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Green Sea Turtle *(Chelonia mydas)* Hatchlings Success:
The Effects of Artificial Lights and other Human Impacts

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By

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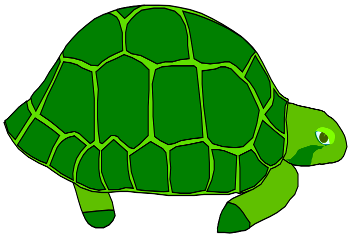

Abstract

Green Sea Turtle Hatchlings Success:

The Effects of Artificial Lights and other Human Impacts

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Sea turtles appeared more than 200 million years ago in the late Triassic period. They grow very slowly, taking an average of 25 years to reach sexual maturity, with a life span averaging 40-50 years. From May to October green sea turtles *(Chelonia mydas)* emerge during the night and follow light cues toward the sea. Recently, beachfront development has increased hatchling mortality rate. When hatchlings emerge from nest, high densities of artificial lights lead them toward the land where they either desiccate and die, or are preyed upon. Short-wavelength high intensity light and the distance of artificial light are the two most important lighting issues. But natural predators such as mammals, birds and big crabs also prey on the hatchlings. In addition, beach vehicles and human footprints are additional human impacts on hatchlings. Reducing the short-wavelengths lights behind urban nesting beaches, extending the distance of buildings behind beaches, and turning off lights in the early evening during the nesting seasons are all recommendations to potentially reduce hatchling mortality rates. Involving environmentally educated volunteers to transplant the clutches from high predator density to lower predator density areas has also been suggested.

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Introduction:

Origins

The sea turtle (Family *Chelonidae*) is one of the ancient animals of the world. Terrestrial turtles belong to the most ancient living reptiles, appearing more than 200 million years ago in the late Triassic period (Lutz and Musick, 1997). Although researchers do not know exactly when turtles first appeared in the sea, they probably began living in the ocean during the early Mesozoic period. For the next 100 million years, during the time of the dinosaurs, sea turtles shared the ocean with a rich diversity of other air-breathing reptiles, including ichthyosaurs and plesiosaurs (Lutz and Musick, 1997).

Taxonomy

The terms “turtle” and “tortoise” are often used interchangeably. Unfortunately this interchange is incorrect, as the term “tortoise” refers to an organism that resides solely on land, such as the desert tortoise (*Gopherus agassizii*) while the term “turtle” refers to an organism that can reside on land or in the water, such as the sea turtle *“Chelonia mydas”*. Green sea turtles are in the kingdom *“Animalia”* (animals), phylum *“Chordata”* (vertebrates), class *“Reptilia”* (reptiles), order *“Testudines,”* family *“Cheloniidae,”* genus *“Chelonia,”* and species *“mydas”*.

Green sea turtles and loggerheads are classified in the same kingdom, phylum, class, and order. Loggerheads belong to the genus *“caretta”* in the *“Cheloniidae/ Testudines”* family. The scientific name of loggerhead is *“Caretta caretta”*.

Physical Features

The following generic definition of *Chelonia* comes from Pritchard (1997), "(they have) one pair of prefrontal scales; horny cutting edge of lower jaw coarsely dentate, and the upper jaw strongly ribbed vertically; bony alveolar surface of upper jaw with a low, but regularly raised auxiliary ridge behind the anterior ridge, which is very strong and terminates anteriorly in a pointed eminence at the posterolateral corner of the permaxillary pit; costal scutes four pairs, well cornified, juxtaposed."

Sea turtle hatchlings weigh an average of 24.6 g and can grow to more than 180 kg during their lifetime. The turtle's carapace, may reach 1.2 m (Carr, 1983). The green sea turtle has flipper-like forelimbs resembling wings, and strong vertical ridges on the upper jaw. It has a single pair of large plates on top of the head, which is not completely retractile likes its terrestrial relatives. Sea turtle hatchlings tend to be dark on top and white on bottom, while an adult's carapace is generally light to brown color with dark mottling on top, and a smooth, keelless shell. Although adult sea turtles are mainly herbivores, eating marine algae, turtle grass, seaweed, and marine plants, their diet can also include items such as jellyfish, mollusks, or crustaceans. Turtles grow very slowly, taking an average of 25 years to reach sexual maturity, with a life span averaging 40-50 years.

Migration

Green sea turtles have a wide distribution, and are found in parts of the Atlantic, Pacific, and Indian Oceans. Loggerhead turtles distribute in subtropical and tropical areas, including the northern and southwestern Indian Ocean, eastern Australia, Japan, and Atlantic Ocean (Limpus, 1994). Tens of thousands of turtles have been tagged worldwide, in an attempt to learn more about their habits while out at sea, and with the expectation that subsequent recaptures at sea would help reveal migratory pathways of each species (Meylan, 1979). Because green sea turtles tend to swim long distances, researchers have also using satellites to track migratory pathways from nesting beaches to resident ground beaches located hundreds or even thousands of kilometers away. The green turtle is known as a site-faithful animal because females return to the same nesting beach each time they lay eggs, every two to three years throughout her lifetime (Fig. 1). Because of this site faithfulness, females are ideal to study migration routes. Colonies are generally located on tropical and subtropical ocean belts, and major nesting sites are usually located on islands and mainland beaches. In general, turtles prefer warm shallow water containing loose, sandy areas with abundant sea grass, and a surface water temperature of about 25°C.

