hendrickson, J. R. 1982. Nesting behavior of sea turtles with emphasis on physical and behavior determinants of nesting success or failure. In: *Biology and Conservation of Sea Turtles*, K. Bjorndal, ed. Smithsonian Institution Press, Washington, D.C. p. 53.

Jackson, D. C. 2000. Living without oxygen: Lessons from the freshwater turtle. *Comp. Biochem. Physiol. A Mol. Integr. Physiol.* 125(3): 299–315.

Lohmann, K. J., B. E. Witherington, C. M. Lohmann, and M. Salmon. 1997. Orientation, navigation, and natal beach homing in sea turtles. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. A. Musick, eds. CRC Press, Boca Raton, Fla. pp. 109–135.

Lutcavage, M., and P. L. Lutz. 1997. Diving physiology. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. A. Musick, eds. CRC Press, Boca Raton, Fla. pp. 277–296.

Lutcavage, M., and P. L. Lutz. 1991. Voluntary diving metabolism and ventilation in the loggerhead sea turtle. *J. Exp. Mar. Biol. Ecol.* 147: 287.

Lutz, P. L. 1992. Anoxic defense mechanisms in the vertebrate brain. *Ann. Rev. Physiol.* 54: 601.

Lutz, P. L. 1997. Salt, water, and pH balance in the sea turtle. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. A. Musick, eds. CRC Press, Boca Raton, Fla. pp. 343–361.

Lutz, P. L., and G. E. Nilsson. 1997. *The Brain without Oxygen*, 2nd ed., Landis Press, Austin, Tex.

Lutz, P. L., and T. B. Bentley. 1985. Respiratory physiology of diving in the sea turtle. *Copeia* 1985: 671.

Lutz, P. L., and A. Dunbar-Cooper. 1987. Variations in the blood chemistry of the loggerhead sea turtle, *Caretta caretta*. Fish. Bull. 85: 37–43.

Lutz, P. L., A. Bergey, and M. Bergey. 1989. The effect of temperature on respiration and acid-base balance in the sea turtle *Caretta caretta* at rest and during routine activity. *J. Exp. Biol.* 144: 155–169.

Miller, J. D. 1997. Reproduction in sea turtles. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. A. Musick, eds. CRC Press, Boca Raton, Fla. pp. 51–81.

Mortimer, J. A. 1990. Factors influencing beach sand characteristics on the nesting behavior and clutch survival of green turtles (*Chelonia mydas*). *Copeia*. 1990: 802.

Mrosovsky, N. 1968. Nocturnal emergence of hatchling sea turtles: Control by thermal inhibition of activity. *Nature* 220: 1338–1339.

Musick, J. A., and C. J. Limpus. 1997. Habitat utilization and migration in juvenile sea turtles. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. A. Musick, eds. CRC Press, Boca Raton, Fla. pp. 137–163.

Salmon, M., and B. E. Witherington. 1995. Artificial lighting and seafinding by loggerhead hatchlings: Evidence for lunar modulation. *Copeia* 4: 931.

Salmon, M., and K. J. Lohmann. 1989. Orientation cues used by hatchling loggerhead sea turtles (*Caretta caretta*) during their offshore migration. *Ethology* 83: 215.

Witham, R. 1991. On the ecology of young sea turtles. *Fla. Sci*. 54: 179.

Witherington, B. E., K. A. Bjorndal, and C. M. McCabe. 1990. Temporal pattern of nocturnal emergence of loggerhead turtle hatchlings from natural nests. *Copeia* 4: 1165–1168.

Chapter 3 Natural and Human Impacts on Turtles

Sarah Milton and Peter Lutz

Key Points

- Sea turtles worldwide are threatened by a variety of natural and human (anthropogenic) forces. Because they use of a variety of habitats (beaches to open oceans to nearshore environments), sea turtles are vulnerable to human impacts at all life stages, although natural mortality is believed to decline with age (increasing size).
- Natural mortality factors include the destruction of eggs on the beach by inundation or erosion, predation at all life stages, extreme temperatures, and disease.
- The primary cause of mortality among juvenile and adult sea turtles is drowning after becoming entangled in fishing gear, primarily shrimp trawls. Mortality has decreased in U.S. waters with the use of turtle excluder devices (TEDs).
- Other significant sources of mortality include direct take (poaching) of eggs and turtles and the destruction or degradation of their habitat.

TED - turtle excluder device, an adaptation to commercial shrimp nets to permit sea turtles to escape.

Natural Mortality Factors

Egg Loss

Turtle eggs are subject to a variety of both natural and anthropogenic impacts. High tides or storms can drown the eggs, cause beach erosion, and wash away nests, and beach accretion can prevent access between nesting areas and the water. Predation on eggs by raccoons, feral hogs, ants, coyotes, and other animals can be quite high. In the 1970s, before protective efforts began at Canaveral National Seashore, Florida, raccoons destroyed 75 to 100 percent of loggerhead nests, although the numbers destroyed on most beaches were considerably lower.

Predation

By emerging from the nest at night, turtle hatchlings reduce their risk of predation, but they still must run a gauntlet of predators between the nest and sea—from raccoons, birds, and ghost crabs on shore to tarpon, jacks, sharks, and other fish in the waters near shore. Although use of turtle hatcheries has fallen out of favor in the United States, past hatchery management problems exacerbated predation by fish. When hatchlings were regularly released into the water at the same location and same time, predatory fish would gather in high numbers for their scheduled meal.

Larger juveniles and adults may be eaten by sharks and other large predatory fish, though predation decreases as turtles' size increases. One study indicated that 7 to 75 percent of tiger sharks sampled in Hawaiian waters inhabited by sea turtles had preyed on green turtles.

Hypothermia

Another natural source of mortality in sea turtles is hypothermia. Water temperatures that dip below 8° to 10°C affect primarily juvenile and subadult turtles residing in nearshore waters, causing them to become lethargic and buoyant until they float at the surface in a condition known as cold-stunning. At temperatures below 5° to 6°C, death rates can be significant. The animals can no longer swim or dive, they become vulnerable to predators, and they may wash up on shore, where they are exposed to even colder temperatures. Large cold-stun events have occurred frequently in recent years off the coasts of Long Island, New York; Cape Cod, Massachusetts; and even in Florida. Intervention and treatment, such as holding the turtle in warm water and administering fluids and antibiotics, greatly reduces mortality.

Disease

Sea turtles are affected by a number of health problems and diseases. Bacterial infections are rare in free-roaming sea turtle populations but higher under captive conditions. Parasitic infections are common, however. Up to 30 percent of the Atlantic loggerhead population, for example, may be impacted by trematodes that infect the cardiovascular system. These heart flukes are associated with severe debilitation, muscle wasting, and thickening and hardening of major blood vessels. This parasite damage may then permit a variety of bacterial infections, including such species as *Salmonella* and *E. coli*.

Brevetoxicosis - **a deadly condition caused by ingestion of dinoflagellate organisms often responsible for red tides; recently linked to deaths of manatees in Florida and common murres in California.**

Another risk comes from dinoflagellate blooms (red tides), which are occurring in increasing numbers around the world as excess nutrient loads pollute coastal waters, conditions that can lead to health problems and mortality in many marine species. Because immediate effects result from aerosol transport, the sea turtles' mode of respiration—inhaling rapidly to fill the lungs before a dive—puts them at particular risk. Chronic brevetoxicosis, a deadly lung condition caused by red tide dinoflagellates, has been suggested as another recent cause of sea turtle mortalities. In Florida, sea turtles had neurological symptoms, and the ones that died had measurable brevetoxin levels in their tissues. More subtle, long-term effects such as impaired feeding, reduced growth, and immune suppression may occur from consuming prey in which the toxin has bioaccumulated.

By far the most prevalent health problem, however, is a sea turtle disease called fibropapilloma (FP), which has been linked to a herpes virus. FP is typified by large fibrous (noncancerous) tumors (Figure 3.1). If external, these tumors can interfere with vision, swimming, and diving, and thus hinder the turtle's ability to feed and escape from predators. Internal tumors can affect organ function, digestion, buoyancy, cardiac function, and respiration. Turtles with advanced FP tend to be anemic and have salt imbalances. FP has reached epidemic proportions among green turtles worldwide and has been documented in the six other species. Some green turtle populations have infection rates of 65 to 75 percent. The disease rate tends to be higher in environmentally degraded areas.

Fibropapilloma - a tumor-forming, debilitating, and often fatal, disease of sea turtles, manifested by formation of multiple fibrous masses of tissue 1 mm to 30 cm in diameter growing from the eyes, flippers, neck, tail, and scutes and in the mouth.

Figure 3.1 A green turtle with fibropapilloma tumors at the base of its flippers. Photo courtesy of Patricia Sposato, Florida Atlantic University.

Anthropogenic Impacts

Fisheries By-catch

In a comprehensive review of sources of sea turtle mortality conducted by the National Research Council (1990), incidental capture of turtles in shrimp trawls was determined to account for more deaths than all other human activities combined (Figure 3.2). Because of sea turtles' exceptional breath-holding capabilities, the large numbers of deaths blamed on incidental catch (i.e., drowning) was at first greeted with skepticism. However, a variety of field and laboratory studies on the effects of forced (versus voluntary) submergence soon demonstrated the vulnerability of sea turtles to trawl nets. One study, for example, showed that mortality was strongly dependent on trawl times: mortality increased from 0 percent with trawl times less than 50 minutes to 70 percent after 90 minutes. Since the enactment of turtle excluder device (TED) regulations, mortalities due to shrimp trawling have decreased significantly in U.S. coastal waters—in South Carolina alone, mortalities decreased 44 percent. Regrettably, regulation, compliance, and enforcement are lower in other nations.

In addition to trawl entanglement, sea turtles have been killed after becoming entangled in other types of fishing gear, such as purse seines, gill nets, longlines (hook and line), and lobster or crab pot lines. The longline fisheries of the Pacific are currently a significant source of sea turtle mortality, especially among leatherbacks. In other waters of the world, such as the Mediterranean, such fisheries impact other turtle species as well. Vessels themselves are another threat. Between 1986 and 1988, 7.3 percent of all sea turtle strandings documented in U.S. Atlantic and Gulf of Mexico waters sustained some type of propeller or collision injuries, though how much damage was post-mortem

Figure 3.2 Trawl-caught sea turtles off Cape Canaveral, Florida. Photo courtesy of Dr. Peter Lutz, Florida Atlantic University.

versus cause of death could not be determined. The highest numbers of deaths occur where boat traffic is highest, the Florida Keys and the U.S. Virgin Islands.

Poaching

While the taking of adult sea turtles is rare in the continental United States and Hawaii, egg poaching may be significant on some beaches, and in many other parts of the world the harvest of both eggs and turtles is high. In some developing countries, the need for protein and income generated by the sale of turtle products—even where sea turtles are protected—undermines conservation efforts. Breeding aggregations, nesting females, and eggs provide ready access to large numbers of turtles.

Calipee **- cartilage**

Egg collection and hunting are primary causes of green and hawksbill turtle mortality worldwide (though all species are affected to some extent). Green turtles are exploited primarily for their meat and cartilage (called calipee), while hawksbills are taken mainly for their beautiful shells, which are used to create a variety of tortoiseshell objects such as jewelry and combs. During the twentieth century, the major importers of sea turtle shell and other products were Japan, Hong Kong, Taiwan, and some European nations. Thirty years ago, more than 45 nations exported turtle products: the primary exporter was Indonesia, with Panama, Cuba, Mexico, Thailand, the Philippines, Kenya, Tanzania, and other countries contributing significantly. Today, the market in turtle products continues, especially in Southeast Asia.

Besides direct take, poaching activities have many indirect impacts on sea turtles that affect every life stage, primarily habitat degradation or destruction.

Figure 3.3 On a nesting beach in North Carolina, homeowners placed sandbags to halt erosion, rendering previous turtle nesting sites inaccessible to sea turtles. Photo courtesy of Matthew Godfrey, North Carolina Wildlife Resources Commission.

Alteration of Nesting Beaches

Anthropogenic impacts on nesting beaches may affect nesting females, eggs, and hatchlings. Beach armoring, such as seawalls, rock revetments, and sandbagging installed to protect oceanfront property, may prevent females from accessing nesting beaches. In some areas, sand may erode completely on the ocean side of structures, leaving no nesting beach at all (Figure 3.3). Where erosion is extensive, property owners or government agencies may try to restore the beach by replenishing the sand supply from offshore or inland sources. While preferable to beach armoring, such beach renourishment projects may cause sea turtle mortality as the result of offshore dredging, and nests already on the beach can be buried by the new sand. Mortalities can be reduced by monitoring dredge operations and relocating nests to other beach areas.

beach renourishment - replenishment of beach sand by mechanically dumping or pumping sand onto an eroded beach; also referred to as beach nourishment.

Other effects of beach nourishment are that renourished beaches may become too compacted for nesting and steep, impassable escarpments may form. In addition, the replacement sand can have different physical properties than the original, altering critical aspects such gas diffusion, moisture content, and temperature, which can affect hatchling sex ratios. In sea turtles, like many reptiles, the sex of the hatchling is determined by incubation temperature; cooler nest temperatures produce mostly males and warmer temperatures produce mostly females.

Near beaches, light from condominiums, streetlights, and swimming pools also affects sea turtles (Witherington and Martin, 2000). Excess lighting deters females from nesting, while hatchlings emerging from the nest tend to move toward the bright artificial lights rather than toward the surf. Disoriented, the hatchlings can succumb to exhaustion, dehydration, and predation; become entrapped in swimming pools; or be crushed by cars or beach vehicles.

High levels of egg poaching, predation, erosion, artificial lighting, and heavy beach usage have been used to justify relocating nests to other beach sites, or in rare cases to hatcheries. While the practice may save threatened nests, it is important to note that, compared to nests left in place, relocation decreases nest success due to changes in incubation conditions, mortality during the move, and problems such as increased predation at release sites.

Pollution and Garbage

While direct effects on sea turtles of pollutants such as fertilizers and pesticides are almost completely unknown, some indirect effects are more obvious, such as habitat degradation. Excess nutrients in coastal waters increase the outbreaks of harmful algal blooms (HABs), which may affect sea turtle health directly, such as during red tide events, or indirectly. Indirect effects include a general degradation of turtle habitat, such as the loss of seagrass beds due to decreased light penetration, and the (mostly unknown) potential for long-term effects on sea turtle health and physiology. The toxic dinoflagellate *Prorocentrum*, for example, lives on on seagrasses so it is consumed by foraging green turtles. This dinoflagellate is of particular interest because it produces a tumor-promoting toxin (okadaic acid) that has been found in the tissues of Hawaiian green turtles with fibropapilloma disease.

Figure 3.4 A hawksbill turtle entangled in plastic line and fishing net. Photo courtesy of Chris Johnson, Marinelife Center of Juno Beach, Florida.

The effects of garbage in the water and on beaches are more direct. Turtles ingest plastics and other debris and become entangled in debris such as discarded fishing line (Figure 3.4). Ingesting plastic can cause gut strangulation, reduce nutrient uptake and increase the absorbance of various chemicals in plastics and other debris. The range of trash found in sea turtle digestive tracts is impressive: plastic bags, sheeting, beads, and pellets; rope; latex balloons; aluminum; paper and cardboard; styrofoam; fish hooks (Figure 3.5); charcoal; and glass. Leatherback turtles are particularly attracted to plastic bags, which they may mistake for their usual prey, jellyfish. Loggerheads—indeed, any hungry turtle—will eat nearly anything that appears to be the right size.

Figure 3.5 This X-ray image of a juvenile green turtle shows fishing hooks and other tackle in throat. The turtle underwent surgery and was released after recovering. Photo courtesy of Chris Johnson, Marinelife Center of Juno Beach, Florida.

Table 3.1 A summary of natural and anthropogenic impacts on sea turtles.

Source of Mortality	Primarily Anthropogenic	Main Life Stage Affected	Impact
Shrimp trawling	Yes	Juveniles/adults	High
Predation (natural)	No	Eggs, hatchlings	High
Artificial lighting	Yes	Nesting females, hatchlings	High
Disease	No	Subadults	High for greens
Beach use	Yes	Nesting females, eggs	High on some beaches
Other fisheries	Yes	Juveniles/adults	Medium
Vessel-related injuries, including propellers	Yes	Juveniles/adults	Medium
Poaching	Yes	Eggs, juveniles, adults	Low to medium
Beach development	Yes	Nesting females, eggs	Low to medium
Cold-stunning	No	Juveniles, subadults	Low
Entanglement	Yes	Juveniles/adults	Low
Power plant entrainment	Yes	Juveniles/adults	Low
Oil platform removal	Yes	Adults	Low
Beach renourishment	Yes	Eggs	Low with monitoring
Debris ingestion	Yes	Juveniles/adults	Unknown
Toxins	Yes	Unknown	Unknown
Habitat degradation	Yes	Hatchlings through adults	Unknown

Source: Adapted from National Research Council 1990.

For Further Reading

Aguirre, A. A., and P. L. Lutz. In press. Marine turtles as sentinels of ecosystem health: Is fibropapillomatosis an indicator? *Ecosystem Health*.

Balazs, G. H., and S. G. Pooley 1993. Research plan to assess marine turtle hooking mortality: Results of an expert workshop held in Honolulu, Hawaii. G. H. Balazs and S. G. Pooley, eds., U.S. Dept. of Commerce, Administrative Report H-93-18, Silver Spring, Md.

Bjorndal, K. A., A. B. Bolten, and C. J. Lagueux. Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. *Mar. Poll. Bull.* 28: 154.

Burkholder, J. M. 1998. Implications of harmful microalgae and heterotrophic dinoflagellates in management of sustainable marine fisheries. *Ecol. Applic.* 8: S37–S62.

Carminati, C. E., E. Gerle, L. L. Kiehn, and R. P. Pisciotta. Blood chemistry comparison of healthy vs. hypothermic juvenile Kemp's ridley sea turtles (*Lepidochelys kempii*). In: *Proc. 14th Ann. Workshop on Sea Turtles Conservation and Biology*, K. A. Bjorndal, A. B. Bolten, and D. A. Johnson, compilers. NMFS Tech. Memo. NOAA-TM-NMFS-SEFSC-351, Miami, Fla., p. 203.

Carr, A. 1987. Impact of non-degradable marine debris in the ecology and survival outlook of sea turtles. *Mar. Poll. Bull.* 18: 352–356.

Cray, C., R. Varela, G. Bossart, and P. L. Lutz. 2001. Altered in vitro immune responses in green turtles with fibropapillomatosis. *J. Zoo. Wildl. Med*. 32(4): 436–440.

Ehrhart, L. M. 1991. Fibropapillomas in green turtles of the Indian River lagoon, Florida: Distribution over time and area. In: *Research Plan for Marine Turtle Fibropapilloma*, G. H. Balazs and S. G. Pooley, eds. NMFS Tech. Memo. NOAA-TM-NMFS-SWFC-156, Honolulu, Hi. 59.

George, R. H. 1997. Health problems and diseases of sea turtles. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. A. Musick, eds., CRC Press, Boca Raton, Fla. pp. 363–385.

Henwood, T. A., and W. E. Stuntz. 1987. Analysis of sea turtle captures and mortalities during commercial shrimp trawling. *Fish. Bull.* 85: 813.

Herbst, L. H. 1994. Fibropapillomatosis of marine turtles. *Ann. Rev. Fish Dis.* 4: 389.

Herbst, L. H., and P. A. Klein. 1995. Green turtle fibropapillomatosis: Challenges to assessing the role of environmental cofactors. *Environ. Health Perspect.* 103(Suppl. 4): 27–30.

Jacobson, E. R., J. L. Marsell, J. P. Sundberg, L. Hajjar, M. C. Reichmann, L. M. Ehrhart, M. Walsh, F. Murru. Cutaneous fibropapillomas of green turtles (*Chelonia mydas*). *J. Comp. Pathol.* 101(1): 39–52.

Landsberg, J. H., G. H. Balazs, K. A. Steidinger, D. G. Baden, T. H. Work, and D. J. Russell. The potential role of natural tumor promoters in marine turtle fibropapillomasis. *J. Aquat. Anim. Health*, 11: 199–210.

Lutcavage, M. E., P. Plotkin, B. Witherington, and P.L. Lutz. 1997. Human impacts on sea turtle survival. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. Musick, eds. CRC Press. Boca Raton, Fla. pp. 387–410.

Lutz, P. L., and A. A. Alfaro-Shulman. 1991. The effects of chronic plastic ingestion on green sea turtles. Report NOAASB21-WCH06134, U.S. Dept. of Commerce, Miami, Fla.

Mack, D., N. Duplaix, and S. Wells. 1982. Sea turtles, animals of divisible parts: International trade in sea turtle products. In: *Biology and Conservation of Sea Turtles*, K. Bjorndal, ed. Smithsonian Institution Press, Washington, D.C.

Meylan, A. B., and S. Sadove. 1986. Cold-stunning in Long Island Sound, New York. *Mar. Turtle Newsl.* 37: 7–8.

Milton, S. L., A. A. Schulman, and P. L. Lutz. 1997. The effect of beach renourishment with aragonite versus silicate sand on beach temperature and loggerhead sea turtle nesting success. *J. Coast. Res.* 13(3): 904–915.

Milton, S. L., and P. L. Lutz. 2002. Physiological and genetic responses to environmental stress. In: *The Biology of Sea Turtles*, Vol. II, P. L. Lutz, J. A, Musick, and J. Wyneken, eds. CRC Press, Boca Raton, Fla. pp. 159–194.

Morreale, S. J., A. B. Meylan, S. S. Sadove, and E. A. Standora. Annual occurrence and winter mortality of marine turtles in New York waters. *J. Herpetol.* 26(3): 301–308, 1992.

National Research Council. 1990. *Decline of the Sea Turtles: Causes and Prevention*. National Academy Press, Washington, D.C. 259 p.

O'Shea, T. J., G. B. Rathburn, R. K. Bonde, C. D. Buergelt, and D. K. Odell. 1991. An epizootic of Florida manatees associated with a dinoflagellate bloom. *Mar. Mammal Sci.* 7(2): 165–179.

Plotkin, P. T., M. K. Wicksten, and A. F. Amos. 1993. Feeding ecology of the loggerhead sea turtle *Caretta caretta* in the northwestern Gulf of Mexico. *Mar. Biol.* 115: 1.

Pugh, R. S., and P. R. Becker. 2001. Sea turtle contaminants: A review with annotated bibliography. NISTIR 6700, Charleston, S.C.

Redlow, T., A. Foley, and K. Singel. 2002. Sea turtle mortality associated with red tide events in Florida. In: *Proceedings of the 22nd Annual Symposium on Sea Turtle Biology and Conservation*, J. Seminoff, compiler. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-SEFSC, Miami, Fla.

Schwartz, F. J. 1978. Behavioral and tolerance responses to cold water temperatures by three species of sea turtles (*Reptilia, Cheloniidae*) in North Carolina. *Florida Mar. Res. Publs.* 33: 16–18.

