Research in Marine Sciences
Volume 4, Issue 3, 2019
Pages 556 - 562

Sea turtles: ancient creatures, mysteries, adaptations, and threatens

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(This version has been translated and modified from its original version in Spanish: Martín-del-Campo, R. and García-Gasca, A. 2018. Tortugas marinas: seres ancestrales, sus misterios, adaptaciones y amenazas, Revista Ciencia UANL, Año 21, No. 91, 16-21, with permission of the editors)

Received: 2019-07-20 *Accepted: 2019-09-06*

Abstract

Turtles are amazing creatures, they have survived for millions of years to changing the environments, shell, retractile neck, and limbs are evolutionary novelties, except for sea turtles, in which neither neck nor limbs are retractile as an adaptation for feeding, swimming, and diving in the ocean. Sea turtles appeared about 110 million years ago; the most ancient sea turtle alive is the leatherback, which appeared about 25 million years ago. Sea turtles perform extensive migrations from mating zones to feeding zones, females lay eggs in the same beaches they were born, hatchlings instinctively crawl to the ocean, where the currents haul them, and they stay in pelagic zones for food and shelter until adulthood. Humans have interacted with sea turtles for a long time; however, overfishing and other anthropogenic activities (such as the production of chemical compounds discharged into the ocean) have negatively affected wild populations. Some evidence indicates that these chemical compounds interact with the genome (the so-called epigenome), altering normal development, producing congenital malformations, and ultimately affecting survival. Thus, on one side, anthropogenic activities have damaged sea turtle populations, but on the other side, sea turtle conservation programs around the world are working to preserve these ancient creatures, we have a responsibility to make things right, it is not too late.

Keywords: Sea turtles; Surviving turtle; Preserve; Ancient creatures.

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1. Introduction

Turtles appeared in the world about 200 million years ago, before large reptiles dominate the planet (Márquez, 1990). Studies in molecular biology suggest that alterations in genes controlling fate of bone cells allowed carapace formation. It is known that regulatory genes (such as *Hox* genes) define and sculpt body plans during embryonic development, and subtle changes in gene function could cause carapace and plastron development in turtles (Spotila, 2004; Lappin *et al*., 2006; Martín del Campo *et al*., 2018a). This structural innovation (the carapace) provides protection and thus became an advantage for turtles; most turtle species have not experienced significant evolutionary changes in the carapace, however, internal structures, limbs, neck, and head suffered substantial modifications (Márquez, 1990).

Some sea turtle species migrated to the ocean and returned to dry land about 150-200 million years ago (between Jurassic and Cretaceous periods), giving rise to different lineages. In the marine environment, turtles experienced several evolutionary changes, the limbs became non-retractile fins so they were able to swim, dive, and compete with other marine species (Spotila, 2004).

"Modern" sea turtles appeared about 110 million years ago and descend from a single linage; at this time, large reptiles dominated the planet, but they suffered a massive extinction event about 65 million years ago, when an asteroid affected near the Yucatan Peninsula in Mexico, triggering substantial climatic changes. Many species were extinct, but others (such as birds and mammals) were able to survive, proliferate, and dominate the planet. Sea turtles persisted to those climatic events, and today there are seven species, the most ancient is the leatherback sea turtle (*Dermochelys coriacea*), which appeared about 25 million years ago (Figure 1) (Spotila, 2004).

2. Main body

2.1. Adaptations of sea turtles

In order to survive, sea turtles have been able to adapt to changing environments. They are ectothermic animals that depend on water temperature and sun exposure to regulate body temperature, while the carapace protects vital organs (Spotila, 2004). They have pulmonary respiration, and therefore inhale air from the surface to perform deep and prolonged immersions (Plotkin, 2007). They also possess cranial glands to excrete salt and maintain osmotic balance (Márquez, 1990). They have sexual reproduction and internal fertilization;

Figure 1. Leatherback sea turtle (Left: from Cancun, Quintana Roo, Mexico; Right: U.S. Fish and Wildlife Service Southeast Region [Public domain])

females are able to nest in an annual, biannual, or triannual basis, depending on the species, food availability, and environmental conditions (Spotila, 2004; Plotkin, 2007). After mating, females are able to store sperm for a long time in grooves located in the middle side of the oviduct; the sperm stays viable to fertilize eggs even until the next mating season (Márquez, 1990). Females accept courtship from several males during the same mating season, and therefore offspring from a single female may be from different males (multiple paternity) (Jensen *et al*., 2006).

