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OF THE
NINETEENTH ANNUAL SYMPOSIUM ON
SEA TURTLE
CONSERVATION AND BIOLOGY

2-6 March 1999
South Padre Island, Texas, U.S.A.

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NOTICE

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PREFACE

The 19th Annual Symposium on Sea Turtle Biology and Conservation was the largest to date. The beautiful venue was the South Padre Island Convention Centre on South Padre Island, Texas from March 2-6, 1999. Key features of the 19th were invited talks on the theme *The Promise, the Pain, and the Progress of 50 years of Sea Turtle Research and Conservation*, a mini-symposium on the Kemp's ridley and an increased emphasis on high quality poster sessions.

Hosts for the meeting included Texas A&M University, the Texas Sea Grant College Program, The Gladys Porter Zoo and Sea Turtle, Inc. Co-sponsors included the National Marine Fisheries Service-Southeast Fisheries Science Center, the National Marine Fisheries Service-Protected Resources Branch, Padre Island National Seashore and the U.S. Fish and Wildlife Service. With the assistance of Jack Frazier, we were fortunate to obtain a $30,000 grant from the David and Lucile Packard Foundation. This grant provided travel support to 49 individuals from 24 nations who presented a total of 50 presentations.

WHY TEXAS?

Most folks, even most Texans, do not realize that in the late 1800s there were as many as four sea turtle canneries operating along the Texas coast to process meat for local sale and shipment. By 1900 the canneries had all gone out of business, lamenting that the fisheries had not experienced good husbandry techniques! When intensive mechanized shrimping began after World War II there were records in the 1950s of up to 50 turtles being caught on a single cruise out of Port Isabel, TX. Intensive trawling subsequently kept sea turtle populations low — until the 1990s. In the 1990s the situation appeared to be changing, possibly due to TEDs and possibly due to strong long-term conservation measures in Mexico. Now it appears that the critically endangered Kemp's ridley has a good shot at eventual recovery. It is clear that Texas and indeed the entire northern Gulf of Mexico is developmental and foraging habitat as well as a migratory corridor for ridleys moving to and from the nesting beach at Rancho Nuevo. There are also lots of greens, loggerheads and leatherbacks using the rich feeding grounds off Texas.

We were also excited about having the turtle Symposium come to Texas to assist us in getting the word out about sea turtle biology. Over the years the symposium has helped states from North Carolina to Florida as well as Mexico to develop pride in their sea turtle faunas. Hopefully some of the same important educational benefits can also be realized in Texas. Indeed the State of Texas, at least in part due to a resolution generated at the Symposium, has proposed a new protected area off Padre Island National Seashore which would provide critically needed migratory routes for sea turtles moving along the coast.

Each year the Sea Turtle symposium is proving to be a critical idea exchange venue assisting us all in our passion for improving the condition of marine turtles, their ocean and their habitats. Putting on such a large meeting is a major undertaking with the requirement for a huge volunteer force. While many others helped, the individuals on the next page put in many extra hours to see that the meeting was a success.

David Owens, 1999 Symposium President

The compilers would like to thank the following people: Mary Anne Compton and David Owens for many hours of assistance with proofreading and editing; Jeff Seminoff, Amanda Southwood, and Larissa Avens for additional assistance with reviewing and editing; Rhonda Patterson for her constant support and lending hand; and all of the authors who kindly proofed their own abstracts and assisted with the final formatting of their figures.

Heather Kalb and Thane Wibbels, 1999 Symposium Proceedings Compilers

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STUDENT AWARDS

There were 52 student presentations – 10 papers and 42 posters with $2250 awarded to 7 recipients. The Awards Committee was composed of Anders G.J. Rhodin (Chair), Ana R. Barragán, Raquel Briseño-Dueñas, Stephen J. Morreale, Frank V. Paladino, James I. Richardson, Michael Salmon, Jeffrey A. Seminoff, Jeanette Wyneken. The awards were financed by the Chelonian Research Foundation.

Paper Presentations

1. Michael C. James. Distribution and conservation of the leatherback turtle (*Dermochelys coriacea*) in Atlantic Canada: research partnerships with the fishing community. (North Atlantic Leatherback Turtle Working Group, Biology Dept., Acadia University, Halifax, Nova Scotia, Canada). $500.

2. Wallace J. Nichols, P. Dutton, J.A. Seminoff, E. Bixby, F.A. Abreu-Grobois, and A.R.S. Hidalgo. Poi or papas? Do Hawaiian and Mexican green turtles feed together in Baja California water. (Wildlife and Fisheries Science, School of Renewable Natural Resources, University of Arizona, Tucson, Arizona, USA). $250.

2. Sandra Storch, Z.M. Hillis-Starr, and R.P. Wilson. Turtles in the reef: a closer look at the activities of hawksbill turtles in a Caribbean internesting habitat. (Abteilung Meereszoologie, Institut für Meereskunde, Germany). $250.

Poster Presentations

1. Sadie S. Curry, D.R. Brown, E.R. Jacobson, and P.A. Klein. Persistent infectivity of chelonian herpes viruses after exposure to artificial seawater. (Interdisciplinary Program in Biomedical Sciences, College of Medicine, University of Florida, Gainesville, Florida, USA). $500.

2. Melissa L. Snover, A.A. Hohn, and S.A. Macko. Detecting the precise time at settlement from pelagic to benthic habitats in the loggerhead sea turtle, *Caretta caretta*. (Duke University Marine Laboratory, North Carolina, USA). $250.

2. Jeffrey R. Schmid. Characterizing developmental habitats and habitat utilization of Kemp's ridley turtles using GIS. (Center for Sea Turtle Research, University of Florida, Gainesville, Florida, USA). $250.

2. Larisa Avens. Possible homing behavior in juvenile loggerheads (*Caretta caretta*) from Core Sound, North Carolina. (Biology Dept., University of North Carolina, Chapel Hill, North Carolina, USA). $250.

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Zen and the Art of Sea Turtle Conservation

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"Education would not be necessary if things were what they seem to be." Parker Palmer

We're all concerned with conserving sea turtles, but how often do we stop and ask ourselves, "Just what *is* a sea turtle?" What is it that we're trying to conserve, trying to understand, trying to save? Since things are not always what they seem to be, I'd like to offer you a different perspective, to use some of the teachings of Eastern philosophy to provide you with a different perspective as we consider the question "What is a sea turtle?"

My first answer is that a sea turtle is earth, air, fire, and water. Almost all civilizations recognize these four elementals in one way or another. Many believe that the physical world we live in, as well as our own bodies, are made up of them. It's also generally recognized that an important result is that all things in the universe are connected. Given some thought, this is an easy thing for many of us to understand, because it's so well supported by modern science.

It's easy to see how a sea turtle is composed, at least partially, of earth. Understanding the atomic theory of matter, we also know that the sea turtle's body contains elements such as iron in its blood, and phosphorus and calcium in its bones, and others atoms that once were part of the solid surface of the planet, formerly bound up in rocks and other mineral deposits. No matter how many millions of years ago this was, we know this matter, these atoms, have not been created or destroyed since they were a part of the earth itself. And so, a turtle is at least part earth, and no one who understands mineral cycling or food chains or geology would disagree.

A sea turtle is also air. From the time it was deposited in an egg buried on a beach, the turtle embryo exchanged gas with the atmosphere, taking in oxygen that percolated down through the porous sand and expelling carbon dioxide out into the beach subsurface. Once the hatchling left the nest, it continued to breathe in and out, exchanging atoms of carbon and oxygen that once were part of its body and part of the atmosphere. The turtle is, after all, the product of organic chemistry, and the all of the carbon in its bodily compounds was once part of the atmosphere. CO_2 diffused into the ocean water, was taken in and fixed by phytoplankton, moved through the food chain, and was present in the food the turtle ate — which in turn became part of the turtle's body. Even the nitrogen now in the turtle's proteins, amino acids, and DNA existed, however long ago, as atmospheric nitrogen before being fixed by some blue-green alga into a biologically available form. You've studied the carbon and nitrogen cycles in school, right? And so, you find yourself in complete agreement with both Buddhists and Hindus that a turtle is at least partly made of air.

Now how about fire? Well, the biggest and most obvious fire we all can see is, of course, the sun. So there you are. As every school child knows, the light energy from the sun beams to the earth across 93,000,000 miles of space and is captured by those wonderful energy transducers we know as chloroplasts. The rest of the story is pure plant and animal physiology — from the manufacture of simple sugars in algae and plants to the release of energy by ATP molecules and the contraction of fibers in the turtle's powerful pectoral muscles, we can trace the energy of the sun's fire right down into the turtle. Does any modern scientist doubt that the energy a sea turtle burns to swim back to her nesting beach is a direct result of the purest nuclear fire in the heavens? And so, the fact that a turtle is partly fire is firmly established in our minds.

As we know, our own bodies are about 70% water. A turtle's body also is mostly water, and our understanding of the hydrological cycle tells us that those water molecules once inhabited clouds, condensed and fell to the earth as rain or snow, flowed down mountain streams into rivers, and on into the sea, where they were swallowed by the turtle or incorporated into and consumed in the food she ate. Yes, clouds, streams, rivers, and snow are all inside each turtle!

Do you have any doubt at all that a turtle is made of earth, air, fire, and water? It takes a lot of rocks, wind, sun and rain to make a sea turtle, or a human being, for that matter. But there just isn't any other way to make them!

And there are important consequences of this. Because a turtle is made of these elementals, the turtle is therefore connected to everything else in the ecosystem, connected to clouds over our cities (whether clean or smoggy), to rain falling on the mountaintops (whether forested or bare), to all the streams that drain into all the rivers that empty into all the seas in the whole world (whether pristine or polluted). There is nothing we do, from farming in Illinois, to driving a car in China, to building a house in Tibet, to clearing forests in Brazil, to dropping bombs in Iraq — that doesn't connect to sea turtles, and it's all because they're made up of earth, air, fire, and water. It's so obvious.

A case could easily be made that sea turtles therefore are connected to everything else in the universe. For where did the atoms that make up the turtle's body come from originally? From the original stardust, that's where . . . Imagine the Big Bang, the event that divided somethingness from nothingness. Whether you believe it just happened or whether God made it happen, what a magnificent event that must have been . . . it produced and scattered matter across fifteen billion years of time and trillions of miles of space — all the way here to Texas — and somewhere along this magnificent journey, this matter was formed into ridleys and human beings! And for the past four billion years or so, these very same molecules, this very same matter, has been moving in and out of all the individuals living on this planet. . . re-organizing itself and flowing in and out of blue-green algae, trilobites, tree ferns, coelacanths, Neanderthals, you, me, and, of course, sea turtles.

"Our physical body is like something we have borrowed." The Dalai Lama

But this isn't Eastern mysticism. . . it's scientific fact.

And there's another important consequence of this established fact. It's that, insofar as our physical make-up is concerned, we are all (including sea turtles) immortal. The atoms may reassemble themselves as they disperse throughout the biosphere in food webs or sequester themselves into the geosphere, atmosphere, or hydrosphere. But they don't cease to exist.

Now, here is the second answer to the question — "What is a sea turtle?" A sea turtle is God.

This idea is actually much older than Buddhism; it dates back at least into pre-Buddhist Hinduism. The only way I know of to get you to understand it is to play pretend for a few minutes. Imagine for a moment that you are God. You know everything, feel everything, see everything, can do anything. There are no surprises for you, nor can there be any surprises. You are the super intelligence, all-powerful, all knowing. Every game you play, you win. Every battle you fight, you win. Every problem you attack, you solve. There is no difference between past and future, because for you, who are omniscient, the past and the present through all eternity coexist in the immediate present moment. There are no challenges; there is no striving. There is no unfulfilled desire. Here is no schedule, no work that has to be done, no place you have to be, since you can be everywhere at once. There is no longing. There is no hunger or want or pain, or discomfort or, impatience, or any negative feeling at all. How very, very, very, VERY. . . . boring! Wouldn't it be nice to have a surprise now and then, something unanticipated to break up the predictable eons?

And so, to entertain yourself, you begin to dream. And in the dreams, you, God, begin to have adventures where you don't quite know what's going to happen. Excitement! Danger! Thrills! But it's still a self-directed dream, it's like going to an adventure movie — even less exciting, it's like gong to an adventure movie that you wrote, directed and produced. It's still too safe, with no real danger, because you know you're just dreaming, because you know you're God. But you find you like being surprised and you like not knowing everything all the time, and this new type of experience isn't only entertaining, it's experiential education and you learn things in a way you can't know them if you simply acquire all your knowledge by intrinsic omniscience.

"And then as time went on, you would dare yourself to do more and more outrageous things, and at some point in the game you would say, 'Tonight I am going to dream in such a way that I don't know I'm dreaming,' and by doing so you would take the experience of the drama for complete reality." Alan Watts

And in this ultimate dream, you would force yourself to forget that you were God, and fracture yourself into millions and billions of individual parts to play out the drama. In order for the illusion to work, each little you would have to forget that you once were all part of the same omnipotent, omniscient being. You would force amnesia on your many new little fractional selves. Because it wouldn't be as interesting if each part knew who it really was. And furthermore, to really make things interesting, you'd have to ensure that all the parts weren't alike — some would have more awareness than others. Some might be intelligent enough to suspect what was really going on, but some would just go on living the dream and never catch on.

"The Hindus have the idea that everybody, not only human beings, but animals and plants, all sentient beings whatsoever, are God in disguise." Alan Watts

And so I leave you with this final thought. What if there is only one dream and one dreamer? What if you were convinced, or if not, what if you began acting as though you thought it might be true that every sea turtle really is a manifestation of God? And what if the person sitting next to you is also god, and the shrimpers are god and even the shrimp themselves are god? What does that say about all the clever things we do for sea turtle conservation?

As we scientists learn more and more about the way the world works, and more and more about turtle biology and the things we can do to manipulate it, every once in a while we should look up from our microscopes and computers and management plans and think about these wise, wise words from a philosopher of science Alfred North Whitehead:

"When you understand all about the sun and all about the atmosphere and all about the rotation of the earth, you still may miss the radiance of the sunset."

BIOLOGICAL STUDIES - ANATOMY, PHYSIOLOGY, AND BEHAVIOR

Green Turtle and Seagrass Interactions

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Some aspects of the interactions between green turtles (and dugongs) and tropical seagrasses were examined. In order to examine the effects of herbivory on the community structure, productivity, and nutritional composition of seagrass, experiments simulating intensive turtle cropping (and intensive and light dugong grazing) were carried out in intertidal seagrass beds at Cardwell (18°14'S, 146°E) and Ellie Point (16°53'S, 145°46'E) on the northeast Queensland coast. Experiments at Cardwell and Ellie Point were monitored monthly for a year before seagrass samples were harvested. A short-term experiment was also carried out at Cardwell only, wherein samples from the cropping plots were harvested after one and two months. Video recording was used for monitoring temporal changes in the species composition and abundance in tropical seagrass communities. Near infra-red reflectance spectroscopy (NIRS) was used to measure the concentrations of the following: nitrogen, organic matter, neutral detergent fiber, acid detergent fiber, lignin, water soluble carbohydrate, and starch and *in vitro* digestibility of dry matter.

The nature and extent of the effects of cropping was related to the nature of the seagrass community, including its species composition and location. The species composition of a monospecific bed of *Halodule uninervis* was not affected by cropping. Cropping increased the net aboveground biomass productivity of *H. ovalis* and *Halodule uninervis*. Recovery times varied for *H. ovalis*, *Zostera/Cymodocea* and *H. uninervis*.

In short-term experiments, cropping increased the leaf nitrogen concentration of *H. uninervis* and the digestibility (*in vitro*) of dry matter of *H. uninervis* increased moderately. Cropping has variable effects on the fiber and lignin contents of *H. uninervis* depending on the plant part, nature and intensity of herbivory and duration of the recovery.

Green turtles (and dugongs) appear to optimize their diet by selecting food species that maximize digestible nutrients. This is achieved by selecting seagrass species that are more digestible and have higher nutrients (e.g. nitrogen and carbohydrates/starch) and/or species which can compensate for grazing. Grazing and cropping improved the seagrass bed as grazing habitat for green turtles (and dugongs).

Measurements of Visual Acuity of the Juvenile Loggerhead Sea Turtle (*Caretta caretta*): An Electrophysiological Response

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The aquatic spatial resolution of the juvenile loggerhead sea turtle's (*Caretta caretta*) visual system was examined using the method of visual evoked potentials (VEPs). VEPs are electric responses of any neural tissue identified to correspond to a stimulus. Testing was performed out of water with each animal restrained and fitted with a "reverse goggle" constructed of 1/8 inch Plexiglas and filled with water.

Two sets of subdermal platinum electrodes were implanted on both sides of the fronto-parietal plate on the dorsal surface of the head (above the optic nerve and optic tectum). Implantation of the electrodes did not require surgery and the animal was neither anesthetized nor curarized. Stimuli consisted of black and white bars of equal width; flickering angle was set for a fixed exchange of the bars. Intensity of the stimuli remained constant but width of the stripe varied with each trial. Electrophysiological responses were collected using a Nicolet Compass computer, and threshold of visual acuity was determined by measuring the dependence of response peak amplitudes on stimulus stripe size. These data elucidate the role of visual acuity in the juvenile loggerhead's perception of its environment.

Mating Behavior in Galapagos Green Turtles

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The Galápagos Archipelago, a territory of the Republic of Ecuador since 1832, straddles the equator in the Pacific Ocean approximately 1,000 km off the coast of Ecuador. The archipelago is volcanic in origin and consists of 17 major islands. Between 1975 and 1980, 6,722 green turtles (*Chelonia mydas*) were tagged in the archipelago: 4,381 at the nesting beaches and 2,341 at the feeding grounds. Although oviposition has been recorded in every month, it occurs primarily between December and June with a peak in February/March. Similarly, copulating pairs of Galápagos green turtles have been observed in every month, with the numbers of pairs varying greatly throughout the year. Copulation is sporadic from May through August, becomes increasingly common during late September, and reaches a peak in mid-December. It tapers off in January and is extremely sporadic from mid-February through April. Thus, copulation has virtually ceased by the time of the egg-laying peak in late February/early March. Copulation occurs throughout the archipelago, particularly in protected lagoons such as Turtle Cove on Santa Cruz Island.

Prior to mating, which occurs at night as well as in the daytime, a potentially receptive female would float virtually motionless at the surface with all four flippers extended laterally. She would turn to face an approaching male, and if he tried to circle her, she would maintain the face-to-face position by gentle movements of her flippers. Usually, several circles are made in this fashion. The male would repeatedly close in on the female and nibble at her neck region, the bites slowly becoming more intense. Contact is maintained by touching foreflippers. When accompanied by a gradual inclining of the bodies toward a vertical position, the position gives the appearance of an embrace. Sometimes the couple would return to the face-to-face floating position and continue circling, but eventually the male maneuvers around behind the female and mounts her, gaining sufficient momentum by suddenly propelling himself forward and sliding up onto her carapace. The male, his concave plastron fitting over her domed carapace, grips the female by hooking the pollex claws of his foreflippers under the anterior margin of her carapace and hooks his powerful tail and sometimes wedges his hindflippers under the posterior margin of her carapace. Once settled in this position, it is very difficult to dislodge him.

Behavior during courtship varies according to the state of receptiveness of the female and the aggressiveness and number of males present. For example, a female surrounded by several males may find it difficult to maintain the face-to-face position, several of the males being able to approach from behind and mount her. Also, a male in a high state of readiness might omit the preliminary stages of courtship and try to mount immediately. Such mountings, however, are usually short-lived, the male easily being dislodged by the female's sudden and continual movements, and the encounters often end with the female swimming off, pursued by one or more males. Even regular courtship does not always lead to copulation; on several occasions I observed a single male and female cease the maneuvers before any attempt at coupling was made. Thus, it appears that successful copulation is not possible unless both partners are willing. One opportunistic male, however, mounted two females that were caught in a net. He even returned to the net two of the next three days, but he never became entangled in it. On two occasions I saw a female mount a male and a male mount another male; on one occasion I even saw a female mount another female. These pairings lasted for only a short while.

While most of my observations on courtship and coupling were of turtles at or near the surface, I often saw copulating pairs resting on the bottom of the lagoons or slowly swimming at depths of 5 to 7 m. Mounting can also take place below the surface. The fastest mounting that I witnessed was of a male swimming rapidly at a depth of 2 m toward a slow-moving female; he suddenly made a 180° turn and mounted her. The speed of the event surprised me and reminded me of a jumping spider in action. On another occasion, after releasing a pair that had been copulating, the female swam off, pursued by the male. Less than half a minute later, they broke surface some 50 m away, like a float just released under water, the male already mounted.

No quantitative survey of the length of time that a pair remained in copula was undertaken because this necessitated lengthy observations on very few animals. One tagged couple, however, first seen copulating at 0730 hrs, was next seen washed up on a mud bank in shallow water, still copulating some six hours later. Both turtles were completely exhausted and made no attempt to move when I approached them. An accompanying escort male, similarly exhausted, was washed up alongside them.

In mating pairs of Galápagos green turtles, the male is generally smaller than the female. The mean straight carapace length (SCL) of 97 males copulating at Turtle Cove between 1976 and 1978 was 77.9 cm (st err=0.421), with a range of 68.5 cm to 91.7 cm; an analysis of variance revealed no significant difference ($P>0.05$) among the three annual means. The mean SCL of 65 copulating females for the same period was 81.4 cm (range 74.2 to 87.5 cm, st err=0.373), and again, no significant difference was found in the annual means. The mean male-female SCL ratio of 42 copulating pairs was 0.958 (range 0.822 to 1.061, st err=0.01); the annual means did not differ significantly. Of these 42 copulations, in only 12 (28.6%, n=4 for each year) was the male larger than the female. Since the responsibility for keeping the pair away from rocks, heavy surf, and other dangers during copulation falls upon the female (the male usually remains immobile and seemingly oblivious to all around him during this period, his flippers being used solely to remain mounted), it would be advantageous for the female to be coupled with a partner smaller and lighter than herself. No correlation was found in copulating pairs between male and female SCL ($P=0.41$, df=1,40), suggesting that mates are selected at random.

A mating pair is often accompanied by one to six escort or attendant turtles, which are usually males, although occasionally female escorts are observed. These male escorts often bite at the neck, shoulders, tail, and flippers of the successful male, presumably in an attempt to dislodge him, and these bites often cause severe damage, sometimes even exposing the flipper bones. Rarely is the female bitten by the escorts; this shows a high degree of discrimination since the female, generally submerged throughout the event, is usually more accessible than the male, who is mostly above the surface of the water. On one occasion I observed an escort male mount a copulating pair to form a threesome. On another occasion, I witnessed a female try, but fail, to mount a mating pair. Usually, however, the escorts simply remain in the vicinity of the copulating couple. Some males that were first observed in copula were later seen as escorts and vice versa. The mean SCL of 12 male escorts was 76.1 cm (range 70.6 to 85.9 cm) compared to a mean of 77.0 cm (range 68.5-85.6 cm, n=50) for copulating males during 1978 at Turtle Cove; the difference in the means was not significant (P=0.5; t-test).

Galápagos green turtles are known to mate more than once. Two females mated with at least three different males each; one within a two-day period (two the first day, one the second) and the other within three hours. One male was seen mating seven times with six different females over a ten-day period. On day 11 he was an escort. I documented three instances of turtles ending up with the same partner after forced separation. One pair captured during copulation and released simultaneously from the boat after 10 minutes, were observed mating together again 30 minutes later. The other two pairs of turtles resumed copulation after just 30 seconds; with these pairs, however, I do not know if the copulation was sustained.

Females are often observed resting at the water line or lying high and dry on beaches adjacent to Turtle Cove during the daytime, especially at low tide, presumably in an attempt to escape the attentions of the males that usually flop around in shallow water close by. With respect to this avoidance of males by females, some areas of Turtle Cove appear to be favored by females, while other areas appear to be favored by males. In Lagoon A, more than twice as many females as males were caught (113 females, 49 males), whereas in Lagoon C, males caught outnumbered the females at least 2 to 1 (224 males, 100 females). In Lagoon C, most turtles were caught by a net stretched across the entrance. Unless males are more susceptible to becoming entangled than females, the figures can be considered to be representative of the "Lagoon C turtles." In Lagoon A, however, where turtles were caught mostly by hand, the figures are slightly biased in favor of the males, since many of the males were captured during copulation. When only one of a copulating pair could be caught, it was usually the male, since he was on top and thus easier and more desirable to capture.

Discussion

The courtship behavior of Galápagos green turtles appears to differ little from that described for green turtles in Malaysia (Hendrickson, 1958), Europa Island (Hughes, 1974), and Australia (Bustard,1972; Booth and Peters, 1972), although Booth and Peters found the adoption of a vertical position by the female, with the plastron facing the male, to be a "refusal" mechanism. I never saw a Galápagos female do this to an approaching male before courtship, although she sometimes assumed such a position during the embrace. It never, however, seemed to discourage the male.

Escort males have also been recorded for green turtle populations in Malaysia (Hendrickson 1958), St. Brandon in the Indian Ocean (Hughes, 1976), Hawaii (Balazs, 1980), and Australia (Booth and Peters, 1972; Tim Jessop, pers. comm.). Escort females have been recorded at Europa Island in the Mozambique Channel (Anonymous, 1971). Although competition among males for an unmated female must be high, I never observed dominance in any Galápagos male sufficient to chase off the others as reported by Hendrickson (1958) for Malaysian green turtles.

Apart from Galápagos, multiple copulations have also been recorded in Australian green turtles by Booth and Peters (1972). Although I have only three records of the same partners reuniting after forced separation, Booth and Peters observed that a female whose partner was dislodged by an escort male usually accepted only the original male, despite being approached by others.

Female avoidance of males by ascending the beach in the daytime is not uncommon in green turtles and has been reported from Australia (Bustard, 1972; Booth and Peters, 1972), and from Europa and Tromelin islands (Hughes, 1974). Regarding special areas for one sex or the other, Caldwell (1962) suggested some degree of spatial segregation by sexes for green turtles in Baja California. Booth and Peters (1972) encountered "female reserves" in their study lagoon in Australia that was frequented only by females (apart from mating couples) and that males appeared to avoid.

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Behavioral Steroid Interactions within the Scramble Mating System of the Polygynous Male Green Turtle

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During vernal courtship male green turtles (*Chelonia mydas*) have been observed to utilize scramble competition polygyny. This is a male mating system in which competitive mate searching supersedes combat as the primary mode of intrasexual competition. We investigated if behavioral steroid interactions within this unusual form of polygyny conformed to the “challenge hypothesis”. We predicted that even though male green turtles fail to provide parental care, behavioral androgen responses would correspond with particular reproductive behaviors utilized in this mating system. In addition, we investigated if the relatively infrequent levels of inter-male aggression induced a corticoid stress response with a subsequent decrease in plasma testosterone.

Behavioral androgen responses were detected, plasma testosterone was observed to increase with both attendant and mounting behavior. Male turtles who were recipient either to intermale aggression or accumulated severe courtship damage exhibited significant decreases in plasma testosterone. No pronounced adrenocortical response was observed in response to either intermale aggression or accumulation of severe courtship damage.

With our findings, we suggest two hypotheses, first testosterone is not maintained at high fixed levels as seen in many mating systems lacking paternal care, because unlike other forms of polygyny, scramble competition (intensive mate searching) as opposed to intermale aggression is the primary sexually selected tactic for mate acquisition. Secondly, as no adrenocortical response was observed during intermale aggression, we suggest male turtles may be benign to such predictable behavioral stresses as a deliberate sexually selected tactic to maximize male reproductive success during courtship.

Magnetic Navigation in Hatchling Loggerheads

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Hatchling loggerheads from eastern Florida migrate from their natal beaches into the North Atlantic gyre, the circular, warm-water current system in which they spend their pelagic years. For young loggerheads, staying within the gyre is critical. Turtles that stray north of the gyre soon die from the cold, whereas those that venture south of the gyre may be swept into south Atlantic currents and carried far from their normal range. An ability to recognize the latitudinal extremes of the gyre, and to respond by orienting in an appropriate direction, might therefore have considerable adaptive value.

For sea turtles and other long-distance migrants, the earth’s magnetic field provides a potential source of worldwide positional information. Several geomagnetic features vary predictably over the earth’s surface, so that different locations within an ocean basin are usually marked by region-specific magnetic fields. To determine if loggerheads can exploit such features in navigation, we studied the orientation behavior of hatchling Florida loggerheads exposed to the fields that exist in three widely separated locations along the North Atlantic gyre’s perimeter. Hatchlings responded by swimming in directions that would, in each case, help keep turtles safely inside the gyre. These results demonstrate that loggerheads can distinguish between magnetic fields that mark different geographic regions. Young turtles probably use such features as navigational markers to help them remain within oceanic areas favorable for growth and development.

Do Green Sea Turtles Learn about Foraging from Conspecifics?

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The evolutionary functions of social living include using conspecific group members to help an individual forage effectively. The term “local enhancement” refers to the idea that one (or more) animal that finds food may draw attention to the food source for other conspecifics in the area (Thorpe, 1963). Thus, other members of the social group could observe and join the successful forager in feeding. This process is one of social facilitation, not to be confused with the more cognitively complex social phenomenon of imitation indicating that a direct copy of behavior would occur.

Flock living birds (Coleman and Mellgren, 1994) have been known to show local enhancement effects, but to date reptiles have not. Green sea turtles (*Chelonia mydas*) were known to live in large herds a few hundred years ago before their numbers were reduced by human predation and abuse. Green turtles are still found in close proximity to each other in feeding and resting areas, and, of course, in their mating habitat. This suggests that they are a social species and thus would show a local enhancement effect with respect to feeding behavior.

In this experiment we used a procedure where a novel box containing food was presented in the home tank of young turtles. In the first condition of the experiment, individual animals were tested. In the second condition, groups of three turtles were tested. In the group condition, one of the three members was given prior experience with finding food in the box. It was hypothesized that this "demonstrator" would provide the basis for local enhancement for the other two turtles, resulting in the pair finding food sooner than the turtles tested as individuals.

Method

A total of 50 green sea turtles (*Chelonia mydas*), 6-7 weeks old were used as subjects. They were randomly divided into two groups of 33 and 17 each.

Testing was done in circular tanks, approximately 1.60m in diameter, and .50m in depth of seawater taken from the Caribbean. A black plastic box, 10 x 7.5cm and 6 cm deep was used to present 15-20 small pieces of fish in the testing tank. The box was attached to a piece of wood that could be fastened to the side of the tank. The box containing the fish was located approximately 3cm below the surface of the water, thus allowing access to the fish, but preventing the fish from being visible to the turtles until they swam over the box. The box was slowly lowered into the tank and attached. The time between putting the box with fish into the tank and the initial approach to the box (coming within 3cm of the box with head oriented towards it), and the initiation of feeding on the fish were measured.

In the individual or solitary condition, each turtle (n=17) was tested by itself. In the group or social condition, 3 turtles (n=33) were in the tank at the same time. One of the 3 had been given previous experience with the box containing fish, and thus served as the demonstrator. The other two turtles were naïve to the presence of the fish and it is their latency to find food compared to naïve turtles tested alone that is of interest.

Results and Discussion

The latency to approach the box and to initiate feeding from the box were significantly lower for turtles in the social condition as compared to turtles tested as individuals (t (38) =3.03; 3.16, p<.01, respectively). These differences are shown in **Fig. 1**. Thus, the presence of a knowledgeable conspecific resulted in more rapid discovery of food compared to individuals tested in isolation. Local enhancement is therefore supported as a possible mechanism used by green sea turtles to find food.

It is possible that the odor of fish might have made this task easier than designed. However, we have conducted control experiments where a neutral object (a white plastic clothespin) was placed in the box rather than fish. Testing individuals in this fashion resulted in no difference in approach latencies compared to turtles tested with fish present. Thus, the presence of fish odor was not a factor in attracting the turtles to the box. However, once the turtle did approach the box, the fish odor apparently did have an effect on the turtle since prior to eating the fish they typically bit the box and the small screw that fastened the box to the wood holder. This indiscriminate biting was only rarely seen in turtles tested with a clothespin in the box.

A small amount of aggression in the form of biting the flipper of another turtle was also observed in the social condition. Interference by physically blocking access to the box was also evident. Turtles were also observed taking food away from a conspecific by simply biting the parts of a piece of fish sticking out of the mouth of the other turtle.

Finally, it should be noted that there are fairly large individual differences in the time the turtles took to find food. The t test statistics reported above where done for separate variance estimates in light of these differences. The standard deviation of the individual condition was higher than that for the group condition. The shorter latency to find food and the lower variability in the time to find food are both reflective of the benefits of social mediation of foraging behavior.

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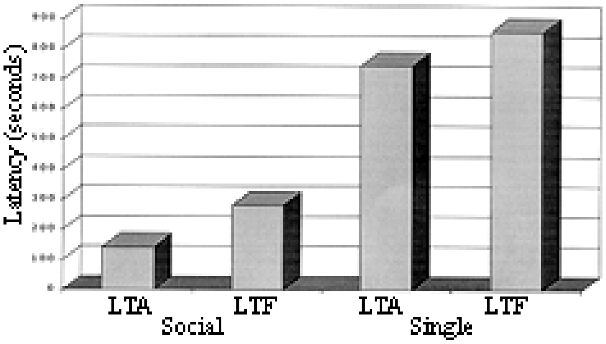

Figure 1.

Acoustic Orientation and Sound Discrimination in Leatherback (*Dermochelys coriacea*) and Olive Ridley (*Lepidochelys olivacea*) Sea Turtle Hatchlings

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The beach environment determines the suitability of sea turtle nesting areas and provides both visual and non-visual sea-finding cues to emerging hatchlings. The influence of the beach environment on sea turtle behavior has important conservation and management implications. The goal of this study was to determine if sea turtle hatchlings could localize airborne surf sounds and discriminate between different acoustic stimuli in sea finding behavior. A total of 167 leatherback and 32 olive ridley hatchlings were collected upon emergence from the nest and tested within experimental sound arenas 1.5 km from Playa Grande in Las Baulas de Guanacaste National Park, Costa Rica. Data were collected on the phonotaxic behaviors of hatchlings to different acoustic stimuli in the absence of other direction finding cues to the surf. Sounds resulting in a positive phonotaxic response were then tested with a 10° beach slope as a conflicting cue.

Results showed leatherback hatchlings could discriminate between different acoustic stimuli and exhibited a positive phonotaxic response towards surf sounds. Leatherback hatchlings oriented down a 10° slope when confronted with sound and slope as conflicting cues. Olive ridley hatchlings exhibited no phonotaxic response to acoustic stimuli, but rather exhibited movement towards a fixed compass heading.

Exploring Operant Conditioning in a Green Sea Turtle

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An exhaustive literature search indicated that there has never been a concerted effort to study the hearing capabilities of any species of sea turtle in a disciplined manner using operant conditioning techniques. The following describes the training program used to prepare a green sea turtle (*Chelonia mydas)* to participate in a hearing study and the development of four experimental designs tailored specifically for a turtle. The project is funded by the Office of Naval Research and is being conducted in collaboration with the Univ. of Maryland, College Park, Maryland.

The subject of this study is named Myrtle. She is approximately 60 years old and she has lived in the New England Aquarium's 200,000 gallon, coral reef exhibit since 1970. Presently 700 fish, a loggerhead turtle, and a Kemp's ridley turtle share the exhibit with her. Myrtle was not moved to a separate area for training and testing because of her popularity with the visitors and the lack of an adjacent holding area.

Despite the numerous distractions inherent to an exhibit setting, Myrtle's introduction to the training program and experimental apparatus proved to be a relatively easy process. She is highly food motivated, comfortable being hand fed, well acclimated to people, and attentive to novel objects. In addition, the divers had inadvertently trained her to respond to a variety of hand gestures in an effort to discourage her from interfering during fish feedings. This provided the basis for teaching Myrtle to respond directionally to a finger point. Similarly, her response to a gesture encouraging her to come to a diver was modified to help focus her attention during training sessions.

The objective of the training program is to determine which experimental paradigm is the most "user friendly" one for a turtle. Initially the program focused on teaching Myrtle a few basic behaviors. These included a recall, stationing on various under water platforms and bars, and touching several different response paddles. The recall, a sound created by tapping two metal pipes together underwater, calls Myrtle to the training area. The other behaviors prepare her for participation in a specific set of experimental designs. In the process of training these behaviors her attention span gradually increased from 10 minutes to about 30 minutes. Brief time outs effectively re-focused Myrtle's attention when she appeared distracted.

The training program was designed to shape Myrtle's behavior with successive approximations and positive reinforcement. The primary reinforcement was smelt or squid, which Myrtle received for each correct response. While testing experimental designs, an incorrect response was acknowledged by briefly removing the response paddle or by beginning a new trial. A hand splash and a buzzer were introduced as conditioned reinforcements. A splash on the water was associated with feeding long before the project began, but it was difficult to determine whether Myrtle was responding to it as a stimulus to return to the feeding station or as a conditioned reinforcement. In contrast, the buzzer was introduced late in the training process. After the buzzer was introduced she began responding randomly and continued to do so until the buzzer was eliminated. If the buzzer had been introduced at the beginning of the training program, as is standard when training marine mammals, it may have been effective.

As it became obvious that Myrtle was responsive to a structured training program, the focus shifted from training specific behaviors to testing a number of experimental designs. All of these paradigms incorporated the following: a set up that was easy for a turtle to maneuver around and operate, a procedure that required Myrtle to touch a paddle in response to hearing a test tone and to stay away from it when she did not hear a tone, and test tones ranging from 280Hz to 640Hz. As Myrtle learned to operate within the limits of four different experimental designs, it became evident that only one appeared to be "user friendly" for this large sea turtle.

The first design consisted of an under water platform, a response paddle, and an under water speaker. Myrtle learned to station on the platform and to touch a paddle in response to a variety of test tones. The response paddle was placed a few inches from her head, making it possible for Myrtle to reach out and touch it with her beak in response to a test tone, or leave it alone in the absence of a tone. Despite its overall simplicity, this design did not work.

Myrtle never seemed to understand that resting on the platform was a discreet response. Consequently, requiring that she station on the platform proved to be an extraordinary demand. A continuous stream of reinforcements was needed to maintain the stationing behavior and to prevent her from touching the response paddle in the absence of a tone. In addition, Myrtle often drifted and made position adjustments to deal with the current. This resulted in frequent, albeit inadvertent, contact with the response paddle in the absence of a test tone. Moving the paddle further away solved that problem but made it necessary for Myrtle to move backwards a few inches to reposition for the next trial. This was time consuming and a very awkward maneuver for her.

Shortly after learning the procedure for the first design, Myrtle stopped eating. This fasting behavior correlated with the breeding and migratory cycle of free ranging green sea turtles. During this fasting period the training program was temporarily abandoned, except for the few occasions when she initiated a session by swimming onto the under water platform. While not motivated by food at this time, a back scratch sufficed as the primary reinforcement.

Since the fasting period lasted five months, it incidentally provided a little insight into Myrtle's memory capabilities. When the training program was reinstated, it was clear that Myrtle remembered all that she had learned earlier in the year. This made it possible to proceed to test the next design.

The second design allowed Myrtle to move constantly from the feeding area to an array of two to four under water speakers. Her task was to touch whichever speaker was the sound source, then return to the feeding area for her reward. As soon as she was reinforced for a correct response at the feeding area, another trial began. This design capitalized on her ability to move gracefully over distance and eliminated the need for any fine tuned movements.

Myrtle seemed to understand that her task was to touch a speaker in response to a test tone, but not necessarily the one broadcasting the sound. In addition, if she was not fed constantly at the feeding area, she tended to randomly touch a speaker in the absence of a test tone. This generalized response and the minimal control inherent to this design made it impossible to determine when she was responding to a tone or just prospecting.

Although Myrtle readily returned to the platform for a reward after touching a speaker, it frequently took at least a minute for her to get there. If the hand splash was not an effective conditioned reinforcement, then the latency between her response and the reinforcement may have made it too difficult for Myrtle to understand that the reward was specifically for touching the broadcasting speaker.

The third design provided more behavioral controls than the previous ones. It consisted of two response paddles and a light box. All were underwater and secured to separate platforms. The platforms were above water and each supported a person who was instructed to reward Myrtle immediately after a correct response at the appropriate paddle. The light served as a start of trial indicator and it stayed on for the duration of each trial. By defining the intra-trial interval this way, random behavior that occurred between trials was irrelevant. Myrtle was taught to initiate a trial by touching the light box. When she touched the box, a light went on, alerting her to listen for a tone. If no tone was heard, she touched a rectangular response paddle. To indicate that she heard a tone, she touched an under water speaker. During a sound trial, the light and sound stayed on for the duration of each trial.

This design had a lot of potential. However, Myrtle's position at the light box was critical. She tended to go to whichever paddle she was facing, regardless of the absence or presence of a test tone. A lot of effort and reinforcement was continually required to help Myrtle maintain the correct station position and to insure that she came back to the box to initiate each new trial. This limited the number of trials that could be conducted in a session.

The fourth design, a go/no go paradigm, is the most appropriate one to use for the actual hearing study. It is a modification of the third design. The light box is suspended from one platform. A response paddle for sound trials and an under water speaker are secured to a second platform. Myrtle touches the box to initiate a trial. A light goes on for one second, indicating the start of a trial. If she does not hear a test tone, she touches the box again. She indicates that she hears a tone by swimming to and touching the response paddle. If it is a sound trial, a tone and light go on simultaneously. The light goes out after one second, but the sound continues to broadcast until she completes the trial.

There are several advantages to this design. Since it is simpler than the third design, there are fewer types of possible errors. Her position in front of the box is not critical. Therefore reinforcements can be used to conduct more trials instead of being used to maintain a stationing position. Occasionally when Myrtle initiates a trial she is oriented at a 45-degree angle facing away from the speaker. If a sound is broadcast when she is in this position, Myrtle tends to respond as if no tone was heard. However, this does not happen often and can be noted in the final analysis.

While learning the procedure for this design, Myrtle exhibited a priority response to temporal light cues over sound. This occurred while employing the following training technique. A start of trial indicator light, initiated all trials.

On a no sound trial the light was turned off after one second. On a sound trial the light was turned off after two seconds. Once she understood the response patterns, the plan was to approximate the duration of the light to a consistent increment, regardless of the type of trial. However, this training technique did not work. It became clear that she was responding to the temporal aspect of the light, and was totally ignoring the sound stimulus. In fact, the temporal light stimuli overshadowed the sound stimuli to such an extent that it became necessary to retrain Myrtle to respond to the test tones. This observation suggests that sea turtles may not be particularly reliant on sound in their daily lives.

Regardless of the experimental design, Myrtle commonly responded incorrectly to trials conducted during or immediately following environmental distractions. For example, her error rate increases when there is drilling in adjacent areas, or when ambient noise increases due to large crowds around the exhibit. Some of the fish in the exhibit compete with Myrtle for her rewards and hover around the training area. Myrtle responds with a variety of territorial displays. Although the other turtles do not appear interested in what Myrtle is doing or eating, she keeps an eye on them and chases the turtles away when they come too close. Myrtle frequently makes errors on trials conducted immediately after distractions of this nature.

In conclusion, Myrtle is responding well to the fourth design. The start of trial indicator light now stays on for one second, regardless of the type of trial that is presented. Once she reaches a consistent 80% response level on both sound and no sound trials, the study will begin to test her baseline hearing range and thresholds by introducing sounds above 640Hz and below 280Hz. During this testing phase of study, the ambient sound will be monitored, Myrtle's position relative to the under water speaker will be recorded, and environmental distractions will be noted for the final analysis.

Ultimately, this project will provide the following for future behavioral research on green sea turtles: a training protocol for studying behavior using operant conditioning techniques, an appropriate experimental design, and hopefully information on the baseline hearing range and thresholds of this species.

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Arteries, Veins, and Nerves. Navigating around the Plumbing of Sea Turtles

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Knowing the locations of arteries, veins and nerves in sea turtles is important because of our needs to safely collect blood samples, administer drugs, as well as repair damaged animals and appropriately and correctly identify organs in stranded animals. The circulatory system may be viewed as a "roadmap" to the organs and tissues. For example, the thyroid gland may be located by first identifying the great vessels of the heart (Brachiocephalic trunk, left aorta, and pulmonary artery). By tracing the Brachiocephalic trunk as it leaves the heart one sees the first branches running anteriorly on each side. These are the thyroid arteries. They frame the single thyroid gland that is encased in connective tissue.

Circulatory structures are of particular significance not only to the turtle, but also to researchers, veterinarians, and caretakers who must draw blood. Most people draw blood from the "cervical sinus" but have little idea of what that structure is or what other structures are in the area. It is most likely that they are in fact drawing from the external or internal jugular veins. These are the largest circulatory structures in the neck and are the ones that are aligned with the nuchal-1st marginal scute junction. They lie deep and sometimes slightly lateral to the dorsal neck muscles that suspend the head. Other vessels in the same general area that might be used for venipuncture are the Vertebral branches off the External jugular which exit medially to the cervical vertebrae. One Vertebral branch joins the dorsal Cervical Sinus and runs along the dorsal surface of the neck. This vessel is small in comparison to the External and Internal Jugular veins. The Carotid arteries lie deep and ventral to the Internal Jugular veins and are surrounded by several layers of muscle. Hence, they will be difficult to locate without a surgical approach.

Because of the variability inherent in the circulatory system, deviations in the pathways of vessels are common. Hence, landmarks may not work some cases.

BIOLOGICAL STUDIES - GENETICS

Male Marine Turtles: Questions Beyond Gene Flow

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Various field based studies have advanced our knowledge of male marine turtle behaviour, but they remain a difficult segment of the population to study. Even as we begin to gain an understanding of male behaviour, their role in population dynamics and gene flow remains illusive without complementary genetic studies. Previous studies using maternally inherited mitochondrial (mt) DNA markers have helped tremendously in delineating regional nesting populations and have provided important information for conservation. However, a broader view may be obtained by also using nuclear markers to assess male and female contributions to population structure. In this paper we discuss aspects of gene flow and philopatry in green turtles from the male's perspective, using both mtDNA and nuclear DNA markers. These results will be interpreted with regard to our knowledge of male behaviour based on tagging studies of males within their feeding and breeding grounds in Australia. This combined approach has provided important insights relevant to the conservation and management of Australia's marine turtles.

Previously, we addressed questions of gene flow at two levels; among populations and within populations. Specifically these data addressed whether males displayed philopatry to their natal regions in their choice of breeding grounds, the extent of male-mediated gene flow, and questions of mating systems, particularly multiple paternity and sperm storage. Analyses were based on sequence information from the control region of the mtDNA and allele frequency data from four nuclear microsatellite loci (FitzSimmons *et al.* 1997a, b). In conjunction with this, our field data focus on questions of site fidelity, breeding migrations and breeding behaviour, through mark recapture studies of turtles at feeding and breeding grounds begun in 1974 (see Limpus 1993).

Our genetic results revealed a moderate level of male-mediated gene flow among Australian nesting populations that varied considerably between adjacent populations. In particular, the results indicated extensive gene flow among the nGBR and sGBR populations (FitzSimmons et al. 1997b). To determine whether males were mating randomly outside of their natal regions the mtDNA haplotype frequencies of breeding males was compared to those of breeding females at three breeding locations, the Gulf of Carpentaria (GoC), northern Great Barrier Reef (nGBR) and southern GBR (**Fig. 1**). Frequencies did not vary for male and females, demonstrating that males, like females are philopatric to their natal regions in their choice of breeding grounds (FitzSimmons *et al.* 1997a). Male philopatry was an unexpected result and suggests that sex-biased gene flow occurs in the absence of sex-biased dispersal, presumably through opportunistic matings during migration. It was hypothesised that some males or females from the sGBR breeding population that use feeding grounds in the GoC and Torres Strait would mate with nGBR turtles while passing through the major courtship area for the nGBR population during their migration south (**Fig. 1**).

How do these hypotheses fit with what is known from field data? Capture of breeding animals during the courtship period shows that both males and females are promiscuous (Limpus 1993, unpubl. data). Also, males appear to be sexually active for about a month (Limpus 1993) whereas females appear to have a peak period or receptivity of less than a week (unpubl. data). Thus, if gene flow is to occur between the nGBR and sGBR populations it most likely involves migrating sGBR males, who are sexually active for a longer duration within a season, mating with receptive nGBR females. Conversely, some sGBR females may become receptive at the beginning of their migration, rather than at the end, or nGBR males are successfully inseminating unreceptive sGBR females as they migrate south.

So why is there less nuclear gene flow between the GoC and GBR populations or between the GoC and western Australian population given that they share feeding grounds (**Fig 1**)? Nesting in the GoC could only have occurred in the last 9,500 years as sea levels rose to fill the area. During that time there has been an apparent shift to winter nesting, presumably because hot sand temperatures in the summer months may diminish embryo survival. This is in contrast to the other green turtle populations in Australia that nest during the summer. This switch in the timing of nesting is apparently coupled to the natal philopatry of GoC breeding males, and has ultimately limited gene flow with the adjacent populations due to a mismatch in the timing of breeding by both males and females. For these populations, this indicates selective pressures operating under relatively short time frames of 190-270 generations (given 35-50 yrs to maturity; Limpus and Chaloupka 1997).

Coupling the observed natal philopatry of breeding males with data on breeding intervals has provided insights into conservation risks and the energetics of breeding. Data on breeding intervals includes information from laparoscopic examinations on males that confirmed non-breeding status in certain years. In summary (**Table 1**), the breeding intervals of males are typically much shorter than for females, with many males breeding in successive years, or after 2-3 years, while females from the same population average 5.8 years (Limpus *et al.* 1994). Such differences in the frequency of breeding can result in differential risks of mortality if migration routes or breeding grounds are located in areas of high risk. For example, if both males and females are harvested at courtship areas then an individual male would be exposed to an overall greater risk during his breeding life span. Additionally, if males are making more frequent migrations than females it suggests differences in energy allocation by males and females which can be assessed under the assumption that both sexes migrate to natal regions for breeding.

To estimate sex-based variation in reproductive energetics, values were extrapolated from Bjorndal (1982) and applied to sGBR breeders, under an assumption that migration distances are not sex-specific (**Table 2**). The estimates serve only as a first approximation, as several values are only educated guesses including: the number of days spent mating, hours/day involved in mating, energetic expenditure of mating and the energetic requirements of producing sperm. Also, the energy required for migration has not been adjusted for the size difference between males and females, and the number of hours spent in activity vs. inactivity are taken from data on green turtles in the southern Bahamas (Bjorndal 1982).

Given all these caveats, the results suggest that if males breed on average every three years, they would have somewhat reduced energy requirements relative to females. As expected, migration accounted for a much greater proportion of a male's total reproductive energy requirement than for females (44% vs. 25%, respectively). If these values are an approximation of reality, they imply an important trade off between migration distance and breeding frequency. Thus we may find that males who breed more frequently than every three years may be turtles that live closer to mating grounds.

In summary, the findings from our genetic studies indicating natal philopatry of males as well as females, and variation in levels of male-mediated gene flow, have provided new insights into historic processes and male behaviour. Nuclear gene flow is limited by the timing of nesting as well as the geographic positioning of feeding grounds, migratory routes and breeding congregations. Natal philopatry of males means that like females, they are at risk from human caused mortality at a wide range of breeding and feeding grounds and during migrations. Natal philopatry of males coupled with frequent breeding migrations suggests variation in energetic tradeoffs relative to females.

Table 1. Breeding intervals of green turtles males captured in the sGBR.

Breeding Interval	Sample Size
1 yr	25
≤ 2 yr	36
≤ 3 yr	13
≤ 4 yr	4
Unknown (>4 yr)	30

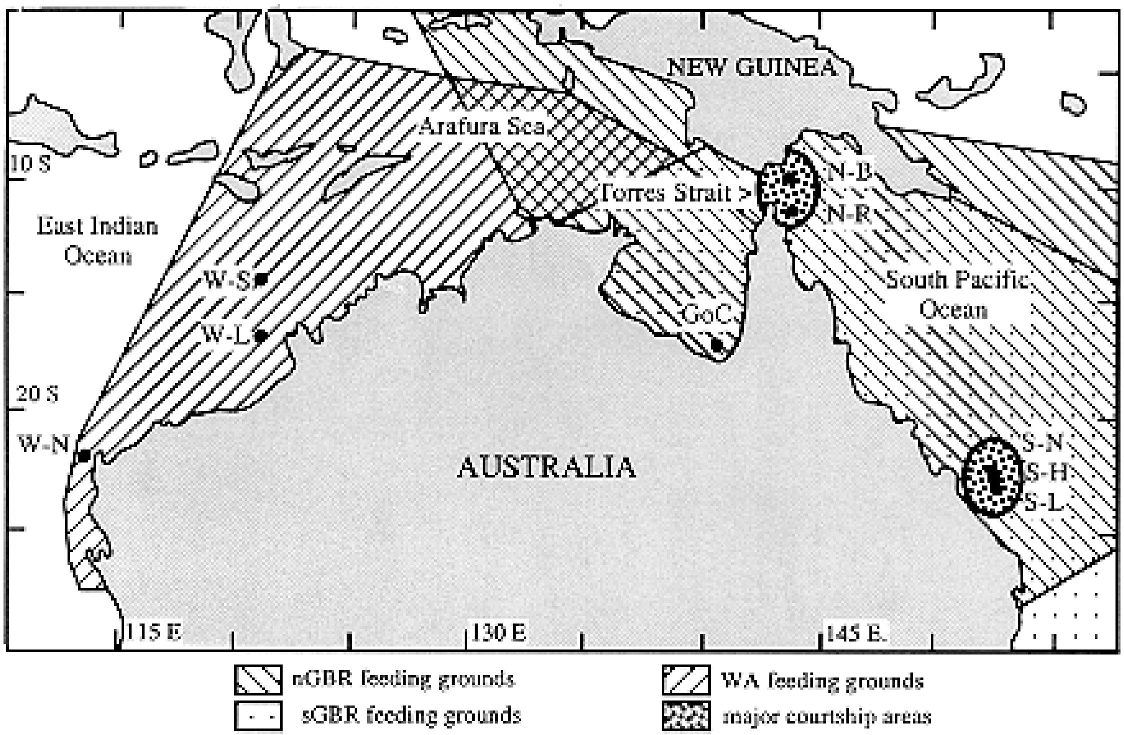

Figure 1. Sample locations for *C. Mydas* showing courtship areas and feeding grounds. Rookeries are as follows: 1)WA; W-N, North West Cape; W-S, Sandy I., and W-L, Lacepede I., 2) GoC; Bountiful I., 3) nGBR; N-B, Bramble Cay and N-R, Raine I.; and 4) sGBR; S-N, North West I.; S-H, Heron I.; S-L, Lady Musgrave I. The extent of feeding grounds used by GoC breeding turtles is unknown.

Table 2. Estimated energetic costs of reproduction for breeding male and female *C. mydas* of the sGBR[1].

Activity	**Unit Rate**	**Respiratory per unit (l O_2/kg/hr)**	**Energy Effort (kJ)**	**Total Energy**	**Total**
Female (130 kg)					
Migration	2.7 km/hr	0.065	61.9/km	1,490 km	92,240
Eggs	1 egg	n/a	259.7	115 x 5.06 eggs	151,120
Nesting	1 nest	0.206	1,075	5.06 nests	5,440
Mating	8 hr/day	0.098	2,005/day	5 days	10,020
Activity	6 hr/day	0.065	168.6/hr	294 hr	48,840
Inactivity	18 hr/day	0.024	61.34/hr	942 hr	57,780
Total reproductive effort					365,440
Annual reproductive effort	(5.78 yr interval)				63,225
Males (~110 kg)					
Migration	2.7 km/hr	0.065	52.1/km	1,490 km	77,570
Sperm	1 egg equiv.	n/a	259.7	10 egg equiv.	2,597
Mating	12 hr/day	0.098	2,540/day	30 days	76,300
Inactivity	12 hr/day	0.024	52.64/hr	360 hr	18,680
Total reproductive effort					175,100
Annual reproductive effort	(3 yr interval)				58,370

[1] values taken from Limpus *et. al*. (1984; 1994); Limpus (1993).

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Multiple Paternity in the Olive Ridley Sea Turtle

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We are currently studying the mating system of the olive ridley sea turtle (*Lepidochelys olivacea*) by investigating whether multiple paternity occurs in this species. Sampling took place in the Galibi Nature Reserve in Suriname, the most important nesting beach for olive ridleys in the Western Atlantic. Blood samples (<0.5 ml) from 10 nesting females were taken from the dorsal cervical sinus. The clutches were transferred to a hatchery immediately after egg deposition. Sampled females were marked using white paint. As none of the females were observed nesting a second time, no successive clutches were sampled. After hatching, blood samples (<0.2 ml) from virtually all of the hatchlings were taken from the dorsal cervical sinus before releasing the hatchlings. Blood samples were stored in lysis buffer at room temperature (BEECS, 1993). In total, blood samples from 53 unrelated individuals were collected to asses allele frequencies.

The occurrence of multiple paternity was investigated using 2 polymorphic microsatellite markers. Paternal genotypes were inferred by comparing on average 60 offspring to their mother in Ei8 (FitzSimmons *et. al.* '95) and Cm84 (FitzSimmons *et. al.* '95, redesigned by K. Kichler, pers. com.), 2 microsatellite loci that display a high variability in the olive ridley (**Table 1**). For all clutches, the number of offspring analyzed was about half of the total number of eggs in the clutches, except for 2 clutches with a low hatching success.

Preliminary Results

In 8 clutches that have been studied so far, 2 clutches were found in which multiple paternity had occurred. In one clutch, 44 of 62 offspring analysed were sired by one male, whereas the remaining 18 were sired by a second male. In a second clutch, 56 of 60 offspring analysed were sired by one male, and the remaining 4 were sired by a second male. In both clutches, the multiple paternity was observed in both loci studied, which makes it highly unlikely that the unexpected genotypes were caused by mutation. The distribution of alleles in the offspring followed mendelian expectations at both loci, except in one clutch in which deviations were found at both loci. All together, these findings show that multiple paternity occurs in the olive ridley sea turtle.

Table 1. Number of alleles, probability of detecting multiple paternity (Westneat *et al.* 1987) and the probability of shared genotypes for Ei8 and Cm84 in the olive ridley population nesting in Suriname.

	# alleles (n=50)	Probability of detection	Probability of shared genotype
Ei8	22	0.74	0.03
Cm84	10	0.52	0.11
Combined		0.87	0.003

Discussion

The probability of detecting multiple paternity for Ei8 and Cm84 combined is 0.87 (**Table 1**). Thus, there is a chance that multiple paternity did occur but went undetected. Additional polymorphic loci will have to be studied in order to rule out this possibility. The Surinam olive ridley population has been declining over the past 30 years. Perhaps in larger, more stable populations the level of multiple paternity would differ considerably.

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Acknowledgements

We would like to thank H. Reichart (LBB), M. Held, C. Bram, and H. Sijlbing (Stinasu) and R. Pané, for making it possible to work in the Galibi Nature Reserve. K. Kichler, N. FitzSimmons and B. Bowen are thanked for providing DNA samples and N. FitzSimmons for providing primers. Finally, we would like to thank L. van Tienen, M. Weijerman, for their help with fieldwork and sampling. Financial support came from the Beijerinck-Popping Foundation, the Treub society (Society for the Advancement of Research in the Tropics), the Symposium Overseas Travel Fund and the David and Lucile Packard Foundation.

Poi Or *Papas*:
Do Hawaiian and Mexican Green Turtles Feed Together in Baja California Waters?

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Black turtle (*Chelonia mydas agassizii*) foraging grounds along the coasts of Baja California, Mexico (**Fig. 1**) were surveyed during 1996-1998. 92 tissue samples were collected and analyzed using standard molecular genetic methods. Haplotypes from feeding areas were compared to those known from nesting populations in the eastern and central Pacific (Dutton *et. al.*, unpublished data). Results suggest that Baja California's *Chelonia* originate from several disparate nesting areas. The majority of the haplotypes found on foraging grounds are of the Michoacan type (80%), however approximately 20% were not.

Hypotheses for the origin of these turtles include dispersal from Hawaiian rookeries (6% were haplotype D; Dutton's nomenclature) or the Islas Revillagigedos, a small archipelago off of the coast of Colima, Mexico. As genetic samples have not yet been obtained from the Islas Revillagigedos we recommend doing so. The hypothesized "Revillagigedos" haplotype (G; Dutton's nomenclature) was significantly more abundant along the Pacific coast when compared to Gulf of California feeding grounds, supporting pelagic dispersal from the archipelago to the feeding grounds on the west coast of Baja California.

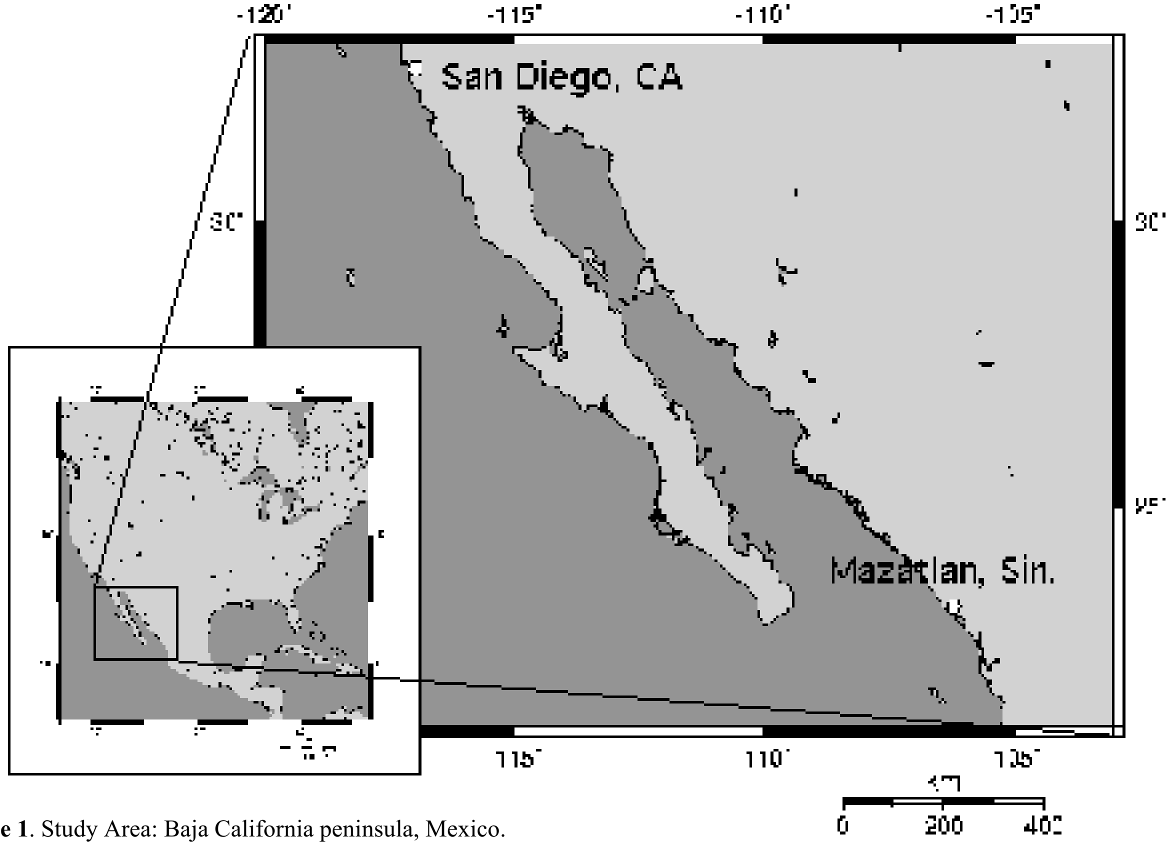

Figure 1. Study Area: Baja California peninsula, Mexico.

Supporting information from tagging and satellite telemetry reiterate the conclusion that a majority of Baja California *Chelonia* originate from and return to nest in Michoacan, Mexico. Three adult female turtles were tracked using satellite telemetry from Gulf of California feeding grounds to the vicinity of Colola, Michoacan. Each of the three turtles had "Michoacan" haplotypes (E,E, and N; Dutton's nomenclature). All tag returns from Baja California feeding grounds have been from Colola or Maruata, Michoacan. None of the 250+ turtles tagged by this project have been found on any nesting beach other than those in Michoacan.

These results represent the first efforts to define management units for the east Pacific green turtle, a population that continues to decline despite nearly three decades of conservation efforts on its principal nesting beaches in Michaocan (Alvarado, pers. comm.). They also represent the first black turtles ever tracked from feeding to nesting areas, a distance of approximately 2000 km. Further, these results suggest that high mortality rates of large subadult and adult *Chelonia* on feeding grounds have likely played a significant role in the slow recovery of several eastern Pacific rookeries.

BIOLOGICAL STUDIES - SEX RATIOS AND TEMPERATURE DEPENDENT SEX DETERMINATION

Long Term Female-Biased Hatchling Sex Ratios at a Leatherback Turtle Nesting Beach

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Since 1993, we have monitored the thermal nesting ecology of leatherback turtles at Playa Grande located on the Pacific coast of Costa Rica. We reconfirm earlier published reports of female biased hatchling sex ratios (1993-1996) using nest and beach temperature data taken since 1996 and by estimating long term hatchling sex ratios using historical climate data. Since 1950, Playa Grande had produced predominately female hatchlings (<< 80.0%). This sex ratio bias is increased further by both natural and anthropogenic differential mortality of male hatchlings. Playa Grande is one of the last remaining nesting areas for Pacific leatherbacks and its long term production of female hatchlings poses unique but controversial conservation and management strategies.

The Effect of Incubation Environment on Loggerhead Hatchlings and a Potential Advantage of Temperature-Dependent Sex Determination

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I studied the effect of incubation environment on loggerhead hatchlings from 14 clutches by comparing the characteristics of hatchlings from eggs at the periphery of clutches (i.e., those in direct contact with the surrounding soil) to the characteristics of hatchlings from eggs in the center of clutches (i.e., those not in direct contact with the surrounding soil). Eggs from the periphery gained more weight (water) during incubation than eggs from the center. Hatchlings from the center eggs were larger in carapace width than hatchlings from the peripheral eggs. Hatchlings from both the peripheral and center eggs crawled at the same speeds, but hatchlings from the center eggs spent more time powerstroking during the first 24 hours in the water than hatchlings from the peripheral eggs. Hatchlings from the center eggs also grew faster and were larger after the first two weeks of post-hatchling growth than hatchlings from the peripheral eggs. Temperatures were monitored throughout the incubation period at various locations within three of the clutches. The center of the clutch was the warmest location and the area most likely to produce female hatchlings. As adults, male loggerheads are able to reproduce twice as often as female loggerheads. To help counter the reproductive advantage of males, female loggerheads might get a reproductive headstart by growing faster and maturing at an earlier age than male loggerheads. If this is the case, then temperature-dependent sex determination is advantageous in loggerheads because it associates female hatchlings with the fastest growth rates.

Statistical Description of Temperature-Dependent Sex Determination in Marine Turtles

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In many reptiles, as well as in some actinopterygians and amphibians, the sexual phenotype is determined at least in part by the incubation temperature of eggs (Pieau *et al*., 1995). This phenomenon has been called temperature-dependent sex determination (TSD). Its occurrence in reptiles (many turtles, all crocodilians, both sphenodons, and some lizards) is puzzling from an evolutionary point of view because its adaptive significance remains largely unknown. TSD occurs in all marine turtles and is generally first characterised in a species by the results of incubation at several constant incubation temperatures. Originally, TSD was described simply using the pivotal temperature (also called the critical or threshold temperature), which is the constant incubation temperature producing an equal number of both sexes (Mrosovsky and Pieau, 1991). More recently, a new parameter has been proposed to describe TSD: the transitional range of temperature (TRT) (Mrosovsky and Pieau, 1991). TRT is the range of constant temperatures in which the incubation produces both sexes. TRT is presumed to describe more adequately the consequence of TSD in natural conditions: when the TRT is narrower, more nests should be unisexual.

A new procedure has been recently introduced to calculate conjointly the pivotal temperature, the transitional range of temperature, and their variance (Girondot, 1999). The estimation is performed using maximum likelihood. We present rapidly here the method, its use to characterise TSD in marine turtles, and a test to compare populations.

Material and Methods

The statistical methodology used is fully described in Girondot (1999) and is summarized here briefly. It is based on the best fit curve of the sex ratio on the incubation temperatures by the function:

$$sr(t) = 1 \Big/ \left(1 + e^{\left(\frac{1}{S}\cdot(P-t)\right)}\right) \qquad \text{equation 1}$$

This equation has all the prerequisites for describing TSD: *sr* goes from 0 to 1 for *S* being positive or from 1 to 0 for *S* being negative with a transition more or less sharp according to the *S* parameter and with an *sr* value equal to 0.5 for $t=P$. The range of temperature producing males and females (TRT) is then simply $|S.k_l|$ with k_l being a constant dependent on l, the sex ratio limit chosen to define TRT (for example $TRT_{5\%}$ indicates that TRT is defined as the range of temperatures producing between 5% and 95% of males): $k_l=2\ln(l/(1-l))$.

The probability (p_i) of the observed distribution of males and females for each u incubation temperature is obtained using a binomial distribution with m_i, f_i, and n_i ($n_i=m_i+f_i$) being the observed number of males, females, and total of sexed embryos, respectively, for a particular temperature t_i and the theoretical sex ratio at this temperature, $sr(t_i)$ based on equation 1:

$$p_i = C_{n_i}^{m_i}\, sr(t_i)^{m_i}\,(1 - sr(t_i))^{f_i} \qquad \text{equation 2}$$

The likelihood of the experiment (L) is then simply:

$$L = \underset{i=1}{\overset{u}{\subseteq}} p_i \qquad \text{equation 3}$$

The adjustment of the P and S parameters for a particular set of incubation temperatures and sex ratio is performed using maximum-likelihood analysis and the variance of the parameters are obtained by the values of the second order derivative at the maximum-likelihood *S* and *P* values (Girondot, 1999). The test for significant difference between λ populations is based on the likelihood ratio test. The null hypothesis (H_0) being that no difference exist between population, the likelihood of the combined data of all experiments (L_c) is calculated as well as the likelihood of each of the λ experiments (L_j). The test is then performed using a χ^2 with 2λ-2 DF:

$$\chi^2 = -2\ln\left(L_c \Big/ \left(\prod_{j=1}^{\lambda} L_j\right)\right) \qquad \text{equation 4}$$

Computer program for MS-DOS and MacOS is freely available on the web page:http://www.biop7.jussieu.fr/perso/girondot.html

Results

The pivotal temperature (*P*) and $TRT_{5\%}$ are shown in **Table 1** for the available data in literature about marine turtles. Three species need to be discussed in further detail.

Chelonia mydas: Only data from Godfrey (1997) are used for the estimations of *P* and *S*. Data from Mrosovsky *et al.* (1984) does not permit to reach some maximum likelihood. It can be easily explained because only 4 incubation temperatures were studied and the two intermediate temperatures produced inverse sex ratio tendency compared to the two extreme temperatures. This could be the result of difference in cooling due to change of substrat for incubation (Mrosovsky, pers. comm.). Miller and Limpus (1980) estimate sex ratio for Australian population of this species at 3 incubation temperatures but none produced mixed sex ratio whereas at least two are required to estimate *P* and *S*. Nine intersexes were originally described in this experiment but further studies have shown that their phenotype were in fact indentical to the most common sex obtained at this temperature (J.D. Miller and C.J. Limpus, pers. comm.). The probability of the observed number of males and females for each incubation temperature has been established based on the hypothesis that sex determination is the same than for Suriname Green turtles. The probability of the observed number of males and females is >0.99, <0.0001 and >0.99 for incubations at 26, 29 and 33°C respectively. Result at 29°C shows that *C. mydas* from Australia therefore exhibits a significant difference for TSD compared to *C. mydas* from Suriname.

Dermochelys coriacea: Binckley *et al.* (1998) reported sex ratio versus incubation temperatures for Leatherbacks nesting at Playa Grande, Costa Rica (Pacific). Based on a visual comparison with data from Atlantic (French Guiana) TSD in Leatherbacks (Rimblot *et al.*, 1985; Rimblot-Baly *et al.*, 1986), they conclude that: " The two temperature versus % female curves for Atlantic and Pacific leatherback populations are virtually identical in pivotal temperature and overall shape. A reanalysis of these data has concluded that Atlantic and Pacific pivotal temperatures are indeed not significantly different but that TRT is significantly larger for Leatherbacks from Playa Grande (Pacific) compared to French Guiana (Atlantic) (Chevalier *et al.*, 1999).

Caretta caretta: TSD has been studied for 6 different geographic origins of animals and permit to use the likelihood ratio test. A significant global difference for TSD is observed (**Fig. 1**). This demonstrates a significant genetic structure of populations for this species as already demonstrated with mtDNA polymorphism (Encalada *et al.*, 1998).

Conclusions

The first method that uses all the informations available to describe TSD in reptiles is presented. When applied to available data for marine turtles, this method permits the calculation of pivotal temperature and TRT and also their standard-deviations.

This method can be used also to distinguish populations of *C. caretta*, *C. mydas* and *D. coriacea* based on their sensitiviy to temperature. This new statistical tool will permit us to enhance the ecological and evolutionary work on temperature-dependent sex determination.

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Table 1: Pivotal temperature (P) and $TRT_{5\%}$ for marine turtles (SD is standard deviation).

Species	Locality	P (SD)	$TRT_{5\%}$ (SD)	Ref.
C. mydas	Suriname	29.14 (SD 0.18)	3.23 (SD 0.464)	1
L. olivacea	World	30.06 (SD 0.24)	3.95 (SD 0.047)	2, 3
C. caretta	North-Carolina, USA	29.15 (SD 0.11)	3.24 (SD 0.353)	4
C. caretta	Georgia, USA	28.19 (SD 0.17)	4.65 (SD 0.706)	4
C. caretta	Florida, USA	29.09 (SD 0.11)	3.18 (SD 0.647)	4
C. caretta	Mon Repos, Australia	27.85 (SD 0.22)	5.89 (SD 0.765)	5
C. caretta	Heron Island, Australia	28.87 (SD 0.22)	4.59 (SD 0.294)	5
C. caretta	Brazil	29.15 (SD 0.06)	1.75 (SD 0.070)	6
E. imbricata	Antigua	29.27 (SD 0.04)	0.97 (SD 0.007)	7
D. coriacea	Costa Rica, Pacific	29.43 (SD 0.01)	1.17 (SD 0.040)	8

1: Godfrey, 1997; 2: McCoy *et al.,*1983; 3: Standora and Spotila, 1985; 4: Mrosovsky, 1988; 5: Limpus *et al.,* 1985; 6: Marcovaldi *et al.,* 1997; 7: Mrosovsky *et al.,* 1992; 8: Binckley *et al.,* 1998.

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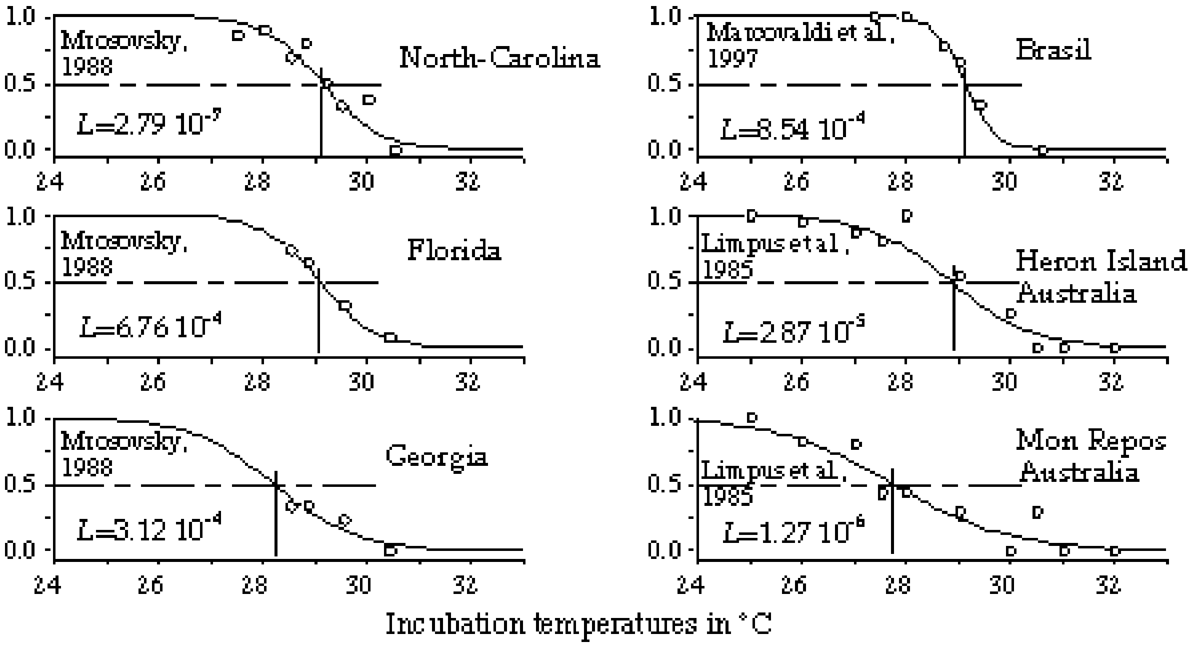

Figure 1: Significant TSD difference between *Caretta caretta* " populations " (χ^2=107.12, 10 DF, p<0.01). The sex ratios (Y axes) are shown in " male frequency ".

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Sex Ratios of Hatchling Hawksbill Sea Turtles from Bahia, Brazil

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More than 90% of all hawksbill nests laid in Brazil are found in northern Bahia. In order to estimate the sex ratio of hatchling hawksbill sea turtles produced on these beaches, we collected 200 eggs from 2 clutches and incubated them at constant temperatures in the laboratory. From this we were able to determine the pivotal temperature (that temperature which results in equal numbers of males and females=29.65°C) and the pivotal incubation period (that incubation period which results in equal numbers of males and females=62.8 days). Using data on incubation periods from 7 nesting seasons (1990/91-1996-97), we calculated the seasonal and overall sex ratio for hatchlings produced on these beaches.

The overall sex ratio was more than 90% female, and from other data we suggest that an extreme female bias in hatchling hawksbills has been produced in Bahia for at least 20 years. We discuss the possible connection between this skewed sex ratio and other particular characteristics of this population of sea turtles, including a relatively low hatching success rate of the nests and the high incidence of hybridization between hawksbills and loggerheads in Bahia.

A Simple Method of Estimating Sex Ratios of Populations of Sea Turtle Hatchlings

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Incubation duration of turtle eggs correlates with temperature. The phenotypic sex of sea turtles depends on the temperature during incubation. Therefore, incubation duration can be used as an index of sex. Figures 1-4 outline a specific way of using incubation durations to estimate sex ratios. These figures are diagrammatic: they illustrate the method, not the precise values to be used which have to be determined for any particular case. However, it might already be known that pivotal temperatures and incubation durations — those giving 50% of each sex — fall in a narrow range for a particular species. If that were the case, then determining the curve in Step 1 (**Fig. 1**) may be replaced by taking data from the literature with only small decreases in confidence. However, if Step 1 is carried out, the investigator also ends up with values for pivotal temperature and incubation duration for that particular population; these might be useful in management.

An advantage of a method relying on incubation durations is that it can be applied retrospectively (e.g., Marcovaldi *et al.*, 1997); many data already exist on incubation duration. It can also be used in remote places where high-tech methods may be difficult, or too costly. Even obtaining accurate sand temperatures is probably more complex than recording incubation durations. However, it must be cautioned that because the curves in **Fig. 1-4** are based on averages, the present method does not estimate sex ratio for an individual hatchling, or even for a clutch, but for a population. A validation of the present method for a particular population of loggerhead turtles is given in Mrosovsky *et al.* (1999). Anyone considering using this method is urged to consult that paper to obtain an impression of the order of accuracy to be expected.

Whether sex ratio is estimated from incubation duration, or by some physiological or biochemical assay, there remains the need to sample thermally changing environments fairly over space and time; ideally this means having information for several years and possibly several beaches (Godfrey and Mrosovsky, in press). No method of estimating sex ratio is devoid of these logistic challenges; in that respect no method of estimating sex ratio is simple. Use of different methods, including the present one, may be appropriate for different stages of an investigation.

Acknowledgement

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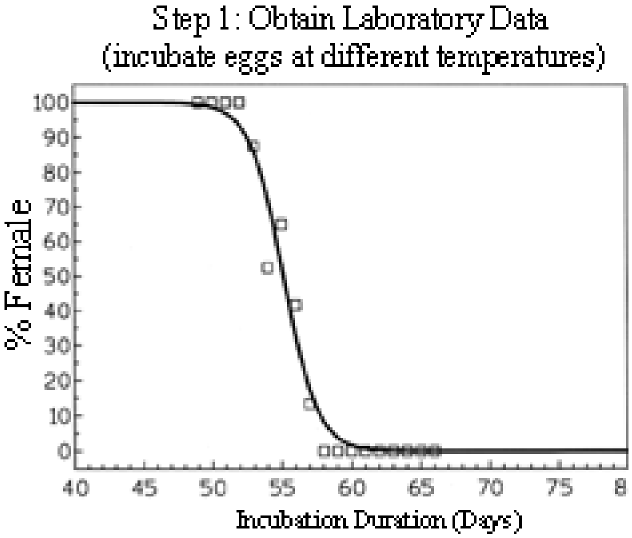

Figure 1. Data points show sex ratio of eggs hatching with particular incubation durations. Sigmoid curve is fitted by computer. Several incubators set at different constant temperatures may be needed to obtain a sufficient spread in durations.

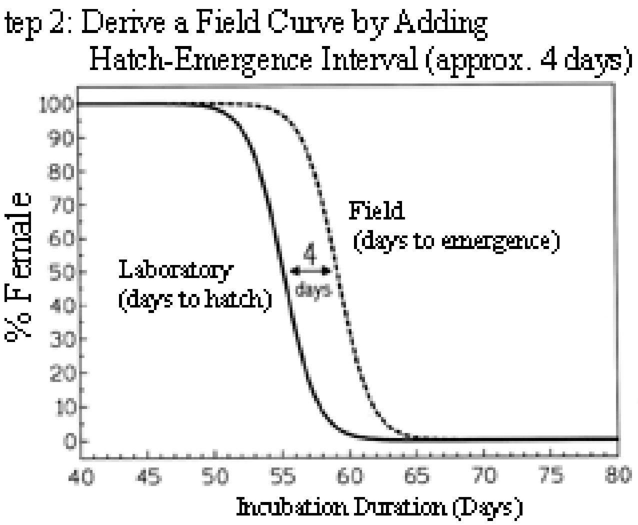

Figure 2. For further discussion on use of a 4-day hatch-emergence interval, see Godfrey and Mrosovsky (1997). Their estimates were based largely on data for loggerhead turtles. More information for other species is needed. A variety of different intervals can be used, to learn how sensitive estimates are to this parameter (Godfrey *et al.*, submitted).

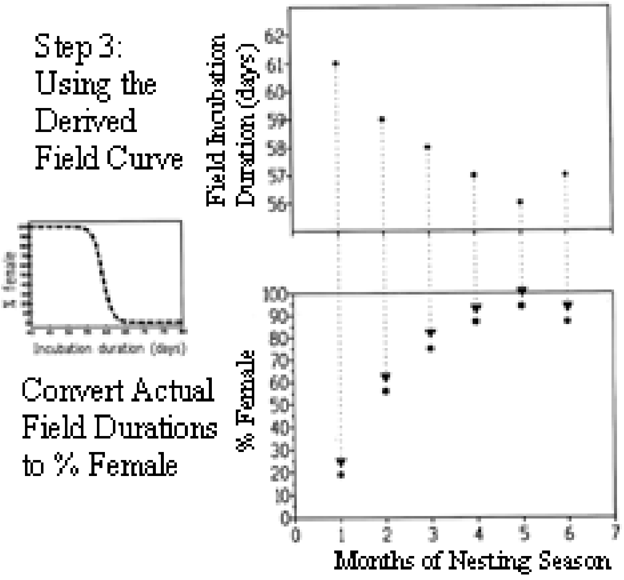

Figure 3. The time bin selected for the x axis is arbitrary. In previous studies a 1/2-month interval has often been used as a compromise between obtaining both reasonable temporal resolution and a reasonable number of data points in each bin. Use of a half-month bin will make it easy to compare new results to previous findings.

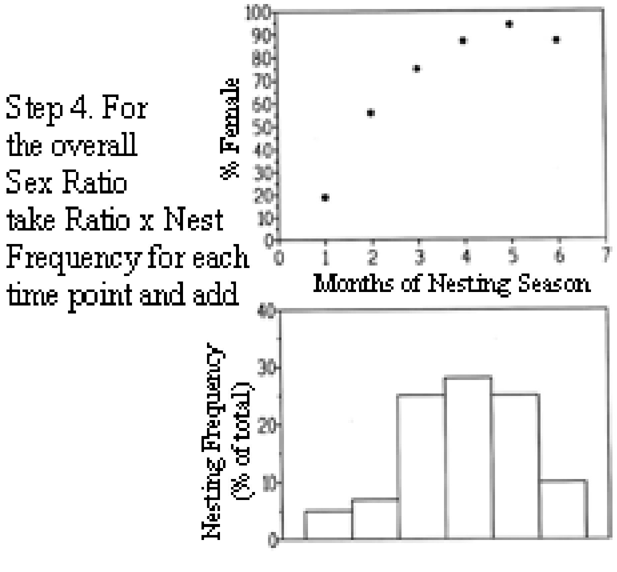

Figure 4. Seasonal nesting distributions may vary from year to year. An average distribution may be used, or sex ratio can be estimated separately for different years.

AT SEA STUDIES

Evidence for Counter-Current Movement of Pelagic Loggerhead Turtles in the North Pacific Ocean Based on Real-time Satellite Tracking and Satellite Altimetry

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During 1997-98, satellite tracking was accomplished with nine loggerhead turtles determined by mtDNA to be of Japanese origin. The turtles were caught and released alive from U.S. commercial vessels operating in the North Pacific pelagic longline fishery at 30 to 35°N latitude (**Fig. 1**). The turtles ranged from 41 to 81 cm in straight carapace length (mean=54.8±12.3 cm; **Table 1**). Personnel of the National Marine Fisheries Service, Observer Management Program, safely and securely attached 180-g Argos-linked Telonics ST-10 transmitters to the carapace of the turtles using fiberglass cloth and polyester resin. Four of the turtles were lightly hooked externally, allowing easy removal of the hooks. The hooks in the other five turtles were deeply ingested, thereby preventing safe removal. Deeply hooked turtles were significantly larger in carapace length than the lightly hooked turtles ($P<0.05$). All turtles were active upon release.

The duration of transmissions ranged from 2.2 to 6.9 months (mean=4.3±1.7 months) during which time the turtles traveled 1300 to 5200 km (mean=2700±1300 km; **Table 1**). Geostrophic currents were computed for 10-day real-time windows along each turtle's path using TOPEX/Poseidon satellite data. Geostrophic currents moved from west to east at an average speed of 0.1 to 0.3 km/hr. All turtles swam from east to west at an average speed of 0.8±0.2 km/hr against the measured geostrophic currents, demonstrating that passive drift was not a mechanism of transport. No significant differences existed between lightly and deeply hooked turtles in terms of transmission time, distance traveled, and speed of travel ($P>0.05$).

Table 1. Size, transmission time, distance traveled, speed of travel, and hooking status of nine loggerhead turtles satellite tracked during 1997-98 in the North Pacific Ocean.

Transmitter ID	Straight Carapace lenght (cm)	Duration of transmissions (months)	Distance traveled (km)	Speed traveled (km/hr)	Hooking status
19580	52.0	3.9	2600	0.9	Lightly hooked
19585	41.0	3.0	1300	0.6	Lightly hooked
24182	45.0	2.2	1700	1.0	Lightly hooked
19599	45.5	6.9	3100	0.6	Lightly hooked
19582	62.0	4.5	3500	1.0	Deeply hooked
19586	81.0	5.9	5200	1.2	Deeply hooked
19598	48.0	6.4	3500	0.7	Deeply hooked
19594	58.0	3.5	1900	0.7	Deeply hooked
24185	61.0	2.4	1400	0.8	Deeply hooked

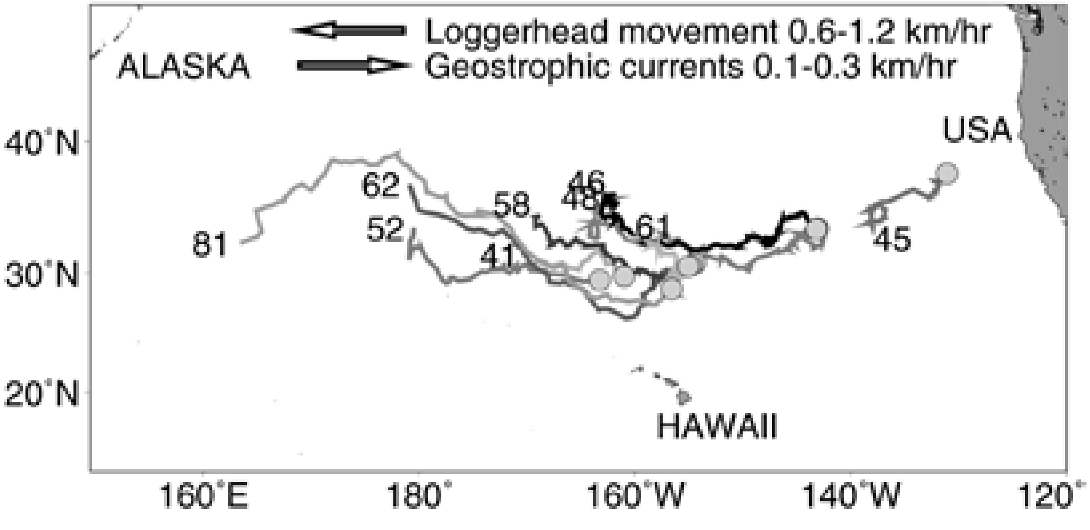

Figure 1. East-to-west movement of nine pelagic loggerhead turtles in the North Pacific Ocean as determined by satellite telemetry. The straight carapace lengths of the turtles are shown as the endpoint of each tracking line.

Foraging Ground Characteristics of Adult Female Hawksbill Turtles Satellite-Tracked from Barbados, West Indies

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Four adult female hawksbill turtles (*Eretmochelys imbricata*), fitted with satellite transmitters as part of the Caribbean Hawksbill Research Tracking Project 1998-99 (NOAA/NMFS), were tracked from their nesting beaches in Barbados to their foraging grounds. Following their post-nesting migrations, the study animals traveled to foraging ground locations in four different countries and have been resident in the same areas for periods of up to four months to date. This paper describes the types of habitats that the study animals have settled in, their home ranges and patterns of diving behaviour at the different locations, potential threats to sea turtles in the areas they have settled in and the legislative protection for sea turtles whilst in the foraging grounds.

Departure of Marine Turtles from Developmental Habitats: Evidence from Bermuda and Panama

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Evidence from fieldwork in Bermuda and Panama allows further characterization of the end of the developmental habitat portion of the life cycle of cheloniid sea turtles. Capture and study (including laparoscopy) of turtles in developmental habitats, in combination with international tag returns, provide information on the size and maturity status of individuals that depart from developmental habitats in these two countries. Data are presented for green turtles from Bermuda and the Caribbean coast of Panama, and for loggerheads from Caribbean Panama. The satellite track of a 79-cm subadult green turtle traveling from Bermuda to the easternmost point of Cuba is presented.