Stabenau, E. K., T. A. Heming, and J. F. Mitchell. 1991. Respiratory, acid-base and ionic status of Kemp's ridley sea turtles (*Lepidochelys kempi*) subjected to trawling, *Comp. Biochem. Physiol.* 99A: 107–111.

Stancyk, S. E. 1982. Non-human predators of sea turtles and their control. In: *Biology and Conservation of Sea Turtles*, K. A. Bjorndal, ed. Smithsonian Institution Press, Washington, D.C. pp. 139-152.

Witherington, B. E., and L. M. Ehrhart. 1989. Hypothermic stunning and mortality of marine turtles in the Indian River lagoon system, Florida. *Copeia* 1989: 696–703.

Witherington, B. E., and R. E. Martin. 2000. Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches, 2nd ed. Rev. Florida Marine Research Institute Technical Report TR-2. 73 p.

Witherington, B. E., and M. Salmon. 1992. Predation on loggerhead turtle hatchlings after entering the sea. *J. Herpetol.* 26(2): 226–228.

Wyneken, J., and M. Salmon. 1996. Aquatic predation, fish densities, and potential threats to sea turtle hatchlings from open-beach hatcheries: Final report. Technical Report for the Broward County, Department of Natural Resource Protection, Tech. Report No. 96-04, Fort Lauderdale, Fla.

Chapter 4 Oil Toxicity and Impacts on Sea Turtles

Sarah Milton, Peter Lutz, and Gary Shigenaka

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.

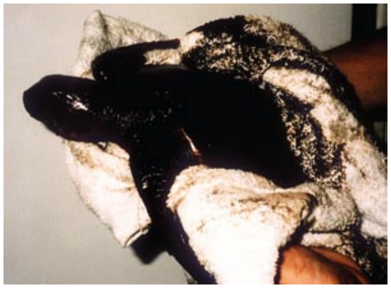


Figure 4.1 A juvenile green turtle oiled during a spill in Tampa Bay, Florida, in 1993. The turtle was rehabilitated by the Clearwater Aquarium and eventually released. Photo courtesy of Dr. Anne Meylan, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute.

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.

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.**

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

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

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

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.

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,

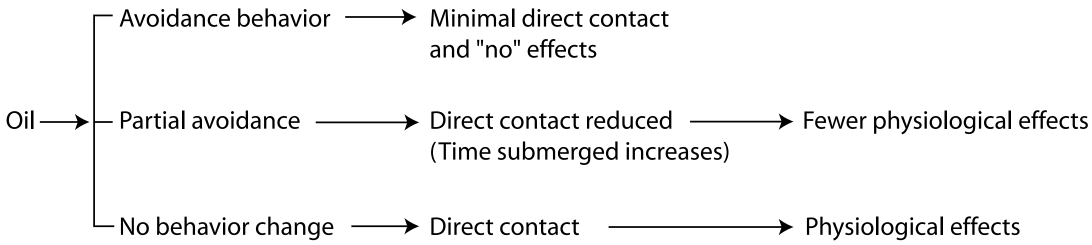


Figure 4.2 Conceptual framework of sea turtle behavioral responses to oil exposure (adapted from Lutz 1989).

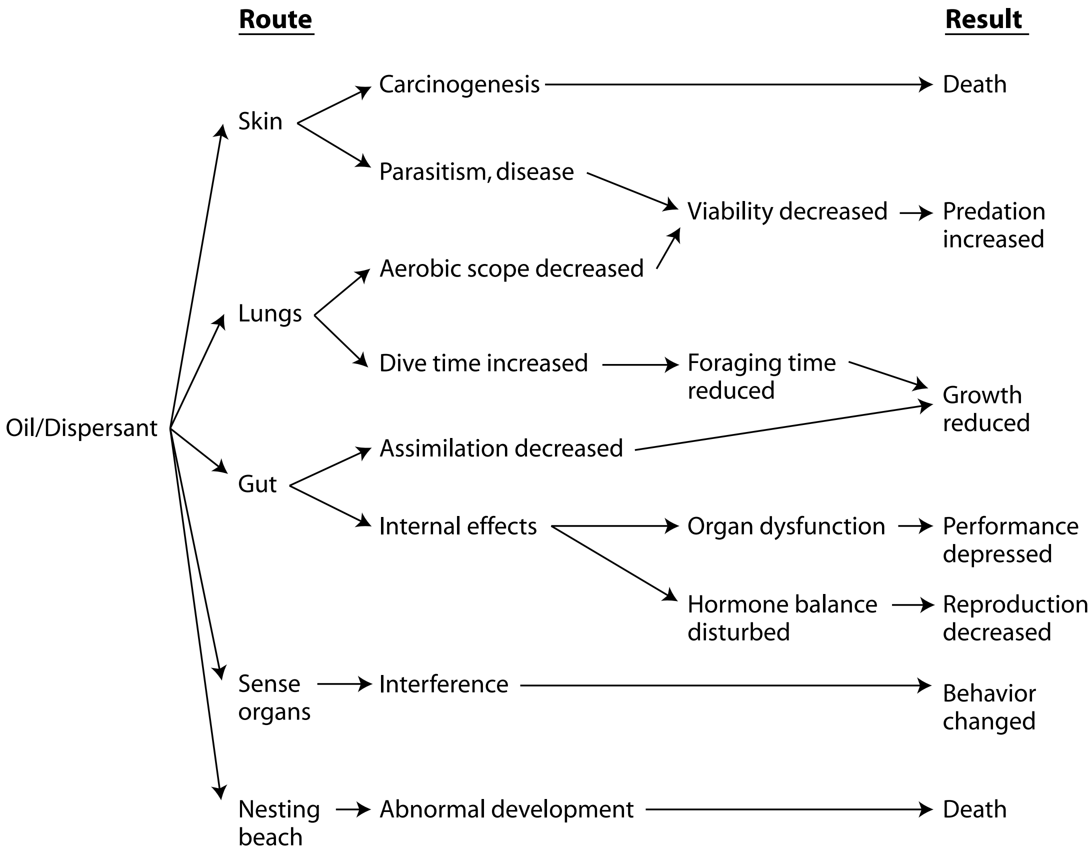


Figure 4.3 Conceptual framework for the effects of oil exposure to sea turtles (adapted from Lutz 1989).

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

Bedinger, C. A. Jr., and C. P. Nulton. 1982. Analysis of environmental and tar samples from the nearshore south Texas area after oiling from the Ixtoc-1 blowout, *Bull. Environ. Contam. Toxicol.* 28: 166–171.

Butler, J. N., B. F. Morris, and J. Sass. 1973. *Pelagic Tar from Bermuda and the Sargasso Sea*. The Bermuda Biological Station for Research, Cambridge, Mass.

Cubit, J. D. 1993. The effects of the 1986 *Bahia Las Minas* oil spill on benthic marine biota of shallow reef flats. In: *Proceedings of the Third International Conference "Effects of Oil on Wildlife."* New Orleans, La., Jan. 28–29, p. A-14.

Dillon, T. M., J. M. Neff, and J. S. Warner. 1978. Toxicity and sublethal effects of No. 2 fuel oil on the supralittoral isopod *Lygia exotica*. *Bull. Environ. Contam. Toxicol.* 20: 320–327.

Florida Institute of Oceanography. 1985. Study of the effects of oil on marine turtles, Vol. 2, Technical Report. Final report submitted by the Florida Institute of Oceanography (FIO) to the U.S. Minerals Management Service, St. Petersburg, Fla. November. 143 p.

Fritts, T. H., and M. A. McGehee. 1982. Effects of petroleum on the development and survival of marine turtle embryos. Contract No. 14-16-0009-80-946, FWS/OBS-82/37. U.S. Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C.

Geo-Marine, Inc. 1980. A report on if, when and where oil from the Mexican oil well blowout (Ixtoc-1) could impact Florida's coastal waters. Report prepared for the Florida Department of Natural Resources, Tallahassee, Fla. 77 p.

Gramentz, D. 1988. Involvement of loggerhead turtles with the plastic, metal, and hydrocarbon pollution in the central Mediterranean. *Mar. Poll. Bull.* 19(1): 11–13.

Hall, R. J., A. A. Belisle, and L. Sileo. 1983. Residues of petroleum hydrocarbons in tissues of sea turtles exposed to the Ixtoc I oil spill. *J. Wildl. Diseases* 19(2): 106–109.

Hays, G. C., J. S. Ashworth, M. J. Barnsley, A. C. Broderick, D. R. Emery, B. J. Godley, A. Henwood, and E. L. Jones. 2001. The importance of sand albedo for the thermal conditions on sea turtle nesting beaches. *Oikos* 93(1): 87–94.

Kira, S., T. Itoh, H. Hayatsu, K. Taketa, Y. Zheng, R. Li, T. L. Holliday, and C. S. Giam. 1994. Detection of waterborne mutagens and characterization of chemicals in selected Galveston sites after an oil spill. *Bull. Environ. Contam. Toxicol.* 53: 285–291.

Levings, S. C., S. D. Garrity, and K. A. Burns. 1993. Effects of oil spills on fringing mangroves: Long-term reductions in nursery areas and persistence of toxic oil residues. In: *Proceedings of the Third International Conference "Effects of Oil on Wildlife."* New Orleans, La., Jan. 28–29, p. A-29.

Loehefener, R. R., W. Hoggard, C. L. Roden, K. D. Mullin, and C. M. Rogers. 1989. Petroleum structures and the distribution of sea turtles. In: *Proc. Spring Ternary Gulf of Mexico Studies Meeting*, Minerals Management Service, U.S. Department of the Interior, New Orleans, La.

Lutcavage, M. E., P. L. Lutz, G. D. Bossart, and D. M. Hudson. 1995. Physiologic and clinicopathologic effects of crude oil on loggerhead sea turtles. *Arch. Environ. Contam. Toxicol*. 28: 417–422.

Lutcavage, M. E., P. Plotkin, B. Witherington, and P. L. Lutz. 1997. Human impacts on sea turtle survival. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. Musick, eds. CRC Press, Boca Raton, Fla. pp. 387–410.

Lutz, P. L. 1989. Methods for determining the toxicity of oil and dispersants to sea turtles. In: *Oil and Dispersant Toxicity Testing: Proceedings of a Workshop on Technical Specifications Held in New Orleans, La.*, T. W. Duke and G. Petrazzuolo, eds. Prepared under MMS contract 14-12-0001-30447, OCS Study MMS 89-0042, pp. 97–101.

National Research Council. 2003. *Oil in the Sea III: Inputs, Fates, and Effects*. National Academy Press, Washington, D.C. 265 p. + appendices.

Odell, D. K., and C. MacMurray. 1986. Behavioral response to oil. In: *Final Report. Study of the Effect of Oil on Marine Turtles*, S. Vargo, P. L. Lutz, D. K. Odell, T. Van Fleet, and G. Bossart, eds. Minerals Management Service Contract Number 14-12-0001-30063, Florida Inst. of Oceanography, St. Petersburg, Fla.

Philott, A. D., and C. J. Parmenter. 2001. Influence of diminished respiratory surface area on survival of sea turtle embryos. *J. Experim. Zool.*289(5): 317–321.

Plotkin, P., and A. F. Amos. 1988. Entanglement and ingestion of marine debris by sea turtles stranded along the south Texas coast. In: *Proc. 8th Ann. Symp. on Sea Turtle Biology and Conservation*, NOAA Tech. Memo. NMFS-SEFC-214, Miami, Fla.

Rabalais, S. C., and N. N. Rabalais. 1980. The occurrence of sea turtles on the South Texas Coast. *Contr. Mar. Sci.*, 23: 123–129.

Raloff, J. 1986. When sea turtles are awash in oil. *Sci. News*, 130(Dec.): 358.

Romero, G. C., G. R. Harvey, and D. K. Atwood. 1981. Stranded tar on Florida beaches: September 1979 through October 1980. *Mar. Poll. Bull.* 12: 280–284.

Slade, G. J. 1982. Effects of Ixtoc-I crude oil and Corexit 9527 dispersant on Spot (*Leiostomus xanthurus*) egg mortality. *Bull. Environ. Contam. Toxicol.* 29: 525–530.

Torrent A., S. Deniz, A. Ruiz, P. Calabuig, J. Sicilia, and J. Oros. 2002. Esophageal diverticulum associated with *Aeroccus viridans* infection in loggerhead sea turtles (*Caretta caretta*), *J. Wildl. Diseases* 38(1): 221–223.

Van Vleet, T., and G. G. Pauly. 1987. Characterization of oil residues scraped from stranded sea turtles from the Gulf of Mexico. *Carib. J. Sci.* 23: 77.

Van Vleet, E. S., W. M. Sackett, S. B. Reinhardt, and M. E. Mangini. 1984. Distribution, sources, and fates of floating oil residues in the eastern Gulf of Mexico. *Mar. Poll. Bull.* 15: 106–110.

Witham, R. 1978. Does a problem exist relative to small sea turtles and oil spills? In: *The Proceedings of the Conference on Assessment of Ecological Impacts of Oil Spills*, 14-17 June 1978, Keystone Colo. pp. 629–632.

Witherington, B. E. 1994. Flotsam, jetsam, post-hatchling loggerheads, and the advecting surface smorgasbord. In: *Proc. 14th Ann. Symp. Sea Turtle Biology and Conservation*, K. A. Bjorndal, A. B. Bolten, D. A. Johnson, and P. J. Eliazar, compilers. NOAA Tech. Memo. NMFS-SEFSC-351, Miami, Fla. p. 166.

Chapter 5 Response Considerations for Sea Turtles

Rebecca Z. Hoff and Gary Shigenaka

Key Points

- Spill responders must consider sea turtle-related tradeoffs in several ways, depending on spill location, time of year, and species of turtle.
- Sea turtles are likely to be at greatest risk when they are aggregating, usually peaking around nesting and hatching periods, and when they are foraging in convergence zones.
- Spill response in sea turtle habitat uses standard techniques, but they are modified to accommodate unique features and sensitivities of sea turtle behavior and life history.
- Several aspects of sea turtle biology and behavior place them at particular risk, including lack of avoidance behavior, indiscriminate feeding in convergence zones, and inhalation of large volumes of air before dives.
- While more common as a management technique, intrusive intervention to remove turtles or nests should be considered a response measure of last resort.

The preceding chapters have shown that sea turtles are vulnerable to oil exposure by many different routes—primarily due to the unfortunate overlap of habitat utilization by turtles and the physical behavior of oil. Turtle habitats include fine-grain sand beaches (nesting), seagrass beds and coral reefs (foraging), and open water convergence zones and sargassum mats (developmental). These habitats are often the places where oil strands or aggregates, hence there is an enhanced potential for sea turtles to encounter spilled oil. Since we know that oil harms turtles, reducing exposure should be the focus of response actions. As Lutz (1989) noted, "the potentially harmful effects of an oil spill on sea turtles must clearly be taken seriously, and any strategy to prevent turtles from encountering the oil must be regarded as a preferred frontline defense."

However, while reducing or preventing turtles from encountering oil is the preferred, obvious, and logical strategy, it is not necessarily easy or even possible. No response action is 100 percent effective, but any reduction in oil exposure reduces the potential stress on threatened sea turtle populations. Spill response planners should thus ask the following questions related to sea turtles:

- What are the open water and shoreline response actions we might consider in the event of a spill in an area frequented by sea turtles?

- Given the habitat preferences and unique features of sea turtle life history, do we need to modify standard response practices to accommodate sea turtles and minimize the impact to their populations?
- How would we do this?
- Can we anticipate spill impacts to turtles well enough that contingency plans will operationally reflect what we know?

USFWS - **U.S. Fish and Wildlife Service (U.S. Department of the Interior).**

Section 7 consultation - **requirement under the Endangered Species Act for federal agencies to address potential impacts of their actions on threatened species.**

NOAA and the U.S. Fish and Wildlife Service (USFWS) share trustee resource responsibility under Section 7 of the Endangered Species Act to address any potential impacts of a spill response on sea turtles and their critical habitat. Area contingency planning must consider possible impacts to listed species from response activities and how to avoid or mitigate them. During an actual response, emergency consultations for Section 7 concerns would be held to consider specific response actions and how they might impact sea turtles. Figure 5.1 shows a schematic of how the consultation process works.

Responses to oil spills depend on the product spilled and the environment at risk. The general features of spill response equipment and strategies are described in other publications.[2] In this chapter, we provide some basic information on response activities that might be considered in sea turtle habitat.

Open-Water Response Options

The overlap of oil and habitat also implies that sea turtles may be at increased risk from response activities themselves. Some of these activities and their impacts are discussed below.

Mechanical Recovery Offshore

Spilled oil on water is contained and collected using equipment such as booms and skimmers.[3] At many spills, mechanical collection is relied upon as the primary on-water cleanup method, but experience has shown that mechanical recovery alone cannot adequately deal with large spills offshore. Prior to the *Exxon Valdez* oil spill, average mechanical recovery effectiveness was typically estimated at around 10 to 20 percent, although it may be up to an average of about 30 percent now (PMG, Inc. 2001). Weather and ocean conditions, the nature of the oil, and other factors can limit the effectiveness of mechanical recovery. For example, containment booms do not perform well in heavy waves, in shallow waters, or in swift currents—an estimated 58 percent of all spills occur in water moving over 1 knot (PMG, Inc. 2001). Even under ideal circumstances, mechanical recovery may not successfully control large spills or oil that has spread over large areas. In such cases, alternative open-water response techniques, such as dispersant application or *in-situ* burning of oil on water, may significantly reduce the time that oil remains on the surface, the formation of tarballs, and the risk that oil will reach shore.

***In-situ* burning** - **response technique in which spilled oil is burned in place.**

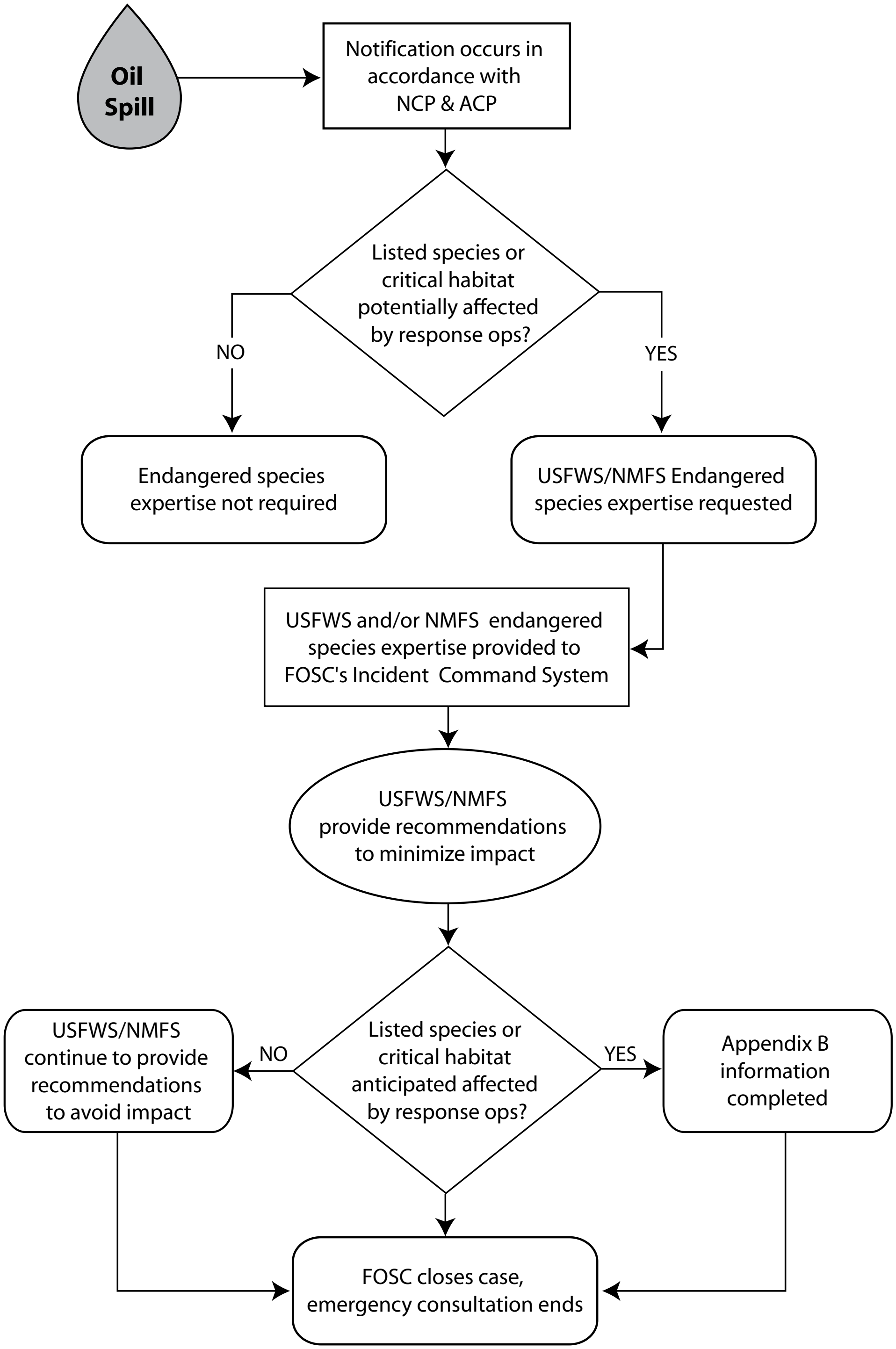


Figure 5.1 Schematic of Section 7 endangered species consultation process (from U.S. Coast Guard 2002).

NCP- National Contingency Plan.

ACP- Area Contingency Plan.

FOSC- Federal On Scene Coordinator.

The timing of a spill would define the threat to turtles imposed by boom deployment at a particular location. A spill at nesting or hatching time could have severe consequences to a turtle population. At other times, impacts might be minimal. In either case, consultation with resource experts and careful monitoring for turtle activity is advisable throughout a spill response in order to consider impacts of proposed response strategies on nesting and hatching events.

Offshore Dispersant Application

Chemical dispersants contain surfactants that reduce the surface tension of oil, enabling the oil layer to be broken into fine droplets that mix into the water column and are dispersed by currents. Most oils will, to some degree, physically disperse naturally from agitation created by wave action and ocean turbulence; chemical dispersants are designed to enhance this natural process. Rapidly dispersing oil early in a spill reduces the oil on the water surface and thus the amount of oil available to be driven ashore by winds. In contrast, oil droplets dispersed in the water column are unlikely to strand ashore because they are driven by currents, not winds. An added benefit of dispersing oil is that dispersants inhibit the formation of tarballs, a known hazard for turtles.

Dispersants are typically sprayed directly onto floating oil as fine droplets, either from aircraft or boats, generally within the first several hours after a spill. Under appropriate conditions, lighter fuel to medium crude oils can be easily dispersed; heavier bunker oils much less so. Weathering increases oil viscosity and may cause formation of water-in-oil emulsions, which are less amenable to dispersion. Among the advantages of dispersants are that they can treat large areas of spilled oil quickly and effectively before the slick can spread significantly; can be applied in rougher weather and sea conditions than mechanical recovery methods; and can be used in areas too remote to deploy mechanical protection and cleanup methods.

ppm - parts per million.