Female sea turtles lay between 50 and 130 eggs in terrestrial environments; these are nesting beaches located in tropical and subtropical latitudes. Eggs are incubated for about 1.5 to 2 months, depending on the species and environmental temperature. After that sea turtle hatchlings make their way to the surface and begin the so-called "swimming frenzy", in which they instinctively crawl to the ocean (Figure 2), trying to avoid predators. Then they are hauled by ocean currents; during this time, they obtain energy from the yolk sac they absorbed while in the egg, and lasts for about one week (Spotila, 2004).

Unfortunately, in spite of the number of eggs, about one out of 1000 hatchlings will make it to adulthood. Little is known about the hatchling phase, but some evidence indicates that they stay in pelagic zones, where marine turns and fronts allow Sargassum accumulation and bring a variety of marine organisms to provide food and shelter (Witherington *et al*., 2012); this period is known as "the lost year", although it may last several years (Márquez, 1990).

Evidences including nuclear and mitochondrial DNA indicate that sea turtle females return to lay eggs to the beach where they were born, although some species are more phylopatric than the other species (Bowen and Karl, 2007). In addition, they are able to perform extensive migrations from mating zones to feeding zones (Figure 3); they possess the ability to orientate using superficial oceanic currents, temperature gradients, or even magnetic signals during navigation (Plotkin, 2007).

2.2. Interaction of man with sea turtles

Sea turtles and humans have interacted for thousands of years (Frazier, 2003). Humans appeared about 1.8 million years ago (during the Pleistocene), and records indicate that

Figure 2. Olive ridley sea turtle hatchlings crawl to the ocean (Left photograph: Rodolfo Martín del Campo, Ceuta Beach, Sinaloa, Mexico; Right photograph: Miguel Betancourt-Lozano, El Verde Camacho Beach, Sinaloa, Mexico)

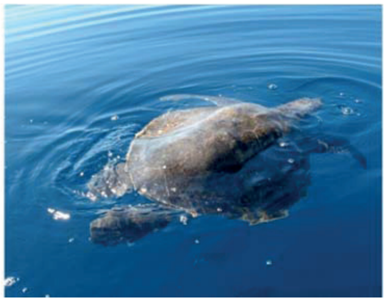

Figure 3. Sea turtle adult (olive ridley) in open ocean [Photograph: Rodolfo Martín del Campo]

turtles have been used as food since ancient Mesopotamia, about 7000 years ago, because bone remains have been found close to the delta of rivers Tigris and Euphrates (Frazier, 2003); records also indicate an organized trade of meat, eggs, and shells. Sea turtles also had a special meaning for people, since the times when Babylonians dominated Mesopotamia (about 3000 years ago), and represented a cultural icon symbolizing the god of knowledge, Enki (Spotila, 2004).

In the Hindu civilization, 2500 years ago, people thought that the world was posed on the back of four elephants, and that these elephants were posed on a giant marine turtle, which swam around the ocean lifting water with its fins (Spotila, 2004). In the Mayan culture, sea turtles were (besides food supply) a cultural and religious symbol; evidence relies on ceramic figures and altars located in ceremonial centers (Frazier, 2003). In Costa Rica (about 1500 years ago), the Chibcha people considered sea turtle eggs as aphrodisiac food, this idea is still valid for some people and it may be due to the large amount of eggs a female sea turtle lays in a single nest (Spotila, 2004). In addition, sea turtles played an important role during European expeditions in the New Continent because they provided food during navigation. Christopher Columbus in 1503 AC discovered Cayman Islands and baptized them as "Dry Turtles" because of the large amount of turtles they saw upon arrival, which were aggregated close to the coast to mate and nest (Spotila, 2004). Unfortunately, by the year 1800 (in the 19th century) the sea turtle population in these islands had disappeared, because after the discovery of America an international market of sea turtles (mainly hawksbills) exported sea turtle-derived products to New York, Great Britain, France, and Japan, among other countries. The sea turtle market expanded to other parts of the world, sailors searched areas to capture this resource because they thought it was unlimited (Meylan and Donnelly, 1999).