Post-Nesting Migrations of Hawksbill Turtles in the Granitic Seychelles and Implications for Conservation

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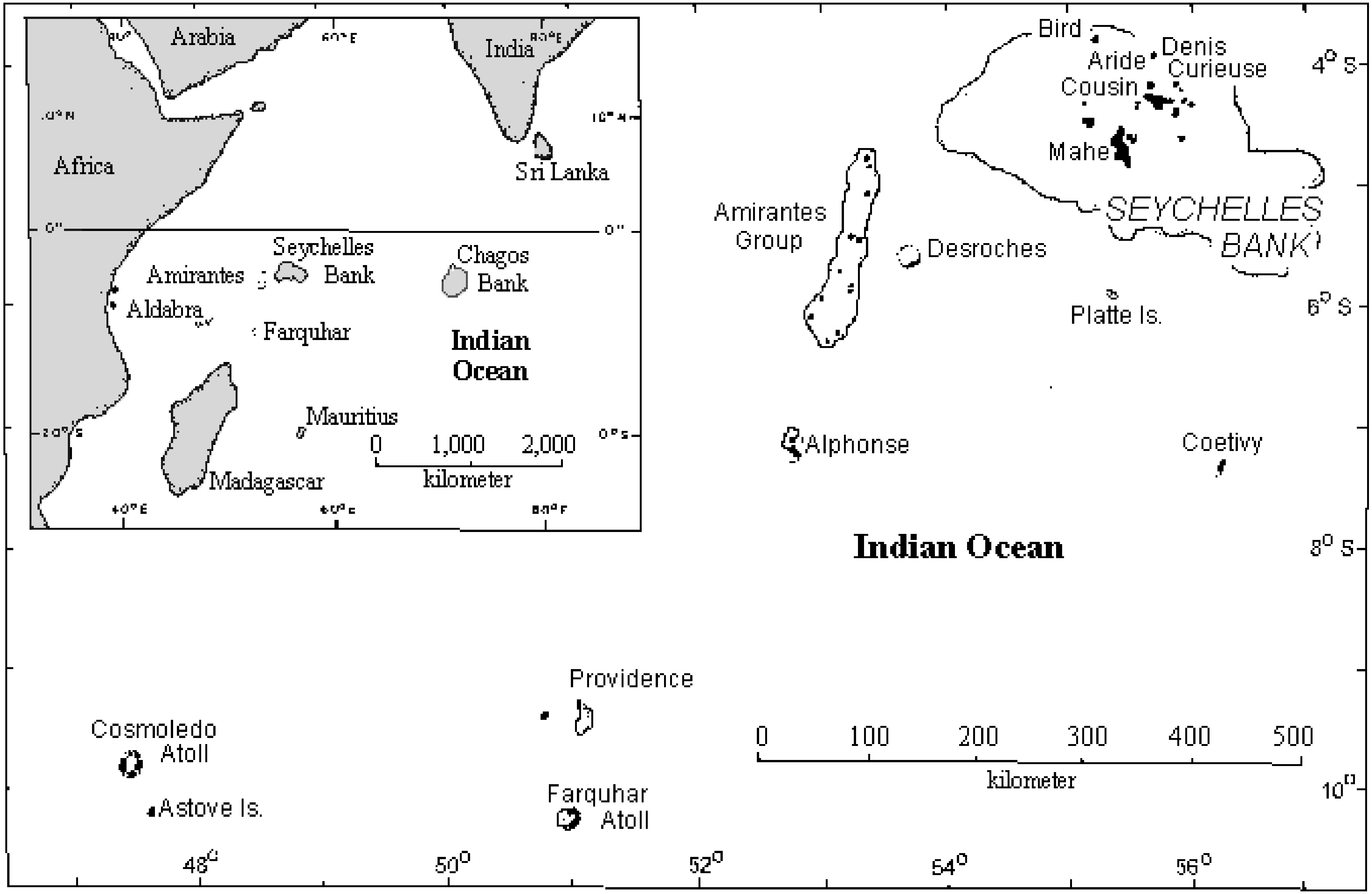
Significant populations of hawksbill turtles *(Eretmochelys imbricata)* nest in the Republic of Seychelles (western Indian Ocean), but in numbers much reduced from historic levels (Meylan and Donnelly, 1999). Hawksbill nesting in Seychelles is most concentrated at the granitic islands of the Seychelles Bank, in the Amirantes Islands group, and on Platte and Coetivy islands (Mortimer, 1984) (**Fig. 1**). Since 1973, more than 750 nesting hawksbills have been tagged at these sites. The tagging programme began in 1973 at Cousin Island (Mortimer and Bresson, 1999), and was expanded in 1980 to Curieuse, in 1981 to St. Anne Marine Park and Aride Island, in 1994 to Cousine Island, and in 1995 to Bird Island. Nesting hawksbills also have been tagged opportunistically at other islands within the Seychelles Bank and on many of the outer islands of the Seychelles since 1981 (Mortimer, 1998). Although inter-island movements of nesting hawksbills have been recorded on the granitic islands of the Seychelles Bank (Mortimer, Hitchins, Bresson, Collie and Roberts, unpubl. data), no tagged hawksbills have been recovered outside the country. Nor have tags been recovered from females captured at points distant to the nesting beaches.

Our lack of knowledge about the resident foraging grounds, where the adult females live during the several-year intervals between nesting seasons, has compromised efforts to effectively manage and conserve both the turtle populations and their foraging habitats. Data obtained from 25 years of tagging nesting hawksbills had not solved this mystery. So, we employed satellite telemetry in an effort to identify the resident foraging grounds and to track the routes taken to reach them.

The Tracking Study

In January 1998, we attached five ST14 satellite transmitters (Telonics of Mesa, Arizona) to post-nesting hawksbill turtles at Cousin Island (4°20'S; 55°40'E), using methods patterned after Balazs *et al*. (1996), and tracked them using the Argos system. Mapping of results was accomplished as described by Ellis and Balazs (1998). Our study has been very successful. **Figure 2** maps the

Figure 1. The Republic of Seychelles (next page).


Arabia
India
Africa
Sri Lanka
Seychelles Bank
Chagos Bank
Amirantes
Aldabra
Farquhar
Indian Ocean
Mauritius
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0
1,000
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kilometer
Bird
Denis
Aride
Curieuse
Cousin
Mahe
SEYCHELLES BANK
Amirantes Group
Desroches
Platte Is.
Alphonse
Coetivy
Indian Ocean
Providence
Cosmoledo Atoll
Astove Is.
Farquhar Atoll
0
100
200
300
400
500
kilometer
4° S
6° S
8° S
10°
48°
50°
52°
54°
56°

movements of the five turtles. As of early March 1999, after 13.5 months, transmitters (#4806, #4807, and #4809) were still sending good position data for three of the turtles. Two of the transmitters (#4805 and #4808) had stopped transmitting after 2.3 and 1.5 months, resp., but not before the turtles are believed to have completed their migration back to the foraging grounds. None of the five turtles traveled beyond the edges of the Seychelles Bank, and none moved farther than 175 km from the nesting beach.

All five turtles displayed similar patterns of movement. After laying their last egg clutch of the season, the five turtles traveled for three to five days in a directed fashion to discrete and different locations on the Seychelles Bank that ranged from 20 to 175 km from the nesting beach. Upon reaching their destinations none of the turtles traveled beyond a radius of about 15 km in any direction. In fact, their travel appeared more restricted as the months passed (**Fig. 2**). Detailed results of this study will be published separately (Mortimer, Balazs, Hitchins, Constance and Nolin, in prep.). The tracking data confirmed in a few months what 25 years of flipper tagging had inconclusively suggested: that hawksbills nesting in Seychelles are likely to spend their adult lives within the territorial waters of Seychelles. Satellite tracking in the Hawaiian Islands has shown similar short-range post-nesting migrations (Ellis *et al*., in press).

Implications for Conservation

The conclusions of our study enhance efforts to conserve sea turtles in Seychelles. A source of frustration when trying to manage sea turtle populations—in Seychelles, as elsewhere—is the disregard turtles have for international boundaries. Some Seychellois complain that it is unfair and futile to expect the people of Seychelles to protect turtles that will only be slaughtered when they migrate from Seychelles to the national waters of another country in the region. The present study provides evidence that hawksbills, which nest in the granitic Seychelles, remain within the territorial waters of Seychelles even after leaving the nesting habitat. As such, they are a resource that belongs to the people of Seychelles, whose responsibility it is to ensure their long-term survival.

Our data provide an incentive to the people of Seychelles to protect their hawksbills. But this only complements the extraordinary action already taken by the Government of Seychelles during the past eight years. In 1993, as a first step towards banning all domestic trade in hawksbill products, the Government devised and implemented the "Artisan Training and Compensation" programme that provided financial assistance to hawksbill artisans to help them find alternate livelihoods. A component of that programme was Government purchase of the remaining stocks of the raw hawksbill shell still in the possession of the

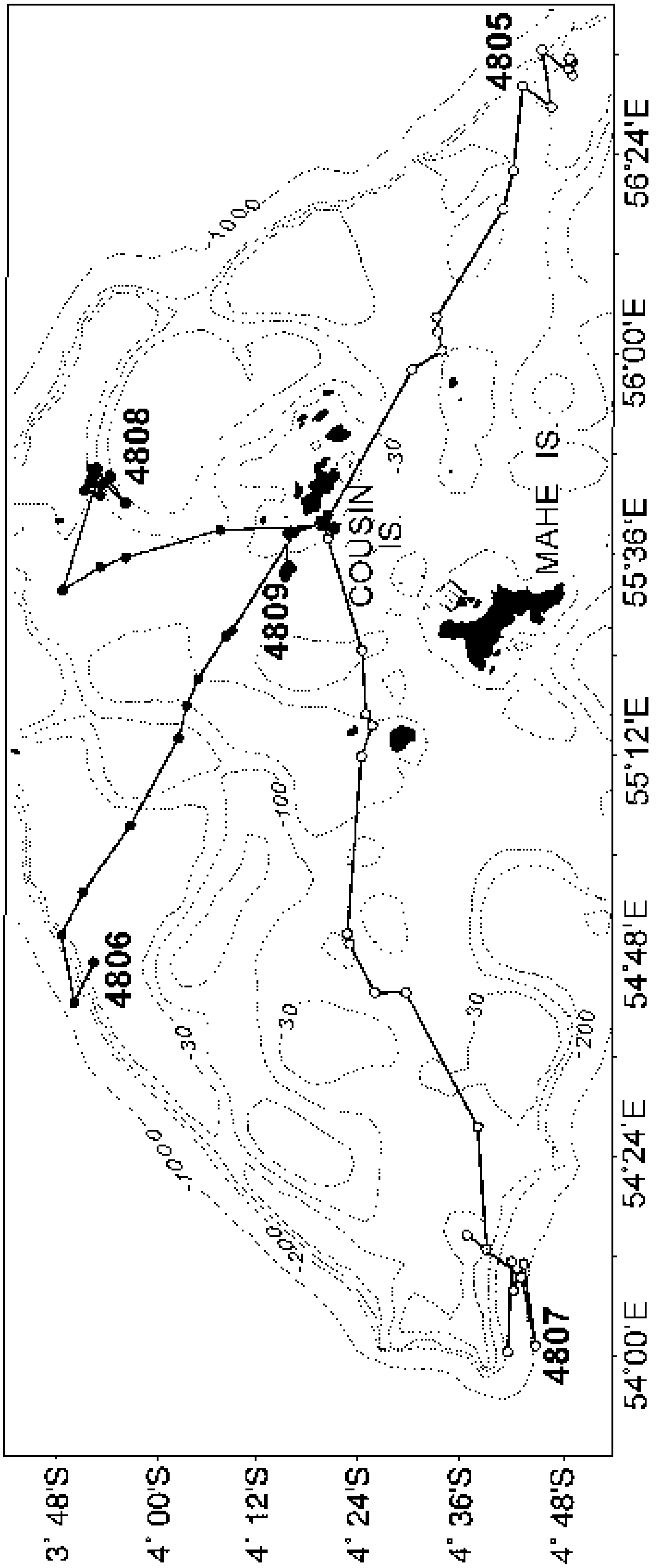

Figure 2. Movements of five satellite tracked post-nesting hawksbills on the Seychelles Bank. Depths are in meters.

artisans. In 1994, a law was passed providing complete legal protection for sea turtles and banning all commercial trade in turtle products. During the past four years the Government has actively promoted enforcement of this legislation, has sponsored public awareness campaigns (Mortimer, in press), and encouraged sea turtle research and population monitoring (Mortimer and Collie, 1998).

Seychelles is the site of some remarkable sea turtle conservation success stories. Green turtle *(Chelonia mydas)* nesting activity has significantly increased at Aldabra since 1968 when the atoll was made a nature reserve (Mortimer, 1988). Likewise, hawksbill-nesting activity at Cousin Island has almost tripled — increasing from some 30 animals in the early 1970's to 70-100 individual turtles nesting annually in recent years (Mortimer and Bresson, 1994). Nearby Cousine Island, protected since 1993, has already documented significant increases in hawksbill nesting activity (P. Hitchins, unpubl. data). The situation at Cousin/Cousine demonstrates that effective protection of nesting beaches can result in the recovery of nesting populations. The turtles nesting at Cousin/Cousine represented about 7% of the total estimated hawksbill nesting population of Seychelles in the early 1980's (Mortimer, 1984). Although hawksbill-nesting populations have declined at many other islands in Seychelles (Mortimer, 1998), new conservation initiatives are underway at some sites. Among them, Bird, Denis, and Aride Islands, and the Marine Parks at St. Anne and Curieuse are taking strong action to protect their nesting hawksbills—in many cases very effectively.

Despite progress made, the long-term survival of hawksbills in Seychelles is not yet assured. Nesting females are particularly vulnerable. They nest in the daytime, returning repeatedly to the same stretch of beach at predictable two-week intervals to lay their eggs. The average female deposits some three to five egg clutches per season, and each clutch laid is usually associated with one or more trial nesting emergences (Mortimer and Bresson, 1999). Thus, an individual female may emerge onto the same stretch of nesting beach some 4-10 times during a single nesting season. Where constant surveillance is lacking, a small number of determined and energetic turtle poachers can still slaughter dozens of adult turtles at a single island during a nesting season. Foraging hawksbills—especially the immature animals that reside in relatively shallow water—are also easy prey for poachers for they are slow swimmers with little fear of humans.

Fortunately, the Government of Seychelles takes this matter seriously. It has reassessed its national priorities and put environmental protection at the head of the list. It appreciates the fact that its pristine environment is a prime attraction for tourists, and that tourism is a major source of foreign exchange for the country. Live turtles have become increasingly popular attractions for visiting tourists who enjoy watching them on the nesting beach and in the water while they snorkel (Mortimer, in press). On 23 November 1998, in conjunction with the Miss World Pageant hosted in Seychelles, the Government publicly burned the stockpile of raw hawksbill shell that it had procured from the tortoise shell artisans in 1993 (Mortimer, 1999). The stockpile had been kept in a sealed container on Mahe since 1993 and could not legally be sold to a buyer outside the country because of CITES restrictions. Conservationists were concerned that by holding on to the stockpile, the Government was inadvertently sending a message to turtle poachers that eventually the trade in tortoiseshell would re-open. There was concern that this might encourage poachers to amass their own private stockpiles of raw hawksbill shell. Thus, the decision was made to destroy the stockpile in order to send a message to the world that Seychelles is serious about environmental conservation, and to send a message to potential poachers inside the country that slaughter of hawksbills would not be sanctioned or tolerated.

We hope other nations that host hawksbill populations will follow the lead of the Government of Seychelles and take whatever strong action is necessary to protect their own populations of this Critically Endangered species. *(Resolution 1999-6* of this Symposium expands on this theme).

Acknowledgments

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Winter Movements of Sea Turtles

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Because of accessibility, most sea turtle studies have focused on nesting beaches. Relatively little information exists on the movements of sea turtles during the winter months. To assess activities of sea turtles when water temperatures become cold, ten loggerheads (*Caretta caretta*) and three Kemp's ridleys (*Lepidochelys kempi*) were instrumented with satellite tags and monitored in the Tampa Bay and Kings Bay regions of Florida (**Table 1**).

The movements of the turtles in the two different areas followed similar patterns. The turtles remained in a general area for days or months at a time and then moved in response to changing water temperatures. Sea turtles responded to changing water temperatures generally by moving to water above 15 °C. These movements coincided to declining water temperatures during the cold winter months and reflected two trends: 1) movement offshore and/or 2) movement south. In response to warming water temperatures in the spring, sea turtles generally moved inshore and north returning to the same vicinity they left in the fall.

Funding for this study was provided by the US Army Engineer District, Jacksonville.

Table 1. Sea turtles captured by trawler, instrumented with a satellite tag and released back into the channel, Kings Bay (KB) and Tampa Bay (TB), FL.

Identification	Species	Sex	SCL	Release	End	Days Tracked
15240TB	*Cc*	Male	96.0	11/15/97	10/13/98	343
15241TB	*Cc*	Subadult	81.7	08/22/97	09/02/98	376
15242TB	*Cc*	Male	99.3	05/31/98	06/12/98	13
15244TB	*Cc*	Female	93.8	11/16/97	07/20/98	245
15245TB	*Cc*	Subadult	62.0	05/28/98	06/28/98	30
15243TB	*Lk*	Subadult	54.9	11/19/97	03/11/98	111
01381TB	*Lk*	Subadult	53.4	11/18/97	05/16/98	177
15240KB	*Cc*	Subadult	69.7	10/29/93	05/29/94	213
15241KB	*Cc*	Subadult	63.2	10/28/93	03/30/94	154
15243KB	*Cc*	Subadult	73.5	11/02/93	04/03/94	153
15242KB	*Cc*	Subadult	65.8	11/02/93	05/03/94	183
15245KB	*Cc*	Subadult	73.6	11/09/93	10/31/94	356
15244KB	*Cc*	Subadult	63.0	11/09/93	04/29/94	172
15246KB	*Cc*	Subadult	68.8	11/11/93	06/28/94	230

The Use of Biotelemetry in Determining the Habitat Utilization and Foraging Ecology of Juvenile Hawksbill Sea Turtles (*Eretmochelys imbricata*) at Buck Island Reef National Monument, St. Croix, U.S. Virgin Islands

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The National Park Service has conducted research on the nesting biology of the hawksbill sea turtle (*Eretmochelys imbricata*) at Buck Island Reef National Monument (BUIS) since 1988. In 1994, the program expanded to study juvenile hawksbill turtles resident and foraging in the coral reef habitat surrounding BUIS. In September 1997, the National Park Service, BUIS and the Virginia Institute of Marine Science (VIMS) entered into a Cooperative Agreement to continue and expand the existing study. The objectives are to collect biological data on juvenile hawksbill turtles, describe their developmental habitat, determine habitat utilization and foraging ecology, and conduct biotelemetry of individual turtles' movements within and outside BUIS. Research elsewhere has suggested hawksbill turtles eat sponge after leaving the pelagic phase of their life cycle. In 1996, with additional staff funded by the U.S. Geological Services Biological Resources Division/NPS Inventory and Monitoring Program, juvenile hawksbill turtles at BUIS were found foraging primarily on zooanthid mat and red algae. In December 1997, NPS/VIMS established a biotelemetry system to collect location data from juvenile hawksbill turtles around BUIS. To date, the biotelemetry, along with in-water observations, has identified juvenile zones of activity around BUIS. The results are beginning to provide a snapshot of the critical juvenile hawksbill developmental habitat at BUIS.

Nearshore Turtle Hatchling Distribution and Predation in Sabah, Malaysia

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Hatchling green turtles (*Chelonia mydas*) emerge from their nests at night and crawl over the beach to the sea using light as the primary cue for seafinding. Once they enter the sea they are usually guided by wave and magnetic cues and head straight offshore. Predation rates decrease as hatchlings distance themselves from their natal nests.

In Sabah the turtles' open sea finding mechanism must be altered slightly to account for the numerous small islands and reefs that prevent a clear offshore migration, and hatchlings face higher rates of predation than elsewhere in the world. To test nearshore orientation and rates of predation, hatchlings were fitted with harnesses and lighted floats and were followed as they left the natal beach.

Swimming trials were carried out off Selingan island (6°10'30'N, 118°03'30'E) in Sabah, Malaysia during March and April and again in December 1998. Green turtle hatchlings were collected from hatchery nests, fitted with a light-bearing float and placed in a Lycra harness to which a Styrofoam float and light were attached with 80 cm of nylon fishing line. The total weight of the light/float averaged less than 2 g ($\bar{x} = 1.92$, SD = 0.064, $n = 21$). In order to determine precise locational data, 21 hatchlings were tracked individually by following 10-15 m behind in a small inflatable boat, and their position and water depth were recorded every five minutes using a Differential GPS (Furuno F-80, ± 10 m) and Hummingbird depth sounder (± 10 cm). To determine rates of predation and only approximate location and depth, 62 hatchlings were tracked in groups of four. During these trials, individual hatchlings towed the same type of light source, but four hatchlings were released simultaneously from the beach, and were tracked by a single boat. The hatchlings' location at point of depredation was determined by triangulation of three bearings on fixed locations using a hand-held compass (± 5°).

Precise positional data (± 5 m) was calculated for the 19 hatchlings tracked with DGPS. Initial swimming orientation for these hatchlings, calculated as the net heading inclusive of current displacement over the first 15 mins, was significantly grouped with an average angle $a = 208.2°$ and vector magnitude $r = 0.868$ (**Fig. 1a**).This orientation was SW and significantly different from a 255° direct offshore heading (V-test: $u = -5.091$, $P < 0.005$). No waves were present in the nearshore waters during the nearshore portion of the trials that might have had an influence on the hatchlings' orientation. Hatchlings tended to swim in a SW direction initially, after which they turned north, or continued further south, until out of the shelter of the island (**Fig. 2**). Final orientations, calculated as the mean net heading over the last 15 mins prior to depredation or release, were found to be more randomly distributed with a weak overall vector $r = 0.484$. The mean overall final bearing of $a = 163.2$ (**Fig. 1b**) is indicative of a gradual shift toward the NW away from the 'direct offshore' heading which hatchlings were expected to have picked up on the beach crawl. After swimming on the same heading for 60 mins or more the hatchlings were collected and released, as they were considered to have acquired and settled into an offshore orientation opposite that of oncoming waves and current.

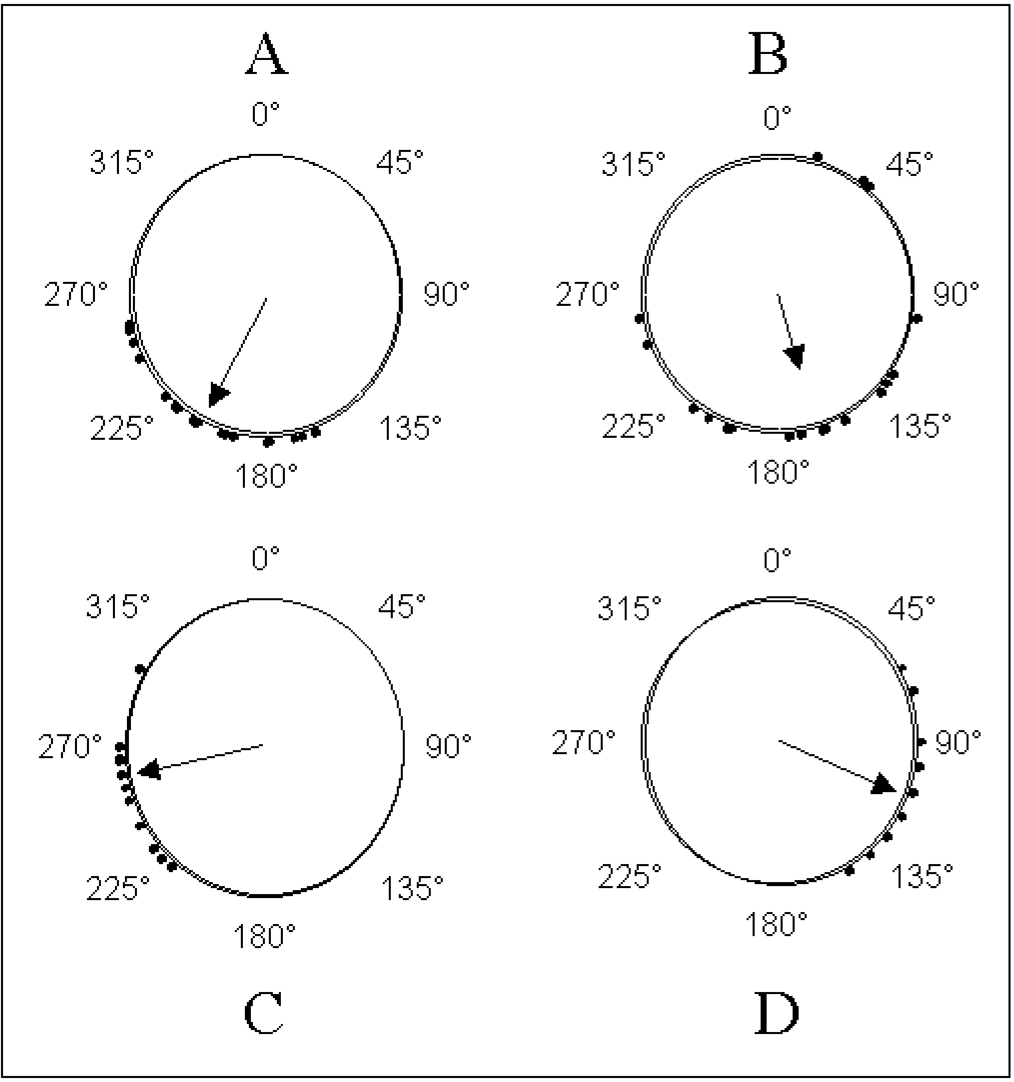
Figure 1. Dispersal patterns for hatchlings leaving P. Selingan.

A-Initial orientation of hatchlings departing W beach during DGPS-tracked trials.

B-Final orientation of hatchlings after dispersal.

C-Initial orientation of hatchlings departing W beach using triangulation method during predation trials.

D-Initial orientation of hatchlings departing E beach using triangulation method during predation trials.



The second set of trials, which only determined an approximate final position (±25 m), included hatchlings released at the W- and the E- facing beaches. Although these trials were aimed mainly at determining rates of predation, and not as detailed and precise as the earlier trials, these data provide an indication of general movements away from the beach. Hatchlings oriented away from the E-facing beach with a mean vector strength *r*=0.911, indicating a strong tendency to orient with an average overall heading *a*=112.1° (**Fig. 1c**). Mean wave direction during these swims was 87.8°, and not uniformly distributed (*r* =0.200). Swim direction was not overly dependant on wave direction, and average swim direction and wave direction were weakly correlated (r^2=0.093), suggesting that around the Sabah islands waves are not primarily responsible for initial hatchling orientation. Analysis of the orientations of hatchlings swimming away from the W-facing beach produced a mean vector strength *r* = 0.949, also indicating a strong tendency to orient with an average overall heading *a*=257.7° (**Fig. 1d**). During these swims, average wave direction was 206.4°, and was slightly more grouped than in previous trials (*r*=0.378). A correlation between swim speed and direction resulted in a coefficient r^2= 0.103.

The total distance covered by hatchlings ranged from 5 m to 6687 m. However, due to the variable time each was followed, the overall average swim speed (1.2 km∞hr^{-1}) was considered a more representative expression of swim performance. The overall mean swim speed under natural conditions ranged from 0.000 to 0.965 m∞sec^{-1}.

Of the 21 hatchlings tracked during the March/April study, thirteen (61.9 %) were lost to predation, and the remainder were collected and released. Predation was determined after the floats/lights were noted to dip suddenly and then disappear or stop moving, and upon closer inspection the line between the float and hatchling was found to be severed. In all but one case the floats were recovered. It is not believed the hatchlings could have broken the 2.5 kg line unaided. These hatchlings were released individually at the same time as multiple nests were released *en-masse* by Park staff.

In the December study, 8 hatchlings were lost from sight, and discarded from overall calculations, as it could not be determined if they were lost to predation or simply out of sight. Of the remaining 54, 22 (40.7 %) were lost to predators (all floats were collected) and the balance were released. These hatchlings were released at the same time as single nests were released by Park staff, except for on two occasions, when two nests of hatchlings were released simultaneously. The predation rate when hatchlings were released *en-masse* (61.9 %) was nearly 50% higher than when hatchlings were released in smaller groups (40.7 %). Overall, 46.7 % of all hatchlings were lost to predators. The average water depth at which hatchlings were taken by predators (x = 6.3 m) was found to be significantly shallower (z Test: z=5.747, P =0) than that at which they were collected and released (x=15.0 m). Only 3 of the 40 hatchlings that were collected were in shallow water (<10 m). It is suggesting that those hatchlings that manage to swim past the reef (past a drop-off and into > 10 m-deep water) have a much greater chance of survival within the first hour of swimming. Of the 43 hatchlings that made it to deep water, only 9 were lost to predators (20.9 %). Of the 30 hatchlings that remained in shallow water, 23 were lost to predators (76.7 %), substantially higher than the rate of predation in deep water.

These trials have shown that hatchlings can and do navigate around small landmasses to head toward the open sea, rather than just swimming directly away from shore, and that they can establish offshore orientations in the absence of waves. The orientation pattern hatchlings adopt as they leave the W shores of P. Selingan suggest that in the absence of waves hatchlings will swim until they pick up other stimuli, in particular as their initial offshore orientation differs from the expected offshore heading and their subsequent change of direction to orient into oncoming waves.

The trials also indicate that a significant amount of predation occurs within the first hour at sea (40 - 60 %). This raises an important management consideration for conservation programmes in which the release of numerous hatchlings is a prime consideration. These rates of predation are six to ten times greater than that reported for other locations and is believed to be, at least partially, a result of the density at which hatchlings enter the sea.

It is believed that part of the unnaturally high predation in Sabah is a result of the manner in which hatchlings are released night after night in the same location, in dense (multiple nest) groups. In addition, although this study did not address the issue of repetitive releases at the same location, it is believed that in contrast to natural emergence cases whereby hatchlings enter the sea at random locations, the continuous release of hatchlings from the same 5 m stretch of beach may be responsible for a certain amount of 'learning' by the local predator population, though further study is need in this region. To optimize the Park's manage-ment procedures though, and those of other locations where similar release practices occur, it is suggested that hatchlings are released fewer at a time, and that the release point be randomly changed to avoid congregations of predators.

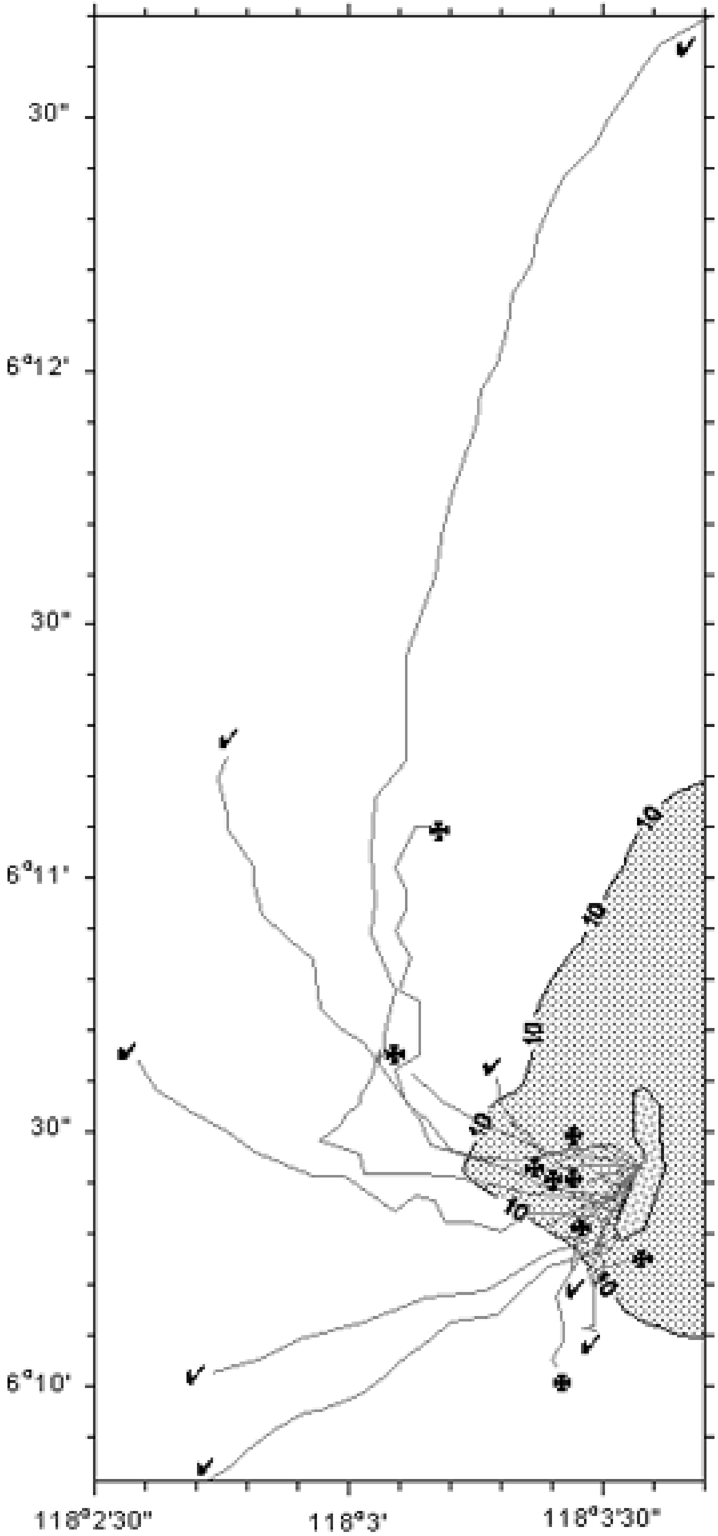


Figure 2. Tracks of hatchling movements as they left Selingan Is. (shaded, lower right). and across the 10 m depth contour. Check marks indicate hatchlings that were released after monitoring, crosses indicate hatchlings that were lost to predators.

Design and Field Testing of an Internal Helix Antenna Satellite Transmitter for Sea Turtles

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The use of satellite telemetry to study the migrations of marine turtles opened up a new avenue of investigation during the 1980's. Technological improvements have reduced transmitter size and increased the sophistication of satellite transmitters to enable the collection of data including geographic position and even dive profiles. Although the specific objectives of satellite telemetry research vary, the desire for regular and long-term, high quality locational data are universal. We have been studying the post-nesting movements of Hawaiian and Floridian green turtles (*Chelonia mydas*), respectively, since 1992 and 1994. While the results of our work, using Telonics ST-14 backpack-style transmitters, are considered highly successful and have elucidated the migratory pathways and identified the resident foraging grounds, we began to see a similar pattern of satellite transmitter performance and transmitter life. Locational data transmitted along the migratory routes were generally frequent and of good quality, but this was followed by a drop in quality once the turtles arrived at their foraging habitat, and rapidly degraded thereafter until locational data ceased.

Conventional satellite transmitters used on sea turtles for the past two decades have been built with an external vertical wire antenna. When used on sea turtles in benthic (non-pelagic) habitats, we suspected vulnerability of the antenna, resulting in signal attenuation or loss. The conclusions most frequently drawn when a satellite transmitter is no longer sending data are that either the unit has fallen off or the batteries have been depleted. Our evidence, working with post-nesting green turtles, indicates that these reasons are unlikely when transmitter models with a proven track record are used and when proven attachment techniques are used. In studying our results over a several year period, and encountering turtles in subsequent nesting seasons that had been previously outfitted with satellite transmitters, we concluded that the antenna was the weakest link of the system. In all cases where transmitters were recovered, the antenna was sheared off at the insertion point of the housing, while the transmitter itself was intact. These recoveries, in both the Atlantic and Pacific, corroborate our suspicion that the external antenna, in contrast to battery capacity, is the primary limiting factor in the duration and quality of successful transmissions.

We met with the manufacturer of our satellite tags, Telonics, Inc. (Mesa, Arizona, USA), in late 1997, to discuss the problem of antenna damage and how it might be overcome. During that visit with Boyd Hansen, Brenda Burger, and Stan Tomkiewicz, we sketched out a satellite transmitter housing that would encase a helix antenna and would be more streamlined than the boxy standard ST-14 unit, in order to provide improved hydrodynamic performance (see Watson and Granger, 1998). Over the next few months, Telonics used these to design and build a prototype ST-14 unit with an internal helix antenna. In 1998, we tested four prototype units, two in Florida and two in Hawaii and, at the same time, deployed three standard ST-14 units, one in Florida and two in Hawaii. The duty cycle (time in hours that the units cycle on and off) was identical within study sites but differed between study sites. The testing of the prototypes was not designed as a comparative study between Hawaii and Florida, but was integrated into our respective, ongoing studies and was intended to compare standard vs. prototype transmitter performance at each location. The attachment technique consisted of an initial layer of silicone elastomer as a base for the transmitter, followed by three applications of polyester resin and fiberglass cloth strips (Balazs *et al*., 1996). The standard ST-14 units were attached with the antenna posterior and a cylinder of fiberglass cloth with an outside layer of kevlar cloth resined in directly in front of the antenna to provide increased protection to the base of the antenna. The prototype units were attached in the same manner, except that the internal antenna was placed anterior and no cylinder was needed.

Results from Hawaii

Data resulting from the prototype units used in the Hawaii component of the study are depicted in **Fig. 1.** The location class codes indicate the relative accuracy of the calculated positions. Codes 1,2,3 have estimated accuracies of less than 1000 m; code 0 has an estimated accuracy of greater than 1000 m; and no accuracy estimates are defined for codes A or B, however these locations can be highly accurate and the researcher must interpret these locations judiciously. The standard external antenna units resulted in twice as many transmissions overall (1835 vs. 767) and about twice as many transmission that resulted in calculated locations. Seventy percent of the transmissions from the prototype did not result in a calculated position ("Z" class data). Despite the reduction in the number of locations calculated from the prototype units, there were enough valid locations to provide a clear definition of the migratory track to the resident foraging habitat.

Results from Florida

Data from the Florida turtles were dissimilar to the Hawaii results in that many fewer overall transmissions were received from both the standard and prototype units (**Fig. 2**). The migratory track and residential endpoint at the

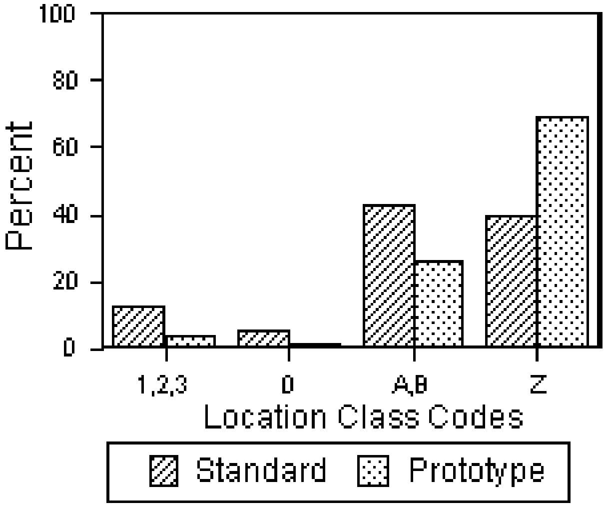

Figure 1. Results from Hawaii, combined standard units vs. combined prototype units.

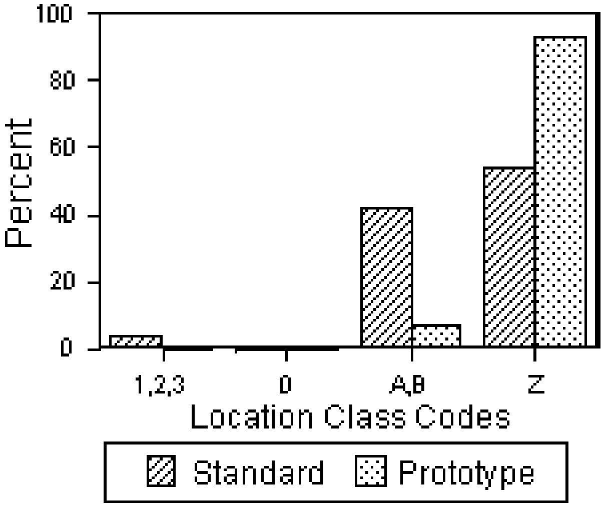

Figure 2. Results from Florida, standard unit vs. combined prototype units.

foraging ground were clearly defined by the data resulting from the standard unit. In contrast, so few data points were received from the two prototype units that neither a clear definition of the migratory track nor confirmation of taking up residence on the foraging grounds could be demonstrated. The standard and prototype units performed similarly with regard to location class codes 1,2,3 and 0, but the standard unit generated a greater percentage of location class A and B positions than the prototype units, which enabled definition of the migratory pathway and confirmation of residence at the foraging site. Ninety-three percent of the prototype unit transmissions were location class code "Z" and no positions could be calculated.

Conclusions

The external antenna outperformed the internal helix antenna with regard to the number and quality of transmissions yielding locational data, six months post-deployment.

As of March 1999, of the three external antenna units, only one (a Hawaii unit) is still transmitting.

As of March 1999, of the four prototype units, all are continuing to transmit regularly, however, only the Hawaii units are currently transmitting location data.

We recommend the standard external antenna ST-14 over the prototype unit when migration routes and resident foraging habitats are unknown for post-nesting green turtles. The rolled cylinder and reverse antenna orientation (antenna posterior) are recommended for improved performance.

Under certain conditions, and for certain applications, the prototype internal antenna unit may be useful for collecting longer-term data. Additional testing on other sea turtle species or under different conditions may be warranted. Telonics, Inc. will build the prototype unit on a cost-order basis. This project has resulted in the mold being available at no additional cost.

Acknowledgments

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Turtles in the Reef: A Closer Look at the Activities of Hawksbill Turtles in a Caribbean Internesting Habitat

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The National Park Service has been conducting long-term studies on nesting hawksbill sea turtles at Buck Island Reef NM, U.S. Virgin Islands for the last 11 years. Over 118 females have been encountered and tagged to date, 27 of which were observed nesting during the 1998 season. Since 1991 several studies have been conducted to investigate the activities of hawksbill turtles at sea using VHF-, ultrasonic and satellite-telemetry. These technologies reveal the home ranges and the migrations of adult female hawksbill sea turtles as well as their surface intervals, but the actual underwater activities of the turtles are not accessed by these methodologies.

Methods

The present study was conducted at Buck Island Reef NM during the 1998 nesting season (July through September). We used data-storing devices (Driesen & Kern, Am Hasselt 25, D-24576 Bad Bamstedt, Germany) to elucidate the underwater behavior of female hawksbill turtles during their internesting intervals. The devices were approx. 12 cm long, 7 cm wide and 3 cm high and weighed less than 200 g in air. With these loggers we were able to monitor 4 internesting intervals from 3 different individuals, 3 intervals being recorded in their entirety. The recording of the 4th stopped due to power failure after 7 days. We present data from female QQD 148, which was successfully equipped twice and experienced Hurricane George during the second period.

Results

After retrieval of the logger each set of downloaded data consists of 6 channels (1. temperature, 2. light, 3. velocity, 4. depth, 5. compass 1 and 6. compass 2). In our setup signals from all channels are recorded in 15 s intervals. We used data from channels 3 through 6 for the presented results. The compass data from channels 5 and 6 are given in mV as signals from two Hall-sensors, mounted on the outer shell of a miniature ship's compass (**Fig. 1**). These data can be used directly to estimate the state of activity of the equipped turtle by examining signal variance over time. Furthermore, after calibration the data can be processed to derive a compass bearing and an inclination or declination angle of the turtles movement. This information can be combined with data on change of depth and velocity to calculate movement vectors (**Fig. 1**).

Integrating the calculated vectors in a 2-dimensional diagram we can derive an impression of the way the turtle moved through the water column on her way to and from the water surface (**Fig. 2**, upper graph). She surfaced at 10:48 am, 11:41am, 12:33 pm and 1:27 pm to breathe. Her descents were relatively steep and direct compared to the circuitous ascents. The parallel plot of the compass output reveals the state of activity of the turtle during the different phases (**Fig. 2**, bottom graph). Movements of the turtle result in a high variation in the mV output of the compass' Hall-sensor (e.g. during surface intervals or ascent/descent, see marked circle) whereas a constant signal shows that the animal was motionless (e.g. during her bottom phases, see marked ellipse). This extra information enables us to identify the distance, that is apparently covered during the bottom phase (ellipse), as an error that results from a) currents that induce a velocity signal while the turtle is lying on the ground, b) waves that pass over the resting turtle that cause a change of depth that results in a false vector (see triangle in **Fig. 1**). During the resting phase these errors add up to a distance of several meters that were, in fact, not covered by the turtle. After correcting for current and wave influences during resting the vectors are used to draw a 3 dimensional route of a set of dives performed by QQD 148 (**Fig. 3**). Her dives can clearly be categorized as resting dives.

We were also able to record the diving behavior of QQD 148 during Hurricane George (21 Sept. 1998). During the time of high wind speeds the turtle was primarily active during the bottom phase (**Fig. 4**). She rested motionless on the bottom for a brief period at a depth of 18 m. To summarize the turtle's reaction to the hurricane different parameters of the dive behavior were compared to the days of normal wind conditions (**Table 1**). During the hurricane the turtle apparently did not leave her normal internesting habitat in the shallow reefs for the greater depths of the nearby drop-off. Her reaction to the turbulent and disturbed water was a shortened surface interval, an active bottom phase and a loss of the regular pattern in maximum dive depth as well as in dive duration.

Table 1. Summarized changes in parameters of diving behavior monitored in QQD 148 during Hurricane George in comparison to days of normal winds.

Parameter:	**Reaction:**
Surface duration	shortened
Dive duration	shortened at onset, some long dives
Bbottom phase duration	- see dive duration -
Quotient dive/surface	initially increased
Duration of descent	no clear reaction
Vertical velocity down	no clear reaction
Duration of ascent	no reaction
Vertical velocity up	no reaction
Maximum dive depth	no general trend, more variation
Activity	swimming during bottom phase

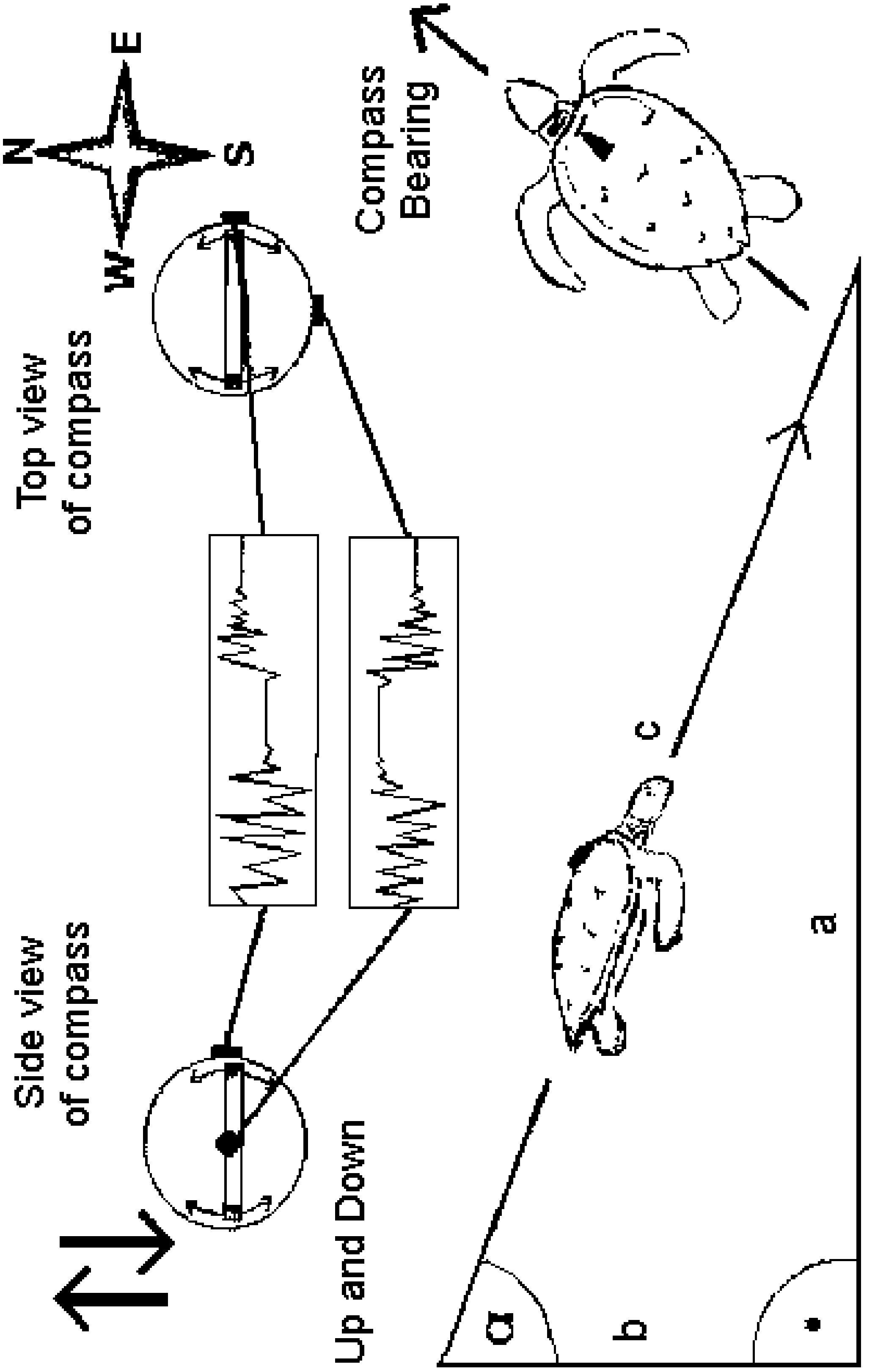

Figure 1. Calculation of vectors using Pythagora's theory: b= depth; a=distance covered over ground per time interval; c=distance swum per time interval; and a =angle of upward or downward movement.

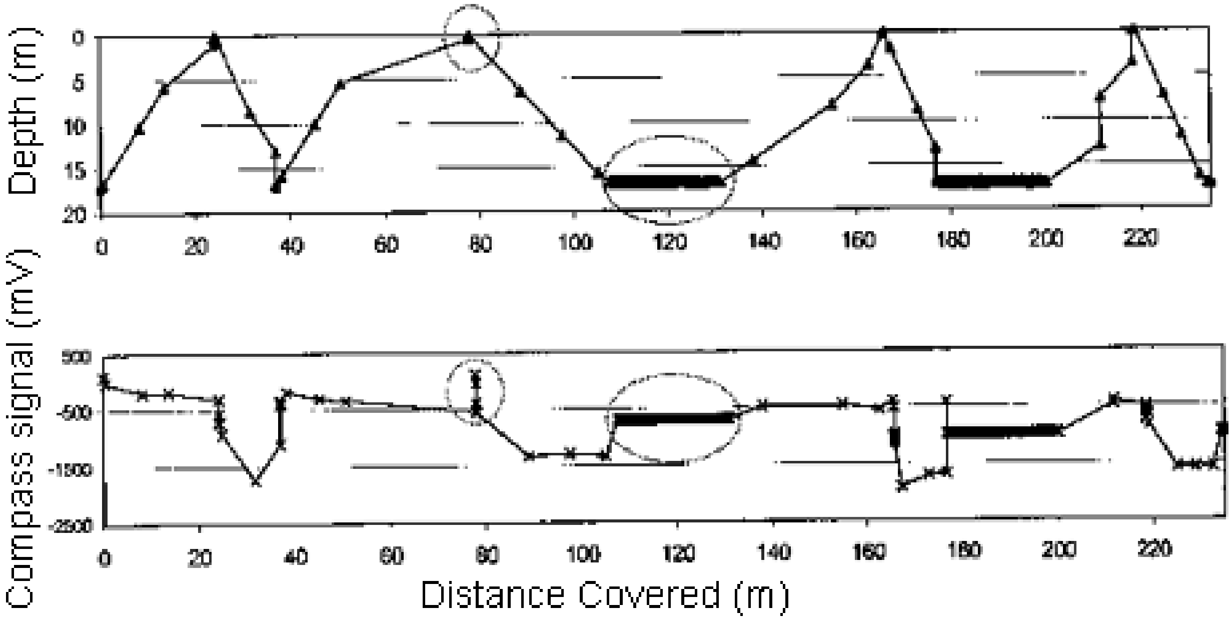

Figure 2. Two-dimensional side view of a set of dives performed by OOD 146 (above) and parallel compass signal (below).

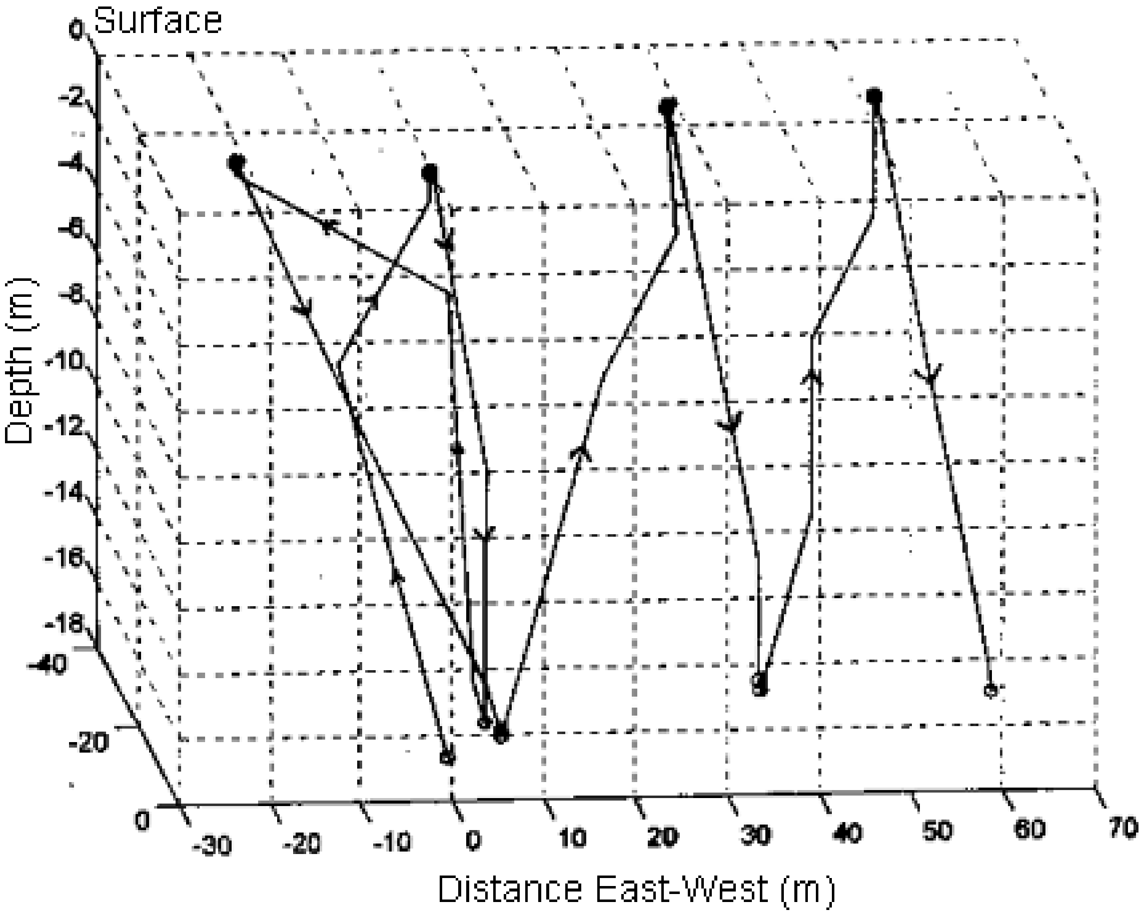

Figure 3. Three-dimensional plot of the same dives shown in Figure2. View from below. The top of the box represents the water surface. The arrows indicate the direction of movement. Open circles-resting on bottom; Filled circles-on the surface.

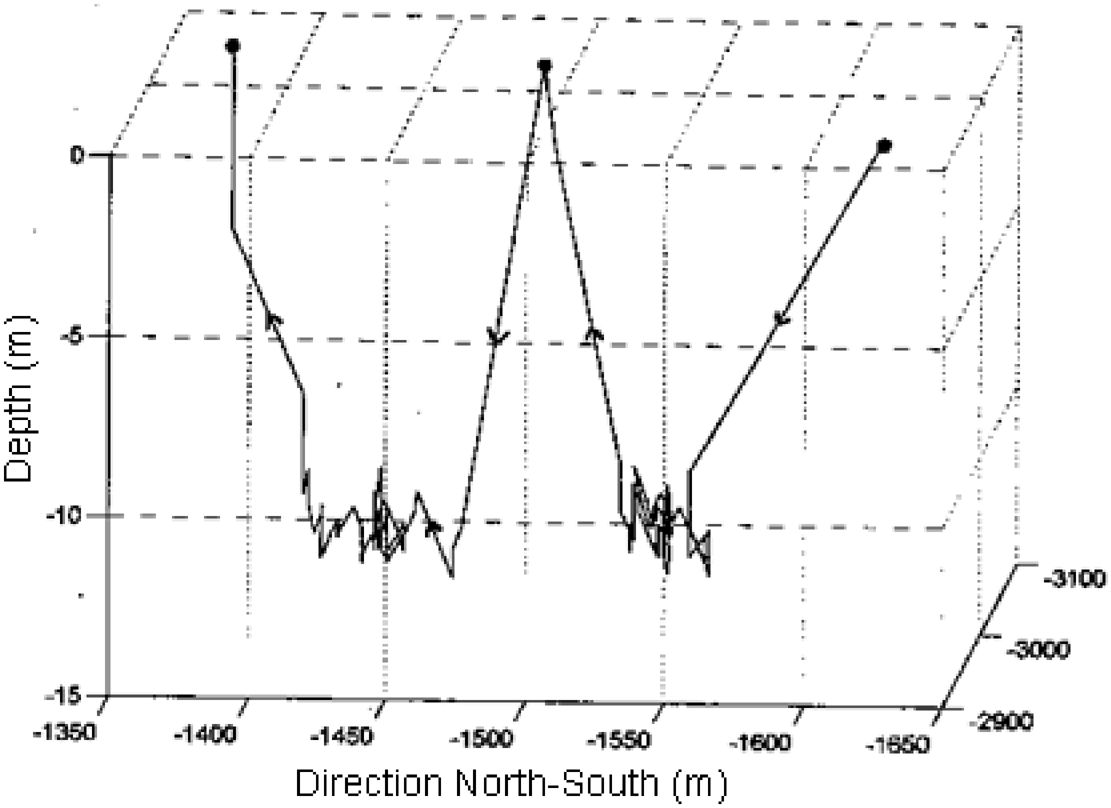

Figure 4. Three-dimensional plot of a set of dives during Hurricane George.

DISEASE AND PATHOLOGY

Survey of Fibropapillomatosis and other Potential Diseases in Marine Turtles from Moreton Bay, Queensland, Australia

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During June of 1998 an initial survey was undertaken to evaluate the health status of green turtles (*Chelonia mydas*) and loggerheads (*Caretta caretta*) at Moreton Bay (27°S, 153°E) near Brisbane in Queensland, Australia. The turtles were captured unharmed by hand and brought aboard a Sea World Australia research vessel where an array of biomedical specimens were collected prior to flipper tagging and release. Biopsies were taken of tumors and of adjacent normal skin followed by fixation in 10% neutral-buffered formalin. Counterpart biopsies were frozen in liquid nitrogen for DNA sequencing (Quackenbush , this volume).

A total of 147 green turtles and 51 loggerhead turtles were captured and examined. Unfavorable weather conditions prevented sampling at locations within Moreton Bay where tumor prevalence is known to be high (40-70%). Approximately 16% of the captured green turtles and 6% of the loggerheads had tumors. These tumors were characterized by small (1-2mm) to large (10-15cm) smooth to papillary masses located in the eyes and mouth and on the neck, flippers and inguinal, axillary and peritoneal areas.

A total of 101 skin biopsies were examined histologically. Fifty-six of these biopsies were from non-tumored areas and 45 were tumors. Sections of normal skin were characterized by epidermis that was *5-7* cells in thickness. There was a thin layer of relatively dense collagen between the epidermis and the relatively loose collagen of the deeper dermis. Within 52 of the normal skin samples there was mild to moderate acanthosis. Eighty percent of the normal skin samples were covered with bacteria and 63 percent of these samples also had fungus. Two percent of the normal skin sections had small blisters between the epidermis and dermis. Five percent of the normal skin samples had a mild infiltration of lymphocytes at the dermal/epidermal junction. Sixty-eight percent of the normal skin sections had mild to moderate dermatitis characterized by lymphocytic cuffing of vessels. Thirteen percent of the normal skin biopsies contained granulomas with parasitic ova within the dermis.

Two primary patterns were found in the 45 tumor biopsies. One was a smooth or nodular type, and comprised 52% of the tumors, while 41% were of the papillary type. Seven percent were of the linear form. The primary characteristics within all of these tumors were similar and included mild to moderate acanthosis and pseudoepitheliomatous hyperplasia. Eighty-four percent of the tumors had acanthosis, 75% had orthokeratotic hyperkeratosis and 77% had pseudoepitheliomatous hyperplasia. Intranuclear or intracytoplasmic inclusion bodies were not found in any of the sections of normal skin or tumors. The dermal portion of tumors was characterized by relatively compact collagen with a low to moderate degree of cellularity. Mitotic figures were not found. Vessels surrounded by lymphocytes were found in 60% of the tumors. Granulomas containing parasitic ova were found in 47% of the tumors. Margins of tumors showed evidence of spread by expansion and not by infiltration. Histologically, these tumors were similar to the tumors that have been observed in green turtles from the Hawaiian Islands (21°N, 157°W). However, the Australian tumors showed a slight difference between the tumors examined from olive ridley turtles (*Lepidochelys olivacea*). Tumors examined from the adult female olive ridley's from nesting grounds at Nancite, Costa Rica and Oaxaca, Mexico showed evidence of a mild to severe cell-mediated response within approximately half of the tumors. This extensive cell-mediated immune response may, in some cases, lead to regression of the tumor.

This study histologically confirms the presence of fibropapillomas in green and loggerhead turtles in Queensland, Australia, the presence of which has been previously reported through visual observations by Limpus and Miller (1994) and Limpus *et al.* (1994a, 1994b).

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Photographic Evidence for the Regression of Fibropapillomas Afflicting Green Turtles at Honokowai, Maui, in the Hawaiian Islands

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My wife, Ursula, and I spend each July and August diving in the waters of Honokowai, West Maui, Hawaii. She's a teacher and I'm a technical writer, and we spend most of our dives watching, photographing, and videotaping Hawaiian green turtles, or *honu*. We can do this because the honu are among the tamest of nature's wild creatures.

We started in 1988, when we met Clothahump, our first sea turtle. By 1990, we had explored Reef 2 and discovered the Turtle House; the two places where turtles congregate at Honokowai. Many of the turtles we saw had fibropapilloma (FP), so we reported this to George Balazs of the NMFS Honolulu Laboratory. George provided us with background information about the disease. From the material he supplied, this quote from Herbst (1994) stood out:

"The number of turtles that develop GTFP in the wild over time (incidence) and the proportions of affected turtles that develop severe disease and die (morbidity and mortality) are unknown. These data are desperately needed if we are to understand the demographic impact of GTFP on wild populations"

We were concerned about the turtles. We wanted to do something. This quote spoke to us because it meant that by turtle watching, we might be able to help.

Methods

We went on to take nearly 4000 pictures and over 150 hours of videotape. In 1997, George reminded us that it was time to quantify things, so we built a database. Then, with George's guidance and help, we set out to analyze this material.

To tell the turtles apart, we relied on the patterns formed by the scales on their faces and their profiles. This pattern allows us to identify individuals from year to year. For each individual, we recorded their profiles, their sexual maturity, and if present, their tag information.

For every year that we saw a turtle, we also recorded a count of tumours by size for external surfaces of the turtle, an overall estimate of the prevalence and severity of FP, and an estimate of the size of the turtle.

To count and evaluate tumours, we used the method developed by Balazs (1991) with the help of John Sundberg, and later refined by Work & Balazs (this volume). This system places tumours in four sizes: A is anything less than 1 cm in diameter, B includes tumours from 1-5 cm, C tumours are from 5-10 cm, and D includes anything over 10 cm.

The method also includes an overall score for the turtle. This is a subjective estimate based on the total number and size of tumours. There are three categories for tumoured turtles: light, moderate, and heavy.

We were keen to assess the impact of FP on juvenile turtles. To do this, we followed size assignments used by Balazs for honu since 1973: juvenile (post-pelagic up to 65 cm), sub-adult (65 up to 85 cm), and adult (larger than 85 cm).

Although we don't take measurements in the wild, photos do let us make estimates by comparison with objects of known size.

Because our data are gathered from images, it isn't possible to get a complete assessment for an animal. For example, we can't check whether a turtle has tumours deep inside the mouth. Sometimes we have a record of only part of a turtle. Our data, therefore, are skewed in a manner that *underestimates* the occurrence of FP.

We define regression as follows: if a tumour has gotten smaller or become undetectable in our photos and video, we call that regression. We first noticed regression in Tutu, who had a size B eye tumour in 1990. By 1993, however, her eye tumour had almost disappeared. Finally, our photos from 1997 leave no doubt that the tumour has vanished.

Since 1996, we've seen more and more animals that show some regression. The question, therefore, was how many tumoured Honokowai turtles were regressing?

Results

We identified 247 turtles with 158 (64%) having had FP at some point. 37% (91) have been seen in more than one summer. We consider these turtles to be Honokowai residents, and we call them "resights." Of the resights, 73% (66) have had FP and 32% (21) of those have regressed.

Of these 21 regressed animals, we have presumed 52% (11) are sexually mature. Three are females that were tagged while nesting at the French Frigate Shoals. The other eight are males, judged by the fact that their tails have grown beyond their hind flippers.

As judged by size, 17% (43 of 247) turtles were classed as juveniles at some point in our records. 60% (26) of these 43 had FP. Nineteen of the juvenile turtles have been resighted. So far, 74% (14) of them have eventually developed FP. We have documented regression for only one resighted juvenile.

Discussion

Course of the disease: In 81% (17 out of 21) regression cases, we saw the turtle get worse before it got better. Infected turtles had light tumours at the onset, got visibly worse in the second summer, and peaked in the third. In turtles that showed regression, tumour growth either stabilized or reversed itself after the third summer. This was usually followed by two summers of steady regression, after which tumours often became undetectable by examination of our images. We have documented this level of regression in 11 cases; all animals that had A and B sized tumours only.

This leaves 10 cases in which the tumours can still be seen. In 7 of these cases, regression is still underway. The other three cases had tumours that reached size C, however.

While these C-sized tumours have regressed significantly, it appears that they might not disappear completely.

Tumour scoring is a reliable indicator: The subjective tumour score does help to predict outcomes. Of the 66 resighted turtles that have had FP:

- 53% (n=35) were lightly afflicted. Of our 21 regression cases, 72% (n=15) were scored as light.
- 33% (n=22) were moderate. 29% (n=6) of the 21 regression cases were moderate.
- 14% (n=9) were scored as heavily afflicted. No turtle scored as heavy has ever regressed.

Moderately afflicted adults can recover: Tiamat is the most severely afflicted adult that we've seen regress. We've known her since 1992, when she was fine. For 1994, however, we classed her as moderately afflicted. Unexpectedly, by 1995 her condition had improved. In 1996, we happily added her to our list of regression cases. We didn't see her in 97, but in 98 she bore an engraved V40 on the right side of her carapace—proof that she had nested at the French Frigate Shoals in 1997.

Only one juvenile has ever regressed: Another moderate case is our most interesting and remarkable story. Kamaha'o is Hawaiian for "remarkable." This is the only juvenile turtle that we have ever seen regress. In 1994, Kamaha'o had eye and mouth tumours, and was notably emaciated. This turtle looked to be doomed. In fact, we're so accustomed to youngsters disappearing on us that we didn't immediately recognize this robust turtle, photographed in 1997, as the tumoured little beast from 1994. It was only in the preparation of this paper that we made the connection. This showed us that FP does not have to be a death sentence for juveniles.

Juveniles affected most severely: Nevertheless, our data show that regression clearly favors larger turtles. To recap: only 5% (1 of 21) regression cases was a juvenile (based on size), while 21% (14 of the 66) resighted turtles that have had FP were juveniles at some point. While our sample is small, this hint that FP cuts a deep swath through the little ones is echoed in data from Kaneohe Bay, Oahu, Hawaii. There, most turtles sampled are juveniles and the FP regression rate is only 4.5% (Balazs *et al*. 2000).

Males vs. females: At first, the regression rate for subadult and adult turtles seems encouraging. 38% (n=20) of 52 larger resighted turtles that have had FP have regressed. It's instructive, however, to look at the 11 sexually mature turtles that we identified in the regression cases: eight of them are male. If our data are typical, almost three times more males are recovering than females. This reflects work done by Koga and Balazs (1996), who report significantly higher FP in female honu based on necropsies of hundreds of stranded animals.

Potential population impact: Since we have no other data to compare, we don't know if what we are seeing is typical of the broader FP picture. We hope it isn't, but if it is, we have a disease that:

- devastates young turtles (juvenile size class) and
- in the larger size classes, exhibits some recovery but favors males by a factor of three.

The implications for the honu are troublesome.

Environmental concerns/Potential for future study: Recent findings by Landsberg *et al*. (In press) have suggested there is preliminary and provocative evidence linking high concentrations of dinoflagellates (specifically *Prorocentrum*) to a high prevalence of fibropapilloma. One of the sites they sampled for these organisms was Honokowai.

Early findings suggest the honu might be suffering from chronic exposure to okadaic acid produced by the dinoflagellates living in the seaweeds that the honu use for food. It is difficult to watch turtles eat when we know it is possible that they are slowly poisoning themselves. Still, we continue to document their foraging habits. For one thing, we hope to understand why the disease affects the little ones so profoundly.

Of course, if FP is indeed fueled by eutrophication, which in turn is caused by run-off, sewage, animal wastes, and the destruction of wetlands, we are forced to wonder about the future of any animal that is dependent on clean water.

Finally, as if the current state of the coastal waters isn't worrisome enough, a new storm cloud blew into Honokowai last summer. Tutu (Hawaiian for grandmother), known since 1990 and our first regression case, showed troubling white anomalies on her neck and shoulders.

While this might be the beginning of a dose of a new type of barnacle we've been seeing on the turtles only recently, or perhaps something else entirely, we cannot rule out the possibility that this could be the harbinger of the return of FP.

Summary

In summary, we have collected a considerable body of photo documentation of the prevalence of FP in a community of Hawaiian turtles. Through retrospective examination of this data, we have shown that about one in three diseased turtles has regressed, but a closer look at exactly which turtles regress reveals disturbing patterns: juveniles rarely regress, and recovering males outnumber females three to one. Finally, there is one last sobering thought—Tutu's condition has raised an ugly, troubling question: is regression permanent?

Acknowledgments

Dr. Larry Herbst, Richie Moretti, and Dr. Grahame Webb for their encouragement and support.

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Marine Turtle Fibropapillomatosis: Hope Floats in a Sea of Ignorance

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It has been 60 years since the occurrence of fibropapillomatosis (FP) in marine turtles was first reported in the scientific literature (see Herbst 1994) and yet only in the past 10 years, as FP has become recognized as a growing threat to these endangered animals, has significant effort been focused on trying to understand the nature of this disease. Yet in this relatively short period of time a tremendous amount of progress has been made toward understanding the cause of this condition, and it is my hope that such progress can continue. Much more, however, remains to be learned about this disease before practical and effective management strategies can be developed and each answer unleashes a cascade of new questions that must be addressed. This presentation reviews what has been learned about FP from observation and experimental studies in order to establish a foundation upon which to frame future studies and management plans.

Most of what we can say conclusively about FP has been gained from a series of experimental transmission studies in green turtles (*Chelonia mydas*). We know from these controlled experiments that FP is a transmissible disease and that tumors contain an infectious agent that can be transmitted to other turtles through skin injection or scratch inoculation (Herbst *et al.* 1995). We know that this agent is very small, is found in the cell free (filterable) fraction of tumor tissue homogenate and that it is inactivated by organic solvents, which strongly suggest that the causative agent is an enveloped virus (Herbst *et al.* 1996b). We also have observed in two cases, spontaneous horizontal transmission from tumor-bearing turtles to naive turtles following co-housing involving extensive physical contact.

These transmission experiments also have implicated a novel tumor-associated herpesvirus in the disease, since herpesvirus replication and shedding was detected in tumors of donor animals and in experimentally induced tumors (Herbst 1994, Herbst *et al.* 1999). In addition, all turtles that developed experimentally induced tumors also developed anti-herpesvirus antibodies (seroconversion) (Herbst *et al.* 1998). The association of this herpesvirus with FP has been confirmed by PCR in a number of studies (see Herbst *et al.* 1999). This herpesvirus remains the main candidate for the etiology of FP and since my first reports of these findings and preliminary genetic analyses of this herpesvirus (Herbst *et al.* 1996a) a number of independent laboratories have focused their efforts on trying to isolate and characterize this virus further. Transmission of FP with purified virus remains the only one of Koch's postulates that must be fulfilled to prove that this virus is the etiologic agent of this disease.

It is evident from experiments that apparently healthy individuals are susceptible to infection and that they need not be debilitated or immune suppressed to develop tumors. It is my opinion that a virus, perhaps the FP-associated herpesvirus, is necessary and sufficient to cause FP in marine turtles. This conceptual model, however, does not preclude the involvement of a variety of cofactors in modulating the severity of the disease and affecting whether or not individuals recover or succumb to it (Herbst and Klein 1995).

If this model of FP as a viral infectious disease is accepted, then the questions that become important in developing practical management strategies to limit the impact of this disease relate to understanding the ecology of this virus. For example, whether or not the virus is shed continuously or intermittently from infected turtles or their tumors, whether or not virus can remain infectious for long periods in the environment outside the host, and whether or not there is an environmental or biological reservoir other than turtles, have tremendous implications for the success of control strategies that rely on isolation or removal of turtles with FP. Ultimately, it may be found that there is no practical way to manage this disease in wild populations short of widespread vaccination.

The prospect that it is impractical to control this disease in wild populations or that the opportunity to bring it under control has been lost, now that it is pandemic (Herbst 1994), must lead us to ponder the long term impact of this pandemic on marine turtles species. Here again, we lack sufficient epizootiologic data, information about the behavior of this disease in populations to generate predictive models. We know that this disease kills some turtles outright and we also know that some turtles recover. We also know that the disease course is prolonged and that, while they are affected with FP, turtles are more susceptible to other mortality factors such as predation, entanglement, and starvation. The long term effect of this pandemic on these endangered populations will depend upon the relative balance between the increment in mortality rate caused by FP and the recruitment rate of individuals to the breeding population, and may not become apparent for several more decades. While this prolonged wait may be discouraging, there is reason to hope that in this time we will continue to learn and eventually gain sufficient understanding of the pathogenesis and epizootiology of this disease to take effective action if required and that it will not be too late.

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Incidence of Fibropapillomas in the Green Turtle (*Chelonia mydas*) in Cuban Waters

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The incidence of fibropapillomas in green turtles in the Cuban shelf quantified between 1983 and 1996. Of the 3390 turtles sampled from the fishery, 20 (0.6%) had visible tumours. Fibropapillomas were mainly found on the neck, eyes and flippers. Affected animals were detected each of the four Cuban fishery zones (northeast, northwest, southeast, southwest). Turtles from 55 to 102 cm SCL were recorded with tumours. A high proportion of affected animals were females, reflecting the sex ratio in the population as a whole.

Introduction

Fibropapillomas in green turtles (*Chelonia mydas*) has been reported from different parts of the world (e.g. Balazs, 1991; Ehrhart, 1991; Limpus and Miller, 1994; Lagueux *et al.*, 1998; Sola *et al.* 1998). In Cuba, fibropapilloma has been noted on green turtles since the mid-1980s, and were called “tumours” or “warts” by fishermen. In this paper, we present data on the frequency of fibropapilloma in green turtles in the Cuban shelf, which will serve to broaden our knowledge on the geographical distribution of the disease.

Materials and Methods

The presence of fibropapilloma on green turtles taken in the turtle fishery at 14 sites throughout the Cuban shelf was recorded, between 1984 and 1996. The location of the fibropapilloma on the body was recorded, along with straight carapace length (SCL), straight carapace width (SCW) data, bodyweight and sex of the animals. A total of 3390 green turtles were examined over the 13 year period. Location and date of capture of turtles were also recorded.

Results and Discussion

A relatively low incidence of fibropapilloma was recorded, with only 20 turtles (0.6% of turtles examined) showing visible external signs of the disease. The first case was recorded in 1985. Ten (50%) of the cases were recorded in 1985 and the remaining cases were from 1986 (4), 1987 (1), 1988 (2), 1990 (1), 1992 (1) and 1994 (1).

Affected animals were recorded in each of the four Cuban fisheries zones, from transit zones (northeast coast), nesting [e.g. Doce Leguas Keys (southeast), Cayo Largo del Sur (southwest)] and foraging grounds (southeast).

Of the 20 affected turtles, 12 (60%) had lesions on only one region of the body, 7 (35%) on two regions and 1 (5%) on three regions. The highest incidence of fibropapilloma was found on the neck (N= 10; 50% of turtles), eyes (N= 8; 40%) and flippers (N= 7; 35%). Other affected areas included the tail, axillary and groin regions (5% each respectively). The exact region of the body for one lesion was not recorded. Tumors were measured in 7 cases, and ranged between 3 and 22 cm in size.

The smallest turtle with tumours was 55 cm SCL, and the largest was 102 cm SCL (**Fig. 1**). Sampling did not include turtles less than 50 cm SCL, and was directed towards larger individuals. Due to the limited number of affected turtles, it is not possible to draw conclusions on the relationship between incidence of tumours and turtle size. However, fishermen have reported seeing small individuals with tumours in lagoons west of Doce Leguas, and so it is reasonable to assume that turtles of even small size classes can be affected. With regard to sex, 18 (90%) of the affected

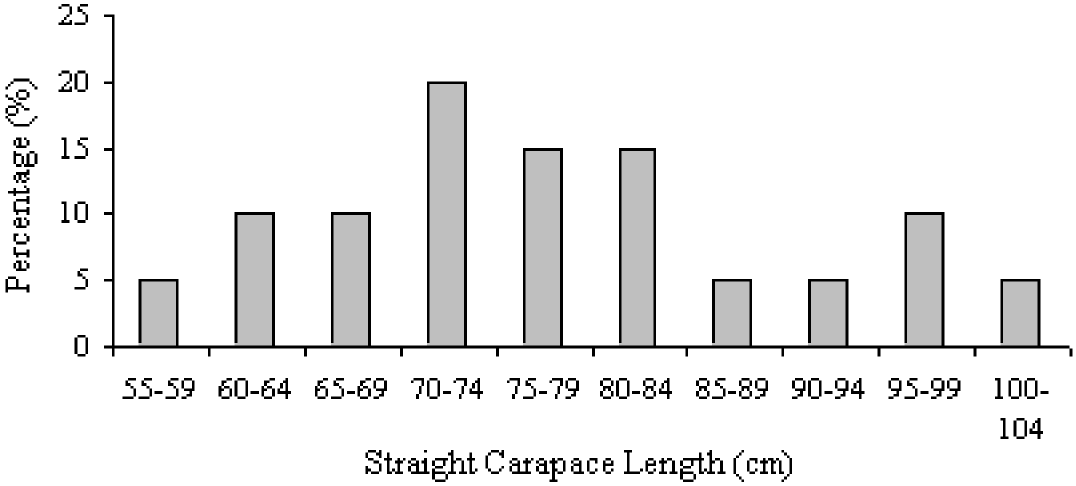

Figure 1. Length composition of green turtles recorded with fibropapillomas.

individuals were females, reflecting the heavy bias towards females in the population.

Since 1996, the turtle fishery has operated at only two sites, with a limited capture quota. This has reduced the opportunity to examine large samples of turtles throughout the Cuban shelf. No fibropapillomas have been reported on nesting females observed at El Guanal beach, which has been monitored since 1982 (Nodarse, *et al.* 1998). Studies have recently started at other nesting sites in Guanacahabibes (Ibarra, pers. com.), and the incidence of fibropapilloma will be recorded.

Acknowledgements

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Head Injury Rehabilitation of Sea Turtles - The Positive Side of a Negative Conundrum

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Sick and injured sea turtles from all over Greece are admitted to the Sea Turtle Rescue Centre (STRC) in Athens, for medical treatment, rehabilitation and release. Since establishment in 1994, 36 of the 113 sea turtles (*Caretta caretta* and *Chelonia mydas*) admitted have had traumatic head injuries. Another 24 exhibited old or healing head injuries secondary to another trauma. This indicates that over 50% of all sea turtles, which pass through the STRC, have suffered from an injury to the head region, at some stage of their life. A turtle with trauma to the head region has a recovery chance of 46%, in contrast to 84% for turtles without trauma to the head region.

For each sea turtle admitted, information on size, weight, general physical condition and injuries is collected. Medical care, weight change, nutrition and behaviour are recorded during rehabilitation. The data, for head trauma cases admitted from 1994 to 1998, have been analyzed to determine factors that may indicate survival, during the rehabilitation period.

Factors That Determine Head Trauma Survival

1. *Turtle size* affects head trauma survival, as indicated by the data (**Fig.1**). When the curved carapace length (CCL) is less than 50 cm, 78% of head trauma cases survive. Recovery is limited to 22% above CCL 50 cm. Juvenile turtles seem to adapt faster to a captive environment. This may be due to lower stress levels (Owens, 1996), and greater immuno-efficiency, in the absence of reproductive hormones (Rosenthal & Mader, 1996). Young turtles are much more responsive to treatment, which leads to a faster recovery. This combined with an increased growth rate allows faster healing. Adult turtles are easily stressed by all aspects of rehabilitation, which delays recovery.

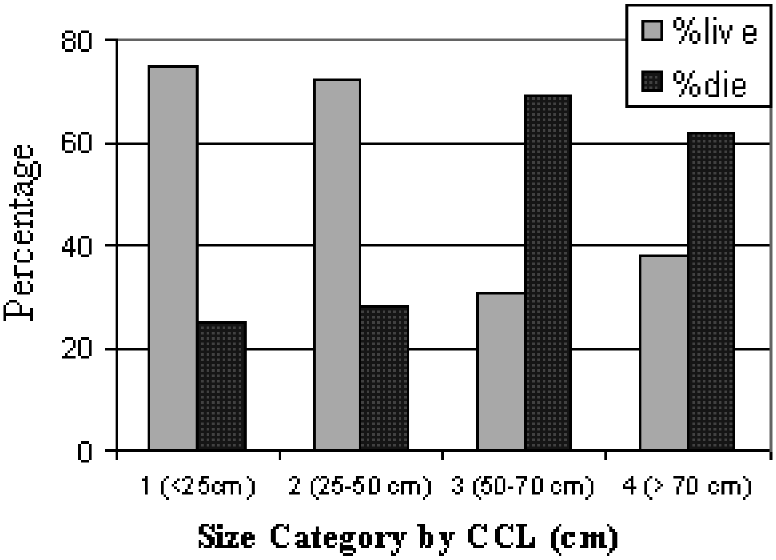

Figure 1. Head injury survival by size categories, 1994-1998.

2. *Weight change* of head trauma turtles that survived showed an average weight loss of 6% in the first two weeks and 1% in week three. Those that died had an average weight loss of 6% in week one, 18% in week two and 8% in week three. Head trauma turtles, (of equivalent CCL) on arrival had the same weight, but did not have the same fate. Weight of a turtle on arrival does not indicate survival chances, however weight change during the first three weeks could be used to indicate survival. Stress induced by captivity, causes voluntary fasting of turtles and subsequent weight loss, which leads to the inability to digest and utilize nutrients (Klingenberg, 1996). This results in immuno-suppression and a fall in metabolic rate, creating an opportunity for pathogenic invasion (Rosenthal & Mader, 1996) - which further stalls recovery.

3. *Location of the head injury* affects survival. 29% of head injuries occurred in the frontal region; 26% to the eyes and nares; 24% in the frontoparietal/parietal region; 21% to the temporal, post ocular and jaw regions. An injury located behind the midline of the frontoparietal scute (**Fig.2**, 'area.1') resulted in 100% death. Penetration of the cranial vault results in direct damage to the brain. If an injury occurs anterior to this region (**Fig.2**, 'area.2'), survival increases to 48%. In this area the brain is superficial, between the nares and eyes on the centreline, with no cranial vault protecting the optic and olfactory areas. There is a risk that injury in this region can cause permanent damage, with additional impairment at the cerebral or higher areas (personal communication R. George, DVM). If the injury is limited to the 'area 3' (**Fig.2**) there is 100% recovery chance. However if such an injury arises in combination with frontal/frontoparietal damage, survival is reduced.

4. *Additional injuries,* that occur before and after admittance for rehabilitation, such as epidermal lesions, provide primary routes for opportunistic pathogenic infection (George, 1996). Only 15% of turtles exhibited damage limited to the head region; 30% had one additional trauma type; while 55% had more than one trauma type. Such injuries include body or flipper lesions, carapace or plastron abrasion, or ingestion of foreign materials. 82% of STRC head trauma cases were initially unable to dive as a result of trauma or respiratory related problems. Of those that recovered, all regained their ability to dive and were released. 58% of head trauma cases expressed ocular infection or damage on arrival. All that recovered regained sufficient vision to be released. The extent of damage

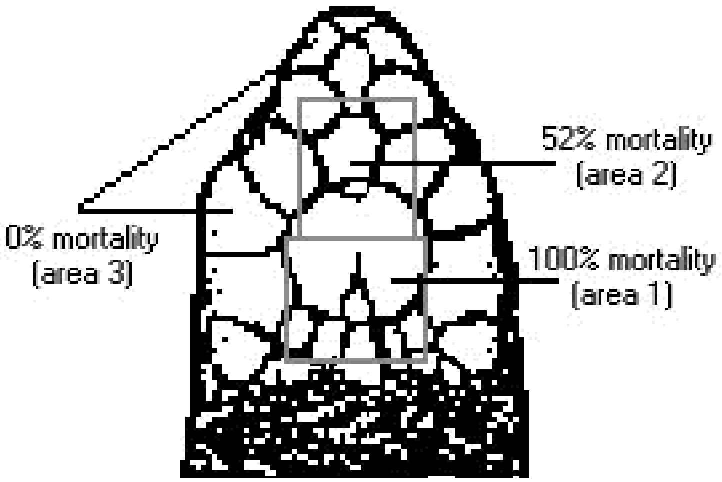

Figure 2. Acute and superficial head trauma areas of a loggerhead turtle.

caused by each additional injury has not been quantitatively evaluated here, nor the degree of susceptibility to pathogenic infection. *Pseudomonas* spp. is a gram-negative bacterium, which has been frequently isolated in head trauma cases at the STRC. It proves fatal if not identified and eliminated at an early stage. It initially appeared in cases as an ocular discharge, spreading to all epidermal surfaces and leads to extensive plastron degeneration. This environment allows the rapid establishment of respiratory disorders, which cause a high turtle mortality rate (Glazebrook *et al.*, 1993).

Head Trauma Rehabilitation

Head trauma rehabilitation, at the STRC, takes 134 days on average. Death of a turtle occurred within the first 24 days. On arrival, head injury turtles are provided with effective medical and nutritional support to combat pathogenic invasion. Treatment includes a combination of intra-muscular systemic antibiotics, and topical antibiotics that are applied to the site of injury with a semi-permeable adhesive wound dressing, Tegaderm™. There is usually further deterioration of the tissues in the area surrounding the injury site. This is replaced by healing tissue, which eventually hardens into a new outer layer. This surface is usually darker and less smooth than the original tissue type. The turtle's epidermal surfaces are cleaned daily to avoid the body harboring and spreading infectious pathogens.

Surfaces with abrasions or lesions, ocular and nasal excretory surfaces, the oral cavity, urine and feces are monitored daily. If a change in color or texture of the epidermis, secretions or excreta occurs, microbiological analysis is used to identify and combat pathogens.

Radiographic evaluation and blood analysis are also important in evaluation of rehabilitation. Turtles are kept in seawater pools at a temperature range of 21°C to 29°C, which are sterilized daily with chlorine to reduce bacteria growth. A turtle that is weak and/or suffering from respiratory tract problems, is kept in minimum water or dry with seawater applied to the head (eyes and nares) and body at regular intervals. This avoids exhaustion of the turtle and possible drowning. Once the turtle's breathing improves and it is stronger it is placed in deeper water.

Head trauma turtles are initially given intracoelemic rehydration fluids. This also reduces the risk of damage to the renal portal system as dehydration increases the nephro-toxicity of drugs applied to help defend the body against pathogen invasion (Klingenberg, 1996). Depending on the size and stress levels of each turtle, they are placed on a liquid diet which is passed into the stomach via a tube (Campbell, 1996). If the turtle voluntarily swallows, a food bolus is placed at the back of the oral cavity. As the turtle recovers, aid in feeding is gradually reduced, until the turtle can eat without assistance. In this phase of recovery the turtle becomes more active with regular diving attempts, until it successfully rests on the bottom of the pool.

Discussion

In 1998 the STRC successfully rehabilitated 46% of head trauma cases, which was double the success of all previous years combined. Analysis of head injury data collected from 1994 to 1998 indicates that success could be determined by:

- size of turtle, younger turtles had greater rehabilitation success
- weight change, in the first three weeks of treatment indicate survival
- injury location, in front of the frontoparietal midline gave increased recovery and
- additional injuries increase risk of pathogen infection and mortality.

An optimal environment is required for successful rehabilitation of head trauma cases. This includes the ability to provide optimum temperature levels, high nutritional provision, correct active and preventative medical care, in a low stress environment. These factors combined, aid recovery by increasing immunity and decreasing the risk of fatal infection by opportunistic pathogens.

Initial diagnostic evaluation of head trauma cases should not be used to conclusively determine each turtle's chance of survival, as there are a number of factors, which cannot be quantitatively assessed. Such factors include health and nutritional state of the turtle prior to injury, period of stranding before being found, depth of injury, degree of secondary injuries and susceptibility to infection. The rehabilitator must be able to assess the recovery progress of each turtle over a period of time, via weight analysis and response to drug therapy. A centre which can fulfill husbandry, sanitation and nutrition requirements for head trauma cases, can successfully rehabilitate and release sea turtles suffering from head trauma injuries into the wild.