Ideally, chemical dispersants should be applied in well-mixed waters, where the dispersed oil plume can be diluted to low levels before reaching productive nearshore waters. After dispersion into the water column, spreading or diluted oil becomes three-dimensional, and concentrations drop rapidly. The highest concentration of chemically dispersed oil typically occurs in the top meter of water during the first hour after treatment. Concentrations of more than 10 parts per million (ppm) of dispersed oil are unlikely below 10 m; even within 1 m, concentrations rarely exceed 100 ppm. The continuous mixing and dilution of open waters are sufficient to rapidly reduce these concentrations; field studies indicate that they decline to nearly undetectable or background levels within several hours of application. Dispersed oil droplets break down by natural processes such as biodegradation. The chemical dispersants applied, like the oil droplets, are diluted by diffusion and convective mixing, and readily biodegrade. Laboratory studies indicate that dispersed oil biodegrades much more rapidly than undispersed oil (within days to weeks).

Untreated surface oil can recoalesce in surface convergence zones even after it has spread to a very thin layer, and surfactants help to prevent this reoccurrence. Since juvenile turtles aggregate along convergence zones, using dispersants should reduce their exposure to oil. Dispersants also reduce adherence of oil droplets to solid particles and surfaces, and may reduce the tendency of oil to stick to turtle skin.

Unfortunately, little is known about the effects of dispersants on sea turtles, and such impacts are difficult to predict in the absence of direct testing. While inhaling petroleum vapors can irritate turtles' lungs, dispersants can interfere with lung function through their surfactant (detergent) effect. Dispersant components absorbed through the lungs or gut may affect multiple organ systems, interfering with digestion, respiration, excretion, and/or salt-gland function—similar to the empirically demonstrated effects of oil alone.

Although early dispersants contained components that were highly toxic to aquatic life, toxicity is significantly reduced in modern formulations. For fish and other species that have been tested, dispersed oil is generally no more toxic than undispersed oil. Lutz created a very general framework for considering toxicity of oil dispersants to sea turtles (Figure 5.2) based on known effects of oil and hypothesized impacts of chemical dispersants, but direct experimental evidence to support the framework has not been generated.

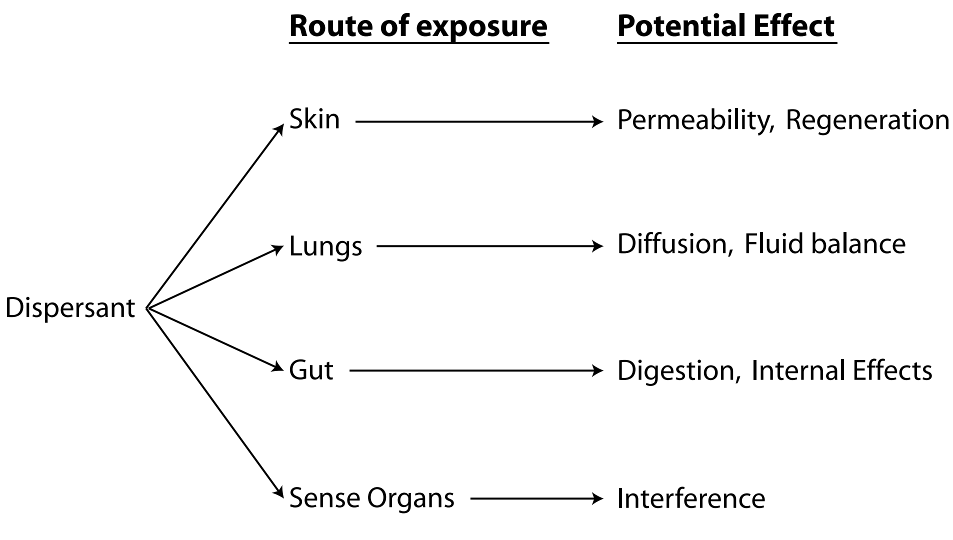


Figure 5.2 Conceptual framework for considering chemical dispersant effects to sea turtles (adapted from Lutz 1989).

As a general practice, surveying to ensure that no marine mammals or sea turtles are present can minimize the likelihood of direct contact with dispersant chemicals. Spraying might also be discouraged where turtles congregate, such as sargassum mats and convergence zones. But even with the disadvantages of dispersants, the consequences of sea turtles coming into contact with and ingesting floating oil (see Chapter 4) may argue for using their use to retard the formation of tarballs.

If applied appropriately offshore, chemical dispersants could be an effective tool for protecting turtles and the nearshore habitats they utilize. Possible effects on organisms in the water column and tradeoffs among resources at risk (such as coral reefs and seagrass beds) should be considered in spill response planning and decision-making.

Most regions that are home to turtle nesting sites and foraging areas have dispersant contingency plans in place. These plans have designated, specific pre-approval zones and guidelines for dispersant use, facilitating the decision-making process should a spill occur.[4]

Offshore *In-situ* Burning

In-situ burning is a response technique in which spilled oil is burned in place. Under appropriate conditions, *in-situ* burning can remove large quantities of oil quickly and efficiently. Although this method has been effectively used for certain shoreline habitats (marshes, for example), consideration here is limited to using it on the open ocean.

In a typical *in-situ* burn in open, marine waters, oil is collected within a fire-resistant, U-shaped boom, towed away from the main slick, and ignited. The boom is towed slowly to maintain the oil toward the back end—at the bottom of the U—and at a sufficient thickness to sustain the burn. Most crude and refined oils will burn on water if the oil layer is at least a few millimeters (more than 2 to 3 mm) thick. The technique is less effective if winds are blowing harder than 20 knots and seas are higher than a half to 1 m, impeding the operator's ability to control the boom and maintain the necessary oil thickness. *In-situ* burning can be used simultaneously with other oil spill response techniques or when other techniques are not feasible. The response window can last several days, although burn efficiency is reduced by significant emulsification, evaporation of lighter and more easily burned volatiles, and spreading of spilled oil. Consequently, burning at sea is most effective early in a spill response.

A major potential advantage of *in-situ* burning is that it can remove large quantities (over 90 percent at maximum efficiencies) of contained oil, potentially exceeding the maximum efficiencies of mechanical and chemical response methods. Burning also requires less equipment and fewer personnel and produces less waste for disposal than other cleanup techniques. In remote areas and near sensitive habitats, where minimizing disturbance is desirable, *in-situ* burning can offer significant logistical and environmental advantages.

Potential disadvantages of *in-situ* burning include production of highly visible smoke and other combustion by-products. Using this method in highly populated areas may be restricted due to concerns about the effect of fine particulate material in the smoke on human respiratory health. Special Monitoring of Applied Response Techniques (SMART) protocols were developed by the U.S. Environmental Protection Agency, the U.S. Coast Guard, NOAA, and the Agency for Toxic Substances and Disease Registry (ATSDR) to monitor particulate levels and provide real-time feedback to responders when burning is conducted near population centers. Such feedback helps responders determine levels at which smoke does not pose human health risks.

ATSDR - Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services.

A practical limitation of burning is that the specialized boom that is used is expensive and not widely stockpiled around the coasts. Despite its limitations, the general consensus among researchers is that *in-situ* burning has a definite role in certain inshore situations (e.g., oil trapped in marshes), in ice, and where oil is being continuously released from a stationary source such as a well blowout (PMG, Inc. 2001).

Presumably, any *in-situ* burning would involve surveying the immediate area for turtles before proceeding. During a 1993 full-scale test of *in-situ* burning off the coast of Newfoundland, wildlife surveillance and hazing teams reportedly spotted a sea turtle in the test area prior to the burn ignition, but there was no indication of adverse effect to it or any other wildlife. Obviously, *in-situ* burning would be an unlikely response choice where sea turtles aggregate—although in such an area, the impacts of prolonged or heavy exposure to untreated surface oil would be evaluated against the risks. The ability of response crews to sufficiently control and steer burning oil away from turtles in the water would be a major factor. Although a burn operation is fairly localized, whether sea turtles would avoid it is not known.

While the effects of smoke on sea turtles in particular have not been studied, at least one physiologist asserts that "lungs are lungs" and the effects should be similar for all air-breathing vertebrates. Evaluating human health risk from smoke plumes has focused on inhalation of very fine particulate material (termed PM10, or particulate material less than 10 microns in diameter) as the greatest risk factor. Fine particles can become lodged deep within the alveoli of the lungs, compromising respiratory capacity. Because turtles must surface regularly to breathe, they are at risk from inhaling gases and particulates present in a plume near the surface. Another hazard is that after a burn, a small percentage of the original oil volume remains as a taffy-like residue, which must be collected and disposed of properly. Since turtles are known to ingest tarballs and other solid materials they encounter, it is important that these residues be removed. In addition, under certain circumstances burned oil can sink, so operational personnel should evaluate the potential for burn residues to be denser than seawater. If this is likely to

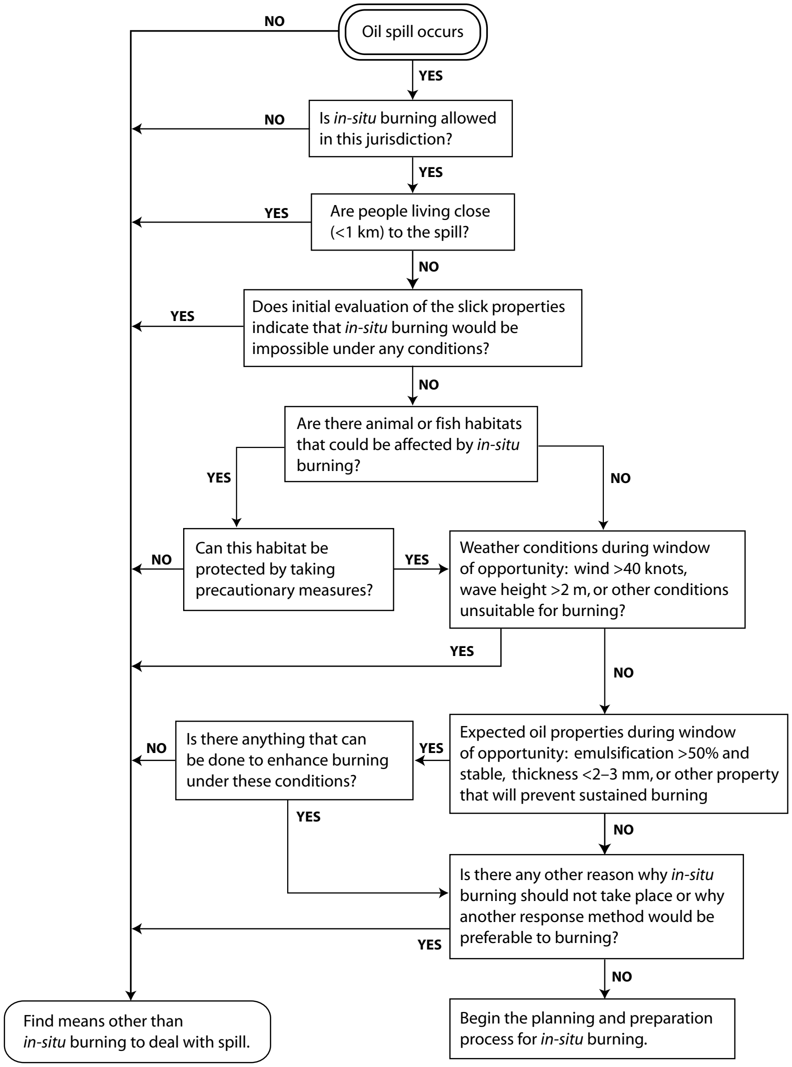
PM10 - particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers.

happen near sea turtle habitat, *in-situ* burning would not be appropriate because sea turtles might try to eat the submerged oil residues.

Laboratory and field studies of potential toxicity effects indicate situ burning does not have adverse effects on the underlying water column beyond those associated with unburned oil. Almost all heat is directed upward and outward, so heat absorbed by the underlying water is generally negligible, particularly where currents continuously exchange water beneath the burn.

Figure 5.3 portrays a decision flowchart for *in-situ* burning that illustrates how wildlife considerations are factored into the overall framework for evaluating use of the technique.

Figure 5.3 Decision flowchart for evaluating in-situ burning as a spill response option (adapted from U.S. Coast Guard and Environment Canada 1998).



Shoreline Cleanup

Oil stranded on shorelines presents the greatest risk to sea turtles during the nesting season (Lutcavage et al. 1997). When oil comes ashore after nests have been dug and eggs laid, the response priority would be to protect the nests during cleanup and make every effort to remove oil from beaches and nearshore areas before eggs hatch and hatchlings head to sea (incubation is two months).

The general requirements for nesting beaches (Chapter 2) are that they be high enough to prevent tidal inundation, porous enough for gaseous exchange, and have moisture and sand grain characteristics that permit effective excavation. Depending on the specific situation and the time of year relative to nesting, many of the usual and accustomed shoreline cleanup methods appropriate for sand beaches may be employed—but with additional caveats. Manual methods, mechanical cleanup (with some constraints), use of sorbents, sediment reworking, and vacuum techniques have all been successfully used to collect and/or reduce the degree of oiling on sand beaches. Oiled wrack or debris could also be collected and disposed—although this would need to be balanced against the increased foot traffic and potential for disturbance.

Passive Methods

Passive response methods rely on some mechanism to collect and hold oil until workers can remove it for disposal. The most common are absorbents and adsorbent booms and pads, which act as sponges to bind and channel oil. Adsorbent equipment, primarily "pom-poms" or snare booms, bind oil to exterior surfaces of oil-attracting (oleophilic) material (Figure 5.4). Either approach requires tending to ensure proper deployment and replacement when saturated with oil.

Figure 5.4 A sea turtle nest endangered by the 1993 Bouchard B155 oil spill in Tampa Bay. The trench and adsorbent snare boom (black material on the ocean-facing side of the nest) are intended to reduce the severity of exposure from any oil stranding near the nests. Photo courtesy of Dr. Anne Meylan, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute.

Oleophilic - **oil-attracting.**

Manual and Mechanical Oil Removal

Both manual and mechanical removal methods work well on sand beaches, and both have been used at turtle nesting sites. Manual removal is preferred because it requires less heavy equipment and tends to remove less sand. Sand removal should be minimized as much as possible on turtle nesting beaches, and beach profiles should not be altered because female turtles coming ashore to dig nests could become disoriented. However, if oiling is extensive and subsurface oiling is present, mechanical methods can be used with some precautions and careful oversight. A combination of mechanical and manual removal methods were used at spills in Tampa Bay and Puerto Rico (see pages 76 and 78).

Disposing of oiled sand is an important aspect of manual or mechanical removal, because it involves transporting potentially large quantities of material to treatment or disposal sites. Offsite treatment, and later replenishment, is an alternative that can be considered, especially where sand is not naturally replenished on beaches. At the *Berman* barge spill in Puerto Rico, oiled sand was treated off-site; however, the cleaned sand was not redeposited on the beach. Instead it was used for construction projects.

Turtle nests should not be disturbed during cleanup activities. This guidance is complicated by the fact that, in most cases, when oil is threatening a nesting beach during nesting season, the majority of sea turtle nests will be unmarked. If nesting locations are known, they can be protected by controlling access routes to the beach, marking and fencing sites, and carefully deploying equipment and personnel. It is unlikely that turtle nests would be directly impacted if shorelines were oiled after eggs had been deposited, since females typically dig nests well above the high-tide line. However, survey and response workers could conceivably crush eggs, and sand could be compacted over nests, which would make it difficult for hatchlings to emerge. At the barge *Bouchard B155* spill in Tampa Bay (page 76), the relatively small number of turtle nests on area beaches made it possible for volunteers to clearly mark nest locations and protect them with a fence. Hatchlings were collected, transported south to another county, and released (A. Meylan 2002[5]). Mechanical cleanup methods were used extensively at this spill, largely because of the challenge of removing thick layers of buried oil. However, response vehicles were restricted to the middle and lower intertidal levels, well away from nesting sites.

Generally, fencing and marking nests after a spill, or when a threat exists, works only for the most recent nests, not for those that have been in the ground for a longer time. Figure 5.4 illustrates some important aspects of the approach resource managers used during the *Bouchard B155* spill: the nest is conspicuously marked (not simply a stake), and it encloses a large area that includes a buffer. The buffer area was a critical protective zone when the beach was worked by heavy equipment (A. Meylan 2002[6]).

Bioremediation

Bioremediation, specifically adding nutrients to a spill area, can speed oil degradation in many habitats, including sandy beaches (Venosa et al. 1996). A major limitation of bioremediation at turtle nesting beaches is that it takes at least several weeks before oil is successfully degraded to background levels. Time is often critical when cleaning oil in turtle habitats. If oiling occurs when no turtles are present or expected within approximately six weeks, then nutrients could be added after the major portion of the oil has been removed by other methods.

One approach considered to be a bioremediation technique on sand beaches is tilling, in which the beach surface is worked with equipment to expose and aerate oil residues. Although tilling is frequently used on recreational beaches (it resembles grooming practices common in such areas), it is not recommended on nesting beaches because it would be disruptive.

Vacuuming

Vacuuming can remove pooled oil or thick oil accumulations from the sediment surface, depressions, and channels. Vacuum equipment ranges from small units to large suction devices mounted on dredges or trucks. Vacuuming can be used effectively on heavier and medium oils, provided they are still reasonably fluid. Lighter, more flammable petroleum products, such as jet fuel and diesel, generally should not be vacuumed.

Indirect Response Impacts

Unintended adverse impacts to turtles may be caused by response activities, and should be anticipated and controlled. Examples include:

- Foot and equipment traffic in nesting areas. Compressing sand in the upper intertidal and dune areas should be avoided because compression makes it more difficult for females to dig nests and for hatchlings to dig themselves out. Equipment and personnel also can crush eggs in nests. Vibrations from heavy machinery may result in hatchlings emerging from their nests during the day, timing that would leave them more vulnerable to predators (S. Milton 2002[7]).
- Artificial light. Any artificial lighting associated with the response should be minimized during the nesting season, because females and hatchlings, which are attracted to bright light, are easily disoriented by artificial lighting. Turtle researchers try to minimize even the use of flashlights at night. Witherington and Martin (2000) provide extensive, detailed information and guidance on lighting considerations that affect sea turtle behavior. This would prove to be a practical and relevant reference during a major spill response in which beach activity could take place at night.
- Artificial barriers on the beach, including berms, sorbents, and booms can prevent hatchlings from reaching the water and adult females from reaching potential nesting sites. For hatchlings, temporary entrapment by a boom can increase the risk of predation during their migration to the water, when they are especially vulnerable to predators.
- Small boat traffic and increased collision risk. Boat operators working in offshore shallow areas need to be cognizant of the risk of colliding with swimming turtles and take precautionary measures.

Preventative Measures

A potential worst-case scenario was faced during the Ixtoc I well blowout in 1979, when the only nesting site of the Kemp's ridley turtle was threatened by oil during the nesting season. When there seems to be no other option, or if a large percentage of an entire species' population may be at risk from oiling, nests may need to be relocated or hatchlings captured and released at a location free of oil.

Relocating Nests

Relocating sea turtle eggs should only be undertaken when other alternatives are not available. Nests should be relocated only within 12 hours of egg deposition, after which moving an egg is likely to disturb the newly attached egg membranes and kill the embryo. Eggs may also be moved after 14 days of incubation (Limpus et al. 1979). The eggs should be handled gently and any unnecessary movement (especially rotation) avoided. If relocation is adopted as an option during a spill, only trained, experienced, and authorized personnel may disturb nests or move eggs. In addition, specific permits from state and federal regulators will likely be necessary for specialists handling turtles and turtle nests.

Capture and Release of Hatchlings

Another mitigation technique is to leave the eggs to hatch naturally from their nests, but to capture the turtle hatchlings before they migrate to the water. Hatchlings are then released at an alternative location, free of oil. This technique was used for Kemp's ridley hatchlings during the Ixtoc I spill (described in greater detail on page 73).

Application of Sea Turtle Information for Spill Response and Planning

ESI - Environmental Sensitivity Index map.

Since we already know that it is a good idea to prevent sea turtles from coming into contact with oil, finding operational and practical spill response information is important in any response planning. An initial question asked at any incident is, "What is at risk?" For turtles, a spill response tool developed and supported by NOAA is the Environmental Sensitivity Index (ESI) atlases, which portray geomorphology (shoreline characteristics) and resource information for an area. Turtles are a major feature of Florida's ESI maps, which depict nesting beaches, in-water distribution, shoreline habitats, species composition, seasonality, relative concentration, nesting beach survey boundaries, and source documentation (Zengel et al. 1998). Much of the information was provided by state biologists and resource managers. Figure 5.5 is an example of the resultant product.