2.3. Anthropogenic activities and their impacts on sea turtles

Besides over-exploitation of sea turtles, wild populations have decreased due to other human activities. After the Industrial Revolution (1760-1840), human activities depended on the industry. From those days until now, the chemical industry has synthesized a number of chemical compounds for different purposes (cosmetics, food additives, pesticides, domestic products, and combustion-derived products, just to mention a few ones). Most of these products are considered pollutants because they have a negative impact on the environment, although depending on some characteristics such as toxicity and degradation time, some are more harmful than other products.

Most contaminants have spread around the world due to discharges and transport through water or air until they reach marine ecosystems. Once in the ocean, contaminants reach different levels of the food chain affecting sea turtle health and decreasing wild populations (Keller, 2013). Some contaminants may affect embryonic development, resulting in congenital malformations (teratogenesis) or modifying hormone pathways (endocrine disruption), decreasing survival, and/or altering sex ratios in the population (Bishop *et al*., 1998).

2.4. Chemical contaminants and embryonic development of sea turtles

In Mexico, six out of the seven sea turtle species arrive to territorial waters and nesting beaches: leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), loggerhead (*Caretta caretta*), green (*Chelonia mydas*), kemp's ridley (*Lepidochelys kempii*), and olive ridley (*Lepidochelys olivacea*). All of them are considered endangered and therefore research on conservation biology, management, and genetics is fundamental.

Some studies have provided evidence that chemical contaminants affect health, survival, and reproduction of sea turtles (Keller, 2013). For instance, Endosulfan, an organic chloride pesticide, highly persistent in the environment, has been recently identified in olive ridley embryos with congenital malformations (Martín del Campo *et al*., 2019a). Endosulfan concentrates in air, water, and soil, where it can reach animals and humans, it bioaccumulates in fat tissues, and biomagnifies through the food chain. In 2011, this pesticide was included in the Stockholm Agreement to be removed from use around the world (UNEP, 2011), although it is still used in some developing countries. This compound has been classified as endocrine disruptor, and in model animals (such as mice) has been proved that are embryotoxic and teratogenic (Singh *et al*., 2006).

During embryonic development, genetic and epigenetic mechanisms work together to establish new structures and body plans. Epigenetic mechanisms regulate gene expression and are sensitive to environmental insults (Dolinoy, 2008). DNA methylation is the most studied epigenetic mechanism and can be reprogrammed during embryonic development upon exposure to environmental contaminants. We have studied locus-specific and global DNA methylation in olive ridley sea turtle embryos with congenital malformations, and its relationship with environmental contaminants such as endosulfan and mercury (Martín del Campo *et al*., 2018b; Martín del Campo *et al*., 2019b). Although preliminary, we have found an association between mercury concentrations and global DNA methylation in sea turtle embryos with schistosomus reflexus, a malformative syndrome found in the olive ridley (Bárcenas-Ibarra *et al*., 2016). Our results indicate that exposure to environmental contaminants may alter the DNA methylation status during development producing aberrant phenotypes, and therefore affecting survival rates in sea turtle embryos.

Conclusion

Historically, the human being has done amazing things, but those wonderful discoveries and inventions have come with a prize. Sea turtles have been able to adapt to changing environments and survive for millions of years, unfortunately, in spite of adaptive mechanisms, wild populations have declined over time. Humans have a responsibility towards wildlife, some anthropogenic activities have damaged sea turtle and other animal populations, however, sea turtle conservation programs are working to preserve all seven sea turtle species alive. It has not been an easy task, we need to change our mentality towards wildlife, the ocean, and the disposal of industrial products, it is not too late to make things right.

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