Chapter 2 Life History and Physiology

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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 logger-head 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.