Nesting

Nesting season typically extends from May to October. Mating areas are usually at sea, but located relatively close to nesting beaches. Female turtles may mate multiple times, with different males, during the mating period. After mating, a female will look for an open beach to nest and lay her eggs. Mortimer (1982), recognized four general requirements for nesting beaches: (1) ease of beach accessibility from the sea, (2) a high beach that can prevent inundation of eggs by tides or the underlying water table, (3) a substrate that can facilitate gas diffusion, and (4) moist sand fine enough to prevent collapse of the egg chamber during digging. Sea turtles usually choose to nest on dark open beaches in areas relatively free of rocks (Mortimer, 1979). In some areas of the world, green sea turtles prefer beaches with tangible vegetation such as large bushes or even trees (Bustard, 1972).

Green sea turtles move by pushing all four flippers forward at the same time (Miller, 1997). Because of this mode of locomotion, each sea turtle species has a unique track path width which can be used for identification. Tracks, path widths, distances from sea edge to nest, and gait patterns left in the sand, all provide researchers a clear indication of which species has attempted to nest.

The general nesting pattern contains seven steps. First, the turtle emerges from the surf and crawls up to the beach. Next, it excavates the body pit, a nesting area about the size of the female’s body, digs the egg chamber by using rear flippers, assumes egg-laying position, and lays the eggs in the chamber. Finally, the turtle fills in the body pit and returns to the sea (Miller, 1997). This complete process generally lasts 2- 3 hours, and the female must be sure to return to the sea before sunrise to avoid overheating.

For successful embryo growth, nesting environments must contain adequate conditions for gas exchange, moisture, and temperature. Because eggs are very sensitive to desiccation, hatchling emergence mortality tends to be relatively high in hot, dry nest conditions. Temperature also influences incubation period. At a temperature of 23 to 25°C, green turtle eggs incubate an average of 94 days, (Packard, 1988) and at 32°C eggs incubate an average of 49 days (Bustard, Greenham, 1968). Sexual differentiation is also based on incubation temperature, with higher temperatures producing more females, and lower temperatures producing more males.

During the nesting season, sea turtles usually lay nine to eleven clutches of eggs at 12 to 14 day intervals in an area. Mean nest depth is 69 cm, and sand temperature ranges in proportion to depth (Chen, Cheng, 1995). The average internesting period is from 10 to 14 days. The average number of eggs laid per event is approximately 90 to 130, depending on the female's body size. Compared to other turtles such as the leatherback which lays large eggs up to 5.3 cm, and 90 g, the green turtle lays a medium-sized egg 4.5 cm wide and weighing 48g. The rest of the marine turtles tend to lay smaller eggs than the green turtle.

Sea turtle hatchlings emerge during the early evening, and will only leave the nest when the external sand temperature is cooler than the interior nest temperature, because they instinctively dig toward the cooler surface after the sun sets (Miller, 1997). When hatchlings emerge from the nest, they face many predatory risks such as birds, small mammals, capture by humans, or other dangerous human activities. Minimizing hatchling mortality rate depends on compelling controls to reduce obstacles near local nesting grounds.

Historical & Current Population Status

Columbus found an abundance of sea turtles in the Cayman Islands, and sea turtles were known to be prolific during the 1500's to the 1700's. But seafarers quickly found sea turtles to be a valuable source of nutrition, and subsequently developed a market for them. By the late 1700's and early 1800's, these markets began to collapse and people started noticing a decline in sea turtle populations. In the beginning, the population decline was ascribed to human harvesting, but in recent times, the sea turtle's fate has been determined by the interaction of many factors. Ehrenfeld (1979) distinguished eight basic factors:

> “1) the use of sea turtles as food by peoples who live where sea turtles are found; 2) the use of sea turtle products in local commerce (for example, sea turtle eggs sent to local markets); 3) the international trade in sea turtle products; 4) the differing attitudes toward conservation in different countries; 5) the incidental destruction of sea turtles that occurs during the fishing of other species; 6) the effects of nesting beach alteration or destruction; 7) the effects of marine and land-based pollution; and 8) the natural recovery rates of the various sea turtle populations under different conditions of exploitation and incidental stress”.

In 1978, the United States Endangered Species Act listed green sea turtles as threatened, except in Florida and the Pacific Coast of Mexico where they are listed as an endangered species (Rillero, 1999). Currently, it is illegal to catch sea turtles or remove their eggs from nesting beaches. Although this policy has reduced commercial harvesting rates, it has not completely eliminated hatchling mortality. Even though people usually do not harvest large numbers of eggs from beaches, many beach environments have been transformed into human habitats. Many residents build houses and recreation areas near the beaches, thus, many sea turtle nesting beaches also record a high sea turtle mortality rate.

Green sea turtles are threatened by both human and non-human factors. Human factors include beachfront developments that produce artificial lights, and a variety of human activity on the beaches. The major non-human stressors are the turtles’ natural predators. Non- human predation has been one of the mortality factors that has affected turtle populations throughout their evolution (Stancyk, 1979). The purpose of this thesis is to determine the major mortality factors of the green sea turtle hatchlings. The major negative impact to be investigated is the presence of artificial lights near the beaches that may mislead hatchlings as they try to orient themselves toward the sea.