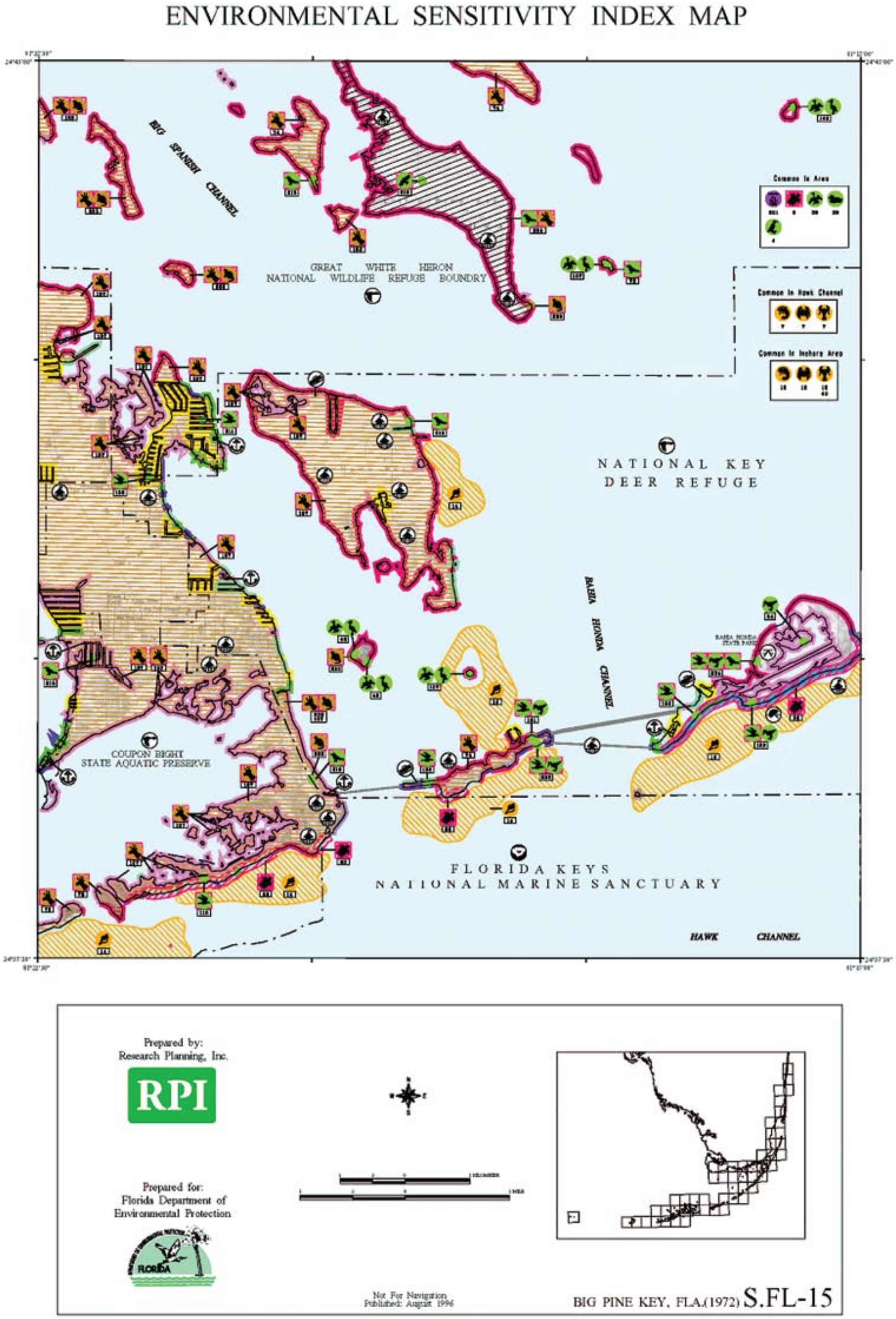
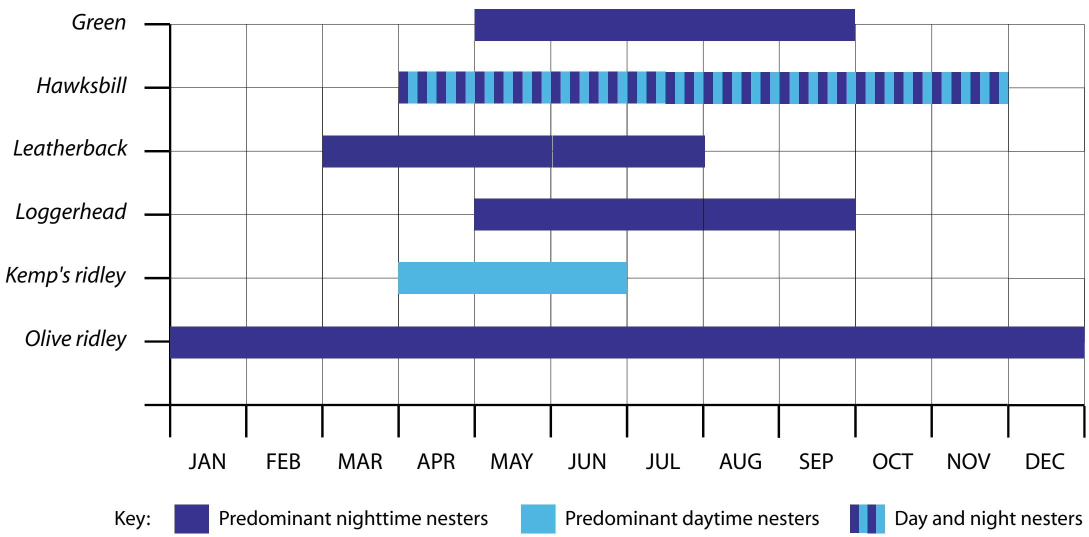


Figure 5.5 An Environmental Sensitivity Index map for South Florida's turtle habitat areas.

In other U.S. waters, there is enough basic information about nesting patterns that can be consolidated into a quick graphic reference that shows which turtles might be at risk at a given time of day and year from an oil or hazardous chemical release and subsequent response to it. Figure 5.6 shows that the middle of the year—from around March through September—is when oil spilled on or near nesting beaches would likely result in the greatest exposure to turtles. Conversely, December through February is a period of low activity near the beaches themselves. The figure also shows the generally observed day and night timing patterns for nesting across species; that is, which species typically come ashore at night and which ones come ashore during the day. As might be expected, this graphic comes with a qualifier; it should be used as a general reference only, and local biological experts should always be consulted as the primary source of information.

Figure 5.6 Times when oil near or on nesting beaches will have the most and least effect on turtles, by species. From Miller (1997) and U.S. Fish and Wildlife Service (2003).



In the United States, the state of Florida has been most active in attempting to provide a standardized approach to interactions with sea turtles and sea turtle nests. Florida has developed comprehensive guidelines for dealing with sea turtles on state beaches. Excerpts from a single section of Florida's "Marine Turtle Guidelines" are included as Appendix B. The full document is available online at http://floridaconservation.org/psm/turtles/Guidelines/MarineTurtleGuidelines.htm.

Appendix B includes only the material that might be instructive for spill response and shoreline survey activities, nesting surveys, and identification of nesting sites. The guidelines describe appropriate ways to identify and mark nesting sites, which might be adapted for use during oil spill responses. While a spill responder needs to have a complete understanding of how various spill containment and cleanup operations may affect sea turtles in the water and on the nesting beach, he or she does not need to have the sort of training that permit holders possess to handle marine turtles, hatchlings, and nests. Florida permit holders have this information already, and other states may have different requirements. As previously noted, anyone engaging in these direct activities with sea turtles would need to be properly permitted and possess this expertise and training.

Readers are encouraged to view the complete Florida guidelines to more fully understand the complexities of managing turtles in close proximity to human populations. While they are specific to Florida (other jurisdictions will have different or perhaps conflicting policies for dealing with turtle issues), they are nevertheless relevant and usable for spill responders in the field.

During a Fort Lauderdale oil spill of undetermined origin in 2000 (see page 79), both the U.S. Fish and Wildlife Service (USFWS) and the Florida Fish and Wildlife Conservation Commission sea turtle staff were asked to provide general guidance on how to minimize impacts to sea turtles. The following simple guidelines were provided (S. MacPherson 2002[8]):

- Daily early morning nesting surveys should be completed prior to any heavy equipment being allowed on the beach.
- Nests should be marked for avoidance by heavy equipment.
- Hatchlings emerging from nests in an area where oil is present on the beach and/or in the adjacent offshore area should be collected and released on a non-impacted beach.
- If oiled turtles start washing ashore, stranding surveys may need to be increased to more than once per day.

Handling and Rehabilitation

Beyond the observation that turtles are seriously harmed by oil contact, we know very little about actual cause-and-effect relationships related to sea turtle oil exposure. Not knowing what physiological systems are most vulnerable, it is not possible to recommend precise rehabilitation measures, except those related to salt gland function (detailed below). Otherwise, little firm information is available on which to base rehabilitation best management practices during an oil spill. As a result, well-intentioned but questionable ad hoc rehabilitation efforts have been documented: for example, in 1990, a young hawksbill turtle covered with crude oil was found off Kralendijk, Bonaire, and taken to a mariculture facility, where it was cleaned with kerosene and detergent (Sybesma 1992).

STSSN - Sea Turtle Stranding and Salvage Network.

While not necessarily oil-specific, there are, however, well-established procedures in many areas of the United States for dealing with stranded sea turtles , defined as those that wash ashore either dead or alive. A national Sea Turtle Stranding and Salvage Network (STSSN), established in 1980, provides protocols for documenting and handling stranded animals (Shaver and Teas 1999). In the event of an oil spill where sea turtles could be affected, state coordinators for the STSSN (where designated) should be contacted, and shoreline assessment activities should be coordinated with these trained and permitted experts. Appendix C is a list of current STSSN coordinators for the Atlantic and Gulf coasts.

Some guidance for handling sea turtles during spills does exist and is included below as reference material and to serve as a possible basis for action. Appendix A, the at-sea handling protocol prepared by Dr. Anne Meylan of the Florida Marine Research Institute, is one example. The protocol was created during the 1993 *Bouchard B155* barge spill in case large numbers of turtles were encountered during the response and cleanup. Although they are simple, common sense guidelines, they provide a consistent and standardized framework for dealing with sea turtles and are a useful addition to spill response guidance in a specific setting.

Another example, which would be applied under the auspices of trained wildlife veterinarians and resource managers, is more narrowly focused on treatment and monitoring of oiled sea turtles in a rehabilitation center. Walsh (1999) provides an excellent overview of general rehabilitation practices for sea turtles, and other experienced wildlife veterinarians and physiologists (e.g., Bossart 1994[9]; Mignucci-Giannoni 1999) have provided insights that might be incorporated into standard operating procedures during cleaning and rehabilitation activities for a given spill. Some procedures are shared with bird-cleaning protocols; others have been found to work well with turtles in particular. The guidelines are:

- Remove surface oiling

  …dishwashing detergent (e.g., Dawn®) or other mild surfactants have been used, along with copious amounts of warm water (Walsh 1999).

  …food oils, such as olive, sunflower, or soy, have been found to be effective in breaking up and removing external oiling (Mignucci-Giannoni 1999; Levy 2002[10])
- Rinse and dry
- Repeat cleaning

  …24 to 48 hours later dependent on health status (cleaning cycle repeated until all physical oiling removed (Mignucci-Giannoni 1999)
- Clean head and oral cavities

  …(cloths dampened with food oil)
- Administer organic fats (mayonnaise)

…via force-feeding tube (Walsh 1999; Levy 2002; Schaf 2002[11]) to facilitate clearance of oil or tar fouling in the esophagus and gastrointestinal tract.

- Orally administer material to coat gastrointestinal lining

  …and provide relief from irritation (olive oil or Pepto-Bismol®) (Mignucci-Giannoni 1999; Bossart 1994[12])

  …if ingestion is suspected, charcoal-containing compounds may decrease absorption of hydrocarbons that can cause organ damage (Walsh 1999)

- Support with fluids

  …(interperitoneal if necessary)

- Monitor output of tears

  …(secretions) from salt glands (see discussion below)

- Reassess health status daily

  …serial blood samples can help to direct therapy (Walsh 1999)

  …consider euthanasia for very poor condition animals (USFWS permits required)

Figure 5.7 An oiled green turtle recovered by the Israeli Sea Turtle Rescue Center in August 1999. This and another individual were cleaned, rehabilitated, and released about two months later. The source of oiling was not identified. Photo courtesy of Yaniv Levy, Israeli Sea Turtle Rescue Center, Hofit, Israel.

Observations in the sea turtle oiling experiments conducted by Lutcavage et al. (1995) (Chapter 4) and at the 1993 Tampa Bay spill suggest that oil exposure can cause turtle salt glands to effectively shut down, at least temporarily. In the Tampa Bay incident, this phenomenon was observed in sea turtles that were cleaned prior to release. Because the salt gland function appears to return to normal slowly, Lutcavage (1994[13]) and Lutz (2002[14]) recommend holding rehabilitated animals for at least 10 to 14 days in isosmotic, one-third seawater and monitoring the osmolarity of salt gland output by collecting and measuring tear salinity with an osmometer.

Osmolarity - the concentration of an osmotic solution, especially when measured in osmols or milliosmols per liter of solution.

As noted in Chapter 2, the sea turtle salt gland is not always turned "on;" that is, it must be stimulated by exposure to a salt load. Differences in osmolarity of secretions are substantial between inactive and active salt glands. Lutz (1996) summarized results from several studies to show that the scant secretions from inactive salt glands measure around 300 to 400 milliosmol/kg (about equal to turtle plasma), while stimulated salt gland secretions average around 1,900 milliosmol/kg, about twice the salinity of seawater. Lutz noted that the osmolarity for salt gland secretions from two species, greens and loggerheads, were nearly equal: 1,900 and 1,854 milliosmol/kg. In a spill rehabilitation setting, veterinary staff should, at a minimum, ensure proper function of salt glands before releasing individuals back to the wild, because animals may be imperiled if released prematurely (M. Lutcavage[15]).

Finally, for veterinary professionals dealing with the basics of sea turtle care and rehabilitation, a recently published NOAA technical memorandum, "The Anatomy of Sea Turtles" (Wyneken 2001) is a key reference document. This profusely illustrated, in-depth technical document should be considered as a remarkable and necessary resource for those involved in veterinary medicine related to sea turtles. It is currently available in three forms: print, CD-ROM, and online in pdf format at http://courses.science.fau.edu/~jwyneken/sta/).

For Further Reading

Allen, A. A., and R. J. Ferek. 1993. Advantages and disadvantages of burning spilled oil. In: *Proceedings of the 1993 International Oil Spill Conference*, March 29–April 1, 1993, Tampa, Fla. pp. 765–772.

American Petroleum Institute (API), National Oceanic and Atmospheric Administration, U.S. Coast Guard, and U.S. Environmental Protection Agency. 2001. Characteristics of Response Strategies: A Guide for Spill Response Planning in Marine Environments. API, Washington, D.C. 78 p.

Caribbean Regional Response Team. 1995. Dispersant Usage Plan. In: Use of dispersants in the Caribbean. Prepared for Caribbean Regional Response Team, Response and Technology Committee, Dispersant Workgroup, San Juan, Puerto Rico. 71 p.

Daykin, M., G. Sergy, D. Aurand, G. Shigenaka, Z. Wang, and A. Tang. Aquatic toxicity resulting from *in-situ* burning of oil-on-water. In: *Proceedings of the Seventeenth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar*, June 8–10, 1994, Vancouver, B.C., Environment Canada, Ottawa, Canada. 2: 1165–1193.

Fingas, M. F., F. Ackerman, K. Li, P. Lambert, Z. Wang, M. C. Bissonnette, P. R. Campagna, P. Boileau, N. Laroche, P. Jokuty, R. Nelson, R. D. Turpin, M. J. Trespalacios, G. Halley, J. Belanger, J. Pare, N. Vanderkooy, E. J. Tennyson, D. Aurand, and R. Hiltabrand. 1994. The Newfoundland Offshore Burn Experiment—NOBE: Preliminary results of emissions measurement. In: *Proceedings of the Seventeenth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar*, June 8–10, 1994, Vancouver, B.C., Environment Canada, Ottawa, Canada. 2: 1099–1164.

Fingas, M. F., G. Halley, F. Ackerman, N. Vanderkooy, R. Nelson, M. C. Bissonnette, N. Laroche, P. Lambert, P. Jokuty, K. Li, G. Halley, G. Warbanski, P. R. Campagna, R. D. Turpin, M. J. Trespalacios, D. Dickens, E. J. Tennyson, D. Aurand, and R. Hiltabrand. 1994. The Newfoundland Offshore Burn Experiment—NOBE: Experimental design and overview. In: *Proceedings of the Seventeenth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar*, June 8–10, 1994, Vancouver, B.C. 2: 1053–1163.

Fingas, M. F., and M. Punt. 2000. *In-situ* burning: A cleanup technique for oil spills on water. Emergencies Science Division, Environmental Technology Centre, Environment Canada, Ottawa, Ont. 214 p.

Fritts, T. H. and M. A. McGehee. 1982. Effects of petroleum on the development and survival of marine turtle embryos, U.S. Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C., Contract No. 14-16-0009-80-946, FWS/OBS-82/37.

International Maritime Organization (IMO). 1997. *Field Guide for Oil Spill Response in Tropical Waters*. IMO, London. 54 p.

Limpus, C. J., V. Baker, and J. D. Miller. 1979. Movement induced mortality of loggerhead eggs. *Herpetologica* 35: 335.

Lutcavage, M. E., P. L. Lutz, G. D. Bossart, and D. M. Hudson. 1995. Physiologic and clinicopathologic effects of crude oil on loggerhead sea turtles. *Arch. Environ. Contam. Toxicol.* 28: 417–422.

Lutz, P. L. 1989. Methods for determining the toxicity of oil and dispersants to sea turtles. In: *Oil and Dispersant Toxicity Testing: Proceedings of a Workshop on Technical Specifications Held in New Orleans*, T. W. Duke and G. Petrazzuolo, eds. Prepared under MMS contract 14-12-0001-30447, OCS Study MMS 89-0042, pp. 97–101.

Lutz, P. L. 1997. Salt, water, and pH balance in the sea turtle. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. A. Musick, eds. CRC Press, Boca Raton, Fla. pp. 343–361.

Mignucci-Giannoni, A. A. 1999. Assessment and rehabilitation of wildlife affected by an oil spill in Puerto Rico. *Environ. Pollution* 104(2): 323–333.

Miller, J. D. 1997. Reproduction in sea turtles. In: *The Biology of Sea Turtles*, Vol. I, P. L. Lutz and J. A. Musick, eds. CRC Press, Boca Raton, Fla. pp. 51–81.

NOAA, Hazardous Materials Response and Assessment Division. 1993. Shoreline countermeasures manual: Tropical coastal environments. NTIS PB94-160926. Hazardous Materials Response & Assessment Division, NOAA, Seattle, Washington. May. 80 p. + appendices.

Potomac Management Group, Inc. 2001. Risk assessment for the Coast Guard's Oil Spill Prevention, Preparedness and Response (OSPR) Program: Phase I—concept development, risk characterization and issue identification. Prepared for U.S. Coast Guard Office of Response (G-MOR) under Contract # DTCG23-00-MM3A01.

Sybesma, J. 1992. WIDECAST sea turtle recovery action plan for the Netherlands Antilles, K. L. Eckert, ed. CEP Technical Report No. 11, UNEP Caribbean Environment Programme, Kingston, Jamaica. 63 p.

U.S. Coast Guard. 2002. Inter-agency Memorandum of Agreement regarding oil spill planning and response activities under the Federal Water Pollution Control Act's National Oil and Hazardous Substances Pollution Contingency Plan and the Endangered Species Act. A guidebook, version 2002. United States Coast Guard, Washington, D.C.

U.S. Coast Guard and Environment Canada. 1998. *In-situ* burning of oil slicks on water—procedures and techniques. Draft report. United States Coast Guard, Washington, D.C.

U.S. Fish and Wildlife Service. 2003. Data from web site: http://northflorida.fws.gov/seaturtles/turtle-facts-index.htm.

Venosa, A. D., M. T. Suidan, B. A. Wrenn, K. L. Strohmeier, J. R. Haines, B. L. Eberhart, D. King, and E. Holder. 1996. Bioremediation of an experimental oil spill on the shoreline of Delaware Bay. *Environ. Sci. and Technol.* 30: 1764–1775.

Walsh, M. 1999. Rehabilitation of sea turtles. In: *Research and Management Techniques for the Conservation of Sea Turtles*. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, pp. 202–207.

Witherington, B. E., and R. E. Martin. 2000. Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches. Technical Report TR-2, Second Edition, Revised, Florida Marine Research Institute, St. Petersburg, Fla. 73 p.

Wyneken, J. 2001. The anatomy of sea turtles. NOAA Technical Memorandum NMFS-SEFSC-470, Miami, Fla. 172 p.

Zengel, S., A. Meylan, H. Norris, M. White, L. Diveley, W. Holton, and K. Moody. 1998. Mapping sensitive sea turtle areas in Florida for oil spill response and natural resources management. In: *Proceedings of the 16th Annual Symposium on Sea Turtle Biology and Conservation*, R. Byles and Y. Fernandez, compilers. NOAA Technical Memorandum NMFS-SEFSC-412, Miami, Fla. pp. 156–157.

Chapter Notes

[1] L. Herbst, College of Veterinary Medicine, University of Florida, Gainesville, FL 32610, personal communication.

[2] See, for example, *Characteristics of Response Strategies: A Guide for Spill Response Planning in Marine Environments* (American Petroleum Institute et al., 2001) for an overview of typical response options for several habitats.

[3] Detailed descriptions of the various containment and collection techniques and equipment can be found in the comprehensive *Field Guide for Oil Spill Response in Tropical Waters*, available from the International Maritime Organization (IMO).

[4] See, for example, the Caribbean Regional Response Team Dispersant Usage Plan (CRRT 1995). See p. 66.

[5] A. Meylan, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, 100 Eighth Avenue SE, St. Petersburg, FL 33701-5095, personal communication, 2002.

[6] A. Meylan, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, 100 Eighth Avenue SE, St. Petersburg, FL 33701-5095, personal communication, 2002.

[7] S. Milton, Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431-0991, personal communication, 2002.

[8] S. MacPherson, U.S. Fish and Wildlife Service, 6620 Southpoint Drive South, Suite 310, Jacksonville, FL 32216, personal communication, 2002.

[9] G. Bossart, Harbor Branch Oceanographic Institution, Ft. Pierce, FL 34946, personal communication, 1994.

[10] Yaniv Levy, Israeli Sea Turtle Rescue Center, Hofit, Israel, personal communication, 2002.

[11] S. Schaf, The Turtle Hospital, Marathon, FL 33050, personal communication, 2002.

[12] G. Bossart, Harbor Branch Oceanographic Institution, Ft. Pierce, FL 34946, personal communication, 1994.

[13] M. Lutcavage, Edgerton Research Laboratory, New England Aquarium, Central Wharf, Boston, MA 02110, personal communication, 1994.

[14] P. Lutz, Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431-0991, personal communication, 2002.

[15] M. Lutcavage, Edgerton Research Laboratory, New England Aquarium, Central Wharf, Boston, MA 02110, personal communication, 1994.

Chapter 6 Case Studies of Spills that Threaten Sea Turtles

Ruth A. Yender and Alan J. Mearns

Key Points

- Sea turtles have been at risk of exposure in many oil spills, particularly in the Caribbean and Gulf of Mexico.
- There are surprisingly few reports of sea turtles or their nest sites being oiled or injured during the response to an oil spill.
- In recent years the typical incident threatening sea turtles is not from crude oil from a tanker, but rather from a fuel oil spill from grounded fishing vessels or cargo ships.
- Despite the potential for oil spills to harm sea turtles, actual incidents in which impacts have been documented are rare.
- Absence of documentation does not imply absence of effect, but is due to the low probability of observing and recovering oiled turtles.
- Most reports of sea turtle impacts are from Florida or the Caribbean.

Past and Present Spills that Threaten Sea Turtles

Planning response activities for spills that threaten sea turtles may be improved by understanding past spills and response to them. How many incidents occurred that threatened sea turtles? What kinds of accidents were most threatening? What products were involved? How many turtles were exposed, threatened, or affected? How did the response minimize injury to sea turtles? By studying and understanding the answers to these questions and considering them "lessons learned," we can improve preparedness and response methods for spills affecting sea turtle habitats.

To answer these questions, NOAA HAZMAT reviewed two sources of data and information on past spills and incidents in ocean areas occupied by sea turtles (accessible on the NOAA HAZMAT website at http://response.restoration.noaa.gov), along with three international case histories that occurred in recent years, but which are not in these databases.

HAZMAT - **NOAA Hazardous Materials Response and Assessment Division**

1. The NOAA HAZMAT Historical Incidents Database contains reports and images from about 1,000 oil spills and chemical accidents from 1977 to 2001. It includes mostly U.S. incidents, some significant international incidents, and incidents in which a spill was averted (no oil spilled), but which at the time posed a threat. It does not include inland events that occurred away from the coast or navigable waterways.