Acknowledgements

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CONSERVATION TECHNIQUES AND PROGRAMS

Is Conservation Working? The Melbourne Beach - Carr Refuge Experience

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There is a stretch of beach in what Dr. Carr called "the Indian River Region" of Florida that has special relevance to the conservation of several species of marine turtles. For members of the sea turtle conservation community who have been involved for a long time, this beach will always be thought of as "Melbourne Beach," because that is what it was called by the first workers who studied marine turtle nesting there, in the 1970's and early '80's. This beach is in Brevard County, Florida and lies 60-80 km south of the most familiar geographic feature on the east coast of the Florida peninsula, Cape Canaveral**.** It extends southward from the incorporated town of Melbourne Beach to Sebastian Inlet, another major feature of the east Florida coastline. Newer and younger members of the sea turtle community are probably already familiar with this stretch of beach as the Archie Carr National Wildlife Refuge, created in 1990 and talked about, to one extent or another at each of the last nine symposia. It is a 21 kilometer stretch of beach that annually supports about 30% +/- 5% of all the loggerhead and green turtle nesting in Florida. Also, It is now beginning to support leatherback nesting at something above a negligible level.

While it would be ideal to enumerate marine turtle stocks through estimates of size and density of juvenile and subadult populations, it continues to be impossible to apply mark & recapture estimation techniques to those populations except in a few, special instances. We are left with what I regard as the "tried and true" method of marine turtle stock assessment, enumeration of nest production on the beaches. Meylan (1982) expressed it succinctly when she wrote, "The nesting beach is perhaps the only practical place to conduct a census of sea turtles... Population censuses are the only tool by which the stability of populations can be monitored and dangerous trends detected." Because of the disproportionately large level of nesting activity by loggerheads and green turtles on the Melbourne Beach/Carr Refuge shore, this beach serves as a "window" to the status of loggerheads in the western Atlantic and of the endangered Florida green turtle. My intention in this paper is to look briefly at the history of marine turtle research prior to the authorization of the refuge and then examine the remarkable post-1990 trends in nest production on this beach. It seems appropriate to do so just now, following the summer of 1998, when those trends culminated in record high levels of nest production for all three species that nest there.

Two subsidiary issues will also be addressed, briefly. One is the matter of displacement. "Is it likely that increases in nesting activity at the Carr Refuge come as the result of movement of females from other, perhaps increasingly disturbed, beaches along the Florida coastline?" Secondly, because of the decided upswing in green turtle nest production I feel compelled to revisit the question of Florida green turtle recovery. "Does the current trend constitute the beginning of the recovery of a formerly huge nesting colony or are we witnessing, in our time, the emergence of a new nesting aggregation on the coast of Florida?"

It is somewhat presumptuous of me to try to answer the question, "Is Conservation Working?" by considering only trends in nest production. Certainly there are many other factors involved. But almost no one would argue that those trends are not of paramount importance or that they are irrelevant.

Let me begin with a bit of history. To the best of my knowledge the first to deal with marine turtles at Melbourne Beach was a group of off-road vehicle enthusiasts led by a man named Billy Turner. Those folks enjoyed, in equal measure as far as I can tell, traversing the beach in modified Volkswagen dune buggies and tagging nesting adult females. Dr. Carr supplied tags and during the period from 1972 through 1979 they tagged 2,910 loggerheads. This work resulted in two papers, by Meylan *et al.* (1983) and by Bjorndal *et al*., (1983); papers that have been overlooked to some extent, but that are replete with useful information about loggerhead reproduction and ecological geography.

In 1978 an organization known as Caretta Research, based at Sanibel Island and led by one of the pioneers of sea turtle research in Florida (Charles LeBuff) began sending workers to tag turtles on this beach, for short periods. I am told that the relationship between the Turner group and the Lebuff group was not always amiable during the two year period during which both tagged turtles at Melbourne Beach. Nevertheless, taggers from Caretta Research continued to come to Melbourne Beach each season until 1985 and we continue to see a few of their tags on turtles to the present day.

In 1976 David and Peggy Carr, Dr. Carr's son and daughter-in-law, conducted aerial surveys of the nesting beaches of the southeastern U.S. Their results showed that, "Both in terms of absolute numbers and of relative density, Brevard County is by far the most important county in the state." Then in 1978, Larry Ogren and another of Dr. Carr's sons, Tom, carried out additional aerial surveys and found marine turtle tracks so abundant at Melbourne Beach that "they looked like spaghetti."

The first attempt at a terrestrial survey of nesting was conducted by Dr. Thomas Fritts' group, with the U.S. Fish & Wildlife Service. In 1980 they traversed the entire coastline from Port Canaveral to Sebastian Inlet, on 28 consecutive days in July. The great majority of nests were in what is now the Carr Refuge and, although they carried out their surveys during less than 25% of the season, they reported 3,933 loggerhead and 122 green turtle nests; more than twice as many for both species as reported on any other beach for the entire season (Meylan *et al*., 1995). But still, there was relatively little recognition of the importance of this beach as critical nesting habitat.

Then in 1982, my students and I came to Melbourne Beach and began systematic, season-long nesting surveys. During the period from 1982 through 1989 we observed an average of 9,300 loggerhead nests per season on this 21-km stretch of beach, with relatively little variation from year to year (**Fig. 1**). There were far fewer green turtle nests during this period, of course (the three high years averaged only 220 nests, **Fig. 2**) but as we moved into the second half of the decade it became clear that, perennially, 25-35% of all the loggerhead and green turtle nesting in Florida occurred at Melbourne Beach, which made up only 2.8% of the beaches surveyed. The sea turtle conservation community began to recognize that this was an extraordinarily important nesting beach, a very special place for sea turtles.

During the same period, beachfront development was proceeding rapaciously. Something needed to be done. Thankfully we did not fall prey to what John Sawhill has recently called “analysis paralysis” -the curious condition that can occur when too many data get in the way of taking decisive action. Thanks to Earl Possardt and a few others, the concept of a new, coastal National Wildlife Refuge, dedicated to the protection of turtle nesting habitat, was conceived. Thanks to many other people and organizations that proposal was well supported when it went to the U.S. Congress and, by 1990, the Archie Carr NWR was authorized.

What has happened since then speaks to the question, “Is conservation working?” The data in the first eight columns on the left of **Fig. 1** (1982-1989) represent the loggerhead nest production figures upon which the refuge concept was predicated. The trend since then has been remarkable. Loggerhead nesting rose by 52% above the old, long-term average, to >14,000 nests in 1990 (**Fig. 1**). Then the question became “Is this an aberration?” “Will this level of nest production be sustained?” Clearly it has; even in the lowest subsequent year (1993) the total exceeded the old average by >1,200 nests. Then, in 1995, a new record to that time was established, nearly 17,000 nests; and then the trend culminated in the most recent season (1998), with >17,600 nests; 90% more than the old, long-term average. That figure implies a density of 840 nests per kilometer or 1,350 per mile.

The green turtle record since 1990 provides even more compelling evidence that some aspects of conservation are working. The data in the first eight columns on the left of **Fig. 2** give the green turtle figures through 1989 that were used to develop the refuge concept. The biennial high year totals have risen sharply since then, with only a slight fallback in 1996. As in loggerheads, the trend culminated in 1998, with 1,656 nests; up 178% above the average of previous high years.

Nesting by leatherbacks at the Carr Refuge was negligible through 1995 (**Fig. 3**).

One way to interpret the data in **Fig. 3** is to note that in the first nine years only four leatherback nests were seen; negligible by any standard. In the last eight years, however, there have been 40 nests, culminating, once again, in 1998, when there were twice as many *Dermochelys* nests as ever before.

On the subsidiary question of displacement from other beaches, I will only note that the trend at the Carr Refuge always reflects the region wide trend: when nesting is up at the Carr Refuge, it’s up throughout Florida; when it’s below average at the refuge, it’s below average throughout the region. Superficially, then, it would appear that the recent increases at the Carr Refuge are not due to displacement from other beaches, but Blair Witherington has done an in-depth analysis of the most recent data and has come up with some interesting results. His paper can be found in the Oral section of this volume titled: Beach Studies and Population Status Reports.

Many of you are aware of the discussion, in the literature, of the survival status of the Florida green turtle.

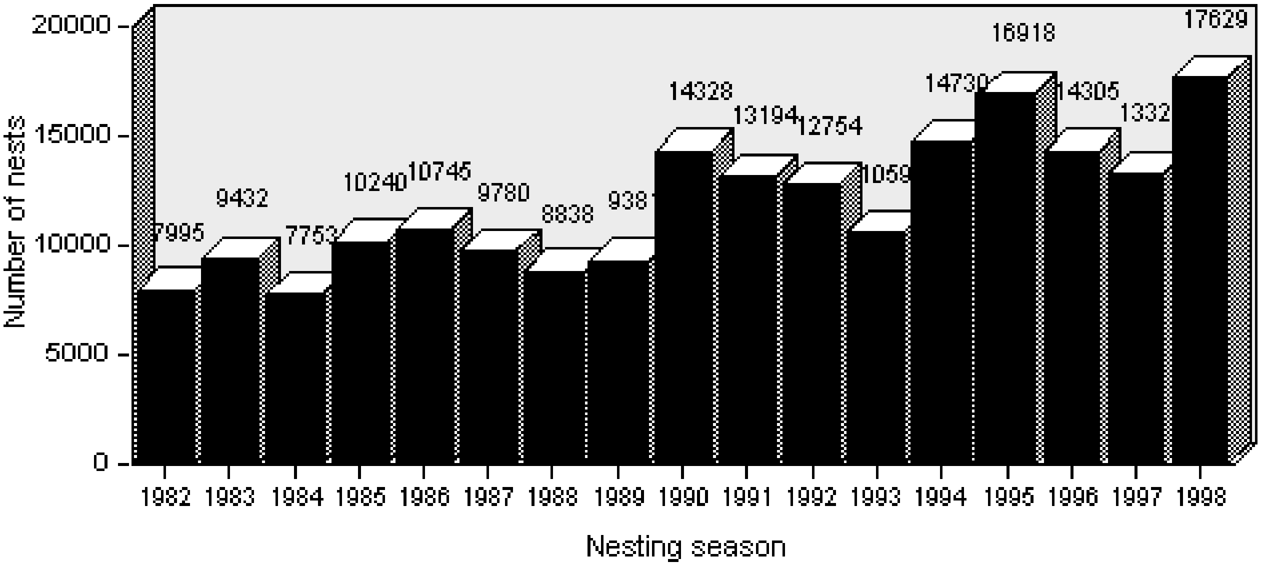

Figure 1. Loggerhead nests deposited within the Carr Refuge study area, 1982-1998.

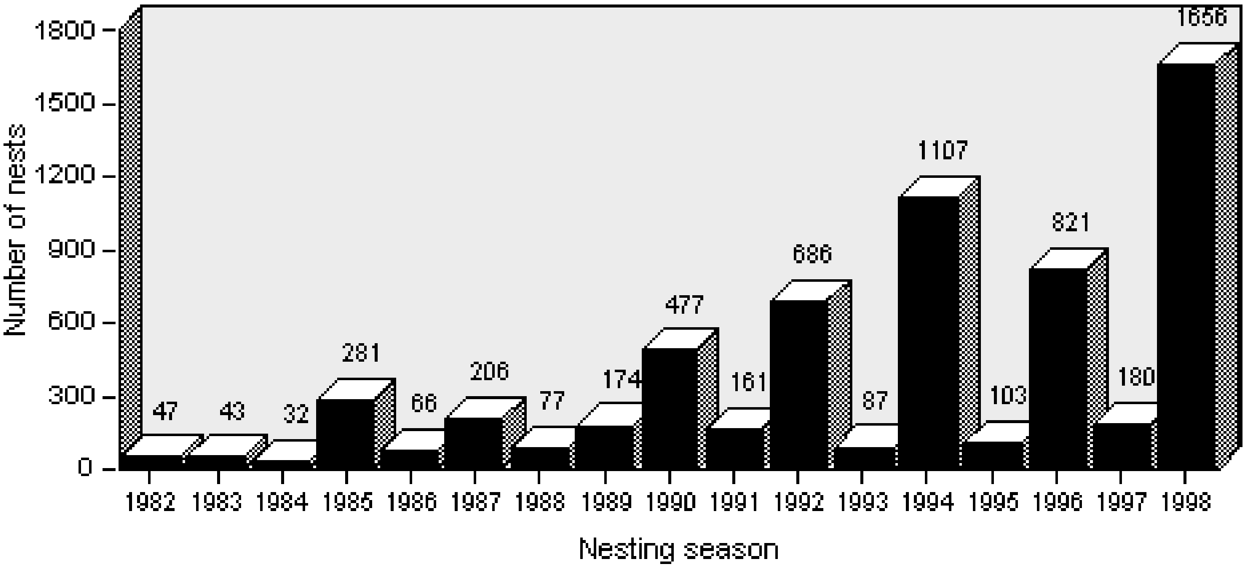

Figure 2. Florida green turtle nests deposited within the Carr Refuge study area, 1982-1998.

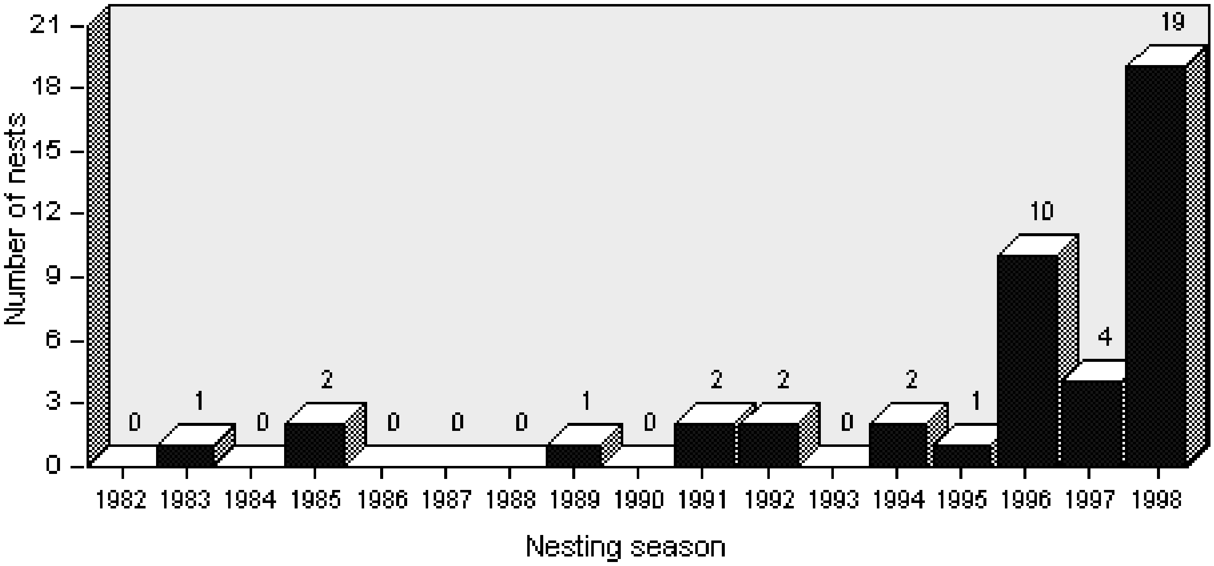

Figure 3. Leatherback nests deposited within the Carr Refuge study area, 1982-1998.

Clearly, Dr. Carr felt that there had been a prodigious green turtle rookery on the Florida coast. At one point (Carr, 1952) he referred to it as "a phenomenal congregation of nesting females," and later, in 1961, as "an immense rookery." He arrived at that opinion by examining old logbooks, storekeepers "account books, housekeeping documents from the colonial period, travelers" stories and the writings of the early naturalists. He believed that the rookery was decimated by the beginning of the 19th century, by European man and the Seminole Indians, just as similar rookeries had been extirpated in the Tortugas, the Cayman Islands and at Bermuda (Carr and Ingle, 1959).

In a cogent and thorough review Dodd (1981) noted that there was little hard evidence to support the position that Florida once supported a large nesting population of green turtles. He questioned whether any green turtles nested on the mainland of Florida at all. Dodd was reviewing data at a time when green turtle nesting was still at a very low ebb in Florida (fewer than 70 known nests per year prior to 1980). Also, one should remember the off-road vehicle group that tagged 2,910 loggerheads at Melbourne Beach in the seven-year period just prior to Dodd's review. They must have covered the beach pretty well, but in that seven-year period they tagged only 18 green turtles; fewer than three per season. Now we are seeing 20 or more per night in the heart of the season. It provides a different perspective on the problem. The question implicit in Dodd's inquiry was, "Is there anything to recover? Was there ever a substantial nesting population in Florida?" In light of the marked increase in green turtle nest production seen at the Carr Refuge and elsewhere in this decade, I believe the question becomes, "Does the current trend constitute the recovery of a formerly very large rookery or are we witnessing the de novo emergence, in our time, of a new nesting aggregation on the Florida coast?" The former of those two alternatives seems to be the more parsimonious.

In searching the old and gray literature for additional sources of information we, of course, did *not* come up with much that Ken Dodd, one of the planet's great bibliophiles, did not consider. We did find a paper (Schroeder, 1924) that states that, in Florida, turtles were captured when they came ashore to lay eggs and discusses the relative commercial value of shelled vs. unshelled eggs taken from the turtles. Another source was a personal letter to Dr. Carr from a W. J. Schubert. As a boy and at the turn of the century, he gathered turtle eggs on Hutchinson Island, between Ft. Pierce and Jensen Beach, for about eight years and stated clearly that he saw green turtles nesting there, but there were far fewer of them than loggerheads. Both of these references seem to affirm that remnants of a decimated green turtle rookery continued to nest in Florida throughout the 19th and 20th centuries. I conclude that the preponderance of evidence suggests that the larger numbers of green turtles now nesting in Florida are derived from that remnant, as the result of conservation practice and protection under the law.

In conclusion, the Carr Refuge now takes its place in the system of refuges, seashores, and parks that are protecting marine turtle nesting habitat along the southeastern coast. It is reasonable to think of the Carr Refuge as the "jewel in the crown." Is conservation working? Well, not all the time, not everywhere; but if we rephrase the question slightly and ask, "Is there reason to believe that some of our conservation practices can and do work for the good of marine turtles?" —then the Melbourne Beach-Carr Refuge experience shows clearly that such evidence exists. Let's be sure that meetings like this one bring us together to continue to fight the good fight, to grow and extend those practices to places and situations where the news is not so good.

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Management of Nests in *Dermochelys coriacea*

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These days, more than ever, the protection of leatherback turtle clutches has become a priority; relocation of eggs to a protected hatchery is an adequate and recommended technique in the Mexican Pacific. A special case is Playón de Mexiquillo, Mexico. During the 1980's, 800 nesting females were recorded per season (Sarti *et al*., 1996); at present, only around 9 females are recorded in a season. For this reason, each clutch protected increases the chance to recruit new individuals to this depleted population.

For years, hatcheries have been an option for clutch incubation in this area, nevertheless, the results show a low number of hatchlings released, compared to *in situ* incubation. In the 1970's, studies about movement-induced mortality started to determine the effect of relocating clutches, highlighting the difference in hatchling production between *in situ* and relocated clutches, as well as the effects of movement and the relationship with the first stages of development (Blanck and Sawyer, 1981; Chan *et al*., 1985; Limpus, *et al*., 1979).

In Mexiquillo, around 50% of the total clutches are protected in hatcheries and *in situ*. Both incubation techniques have yielded good results in general, with 184,770 hatchlings released in 15 years. However, the differences in hatch success between *in situ* and relocated clutches has inspired studies in order to understand the effect of these conservation techniques over wild populations. The present study evaluated the results of incubation in term of hatch success, embryo mortality and eggs without apparent development (EWD) in relocated and *in situ* nests, and the percentage of EWD as a product of the factors that acted during the relocation of clutches, such as form of collection, time of transportation and distance.

Methods

A four km stretch of beach was patrolled, including 400 meters destined for nests left *in situ*. For the relocated clutches, we measured the distance between the nest site and the hatchery (point zero), recorded notes on collection technique (directly from the cloaca in a plastic bag or grabbing them from the bottom of the nest), and the time between initial collection and reburial. The nests were opened after the incubation period, once the hatchlings have emerged to the surface. The contents were categorized in order to calculate each of the following incubation parameters:

%Hatch Success = (total hatchlings or total number of eggshells/total eggs) X 100

%Embryo mortality = (total embryos/total eggs) X 100

%EWD = (# eggs without development/total eggs) X 100

In order to compare the mean value of both treatments (hatchery vs. *in situ*), we used a Student's t test. Attachment of the embryo to the eggshell occurs within a few hours of laying and is associated with the organization of the extra-embryonic membranes, thus the lack of development in some eggs (EWD) could be caused during this early stage. Therefore, EWD was as the parameter to evaluate the effects of clutch relocation. To evaluate the effect of the form of collection, time of transportation and distance over this percentage, an ANOVA test was applied with three classification criteria.

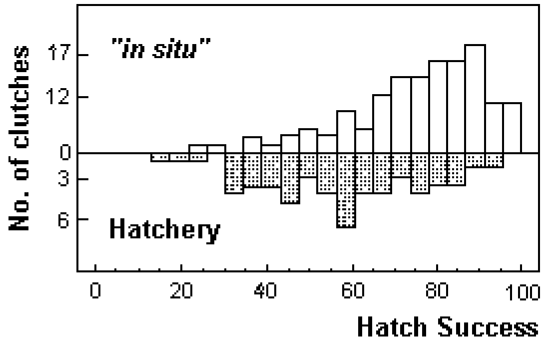
Results and Discussion

There were significant differences between *in situ* incubation and the hatchery for all three parameters (**Table 1. Fig. 1**). *In situ* nests had a higher rate of hatchling production, however it is the hatchery technique that guarantees survival of the clutches from poachers. Embryo mortality for *in situ* conditions was less than half of that observed in relocated clutches (**Fig. 2**). In addition, it was noted that during the start of the nesting season embryo mortality occurs in the early stages while at the end of the season mortality occurs during the later stages. Finally, 16.6 % of the eggs in *in situ* incubation did not development (EWD), while 23.7% of the eggs in relocated clutches showed no development (**Fig. 3**).

Table 1. Incubation parameters.

Parameter	*In Situ*	Hatchery
% Hatch Success	75.1 ± 16.4	57.4 ± 19.9
% Embryo Mortality	8.1 ± 9.36	18.8 ± 15.7
%EWD	16.6 ± 12.14	23.7 ± 16.8

The results of ANOVA indicated that hand collection of the eggs, from the bottom of the nest, increased the number of EWD (from the bottom of the nest = 27.8% ± 0.03; directly from the cloaca = 20.1% ± 0.02; p=0.046). Also, transportation distances longer than 500 meters and taken from the bottom of the nest have a significant effect (collect from the bottom and relocation farther than 500 m = 37% ± 0.05; collect directly from the cloaca and relocation from any distance = 14% ± 0.04; p=0.0221). Likewise, the relocation of clutches from further distances and the increase in time between collection and reburial had significant differences (distances larger than 500 m with time above 180 min = 37% ± 0.05; distances under 500 m and time lower than 180 min = 21% ± 0.03; p=0.0036). The combination of these three factors that involves a large manipulation of the eggs shows that they work in conjunction, resulting in EWD percentages higher than 20%.



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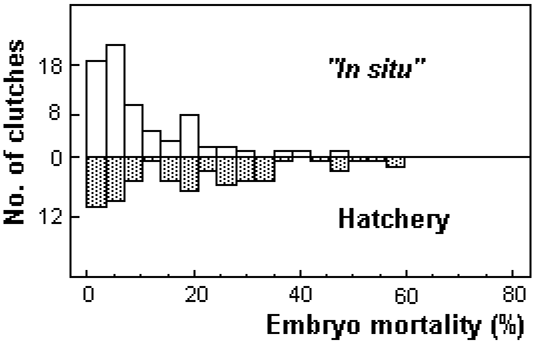

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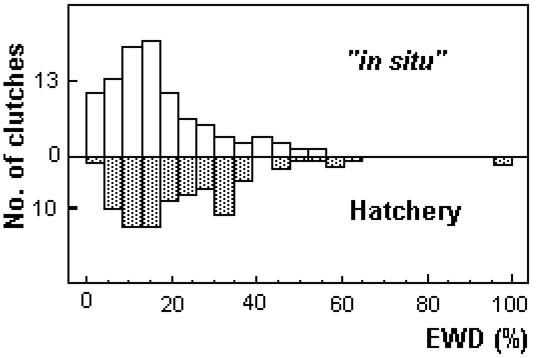

Figure 3.

The literature indicates that leatherback nests have a hatch success below 70%, even in nests *in situ*. This species is very sensitive to changes in incubation environment. The most notable differences in this study among the two incubation treatments were in hatch success and embryo mortality. The presence of hatchlings and dead embryos confirmed that development continued after reburial, and that the mortality was due to problems in the incubation chamber. Some authors say that the viability of sea turtle eggs is between 80% and 90 %, therefore the EWD can be considered as very early embryo mortality.

The collection of eggs with a plastic bag directly from the cloaca is a simple practice, that together with a rapid transportation and reburial in the hatcheries, minimizes the manipulation of the clutches. Attention must be paid to the selection of a new incubation site, since the hatchery location, nest depth, and compaction of the sand covering the clutch directly influence nest temperature and humidity, important parameters for development.

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The Role of a Non-Governmental Organization in Sea Turtle Conservation and Management Planning in Greece

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The European Union passed the Habitats Directive (92/43) in 1992, which lists habitat types and species within Europe that are considered important for preservation. The Directive instructs Member States to designate and protect “Special Areas of Conservation” where these are found. The loggerhead sea turtle, *Caretta caretta,* is listed as a highest priority, and since Greece is the only E.U. country that hosts any significant nesting activity, every main nesting beach was proposed for designation. The significant experience of the STPS regarding sea turtle conservation and management in Greece over the last years, led E.U. and Greek authorities to rely on this NGO to draft plans and protection legislation. In nesting areas where it had been monitoring and protecting nests for many years, the STPS found itself in the unique role of preparing the management plans. This allowed the organisation to actually begin and test implementation strategies in cooperation with the local authorities. These activities build support at the local level, facilitate the passage of protection legislation at the national level, and allow the NGO to focus and improve their sea turtle protection efforts.

Introduction

The Sea Turtle Protection Society of Greece has been monitoring nesting beaches throughout Greece since 1984. A nationwide survey during the 1980s allowed us to identify the areas of densest nesting, and led to the establishment of permanent monitoring and nest conservation projects in the six most important areas. These are on the island of Zakynthos, Kiparissia and Lakonikos on the Peloponnesus and three beaches on the island of Crete (Rethimno, Hania, and Messara). On these six monitored beaches there are a total of between 2,000-3,800 Loggerhead sea turtle nests laid each year. These summer projects involve beach monitoring, nest protection, and public awareness of both locals and tourists.

Much of this work has been funded by various mechanisms of the European Union. (including ACNAT & MEDSPA). Although sea turtles are legally protected under several Greek national laws (PD 67/81), only one of the nesting areas has ever received any legal protection or conservation designation: this is Zakynthos. Protection measures here were strict, but provided little in the way of alternatives for the local tourism-driven economy, and have remained largely unenforced. This has led to a long campaign by STPS and other NGOs for the establishment of a National Marine Park.

In 1992 the E.U. passed the so-called Habitats Directive (92/43), which contains a comprehensive list of habitat types, and endangered species that require conservation within Europe. This directive ‘instructs’ member states to identify sites where these habitat types or species occur, submit this list the E.U., develop conservation management plans, and pass legislation to establish these protected areas. This network of Special Areas of Conservation (SACs) is collectively known in Europe as Natura 2000.

The loggerhead sea turtle (*Caretta caretta*) is listed as a *‘priority’* species under Annex II, meaning that any site where they occur in significant numbers requires protection. Greece is the only country in the E.U. that hosts nesting beaches of significance. All six main nesting areas were included in the first list of SCIs (Sites of Conservation Importance) proposed by the Greek government. In some areas, the entire nesting beach was included (e.g. Messara, Kiparissia), whilst in others only parts of the beach fell inside the site (Rethimno, Hania, Lakonikos). In all cases the sites included many other habitat types (e.g. sand dunes, river corridors, wetlands) and several sites included large marine areas of Seagrass (*Posidonia*) beds.

A funding mechanism, LIFE, was instituted by the E.U. to enable member states to implement the Habitats Directive. This funds projects in areas proposed for inclusion as SCI/SAC. STPS has been the recipient of three-year duration LIFE projects in Crete, Lakonikos and Kiparissia, the latter two of which are currently ongoing. These projects run all-year round, with lobbying for conservation measures and preparation of management plans, and monitoring and nest protection operations during the nesting season.

Why did the job of preparing management plans fall to an NGO?

This is a role usually undertaken by the relevant departments of the Ministry of Environment. In Greece, with hundreds of sites, covering 15% of the country's surface area, the task of setting up the Natura 2000 network was a huge one. The prevailing political climate afforded zero support for large-scale expansion of the size of the civil service. This left the E.U. and the Ministry of Environment nowhere to go but to the NGOs. Luckily, there were several national NGOs with existing long-term projects, and considerable experience in both the subjects and the sites. The STPS has been operating for 15 years, and had successfully completed several large E.U.-funded projects in this time, often under difficult and adverse conditions. For sea turtles, sand dunes, and general coastal management issues, the STPS is recognized as the main authority in Greece.

Strategy

In the first LIFE project on Crete, which ran from 1995-97, the STPS discovered that in the process of preparing management proposals for the E.U., they were forced to analyse their conservation priorities, and develop strategies and techniques to best suit. It was realised that there was no need to simply make proposals, when the LIFE-funding enabled them actually begin to try out these management activities. The benefits of this were two-fold:

1. Get the Proof: It was felt that if it could be proven that particular management proposals had already been tried out, and successfully so, then the E.U. and the Greek Ministry of Environment would be much more likely to adopt them in the eventual legislation. Also, it was known from experience in Zakynthos, that both local authorities and local residents dislike 'surprise' laws from Athens regarding 'their' environment. By being able to involve them in the actual management activities, this was proof of *true local support*, or at least a real acceptance.

2. Don't Wait for a Protected Area: Once again, experience in Zakynthos showed that maybe the establishment of a Protected Area should not be the main objective in Greece. Rather, the objective should be to involve local individuals and authorities in some of the regular management activities, and in such a way, that although entirely voluntary to begin with, it becomes increasingly obligatory as time goes on. This means that even if the legislative protection is a long-way off, the conservation activities are continued.

Some examples from Crete: umbrellas and sunbeds.

In Greece, it is possible to lease space on public beaches to install permanent umbrellas and sunbeds, which are then rented out to tourists. This is a highly profitable enterprise and has led to large stretches of nesting beach at Rethimno being so covered. These obstacles on the beach impede and block the female sea turtles from reaching the back of the beach where they prefer to nest. A little bit of analysis about where turtles like to nest, and their behaviour as they climb the beach, allowed us to come up with this simple diagram (**Fig. 1**.).

This shows how the layout of umbrellas and sunbeds affects both availability of, and accessibility to nesting space. STPS project volunteers started clearing up the sunbeds at night on the most densely nested section of Rethimno. This wasn't exactly ideal, but it was the first time that anyone in the area had begun to change standard practices. Then cooperative owners started after contact with us. We allowed them to 'choose' whether they wanted to stack sunbeds behind umbrellas or remove them from the beach completely.

This was combined with a lobbying effort to Local Authorities in order to maintain significant areas of the beach free from umbrellas (often between 50-75% of the area). Two years later, the stacking of sunbeds has been included as an obligation in the lease contract from the State Land Office.

A decision-tree (**Fig. 2**) was developed to help volunteers decide whether to cage a nest *in situ*, or transfer it away from umbrellas. This helped those STPS volunteers working on the beaches understand a little better that umbrellas are not necessarily the worst thing on the beach, and that turtle nests can happily coexist with umbrella operators.

The Blue Flag is recognized throughout Europe to signify clean, safe bathing beaches, and is much sought after by hoteliers and Local Authorities. Until recently, there was no endangered species component in their criteria. After some lobbying by the STPS on Crete, it was decided to include turtle-friendly beach management as one of the criteria. This included stacking sunbeds and reducing light pollution as factors.

Cleaning the beach

Cleaning of the beaches was carried out by the Local Authorities using either heavy machinery, or not done at all. Over several years, STPS succeeded in the public relations department by performing regular clean-ups by volunteers. This, and regular complaints about the use of heavy machinery on the nesting beaches, led to the STPS being invited to participate in a decision-making capacity on a new local government body responsible for beach cleaning in Rethimno. From here we were able to guide the selection of appropriate technologies and methods.

Lighting

Light pollution causes severe hatchling disorientation. Previously this was dealt with by transferring nests laid in lit areas, or by 'nest shading' where a darkened runway is created forcing the hatchlings towards the sea. Thanks to some excellent information material from the USA, the efforts of the project workers were redirected to switching off the problem lights or shielding them. This allowed us to greatly reduce the number of times we had to 'interfere' with the nest or hatchlings.

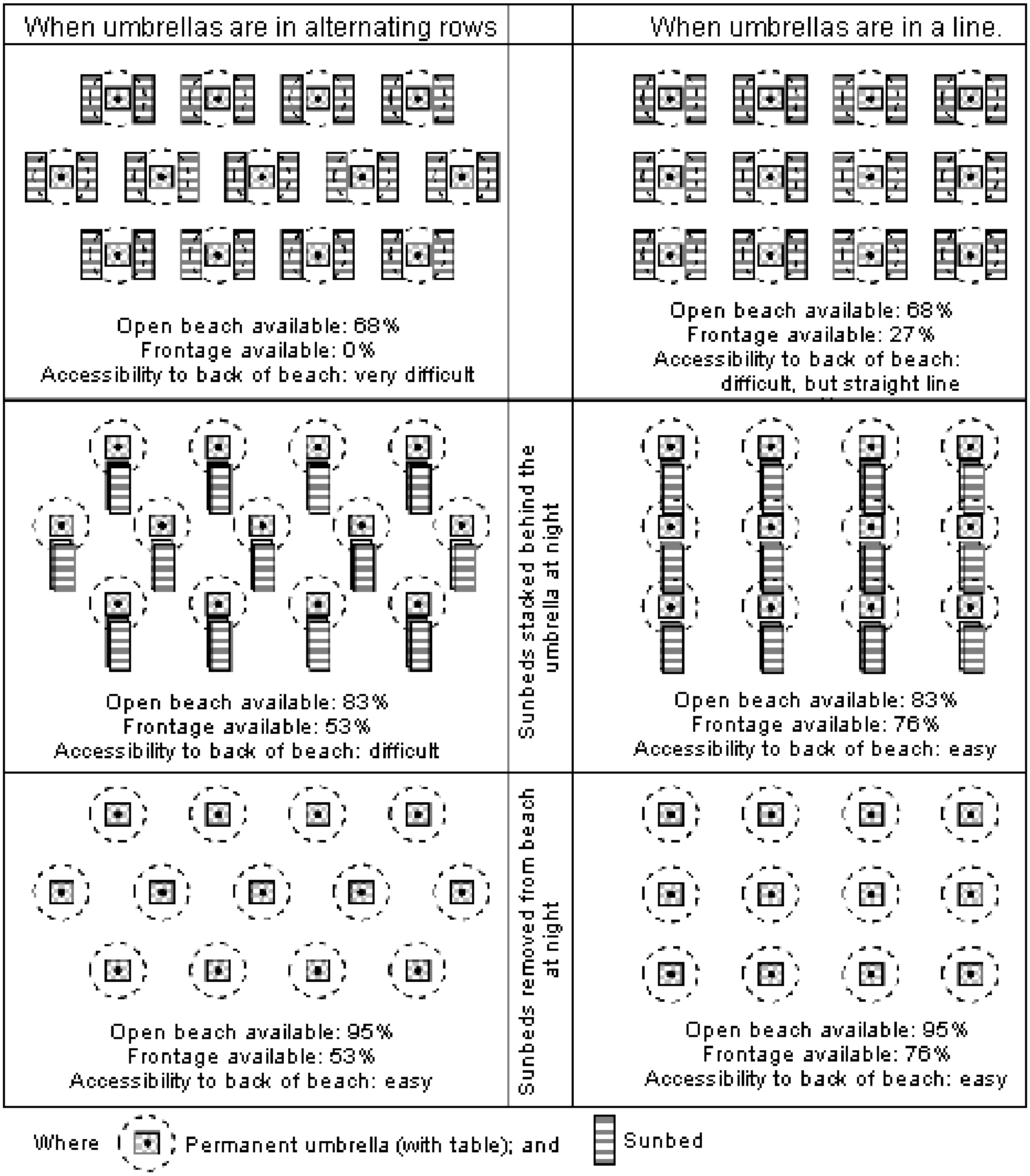

Figure 1. Layout of umbrellas and sunbeds affects both availability of, and accessibility to nesting space.

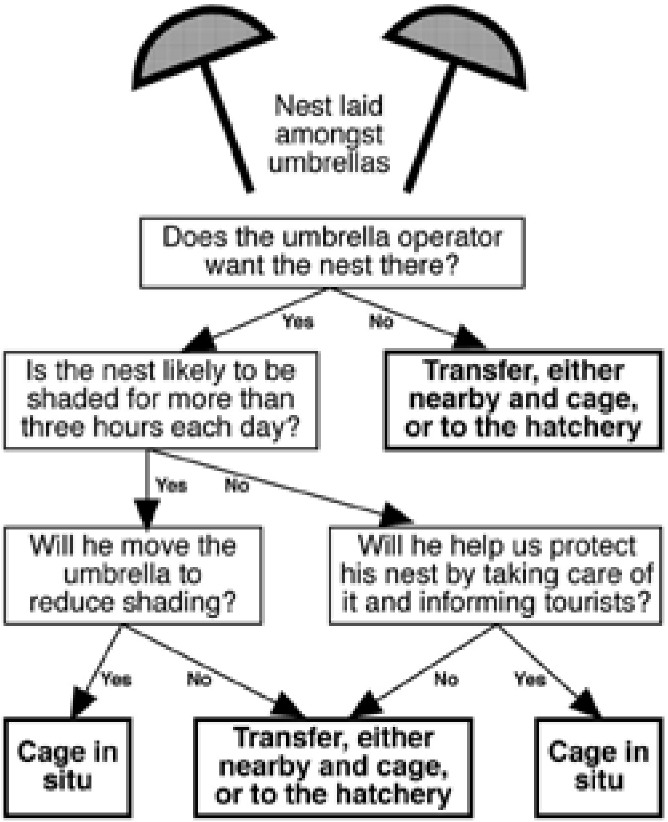

Figure 2. A decision-tree to help volunteers decide whether to cage a nest *in situ*, or transfer it away from umbrellas.

Conclusion

To conclude, we have outlined several of the new techniques used by STPS for conservation management:

- voluntary compliance before obligations (sunbeds/lighting);
- enhancement of existing institutions (Blue Flag), and
- establishment of new institutions that include STPS in decision-making (beach cleaning).

We believe that these solutions increase support for turtle conservation, and establish a good foundation, whether or not the area eventually receives legal protection.

Acknowledgements

The authors would like to thank the Crete project leader Thanos Belalides, and those who worked with him for their hard work and dedication. This project was funded by the European Union under the LIFE program.

Distribution and Conservation of the Leatherback (*Dermochelys coriacea*) in Atlantic Canada: Research Partnerships with the Fishing Community

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In Atlantic Canada, commercial fishermen observe and interact with leatherback turtles more than any other group. However, historically, most of their observations of this species are unreported. Recognizing the unique challenges associated with conserving leatherbacks in the marine environment and the value of recruiting fishermen as research partners, we initiated a fishermen-scientist collaborative program in 1998. Its purpose is to assess the abundance and distribution of leatherback turtles seasonally encountered in Maritime waters and to facilitate the tagging, photo-identification, treatment and release of leatherbacks stranded or entangled in fishing gear. As part of this effort, fishermen are trained in marine turtle identification and appropriate turtle and environmental data collection techniques. To date, 217 commercial fishing vessels in Nova Scotia, Newfoundland and Prince Edward Island are participating in this program and since June 1998, we have received the details of 201 leatherback sightings. These results demonstrate that leatherbacks regularly enter Maritime waters. Moreover, they suggest that historical evaluations of leatherback abundance in Eastern Canada may be overly conservative.

Mediterranean Sea Turtles in Need of a Regional Conservation Strategy

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The circumglobal species *Caretta caretta* and *Chelonia mydas* have evolved distinct populations within the Mediterranean. It is estimated that the Mediterranean loggerhead population is the third largest in the world after those of Oman and the United States. While nesting areas in the Mediterranean are concentrated in the eastern basin, sea turtles seem to migrate long distances for exploiting various habitats.

Furthermore, a large contingent of immature loggerheads, originating from the southeastern USA, enters the

Mediterranean through the Straits of Gibraltar and utilizes the western basin as feeding grounds. They frequently interact with the longline fishery there.

Exploitation by humans reached a peak in the early 1960s when a sea turtle fishery was active in the eastern Mediterranean. Today, despite legislation, there is still traditional consumption in some coastal communities, which may well exceed the sustainability of existing populations.

Sea turtles in the Mediterranean are protected under several international conventions (Bern convention, CMS, etc.). However, the convention that encompasses all Mediterranean countries is the Barcelona Convention. While the parties to this convention have already developed a specific Action Plan, a Regional Conservation Strategy is needed in order to define main actions and set priorities for research, conservation and management. Furthermore, a common strategy would develop cooperative mechanisms for assessing conservation status, identifying and protecting critical areas, monitoring population trends, and enforcing international agreements.

Sea Turtle Protection in the Guayana Shield Region: Optimization of Collaboration and Conservation

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In the Guayana Shield region, it appears that sea turtles do not show fidelity to a specific nesting beach, but to a large nesting zone including Venezuela, Guyana, Suriname, French Guiana and northern Brazil. No population dynamic study or conservation strategy in general is possible without a strong collaboration of the different countries in the nesting zone.

Background

The coastal region of the Guayana Shield is visited by several sea turtle species: leatherback, olive ridley, green, hawksbill and loggerhead. The presence of five different sea turtle species gives the institutes, working on sea turtle conservation in this area, a large responsibility for preserving and protecting these species and the biodiversity of their natural environment.

The leatherback turtle has suffered a large worldwide decline in the last decade, which makes it one of the most endangered sea turtle species. The estuary of the Marowijne River is visited by more than half of the world population of leatherback turtles, but the number of nesting females in the estuary has declined severely. For the Guayana Shield region this means that this species deserves high priority in conservation efforts with global importance.

This region still contains the largest population of nesting olive ridley females in the western Atlantic Ocean, but that number is declining very fast. Because of the regional importance, a high priority in conservation efforts should be given to this species as well.

The green turtle, the hawksbill turtle and the loggerhead turtle do occur in the coastal waters of the Guyana shield region. Because of their current status in French Guiana and Suriname no special conservation efforts are made for these species, but they will benefit from the conservation activities carried out anyway.

Early history

Joop Schulz from the Netherlands can be considered as the pioneer in the field of sea turtle research and conservation in the Guayana Shield region. He started his work in the 1960s, founded STINASU in 1969 and continued his work successfully until 1978. Starting in 1965 he was assisted by Peter Pritchard, who started working in Guyana and put up a consistent framework for research on and conservation of sea turtles. Peter Pritchard is still the main force behind the actual work carried out in Guyana.

The first census In French Guiana was carried out in the late 60s by Schulz and Pritchard. Jacques Fretey started his work in 1977 and was later assisted by Marc Girondot. In 1986 the Kawana-project was created, integrating European volunteers into the conservation work. In 1997, Marc Girondot continued the work. WWF has been funding the sea turtle conservation effort in French Guiana without interruption since 1977.

In the mid-1970s, Henk Reichart started his work on the Surinam beaches for STINASU. STINASU has been and still is executing conservation and research activities in Suriname. Henk Reichart, Jacques Fretey and Peter Pritchard drew the world's attention to the status and the problems of sea turtles in the Guyana shield region with various articles.

Recent history

In 1995, Biotopic started its work on the Surinam beaches with the primary objectives being research and active beach protection. The second project began in 1997; research activities were extended and, in collaboration with

STINASU, a conservation program was added. The philosophy was that for successful conservation of sea turtles in the Guayana Shield region collaboration between Suriname, French Guiana and Guyana was needed. In that year Biotopic and STINASU took the initiative to organize a symposium in Suriname. The goal of this meeting was to exchange information between the three countries. To attract regional attention for this symposium work visits were made to French Guiana and Guyana.

It was fairly easy to get in contact with the French team. In 1997 some joint expeditions were undertaken to remote beaches and members were exchanged between the two research teams. The two teams' methods differed greatly. Because of practical problems the French team and officials weren't able to attend the symposium in 1997.

In 1998 contact was intensified. At various meetings, initiatives were put forward to combine conservation efforts. This resulted in the attendance of a diverse French delegation at the second symposium. This delegation consisted of researchers, the curator of the Awana Nature Reserve and officials of the French Guianese ministry of environmental issues. This symposium was very successful.

Contact with the Guyanese representatives was somewhat more difficult. Both in 1997 and 1998 officials reacted distantly. The research areas are very remote and difficult to get to. Contacting the Guyanese researchers was also very difficult. Unfortunately we were not able to persuade representatives to attend the symposia.

Nowadays, Mr. Romeo de Freitas is doing most of the work on the Guyanese beaches and in 1998 received a Conservation International Award for his work. It is our goal to involve him in the international collaboration in the Guayana Shield region.

Actual status

At the end of 1998, WWF, which is responsible for funding the Guayana Shield conservation program, initiated a number of meetings in Europe between the French WWF/ Kawana-team and Biotopic. This was the first step towards the creation of a regional conservation program for the Guayana Shield. The goal of these meetings was to coordinate the future programs of both teams.

A regional conservation program for the Guayana Shield will be prepared, taking into account the roles of each counterpart in each country. During the next few months, a proposal will be submitted to several international organizations like WWF, IUCN, WIDECAST and STINASU. A free copy can be obtained at the French WWF office.

The main priority was given to the leatherback turtle with a second priority given to the olive ridley turtle. For the leatherback turtle we decided to focus on research and conservation at the population level. Identification and quantification of the threats are needed. Science was put forward as a conservation tool for sea turtle protection to fill the lacks in knowledge we need for an optimal conservation program. To save the world's largest population of leatherback turtles we agreed on the following aspects to execute in Suriname and French Guiana:

- The use of coastal flights to determine the most important beaches for conservation activities.
- The use of PIT tags for population monitoring and to have a better view on beach fidelity. Johan Chevalier and Marc Girondot have a poster on this issue at this symposium (see Poster section: Population Status and Studies: South America)
- The use of ARGOS satellite tracking to better understand inter- and intra-seasonal movements.
- The use of DNA research to better define the population. Willem Hoekert of Biotopic has already done a pilot study on this issue.

We suspect that the mass scale of egg poaching is the largest threat for the survival of the olive ridley turtle in the Guayana Shield region. In Suriname this is one of the primary threats to the leatherback turtle as well. To deal with this problem attendance and control on the beaches is necessary. These activities should be done by the local authorities.

We hope that eventually the Venezuelan, Guyanese and Brazilian teams will join this initiative. We consider this annual symposium as a very useful platform to make the first contacts for international collaboration for sea turtle conservation in the Guayana Shield region.

Conclusion

It takes a lot of effort to combine all conservation activities into a regional program for optimal conservation of sea turtles. Next to a solid scientific background, visits for networking as a start for a fruitful contact, regional meetings and an exchange of information in good confidence instead of concurrence are needed to accomplish a cooperative conservation program. Initiative steps can be taken by institutes sponsoring different conservation groups in neighboring areas, but also by these groups themselves. For an ideal concept for conservation of sea turtles in a specific region, international collaboration is certainly needed. We are confident that sea turtles will benefit from this way of regional collaboration.

Acknowledgements

We would like to thank H. Sijlbing and K. Mohadin (STINASU), WWF and DIREN Guyane for making it possible to work in Suriname, WWF and DIREN Guyane for organising the Kawana-project in French Guiana, H. Reichart and M. Fontaine (WWF) for advising and initiating, W. Hoekert, A. Schouten en M. Weijerman (Biotopic foundation) for initiating the Suriname-project, the villages of Langamankondre, Christiaankondre, Ya:lima:po and Awala for their hospitality and Iwan Brave for housing. Financial support came from WWF, the Treub Society (Society for the Advancement of Research in the Tropics), the Dutch Embassy in Paramaribo, Suriname, the Symposium Overseas Travel Fund and the David and Lucile Packard Foundation.

Operationalizing a Transfrontier Management Area for Sea Turtles: the Case of Turtle Islands Heritage Protected Area

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In May of 1996, a Memorandum of Agreement (MOA) was signed by the Governments of the Philippines and Malaysia, formally establishing the Turtle Islands Heritage Protected Area (TIHPA) as the world's first ever transfrontier management area for sea turtles. This was widely recognized by conservationists as a landmark agreement as well as a novel and probably the most effective and pragmatic approach to conserving sea turtle populations straddling the borders of two or more states.

This paper presents the mechanisms employed and efforts undertaken over the past two years by the Joint Management Committee (JMC) and Joint Technical Working Group (JTWG) of the TIHPA to ensure that the spirit and goals of the MOA are achieved. Highlights of the meetings of the JMC as well as the salient points of the Rules of Procedure adopted by the JMC are presented. Some issues and challenges are also presented

Background

The Turtle Islands is a group of nine islands straddling the Treaty Limits between the Philippines and Malaysia in Northern Borneo. The Turtle Islands support ASEAN Region's largest aggregation of green turtles (*Chelonia mydas*). More than 5,000 nesters contribute to the annual total green turtle egg production of approximately two million eggs. Three of the nine islands lie on the Malaysian side of the Treaty Limits while the nine other larger islands are on the Philippine side.

Genetic studies as well as tagging experiments revealed that the green turtle population on both sides of the border is in fact a single population unit. These findings prompted management authorities from both countries to initiate efforts to establish a transborder protected area to more effectively conserve their sea turtles. The need to conserve this shared resource as a single management unit became obvious.

Working within the framework of the Association of Southeast Asian Nations (ASEAN), the ASEAN Working Group for Nature Conservation (AWGNC) became the forum for the development of a regional conservation program. With funding support from WWF, the First Symposium Workshop on Sea Turtle Conservation was conducted December 1993, in the Philippines to formulate the regional plan. One of the highlights of the regional plan is a recommendation to declare regionally significant sea turtle populations such as the Turtle Islands in the Sulu Sea as ASEAN Heritage Conservation Areas.

The establishment of the Turtle Islands Heritage Protected Area was proposed by the Philippine delegation at the Second RP-Malaysia Joint Commission for Bilateral Cooperation (JCBC) in 1995. A Joint Technical Working Group was created to finalize the agreement. Thus in May 31, 1996, the Governments of the Philippines and Malaysia forged an agreement establishing the Turtle Islands Heritage Protected Area, the world's first transfrontier protected area for sea turtles.

Operational Mechanism

The MOA created a Joint Management Committee (JMC) to oversee the successful development and implementation of an integrated conservation program. The JMC serves as the policy-making body of the TIHPA and may coordinate/collaborate with relevant international organizations. The JMC is mandated to study and recommend to their respective authorities the enactment of laws as may be necessary to pursue the purposes of the MOA. The JMC which meets at least once a year reports to the JCBC. The first official meeting of the JMC in May 1997 formally established the its membership comprising a total of 10 members, i. e., five from Malaysia and five from the Philippines. The Malaysian members include : 1) Director of Sabah Parks (Chairman); 2) Director, Resource Management Section, Federal Department of Fisheries; 3) Permanent Secretary, State Ministry of Tourism and Environmental Development of Sabah; 4) Representative of the Federal Attorney General Chambers; and 5) Assistant Director, Park Management & Operations Section, Sabah Parks

Membership from the Philippine include: 1) Director, Protected Areas and Wildlife Bureau, Department of Environment and Natural Resources (Chairman); 2) Representative from Maritime and Ocean Affairs Unit, Office of the Undersecretary for Policy, Dept. of Foreign Affairs; 3) Assistant Chief of Staff for Plans and Programs, AC5 Southern Command, Armed Forces; 4) Director, Special Concerns Office, DENR – Autonomous Region for Muslim Mindanao (ARMM); and 5) Vice President for Conservation and Field Operations, WWF-Philippines.

An implementing agency was designated by the respective parties to be in charge of all matters concerning TIHPA and to serve as focal points. For the Philippines, the implementing agency is the Protected Areas and Wildlife Bureau of the Department of Environment and Natural Resources (PAWB-DENR), while for Malaysia, it is the Sabah Parks. These two agencies also serve as secretariats for the JMC meetings. However, both parties are allowed to designate another agency, department or office as the secretariat from time to time.

Both parties are also allowed to invite technical or legal consultants whenever the situation or meeting require. In addition, the JMC may create Joint Technical Working Groups (JTWG) to perform tasks identified by the Committee. Since the MOA was signed, JTWGs have been formed to formulate a Joint Management Framework, prioritize activities identified in the framework, conduct a Strategic Destination Planning, and strategic planning for TIHPA.

The Rules of Procedure

At the first meeting of the JMC held in Sabah, Malaysia, the need for a set of operating procedures (now referred to as the Rules of Procedure) was identified. The ROP provide the guidelines and rules to be followed by the JMC in conducting its meetings and in carrying out its mandate. The Malaysian delegation was tasked to draft the ROP which was subsequently approved in principle at the second meeting of the JMC held the following year in Manila, Philippines. The ROP has been submitted to the Attorney-General Chambers of Malaysia for consent.

A total of 23 rules under 13 sections are adopted in the ROP. These include among others, the place and dates of JMC meetings; the designation of implementing agencies, subcommittees and secretariat; conducting JMC business (e.g., creation of small working groups during its meetings, review and approval or proposals, decisions adopted only by consensus, chairmanship); joint reports; disputes settlement; amendments to the ROP; and changing the composition of the JMC.

JMC Meetings and Resolutions

The JMC has officially met twice since the MOA was signed May 1996. Hosting and venue of the meetings alternated between the two parties. The first meeting was held in Sandakan, Sabah, Malaysia on May 4 to 7, 1997 while the second meeting was held in Manila, Philippines on June 17 to 19, 1998.

The first meeting formally established the JMC. The JMC likewise agreed on some administrative matters including Chairmanship and hosting of meetings; future changes to the JMC composition, engagement of technical advisors, and sharing of meeting expenses.

A committee comprising of six members, three from each party, was formed to discuss the points to be included in the ROP. The Meeting agreed that the Malaysian delegation draft the ROP, and submit the same to the Secretariat for distribution and discussion during the next meeting.

The JMC also discussed funding issues and agreed that both parties shall individually set up their respective sustainable financing mechanism in accordance with the laws of their respective country. The Meeting also agreed that all proposals to utilize funds for TIHPA by the both parties shall be submitted to the JMC for approval. The meeting requested the assistance of WWF-US financial specialist to assist in the establishment of a sustainable financing scheme for TIHPA

The second meeting adopted the Rules of Procedure and agreed to submit the same to the Malaysian Attorney-General Chambers for consent.

Members of the JTWG and consultants reported on their activities and accomplishments including plans for conducting satellite telemetry; implementation of the MacArthur funded project; ecotourism strategic planning; framework for the joint management plan; and new projects.

The meeting adopted the Ecotourism Guidelines which was prepared by the PAWB-DENR and WWF-Philippines as long as these do not contradict with their respective national laws. Both parties likewise agreed to develop its own Master Plan with a unified long term goal. The respective master plans will be presented in the next Meeting for integration and adoption.

On-going and Planned Activities

Below are projects and activities currently underway or being planned under the auspices of the JMC. These projects go through the JMC for evaluation and approval prior to implementation. Project executants also report progress to the JMC during its meetings.

- Satellite telemetry of nesters from TIHPA
- Digital aerial videography and GIS mapping
- Development of management, research & education programmes for TIHPA
- Ecological studies and publication of a book on the ecology of the Turtle Islands
- Training on gender sensitivity and micro-enterprise development for Muslim women in the Turtle Islands
- Continuing implementation of conservation programs of Sabah Parks and PAWB-DENR
- Social, institutional, and gender analyses for the implementation of integrated conservation & development project (ICDP) for the TIHPA.

Issues and Challenges

While the TIHPA has made significant accomplishments over the past two years, several issues and challenges require serious attention.

One issue that remain to be resolved is the continuing harvest of turtle eggs by legal permitees in the Philippines. Recognizing the importance of turtle eggs as a source of livelihood for the local communities, the management authority in the Philippines allow for a regulated harvest of turtle eggs. Although the permit issued to qualified residents is intended only for local consumption, harvested eggs are nevertheless marketed to Sabah due to its proximity to the Philippines. WWF-Philippines is now implementing an Integrated Conservation and Development Project (ICDP) that is envisioned to provide alternative livelihood to residents and slowly wean them away from egg harvesting.

An issue that was discussed at the last JMC meeting is the need to engage the active participation of other adjacent countries in the region which may be within the migratory range of sea turtles from the TIHPA. It was recognized by the JMC that any success achieved through the joint management of the TIHPA can simply be negated by exploitation activities of range countries.

It seems inevitable that some areas within TIHPA will be developed into an ecotourism destination. While this should not be seen as a negative development, the JMC should ensure that any tourism development within the TIHPA complies with the guidelines formulated by the JTWG. This will ensure that both goals of sea turtle conservation and development are achieved for the long term benefit of the local communities.

Finally, another important challenge is achieving sustainability of the joint management program. There is therefore a need to establish and operationalize sustainable financing mechanisms.

Acknowledgements

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CONSERVATION TECHNIQUES AND PROGRAMS - COMMUNITY PROGRAMS

Community Participation in Turtle Conservation in Sri Lanka: a Summery of Community-Based Turtle Conservation Project's (TCPs) Activities in Sri Lanka

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Five of the world's seven species of marine turtle come ashore to nest in Sri Lanka. Despite the protection of marine turtles under government legislation since 1972, Sri Lankan fishermen are still exploiting marine turtles for their meat, eggs and shell. The TCP predicts that the marine turtle populations of Sri Lanka will decline to extinction within the next few decades because of the above mentioned threats.

Sri Lanka's marine turtle populations can recover from this inevitable decline, but only if effective conservation measures are carried out immediately and are continuous for at least the next 10 years. In order to facilitate the necessary recruitment of hatchling turtles into the local turtle populations, as many nests as possible must be allowed to hatch naturally and the hatchlings allowed to make their way to the sea. Where it is not possible to protect marine turtle nests "in situ," scientifically managed hatcheries should be established. Marine turtle by-catch in fishing gear must be reduced, critical habitats must be protected and rookery-monitoring programmes must be established at the most significant rookeries. These measures will only be effective if the coastal communities of Sri Lanka are involved and informed. To achieve this, coastal communities must be educated about the importance of conserving the coastal ecosystems on which they depend.

Turtle Conservation Project (TCP) in Sri Lanka was established in 1993 to address the issue of marine turtle conservation through research, education and community participation. The TCP has launched three major community-based turtle conservation programmes to address the identified threats to marine turtles of Sri Lanka.

The TCP has selected Rekawa, a small village on the South coast of Sri Lanka, approximately 10 km east along the coast from Tangalle, for community-based turtle conservation activities. Rekawa is located on the border of the intermediate and dry climatic zones of Sri Lanka, and borders on a large saline lagoon surrounded by extensive mangrove forests. There are no electricity or telephone lines in the village and the majority of households do not have running water. Water is primarily obtained from roadside storage tanks.

The village is divided in to two divisions, Rekawa East and Rekawa West, and the numbers of families in these divisions are 121 and 144 respectively (Foerderer, 1996, in press). Income generation activities for the families in the Rekawa area include agriculture (47%), lagoon fishing (10%), sea fishing (18%), coral mining (9%) and others (17%) such as masonry, carpentry, government services and labor.

The community of Rekawa village has suffered several setbacks in the last decade. During the late 1980's and early 1990's, Rekawa was the location of political violence which bereaved many families of their skilled men-folk. An irrigation system designed by the government to improve the quality of the agricultural land surrounding nearby Tangalle drained Rekawa of its groundwater. The groundwater was eventually replenished by saline water from the sea and Rekawa lagoon, which rendered the land unsuitable for agriculture unless there are heavy rains. These events have resulted in low incomes for most of the families in Rekawa with approximately 57% of the families dependent to some degree on government welfare.

Rekawa's Natural Resources. Because Rekawa is located on the border of two climatic zones there is a high local biodiversity. As well as the mangrove forests, the local vegetation consists of scrub jungles, medicinal plants, fruit trees and a wide variety of wildlife including 150 resident and migratory birds, 27 species of mammals, 23 species of reptiles, many arthropods and aquatic life.

Community Participation. TCP has initiated three major community based turtle conservation programmes in Sri Lanka, in order to conserve the marine turtles. These programmes are listed and described below:

i). An in situ *nest protection and research programme* is managed by a full-time coordinator and supervised by 5 full-time research officers, 3 of whom were recruited from the University of Peradeniya, the Department of Wildlife Conservation (DWLC) and the National Aquatic Resources Agency (NARA).

The programme employs 17 former turtle egg poachers to assist TCP, DWLC, NARA and University of Peradeniya research officers in the collection of biological data and the *in situ* protection of marine turtle nests. These nest protectors patrol the beach and guard the nests from predators.

The TCP aims to make this programme sustainable by organizing turtle-sensitive, nocturnal "Turtle Watches" for fee-paying visitors.

ii). The TCP school workshop programme and South-West coast beach survey. The TCP has conducted a series of educational workshops for pupils and teachers in schools along the southwest coast (phase 1). At the lectures, pupils and teachers were invited to set up school turtle conservation groups and are invited to participate in the TCP Southwest coastal beach survey (phase2). So far over 1,500 pupils and teachers from 130 coastal schools have participated in the educational programme. During this programme, the TCP distributed the school educational materials that were produced by the TCP in cooperation with the GTZ and the Coast Conservation Dept (CCD).

15 potential school conservation groups have been identified and over 450 pupils and teachers have volunteered to participate in the Southwest coast beach survey. The TCP School lecture programme coordinator, in charge of this programme predicts that there will be a total of approximately 50 school conservation groups when the series of workshops has been completed at all central schools within the extended programme boundaries from Kirinda to Puttalam.

The proposed third phase of this programme, will aim at strengthening the school turtle conservation groups and encouraging them to actively participate in the design, funding and implementation of turtle conservation and awareness raising activities in their local communities. The TCP also aims to undertake an extension of this programme to include the area between Colombo and Chilaw.

iii). Environmental education workshops. In October 1995, the TCP launched a wide-ranging programme of environmental education workshops in the Rekawa community. In March 1996, 14 Rekawa community members graduated from an initial 6-month training programme during which they were trained in educational methods and taught about various environmental subjects relevant to their locality.

These Community Environmental Education Trainers (CEET's) conducted environmental education workshops for school children and community groups in the Rekawa area. The workshops focused on the environment as a whole using techniques such as participatory resource mapping to identify conservation issues and seek sustainable solutions to problems of destructive exploitation.

The TCP currently employs 4 CEET's to run the core environmental and educational programmes such as model medicinal garden project, mangrove nursery, free herbal drink project and library project in Rekawa.

English classes for Rekawa Community members. The TCP has been conducting English language classes in Rekawa since January 1994. These classes employ volunteer teachers from the UK and are attended by approximately 350 community children, adults and English teachers from Rekawa and the surrounding area. With these classes, the TCP aims to improve the employment prospects of participating community members in non-resource dependent jobs and therefore reduce community dependency on environmental exploitation. The classes also helped improve the communication abilities of community members who are employed in TCP research and conservation activities in Rekawa and also they will act as tour guides for the nature trail programme.

Marine Turtle Conservation Workshops/Exhibitions. The TCP has conducted several workshops and exhibitions to increase awareness about marine turtle exploitation in Sri Lanka and the work of the TCP in trying to implement sustainable community participation strategies to combat these threats. Many of these workshops were organized by the CEET's of TCP for important government and non-government institutions such as the Teacher Training College at Unawatuna, the Ceylon Tourist Board, Fisheries Societies, Police station-Tangalle etc.

The Protection Program of the "Caná" Sea Turtle (*Dermochelys coriacea*), and the Participation of the Community; a Cultural Appropriation of a Preservation Process at Acandi and Playona Beaches, Uraba Gulf, Colombia

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The Urabá Gulf is one of the 19 nesting sites of *Dermochelys coriacea* of worldwide importance. The leatherback sea turtle, named by the locals as "tortuga caná", arrives at Acandí and Playona beaches between February and July every year. Rueda *et al*. (1992) concluded that this population is probably the largest one among the Colombian Caribbean Coast nesting populations.

In 1993, the Darién Foundation, an environmental NGO working with the communities to conserve and sustainably manage the biodiversity within the Chocó Biogeographic region, organized a protection program for the Caná sea turtle, which included: education, protection and research.

Aside from the need to protect the species because of its critical situation, the caná sea turtle presents itself as an excellent symbol for the region to be used to develop environmental education and a nature sensitization process. In addition to changing the peoples' attitudes towards the caná itself., the community could become more interested and respectful to nature as a whole.

One of the main problems has been the egg poaching on the nesting beaches. The predation caused by humans and dogs approached 100% before the start of the conservation activities. The fishing industry has also had a large impact, not only on the species but on the marine ecosystem of the Urabá Gulf. The conservation efforts were concentrated with the local people. With only a few volunteers and almost no financial support the work has been done under very difficult conditions for 6 years. The research done by biology students of the University of Antioquia has provided good information to be used as a basis for future management plans.

We have tried to save as many eggs as possible and to protect the hatchlings from predation. In addition, we searched for ways to ameliorate the natives' living conditions as a way to lower poaching pressure upon eggs without causing confrontation with the locals.

The apropriation of the process by the local community through cultural and recreational activities has had valuable results. Songs of many different genres have been written by the locals, as well as graffiti and drawings using the theme of the caná. The town of Acandí has even raised a statue of the caná, and various streets and stores have been named caná.

Every year around Easter time the whole population of Acandí celebrates their commitment to the environment with a parade, in which they choose their "Caná Queen" for the season. This is their way of welcoming the caná females to their beaches, and recognizing the efforts of locals in improving the conditions of the town through environmental awareness.

The children play their part by cleaning the beaches and keeping track of the hatchlings, helping the new-born to reach the sea.

The interaction with the local and national authorities has been focused on defining these nesting sites as special management areas. We are involved in the process of defining the conservation status for these "critical areas" included in the Resolution #1427 on 1996, of the Ministery of Environment. We believe that the population must have a protagonist role in these discussions, since they are the ones who may or may not take care of the sea turtles, with or without financial support, with or without projects, and with or without volunteers and specialists in the field.

It is necessary to create sustainable production alternatives such as fish breeding, handicrafts manufacturing, ecotourism, and others which will increase the living standards of the people. We will be working on this in the near future.

The joint efforts and enthusiasm of several dedicated people have made it possible to go forward with this process, and therefore the caná will have better chances to continue its reproductive cycle after becoming a symbol of respect for all living forms to the local people.

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"Community Participation" in Sea Turtle Conservation: Moving Beyond Buzzwords to Implementation

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Local communities are the single greatest potential asset in support of sea turtle conservation. We are in an era where resources necessary for management are increasingly limited, and where utilization continues despite laws and protected areas. Local communities, who have often been blamed for destroying sea turtles and their habitats, can enhance current efforts to conserve sea turtles through their active participation in collaborative implementation using tools compatible with their cultures. Many projects around the world are now providing insights into the benefits of this common-sense partnership and into the challenges and needs of this strategy.

Importance of Community Participation

There are numerous reasons why community participation is important. Three reasons, the more obvious ones, are as follows:

(1) Despite common perceptions of local communities, they are undeniably a *stakeholder* in sea turtle conservation. They often influence the status of sea turtles in a locality by using sea turtles and/or their habitats. Their presence in areas can present challenges to protection measures. Furthermore, they are often impacted by such protection measures, causing their own difficulties. Their isolation from the conservation process is therefore no longer an option.

(2) The lack of human power and physical presence to ensure conservation is often blamed as reason for failure. Local communities provide *long-term presence* in coastal environments with *great human resource capacity*. While the presence of government agencies and NGOs is often tentative in many rural areas, local communities provide the only permanent presence for the location.

(3) While local people may lack the technical "education" and "science" that we often demand of turtle researchers and managers, they are by no means lacking in valuable *experience and knowledge*. Their historical and cultural ties with turtles hold decades of skill and

observation that can fill critical gaps in information required for conservation.

Assumptions

Of the many assumptions that make community participation a challenge to implement, I would like to point to two of them:

(1) Some assume that "*a community is well defined*." Often members of a community identify themselves based on the administrative divisions given by their respective municipalities. In more rural areas membership in a community may be based on the proximity of a household to the closest village center. Some communities are culturally defined based on political or social identities. Identifying the extent of the community is important in order to ensure equitable participation and distribution of benefits. (In this paper the definition of "community" is based on what the people living in a locality define it to be.)

(2) Some believe "*a community speaks with a unified voice*." Like in any group of people, there lies within a community a variety of opinions, positions, and expectations. It is therefore unrealistic to assume that there will not be divisions and conflicts. However, many communities have their own decision making process and often work towards a consensus or majority opinion. The position presented by a community's leadership may become the overall decision, although such leadership itself may sometimes be a point of contention. Conducting stakeholder analyses and ensuring the presentation of diverse viewpoints at community forums can assist in identifying the more accepted course of action. Such analyses will however reveal that individual decisions will often change when confronted with group decision making.

Current Characteristics

A majority of sea turtles projects that have a community participation component have several similar characteristics. Some of them are as follows:

(1) The mechanisms for facilitating community participation is an *evolving process*. Experiences are based primarily on trial and error. Solutions are location specific, resulting in the absence of a general formula for its implementation.

(2) There are a *variety of definitions* for the common terms used in this regard, such as community, community participation, and community-based conservation. Many of these terms have so many definitions to the point of being ill-defined despite their extensive use. Some definitions are certainly oversimplified, while others are complex beyond achievement. The definition often depends on who is making the definition, with differences between those made by managers and by participating community members of the same project, and also differing from project to project and location to location. Currently used definitions of "participation" vary from a children's education program or a community slide show to activities designed, implemented, and owned by community people.

(3) The most common strategy under the label "community participation" is in the *education* of local community groups followed by *employment* of community members as an alternative to consumptive utilization (such an in employing former egg collectors to patrol beaches and protect nests).

(4) *Leadership* is identified as a crucial factor in the establishment and promotion of community participation. A majority of projects/ activities were initiated by leadership from outside of the community, primarily by researchers and NGOs working with sea turtles in the area. The continued presence of such leadership directly within the community is often required for the continuation of such initiatives.

(5) A majority of projects with advanced community participation recognize that *Conservation has to be integrated with community development*. Their activities therefore go beyond sea turtle conservation, to include health, literacy, and skill training, directed at improving the living conditions within the community.

Critical Requirements for Advancement

Some critical requirements for advancing community participation are:

(1) A *clearer definition of community participation* is certainly needed. At least the target goals over time need to include: a) education of both communities and managers; b) direct benefits to communities; c) active participation of and collaboration with community members; d) decision making by local people; e) working towards local leadership, management, and ownership, and f) strengthening community organizations. (In this paper the term "community participation" encompasses these six goals.)

(2) *Conflict resolution* is necessary. Any situation that involves multiple stakeholders, and especially when such stakeholders interact, there will always be a variety of viewpoints and demands, sometimes resulting in conflicts. Another common conflict is between local communities and externally implemented conservation projects (one that is often denied by many project managers). While resolving such conflicts is often dodged, if addressed they can lead to constructive outcomes. They will however require mediation and facilitation for reaching equitable solutions. In some cultures there exists mechanisms for reaching consensus. It goes without saying that conflicts often escalate to unmanageable proportions if left unsolved.

(3) It is a common belief that education by itself should yield action. At numerous locations project managers have been frustrated by the lack of response by local people to education programs. While education is a vital first step, education by itself has great limitations. *Education has to go hand-in-hand with opportunity*; that is opportunities to implement the information conveyed, be it training in sea turtle management or alternatives to utilization.

(4) *Employment alone is unstable*. While employment is a critical step, along with education, it is dependent on the continued availability of funds to maintain these appointments. Given the funding crises faced by many projects

such continued emphasis is unsettling. I have heard on many an occasion from employed community persons that if their employment is terminated they will have little choice but to return to utilizing resources in the area, which may very well include sea turtles. Therefore, *economic diversification should be the long-term objective*, which can include sources of income other than direct employment by the project, such as cooperatives and cottage industries, for which the community itself can be responsible.

(5) It is also necessary to *invest in understanding the human component* of conservation. The greatest investment of resources, time, and effort, is in the research and understanding of the biological issues surrounding sea turtles. But if it is people who are creating the need for management efforts, why are such investments into the human dimensions so few? In some instances understanding the socio-cultural aspects of the associated people are equally, if not more, important than the biological aspects of the resource. We are often quick to find out how successful activities have been on reducing sea turtle mortality and species recovery, but we often forget to even inquire as to the impacts of those same activities on the people that were involved. For example projects implement economic alternatives to consumptive utilization, but very few, have conducted follow up studies to ensure that the alternatives are economically sustainable and without negative impacts on the associated people. Topics that need attention include the cultural and economic values of sea turtles to different communities, and the monitoring and evaluation of impacts of current conservation practices on associated people.

Promotional Activities

The following activities are being pursued to promote community participation and facilitate its implementation:

(1) *Information exchange* is the most critical step necessary for promoting community participation. Projects will benefit from knowing what other projects are out there with community participation initiatives, and of the different approaches that they have undertaken for this purpose. Specific actions for information exchange include: a) the exchange of contact information and materials between projects (such as brochures, newsletters, and reports); b) the sharing of project descriptions and activities through presentations at conferences and workshops, as we have seen at the annual sea turtle symposiums; and c) site visits by project leaders both to and from successful programs.

(2) *Mutual assistance between community projects* in order to provide projects with feedback on proposed activities, as well as on options available for managing challenging situations, is also necessary. Numerous projects have undertaken very similar approaches and often experienced very similar obstacles. Mutual assistance can enable projects to avoid reinventing the wheel as well as save limited resources.

(3) *Training of project managers* in issues pertaining to community participation is certainly warranted, especially when there is an emphasis on managers trained only in the biological sciences to lead conservation projects. Since community participation is a social and political process, and multi-disciplinary in understanding and implementation, providing managers with exposure to the social sciences is necessary. A greater understanding and use of non-biological information and tools is a requirement. Project visits and on-site training can encourage managers to expand their current approaches. Topics for such training include community surveys, conflict resolution, and facilitation of collaborative decision making.

Conclusion

Active community participation in sea turtle conservation is the most practical approach to establishing sustainable sea turtle programs, primarily in developing countries. We need to move towards expanding community roles, while communities too need to move towards taking greater responsibility for their participation, as a result of their increased involvement. More people with more hands and minds can only improve current efforts to conserve sea turtles. Greater integration of communities and sea turtles can only be beneficial to both.

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THREATS - FISHERIES, COASTAL ARMORING, AND BEACH RENOURISHMENT

Incidental Capture of Sea Turtles by Costa Rica's Longline Fleet

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The incidental capture of sea turtles by longline pelagic fishery operations has been studied primarily in the North Atlantic and North Pacific Oceans (Lutcavage, *et al*., 1997). High numbers of loggerhead sea turtles (*Caretta caretta*) are captured in the distant northeast Atlantic and North Pacific Oceans during the seasonal swordfish fishery, (Balazs and Pooley, 1994; Witzell, 1998). Furthermore, expanding industrial longline fishery operations east of the Galapagos Islands may be inhibiting conservation efforts at Central American and Mexican nesting beaches for the eastern Pacific leatherback (*Dermochelys coriacea*) (Arauz, 1999).

Basic distribution patterns of sea turtles at sea are needed to evaluate the impact of longline fisheries on sea turtles, and thus develop methods or fishing policies that protect these endangered species. However, in Latin America, in spite of being acknowledged as one of the key issues to understanding the current status of sea turtles, detailed and systematic information on interactions with industrial fisheries is scarce (Frazier, 1997). This paper describes the incidental capture of sea turtles during two longline-fishing cruises in Costa Rica.

Methods

Observer data were collected during two longline-fishing cruises. One was on a former industrial shrimp vessel modified for longline fishing (Nov. 11, 1997) and the other was on a 19 m longline research vessel belonging to the Costa Rican Technical Training Institute (INA) from Oct. 5-19, 1998. The former is classified as an "Industrial Vessel", of which 6 are registered in Costa Rica, while the later is classified as an "Advanced Artisanal Vessel", 450 of which are registered in Costa Rica (19-23 m long, 6 to 8 weeks autonomy, longlines from 70 to 120 km).

During the cruise on the industrial vessel, turtle catch and mortality were recorded for two sets (Vargas, 1997). During the second cruise, turtle catch and mortality were recorded along with information on the total catch (sharks, rays, billfish and maji-maji) during 7 sets (Rodríguez, 1998).

Results

The two sets by Vargas (1997) were located east of the Galapagos Islands, at 0°22'51"N and 92°06'10"W, and 0°09'18"S and 91°58'57"E. The mean depth was 25-50 m, the length of the motherline was 72 and 80 km resp., and the target species were billfish and shark. A total of 34 turtles were caught on 1,750 hooks during two sets for a Catch Per Unit Effort (CPUE) of 1.42/100 hooks. Of the turtles captured 55% were olive ridleys (*Lepidochelys olivacea*) while 45% were Eastern Pacific greens (*Chelonia mydas agassizzi*) (**Table 1**). Mortality was 8.8%. During an additional set in the same location, two juvenile leatherbacks (carapace length no greater than 60 cm) were captured, hooked in the shoulders. Unfortunately, no information was being recorded at the time, but both captures were recorded on video.

The seven sets by Rodríguez were located within the Exclusive Economic Zone (EEZ) of Costa Rica (**Fig. 1**). Mean depth ranged from 72 to 90 m, the length of the mother line ranged from 7.4 to 16.6 km. Target species were billfish and maji-maji. During the 7 sets, 1804 hooks were deployed, capturing 26 olive ridleys for a CPUE of 1.44/100 hooks and 0% mortality. Of the turtles captured 23 (88.5%) were hooked in the mouth and 3 (11.5%) were hooked in either the flipper or mouth (**Table 1**).

A further analysis of the total capture (commercial and non-commercial species) is provided in **Table 2**. Of the 99 turtles captured, 26 (26.26%) were olive ridley sea turtles.

Discussion

The incidental capture of sea turtles (measured by CPUE) by the Costa Rican longline fleet is high when compared to results from the North Atlantic (Witzell, 1998), but average when compared to reports from the Brazilian South Atlantic (Barata, 1998).

After nesting olive ridley sea turtles disperse over a large geographic area and migrate independently (Plotkin, 1995). The catch rates recorded in this paper indicate an important interaction of both olive ridley and Pacific green

Table 1. Description of longline sets and sea turtle incidental capture by an industrial Costa Rican long line vessel, November, 1997 (Vargas) and an experimental vessel in Costa Rica's Exclusive Economic Zone, October 1998 (Rodríguez, 1998).

Type of Vessel	# Sets	Depth (m)	# Hooks	Length of Mother Line	# Turtles	CPUE	% Species Composition	% Mortality
Industrial	2	25-50	1750	72-80	34	1.94	55 *L.o.* 45 *C.m.a.*	8.8 (total)
Experimental	7	72-90	1804	7.4-16.6	26	1.44	100 *L.o*	0

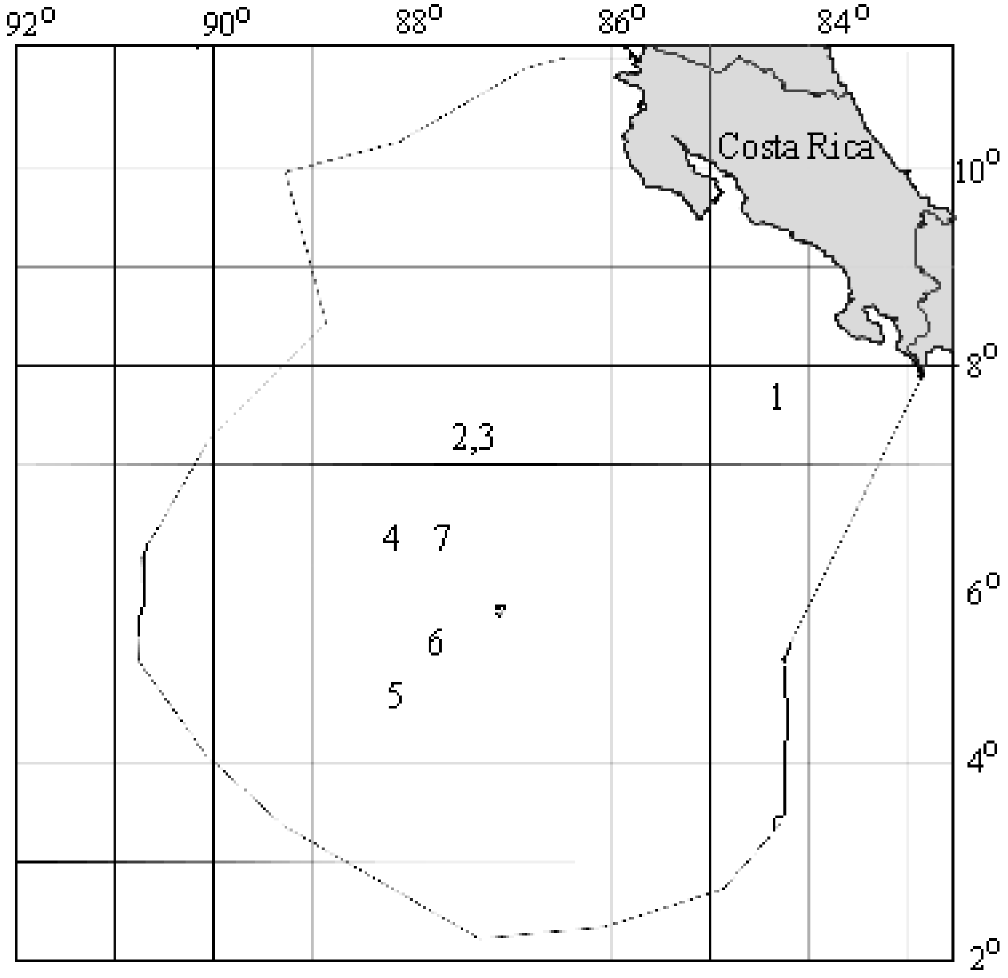

Figure 1. Location of the seven sets recorded by Rodríguez, 1998 within the Economic Exclusive Zone of Costa Rica.

Table 2. Total Number of individuals by species captured during 7 industrial long line sets, in Costa Rica's Exclusive Economic Zone (Rodríguez, 1998).

Species	**Common Name**	**Sets**						
		1	**2,3**	**4**	**5**	**6**	**7**	**Total**
Prionace glauca	Blue shark	-	-	8	3	1	1	13
Carcharhirus falciformis	Creole shark	1	20	1	3	3	-	28
Sphyrna lewini	Scalloped hammerhead shark	1	-	-	-	1	-	2
Galeocerdo cuveiri	Tiger shark	-	-	1	-	-	-	1
Sphyrna zygaena	Smooth hammerhead shark	-	-	-	1	-	-	1
Carcharhinus longimanus	Dog shark	-	-	1	-	-	-	1
Alopias superciliosus	Thresher shark	-	-	1	-	-	-	1
Tetrapturus audax	Striped marlin	-	1	-	-	-	-	1
Makaira mazara	Blue marlin	-	-	-	-	1	-	1
Istiophorus platypterus	Sailfish	2	-	-	-	-	-	2
Coryphaena hippurus	Maji-maji	3	-	1	-	-	-	4
Sting rays		2	2	8	4	1	1	18
Lepidochelys olivacea	Olive ridley sea turtle	15	2	7	2	-	-	26
TOTAL		24	25	28	13	7	2	99

sea turtles with the longline fishery. Even though mortality is relatively low, in reality it may be much greater, depending on the manipulation of sea turtles by fishermen while removing or recovering fishing gear. A major concern is the expansion of the longline fleets of Central America and Southern North America. Since evidence suggests that the Eastern Pacific leatherback follows post-nesting routes within the EEZ towards Cocos Island on their southward migration toward feeding grounds in South America (Morreale, *et al*., 1996; Eckert and Sarti, 1997). It is of extreme importance to increase research in this field throughout Central America, including a campaign among fishermen to release turtles unharmed when possible.

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The Kemp's Ridley and the Gulf Of Mexico Shrimp Fishery

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The offshore shrimp fishery of the Gulf of Mexico has made significant contributions to the recovery of the Kemp's ridley sea turtle. As an industry they have voluntarily provided significant financial and logistical support of the nesting beach protection effort. Logistical support provided includes constructing a base camp facility at Tepehuajes, providing three-wheel vehicles for beach surveys, and providing other equipment and materials as requested. Nesting beach protection has been demonstrated to be one of the most important, if not the most important factor accounting for the observed recovery of this sea turtle. Further, the industry has demonstrated a high compliance rate (over 98%) with the TED requirements imposed since 1990. These contributions have not been without cost. Shrimp loss with the approved TED that can be used under Gulf conditions is, as was predicted by the National Marine FisheriesService, about 19%. These losses correspond to a reduction in the number of offshore vessels participating in the fishery down to 1960 levels. Further, as documented by Texas A&M economic studies, those vessels remaining in the fishery have a net profit level of about 4%, a narrow margin between profitability and loss. Funds available for vessel maintenance are restricted to the bare minimum needed for safety, leading to an overall decline in the fleet. Vessel units continue to decrease, as many are retiring several old vessels and replacing them with a single new vessel. Despite these contributions to Kemp's ridley recovery and the costs incurred, the Gulf shrimp industry continues to be singled out by some sea turtle conservation extremists as being the major impediment to Kemp's ridley recovery. It is as if no contribution has even been made, and as if a marked recovery is not in progress. This view is fundamentally and ethically wrong, and is certainly not conducive for developing a partnership in sea turtle conservation.

A Spatial Analysis of Sea Turtle Abundance and Shrimping Intensity in the U.S. Gulf of Mexico

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By-catch in shrimp trawl fisheries has been determined to be a major source of mortality for large juvenile and adult sea turtles. As a result of this high mortality, Turtle Excluder Devices (TEDs) were developed. Since 1995, TED compliance has been high (~97.6%) in the Gulf of Mexico and most shrimpers are properly installing and using TEDs. But sea turtle mortality remains a problem in the Gulf of Mexico. Significantly increased strandings, including a high proportion of Kemp's ridleys, occurred throughout the southeast in 1994, and strandings were again high in 1995, especially in Louisiana and Texas. Some have suggested that TEDs alone may not provide adequate protection for sea turtles in the Gulf of Mexico and that managers should evaluate the potential for seasonal or spatial closures as a supplement to TEDs.

In order to examine the scientific feasibility of area closures for sea turtle protection, we determined the spatial dynamics of sea turtles and shrimp fishing for the United States Gulf of Mexico waters. Relative sea turtle abundance was obtained by analyzing NMFS aerial survey data in September, October, and November of 1992, 1993, and 1994. Although we would have preferred to have access to data on sea turtle and shrimp fleet distributions across the peak of the shrimping season (April to October), these are the only comprehensive aerial survey sea turtle data available. Turtle sightings were grouped by depth zones and NMFS fishery statistical zones, and strip transect methods were used to estimate the relative abundance of sea turtles in each subzone. The basic premise behind strip transect methodology is that a strip of a specific width is defined in the aerial survey process and only the animals within this strip are counted. In this study, the effective strip width was 50 to 250 meters on both sides of the survey platform. Sea turtle observations were converted to density by dividing the number of sea turtles observed in the subzone by the total area surveyed in the subzone.

Average shrimping intensity was calculated for each subzone for all months of 1992, 1993, and 1994 as well as for the months of the aerial survey (September through November). Gulf of Mexico shrimping effort was collected through the NMFS port agent program. The shrimping effort data was measured in "days fished" (24 hours of actual fishing) and the shrimping effort value for each subzone was standardized into days fished/km^2.

The overlap of relative sea turtle abundance and shrimping intensity will provide valuable insight into the spatial dynamics of the U.S. Gulf of Mexico. Sea turtles were observed at much higher rates along the coast of Florida compared to the Western Gulf; the highest density of sea turtles was observed in the Florida Keys region (0.525 turtles/km^2). Shrimping intensity was highest in the Western Gulf along the coast of Texas and Louisiana (where relative turtle abundance was noticeably reduced), for both annual and fall estimates. The fall shrimping intensity is lower than the annual estimate, but the spatial pattern of shrimping effort in the fall appears fairly consistent with the year-around pattern. In the Eastern Gulf, one area of high shrimping intensity does occur outside the Dry Tortugas Shrimp Sanctuary in southern Florida.

Among alternative management scenarios, area closures in conjunction with continued TED requirements would probably best prevent sea turtles from future extinction. Recently, a strong case has been made for closing the waters off Padre Island National Seashore, Texas. This beach has the potential to become a second nesting site for the highly endangered Kemp's ridley sea turtle, but many large juvenile and adult female Kemp's ridleys continue to strand on Texas beaches. This study demonstrates that both shrimping intensity and sea turtle abundance are relatively high in south Texas, at least in the fall. If these patterns are consistent throughout the most intense shrimping period (in the summer), a seasonal closure of these waters to shrimping could contribute strongly to the development of a second nesting colony for Kemp's ridleys.

This project also clearly identified the relatively high abundance of sea turtles and low shrimping intensity in south Florida waters. Restricting shrimping in these areas would have a much smaller economic impact on the Gulf shrimping industry as a whole than closing most other areas, but it would clearly have local effects. Furthermore, if managers want to consider seasonal or areas closures, closing an area with little shrimping activity and high sea turtle abundance may be easier to implement than in most other Gulf areas.

Sea turtle relative abundance and shrimping intensity are not uniformly distributed over the U.S. Gulf of Mexico, but the primary sea turtle protection strategy, TEDs, has been uniformly applied to all waters. It could be that in addition to TED requirements, future sea turtle protection should look at a more spatially explicit approach to managing these endangered and threatened species. Area closures are one such option.

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The Impact of Coastal Armoring Structures on Sea Turtle Nesting Behavior

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I surveyed three beaches on the East Coast of Florida to compare the nesting behavior of loggerhead turtles (*Caretta caretta)* in front of seawalls to that of loggerheads on adjacent, non-walled beaches. Beach profile data were used to examine spatial relationships of turtle nests and seawalls and to describe physical changes in the beach during the nesting season. A total of 252 turtle emergences from the water and onto the beach were documented over the 25-day survey period. Fewer turtles emerged onto beaches in front of seawalls than onto adjacent, non-walled beaches, and of those that did emerge in front of seawalls, more returned to the water without nesting. The lower number of emergences on beaches with seawalls suggests that nest site selection was made by some turtles before emerging onto the beach. Of the 52 crawls recorded in front of the seawalls, 37 (71%) of them indicated that the turtles had come into contact with the walls. Of those turtles that contacted a wall, 32 (86%) returned to the water without nesting.

My nesting data and beach profile data indicated that turtles nested at higher elevations on non-walled beaches than they did on beaches with seawalls. Seawalls blocked the turtle's access to higher elevations and resulted in an increase in abandoned nesting attempts.

As coastal armoring becomes more prevalent on a given stretch of beach, the probability of a turtle emerging in front of the structure will increase, thereby increasing the probability of non-nesting emergences. A simulation model was derived using data from this study to show the cumulative effect of increased shoreline armoring on turtle nesting emergences. This model can be used to forecast changes in turtle nesting activity on armored beaches around the state.

Sand on Florida Nesting Beaches: Does Size Really Matter?