Materials & Methods:

This research was based on a literature review, thus all data was gathered from the UNLV library. I searched ecological and conservation journals, including Conservation Biology, Ecology, Journal of Wildlife Management and Oecologia to locate research dealing with green sea turtles, and more specifically articles dealing with sea turtle hatchling success. I examined articles dating back as far as 1960 and compiled data from many different studies looking for data concerning three major impacts of turtle hatchling mortality, artificial lights near the beach, non-human predators, and human activities on the beach. In order to gather more data, I assumed loggerhead and green sea turtle have the same general hatchling behaviors.

Results:

Artificial Lights and Illumination Near the Beach

Under natural conditions the land portion of a beach tends to be darker than the ocean due to the reflection of moonlight off the ocean's surface. Accordingly, when sea turtle hatchlings emerge from their nests at night, they immediately crawl toward the ocean (Peters and Verhoeven, 1994). The relatively bright horizon over the ocean provides the optical cues to guide hatchlings toward the sea (Mrosovsky and Kingsmill, 1985). This behavior requires two visual mechanisms, a positive phototaxis and a response to differences in horizon elevation. The positive phototaxis of sea turtle hatchlings refers to crawling toward illumination (Mrosovsky, 1972). The other mechanism is a response to differences in horizon elevation which means hatchlings crawl away from high silhouettes produced by trees, dunes and other objects behind the nest, and toward the lower beach horizon (Limpus, 1971). Some experiments have shown a strong propensity of hatchlings to move towards illumination sources. Sea turtle perception of light is dependent upon the light's wavelength and intensity. Recently, human development near or on beachfront property has greatly increased the amount of light visible from the beach (Witherington and Bjorndal, 1991a).

Witherington and Bjorndal (1991) examined the influence of light wavelength and intensity on sea turtle hatchlings. Loggerhead and green sea turtle hatchlings were exposed to five different sets of lighting conditions. Results of tests performed in complete darkness found that hatchlings often circled or walked along the walls of the dark testing box. However, when a light source was added, hatchlings moved toward the light, typically on a direct path. Two different light sources were used in the experiment. The standard light source used a tungsten lamp powered with a 3.0 V DC source with a blue gel filter and emitted constant blue tinted light (520nm) and intensity (1.4; 1.26×10^{15} photons/sec x meters^2). The adjustable source varied in color and intensity. In the first set of the second trial, researchers illuminated both the adjustable light source and the standard light source. They set up the adjustable source to vary among five monochromatic colors and six intensities. Both turtle species preferred the adjustable source in the shorter wavelength treatments which were 360nm (near ultraviolet), 400nm (violet), 500nm (blue- green) with different intensities. The highest log intensity of 5.5 could only be reached at the longest wavelength (600nm and 700nm), but hatchlings moved away from these two lights at all intensity levels (Fig. 2). Log intensity 0.7 at

500nm has a measured illuminance level similar to that of a moonlit night. There was a positive relationship between intensity and preference of shorter wavelength lights. Green sea turtle hatchlings had similar behavior responses to spectral light (Fig. 3). During the second set of the second trial, researchers set the adjustable resources off (intensity = 0) and tested both species. The results showed that hatchlings moved towards the standard source.

To determine if hatchlings were attracted or repelled by light of specific color and intensity, researchers illuminated one window with the adjustable source and kept the other window dark. They used eight monochromatic colors with 3.5 intensity in the first set of this trial. The results showed that hatchlings significantly preferred the window lit with wavelengths of 360nm, 400nm, and 500nm. However, turtles chose the dark window over the 560nm, 580nm, or 600nm lights. From those windows lit with 540nm and 700nm lights, loggerhead hatchling performances could not be distinguished from random for either window (witherington and Bjorndal, 1991). In the second set, researchers used maximum source intensity with eight monochromatic colors. Each of the wavelengths with maximum intensities of the source were 3.5 (360nm), 4.0 (400nm), 4.8 (500nm), 5.0 (540nm), 5.2 (560nm), 5.3 (560nm), 5.5 (580nm), 5.5 (600nm), and 5.7 (700nm) log units. Hatchlings significantly preferred treatments with 360nm, 400nm, 500nm, 540nm, and 700nm wavelengths, but for the 600nm, all loggerhead hatchlings chose darkened areas over lighted areas.

Salmon et al (1995) hypothesized that city lighting causes turtle hatchlings to experience disorientation and misorientation. This group found that in some cases, females nested after city lights were turned off, although many turtle neonates emerged earlier while the lights were still on. Also, light exposed from gaps between adjacent buildings situated behind nesting areas was found to guide turtles toward the road. They chose to test an urban beach site located on Boca Roton Beach, Florida. There were ten hatching regions situated in city parks. The ten parks named from south to north are 1.) Whitehall South, 2.) Stratford Arms, 3.) Cloister del Mar/ South Inlet Park, 4.) Sable Point, 5.) Boca Mar, 6.) Pavilion South Beach Park, 7.) Pavilion Red Reff Park, 8.) Ocean View/ Lake View, 9.) San Remo, and 10.) Spanish River Park (Fig. 4). Experiments performed at these sites showed that normal orientation occurred in the South Beach and Red Reef Parks where tall Australian pine trees formed a high barrier to light coming from behind the beach. Under these conditions, hatchlings crawled on straight paths toward the ocean. However, they became disoriented in other beach areas where barriers were lower and incomplete, allowing diffused streetlights to illuminate the beach. When there were only a few lights emanating from an area like Ocean View/ Lake View Park, individual neonates crawled in divergent directions, even though the paths were straight. When lights provided strong illumination, neonate paths showed occasional loops, and crawl directions varied and changed frequently. When turtles were exposed to discrete, bright light sources coming from two different directions, the lights caused turtles to experience misorientation. Results showed that when lights behind the beach remained on at Red Reef Park, turtles were attracted toward the light source, but crawled toward the ocean when the lights were turned off.