2. The 1992 NOAA HAZMAT Case History document includes information on 110 "significant" spills that occurred worldwide between 1967 and 1991. To these we added three additional international case histories that occurred in recent years, but which are not in these databases. Case histories summarized in this chapter are ones that exceeded 4 million gallons (gal) total (419,000 gal in U.S. waters); involved the use of dispersants; involved bioremediation; or involved severe environmental impacts (more than 500 birds and 100 mammals killed, over a mile of intertidal zone smothered, fisheries closed, etc.).

Both information sources were searched for spills that may have threatened sea turtles or their nesting sites and habitat. A word of caution. First, the information is not comprehensive, that is, not all spills and potential spills were reported. Therefore, interpretation of trends and frequencies need to be taken with a grain of salt. Second, these are mainly response reports and may not contain additional follow-up information, such as that appearing in the literature or in government or industry damage assessment and restoration reports many years after the initial spill response.

The Big Picture: 1967–2001

The years 1967 to 2001 included 126 incidents. Despite a long history of major oil spills, the case history files indicate that few incidents reported oiling, contaminating, or killing of sea turtles or oiling of nesting sites. Either turtles were rarely impacted or the historical files are not sufficiently complete or detailed to document injuries, protection strategies, or rehabilitations.

Number of Incidents

Of the incidents documented,104 mentioned sea turtles, and 91 incident reports suggest marine turtles may have been at risk. Oil or fuel actually spilled in only 67 of the 91 cases. Of these, oiled, injured, or dead sea turtles were reported in only seven cases: *Witwater*, *Alvenus*, Trague Beach (Guam), Gulf War, *Vista Bella*, *Barge Bouchard*, and *Barge Morris J. Berman*.

Locations of Spills

Of 110 incidents reported in the1992 NOAA HAZMAT Case History Report, 43 occurred in tropical and subtropical waters, approximately 30° N to 30° S, half of which were also reported in the historical incidents database. Only four (*Alvenus, Peck Slip, St. Peter,* and Virgin Islands Water and Power), explicitly listed turtles or nesting sites as resources at risk.

Volume Spilled

About 770 million gal of oil and fuel were spilled, most of it by the three largest and longest marine spills in history:

- the 1991 Gulf War spill in Kuwait and Saudi Arabia (252 million to 335 million gal);
- the 1979 Ixtoc I platform blowout in Campeche Bay, Gulf of Mexico, (147 million gal); and
- the 1983 Norwuz spill in the Arabian Gulf (79 million gal).[1]

Median volume of all tropical spills from 1967 to 2001 was 38,900 gal. Excluding the three mega-spills, the median volume was relatively unchanged (34,985 gal). From the 1960s through the 1980s, most larger oil spills were from shore facilities, damaged tankers, and oil platform accidents. Several nearshore spills resulted from vessel groundings.

Materials Spilled

Many potential or actual incidents involved two or more oil products. Of 121 separate (specific) products, only 42 (35 percent) were crude oils; the remaining 79 products (65 percent) were fuels, lube oils, and other refined products.

Response Methods

Responses mainly involved conventional methods for protection (booming) and removal (skimming, shoreline cleanup). Dispersants were used or considered on 34 spills—some successfully, others with little or no success. Most dispersants were used on international (non-U.S.) spills, but seven were in Puerto Rico, four in Texas, three in Louisiana, and one in New Jersey. There is no information about the extent to which oil or dispersants affected sea turtles.

The Past Decade (1992–2001)

Large crude oil spills decreased in frequency and volume in the last decade (NRC 2002). Seventy-three actual or potential spills occurred in tropical areas or at times when turtles were indicated as resources at risk.

Spill Locations

Geographically, most incidents occurred along the Gulf of Mexico (26) and Florida's Atlantic coast (9). Another 16 occured in the Caribbean (13 in Puerto Rico alone), 12 in Atlantic states north of Florida, 9 in the Pacific, and 1 in South America. Of these 73 cases:

- Sea turtles and their nest sites or habitats were noted at risk during response in 40 (55 percent) cases.

- Only three (4 percent) occurred where turtles or nest sites were noted as oiled or otherwise protected or rehabilitated.
- Fifty-two (71 percent) resulted in actual spills.
- Fifty-four incidents (74 percent) were from vessels; 13 (18 percent) were from pipelines, platforms, or docks.

Volume Spilled

The total volume spilled was 3.3 million gal: 2.5 million gal from vessels and 738,400 gal from stationary sources. The median incident release (including averted spills) was only about 3000 gal, a ten-fold decrease from the medians in the 34 years from 1967 through 2001. The median volume from mobile sources was 4,032 gal, ranging from 126 to 287,185 gal; from stationary sources, the median was 12,600 gal, ranging from 42 to 284,465 gal.

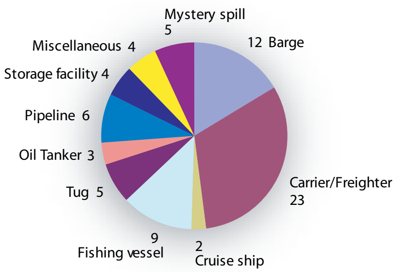


Figure 6.1 Sources of oil spilled in tropical areas, 1992–2001.

Sources

Among the mobile sources (Figure 6.1), 23 (43 percent) were from freighters (carriers), 12 (22 percent) from barges, 9 (17 percent) from fishing boats, and 5 (9 percent) from tugboats. Only 3 incidents (6 percent) involved tankers. Among stationary sources, 6 spills (46 percent) were from pipeline breaks, and 4 (31 percent) were from storage facilities.

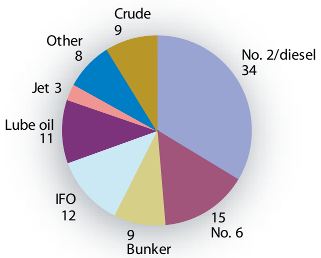


Figure 6.2 Types of oil and fuels spilled in tropical incidents, 1992–2001.

Material Spilled

As shown in Figure 6.2, the most frequent material was diesel or No. 2 fuel oil (34 cases), followed by No. 6 fuel (15), intermediate fuel oils (12), lube oil (11), Bunker C (9), crude oil (9), other refined products (8), and jet fuel (3). Thus most spills threatening turtles during the past decade involved refined products (89 percent), not crude oil. Twenty of the 54 incidents spilled more than one product for a total of 101 product spills.

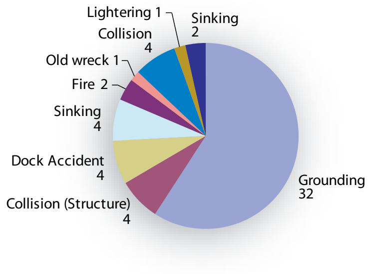


Figure 6.3 Causes of incidents in tropical areas, 1992–2001.

Cause of Spills

Fifty-four spills were from mobile sources (vessels), 13 from stationary sources, and 6 from other sources.

Of the spills from mobile sources (Figure 6.3), 32 (60 percent) were from vessel groundings, and the rest from collisions, dock accidents, sinkings, fires, and lightering. Of all spills in tropical waters between 1992 and 2001, most (85 percent) occurred from the shoreline or very close to shore.

Response Methods

Responses to most spills involved traditional methods of containment (boom) and removal (skimming, shoreline cleanup). Dispersants were used or considered on 12 spills; spills were averted in 3 incidents. Three dispersed spills occurred in Puerto Rico, 2 in Texas, and 1 each occurred at St. Eustatius, Galapagos Islands; New Jersey; and Punta del Este, Uruguay. There is no information about the extent to which oil or dispersants affected sea turtles.

Selected Case Studies

Although many oil spills have occurred in areas populated by sea turtles, cases of large numbers of turtles directly impacted by a spill are very rare. This may be due, in part, to the fact that sea turtles have wide ranges and usually are highly dispersed. In assessing impacts from past spills, it is important to recognize that the effects of oil on sea turtles probably are not well-reflected by the few reported observations of oiled turtles. Documenting the number of turtles affected by an oil spill is difficult. Many impacted turtles are unlikely to be observed or recovered. Furthermore, most reports of spill-related sea turtle impacts are anecdotal, and the cause of death is usually poorly documented. Oil spills where impacts to sea turtles have been documented are summarized briefly below.[2]

1968 Oil Tanker SS *Witwater*

The oil tanker SS *Witwater* ruptured in heavy seas off the Carribean coast of Panama on 13 December 1968, spilling over 588,000 gal of diesel and Bunker C oils approximately 3.7 km northeast of Galeta Island (NOAA 1992). The oil eventually washed onto sand beaches, rocky coasts, and mangroves on Galeta Island. High winds caused a spray of mixed seawater and oil to cover trees and shrubs in the suptralittoral zone up to 2 m above mean high-tide level. Red and black mangrove trees were severely oiled, killing most red mangrove seedlings, the algal community, and invertebrates. Researchers also observed dead and dying young sea turtles on oiled mangrove beaches two months after the spill, however the exact cause of death was not determined (Rutzler and Sterrer 1970).

1979 Ixtoc I Well Blowout

On 3 June 1979, the Ixtoc I, an offshore exploratory oil well located 80 km off Ciudad del Carmen, Mexico, suffered a massive blowout of its wellhead and began releasing oil into the Bay of Campeche. Thousands of barrels of oil were released daily until the spill was brought under control in late March 1980 (Hooper 1981). The oil drifted north, eventually impacting portions of the Mexican and Texas coasts. During the interval between the release of oil and its impact on shorelines, weathering significantly altered the oil's original physical and chemical properties, and a water-in-oil emulsion, or mousse, formed.

The spill threatened a primary nesting beach of the Atlantic Kemp's ridley sea turtle near Rancho Nuevo, Tamaulipas, Mexico. The nests were aggregated in arribadas of thousands of females. In Mexico, hatching begins in mid-June, and the hatchlings continue to emerge until mid-September, then swim west and north during the next two months.

MDF - **Mexican Department of Fisheries.**

The Ixtoc I blowout occurred after nesting but before all hatchlings had migrated across the beach to the water. Due to concerns that the young turtles would become oiled onshore or ingest oil in the water, the Mexican Department of Fisheries (MDF) and the U.S. Fish and Wildlife Service (USFWS) planned to airlift approximately 9,000 turtle hatchlings if the oil threatened the nesting beach. By July 23, oil was observed less than 50 km from Rancho Nuevo, so MDF and USFWS moved 9,000 hatchlings to protected lagoons, but by July 27 high seas flowed over islands protecting the lagoons and oil and tarballs began washing onto the nesting beach. The 9,000 hatchlings were held on shore until July 29 then evacuated by helicopter to a patch of sargassum in clean water less than 25 km offshore (Golob and McShea 1980).

More than 200 gal of oil were reportedly recovered during cleanup of the beach and lagoons near Rancho Nuevo (Golob and McShea 1980), but oil was still evident on the beach during the nesting season the following year (Fritts and McGehee 1982). Eventually, oil impacted over 257 km of the south Texas coast, beginning in August and September 1979. By the time the oil reached Texas it was highly weathered and had washed ashore primarily as tarballs, tarmats, or mousse. Environmentally sensitive, economically important beaches in Texas were cleaned daily using rakes and shovels rather than heavy equipment, which removes too much sand. An estimated 7,646 cubic meters of oiled sand was removed along the Texas coast (NOAA 1992).

Both live and dead oiled sea turtles were observed along the Texas coast after the spill (Lutcavage et al. 1997). Six live green turtles and one live Kemp's ridley turtle were collected during the response. Only one, a green turtle, required cleaning and rehabilitation, and was eventually released (Hall et al. 1983; Hooper 1981). Rabalais and Rabalais (1980) reported that in August 1979, five dead juvenile green turtles washed ashore on Padre and Mustang Islands, Texas, all heavily fouled with oil, which may have contributed to their deaths. Two oiled green turtle carcasses and one oiled young Kemp's ridley sea turtle carcass recovered from Laguna Madre, Texas, were shipped to the federal Patuxent Wildlife Research Center to determine cause of death. Autopsies found that while external oil was present on all three turtles (oil was found in the mouth and esophagus and all three had evidence of petroleum hydrocarbons in lung, esophageal, intestinal, liver, and kidney tissues), but the cause of death could not be determined conclusively (Hall et al. 1983). The amount of oil present was considered unlikely to have prevented normal movement or have been otherwise fatal. Two of the turtles were in poor condition, but had no apparent oil-caused lesions. Hall et al. reported that tissue chemical analysis indicated that oil exposure had been chronic, and it was this prolonged exposure that may have caused the turtles' poor body condition, which in turn led to death, either from oil toxicity or some another undetermined cause.

Despite early concerns about potential long-term impacts of residual oil affecting orientation cues or hatching success, there is no indication this oil spill significantly adversely affected Kemp's ridley sea turtles (Delikat 1980 and 1981). This conclusion is supported by the results of the study by Fritts and McGehee (1982), discussed in Chapter 4.

1983 Nowruz Oil Spill

Between January and October 1983, an estimated 42 million gal of oil were spilled into the Persian Gulf, primarily from several spills associated with the Iran-Iraq War (Miller 1989). In January 1983, oil began to discharge from a well in the Nowruz oil field, in Iranian territorial waters. Two other platforms damaged by military action in March 1983 contributed to the spill, as did other smaller spills and ballast pumping. Large areas of sheen, tarballs, and weathered oil rafts were reported in the Persian Gulf during April, May, and early June. Oil coated rocky shorelines, sandy beaches of offshore islands, and the Saudi Arabian mainland. On sandy beaches, sand movement during several tidal cycles buried and fragmented the stranded oil. Tarballs were deposited in the intertidal and adjacent subtidal areas of Saudi Arabia, Bahrain, and Qatar.

Between March and mid-April 1983, many dead animals were found along the Persian Gulf coast, including over 56 green and hawksbill sea turtles. Only a portion of the coastline was monitored, so the number of turtles killed may have been higher. Some accounts indicated as many as 180 hawksbill turtles were killed off the islands of Jana and Karan (Lutcavage et al. 1997). Burchard (as cited in Miller 1989) estimated that over 500 sea turtles of both species were killed, representing nearly total annihilation of the hawksbill population and a major portion of the green turtle population. The direct and indirect impacts to sea turtles from oil on nesting beaches and other sea turtle habitat remains unknown but Miller (1989) concluded the impact likely was severe.

1984 Oil Tanker *Alvenus*

The oil tanker *Alvenus* grounded in the Calcasieu River bar channel, 18 km southeast of Cameron, Louisiana, on 30 July 1984. The hull was ruptured, spilling approximately 2.7 million gal of medium and heavy Venezuelan crude oils. Rough weather hampered offshore recovery efforts, the oil moved slowly westward, eventually washing ashore near High Island, along the Bolivar Peninsula, and in Galveston Bay, Texas. Shoreline cleanup techniques included using road graders to move beached oil above the high-tide zone. During the response, one oiled sea turtle was cleaned and released (NOAA 1992).

1991 Gulf War

Approximately 252 million to 335 million gal of oil were spilled during the Gulf War beginning in late January 1991, the largest oil spill ever recorded in the marine environment. The major sources were four sunken and leaking vessels, including Iraqi oil tankers, and release of oil from the Kuwaiti Mina Al-Ahmadi Sea Island terminal and the Iraqi Mina Al-Bakr loading terminal (Al-Majed et al. 2000). An estimated 335 million gal spilled directly into the Persian Gulf, forming a 1,554-square-km oil slick. Tarmats up to 30 cm thick formed on impacted beaches between Safaniya and Abu Ali Island, Saudi Arabia. Cleanup operations recovered over 42 million gal by April 1991 (NOAA 1992).

Estimates of the number of sea turtles killed by the oil spilled during the Gulf War range from tens to hundreds, but are not well-documented (Lutcavage et al. 1997). One stranded green turtle that was recovered and necropsied contained over 4,000 ppm of oil in its liver and 310 ppm in its stomach, but no external indication of oil (Lutcavage et al. 1997). Interestingly, prior to this spill, recommendations for sea turtle conservation in Saudi Arabia had concluded that "…the ongoing high level of oil pollution into the Persian Gulf must be substantially reduced if sea turtle populations throughout the region are to survive at their current levels" (Miller et al. 1989).

1991 Barge *Vista Bella*

On 6 March 1991, the Trinidad-registered barge *Vista Bella* sank in 600 m of water about 19.3 km northeast of Nevis Island in the eastern Caribbean, after a towing cable snapped. The barge carried around 560,000 gal of No. 6 fuel oil. By March 13, oil, tarballs, and oiled debris had washed ashore on sea turtle nesting beaches on the north shore of St. Kitts, including Conaree. By March 21, tarballs and tar patties began appearing on St. John, and tarballs washed ashore on St. Thomas, St. Croix, Culebra, Vieques, and the main island of Puerto Rico shortly thereafter. Several beaches in the British Virgin Islands were oiled, and one oiled hawksbill attributed to the spill was recovered near Guayama, Puerto

Rico (Eckert et al. 1992; Eckert and Honebrink 1992). During this incident, the French Navy applied the dispersant Finasol OSR7, but details of the application are sketchy.

Surf-washing - a technique for removing oil from deposited beach material in which oil or oiled sediments are moved to a tidal elevation where they may be exposed to higher levels of wave energy (i.e., "washed"). The reworking of surface or subsurface sediments accelerates natural degradation processes.

1993 Barge *Bouchard B155*

On 10 August 1993, a freighter and two tugs collided in Egmont Channel in lower Tampa Bay, Florida. During the collision, the barge *Bouchard B155* released 336,000 gal of heavy No. 6 fuel oil from one of its cargo holds. By August 15, most of the floating oil had washed ashore and coated approximately 23 km of sandy beach, several mangrove islands, and seawalls. On some sandy beaches, stranded oil was buried by several centimeters of clean sand deposited during high tides. Large, thick oil mats coated mangrove roots, oyster beds, seagrass beds, and tidal sand flats around four mangrove islands in Boca Ciega Bay. The oil was very heavy and emulsified, and large oil patches submerged and stabilized in the bay sediments and some offshore areas. Several large, contiguous, thick mats of submerged oil were found just offshore of gulf beaches in 1.8 to 6 m of water and inside the entrance to Boca Ciega Bay at John's Pass and Blind Pass.

Figure 6.4 A nesting beach oiled after the 1993 Bouchard B155 *spill in Tampa Bay, Florida. Photo courtesy of Dr. Anne Meylan, Florida Marine Research Institute.*

Cleanup of impacted sandy beaches consisted primarily of manually removing the surface oil, mechanically removing subsurface oil, and "surf-washing" stained sand. Heavy equipment, such as front-end loaders and graders, was used for sand removal and surf-washing. Final beach grooming was done with graders and disking equipment, normally to a depth of 30 cm. Oil around the mangrove islands was vacuumed using grounded barges staged in shallow sand flats, followed by manual removal within the mangrove edges. Submerged oil patties and tarballs were removed manually. Attempts were made to vacuum submerged oil mats west of Eleanor Island in Boca Ciega Bay.

Sea turtle nesting beaches and foraging areas were oiled, then disturbed by cleanup operations (Figure 6.4). Loggerhead, Kemp's ridley, green, and hawksbill turtles occur in the affected area. The Florida Department of Environmental Protection et al. (1997) summarized sea turtle impacts. Loggerhead sea turtles, the most common, were impacted most severely: 4 hatchlings were recovered dead, and 12 live hatchlings were recovered oiled and were cleaned, rehabilitated, and released. Of these 12, 3 were oiled, 2 were trapped behind booms with oil, and 7 had no trace of oil but were disoriented by lights associated with the response (A. Meylan 2002[3]). One oiled, live juvenile green turtle was recovered offshore in an oiled windrow and was cleaned and released (Figure 6.5). Many loggerhead nests on beaches in the spill area had not yet hatched: 115 nests were marked as being at risk, 96 were on oiled beaches, 14 had to be protected by booms or trenches, 2 were inundated with oil and subsequently had a lower than normal hatching success rate (5 percent of eggs, compared to 50 to 90 percent normally), and 29 hatched during the spill and response. One unmarked nest was run over

Figure 6.5 A juvenile green turtle oiled during the 1993 Bouchard B155 *spill in Tampa Bay, Florida. Photo courtesy of Dr. Anne Meylan, Florida Marine Research Institute.*

by a bulldozer, crushing 5 eggs; the remaining eggs were transplanted but less than a third hatched. Approximately 1,530 loggerhead hatchlings from 23 of the 29 nests that hatched were restrained and released into the water in Sarasota County. Approximately 413 hatchlings from the other 6 nests were not restrained and entered waters that may have contained oil. An estimated 27 loggerhead hatchlings from a nest at Egmont Key State Park were likely taken by predatory birds after they emerged during the response and were impeded from reaching the water by a containment boom left on the beach. Overall, approximately 212 hatchlings were killed, and 2,177 were potentially injured by oil exposure and response activities.

For more than a year after cleanup, unrecovered submerged and buried oil chronically oiled beaches in the Tampa area during storms. In January 2000, several years after the spill, submerged oil entrained in bottom sediments of sheltered coastal inlets was uncovered during inlet dredging and beach renourishment (Upham Beach) at Blind Pass Inlet. Initial dredging operations remobilized the oil, which had weathered very little because it was buried. The oil washed ashore as tarballs and patties and coated some shorelines. The possibility of mobilization of submerged oil during these activities or during storms, as well as placement of dredged oiled sand on renourished beaches, caused concern about potential impacts on sea turtle nesting areas. Sea turtles begin nesting in the area in early May. A plan was developed to remove the submerged oil in Blind Pass and John's Pass in conjunction with the dredging and beach renourishment program. Oil was to be removed from the sand prior to placement on beaches as part of the beach renourishment operations. Turtle nesting beaches were monitored and surveyed to ensure that no oil was deposited as a result of these operations.

1994 Barge *Morris J. Berman*

On 7 January 1994, the tank barge *Morris J. Berman* grounded on hard rocky and coral bottom in the surf zone 274 m off San Juan, Puerto Rico. The barge drifted ashore after the towing cable parted from its tug. The barge was carrying heavy No. 6 fuel oil, which began discharging immediately and impacting nearby shoreline and shallow intertidal habitats. Oil was lightered off the *Morris J. Berman* to another barge, until it became too viscous and difficult to pump. Oil continued to leak from the barge and re-oil the nearshore environment for several days, until the vessel was refloated, towed to a scuttling site 37 km northeast of San Juan, and sunk.

More than 48 km of Puerto Rico's north shore were ultimately fouled by the spilled oil. Two shallow lagoons near the grounding site acted as natural catchment areas and oil accumulated on the surface and bottom in large mats. In early February, oil impacted shorelines in northwestern Puerto Rico, when a convergence zone concentrated debris and oil was released when the barge was scuttled. Some oil was buried, forming oily sand layers, and some oil was submerged in sheltered areas and bays in the form of oil and sand mats.