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Information on grain size distributions, mean grain size and the sorting coefficient for sediments on Florida nesting beaches was summarized to characterize the different nesting substrates in the state. Information from three renourished beaches before and after fill placement was also analyzed to determine the "similarity" of the nourished beach to the native, or non-nourished, beach sands. Nesting information for loggerhead turtles (*Caretta caretta*) submitted either as part of the fill placement project monitoring or the Index Nesting Beach Surveys was analyzed to document nesting and reproductive success before and after fill placement.

Introduction

Previous surveys of 27 beach restoration projects indicated that nesting success, or the ratio of the number of nests to the total number of emergences, for loggerhead turtles was significantly lower (32% decline) the first nesting season after fill was placed on the beach than pre-project rates (Trindell *et al.* 1998). At most locations, nesting success increased to pre-project levels by the second year following construction, but at some projects, nesting success, and the number of nests deposited, did not. Failure of nesting activity to recover following construction may be attributable to a number of causes, including changes in the mean grain size and the sorting coefficient in the nesting substrate.

Methods

We assessed 1) the average grain size and sorting for sands on Florida beaches that have reportedly never been nourished; and 2) changes in grain size and sorting on beaches that have been nourished. Where sufficient information was available, we assessed loggerhead turtle nesting and hatch success in areas with known grain size, both before and after nourishment. Sand grain size information was obtained from the Florida Dept. of Environmental Protection joint coastal permit files and monitoring reports. A total of 13 projects were reviewed to assess native sand grain size and sorting prior to and after beach nourishment. Information on sand grain distributions was also taken from the literature or unpublished reports to the Department (Martens, 1935; Ackerman *et al.,* 1990). Mean grain sizes and sorting coefficients were calculated using the Moment Method (Balsillie, 1995).

Marine turtle nesting information was collected by authorized permittees during required monitoring for nourishment projects or as part of the Index Nesting Beach surveys. For comparisons of marine turtle nesting patterns with sediment grain size, nesting data was obtained from the beach area where the sediment sample was obtained. Where sufficient data was available for analysis, sand characteristics and loggerhead nesting were compared using the SAS System for Windows v.6.12 (SAS 1985). All data were tested for normality prior to analyses; means and 1 standard error of the mean are presented.

Results

No consistent pattern of loggerhead turtle nesting density and average grain size or sorting was detected when all data were pooled and inspected. Beaches on the East

Coast (n=11) had average grain sizes ranging from approximately 0.48 to 0.7 mm (**Fig. 1**). West Coast beaches (n=4) had a greater average grain size and were more poorly sorted.

Comparisons of nourished and native (non-nourished) areas within a beach indicated that 66% of the nourished beaches had mean grain sizes coarser than native beaches and 22% of the nourished beaches had mean grain sizes finer than native beaches after fill placement.

A site-specific assessment of loggerhead nesting before and after nourishment was made for three projects where grain size changes were noted. The 1997 Ocean Ridge project (Palm Beach County) consisted of the placement of almost 700,000 cubic yards of fill. Sands on the native beach (1992) had an average grain size of approximately 0.38 mm (± 0.005) and were moderately sorted (0.55 sorting coefficient ±0.05). Prior to nourishment, nesting emergences ranged from 44 to 141 per km, with approximately 28 nests per zone (±19.5; n=2 zones) for those zones with grain size data. After fill placement, the mean grain size (0.67 mm±0.14) and the sorting coefficient (0.99±0.25) increased, while nesting success declined from 54% (±7) to 37% (±3) (Davis and Howard, 1998). Reproductive success also differed for Ocean Ridge beaches before (1997) and after (1998) fill placement as hatching success and emergence success (the ability of hatchlings to escape on their own) were significantly lower after fill placement (p=0.0002, ANOVA, $F_{1,5}$=160.29 for hatching success and p=0.0002, ANOVA, $F_{1,5}$=192.71 for emergence success).

The 1996 Collier County projects involved placement of fill on three beaches, Naples (800,000 cubic yards), Parkshore Beach (90,700 cubic yards), and Vanderbilt Beach (327,300 cubic yards). We compared areas that received fill and adjacent areas that were not filled during 1996. On non-nourished beaches, nesting emergences ranged from 0 to 28 per km, with approximately 2 nests per km (±0.88; n=3 zones) on Naples Beach, 18 nests per km (n=1 zone) on Park Shore Beach, and 7 nests per km (±1.5; n=2) on Vanderbilt Beach (Kraus *et al*., 1999). The sands on these non-nourished beaches were fairly coarse (1.18 mm (±0.24) to 2.86 mm) and poorly sorted (2.01 mm (±0.39) to 5.17). Sands on nourished beaches were also fairly coarse (0.75 mm ±0.18 to 2.73 mm ±0.64) and poorly sorted (1.52±0.32 to 3.89±0.59). The results of a stepwise regression (backward) of dependent variables confirmed that the number of nests deposited on nourished and non-nourished beaches was significantly related to both mean grain size and sorting coefficient (p=0.0004, $F_{2,15}$=14.08, R^2=0.65, Stepwise Regression)

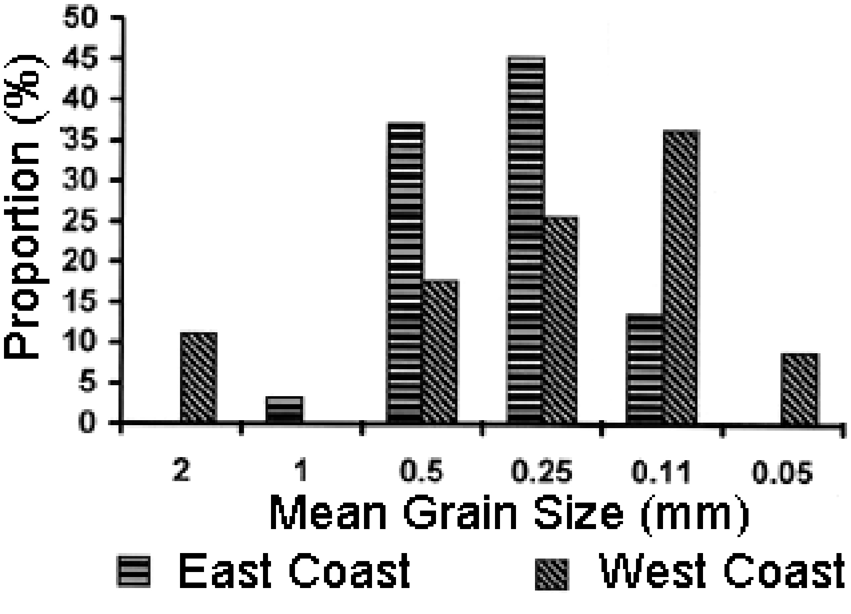

Figure 1. Comparison of East Coast and West Coast beaches.

The final project examined was at Hutchinson Island (1995), which involved the placement of approximately 1.3 cubic yards of sand along 4 miles of beach. During 1997, the mean grain size for non-nourished beaches was 0.5 mm (±0.14) with moderate sorting (0.67±0.06). Nourished areas had an average grain size of 0.6 mm (±0.23) and were poorly sorted (0.92±0.27). The number of loggerhead nests on the non-nourished beach averaged 237 nests/km, with 134 to 155 nests/km deposited on two nourished sites. Overall, mean grain size and sorting were higher on nourished sites compared to the adjacent control during 1997 and the number of loggerhead nests and nesting success were significantly lower on nourished sites. There were no differences for hatch success, which was relatively low on both the control and nourished sites (Ernest and Martin, 1998).

Discussion

Loggerhead turtle nesting patterns vary across many different sediment types and grain sizes in Florida. Our review indicates that mean grain size and the sorting coefficient of the nesting beach sand may influence marine turtle nesting. Nest numbers declined on beaches with increased sand grain size, or increased coarseness, after nourishment and as the sorting coefficient increased.

Larger sand grain diameters have been correlated with increased abandonment of nesting attempts as well as increased mortality of hatchlings and eggs for green turtles (*Chelonia mydas*) on Ascension Island and Aldabra Atoll (Mortimer, 1990). This previous study compared sand characteristics from individual successful or abandoned nesting sites. In our review of sediment characteristics and marine turtle nesting, pooled for larger segments of beach, the number of nests and nesting success can decline after nourishment if coarser material is placed on a nesting beach. These changes can be persistent.

Assessments of changes in average grain size and impacts on marine turtle nesting on nourished beaches are complicated by the absence of nesting habitat on the pre-project beach, since prior to nourishment "eroded" beaches are relatively narrow and may lack suitable nesting habitat. Often, managers must chose between no beach, which increases the demand for coastal armoring, or a beach built from material that is not similar to the native beach. Marine turtles have been documented to nest in substrates which produce zero reproductive success (Mortimer, 1990), and the mere act of placing sand on an eroded shoreline is not automatically a benefit to marine turtles. Finally, there appears to be a desire to utilize coarser grain sand for beach nourishment, since these types of sand typically last longer and many of the "best" sand sources are depleted. Additional information on changes in marine turtle nesting and reproductive success is needed so that managers can adequately assess and minimize impacts to marine turtles due to nourishment using these coarser substrates.

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OLIVE RIDLEY ARRIBADA POPULATIONS

Arribada Dynamics at Ostional, Costa Rica

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The massive nesting behavior of the olive ridley marine turtle (*Lepidochelys olivacea*) may be observed in four major locations in the world. Each of these beaches show unique conditions of density, timing, frequency and hatching success.

Observations and analysis, using custom software, of the nesting characteristics of the 12 to 14 arribadas that may occur, show unique fluctuations in the INTER and INTRA nesting periods with the resultant effects on hatching success.

This data is being used for management decisions in the Ostional National Wildlife Refuge.

Solitary Nesting Activity in the Ostional Wildlife Refuge, Costa Rica and the Impact of Poaching (during Solitary Nesting) and Harvesting (during Arribadas) on Olive Ridley Sea Turtle Nests (*Lepidochelys olivacea*)

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The Ostional Wildlife Refuge is well known for the occurrence of the massive synchronized nesting of olive ridley sea turtles (*Lepidochelys olivacea*), an event known as an "arribada". Ostional is the only nesting beach where harvesting and commerce of eggs are allowed, under a management plan that has the two-fold benefit of providing the community with a source of income, as the eggs are highly prized as "bocas" or appetizers in local cantinas, while egg harvesting may also improve incubation conditions, thus increasing hatching success. (Alvarado and Ballestero, 1985; Cornelius, *et al.,* 1991). Solitary nesting also occurs throughout the year in Ostional. These nests are important to the maintenance of these populations, as they manifest higher hatching success rates when compared to arribada nesters (Castro, 1987), and the community is committed to protecting these nests as well. In spite of it's biological importance, solitary nesting has never been evaluated in Ostional, nor has the magnitude of poaching and the efficiency of community controls.

This paper will describe solitary nesting activity in the Ostional Wildlife Refuge from July 22 to December 1998. In addition, poaching and the efficiency of community control were evaluated. Finally, a preliminary study was carried out to compare hatchling production between harvested and non-harvested areas of the beach during an arribada.

Methods

The 7-km beach was divided into 50-meter wide sectors. Daily monitoring of solitary nesting olive ridley sea turtles was carried out, and the number of nests poached, predated and undisturbed or "survived" per sector was recorded.

The legal harvesting regime during arribadas was experimented with so as to compare hatchling production per square meter in harvested and non-harvested areas of the beach. Harvesting during the first 36 hours of the arribada (as established by the Management Plan) was allowed in three 50 m sectors, while no harvesting was allowed in two 50 m sectors. In each of these harvested and non-harvested areas, three 1m^2 plots were dug to determine nest fate. Nest fate was categorized as "fresh nests" (eggs laid during the current arribada), "developing nests" (eggs laid during a previous arribada which showed the presence of a viable embryo), "rotten nests" (eggs that had spoiled, with or without embryonic development) and "cooked nests" (nests which had the appearance of being hard-boiled, due to the high sand temperature).

Hatchlings were collected in December and January from the October and November arribadas respectively. A 10 m long wire barrier was constructed at the birm in the middle of each experimental plot. Hatchlings were collected every half an hour during the massive hatchling emergence, after which they were counted and released into the sea.

Results

Solitary Nests. Solitary nesting activity was grouped into 7 areas of 20 sectors each (**Fig. 1**); El Rayo (1– 20), El Rayo II (21 to 40), Pueblo (41 to 60), Main Nesting Beach (61 to 80), Nosara I (81 to 100), Nosara II (101 to 120), and Nosara III (121 to 140). From July 22 to December 31 of 1998, 9,863 solitary olive ridley nests were recorded. Of these, 78.4% nests survived the first 24 hours, 16.2% were poached during or soon after oviposition, and 5.4% were predated by pigs, feral and domestic dogs, cats, raccoons, coatis, crabs and vultures.

Solitary nesting occurred throughout the 7 km stretch of beach, with greatest activity recorded in the central areas, from El Rayo II to Nosara I (1600 to 2200 individuals/area) with lesser activity in the extreme northern and southern areas (<800 individuals/area). Poaching was recorded throughout the beach, with higher poaching rates towards the southern end, mainly Nosara I and Nosara II (52.6%) (**Fig. 2**).

Peak nesting activity occurred in August and October, with a decrease in activity during September (**Fig. 3**). However, the highest poaching rates were recorded during July (30.2%) and Dec. (23%). On an average per month, 16.2% of the nests laid were poached. 10 leatherback turtles (*Dermochelys coriacea*) also nested, in addition to 2 false crawls, between November, 1998 and January 12, 1999. One

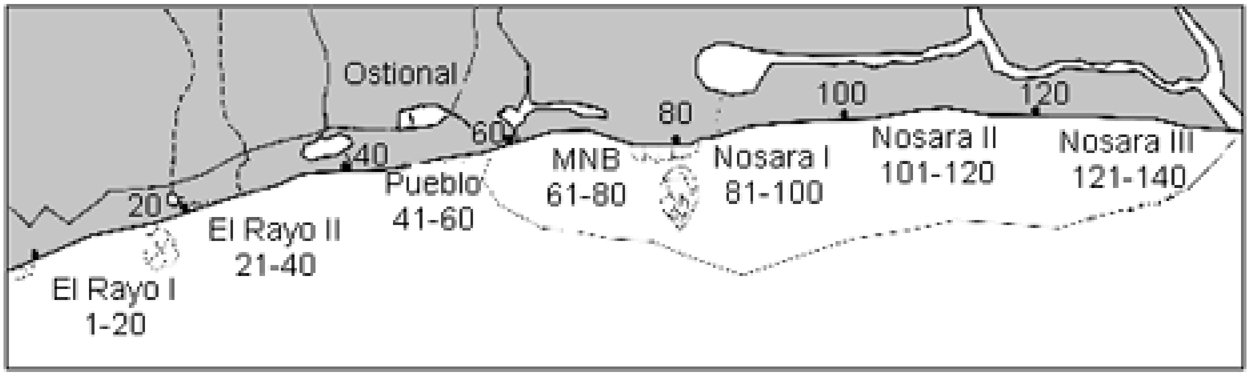

Figure 1. Areas of the nesting beach of Ostional, with a marker every 20 sectors of 50 ms each.

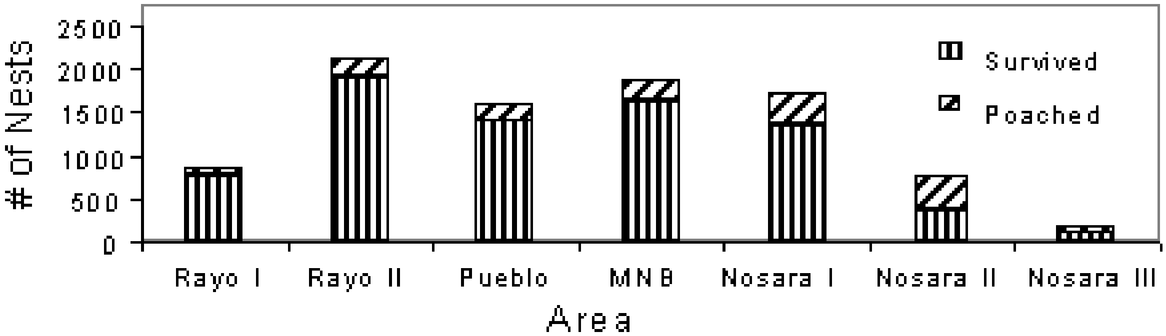

Figure 2. Solitary nesting activity and poaching per area in the Ostional Wildlife Refuge, Guanacaste, Costa Rica, from July 22 to December 31, 1998.

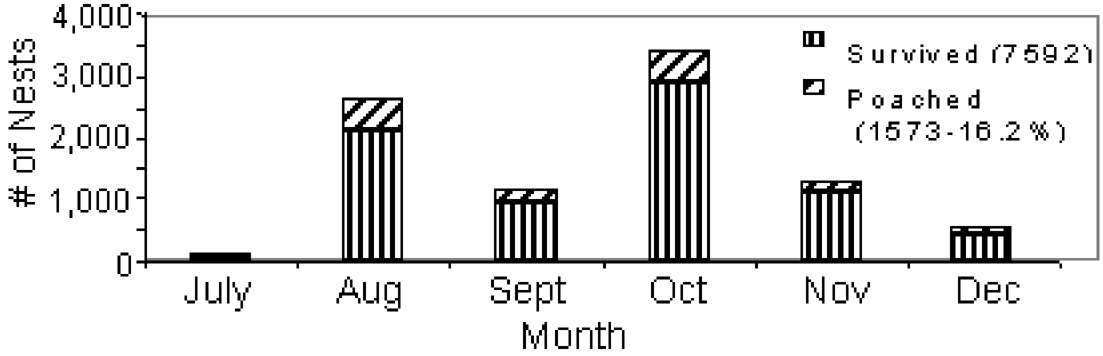

Figure 3. Solitary nesting activity and poaching per month, in the Ostional Wildlife Refuge, Guanacaste, Costa Rica, from July 22 to December 31, 1998.

of the false crawlers had a pit tag from Las Baulas National Park in Playa Grande, Guanacaste, Costa Rica.

Nest Fate in Harvested and Non-Harvested Sectors of the Beach. **Table 1** shows a summary of our nest fate study in harvested and non-harvested sectors of the arribada beach, for October and November arribadas. Non-harvested areas always presented high loss in the "rotten nests" category (45.5%-67.8%), while harvested areas showed increasing "rotten nests" rates from Oct. to Dec. (<1%, 25.1%, and 68% respectively). In November, the percentage of developing nests in harvested areas was 24.9%, much higher than in the non-harvested areas (6.1%), which would be expected if we assume that egg harvesting improves incubation conditions. However, in December the percentage of developing nests decreased to only 7.1%, while in the non-harvested areas it increased to 30%.

The overall percent hatchling production per square meter for October and November was found to be higher in the non-harvested sectors (2.4%) as compared to the harvested sectors (1.8%). Statistical analysis for significance was not done due to the small sample size.

Discussion

Poaching seems to occur as an opportunistic activity. For instance, poaching is greater in the Southern extreme of the 7 km beach, which is easily accessible to poachers from the nearby southern town of Nosara, who take advantage of the weaker controls due to the more difficult access from

Table 1. Fate of nests in harvested and non-harvested sectors of the beach.

	October (%)		**November (%)**		**December (%)**	
	Harv	**Non-harv.**	**Harv.**	**Non-harv.**	**Harv.**	**Non-harv.**
Fresh Nests	21.2	49.9	29.9	20	14.2	24.5
Rotten Nests	<1	50.1	25.1	67.8	68	45.5
Cooked Nests	78.8	<1	20.1	6.1	10.7	<1
Developing nests	-	-	24.9	6.1	7.1	30

Ostional. Poaching activity is also higher during the beginning and the end of the season, when fewer rangers are hired for control. Even though this pattern proves that protection by community hired rangers does have a positive effect, a considerable amount of poaching is also recorded directly in front of the community (Pueblo).

In both Nancite and Ostional, Cornelius *et al.* (1991) had found a higher proportion of hatched nests in areas that were frequently washed by incoming tides. We also found this in our experimental harvesting regime sectors. One of the areas, in which no harvesting was allowed, had an estuary behind it that broke into the ocean during the wet season. This area produced a higher number of hatchlings/m^2 than all the other experimental areas. The non-harvested areas also had a greater density of fresh nests per square meter (0.8) compared to that of harvested areas (0.7).

Management Options. Harvesting must be confined to the arribada areas of the beach during the first 36 hours, and stronger measures taken against poaching. Guards should be posted strategically at the south end of the beach where a large number of solitary nests are laid and poaching is greatest. Educational programs in the community against poaching should be implemented, and stronger sanctions must be imposed by the Ostional Development Association.

Nest fate and hatchling production is obviously greatly influenced by environmental and physical factors. Unfortunately because of our small sample size and short duration of study, we could not come to any definitive conclusion on a comparison of the results for hatchling production in harvested and non-harvested areas. Methods must be developed to collect data over a long time span.

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Can the Olive Ridley Turtles in Orissa, India Be Saved - A Review of the Scientific Facts Available

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Olive ridley turtles, *Lepidochelys olivacea,* nest in low densities all along the eastern coast of India. However, the most important nesting beaches lie in Orissa, where the mass nesting occurs. The olive ridley turtle is well known for its annual mass nesting or arribada, when several thousand turtles migrate to the breeding ground to mate and nest simultaneously. The 480 km Orissa coast harbors three such mass nesting beaches. These are the Gahirmatha rookery near the mouth of rivers Brahmani and Baitarani along the northern Orissa coast, the rookery near the mouth of river Devi located 100 km south of Gahirmatha, and the Rushikulya rookery located 320 km south of Gahirmatha near the mouth of river Rushikulya along the southern Orissa coast. A significant portion of world's olive ridley population that migrates every winter to the Indian coastal waters nests at these three rookeries.

The Gahirmatha beach was the first of Orissa's nesting beaches to be made known to the scientific community during the mid-1970s by the FAO/UNDP crocodile project (Bustard 1976). Substantial nesting has been recorded at this site with over 100,000 turtles in most years and over 600,000 turtles in peak years (Dash and Kar 1990). Due to a cyclonic storm and beach erosion, the Gahirmatha beach was considerably reduced in size when a 3 km long spit broke away from the mainland in 1989, reducing the 10 km nesting beach to a 3 km island. From 1990 the arribada continued in this island and the last arribada recorded here was in 1996. Since 1997 this 3 km long island has further been fragmented into two parts and has been greatly reduced in length, width and height. Where as the average beach width was 140 m in 1996, it was reduced to only 60 m in 1997. Reduction in beach height also resulted in frequent inundation of nesting ground. While 83% of the tracks monitored (n=800) in 1996 resulted in nests, only 23% (n=1990) monitored during 1997 and 1998 resulted in nests, thus indicating unsuitability of beach conditions for the turtles to nest.

The rookery near the mouth of river Devi was discovered in 1981 (Kar 1982) and was then completely forgotten by the scientific and conservation community. Since then much of the nesting area at this rookery has been altered by a Casuarina (tree) plantation and the nesting population has shown a considerable reduction in number (Pandav *et al.* 1994). The Rushikulya rookery was discovered in March 1994 (Pandav *et al.* 1994 a & b). Since 1994, olive ridleys have been nesting en-masse at this rookery with considerable fluctuations in the number of nesting females from 60,000 in 1995 to 8,000 in 1998.

All five species of sea turtles that occur in India (including the olive ridley) are legally protected. They are included in Schedule I of the Indian Wildlife Protection Act (1972), as well as in Appendix I of Convention of International Trade in Endangered Species of Wild Flora and Fauna (CITES) that prohibits trade in turtle products by signatory countries. The mass nesting beach at Gahirmatha is a part of the Bhitarkanika Wildlife Sanctuary. The coastal waters off Gahirmatha were declared a marine sanctuary in 1997. The coastal waters off Devi and Rushikulya rookeries have been declared a no-fishing zone during the turtle breeding season.

Despite the legal protection given to the sea turtles, the sea turtle population migrating to the coastal waters off Orissa has been declining in recent years. The death of several thousand adult breeding individuals in Orissa each year has become a major concern of the national and international community. The biggest cause of mortality is the incidental capture of adult turtles in trawling nets. Uncontrolled shrimp trawling in areas of high sea turtle concentration has resulted in heavy mortality of adult sea turtles during the last decade. Dash and Kar (1990) reported the stranding of 4,682 adult olive ridleys at Gahirmatha rookery between September 1978 and May 1983. In 1993, during a six-month survey by Wildlife Institute of India (WII), 5,400 dead olive ridleys were found washed ashore along the 480 km Orissa coast (Pandav *et al.* 1997). Since then more than 30,000 dead adult olive ridleys have been documented in Orissa (Pandav and Choudhury 1999). Mortality due to illegal near shore trawling and gill netting has been increasing each year. It reached a record high in 1998 with 13,500 turtles found along 282 of the 480 km coastline (Pandav and Choudhury 1999), hence, the actual number of dead turtles washed ashore the Orissa coast could have been much higher.

A second major cause of disturbance is artificial lighting along the coastline. Developmental activities such as establishment of a missile test range and construction of a major port near Gahirmatha and mushrooming growth of aquaculture farms and chemical industries near Rushikulya rookery have resulted in increased lighting near the nesting beaches. Human consumption of sea turtle eggs and meat is minimal in Orissa. However, heavy predation on sea turtle nests by feral dogs and jackals take place at Rushikulya rookery after mass nesting. Estimates show that almost 25-30% of the eggs laid during an arribada are predated at Rushikulya rookery. The planting of Casuarina trees in some of the prime nesting grounds has further restricted the nesting space available. In addition, Casuarina trees with their thick litter renders the beach unsuitable for nesting turtles.

The first step towards solving these problems is strict enforcement of the ban on mechanized fishing in near shore areas and in areas of high sea turtle concentrations. The Government of Orissa has declared the coastal waters off Gahirmatha a marine sanctuary and the coastal waters off the other two rookeries as closed areas. Besides this, the Orissa Marine Fishing Regulation Act of 1983 prevents any kind of mechanized fishing within 5 km of the shoreline. However, the enforcing agencies, the Forest Department and State Fisheries Department, lack the infrastructural facilities to enforce the ban on fishing in these areas. The concerned agencies should be provided with adequate sea going vessels and personnel for strict enforcement of these bans. The use of turtle excluder devices (TEDs) should be made mandatory for trawlers operating in the coastal waters beyond 5 km from the shoreline. However, use of TEDs alone will not bring down the turtle mortality because turtles are also caught and killed in gill nets and TEDs can not be used in gill nets. Therefore, strict enforcement of the existing law on no fishing zones along with TEDs in other fishing zones seems to be the best answer to reduce turtle mortality.

A major step towards saving this population would be giving protected area status to the sea turtle nesting beaches as well as the coastal waters having high sea turtle concentration. Of the three nesting beaches in Orissa, only Gahirmatha and its coastal waters are legally protected. The nesting beaches at Devi and Rushikulya rookeries lack any kind of protected area status, thus making them vulnerable to anthropogenic disturbances. The tagging studies by WII (Pandav and Choudhury, unpublished data) have revealed the movement of turtles between these three rookeries and have demonstrated that turtles use more than one rookery for nesting during a season. This implies that turtles nesting off the coast of Orissa may be part of a single population, meaning that turtles at all three rookeries are equally important. Further, if the nesting beach at Gahirmatha continues to decline due to geographical factors, these turtles may nest at other rookeries and it is important that these alternate nesting beaches are ‘turtle friendly’. Thus protection of all three rookeries is extremely crucial for the survival of turtles in Orissa.

Acknowledgements

The data presented here were collected as part of Wildlife Institute of India’s sea turtle research program in Orissa. We thank the Packard Foundation and the Barbara Delano Foundation, USA for providing travel grants to participate in the symposium.

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Possible Threats to and Conservation Measures for the Nesting Olive Ridley Populations, *Lepidochelys olivacea,* at Andhra Pradesh Coastline, India

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Abstract

Olive ridley sea turtles, *Lepidochelys olivacea,* found in the Indian Ocean and its bay islands are highly vulnerable from various threats. At Gahirmatha in Orissa state, India, the olive ridleys have their largest rookery (mass nesting). Every year around February, the breeding populations migrate from the Indian Ocean to the mass nesting sites after travelling from the coastal waters of Tamilnadu and Andhra Pradesh. Even though these migratory populations are protected under Schedule I of the Indian Wildlife (Protection) Act, 1972, their exploitation is continuing in the coastal villages of Andhra Pradesh. Live turtles are captured incidentally in courtship activity or subjected to strandings of nesting turtles for meat, shell and calipee. Other possible threats identified in the region are human interference to their nesting habitats, nests and hatchlings, due to major construction works and artificial illumination on the beaches.

In every breeding season (November to March) it was estimated that from 2000 to 3000 live turtles of breeding stock are subjected to indiscriminate exploitation and as many carcasses (dead turtles > 2 per km) on coastline due to trawl fishing and instant mortality. Besides live turtles, freshly laid nests are predated by jackals, foxes and domestic dogs and are also excavated by beachcombers, resulting in 90% losses. To prevent these possible threats, conservation programs were initiated to reduce the mortality of nesting turtles, and to protect the nests, eggs and hatchlings. Also a management plan was formulated for the development of important nesting habitats and feeding grounds of olive ridleys in this region.

Introduction

Of the world’s seven species of sea turtles, five species: the green turtle (*Chelonia mydas*); loggerhead (*Caretta caretta*); hawksbill (*Eretmochelys imbricata*); leatherback (*Dermochelys coriacea*) and the olive ridley (*Lepidochelys olivacea*) are distributed in the Indian Ocean and placed in Schedule I of the Indian Wildlife (Protection) Act, 1972. These species are also listed in Appendix I of the Convention on International Trade in Endangered species of wild fauna and flora (CITES, 1975). All the five species nest on the coasts of the Indian Ocean and its Bay Islands, while the olive ridleys have their largest (mass) nesting site at Gahirmatha of Orissa state in Northern Indian Ocean (Kar, 1980).

In winter months (January to March) olive ridleys migrating from the Indian Ocean to the coasts of Orissa for mass nesting (arribada) pass through the coastal waters of Tamilnadu and Andhra Pradesh. During migration these breeding populations are utilizing the nearby suitable habitats to lay their nests sporadically, along the coastline of Andhra Pradesh (Raja Sekhar, 1987). These migratory turtles are exploited by the local people for meat, shell and calipee, also the nests, eggs, and hatchlings subject to over predation by canine predators. Apart from biotic interferences, the developmental activities and intensive shrimp fishing along the coastline cause threats to the survival of olive ridleys in the region.

Study Area

The coastline between Kalingapatnam (Vamsadhara River) in the north and Kakinada (Godavari River) in the south is an important area. As a migratory corridor for olive ridleys, it has been selected for the present study. These coastal areas have different shore conditions ranging from rocky to shallow sandy shores with several rivers entering into the North Indian Ocean (Bay of Bengal). There are 53 villages on the coastline (population around 6,3,000) most of which belongs to fishing tribes. A total of 600 to 700 trawls operate along the coastline and 2000 to 3000 of traditional catamarans also operate from the coastal villages. Major industries, fishing harbours and shipping ports are located at the coasts of Visakhapatnam and Kakinada (**Fig. 1**).

Observations

Survey work has been conducted along this coastline during winter months (December - March) in 1996-97 and 1997-98. A major part of the survey was made on foot with the assistance of natives of the region when required. The status of these breeding turtles and possible threats to these nesting turtles were determined based on:

- Human interference (Exploitation of breeding turtles).
- Disturbances (Human and Predatory) to the nesting turtles, nests and hatchlings.
- Incidental catches of migratory turtles.
- Coastal developmental activities and marine pollution.

Human Interference (Exploitation of Live Turtles): The olive ridleys were captured during courtship or on shore during nesting activity and brought to villages for trade or personal consumption. These turtles were turned on their backs for up to 3 to 4 days in the hot sun before slaughter and sale in nearby weekly markets. During the period 1968 female olive ridleys (85.00%) were caught from courtship activity; 280 were captured (12.00%) on shore during their nesting activity and 45 turtles are subjected (2.00%) to stranding accidentally trapped in fishing nets spread on the shoreline. Some times canine predators (jackal and hyena) attacked the nesting turtles and killed them on shore and 22 of such evidences (1.00%) were recorded during the study period (**Table 1**).

Human and Predatory Disturbances: Domestic dogs and predators like foxes, *Vulphus bengalensis*, jackal, *Canis aureus*, hyena, *Hyaena striata* preyed upon the freshly laid nests accounting for 43.58% of the disturbances; these same animals preyed upon the nests at later stages for 3.42% of disturbances before hatchling (middle of incubation). Newly emerged hatchlings fall prey to crows, owls, white-bellied sea eagle, and ghost crabs. Freshly laid nests excavated by beachcombers accounted 954 nests for personal consumption or for sale (53.00%) in local markets (**Table 2**).

Incidental Catches and Accidental Mortality: The fishing activity was intensive all along the coast from River Godavari at Kakinada to Vamsadhara river of Kalingapatnam. For deep sea fishing 600 to 700 trawls were extensively used in the port areas of Visakhapatnam and Kakinada and Kalingapatnam, with gill and drag nets for shrimp catches. Many of the migratory turtles are accidentally trapped in gill or dragnets, then wash ashore as dead carcasses. The density of carcasses was 4 per km at Godavari river mouth and > 2 per km for the remaining coastline. There was a total of 926 carcasses in 1996-97 and 1158 during 1997-98. Kakinada coasts had the highest percentage (35.17%) of carcasses, Visakhapatnam had 30.90%, followed by Kalingapatnam with 18.00, and Pentakota with 15.93% respectively (**Table 3**).

Coastal Development and Pollution Threats: In recent times the coastline of Andhra Pradesh is subjected to major developmental activities for setting of Industries, Road formations, Brackish water Shrimp farming, Agriculture and Commercial plantations. At the major nesting beaches (Godavari river and at the Vamsadhara river mouths) placement of permanent nets for intensive seed collection (average density of 25-30/km) prevents the turtles from nesting.

The other potential threats to the nesting habitats include human settlements nearer to shore line with an average

Table 1. Exploitation of nesting olive ridleys for meat, shell and calipee during 1996-1998.

Type of exploitation	Study period		
	1996-97	1997-98	Total (%)
Turtles caught during courtship activity	948	1020	1968 (85.00)
Caught while nesting	170	110	280 (12.00)
Trapped in nets on shoreline (strandings)	25	20	45 (2.00)
Nesting turtles killed by dogs or predators	9	12	22 (1.00)

Table 2. Nest predation during 1996-1998.

Type of disturbance	1996-1997	1997-98	Total (%)
Human excavated nests	442	512	954 (53.00)
Nests disturbed by predators (freshly laid nests)	363	420	783 (43.58)
Nests disturbed at the time of hatching by domestic dogs/ predators	24	36	60 (3.42)

Table 3. Number of carcasses found near major port areas 1996-1998.

Coastline area	Dead Turtles on Shore		Total	%
	1996-97	1997-98		
Kakinada (Godavari River)	342	391	733	35.17
Pentakota	134	198	332	15.93
Visakhapatnam	326	318	644	30.90
Kalingapatnam (Vamsadhara River)	124	251	375	18.00
Total for the period	926	1158	2089	

density varied from 200 to 400 per km. Pollution from nearby industries causes severe threat to marine environment at Kakinada and Visakhapatnam coastline (**Table 4**).

Discussion

The Andhra Pradesh coastline is a migratory route or pathway for the olive ridleys to approach Gahirmatha beaches in Orissa state, where the largest 'arribada' was reported by Bustard (1976). It is most likely that a good number of turtles sporadically nest along the coastline of Northern Andhra between Godavari River mouth to Vamsadhara River. Frazier (1980) described various conditions of exploitation of sea turtles in the Indian Ocean and explained the reasons for subsistence economy of local inhabitants.

Subsistence pattern of hunting for the olive ridleys was reported along the coasts of Orissa and West Bengal (Das and Kar 1986). However such large scale commercial exploitation was not intensified in the Andhra Pradesh coastline. Incidental catches of turtles in the trawl nets, poaching of nesting turtles and destruction of nests were intensive all along the coastline, not only removing the turtles but severely limiting their reproduction.

In spite of several protection measures (Wildlife Protection Act, 1972) sea turtles are intensively subjected to over exploitation for their meat, shell, eggs, and calipee, all along the coastline by the subsistence economy. Apart from biotic interference the breeding habitats of these turtles are faced with severe threats from beach erosion, sand mining, formation of roads, encroachments and to a larger extent marine water pollution.

Pollution sources from nearby industries, mostly of untreated or semi-treated effluents from the Nagarjuna and Godavari fertilizer plants and the discharge of hot waters (30-40°C) from NTPC Gas Based Power Project (GBPP) at Kakinada Bay cause synergistic effects to the marine coastal environment and threaten the Godavari mangroves which are an important breeding and feeding habitat to olive ridleys. Oil drilling sites nearer to Hope Island and Sacramento shoals cause long-term detrimental effects to the nesting habitats. Other possible threats are from the increasing rate of human settlements, conversion of coastal habitats for aquaculture, and industrial pollution to coastal areas nearer to the nesting habitats.

To mitigate these possible threats the following programs were initiated for the conservation of olive ridley sea turtles along the coastline.

1. Subsistence hunting can be avoided through intensive education programs in all 53 fishing villages of the study area to bring awareness of the importance of sea turtles.
2. Use of TEDs (Turtle Excluder Devise): There are around 600-700 shrimp fishing trawls operating from Visakhapatnam and Kakinada Port. TEDs should be introduced progressively after teaching boat owners about the importance of sea turtles. Mandatory implementation may be necessary.
3. Protection of sea turtle nests '*In situ*' from the areas where the nests are likely to be poached or disturbed, or other threatening factors and survey of turtle nesting sites in the remaining coastline.
4. Strict implementation of the Wildlife Protection Act of 1972 and severe punishment for the commercial exploiters of sea turtles and their eggs. Declare Sacramento and Hope Islands near Kakinada, Andhra Pradesh as a sea turtle sanctuary and ban all fishing and other activities that are detrimental to the turtles and their nesting habitats.

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I express my sincere gratitude to the Packard Foundation, USA for travel assistance. I take this opportunity to acknowledge Ms. Marydele Donnelly Regional Chair, Travel Committee Asia and Pacific and the

Table 4. Possible threats to the olive ridley sea turtle nesting habitats along the coastline of Andhra Pradesh

Name of the area (Coastal habitat)	Developmental activities on the coast line	Possible threats
Kakinada coast, Hope Island and Sacramento shoals of Godavari River adjacent to Coringa Wildlife Sanctuary	Brackish water shrimp culture, Port operations, Godavari & Nagarjuna fertilizer plant, NTPC Gas based Power Project, ONGC Oil drilling sites, Extensive Shrimp seed collection,	Pollution destruction of mangrove forests and erosion
Pentakota beach	Shrimp farming, agriculture sand mining,	Shrinkage of coastline Casuarina plantations
Visakhapatnam coast	Port operations, fishing harbour sand digging & quarry mining-shipping activities and salt manufacturing units, shrimp hatcheries, Visakha Steel Plant	Urbanization shrinkage of coastline and pollution & lighting
Kalingapatnam Vamsadhara river	Sand mining, shrimp farming Erosion and Coconut plantations	Coastal erosion

organizing committee of 19th Annual Sea Turtle Symposium. I am thankful to Prof. M.V Subba Rao, Department of Environmental Science, Andhra University for the help in conducting the survey and also thanks are due to A.P. Forest Department.

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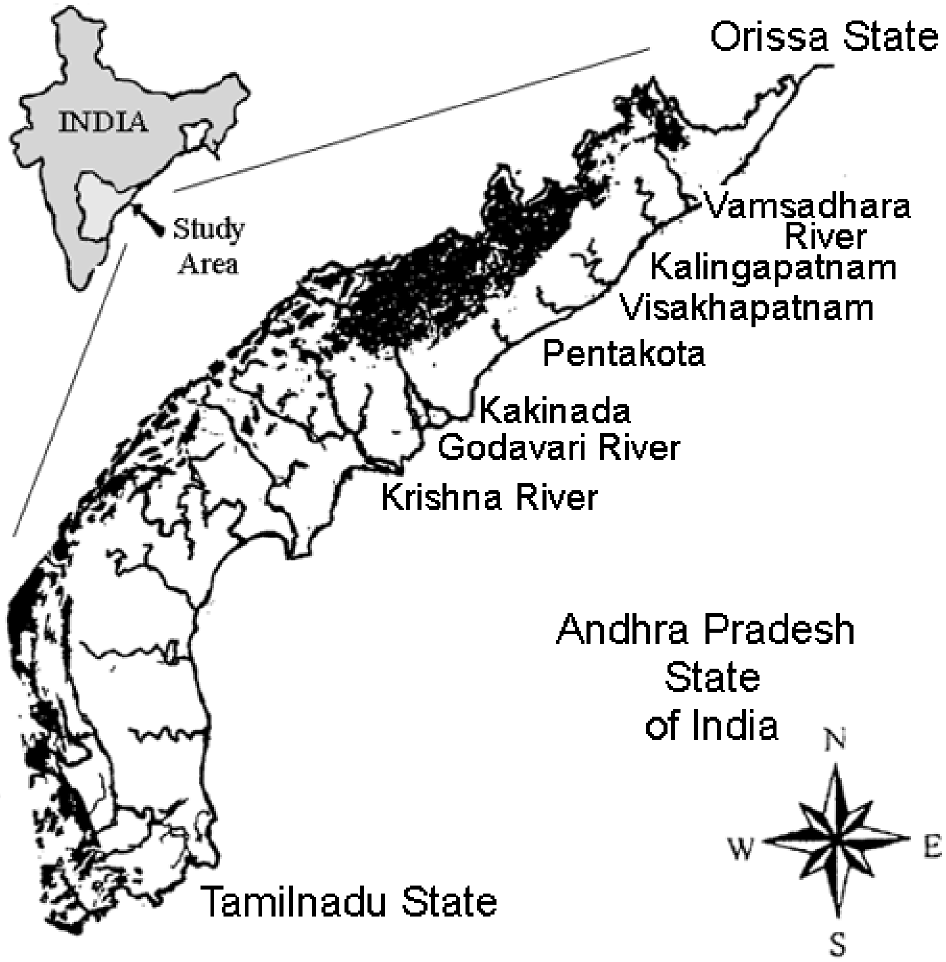

Figure 1. The shoreline of Andhra Pradesh state located to the south of the state of Orissa, India.

Analysis of Synchronized Mass Nesting Activity (Arribada) by Olive Ridley Sea Turtles (*Lepidochelys olivacea*) in the Ostional Wildlife Refuge, Guanacaste, Costa Rica

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The method used to estimate the size of arribada nesting assemblages in Ostional, developed by Cornelius and Robinson in the early 1980's, uses 3 fixed 10x15 m quadrants that are then extrapolated to the 880 m Main Nesting Beach (MNB). However, it is common for the main aggregation of nesting turtles to shift a bit north or south of the MNB (Ballestero *et. al*., 1997). Consequently, the static quadrant method could not follow nor describe the course of the arribada. The current status and recovery potential of these species can only be assessed using the long term monitoring of demographic variables, and by employing robust and reliable statistical methods for data analysis (Valverde and Gates, 1999).

In this paper, we estimate the size and distribution of 5 consecutive arribadas, from August to December of 1998, using the "Strip Transect in Time Instantaneous Count" method (IC) (Valverde and Gates 1999).

Methodology

Wooden stakes were placed at the vegetation line every 50 m for the entire 7 km length of the beach (**Fig. 1**). Transects the width of the technicians arm length, were walked perpendicular to the high water mark or berm every two hours, during which Egg Laying Females (ELF) and Total Turtles (TT) present (including ELF) were counted. Counts officially started the morning after the first night of the arribada, and continued throughout the arribada event. Since large numbers of turtles deposit their eggs below the berm and it is often difficult to define the berm, transects were extended to the water's edge after August. This modification also obliged us to adjust transect length with tides.

Results

The August arribada had a duration of 7 nights (Aug.15-21), with an estimate of 22,644 ± 4643 and 41,146 ± 8436 ELF and TT (**Table 1**). The majority of nesting activity occurred on the 880m stretch of the MNB, although the entire space used was 3 kms (**Fig. 2**). Greatest nesting activity occurred on August 18, after which nesting activity waned until August 21 (**Fig. 3**).

The September arribada had a duration of 6 nights (Sept 28-Oct 3), with an estimate of 80,542 ± 14,279 and 91,559 ± 11,982 ELF and TT (**Table 1**). The geographical distribution of the arribada nesting activity was limited to under 2 km of the beaches known as "El Rayo I" "El Rayo II" and "Pueblo" (**Fig. 2**). Greatest nesting activity occurred on September 30, after which nesting activity steadily waned until October 3 (**Fig. 4**).

The October arribada had a duration of 5 nights (Oct 27-31), with an estimate of 78,237 ± 10636, and 135,029 ± 16,008 ELF and TT (**Table 1**). The distribution of this arribada was 2.25 km, occurring in "El Rayo II" and "Pueblo" (**Fig. 2**). This arribada is noteworthy as the first published account of an arribada with a bimodal distribution. Greatest nesting activity was recorded on October 29 (**Fig. 5**).

The November arribada had a duration of 5 nights (Nov 25-29), with an estimate of 45,424 ± 3,823 and 50,515 ± 6859 ELF and TT (**Table 1**). Nesting activity covered roughly 3 kms of the beaches known as "El RayoI", "El Rayo II" and "Pueblo" nesting occurred almost to the Northern most end of the beach (**Fig. 2**). Nesting activity decreased roughly 40% on November 28, only to increase again on the 29 (**Fig. 6**).

The December arribada had a duration of 4 nights (Dec.16-19), with an estimate of 6,237 ± 2901 and 6,248 ± 3,372 ELF and TT (**Table 1**). The absolute direct count of visiting turtles was 7,790 ± 2,642. Nesting activity covered less than 2 km, in "El Rayo II" and "El Pueblo" **(Fig. 7)**.

Conclusion

Due to the size of the beach at Ostional and the unpredictability of the nesting behavior of the turtles, it is paramount that any studies on the arribadas be flexible enough to cope with their spatial and temporary distribution. The IC method allows a relatively small number of people to monitor the arribadas with little advanced training, and relatively simple preparatory posting of the beach. During the dry season, when arribadas are much smaller, direct counts should offer a more reliable estimate. It appears that the nesting population, as compared to the limited data from years past, seems to be relatively stable (Ballestero *et al*. 1997). In order to coordinate research and conservation efforts more effectively, it would be extremely beneficial if all researchers at arribada beaches around the world would use the IC method in addition to any other methods already in use, allowing easy comparisons of nesting activity.

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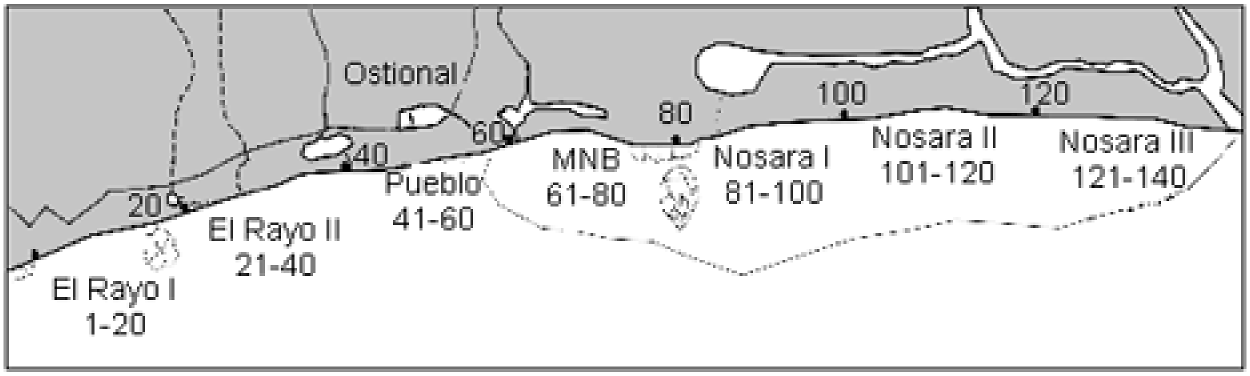

Figure 1. Map of Ostional, with markers every 20 sectors of beach.

Table 1. Estimated number of Egg Laying Females (ELF) and Total Turtles (TT) in five consecutive arribadas, using the Strip Transect in Time Instantaneous Count Method (Valverde and Gates 1999), including one direct count* for comparison, in the Ostional Wildlife Refuge, Guanacaste, Costa Rica. 1998.

	Egg Laying Turtles			Total Turtles		
Date	Estimated	CV	SE	Estimated	CV	SE
Aug 15 - 21	22644	4643	2321	41146	8436	3126
Sept 28 - Oct 3	80542	14279	6935	91559	5991	11982
Oct 27 - 31	78237	10636	5318	135028	16008	8003
Nov 25 - 29	45424	3823	3292	50515	6859	3429
Dec 16 - 19	6237	2901	1451	6247	3372	1686
Dec 16 - 19*	7790	2642	1321			

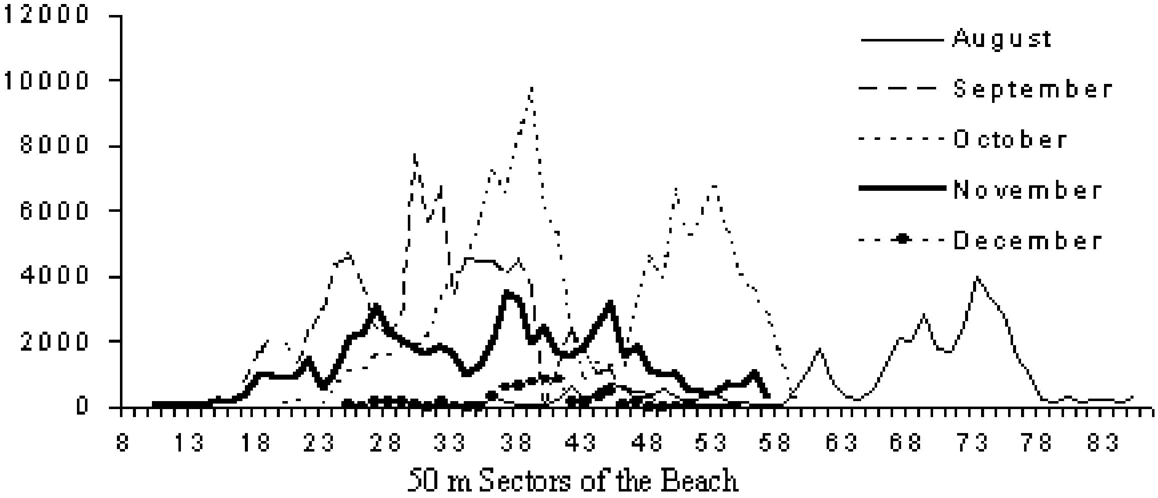

Figure 2. Distribution of turtles (Total Turtles per 50 ms sector) during 5 consecutive arribadas in the Ostional Wildlife Refuge, Guanacaste, Costa Rica, 1998.

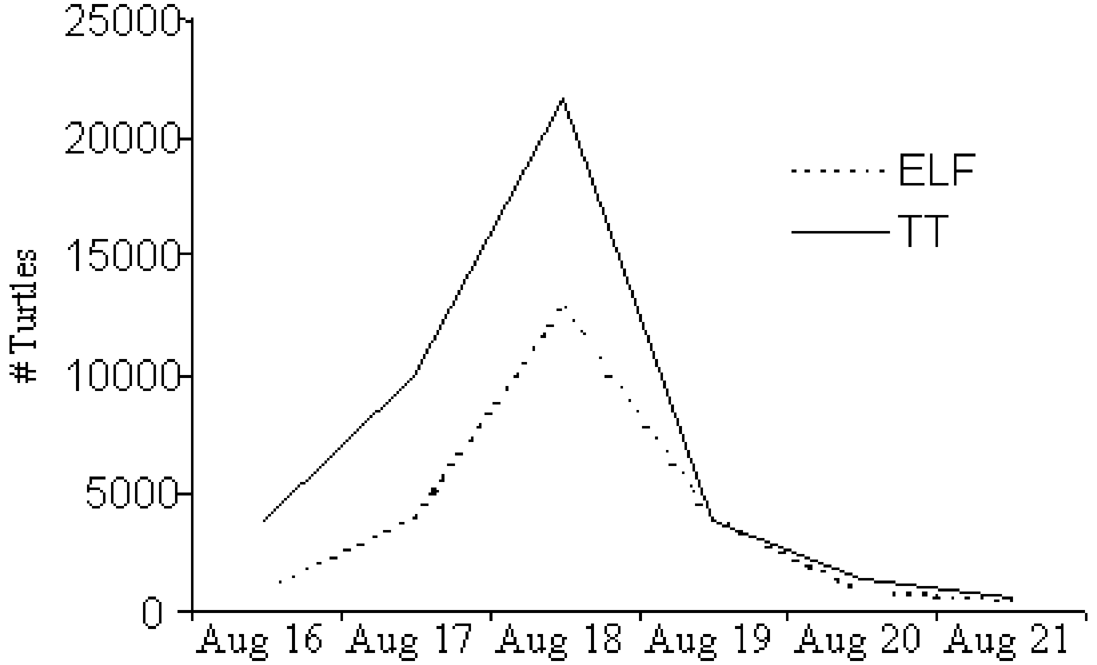

Figure 3. Egg Laying Females (ELF) and Total Turtles (TT) activity by dates. August arribada at Ostional, Guanacaste. 1998.

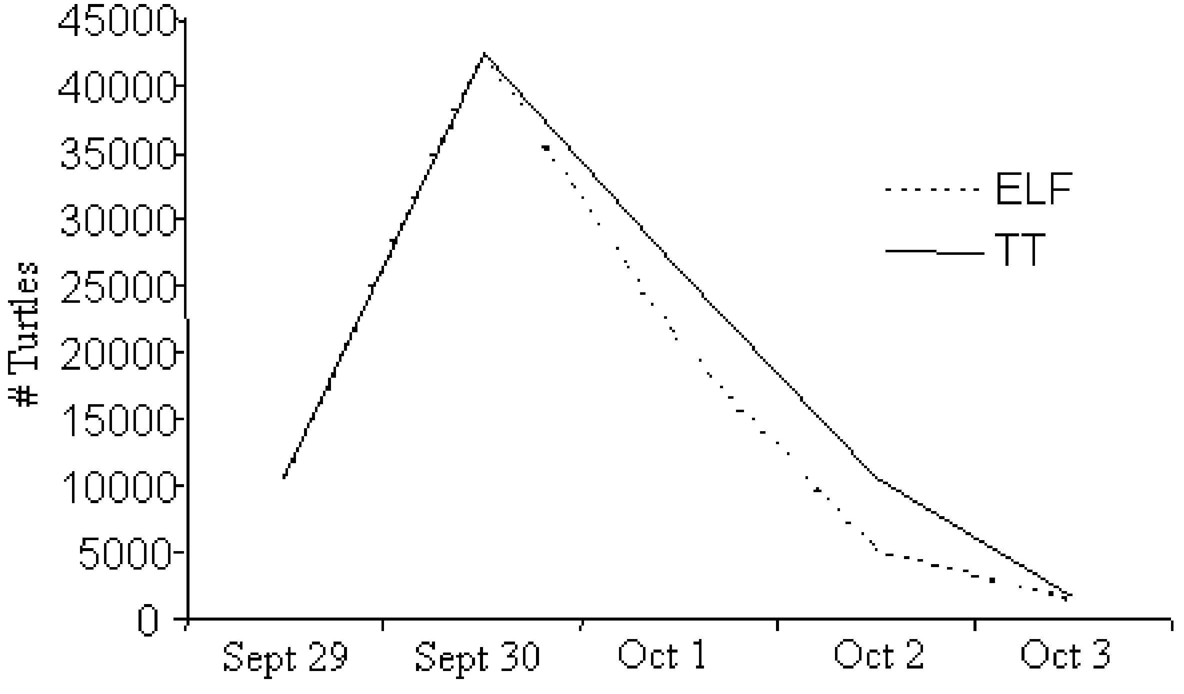

Figure 4. Egg Laying Females (ELF) and Total Turtles (TT) activity by dates. September arribada at Ostional, Guanacaste. 1998.

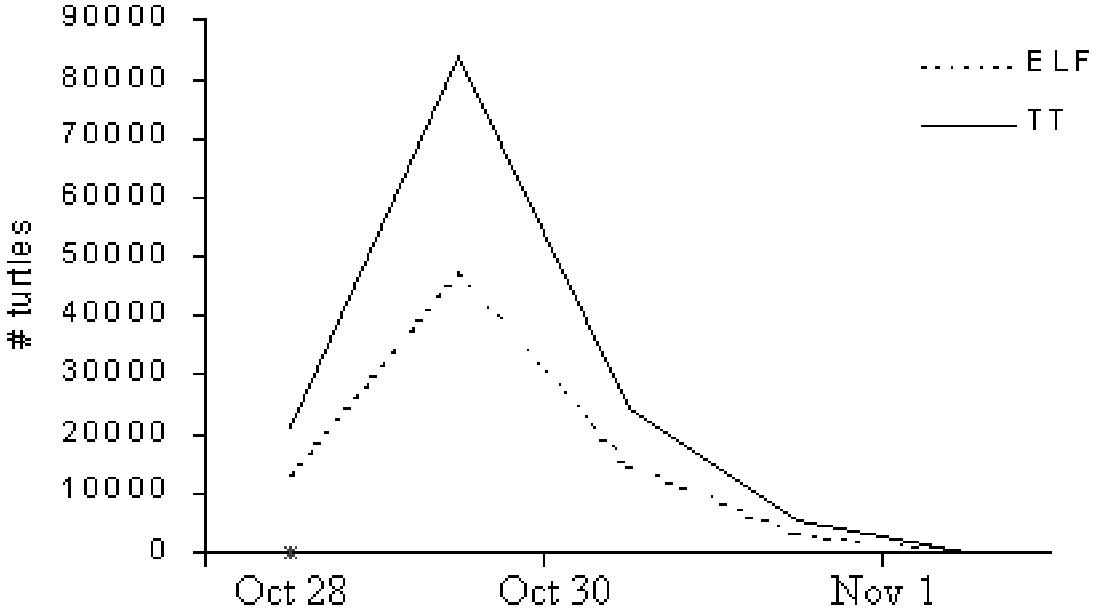

Figure 5. Egg Laying Females (ELF) and Total Turtles (TT) activity by dates. October arribada at Ostional, Guanacaste. 1998.

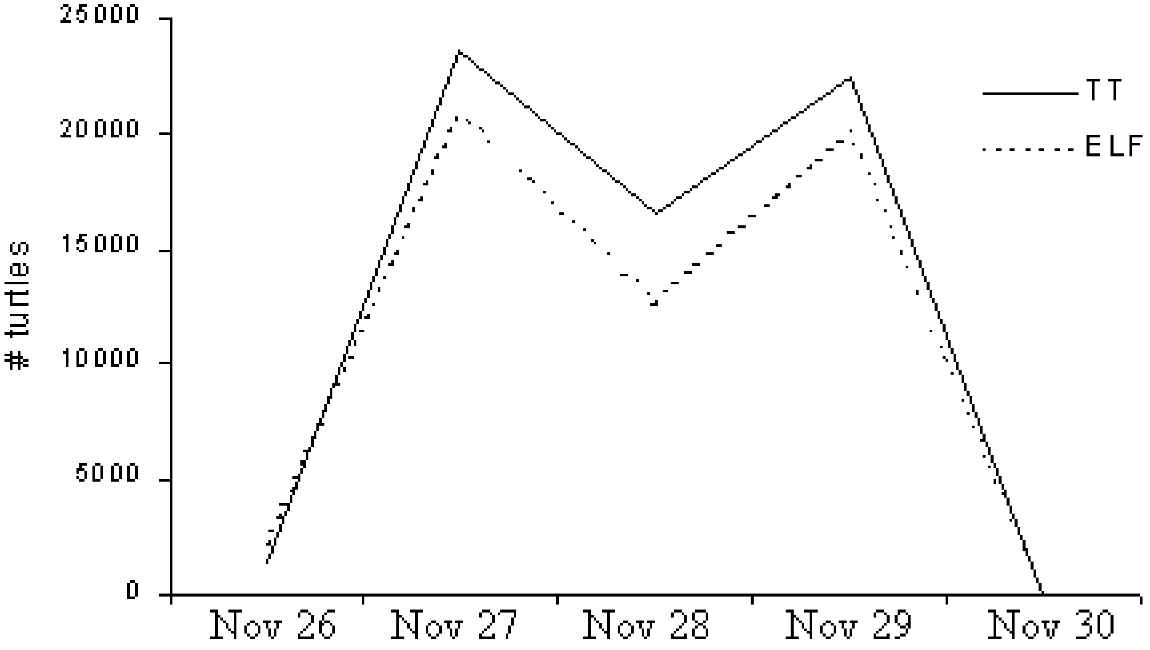

Figure 6. Egg Laying Females (ELF) and Total Turtles (TT) activity by dates. November arribada at Ostional, Guanacaste. 1998.

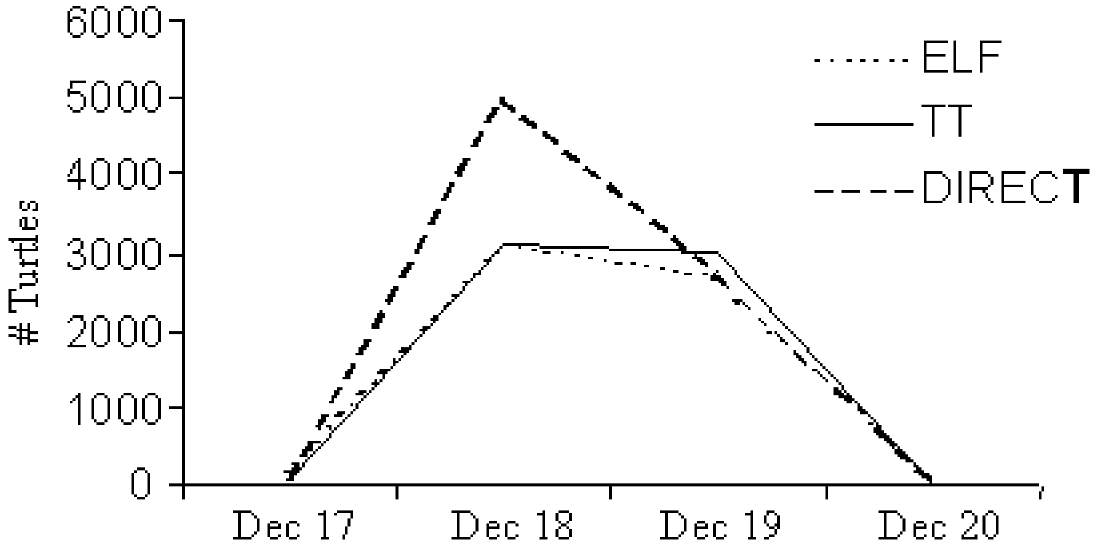

Figure 7. Egg Laying Females (ELF) and Total Turtles (TT) activity by dates. December arribada at Ostional, Guanacaste. 1998.

POPULATIONS STATUS AND BEACH STUDIES

Preliminary Report on the Status of Marine Turtle Nesting Populations on the Mediterranean Coast of Egypt

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Two species of marine turtle regularly nest on the Mediterranean coast: the green turtle (*Chelonia mydas*) and the loggerhead turtle (*Caretta caretta*). In every country in which these two species nest their breeding ground are threatened by coastal development from either industry or tourism. Estimates suggest that only about 2000 female loggerheads and 500 green turtles are nesting regularly on Mediterranean beaches. The major nesting beaches are in Turkey, Cyprus and Greece, however as the number of nesting females is so low, the smaller satellite rookeries that might exist in Israel, Libya, Syria, Tunisia and Egypt are becoming increasingly important. Of all the countries in the southeastern Mediterranean basin, the status of nesting marine turtles in Egypt is perhaps the least well documented. For this reason researchers from the University of London, Suez Canal University, and the Egyptian Environmental Affairs Agency, have initiated a 3 year study to identify important marine turtle nesting beaches along the Mediterranean coast of Egypt. The study has been funded by a grant from the British Government through the Darwin Initiative for the Survival of Species program. This paper outlines the results of the first year's field studies; it identifies those areas in which turtles are nesting and indicates where the survey should be focused in future years.

Methods

The first year of the survey involved a reconnaissance of the entire Egyptian Mediterranean coast from Gaza in the east to Libya in the west. Surveys were done on foot by teams of 3-4 biologists. All the sandy beaches along the Mediterranean coast were surveyed at least once during the 1998 nesting season from 1/6 to 7/9. Those beaches on which evidence of nesting activity was found were surveyed three times during the season. The survey team would walk a suitable sandy beach from end to end providing 100% coverage of each potential nesting beach. They would note the position of any emergence tracks and if a nest had been excavated on the track the team would attempt to locate the position of the egg chamber to confirm that egg deposition had occurred.

Results

El Salum to Alexandria - Only three sets of loggerhead emergence tracks were recorded in this area during the 1998 survey. These tracks were found just east of Sidi Barrani. As the tracks were all found on the same day in close proximity to each other and were of approximately the same size, it is reasonable to assume that the same individual made them. Egg deposition could not be confirmed. These results would seem to confirm those of Kasparek (1993) that negligible marine turtle nesting is occurring in this region.

Alexandria to Port Said - No evidence of marine turtle emergence or nesting was found in the Nile Delta region. This may be because the sand in the delta has a large amount of mud and clay associated with it that may make the substratum unsuitable for nesting. However, the sandy beaches from Izbat Jamasa al-Ghariyab to Baltim, and the beaches of the Lake Burullus sand spit would appear to be suitable for marine turtle nesting.

Port Said to Rafah - The beaches of the Northern Sinai have the most marine turtle nesting activity of all Egypt's Mediterranean coast. In total 106 emergence tracks were observed along the Northern Sinai coast during the 1998 season of which 20% were confirmed to have resulted in egg deposition. Nesting by both green and loggerhead turtles was confirmed. Tracks were found on the beaches from Rafah to Romana, however, the greatest concentration of emergences and nests were found in the Lake Bardawil to El Arish region.

The results of the 1998 field season surveys are summarized in **Fig. 1**, a ranking of 1 indicates the area most heavily utilized for marine turtle nesting and a ranking of 8 indicates that no evidence of nesting was found in this area.

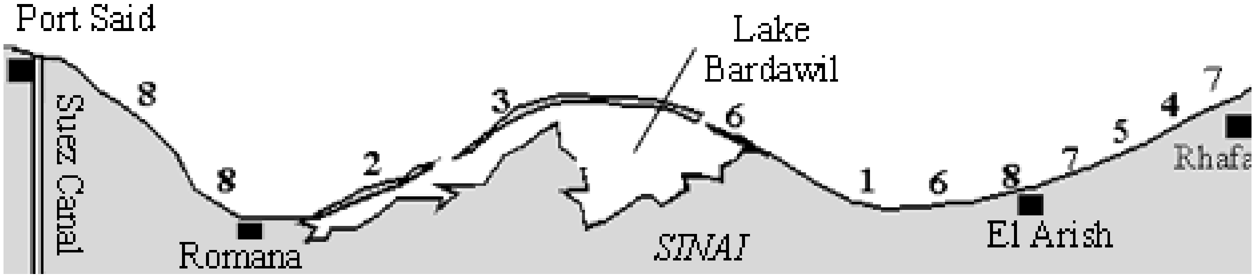

Figure 1. The results of the 1998 field season surveys, a ranking of 1 indicates the densest nesting areas while a ranking of 8 indicates that no evidence of nesting was found in the area.

Discussion

Preliminary results indicate that the northern Sinai is the most important region of the Egyptian Mediterranean coast with respect to marine turtle nesting; in comparison, nesting activity in the delta and western regions is negligible. The next two years' survey results, which will concentrate on the Northern Sinai region, should reveal the relative importance of this area with respect to the other satellite rookeries in neighboring countries such as Israel, Syria, Libya and Tunisia. A conservation plan to safeguard turtles utilizing the northern Sinai region as nesting grounds will involve an intensive survey of the region and the establishment of a hatching area within Zaranik Biosphere Reserve, on Lake Bardawil, vulnerable nests can then be transplanted to this protected site. This will also provide the scientific team with the opportunity to collect fundamental information about turtles nesting in Egypt, such as hatching success rates, nest temperatures, incubation period, length of nesting season etc.

Acknowledgments

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Agonies and Ecstacies of 25 Years of Sea Turtle Research and Conservation In India

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India as well as Pakistan has a long history of trade in turtle products. Between 1963 and 1974, India exported 102,022 kg of sea turtle products valued at roughly $100,880. The products included sea turtle meat, oil and tortoise shell. The domestic trade was substantial especially for the olive ridleys nesting in Orissa. Even up to 1970's it is estimated that 50,000 to 75,000 mature adults were harvested primarily for meat and secondarily for skin and oil from the Orissan coast mainly for the Calcutta market (Biswas, 1982; Dash and Kar, 1990). Similarly eggs were collected in large numbers from Gahirmatha rookery and other important nesting areas in Orissa for human consumption and as a supplement for feed of domestic animals (Dash and Kar, 1990). Prior to 1975, from Gahirmatha alone, a nominal egg tax (anda kara) was collected for a boat load of eggs containing about 35,000 to 1,00,000 eggs depending on the size of the boat (Dash and Kar, 1990). The estimated legal take in the 1974-1975 season was 800,000 eggs (FAO 1975-see Kar and Bhaskar, 1982).

Up to the 1970's our knowledge on the sea turtles that visited the coasts of India remained limited. However, the endangered status of the sea turtles led to a spurt of activity and therefore, we have considerable data on the activities of the sea turtles that visit the coasts for nesting. Unfortunately, our knowledge of their habits, migratory routes and activities of both the hatchlings and the adults after they leave the coast, remain negligible.

Altogether five species representing each of the five genera are known from the Indian seas. These include the leatherback (*Dermochelys coriacea*), the green (*Chelonia mydas*), the hawksbill (*Eretmochelys imbricata*), the loggerhead (*Caretta caretta*) and the olive ridley (*Lepidochelys olivacea*). Sea turtles have been recorded from the eastern and western coasts, as well as the neighboring islands in the Indian Ocean (Kar and Bhaskar, 1982).

Long term research and conservation efforts have been taken up in two states, in Tamil Nadu (Silas and Rajagopalan, 1984; Rajagopalan, 1989) and in Orissa mainly by the wildlife wing of the State. Unfortunately, research and conservation activities have been concentrated in Orissa since the 1990's making it difficult to determine the status of sea turtles at a National level.

Since 1997, a high-powered committee under the chairmanship of Honourable Chief Minister of Orissa, has been reviewing and formulating plans for conservation. Recently, the Ministry of Environment and Forests, Government of India, has set up an expert committee. A status survey, building of database and implementation of TED regulations etc. are envisaged through this committee.

Considerable data is available on the breeding and nesting habits of the olive ridleys (Dash and Kar, 1990; Mohanty-Hejmadi, 1992; Mohanty-Hejmadi and Sahoo, 1994; Pandav *et al*., 1994). Unfortunately, there has been no mass nesting two years in a row (1997,1998) at Gahirmatha and the mortality is substantial. This year there is a good congregation of turtles at the three mass nesting sites (Gahirmatha, Devi and Rushikulya estuaries) but no mass nesting yet. The mortality in the core area of Gahirmatha sanctuary has been reduced due to the protection enforced through the wild life wing, coast guards and Indian navy; however, the mortality is high south of the sanctuaries due primarily to the non-implementation of the Marine Fisheries Regulation Act (OMFRA) by the fisheries department.

A long-term tagging program was initiated in 1978 and there has been recovery of two from Sri Lanka (Kar, 1992; Pandav and Choudhury, 1998). Unfortunately, a proposed satellite-tagging program did not materialize in 1997 as the required permission was granted after the season.

The highlights of sea turtle conservation program include the protection given to sea turtles through the Wildlife Protection Act of 1972, the declaration of Bhitarkanika Wildlife Sanctuary in 1974 which included turtle nesting areas, the ban on collection of eggs in 1975, the systematic data collection on nesting turtles, the international letter campaign to the then Prime Minister, the late Indira Gandhi, resulting in better protection of the Gahirmatha area, and the discovery of the second and third mass nesting sites at Devi (Kar, 1982) and Rushikulya (Pandav and Choudhury, 1994) estuaries. Good mass nesting from 1990 to 1996 was indicative of the success of the conservation efforts. Association of Universities (Utkal and Sambalpur) and Institutes (Central Marine Fisheries and Research Institute, Madras and Wildlife Institute of India, Dehradun) have intensified the research activities.

It is also heartening to note that a TED program was facilitated by Dr. Pamela Plotkin and myself in 1994. A training-cum-demonstration workshop on TEDs was held at Paradeep, Orissa in November 1996 followed by one at Cochin in Kerala State. Project Swaraj is the primary agency for the manufacture of “Georgia Jumper” TED’S. Orissa Fisheries department has notified making TEDs compulsory for renewal of licenses for trawlers, but it is yet to be implemented. Government of India has provided money to the wildlife wing, Orissa; for fabrication of TEDs. Two workshops were held by the wildlife wing recently at Paradeep and Dhamra for training and installation of TEDs with trawler owners and fishermen.

Considerable data is available on the developmental biology namely on development, temperature dependent sex determination, karyotype and calcium mobilization etc. of the olive ridleys of Gahirmatha (compiled by Mohanty-Hejmadi, 1993; Sahoo *et al.*, 1996,1998).

Periodic seminars and workshops have helped focus on different aspects of conservation. Noteworthy are the two international seminars, one in 1996 in Mombasa under the auspices of New England Aquarium, USA and another in Bhubaneswar under the auspices of IUCN, CMS, NOAA, etc., on Indian Ocean populations. A very active press and media are continuously highlighting the mortality and lapses in protection. Awareness programs by wildlife wing, Orissa and several NGOs have intensified in the last two years.

The declaration of Gahirmatha Wildlife (marine) Sanctuary has provided added protection to the area. A total of 197 fishing vessels were seized in 1998 and out of the 38 seized in 1999, 21 are trawlers and 17 are gill netters. This enforcement has led to the reduction of mortality at Gahirmatha to 1653 as opposed to 3544 last year.

The construction of Tachua jetty which was much in the news a few years back was not fully commissioned as envisaged in the original plan after a long court case (World Wide Fund for Nature vs. Orissa Government).

At the moment the threats to sea turtles in India include fishing by trawlers and gill netters in coastal waters, lighting in ports, jetties, industries and coastal development activities, damage by predators and disturbances by local people. Increase in fishing related mortality and no arribada in two successive years (1997,1998) are matters of great concern at present. The great question is whether all the efforts that are being made can save the spectacular arribadas to see in the next millenium.

Table 1. Yearly totals of olive ridleys at Gahirmatha. (Courtesy wildlife division, Government of Orissa).

Year	Emerging females (in 100,000=1 lakh)	Dead turtles
1978-79	2.30	-
1979-80	1.30	-
1980-81	2.00	-
1981-82	2.00	-
1982-83	0.176	512
1983-84	6.193	2634
1984-85	4.684	3418
1985-86	2.918	5436
1986-87	0.500	2404
1987-88	6.360	3348
1988-89	0.010	2576
1989-90	3.150	2429
1990-91	2.070	1210
1991-92	6.590	1119
1992-93	3.840	1356
1993-94	6.874	4846
1994-95	6.945	4377
1995-96	3.395	1244
1996-97	2.900	3634
1997-98	0.001 (lll)	5322
1998-99	0.0006 (64)	3791

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The Current Situation of the Leatherback Population on the Pacific Coast of Mexico and Central America, Abundance and Distribution of the Nestings: an Update

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In the early 80's, Mexico was considered one of the most important countries for the nesting of the leatherback turtle. Three main nesting beaches were known along the Pacific Coast of Mexico: Chacahua, Oaxaca, (Márquez, *et al.* 1976) Tierra Colorada, Guerrero and Mexiquillo, Michoacán. (Márquez, *et al.* 1981, Pritchard, 1982) In these areas, up to 100% of the clutches were poached by local people, therefore activities for the protection of eggs and evaluation of the nesting population were implemented. Unfortunately, these protection activities haven't existed continuously for all the beaches; only Mexiquillo has a complete database of nesting females and hatchling production since 1982.

In the mid-80's, 500 leatherback nests per night were still recorded during peak season, representing around 5,000 nestings in a season for each one of the three main beaches (Pritchard, 1982). In the early 90's, a drastic decline in the number of nestings and females was observed, showing less than 100 nestings (Sarti *et al.* 1993), which represented barely over one dozen females nesting for each one of these beaches. For this reason, in 1994 a program was started to evaluate the population along the Pacific coast of Mexico. The priorities of this program were to assess the possible causes of the decline, to learn the actual status of the population in Mexico and to propose strategies to stop the decline and eventually recover the population. The principal methods used in the program have been the count of bodypits made by the nesting females, the evaluation of clutches and tag-recapture of nesting females using monel and PIT tags, as well as aerial surveys along the Mexican Pacific coast, from Tijuana to Puerto Madero, Chiapas, with ground verification at each key beach.

The estimation of the total number of nestings in this area was obtained from aerial survey data and beach work. Three sources of error have been considered (Sarti *et al.* 1996):

E1=error due to track and bodypit aging

E2=error due to the difficulty of observation from the air

E3=error caused by doing the survey prior to the end of the season (nestings that haven't occurred yet)

The results of the surveys from the past seasons for the Pacific coast of Mexico, including total count corrected for the error factors, and the estimated number of females are shown in **Table 1**.

Table 1. Total leatherback nestings counted and total of females estimated to nest along the Mexican Pacific coast per season. *Value corrected for E1 and E2 only. **Number of females only includes tagged females at the key beaches.

Season	Nestings	Females	Reference
1995-1996	5,354	1,093	Sarti, *et al.* 1996
1996-1997	1,097	236	Sarti *et al.* 1997
1997-1998	1,596	250	Sarti *et al.* 1998
1998-1999*	799*	67**	This paper

For the last 2 seasons, along the Mexican Pacific coast we have counted around 1,000 nestings, representing slightly more than 200 nesting females. The total value for the 95-96 season is similar to the one reported for Mexiquillo, in only 4 km of beach in 1986. The rest of the seasons have counts equivalent to only one fifth of the nestings recorded for a single beach in the mid-80's. The results of this research have shown a drastic and worrisome decline in the number of nestings and females on the beach each year. It's evident that this population has now collapsed.

About 40% of the leatherbacks nesting in Mexico is concentrated along approximately 50 km of beach, which represents almost 1% of Mexico's Pacific coastline. Although these beaches have at present monitoring and protection programs, egg poaching continues to be a serious problem.

The beach of San Juan Chacahua, Oaxaca, formerly considered among the leatherback's largest rookeries in the 80's, now has less than 50 observed nestings registered per season. This represents 6 to 10 females nesting a season, and a density of 5 nests per 12 km. The beaches of Mexiquillo, Michoacán and Tierra Colorada, Guerrero, continue to be the main leatherback nesting beaches in the Mexican Pacific. Nevertheless, during the last season Mexiquillo's nesting numbers have dropped far below the ones observed in Tierra Colorada.

Three beaches are now considered as major rookeries in Mexico: Mexiquillo, Tierra Colorada and Llano Grande. They are regarded as key beaches and the focus of greatest monitoring and protection. Other secondary nesting areas include Barra de la Cruz, Marquelia and Playa Venturas, where nesting densities range from 5 to 8 nests per km. While protection activities occurred at Barra de la Cruz, we should consider implementing new programs at the other beaches.

In order to find out more about the distribution and abundance of the leatherback in the Eastern Pacific, this nesting season, the scope of population evaluation was extended to cover Central America. An aerial nesting survey of the entire Pacific coast from Tijuana, Mexico to the Panama border with Colombia was done during late January and early February, 1999. The purpose was to survey known nesting sites across this broader area, and to search for undocumented leatherback nesting sites. Estimates from this aerial survey were corrected for the error sources as described before, but not including E3 since the season is not over yet.

We surveyed approx. 6,110 km of coast, comprising seven countries. From the total surveyed area, leatherback nesting occurred in only 1,501 km of coast.

Due to weather conditions, some important nesting areas remained unsurveyed, namely the Nicoya Peninsula in Costa Rica, which holds some of the largest known nesting grounds for the leatherback (Spotilla *et al.* 1996). Military restricted areas were not covered either. It is important to note that the unsurveyed zone included Playa Grande and Playa Langosta, major nesting beaches for the leatherback. We don't have the number of nestings for these beaches to date, but it's likely that it surpasses the figure for the key beaches in Mexico. A separate aerial survey was done by another research team in Costa Rica that covered the key areas including Playa Grande that we were unable to cover. These data will add significantly to the results presented here.

We estimated a total of 885 nestings to date this season in the surveyed area. Based on aerial count, the countries with most nestings, were Mexico, Nicaragua and Costa Rica, as shown in **Table 2**.

Table 2. Results of aerial survey from Mexico to Panama during Jan-Feb 1999. *Without unsurveyed area.

Country	Number of Nestings
Mexico	799
Nicaragua	61
Costa Rica*	11*
Guatemala	6
El Salvador	4
Panama	4
Honduras	0
TOTAL	885

No new important nesting beaches were found between Tijuana and the border of Panama and Colombia, so the movement of females to new nesting areas, as a possible explanation for the reduction of nestings in previously known beaches, can be discarded.

Among the suggested causes for the decline of the leatherback Pacific population is a high rate of egg poaching at the different nesting beaches prior to the implementation of protection programs. This resulted in very few or no hatchlings being produced for an unknown period. We may possibly be witnessing now the effects of this lack of recruitment to the wild population. The survivors of the first hatchlings released as part of the protection programs, should be around 17 years old by now. Almost nothing is known regarding the age to sexual maturity on this species, but certain evidence suggest that leatherbacks could reach it at the age of 8 to 20 years old.

In Mexiquillo, the best known of the key beaches in Mexico, 184,770 hatchlings have been released from the protection program since 1982. This could represent around 7,000 to 11,000 hatchlings released per season. Intensive tagging efforts have been implemented at this beach, where up to 80% of the females were tagged. It is interesting to note that during the 80's, around 30% of the nesting females per season were remigrants, but in the past four seasons, we have no evidence of remigrations, even with more efficient tagging methods such as PIT tags. This could indicate a high mortality rate of females at sea and the probability that the females encountered at present are the product of the first protection efforts.

The slaughter of females on nesting beaches in Mexico has been detected as a serious threat at some beaches. In 1995, 25 leatherback carcasses were counted on the beach of Piedra de Tlacoyunque, Guerrero. In the following years we haven't found evidence of slaughter of that magnitude at any beach, nevertheless, we know of the killing of 1 to 5 females on the beaches.

Regarding mortality at sea, leatherbacks are known to be captured by Pacific swordfish fisheries, in particular the Hawaii based longline fishery as well as artisan and commercial fisheries in Chile and other South American waters (Eckert y Sarti, 1997). Data has been collected on incidental sea turtle take in the Hawaii longline fishery, but not much is known about take levels in the Chilean and other South American fisheries. Some direct and indirect evidence shows that these fisheries have impacted the leatherback nesting population in Pacific Mexico. Part of this evidence is:

- The recovery in the Chilean fishery of tags placed in females nesting in Mexico.
- The observation that the decline of the nesting numbers in Mexico in the late 80's coincides with the increment of the fleet size and fishing efforts with gillnets in Chile (Márquez y Villanueva 1993; Frazier y Montero 1990).
- Results from satellite telemetry that show that leatherbacks move south to areas off Peru and Chile (Eckert y Sarti, 1997)
- genetic studies that indicate that some leatherbacks captured in the Hawaii longline fishery belong to the East Pacific nesting stock (P. Dutton, *pers. comm.*)

Because of these facts, we recommend that:

- Mexico should take relevant and immediate action to avoid the total collapse of this species in the Eastern Pacific, considering the recognized importance that this country's rookeries had in the early 80's.
- Population recovery should be accomplished by establishing effective protection programs for eggs in the beaches and production of hatchlings.
- International agreements should be implemented and enforced with the countries involved in leatherback bycatch, in order to minimize the rate at which this species is disappearing from the eastern Pacific Conservation projects must be supported for beaches of primary and secondary importance along the eastern Pacific

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Impacts from Development, Nesting Population Trends and the Future of Marine Turtles at Paka-Kertih, Terengganu

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The Paka-Kertih turtle rookery (4º41'-4º38' N, 103º20'-103º24' E) is located within the sub-district of Kuala Paka in the east coast state of Terengganu, Peninsular Malaysia. The area experiences monsoonal rains between the months of November-January and mean annual rain is 3,082 mm; mean annual temperature is 27.22ºC while mean annual relative humidity is 81.80%. The coastal area experiences diurnal tides with amplitude ranging between 1.5-3.0m. The turtle nesting beach at Paka-Kertih totals about 11.5 kilometers and the continuity of the beach is broken by scattered rocky headlands of granite. The four main nesting beaches, in a north to south direction and their length are: Rhu Kudung (2.3 km), Tanjung Batu (3.0 km), Cagar Hutan (1.5 km) and Ma' Daerah (1.7 km). Leatherback, green and olive ridley turtles nest at Paka-Kertih and nesting numbers used to be significant i.e. 50%, 45% and 15% respectively in comparison to overal nesting numbers on mainland Terengganu. The discovery of petroleum in the state in 1978 promoted the development and expansion of petroleum-gas based industries along the coast. Rapid coastal development in the area especially by the oil and gas industry, housing development, power stations and the construction of ethylene and polyethylene plants (a joint venture of British Petroleum Malaysia and Petroleum Nasional Malaysia) have severely degraded the nesting beaches and have had impacts on turtle nesting. Although an Environmental Impact Assessment was conducted for the proposed development, other factors overruled the mitigating measures proposed in the report.

In Peninsular Malaysia, turtles and turtle hatcheries are managed by the Marine Parks Unit of the Federal Department of Fisheries Malaysia (DoFM) in collaboration with respective state governments. Turtle research is coordinated through the Southeast Asian Fisheries Development Centre (SEAFDEC) through Federal Government and government aid agency (GAA) funding. The Fisheries Act 1985 allows respective state governments to draw up their own rules and regulation with regard to turtles and inland fisheries. As a result, some states have been relatively proactive in turtle conservation efforts whilst others are deplorable. In most states, state laws offer some form of protection to adult turtles, but generally serve as mechanisms to regulate the commercial exploitation of turtle eggs through a licensed egg collection system.

This brief presentation highlights some of the turtle conservation issues at Paka-Kertih, what is happening to the turtle populations and how WWF Malaysia has attempted to address these issues.

Materials and Methods

I investigated marine turtle nesting densities at Paka-Kertih (Sharma, 1995; 1997) between 1994-1996 and monitored coastal development while studying the reproductive ecology of painted terrapins (*Callagur borneoensis*) at the same site. Apart from nesting surveys, I also examined hatchery management techniques. Prior to this, Mortimer and Dzuhari (1991) investigated turtle nesting densities at the same site in relation to the amount of artificial light, removal of beach vegetation, sand mining and bull-dozing, and outflow of liquid waste in 1991. Due to impending development projects at the nesting beaches, WWFM conducted a short study in 1993 and provided the Terengganu state government with recommendations on how and where to develop, if at all proposed development projects were to be approved by the Terengganu state government (Davison, 1993). This was followed by a turtle management report to the Terengganu Turtle Sanctuary Advisory Council (chaired by the State Secretary) (Sharma, 1995) and later in 1996 a report on the coastal and estuarine land-use management around the Paka-Kertih (Muhammad Nasir, 1996). Further to this, we reviewed all state and federal legislation affecting marine and freshwater turtles and provided recommendations for change to the Department of Wildlife and National Parks, the Department of Fisheries and the Terengganu Turtle Sanctuary Advisory Council (Gregory and Sharma, 1997).

During nesting surveys, the following information was gathered:

i) the turtle species,
ii) location of nest,
iii) nesting versus non-nesting emergence and
iv) emergences with attempted but unsuccessful nesting.

In investigating hatchery management techniques, the following was scrutinized:

i) hatching success in relation to incubation treatment. The Department of Fisheries Malaysia generally incubates 50% of all eggs submitted by licensed egg collectors, in sand fully exposed to direct sunlight and 50% of eggs under artificial shade.

ii) possible cause of embryonic mortality through gross examination of unhatched eggs and lastly,

iii) incubation of eggs and hatchling release techniques.

Data that was not gathered during the current study was obtained from the Department of Fisheries Malaysia

Results and Discussions

Development impacts: Mortimer and Dzuhari (1991) found that the site for the proposed ethylene and polyethylene plants were important for turtle nesting as 44.3% of nesting emergences occurred here and 47% of all egg deposition was recorded at this site. They also found that the distribution of turtle nesting emergences was inversely proportional to the intensity of the artificial light visible on the beach at night. This was largely the gas flares that literally turned night into day. This relationship was especially clear for green turtles but less so for olive ridley turtles and leatherbacks. Nesting density was also low at the sites where artificial lights were very bright but evenly distributed at sites that were dark. It was also clear that turtles avoided nesting on sections of the beach where vegetation had been removed for pipeline construction and sand mining and removal of beach sand. Mortimer and Dzuhari (1991) also predicted the potential impacts of the jetty and breakwater construction on marine turtle nestings but were unable to suggest ways to directly mitigate the impact given that construction would occur during turtle nesting season, to avoid the monsoon.

In mid 1993, site clearance and initial engineering work began at BP Chemicals' ethylene and polyethylene joint venture projects that proposed to transformation 250 acres of undisturbed coastal vegetation to a world-scale petroleum complex. In July 1994, a 700m long trestle jetty was being constructed. This was connected to a one kilometre long breakwater, positioned parallel to the shoreline in front of the plants. Additionally a huge pipeline system for the cooling tower system of the YTL Power Plant was being developed. Beach vegetation in certain areas close to the Kertih river mouth was also being cleared and construction work to revet the rivermouth was underway. During most of the abovementioned, noise pollution levels from machinery were high particularly at the jetty and pipeline construction sites, both during the day and night.

Nesting population trends: Generally, turtle egg deposition at Paka-Kertih is on the decline. From a combined 500 egg clutches deposited in 1988, an average of 240 egg clutches was calculated between the years 1996-1998. **Figure 1** shows the number of nests deposited at the various nesting beaches (i.e. Ma' Daerah, Cagar Hutan, Tanjung Batu and Rhu Kudung) from 1988 to 1998. There appears to be a general decline in the number of egg clutches deposited in the Rhu Kudung area, particularly in the last three years (1996-1998). This coincided with the construction and operation of the ethylene and polyethylene plants. It is disturbing to note that more such plants have been proposed for the state and the impacts will be more visible. Nesting appears to have increased in Ma Daerah and Cagar Hutan since 1993 and nesting densities appear to have returned to levels calculated for the 1988 season. In 1998, Ma Daerah, the most pristine of the nesting beaches recorded the highest density of nests with close to 90 nests per kilometer of beach (**Fig. 2**). From 1996 to 1998 nesting density at Rhu Kudung was below 5 nests per kilometer of beach and the figure was the same for Tanjung Batu in 1998 (**Fig. 3**). The apparent general drop in nesting density at Cakar Hutan and Ma' Daerah appears to be related to pipe-laying and sand mining at Cakar Hutan during those years and partial land clearing close to Ma Daerah for a tourist resort and golf course. Davison (1993) also reported that the nesting beaches were heavily polluted with solid wastes during his study and this may have deterred turtles from successfully nesting. Whilst coastal development may have had its impacts on marine turtles and nesting activity, the overall decline in the nesting population is presumably, amongst other things, a combined effect of the long-term harvest and human consumption of eggs and adult mortalities through incidental capture in fishing gear. In addition, the impacts of coastal development such as the construction of jetties and breakwaters and its effect on sediment or sand transport along the coast has not been well documented although this slide clearly shows how the beach profile has been altered to form steep slopes which turtles generally avoid. Nevertheless, some beaches are beginning to experience bad erosion and these become useless to marine turtles.