The location of beach lighting also affected turtle orientation. Tests were conducted near a condominium stairway and porch, and on a patch of beach north of the building at Boca Mar. Results showed that most turtles crawled to the sea, although their paths were often looped and sinuous. The light from outside a hallway of a tall condominium (Cloister del Mar) illuminated the southern half of South Inlet Park (# 3 of Fig. 4). Tests were conducted at this park with three locations varying in distance from the buildings generating light sources. Hatchlings' seafinding performances were affected at all three sites. Results showed mean headings were southeast, and that seafinding performance became scattered, and their tendency to orient south increased as they approached the building. Salmon, et al (1995) had another examination was a laboratory experiment to test how the object silhouette placement affected turtles' orientation. Light wavelengths were confined to 420 – 620nm, with maximum transmission (74%) at 520nm which detected with greatest sensitivity by dark adapted juvenile green turtles (Granda and O' Shea, 1972). In the controls, turtles crawled toward the brighter areas without any silhouette, but when an object silhouette was placed against the light source, hatchlings' orientations were in the opposite direction. Salmon et al (1995) used urban horizontal extent (object height is 15° from surface) silhouettes to test the turtles' orientation. The extent silhouettes were rectangular shapes simulating dark buildings. Researchers discovered the more narrow horizontal extents (40°), the more hatchlings showed scatter in orientation. Hatchlings are well oriented to the water with widest horizontal extents. They also tested the effect of light gaps and silhouette shape. When presented with curved silhouettes containing light gaps, most turtles crawled to the right or left about 45° of directly away from the silhouette and gaps.

During the summer nesting season, Robert W. McFarlane (1963) found large numbers of hatchlings killed by automobiles on highways paralleling beaches. The examination area was located at the northern end of the public bathing beach at Ft.

Lauderdale, Florida. The results found that only six turtles had proceeded directly to the water. Fourteen hatchlings started in the wrong direction, but eventually circled and entered the water. Only 20 turtle hatchlings out of 115 hatchlings made it to the ocean. The major impact was found to be the combined effect of the illuminated Ft. Lauderdale skyline and a mercury vapor streetlight approximately 150 feet beyond the nest.

Similar results were obtained in studies done in other parts of the world. Peters and Verhoeven (1994) studied loggerhead turtle hatchlings affected by artificial lights on the western side of the Böksu delta, south of the town of Silifke on the Turkish Mediterranean coast. Studies were conducted at two sites, near the village and paper factory in June and July of 1992. There, high numbers of hatchlings were either crushed by cars or wandered further inland, attracted by major street lights directly behind the beach, or to the very bright lights of the paper factory. Researchers quantified number and orientation of hatchling tracks by dividing the area around the nest into four quarters in both study sites. The first quarter was facing the sea, the second quarter was facing roughly Northwest, quarter three was facing inland, and quarter four was facing roughly Southeast. The results in area A (Fig. 5) showed that only 21% of hatchlings showed direct seaward orientation in the first quarter. Most of turtles proceeded toward individual streetlights directly behind the beach or to the bright lights of the paper factory. Results showed a 72% mortality rate in quarters 2 and 3, where the majority of hatchlings were crushed by cars or wandered further inland. In quarter four, where it was dark, there was only a 7% mortality rate. Area B which is further from village and paper factory still showed that 52% of hatchlings in quarters 2, 3, and 4, did not crawl toward the surf. The results of individual quarters were 24% in quarter two, 21% in quarter three and 7% in quarter four.

Non-Human Predators of Sea Turtle Hatchlings

Non-human predators are another potential impact on sea turtle hatchling survival. The most predominant land predators for hatchlings include mammals, birds and crabs (Stancyk, 1979). Mammal predation tends to have less influence on hatchlings than on eggs (Hopkins et al. 1979, Fowler 1978, Hughes 1974) because hatchlings are available for a shorter period of time than are eggs. Also, nesting turtles leave the nest for long periods of time, leaving their eggs exposed to possible predation.

Turkey vultures *(Coragyps atratus)* were frequent and efficient predators of hatchlings at Tortuguero, Costa Rica (Fowler, 1978). The bird (*Ocypode* spp.*)* is the most common predator; and tends to capture hatchlings as they emerge at night. Coconut crabs (*Birgus* spp.) and land hermit crabs (*Coenobita* spp.) have also been noted as hatchling consumers (Frazier 1971, Hughes 1974). Caldwell (1959) noted that only larger crabs could capture and hold a struggling hatchling, and Hughes (1974) noted that crabs probably only capture turtles with poor orientation abilities. Although crabs capture hatchlings when they emerge, their effects on hatchling production are probably minor (Stancyk, 1979). The greatest predation of hatchlings most likely occurs after they enter to the sea (Bustard 1979; Hirth 1971; Richardson 1979). Small sharks, barracuda, snook, jackfish, and snappers are all known to prey on turtle hatchlings once they enter the water (Stancyk, 1979).

