

Introduction to the Evolution, Life History, and Biology of Sea Turtles

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Seven species of sea turtles representing two families, Cheloniidae and Dermochelyidae, are the only living members of what has been a large and diverse marine radiation of cryptodiran turtles. These seven species include the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), Kemp's ridley (*Lepidochelys kempii*), olive ridley (*Lepidochelys olivacea*), flatback (*Natator depressus*), and leatherback (*Dermochelys coriacea*) turtles. An eighth species, the black turtle or East Pacific green turtle (*Chelonia agassizii*), is recognized by some biologists, but morphological, biochemical, and genetic data published to date are conflicting, and the black turtle is currently treated as belonging to *Chelonia mydas*.

Sea turtles inhabit every ocean basin, with representatives of some species found from the Arctic Circle to Tasmania. Hawksbills are perhaps the most confirmedly tropical of the sea turtles, whereas leatherbacks are known to make forays into colder, sometimes polar, waters. With the exception of Kemp's ridley and flatback turtles, sea turtles are cosmopolitan in distribution. Kemp's ridley is restricted principally to the Gulf of Mexico and the eastern seaboard of the United States, with some individuals occasionally found along the shores of the United Kingdom and western Europe. The flatback is endemic to the Australian continental shelf.

The living sea turtles are a monophyletic group (derived from a common ancestor that has not given rise to other living turtles) of the suborder Cryptodira. This suborder includes those turtles that close their

jaws by contracting muscles over a cartilage on the otic chamber (Gaffney, 1975). In all living cryptodires, the head is retracted in a vertical plane and assumes an S-shape between the shoulder girdles (Gaffney and Meylan, 1988). Living sea turtles have a reduced ability to retract their heads compared to other living cryptodires, but thick, nearly complete skull roofing confers additional protection to the head. The oldest members of this sea turtle radiation date back 110 million years to the early Cretaceous (Hiryama, 1998). An earlier (late Jurassic) lineage of cryptodiran sea turtles, the family Plesiochelyidae, is considered to be independent of that which produced the living forms (Gaffney and Meylan, 1988).

Sea turtles are considered highly derived morphologically and have many adaptations for life in the sea. All species share features such as paddle-shaped limbs, in which all movable articulations between the distal bony elements are lost and three or four digits of the hand are markedly elongate. Lacrimal, or tear, glands are remarkably enlarged and modified to remove excess salts from body fluids; the salts are derived mostly from drinking sea water. Sea turtle shells are characterized by a reduced amount of bone. Sea turtles are also streamlined to various degrees, which improves their hydrodynamic efficiency. An enlarged shoulder girdle with a markedly elongate coracoid serves as an attachment site for the well-developed pectoral muscles which are used for swimming.

A generalized life-history model (Hirth and Hollingworth, 1973; Carr *et al.*, 1978) developed with data from the green turtle, and elaborated upon by

numerous other authors, provides a framework for understanding and refining the life histories of all species of sea turtles. Although each species diverges from the model in significant ways, the phenomenon of seasonal and ontogenetic shifts in habitat occupation appears to explain much of the observed movements and migrations. Upon leaving the nesting beach as hatchlings, green turtles, loggerheads, and hawksbills begin a pelagic (open ocean) phase that is believed to last at least several years. They are often found at sea in association with weed lines or drift lines that exist near frontal boundaries near major currents. Passive drifting with currents has been demonstrated in the immediate post-hatching period. The flatback seems to be an exception to this pattern; hatchlings remain in coastal waters and apparently lack a pelagic phase (Walker and Parmenter, 1990). The habitats of post-hatchling leatherbacks and ridleys remain unknown.

This early pelagic phase, originally referred to as the "lost year" by Archie Carr, varies in duration among species and among populations. Western Atlantic loggerheads, for example, remain in the pelagic environment until they are well over 40 cm in straight carapace length, whereas Atlantic green turtles, hawksbills, and Kemp's ridleys 20-30 cm in carapace length are commonly found in shallow-water habitats.

Carr *et al.* (1978) discussed the concept of "developmental habitats" and defined them as places where immature sea turtles commonly occur but where adults of the same species are rarely, if at all, found. These may consist of one or a series of habitats (generally coastal feeding grounds) through which turtles pass as they grow to adult size. Entry into, and departure from, developmental habitats appear to occur at predictable sizes for some species. Individual turtles are often caught repeatedly in the same area over intervals of several years, implying residency in these developmental habitats. The amount of time the various species remain resident in any particular developmental habitat before moving on to the next is poorly known.

Estimates of growth rates in wild individuals indicate typically slow growth, with age-to-maturity ranging 15 to 50 years or more, depending on the species and geographic area (Balazs, 1982; Bjorndal and Zug, 1995). Adult turtles spend most of their lives in the adult foraging ground (with or without immatures), an area that is usually separate from the nesting beach. Adult foraging grounds may be fixed in space, such as seagrass beds, or transitory, such as areas in the

ocean with seasonably predictable blooms of jellyfish or benthic invertebrates. During the reproductive season, adult turtles travel to the vicinity of the nesting beach, where they may remain for up to several months. Mating takes place along the migratory corridor, at courtship or breeding stations, and in the vicinity of the nesting beach. During the reproductive season, both males and females may be found in the longshore waters off the nesting beach, also called the interesting habitat.