A look at the Paka-Kertih hatchery data in 1994 also revealed that even in applying the recommendations to shade some developing egg clutches to avoid excessive female hatchling production in the extremely hot Terengganu sands, eggs incubated under direct sun light experienced lower hatch rates for green, olive ridley and leatherback turtles compared to those incubated under artificial shade. Whilst more eggs can be saved from being roasted and in maintaining the need to produce female hatchlings, further investigations will have to be made and egg management techniques from elsewhere will have to be learned and applied. This is sadly beyond the jurisdiction of WWF Malaysia since the Department of Fisheries has assumed to have acquired sound knowledge on the subject having received some exposure and training in the past. Although turtle experts have provided both technical training and management recommendations to the DoFM staff in the past, there is still a long way to go in terms of implementation of these and appreciation of the urgency of the problems. It is sometimes also the case of staff having undergone limited training, becoming experts overnight, and executing numerous things that are more detrimental to turtles.

So, what is the future for marine turtles at Paka-Kertih?

It is generally acknowledged that in most sea turtle conservation programs, active participation by local communities utilizing the resources are crucial. While general turtle conservation activities have been conducted previously, WWF Malaysia and the Department of Fisheries are about to embark on a specific local community turtle awareness program nicknamed the 'Turtle Roadshow' in late March 1999. The primary objective is to bring the necessary conservation messages to coastal communities in 17 important nesting sites throughout Peninsular Malaysia and to obtain positive initial responses. Through a series of audio-visual aids, print media and dialogues with village elders, fishermen, local teachers, local government offices and school children, it is envisioned that the necessary grassroots support towards marine turtle conservation efforts will be obtained.

In addition, a recently developed 'Marine Education Kit' by the Department of Fisheries and WWF Malaysia

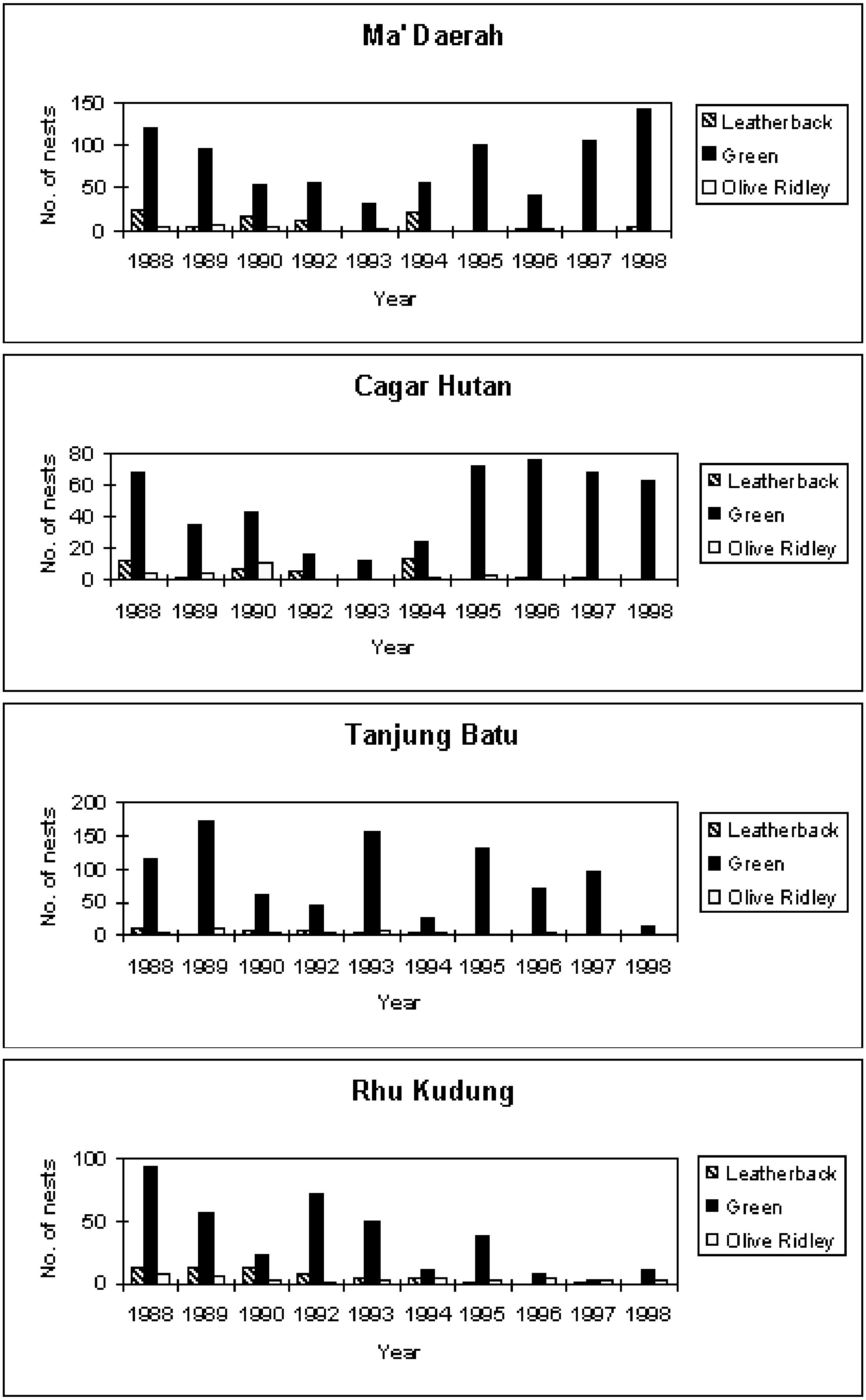

Figure 1. Yearly number of nests deposited on four Malaysian beaches.

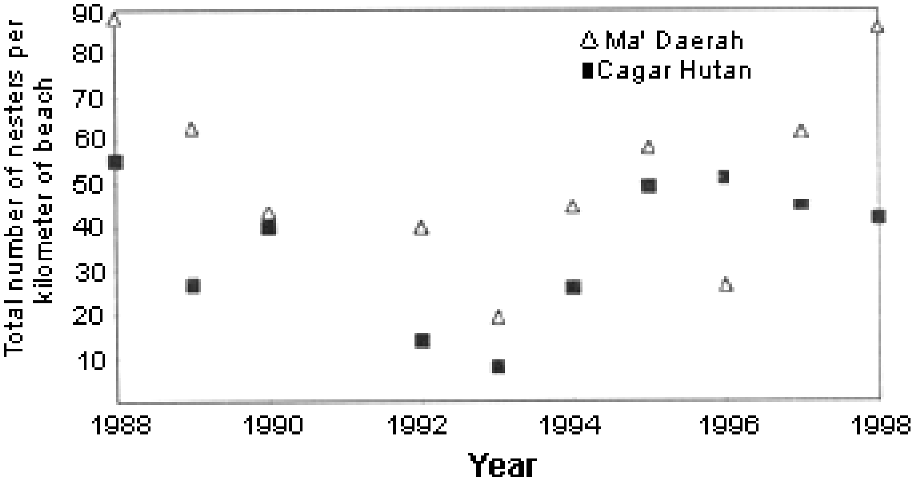

Figure 2. Relationship between total number of marine turtle nests per kilometer of beach and nesting season at Ma'Daerah and Cagar Hutan, Terengganu.

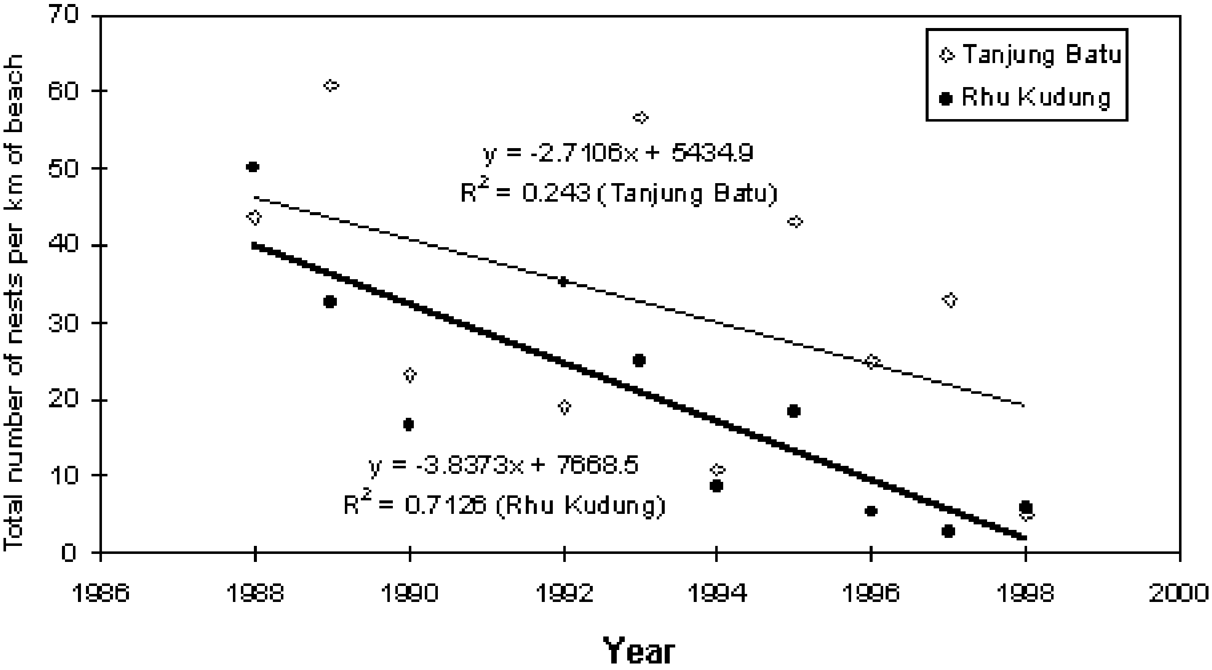

Figure 3. Relationship between total number of marine turtle nests per kilometer of beach and year at Tanjung Batu and Rhu Kudung, Terengganu.

devotes a whole module to the importance of protecting turtle nesting beaches and promotes marine turtle conservation. Over the last two years, WWF M and the DoFM have conducted numerous workshops for school-teachers, focussed on the contents of the MEK. This is for teachers to use concepts and lessons learned in the marine education kit across the formal school curriculum.

A simple hatchery management guidelines manual is being produced in the local language so that the locals who are temporarily employed as hatchery caretakers during the nesting season can practice important hatchery management techniques. While the manual will deal with things that seem trivial such as proper hatchling release methods, proper egg incubation methods, prevention of egg and hatchling predation, I suspect that a lot of advice is going to be necessary in relation to incubation temperatures and hatchling male/female sex-ratio production.

We are also now working with BP Malaysia to address the current threats to turtles at Paka-Kertih and stakeholder consultations are underway.

So, in conclusion, the long-term survival of marine turtles at Paka-Kertih is uncertain. While recommendations for what appears to be the best conservation and management practices have been imparted to the Department of Fisheries and the local state governments, through management reports to key officials and training workshops for ground staff and the like, the biggest hurdle in marine turtle conservation appears to be the lack of political will, generally the non- or partial implementation of recommendations made by respected turtle scientists and a total lack of understanding and ignorance on the biological needs of marine turtles. As the results of hard science become available and appropriately applied in conservation efforts, turtle populations continue to be decimated.

Local grassroots support will be crucial in making local governments realize that current commercial harvest and consumption levels of marine turtles eggs cannot and will not go on forever and that bold steps must be taken to ban the human consumption of turtle eggs immediately. This is a start, a possibly late but a very important start, if at all there is going to be any hope that coastal Malay children like these will be able to view these magnificent reptiles as they come ashore to lay their eggs, or even continue to consume turtle eggs as their forefathers have been doing so since ancient times.

Some of the things I have managed to touch on briefly today are not unique to Paka-Kertih, but true to many parts of Peninsular Malaysia. Whilst we continue our endeavors to save turtles, as Dr. Nicholas Mrosovsky has pointed out during this meeting, there are some successes which we need to make a lot of fuss about. Nevertheless, before I left to come out here, a draft environmental impact assessment report was released where the consultants detailed how a large scale land reclamation project along the entire coast of Melaka, west of the country, would not be detrimental to the largest hawksbill turtle population in the Peninsula. The report suggested that the turtles would relocate themselves and nest elsewhere although for the most part, the west coast is lined with mangrove and mud. This in my opinion is a classic case where state governments responsible for approving developmental proposals pay no heed what so ever to the intrinsic needs of local biodiversity.

Acknowledgements

I would like to thank the Packard Foundation through the organizers of the 19th Annual Symposium on Sea Turtle Biology and Conservation and WWF Malaysia for graciously funding my trip and making it possible for me to participate in this event.

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A Close Look at Encounters

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A 14-year saturation-tagging programme of loggerhead sea turtles *Caretta caretta* has been conducted on the Greek Island of Kefalonia. A high encounter rate (100%) with nesting adults on Mounda Beach has allowed an accurate life history to be compiled for a number of animals. Fairly accurate predictions have been made for remigration, inter-nesting period, spatial fidelity and possible site infidelity. The position of all nests was recorded using triangulation. Most nests were exhumed after hatchling emergence activity ceased, which produced accurate nest success-rates. Intermittent hatchling emergence, possibly preceded by intermittent hatching, is commonplace. A detailed examination of undeveloped eggs was performed, following nest excavation. The microclimate within five developing nests was studied, using temperature data loggers above and below the clutch. The sediment grain-size and water content was determined for all nests.

Materials and Methods

Mounda Beach

The 2.8 kilometre beach is situated at the south-eastern tip of Kefalonia and is where the main nesting effort occurs. The loggerhead rookery is small (n =148 turtles between 1985-1998) but biologically important. No predators have been observed at the site and there is no indigenous egg-trade. Most nests are laid well above the strand line. Intermittent hatchling emergence is common, with some nests being active for 21 days. A resident population of male *Caretta caretta* seems to be in the lagoon at Argostoli throughout the year.

Nesting Beaches

Three definitions were used in this study to describe nesting sites: Primary -- a turtle's usual nesting site, which is used in most years; Secondary--a beach that is used when access to the primary site is prevented; Emergency--a broadly suitable beach that is used rather than dumping the eggs at sea.

Four aspects of fidelity:

1) Remigration - The period between successive nesting seasons at Mounda Beach.

2) Inter-nesting period - The interval between successive clutches laid in the same season at Mounda Beach.

3) Temporal fidelity - The date that a turtle laid her first clutch of a season at Mounda Beach.

4) Spatial fidelity - The particular point on the beach that a turtle laid her nests. Substrate differences exist between the Potomakia and Kaminia ends of the beach. Turtles that have not stranded at both ends may not know that Potomakia is much easier to excavate.

Results

Results are available from the author and cover the following areas:

Sediment grain-size and water content for all nests and control sites.

Life histories for most females, which include the number of clutches produced, remigration period and inter-nesting interval. The success rate of nests and total egg numbers. The duration of an individual's nesting season and possible site infidelity. Intra-beach spatial fidelity; only two out of 15 turtles nested at both ends of the beach during 1998.

Surveys of secondary nesting beaches were carried out weekly. These were used in conjunction with radio telemetry examining migration and inter-nesting habitat use.

Temperature data loggers recorded the incubating nest microclimate every 2.5 hours and the effective depth of diurnal temperature fluctuations on the substrate.

Intermittent hatchling emergence: 2-13 days during 1998.

The stage of development for unhatched eggs and numbers of neonate mortalities.

Discussion

One turtle [C66][552] has nested in 10/14 years and now is in an annual remigration cycle, laying two clutches each season (1995-1998). The life history for a turtle can be used to predict possible nesting years. The frequency of remigration can change but is fairly consistent, with most animals in a biennial or triennial cycle. Most turtles are never seen again after their initial nesting year (67%). It is not known when an animal has died because no tagged mortality has been reported to date.

Only one turtle [C158] could have laid a nest elsewhere during 1998, as there was a 38-day inter-nesting period between successive nests at Mounda Beach. A turtle could have laid nests at other sites before arriving at Mounda, or after leaving.

Experienced animals tend to nest if they strand and cover the nesting site more efficiently than neophytes. The assumption that the year of tagging is the first nesting year is probably erroneous. Turtles returning to Mounda Beach on a subsequent occasion are termed as resident, regardless of the remigration period. All residents laid two or more clutches during 1998; while all single nests were produced by neophytes.

Most turtles have an individual but regular start date to their nesting season. This can alter according to the number of clutches that an animal produces. An individual may arrive earlier in years that she lays three clutches than when she only produces two.

The high encounter rate (100%) with nesting adults enabled accurate records to be produced. Most nests (32 out of 33 nests in 1998) were excavated after hatchling emergence ceased and all recovered eggs were examined to determine possible reasons for non-development. An unusually high number (22% of all eggs) were yolked and undeveloped in 1998; compared with about 10% in other years. Most of these eggs had solidified yolks. This was possibly due to the exceptionally high temperatures experienced during 1998. The substrate surface temperature was >50C by 11:00 each morning during July and August. My colleague (JDR Houghton) is investigating the effect of elevated temperatures on the sex ratio of developing embryos.

One nest (26M) had a foreshortened incubation period of 47 days, from oviposition on 23rd/24th July 1998 until first emergence 8th September (mass emergence 20-30 hatchlings, followed by 2 on 9th Sept, >29 hatchlings on 10th Sept, 13 on 12th Sept, 5 on 14th Sept). (Turtle's tag numbers [C113][580]). Several other nests had the first emergences at 49/50/51 days. Although other places around the world experience hotter temperatures, the population is probably adapted to local conditions, and maintaining an incubation period of around 58 days.

Intermittent hatchling emergence was less prominent during 1998, with several mass-emergences occurring. These were virtually unknown at Mounda until 1998. It is possible that intermittency is more widespread than currently reported, because nests are excavated too early. A number of research sites excavate nests the day following first emergence. At Mounda Beach a nest may not be excavated until five weeks after the first hatchling appears. Live and vigorous neonates are often found in the egg-chamber or the sand column on their way to the surface, during excavations.

Turtles that nest on secondary beaches may be from a different population or, they may use different nesting sites in different years depending upon long-term weather and hydrographic cycles.

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Sea Turtle Nesting in Florida, USA, during the Decade 1989-1998: an Analysis of Trends

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Counts of sea turtle nests on nesting beaches provide the most widely used indicators of sea turtle abundance. In the State of Florida, USA, approximately 1260 km of beach were surveyed for sea turtle nesting activity in 1998. Within this total surveyed coastline, a 389.6-km set of index beaches was monitored using a standardized protocol that allows the detailed assessment of nesting trends. This index of beaches is the focus of Florida's Index Nesting Beach Survey Program, which has been in place since 1989. The purpose of this abstract is to describe an assessment of sea turtle nesting trends for ten years of Index Nesting Beach Survey data.

Methods

The Index Nesting Beach program comprises thirty beach sites representing the principal sea turtle nesting areas of Florida (northeast, central, and southeast Atlantic coast, and the southwest and northern coast/panhandle on the Gulf of Mexico). The season that Index surveys take place also is representative and is standardized among beaches to begin 15 May and end 31 August each year. Approximately 70 % of all the sea turtle nesting in Florida occurs at Index beaches during the Index season. Three beach sites in the Florida Panhandle (65.5 km, approximately 0.2 % of Index nesting) and three sites on the Atlantic coast (7.5 km, approximately 1.5 % of Index nesting) were surveyed less completely (spatially and temporally) than a core set of beaches used in this study for trend analysis. This core set of beaches provided data for a ten-year database that is 97.1 % complete in the number of nesting records.

Nesting surveys at Index beaches are conducted by daily appraisal of tracks that have resulted from nightly nesting attempts by female turtles. Characteristics of tracks are used to assess the species of the turtle that made the track and whether the track resulted from a nest or from an abandoned nesting attempt. Track assessment skills are reinforced at yearly pre-season workshops, which all Index beach-surveyors are required to attend. The accuracy of daily track surveys is tested during the season by observing nesting turtles at night on a sample of beach sites and by comparing these known nest/species identifications to the identifications made by surveyors the following morning. Preliminary results show that the error rate in nest identification (nest versus non-nest) is 7.9% for loggerhead tracks ($n = 416$) and 12 % for green turtle tracks ($n = 41$), and that error in species identification is 1.4 % ($n=139$).

The resolution of the data collected from Index surveys is such that each track is identified to species and as a nest or abandoned attempt, is located within an individual beach zone of approximately 0.8-1.0 km in length, and is recorded for an individual day of an annual nesting season. Consistency of the methods used during the ten years of the program and among all Index beaches make the resulting data base a relatively representative and unbiased assessment of sea turtle nesting and, therefore, appropriate for the analysis of temporal and spatial trends.

Results and Discussion

Nesting by three species was recorded by Index surveys during the period 1989-1998. In order of prevalence the species were the loggerhead (*Caretta caretta*), the green turtle (*Chelonia mydas*), and the leatherback (*Dermochelys coriacea*).

The spatial distribution of loggerhead and green turtle nesting was similar, each having peaks in nesting on the Atlantic coast near latitude 27° N and near latitude 28° N (**Fig. 1**). Leatherback nesting was largely restricted to the Atlantic coast near 27° N (**Fig. 1**).

During the ten-year period at the core set of Index beaches, the annual number of loggerhead nests ranged 39,091 - 59,917 nests (mean = 49,643, $s = 6788$, $r = 0.48$, $p = 0.16$), green turtle nests ranged 267 - 4229 nests (mean = 1458, $s = 1316$, $r = 0.45$, $p = 0.20$), and leatherback nests ranged 27 - 130 nests (mean = 69, $s = 29$, $r = 0.88$, $p < 0.001$). Nesting numbers for green turtles showed a clear bi-annual periodicity, with odd years having low nesting and even years having high nesting during the ten-year period. Grouping green turtle nesting into two-year (high-nesting/low-nesting) blocks did not improve the correlation coefficient enough to allow a determination that slope was different from zero ($r = 0.79$, $p = 0.11$). We conclude that, over the ten-year period of the study, loggerhead and green turtle nesting in Florida appears to be stable or increasing, and that leatherback nesting is increasing significantly.

Because individual beach zones on Index beaches have been consistently surveyed as discreet units over the ten-year period, each can be considered as a discreet spatial entity for the purpose of detecting spatial trends. Correlation coefficients describing ten-year slopes at each surveyed beach zone show considerable variation in temporal trends among beach zones (**Figs. 2 and 3**). Of note is the stretch of beach on the Atlantic coast approximately 0.3° north and south of 28.0° N and the Index beach sites on the southern Gulf of Mexico (approximately 26.0° - 26.5° N). Beach zones in these areas show ten-year correlation coefficients that are nearly all positive for both loggerhead nests (**Fig. 2**) and for green turtle nests (**Fig. 3**; a trend assessment is not made for the sparse green turtle nesting on the Gulf of Mexico). These beach zones are generally characterized as having relatively sparse human habitation (undeveloped dune as in parks and wildlife refuges, or low-density single-family, non-resort development) and relatively little artificial illumination (well-enforced light-management ordinances are in place).

It is possible that some of the variation in temporal trends along the Florida coastline is the result of turtles moving from heavily developed, lighted beaches to beaches that are darker and less disturbed. We realize the subjectivity of this appraisal. However, we submit a tentative conclusion that underscores the value of undisturbed nesting beach refuges for sea turtles. It is that coastal sea turtle refuges are likely to support a higher proportion of a region's nesting turtles as areas adjacent to the refuge beaches become more disturbed by human habitation.

Acknowledgements

Florida's Index Nesting Beach Survey program was conceived by Barbara Schroeder, Alan Huff, Earl Possardt, Lew Ehrhart, Anne Meylan, Erik Martin, and Blair Witherington. Data entry and verification was by Carrie Crady, Carolyn Farmer, Layne Bolen, and Chris Koeppel. Many people served as nesting beach surveyors, but principal supervisors of nesting surveys were Clif Maxwell, Robert Rahberg, Mary Duffy, Russ Ferris, Bob Joseph, Chad Loch, Mort Hanson, Jan Hanson, Randy Hester, Bert Charest, J.B. Miller, David Parker, Andrew Rich, Mike Evans, Kevin Marczak, Wendell Simpson, John Stiner, Ron Hight, Mark Epstein, Don George, Terry O'Toole, Paul Tritaik, Karen Frutchey, Dan Griffin, Diane Oliver, Jonathan Gorham, Mike Bressette, Erik Martin, Bob Ernest, Mark

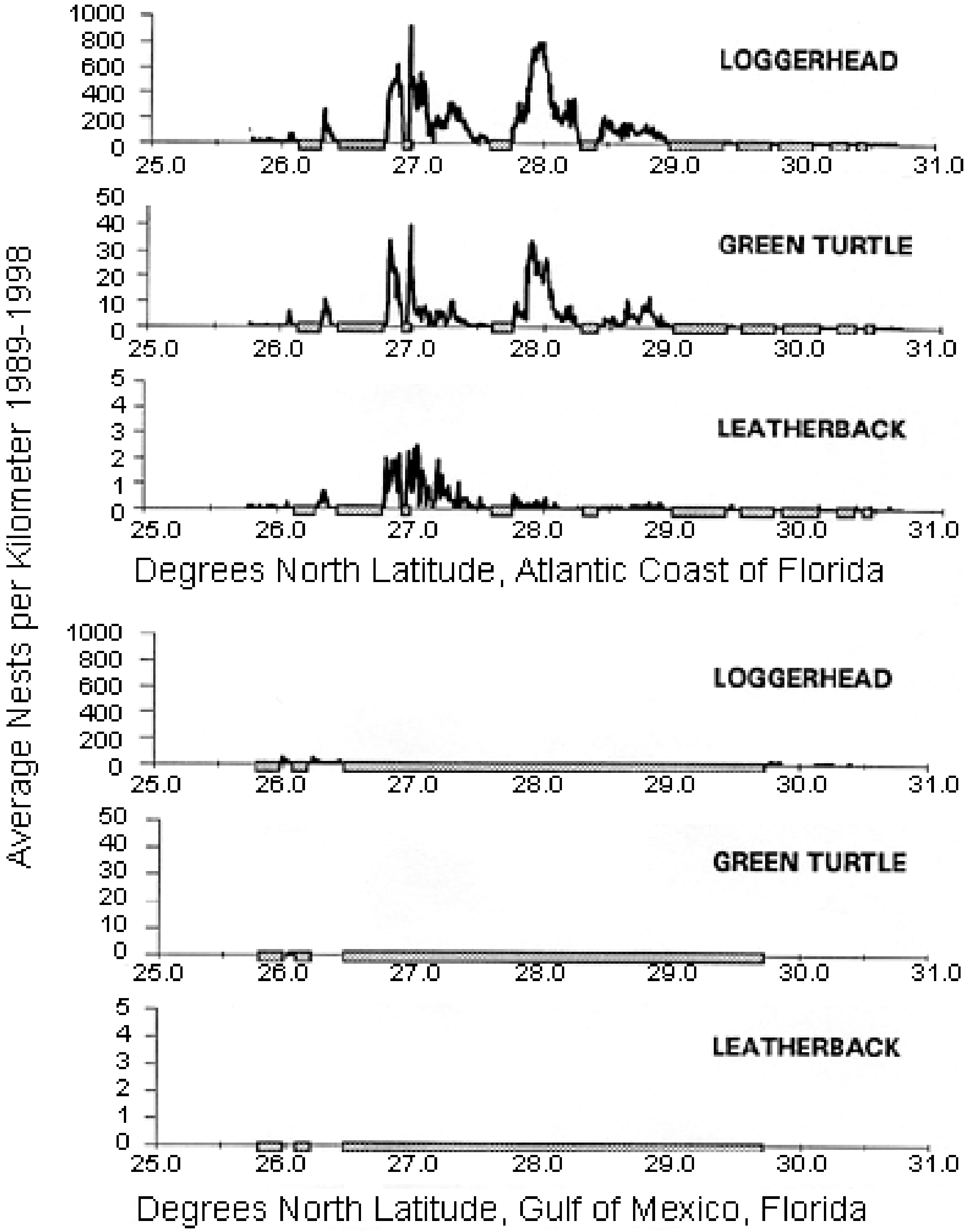

Figure 1. Spatial distribution of sea turtle nests counted during index nesting beach surveys in Florida, USA, 1989-1998. Shaded bars on the axes indicate stretches of beach that were not surveyed. In the northern most Gulf of Mexico only the years 1997 and 1998 are represented

Mercadante, Jane Provancha, Angy Chambers, Olin Miller, Lew Ehrhart, Dean Bagley, Ron Johns, John Griner, Ryan Noel, Peter Quincy, Larry Wood, Kirt Rusenko, Joe Smyth, Sid Leve, Brian Christ, Jim Hoover, Bill Ahern, Beverly Ball, Robert Steiger, David Addison, Bruce Hagedorn, Dennis Teague, Kennard Watson, Joe Mitchell, Meg Lamont, Steve Shea, Bonnie Mowery, and Matthew Allen. This research was funded by the Florida Department of Environmental Protection Marine Turtle Protection Trust Fund, by the Florida Game and Freshwater Fish Commission Non-game Wildlife Program, by the U S Fish and Wildlife Service, and by the volunteer service of data collectors.

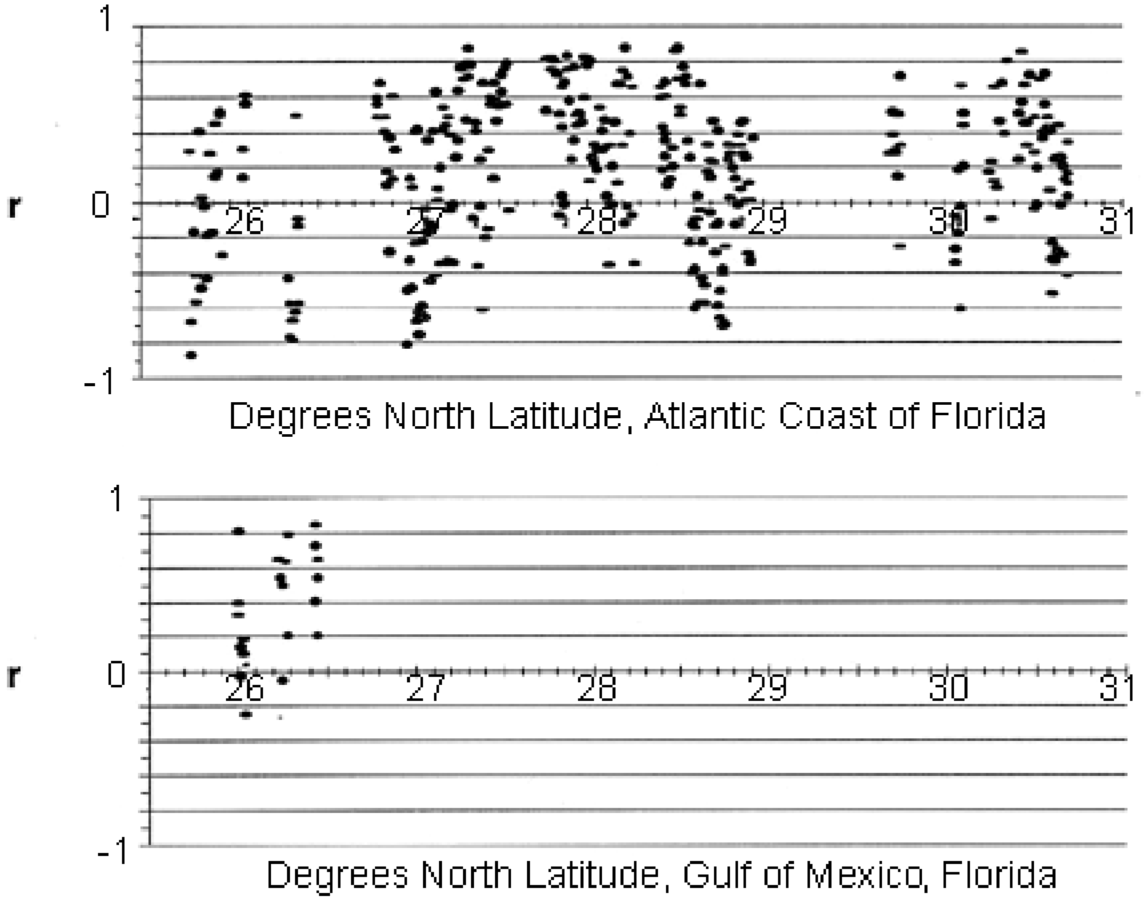

Figure 2. Loggerhead nesting trends by individual beach zones for Atlantic and Gulf-of-Mexico coasts of Florida during the period 1989-1998. Trends are described by correlation corefficients (r) for each zone (zones are approximately 0.8-1.0 km). Correlation coefficients >0.63 and <-0.63 represent significant slopes at alpha=0.05.

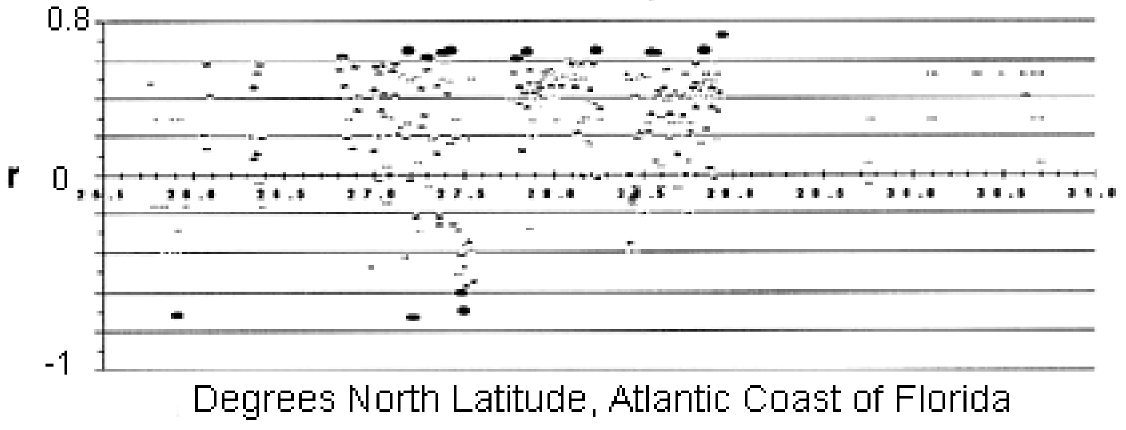

Figure 3. Green turtle nesting trends by individual beach zones for the Atlantic coast of Florida during the period 1989-1998. Nesting on the Gulf coast is not numerous enough to assess trends. Trends are described by correlation coefficients (r) for each zone (zones are approximately 0.8-1.0 km). Correlation coefficients >0.63 and <-0.63 represent significant slopes at alpha=0.05.

First Attempt toProtect the Hawksbill Turtle (*Eretmochelys imbricata*) Rookery at Segama Islands, Java Sea, Indonesia

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In the last 10 years, the hawksbill turtle population in the Java Sea has drastically declined up to 85%. This decline was primarily caused by the harvest of adult and subadult turtles for export to Japan for the Bekko industry (tortoise shell) until 1991 and by the poaching of most eggs by the local inhabitants.

The hawksbill protection project was initiated at Segama Islands in December 1997. We asked lighthouse guards to observe nesting conditions and to protect nests from poachers. We regularly visited the site to investigate nests by excavating them. The total number of nests from Dec. 1997 to Nov. 1998 was 133 with an average of 139.2 (SD=36.8) eggs per clutch. 110 nests were left in natural conditions without handling. Emergence success was 62.6% (N=69) and it was estimated that 9,103 hatchlings entered the sea. Additionally we conducted a tagging program with nesting females. Nearly the same project has been carried out at 3 other rookeries in Java Sea.

ANCIENT TURTLES: TRADITIONS AND FOSSILS

Turtle Sacrifice to the Temple Gods in the Penghu Islands of Taiwan

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Fourteen days after the Chinese New Year, the PengHu islanders offer sacrificial images of sea turtles to their temple deities to ensure peace, prosperity, and good fortune. These rituals of devotion last for three days as part of the Lantern Festival — the most important celebration of the Lunar New Year in PengHu. During this time, the temples are crowded day and night with worshippers burning incense and praying for favors and divine guidance. Others are there to show appreciation for wishes granted the previous year. Rice cakes made into all shapes and sizes of sea turtles are the most common items placed in the temples as sacrifice. Other offerings include turtle images fashioned from gold and coins. The PengHu people believe that the sea turtle is an auspicious creature, blessed with good luck and long life. Ling (1972), writing in Chinese, has drawn comparisons between the PengHu ceremonies and the ancient Polynesian practice of sacrificing and feasting upon sea turtles at stone altars in the remote Tuamotu Islands (Emory 1947). Sea turtles nest in PengHu, but presently only in small numbers mainly on the island of WanAn (Chen and Cheng 1995). Satellite tracking has recently shown that seasonal migrations to this location occur from several distant foraging areas, including Hainan, Hong Kong, China, Okinawa and southern Japan (Cheng and Balazs 1998). Real turtles are not sacrificed during the PengHu ceremonies, although Ling (1972) speculates that they probably were used for this purpose in the distant past (see also Allan 1991).

The Islands and the People- PengHu, called Pescadores (Fishermen Islands) by early Portuguese explorers, consists of 64 small coral and basalt islands located in the Taiwan Strait at 23.5° North, 119.5 ° East, about 100 km south of Fukien province in China and 60 km west of Taiwan. The area is a dividing point between the East and South China Seas characterized by hot summers, cold winters, and strong northeast monsoons. Immigrants first came to PengHu from Fukien over 800 years ago, or 400 years earlier than the settlement of Taiwan by the Han Chinese. The traditions, beliefs, and language of the PengHu people have retained some of their own identity as the result of geographical isolation. There are about 96,000 residents in 97 villages located on the 20 inhabited islands. Most people live on the main island (PengHu) in or around the modern city of Makung. At last count, there were 174 community temples dedicated to various Gods. Thousands of other small temples or shrines exist in homes and businesses throughout PengHu for personal family worship. The PengHu folk religion is a blend of Chinese Taoism, Buddhism and complex supernatural concepts not easily understood within Western thought or language. Community temples are architecturally intricate, visually stunning, and costly. The roofs are particularly striking, rising upward in peaks that support ceramic figures of Gods, dragons, and other mystical beasts. Another prominent feature seen nearly everywhere throughout the PengHu landscape is the walled cement graves of ancestors adorned with colored tiles. The following quote from a tourist guidebook exemplifies the religious fervor of the people: "PengHu is an oceanic country. Most of the residents live by fishing. PengHu's coastline is very long and most of the residents live on the sea, so they have to face the challenge of evil waves. Facing the changeable nature, it is more violently required for them to pray to Gods. So they respect heaven and earth and are afraid of Ghosts and Gods. Due to this factor, the density of temples in PengHu is the number one in Taiwan, and the temples are very luxurious. When you travel here, it seems you are in paradise. She is the hometown of the sea, a pretty archipelago, the 'Hawaii' of Taiwan."

Ma-tsu the Sea Goddess- There is a special relationship with the deity, Ma-tsu, and the turtle sacrifice ceremonies of PengHu (**Fig. 1**). The coastal people of the China region, and especially Taiwan, have a deep and widespread devotion to the Goddess Ma-tsu as the guardian of fishermen, ocean travelers and all who live near the sea. In Taiwan, many consider her to be their "Patron Saint." Ma-tsu was born with auspicious signs on Meichou Island, Fukien on the 23rd day of the third moon in 960CE. As a pious young girl named Mo-Lin, she was given special charms and insights by Taoist Masters. Later she used supernatural powers to save her father and brothers when their boat capsized. Other stories were told of her merciful intervention. When she died in 987CE, a temple was built in her village to attract continuing favors. Word of her miracles spread throughout the region and, by imperial decrees issued during the following centuries, she received imposing high titles, including Tien Hou (Consort of Heaven). This is the name she is commonly called in the vicinity of Hong Kong. When immigrants came to PengHu from Fukien, they built a temple for Ma-tsu in honor of the protection and safe navigation the Goddess gave during the ocean voyage. Today, throughout China and Southeast Asia, there are an estimated 5000 temples dedicated to Ma-tsu, with more than 200 million followers that believe in her protective powers (see for example <www.matzu.com.tw> and <www.shanghaisteve.com>).

A Visit to Five Temples - On February 11-12, during the 1998 Lantern Festival, we visited PengHu as the guests of local officials to observe, photograph and learn about the turtle sacrifice ceremonies. We (the three authors) were accompanied by our friends, Jeff Chen and Louise Shen of Rationalism Production House in Taipei. The interest in making such a trip first arose in the 1970's, when Shun-Sheng Ling sent GHB a copy of his report on turtle sacrifice (Ling 1972). Five temples were visited, one after the other, during a 10-hour period extending from mid-afternoon to the early morning of the next day. It should be noted that the temples are the "official residences" or "palaces" of the Gods, rather than gathering places for congregations. Hence a memorable feature of this trip was the genuine acceptance and hospitality by the PengHu people of our presence in the temples. Short descriptions of the five temples visited are as follows:

Ocean Spirit Temple- This temple was remarkable for the large number of stylized and colorfully decorated rice cake turtles arranged row after row on tables throughout the temple. When a turtle was purchased, as an offering, from the temple priest it was turned around so the head faced the deity. A paper sign was then placed on the turtle with the worshippers name and request written on it for the God to see. For example, one such request asked for "happiness, handsome salary, long life and joy."

Tien Hou Ma-tsu Temple- Built in 1592, this is the oldest existing Ma-tsu temple in PengHu and all of Taiwan. The original structure is located behind the present modern temple building containing the Ma-tsu deity. A sea turtle fashioned from bags of rice flour totaling 6000-kg was present inside the main entrance. This huge turtle, with decorative flashing lights, was surrounded by a wishing-pond where coins were tossed as offerings. A golden-robed figure of Ma-tsu stood upon the turtle's back. Boiled eggs dyed various colors were presented by women attendants who warmly welcomed all who entered. The priests gave worshippers pouches of silk cloth containing incense ashes from the temple. Finely embroidered Chinese characters on these 'peace and protection' amulets proclaimed "The Heavenly Queen's Palace in PengHu." A plaque in the original temple building illustrated the ocean path taken across the Taiwan Strait when the Ma-tsu deity was first brought from Fukien to PengHu. We noted that this route was similar to the one taken by some of the migrant turtles tracked by satellite from PengHu. Sticks of incense commonly placed on the backs of the rice cake turtles, with smoke rising symbolically to the heavens, reminded us of the transmitter antennas on migrating turtles sending electronic messages skyward to satellites.

Golden Turtle Temple- Located at Shantsuei village, the sacrificial centerpiece of this temple was a 3.3 kg pure gold sea turtle, mechanically "swimming" in a pond formed within the back of a large concrete turtle painted gold (**Fig. 2**). When a brilliant red cloth was drawn back during formal unveiling ceremonies, the Golden Turtle rose to the surface to start life-like flipper strokes and head movements in rhythm with recorded temple music. The same music and appearance of the turtle from beneath the water was repeated every several minutes, to the delight of all present. Live goldfish and small freshwater turtles swam in the pond with the Golden Turtle. Young women stylishly dressed in fine clothes, as almost everyone seemed to be for the ceremonies, greeted us at the temple entrance with smiles and gifts of small rice cake turtles. As was seen at all the temples visited, two crescent-shaped pieces of wood were dropped three times by worshippers asking for the divine favors. The orientation (up or down) of the pieces on the ground determined if the wish would be granted. In addition, if the correct sequence resulted, the person might be allowed to keep the Golden Turtle, or other precious sacrificial items, for a year. Great wealth and other good fortune were said to result from such an outcome. Outside, in the temple courtyard, there was a carnival-like atmosphere that included live entertainment, food vendors, children at play, and merchants selling all sorts of items.

Figure 1. Giant sea turtle fashioned from 6000 kg of rice flour located inside "The Heavenly Queen's Palace" in PengHu. An image of the Sea Goddess Ma-tsu stands on the turtle's back.

Fishing Boat Temple - Located at Waian Village, this setting consisted of a large cement courtyard with two small temples side-by-side. We arrived late at night, but could see the sky brilliantly illuminated from miles away by the lights of squid fishing boats berthed in the harbor. Aerial fireworks from the boats, and massive strings of firecrackers in the courtyard, were periodically ignited during our visit. The throng of worshippers both inside and outside the temples caused us to blend into the crowd, seemingly unnoticed by local residents. Although GHB was the only Westerner known to be present here, and at the other four temples visited, no one seemed to pay much attention to this anomaly, except with smiles and other gestures of friendship. The remarkable ceremonies seen at Waian included a ritual of the deity leaving its temple image and entering a human "God representative." Once taken over by the God, this special person was carried by litter around the village. This short procession was followed by more lengthy rituals of unusual ancient chants, music and dance to coax the God to come out of the person and return to the temple idol. Most of these ceremonies occurred inside the temple. In sharp contrast, at the same time modern entertainment took place in the courtyard involving stage shows with singing, dancing, and the awarding of raffle prizes.

Gold Temple - Located near Makung Harbor, this splendid temple, replete with luxurious ceiling and wall carvings and gold inlay, had only recently been built at a reported (but very believable) cost of US$35 million. Numerous pure gold sea turtles from 2-30 cm in length, housed in glass cases, were positioned around the deity. Also notable in this temple was an attractive 180-kg rice cake turtle with a colorful tiger design on its back.

Turtle Sacrifice at the Nineteenth Annual Sea Turtle Symposium - The day this paper was presented at the 19th Annual Symposium in Texas coincided with the 1999 turtle sacrifice ceremonies in PengHu, taking place halfway around the world. To provide realism, the talk was given in the presence of a small temple altar complete with an image of Ma-tsu that included ceremonial red lights, candles, paper money and an electric (non-smoking) incense blazer. Rice cake turtles, hand carried a few days earlier from PengHu by I-JC and H-CW, were also on display. Souvenir pictures of the 6000-kg rice cake turtle were distributed. The numerous photographs shown of the 1998 visit to PengHu, as part of the Symposium presentation, will appear on a website created for this purpose.

The ultimate message we want to convey in this paper is that, globally, the cultural heritage relating to sea turtles is diverse, deep and significant. More information of this nature needs to be uncovered, presented at symposia, published in the literature, and ultimately used to integrate appropriate conservation practices in line with local customs and beliefs. The presentation at the symposium closed with the following reading from an essay by Lyall Watson (Lindsay 1995): "We are the pattern-makers, the watchers of the world, sorting through the entrails of the earth in an endless search for meaning. It has always been this way, as though consciousness carries with it the penalty of a pressing need to know. So we look for signs in everything, reading nature like a book, hoping always to come across some sort of message hidden between the lines. Some clue, some hint of direction, anything that will make it easier to understand who we are and what on earth we should be doing. There are no easy answers."

Figure 2. Golden Turtle Temple at Shantsusei Village, PengHu. A 3.3 kg pure gold robotic sea turtle "swims" in a pool of water in the back of a large golden-painted turtle adorned with red ribbon.

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Fossilized Cretaceous Sea Turtle Nest From Colorado

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The first described fossilized sea turtle nests occur as sedimentary structures preserved in the Fox Hills Sandstone, Elbert County, Colorado. They are Cretaceous analogs to recent loggerhead sea turtle nests studied on St. Catherines Island, GA (Marsh and Bishop, 1993). Although sea turtles have an extensive geological record extending at least into the Jurassic and Early Cretaceous (Nicholls, 1997; Hirayama, 1997) and are abundant in modern seas (Lutz and Musick, 1997), traces of their terrestrial nesting activities (Caldwell, Carr, and Ogren, 1959; Witherington, (pub. comm.), Hailman and Elowson, 1992) have not been well documented in the literature and fossil traces have only recently been described (Bishop *et al.*, 1997).

Modern Loggerhead Nests

Studies of loggerhead sea turtles on St. Catherines Island, Georgia (Brannen and Bishop, 1993; Bishop and Marsh, 1994), have demonstrated a spectrum of sedimentary structures produced by nesting sea turtles and which are potentially represented by trace fossils preserved as sedimentary structures in ancient near-shore, marine sedimentary rocks. These biogenic structures include: 1) large crawlways produced by mature female turtles crawling from, and back to, the sea across the beach to nest, 2) small scale crawlways made by hatchlings as they emerge from the nest and scamper to the sea, and 3) distinctive disrupted sediments of the nest area, including the body pit, egg chamber, and covering pit.

Loggerhead sea turtles nesting on the Georgia coast construct elliptical nest structures which mask underlying body pits and egg chambers with a thin veneer of bioturbated sand produced in their covering activity. Georgia loggerhead nests consist of superjacent disrupted layer filling a broad, shallow depression formed during covering (the covering pit) which hides the area in which the turtle actually excavated for nesting (the body pit), which in turn overlies the small, vertical-walled, urn-shaped egg chamber. Study and documentation of over 842 nests and associated crawlways, with detailed trenching of 44 of these, has led to a model of the sedimentary structures associated with nesting of the species *Caretta caretta* Linnaeus, 1758. Loggerhead nests tend to be elliptical disturbed areas averaging 2.24 m long and 1.98 m wide with egg chambers averaging 23.1 cm in length, 18.52 cm in width, and extend approximately 26.80 cm into the substrate beneath the filling of the body pit, for a total average depth of about 46.8 cm. Erosional events may truncate or obliterate the sediments containing the structures, making them easy to overlook or misinterpret if seen in the fossil record while depositional events might tend to preserve them.

These studies of recent loggerhead sedimentary structures made during monitoring activities on St. Catherines Island were postulated at a meeting of the Rocky Mountain Section of the Geological Society of America to present a model for geological searches for nesting structures potentially produced by ancient sea turtles nesting in the Western Interior Seaway (Brannen and Bishop, 1996). Our intent was to place before geological colleagues the visual patterns of sea turtle nests, which we expected someone to see in ancient nests in shoreline sandstones of that area (Hansen, 1969). Fieldwork on fossilized Ghost Shrimp burrows in January of 1997 led to the discovery and recognition of the first described fossilized sea turtle nest in the Cretaceous Fox Hills Sandstone near Limon, Colorado.

Cretaceous Sea Turtle Nesting Structures

The Cretaceous Fox Hills Formation near Limon, Colorado (**Fig. 1**) preserves a continuous sequence of foreshore, backshore, and aeolian sediments (**Fig. 2**) of a shoreline facies tract. Preserved in the horizontally laminated backbeach facies are sedimentary structures representing a body pit, two egg chambers, and a crawlway in association with root traces and mud cracks. One nest structure, in place in the exposed vertical face of a small cliff, is 28 cm wide, 31 cm deep with overlying sand layers collapsed into the egg chamber and having egg molds preserved in its bottom (**Fig. 4**). A second nest structure, representing the bottom of a washed out egg chamber, was collected as a broken block immediately below the body pit. Lying approximately 2.2 m east of the *in situ* egg chamber and slightly higher stratigraphically is a body pit 103 cm wide and 25.0 cm deep scoured into the laminated backbeach sands and filled by bioturbated sand (**Fig.6**). Some 7.6 m southwest of the *in situ* nest structures and at the level of the body pit is a series of chevon-folded sandstone layers bracketed between undisturbed horizontal sandstone layers above and below, a structure comparable to a vertical cross section of a row of flipper push marks in a sea turtle crawlway (**Fig. 8**). These structures are directly comparable in size and morphology (**Figs. 3,5,7**) with recent analogs, loggerhead-nesting structures from St. Catherines Island, Georgia.

Conclusions

The serendipitous discovery of the first fossilized sea turtle nesting structures in 1997 presents a case study for the power of integrated natural history. The collaborative fieldwork done on ancient ghost shrimp burrows (usually assigned to the trace fossil genus *Ophiomorpha* Ludgren) by Bishop, Pirkle, and Marsh in 1997, led to discovery, recognition, and description of the first fossilized sea turtle nesting structures. The contingency demonstrated by these seemingly non-related events is remarkable, as is the substantiation of the power of the observational scientific method (Gould, 1989). The morphology of the sedimentary structures, their sizes and proximity, and their association with other sedimentary structures of the strand facies are consistent with their interpretation as nesting structures of an ancient sea turtle, the first described from the fossil record.

Acknowledgements

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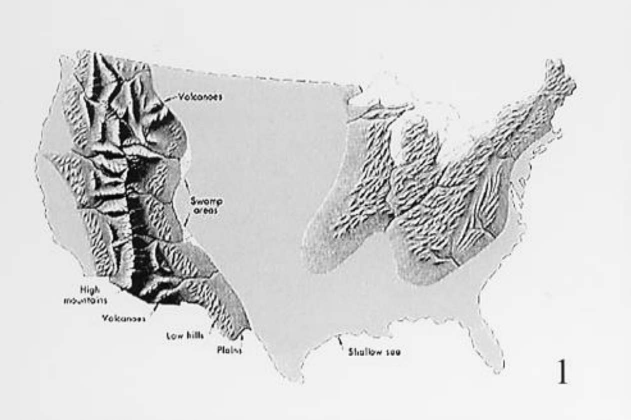
Figures on the next page. Figure numbers are in the white circles.

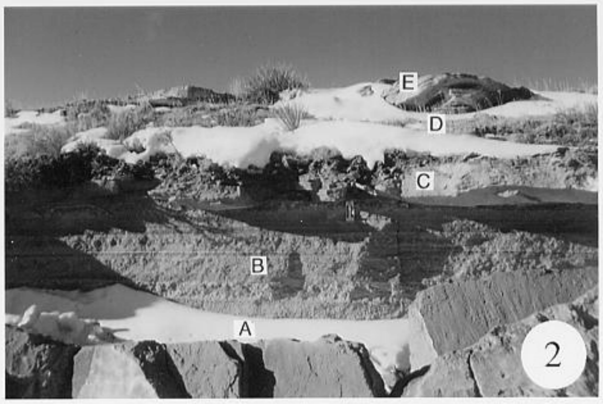
Figure 1. Paleogeographic map of the United States during the Late Cretaceous showing the approximate position of the Limon Seashore (after USGS Bull. 1291);

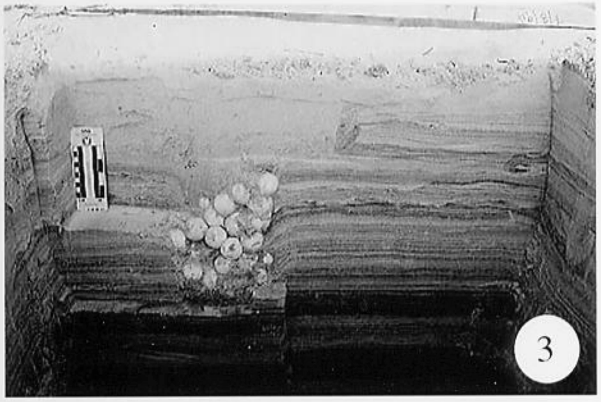
Figure 2. Facies tract at Limon, vertical section represents lateral facies tract present on ancient seashore (Pirkle photo);

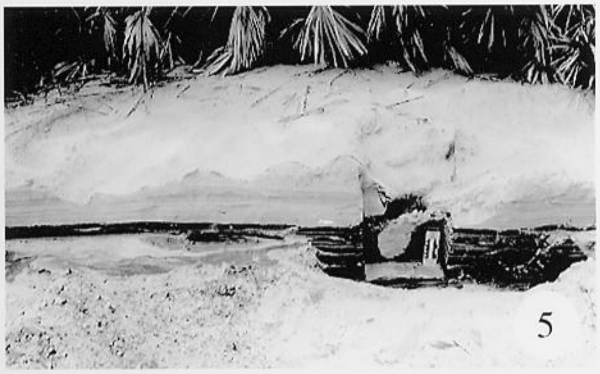
Figure 3. Loggerhead sea turtle nest trenched to show vertical section across egg chamber (note horizontally laminated sands collapsed into egg chamber by fluidization);

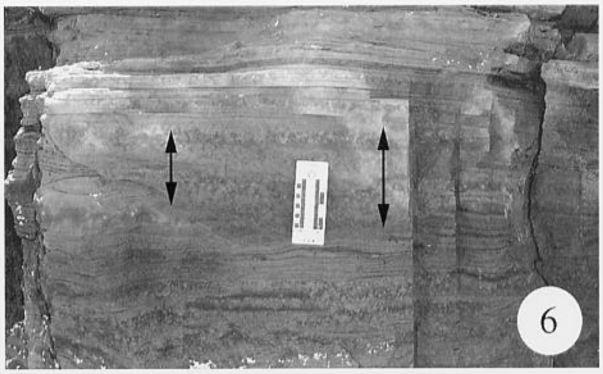
Figure 4. Cretaceous sea turtle nest in vertical cliff face showing similar collapse of overlying sand layers into egg chamber preserving egg molds at bottom;











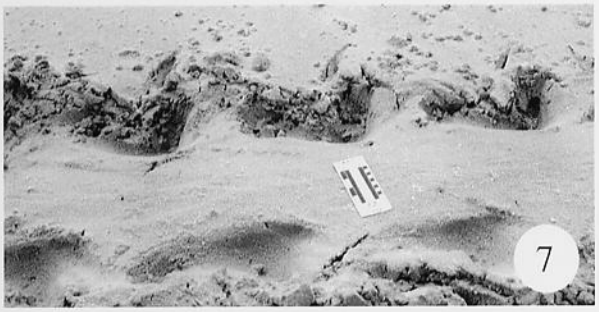


Figure 5. Modern loggerhead covering pit trenched to show vertical aspect of basal heavy mineral sand and egg chamber (eggs moved previous day);

Figure 6. Cretaceous covering pit in vertical cliff face showing disruption of horizontal laminations in back beach sediment and bioturbated covering pit;

Figure 7. Oblique view of loggerhead crawlway in soft sand showing prominent flipper push marks;

Figure 8. Fox Hills crawlway exposed in vertical cliff face showing flipper push marks bracketed between underlying and overlying horizontally bedded sandstone beds. Scale=10 cm.

The Paleontology and Phylogenetics of "Sea Turtles"

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Although living sea turtles form a monophyletic group, members of the Testudines have exploited the marine environment on at least four occasions, making "sea turtles" polyphyletic. Evidence from living relatives, morphology, geographic distribution, and sedimentary context can be used to argue that at least two groups of pleurodires and two groups of cryptodires have made extensive use of marine environments. Ongoing studies of extinct pelomedusoid pleurodires (formerly the Pelomedusidae) suggest that two groups with presumed marine members were quite diverse. These include the family Bothremydidae and a group that is tentatively treated as a subfamily of the Podocnemididae: the Schweboemydinae. The two groups of cryptodires that are clearly marine are the Jurassic/Cretaceous family Plesiochelyidae (including the Thalassemydidae) and the Cretaceous to Recent Superfamily Chelonioidea. The former includes about 20 named genera but the monophyly and relationships of this group need to be reexamined. Current knowledge of the latter group suggests that it's members are best attributed to four families. A paraphyletic Toxochelyidae plus a monophyletic Cheloniidae make up the sister group to a clade composed of the families Protostegidae and Dermochelyidae, each of which are monophyletic. The diversity of these groups and the relationships of these and groups with more minor marine forays will be discussed in a phylogenetic framework.

POSTER PRESENTATIONS: BIOLOGICAL STUDIES - ANATOMY AND PHYSIOLOGY

Some Morphometric Variables of the Skull in Sea Turtles

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During the development of the "Diagnosis of the Current Situation of the Sea Turtles in the Gulf of Venezuela" project the skeletal remains of many sea turtles were found. An inventory of the most commonly found remains is currently being conducted to develop a basic, referential osteological collection and to characterize each species' cranium. It is hoped that this project will set a precedent of standardized craniometric measurements to be collected and will facilitate the identification and study of the local sea turtle species.

Skulls were used for this study due to the clear differences between species and because they were usually complete at the time of discovery. Ten craniometric measurements were chosen that could be clearly defined (Kamekazi and Matsui, 1998).

Objectives

•Offer alternatives in the use of cranial measurements in pieces or samples of sea turtle.

•Create a basic and referential osteologic collection for future skeletal studies of sea turtles.

•Begin skeletal characterization for the different sea turtle species present in the zone of study.

Methodology

Groups of two to five people made 12 collecting trips for a total of 33 days between Jan. 1998 and Jan. 1999. A Vernier (calibrator), a metric tape, and a ruler were used to make the cranial measurements.

The following measurements were recorded:

- Height of the nasal opening (AAN),
- Height of the ocular hole (AOO),
- Width to the level of the condyles (ANC),
- Longitude basisphenoid-premaxilar (LBP),
- Height of the premaxilar (APM),
- Height of maxilar (AMX),
- Longitude interocular (LIO),
- Height of the orbital to the maxilar (AOM),
- Height maximal cranial (AMC), and
- Longitude maximal cranial (LMC).

Results and Discussion

Thirty crania were found on the beaches of Porshoure, Puyatsi and Castilletes, in the Paez Municipality and on Toas Island of the Padilla municipality, in Zulia state. Of those, 17 were *Chelonia mydas*, 7 *Caretta caretta*, 5 *Eretmochelys imbricata*, and 1 *Dermochelys coriacea*.

Due to the small number of samples obtained, we cannot offer any statistically trustworthy results. It is hoped that at the conclusion of this study a larger number of skulls will be collected and a clear craniometric definition can be made for each of these species in the Gulf of Venezuela.

Very few skulls were found in comparison to the number of shells. This is because of the skulls medicinal and traditional use by the inhabitants and fisherman of the area. This information can be useful in the future by helping to establish a predictive relationship between the number of skulls and shells found.

The Effects of Nest-Site Environment on Leatherback Turtle Embryos (*Dermochelys coriacea*): Developmental Success and Mobilization of Calcium during Development

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Laboratory incubation of eggs (n=251) collected from leatherbacks nesting at Las Baulas National Park, Costa Rica, demonstrated that calcium mobilization during development is affected by sand moisture content and sand temperature. Calcium concentrations of egg components (eggshell, yolk plus albumen (Y+A), and embryo) changed significantly through time for both viable and undeveloped eggs. For developed eggs, eggshell calcium concentrations decreased 42.9% by Day 60 of incubation. Y+A calcium decreased (20.8%) until the last quarter of incubation, but then increased (21.5%) until the time of hatching. For undeveloped eggs, eggshell calcium concentrations decreased by 25.7%, with the rate of decrease slowing significantly beyond the second half of incubation. In contrast, Y+A calcium increased by 41.2%. Embryos incorporated a higher proportion of calcium when incubated at lower sand moistures (5% H_2O) and temperatures (28.5°C). The total mass of freshly oviposited eggs was negatively correlated with calcium concentration per gram of eggshell ($r = 0.569$), indicating that eggshell calcium decreases as egg mass increases. The developmental success (24.1%) and hatching success (7.4%) of incubated eggs were more dependent on temperature than on moisture, with an increase in mortality as sand temperature increased. For the beach (Playa Grande), developmental (37.4%) and hatching success (19.8%) were similar in magnitude to the results obtained from the laboratory. Mean hatching success from prior nesting seasons (1993-94, 1995-96) at Playa Grande was 54.2% or greater (Steyermark *et al*., 1994; Binckley *et al*., 1998), which is significantly higher than was observed in this study for both beach and laboratory incubated eggs.

A Comparison of Total Lipid Content and Fatty Acid Composition of Egg Yolks from the Green Turtle, *Chelonia mydas,* and the Red-Eared Slider, *Trachemys scripta*

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Fresh green turtle and red-eared slider eggs were obtained from the Cayman Turtle Farm, Ltd. (Grand Cayman, BWI) and the Concordia Turtle Farm (Wildsville, LA, USA) respectively and frozen for analysis. Lipids were extracted using a methanol-chloroform protocol modified from Folch (1957). Total percent lipid ranged from 15-19% in the green turtles and 12-20% in sliders. Lipid classes were determined by peak location and retention time using thin layer chromatography (TLC). Fatty acid profiles for both species were found using gas chromatography (GC), and included both saturated and unsaturated forms. Little information is available, in turtles, regarding the effect of egg content on hatching success. The goal of this analysis is to examine the lipid profiles and hatchling viability in both captive-reared and wild populations of these species.

Introduction

Yolk of turtle eggs provides embryos with vital nutrients for embryonic development and in most cases constitutes the total parental investment in the offspring (Congdon *et al.*, 1983). For sea turtles, yolk lipids also sustain neonates through their departure from the beach and the swimming frenzy. The lipid profile of the yolk is determined by a combination of maternal dietary intake and metabolism (Noble *et al.*, 1996). Under captive conditions, it has been reported for alligators (Noble *et al.*, 1993) and ostriches (Noble *et al.*, 1996) that fatty acid profiles in the yolk differing from those in the wild are associated with decreased hatching success. The current study examines the lipid and fatty acid components of captive-raised green sea turtle*s* and red-eared sliders.

Materials and Methods

- Fresh green turtle and red-eared slider eggs were obtained from the Cayman Turtle Farm Ltd. (Grand Cayman Island, BWI) and the Concordia Turtle Farm (Wildsville, LA, USA), respectively. Yolk samples of 1-2 ml. from whole eggs (0-72 hours old) were frozen at -20°C and transported back to Texas A&M University (TAMU) for analysis.
- Total lipid content was determined gravimetrically from a known weight of yolk extracted using a methanol–chloroform protocol.
- Lipids were fractionated into their major classes by TLC using a hexane:ether:formic acid (80:20:1) solvent system.
- Fatty acid components of each sample were found with a GC and a menhaden oil standard was used to identify peak locations.
- A Student's t-test was used to compare samples.

Results

- In sliders, average lipid content ranged from 12–19.8% wet weight. One significant difference was found between the four samples determined to be from infertile eggs and the one determined to be fertile ($p=0.03$, $n=5$). Average lipid content in the green turtle samples ranged from 14.6–18.7% wet weight ($n=7$) (**Table 1**).
- There was no significant difference between the samples from females with "+" and "-" nesting histories (**Table 1**).
- Interspecific comparisons revealed no significant difference between the slider (avg. 17.2%) and green turtle (avg. 16.9%)(**Table 1**).
- In all cases, triacylglycerols and phospholipids were the most abundant, followed by low to moderate levels of cholesterol esters, and very low amounts of cholesterol (**Table 2**).
- Lauric acid (12:0) was present in all *C. mydas* samples, and absent in all those of *T. scripta*. Linoleic acid (18:2n6) was found in significantly larger amounts in sliders than in green turtles ($p=0.00$). Fatty acids found in trace levels (< 1.0%) were not reported (**Table 3**).

Conclusions

The amounts of total % lipid in the two turtles studied were not indicative of differences between species. The major lipid classes present in *T. scripta* and *C. mydas* eggs are similar to those reported for other birds and reptiles (Noble *et al.*, 1993; Noble *et al.*, 1996). Striking differences between taxonomic groups were not evident without looking at fatty acid profiles. This study found several differences between fatty acids in sliders and green turtles, and would predict that when compared with wild populations, even more would be found. Polyunsaturated fatty acids in the C18 group cannot be synthesized and must be obtained from the diet (Noble *et al.*, 1996). The difference found in the amounts of linoleic acid between the two species suggest that diet may directly effect yolk lipid composition.

Yolk lipids are not only important for the energetic requirements of the developing embryo, but for its survival (Noble *et al.*, 1993). Research in various bird species has identified the C18 lipids as being critical to hatchling viability, especially during the final stages of incubation (Noble *et al.*, 1996). Red-eared slider samples in this study, from a captive population with greater than 85% hatch success, were evaluated as a comparison to the species of primary interest, the green sea turtle. It is presently unclear if the C18's seen in captive animals match those found in successful wild populations. It is known, however, that the captive population at the Cayman Turtle Farm exhibits a significantly lower hatch percentage than that reported for most wild populations. Future work will require yolk samples from wild green turtles, as we hope to elucidate the reason or reasons for reduced hatching success. Evaluating the nutritional needs of embryos directly relates to the needs of adult sea turtles, and the viability of their offspring. The results of this study could lead to a revision of current feeding protocols for animals kept in captivity or for rehabilitation, as well as improving the understanding of recent declines in wild sea turtle hatching success worldwide.

Table 1. Total Percent Lipid (wet weight). Fertility in *T. scripta* eggs was determined by visual assessment and dissection. All *C. mydas* eggs were of unknown fertility, and nesting history for each female was classified as "+" if hatch success was >50% and "-" if hatch success was <50%, based on farm records. Among all samples, no difference was seen between those greater than and less than 24 hours old.

T. scripta	Date Collected	Sample Age (hr)	Egg Viability per Female	Avg. % Lipid
TS1	8/07/98	24-36	not fertile	19.8
TS2	8/07/98	24-36	not fertile	17.6
TS3	8/07/98	24-36	not fertile	17.9
TS4	9/07/98	48-60	not fertile	18.6
TS5	9/07/98	48-60	fertile	12
C. mydas				
uk2	15/07/98	72	?	14.7
162#1	17/07/98	fresh	-	16.9
162#2	17/07/98	fresh	-	18.7
268	21/07/98	fresh	-	18
207	21/07/98	fresh	-	14.6
113	21/07/98	fresh	+	17.1
243	21/07/98	fresh	+	18.3

Table 2. Relative abundance of lipid classes (by peak).

T. scripta **Lipid Class**	**TS1**	**TS2**	**TS3**	**TS4**	**TS5**
Triglycerides	3	3	3	4	4
Phospholipid	3	3	3	3	4
Cholesterol	1	1	1	1	1
Cholesterol Ester	0	1	1	2	2

Lipid Class ***C. mydas***	**207**	**162 #1**	**162 #2**	**268**	**UK1**	**UK2**	**243**	**113**
Triglycerides	3	3	4	4	3	3	4	4
Phospholipid	3	3	3	3	4	3	3	4
Cholesterol	1	1	0	1	1	1	0	1
Cholesterol Ester	0	2	0	1	3	1	0	1

Table 3. Fatty Acids. Fatty acid profiles measured by average percent area for *T. scripta* and *C. mydas*. In nearly all cases, the most abundant fatty acid was the C18 polyunsaturate, oleic acid.

Peak	**Fatty Acid**	**Saturated vs. Unsaturated**	**Sample Avg% Area** ***T. scripta*** **range**	***C. mydas*** **range**
12;0	lauric acid	S	0-0	4.07-9.91
14;0	myristic acid	S	2.12-2.49	5.33-6.88
16;0	palmitic acid	S	18.7-21.2	9.65-15.7
16;1	palmitoleic acid	U	0-7	0-5.38
18;0	stearic acid	S	3.94-7.26	3.04-8.33
18;1	oleic acid	U	20.4-36.9	33.8-41.9
18;2n6	linoleic acid	U	16.4-19.8	8.1-12.3
18;3n6	g-linolenic acid	U	0	0-2.37
20;1		?	1.03-1.17	0
20;3n6	dihomo-g-linolenic acid	?	0	0-2.850
20;4n6	arachidonic acid	U	1.38-2.05	2.29-3.7
22;5n3	docosapentaenoic acid	?	0.93-1.13	0-1.03

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Allometric Growth in Hatchling Sea Turtles: A Comparison between Loggerheads and Leatherbacks

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We compared allometric growth during the first five weeks of development between hatchling leatherback and loggerhead sea turtles. Leatherbacks begin development at a larger size and mass; they also possess proportionally larger front flippers than loggerhead hatchlings. In both species, the rear flippers grew in proportion to carapace length. However, head width and length, body width, and front flipper length grew proportionally faster (relative to carapace length) in loggerheads than in leatherbacks. Thus, growth rates of the axial and appendicular skeletons can vary independently to alter body shape (and presumably these differences also reflect differences in physiology and behavior) through ontogeny. We present several hypotheses to relate these structural contrasts to differences between the species in hatchling ecology and behavior.

Caretta spends much of its pelagic existence as "drifters" (Bolten *et al*., 1994). We presume that drifting is briefly interrupted to forage for food detected at close range. Such a life style suggests that young loggerheads devote most of their energy to growth. Growth involves a proportional widening of the carapace as it develops prominent spines on the lateral and dorsal surface, which reduces hydrodynamic efficiency. But such a loss is of little importance to an animal that is relatively inactive. In contrast, leatherbacks probably swim continuously in their search for widely distributed (gelatinous) prey (Wyneken and Salmon, 1992). This puts a premium on retaining a hydrodynamically and energetically efficient body shape.

Loggerhead hatchlings and juveniles at sea feed on a variety of plant and animal prey (Witherington, 1994; Bjorndal, 1996), including animals with protective shells (snails, crustaceans, goose and acorn barnacles). Selection should favor individuals capable of processing larger (and more nutritious) animal prey, including those protected by shells. The proportionally more rapid increase in head length and width (and thus, in jaw structural and muscular strength) with size in loggerheads may reflect such a change. Leatherbacks, in contrast, are dietary specialists (on gelatinous prey). capable of slicing portions of jellyfish that can be consumed "at leisure".

The rear flippers of both species grew in proportion to the change in body size. However, front flipper length increased proportionately faster with size in loggerheads than it did in leatherbacks. The reasons are not obvious. One hypothesis is that hatchling leatherbacks initially have longer flippers to expedite diving performance when muscular strength is limited. They may subsequently partition more time/energy to the development of their pectoral muscle than they do to flipper length. In contrast loggerheads may, as hatchlings, have flippers designed to produce sufficient thrust to reach critical oceanic currents. As they age, they may subsequently increase flipper length as they become large enough to abandon *Sargassum* matts and forage (during shallow dives) beneath the ocean surface.

Our results suggest, first, that further analysis of allometry in sea turtles may prove of value in understanding how hatchling growth is adapted to the demands of their developmental habitats. Second, growth patterns may be partitioned in different ways as size changes. Indeed, such relationships have already been found in loggerheads (Kamezaki and Matsui, 1997). Most growth models simply extrapolate size changes from one age class to another. The alternative view is that growth can be partitioned ontogenetically into stages ["stanzas"; Chaloupka and Musick, 1996] that affect different parts of the body in different ways. These stanzas can only be understood by studying proportional growth through all stages of development. That remains as a future undertaking.

Our results suggest that similar comparisons should be made among other species of sea turtles, and at both early and later ontogenetic stages. Such comparisons should improve our understanding how each sea turtle species is adapted to the unique set of ecological habitats it occupies at different stages of ontogeny.

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Morphological Characteristics, Nesting Frequency, and Plasma Hormones in Female Green Sea Turtles (*Chelonia mydas*)

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The reproductive physiology of nesting green sea turtles (*Chelonia mydas*) was studied at Heron Island from 1995 to 1998. Data indicate that the green sea turtle lays an average of 6 clutches per nesting season with a remigration interval of 6 years. Remigrant turtles are larger than primary tagged turtles and tend to commence nesting earlier in the season. Turtles nesting earlier in the season tended to lay more clutches of eggs for the season than turtles first recorded nesting later in the season.

Plasma corticosterone and testosterone are correlated and both are elevated during the start of the season and decline towards the later clutches laid for the individual. Corticosterone and triglycerides are highest in turtles arriving to the nesting beach early and laying more clutches for the season. Size of the turtle doesn't appear to influence plasma corticosterone, testosterone or triglycerides. Catecholamine levels in nesting turtles were not related to any of the above parameter's and were typically low for the entire season. These data suggest that hormonal regulation of the nesting season can be influenced by both the morphological characteristics of the individual, as well as nesting frequency and seasonality.

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Inguinal Gastrotomy in Captive Marine Turtles at the Mexican Turtle Center

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The Mexican Turtle Center, located in the community of Mazunte, municipality of Santa María Tonameca, Oaxaca, was created by a presidential promulgated ordinance on 24 September 1991. It is a research center devoted to the study of the processes of adaptation and maintenance in captivity of all species of marine turtles that live in the Mexican seas, as well as some species of terrestrial and freshwater turtles (Vasconcelos & Albavera, 1995).

The facilities of the Mexican Turtle Center are designed for the captive maintenance of marine turtles and are made up of 18 aquariums with a total capacity of 450 m^3, 97 tanks of fiberglass with a capacity of 14 m^3, and 8 tanks and 2 concrete basins with a capacity of more than 150 m^3, all of which are in roofed areas. A hydraulic infrastructure allows the total replacement of water in all containers within 24 hours (Harfush, López and Hernández, 2000). The Mexican Turtle Center houses seven of the eight known species of marine turtles.

During the maintenance and adaptation of marine turtles to captivity it is common that some individuals may develop one of several pathologies and physical alterations, for which, if they don't receive timely and appropriate medical attention, death could result. As soon as any physical evidence of illness in any individual is detected, or simple changes of behavior that could be related to its health, the animal in question is immediately isolated for observation and possible treatment. The main illnesses afflicting the Center's captive turtles are: infections in several systems, parasites and gastrointestinal occlusions (Harfush, López and Hernández, 2000). The latter is caused by the ingestion of foreign objects, which due to their weight and characteristics, interrupts the digestion in the stomach and the first portions of the small intestine.

These foreign objects conform to a wide range of elements in their diet and are mainly: gravel, plastic plants used in the decoration of the aquariums, pieces of stone, pieces of aeration hose, plastic thread, carapace scutes, metal tags, spectacles and their pieces, as well as many other articles that fall into the tanks and aquariums due to the negligence of visitors and technical personnel at the Center.

Materials and Methods

The clinical signs of intestinal occlusion are often suggestive: anorexy; muscular flacidity in lower jaw, neck, front and rear flippers; and difficulty in submerging. All of which can result in shock and death.

Diagnosis. In order to confirm the diagnosis quickly and try to determine the cause of the problem, the turtle is submitted to x-ray analysis with and without preparation. (Slatter 1995, Marescaux, 1997).

Treatment. Cisaprida is orally administered at a dose of 1 mg/kg. of weight, 3x/day for 10 days. If there is no favorable response, the treatment is suspended and it is considered necessary to undertake inguinal gastrotomy surgery.

Surgery.

· Preanesthetic medication: Difenhidramina: 1 mg/kg. of weight.

· Anesthetics: Ketamine hydrochloride: 55-88 mg/kg., of intra muscular weight .

· Xylocaine with Epinephrine 3cc subcutaneous in the zone of incision.

· Position: Vertical dorsoventral.

· Antiseptic: Region of left groin.

· Instruments: From general surgery.

· Sutures: Vicryl monofilament thread caliber 00 and nylon caliber 0.

Description of the surgery. Once anaesthetized the turtle is placed in a dorsoventral vertical position and 3cc of Xylocaine with Epinephrine is injected in the region of the left groin, at the place of the incision, including subcutaneous skin, fat and muscles. Two cm from the plastron, an incision of approximately 7 cm is made, embracing skin, fat, muscular tissues and peritoneo visceral. With the help of the Farabeuf separators the first portions of the small intestine can be observed inside; then with a sterile gauze and Babcock pincers the most accessible part of the stomach is extracted, allowing the obstruction to be located. Next, in the greater curve of the stomach, in a more or less avascula zone, a large incision is made that allows the extraction of the foreign objects without causing excessive tissue rupture. Next the gastric content is emptied and the foreign bodies extricated with the help of an intestinal clip or right clamps. In order to unite the medial borders of the wound of the stomach a Connel suture is applied and on this, a Cushing suture using re-absorbable monofilament thread, caliber 00 (vicryl). After this the stomach is re-accommodated in the celonic cavity and the borders of the groin wall sutured; the peritoneal borders are sutured with surgete points that start at the posterior of the wound; next the rectum muscles are sutured with points in X, that embrace part of the aponeurosis. Lastly, the skin is united with separate points embracing cutaneous muscle, using monofilament thread caliber 0 (nylon) (Alexander, 1986; Harfush, López and Hernández, 2000).

Results

After surgery the intervened turtle is placed on a polythene mattress in a tank with a constant flow of salt water sprayed over the whole body. The application of antibiotic and disinflamatories are carried out daily for 5 days, together with a revision and cleaning of the wound, as well as the supply of 20 ml of serum enriched with vitamins and minerals in the subcutaneous every three days for 15 days. After treatment and aftercare the turtle is housed in an individual tank with a constant flow of sea water and maintained under observation.

The results of these surgeries have been satisfactory, since the individuals upon which it has been performed, including green (*Chelonia mydas*), black (*C. agassizi*), hawksbill (*Eretmochelys imbricata*) and loggerhead (*Caretta caretta*) turtles are all currently held in captivity and in good health, demonstrating normal feeding, behaviour, floatability and swimming characteristics.

Discussion

There have been no bibliographical reports of gastrointestinal occlusion in marine turtles held in captivity; this seems to be due to the fact that it is an illness that occurs infrequently.

The symptoms shown by the turtles, as well as the discoveries from x-ray, suggest the use of such alternatives as surgery at gastric level. One of the best characteristics of this surgery is the use of such parenteral anesthetics as Ketamine Hydrochloride, which does not risk the life of the turtle, and permits the opportune correction of an alteration in the digestion at stomach level and first portions of the intestines.

Because the use of laxatives and promoters of peristaltis don't work satisfactorily in cases of serious gastric occlusions, the inguinal gastrotomy, although a technique of recent execution, could turn out to be a viable alternative for the safe correction of the problem.

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Diet Dependent Growth in Green Sea Turtle Hatchlings

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Hatchling sea turtles are opportunistic feeders. They will consume a variety of foods during their early development, but as adults they become more specialized in their choice of foods (Bjorndal, 1996). Hatchlings maintained in captivity for a period of time (e.g., those maintained in headstarting programs) should be provided with food that will maximize their growth. Both quantity and quality of the diet influence growth rates. By holding constant the quantity of food, qualitative aspects of the diet (e.g., the type of food) can be evaluated. In this project, two experiments were designed to evaluate the growth of hatchling green sea turtles *(Chelonia mydas)* over the first month of life.

Experiment 1: Method

The objective of this experiment was to evaluate growth rates of hatchling green sea turtles fed a single food item over the first month of life. Four groups of hatchlings (n=20/group) were fed one of four diets for one month following nest emergence. Hatchlings received either sargassum (i.e., *Thallasia*), verdolaga (a terrestrial plant favored by *C. mydas*), fish found in local waters, or commercially produced food pellets. Feeding occurred three times each day beginning day 4 post-emergence. Hatchlings were weighed and measured (curved carapace length and width) at 1, 10, 17, 24, and 31 days post-emergence.

Experiment 1: Results

The table shows changes in carapace length and width and the weight gains of the four diet groups determined on the day of emergence and on day 31 post-emergence. There were no significant differences among the groups on the day of emergence. However, beginning on day 17 post-emergence, hatchlings maintained on a diet of either fish or pellets exhibited significant increases in growth (p values $<$ 0.05 for all measures) relative to those fed either sargassum or verdolaga alone. On day 31, groups fed sargassum or verdolaga alone were statistically identical to one another. Relative to these groups, the average carapace length and width of those fed pellets alone had increased by 15% and 9% respectively; for those fed fish alone, length and width had increased by 25% and 28% respectively.

Over the first month of life, separate groups of hatchlings fed either pellets or fish had doubled their weight (from 23 grams to 46 grams) while those fed sargassum or verdolaga gained only 7 grams (growing from 23 grams to 30 grams). Four turtles died during the course of the experiment, one from each of the groups fed sargassum or verdolaga, and two from the group fed pellets.

Experiment 2: Method

The objective of this experiment was to evaluate growth in hatchling green sea turtles when diets of sargassum mixed with other food items were provided. This experiment was conducted the year following Experiment 1 but under the same general conditions at the turtle facility of Isla Mujeres. Separate groups of hatchlings (n=20/group) each day received diets of approximately 10 grams of sargassum mixed with either 10 grams of verdolaga, fresh fish, or pellets. The control group received sargassum alone (about 20 grams). Carapace length, width, and body weight were measured on days 1, 10, 17, 24, and 31 post-emergence.

Experiment 2: Results

There were no significant differences among the groups on any measure on the day of emergence. As shown in the table, carapace measurements made on day 31 were lowest among those hatchlings that received sargassum alone or in combination with verdolaga. Compared to hatchlings of the former groups, significant carapace growth (p values <0.02) was evident in the groups fed sargassum in combination with fish or pellets. Comparisons of the latter groups with the former indicated that carapace length and width had increased by 19% and 17% resp.

The table also shows the weight gains of the four groups fed mixed diets over the first 31 days post-emergence. Hatchlings given fish or pellets in combination with sargassum were significantly heavier after one month (growing from 25 grams to 46-48 grams, a 88% increase) than those given sargassum alone or sargassum in combination with verdolaga (growing from 25 grams to 28-32 grams, about a 20% increase). Mortality was higher for those hatchlings fed sargassum alone (50%) and sargassum plus verdolaga (35%) as compared to those given pellets mixed with sargassum (15%) or fish (5%).

General Discussion

After leaving the nesting beach, it is thought that hatchlings select sargassum rafts as habitats. Analyses of the stomach contents of young green turtles foraging in the Caribbean confirm that *Thallasia* is the main constituent of the diet. However, hatchlings of this species are omnivorous with a strong tendency toward carnivory (Bjorndal, 1996). Findings from our project specifically suggest that a variety

Table 1. Mean (+ SEM) Curved Carapace Length, Curved Carapace Width (cm) and Body Weight (gm) for hatchling green sea turtles (*Chelonia mydas*).

Experiment 1		**DAY 1**				**DAY 31**		
Group	**N**	**CCL**	**CCW**	**BW**	**N**	**CCL**	**CCW**	**BW**
sargassum	20	5.06 (+ 0.03)	3.83 (+ 0.02)	23.3 (+ 0.5)	19	5.51 (+ 0.04)	4.51 (+0.03)	29.4 (+ 0.3)
verdolaga	20	5.07 (+ 0.03)	3.99 (+ 0.06)	22.8 (+ 0.6)	19	5.51 (+ 0.04)	4.45 (+ 0.03)	30.2 (+ 0.4)
fish	20	5.01 (+ 0.03)	3.87 (+ 0.06)	23.2 (+ 0.5)	20	6.87 (+ 0.06)	5.73 (+ 0.06)	48.7 (+ 1.4)
pellets	20	5.04 (+ 0.04)	3.91 (+ 0.03)	22.8 (+ 0.6)	18	6.31 (+ 0.09)	5.39 (+ 0.07)	45.0 (+1.4)

Experiment 2		**DAY 1**				**DAY 31**		
Group	**N**	**CCL**	**CCW**	**BW**	**N**	**CCL**	**CCW**	**BW**
sarg (alone)	20	5.11 (+ 0.02)	4.00 (+ 0.02)	25.1 (+ 0.2)	10	5.61 (+ 0.07)	4.69 (+ 0.04)	28.8 (+ 0.6)
sarg + verd	20	5.14 (+ 0.03)	4.04 (+ 0.02)	25.2 (+ 0.2)	13	5.85 (+ 0.11)	5.01 (+0.11)	31.5 (+ 1.3)
sarg + fish	20	5.17 (+ 0.02)	4.02 (+ 0.02)	24.8(+ 0.2)	19	6.83 (+ 0.10)	5.75 (+ 0.07)	46.4 (+ 1.2)
sarg + pell	20	5.13 (+ 0.03)	4.00 (+ 0.02)	24.0 (+ 0.2)	17	6.66 (+ 0.07)	5.62 (+ 0.07)	49.9 (+ 0.9)

of dietary items are avidly consumed by hatchlings held in captivity; the consumption of fish and protein pellets resulted in significant and rapid growth in the short term. As noted by Chaloupka and Musick (1996), the estimation of age based on size may be biased by demographic factors such as foraging and developmental habitats. Our data for captive hatchlings empirically support their contention that considerable variability in growth between and within individuals can result from the quality of the diet. In future work, we plan to address how diet selection in a free-feeding, captive situation may influence age-related growth rates in this species. Such research may have practical benefits for those involved in headstarting programs. The findings may have heuristic value for the development of models of population dynamics.

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Ultrastructural and Biochemical Study of Egg Shell Calcium Utilization during Embryogenesis in the Olive Ridley *(Lepidochelys olivacea)* Sea Turtle

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The eggshell plays a significant mediating role between its living content and the external environment. Permeability to gas and water, mechanical stability and potential calcium reserve are some of the requisites of the eggshell (Schleich and Kastle, 1988). Thus, in terms of survival of an oviparous species, the structure of an eggshell is of primary importance to the embryo, not only as a protective covering but also in the exchange of heat and water with its surroundings.

Turtle eggs are of two types, flexible and rigid based on their structure (Packard *et al*., 1982). Freshwater turtle eggs have mostly rigid shells, while sea turtle eggs are flexible with a complex microstructure. Reports on structural characteristics of eggshell are available for the green turtle, *Chelonia mydas* (Solomon and Baird, 1976,1977), leatherback, *Dermochelys coriacea* (Chan and Solomon, 1989; Solomon and Watt, 1985; Solomon and Tippett, 1987), loggerhead, *Caretta caretta* (Schleich and Kastle, 1988) and Kemp's ridley, *Lepidochelys kempi* (Hirsch, 1983). The olive ridley, *L. olivacea*, is the most abundant marine turtle with the largest rookery in Gahirmatha, Orissa, India. We studied the ultrastructure of the eggshell of this species (Sahoo, *et al*., 1996a, 1996b) as well as the profile of calcium utilization during the developmental period (Sahoo, *et al*., 1998).

The fresh eggshell consists of about 6.3% moisture, 70.6% volatile materials and 29.4% residual materials. Calcium carbonate is the major constituent of the eggshell (52.7%). The shell of abnormal eggs (very large or very small) contains lower levels of calcium in comparison to the normal eggs.

Qualitative and quantitative chemical analyses of egg shells at different stages of development revealed that calcium is the major component (21.08%) while others (potassium, magnesium and sulphur) are present in trace amounts. Phosphorus is absent in eggshells. Changes in the calcium contents in the eggshell starts around the 40th day of incubation at 29.5°C and there is about 64% loss in calcium reserve of the eggshell by hatching. The yolk and albumen of the egg together contain about 44 mg of calcium (yolk 37 mg, albumen 7 mg). The freshly emerged hatchling contains about 108 mg of calcium. The calcium content of the yolk and albumen provides only 40% of the amount needed by the hatchling and the rest 60% (64 mg) is supplied by the eggshell. The fresh eggshell contains about 191 mg calcium whereas the hatched eggshell has only 69 mg.

The calcium carbonate component in the eggshell is present in its aragonite morph without calcite or vaterite. The eggshell is composed of an inorganic calcareous layer and an inner organic fibrous shell membrane followed by a very smooth boundary layer. The calcareous layer consists of loosely arranged irregularly oriented nodular shell units with distinct and irregular open spaces among them. Each shell unit is formed by a spherulite aggregate of needlelike aragonite crystals radiated from a primary spherite.

The eggshell undergoes significant changes in its ultrastructure from laying to hatching as a result of calcium resorption. Reduction in shell thickness and absence of discernible structures in the calcareous matrix of the hatched eggshell are the result of calcium resorption. The eggshell of 42 day old embryo at 29.5°C shows some changes in its structure like flaking of the primary spherite from the shell membrane and partial loss of aragonite crystals from the shell units. This is because the embryo starts mobilizing calcium from the eggshell at this stage.