Human Activities

Summer is not only the major nesting season of sea turtles, but also a season of many beach- oriented activities. The most important affects on sea turtles are beach vehicles, people walking on the beach, and fishing in the ocean. Heavy beach vehicles can crush developing eggs and pre-emerged hatchlings on the beach, and hatchlings can easily to fall into tire ruts and have difficulty escaping (Hosier et al, 1981). Also, vehicles can disturb nesting females and crush emerging hatchlings crawling to the ocean (Lutcavage, et al 1997). People visit beaches at night, and often are unaware of emerging hatchlings, thus may step on unseen hatchlings who haven't emerged from underground (Mann, 1978).

After hatchlings have entered the ocean, the fishing industry often has additional impacts on sea turtles. Worldwide, shrimp trawling capture more sea turtles than any other commercial fishery (Hillestad, 1979). Shrimp trawling occurs in temperate and tropical zones in relatively shallow waters near shore which also seems as good sea turtle habitat (Hillestad, 1979). In recent studies in Georgia and South Carolina (Hillestad, et al 1978) trawlers captured mostly young age adults with carapace length ranging from 55 cm – 75 cm, and the captures occurred in July, coinciding with peak nesting season in both areas (Fig.4, 5).

Discussion:

The major negative impact on sea turtle hatchlings appears to be sensitivity to light. Artificial lights near urban beaches have been shown to mislead hatchlings as they attempt to orient themselves toward the sea. Green sea turtle hatchlings were attracted to artificial light sources (Mrosovsky and Shettleworth, 1968) and lightly tinted objects

(Carr and Ogren, 1960) and also moved toward light sources irrespective of beach slope.

Research has shown hatchlings were attracted to short- wavelengths at maximum intensity, which the color ranges were near- ultraviolet, blue, green and yellow, and avoid longer- wavelengths that the color ranges were near- yellow to the red.

Given this understanding, when beach- front lighting is necessary, short-wavelength lighting should be minimized, as they might attract hatchlings thus increasing mortality rates (Witherington and Bjorndal, 1991). The distance of lights from beach front buildings is important because horizontal extent and silhouetting of objects blocking light from the vision of turtles are also important in sea finding behavior (Rhijn, 1979; Rhijn and Gorkum, 1983). In situations where buildings exist near urban nesting beaches, local lighting regulations should emphasize the reduction of beach- front lighting. Turning off or shielding lights is also an effective way to reduce misorientation problems (Raymond, 1984). Dune and vegetation restoration effects also can be a simple and effective way to protect hatchlings from lighting problems in urban areas. High dune and vegetation barriers can black the lights behind the beach (McFarlane, 1963).

Another method of reducing hatchling is curtailing human activity near nesting areas during the nesting seasons. Unfortunately, sea turtle hatchlings are not easy to manage and protect once they reach the water. Thus to increase green sea turtle populations, conservation efforts need to be focused on protecting hatchlings as they emerge on the beach and move towards the sea. Local regulation can implement reducing human activities on the beaches and hire workers to reduce the non-human predators.

A variety of methods have been employed to control non-human predators. Chemical controls, trapping or shooting, hatcheries, and transplants have all been used in an effort to control predation. Chemical control is not a good method to use, because the poisons also can non-target organisms. In addition, chemicals might harm hatchlings or eggs in their chambers on developing beaches (Stancyk, 1979). Trapping and shooting predators could be another control method but may serve to decrease the existing population of predators in the short run (Davis and Whiting 1977; West, personal communication). Involving environmentally educated volunteers to transplant hatcheries is a good strategy for increasing turtle population.

Crawling toward bright light sources is a natural behavior for sea turtles. At non-developed beaches, the mainland is darker than the open sea and sea turtles will follow the light cues toward the water. Today, humans produce more lights on beaches which cause many sea turtles to become disoriented by the lights and crawl toward the land, thus increasing hatchlings mortality. Beach front developments need to be reviewed and evaluated based on the extent and effect light intension may be having on sea turtle hatchlings and other animals that rely heavily on phototaxis cues.