Potential impacts to sea turtles and other wildlife were a major concern during response. Intensive cleanup efforts began in the affected shoreline areas immediately because nesting sea turtles were due to arrive within weeks. Guidelines developed by natural resources trustees and response agencies to minimize cleanup impacts addressed sand removal, nighttime activities, use of all-terrain vehicles and other equipment, and any other cleanup operations that might impact sea turtles or their nesting habitats. Sand beaches contaminated with continuous oil deposits were cleaned by manual removal, taking precautions to remove a minimal amount of clean sand. Heavy equipment, including backhoes and front-end loaders, was used to remove large areas of heavily oiled sand and buried tarmats. Machinery movements were closely monitored to prevent unnecessary traffic across the beach and sand dunes. Wood-frame and chicken-wire screens were used to sieve scattered tarballs out of the sand in some areas. Submerged oil was removed manually by divers using manual techniques, vacuum transfer units, pumps, and submersible dredges. Beach rock, riprap, and seawalls were cleaned with pressure washers and chemical cleaners. Oil in some locations was left to weather naturally due to inaccessibility, low levels of human use, or exposure to high-energy waves.

Figure 6.6. Juvenile green turtle recovered during the Morris J. Berman *barge spill in the waters off Culebra, Puerto Rico. The turtle exhibited signs of eye irritation. It was cleaned by the Puerto Rico Department of Natural Resources and released off the island of Vieques. Photo courtesy of Bradford Benggio, NOAA.*

During the response, two oiled green turtles were recovered, cleaned, rehabilitated, and released by the Puerto Rico Department of Natural Resources and Caribbean Stranding Network facilities in San Juan. One turtle was oiled on its neck, flippers, and back; the other one had patchy oiling (Petrae 1995). At least three additional sea turtles (one green and two hawksbills), affected by oil that was not attributed to the *Berman* spill, were also collected. In addition to turtles, thousands of live and dead oiled organisms washed ashore (Mignucci-Giannoni, 1999), including birds, invertebrates, and fish (Petrae 1995, Mignucci-Giannoni 1999).

2000 Fort Lauderdale, Florida, Mystery Spill

On 8 August 2000, a spill of unknown origin began washing up along Florida's east coast from North Miami to Pompano. Tarballs from 16 mm to pancake and mat size impacted several beaches, sometimes mixed with wrack. The oil was heavy and highly weathered. Submerged oil mats and patties, unevenly distributed and of varied sizes and thicknesses, were also found in nearshore troughs from John U. Lloyd State Park to Hollywood Beach. The submerged oil mats were sticky, mixed with seagrass and sediment, and in some areas continuous, much of it buried under a thin layer of sand. Oiled shorelines were manually cleaned within days; some submerged oil was removed manually by divers.

Hatchling sea turtles were a priority concern during this incident. At the time of the spill, an estimated 530 sea turtle nests were on beaches in the area. In John U. Lloyd State Park, one of the most heavily impacted areas, 43 surveyed nests were expected to hatch within days of the oil stranding. Eight were green turtle nests, the remainder were loggerhead nests. In addition to potential impacts from shoreline oiling, the submerged oil and tarballs presented a serious risk to hatchlings and turtles swimming nearshore.

Known sea turtle nests were monitored 24 hours a day, and hatchlings were captured for release in clean areas. Beaches were monitored for new tarball strandings and cleaned immediately. Stricter cleanup standards were established for turtle nesting beaches than other impacted areas (no more than 5 percent oil cover). Volunteers raked areas seaward of turtle nests to clear wrack and tarballs.

NRDA - Natural Resource Damage Assessment.

More than 137,000 loggerhead, green, and leatherback hatchlings (hatched within the previous 30 days) were estimated to be in the area and potentially exposed to oil. Natural Resource Damage Assessment (NRDA) modeling estimated that over 70 adult (mostly nesting females), and over 300 post-pelagic juvenile sea turtles in the area were potentially exposed to oil. The model also indicated that some sea turtles were likely killed by the oil, even though no oiled turtles were recovered. The model estimate for hatchling mortality was 7,800. Loggerheads, which are most abundant in the area, were presumed most seriously impacted; green and leatherback turtles were presumed affected to a much lesser extent.

2001 Auxiliary Oiler USS *Mississinewa*

In November 1944, the U.S. Navy auxiliary oiler USS *Mississinewa* was sunk by a Japanese manned suicide torpedo in Ulithi Lagoon, Yap Island, Federated States of Micronesia. The vessel was reportedly loaded with 440,000 gal of aviation gasoline and a full load of fuel oil. The *Mississinewa* rested on the bottom for decades, but in July 2001 a tropical storm disturbed the wreck site and oil leaked to the surface.

The island group comprising Ulithi Atoll is quite large and is one of the most important green and hawksbill aggregating and nesting areas in the western Pacific Ocean. Although comprehensive population surveys had not been conducted, several hundred green turtles were counted and tagged during a census undertaken shortly before the spill (S. Kolinski 2001[4]); about 1,000 migratory (nonresident) green turtles were estimated to use the atoll each year. The timing of the oil release (reported to U.S. authorities in August 2001) was of particular concern: it was about the expected peak during hatching.

No impacts to turtles were reported during the shoreline surveys or salvage operations that followed. Turtles are an important aspect of Ulithi native society, providing food and representing a central focus for mythology and a cultural governance system extant for hundreds of years: " . . . myth-makers have served to endow the sentiment toward sea turtles with an aura of antiquity and sacredness ..." (Lessa 1984). To the extent that strict cultural traditions strongly influence turtle harvests in the islands, they represent a de facto conservation ethic. A catastrophic incident affecting the continued viability of sea turtles in the region would have far-reaching effects, to the turtles and to the social fabric of the human inhabitants. The deterioration of that social fabric would further weaken traditional controls on harvest, accelerating the demise of the region's turtles.

Impacts of Tarballs

Impacts on sea turtles of tarballs not associated with a particular oil spill have been documented frequently (Carr 1987). Witham (1983) reported several instances of small sea turtles impacted by oil or tar along the Florida coast. In many cases, tar sealed the mouths and nostrils of the small turtles, and several turtles had ingested tarballs.

Witherington (1994) found that over 34 percent of post-hatchling sea turtles captured and examined in the Atlantic Ocean off Florida in 1993 contained tar in their stomachs and esophagi, and over half of the turtles had tar caked in their jaws. A subsequent survey of 66 neonate loggerhead turtles captured in downwelling lines near the Gulf Stream front off Florida (Witherington 2002) documented ingested tar in 20 percent of them. Chemical analysis of the tar samples indicated multiple sources and degrees of weathering.

Neonate - post-hatchling.

Van Vleet and Pauly (1987) chemically analyzed tar found in or on several stranded sea turtles collected along the Florida coast and throughout the Gulf of Mexico; they concluded the tar had originated from crude oil tanker discharges. They also reported that analysis of internal organs and feces from dead and live sea turtles indicated that turtles actively ingest floating oil and that oil residues may remain in the turtles' digestive tracts for several days. The researchers suggested that crude oil tanker discharges are having a significant impact on marine turtle populations in the eastern Gulf of Mexico.

Oil-Related Strandings

It has been estimated that approximately 1 percent of annual sea turtle strandings are associated with oil.[5] Higher percentages are attributed to oil in South Florida (3 percent) and Texas (3 to 6 percent) (Lutcavage et al. 1997), while much lower percentages characterize strandings in Hawaii (one individual in 18 years) (G. Balazs 2002[21]). Specific counties in Florida and Texas reported high rates for particular years (over 37 percent, for example, in Dade County, Florida). Work by Vargo et al. (1986) indicated that juveniles are more affected than adults and that certain species, such as green turtles, are more affected than others, perhaps due to habitat preference and location of nesting beaches.

Among the impacted sea turtles, tar is often found in the mouth, esophagus, or stomach, particularly in hatchlings and young turtles. Small sea turtles have been found completely mired in oil. Oil removed from stranded sea turtles in Florida and Texas has been identified primarily as tanker discharges.

Bugoni et al. (2001) recovered and examined dead, stranded sea turtles on the coast of Brazil and found that oil was a relatively minor occurrence in the green turtles examined between 1997 and 1998. Of 38 individuals examined, only one contained oil. By far, plastic debris (bags and ropes) was the most common anthropogenic material found (in 16 and 15 individuals, respectively).

The Future

While we cannot predict the future, trends over the past 20 to 30 years provide clues to what could happen in the coming decade. The typical tropical spill that NOAA responded to during the past decade involved a vessel grounded nearshore and spilling about 4000 gal of diesel or No. 2 fuel oil. The typical vessel was a freighter, bulk carrier, or fishing vessel. This would suggest that, in the United States, to protect sea turtles and their habitats response planners should anticipate small- and medium-sized nearshore fuel oil spills. However, this will not be the case for other parts of the world's oceans, where the prevalent oil types and transportation modes differ.

Concerns

Review of the case history files permits us to define some areas of concern or improvement. For example, listing sea turtles in a spill notification phase has not always been consistent: turtles are sometimes listed as resources at risk, and other times not. During 1992 to 2001, sea turtles or turtle habitat were a concern in only about half the actual or potential spills within their nominal range. Turtles and nesting beaches are more frequently mentioned in response progress reports, but in many cases were not mentioned at all, even for incidents that occurred in turtle territory. This suggests that the incidents were either not considered a real risk despite the potential or (less likely) the threat was simply overlooked.

The body of case histories does not reflect a pattern of significant impact of oil spills on sea turtles. Thus, it is possible that sea turtles have not been seriously affected by spills. It is also possible that impacts on turtles were not reported because impacted individuals were not observed or were only discovered after response actions were terminated. If that is the case, more work is needed to connect damage assessment and restoration information to response information.

While the public and media tend to view crude oil spills from large tankers as threats to wildlife, most incidents were from vessels other than tankers and from stationary sources such as pipelines and dock facilities. This distribution among spill sources is consistent with other larger assessments, such as that done by the National Research Council (2002). Most knowledge about the effects of oil on sea turtles—scant as it is—is based on exposures to crude oil, but we now realize that information is also needed about effects of fuel oils and dispersed oil, and effectiveness of shoreline and nest site protection strategies. While it seems unlikely that intentional oil exposure experiments with live sea turtles will be permitted or accepted anytime in the near future, other biochemical or molecular assays that could be performed *ex situ* may be one way to obtain toxicological information without harming or stressing threatened turtles.

For Further Reading

Al-Majed N., H. Mohammadi, and A. Al-Ghadban. 2000. Regional report of the state of the environment. ROPME/GC-10/001/1. Revised by A. Al-Awadi, Regional Organisation for the Protection of the Marine Environment, Kuwait. 178 p.

Bugoni, L., L. Krause, and M. V. Petry. 2001. Marine debris and human impacts on sea turtles in southern Brazil. *Mar. Poll. Bull.* 42(12): 1330–1334.

Carr, A. 1987. Impact of nondegradable marine debris on the ecology and survival outlook of sea turtles. *Mar. Poll. Bull.* 18: 352-356.

Delikat, D. S. 1980. IXTOC I oil spill and Atlantic ridley survival. In: *Coastal Zone 1980*, Volume I, B. L. Edge, ed. American Society of Civil Engineers, New York. pp. 312–319.

Delikat, D. S.. 1981. IXTOC I oil spill—Atlantic ridley sea turtle survival. *Underwater Nat*. 13(1): 13–15.

Eckert, K. L., and T. D. Honebrink. 1992. WIDECAST sea turtle recovery action plan for St. Kitts and Nevis, CEP Technical Report No. 17, UNEP Caribbean Environment Programme, Kingston, Jamaica. 116 p.

Eckert, K. L., J. A. Overing, and B. B. Lettsome. 1992. WIDECAST sea turtle recovery action plan for the British Virgin Islands, CEP Technical Report No. 15, UNEP Caribbean Environment Programme, Kingston, Jamaica. 116 p.

Florida Department of Environmental Protection, National Oceanic and Atmospheric Administration, and U.S. Department of the Interior. 1997. Damage assessment and restoration plan/environmental assessment for the August 10, 1993, Tampa Bay oil spill: Volume I —ecological injuries. NOAA Restoration Center, Southeast Region, St. Petersburg, Fla. pp. 47–51.

Fritts, T., and M. A. McGehee. 1982. Effects of petroleum on the development and survival of marine turtle embryos. FWS/OBS-82/37 Contract NO. 14-16-0009-80-946. U.S. Fish and Wildlife Service, U.S. Dept. of the Interior, Washington, D.C.

Golob, R., and D. McShea. 1980. Special report: Ixtoc I. *Oil Spill Intelligence Rept.* 3(1): 1–36.

Hall, R. J., A. A. Belisle, and L. Sileo. 1983. Residues of petroleum hydrocarbons in tissues of sea turtles exposed to the Ixtoc I oil spill. *J. Wildl. Diseases* 19(2): 106–109.

Hooper, C. H., ed. 1981. The IXTOC I oil spill: The federal scientific response. NOAA Hazardous Materials Response Project, Boulder, Colo. 202 p.

Hutchinson, J., and M. Simmonds. 1992. Escalation of threats to marine turtles. *Oryx* 26: 94–103.

Lessa, W. A. 1984. Sea turtles and ritual: Conservations in the Caroline Islands. In: *The Fishing Culture of the World: Studies in Ethnology, Cultural Ecology and Folklore*, Volume II, B. Gunda, ed. Akadémiai Kiadó, Budapest. pp. 1183–1201.

Lutcavage, M. E., P. Plotkin, B. Witherington, and P. L. Lutz. 1997. Human impacts on sea turtle survival. In: *The Biology of Sea Turtles*, P. L. Lutz and J. A. Musick, eds., CRC Press Inc., Boca Raton, Fla. pp. 387–409.

Lutz, P. L., and M. Lutcavage. 1989. The effects of petroleum on sea turtles: Applicability to Kemps' ridley. In: *Proceedings of the First International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management,* C. W. Caillouet, Jr. and A. M. Landry, Jr., eds. TAMU-SG89-105, Texas A&M University Sea Grant Program, Galveston. pp. 52–54.

Mignucci-Giannoni, A. A. 1999. Assessment and rehabilitation of wildlife affected by an oil spill in Puerto Rico. *Environ. Poll.* 104: 323–333.

Miller, J. D. 1989. Recommendations for the conservation of marine turtles in Saudi Arabia, Volume I. MEPA Coastal and Marine Management Series Report No. 9. Meteorological and Environmental Protection Administration (MEPA), Ministry of Defence and Aviation, Kingdom of Saudi Arabia. 63 p.

Miller, J. D., C. J. Limpus, and J. P. Ross. 1989. Recommendations for the conservation of marine turtles in Saudi Arabia, Volume II. MEPA Coastal and Marine Management Series Report No. 9. 209 p.

National Research Council 2003. *Oil in the Sea III: Inputs, Fates, and Effects*. National Academy Press, Washington, D.C. 265 p.

National Oceanic and Atmospheric Administration (NOAA). 1992. Oil spill case histories: 1967–1991. Summaries of significant U.S. and International Spills. Report No. HMRAD 92-11 to the U.S. Coast Guard Research and Development Center. Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration, Seattle, Wash.

Petrae, Gary, ed. 1995. Barge *Morris J. Berman* spill: NOAA's scientific response. HAZMAT Report No. 95-10. Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration, Seattle, Wash. 63 p.

Rabalais, S. C., and N. N. Rabalais. 1980. The occurrence of sea turtles on the south Texas coast. *Contrib. in Mar. Sci.* 23: 123–129.

Rutzler, K., and W. Sterrer. 1970. Oil pollution damage observed in tropical communities along the Atlantic seaboard of Panama. *Bioscience* 20: 222–224.

Van Vleet, E. S., and G. G. Pauly. 1987. Characterization of oil residues scraped from stranded sea turtles from the Gulf of Mexico. *Caribbean J. Sci.* 23: 77–83.

Vargo, S., P. Lutz, D. Odell, E. Van Vleet, and G. Bossart. 1986. Effects of oil on marine turtles, Volume 1: Executive summary. Florida Institute of Oceanography. Final Report MMS NO 14-12-0001-30063. 12 p.

Vargo, S., P. Lutz, D. Odell, E. Van Vleet, and G. Bossart. 1986. Effects of oil on marine turtles, Volume 2: Technical report. Florida Institute of Oceanography. Final Report MMS NO 14-12-0001-30063. 180 p.

Witham, R. 1978. Does a problem exist relative to small sea turtles and oil spills? In: *Proceedings of the Conference on the Assessment of Ecological Impacts of Oil Spills*, Keystone, Colo. American Institute of Biol. Science. pp. 630–632.

Witham, R. 1983. A review of some petroleum impacts on sea turtles. In: *Proceedings of a Workshop on Cetaceans and Sea Turtles in the Gulf of Mexico: Study Planning for Effects of Outer Continental Shelf Development*, C. E. Keller and J. K. Adams, eds. USFWS/OBS-83/03. Prepared by the U.S. Fish and Wildlife Service for the Minerals Management Service, Metairie, La. 42 p.

Witherington, B. E. 1994. Flotsam, jetsam, post-hatchling loggerheads, and the advecting surface smorgasbord. In: *Proceedings of the 14th Annual Symposium of Sea Turtle Biology and Conservation, Miami, Florida*, K. A. Bjorndal, A. B. Bolten, D. A. Johnson, and P. J. Eliazar, eds. NOAA Technical Memorandum NMFS-SEFSC-351. pp. 166–168.

Witherington, B. E. 2002. Ecology of neonate loggerhead turtles inhabiting lines of downwelling near a Gulf Stream front. *Mar. Biol.* 140: 843–853.

Chapter Notes

[1] By comparison, the *Exxon Valdez* spill in Prince William Sound, Alaska, was 10.9 million gal.

[2] This listing is not comprehensive.

[3] A. Meylan, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, 100 Eighth Avenue SE, St. Petersburg, FL 33701-5095, personal communication, 2002.

[4] S. Kolinski, Department of Zoology, University of Hawaii at Manoa, 2538 McCarthy Mall, Honolulu, HI 96822, personal communication, 2001

[5] As identified by the U.S. Sea Turtle Stranding and Salvage Network.

[6] G. Balazs, Marine Turtle Research Program, NOAA/NMFS Southwest Fisheries Science Center, 2570 Dole Street, Honolulu, HI 96822-2396, personal communication, 2002.

Conclusions

We have presented a large amount of material for your consideration in this document. Our intent was to consolidate a body of disparate information on sea turtles into a single place, and interpret it within the framework of oil effects and spill response activities. Our conclusions include the following:

- Six species of sea turtles are found in the United States or in U.S.-territorial waters: leatherback, green, Kemp's ridley, hawksbill, loggerhead, and olive ridley.
- All six turtle species are listed under the Endangered Species Act, thus are subject to special protection.
- Sea turtles worldwide are threatened by a variety of natural and anthropogenic influences. Among those of human origin, incidental catch and death in fisheries for other species is the most prevalent.
- Aspects of the life histories of sea turtles place them at heightened risk due to the intersection and overlap with areas where oil collects.
- Even though direct exposure studies are quite limited, there is strong, if dated, information that indicates oil is harmful to turtles. Dermal tissues and membranes appear to be particularly sensitive to exposure.
- Fresh oil harms sea turtle eggs; weathering reduces the toxic effect.
- Spills in which turtle injury has been documented are relatively rare.
- The threat from oil spills was demonstrated by Ixtoc I, in which the only known nesting site for a highly endangered turtle species was narrowly missed, and by the growing transport of petroleum products across waters representing important turtle habitat.
- In the U.S. waters where sea turtles are found, historical records suggest that the most prevalent spills have involved refined fuel oils from barges or freighters and have occurred as a result of vessel grounding.
- Response activities have the potential to adversely affect sea turtles, both on the water and on the beach. Probably the greatest potential for impact exists in beach-

related oiling and cleanup, which could disturb nesting females, nests, and hatching turtles, due to the large numbers of animals that could be affected in a relatively small area.

Our goal in structuring a response to an oil spill in sea turtle habitat will be to evaluate the tradeoffs of various actions against the effects to all of the identified resources at risk. When sea turtles are judged to be a priority for protection, then we can modify the response to accommodate some of the many special aspects of sea turtle biology that have been discussed here and elsewhere. While we are not likely to completely eliminate spill-related stress to potentially affected animals, we may be successful in reducing one source of stress to these threatened populations. In doing so, we improve their chances for survival in an increasingly challenging ocean environment.

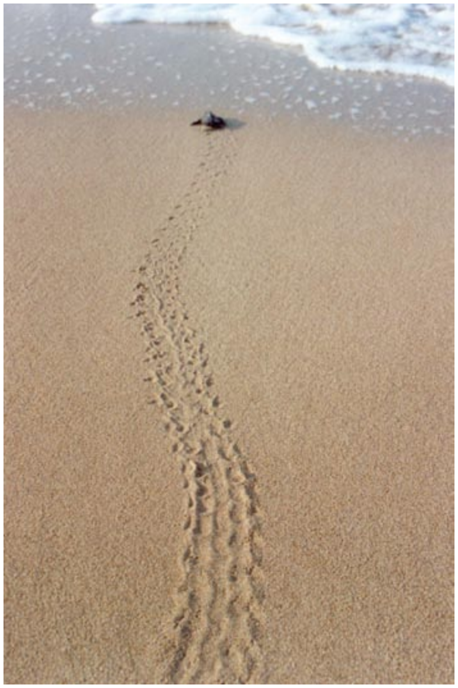


Photo courtesy of Dr. Asaf Senol, Department of Environmental Protection, Ministry of Tourism and Environment, Turkish Republic of Northern Cyprus.

Glossary

ACP: Area Contingency Plan

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

arribada: mass nesting aggregation; Spanish, meaning literally, "arrived."

ATSDR: Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services.

bbl: petroleum barrel, equal to 42 U.S. gal.

beach renourishment: replenishment of beach sand by mechanically dumping or pumping sand onto an eroded beach; also referred to as beach nourishment.

brevetoxicosis: a deadly condition caused by ingestion of dinoflagellate organisms often responsible for red tides; recently linked to deaths of manatees in Florida and common murres in California.

Calipee: cartilage

carapace: dorsal (top) shell of a turtle.

cheloniid: hard-shelled sea turtles composed of the genera *Chelonia*, *Caretta*, *Lepidochelys*, *Eretmochelys*, and *Natator*; contrast to dermochelyid.

CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora.

dermochelyid: leathery-shelled sea turtles (i.e., leatherback).

diverticulum: an abnormal saclike pouch projecting from a defect in the wall of a tube or cavity.

endangered: Any species of animal or plant that is in danger of extinction throughout all or a significant part of its range (from the Endangered Species Act of 1973).

ESI: Environmental Sensitivity Index map.

fibropapilloma: a tumor-forming, debilitating, and often fatal disease of sea turtles, manifested by formation of multiple fibrous masses of tissue 1 mm to 30 cm in diameter growing from the eyes, flippers, neck, tail, scutes, and in the mouth.

FP: see fibropapilloma.

hematocrit: red blood cell volume.

hemorrhagic enteritis: bleeding inflammation of the intestine.

***in-situ* burning: response technique in which spilled oil is burned in place.**

lachrymal gland: tear glands highly modified to excrete excess salt.

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.

MDF: Mexican Department of Fisheries.