The eggshell structure and characteristics of this species are typical of marine turtles. The pliable nature of the marine turtle eggshells is a function of ill-defined shell units. In the olive ridley turtle however, the shell units are more clearly defined in comparison to those reported for the loggerhead (Packard and Hirsch, 1986) or leatherback (Chan *et al.*, 1985). Numerous pore-like spaces have been reported for the loggerhead (Packard and Hirsch, 1986), but are absent in the leatherback (Chan *et al.*, 1985). In the present species, however, irregular open spaces were distinctly visible between the shell units. This loose arrangement of shell units with no interlocking arrangement allows the shell to expand from 38 mm during laying to about 52 mm in size towards the end of incubation period (unpubl. results).

The subsurface organic shell membrane, which is fibrous and netted, serves as the substrate for initiation of crystal growth. In the olive ridley, like other chelonians (Young, 1950; Solomon and Baird, 1976), the shell membrane is single layered, not paired as observed in avian eggs (Becking, 1975). Further, the width of the fibrous organic membrane is about half of the total thickness in the olive ridley (Sahoo *et al.*, 1996b).

During the development of the turtle eggs, the absorbed water and the pore spaces in the shell help capillary exchange of water with environment while the netted substrate and the loosely packed crystallites support adequate air circulation to prevent building up of carbon dioxide around the egg.

The olive ridley turtle eggshell is constituted solely of aragonite (Sahoo *et al.*, 1996a). The green and leatherback turtle eggshells contain around 5% calcite and traces of vaterite besides aragonite (Solomon and Baird, 1976; Solomon and Watt, 1985). The presence of calcite blocks sometimes makes the eggs prone to fungal and other microbial infections thereby reducing the overall hatching success (Solomon and Tippett, 1987). The higher degree of hatching success in Gahirmatha olive ridley eggs as reported by Mohanty-Hejmadi (1993), could be therefore, due to the lack of calcite blocks in their eggshells.

The inorganic profile of the olive ridley eggshell shows calcium being the major constituent and present in a higher proportion (21%) than reported for green turtles (Solomon and Baird, 1976). Solomon and Baird also reported the presence of phosphorus in green turtles and considered it to be the key factor in the formation of aragonite crystals. Well-defined aragonite crystals without any phosphorus in the olive ridleys in the present study do not support this view (Sahoo *et al.*, 1996a).

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Amino Acid Composition of the Muscle of Marine Turtles (*Eretmochelys imbricata* and *Chelonia mydas*)

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The amino acid composition of the muscle of an animal is a good reference point to establish the amino acid profile of its diet. The amino acid compositions of the muscle of the hawksbill turtle (*Eretmochelys imbricata*) and the green turtle (*Chelonia mydas*) are presented here. Both species were similar with regard to protein (15.7% and 16%), lipid (1.0% and 0.4%) and ash (1.0 and 1.1%) contents (*E. imbricata* and *C. mydas* respectively), and their amino acid profiles. The most represented essential amino acids were: lysine (0.65 & 0.59); leucine (0.62 & 0.64); and arginine (0.46 & 0.45 g/100 g protein), for *E. imbricata* and *C. mydas*, resp.

Introduction

The development of large scale rearing operations for marine turtles will ultimately necessitate the development of commercial diets which can provide the essential nutritional requirements of the animals. Information on the amino acid composition of the muscle of an animal is important in optimizing the protein composition and cost of artificial diets. For example, in crustaceans, the tail muscle has been used as a reference to evaluate the quality and origin of protein in artificial diets (Gallardo *et al.*, 1989 and Diaz *et al*. 1998).

It has been determined that hatchling *C. mydas* have a dietary requirement for lysine, tryptophan, methionine, valine, leucine, isoleucine, phenylalanine, histidine and threonine; arginine is considered to be semi-essential (Wood, 1974). With the exception of histidine, threonine and arginine, the quantitative requirements for these amino acids have been determined for *C. mydas* (Wood and Wood, 1977a, 1977b). However, no comparable data are available for other species marine turtle.

Research within the ranching program for *E. imbricata* in Cuba (Nodarse *et al.*, 1998; ROC, 1998) has resulted in an acceptable artificial ration for this species (Pelegrin *et al.*, 1994; unpublished data). Preliminary results are presented here on the amino acid composition of *E. imbricata* and *C. mydas* muscle. These are considered important baseline data with which artificial diets can be improved further.

Methods

Samples of muscle (4 samples from each species) were taken from wild, adult *E. imbricata* and *C. mydas* collected at Cocodrilos, on the southwest coast of the Isle of Pines, Cuba. They were kept in liquid nitrogen until their transfer to the Fisheries Research Center in Havana, where the chemical composition was determined by bromatological techniques (CS. 93-01-105, 1987). Total nitrogen was determined by Kjeldahl's technique (AOAC, 1980).

The amino acid composition was determined by homogenization and lyophilization, as described by Gaitonde and Dovey (1970). Once lyophilization was complete, samples were treated with 6N hydrochloric acid under reflux conditions and 110C. Before hydrolysis, samples were oxidized with a mix of hydrogen peroxide, formic acid and phenol to prevent the denaturation of sulfur-containing amino acids. Thus, cysteine and methionine were determined as cysteic acid and methylsulfone respectively. Amino acid analyses were carried out by chromatography of exchange, using a "Biochrom 20" autometric self-analyzer. Values for serine, isoleucine and valine were multiplied by 1.06 to offset the negative effect of the acid hydrolysis on those amino acids (Mason and Bech-Anderssen, 1994). Amino acid composition was calculated as grams of amino acids / 100 grams of protein.

Results and Discussion

The amino acid requirements for hatchling *C. mydas* have been determined (Wood, 1974; Wood and Wood, 1977a, 1977b), but no published data are available for *E. imbricata.* Our results indicate that both species are similar with regard to their general composition (water, protein, ash), with lipid levels being slightly higher in *E. imbricata* (**Table 1**).

Both species were also similar with regard to amino acid composition (**Table 2**). The amino acid profile for *C. mydas* here was similar to that derived for hatchling *C. mydas* in the Cayman Islands (Wood 1974; Wood and Wood, 1977a, 1997b), with the exception of valine, leucine and isoleucine, which were in much higher concentrations in the Cuban samples. The most represented essential amino acids were lysine (0.65 and 0.59), leucine (0.62 and 0.64), and arginine (0.46 and 0.45 g/100 g protein) for *E. imbricata* and *C. mydas* resp. (**Table 2**).

Quantification of the amino acid composition of a protein source used in a diet, is one means of evaluating the efficiency of that diet for a species (Mitchell and Block, 1946). These preliminary data on the amino acid profiles for *E. imbricata* and *C. mydas* muscle will allow protein sources used in the formulation of artificial diets to be evaluated more critically.

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Table 1. Composition of muscle of *E. imbricata* and *C. mydas* (N= 4 for each species).

%	*E. imbricata*	*C. mydas*
Protein	15.7	16.0
Moisture	82.0	81.4
Ash	1.0	1.1
Lipid	1.0	0.4

Table 2. Amino acid composition (g/100 g protein) of the muscle of *E. imbricata* and *C. mydas* (N= 4 for each species).

Amino Acid	*E. imbricata*	*C. mydas*
Glutamic acid	1.24	1.25
Asparagine	0.69	0.71
Lysine	0.65	0.59
Leucine	0.62	0.64
Arginine	0.46	0.45
Valine	0.43	0.44
Isoleucine	0.40	0.41
Alanine	0.39	0.40
Histidine	0.38	0.30
Glycine	0.29	0.31
Threonine	0.28	0.26
Serine	0.24	0.19
Methionine	0.20	0.21
Phenylalanine	0.20	0.13
Cysteine	0.13	0.12
Tyrosine	0.04	0.05

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Mercury Concentration in Keratinized Scutes of Sea Turtles: A Comparison of Two Populations

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Mercury contamination in aquatic systems has been recognized as a serious environmental problem. Mercury, a non-nutrient metal, is one of the most serious threats to marine life. Historically, blood sampling was the only technique used for detecting the accumulation of mercury in live sea turtles. More recently however, it has been shown that keratinized scute tissue is more accurate than blood in reflecting the total mercury accumulation. In 1997 this technique was evaluated in a study on the Kemp's ridley sea turtle (*Lepidochelys kempii*) in the Gulf of México. This analysis established that scraping of keratinized scutes of the carapace is a highly sensitive, minimally-invasive technique for monitoring mercury. In the current study, this technique was similarly employed for detecting mercury contamination in black sea turtles (*Chelonia mydas agassizii*). All turtles were captured near Bahia de los Angeles, México, an important feeding and developmental area for black sea turtles in the Gulf of California. Due to the past gold mining and associated mercury leaching operations in the region this may be a potential exposure site of mercury contamination. In total, 17 individuals were studied. Scute analysis of these herbivorous black turtles revealed a mean mercury level of 50.9 ppb which is significantly lower than that found in the 1997 study of a carnivorous Kemp's ridley population. These results are suggestive of mercury bioaccumulation up the food chain in sea turtle habitats. By correlating capture data, dietary composition and mercury levels, a more thorough understanding of the differences in toxicological uptake of mercury in different life stages and between different species of sea turtles can be obtained.

Introduction

Mercury contamination of aquatic systems is a serious environmental problem (Laws, 1993), although little is known regarding its accumulation and effects on sea turtles. In species in which this biologically nonessential metal has been studied, it impairs growth and reproduction, neurological development and motor coordination, vision, hearing, respiration, blood chemistry, metabolism and osmoregulation (Eisler, 1987). However, because of its high lipid solubility, mercury has a particular affinity for the central nervous system, where it interrupts the sulfhydryl enzymes of protein synthesis critical to normal neurological function (Osweiler, 1996).

Detection of mercury and other heavy metals in keratinized tissues has been used as an indicator of biotic accumulation in people (Willhelm, 1991), domestic animals (Sakai, 1995) and wildlife (Mason, 1986). Tissues such as hair, skin, nails and feathers are rich in sulfhydryl-containing amino acids which avidly bind metals. The carapace of sea turtles is covered by keratinized plates of tissue called scutes (Mader, 1996). Collection of keratinized tissue from the scutes of sea turtles has been shown to be a highly sensitive, non-invasive sampling technique for monitoring mercury (Presti *et al.*, 2000). A 1997 study was conducted to determine mercury levels in blood and scutes of Kemp's ridley sea turtles in the Gulf of México. It was demonstrated that mercury concentration in the scutes was on average 36 times higher than in the blood. Mercury concentrations in the scutes were also higher than previously reported in organs of Kemp's ridley turtles (5.3 times > liver, 2.5 times > kidney) (Landry and Sis, 1992; Presti *et al.,* 2000). This data provides insight into the metabolism, excretion and long-term accumulation of mercury in sea turtles.

The current study focuses on the black sea turtle near Bahia de los Angeles, Gulf of California, México. This region is an important feeding area and developmental habitat for black sea turtles originating from nesting beaches of southern portions of the Eastern Tropical Pacific (Clifton, 1982). This region is also adjacent to historic gold mining and mercury leaching operations, suggesting that it is a potential point source of mercury contamination. Black turtles in the Gulf of California have been found to be omnivorous, but forage primarily on red algae (Seminoff *et al.*, 1998). Further, because there is an existing knowledge of the foraging and movement patterns of black sea turtles in this study area, we can more adequately interpret the presence or absence of mercury contamination.

Methods

Sample Collection: The field study site was Bahia de los Angeles, México on the central eastern coast of the Gulf of California. Sea turtles were captured in entanglement nets (100m x 8m). Nets were frequently monitored during the entire trapping period to prevent drowning mortality. Individual capture data were obtained for each turtle, including straight carapace length and body weight. Diet analysis was performed by gastric lavage, the gentle flushing of food particles through an esophageal tube (Forbes and Limpus, 1993). Turtles were housed at the Centro Regional de Investigacíon Pesquera, Sea Turtle Research Station.

Superficial scrapings of the scutes of the carapace were obtained from both captive (n=4) and wild (n=13) black sea turtles. Approximately 0.1 g of tissue was removed using a plastic scraping tool and frozen for storage in a whirl-pak bag. Samples were taken from areas on the carapace that were free of algae and barnacles. Only the most superficial keratinized layer was used with no penetration to the underlying keratinaceous-bone interface.

Sample Analysis: Samples were analyzed at the Laboratory for Oceanographic and Environmental Research at Texas A&M University at Galveston. Tissue samples were stored in Teflon vials and digested in ultra pure nitric acid, according to a protocol developed by Orvik (1997). All samples were analyzed for mercury using an automated version of the cold vapor atomic fluorescence technique described by Gill and Bruland (1990). Mercury vapor was pumped through a tube, collected on a gold trap, and measured by the fluorescence cell of the spectrophotometer. Method blanks, containing 1g deionized water, accompanied each set of samples to monitor contamination. A certified standard reference material was also analyzed with each set of samples to maintain quality control.

Results

Scute scrapings were taken from 17 black sea turtles in Bahia de los Angeles, Mexico. These sea turtles ranged in size from 45.7-89.1 cm straight carapace length and 13.6-99.5 kilograms body weight. Gastric lavage was performed on all of the turtles sampled. They were found to eat mainly algae including *Gracillaria spp.*, and *Codium spp.* Mercury was detected in scutes of 16 out of the 17 black sea turtles sampled. The values detected ranged from 0–308.7 ppb.

Discussion

Mercury is a non-essential metal and, therefore, any accumulation of mercury is considered to be contamination. Since mercury was detected in the scutes of all but one of the turtles sampled, there is evidence that this population of sea turtles has been exposed to mercury contamination. However, these levels are not considered to be relatively high levels. In fact, mercury levels found in black sea turtles were on the average lower than the levels measured in Kemp's ridley sea turtles in the Gulf of Mexico (Presti *et al.*, 2000). These two populations are being compared due to their differences in foraging ecology. Levels of mercury were found to be lower in the herbivorous black sea turtles than in the carnivorous Kemp's ridleys. These results are suggestive of bioaccumulation of mercury up the food chain in sea turtles. Further investigation is warranted to study mercury accumulation found in sympatric populations of different species of sea turtles.

A positive correlation between size and mercury levels was shown in the Kemp's ridley population (Presti *et al.*, 2000). When divided into two size classes, there was a greater correlation between size and mercury levels in the larger group of turtles (the larger the turtle, the more mercury was found). However, the same correlation was not found with the black sea turtles. There was a lower correlation with size in the larger black turtles ($R^2 = .145$) than was found in the smaller size group (R^2=.332). This may possibly be explained by examining the ecology and migration of black sea turtles in the Gulf of California. Radio and satellite tracking have shown that larger sea turtles come in and out of the Bahia de los Angeles area at a much faster rate than juvenile turtles. It has been shown that the smaller black turtles stay in that region for a much longer period of time to use it as a developmental feeding habitat (Seminoff *et al.*, 1998). Due to the past gold mining history and mercury leaching operations in Bahia de los Angeles, this town may be a potential exposure site of mercury contamination, which may pose the highest risk to juvenile sea turtles. However, the sample size of this study was small and further investigation is needed to substantiate any conclusions.

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Body Temperatures of Leatherback Sea Turtles during the Internesting Interval

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Leatherback sea turtles (*Dermochelys coriacea*) have a wide geographic range, which extends from the tropics all the way to the frigid waters of the North Atlantic Ocean. Friar *et al*. (1972) found that leatherback turtles can maintain body temperatures (T_b) up to 17°C above water temperature (T_w) while migrating through the North Atlantic, and this finding sparked great interest in the thermal biology of leatherback turtles. Subsequent research showed that physiological traits such as large body size (300 - 600 kg) (Paladino *et al*., 1990), counter-current heat exchangers in the flippers (Greer *et al*., 1973), and deposits of brown fat beneath the carapace (Goff and Stenson, 1988) may contribute to the turtle's ability to thermoregulate. Most reptiles thermoregulate behaviorally, but the extent to which leatherback turtles use behavioral means, such as basking and altering dive patterns, to control T_b is not known.

In order to discern the effects of dive behavior (dive depth and dive time) on T_b, we simultaneously recorded dive variables, T_w and T_bs from freely diving leatherback turtles during the internesting interval. Instruments were deployed on nesting leatherback turtles at Playa Grande, Costa Rica under UBC Animal Care and MINAE guidelines. Thermistors implanted above the right front shoulder and the left rear flipper measured subcarapace T_b in 3 turtles. Additionally, stomach temperature telemeter (STT) pills were used to monitor stomach temperature of 4 turtles. For animals that maintain T_b higher than T_w, rapid fluctuations in stomach temperature are indicative of prey or water ingestion, and we hoped to explore the possibility that leatherback turtles forage during the internesting interval. Temperature and dive data were stored in custom-designed data loggers attached to the turtle's carapace. Instruments were removed when turtles returned to the beach to lay more eggs. All of the turtles in this study returned to the beach several more times following removal of thermistors and data loggers.

We found that leatherback turtles maintained T_b several degrees higher than surface T_w for the majority of the internesting interval (**Fig. 1**). Subcarapace T_b was 27-30.5°C, while T_w ranged from 16-27.5°C. T_b was slightly lower during extended periods of deeper diving, but usually did not vary during individual dives. A notable exception is the 1°C drop in T_b that occurred during the 67 min dive indicated by the asterisk in **Fig. 1**. The flat-bottom profile of this dive suggests that the turtle may have been resting on the sea floor, where T_w was 21°C. Prolonged exposure to cooler water may have the effect of decreasing T_b if the turtle is inactive. Higher T_bs towards the end of the internesting interval when turtles were not diving deeply suggests that turtles may raise T_b by remaining in warm shallow waters. Turtles rarely spent more than 10 min at the surface in between dives, so it is unlikely that they rely on surface basking to maintain elevated T_b during the internesting interval. Maintenance of elevated T_b is probably due to the heat-conserving benefits of large body size.

Two of the four turtles with STT pills showed marked fluctuations in stomach temperature that may be due to prey ingestion. Rapid drops in stomach temperature of 2-3°C were common during the first few days of the internesting interval for these 2 turtles (**Fig 2**). Temperature returned to the pre-ingestion level within 30-60 minutes. The long recovery period suggests that these turtles were ingesting prey and not water alone. However, neither of these turtles displayed a diel diving pattern, which is commonly associated with foraging (Eckert *et al*., 1989). The fact that the temperature fluctuations ceased after the second or third day of the internesting interval is also puzzling, as turtles did not alter their dive behavior. Since the STT pills were small enough to pass easily through the digestive tract, it is possible that the pills may have already passed from the stomach to the small intestine after a few days. If this was the case, temperature fluctuations due to ingestion would no longer be detected. Laboratory simulations of prey and water ingestion will have to be conducted before any conclusions can be drawn from the stomach temperature data.

Acknowledgments

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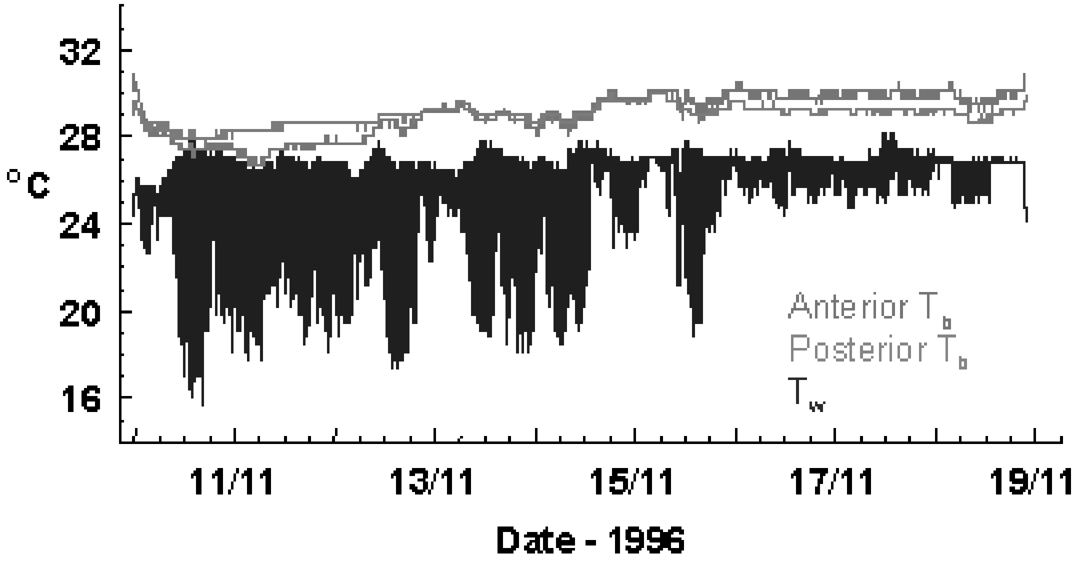

Figure 1. Subcarapace T_b and T_w for turtle 8866 during the internesting interval. T_b was maintained several degrees higher than T_w for the majority of time at sea. T_b usually did not vary during individual dives, but a drop in T_b of 1°C was observed during the exceptionally long dive (67 min) denoted by the asterisk.

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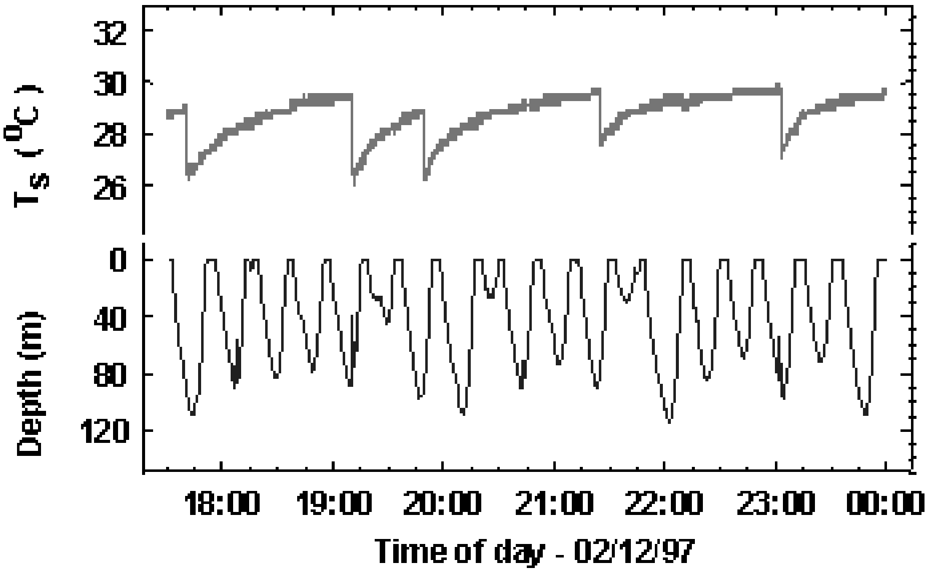

Figure 2. Six hr section of the stomach temperature trace (top) and the corresponding dive trace (bottom) for turtle 1616. Fluctuations in stomach temperature occurred frequently during the first 3 days of the internesting interval for this turtle.

The Importance of Diet and Pre-Ovulatory Parental Investment in the Development of Hatchlings: A Stable Isotope Approach

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Turtles do not exhibit parental care and therefore a major proportion of reproductive investment to eggs provides resources which are used for both embryogenesis and to fuel the hatchling after pipping. This preovulatory parental investment, in the form of yolk reserves and fat bodies in hatchlings, plays a vital role in increasing the survival chances of hatchlings.

We investigated the embryonic development of the freshwater red-bellied turtle, *Pseudemys rubriventris*, as a model for sea turtle hatchling development. Eggs from a natural nest were collected periodically throughout the 70 day incubation period. The chemical and isotopic composition of different egg components and their respective biochemicals was measured. Stable isotope analysis of individual biochemicals (e.g. fatty acids and cholesterol) can determine which compounds have been directly provided by the mother versus those that are synthesized de novo.

The yolk of a freshly-laid egg contained similar biochemicals to those present in late-stage embryo-associated yolk sacs, although 59% (by weight) of the yolk had been utilized during embryogenesis. The distribution of biochemicals in yolk sacs of the freshwater turtle was similar to that present in yolk sacs of *Chelonia mydas* confirming the validity of the red-bellied turtle as a model for sea turtle hatchling development.

The concentration of biochemicals present in muscle tissue and yolk sacs of hatchlings allows a quantitative assessment of the proportion of parental investment in embryogenesis and post-hatchling care. Furthermore, the isotope composition of essential biochemicals (i.e. compounds which cannot be synthesized de novo) provides information on the importance of specific dietary components to the production of viable hatchlings.

BIOLOGICAL STUDIES - GENETICS

Population Structure of Olive Ridley Rookeries in the Eastern Pacific: What Does the mtDNA Data Offer Management Practices?

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With the aim of studying genetic structure of *Lepidochelys olivacea* populations in the Eastern Pacific (EP), mtDNA control region sequences from five rookeries (four from Mexico, one from Costa Rica) were analyzed. Eleven haplotypes were identified, with genetic diversities comparable to those of other sea turtle species. Two haplotypes were found in all EP rookeries. The one that was dominant in all Mexican rookeries (freq > 0.60) occurred at significantly lower frequencies (0.40) in Costa Rica. The other, scarce in Mexico (0.06-0.20), was found at intermediate levels in Costa Rica (0.33). ANOVA analysis demonstrated a lack of significant genetic structure among studied populations of the EP (FST=0.018), suggesting high rates of inter-rookery genetic exchange, a result corroborated by tagging evidence of females nesting at more than one beach.

This suggests panmixia among the olive ridley colonies in the EP, at least within an evolutionary time scale (many generations), though with an incipient differentiation between Mexican and Costa Rican rookeries if Mexican rookery data are combined ($F= 0.062$, $P< 0.05$). In contrast, information derived from census studies denotes the presence of independent demographic trends between colonies, suggesting that within the shorter time frames that are relevant to management and conservation programs (decades) the genetic exchange between rookeries is too slow to permit recolonization of decimated populations. Application of the precautionary principle, in conjunction with an integrated analysis of the information produced by the present study, suggests the need to consider the different rookeries of *L. olivacea* in the EP as independent management units for the purposes of their conservation. Inventory of haplotype data will also be useful for identifying regional source for olive ridley turtles found in feeding and migratory routes of the Pacific basin.

Genetic Stock Origin of Sea Turtles Caught in the Hawaii-Based Longline Fishery

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Genetic analysis was used to identify the stock origin of sea turtles caught incidentally in the Hawaii-based pelagic longline fishery, which targets tuna and swordfish in the North Pacific. Mitochondrial DNA (mtDNA) control region sequences were compared with data obtained from key nesting beaches throughout the Pacific in order to determine stock origin. In addition, leatherback samples obtained from animals caught by the California driftnet fishery, and from strandings on the U.S. west coast were included in order to make inferences about migration. Due to genetic homogeneity among geographically proximate regional populations, and incomplete sampling of all regional rookeries in the case of leatherbacks (see Dutton *et al.* 1999) and olive ridleys (see Bowen *et al.* 1998), stocks were defined as being either western/Indian Pacific or eastern Pacific. This is the level at which the stocks can presently be distinguished by unique haplotypes in these two species. Some of the olive ridley haplotypes found in the fishery samples are new ones that have not been detected at rookeries sampled to date. The designation of stock origin in these cases was based on nearest similarity with either known western/Indian Pacific or eastern Pacific haplotypes.

The majority of loggerheads caught by longlines were from Japan (**Table 1**). Eight of the 10 leatherbacks sampled to date had haplotypes from the western Pacific, while two were of eastern Pacific origin (Mexico and Costa Rica).

Table 1. Origin of turtles sampled from by-catch in the Hawaii-based longline fishery, based on mtDNA analysis.

Species	n	Stock	Origin
Loggerheads	3	95%	Japan
		5%	Australia
Olive ridleys	17	44%	Indian/western Pacific
		36%	E. Pacific
Leatherbacks	10	80%	Indian/western Pacific
		20%	E. Pacific
Greens	4	25%	Hawaii
		75%	E. Pacific

In addition, two leatherbacks caught by driftnets in California coastal waters were of western Pacific origin, confirming a tendency for transoceanic migration by leatherbacks from nesting beaches in the western Pacific

(Malaysia, Indonesia and Solomon Islands) to foraging areas off of California. Eight of the 14 olive ridleys (43%) were from Indian and western Pacific rookeries, while the rest (57%) were from eastern Pacific rookeries in Mexico and Costa Rica, indicating that animals from both sides of the Pacific converge on the pelagic environment in the North Pacific (**Table 2**). Green turtles were rarely encountered, however, surprisingly three of the four greens caught at sea were of eastern Pacific (Mexico) origin, the fourth animal being of Hawaiian origin.

Table 2. MtDNA haplotypes for olive ridleys caught in the Hawaii-based longline fishery. Haplotypes are those given for rookeries by Bowen *et a*l. (1998), except where indicated.

Haplotype	Frequency	Stock Origin
J	1	Indian/western Pacific
M	2	Eastern Pacific
N	6	Eastern Pacific
LO1*	1	Indian/western Pacific
LO2*	4	Indian/western Pacific

*New haplotypes closely related to those published by Bowen *et al.* (1998) for Indian/western Pacific rookeries

Further sampling is planned to increase sample sizes from the longline fishery, and also to expand the rookery database to include additional nesting populations, particularly for leatherbacks and olive ridleys in the western and Indian Pacific. Analysis of multiple nuclear markers (microsatellites) is also underway to enable resolution of stock ID in cases where the mtDNA haplotype is one found at rookeries on both sides of the Pacific. These results will enable managers to better assess fisheries impact on particular stocks.

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Genetic Identification of a Nesting Colony of Green Turtles, *Chelonia mydas,* from the Western Cuban Shelf

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Tag-return data have provided good evidence that the Cuban shelf has both beaches and foraging grounds for green turtles (*Chelonia mydas*). In the present work, a nesting population from Guanahacabibes, on the west Cuban shelf has been characterized using DNA molecular markers. Three haplotypes were found, two of them are new reports. One seems to be a previously hypothesized haplotype. The presence of this haplotype helps to clarify the phylogeny and population structure of the western Caribbean group of green turtles. This is the first genetic investigation on the endangered *Chelonia mydas* on the Cuban shelf.

Introduction

Tag-recapture data indicate that "Cuban" turtles are a shared resource (Moncada, 1998) with, primarily, Costa Rica, Yucatan and Florida. A study was conducted to identify the haplotypes of the green turtles that nest on Cuban beaches. These haplotypes were compared with those found in Costa Rica, Yucatan and Florida populations to clarify the status of the Cuban population and the relationships of western Caribbean green turtles.

Materials and Methods

DNA extraction and amplification: Fifteen embryos were collected from Playa Antonio, Guanahacabibes Peninsule, Pinar del Río, on the southwestern coast of the Cuban shelf, during the nesting season (June-July, 1998). The embryos were preserved in 70% ethanol at room temperature. The extraction of the total DNA was performed using a standard phenol:chloroform extraction protocol. Amplification of the control region of mtDNA was performed using PCR methods (Mullis and Faloona, 1987) with primers TCR5 and TCR6 designed by Norman *et al.* (1994) producing a 385 base-pair (bp) fragment. Amplification products was purified using the High Pure PCR Product Purification Kit (Boehringer Mannheim).

Sequencing: All amplification products were directly sequenced on both strands by the dideoxy chain termination technique (Sanger *et al.* 1977), using the Thermo Sequenase (Amersham) sequencing kit, with 33 P-dNTP and primers TCR5 and TCR6. Sequencing products were resolved on 6% polyacrylamide sequencing gels, visualized by autoradiography, and read at least twice by two different observers.

Alignments: This work used the same numeration for the polymorphic sites as Encalada *et al.* (1996), although the sequences obtained in this survey begin in the position 198 of the cited numeration. For this reason the positions 164 and 167 referred to in Encalada *et al.* (1996) are ignored in this analysis.

Data analysis: The different haplotypes detected were used to calculate haplotype and nucleotide diversities (Nei, 1987). The frequencies were analyzed with a G test (Sokal and Rohlf, 1981). Sequences were aligned with MUST (Philippe, 1993). The haplotypes were linked by eye into an unrooted parsimony tree.

Results and Discussion

This represents the first genetic characterization of a Cuban green turtle population. Because tag-recapture data (Moncada, 1998) indicate that exchanges of turtles of the Guanahacabibes zone have been with Florida, Mexico and Costa Rica populations, the homologous regions of the haplotypes from these localities (Encalada *et al.* 1996) were included in all the data analyses.

In the Cuban population, two polymorphic sites were found that defined 3 different haplotypes (**Table 1** and **Fig. 1**). Cuba I, the most common haplotype, has a 6 bp insertion in position 540; Cuba II is identical to the homologous region of haplotype I of Encalada *et al.* (1996). Cuba III, with a transition (C-T) in position 321, has the same sequence as a hypothesized ancestral haplotype proposed by Encalada *et al.* (1996) to connect haplotypes I, Hyp 2 and XIII (**Fig. 1**). Cuba II was present in all analyzed populations (**Table 2**). Cuba III is the least frequent haplotype in the Cuban population.

Measurements of population variation are presented in **Table 2**. The highest haplotype diversity value was observed in Cuban population (h=0.86), higher than the overall diversity estimate (h=0.40), however, the nucleotide diversity (Nei, 1987) was low (p=0.0011), similar to the overall estimate (p=0.0009).

The high haplotype diversity value for the Cuban population could be attributed to low human activity because Guanahacabibes belongs to a biosphere reserve. The low nucleotide diversity in the Cuban population could be explained by all the Cuban haplotypes being derived from a single ancestral haplotype, probably haplotype I or III (Encalada *et al.*, 1996).

When the haplotype frequencies in the Cuban population were compared to Florida, Mexico and Costa Rica populations by means of a G test (Sokal and Rohlf, 1981), significant differences were found in each case indicating isolation or demographic independence of the Cuban population.

This is the first genetic investigation of the endangered *Chelonia mydas* on the Cuban shelf. A more extensive approach (increasing the sample size and the target region spanned with the primers) could elucidate some questions that still remain unanswered about the origin, distribution, dispersal movements and migratory behaviour of this group.

Table 1. Polymorphic sites included in the mtDNA control region sequences spanned by primers TCR5 and TCR6 for the haplotypes found in the populations connected with Cuban populations according to tag-recapture data (Mexico, Costa Rica and Florida) (Moncada, 1998). The haplotype marked a is identical to haplotypes I, III and XVIII of Encalada *et al.* (1996) when excluding positions 164 and 167. Haplotypes marked b are from Encalada *et al.* (1996)

Haplotypes	204/6	220/22	242/44	243/45	255/57	321/123	343/145	355/157	438/240	442/244	481/283	502/304	504/306	Addition
Cuba I	G	G	G	A	T	T	C	T	G	G	T	A	G	+
CubaII[a]	G	G	G	A	T	T	C	T	G	G	T	A	G	-
CubaIII	G	G	G	A	T	C	C	T	G	G	T	A	G	-
II[b]	G	G	G	G	T	T	C	T	G	G	T	A	G	-
V[b]	A	G	G	A	T	C	C	G	A	G	C	G	A	-
XV[b]	G	G	G	A	C	T	C	T	G	G	T	A	G	-
XVI[b]	G	A	G	A	T	C	T	T	G	G	T	A	G	-
XVII[b]	G	A	G	A	T	C	C	T	G	A	T	A	G	-

Figure 1. Maximum parsimony tree describing interrelationship among the 9 mtDNA haplotypes from green turtles nesting and/or visiting Cuba according to tag-recapture data.

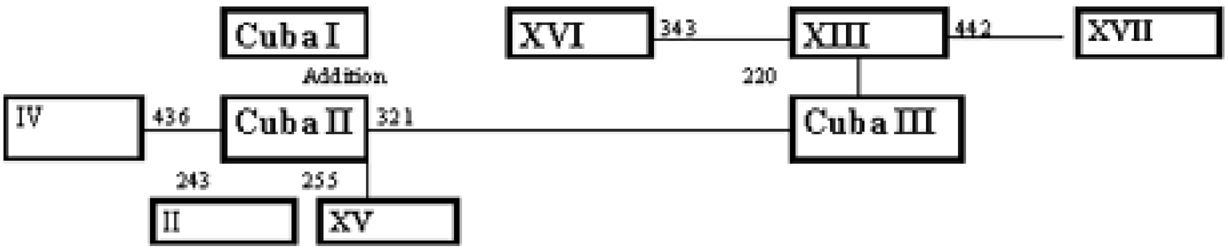

Table 2. Distribution of green turtle haplotypes in the Cuba, Mexico, Florida and Costa Rica populations. Frequency data from Mexico, Costa Rica and Florida are also from Encalada *et al*. (1996) with haplotypes I, III and XVIII pooled.

Haplotypes	**Populations**			
	Cuba	**Florida**	**Mexico**	**Costa Rica**
Cuba I	8(0.53)			
CubaII[a]	4(0.27)	23(0.96)	15(0.75)	15(1.00)
CubaIII	3(0.20)			
II[b]		1(0.04)		
V[b]			1(0.05)	
XV[b]			1(0.05)	
XVI[b]			1(0.05)	
XVII[b]			2(0.10)	
G values in respect to Cuban population	G=21.43***	G=16.90***	G=15.34***	
Haplotype diversity	0.86	0.08	0.44	0.00
Nucleotide diversity	0.0011	0.0001	0.0021	0.00
Overall Haplotype diversity=0.398	Overall Nucleotide diversity =0.0009			

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Nucleotide Substitution on Patterns in Sea Turtle mtDNA D-Loop Sequences

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The control region (d-loop) of mitochondrial DNA has been used increasingly in sea turtles to study population structure and for the identification of natal origins of individuals in feeding ground aggregations. In order to gain insight into the dynamics of its evolution within the group, nucleotide substitution patterns were analyzed. Within and between species comparisons were made for 88 haplotype sequences from the seven extant species, available as published data or provided from original unpublished research results.

Evolutionary rates were derived from comparisons of genetic distances vs. divergence times between lineages.

Values (% substitutions/site/My) ranged from 1.5 (between *Lepidochelys* spp) to 0.19 (between Dermochelyidae and Cheloniidae). There was no evidence of the saturation effect that has been reported for cytochrome b in sea turtles and for d-loop sequences in some taxonomic groups. Sequence variation was distributed evenly throughout the region analyzed and not concentrated in the 5′and 3′ ends as has been found for some vertebrates. Various conserved sequence blocks were identified. The nucleotide composition was not homogenous, with adenine and thymine being far more frequent than cytosine and guanine. As in other groups, transitions were much more common than transversions (4.14 average overall ratio), although the proportion varied greatly between species. Transitions did not reach saturation even at divergence levels beyond 60 million years.

As in previous studies, phylogenetic analyses showed a marked separation between the Atlantic and Pacific *Chelonia mydas* haplotypes, placed *Eretmochelys imbricata* haplotypes with the Carettini, and, in most, *Natator* is placed nearest to *Chelonia*. Placement of *Lepidochelys* genus is ambivalent.

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Genetic Study of the Mating System of the Eastern Pacific Green Turtle, *Chelonia mydas*, using Microsatellites: Preliminary Results

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Extensive behavioral studies of the eastern Pacific green turtle (*Chelonia mydas*, a.k.a. the black turtle, *Chelonia agassizii*) show that courtship and mating activity is intense in the vicinity of the principal nesting beaches off Colola and Maruata beaches in Michoacán, México. Although mating is observed throughout the nesting season, it is not known whether this activity results in fertilization of eggs to be deposited later by the females. In Colola, male turtles compete aggressively for the females, and up to six males at a time have been seen trying to displace a mounted male. Males are often displaced several times, and thus more than one could fertilize the receptive female. However, it is not known whether this behavior results in effective fertilization by multiple males. Recent genetic studies on leatherbacks and Australian green turtles show that multiple paternity, surprisingly, is very rare, suggesting that sea turtles have a capacity to store sperm. This study reports preliminary results. Ongoing studies include direct sampling of males observed mating with the females that are monitored, and their contribution, if any, to clutches subsequently laid by these females.

Introduction

The population of green turtles, *C. mydas*, that nest along the coast of Michoacán in México, have special melanistic characteristics which have led some authors to consider this a separate species (*Chelonia agassizii*; Bocourt, 1868, Márquez, 1990), and others a subspecies (*Chelonia mydas agassizii*. Kamezaki and Matsui, 1991). One of the intriguing behavioral characteristics of this population is the aggressive and often violent courtship and mating that occurs. Competition between males is intense; groups of up to 6 males have been observed vying for a female's attention. If the female is receptive, courtship begins, and one of the males mounts her and attempts to stay attached for long periods. The accompanying group of males often attack and try to displace the mounted male, sometime inflicting wounds on each other and the female (Alvarado and Figueroa, 1991).

In addition, mating is observed near the nesting beaches throughout the season, unlike other populations where mating is observed primarily at the beginning of the season. Alvarado and Figueroa have questioned whether this mating later in the season is effective (e.g. results in fertilization), or whether the females are no longer reproductively receptive during this time.

Modern molecular techniques now make it possible to test these theories. One would expect multiple paternity in clutches of this population given the observed mating behavior. This question, however, becomes more intriguing in the light of a recent study by FitzSimmons (1996) on green turtles in Australia, where multiple paternity was found to be rare. In a similar study in leatherbacks, Dutton *et al.* (1996a) have found no evidence of multiple paternity.

This study uses microsatellites as genetic markers to study paternity in the nesting population at Colola beach in the state of Michoacán, México. Sampling was only recently completed, so here we present preliminary results. The existence or absence of multiple paternity in this endangered population may have important implications for the conservation of the turtles since it might affect the genetic variability.

Objective

To determine the extent of multiple paternity among clutches laid by the green turtle, *C. mydas*, on Colola beach in the state of Michoacán, México.

Methods

Sample gathering: The biological material, blood and tissue was obtained from adult turtles (Owens and Ruiz, 1980) or from dead offspring (taking advantage of the fact that some offspring die from natural causes) depending on availability in the field. The solid tissue was preserved in a saturate solution of NaCl-DMSO and the blood in lysis buffer (Dutton, 1996b).

Microsatellite amplification: For this preliminary analysis the microsatellite loci Cm3 and Cm72 (FitzSimmons, 1996) were used to determine the variability of these loci in the Michoacán nesting population and to assess their usefulness in detecting multiple paternity. These particular loci were chosen because they proved to be the most polymorphic within the Australian green turtle population. Genomic DNA was amplified with PCR using fluorescent dye-labeled primers and the allele sizes of the resulting products were determined with an ABI 377A automated sequencer using GENESCAN software.

We obtained the probability of detection of multiple paternity for each locus (d) and across both loci (D), as well as the probability that two members of the same population share a common genotype (Westneat *et al.* 1987; Hanotte *et al.* 1991 taken from FitzSimmons, 1997).

Progress to date

Sampling: Samples have been collected from 15 female green turtles and 839 of their offspring at Colola, between October 1998 and January. Several clutches laid by the same female were sampled through the season. Additional samples from nesting females were analyzed to determine population frequencies for Cm3 (n=29) and Cm72 (n=28).

Results-microsatellite analysis: To date 2 microsatellite loci, Cm3 and Cm72, have been analyzed (**Table 1**). Both loci are highly polymorphic, with 16-21 alleles in the nesting population at Colola.

Table 1. Number of alleles and the probability of shared genotype detection from different fathers for each locus (d), both loci combined (D), and the probability that in the same population two members have the same genotype.

Locus	Number of Alleles	d	Probability of Shared Genotype
Cm3	16	0.728	3.017×10^{-2}
Cm72	21	0.833	1.158×10^{-2}
overall		(D)0.954	3.496×10^{-4}

Discussion

The results obtained for the probability of detecting alleles from different fathers in a nest is high (D=0.95) even with only two loci. Similarly, the probability that two randomly chosen members of the population have the same genotype is also low (3.496×10^{-4}). The use of these markers is thus very feasible in assessing the presence of multiple paternity. The capacity to detect multiple paternity (if it exists) will be enhanced as we use additional loci.

Some of the scenarios that we may find are:

1) *Single paternity for all clutches laid throughout the season*: This would imply sperm storage by females from a single successful copulation, that the female is receptive only during a short period of time, and/or some sperm from specific males displace others under circumstances of sperm competition.

2) Single paternity within clutches, but different fathers fertilizing different clutches. This would suggest that observed mating by different males at different times of the season is effective, but that sperm storage is unlikely, or some sperm from specific males displace others under circumstances of sperm competition.

3) *Multiple paternity involving the same fathers in all clutches throughout the season*. This would suggest that the female is receptive to fertilization only at the beginning of the season, and that sperm is stored from multiple copulations occurring during a receptive period and used to fertilize subsequent clutches.

Further work

All samples collected to date will be analyzed with an array of microsatellite markers in order to infer paternity. During the upcoming nesting season, behavioral observations will be made, and both males and females from mating pairs will be sampled in order to directly test these mating hypotheses.

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-Sampling was carried out under permit No. 750-9400/98 issued on September 14th 1998 by the DGVS of the INE-SEMARNAP. Microsatellite analysis was carried out at the U.S. NMFS Southwest Science Center in La Jolla, CA with samples imported under CITES permit no. US786600.

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BIOLOGICAL STUDIES - SEX RATIOS

Sex Ratios of Immature Sea Turtles: Does Water Temperature Make a Difference?

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The natural sex ratios of sea turtles have been of interest since the discovery of temperature-dependent sex determination (TSD) in sea turtles (Owens and Hendrickson, 1978). During a 1995-1997 study on the index abundance of sea turtles in the Pamlico-Albemarle Estuarine Complex, North Carolina (Epperly *et al.* 2000), the NOAA Beaufort Lab, utilizing a serum testosterone sexing technique, determined the sex ratio of loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) sea turtles to be the most skewed yet published for a foraging population (Owens, 1996). Although serum testosterone titer has been determined to be an accurate indicator of the sex of immature sea turtles, testosterone levels in immature turtles may vary directly with ambient temperature (Owens, 1996). In November, 1997, surgical observation of the gonad was performed on a sample of 55 turtles via a laparoscopic entry into the peritoneum (Wood *et al.*, 1983). At this time, water temperatures were <15°C. The testosterone titers of 9 of the 15 lap'ed male loggerheads were <30 pg/ml, mis-classifying their sex. The green turtles (1 male and 5 females) were classified correctly. To determine whether testosterone titers are depressed by cold water temperatures, we sampled additional loggerhead and green sea turtles in 1998 from both warm (≥ 20°C) and cold (<20°C) water temperatures.

Sea turtles captured in pound nets set in Core and Pamlico Sounds, North Carolina, were sampled from May-November, 1998. Blood samples were drawn from the dorsocervical sinus (Owens and Ruiz, 1980) or from the jugular vein, and were analyzed to determine testosterone titers of the individual. All blood samples were stored with lithium heparin on ice no more than 8 hours and centrifuged with a desktop clinical centrifuge. The serum was pipetted off and stored at -70°C. Frozen serum samples were shipped on dry ice to College Station, Texas where a serum androgen sexing technique was used to sex the sea turtles following a testosterone radioimmunoassay procedure (Wibbels *et al.* 1987; Owens, 1996; Valverde, 1996).

We sampled 114 loggerhead and 9 green turtles captured in warm (≥20°C) water temperatures and 155 loggerhead and 15 green turtles captured in cold water temperatures. Although clearly biased towards females (2.6:1) (**Table 1**), the percentage of male loggerhead turtles (27%) sampled in warm water was comparable to the percentage of male loggerheads verified by laparoscopy in 1997 (32%)(N=47). Serum testosterone ranged from 1.32-16.60 pg/ml for females and 45.70-1142.00 pg/ml for males with only one unknown (22.70 pg/m) (**Table 1**). In contrast, the percentage of male loggerhead turtles (7%) sampled in cold water was significantly lower. Serum testosterone ranged from 0.34-18.30 pg/ml for females and 30.50-121.00 pg/ml for males with five unknowns (20.00-20.90 pg/m) (**Table 1**).

Apparently, cooler temperatures do depress testosterone titers, thus biasing results against males (towards unknowns and females). We pooled the results of loggerheads sampled since 1995 and compared testosterone titers to water temperature. As water temperatures decreased throughout the season, the observed upper range of testosterone titers declined. We were able to quantify this relationship through the recapture of a male loggerhead (48.00 pg/ml) initially captured when water temperature was 24°C. His testosterone level dropped to 11.50 pg/ml when recaptured in colder waters (14°C). After applying a warm water (≥20°C) cutoff to the 1995-97 data, we combined it with the 1998 data to determine sex ratios for this loggerhead population (**Table 1**). The resulting sex ratio (3.23:1), although still biased towards females, is comparable to other United States immature loggerhead sex ratio studies to date (Owens, 1996).

Interestingly, green turtles did not display the same effect of temperature on testosterone titers. In warmer water temperatures, green turtles had a lower percentage of male turtles (22%) than in colder water temperatures (27%) (**Table 1**). This relationship held true when we included the data since 1995: there were more males in colder water temperatures (22%) than in warmer (16%) and there were higher testosterone levels at lower water temperatures. Schroeder and Owens (1994) felt that warm water temperatures in a captive situation may have been a factor in elevated green turtle testosterone titers. However, since their blood samples were taken after 6 weeks in captivity, it is not known for certain whether temperature or possible stress due to captivity were the cause of the increased testosterone levels. Likewise, since our pooled sample of green turtles captured in warm water temperatures was relatively small (N=25), additional sampling of green turtles in warm water temperatures will be necessary in order to determine if warm water is influencing testosterone levels in green sea turtles.

Although testosterone levels have been used successfully to determine sex ratios of immature sea turtles, care should be taken when obtaining the sample. It has been noted that captive stress may alter testosterone levels (Owens, 1996) and apparently, water temperature can too. It is not known at which temperature testosterone levels begin dropping enough to result in a mis-classification of sex. Owens *et al.* (1984) found the testosterone titer technique to be accurate when ambient water temperatures were between

Table 1. Sex ratios of immature loggerhead and green sea turtles based on testosterone titers.

Species	**Year**	**Cold water temperature (<20°C)**			**Warm water temperature (≈20°C)**		
		#/Sex	**Testosterone (pg/ml)**	**Ratio (F:M)**	**#/Sex**	**Testosterone (pg/ml)**	**Ratio (F:M)**
C. caretta	1998	139F	0.34-18.30	12.63:1	82F	1.32-16.60	2.64:1
		11M	30.50-121.00		31M	45.70-1142.0	
		5U	20.00-20.90		1U	22.70	
	1995-1998	388F	0.00-19.70	11.41:1	123F	0.00-17.30	3.23:1
		34M	30.50-174.00		38M	45.70-1142.0	
		17U	20.00-27.90		4U	20.30-28.90	
C. mydas	1998	10F	2.45-7.58	2.5:1	7F	1.41-7.02	3.5:1
		4M	23.40-142.00		2M	29.60-67.80	
		1U	14.80		0U	—	
	1995-1998	38F	0.00-9.37	3.45:1	20F	0.00-9.77	5.0:1
		11M	20.30-142.00		4M	29.60-67.80	
		1U	14.80		1U	14.30	

No turtles were sampled when water temperatures ≥ 20°C in 1995

19° and 27°C, however, we noted a significant drop in testosterone titer for at least one male loggerhead when the water temperature dropped to 14°C. Whenever possible, it is always a good idea to verify a subsample of the population from which testosterone titers were taken to determine the sex ratio of a population.

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The Effect of Temperature Change On the Sex Ratio of Kemp's Ridley Nests in the Hatchery Center at Rancho Nuevo, Tamaulipas, Mexico

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During the 1997 Kemp's ridley nesting season at Rancho Nuevo, Mexico, a study was conducted to evaluate the effect of temperature on the sex ratio of nests transferred to the hatchery center.

On May 24, 120 nests were deposited during an "arribazon". The clutches were divided into two groups in the hatchery: 40 nests were shadowed with a plastic mesh (used in hothouses for plants), while 67 nests were treated as usual, that is, exposed totally to the solar light. A temperature telesensor was installed at the same depth (30 cm) in three nests for each group during the incubation period. An analysis of covariance was carried out in order to determine if the variation in temperature was the same in all of the nests. At the end of the incubation process, 53 and 62 samples (with and without shade, resp.) of deformed or unhatched embryos and dead hatchlings were collected and preserved. The sex of each sample was determined by the histology of hematoxylin-eosin stain technique, using cuts of 10 microns and by observing the cellular structure.

The incubation temperature of the shaded group averaged 30.2°C with a standard deviation of 1.6°C. Of the hatchlings and embryos sampled, 50% were males, 32% were females, and 16% were unclassified because of gonad loss.

The temperature average for the unshaded group was 31.1°C with a standard deviation of 1.4°C. This sample was 100% female.

The results show that temperature variations of approximately 1°C, has a marked difference in the proportion of sexes for this species. We conclude that the temperature threshold could be similar to that of *Lepidochelys olivacea.*

The Sex Ratio of Green Sea Turtle Hatchlings on Wan-An Island, Taiwan

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Nest temperature determines the sex ratio of sea turtles during the mid-third period of incubation. With the temperature logger, we are able to determine the sex of turtle in situ without sacrificing any individual. The sex of the green sea turtle hatchlings that incubated in the beaches of Wan-An Island, Taiwan were determined in the summer of 1996 and 1997. A total of 29 nests were measured. Results showed that 82-86% of the hatchlings that incubated at Wan-An Island were females. This could be related to 75% of the nests deposited in July and August, when the nest temperature fell above the upper limit of pivotal range. The incubation temperatures were also lower in the nests that were deposited in the open beach instead of in the grassland, thus producing more male hatchlings. The implications for sea turtle conservation with temperature-dependent sex determination were considered.

Preliminary Findings of an Investigation of Loggerhead *(Caretta caretta)* Nest Incubation Temperatures in Northwest Florida, USA

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Preliminary analysis of incubation periods for Florida Panhandle beaches indicates they may be considerably longer than incubation periods on East Coast beaches, with many nests hatching after 70 days. Researchers have previously determined that longer incubation periods correspond to lower incubation temperatures and the production of a higher percentage of male hatchlings (Marcovaldi *et al*. 1997). Therefore, it is likely that panhandle beaches are producing more males than East Coast beaches. In order to determine the subsequent sex ratio of loggerhead hatchlings produced on panhandle beaches, a cooperative study was initiated in 1998 to determine nest incubation temperatures, hatchling sex ratios, and nesting beach characteristics at four sites across the Florida Panhandle. Participants in the study include federal, state, academic, and volunteer organizations involved with sea turtle nesting beach activities in Northwest Florida. During the 1998 nesting season, electronic data loggers were used to monitor sand temperatures and *in situ* loggerhead nest temperatures on four panhandle beaches. Sand characteristics and weather conditions were also monitored within the experimental areas, but no analysis of sex ratios was attempted during the pilot year of the study. A large portion of the project's equipment and data was lost to Hurricane Earl in September; however, the 1998 season allowed for development of methods and techniques which will be utilized during the 1999 nesting season.

Spatial and Temporal Changes in Sex Ratios of Green Turtle (*Chelonia mydas*) Hatchlings in Pulau Redang, Malaysia

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The most common measure with regard to sea turtle conservation is the protection of eggs during incubation. Current practices include incubation of eggs in open air beach hatcheries, styrofoam boxes and in relocated as well as *in-situ* nests. It has now been established that incubation temperature of sea turtle eggs affects the sex of the resulting hatchlings (Morreale *et al.*, 1982, Mrosovsky, 1995). Higher temperatures produce female hatchlings, lower temperatures yield males, while intermediate temperatures produce mixed proportions of males and females.

Information regarding natural sex ratios of the hatchlings from nesting beaches, as well as typical adult sex ratios in undisturbed environments is required before decisions can be made on sex ratios to be produced under controlled conditions. To date there is no published information on natural sex ratios of sea turtles in Malaysia. This study was conducted to fill the gap. The results will assist in providing basic guidelines in hatchery management with regard to incubation temperatures since current practices in Malaysia do not take into consideration sex ratios of the hatchlings produced.

Methods

Pulau Redang is an island off the coast of Terengganu with the largest concentration of nesting green turtles in Peninsular Malaysia (Liew and Chan, 1993). There are three major nesting beaches on this island, Chagar Hutang, Mak Kepit and Mak Simpan. This study was conducted on Chagar Hutang beach (05°48.35 N, 103°00.50 E).

The beach was divided into two thermal zones following Horikoshi (1992). These two zones represented the shaded portion of the beach with vegetation and within two metres of dense vegetation, and the open beach which was located between the shade zone and the high tide mark. A total of 24 nests from different parts of the beach were selected to be monitored. Criteria of selection was based on the date of oviposition, as well as nest location. Sampling was spread out evenly in three phases during the months of May to August in order to trace temporal differences. The three phases were 9 May to 22 June, 23 June to 31 July, and 1 to 31 August. These months were chosen as they represented the peak of the nesting season. Nests that were laid after August were not sampled as the emergence of the hatchlings from these nests would coincide with the North East Monsoon.

Nest temperatures were measured using a thermocouple thermometer and self-constructed probes following Spotila *et al.* (1983). The temperature probes were inserted in the center of the turtle nest as oviposition occurred. Temperatures were recorded at 1700 hours every other day from May to mid-October.

20 hatchlings from each nest were sampled at random, prior to emergence to avoid predation or early emergences, and were sacrificed to determine their sex. Sexing of the hatchlings was based on methods described in Miller and Limpus (1981) and Spotila *et al.* (1983).

Results

The nest temperatures were monitored throughout the entire incubation period, with special attention paid to the middle trimester of incubation. The open beach zone produced 85.4% female hatchlings, while the shade zone produced 52.9% females. The hatchling sex ratio was different between the two zones (Chi Square test, $v=1$, $p<0.05$). The number of females produced in the open beach was greater than those produced in the shaded zone (Two sample t-test, df=22, $p<0.05$). There were no significant differences in incubation temperatures for the open beach and the shade nests during the middle trimester (Two sample t-test, df=22, $p>0.05$) or during the entire incubation (Two sample t-test, df=22, $p>0.05$).

The three temporal phases of sampling from May to August produced percentages of 87.5%, 56.9% and 63.2% females, respectively. A statistical test conducted on the data however showed that the difference in the number of female hatchlings between the three phases were not significant (One Way ANOVA, df=2, $p>0.05$).

Discussion and Conclusion

Average incubation temperatures during the middle trimester for both zones ranged from 27.9°C to 31.5°C, in comparison to Horikoshi (1992) who found that the mean incubation temperature for nests in Costa Rica, ranged from 27.0°C to 30.7°C during different nesting seasons. No differences between the nest temperatures during the middle trimester and the entire incubation period were detected, although this may have been due to the location of the shaded nests, which were 2 metres from dense vegetation and significantly shallower than the nests in the open beach. Nevertheless, the number of female hatchlings produced in the open beach zone was significantly higher than the shaded zone.

There was a seasonal trend in the sex ratios of hatchlings produced with different proportions of females produced during the three phases of sampling. In the first phase, when the nests were subjected to higher temperatures, more female hatchlings were produced. The percentage of female hatchlings dropped in accordance to temperature in the second and third phases of sampling. Godfrey *et al.* (1996) found that green turtles nesting in Suriname during different seasonal periods experienced different incubation temperatures and had different sex ratios.

It was evident that the percentage of female hatchlings produced in 1995 was relatively high. Limpus (1991, 1993) recommended that a sex ratio of 60% to 80% female hatchlings is acceptable based on the strong female-biased sex ratios at most feeding sites. Several sea turtle rookeries around the world were found to have produced female-biased hatchlings (Standora and Spotila, 1985; Spotila *et al.*, 1987; Mrosovsky and Provancha, 1989; Wibbels *et al.*, 1989)

When it became known that the sex of sea turtle hatchlings was determined by incubation temperature and since large scale transfer of eggs to hatcheries was common, it became necessary to know if the sex ratios obtained from these hatcheries varied from those found naturally. A difference in temperatures between the hatcheries and undisturbed nests produces a scenario which is detrimental to the survival of sea turtles. Research has to be carried out to determine the natural sex ratios of sea turtles and the temperatures causing them.

The importance of spatial and temporal distribution of green turtle nests is that it influences the overall sex ratio of the hatchlings produced from this nesting beach. More in-depth studies to assess the effects of temperature-dependent sex determination on natural beaches as well as in hatcheries should be carried out by Malaysian sea turtle programs. At present, small scale experiments are being conducted to avoid the production of 100% female hatchlings in open air beach hatcheries (Kamarruddin, 1996). Ideally, the sex ratio of hatchlings emerging from *in-situ* nests needs to be determined for as many nesting beaches as possible and non-sacrificial methods should be developed. The data obtained will help provide guidelines regarding hatchling sex ratios which should be produced from hatchery programs.

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Sand Temperatures of Green Turtle Nesting Beaches in the Hawaiian Archipelago

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Sea turtles possess temperature-dependent sex determination or TSD in which the incubation temperature of the egg determines the sex of the hatchling (reviewed by Wibbels *et al.*, 1993; Mrosovsky, 1994). Previous studies of sea turtles indicate that TSD can produce highly biased hatchling sex ratios on some nesting beaches (Mrosovsky and Provancha, 1989; 1992; Marcovaldi *et al.*, 1997; Hanson *et al.*, 1998). As such, hatchling sex ratios are of conservational interest (Mrosovsky and Yntema, 1980; Morreale *et al.*, 1982). However, there are a number of logistical difficulties associated with studying hatchling sex ratios in sea turtle populations, including the inability to sex hatchlings based on external morphology. Traditionally, hatchlings have been sexed by gonadal histology which requires the dissection of hatchlings (Yntema and Mrosovsky, 1980). More recent studies have employed alternative methods in an attempt to predict sex ratios without killing hatchlings (Mrosovsky and Provancha, 1992; Godfrey *et al.*, 1996; Marcovaldi *et al.*, 1997; Hanson *et al.*, 1998). These methods include the estimation of sex ratios based on sand temperatures on the nesting beaches.

In the current study, sand temperatures (at nest depth) were examined over three consecutive nesting seasons on two nesting islands for the Hawaiian green turtle, *Chelonia mydas*, at French Frigate Shoals.

Methods and Materials

The French Frigate Shoals is an atoll located approximately 800 km northwest of Oahu in the Hawaiian Archipelago (latitude 23° 52 N, longitude 166°17 W). Over 90% of Hawaiian green turtle nesting occurs on the French Frigate Shoals (Balazs, 1976; 1980). Nesting at French Frigate Shoals occurs on six small islands (Balazs, 1980), with the majority occurring on East Island.

Sand temperatures were monitored on East Island and Tern Island. Sand temperatures were monitored with Hobo temperature data loggers and Optic Stowaway data loggers (Onset Computer Corp., Poccasett, MA, USA). Prior to use each season, the data loggers were calibrated in laboratory incubators. The data loggers were deployed on both East Island and Tern Island during 1995, 1996, and 1997. Data loggers were programmed to record temperature every 3.2 hr. On East Island, data loggers were distributed throughout the island in locations which historically had the greatest nesting activity (Balazs, 1980). On East Island, the data loggers were distributed evenly along the sand beach extending from the south sea wall at a distance from the water where the majority of nesting activity occurs. All data loggers were buried in the sand at a depth of approximately 45 cm, which approximates the depth of the center of the egg clutch in a Hawaiian green turtle nest (Balazs, 1980). At this depth, the maximal daily fluctuation in temperature was typically 0.2°C or less (average maximal daily temperature fluctuation=0.11°C±0.4, mean±SE). The number of data loggers deployed each year was: 1995, East Island N=8, Tern Island N=4; 1996, East Island N=7, Tern Island N=4; 1997, East Island N=4, Tern Island, N=6.

A previous six year study on Tern Island indicated that nesting normally begins in mid May, with the majority of nesting (approx. 65 to 70%) occurring during June and July (Niethammer *et al.*, 1997). Nesting then declines in August and ends in September (Niethammer *et al.*, 1997). That study also indicated that the average duration of incubation for eggs (yearly averages) on Tern Island ranged from 62.5 to 70.5 days (Niethammer *et al.*, 1997). Considering that the temperature sensitive period of sex determination occurs during the approximate middle third of the incubation period (Yntema and Mrosovsky, 1982; reviewed by Wibbels *et al.*, 1991), mid June through mid September would represent the approximate time period during which temperature would affect the sex of the majority of hatchlings. During each year of the current study, data loggers were deployed during early June and recovered no sooner than early September. Thus, the data collected during this study included the time period during which sand temperature influenced sex determination in the majority of hatchlings produced during the 1995, 1996, and 1997 nesting seasons.

Results and Discussion

During the mid June through mid September periods of 1995 through 1997, the sand temperatures recorded on East Island and Tern Island were in the range of approximately 25 to 29°C. In general, these temperatures appear cool in relation to sex determining temperatures. In sea turtles, relatively warm incubation temperatures (approx. 31°C or above) produce all females, whereas cooler incubation temperatures (approx. 27°C or below) produce all males (reviewed by Mrosovsky, 1994). The "pivotal temperature" is the temperature which produces an approximate 1:1 sex ratio (Mrosovsky and Pieau, 1991). Although pivotal temperatures can vary, previous studies suggest they normally range between approximately 28.5 to 30.0°C in sea turtles, including green turtles studied in Suriname and Costa Rica (Morreale *et al.*, 1982; Mrosovsky *et al.*, 1984; Standora and Spotila, 1985; Spotila *et al.*, 1987; Godfrey *et al.*, 1996). The pivotal temperature for Hawaiian green turtles is unknown. If the pivotal for Hawaiian green turtles is similar to that of green turtles in Suriname and Costa Rica, then the majority of temperatures recorded in the current study would be below the pivotal. This would suggest that male biased hatchling sex ratios were produced during 1995, 1996, and 1997 on East Island and Tern Island.

However, there are at least two alternative hypotheses. It is plausible that temperatures within the nests may be slightly higher than adjacent sand temperatures due to metabolic heating. Further, it is also possible that the pivotal temperature for Hawaiian green turtles may be relatively low in comparison to those estimated for other green turtle populations. That is, the pivotal temperature for the Hawaiian green turtle may have evolved relative to the nesting beach temperatures at French Frigate Shoals. Either of these scenarios could facilitate the production of unbiased or even female-biased sex ratios at the temperatures observed in the current study. Thus, the results of the current study show the need for future studies addressing the incubation temperatures within nests at French Frigate Shoals and addressing the pivotal temperature in Hawaiian green turtles.

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Incubation Temperatures in Kemp's Ridley Nests during the 1998 Nesting Season

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Sea turtles possess temperature-dependent sex determination or TSD (Mrosovsky, 1994), in which the incubation temperature of the egg determines the sex of the hatchling. This type of sex determination has the potential of producing highly biased sex ratios. A variety of past studies have suggested that in some cases (e.g. strong male biases), such biases could decrease the effectiveness of sea turtle nesting beach conservation programs (Mrosovsky and Yntema, 1980; Morreale et al., 1982; Mrosovsky, 1983; Wibbels *et al.*, 1989). Therefore, it is advantageous to monitor hatchling sex ratios in nesting beach programs.

There are a number of logistical difficulties associated with studying hatchling sex ratios in sea turtle populations, not the least of which is the inability to sex hatchlings based on external morphology. Traditionally, hatchlings have been sexed by gonadal histology which requires the sacrifice of hatchlings (Yntema and Mrosovsky, 1980). Recent studies have employed alternative methods in an attempt to predict sex ratios without killing hatchlings (Mrosovsky and Provancha, 1992; Godfrey *et al.*, 1996; Marcovaldi *et al.*, 1997; Hanson *et al.*, 1998). These methods include the estimation of sex ratios based on incubation temperatures in the nests.

In the current study incubation temperatures were examined in Kemp's ridley nests during the 1998 nesting season. The recovery program for this severely endangered sea turtle is coordinated by Instituto Nacional de la Pesca (Marquez-Tamaulipas, Mexico).

Methods and Materials

Sand temperatures and nest temperatures were monitored with Hobo temperature data loggers and Optic Stowaway data loggers (Onset Computer Corp., Poccasett, MA). These are relatively small units that can be programmed to record temperatures at a variety of time intervals. They contain a thermistor probe, and at the temperatures common in sea turtle nests, are precise to approximately 0.3°C or better. They are programmed to record temperature by temporarily connecting them to a personal computer loaded with the appropriate software. After they have acquired the temperature data, the units are reconnected to a personal computer to download data. The data loggers were calibrated in custom incubators which maintain a constant internal temperature of ±0.2°C.

Data loggers were used to monitor sand and nest temperatures in egg corrals at Rancho Nuevo, Tepehuajes, and Playa Dos. Sand temperatures were monitored throughout the nesting season in all three corrals. This was accomplished by burying five dataloggers at mid-nest depth (approximately 30 to 35 cm) throughout each corral. These dataloggers were buried during April and recovered in late August. Data loggers were also placed directly into the approximate center of the egg clutches to monitor temperatures within individual nests in the egg corrals throughout the nesting season. Temperature was monitored in a total of 89 nests. The nests in which temperature was monitored were laid on dates ranging from early April to mid July, which included the great majority of nesting. Temperature variation within nests was investigated by placing data loggers at the top, middle, and bottom of the egg mass in several nests. Additionally, a fourth data logger was buried adjacent to each of these nests at mid nest depth, in order to compare sand temperature to nest temperature.

Results and Discussion

In general, sand temperatures in all three egg corrals were similar. Early in the nesting season, sand temperatures were relatively cool (e.g. approximately 28°C), but temperatures rose to approximately 30°C by mid May and remained above that level for the remainder of the nesting season. Temperature variation was detected within individual nests. During the first two thirds of the total incubation period, the temperatures within the nest varied by a maximum of approximately 1.0°C. During the last third of incubation, the temperature in the middle of the egg mass was higher than regions at the top or bottom of the egg mass (presumably due to metabolic heat). Sand temperatures at mid-nest depth adjacent to the nest were typically within 1.0°C or less of the temperatures within the nest.

Previous studies by Aguilar, 1987, and Shaver *et al.*, 1988, provide estimates of the effects of specific temperatures on sex determination in the Kemp's ridley. Those studies suggest a pivotal temperature near 30°C (temperature producing a 1:1 sex ratio) and that temperatures of approximately 31°C or greater produce most or all females. Using those data as a reference, nests laid early in the nesting season (April) would be predicted to produce males or both males and females, whereas, nests laid during or after mid May would be predicted to produce most if not all females. Kemp's ridley nesting normally begins in April, extends through May and June, and decreases during July. Therefore, the temperature data indicate an overall female bias during the 1998 nesting season.

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This research is part of a collaborative Kemp's Ridley Recovery Program which is coordinated by the Instituto Nacional de la Pesca, and involves a number of other agencies and universities, including the Universidad del Noreste, the Gladys Porter Zoo, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the Univ. of Alabama at Birmingham. This research was sponsored in part by the National Oceanic and Atmospheric Administration, U.S. Dept. of Commerce, and the Mississippi-Alabama Sea Grant Consortium under Grant # NA56RG0129.

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GEOLOGY, ECOLOGY, CLIMATOLOGY AND PALEONTOLOGY

Importance of Beach Slope on Hatching Success

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Beach slope is an important factor in the breeding success of marine turtles because it helps maintain the eggs above the water line. The eggshell is porous to allow an exchange of gases and liquid from the inside of the eggs to the outside. Geographical characteristics were analyzed at three nesting beaches in order to compare the effect of the average beach inclination and to quantify the minimum inclination required for hatching success.

Nest depth was recorded and averaged for each of the observed species. The zones of influence of each species were analyzed in order to find the factors that conform a relatively good beach for the nesting turtles. Influence of pluvial precipitation in marine turtle nests was analyzed to establish the safety limits in which a nest is not affected by the rain.

The first beach analyzed was Tortuguero, Costa Rica, where the green turtle (*Chelonia mydas*) nests. Samples were collected along five miles of shore line from the mouth of Tortuguero River to the south. Measurements (n=44) were taken every eighth of a mile from the tide line to the upper end of the beach as well as from the tide line to the nests, to obtain the average distance from the nest site to the tide line.

The second beach, Ostional, Costa Rica, is one of the most important nesting sites for the olive ridley (*Lepidochelys olivacea*) in the Pacific Ocean. The beach is approximately 8 km long. Samples were taken every 50 meters (n=140). The work here was done with the help of Asociacion de Desarollo Integral de Ostional (ADIO A.C.).

The third group of measurements was taken on the beach of Majahuas, Jalisco, Mexico, where a more complete geographical analysis of the beach was carried out. Along this shoreline more olive ridleys nest. A three-way comparison of the beaches was made to observe significant geophysical characteristics in the decision-making female ovipositors.

Distribution and Ecology of the Diamondback Terrapin (*Malaclemys terrapin*) in South Carolina Salt Marshes

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I studied two aspects of diamondback terrapin ecology. The first used data on the incidental catch of *Malaclemys terrapin* provided by Inshore Fisheries (South Carolina Marine Resources Division, Dept. of Natural Resources). My objectives were to investigate the distribution of *M. terrapin* in South Carolina, including correlations with physical and geographical variables. I developed a model to explain variation in terrapin distribution using six main effects: year, month, site, location nested within site, water temperature and salinity. Two significant effects, month ($P<0.05$, df=8) and location nested within site ($P<0.05$, df=220), accounted for approximately 25% of the variation in *M. terrapin* distribution. I hope that continued data collection will allow monitoring of *M. terrapin* populations in regions supporting a large crabbing industry and areas undergoing coastal development

The second aspect of terrapin ecology that I studied used manipulative experiments to determine the importance of *Malaclemys* as a predator of the salt marsh periwinkle (*Littorina irrorata*). In areas of salt marsh where terrapins were excluded, there were significantly more *Littorina* compared to control areas of natural terrapin density ($P<0.05$, df=3). Experimental evidence that *Malaclemys* is an important predator of *Littorina* challenges traditional salt marsh food webs, and supports *Malaclemys* as a sentinel species in southeast salt marshes.

Influence of the Climatic Conditions on the Nesting Frequency of Kemp's Ridley at Rancho Nuevo, Tamaulipas, México

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The breeding physiology of marine turtles has seasonal and daily rhythms. Some of them are timed by environmental cues like the day length, temperature changes, phases of the moon, etc. (Márquez *et al*., 1976; Dodd, 1988). However the description of the breeding cycles and their timing cues with wild animals is more difficult than with animals in a laboratory setting. Therefore in this paper we will try to describe the cyclic patterns of nesting frequency of Kemp's ridley turtles using Spectrum Analysis, a kind of time series analysis (Bloomfield, 1976). Wind direction, wind speed, air temperature, and rain were selected as "cues" and were also submitted to spectrum analysis. The aims of this paper were to describe 1) cycles of nesting frequencies and environmental variables and 2) the periodicity and amplitude (i.e. mean quadratic amplitude) of those cycles.

The annual and monthly climatic changes of the region between Soto la Marina estuary and Punta Jerez were also described to find the meteorological phenomena of monthly and annual periodicity that can affect the nesting grounds. Those stations are on the border of the zone with the highest nesting density.

Methods

Daily number of nests counted in Rancho Nuevo camp between 1979 and 1996 were analyzed. In the data more than 90% of total nests laid in each nesting season (April-August) are included.

Spectrum Analysis must be done with the longest series of data available (Bloomfield, 1976), however the time series of climatic data of Rancho Nuevo are very short. Therefore we used data from Soto la Marina and Punta Jerez since the three locations are in the same warm, semi-humid climatic zone. The characteristics of the weather stations are in **Table 1**.

First we compared the air temperature and rainfall measured at Rancho Nuevo with those from Soto la Marina for 361 days between 1981 to 1985. A single factor Analysis of Variance was used to analyze the temperature data, while a Kruskal Wallis test was used on the rain data (Zar, 1974). Also a correlation analysis was applied to describe the similarity of the trend of each variable on both places.

Two groups of data were analyzed with Spectrum Analysis:

1) The daily number of Kemp's ridley nests (NN), air temperature (AT), rainfall (PP) and wind direction (WD) and wind speed (WS) measured in Soto la Marina from March 1 to August 31 during the years 1979-1996.

2) The average monthly air temperature (AT) and total precipitation (PP) from Soto la Marina and Punta Jerez.

The spectrum analysis (Filonov *et al.*, 1998) consisted of applying a Fourier transformation to a periodogram generated from the data. The spectrum was obtained by smoothing periodogram every 5 frequencies. To correlate the spectrum of each meteorological variable with the number of nests, the coherence function was estimated for each pair of variables in group 1: AT:NN; WD:NN; and WS:NN. Also the phase difference analysis was applied to each pair to determine whether the cycles happen at the same time or if they were out of phase. The coherence analysis was not applied to rain because it did not have a cyclic pattern at this scale.

Table 1. Characteristics of weather stations. Source: Servicio Meteorológico Nacional (SMN)/CONAGUA.

Characteristics	Soto la Marina	Punta Jerez
Geographical coordinates	23° 46'N - 98° 13' W	22°53' N- 97°46' W
SMN Identification	28152	28078
Altitude	12 m	2 m
Length (monthly data)	1927-1996	1925-1961

Results and Discussion

1. *Comparison between Soto la Marina and Rancho Nuevo*. There were some differences in magnitude between AT and PP at each place, but AT of both places were correlated ($R>0.7$; $p<0.05$). Because of these results and the continuity of the coastline between both locations, it is possible to assume that the variations in AT are similar throughout the nesting area, in spite of the microclimatic characteristics of each locality. Thus the Soto la Marina data will be used to represent all of the nesting area.

2. *The short time fluctuations and their relationship with the number of nests (NN).* Some cycles were found in the spectrum of NN (periods are shown in the **Table 2**) and they were significant because the spectrum had a very high confidence level. This supports the hypothesis that the nesting frequency at Rancho Nuevo has a cyclic pattern.

Periods of 3-7 days in the AT, WD, and WS spectra were the most significant. The rain spectrum was not cyclic on a daily scale. AT, WD, and WS were coincident with NN periods and the coherence estimations show few differences between spectral pairs. Phase difference analysis indicated that there were no delays between pairs of variables and that the meteorological variation and nesting frequency variation happened simultaneously.

Also in the NN spectrum there were cycles with periods of 20 and 26 days, but they were less significant. Their presence can be an indicator of the female fecundity because the average interval between the serial nests of some females, identified with mark-recapture technique, fluctuated between 20 and 30 days.

Table 2. Periods (in days) of the predominant cycles in the spectra of the daily time series of the air temperature and wind (time series from group 1) and number of nests laid.

Characteristics	Mean periods (days)
Nest laying (number)	3, 4, 5, 6, 7, 10, 20, 26
Air temperature	3, 4, 5, 7, 14, 22
Wind velocities	3, 4, 5, 6, 7, 14, 22, 28
Wind direction	3, 4, 5, 6, 7, 14, 22, 28

3. *Long term cycles.* The annual periodicities were alike in the spectra of AT and PP of Soto la Marina and Punta Jerez (**Table 3**). There were cycles of eleven years related with the sun spot activity, but their relationship with the climate is weak. The square mean amplitude of this cycle is near to 0.28°C, which means that it approximately

contributes to temperature variability on this quantity.

Table 3. Period (in years) of the predominant cycles in the spectra of the time series of the AT and PP (group 2). Mean square amplitudes of the oscillations are shown in parentheses and their units are the same as the original series (°C and mm).

Variables	**Mean periods & square mean amplitudes of oscillations**	
	Soto la Marina	**Punta Jerez**
Air Temp.(ºC)	0.5(0.7), 1(3.1), 2(0.13), 3.5(0.12), 7(0.14), 11(0.28)	0.5(0.70), 1 (3.1), 2.5(0.07), 3.5(0.12), 7 (0.14)
Precipitation (mm)	0.5(6.5), 1 (24.2), 2.5(5.4), 7(5.3), 11(5.2)	0.5(8.3), 1 (24.0), 2.5(5.4) ,3.5(4.7), 7(6.3)

There were also cycles in AT and PP spectra with periods between 2.5 to 7 years, related with El Niño-Southern Oscillation (ENSO). Mean square amplitude (AT=0.13-0.14 º C; PP=4.7-6.3 mm) for these variables were small. The ENSO probably changes the climate and the sea surface temperature (SST) of a large area of the Gulf of Mexico, according with its magnitude and its positive relationship with the Pacific/North America pattern. White and Downton (1991), Ropelewski and Halpert (1986), Rogers (1984) and Livezey *et al*. (1997) have indicated that these phenomena diminish the sea surface temperature (SST) and increase rainfalls and winter storms over the southeastern USA and the northern Gulf of Mexico.

These changes may modify the arrival time of the females to the nesting grounds and affect their physiological condition. In Rancho Nuevo, the number of nests was plentiful in May and between May and June after some "El Niño" years, whereas in other years ("No-Niño") they were more abundant between April and May. These delays are probably the consequence of the influence of the climatic phenomena.

4. Seasonal fluctuations. The most representative cycles in the spectra are related to the annual and half-year cycles (**Table 3**). The mean square amplitude of the annual cycles for the AT and PP time series were alike in Soto la Marina and Punta Jerez. This means that the fluctuations at this scale are similar along the nesting beach. The annual harmonics of AT and PP are related, but the phase analysis shows that the highest temperature is reached 1.5 months earlier than the highest rainfall.

On the other hand, the amplitude of the half-year cycles was lower than the annual (**Table 3**). The results of coherence and phase analysis applied to half-year cycles of Punta Jerez were similar to the annual cycle, but results for these analyses were not significant with Soto la Marina data. Soto la Marina is dryer than Punta Jerez and maybe the rain in this place, located North of the nesting beach, is influenced more by hurricanes or other phenomena without a definite periodicity.

The effect of annual and half-year cycles and the delay between temperature and rain on the nesting females is not known, but it may help to explain their spatial distribution along the nesting beach.

Conclusions

This report describes the time series analysis of temperature, rain and wind in the center of the Tamaulipas coast where the Kemp's ridley nesting beach is located.

The cycles of 3 and 7 days were significant in the spectra of temperature, wind and in the nesting frequency and they occurred simultaneously. It probably means that the synoptic and short time cyclic changes of the coastal weather have some effect on the laying frequency of the nesting females.

The main variations of mean conditions of the air temperature, wind and rain are present in annual and half-year cycles, but also there are other fluctuations of minor magnitude whose periods are from 2 to 7 years, related with the ENSO and possibly with other atmospheric processes. The behavior of the turtles probably changes depending on the spatial scale, intensity and frequency of those cyclic changes.

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The Influences of Climatological Anomalies on Marine Turtle Nesting Beaches at Sebastian Inlet, Florida.

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In Florida, summer usually begins during the wet season in June. Temperatures over 32°C occur daily, yet afternoon showers typically cool the summer heat. Droughts, which are more common in winter months, may extend into late spring or early summer (Fernald and Purdum, 1992). Since rain is the chief source of moisture in beaches (Ackerman, 1997), low precipitation may affect the physical conditions of the sand. Cornelisen (1996) found that smaller grain size was correlated with higher moisture content in a nesting beach near Sebastian Inlet, Florida. Coarse sand holds water less tightly than finer sands, and will therefore lose moisture more readily. In periods of drought, this may lead to undesirable effects on nesting loggerhead turtles.

Low rainfall may affect both nesting and reproductive success. Nest chamber construction can be impeded in dry coarse sands (Mortimer, 1990). High sand temperatures combined with dry sand can speed up incubation times (Miller, 1985). Moisture content is also likely to be an important determinant in reproductive success. Increased water levels can impede gas exchange across the eggshell (Packard *et al*. 1977; Ackerman, 1991) and decrease success (McGehee, 1990). Also, eggs may need to take up water during incubation (Ackerman, 1997). For example, McGehee (1990) found that eggs incubated in sands at 0% saturation had lower hatching success, whereas those at 25% had the highest.

Predicted future climatological changes may bring even more uncertainty for nesting turtles. Temperature change and altered rainfall patterns are just some of the variables involved. Individual beaches are likely to respond differently to these global changes. The objective of this study was to measure physical variables of two nesting beaches with different grain sizes and show how a drought period affected nesting on these beaches

Methods

This study was conducted within the Archie Carr National Wildlife Refuge, near the Sebastian Inlet, Sebastian, Florida. Two beaches were examined for physical and biological data, a natural beach and an "old renourished" beach, with the last renourishment occurring in 1992. The north beach (natural) is a coarse beach with a mean grain size of 0.51mm while the south beach (old renourished) is a finer beach with a mean grain size of 0.40 mm. In 1998, the north beach was moved approximately 600 m north due to logistical problems accessing the beach. A statistical analysis showed there were no differences in beach properties between the two sites.

Air temperature data were obtained from NOAA and the FIT weather station. Rainfall data were obtained from the Sebastian Inlet State Recreation Area. Based on nest location, beaches were divided into four transects each with two stations on each transect, one at the toe of the dune and one at mid-backshore. Each station was sampled at 30 and 60 cm and an average was taken to represent that station. Physical parameters measured included beach temperature, beach moisture, and depth of water table. Beach temperature was measured using thermocouples over a twenty four-hour period with readings occurring every three hours. Beach moisture was determined by calculating percent moisture for each sample. To measure the depth of the water table, one transect of well points with three stations were installed on each beach according to methods listed by Hvorslev, 1949. Measurements of water table depth were taken with temperature measurements.

North and south beach were traversed on foot each day at dawn from 1 May until 31 August and every third day after that until 15 September. Locations and dates for all nests and false crawls were recorded. Nests were inventoried four days after hatchling or at 60-70 days post-laying if no emergence was observed. Disturbances made comparisons problematic, therefore no raccoon depredated or washed out nests were included. During nest inventories, all unhatched eggs were opened and categorized as "infertile type", addled (undifferentiated early development), embryo, fetus, pipped dead or unknown (most unknowns were ghost crab depredated). Un-emerged live and dead hatchlings were categorized as dead in the nest (DIN). Nesting success was defined as female nesting emergences / female total emergences X 100. Reproductive success (emergence success rate or ESR) was defined as (hatched eggs-dead in the nest) / total eggs X 100.

Statistical analysis was done to determine if significant differences were present between years. A seasonal analysis was done on air temperature as record breaking temperatures were present over much of the summer. The rainfall analysis only included data from May and June as that was the critical period of drought. Physical parameters were analyzed for May and June data only because this was the critical anomalous period. Water table analysis was done descriptively since no water table readings were taken in 1996. Cheeks (1997) found that after metabolic heat of the clutch takes over during the middle part of egg incubation, rainfall events do not affect temperature within the clutch. Based on this finding, the biological data included nests that were laid up to July 9. This date signified the end of the second stage of incubation for the latest laid nests included in this study. Air temperature, beach temperature, and beach moisture content were analyzed using the Scheirer-Ray-Hare Extension of the Kruskal-Wallis Test due to non-heterogeneous data (Sokal & Rohlf, 1995). Reproductive success was analyzed using a Mann-Whitney U test while incubation duration was analyzed using a t-test. A two way ANOVA was performed on rainfall data.

Results and Discussion

Results of the air temperature showed a significant difference for year and month ($p<.001$). Tukey's comparison showed that 1998 was significantly different than 1997 and 1996 for May, June, July, and August where 1996 and 1997 were not significantly different for any of these months. These data support the notion that the summer of 1998 was significantly hotter than previous years. The only significant finding in the analysis of rainfall was that years differed statistically ($p=.012$). We found that 1996 and 1997 were significantly different from 1998, but were not different from each other.

Results of the beach moisture analysis show both beach and year were significant ($p<.001$). All three years differed significantly as well as both beaches. Graphical analysis indicates percent moisture was quite low in 1998 for both beaches when compared to previous years. Sand temperature was significantly different between years and beaches ($p<.001$). Once again, all three years were significantly different from each other, as well as both beaches. Graphical analysis shows 1998 temperatures were highest.

Looking at seasonal water table data, depth increased in 1998 when compared to 1997, meaning the water table was located deeper in the beach. Water table depth increased differently on each beach due to beach characteristics, most importantly mean grain size and beach elevation. This increase in water table depth caused turtle nests to be further away from a critical source of moisture, thus limiting their hydric environment.

Nests and False crawl totals during May and June were significantly different among years and study sites (Chi-square, $P<0.001$). Days to emergence was not significantly different between study sites, but 1996 was significantly lower, possibly due to smaller sample size. Over the entire season, days to incubation increased significantly in 1998 in both study sites. Results from the emergence success analysis report significant differences between beaches in 1996 and 1997, but not in 1998.

This study showed that drought and high temperatures had an impact on the physical nesting environment of marine turtles. The most important physical parameter altered was moisture content of the beach. Moisture content fell due to lack of rainfall, increase of water table depth, and high air and sand temperatures inducing evaporation. This impact in turn affected nesting success, days to emergence, and emergence success.

The north beach normally has a higher nesting success than the south beach, possibly due to the coarseness of the sand on the north beach. This coarser beach allows water to percolate down through the sand, and in years of normal rainfall, it keeps nests from receiving too much moisture. The south beach tends to have more moisture trapped in its finer material, sometimes creating less than optimal conditions. In 1998, this situation reversed. On the north beach, the coarse sand was unable to remain cohesive when nesting females were digging nests. Collapsing nest chambers during low rainfall can be problematic, especially in sands with larger grain sizes (Mortimer, 1990). In 1998, the sand often caved in during the crucial period for nesting. Turtles that did nest on the north beach generally created nests that were shallower and not always properly formed. Conditions on the finer south beach allowed beach sand to remain cohesive even under low moisture situations, so nesting turtles were able to dig properly shaped nests and did not encounter nest cave ins. We found 1998 brought a decrease in nesting success to the north beach and an increase in nesting success to the south beach.

Emergence success decreased on the north beach with respect to past years and increased on the south beach. The lack of rainfall in 1998 may have introduced better incubation conditions for the "old nourished" beach as compared to previous years. In past years, the south beach contained more moisture, possibly impeding gas exchange across the eggshell and causing lower success. On the north beach, more hatchlings were found dead in the nest. We believe this is due to chamber collapse upon hatchlings while they were still in the nest. The coarse sand of the north beach was not able to retain its shape without the average amount of moisture, causing it to crumble when hatchlings began moving in the nest. An increase in hatchling emergence was seen on the south beach. This may be tied to the fact that the finer grained material was able to hold its shape better in the absence of "normal" moisture.

Conclusions

Drought and high temperatures impacted physical aspects of the nesting environment by reducing beach moisture and raising sand temperatures. Higher beach temperatures further impacted moisture content by inducing evaporation. Lack of moisture on the beaches affected nesting turtles' abilities to excavate nest chambers, shortened incubation duration, and affected hatchling emergence success. If seasonal averages are taken, one does not see climatological, physical, or biological anomalies. After the drought ended, things returned to normal. If data are averaged over the entire season, 1998 is indistinguishable as an exceptional year. Clearly this creates an argument for keeping monthly totals instead of creating a single number to represent the season. This allows the distinction of abnormal events and gives a clearer picture of what is happening.

Beach location was also significant for how nesting was affected by the climatological anomalies. Usually, the north beach stands out as the optimal nesting beach for turtles. During the drought and extreme temperatures of 1998, the "old renourished" south beach behaved as the natural north beach usually does. Grain size of the beaches appears to have a strong influence on how a beach will react to a set of conditions. This may be an important point when discussing beach restoration. When nourishment of a beach is proposed, it will be important to regulate characteristics of fill material. This study gives some insight as to what characteristics are important to monitor.