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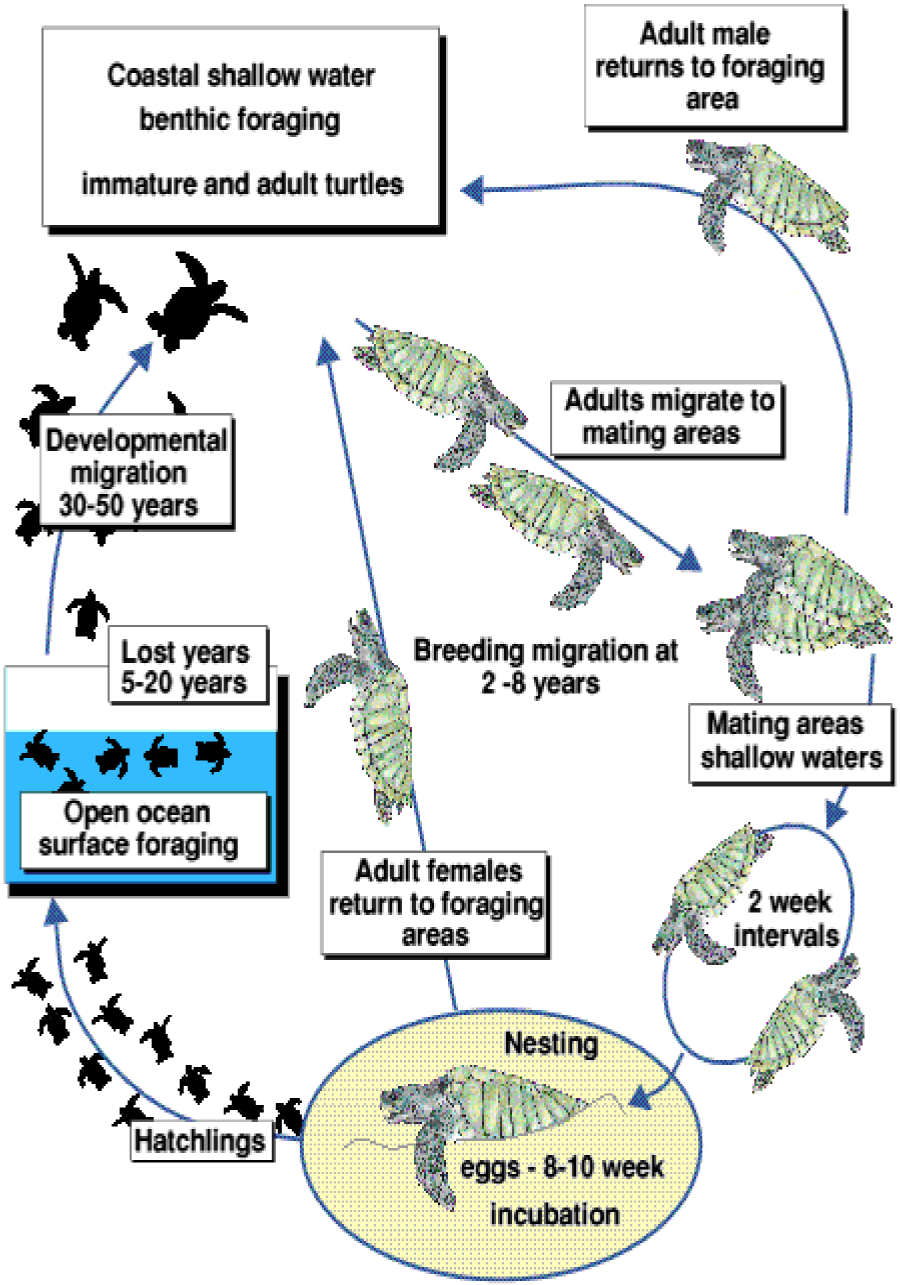

Figure 1. **Generalised life cycle of sea turtles**

From Euro Turtle on 4/7/00, the web site is http://www.exeter.ac.uk/telematics/EuroTultle/biology.htm by R.H.C Poland. Last modified 7/14/98

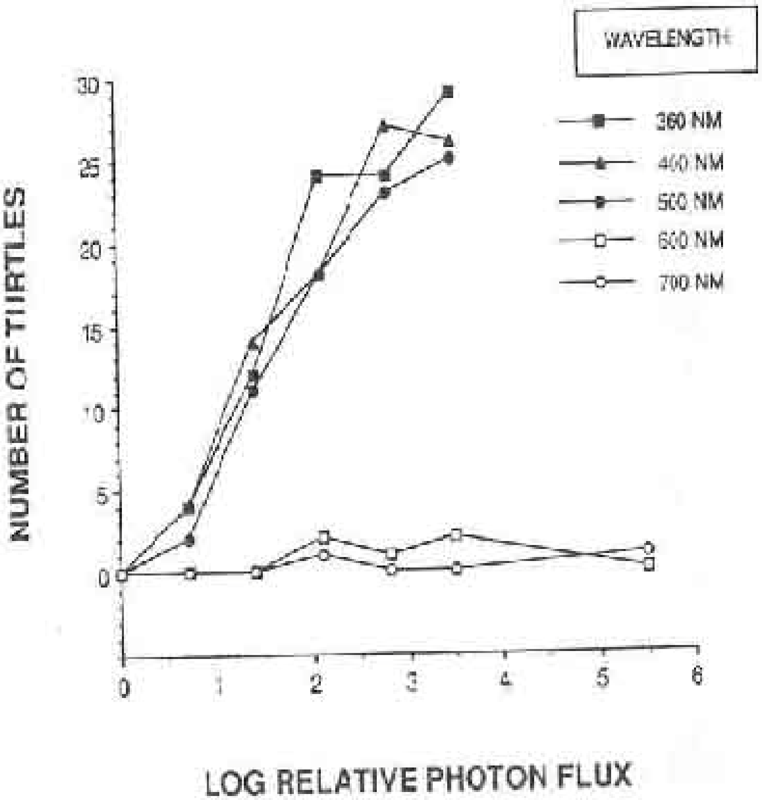

Fig 2. Loggerhead hatchlings choose a light source varying among the wavelengths and intensities specified, over a source of constant color and intensity. All represented hatchlings chose one of the two sources. Colors are near-ultraviolet (360nm), violet (400nm), blue- green (500nm), green (540nm), green – yellow (560nm), yellow (580nm), yellow- orange (600nm), and deep red (700nm) (Witherington and Bjorndal, 1991).