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

nares: external nostrils.

neonate: post-hatchling.

NMFS: National Marine Fisheries Service (NOAA).

NOAA: National Oceanic and Atmospheric Administration. (U.S. Department of Commerce).

NRDA: Natural Resource Damage Assessment.

oleophilic: oil-attracting.

osmolarity: the concentration of an osmotic solution, especially when measured in osmols or milliosmols per liter of solution.

phalanges: long "finger" bones of a turtle flipper.

plastron: ventral (bottom) shell of a turtle.

PM10: particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers.

ppm: parts per million.

pyrosoma: pelagic colonial tunicate; most species inhabit tropical waters, with some up to 4 m in length.

RAR: resources at risk.

sargassum: genus of brown algae, also known as gulfweed. There are 15 species in the genus, and each has air bladders. Some species are free floating. Off the U.S. coast, south of Bermuda, is the Sargasso Sea, a large (two-thirds the size of the United States), loosely-defined portion of the Atlantic Ocean where an estimated 7 million tons of live sargassum may be found.

SCL: straight carapace length.

scute: plates of the sea turtle shell.

Section 7 consultation: requirement under the Endangered Species Act for federal agencies to address potential impacts of their actions on threatened species.

surf-washing: a technique for removing oil from deposited beach material in which oil or oiled sediments are moved to a tidal elevation where they may be exposed to higher levels of wave energy (i.e., "washed"). The reworking of surface or subsurface sediments accelerates natural degradation processes.

STSSN: Sea Turtle Stranding and Salvage Network.

TED: turtle excluder device, an adaptation to commercial shrimp nets to permit sea turtles to escape.

threatened: any species likely to become endangered in the foreseeable future (from the Endangered Species Act of 1973).

USFWS: U.S. Fish and Wildlife Service (U.S. Department of Interior).

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.

Appendix A: Protocol for Recovery of Oiled Marine Turtles at Sea

Produced as guidance during the 1993 *Bouchard B155* oil spill in Tampa Bay, Florida, by the Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute

Protocol for Recovery of Oiled Marine Turtles at Sea

1. Bring turtle on board (dipnets are useful for small turtles).
2. Determine health status (live, dead, injured) and degree of fouling by oil.
3. Determine position at sea (latitude/longitude, Loran reading, GPS coordinates, landmarks, etc.).
4. Contact the Florida Marine Patrol to report the recovery of the turtle, and inform them whether you can transport the turtle to the Pinellas Oiled Wildlife Response Center at Fort Desoto. Alert the Response center that a turtle is being brought in and estimate your time of arrival. Turtles should be brought in as soon as possible.
5. If the turtle is alive, keep it out of the sun and keep it moist with towels or wet it frequently. Do not put it in water in which it can submerge.
6. If a camera is available, take a few photographs of the animal to document its condition at the time of recovery.
7. Record the place and time of discovery of the animal and any relevant information about oil conditions at the site to pass on to the Wildlife Response Center. Provide your full name and contact numbers.
8. Deliver the animal to the Pinellas Oiled Wildlife Response Center at Fort Desoto.
9. Turtles found dead or that die in transit should be kept cool (with ice, refrigerator, freezer, shade) until transferred to the Response Center.

Protocol communicated by:

Dr. Anne Meylan

Florida Marine Research Institute

Florida Fish and Wildlife Conservation Commission

100 Eighth Avenue SE

St. Petersburg, FL 33701-5095

APPENDIX B: Excerpted Sections from Marine Turtle Guidelines, State of Florida Fish and Wildlife Conservation Commission

Note: Included as an informational reference only. Spill responders are not authorized to perform these activities unless specifically permitted by state and federal agencies.

Full citation:

Florida Fish and Wildlife Conservation Commission. 2002. Sea Turtle Conservation Guidelines, April, 2002 Revision. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida. 61 pp. + appendices.

SECTION 2 - NESTING BEACH SURVEY ACTIVITIES

Summary

If your permit authorizes you to conduct nesting surveys you are also authorized to conduct the following activities:

- mark nests
- conduct hatching success evaluations
- rescue and release hatchlings

Unless specifically stated on the permit, personnel are NOT authorized to conduct the following activities:

- relocate nests
- screen nests with self-releasing screens/cages
- screen nests with restraining cages
- use a self-releasing hatchery
- use a restraining hatchery
- use probes (other than fingers) to locate clutches
- conduct nighttime surveys
- conduct public hatchling releases

Activity Description

This activity involves the daily survey of a specific beach area (as specified on the permit) to identify, enumerate, and evaluate nesting activities. In nesting surveys, surveyors count and identify "crawls," which are the marks left in the sand by sea turtles that have attempted to nest. The official sea turtle nesting season varies across the state due to geographic differences in the seasonality among the various sea turtle species. For most of the state, nesting season is between May 1, when loggerheads begin nesting, and October 31, after which period most nests of each species have hatched. In Brevard through Broward Counties, where the majority of leatherback nesting occurs, nesting season is between March 1 and October 31.

For best viewing of crawls, nesting surveys should begin shortly after sunrise but never earlier than ½ hour before sunrise. Because of potential disturbances to nesting females and the difficulty of locating and interpreting crawls in the dark, nesting surveys may not be conducted at night.

Surveyors should traverse the beach along (and seaward of, if possible) the most recent high tide line. This is important not only for ensuring that turtle crawls are not obscured before they can be evaluated, but also for avoiding impact to nesting Wilson's plovers and other nesting shorebirds. Surveyors should become familiar with and keep alert for shorebird chicks in the intertidal zone as well, since they use this habitat once they leave their nests. For additional information on how to identify and protect shorebirds, contact FWC's Division of Wildlife at (850) 488-3831. You can also contact the USFWS (USFWS, Migratory Birds and State Programs, 1875 Century Boulevard, Suite 240, Atlanta, GA 30345-3301).

Figure 2-1. Crawl crossed out using foot.

Upon discovery of a crawl, surveyors should make a visual determination as to whether the crawl was a nesting emergence (i.e., a nest) or non-nesting emergence (often called a "false crawl"); they should also determine what species of turtle made the crawl. All crawls should be recorded on a data sheet. If a crawl is clearly identifiable as a nest and the nest does not have to be screened, caged, precisely marked, or relocated, the surveyor should not dig into the nest simply to verify the presence of eggs. After each crawl is evaluated and documented, the tracks should be marked to avoid duplicate reporting. To accomplish this, a surveyor may obliterate a section of the upper track (not the nest site) by sweeping his/her feet across the track (Figure 2-1) or by crossing over the track (well above the high tide mark but not over the clutch) with a survey vehicle (Figure 2-2).

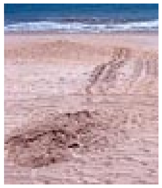


Figure 2-2. Crawl crossed out using ATV.

Nesting surveys may only be conducted within the boundaries specified on the permit. Ideally, boundaries should not change, either within a season or from year to year. Requests for expansion of authorized nesting survey areas must be submitted in advance and in writing to FWC, Bureau of Protected Species Management. It is imperative that survey areas do not overlap. Please inform FWC immediately of any reduction in survey efforts so that steps can be taken to ensure continuity in nesting beach coverage. It is extremely important that FWC be informed of any changes in monitoring effort in order to maintain accurate and consistent nesting survey records.

Survey boundaries should be permanent and specific. GPS coordinates are highly desirable, in addition to physical landmarks such as state roads, county lines, etc. Street addresses are preferable to condominium names, which may change at any time. FWC has latitude and longitude coordinates, most collected with differentially corrected GPS, for every INBS beach and for all zones within these beaches. If INBS zone markers are lost, contact FWC for the coordinates that would allow correct repositioning of missing zone markers.

SPECIES IDENTIFICATION AND DETERMINATION OF NESTING SUCCESS

The tracks and other evidence left on the beach after a sea turtle has emerged (crawls) can be used to identify what species of turtle came up and whether or not it nested. The following outline describes how to use crawl evidence to make these identifications.

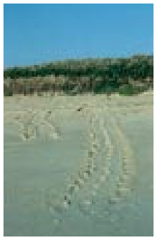


Figure 2-3. Incoming vs. outgoing track (this turtle had a right rear flipper injury).

I. Identify which is the incoming (emerging) track and which is the outgoing (returning) track.

- As a turtle crawls it pushes sand backward with each flipper stroke.
- If one track is shorter, it will be the incoming track (Figure 2-3).
- If tracks overlap, the outgoing track will be on top.

II. What species made the crawl (loggerhead, green turtle or leatherback)? Note: Although hawksbills and Kemp's ridleys occasionally nest on Florida beaches, nesting is rare and their crawl and nest-site characteristics are similar to the loggerhead. Minimal discussion will be provided below for hawksbills and Kemp's ridleys. (Track widths listed below for loggerhead, green turtle, and leatherback were provided by Erik Martin, EAI. All artwork was provided by Dawn Witherington).

Figure 2-4: tracks from a sea turtle with an alternating gait, no tail drag mark, and track width typically ranging from 70 to 124 cm (27.6 to 48.8 inches) with a mean of 94 cm (37.0 inches): loggerhead turtle (*Caretta caretta*). Species with similar tracks: hawksbills (*Eretmochelys imbricata*) typically leave a wavy tail-drag mark near the track center (Figure 2-5) and hawksbill track widths typically range from 70 to 85 cm (27.5 to 33.5 inches). Kemp's ridley (*Lepidochelys kempii*) seldom leave a conspicuous tail-drag mark and a ridley track width ranges from 70 to 80 cm (27.6 to 31.5 inches). Both hawksbills and Kemp's ridleys crawl with an alternating gait, like loggerheads. Kemp's ridleys are

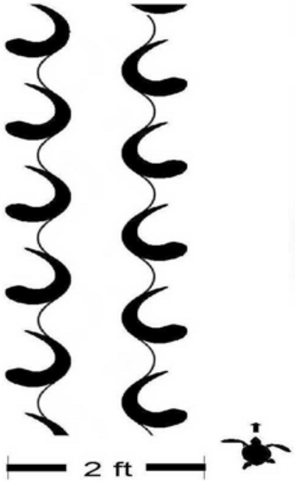


Figure 2-4. Loggerhead track

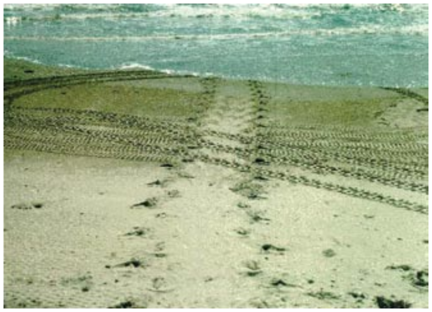
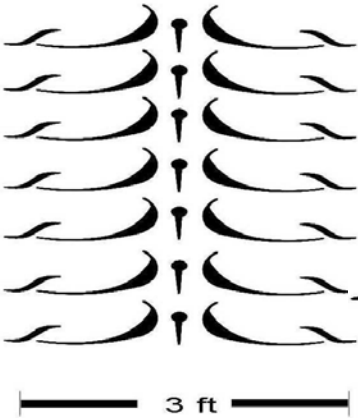


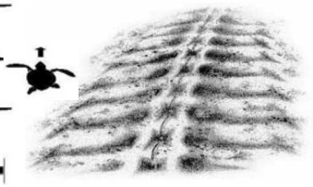
Figure 2-5. Hawksbill and Kemp's ridley tracks.

Kemp's ridley tracks.

Hawksbill tracks.

Figure 2-6. Green turtle track





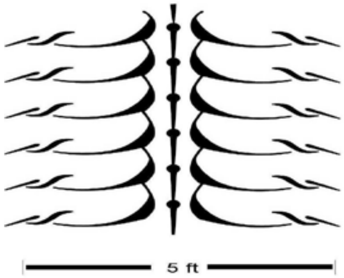


Figure 2-7. Leatherback track

predominantly daytime nesters. If you find a turtle nesting during the daytime, be sure to look at it closely (and take pictures if possible) to determine its species. Kemp's ridleys also pack the sand down by rocking their bodies from side to side during nest covering (unlike the other species that use their rear flippers to "knead" sand to compact it).

Figure 2-6: tracks from a sea turtle with simultaneous limb movement, a center drag mark from the tail (the center drag mark may be a solid or broken line), and track width typically ranging from 95 to 144 cm (37.4 to 56.7 inches) with a mean of 119 cm (46.8 inches): green turtle (*Chelonia mydas*).

Figure 2-7: tracks from a sea turtle with simultaneous limb movement, a center drag mark from the tail, and track width typically ranging from 175 to 214 cm (68.9 to

84.3 inches) with a mean of 196 cm (77.2 inches); track path sometimes circling or sinusoidal (S-shaped): leatherback turtle (*Dermochelys coriacea*).

Note: Flipper injuries to turtles may alter track appearance (Figure 2-8). Characteristics of the nest (given below) should be used in conjunction with track characteristics to identify species.

If the crawl is from a loggerhead, is it a nest or a non-nesting emergence? It is important to record both types of emergences. One should NOT dig into the nest to confirm the presence of eggs unless the nest is to be screened, caged, or marked for later determination of hatching success.

A. Identify emerging and returning tracks by their direction (see I.).

B. Follow the path taken by the turtle and look for the following attributes.

1. Evidence of covering the nest with the front flippers (Figure 2-9). If present, the crawl can be considered a NEST.

a. Presence of a secondary body pit and/or escarpment.

b. Sand "misted" or "thrown" over the emerging track.

2. Evidence of an abandoned nesting attempt. If present, the crawl can be considered a NON-NESTING EMERGENCE (i.e., false crawl).

a. Very little or no sand disturbed other than tracks (Figure 2-10).

b. Back stop with sand pushed back (not thrown) over emerging crawl, typically between two mounds of sand piled by the front flippers during construction of the primary body pit (Figure 2-11).

c. Considerable amount of sand disturbed from a digging effort, but with the crawl exiting the disturbed area and continuing toward the dune before turning toward the ocean (Figure 2-12).

d. Considerable amount of sand disturbed from a digging effort, but with a smooth-walled or abandoned/open egg chamber (15–25 cm diameter) in the center of a pit within the disturbed area (Figure 2-13).

IV. If the crawl is from a green turtle, is it a nest or a non-nesting emergence?

A. Identify emerging and returning tracks by their direction (see I. above).

B. Follow the path taken by the turtle and look for the following attributes.

1. Evidence of front flipper covering. If present, the crawl can be considered a NEST.

Figure 2-8. Loggerhead turtle track with right rear flipper injury.

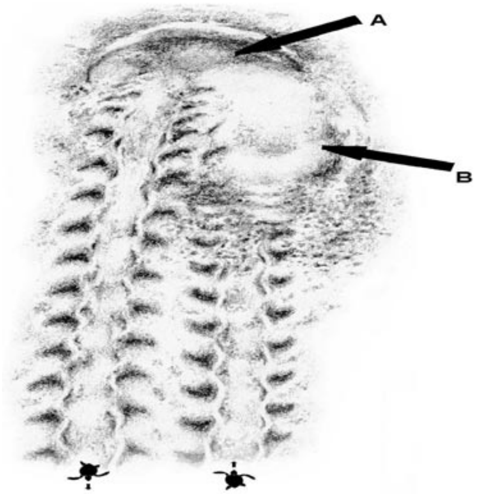


Figure 2-9. A loggerhead nest site showing a secondary body pit (A) and a mound of thrown sand that is wider than the track.

Figure 2-10. A loggerhead false crawl showing no evidence of disturbed sand other than the track.

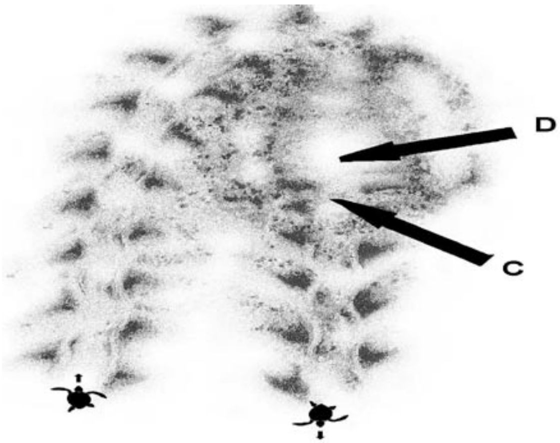


Figure 2-11. A loggerhead false crawl showing a small abandoned primary body pit (C) and a mound of pushed sand (D) no wider than the track and lying between two conspicuous ridges.

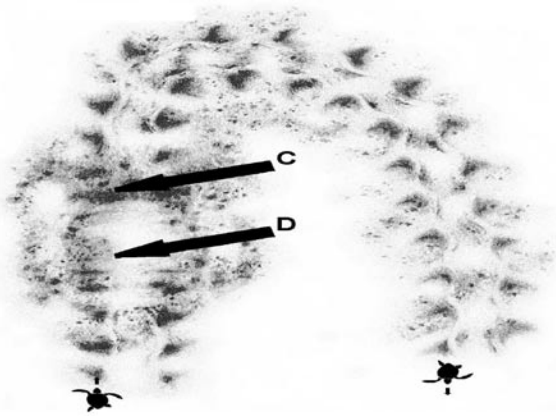


Figure 2-12. A loggerhead false crawl showing an abandoned primary body pit (C) and a mound of pushed sand (D) no wider than the track and lying between two conspicuous ridges. As is rarely found in nests, a track continues up the beach from the site where the turtle's last digging occurred.

a. Sand thrown into a mound covering more than 2 m of the emerging track and a deep (20–50 cm) secondary body pit with an escarpment (Figure 2-14).

2. Evidence of an abandoned nesting attempt. If present, the crawl can be considered a NON-NESTING EMERGENCE.

   a. Very little or no sand disturbed other than tracks (Figure 2-15).

   Less sand thrown over the emerging track and a smaller body pit than described in 1a above.

V. If the crawl is from a leatherback turtle, is it a nest or a non-nesting emergence?

A. If the disturbed sand in the crawl covers a large expanse of beach (>4 square meters) with sand thrown in multiple directions, the crawl can be considered a NEST.

B. If the crawl is less extensive than in A, the crawl can be considered a NON-NESTING EMERGENCE.

Note: The extent of the excavations described for all species above will be influenced by vegetation, sand compaction, and objects encountered by turtles while digging. There is some variation in the behavior of turtles, and the above guidelines will not lead to a correct determination in every case. They are offered solely to help you with the task of determining whether a nest has been made.

NEST MARKING

Not every sea turtle nest needs to be marked. Marking is necessary for protection from hazardous activities being conducted on the beach or to obtain information on reproductive (hatching) success. Nest-marking methods for each of these two objectives are slightly different. Please keep in mind when driving stakes that at least some undiscovered and/or unmarked clutches are probably present on every beach. Drive stakes with caution.

I. Marking nest sites to protect buried eggs from hazardous activities

The goal of this marking method is to clearly identify the nest area and protect it from human activities such as beach cleaning, vehicular traffic, or construction. Any such construction activity that occurs on the nesting beach during nesting season, including beach cleaning, must have a valid permit from the DEP (see Section 1 for additional information on construction permitting). Activities such as the placement of beach furniture may, at the discretion of DEP, be exempted from permitting.

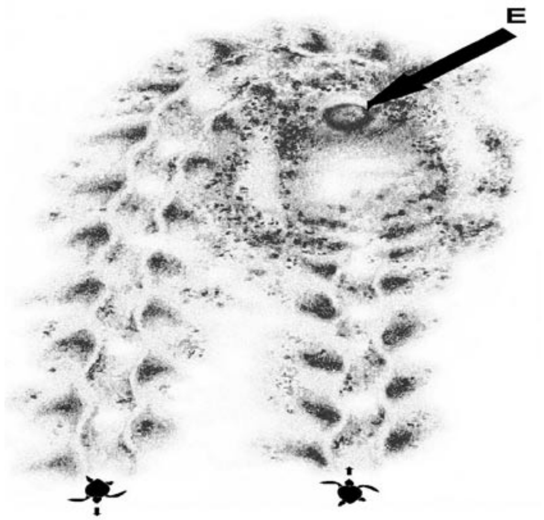


Figure 2-13. A loggerhead false crawl showing a primary body pit with an abandoned egg cavity (E).

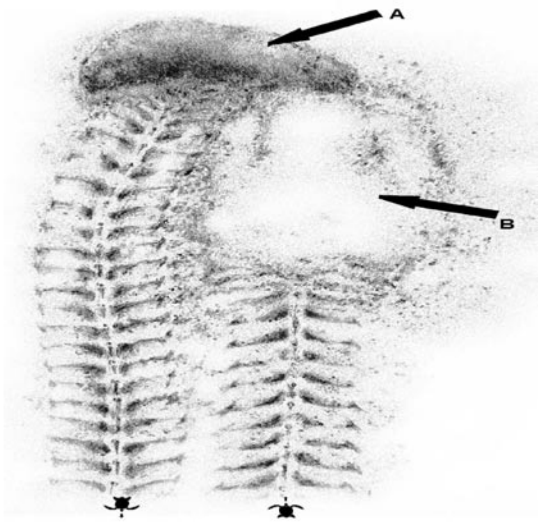


Figure 2-14. A green turtle nest site on an open beach showing a secondary body pit (A) and a mound of thrown sand (B) that is greater than twice as long as the visible secondary body pit. Note that smaller nest mounds are expected when obstacles or vegetation impede digging.

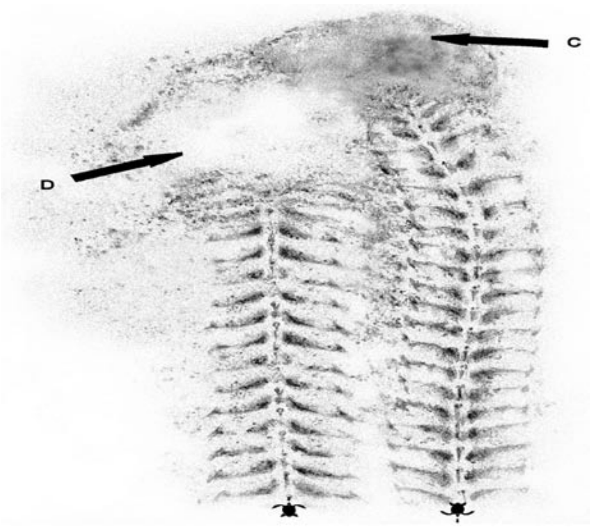


Figure 2-15. A green turtle false crawl on an open beach showing an abandoned primary body pit (C) and a mound of thrown sand (D) that is smaller than twice as long as the visible primary body pit. Note that many green turtle nests may have body pits and nest mounds that look similar to this.

If at all possible, visually inspect the site to determine whether a nest exists. We do not recommend that nests be dug into simply to verify the presence of eggs. If you are not sure whether eggs were deposited, be conservative and mark the area as a nest. The entire disturbed area (where digging has occurred) should be delineated with stakes (Figure 2-16). Construction permits generally require that the nest site be marked with a radius of at least three feet, centered at the approximated location of the clutch. The stakes should extend about 36" above the sand. To further identify the nest site, surveyor's ribbon can be tied from the top of one stake to another to create a perimeter around the nest site. Additionally, a nest sign can be attached to one of the stakes used to create the perimeter (signs are available from FWC—see Appendix C). A nest-identifying number and the date the eggs were laid should be placed on at least one of the nest perimeter stakes. At least one additional stake should be placed a measured distance from the clutch location at the base of the dune or seawall to ensure that a future location of the nest is possible should the nest perimeter stakes be lost.