The International Panel on Climate Change (1995) predicts that with global warming a 1.5-4.5°C global temperature increase will be seen. Currently, no reliable estimates of precipitation are available in association with global warming. Precipitation has been unpredictable in the past, making it difficult to predict what will occur in the future. It is predicted that hurricanes will become more prevalent, increasing coastal erosion and potentially inundating late-stage nests (Fernald and Purdum, 1992). If these predictions hold true, this study may provide us with a window of what is to come for marine turtle nesting. With beach nourishment becoming a more favorable means of beach restoration (compared to sea walls and other preventative measures), it is imperative that regulations be made on the type of fill allowed. Results of this study indicate beach nourishment using finer grained material may create more optimal nesting conditions than natural beaches in future years.

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One Hundred Million Years of Sea Turtles in Texas

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Sea turtles are current inhabitants of the Gulf of Mexico, including the Texas coast. The fossil record of north-central Texas provides an historical perspective for this region because sea turtles are known from marine sediments ranging in age from 112-80 Ma in the Dallas-Fort Worth area. Their occurrence is associated with repeated sea level transgressive-regressive cycles and the establishment of the Western Interior Seaway, which divided the North American continent from the Arctic Ocean to the ancestral Gulf of Mexico. The oldest sea turtles reported in Texas are toxochelyids from the Glen Rose Formation (112 Ma). Other taxa occur in the Paw Paw and Woodbine Formations between 110-96 Ma. Osteopygids are known from the Eagle Ford Group (95 Ma). Protostegids, the sister taxon to extant dermochelyids, are the largest known sea turtles. Their distribution in the Dallas-Fort Worth area is limited to the Taylor Group (approximately 80 Ma), although their record elsewhere extends to the Cretaceous-Tertiary boundary. Of the six sea turtle lineages, two went extinct near the K-T boundary. The modern sea turtle fauna from the Texas coast may be more diverse at the specific level, and more endangered, than at any time in its prior history.

Introduction

This study documents the age and diversity of fossil marine turtles from Texas. Distinctive strata exposed in the Dallas-Fort Worth Metroplex reflect transgressive-regressive marine cycles between approximately 110 and 84 million years ago, preserving terrestrial, freshwater, and marine vertebrate fossils (**Fig. 1**). The marine turtle assemblages of Texas document the earliest records of sea turtles in North America and the diversity of sea turtles in the area now known as the Gulf Coastal region during the middle portion of the Cretaceous.

Discussion

Three families of sea turtles are represented in the Cretaceous of north-central Texas: Protostegidae, Toxochelyidae, and Cheloniidae. The greatest number of fossils recovered belong to Protostegidae.

Protostegids first appear around 110 million years ago in Brazil (Hirayama, 1998) and 100 million years ago in Texas. Protostegids decline drastically to extinction by 65 million years ago, the Cretaceous-Tertiary boundary event. Much of our knowledge of this group is based on the classic descriptions by Zangerl (1953). *Protostega* was one of two

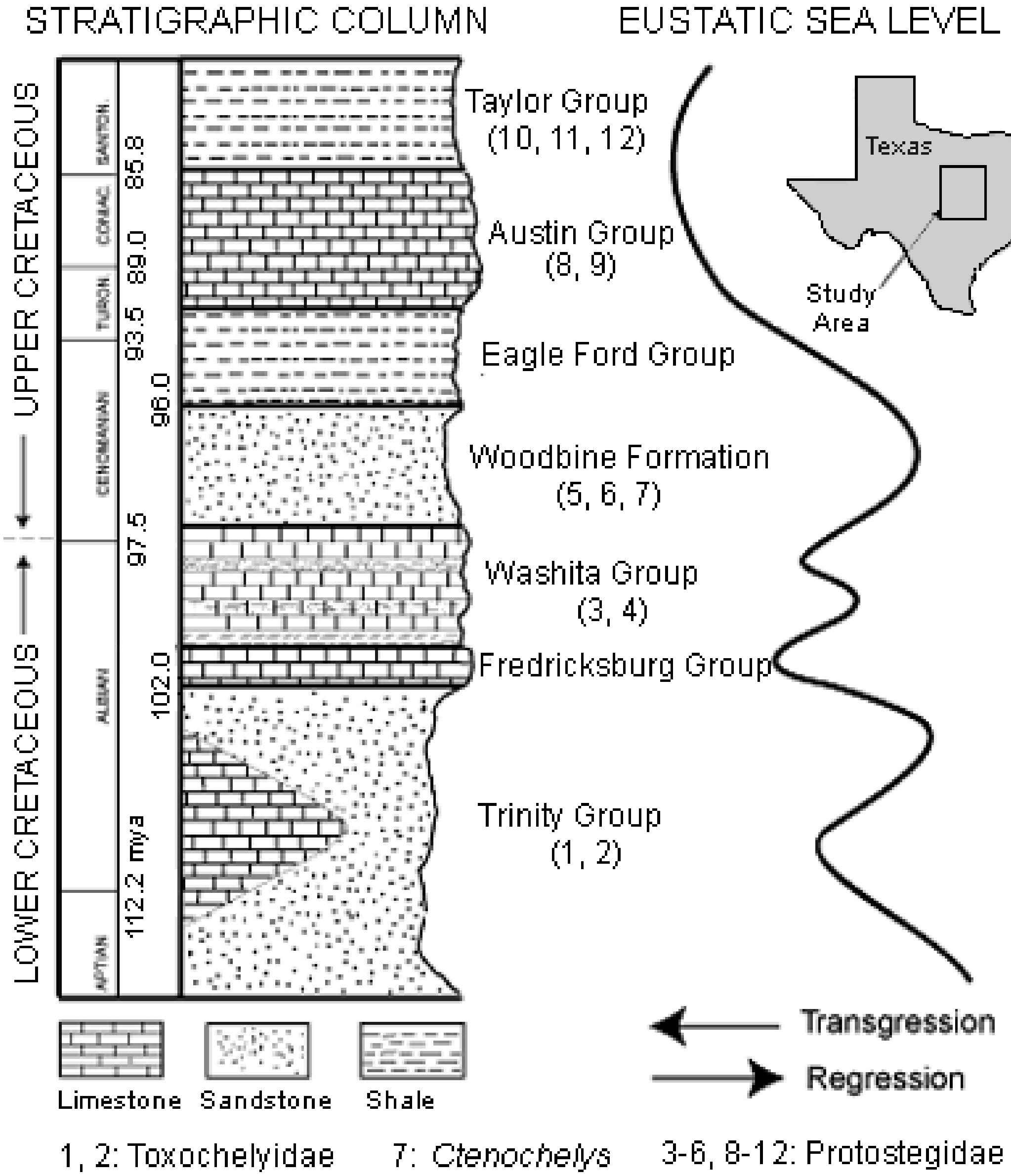

Figure 1. Distinctive strata exposed in the Dallas-Fort Worth Metroplex (Texas, U.S.A.) reflect transgressive-regressive marine cycles between approximately 110 and 84 million years ago.

giant sea turtles of the Cretaceous, along with its sister group *Archelon*. Large size was accompanied by a reduction of the carapace and plastron elements. The closest living relative to the Protostegidae is the leatherback turtle, *Dermochelys coriacea.* Toxochelyidae is the oldest family of sea turtles in Texas, represented by two specimens, both occurring around 110 million years ago.

Toxochelyidae represent a transitional stage from chelydrids to cheloniids based on comparative morphology of limbs. While the forelimb is derived as a flipper as in cheloniid sea turtles, the hindlimb retains more primitive chelydrid characters. Thus, either cheloniid or chelydrid locomotion could be achieved in shallow or deep waters. The small size of toxochelyids is primitive.

The family Cheloniidae is represented by an unusual specimen approximately 96 million years old. The neural spine of the carapace is elongate, a characteristic of *Ctenochelys*. The height of the spine suggests that this is a primitive form of *Ctenochelys.* Reduced body size is also characteristic. This specimen is the only fossil member of this genus currently known from Texas.

One of the most important evolutionary events in sea turtle history was their successful diversification during the middle portion of the Cretaceous as illustrated by the presence of three families in Texas approximately 100 million years ago. Currently the waters off the Texas coast are home to ridleys, greens, and loggerheads, all cheloniids, and leatherbacks. Cheloniids are represented in the Texas Cretaceous by *Ctenochelys*, and the closest Cretaceous relative of leatherbacks is *Protostega*.

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AT SEA STUDIES

Interactions between Bottlenose Dolphins and Sea Turtles in Golfo Dulce, Costa Rica

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We report observations of bottlenose dolphins interacting with Pacific green and olive ridley sea turtles in Golfo Dulce, an embayment in Costa Rica. A total of 428 dolphin surveys were conducted from September 1991 through December 1992. We observed dolphins 529 times and recorded 20 interactions with sea turtles, of which 18 occurred during the late wet season of 1991 (LW91). Interactions lasted a median of 3.2 min (IQ=1.56-6.30, n=18); they involved one turtle and an average of 1.4 dolphins (sd=0.77, n=19). Twenty photo-identified dolphins (17 adults, 3 juveniles) interacted with sea turtles, representing 43% of dolphins identified in LW91. During these interactions, dolphins used their rostrums to push the turtle forward and down under the surface, then flipped the turtle over. In all instances the turtle was apparently unharmed at the end of the interaction. Dolphins were foraging before the interaction occurred in 94% of events during LW91. Incidental observations indicated that unidentified fish were swimming under the sea turtle.

The high number of interactions during LW91 was related to an overlap in distributions of dolphins and sea turtles, both of which were explained by the presence of floating plant material (Acevedo-Gutiérrez & Burkhart in press; F= 28.39, p=0.01, respectively). No such overlap was recorded during the rest of the study period, including LW92. Thus, though we can not rule out play, results suggest that dolphin interactions with sea turtles were opportunistic and related to feeding, occurring when the distribution of species overlapped and dolphins were looking for food.

Early Post-Nesting Movements of Loggerhead Turtles (*Caretta caretta*) on the Southwest Coast of Florida

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The ability of sea turtles to migrate long distances between foraging areas and specific nesting beaches is well known (Mortimer and Carr 1987; Bowen 1995; Papi 1995; Bowen *et al* 1996; Renaud *et al* 1996). This homing ability is also evident during the nesting season as gravid females typically nest repeatedly on the same beach. The fidelity of female sea turtles to their respective nesting beaches is remarkable. In two studies, when gravid loggerhead turtles (*Caretta caretta*) were relocated considerable distances from their nesting beaches, nearly all soon returned to the same area (Murphy and Hopkins-Murphy 1990; Papi *et al* 1997). While these studies focused on relatively long-range navigation after displacement, the natural movements of females between in-season nesting events in most rookery areas are less well known. In studies of internesting movements of green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*), neither species appeared to range very far from their nesting beaches (Mortimer and Portier 1889; Starbird and Hillis 1992). More extensive internesting movements were recorded for loggerhead turtles (Stoneburner 1992), leatherback turtles (*Dermochelys coriacea*)(Eckert 1993), and Kemp's ridley turtles (Mendonca and Pritchard 1886). While the differences in movement may have been species-dependent, they may also have been a function of the proximity of suitable habitat to each individual site.

Each year many of the reproductive females in a population frequent nearshore waters. During these times, they are more vulnerable to being hit by boats and jet skis, harassment, entanglement in nets and trawls and ecological disasters such as oil spills. Additional data on the extent of internesting movements, habitat dimensions, and the ecological needs of turtles during the reproductive season are essential in order to develop effective conservation and management programs (Meylan 1995). This need is particularly evident in southwest Florida where rapid population growth is placing increasing demands on the marine environment. The objectives of this study were to investigate the initial post-nesting movements of females between nesting events using radio and sonic telemetry.

Materials and Methods

This study was conducted through the 1996 to 1998 nesting seasons on Key Island located south of Naples, FL (**Fig 1**). No telemetry tags were deployed prior to mid-June so as to minimize the chance of male turtles damaging tags if they attempted to copulate with a tagged female. The probability that a turtle might be tracked more than once was maximized by selecting only those females that had been flipper-tagged earlier in the nesting season.

Floats for the radio tags (Telonics MOD-555 HP) were made from blocks of balsa wood sanded into an oblong shape to reduce drag. The tags were inserted in a hole drilled in the base of the float. Seven coats of fiberglass resin were then applied followed by three coats of antifouling paint. Floats were attached to a 75 cm tether made by connecting two rubber snubbers (Atlantic & Gulf Fishing Supply Corp., #2021-1). Sonic tags (Sonotronics CHP-87-L) were attached with aluminum wire threaded through small holes at each end of the tag and wrapped around the tag lengthwise. Electrician's tape was wrapped around the middle of the tag thus forming loops at each end of the tag.

Post-nesting females were restrained with a portable plywood box held in place with 1.25 cm lengths of rebar pushed into the sand. Radio tags were attached by drilling a hole in the posterior-most peripheral bone of the carapace. A nylon wire tie was used as a breakaway link to which the tether was attached. Sonic tags were attached to the opposite side of the carapace beneath the posterior-most peripheral bone. Two holes were drilled and the tags attached with nylon wire ties. Prior to drilling, the carapace was scrubbed with a brush and bathed with betadine. All the nylon wire ties were threaded through pieces of surgical tubing and wiped with Neosporin prior to insertion in the holes.

The location of the turtle was recorded prior to release. Tracking began as soon as the turtle entered the water. A Geographic Positioning System (Garmin GPS 75) was used to determine the location of the boat relative to the turtle. An open 21 ft boat with a tiller-mounted, four-stoke 35 hp outboard was used for tracking.

Two radio receivers (AVM Instruments Co. Ltd. LA12-Q) were used. One was equipped with a hand-held three-element yagi antenna and used as a backup if contact was lost with the sonic tag. The radio tags had a range of ca 8 km while sonic beats could be detected from ca 1 km. The other radio receiver was set up on the beach and monitored periodically at night beginning nine days after a turtle was first tracked. A seven-element yagi antenna was used with this receiver. Bearings were obtained from a compass mounted on the antenna pole. A Sonotronics directional hydrophone and receiver (USR5W) were used for sonic tracking. A compass mounted on top of the PVC hydrophone stanchion was used to obtain bearings. Radio and sonic tags were removed from any turtle found nesting after 25 July.

After release, contact was maintained continuously with the hydrophone. The boat was allowed to drift until the sonic signal faded noticeably. A bearing was recorded and the boat operated at idle speed until the signal began to strengthen. The motor was then shut down and the process repeated. This protocol was used to maintain maximum distance from the turtle so as to try and keep any disturbance of behavior to a minimum. The radio receiver was left on to pick up radio pulses. When signals were received, the antenna was swung through an arc to attempt to obtain a bearing.

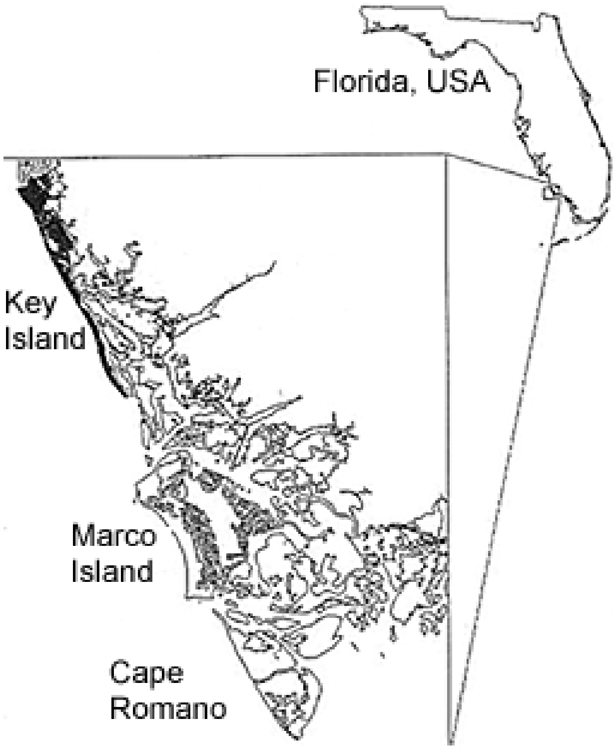

Figure 1. Location of Key Island, Florida.

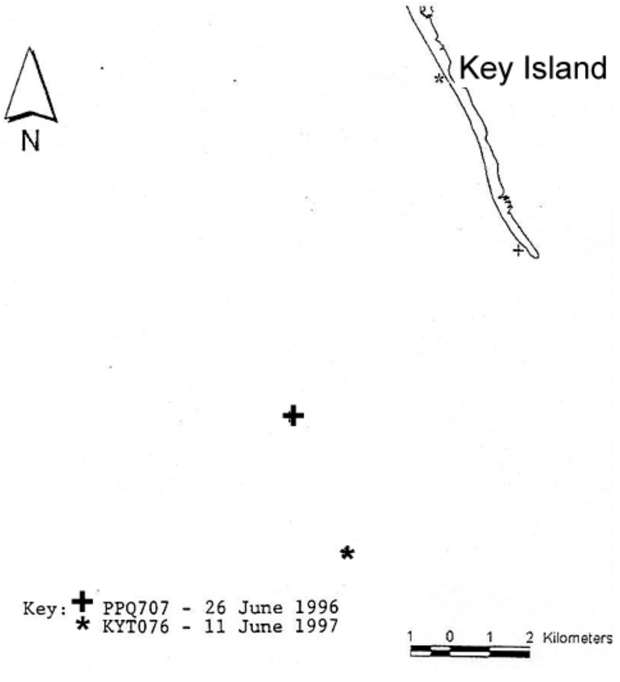

Figure 2. Initial and final locations of turtles tracked primarily with radio telemetry.

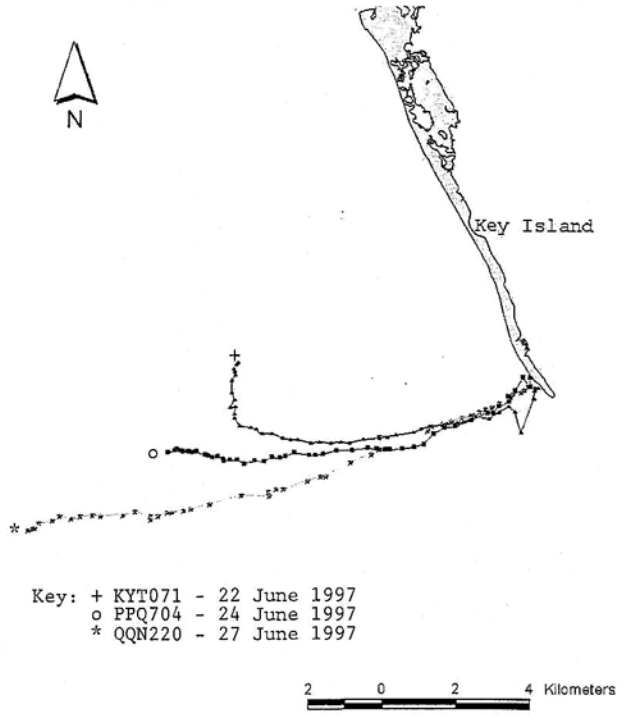

Figure 3. Routes of turtles tracked one time in 1997.

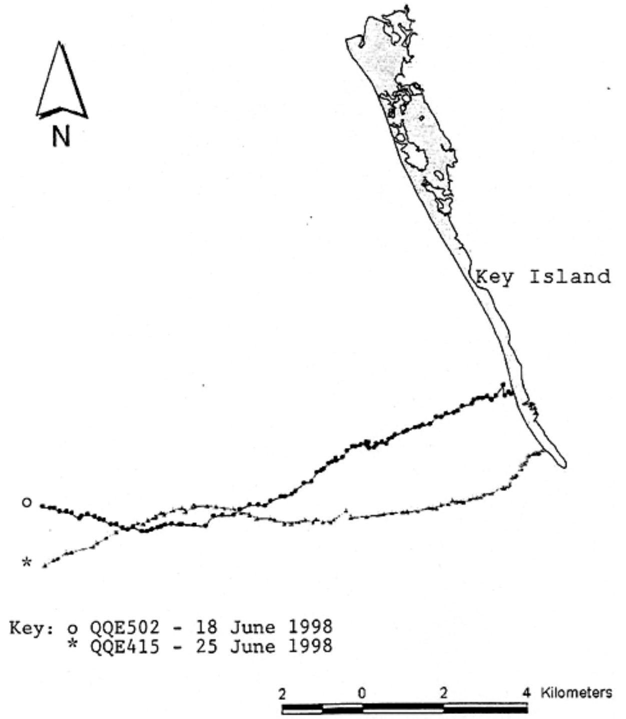

Figure 4. Routes of turtles tracked one time in 1998.

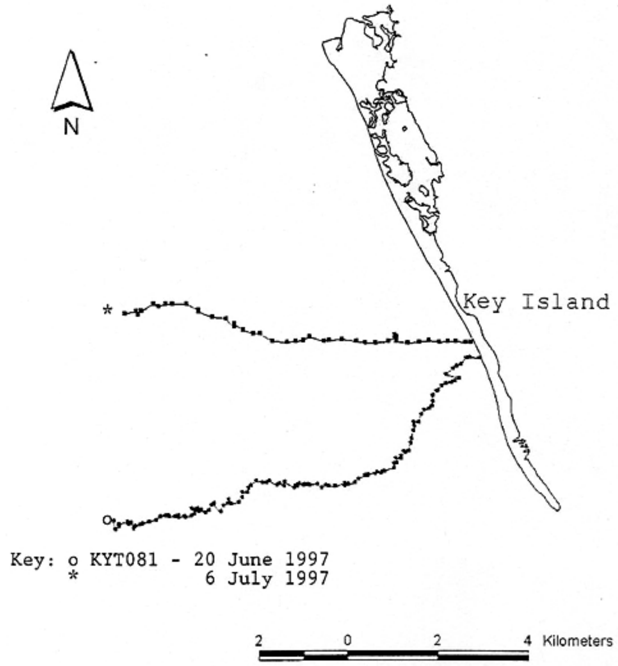

Figure 5. Route of one turtle tracked twice in 1997.

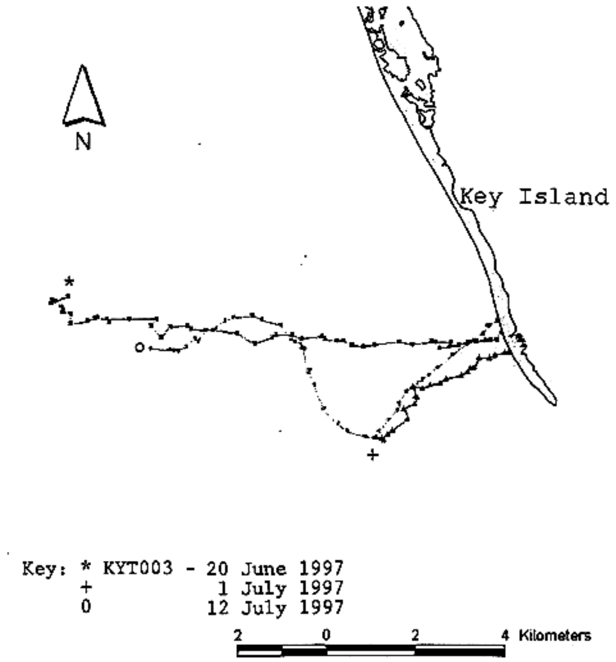

Figure 6. Route of one turtle tracked three times in 1997.

Results

Nine turtles were tracked during this study (**Table 1**). Of these, seven were tracked once. Turtles PPQ707 and KYT076 were initially tracked with sonic signals, however, contact was lost early in each case so radio telemetry was relied on for most of the tracking period (**Fig. 2**). The final offshore locations of these turtles are likely accurate to about 1 km. The paths of the turtles in **Fig. 3-6** were determined primarily with sonic telemetry. Given the range of the sonic tags (ca 1 km), the error in the location of the turtle in relation to the boat was estimated to be ca 0.5 km. Five turtles were tracked once (**Fig. 3 and 4**). The other two turtles were tracked more than once, one twice and another three times (**Fig. 5 and 6**). Both turtles were encountered renesting on Key Island but were not detected with the land-based radio receiver prior to nesting. Only one turtle was detected with the land-based receiver. On 2 July 1997 a storm forced termination of the tracking of KYT003 after only 3 hr. Later that afternoon, a very weak radio signal was detected on the Key Island beach on a bearing of 270 degrees. This indicated that the turtle was still within ca 8 km of land, but had moved further offshore.

Table 1. Telemetry data for early post-nesting females from Key Island, Florida.

Turtle Tag#	**Date tracked**	**Hours tracked**	**Straight line distance (km)[1]**	**Total distance traveled[2]**	**Rate (km/hr)[3]**
PPQ707	06/26/96	4.85	na[4]	na[4]	na[4]
KYT076	06/11/97	5.38	na[4]	na[4]	na[4]
KYT071	06/22/97	5.00	7.35	11.12	2.2
PPQ704	06/24/97	6.40	9.18	10.40	1.6
KYT081	06/26/97	6.65	8.18	11.93	1.8
KYT081	07/06/97	6.37	7.05	7.82	1.2
QQN220	06/27/97	6.27	12.88	13.77	2.2
KYT003	06/20/97	6.13	9.10	12.00	2.0
KYT003	07/01/97	3.05	3.35	3.95	1.3
KYT003	07/12/97	6.87	7.09	10.36	1.5
QQE502	06/18/98	8.25	10.77	13.06	1.6
QQE415	06/25/98	8.17	11.30	12.78	1.6

[1] Distance from starting point on beach to last location offshore. [2] Total of distances between GPS coordinates recorded for each turtle. These data were used to determine rates of movement. [3] Based on rate of movement of boat in relation to location of turtle. Estimated error ca. 1 km/hr. [4] The majority of GPS readings obtained from radio telemetry were not considered accurate enough to determine total distance traveled.

While tracking newly tagged turtles the radio receiver was set to different frequencies to listen for radio signals from previously tagged turtles. None were detected nor were any sonic signals heard from turtles other than the one being tracked. The only evidence that the turtles were in the area after the initial tracking ended came from a fisherman who returned a radio transmitter he found drifting on 17 July 1997. It was ca 24 km offshore approximately 1 km north of the northern end of Key Island. The turtle (KYT084) was tracked on 27 June until she was ca 13 km offshore. She nested again on Key Island on 18 July.

Discussion

The short periods during which radio pulses were received were typically too brief to obtain useful bearings. After the initial two tracking efforts, sonic telemetry was relied on almost exclusively.

The tracking data indicated that the initial post-nesting movements were typically in an offshore direction **(Figs 2-6**). Whether or not the general location of the boat in relation to the tagged turtles may have altered behavior is unknown. The relatively short 1 km range of the sonic tags suggests that the turtles could have been startled periodically. However, most of them headed offshore on fairly regular courses, not in the irregular patterns one might expect if they were constantly being alarmed.

This study suggests that the loggerhead turtles in this region disperse considerable distances immediately after nesting. The floor of the Gulf of Mexico in this region slopes very gradually. The bottom is sandy with little structure. Typically depths do not exceed 12 m until one is ca 24-32 km offshore. Hard bottom features such as rock formations that may be attractive to turtles are more prevalent at those depths and could be contributing factors to dispersal. How far the turtles go and the extent to which they disperse are questions that were beyond the scope of this project.

Acknowledgements

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Homing Behavior in Juvenile Loggerheads (*Caretta caretta*) from Core Sound, North Carolina, USA

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The sounds of North Carolina provide a developmental habitat for the juveniles of several sea turtle species, of which loggerhead turtles are the most common (Epperly *et al*, 1995). Previous studies have indicated that juvenile loggerheads in coastal areas may inhabit preferred feeding areas (Byles, 1988; Mendonca & Ehrhart, 1982). This type of site fidelity has also been anecdotally reported for juvenile loggerhead sea turtles in Core Sound, North Carolina.

To study the possible homing behavior of these turtles, two studies were conducted during the summer and fall months of 1998. The first was a capture-mark-recapture (CMR) study performed to test the hypothesis that juvenile loggerhead sea turtles are able to return to specific areas within the sound after being displaced. Forty-three turtles captured in pound nets in Core Sound were tagged, displaced to locations ranging from 17 to 50 km away from the capture site, and released. Approximately 21% of these turtles were subsequently recaptured in the immediate vicinity of their original capture site. Of these, 44% were caught in the same net in which they were originally captured and 33% of the recaptured turtles were caught multiple times. These results provide evidence that juvenile turtles are able to return to specific areas within the sound following forced displacements.

The second study was a preliminary study in an outdoor arena, carried out to determine whether juvenile loggerheads will manifest homing behavior under conditions in which guidance cues can be readily manipulated. Turtles captured in Core Sound were displaced approximately 30 km southwest and were harnessed to a tracking system in a circular, water-filled orientation arena (**Fig. 1**). After an initial acclimation period, each turtle was permitted to swim for 10 minutes while its orientation was monitored. The turtles oriented significantly toward the east-northeast,

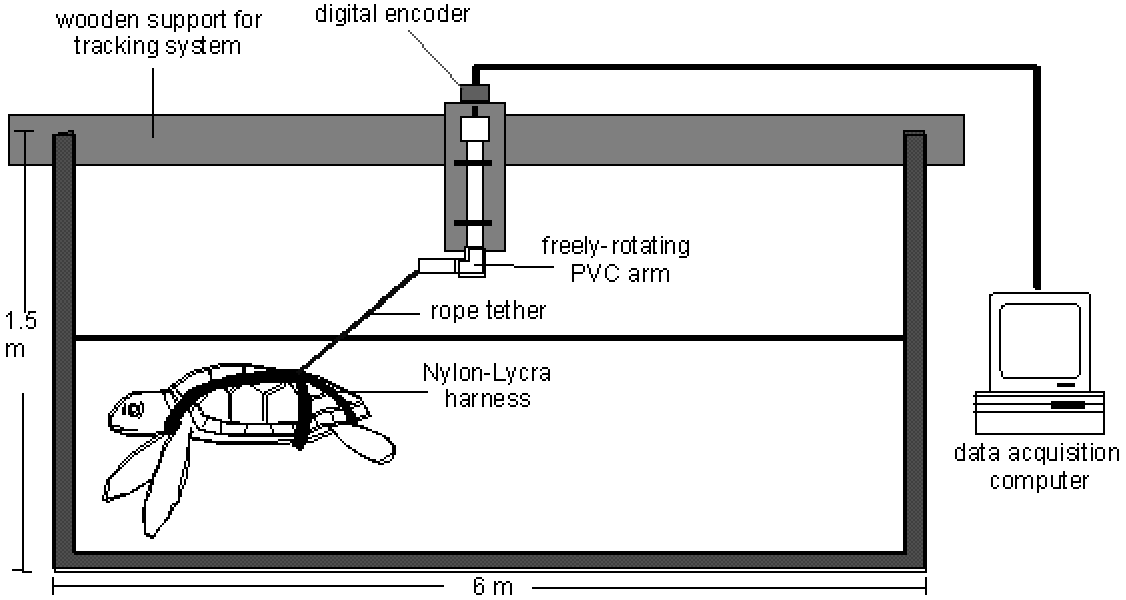

Figure 1. Side view of the experimental arena used to test the orientation of juvenile loggerhead sea turtles (turtle not to scale). Turtles were harnessed and allowed to swim in the tank at the end of a tether. As the turtles swam, the PVC arm and digital encoder tracked their orientation, sending an electrical signal to the computer, which interpreted that signal as a directional heading. Each turtle's orientation was recorded every 30 seconds during the 10 min trials and the turtles were observed to ensure that they were swimming constantly and maintaining a course (not circling the tank).

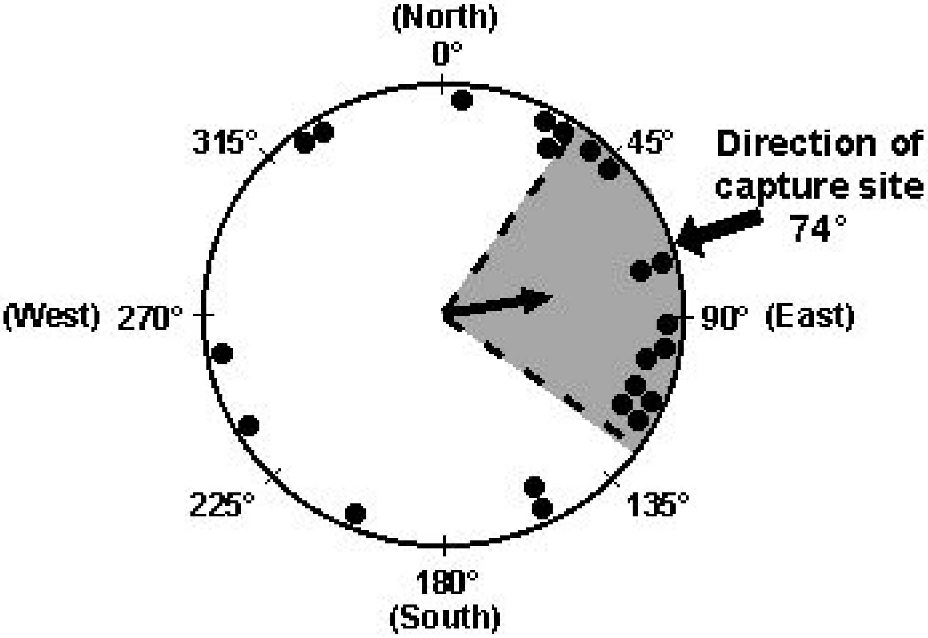

Figure 2. Orientation of loggerheads in the laboratory setting (sample size = 22). Each dot represents the mean heading of an individual turtle over its 10 min trial. Arrow extending from center of diagram represents the mean heading of the group of turtles tested. The arrow on the outside of the circle represents the direction of the capture site. Turtles were significantly oriented (p<.005, V-test (Zar, 1996) with a mean angle of 80°, a direction that corresponded closely with the most direct path back to the capture site. Dotted lines represent the 95% confidence limits of the mean heading.

a direction that corresponded closely with the most direct path back to the capture site (**Fig. 2**).

Although additional tests must be carried out, these initial results are consistent with the hypothesis that juvenile loggerhead sea turtles can determine their position relative to a preferred area and will attempt to return to that area when displaced. The reliable directional preference exhibited by the turtles in the outdoor arena will make it possible to conduct future experiments in which the sensory information available to the turtles is manipulated. Observation of the turtles' responses will yield information regarding which cues are necessary for orientation.

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Relative Abundance and Distribution of Sea Turtles in the Marine and Estuarine Waters of Palm Beach County, Florida, USA based on Aerial Surveys, 1990-1993

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Palm Beach County (PBC) in cooperation with the Florida Dept. of Environmental Protection flew a total of 53 complete aerial surveys of PBC marine and estuarine waters between 1990 and 1993 to determine the relative abundance and distribution of West Indian manatees (*Trichechus manatus latirostris*) and other marine mammals. These aerial survey data provide insight into the seasonal distribution and habitat use patterns of free-ranging marine mammals. Marine turtles were also sighted during these surveys, and this report provides a summary of these sightings.

Methods

Aerial surveys were conducted in a Cessna 172 high-wing aircraft twice per month at an altitude of 125- 200 meters and a speed of 75-100 knots. A standard flight path was flown each survey day with the same observer sitting in the right hand seat. Marine mammal and marine turtle sighting locations were plotted on 1:40,000 National Ocean Survey nautical charts. Environmental conditions affecting the observers ability to see under the water surface such as water clarity, cloud cover, and wave height were highly variable, and were recorded on each map page. Analysis of these environmental variables are outside the scope of this report. A more detailed discussion of marine mammal aerial survey methodology and biases can be found in Ackerman (1994). Although all marine mammals sighted were circled to verify counts of individuals, time constraints prevented the use of this technique on marine turtles during this study. Circling sighted turtles would have had dubious benefits due to the turtle's propensity to dive quickly, apparently spooked by the passing aircraft.

The near shore waters of the Atlantic Ocean out to approximately 4-6 meters in depth within PBC were surveyed from north to south between approximately 9:00 a.m. and 10:30 a.m. each survey day at an altitude of approximately 200 meters and a speed of 100 knots. At the Palm Beach/Broward county line the flight path shifted westward to the Intracoastal Waterway (ICW), and the survey altitude and speed were decreased. Estuarine waters within PBC were then surveyed from south to north between 10:00 a.m. and 4:00 p.m. at an altitude of approximately 150 meters and a speed of 75-80 knots. The numerous residential finger canals adjacent to the ICW were not surveyed due to time constraints. Several passes were made over each segment of the ICW, while only one pass was made along the Atlantic at a somewhat greater speed and altitude. The result was a more intensive survey of estuarine waters than along the Atlantic. Virtually all sightings occurred when turtles broke the surface to breathe and subsequently submerged with vigorous swimming activity. In almost all cases the marine turtles sighted were not identified to species due to a relatively high survey altitude. This was particularly true for the smaller size class turtles which commonly occurred along the survey route. No leatherback turtles were sighted during the study.

Results And Discussion

Aerial survey counts represent only a minimum estimate of the actual number of sea turtles present. The relative abundance and distribution of turtles as determined by aerial surveys can provide valuable insight into the seasonal distribution and habitat use patterns of the free ranging sea turtle population.

A total of 90 marine turtles were sighted during 53 complete surveys (**Fig. 1**). Turtles were sighted during 33 of the 53 flights (62.3%). The mean number of turtles observed per survey was 1.7 (SD=2.0), with the highest single count of 10 turtles occurring on 09 September 1992.

The average number of turtles sighted per flight by month was highest in Sept. (n=5, x=5.2±3.6 SD) and June (n=5, 0=3.4±0.9 SD), and lowest in Nov. (n=2, 0=0±0.0 SD) (**Fig. 2**). Low counts occurred in March, May (n=4, 0=0.5±0.6 SD) and Dec. (n=6, 0=0.5±0.8 SD). Peak numbers of turtles were present during the month of Sept. The highest monthly counts occurred from June through Sept., but the pattern was highly variable. Peak counts in both the ICW and the Atlantic occurred in Sept. (**Fig. 3 and 4**). High counts occurred in estuarine waters from July through Sept. Counts were higher in the ICW than the Atlantic in July and August.

Relative seasonal abundance was further examined by dividing the year into four quarters (**Fig. 5**). Counts were highest in the Fall (Sept.-Nov., n=12, 0=2.8±3.3 SD), followed by the Summer (June-Aug., n=13, 0=2.5±1.4 SD), Winter (Dec.-Feb., n=16, 0=0.9±1.2 SD), and Spring (March-May, n=12, 0=0.8±0.8 SD). Counts were much higher in the Fall and Summer than the Winter and Spring. A few more turtles were sighted in the Atlantic than in the ICW during all except the Spring quarter. Counts were much higher in front of the Breaker's Hotel than in the rest of the Atlantic in the Fall (**Fig. 6**), while counts at the Breaker's were somewhat lower than the rest of the Atlantic during the Summer, suggesting peak Fall use of this resource. Low counts in the Atlantic occurred during the Winter and Spring quarters, with the Breaker's accounting for most of the sightings. Counts in estuarine waters steadily increased from the Winter through the Spring, Summer, and Fall (**Fig. 7**). Counts in the Lake Worth Lagoon system (LWL) were slightly higher than the rest of the ICW in the Winter, and much higher during the Spring through Fall quarters.

A total of 47 turtles (52.2%) were observed in the Atlantic, while 43 (47.8%) were observed in the ICW. Although PBC has approximately 41 kilometers of nearshore reef outcrops, 27 (57.4%) of the Atlantic sightings occurred along a 4 km stretch of nearshore reef in front of the Breaker's Hotel (Breaker's) on Palm Beach (**Fig. 1**). Reef outcrops within the 4.5 m bathymetric contour are subject to more dynamic littoral drift processes, resulting in ephemeral changes in areal extent and profile. These changes, combined with increased storm scour, result in the loss of persistence and environment needed to support the epifaunal growth upon which turtles forage. Areas of reef near the Breaker's are situated waterward of the 4.5 m contour, and are of generally higher relief and internal complexity than other nearshore outcrops. The result is a more beneficial foraging and resting habitat. Smaller size class turtles commonly occurred here, suggesting that this reef line may be important habitat for juvenile sea turtles. Additionally, 35 (81.4%) of all sightings in the ICW occurred within the LWL system. Most estuarine sightings occurred within a few kilometers of an inlet where higher water quality contributes to support of more and varied benthic resources. These sightings suggest that the LWL system is regularly utilized by both large and small size class sea turtles. Further use of aerial surveys may reveal insight into the relative abundance and habitat use patterns of sea turtle populations in other areas.

Acknowledgments

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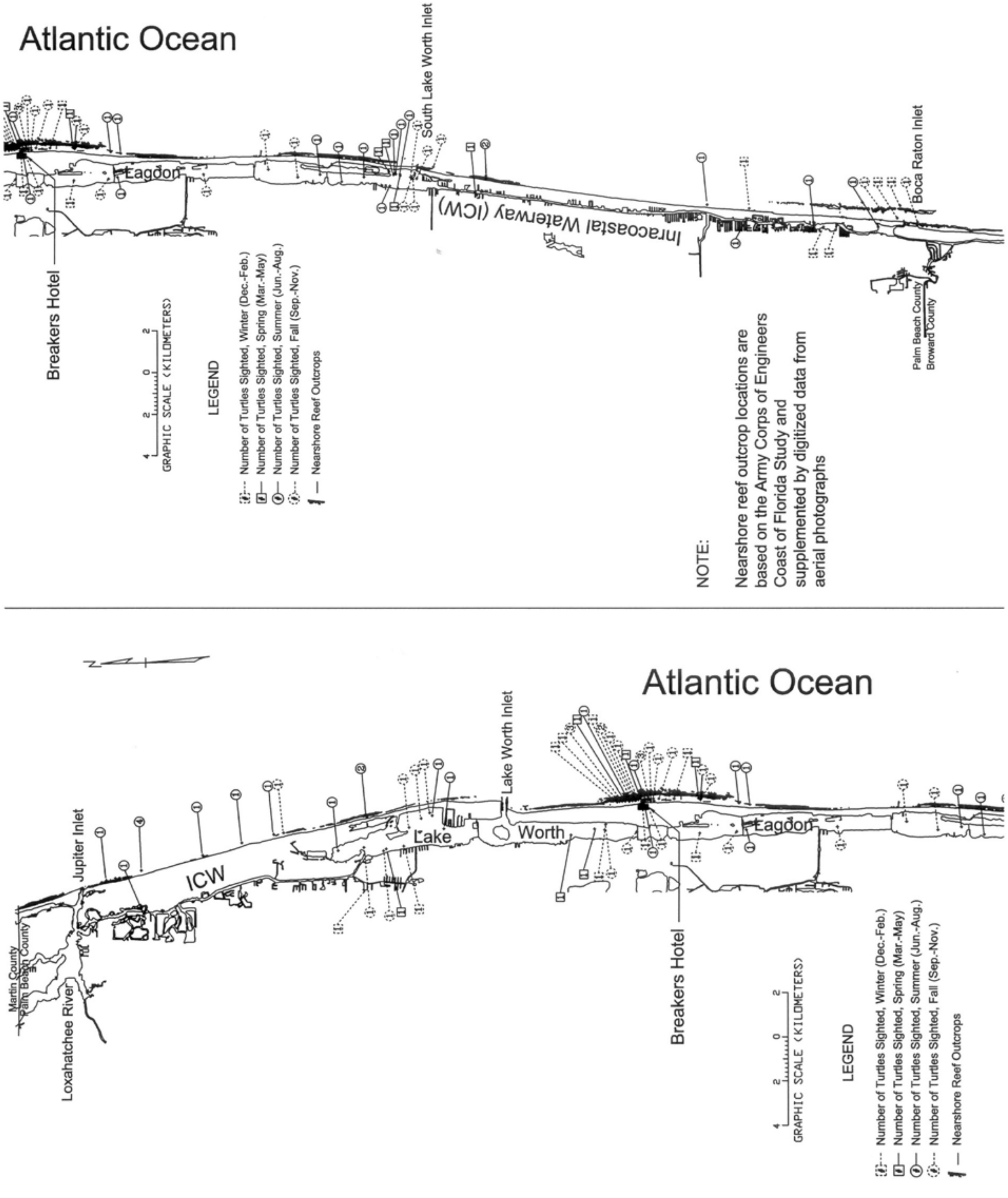

NOTE:

Nearshore reef outcrop locations are based on the Army Corps of Engineers Coast of Florida Study and supplemented by digitized data from aerial photographs

Figure 1. Map of Sea Turtle Sightings from Aerial Surveys of the Marine and Estuarine Waters of Palm Beach County, FL, USA, 1990-1993.

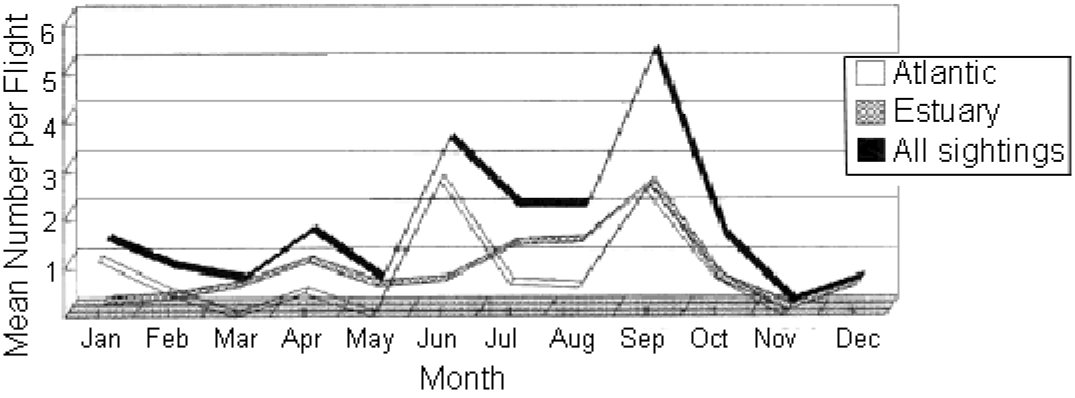

Figure 2. Mean number of turtles sighted per flight by month.

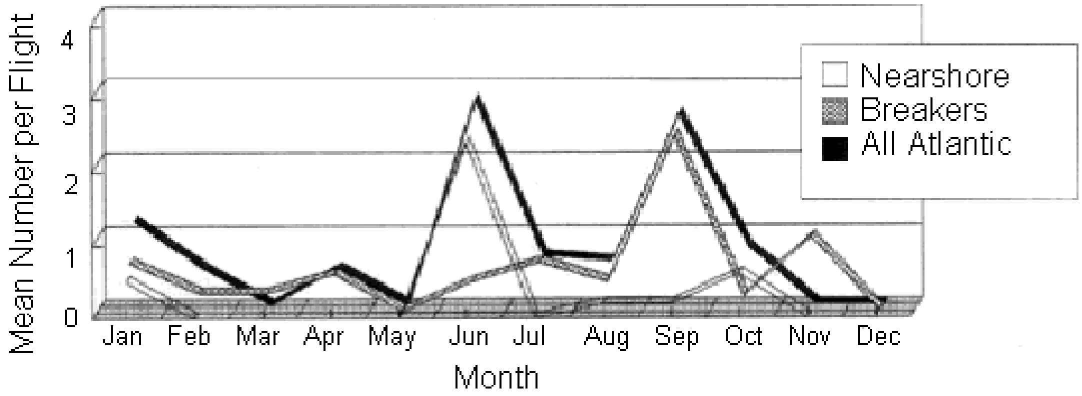

Figure 3. Mean number of turtles sighted in the Atlantic Ocean per flight by month.

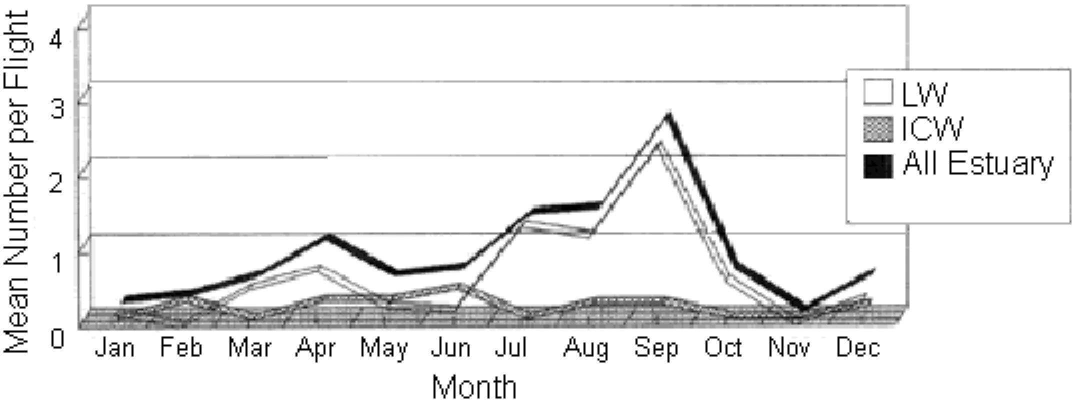

Figure 4. Mean number of turtles sighted in the estuary per flight by month.

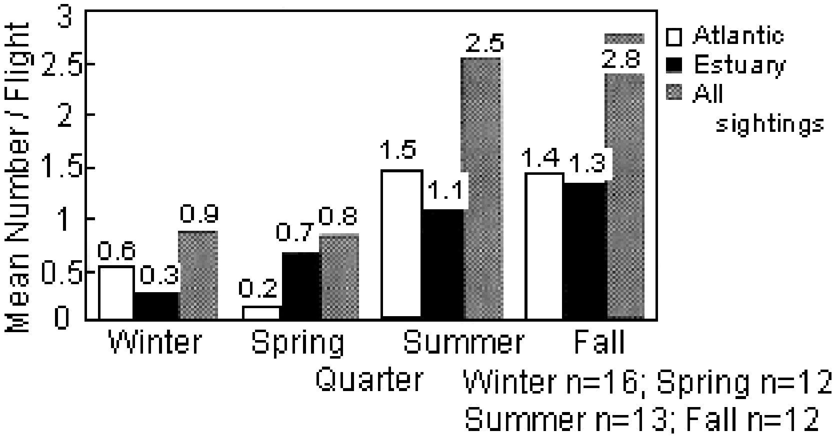

Figure 5. Mean number of sea turtles sighted per flight in each quarter.

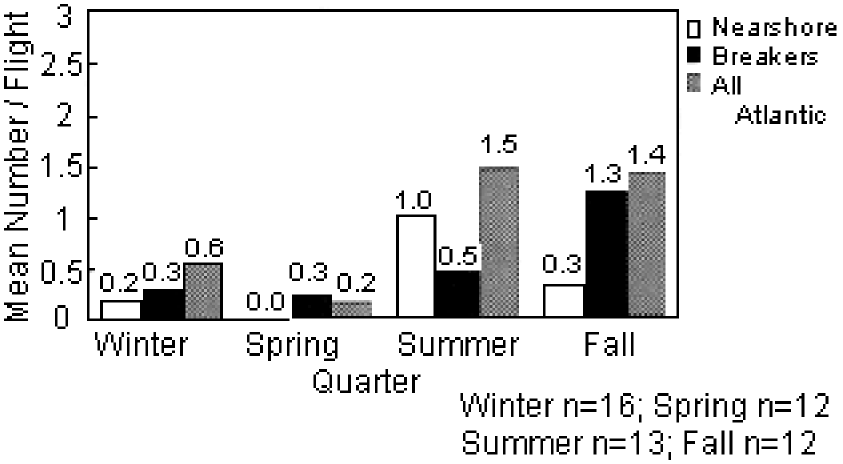

Figure 6. Mean number of sea turtles sighted in the Atlantic each quarter.

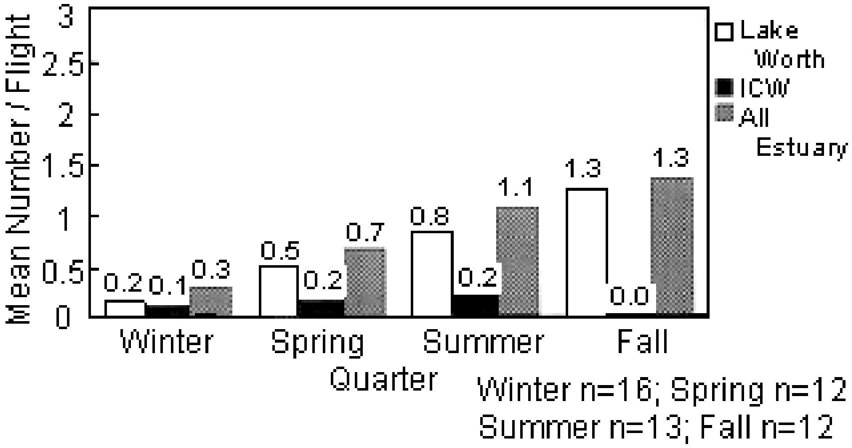

Figure 7. Mean number of sea turtles sighted in the estuary each quarter.

Green Turtle Diving and Foraging Patterns at Puako, Hawaii

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Puako, on the west coast of the Island of Hawaii (19°58.480' N, 155°50.650' W), is a 4.8 km stretch of submerged lava platform bordered by coral reef. The lava platform has large shallow areas of macroalgae providing substantial forage for green turtles, (*Chelonia mydas*). This area has been a study site of ours since the 1980's and nearly 200 green turtles have been tagged there (Balazs *et al.* 1998).

The primary food source for green turtles at Puako is an intertidal red alga, *Pterocladia capillacea*. The daily behavior patterns of juvenile and subadult green turtles in Hawaii have been studied by several investigators (Balazs 1980, 1981; Balazs *et al.* 1987; Brill *et al.* 1995; Laber and Waller 1994 and Rice *et al.* 2000). Green turtles spend most of their lives residing in coastal areas, where they alternate between periods of feeding and resting. Other studies have demonstrated long-term site fidelity of juvenile and subadult green turtles (Balazs, 1981; Laber and Waller, 1994), but information is limited about short-term movements and habitat use (Brill *et al.*, 1995). Detailed, long-term allocation of time to foraging versus resting behavior is still largely unknown. Our study involved determining the relative allocation of time spent foraging and resting, the distribution of these activities over the 24 hr day and the estimated home range of two subadult green turtles.

Materials and Methods

Two subadult turtles were fitted with Wildlife Computer MK5 Time Depth Recorders (TDR) and Sonotronic CHP-87-L sonic tags. They were attached to the right third lateral scute (turtle T28) and the left third lateral scute (turtle T97) using silicon elastomer, fiberglass cloth and resin (Balazs *et al.* 1996). T28 had a straight carapace length (SCL) of 78.5 cm (65.9 kg) and T97 had an SCL of 64.4 cm (36.4 kg). T28 and T97 were each recaptured on four different occasions. Data were downloaded in the field using the Wildlife Computer's interface hardware and a Macintosh Powerbook. The length of time between downloads was dependent on our ability to capture the animal. The MK5 sampling protocol was set to record depth every minute and temperature every 3 minutes. Sampling was suspended if the TDR was dry (emergent) with time recorded. The data were graphed using Microsoft Excel.

Results and Discussion

There were 55 visual observations made at the capture site during the study and presence/absence of the subject turtles was noted each time. In addition, there were reports of sightings of both turtles by scuba divers in the area (N=10). These observations were used to compare observed behavior with TDR data and helped us to define resting versus foraging behavior (**Fig. 1**).

Turtles T28 and T97 where monitored for 6 and 13 months respectively, and we obtained 77 full days of diving data from T28 and 187 days from T97. The two behaviors that show up relatively clearly are resting behavior and foraging behavior. Foraging is characterized by shorter dive times in shallower water (<10 min., <2 m) and resting in deeper water for longer periods of time (>10 min., >2 m) (Rice *et al.*, 2000). Diurnal and nocturnal behaviors were analyzed. Daytime was defined as 0600 to 1915 hr. One set of data from each turtle was corrupted and found unusable.

Resting Dives

Resting dives showed a square profile (**Fig. 1**). The average number of resting dives in 24 hours was 11 for T28 and 18 for T97. Average dive length was 44 and 24 min,

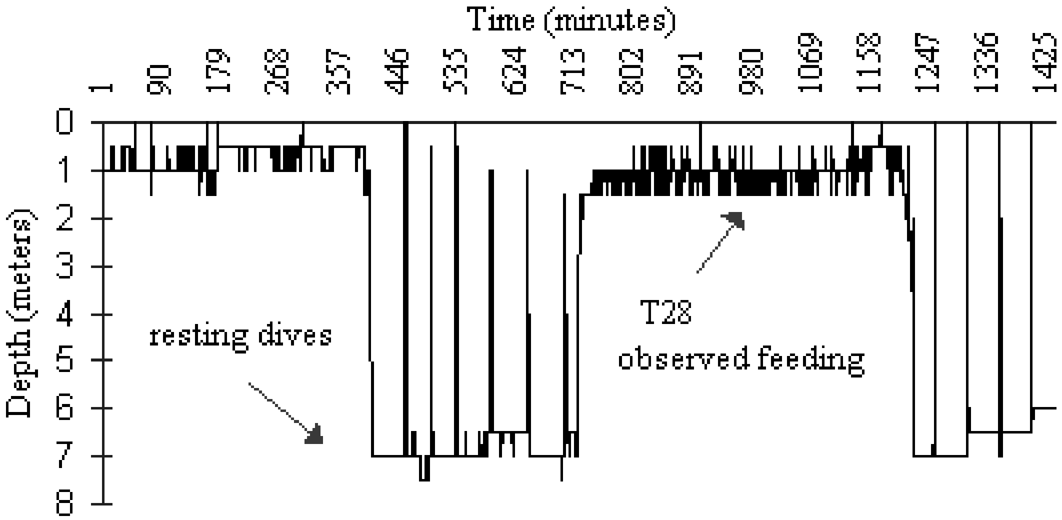

Figure 1. A 24 hr graph of the diving behavior of T28 starting at 0 hr

respectively. The maximum dive time was 75 min (T28) and 72 min (T97). The average amount of time spent on resting dives during a 24 hr period was 10 hr and 5 hr respectively. The maximum dive depth was 16 m (T28) and 40 m (T97). The unusually deep dive for 11 min to a depth of 40 m made by T97 is the deepest dive we have recorded on any TDR tagged green turtle in Hawaii. Other deep dives made by T97 were to 23, 30 and 31 m.

The resting dive data for T97 may be unusually low because this animal spent 30 full days (24 hr periods) out of 182 data days in water less than 2 m deep. None of this time was counted as resting time because we were unable to distinguish between foraging and resting dive profiles in water this shallow.

Foraging Behavior

T28 spent an average of 8.2 hr exhibiting foraging behavior during the day and 6 hr at night. This represents a significant difference ($P<0.01$). Turtle T97 spent an average of 9.6 hr exhibiting foraging behavior during the day and 9.4 hr at night. There is no significant difference between these two lengths of time ($P>0.5$). Again, the shallow water behavior of T97 may have had a significant impact on these values.

Basking Behavior

There was one incident of terrestrial emergence (basking) behavior. T97 spent 5.5 hours basking on 1/28/97 from 1609 hr to 2136 hr. This was the only time that the TDR data indicated dry conditions. Since the early 1990's, basking behavior by juvenile and subadult green turtles along the west coast of the Island of Hawaii has been on the increase.

Probable Home Ranges

The two turtles at Puako exhibited very predictable behavior over the course of the study. They were observed a total of 40 times feeding at the original capture site. They were seen only within approximately 1 km north or south of their original capture site. Since they feed predominantly in shallow water, their estimated feeding area is approximately 20,000 m^2 (assuming uniform distribution of forage and a 10 m wide algal growth band). Our turtles had a fairly small home range compared to those in the Kaneohe Bay study where study animals traveled a maximum of 3,000 m from the capture site (Brill *et al.* 1995). The size of the home range of the Puako turtles may also be a function of the distance between forage and resting areas. At Puako, this is only about 300 m. Although it was not studied, forage availability would be an important parameter in determining home range also.

Time Allocation

T28's and T97's diel patterns appear to be quite different from those of a turtle studied at Punalu'u, Hawaii using the same TDR technology (Rice *et al.* 2000). In the Punalu'u study there was a more marked diurnal feeding behavior than in the Puako study, and the total amount of time spent at foraging depths was greater for the Puako turtles. Mitigating circumstances at Puako may help explain the differences. Puako is a very protected area in the lee of the island. The shallow areas where the turtles feed at Puako are very calm and turtles could spend large amounts of time in the area resting, expending little energy. Conversely, Punalu'u is a high wave energy site which is rarely calm and turtles probably cannot rest in the shallow waters. In addition, the growth of macroalgae forage at Punalu'u, although unquantified, appears to be greater than that at Puako. This would potentially necessitate greater forage time to accumulate the same caloric value of macroalgae at Puako.

Both Puako and Punalu'u turtles appear to show strong site fidelity and a propensity to forage during the daylight hours in shallow waters. The home ranges of all three turtles are probably a function of the distance between their offshore resting site and their near shore forage pastures which direct observations have revealed to be within approximately 300 m at Puako and 500 m at Punalu'u.

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Movements and Diving Behaviour of Pelagic Stage Loggerhead Sea Turtles in the North Atlantic: Preliminary Results Obtained through Satellite Telemetry

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The largest loggerhead sea turtle (*Caretta caretta*) nesting aggregations in the North Atlantic are in the southeastern USA with an estimated 50,000 to 70,000 nests deposited each year. After emergence, hatchlings swim for the open ocean. It is believed that many are taken by the Gulf Stream and the Canary Current and passively drift to open ocean waters in the eastern Atlantic (Carr 1986). Turtles are sighted again at their natal coasts at a size of 40-55 cm straight-carapace-length. The time in-between is called the juvenile pelagic stage. Bolten *et al*. (1998) showed that turtles in the Madeira and Azores Archipelagos belonging to this life stage originate almost exclusively from Florida nesting beaches.

A significant proportion of a loggerhead's life is spent as a pelagic turtle. Estimates range from 10 to 30 years. It is a critical life history period where most growth occurs. Yet, it is not known how this time is spent nor where exactly the turtles go.

To resolve these questions a satellite tracking program was initiated in 1998. This study sets out to determine both movements and diving behaviour for pelagic stage loggerhead sea turtles captured at Madeira Island/Portugal.

Methods

A total of 10 juvenile pelagic stage loggerhead turtles were hand-captured by boat and dipnet and equipped with satellite-linked time-depth-recorders (SDR-T10-Wildlife Computers). The SDR's each weighed 320 g and were attached as backpacks following Balazs *et al*. (1994). Turtles were released on average 7.6±2.7 days after capture. Experiments were done in two blocks: 5 turtles were equipped in April-May 98 (spring), and 5 in Sept. 98 (fall) (**Table 1**). Every day SDR's recorded the following parameters: maximum-depth, dive duration and time-at-depth in cumulative histograms for the previous 6 hr period; cumulative time at surface for each 6 hr; maximum depth over the last 24 hr; prevalent condition of wet (submerged) or dry (surfaced) for each 20 min block of the day; and running parameters of SDR like battery voltage and internal clock drift.

Results

Movements: Turtle tracks ranged widely, covering thousands of kilometres (**Fig. 1**). A large proportion of the tracks remain within the Portuguese 200 nautical mile EEZ's. Turtles released in spring and fall used different migration routes: 4 spring turtles moved northward, 4 fall turtles moved southward, one in each group went in the other direction. Northward going turtles move against the prevalent currents.

Diving: Pelagic turtles are generally shallow divers (**Fig. 2A**) and submergence times are normally short (**Fig. 2B**). Turtles remain most of the time just below the surface (**Fig. 2C**) but have a second peak at 10-25 m depth, where they spend an average 20% of their time. Occasionally turtles dive very deep and for very long. The maximum dive parameters are given in Table 1. No correlations were found between any of the maximal diving parameters and body size.

Discussion

Given that the turtles remained quite some time within the Portuguese EEZ's of Madeira and Azores, these areas should be considered important developmental areas for North Atlantic loggerhead sea turtles. This was already believed by Carr when in his search for the "lost year" he found the missing size classes at the Azores (Carr 1986a, Carr 1986b). However his "passive drift hypothesis" (Carr 1986) seems not to hold for the larger juveniles as in this study. Turtles actively swam long distances against

Table 1. Pelagic loggerhead sea turtles equipped with satellite transmitters and their transmission periods till February 2nd 1998. Maximum dive depth and submergence times are also given. Dives of over 100m and submergence times over 180 minutes are shown also by the smaller turtles (Group: 1= released in spring; 2= released in fall 98; SCL=straight-carapace-length).

Release Group	Turtle Name	SCL (mm)	Weight (g)	Date Released	Date Lost	Days Tracked	Maximum-Depth (m)	Max. Submerg. Time (min)
1	Carla	339	7 500	27/05/98	01/11/98	158	114	180-240
2	Samina	400	9 200	10/09/98		over 161	86	180-240
2	Tamia	399	11 000	10/09/98	06/11/98	57	144	120-180
1	Lídia	413	12 000	01/04/98	30/12/98	273	118	90-120
2	Sofia	445	12 500	10/09/98	10/01/99	123	94	180-240
1	Magda	461	14 300	18/05/98	03/09/98	108	148	60-90
1	Maria	462	15 100	27/05/98		over 267	120	180-240
2	Helena	483	17 500	10/09/98		over 161	124	180-240
2	Isabel	523	21 000	10/09/98		over 161	196	180-240
1	Délia	576	29 500	18/05/98		over 276	152	90-120

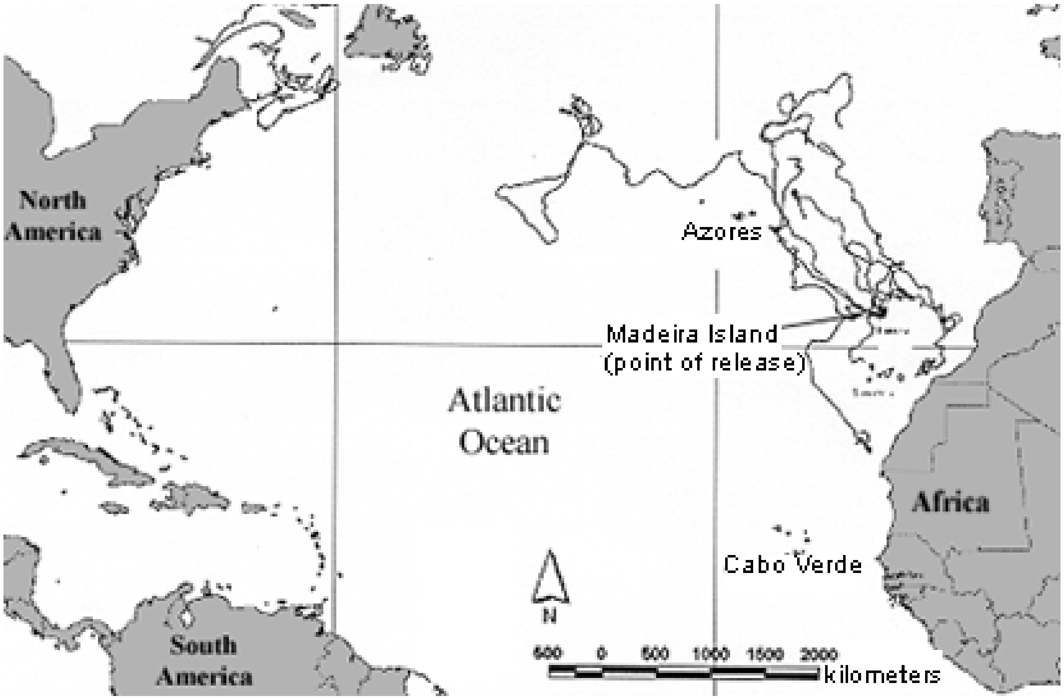

Figure 1. Movement tracks of tagged turtles in the North Atlantic Ocean. All turtles were released off Madeira Island at the same location 3 nautical miles offshore Funchal. Turtles going north were, with the exception of one, released in spring 98; turtles approaching the African coast were, with the exception of one, released in fall 98.

prevalent currents. It might still be true for smaller hatchlings, too small to be equipped with satellite transmitters. The term prevalent currents is used here, since current patterns were not calculated on a real time basis. A detailed analysis is needed to understand how much of this apparent against-the-current movement is real. Turtles might take advantage of small countercurrents to reduce their energetic expenditure.

Our data show for the 1st time pelagic sea turtle diving behaviour. Dives are generally shallow and turtles remain just below the surface. Some time is spent between 10-25 m depth, which might reflect the general feeding depth or might be a safe depth to escape bad weather conditions. Occasional deep dives show that juveniles have similar capacities as published for adult loggerheads (Sakamoto *et al.* 1990). Thus they do not follow the general pattern of other divers, where larger individuals can dive deeper and longer than smaller ones (Kooyman 1989). This probably means that even these extreme dives are well within their dive capacities and that they do not reach any physiological limit.

Figure 2. Number of dives per bin for 3 dive parameters recorded: maximum-depth, dive-duration, and time-at-depth. Note the different scales used on the right and left sides of each graph (Group1= turtles released in spring, Group2= fall; bars are standard deviations).

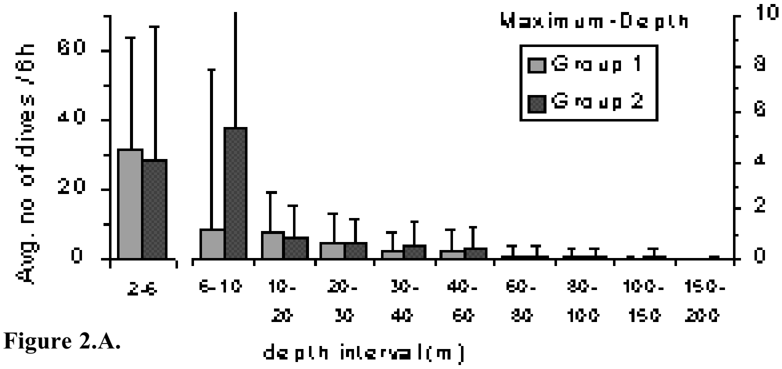

Figure 2.A.

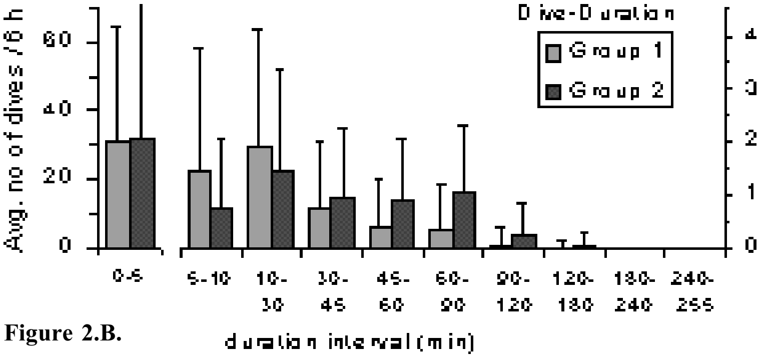

Figure 2.B.

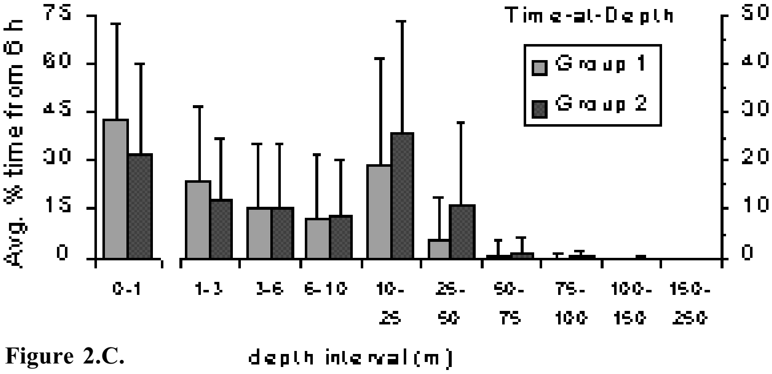

Figure 2.C.

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Present Situation of Marine Turtles in Uruguay

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The Republic of Uruguay is located in the Western Hemisphere, between the 53rd and 58th meridians and in the neo-tropical zone, between parallels 30° and 35° latitude south. It has a surface area of 178,000 km^2 and borders with Brazil in the north and northeast and with Argentina to the west. It has 210 km of Atlantic coast and 320 km of coast in Rio de la Plata, which belong to 6 states (Rocha, Maldonado, Canelones, Montevideo, San Jose and Colonia).

Four species of sea turtles can be found in Uruguayan waters: the green (*Chelonia mydas*), loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*) and olive ridley (*Lepidochelys olivacea*). They are protected with 7 laws (13833, 14205, 14484, 15626, 16062, 16320 and 16736) by a decree from the Agriculture, Livestock and Fisheries Ministry. Uruguay is also a signatory of the Bonn Convention and CITES, which obligate it to protect such an important resource. More recently (December, 1998), Uruguay signed the Inter-American Convention for Sea Turtles, which represents a very important step towards the conservation of these species.

The locations with the most records for sea turtle sightings are Barra del Chuy, La Coronilla, Santa Teresa, Punta del Diablo, Barra de Valizas, Cabo Polonio and La Paloma. These localities are in the State of Rocha along the Atlantic Coast. These species do not nest in Uruguay since it is out of the tropical range. Although leatherback nesting was reported in Brazil, 500 km from the Uruguay border (Soto *et al*, 1997).

The green turtle is the species that gets the closest to the Rochan beaches, and sightings have been reported by surfers and swimmers at very few feet of distance (Garat, pers.comm.). All sightings are of juvenile individuals, thus it is thought that they are in an important feeding ground. In October 1997, in the locality of Cerro Verde, Rocha, the illegal capture of three juvenile green turtles in a net was reported (Pablo Fallabrino, pers.comm.), which shows that turtle meat consumption is still occurring in the country, in spite of claims to the contrary. The capture occurred inside Santa Teresa National Park, and reflects the notorious lack of surveillance in that protected area.

Three leatherback strandings were reported in less than six months. The first occurred in mid 1997 in the locality of Playa Grande in Santa Teresa National Park. The carcass, an adult measuring 157 cm curved carapace length and 117 cm carapace width, was highly decomposed and impossible to check for tags or to collect tissue samples. The sex could not be determined. The second stranding occurred in March in the locality of Piriapolis, Maldonado State (Ronqui, pers.comm.). No other information was available. The third stranding was of an adult female found on April 9, 1998 in the zone of La Barra (Juan Hernandorena, pers.comm.). These strandings could be related to incidental capture occurring in Uruguayan or Brazilian waters.

Between 1994 and 1996, Achaval reported a capture index of 1.8 individuals/1000 hooks (*C. caretta* and *D. coriacea*), and of these 1.9% were dead. The remaining 98.1% were released, but no information exists on the survival rate of these turtles since most of them had the hooks still attached. The information from Brazil includes 10 to 15 individuals (*C. caretta* and *D. coriacea*) captured by a single ship in 2 weeks (Bager, pers. comm.)

In November, 1998 a live loggerhead stranded in Playa Ramirez, Montevideo. The turtle was brought to a particular aquarium, but its final destination is unknown (Estrades, pers.comm.). Regarding the olive ridley we have only data from old carapaces, but no recent stranding has been reported.

Another example in Uruguay was reported in February 1997, when an accidental oil spill occurred in front of Isla Lobos, Maldonado. The impact of this event on the sea turtle population is unknown, but it caused the death of several sea lions. Another possible source of problems is water pollution, since 60% of the Uruguayan population lives in the coastal environment.

As can be noted, there is a lack of knowledge about the Uruguayan sea turtles, therefore it is essential to develop new lines of research in the issue and so learn to conserve our resources.

Acknowledgments

We want to thank Biol. Federico Achaval from the Universidad de la Republica Oriental del Uruguay and Biol. Alex Bager from the Museu Oceanografico Prof. Eliezer de C. Rios, Rio Grande, Brazil for the sharing their work and experience with us. We would also like to thank the David and Lucile Packard Foundation for economic support and Biol. Ana. R. Barragan for assistance in translation.

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Satellite Tracking of an Adult Male and Female Green Turtle from Yucatan in the Gulf of Mexico

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Marine turtle migrations are principally studied by tagging, usually with metal or plastic tags. This technique provides information on the locations where turtles were tagged and recaptured, but does not reveal the routes and speed of travel. Satellite telemetry is a technologically advanced method that establishes the turtle's pathway during the actual migration. The use of satellite transmitters began in the late 1970's, and has permitted migration tracking for both terrestrial and marine animals. Over the years there has been a reduction in the size and weight of the transmitters with improved design and battery reserve. In addition, the method of attachment to the carapace of marine turtles has been perfected so as to be safe and secure (Balazs *et al*., 1996).

The migrations for two green turtles (*Chelonia mydas*), a male and a female, were satellite tracked after a breeding season at Isla Mujeres, Quintana Roo, Mexico (Lat. 21.2N, Long. 86.7W). Two Telonics, Inc. (Mesa, Arizona USA) ST14 satellite transmitters linked to the Argos global tracking system, were attached to an adult male (ID 22132) and adult female (ID 4804), using Silicone Elastomer and fiberglass cloth with polyester laminating resin. The turtles were obtained from the Isla Mujeres Marine Turtle Research Station of the National Fisheries Institute (Instituto Nacional de la Pesca; SEMARNAP). This facility had 70 green turtles (about one-third males and two-thirds females) in an 800 m^2 enclosure with access to a beach where females nested at various times during the season. The turtles were captured near Isla Holbox and Isla Mujeres during April - May 1998, and kept in the enclosure until being set free in early October 1998. A transmitter was attached to the female on 2 October 1998. Data were first received from the transmitter on 4 October at which time the turtle was in front of Cabo Catoche, Yucatán (Lat. 22.1N, Long. 86.9W) traveling northwest from Isla Mujeres. During the next 10-12 days she migrated northeast across the lower Gulf of Mexico and arrived off the coast of extreme southwest Florida, north of the Florida Keys, in mid-October. The turtle remained in this vicinity (centered around Lat. 25N, Long. 81W) for the duration of transmissions during the following five months. This area is a known resident foraging habitat for adult green turtles that nest in Florida (Schroeder *et al*., 1996).

The male, also tagged with a satellite transmitter on 2 October 1998, went to the northeast, staying along the Quintana Roo littoral between Isla Holbox and the shore (Lat. 21.5, Long. 86.9), where it was originally captured, keeping within an approximately 90 km^2 area. Females nesting in the Yucatán Peninsula show a high two year internesting interval. Green turtle nesting beaches in Yucatán, such as Isla Aguada, Campeche and Las Coloradas, show high nesting abundance during even years (1990, 1992, 1994, etc.) and low numbers during odd years (1991, 1993, 1995, etc.), for 18 years of monitoring data. Flipper tagging has shown little interchange between these two groups (even and odd years). However, adult males studied in the Isla Mujeres project have been captured in the same nearby zone during various consecutive years (Rolando Chan, pers. comm.). This could indicate significant differences between males and females in their reproductive behavior, migration routes and feeding grounds.

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Buck Island and Back -- Hawksbill Turtles Make Their Move

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During the past eleven years the National Park Service's Buck Island Sea Turtle Research Program has participated in a series of research activities to answer the question "do hawksbill sea turtles make reproductive migrations?" We approached the question with both low and high tech methodologies. Low tech methods include saturation tagging of all nesting hawksbill turtles coupled with the promise of a long distance tag recovery. Three out of 118 nesting hawksbill females tagged on Buck Island Reef nesting beaches have been recaptured on their foraging grounds off Central America and Cuba.

The first, QQD 035, was recovered in Nicaragua at Witties Cay, in the Miskito Cays (13°58' N, 82°54' W). The approximate distance traveled from Buck Island Reef was 2000 km. QQD 506 was first tagged on July 28, 1997 while nesting on Buck Island Reef. Her tag recovery was reported to NMFS by a Cuban fisheries officer after she was captured in the "traditional harvest area" at Cayo Guajaba (northwest Nuevitas), Cuba, on February 9, 1998 (21°80' N, 77°30' W). The approximate travel distance from Buck Island Reef was 1400 km. QQD 505 was first observed nesting on Buck Island Reef on July 10, 1997. Her tags were purchased from a Miskito Indian on May 9, 1998 for $5.00 US. The fisherman captured the turtle by hand while diving on the east side of Southeast Rock, Nicaragua (14°10' N, 82°45' W). The approximate distance traveled was 2000 km.

High tech methods include tracking the post-nesting movements of nesting hawksbill females via satellite transmitters. In 1998, in cooperation with the National Marine Fisheries Service's Caribbean Hawksbill Satellite Telemetry Project, two Buck Island Reef nesting hawksbill turtles were fitted with satellite transmitters. The movements of the two satellite turtles were monitored through the ARGOS, Inc. Data Collection and Location Service.

On the morning of September 17, 1998, a transmitter was successfully attached to PPW 840 and she departed the beach. On September 20, 1998, the day before hurricane Georges passed over the islands of St. Croix and Buck Island Reef NM, she was 63 miles north of St. Croix headed toward the British Virgin Islands. She traveled an average of 61 km per day to cross the Puerto Rican Trench (10,000 feet deep). On October 1, 1998, she was ENE of Virgin Gorda in Necker Island passage in the vicinity of Hawks Bill Bank and continues to transmit from this area.

The second satellite transmitter was attached to QQD 374 the following day, September 18, 1998. She was released with her satellite transmitter and transmitted several excellent signals between September 18 - 19 in the vicinity of Buck Island Reef. QQD 374 remained between Buck Island and St. Croix for another internesting interval. She attempted to nest again between October 6-10 and finally nested successfully on October 12, 1998. After laying her fifth nest at approximately 9:30 pm AST she left Buck Island Reef and headed north toward St.Thomas, in the northern U.S. Virgin Islands.

Twenty-four hours after leaving Buck Island Reef NM she was across the Puerto Rican trench having traveled an average of 53 km per day. Arriving near Frenchman's Cap near the island of St. Thomas, U.S. Virgin Islands on October 13, she moved around the island of Culebrita and passed between Culebra and the mainland of Puerto Rico between October 13 to 18, 1999. She has been located off Puerto Rico's southeast coast consistently since then near the town of Punta Figuras.

The three long-distance tag recoveries began to provide information that hawksbill turtles nesting on Buck Island Reef NM do not remain near their nesting beaches during their non-reproductive phase, but migrated back to some distant foraging ground. This low tech information combined with the results of the high tech satellite tracking of post-nesting hawksbill turtle migrations has shown fairly conclusively that hawksbill turtles are a migratory species moving between their foraging and nesting areas, some thousands of kilometers apart. The capture of three Buck Island Reef NM nesting hawksbill females during their reproductive migrations through foreign waters is conclusive evidence that hawksbill turtles are still seriously threatened by ongoing turtle fisheries in spite of international efforts throughout the Caribbean to protect hawksbill turtles. The "question" of whether or not hawksbill turtles make reproductive migrations seems to be answered--yes, they do make reproductive migrations. What remains to be determined is just who is responsible for the protection of the migrating hawksbill sea turtle?

Acknowledgments

The authors would like to thank the National Park Service, NOAA-National Ocean Service, National Marine Fisheries Service, and all the technicians and volunteers that work so hard every season to make the BISTRP successful.

Investigations on At-Sea Mating and Reproductive Status of Olive Ridleys, *Lepidochelys olivacea*, Captured in the Eastern Tropical Pacific

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Little is known about the timing and location of mating in sea turtles relative to when and where females go ashore to lay eggs. Marine turtles frequently are observed mating in the waters adjacent to beaches on which females emerge to oviposit (Booth and Peters 1972, Hughes and Richard 1972, Balazs 1980, Ehrhart 1982, Alvarado and Figueroa 1989). Although the consensus seems to be that females mate with males directly offshore of nesting beaches just prior to egg laying, two separate observations indicate that these events may be more separated, both spatially and temporally. The first observation is at beaches where there are emergences of hundreds to thousands of nesting females ("arribadas"), few mating pairs are normally seen offshore relative to the number of females that emerge to nest (Plotkin *et al.* 1996). The second observation is that pairs of mating turtles are sometimes seen hundreds of kilometers offshore of the mainland (Pitman 1990). Nothing is known about the reproductive behavior and biology of oceanic sea turtles. Sightings have been recorded to establish that the olive ridley (*Lepidochelys olivacea*) is the most abundant sea turtle in the open ocean waters of the Eastern Tropical Pacific (ETP) (Pitman 1990). To learn more about the reproductive biology of oceanic turtles of the ETP, we conducted the first year of a three-year study on their mating behavior and reproductive status.

Methods

We participated in the Stenella Population Abundance Monitoring (SPAM) cruise with NOAA/NMFS Southwest Fisheries Science Center, July to December 1998. The study site extends from 25°N to 15°S, from the coast of the Americas to 155°W.

We captured turtles in two ways during the SPAM survey. The most successful method involved catching turtles from a small boat. The second method was performed directly from the ship using a purse net lowered off the bow of the ship on a 20 foot fire pole. We recorded turtle behavior at capture and categorized them as mating, basking, swimming, feeding or other. We recorded location (Latitude and Longitude) where the turtle was captured. Once on board we placed the turtle in a dorsal recumbent position on a car tire. We recorded over-the-curve carapace length (CCL), curved carapace width (CCW), straight carapace length (SCL), straight carapace width (SCW), and three tail lengths measurements (plastron to tail tip, carapace to tail tip, and cloaca to tail tip) using a tape measure and calipers. We recorded turtle mass using a Pelouze electronic scale. Turtles were tagged on both front flippers.

We collected approximately 5 cc of blood from the cervical sinus of each turtle (Owens and Ruiz 1980) with a 21G 1°" hypodermic needle and a 10 cc syringe. The blood was centrifuged for 5 minutes. The serum was frozen and will be used to measure testosterone levels. The red blood cells were preserved in a lysis buffer solution for future genetic studies.

We also used an ultrasound scanner (a portable Pie Medical 100 LC-Digital ultrasound scanner with 5.0 MHz linear probe) to determine the reproductive status of females in the field. Coupling gel was applied to the probe and the inguinal region of the turtle. Both ovaries and oviducts were imaged to identify presence/absence of oviductal eggs and large ovarian follicles (Rostal *et al.* 1990). Eggs were identified during ultrasound by the double ring present, while follicles lacked this structure. Images were saved electronically to diskette.

Results

A total of 149 olive ridleys were captured and sampled, including 8 mating pairs. Three mating pairs were captured in coastal waters adjacent to Mexico, one mating pair was adjacent to Guatemala, two mating pairs were adjacent to Costa Rica, and two mating pairs were located further offshore of El Salvador and Nicaragua (**Fig. 1**). Most solitary olive ridleys captured were located in waters along the coast of Central America, however there were a few captured further offshore (**Fig. 1**). At capture, 5 turtles were observed swimming, 1 turtle was feeding, 1 turtle was caught on a fishing hook, 133 were basking, and 1 turtle was dead. We identified 51 female turtles, 62 males, and 33 juveniles (sex undetermined). Three turtles were not identified to sex. Size distribution was compared using SCL (**Fig. 2**). Females ranged in size from 46.7-66.3 cm. Males ranged from 51.2-67.8 cm. Juveniles ranged from 20.2-67.8 cm. The distinction among adult turtles and juveniles was unclear. Therefore we combined the SCLs of females and juveniles together until positive identification of sex can be determined through analysis of serum testosterone levels. This identification will help us to establish a method for future juvenile/adult classification. Adult males were easily identified by tail length and hooked claws.

A total of 32 ultrasonography scans were conducted on adult females. There were 12 gravid females (38%) and 20 turtles that had depleted ovaries and no eggs (62%). Four solitary females were gravid with eggs and two solitary females were gravid with large ovarian follicles. We observed evidence of intromission (cloacal secretions, semen, extended cloaca, and extended penis) in 4 mating pairs. Only 7 of the 8 mating females were scanned. The scans showed that 6 were gravid. Three mating females were gravid with large ovarian follicles, 3 mating females were gravid with eggs, and one mating female had depleted ovaries. One of the females with

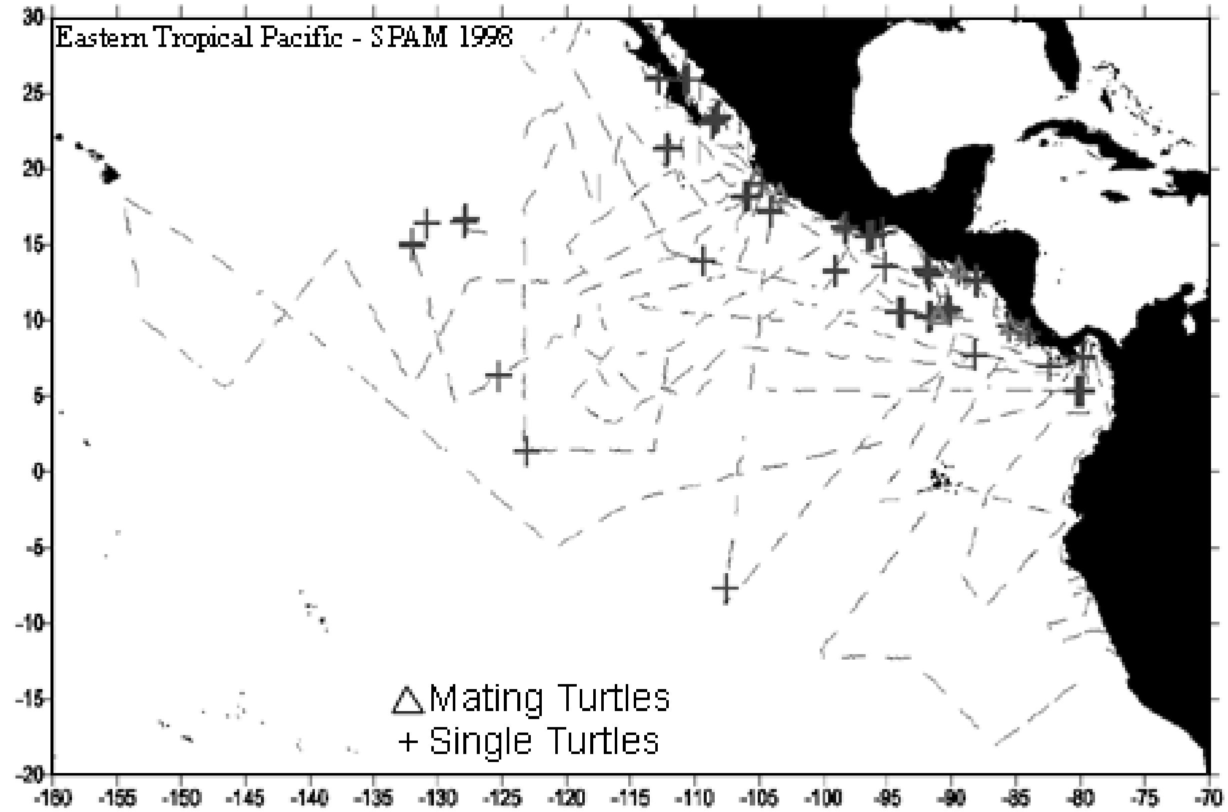

Figure 1. Location of solitary and mating olive ridley captures during July-December 1998.

eggs was actively copulating at capture. Females gravid with eggs were captured near shore, however, one solitary turtle with eggs was captured several hundred kilometers off shore.