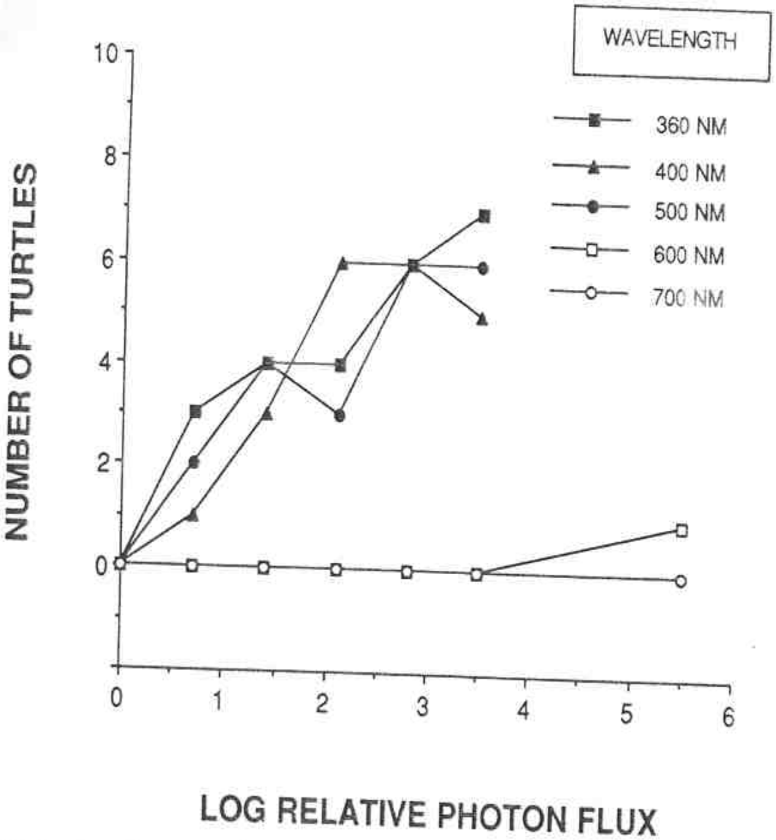

Fig.3. The number of green sea turtle hatchlings choose a light source varying among the wavelengths and intensities specified, over a source of constant color and intensity (Witherington, Bjorndal, 1991).

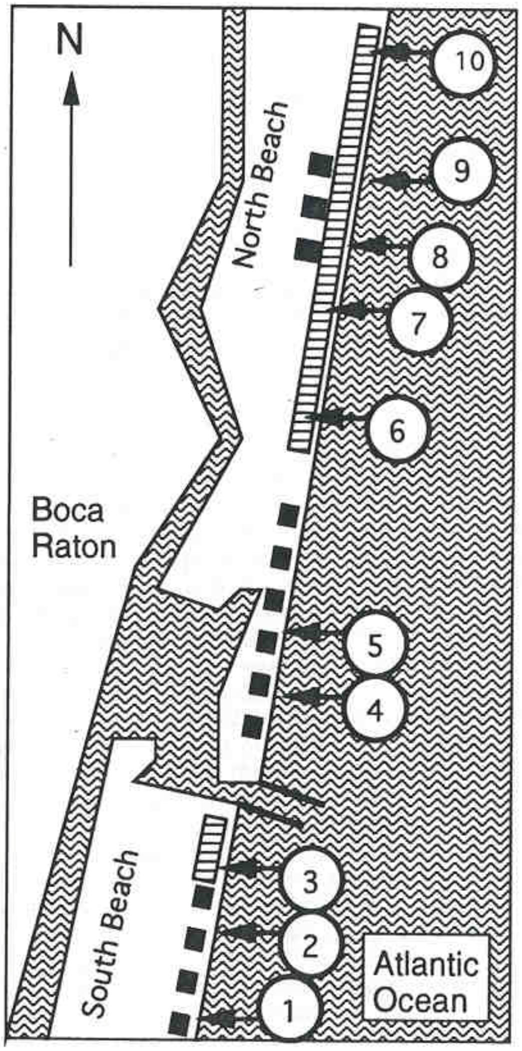

Fig. 4. The study area in the Boca Raton Beach, Florida, where lighting infringe on seafinging behavior. Black rectangles are condominiums. The ten hatched region parks are: 1. Whitehall South; 2. Stratford Arms; 3. Cloister del Mar/ South Inlet Park; 4. Sable Point; 5. Boca Mar; 6. Pavilion, South Beach Park; 7. Pavilion, Red Reef Park; 8. Ocean View/ Lake View; 9. San Remo; 10. Spanish River Park (Salmon et al, 1995).