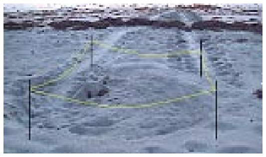


Figure 2-16. Entire disturbed area of nest site marked.

II. Marking nest sites to determine hatching success

The goal of this marking method is to allow an investigator to locate the clutch in order to evaluate the hatching success of a nest. Nests should be marked by locating the precise location of the clutch at a fresh nest site by carefully digging shallow, finger probing holes into the nest, by finger-probing for softer sand over the clutch, and by verifying the location of the eggs. Digging into a nest may alter the incubation environment if not done carefully and with lengthy training. It is preferable to avoid digging into a nest site unless the nest will be screened, caged, relocated, or marked for hatching success.

Figure 2-17. Approximate location of egg chamber in a typical loggerhead nest.

To locate the clutch in a fresh nest, note the characteristics of the nest site to predict the location of the clutch. To approximate the location of a loggerhead clutch, follow the tracks emerging from the water and leading towards the nest site. Commonly, the clutch is located about two feet into the broad disturbed area (the nest mound) from this approach; it is generally centered between the edges of this area. To estimate the location of a green turtle clutch, measure about three feet back from the escarpment created by the final covering activities. On leatherback nests, measure about 4.5 feet from the escarpment created by the final covering activities.

To precisely locate the clutch within the approximated area, dig gently and systematically by hand into the nest site. Focus the digging effort at the center of the mound of sand that was piled by the nesting turtle. Probe with fingers only, feeling for the softer (less compact) sand that will be on top of the clutch. Do not use shovels or any other tools. Once the soft sand is found, and the eggs beneath are verified, fill the hole with moist sand and gently pat the sand surface above the eggs with your hand. Replace the dry sand over this area to the depth present before you began, and place a temporary marker over the clutch site. Rebury any other holes dug in the nest site so that the nest site is restored to its original condition.

To mark the nest site, measure the exact distance from the precise or approximate clutch location to two separate marking stakes on the dune that are aligned so that a straight line between them orients directly toward the location of the clutch (Figure 2-18). If the clutch location is approximate, note the distance between the approximate clutch location and the edges of the disturbed area in each of four opposite directions. Both stakes should be labeled with an identifying nest number and the date the eggs were laid. On beaches where removal of marking stakes by the public is a potential problem, an additional stake, driven deeply and hidden from view, should be placed a measured distance landward of the first two. As added insurance, an aluminum marker can be buried hand-deep and 24" from the approximate clutch location in a standardized direction. This metal marker can be found later with a metal detector.

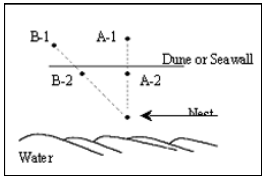


Figure 2-18. Site A stakes are directly landward of the nest in dune vegetation or at the base of a seawall. Site B stakes are in a similar position as Site A but located at an angle from the nest. Stakes A-1 and B-1 should be sunk deeply so that they are not conspicuous to someone not looking for them. Precisely measure the distance from stakes to the clutch location. Then, sink additional stakes (A-2 and B-2) directly between the clutch and the dune stake(s).

Use the marking stakes to find the egg chamber. Many times, a clutch may not produce hatchlings and the location of the clutch will not be indicated by the conspicuous signs of hatchling emergence. Moreover, some hatchling emergence evidence near the nest site may be from a nest other than the one that was marked for hatching success. To accurately determine overall hatching success, it is very important that the clutches from all marked nests be found and evaluated. A nest from which hatchlings did not emerge will be more difficult to locate again, but an inability to find these nests, and their exclusion from the sample representing one's beach, will result in overestimating hatching success for the beach. Please make the greatest effort possible to locate all nest cavities after waiting the appropriate length of time.

HATCHING SUCCESS EVALUATIONS (NEST INVENTORIES)

Hatching success must be determined for all caged, screened, and relocated nests. Hatching success may also be conducted on all other nests or on a sample of nests on the beach. A hatching success evaluation involves the excavation and inventory of a post-emergent nest to determine the fate of each egg. Because sea turtle eggs are subjected to a variety of incubation environments, including many that are affected by human activities, we encourage you to conduct nest inventories for hatching success on a representative sample of the nests in your survey area each year.

Selecting Nests To Be Marked for Inventory

A proper, representative sample of nests will allow assessments of hatching success that can be compared to other beaches and to other nesting seasons. To properly represent the beach, nests in a marked sample must be chosen by a system that removes seasonal, spatial, and observer bias. A sample of nests that is not properly representative can over- or under-represent certain zones on the beach or certain portions of the season. For example, a sampling strategy whereby a set number of nests are marked each day will always under-represent the middle of the nesting season. A sample of nests that is poorly representative, no matter how numerous, will yield potentially misleading information about hatching success.

Like selecting a representative sample of nests, it is also important to use (monitor and inventory) nearly every nest in the sample. Because the most difficult-to-find nests often have the poorest hatching success, the more these nests are excluded from a sample, the more the sample paints a rosier picture of hatching success than actually exists. Before giving up on finding a sample nest, one should feel confident that they know the fate of the nest and that failure to find it is due to its destruction (e.g., from erosion) and not due to imperfections in nest-marking techniques (e.g., stakes washing away from a surviving nest).

The best way to select a representative sample of nests is to decide in advance which nests of the season will be in the sample. If all nests on the beach can be marked and inventoried, then this selection is simple; mark and inventory all nests (but be sure not to overestimate how many nests can be sampled; marking nests is easy, inventorying them is difficult). However, if only part of the nests on a beach can be sampled, then every nth nest should be marked as a sample nest. With this technique, "n" is a number that sets a pace for nest marking that results in a sample size that is adequate, but not too large to handle. Here are some examples of how to use this technique:

On beach A, surveyors feel they can mark, monitor, and inventory about 100 nests. In an average season, this beach gets about 2000 nests. Here, marking every 20th nest will reach the goal if the season is average. Note that the 20th nest is independent of the date of the season. For example, if on the first day of the season there are 19 nests, the first marked sample nest will be the first nest encountered (nest number 20) on the second day of the season. The second sample nest will be the 40th nest, the third will be the 60th … etc.

Using a subtle modification to the above technique, some surveyors may wish to mark sample nests only one day per week. This is fine. To adjust the sampling protocol, divide your "n" by 7 to determine what nests to mark on the one day per week when nest-marking is done. For example, if your calculations are that every 35th nest at your beach needs to be marked in order to keep a pace that would result in 100 nests marked, then every 5th nest marked one day-per-week would keep the same pace and give an adequate sampling of nests. This math gets only slightly more difficult if the "n" for the beach is not divisible by 7. For instance, if 2500 nests are expected, and 100 sample nests are needed, (which gives a daily pace of marking every 25th nest) then the pace for marking nests one day-per-week would be 25 divided by 7, or every 3.6th nest. Of course, there are no fractional nests. In this case one can approximate a pace to achieve 100 nests by choosing two alternating n's that bracket the number calculated. In this case, 3 and 4 bracket 3.6, and a proper pace would be to mark the 3rd, then 7th, then 10th, then

14th nests … etc. FWC staff can help with any questions on proper sampling of nests for hatching success.

Marked nests should be monitored on a regular basis, preferably each morning during the incubation period. Predation to the nest and other significant events should be noted. It is important to give marked sample nests the same treatment as other nests. Do not relocate, screen, or cage a nest just because it is a sample nest. During sample-nest monitoring, treat sample nests like other nests, that is, "clean up" depredated sample nests only if this practice is carried out for all other nests.

Nest Inventory

To conduct a nest inventory, begin by excavating the nest. Carefully dig down into the nest chamber with your hands until you reach eggs or eggshells. D o not use shovels or other tools. If you encounter live hatchlings before reaching any eggs or eggshells, the hatchlings have probably not finished emerging. Quickly cover the egg chamber with moist sand and return the site to its original condition. Wait at least 24 hours before excavating again.

Carefully remove the contents of the nest and place them in a pile on the sand or in a tray for easier sorting (Figure 2-19). Separate the contents into the following categories: hatched eggs (empty eggshells), live hatchlings, dead hatchlings, pipped eggs with live hatchlings, pipped eggs with dead hatchlings, and unhatched eggs (Figure 2-20). In pipped eggs, the turtle has broken through the egg but the hatchling is not completely free of its eggshell. Pipped eggs range from those with just a small hole to those with large tears.

Determine and record the number of eggs that hatched by carefully counting the eggshells (Table 2-1). Count each eggshell that is more than 50% complete as one hatched egg and disregard the smaller pieces. Be sure that all the eggshells are completely separated from each other. Record the number of live and dead hatchlings. These will account for some of the hatched eggs. The rest of the hatched eggs represent hatchlings that emerged from the nest. To determine the number of hatchlings that emerged from the nest, subtract the sum of live and dead hatchlings from the total number of hatched eggs. The sum of the live, dead, and emerged hatchlings should equal the number of hatched eggs.

Figure 2-19. Removal of nest contents.

Hatched eggs

Unhatched eggs

Pipped egg with dead hatchling

Partially developed embryo

Egg with no discernible embryo

Figure 2-20. Categories of the contents of a nest.

Hatched eggs		98
Live in nest	=	3
Dead in nest	=	1
Live pipped		0
Dead pipped		1
Unhatched eggs		5
No discernable embryo	=	3
Partially developed embryo	=	1
Fully developed embryo	=	1
TOTAL # EGGS	=	104

Next, determine and separately record the number of pipped eggs with live hatchlings, the number of pipped eggs with dead hatchlings, and the number of unhatched eggs. Finally, determine the number of eggs originally present in the nest by adding together the hatched eggs, the pipped eggs, and the unhatched eggs. After completing the nest inventory, the nest contents can be reburied within the original egg chamber.

A nest inventory may only be conducted either 72 hours after the first sign of emergence or 70 days after the eggs were deposited (80 days for leatherbacks), whichever occurs first. Digging into a nest before some hatchlings have emerged may adversely affect these hatchlings. Because cooler temperatures sometimes delay hatching and emergence, a nest that has been subjected to inundation, excessive rainfall, shading, or cool fronts, should not be excavated until 80 days after egg deposition or 96 hours after the first emergence. It is important to allow all hatchlings to emerge naturally before excavating the nest.

Note: If the first emergence of a nest has occurred (more than 3 hatchling tracks) and the hatchling tracks indicate a clear sign of disorientation you should contact the property owner responsible for the offending light(s), explain the situation, and ask them to turn the light(s) off. If the property owner cannot be reached or is not receptive to turning off the light(s) you may place a temporary restraining cage over the nest to contain the next emergence of hatchlings…

For the subsampling technique to succeed, a sampling plan based on the total number of nests expected has to be devised before the nesting season so that the sample of nests marked for evaluation will represent hatching success over the entire nesting season and nesting beach. The easiest way to do this is to mark for evaluation all nests made every other day, or every three days, or every five days, etc. (for a statistically valid sample, you should try to mark and evaluate at least 100 nests). Once a sampling plan is initiated, it should be followed throughout the nesting season. FWC sea turtle program staff are available to assist you in developing the best approach for your particular survey area.

When a nest marked for evaluation is completely depredated (all the eggs are destroyed), record this (no further evaluation is necessary). This nest is a very important part of your sample to accurately determine overall hatching success. Do not select another nest as a replacement. When a nest marked for evaluation is partially depredated, remove and count the depredated eggs. Cover the egg chamber with moist sand, and return the site to its original condition. Record the nest as partially depredated and record the number of eggs that were depredated. Then, at the appropriate time, inventory the remainder of the nest.

During nest inventories, some live hatchlings or pipped eggs with live hatchlings may be encountered. If this happens often, try waiting a day or two longer before conducting the inventory. Pipped eggs with live hatchlings or live hatchlings that have prominent yolk sacs may be carefully re-buried at the top of the egg chamber or held on moist sand (not in water) until ready for release. If pipped eggs or hatchlings are held on moist sand, they are to be kept in a darkened, quiet, temperature-controlled area. When ready, these hatchlings are to be released on the beach at night and allowed to crawl to the water. See the following section for more information on the rescue and release of live hatchlings.

HATCHLING RESCUE AND RELEASE

This activity includes salvaging live hatchlings (primarily disoriented hatchlings or those found at the bottom of excavated nests) and ensuring that they reach the water safely. Hatchling rescue and release does not authorize permit holders to conduct public hatchling releases. See Section 7-4 for information on conducting public hatchling releases.

Due to the short duration of the hatchling frenzy period, hatchlings should be released as soon as possible following rescue. All hatchlings found during darkness are to be released immediately. Small numbers of hatchlings (<5) that are found disoriented or at the bottom of nests during daylight excavation may also be released on the beach immediately (but no later than 9 am). Otherwise, rescued hatchlings must be released the following night. Hatchlings collected from excavated nests should never be held in water. Small Styrofoam or plastic coolers lined with damp sand work well as temporary holding containers. The lid of the cooler should be placed loosely over the top to provide a near-dark environment. Once placed in a holding container, hatchlings should not be handled or disturbed until they are ready for release. Activity causes increased expenditure of limited energy stores.

Hatchlings should be placed on the beach and allowed to crawl to the water on their own. Artificial lights should not be utilized during hatchling releases. This applies to any members of the public observing such releases, as well as all permitted personnel involved in the release. A quick check of the release area with a small flashlight a short time after release will insure that all hatchlings have reached the water. Occasionally, individual hatchlings may need assistance in reaching the water. In such cases, they may be moved closer to the water's edge or placed in the shallows and allowed to swim off on their own.

In some cases, weak hatchlings may need to be held for slightly longer periods (1-2 days) to allow them to recover. However, holding hatchlings overnight should not be a routine event. If hatchlings require further holding, contact FWC to arrange for their transfer to an authorized rehabilitation facility.

HATCHLING AND ADULT DISORIENTATION

Although sea turtles do nest on beaches with artificial lights, there is much evidence suggesting that they prefer darker beaches. When sea turtles choose to nest on lighted beaches, their hatchlings are at great risk. In Florida, artificial lighting is probably the single greatest human threat to emergent hatchlings trying to reach the ocean.

Both hatchlings and nesting adults exposed to artificial lighting can be led in the wrong direction (become misoriented) or meander and circle (become disoriented). It is extremely important that sea turtle permit holders who conduct nesting surveys look for and document signs of disorientation. These events should be reported on the standard reporting forms. Because we may be able to immediately resolve a lighting problem and thus avoid subsequent problems, it is very important that you inform the FWC Tequesta office of all disorientation events as soon as possible. You can fax the forms to Tequesta at: (561) 743-6228.

Some indirect tracks from adult turtles may not be due to artificial lighting. Adult females in search of a nesting site may wander on the beach for a period of time looking for a suitable nesting site. Leatherback turtles are known to make orientation circles on their way back to the ocean after nesting. A diagram of the crawl should be included with adult disorientation reports to help assess the actions of the turtle.

Wind and rain may obscure tracks, making it difficult to document hatchling disorientation. Still, every effort should be made to count the number of hatchlings disoriented. Counting the tracks farther from the nest, in the area where the tracks spread out, is generally a little easier than trying to count the tracks right next to the egg cavity.

Identifying the light source is also important. If the disorientation was documented during a morning survey, and if time and personnel permit, a subsequent nighttime lighting survey would be useful in identifying the light source. The address of the property, and the number, type, and location of lights are important to the local code enforcement persons and/or FWC. Several counties and municipalities have lighting ordinances. A list of local ordinances and contact numbers can be found in Appendix C. In cases where a local ordinance is in place, the local code enforcement person is generally responsible for ensuring compliance with the ordinance. In areas where there is no local ordinance, FWC tries to work with the property owner to correct the problem light(s). Please notify the local code enforcement office and/or FWC as soon as possible after a disorientation event.

NEST RELOCATION

Summary

This section is specifically intended for those persons whose permit authorizes them to relocate nests. These personnel are also authorized to:

- mark nests

Personnel are not authorized to conduct the following activities unless specifically stated on their permit:

- conduct nesting surveys
- protect nests with self-releasing screens/cages
- protect nests with restraining cages
- use a self-releasing hatchery
- use a restraining hatchery
- relocate a clutch at anytime after 9:00 a.m. the morning following deposition
- use probes (other than fingers) to locate clutches.

ACTIVITY DESCRIPTION

Moving sea turtle eggs creates many opportunities for adverse impacts. Movement alone is known to kill developing embryos by disrupting delicate membranes that attach to the inside of the egg. Because the incubation environment greatly influences the developing embryo, nest relocation can involve the transfer of eggs from an appropriate environment to an inappropriate one. For this reason, nest relocation is considered a management technique of last resort.

Natural events, like storms, that accelerate beach erosion and accretion can sometimes reduce hatching success in existing nests. While damage from storm events can be severe, it is difficult to predict the precise areas where the storm is most likely to inflict damage. Because of the negative effects of relocating eggs and the unpredictability of storm events, FWC does not generally authorize permit holders to move nests out of areas threatened by storms. As a general rule, nests should only be relocated if they are low enough on the beach to be washed daily by tides or if they are situated in well documented high-risk areas that routinely experience serious erosion and egg loss (e.g., nests laid near river mouths or beneath eroding sea walls).

FWC does not generally authorize nest relocation for heavy foot traffic, lighting problems or beach cleaning. Foot traffic is not known to cause problems for nests, but if traffic is heavy, a nest can be marked so that it will be avoided by pedestrians. If a nest is made near a light that may misorient the hatchlings, efforts should focus on getting the light turned off or shielded (if protection is necessary, the nest should be caged). If nests are deposited on beaches that are periodically raked with mechanical equipment, beach raking should be discontinued or the nests should be marked clearly so that they can be avoided by the beach cleaners.

When a nest does require relocation, the eggs must be moved no later than 9:00 a.m. the morning following its deposition. About 12 hours after deposition, the potential for movement-induced mortality in sea turtle eggs increases rapidly. Eggs should be moved no later than 12 hours after deposition (turtles may nest as early as 9:00 p.m. the preceding night). To relocate a nest, find the location of the egg chamber by gently and systematically digging by hand, and probing with fingers only. Never use shovels or any other tools for either digging or probing. Once the eggs are located, carefully remove the sand from around the top eggs. Individual eggs should be gently lifted from the egg chamber and placed into a rigid container with a 2″–3″ layer of moist sand on the bottom. When moving eggs, be sure to maintain each egg's original orientation; do not rotate eggs in any direction and avoid abrupt movements. As eggs are placed in the container, be sure that they do not roll. Eggs are to be shaded if relocated after sunrise. The easiest way to do this is to lay an open umbrella on its side (because there may be eggs incubating nearby, do not stick the umbrella into the ground) or place a towel over the top of the container holding the eggs. When all eggs are in the container, cover them with a layer of moist sand.

Find a suitable nearby location on the beach that is successfully used by nesting turtles. Be sure that the new nest site is above the high tide level but not in dense vegetation. With your hands, dig a new nest chamber to the same depth, size, and shape of the original nest. The shape of the nest chamber should be such that there is a spherical bottom and a slightly narrower neck. The depth of a loggerhead nest chamber should be

18–22 inches and the diameter of the spherical bottom should be volleyball to basketball size. The neck should only be 2–4 inches more narrow than the bottom. Clutches that are greater than or less than average may require respective nest-chamber dimensions that are larger or smaller. Place the eggs in the new egg chamber by transferring them one at a time while continuing to maintain each egg's original orientation. After all the eggs have been transferred into the new egg chamber, cover them with the moist sand excavated from the egg chamber. Dry sand should not be allowed to fall into the egg chamber. Once the eggs are reburied to the upper level of the surrounding moist sand, gently pat the sand surface above the eggs with your hand. Replace the dry sand over this area to the depth present before you began. The relocated nest can then be marked and later evaluated for hatching success.

SPECIAL PERMIT CONDITIONS FOR USING HATCHERIES

Because the use of hatcheries requires that eggs be relocated, it is not considered a preferred management technique (see FWC's Sea Turtle Conservation Guidelines, Section 2, Nest Relocation). However, the use of hatcheries is authorized by FWC in a limited number of areas where artificial lighting problems are extreme. These areas typically have little or no sections of beach where nests can be left *in-situ* without emerging hatchlings becoming disoriented by artificial lights. Persons authorized to relocate nests to a hatchery must follow the guidelines for Nest Relocation in Section 2 of the Sea Turtle Conservation Guidelines. Nest success evaluations are required for ALL nests relocated to self-releasing or restraining hatcheries.

Self-releasing hatcheries are typically located on dark areas of beach. Nests placed in a self-releasing hatchery should be spaced uniformly at least one meter apart and marked using a stake(s). The purpose of marking nests in a self-releasing hatchery is to ensure that previously relocated nests are not inadvertently dug up or placed too close to each other. Stakes are also needed later to evaluate nest success. Nests in self-releasing hatcheries must be checked daily by permitted personnel [to monitor threats to the nests].

Restraining hatcheries are utilized in areas where there are no sections of the beach dark enough to allow hatchlings to emerge and find the water on their own. Restraining hatcheries must be checked for emerging hatchlings at least three times a night (once between 9 p.m. and 11:00 p.m., once between 12:00 a.m. and 2:00 a.m. and once between 3 a.m. and 5:00 a.m.) beginning 45 days after the first clutch is deposited in the hatchery and ending when all nests in the hatchery have emerged. Release locations should be varied to avoid creating a feeding station for in-water predators. During the day, the hatchery must be checked at least once every half hour unless the seaward side of the hatchery can be opened in such a way that hatchlings emerging during the daytime can escape the hatchery and crawl to the ocean on their own.

Hatcheries must be situated in areas that mimic good-quality sea turtle nesting habitat. If located on the seaward side of a primary dune the hatchery should be at least one-meter vertical distance above the level of the highest spring tides to prevent excessive inundation of the eggs. Hatcheries should be located in areas exposed to the sun most of the day and where vandalism is not a concern. Hatcheries should not be situated near drainage or outfall pipes. Hatcheries must be in good physical repair and maintained in such a way that vegetation does not encroach into the hatchery. To prevent infestation from fungus and bacteria, the sand in the hatchery must be replaced every year prior to the beginning of the nesting season to a minimum depth of three feet.

Hatcheries may not be used to store any type of equipment other than nest marking materials (i.e., stakes, bottomless buckets, etc.). Under no circumstances may hatcheries be used to store vehicles (e.g., ATV's), gasoline, or other equipment that may be potentially harmful to incubating nests or that pose an entanglement risk to emerging hatchlings.

Appendix C: Sea Turtle Stranding and Salvage Network (STSSN) Coordinators

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NOAA/National Marine Fisheries Service 6/6/03

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