Different species of sea turtles share many behaviors, especially those involved in reproduction. For this reason, methodologies for studying or managing sea turtles at the nesting beach are very similar for all the species. Female sea turtles typically nest more than once per reproductive season; most do not nest in consecutive years. Nesting behavior is highly stereotypic. Species-specific differences exist in parameters such as nesting habitat preference, nesting strategy (aggregated vs. solitary), size at first reproduction, average clutch size, and details of the nest size and construction. One highly divergent reproductive behavior is that of nesting in huge aggregations over a period of a few days. These mass arrivals, or *arribadas*, are formed only by Kemp's and olive ridleys.

All sea turtles appear to exhibit migratory behavior at different times in their lives. Reproductive migrations between feeding grounds and nesting beaches are the best documented because of the ease of tagging adult females on nesting beaches. Journeys spanning many thousands of kilometers are known to occur. The seasonal movements of sea turtles in search of food may also be considered as migrations. For example, leatherbacks nesting in the Wider Caribbean region return to jellyfish-rich waters in the northern and eastern Atlantic basin after breeding. Immature turtles travel between successive developmental habitats, which may be separated by hundreds or thousands of kilometers. What has been gleaned about migratory behavior of sea turtles from recaptures of tagged turtles has been greatly augmented in recent years by the use of molecular genetics (to identify the nesting beach origin of turtles captured at sea) and satellite telemetry. The latter yields information about the actual course of travel, rather than point-to-point capture data.

Because of their wide-ranging migratory nature, sea turtles require international cooperation to ensure their survival. All seven species of sea turtles are included on the IUCN Red List of Threatened

Animals (Baillie and Groombridge, 1996): Kemp's ridley and the hawksbill are considered Critically Endangered; loggerheads, green turtles, olive ridleys, and leatherbacks are listed as Endangered; and flatbacks are considered Vulnerable. These categories reflect the global status of whole taxa and are based on criteria such as population level, population trends, extent of occurrence, and probability of extinction in the wild.

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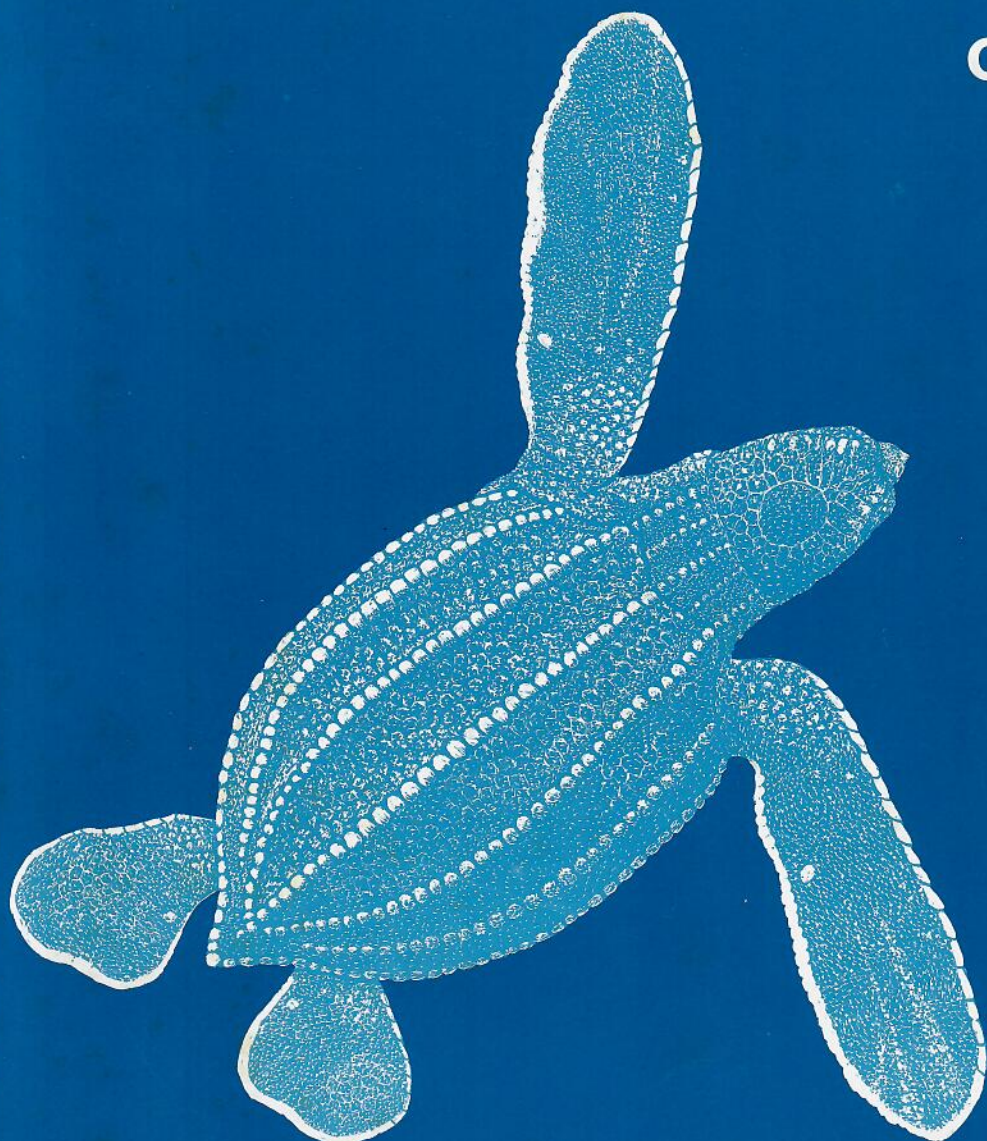
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Research and Management Techniques for the Conservation of Sea Turtles



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