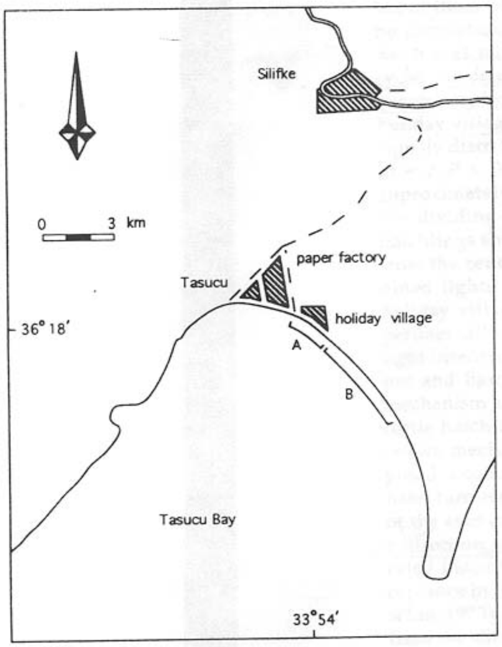

Fig.5. Map of the study site of the Göksu deta, Turkey. This is the main sources of artificial light. A and B are Loggerhead turtles' nesting zone (Richard and Thomas, 1994).

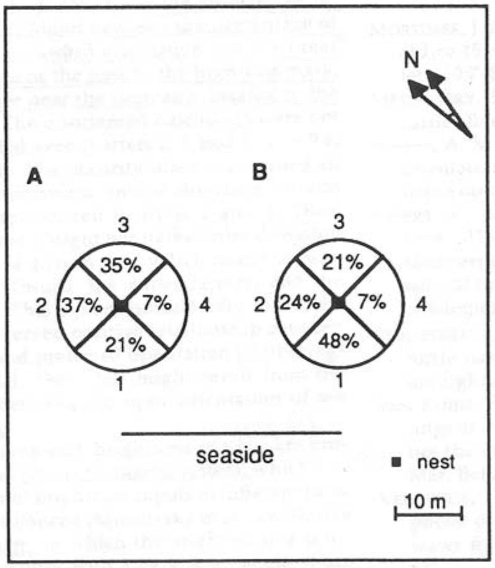

Fig. 6. Distribution of Loggerhead hatchling tracks (as % of total). A: the area is directly in front of the light sources (N=330 tracks; 6 nests). B: the area SE away from the holiday village (N=490, 17 nests) (Richard and Thomas, 1994).

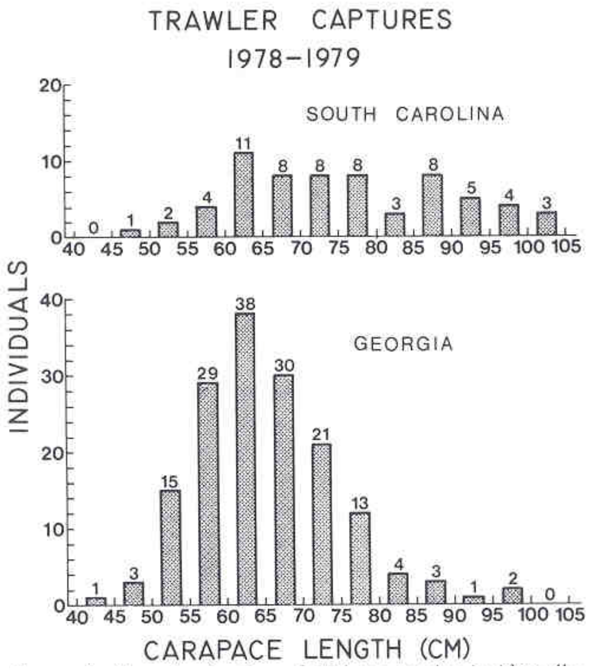

Fig. 7. Carapace size distribution of 224 sea turtles incidentally captured by shrimp trawlers in Georgia and South Carolina, 1978-79 (Hillestad,1979).

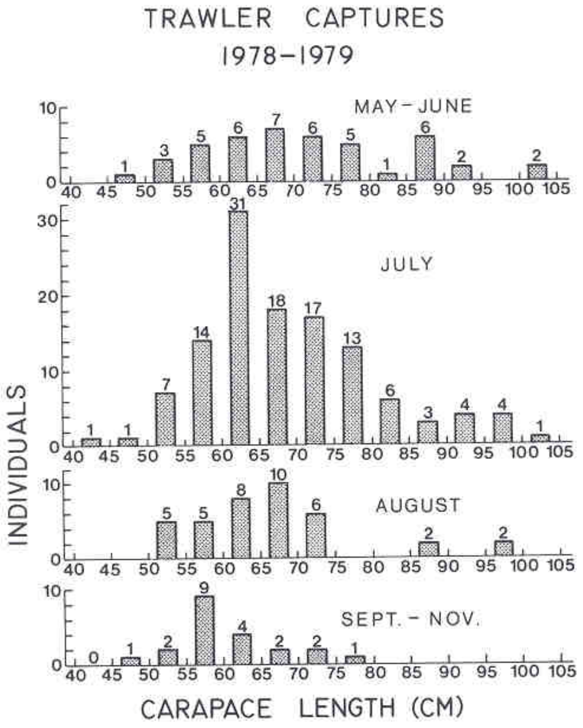

Fig.8. The carapace size distribution of 224 sea turtles incidentally captured by shrimp trawlers during high nesting season in Georgia and South Carolina, 1978-79 (Hillestad, 1979).