Conclusions

Few mating pairs of olive ridleys were seen this year in comparison to previous years when cruises were conducted in the ETP. Two legs of the cruise traversed coastal waters from Mexico to Panama. The number of turtle sightings in coastal waters was significantly lower than previously reported. This is unusual, considering that the coast of Central America is a major nesting site for olive ridleys. Our shipboard observations of relatively few mating turtles and relatively few gravid females coincide with reports of low numbers of olive ridley nesting observed in Mexico and Central America during the 1998 nesting season (Randall Arauz and Raquel Briseño-Dueñas, pers. Comm.). We believe that the 1997-1998 El Niño affected reproduction and resulted in a decreased number of mating and nesting olive ridleys. We will be analyzing the serum testosterone data with the ultrasound data. The serum T levels from this study will be compared with the serum T levels from olive ridleys captured in the ETP during previous cruises and at the Nancite breeding ground.

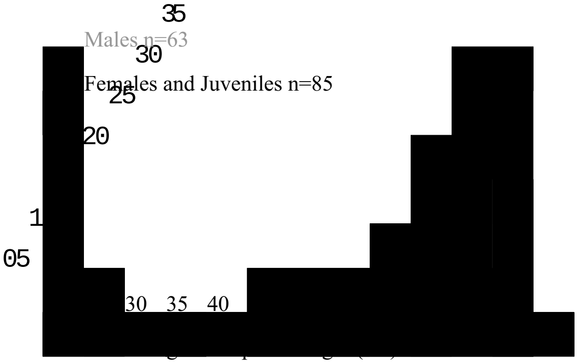

Figure 2. SCL measurements for all olive ridleys captured during July-December 1998.

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Distribution and Abundance of Juvenile Hawksbill Turtles (*Eretmochelys imbricata*) on Feeding Grounds at Río Lagartos, Yucatán, Mexico

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The hawksbill turtle has been designated as a critically endangered species. A priority listed in the World Strategy for the Conservation of the Marine Turtles (WSCMT) prepared by the IUCN/ CSE is the study of the aquatic stages. Biological and ecological information of these stages is necessary to do an integral analysis of the population. However, due to the difficulties of submarine research, the studies of these topics have been very limited.

Yucatán Peninsula is one of the most important nesting zones for the hawksbill turtle in the world (Meylan and Donnelly, 1999). At the northeast end of the Peninsula is the Río Lagartos Biosphere Reserve (RLBR); the marine area of this Reserve is an important feeding ground for juvenile hawksbills.

The objective of this study was to present the distribution and density of the hawksbill juveniles in Río Lagartos, Yucatan, Mexico.

Methodology

The data were obtained from two sources. One was by visual census over randomly chosen linear transects (10m x 1km) by free diving or Scuba. Location, depth, type of bottom, and megabenthic organisms were registered. The other method was with the help of lobster fishermen of Rio Lagartos, who catch juveniles during their dives. At the end of the fishing trip, they bring the juveniles to the coast for tagging, measuring and then releasing them. The name and depth of the catch site are recorded. The study area was divided into 6 zones (A-F) along 10 km of the coast.

Using the different types of data, we evaluated the distribution with the variation coefficient and the density of turtles per 10 hectareas (ha). Furthermore, we roughly estimated the juvenile hawksbill turtle population size in the 500 km^2 of the study area.

Results

We conducted 67 transects covering approximately 60 ha during which 15 juveniles were observed and 6 were caught. The most observations were made in zones D (60%) and B (28.5%) in water depths of 4-6 m (40.9%) and 6-8 m (33.3%) (**Fig. 2 and 3**). This yields a density of 2.5 turtles observed /10 ha.

The fishermen from Rio Lagartos captured 396 hawksbill juveniles in zones (listed from most to least abundant) B, C, D and A. Zones E and F belong to the lobster fishermen of El Cuyo who don't participate in this program (**Fig 4**). The highest abundance of turtles were caught in water 3-4 fathoms (5-7 m) deep (**Fig. 5**). Considering that the fishermen search an average of 10 ha/day (Rios *et. al*., 1998), this yields an average density of 1.66 captured juvenile hawksbills/10ha.

Lobster fisheries studies have reported that each boat checks, on average, 10 ha/day (Ríos *et. al*., 1998); considering this, there were not significant differences of the density of turtles between regions or between depths. Also, we observed that the standard deviation is directly proportional to their density average (**Fig. 6 and 7**).

Discussion

Distribution. The preferred habitat for juvenile hawksbills was between 4-8 m in depth, dominated by a hard bottom encrusted by filamentous, fleshy and leafy macroalgae, as well as erect and encrusting sponges**.** The results of van Dam and Diez (1997) from Mona Island Puerto Rico, mention that juveniles make dives down to 34 m in depth. In this study, the vast majority of dives were to water depths of 7 m or less. Decompression problems only allow lobster fishermen to catch juveniles in shallow dives, but when they did dive to 20 fathoms in depth, only adults or larger turtles were sighted.

The variation coefficient (S^2/average) is 1.16, this supposes a degree of aggregated distribution, so extrapolating can overestimate the population size (**Table 1**). Nevertheless, we thought it was appropriate to carry out detailed studies on this aspect.

Table 1.

# Turtles	Avg/Ha	Variance	Variation coefficient
Linear transects	0.25	0.29	1.16

Density. Juvenile densities reported by León and Diez (1999) in the Dominican Republic varied from a high of 96.8 and 58.3 turtles/km^2 in a reef habitat to a low of 5.6 turtles/km^2 in sparse hard bottom habitat. Compared with the value yielded by the prospective dives (2.5 turtles/10 ha=25 turtles/km^2) density in Rio Lagartos is a medium value. If the fishermen have a similar efficiency to that of the prospective dives (40%), then the density increases to 4.09 turtles/10 ha (40.9 turtles/ km^2) which is closer to the high values seen in Jaguara National Park in the Dominican Republic.

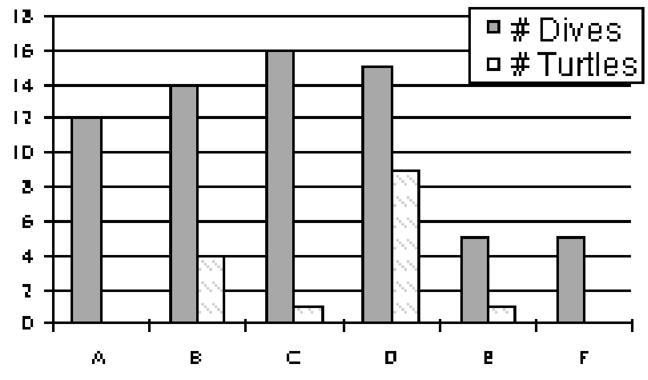
Population Size. The estimated juvenile turtle density oscillated between 0.34 and 4.09 turtles/10 ha. Extrapolating the density values from the prospective dives to the entire shore (<10 m) of Rio Lagartos Biosphere Reserve (500 km^2) yields an average 12,500 turtles (**Table 2**), ranging in size from 20 to 60 cm SCL.

Table 2.

	Number of Turtles		
	Captured per 10 ha	**Observed per 10 ha**	**Population Size**
Prospective Divings	1.00	2.50	12,500
Cooperatives (Total data)	0.13	0.33	1,650
Cooperatives (10 major capture days)	0.25	0.63	3,150
Cooperatives (by receipts)	1.66	4.09	20,500

To this respect, we are carrying out studies with satellite images in order to more precisely determine the hard bottom foraging areas which the developing hawksbill turtles prefer. Likewise, we are analyzing the tagging and recapture program results using the Jolly-Seber method to make an alternative estimation of the population size.

Habitat of the Campeche Bank is similar all along the coast (from Isla Holbox to Laguna de Terminos, 450 km long), and juvenile hawksbills have been reported in most of the sites, so we expected an increase in the hawksbill population.



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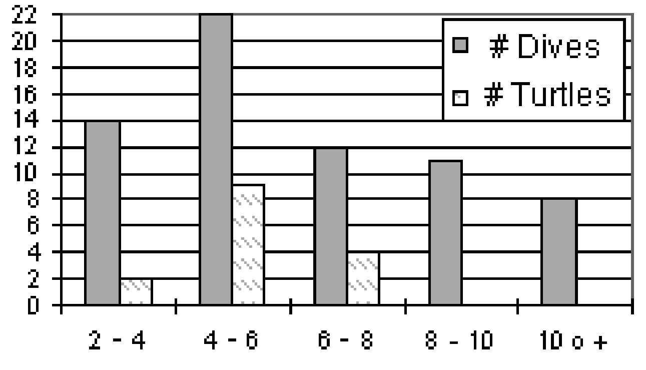

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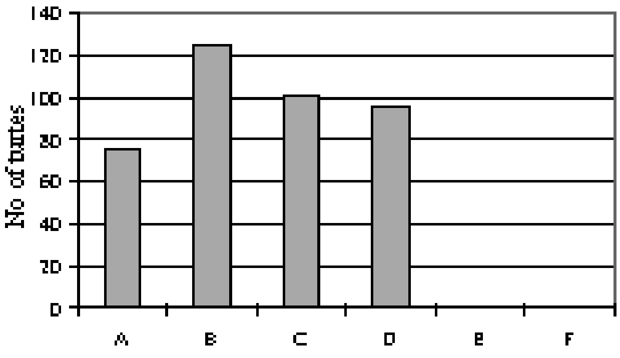

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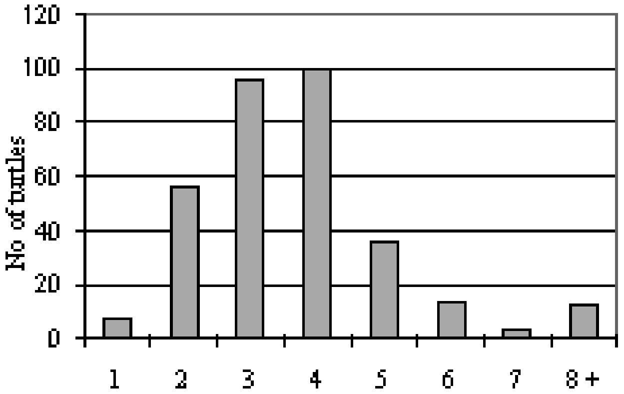

Figure 5.

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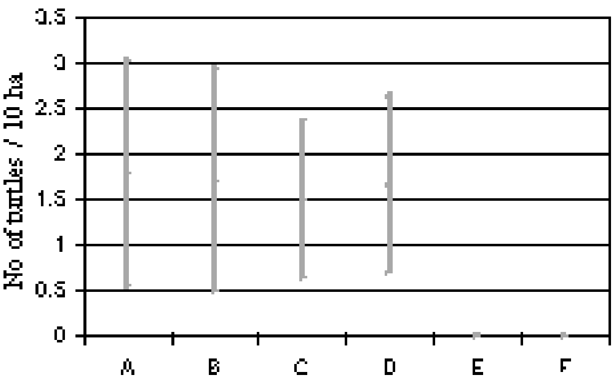

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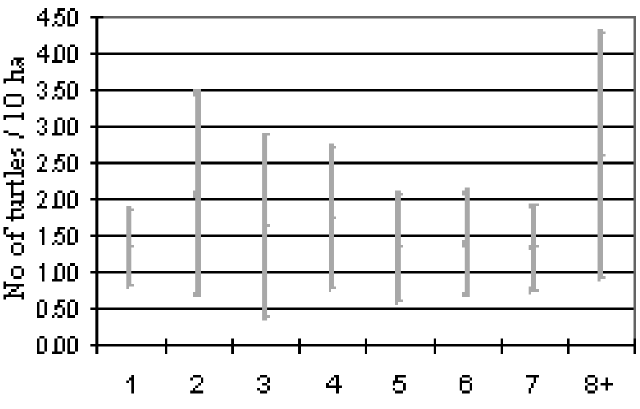

Figure 7.

Recaptures of Tagged Turtles from Nesting and Feeding Grounds Protected by Projeto TAMAR-IBAMA, Brasil

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Tagging of marine turtles has generated a wealth of information about routes and extent of migrations between feeding and nesting grounds. For instance, intensive tagging efforts on Ascension Island and in the Guianas revealed that many nesting turtles later were in the waters of Brazil, presumably at or en route to their feeding grounds (Pritchard, 1973; Carr, 1975; Schulz, 1975). Since 1980, Projeto TAMAR-IBAMA has been studying and protecting the marine turtles that occur in Brazil, and has been actively tagging turtles either on the nesting beaches or in the waters of feeding grounds on the coasts of Ceará and São Paulo (for more details, see Marcovaldi and Laurent, 1996, and Sanches and Bellini, in press). In all cases, the same methodology was used: Inconel or monel tags, model #681, were placed on the trailing edges of the front flippers. Morphometric data were also collected at the time of tagging, when possible. Given the length of coastline monitored by Projeto TAMAR-IBAMA (around 1100 km), and the efforts of Projeto TAMAR-IBAMA to increase environmental awareness (through environmental education programs and through the national media), Projeto TAMAR-IBAMA regularly receives information about turtles that have already been tagged, either directly from Projeto TAMAR-IBAMA staff, or indirectly through local fishermen, etc. In addition, Projeto TAMAR-IBAMA exchanges information with other sea turtle conservation programs in other countries.

Here we present data on tag returns of turtles that were marked with tags bearing the name and address of Projeto TAMAR-IBAMA, and who were recaptured (either alive or dead) in locations different from where they were marked (i.e. we do not include those animals encountered more than once on the same nesting beaches or the same feeding grounds). To date, we have 51 recaptures of turtles, most of which were recaptured in Brazil. In addition, we have some international recaptures in distant countries such as

Nicaragua and Senegal. Relevant data on all recaptures are given below in tabular form.

Acknowledgements

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Table 1. State abbreviations: AL=Alagoas; BA=Bahia; CE=Ceará; ES=Espírito Santo; RJ=Rio de Janeiro; RG=Rio Grande do Sul; RN=Rio Grande do Norte; SC=Santa Catarina; SE=Sergipe; SP=São Paulo; State: D=dead, A=alive; Stage: J=juvenile, F=female, M=male. (Continued on next page.)

Species Tagged	Location	Latitude	Longitude Tagged	Date Recaptured	Location	Latitude	Longitude	Date Recaptured	State	Sex	Record
Hawksbill	Atol das Rocas-RN	03ϒ52’S	33ϒ49’W	01/90	Senegal – Africa	14ϒ43’N	18ϒ52’W	07/90	D	J	001
Hawksbill	“ “	“ “	“ “	04/93	Fortaleza – CE	03ϒ45’S	38ϒ35’W	09/96	D	??	002
Green	Almofala - CE	02ϒ56’S	39ϒ49’W	08/94	Nicaragua – Central America	14ϒ30’N	85ϒ14’W	03/98	D	J	001
Green	“ “	“ “	“ “	06/96	Trinidad-Tobago – Caribbean	10ϒ03’N	63ϒ14’W	11/97	D	J	002
Green	“ “	“ “	“ “	03/98	Jericoaquara – CE	02ϒ40’S	40ϒ30’W	10/98	D	J	003
Green	“ “	“ “	“ “	07/98	Jericoaquara – CE	02ϒ40’S	40ϒ30’W	10/98	D	J	004
Olive ridley	Abaís - SE	11ϒ17’S	37ϒ15’W	12/90	Lauro de Freitas-BA	12ϒ53’S	38ϒ19’W	01/96	D	F	001
Loggerhead	“ “	“ “	“ “	01/91	Almofala – CE	02ϒ56’S	39ϒ49’W	08/94	D	F	002
Olive ridley	“ “	“ “	“ “	12/93	Armação – SC	26ϒ46’S	47ϒ39’W	01/97	D	F	003
Olive ridley	Pirambu - SE	10ϒ44’S	36ϒ50’W	01/95	Maceió – AL	09ϒ39’S	35ϒ44’W	01/95	D	F	004
Loggerhead	Ponta dos Mangues - SE	10ϒ33’S	36ϒ34’W	12/95	Aracaju – SE	11ϒ34’S	36ϒ51’W	04/96	D	J	005
Hawksbill	Praia do Forte - BA	12ϒ49’S	38ϒ15’W	02/88	Arembepe – BA	12ϒ53’S	38ϒ55’W	02/88	D	F	001
Loggerhead	“ “	“ “	“ “	10/90	Lauro de Freitas–BA	12ϒ53’S	38ϒ19’W	01/93	D	F	002
Loggerhead	Arembepe - BA	12ϒ 53’S	38ϒ55’W	10/90	Abaís – SE	11ϒ17’S	37ϒ15’W	01/98	D	F	003
Loggerhead	Subauma - BA	12ϒ18’S	37ϒ46’W	10/95	Sítio do Conde – BA	11ϒ58’S	37ϒ36’W	11/97	D	F	004
Loggerhead	Comboios - ES	19ϒ38’S	39ϒ49’W	01/83	Pontal do Ipiranga – ES	19ϒ22’S	39ϒ42’	04/98	D	F	001
Loggerhead	“ “	“ “	“ “	02/86	Açores – Portugal	39ϒ24’N	28ϒ 08’W	06/89	A	J	002
Loggerhead	“ “	“ “	“ “	11/93	Guriri – ES	18ϒ56’S	39ϒ45’W	07/97	D	F	003
Loggerhead	Povoação - ES	19ϒ22’S	39ϒ48’W	11/95	Rio de Janeiro – RJ	22ϒ54’S	43ϒ04’W	08/96	D	F	004
Green	Trindade - ES	20ϒ30’S	29ϒ49’W	03/92	Lagoinha – CE	03ϒ45’S	39ϒ10’W	06/92	D	F	001
Green	“ “	“ “	“ “	02/92	Senegal – Africa	14ϒ43’N	18ϒ52’W	07/92	D	F	002
Green	“ “	“ “	“ “	02/92	Comboios – ES	19ϒ38’S	39ϒ49’W	09/93	D	F	003
Green	“ “	“ “	“ “	01/95	Carneiros – PE	08ϒ03’S	34ϒ52’W	01/98	D	F	004
Green	“ “	“ “	“ “	01/95	Praia do Forte – BA	12ϒ49’S	38ϒ15’W	08/98	D	F	005
Green	“ “	“ “	“ “	01/96	Fortaleza – CE	03ϒ45’S	38ϒ35’W	09/96	D	F	006
Green	“ “	“ “	“ “	01/96	Jacaraípe – ES	20ϒ08’S	40ϒ11’W	12/96	D	F	007

Table 1. Continued.

Species	Location	Latitude	Longitude	Date	Location	Latitude	Longitude	Date	State	Sex	Record
Tagged			Tagged	Recaptured				Recaptured			
Green	Ubatuba -SP	23ϒ05'S	45ϒ00'W	08/92	Cananéia – SP	25ϒ12'S	47ϒ12'S	11/92	A	J	001
Green	“ “	“ “	“ “	02/92	Ilha Grande – RJ	23ϒ08'S	44ϒ10'W	06/92	A	J	002
Green	“ “	“ “	“ “	08/93	Iguape – SP	24ϒ51'S	47ϒ37'W	01/94	A	J	003
Green	“ “	“ “	“ “	10/93	Penha – SC	26ϒ46'S	47ϒ39'W	03/95	A	J	004
Loggerhead	“ “	“ “	“ “	04/94	Atafona – RJ	21ϒ38'S	41ϒ03'W	09/94	D	J	005
Green	“ “	“ “	“ “	07/94	SãoSebastião – SP	23ϒ49'S	45ϒ25'W	11/94	D	J	006
Green	“ “	“ “	“ “	07/94	Santa Cruz – ES	19ϒ58'S	40ϒ09'W	10/94	D	J	007
Green	“ “	“ “	“ “	08/94	Copacabana – RJ	22ϒ54'S	43ϒ12'W	08/94	D	J	008
Loggerhead	“ “	“ “	“ “	01/95	Cocanha – SP	23ϒ35'S	45ϒ17'W	01/95	A	J	009
Green	“ “	“ “	“ “	02/95	Parati – RJ	23ϒ13'S	44ϒ42'W	02/95	A	J	010
Green	“ “	“ “	“ “	03/95	Jacaraípe – ES	20ϒ08'S	40ϒ11'W	02/98	D	J	011
Green	“ “	“ “	“ “	05/95	Abrolhos – BA	17ϒ20'S	38ϒ35'W	06/95	D	J	012
Green	“ “	“ “	“ “	06/95	Rio das Ostras–RJ	22ϒ31'S	41ϒ56'W	95/96	D	J	013
Green	“ “	“ “	“ “	08/95	Praia do Hermenegildo-RJ	33ϒ35'S	53ϒ15'W	12/96	D	J	014
Green	“ “	“ “	“ “	10/95	Bertioga – SP	23ϒ55'S	46ϒ09'W	10/95	D	J	015
Green	“ “	“ “	“ “	06/96	Santa Cruz – ES	19ϒ58'S	40ϒ08'W	10/94	D	J	016
Green	“ “	“ “	“ “	07/96	Cananéia – SP	25ϒ12'S	47ϒ12'S	11/96	A	J	017
Green	“ “	“ “	“ “	07/96	Guanabara – RJ	22ϒ54'S	43ϒ14'W	11/96	A	J	018
Green	“ “	“ “	“ “	08/96	Piuma – ES	20ϒ50'S	40ϒ43'W	??	D	M	019
Green	“ “	“ “	“ “	10/96	Baía deSepetiba – RJ	22ϒ55'S	43ϒ56'W	02/97	D	J	020
Green	“ “	“ “	“ “	10/96	Baía de Guanabara -RJ	22ϒ54'S	43ϒ14'W	05/97	A	J	021
Green	“ “	“ “	“ “	11/96	Ilha Grande – RJ	23ϒ08'S	44ϒ10'W	01/97	D	J	022
Green	“ “	“ “	“ “	07/97	Itaipuaçu/RJ	22ϒ54'S	43ϒ14'W	07/97	D	J	023
Green	“ “	“ “	“ “	07/97	Conceição da Barra -ES	18ϒ35'S	39ϒ43'W	10/97	A	J	024
Green	“ “	“ “	“ “	07/97	Comboios – ES	19ϒ38'S	39ϒ49'W	10/97	D	J	025
Green	“ “	“ “	“ “	01/98	Niterói – RJ	22ϒ53'S	43ϒ06'W	07/98	D	J	026
Green	“ “	“ “	23ϒ05'S	08/98	Bombinhas – SC	27ϒ09'S	48ϒ30'W	11/98	D	J	027
Total											**053**

Baseline Data on the Seaward Orientation of Atlantic Loggerhead (*Caretta caretta*) and Florida Green (*Chelonia mydas*) Sea Turtle Hatchlings on a Naturally Lit Beach in East Central Florida

Mario J. Mota

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The detrimental effects of light pollution on the orientation of sea turtle hatchlings are well documented. Since the early 1980's biologists at Kennedy Space Center have monitored hatchling emergences in order to document any impacts the space program has on their seaward orientation. Although tremendous improvements in light management were made, and nest disorientations were reduced to almost zero, no local baseline data on the hatchling's innate seaward behavior exist. We did not know if a 2-5% disorientation rate could be considered a "natural" phenomenon.

This study looks at the assessed orientation of sea turtle hatchlings on an isolated beach amidst essential marine turtle habitat encompassing the Merritt Island NWR and Canaveral National Seashore in east central Florida. Forty-six loggerhead (*Caretta caretta*) and Florida green (*Chelonia mydas*) sea turtle nests were monitored at the midway portion of this 58 km coastline.

Hatching success had a mean of 71% and no nest disorientations were recorded in a 4-month period (July-October). Data collected included dune height, beach slope, celestial light, and distance crawled. Compass headings (range, mode, and direction of ocean) were also recorded for the hatchlings' tracks. Dune height varied from 1.7 m to 5.0m, and it was not significantly correlated to length of crawl or to crawl range span that had a mean of 29.5°. Crawl mode deviated from direct ocean angle by an average of 2.5°.

This study reinforces our concept of the sea turtle's homing abilities, and reaffirms the urgency for conservation efforts to preserve the disappearing unlit native Florida coastlines that provide vital sea turtle habitat.

Introduction

In Florida, the coast from New Smyrna Beach south to Boca Raton accommodates 80% of all the sea turtles that nest on the east coast of the United States (Van Meter 1992). This coastline is especially important on a global scale because it is the second largest loggerhead rookery on earth. Albeit the loggerhead is the most abundant sea turtle, the green sea turtle and the leatherback (*Dermochelys coriacea*) are also present. All three species of sea turtles are federally protected.

When all beach sections of this Florida rookery are ranked according to highest nesting density, three of the top ten are located within Kennedy Space Center (KSC) and Cape Canaveral Air Station (Ehrhart, 1979). Sea turtle nesting at KSC has been monitored since the 1970's and trends are described in Provancha and Ehrhart (1987).

Although sea turtles spend their lives in the open ocean, there are two occasions when they can be found on their natal beaches. These are during a hatchling's seaward crawl and the adult's return to nest. While on the beach, sea turtles are subjected to a multitude of perils including photopollution. Photopollution is a term used to describe detrimental light that can severely disrupt a hatchling's ability to properly orient toward the sea (Carr and Ogren, 1960). Other factors such as celestial body positioning and brightness, can also avert adult sea turtles' nesting emergence and influence a hatchlings' seaward trek.

Five structures near the KSC beach are considered to be potential photopolluters. These are the Space Shuttle Launch Complexes 39A and 39B, Titan Launch Complexes 40 & 41, and the KSC Conference Center (KSCCC). Launch pads are potential sources of photopollution because of height and operational lighting regimes, particularly during launch events.

In order to monitor any detrimental impact these five structures have on sea turtles, the KSC's Ecological Programs Group systematically monitors the beach during nesting season. Since 1990, data were collected on the number and location of hatchling disorientations, and these data are used to continuously improve KSC's outdoor lighting policy and guidelines. The average number of hatchling disorientations was relatively high (41 nests/year) from 1990-92. However, in 1993 a new lighting policy was implemented which dramatically reduced the average number of disorientation events to 3 nests/year (1993-98). This reduction can't be attributed to a corresponding decrease in nesting activity, and is presumably indicative of improvements made at the CCAS and KSC pads as well as the KSCCC. Other factors such as changes in dune and vegetation structure could have played a minor role by shielding the visibility of lights from the beach. These changes, however, were very minor and could not solely account for the overall reduction in disorientations.

Although tremendous improvements in light management were made, and nest disorientations at KSC were reduced to almost zero, no local baseline data on a hatchling's innate seaward behavior existed. This study focused on whether the 2-5% disorientation rate presently observed at KSC could be considered a "natural" phenomenon or if it was attributed to KSC-related activities.

In order to properly evaluate sea turtle hatchling behavior on a naturally lit beach, the 58 km coastline separating New Smyrna Beach and Kennedy Space Center, Florida was selected. This area encompasses Canaveral National Seashore (CANA) and the Merritt Island NWF. This stretch of beach is part of a barrier island system and has extremely low impacts from nocturnal human activities and photopollution sources. Because of its isolation, this is one of the last Florida beaches with relatively undisturbed marine turtle nesting habitat.

The primary dune varies in height between 1.7 meters to over 5 meters at mean low tide. It supports plant communities that include sea oats (*Uniola paniculata*), beach grass (*Panicum amarum*), saw palmetto (*Serenoa repens*), and sea grapes (*Coccoloba uvifera*). Resident animal species include the Florida scrub-jay (*Aphelocoma coerulescens*), eastern indigo snake (*Drymarchon corais couperi*), gopher tortoise (*Gopherus polyphemus*), bobcat (*Felis rufus*), and the old sea turtle nemesis, the raccoon (*Procyon lotor*).

Material and Methods

The most isolated 3.6 km midsection of the CANA beach was chosen as the location for this study. During nesting season, the National Park Service staff patrols the beach nightly, and every nest is marked and labeled with species and nesting date. Wire frames with mesh large enough to permit hatchlings to crawl out are secured above the nest in order to discourage predators. A few days after the hatchlings have emerged, a 10% subsample of nests are excavated and the reproductive success calculated.

Daily surveys monitored both loggerhead and green sea turtle hatchling emergences for disorientation events. Because of the relatively low nesting density, any opportunist emergence observed outside the study area was also recorded, but not included in the final data analysis. Overall, a total of forty-six nest emergences were recorded, of which 39 were loggerhead and 7 were green sea turtles. For data analysis, thirty-one nests were used, which consisted of 25 loggerhead and 6 green sea turtles.

When a disorientation event was found, compass bearings were recorded for the hatchling's directional mode, angular range, outliers, most direct ocean angle, and direction of potential light sources. The number of hatchlings that circled around the nest, or on their path to sea, were also determined and total distance crawled to the ocean measured.

A Suunto Clinometer was used to measure the dune slope angle at each nest, as well as at each beach section marker. Measurements were made from the mean low-tide point to the top of the dune. This angle was used to calculate dune height and a dune profile for the CANA beach.

Because celestial light is known to cause a reduction in nesting, ambient light was recorded for each moon phase. A 4 p Licor™ quantum sensor was deployed on the primary dune in the midsection of the study area. Light readings were recorded every hour by a Licor™ Datalogger and results correlated to hatchling emergences.

Discussion and Conclusion

Hatchling success had a mean of 71% and none of the forty-six sea turtle nest emergences observed (31 within the study area) had hatchling disorientations.

Compass measurements for mode of crawl and direct ocean angle differed on 12 of the 31 nest emergences observed in this study. These differences were small and the maximum recorded was 20 degrees. Overall, Mode and Ocean readings differed by a mean of 2.5 degrees. When a paired t-test was done, the results were not statistically significant ($p < 0.05$).

The hatchlings' seaward tracks had an angle span that ranged from 10 to 55 degrees, and had an overall mean of 29.5 degrees. This disparity in range span could be a factor of the distance crawled by the hatchlings. Hatchlings emerging from clutches located high on the beach crawled longer distances than those emerging from nests closer to the ocean. However, a correlation between range span and distance crawled had a r^2=0.00. This indicates that differences in crawl range were not directly related to nest location, but further research is needed to investigate how small differences in beach profile can influence hatchling tracks.

This pilot study focused on the homing abilities of sea turtle hatchlings in a naturally lit beach. Because no nest disorientations were observed, it reaffirms the urgency to abate lighting on prime nesting beaches. Conservation efforts must be taken to preserve disappearing native beaches that are vital for the survival of the species.

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Predation of Leatherback Turtle Hatchlings by Near Shore Aquatic Predators

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Fish predation on hatchlings has been suggested as the single largest factor that influences the survival of the endangered leatherback turtle (*Dermochelys coriacea*). However, the role of aquatic predators and the effect they play on hatchling success is virtually unexplored. Our objective was to determine the species of predatory fish that prey on leatherback hatchlings within the tidal zone.

Our study was conducted from May through August 1998 on Sandy Point National Wildlife Refuge, St. Croix, U.S. Virgin Islands, an area that represents the largest population of nesting leatherback turtles in U.S. jurisdiction. Predatory fish were caught using hook and line technique. Bait consisted of dead hatchlings supplied by USFWS personnel. Hatchling lures were cast onto the beach from a boat anchored 20 meters offshore and retrieved at a pace mimicking a swimming hatchling. Additional supporting data included observations made by snorkelers who followed hatchlings at dusk, and also observations from shore.

Tarpon (*Megalops atlanticus*) were the predominate predator off Sandy Point while other predators such as the horse-eyed jack (*Caranx latus*) were less frequently observed. Of 4,000 casts tarpon hits occurred 0.725% of the time, followed by unidentified fish (0.9%) and horse-eyed jack (0.075%). 98.3% of the casts were successfully retrieved. However, the mortality rate experienced by live hatchlings that were followed by snorkelers and hatchlings that were observed from the beach was 60% (n=58) and 71% (n=31), respectively. 91% of the hatchlings followed by snorkelers were consumed by tarpon. Our results suggest that tarpon could negatively impact the leatherback population of Sandy Point.

Biology and Conservation of Loggerhead Turtles (*Caretta caretta*) in Baja California, Mexico

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There is a notable paucity of information available on the life history of loggerhead turtles (*Caretta caretta*) in the eastern Pacific Ocean. In order to contribute to our understanding of the distribution, movement and ecology of loggerheads feeding along the Pacific coast of Baja California Sur, Mexico, we initiated community-based surveys and satellite telemetry research in the region. Our preliminary results indicate that the loggerhead population off the Baja California coast is comprised largely of juvenile turtles (mean SCL=60.8cm, range 35.3-80.4cm, SD=9.3, N=58) feeding predominantly on pelagic red crabs (*Pleuroncodes planipes*). The turtles appear to follow the wide California current southward and may continue westward as they follow the path of the north Pacific gyre. Turtles in the region are caught in a variety of fishing tackle including shark lines, gill nets and shrimp trawls and are occasionally consumed in fishing communities. The success of this project has depended on community involvement and has resulted in the establishment of a long-term sea turtle conservation research and education program in the region.

Introduction

Reports of loggerhead turtles (*C. caretta*) in the eastern Pacific date back over 50 years (Shaw 1947). Apart from several brief descriptions of their occurrence along the coast of Baja California (Márquez 1969, Bartlett 1989, Ramirez Cruz *et al.* 1991) there had been no studies of their distribution and movement. Recently, several papers and reports have described the genetic affiliation of Baja California loggerheads with loggerheads nesting in Japan (Bowen *et al.* 1995), incidental catch of Pacific loggerheads (Bolten *et al.* 1996) and their trans-Pacific migration from Baja California to Japanese waters (Nichols *et al.* 2000, Resendiz *et al.* 1998, Nichols 1999). It is clear from these studies that some sea turtles born on Japanese nesting beaches make trans-Pacific developmental migrations encompassing the entire North Pacific basin in a manner similar to Atlantic loggerheads (Bolten *et al.* 1998).

Seasonal cold water upwelling along the Pacific coast of Baja California, Mexico, and outwelling from the Bahia Magdalena-Bahia Almejas mangrove system result in a rich assortment of marine life in this region (Aurioles-Gamboa and Perez-Flores 1997). In the spring and summer this region provides food for developing loggerheads who gorge themselves on the abundant pelagic red crabs, *P. planipes* (Villanueva 1991).

This study presents information on seasonal distributions, movement and stranding of loggerhead turtles in this critical developmental region. The many ways that local fishing communities in the region have supported and participated in this project have been critical to its success.

Methods

Sea turtles were located at sea while they were basking at the surface. On calm, sunny days turtles could be located by spotting terns (*Sterna* sp.) perched atop their dry carapaces. Turtles were caught by hand and held on board on rubber matting while measured and tagged. Inconel flipper tags (National Band and Tag Co., Kentucky, USA) were applied to the fore-flippers of each turtle. Satellite transmitters, models ST-3 and ST-6 (Telonics, Inc., Mesa, Arizona, USA), were deployed on a total of three loggerhead turtles along the Pacific coast of Baja California using the attachment technique described by Balazs *et al.* (1996). Open-water surveys for basking loggerhead turtles were conducted during the summer and fall of 1997 and 1998 in waters near Punta Abreojos and Bahia Magdalena, BCS, Mexico. Surveys were conducted up to 30 miles offshore on calm days (Beaufort 0 or 1) from 22-foot fishing "pangas" with outboard motors moving at approximately 15 knots. Boats held two observers and a driver. Surveys for stranded loggerheads were conducted on foot throughout the year on Pacific beaches near Bahia Magdalena, Baja California Sur, between May 1994 and January 1999. Examining and analyzing stomach samples from a total of four stranded loggerhead turtles allowed investigation of the diet of Baja California loggerheads.

Results

Movement. All three loggerheads tracked by this project left the region in a southwestern direction somewhat consistent with the flow of the California Current. Detailed data will be presented elsewhere.

- Loggerhead PAO204 (PTT 01085), 64 cm (SCL), was tracked for a total of 268 days from 3 July 1998 to 18 September 1998.
- Loggerhead PAO205 (PTT 05520), 73.4 cm (SCL), was tracked for a total of 78 days from 11 September 1997 to 5 June 1998.
- Loggerhead BLA099 (PTT 07667), an 83 cm adult female, was tracked for a total of 368 days from 12 August 1996 to 14 August 1997. Bowen *et al.* (1995) had previously determined this turtle to be of Japanese origin.

Abundance and Distribution. Surveys at sea resulted in sightings of loggerhead turtles during all seasons. However, peak numbers occurred during the summer of 1997 (**Table 1**). During the 1998 summer and fall surveys *P. planipes* were not observed and fishermen indicated that the waters were especially warm and that the fishing was poor. Stranding data indicate a peak in late spring and summer followed by a decline in numbers of stranded turtles in the fall and winter. Stranded turtles encountered in winter months showed advanced decomposition and had likely been present on the beach for up to several months. None of the stranded turtles appeared to have suffered any type of trauma. Both at sea and stranding surveys always involved the participation of members of the local fishing communities. In the case of Punta Abreojos surveys, the entire fishing cooperative was enlisted to aid in our survey efforts. The range in size for all turtles encountered along the Pacific coast of Baja California during this study was 35-80 cm (SCL) with a mean of 61 cm (N=58). Eleven turtles were captured in the Gulf of California with a mean SCL of 49 cm (28-93 cm).

Feeding. Four stomach content samples of stranded loggerhead turtles were obtained from Bahia Santa Maria, BCS, Mexico in the summer of 1998. All four samples contained only *Pleuroncodes planipes*, the pelagic red crab. Interviews with fishermen who regularly capture and consume loggerhead turtles in the region support these observations. During this same period 15 Humboldt squid (*Dosidicus gigas*) were also examined and were found to be feeding entirely on *P. planipes*.

In the waters near the Pacific coast of Baja California the most common sea turtles appear to be juvenile pelagic loggerheads moving in a generally southwestward direction with the currents. In the spring, with the winds from the north, the California current runs along the Baja California coast, weakening through the summer and into the fall and allowing for the influence of the Davidson current from the south along the coast (Wyrtki 1965). This pattern of the surface currents may have been disrupted and/or enhanced during the recent El Niño event, resulting in anomalous warm surface waters and lower productivity—by summer 1998 conditions had begun to return to "normal".

The loggerhead turtles in this region appear to be feeding primarily on *Pleuroncodes planipes*, the pelagic red crab or "langostilla", and turtles are likely to be found closer to shore during the spring and summer when aggregations of their prey are most abundant. The standing stock of the benthic phase of this species is estimated to be from 300 to 500 thousand metric tons with densities to 40 crabs/m^2 (Aurioles-Gamboa and Perez-Flores 1997). The crabs reproduce in spring and the pelagic phase may last for up to two years. After the third year crabs become entirely benthic and retreat to cooler, deep water in the late summer when the influence of the Davidson current prevails along the coast. Stomach content analyses support the observation that these turtles feed on pelagic phase crabs during summer months.

Another location where loggerhead turtles are occasionally found is the Midriff Island region of the Gulf of California, an area known for occasional "blooms" of *P. planipes*. Felger *et al*. (unpublished data) reported that loggerheads in the Canal de Infiernillo region, between mainland Sonora, Mexico and Isla Tiburon, also feed on bivalves such as *Laevicardium elatum*, *Modiolus capax and Dosinia ponderosa*, however the turtles in that region were generally not found as close to shore as *Chelonia* commonly are.

Stranding patterns suggest that incidental catch is a hazard for the turtles as they enter these coastal waters in the spring and summer (**Table 2**). None of the stranded turtles showed signs of hooking or trauma so it seems likely that the cause of mortality is a net-based fishery. Shark and California halibut (*Paralichthys californicus*) fishermen have been cooperative with this study and report regular loggerhead bycatch. Loggerhead turtles caught by shark fishermen are often released alive, whereas those caught in gillnets are typically dead. The halibut fishery coincides with the movement of *P. planipes* to the shallower continental shelf and involves the use of bottom gillnets or "tresmayo". The shark fishermen utilize hook and line sets from 20+/- km offshore.

Our stranding surveys generally only included the 12 miles of Pacific beach within the area known at Bahia Santa Maria, Baja California Sur. It is notable that the few data available from north of this bay (Cabo San Lazaro and the outer Pacific beaches) suggest that stranding may occur along the entire Pacific coast during the spring and summer months. It seems likely that the total number of stranded loggerheads in Baja California alone could be in the thousands annually.

We plan to continue our studies of the pelagic movement of Baja California loggerhead turtles and to study their foraging, basking and diving behavior. Ongoing efforts will continue to survey stranding rates along the Pacific coast of Baja California near Bahia Magdalena. In the spring and summer of 1999 we will accompany shark and halibut fishermen during their activities to study loggerheads and to work with them to develop methods that minimize impact on turtle populations.

Conclusions

1) Loggerhead turtles are the most abundant sea turtle species in pelagic waters near Baja California during spring and summer months.

2) The Baja California loggerhead population is comprised of predominantly juvenile turtles feeding principally on *Pleuroncodes planipes*.

3) Satellite telemetry provides a useful method for studying the movement and behavior of juvenile Pacific loggerheads, especially due to their tendency to spend long periods of time basking at the surface, and suggests a southwestern trend in loggerhead movement in the region.

4) Seasonal incidental catch of loggerhead turtles related to gillnet, halibut and shark fisheries is likely a significant source of mortality in the region.

Further investigation of the movement, abundance and mortality rates of these animals is needed.

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Table 1. At-sea sightings of loggerhead turtles in Baja California Sur, Mexico (1997-1998).

Date	Location	Total hours of survey	# of Sightings
July 1997	Bahia Magdalena, BCS	13	5
Aug 1997	Punta Abreojos, BCS	30	20
July 1998	Bahia Magdalena, BCS	15	4
Aug 1998	Punta Abreojos, BCS	24	1
Nov 1998	Punta Abreojos, BCS	28	1

Table 2. Strandings of loggerhead turtles on Isla Magdalena, Baja California Sur, Mexico (1994-1999).

Date	Location	# of Turtles	MeanSCL (cm)	Range (cm)
May 1994	Pacific coast of Isla Magdalena	210	na	na
June 1997	Bahia Santa Maria, BCS	32	59.5	35.3-80.4
May 1998	Bahia Santa Maria, BCS	7	63	53-73.2
Aug 1998	N. end of Cabo San Lazaro, BCS	40	na	na
Nov 1998	Bahia Santa Maria, BCS	11	60.1	46.8-76.5
Jan 1999	Bahia Santa Maria, BCS	3	59.4	57-62.4

Obake Turtles of Hawaii

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Green turtles (*Chelonia mydas*) in the Hawaiian Islands exhibit some interesting and unusual behaviors (Whittow and Balazs 1982; Balazs 1996; Rice *et al.* 2000). Digital video was used to capture two of these activities in real time. Juvenile green turtles are seen colored bone-white from silt on their carapace as they bask motionless on lava rock shores at Kiholo Bay on the Island of Hawaii. At Midway Atoll, 2000 km away at the opposite end of the Hawaiian chain, green turtles are pictured as they rest underwater at night beneath a cargo pier in a surrealistic setting of rusting crossed girders and cement debris. We gave the turtles found in these two areas the name "Obake", the Japanese word for ghost. Our 11 minute video presentation shows the eerie and strangely attractive contrasting images of the obake turtles resting in murky waters late at night and basking on black rocks in the bright midday sun.

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Seasonality and Capture Location Relationships for Sea Turtles in New York State

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This study represents the 18th year of a continuing study (Sadove *et al.* 1998) of the temporal occurrence of sea turtles caught in pound nets around the eastern end of Long Island, New York. Long Island is 120 miles long and roughly oriented in an east/west plane divided into two fork-like peninsulas on its eastern end.

A reward system was established with local fishermen to provide an incentive to report and hold the turtles after capture. Reports to a 24 hr pager system by the fishermen ensured that the sea turtles incidentally caught in pound nets were immediately recovered. Pound net locations were the same as those obtained during the 1997 study using a global positioning system. Pound nets are fixed gear nets consisting of a vertical net running perpendicular to the shore, the "leader", which leads into a box or hexagonal net on its seaward end. Fish migrating along the beach are directed by the "leader" into the trap. Sea turtles swimming near shore are periodically caught in these nets.

Standard morphometrics were taken on the sea turtles caught in the pound nets. Turtles were transported to Southampton College where they were held in flowing seawater tanks for a brief period. Maximum holding time before turtles were tagged and released was forty-eight hours. Whenever possible, turtles were released at or near the original location of capture.

Data collected during 1998 were compared to similar studies conducted over the last seventeen years. These data consist of 519 captures including 101 green, 298 loggerhead, and 120 Kemp's ridley. All turtles captured during this study were juveniles. Mean carapace lengths and standard deviations were greens: 33.04±5.05, loggerheads: 45.52±17.98, and Kemp's ridleys: 2.34 ±3.53. Arrival of sea turtles into the study area varied by species and date. The earliest and latest captures for greens, loggerheads, and Kemp's ridleys were June 30, 1994, June 24, 1991, and July 9, 1991 respectively.

Using this data set, a trend between capture locations for sea turtles and time of year was observed. **Figure 1** illustrates captures made during the first third of the season (June 1–July 31). A clear concentration around the south shore of the north fork is demonstrated. Captures made during the middle third of the season (Aug. 1–Sept. 30) are shown in **Figure 2**. During this time period, the captures were more generally dispersed throughout the waters of eastern Long Island. Captures made during the last third of the season (Oct. 1– Nov. 30) are shown in **Figure 3**. During this period the turtles tend to be more prevalent around the north shore of the south fork. These figures collectively demonstrate a temporal distribution of sea turtles around the eastern end of Long Island.

Distribution of sea turtles in the waters of eastern Long Island during 1998 was similar to that observed during the previous seventeen years. At the start of the season, sea turtles are probably still moving in a northerly direction and move close to shore to feed, resulting in a majority of incidental captures along the south side of the north fork of

Long Island. The sea turtles spend the middle of the season feeding in the waters between the north and south forks. Movements of sea turtles around the waters of Long Island for food result in captures occurring in a more random manner. Previous telemetry studies (Morreale *et al.*, 1992) have shown that, towards the end of the season, the turtles begin to head south. The beginning of this southerly migration results in captures along the north shore of the south fork and also explains the few captures of turtles on the north coast of Long Island (Long Island Sound) traveling south from New England waters.

Collectively, these data demonstrate that movements of sea turtles in the waters off eastern Long Island are related to their overall seasonal movement patterns. Although such extensive long-term data have not been collected throughout the northeastern United States, the data presented here tend to support a repeatable pattern of capture. Patterns of arrival and distribution for all three species presented here provide details for future management activities necessary to protect these species.

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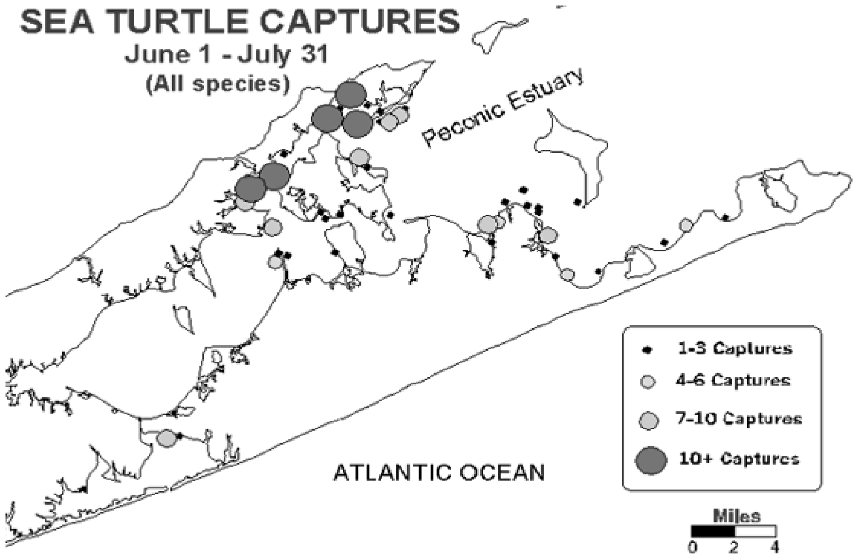

Figure 1. Location of sea turtle captures (all species) from pound nets in waters around eastern Long Island for June 1-July 31 in the years 1984-1998.

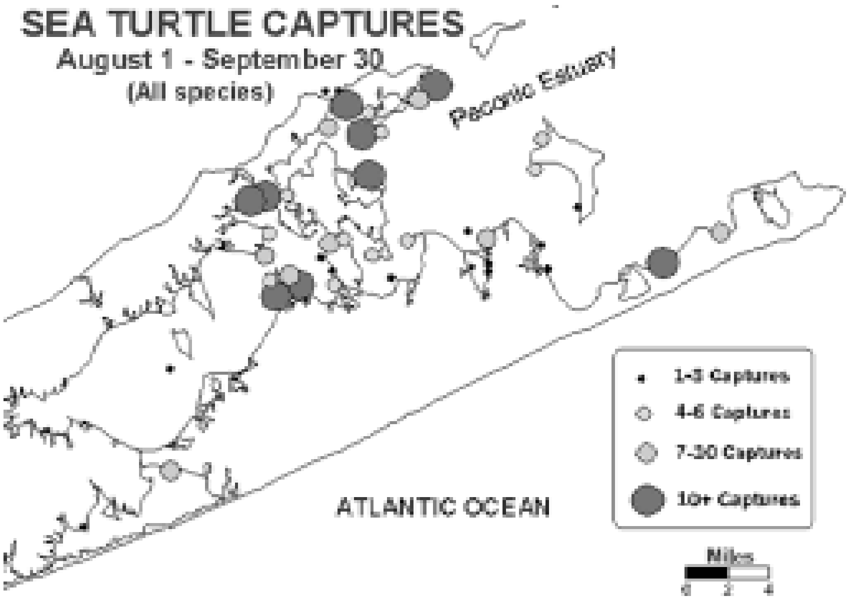

Figure 2. Location of sea turtle captures (all species) from pound nets in the waters around eastern Long Island for August 1-September 30 in the years 1984-1998.

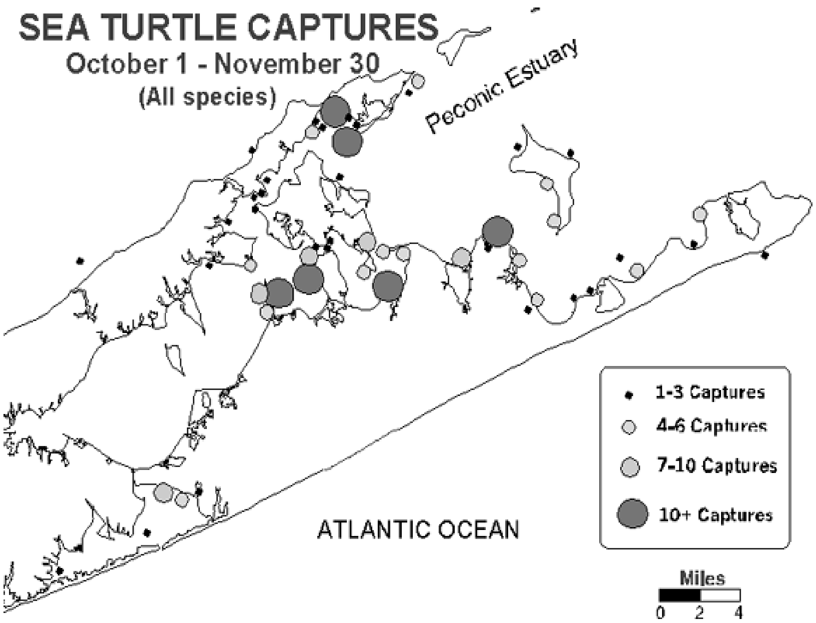

Figure 3. Location of sea turtle captures (all species) from pound nets in the waters around eastern Long Island for October 1-November 30 in the years 1984-1998.

Detecting the Precise Time at Settlement from Pelagic to Benthic Habitats in the Loggerhead Sea Turtle, *Caretta caretta*

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Studies to develop and refine methods to estimate age from growth layers in cross sections of *Caretta caretta* humeri recently resulted in the discovery of a change in the layering pattern that is hypothesized to correspond to the transition from pelagic to benthic stages in loggerheads. It is possible to identify, in each individual between 47 - 68 cm SCL, the exact growth layer in the bone (hereafter called the settlement line) where the transition occurs. Results of analyses of stable isotope ratios for carbon and nitrogen reveal 3 distinct zones, indicating changes in diet. The innermost bone has N and C isotope compositions reflective of marine plankton feeding. Bone external to the settlement line has isotope compositions consistent with feeding on marine benthic organisms. Bone just internal to the settlement line is transitional. The settlement line is recognized visually in bone sections as a transition in bone growth: growth layers internal to it are narrow and those just external to it are thicker. The greater thickness of the growth layers external to the settlement line suggests an increase in growth rates in the turtles after the change to a benthic diet. A regression analysis of carapace length with years since settlement suggests that *C. caretta* are about 52 cm SCL when they settle to the benthic habitats of North Carolina.

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Tracks & Tracking

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Although the main nesting effort by loggerhead sea turtles *Caretta caretta* on the Greek island of Kefalonia occurs on Mounda Beach, evidence of emergences have been found at other beaches around the island. Mounda Beach is patrolled from May until October each year, with the nesting season running from early June until mid-August. Regular surveys were conducted at other beaches that provided suitable nesting conditions

The aim of this study was to identify any turtles found on secondary beaches and to record instances of infidelity by Mounda turtles. The only definite way of showing infidelity would be to encounter a tagged loggerhead nesting on another beach; to date this event has not happened. A novel approach was used, combining VHF radio telemetry, the track characteristics for emergent adults at Mounda Beach, and the known life history of the current year's nesting turtles (1998).

Materials and Methods

Track Characteristics: The tracks of all adults emerging at Mounda during 1998 were measured. The inter-humeral span and the groove created when the plastron was dragged across the substrate proved to be the most reliable measurements. The track was divided into uptrack and downtrack, with a wet and dry zone on each. Track patterns were easily damaged by both human and natural impacts, such as sandstorms.

Radio Telemetry: VHF transmitters were attached to three loggerheads during oviposition and their subsequent movements were tracked when they returned to the sea. The transmitters operated at slightly different frequencies. Several receiving posts were established around the island, covering most of the coastal waters and suitable secondary nesting sites. Transmitters were secured to *Caretta caretta* using Isopon P40, a polyester resin. If an animal nested at a site other than Mounda, the position could be fixed using triangulation from two or more receiving posts. The characteristics of any tracks found at the position of the radio fix could be measured and compared with those obtained from known turtles at Mounda.

VHF Telemetry Equipment: Transmitters 2-stage, crystal controlled, transmitter-Model 201 (3-volts). Enclosed in clear waterproof resin, with a 40 cm wire aerial. Integral battery provided 130 days continuous operation. Overall length 46.3 mm, diameter 20.55 mm, weight in air 28 g, specific gravity 1.12. Operating frequency 173 megahertz. Transmitting 56 pulses per minute, with 1100 milliseconds interval between pulses. Supplier: Advanced Telemetry Systems Incorporated (ATS). 470 First Avenue North, Box 398, Isanti, Minnesota, MN55040 United States of America. Tel:+1-612-444-9267. E-mail atstrack@compuserve.com URL: www.atstrack.com.

Receivers VHF/UHF Communications Receiver - Model FRG9600. Frequency range between 60 MHz-905 MHz. Maximum power supply 13.8 volts D.C. input. The unit (length 22 cm, width 17.5 cm, height 8 cm) can be operated whilst in the vertical or horizontal plane, and was in a padded carrying case during use. Supplier: Yaesu Musen Company Limited, CPO Box 1500, Tokyo, Japan.

Antennae folding 3-element, Yagi antenna for high frequency use >140 MHz. Model number F170-3FB, 00174. Antenna has high gain, is electrically stable and mechanically robust. Supplier: A. F. Antronics Incorporated, 1906 Federal Drive, Urbana, Illinois, United States of America.

Power pack Dry-fit 12-volt 6.5 amp/hour sealed lead/acid battery was used to power the receiver. Part number 07-1-90432. Supplier: Sonnenschein Batteries Incorporated, Cheshire, Connecticut, CT06410.

Battery charger 12-volt transformer - Stock number 591-411 was used to charge the power packs from mains electricity supply, 220 volts A.C. at 50 hertz. Recharging time was directly related to prior usage, for example 8 hours receiver use would require about 8 hours recharging time. Supplier: R. S. Components, Northampton, England.

Two Admiralty Charts charts were used: **189:** Nisos Sapientza to Nisos Paxoi. Scale: 1:300,000 metres. **203:** Nisos Zakinthos to Nisos Paxoi. Scale 1:150,000 metres. Standard techniques were used to fix positions onto the charts. GPS was not available.

Life History: The detailed life history for known loggerheads at Mounda was used to determine if infidelity could have occurred, based on the internesting period and number of clutches a turtle laid during successive remigrations. A typical life history also contained the nest success rate where known, the number of eggs laid in a season and the number of days spent at Mounda Beach during a nesting season. All available data from previous years (1985-1998) were included in the life history but the records for some animals were incomplete. The Sea Turtle Protection Society of Greece (STPS) was consulted about turtles tagged on Zakynthos.

Results

Detailed results are available from the author and fall within the following areas:

- The tracks from 60 emergences, nesting and non-nesting, made by 15 animals were measured;
- 3 loggerheads were fitted with VHF transmitters during nesting but were only tracked for approximately 6 hours in each instance before transmissions were lost; and the known life history for each animal was used to determine if nesting-site infidelity could have occurred.
- The records for certain animals span the period 1985-1998.

All suitable nesting beaches around the island of Kefalonia were surveyed weekly for signs of emergence.

Discussion

The track characteristics of *Caretta caretta* were measured in an attempt to identify unseen animals from their "footprints". These data were intended to corroborate evidence gathered during a radio telemetry study of internesting habitat use and nesting site infidelity. Two measurements proved to be fairly consistent over a number of emergences made by the same turtle. These were the inter-humeral span and the plastron groove in the centre of the track. A difference was apparent between the uptrack and downtrack, probably because the method of locomotion changes slightly; with the turtles tending to push with their hind flippers, either alternately or together, when going downhill. On the uphill journey, the motive power was provided by the forelimbs alone. The substrate affected the preservation of the track, with damp sand holding a more accurate pattern. The wet and dry zones were measured on the uptrack and downtrack, with three replicates taken whenever possible. The track patterns were easily destroyed by human activity, sandstorms and wave action; which resulted in gaps in the data.

Turtle [C13][C106] showed the least variation in track characteristics (Plastron groove: Mean width=8.1 cm, S.E.=0.08, 95% Confidence=0.2; Inter-humeral span: Mean width=63.9 cm, S.E.=0.51, 95% Confidence=1.2). Another loggerhead [C281] produced the largest data set of the season, with 5 nests and 4 (possibly 6) non-nesting emergences.

There was insufficient evidence to show conclusively that the same animal made different tracks, although the results were encouraging. It should be possible to place a turtle into a size-class, once a larger data set has been collected. This pilot study forms the basis of future work, which will be conducted over a number of years to incorporate different groups of remigrants.

The telemetry study failed as far as nesting site infidelity was concerned but it did show that an extended surface interval followed a long dive. For instance, a 38 min dive was followed by a 7 sec period at the surface, compared with 3 sec after a 2 min dive. A detailed series of validation trials was conducted. After deployment, the transmitters were received clearly for several hours in each instance and then were not detected again. Possible reasons were that the transmitters became dislodged and sank, resulting in loss of reception, as VHF waves attenuate rapidly in water. This probably was the case for turtle [617][611], as she returned to Mounda Beach without the transmitter on August 4, 1998. Loggerhead [C158] probably migrated immediately after transmitter attachment and traveled south of Zakynthos, so transmissions were not detectable from Kefalonia. This loggerhead [C158] had a 38 day internesting period between her two nests at Mounda and could have laid a nest at a secondary beach. Unfortunately the transmitter was fitted at the end of this period and her previous movements remain unknown. The loggerhead [C113][580] probably migrated also, as a study of her life history shows the maximum clutch number to be three in any season, and the transmitter was fitted as she laid her third nest. This animal might only use Mounda as a secondary-nesting site because she remigrates on a triennial basis and alternates between one and three clutches per season (1989-1998).

Future Studies

Coded transmitters will be used, which operate at the same frequency. This should improve the chance of detecting a turtle during the brief surface interval. Data Storage Tags, recording depth, swimming speed, water temperature and compass heading, will be attached alongside transmitters and removed during subsequent emergences. Adhesive experiments are currently being conducted using a range of materials. The measurement of tracks will be continued and compared with 1998 results. Comprehensive life history data will be collected and compared with previous years.

Acknowledgments

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METHODS AND METHODOLOGY

The Use of GIS Technology in Sea Turtle Conservation - A Practical Approach

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Volusia County, Florida developed the country's first Habitat Conservation Plan for sea turtles. This led to the issuance of an Incidental Take Permit from the U.S. Fish & Wildlife Service. As part of this permit the County was required to develop a comprehensive sea turtle monitoring program. The use of Geographic Information System (GIS) technology was identified as a valuable management tool.

GIS technology serves many management functions, including, but not limited to:

- Documenting the temporal and spatial distribution of sea turtle nests;
- Documenting natural processes and human activities impacting sea turtles;
- Evaluating the effectiveness of measures taken to minimize vehicular impacts to sea turtles on County beaches;
- Re-establishing nest barriers in the event they are lost, and;
- Determining the effectiveness of the Natural Beach Management Areas (non-vehicle access areas) and the Conservation Zones on nest fate and reproductive success.

The County utilizes a Trimble ProXL System, a real-time, sub-meter accurate device, to obtain the latitude/longitude points. This data is then incorporated into ArcView software for generating maps and performing management analysis tasks.

Skeletochronology, Validation in a Long Term Recaptured Adult Loggerhead (*Caretta caretta*)

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Skeletochronology is a technique used to determine age by counting periodic incremental growth marks that have been deposited on hard parts such as scales or bone. Most skeletochronological studies of age and growth in sea turtles have not included validation studies to determine that the marks are laid down annually. We report here the recovery of an adult female loggerhead sea turtle marked eight years previously with oxytetracycline (OTC). Seven (dense) arrested growth marks and eight summer season growth zones were identified in the right humerus, distal to the OTC mark, validating the use of skeletochronology for age and growth studies in adult loggerhead sea turtles. The number of growth marks present show that OTC can be used in long term (>8 year) growth studies. Additionally, we show that the growth marks are not equally distinguishable around the humerus. Collection of biopsies from appropriate regions of the humerus in live turtles is important. Only whole humeral sections should be used in back calculating size at age. Skeletochronology is a valuable method of studying age and growth in western Atlantic loggerheads. This technique can provide valuable estimates of sea turtle age and growth over large size ranges of individuals salvaged from strandings, providing growth marks have been validated.

How Many Hatchlings Were There?

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An important parameter for evaluating conservation programs is the total number of hatchlings that reach the sea, however, inconsistencies exist among the values reported in several publications. Some report only the number of hatchlings found on the surface, or the number of hatchlings tracks or the number of eggshells inside the nest, but these figures do not necessarily represent the actual number of hatchlings produced or those that reach the sea with possibilities of being recruited to the wild population.

In this study we analyze the contents of olive ridley nests incubated in a hatchery in Mexiquillo, Mich. (Mexico), to obtain the total number of hatchlings produced and released in the 1996-97 nesting season. All turtles that broke the eggshell, whether they came out of it or not, were considered hatchlings. The pipped hatchlings and embryos found alive were kept with special care until they were ready to be released. All of the categories found alive were released.

Considerations

- The total of hatchlings is not equal to the number of hatchlings released.
- It is important to consider all categories of hatchlings outside and inside the egg chamber.
- Pipped and embryos found alive in the chamber were released after they complete their development.

- Some programs do not differentiate between terms and formulas for hatchlings produced and hatchlings released, and it's not possible to make comparisons between them.
- Due to this lack of standardization of terms in some programs, it is not possible to know the real production of the categories mentioned in this study.

The differences in the totals have implications for the application of management techniques.

Acknowledgments

We want to express our gratitude to all those people who helped us with the field work; Lynn Jimenez, NMFS and INP for support to attend the Symposium.

Categories	Live L	Dead D	Total L+D	Hatchlings Released
Hatchlings				
Emerged	32, 309	659	32,968	32, 309
In The Chamber	2, 625	1,172	3,797	2, 625
Pipped	439	3,504	3,943	439
Total Hatchlings	**35,373**	**5,335**	**40,708**	**35,373**
Unhatched Eggs (Embryos)	2	8,726	8,728	2
Total (Hatchlings+Embryos)	35,375	14,061	49,436	35,375
Undeveloped Eggs	——	——	6, 595	——
Total Eggs			**56,031**	

Bias-Free Estimates of Measurement Error in Sea Turtle Morphometric Data Collection

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Quantification of measurement error is a critical factor in somatic growth rate studies, particularly with slow growing animals. Measurement error has been infrequently addressed in the sea turtle field (Shoop and Ruckdeschel, 1986; Frazier, 1998), but most estimates of error have been generated by repeated measurement of an individual turtle, by either one or several observers. As noted by Frazier (1998), whenever observers are aware data are being collected for calculating measurement error, there is an almost unavoidable bias to minimize error. In our study, straight and over the curve measurements were collected under routine field conditions by multiple observers who were unaware the data would be used for measurement error calculations. In this study we present unbiased error data for linear and over the curve measurement methods performed on juvenile green turtles (*Chelonia mydas*) between July 1994 and July 1997. In order to quantify measurement error, we examined measurement data from 41 green turtles which had been captured and recaptured over short time intervals at the St. Lucie Nuclear Power Plant. Data from these 41 short-term recaptures were used to calculate a mean absolute value of error for each measurement method.

Methods

The St. Lucie Power Plant is located in St. Lucie County, Florida on Hutchinson Island, a 36 km long barrier island bordered by the Atlantic ocean on the east and the Indian River Lagoon on the west. Cooling water for the plant is pulled from the Atlantic Ocean into an intake canal system. Sea turtles are entrained with this cooling water and are captured from the power plant's intake canal by tangle nets, dip nets or hand capture by divers. Straight line measurements were made with forestry calipers and over the curve measurements with a tailor's tape. Turtles selected for this study were recaptures from our tagging program with intervals of less than 14 days, where true growth is negligible (less than 0.01 cm from our growth data). Therefore, any measurement differences between subsequent recaptures are attributable solely to measurement error. Forty-one recaptured green turtles were used to calculate an absolute value of error for straight standard and curved standard length measurements. Measurements at first capture and at recapture were made by any one of six different observers under routine field conditions. At no time did any of these observers know that their measurements would be used to calculate measurement error. A matched pairs *t*-test was used to assess differences in error between measurement methods.

Results

Results indicate that measurement error for experienced observers is small (0.2 cm for straight length measurements), but is sufficient to obscure real growth over time intervals of 1-2 months. In all cases, straight line measurements were found to be more reliable than over the curve measurements. Error was calculated at an absolute mean of 0.21 cm for straight length measurements and 0.44 cm for over the curve measurements. Error rates for curved length measurements were significantly greater than those for straight measurements (matched pairs *t*-test, $t = 3.52$, $P = 0.01$).

Discussion

Determining how much of the measured "growth" increment is attributable to measurement error is critical when working with slow growing animals (Bjorndal and Bolten, 1988). The effect measurement error has on morphometric data collected in the field is an important aspect of any growth rate study and must be addressed to validate any findings. Our approach to calculating measurement error by simply examining, *a posteriori,* measurements that were routinely collected may be applicable to many data sets out there that have recaptures over a suitably short time interval, such as intensive netting efforts or the renesting of adult turtles within a single season. This "double blind" approach eliminates a major and otherwise almost unavoidable bias in the calculation of measurement error.

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Assessment of Potential Sea Turtle Nesting on the Peninsula De Paria, Sucre State, Venezuela

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In Venezuela there are five species of sea turtles: *Chelonia mydas, Eretmochelys imbricata*, *Caretta caretta*, *Lepidochelys olivacea* and *Dermochelys coriacea*. Only *L. olivacea* does not nest in the country. The Península of Paria (Sucre State) seems to be the most important mainland area for nesting. However, information on the specific beaches and number of females nesting, as well as, sources of mortality and other risks is incomplete. A long term goal of this study is to propose guidelines for research and conservation efforts by governmental and non-governmental organizations in the Peninsula of Paria. The proposed guidelines will be part of the follow-up efforts recommended in the Sea Turtle Recovery Action Plan for Venezuela which is currently in its final phase (Guada & Sole, in final review).

Methods and Preliminary Results

We have predicted the potential sea turtle nesting sites in the Península de Paria, considering the preferences of the different species for certain types of nesting habitat, and the environmental characteristics of the area, using cartography and aerial photographs of the coast line. Field work during the reproductive seasons of 1997 and 1998 was carried out to test the predictions on potential nesting sites. Additionally, we have listed the impacts on sea turtles in the area. The results are currently being analyzed. We are interested in knowing if this approach will be useful for predicting potential nesting beaches for sea turtles in other areas.

Acknowledgments

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Using GIS to Study Habitat Use by Subadult Loggerhead Sea Turtles (*Caretta caretta*) at the Flower Garden Banks National Marine Sanctuary in the Northwest Gulf of Mexico

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Satellite tracking has proven to be a useful tool to study the habitat use and migration patterns of terrestrial and marine animals, including the loggerhead sea turtle (Timko and Kolz 1982; Stoneburner 1982; Byles 1988a, b; Byles and Dodd 1989; Keinath *et al.* 1989; Byles and Keinath 1990; Hays *et al.* 1991; Renaud and Carpenter 1994). Satellite transmitters have been used to track subadult male and female loggerhead sea turtles at the

Flower Garden Banks National Marine Sanctuary since 1995. The development of Geographic Information Systems (GIS) has afforded us an opportunity to integrate physical and oceanographic features with the geographic locality retrieved via satellite telemetry. The purpose of this poster is to illustrate a variety of uses of GIS to study the habitat use of the Flower Garden Banks National Marine Sanctuary by large juvenile loggerheads.

The Flower Garden Banks NMS

The Flower Garden Banks National Marine Sanctuary (NOAA - Dept. of Commerce) is located approximately 110 miles south of the Texas/Louisiana border, in the Northwest Gulf of Mexico. It was designated as a Sanctuary in 1992. The banks are the northernmost coral reefs on the continental shelf of North America, existing at the very limits of coral reef building tolerance. The East and West Flower Garden Banks are true coral reefs rising to within 18 meters of the ocean surface. The East Bank is a pear shaped dome with a reef crest of about 250 acres. The oblong shaped West Bank has a reef crest of a little more than 100 acres. The third, and smallest bank, Stetson Bank, became part of the Sanctuary in 1996. The crest covers around one acre. It is not a coral reef because it is subjected to slightly lower temperatures than the two Flower Garden Banks during the winter months-temperatures not within the tolerance levels for corals to build reefs. It is, however, an extremely rich marine habitat–a fire coral and sponge community built upon claystone outcroppings.

Turtle Capture

Six large (~50-100kg) juvenile loggerheads have been captured over the period of this study. For all but one of the captures, the animals were resting underneath ledges at approximately 28 meters. The animals were directed into a catch bag constructed after a model designed by NMFS Galveston (Renaud 1994). One animal was guided from behind into the open catch bag while she was swimming in the water column at around 20 meters depth. Once on the surface, the animals were floated into an aluminum basket, and winched onto the deck of the support vessel.

Methods

GIS layers were either constructed or imported from another source and integrated into an ArcView GIS Version 3.1 program.

Sea Turtle Location and Sanctuary Boundary Layers: Data were manually input into an Excel spreadsheet, then converted to Database Format (DBF), and transferred into ArcView Shapefiles (SHP)

Bathymetry Layer: Arcinfo gridfiles on CD-ROM obtained from USGS were converted into ArcView gridfiles. The density of the bathymetry was thinned out from 5m pixels to 25m pixels with PV Wave, a program which is used to manipulate large numerical data sets.

Coastline Layer: Imported from a standard software package– data was already in SHP format.

Platform Location Layer: Data was downloaded from Minerals Management Services Website, converted into DBF, then SHP format.

Location Classes

3	4 messages received, at least 2 of 4 plausibility tests, 1000m accuracy
2	4 messages received, at least 2 of 4 plausibility tests, 350m accuracy
1	4 messages received, at least 2 of 4 plausibility tests, 150m accuracy
0	4 messages, no accuracy reported
A	3 messages, 2 plausibility tests, no accuracy estimate
B	2 messages, 2 plausibility tests, no accuracy estimate

Location Accuracy: Data retrieved from the satellite transmitters are processed by Argos. The points are rated according to their accuracy, as listed above.

Interestingly enough, from the map that was produced from the data received from the transmitters, it indicates that the animals rarely visit the reef crest (high diversity reef) of the bank. The animals are often sighted on the reef crest by researchers and-in fact, this is the location of all captures. It leads me to question the accuracy of the locations. On a broad scale, the information received from the satellite locations is useful, but care must be taken when attempting to analyze location data.

Site Fidelity: Loggerheads have been documented to show strong site fidelity. We were able to confirm that these animals prefer one bank over the other, however, using the different GIS layers, we were able to see that in some cases, the animals possibly make the 12 mile journey over to visit the second Flower Gardens Bank.

Daily Activity: Comparisons between day and night location data can be illustrated using GIS. Day and night data points may be separated by taking the sunrise and sunset times on the 15th day of each month and applying those times to each day of a given month.

One example showed that there was no clear difference between activity during the night and day hours. During the course of the research, we hypothesized that the male turtle, Triton, was spending his nights sleeping on the reef crest, while foraging in deeper water during the daytime hours. After analyzing the GIS maps, we can now see that we were incorrect in this assumption.

Seasonality: It is easy to compare different parameters for an individual using GIS – for example, we have compared Summer activity (March 21-September 22) to Winter activity (September 23-March 20) for one individual.

In one example we would easily have come to the conclusion that the animal had an expanded foraging area during the summer months. We have to be careful when evaluating this type of information, as there are other factors that need to be considered. Weather conditions are generally less favorable during the winter months– increased wave heights, for example. This may certainly decrease the opportunities for transmissions to the satellite, thus giving an incomplete picture of the true movements of the animal. On the other hand, the picture may be accurate, as a decrease in water temperature may cause decreased movements by the animal.

Other Uses: GIS can answer questions that may address the impacts of man made structures for which GIS layers are available–in our case, oil platforms. The Gulf of Mexico is home to around 6000 oil platforms, many of which are well within the range of a sea turtle captured at the Flower Garden Banks National Marine Sanctuary. It is standard practice to survey platforms for loggerhead turtles before a platform is removed by explosives. NMFS (Galveston) has shown that some loggerheads express fidelity for these platforms. We were curious whether the Flower Gardens animals were spending time at any of the platforms nearby. When we imported the GIS layer made available to us by Minerals Management Service (MMS), we were able to conclude that these animals were not spending any significant time at the oil platforms within their ranges.

Acknowledgments

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Magnetic Field Distortions Produced by Wire Nest Cages

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Loggerhead sea turtles return to their natal beach region to mate or nest[1]. The sensory basis of this homing is not known. One hypothesis is that hatchlings imprint on magnetic features of the natal beach[2,3] and use them in homing. If such imprinting occurs, however, then turtles that experience an unnatural field during development may have difficulty navigating back to the appropriate region.

A common conservation practice is to enclose turtle nests in galvanized wire mesh cages to protect eggs from raccoons, foxes and other predators. Two cage designs, a cube and a dome, are often used. We investigated whether these protective cages altered the local magnetic field at the position of the developing eggs. Specifically we asked:

•Do nest cages distort the local magnetic field?

•Is there a difference in field distortion at different levels or between different cage designs?

•What are the geographical equivalents of these distortions that might cause navigational errors if sea turtles are homing using these cues?

Methods

One cube-shaped and one dome-shaped galvanized steel wire cage were tested.

Each cage was placed in an area with good uniformity of the earth's magnetic field. The cube cage was similar in design to a popular design[4]; its dimensions were 60x60x60 cm. The dome cage was a prototype design with dimensions 90x90x45. Both cages were previously used on south Florida beaches.

Measurements of the magnetic field were made 20, 40 and 60 cm below the edge of each cage at nine different points: below the center, each corner, and each side midpoint. Cages were aligned with one side parallel to the north-south axis of the local magnetic field. The horizontal and vertical components of the magnetic field were measured using a Schonstedt DM2220R digital magnetometer.

From these measurements, field intensity and inclination angle were calculated and compared to the value with no cage present. The magnitude of the changes at each point was averaged for each distance, and this "plane average" was used for comparison.

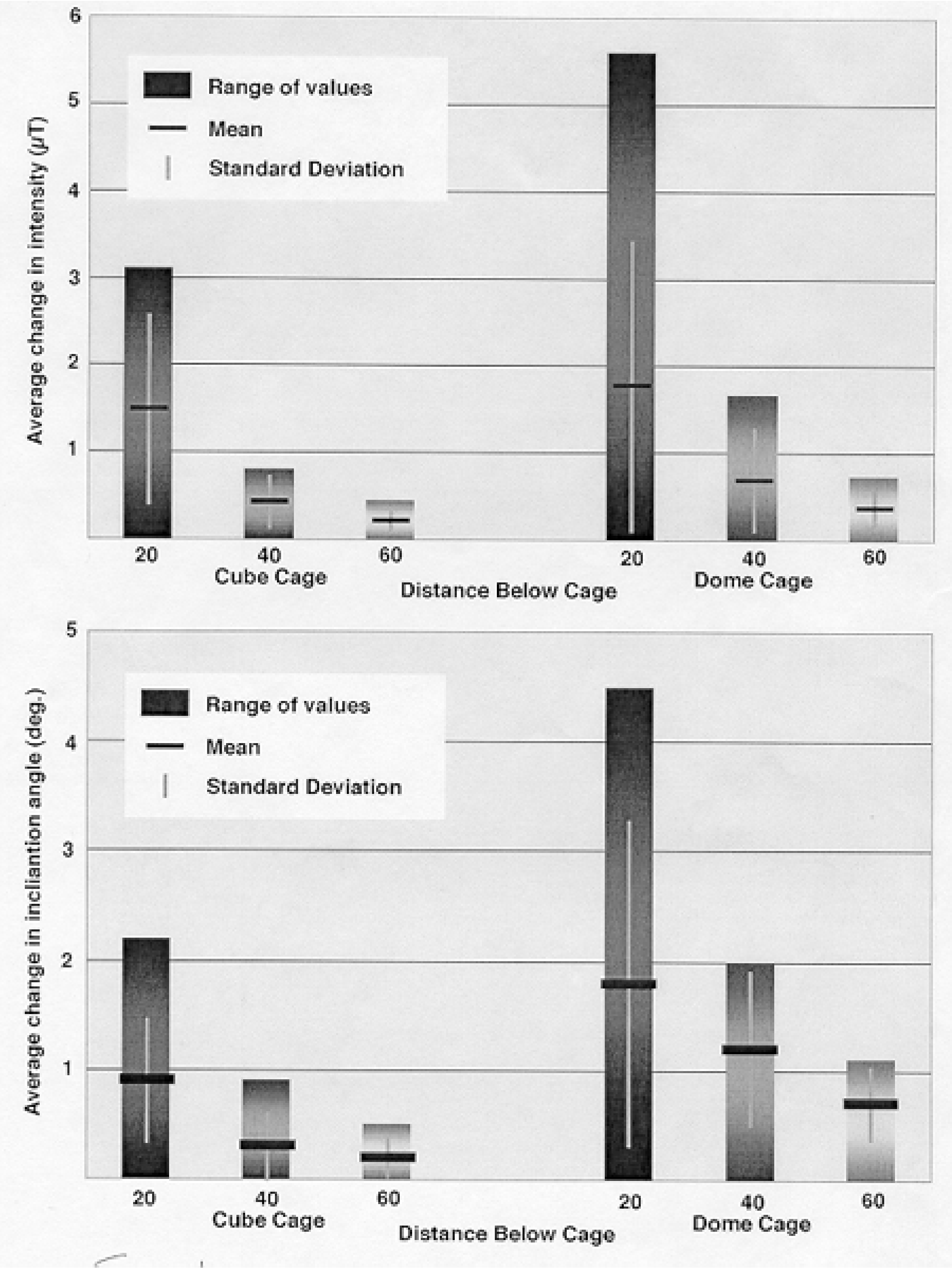

Figure 1. Comparisons between cage types and measurement levels. The range of measurements, mean and standard deviation of the magnitude of field distortions at each level are indicated.

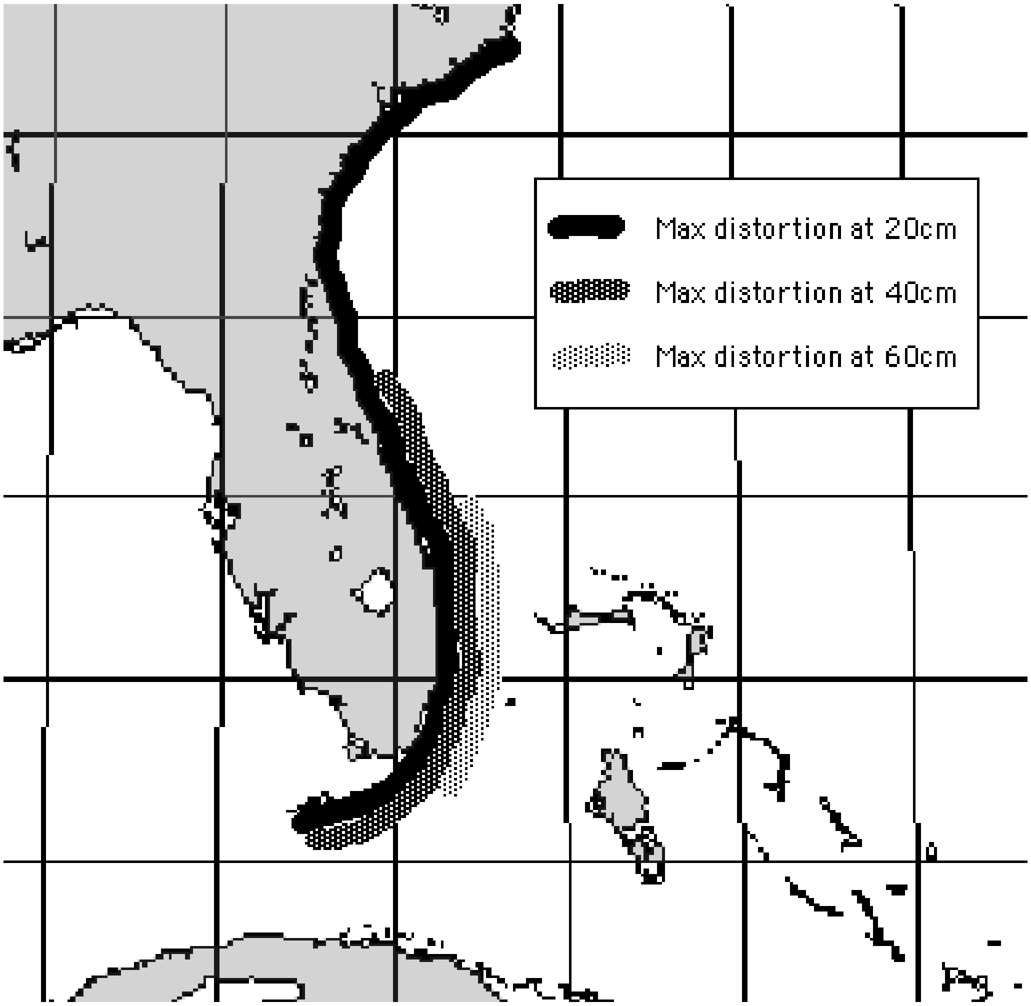

Figure 2. Possible navigational errors caused by field distortions. For this example, the geographic range of the shoreline equivalent to the inclination angle measurements made below the dome cage is shown. If turtles imprint on inclination angle at their natal beach and use this information for homing they may return to a different region along the coast. Other ways of using the geomagnetic information could lead to either larger or smaller displacements.

Results

The local magnetic field had a uniform intensity of 48.6µT and inclination angle of 64.3° at all 27 test points without a cage present.

Measurements of distortion below cages varied widely but were generally more severe closer to cages and more severe under the dome cage than under the cube cage (**Fig. 1**).

Discussion

Each cage measurably altered the inclination angle and intensity of the magnetic field beneath it, but the magnitude of field distortions decreased with distance below the cage (**Fig. 1**). Thus, the field change that developing eggs will experience depends on their position relative to the cage. Distortions caused by the dome cage appear more severe at each level than those of the cube-shaped cage. Since the magnitude and direction of distortions varied widely, and individual cages are likely to differ greatly there is no way to predict the field deviations at any specific location.

Though the geographical distance corresponding to changes in magnetic field parameters of this magnitude vary with location, there is no way to predict what effects these alterations may have on the homing ability of individual turtles.

Using current geomagnetic maps and the data obtained with the cages tested, hypothetical geomagnetic positional displacement was calculated for a typical loggerhead nesting area near Boca Raton, FL (**Fig. 2**).

Because nest depth and cage position relative to the eggs may vary, the averages calculated should be used only as relative comparisons between depths and between cage designs. We emphasize that, at present, no direct experimental evidence exists to support or refute the magnetic imprinting hypothesis. Thus, the potential risk of disrupting magnetic navigation must be weighed against the very real threat of nest depredation. Appropriate choices of construction material and cage design can minimize effects of field distortion in areas where cages are needed.

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A Method for Selecting Survey Timing and Duration for Hawksbill Nesting Beach Studies

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Nesting beach surveys for hawksbill turtles are hampered by factors that relate to detectability and protracted nesting seasons. Using a simulation exercise on long-term data set that covers saturation tagging of a nesting population in the eastern Caribbean, survey duration and timing are optimized. The results suggest that valid estimates of the expected number of nesters emerging in any year can be gained from surveys covering a fraction of the major hawksbill nesting season.

Prevention and Control of Fly Larvae that Infest Sea Turtles

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Since their appearance on the planet, marine turtles have been preyed upon by a great number of animals, but it has been, possibly, in the last hundred years that the pillaging has intensified, in great measure due to the indiscriminate direct consumption by man and his introduction of domestic animals onto the beaches, in addition to the wild ones. However, other predators exist that are much more discreet but just as harmful as man: insects. Between them, the beetle (*Omorgus suberosus fabricios*) and the fly of the Sarcophagide family, can kill up to 100% of hatchlings in a nest. The fly impacts a nest after the hatchlings have broken out of their shells and spill the amniotic liquid into the sand. Fly larvae are deposited on the surface of the nest and in just 6 hours the larvae reach the hatchlings, and begin feeding on the yolksac, causing death.

Since 1988, in order to prevent the infestation of fly larvae, a protection program was implemented on Escobilla beach. Ten days before the hatchlings emerge, a cloth is placed over each one of the hoops that protects the nests, assuring the reduction of fly infestations and, therefore, an increase in hatchling survivorship. This technique was introduced in 1989 at Rancho Nuevo, where it is still used effectively. It has been similarly used in other turtle projects in the Mexican Republic.

For the control of the adult fly, insect traps have been used. They consist of a white colored, wooden cross that is covered in a transparent, odorless and colorless glue. At the base of the trap is placed attractive bait. The fly, attracted by the bait, flies towards the cross and becomes stuck. This technique has been very effective for the control of fly larvae in the wild or in corrals where the eggs of sea turtles are incubated

Using a Geographic Information System (GIS) to Map the Nesting Beaches of Florida, USA

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As part of the Statewide Nesting Beach Survey program, the Florida Department of Environmental Protection (FDEP) collects data on the frequency, geographic extent, and timing of the nesting activity of marine turtles in Florida. The software program ArcViewwas used to create a map of the areas surveyed by permit holders and to link individual beaches to annually reported nesting data. Using a Geographic Information System (GIS) to map the nesting beaches enables FDEP to analyze the data visually and to overlay other layers of pertinent data such as information concerning coastal management (e.g. property ownership, presence of armoring, human population density). The GIS also helps in the maintenance of discrete survey boundaries and the identification of nesting areas that are not being monitored. This project will eventually be available to the general public and others in a CD-ROM produced by the FDEP.

The Argos Data Collection and Location System Preparing for the Future

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The Argos system has provided satellite-based data collection and geo-location to its user community for 20 years. The Argos system has unique capabilities that differentiate it from other communications systems. These capabilities make Argos the system of choice for biologists operating in remote or harsh environments.

The launch of NOAA - K began the first of a number of Argos enhancements scheduled for the near-term future. NOAA-K, successfully launched in May 1998, carries the first Argos-2 instrument, which features a wider bandwidth, increased onboard processing capabilities, and a more sensitive onboard receiver. This translates into greater system capacity, higher data throughput, and lower Argos transmitter power requirements.

Beginning with the launch of the Japanese satellite, ADEOS-2, in 2000, Argos will introduce a downlink messaging capability. This will provide the ability to remotely control transmitting platforms, which will lead to greater flexibility, improved performance, and generally more effective and economical data collection.

Argos-3, featuring still greater capabilities, is being planned for future satellite systems, such as the European METOP series, and the converged U. S. National Polar Orbiting Environmental Satellite System (NPOESS). NPOESS will combine the instrument requirements of NOAA and the USAF into one satellite series. Argos will continue to seek out user requirements as it prepares for the future of satellite telemetry beyond 2010.

Characterizing the Developmental Habitats and Habitat Utilization by Kemp's Ridley Turtles using GIS

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Characterizing the developmental habitats and determining habitat utilization of Kemp's ridley turtles have been identified as priority research tasks. Geographic information systems (GIS) are commonly used to georeference observations of wildlife species to resource maps in order to analyze animal-habitat relationships. Kemp's ridley turtles were tracked via radio and sonic telemetry and their combined locations were used to delineate a study area polygon east of the Cedar Keys, Florida. Benthic samples were systematically collected within the polygon and each site was characterized according to the substrates (mud, sand, shell, and rock) and biological assemblages (seagrasses, green algae, red algae, and live bottom) contained within the sample. A GIS habitat map was produced by hierarchically layering the biological assemblages on a base map of benthic substrates. Habitat utilization by the turtles was estimated by overlaying their foraging ranges and locations on the habitat map. The proportions of available and utilized bottom types generated from GIS analyses were then used to test for habitat preferences by Kemp's ridley turtles.

Using Carapace-Mounted Submersible Cameras to Study Foraging in Black Sea Turtles

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The ecology of marine organisms is often difficult to study due to their submerged existence, inhibiting the ability of researchers to answer basic questions regarding movements, habitat use, feeding, and social behavior. Equipping animals with a variety of telemetry packages has increased our ability to study feeding (stomach temperature sensors, Heath and McGinnis 1980), physiology (heart rate sensors, Kooyman *et al.* 1992), diving (time-depth recorders, Le Boeuff *et al.* 1986), and movements (radio, Dizon and Balazs 1982; sonic, Braun *et al.* 1997; and satellite transmitters, Nichols *et al.* 2000). Despite this, aspects such as feeding and microhabitat selection of many species remain poorly known.

Use of animal-borne imaging and data logging systems (Crittercams) has enabled researchers to increase their understanding of the elusive behaviors of a variety of marine animals (Marshall 1997). During periods of submergence, the devices monitor the movements and behavior of marine organisms through video, audio, and time-depth-recorder (TDR) technology. Carapace-mounted camera (CMC) systems have been deployed in the wild on 22 marine species (Marshall 1997) including 4 sea turtles: hawksbill (van Dam and Diez, 2000), black (Seminoff *et al.* this study), loggerhead (Marshall 1989), and leatherback (Paladino pers. comm.). Here we report on the deployment of carapace-mounted submersible cameras on black sea turtles in the Gulf of California.

Between 1997 and 1998 CMCs were deployed on 8 black sea turtles at the Bahia de los Angeles feeding area of the central Gulf of California. This region is considered an important feeding habitat within the Gulf due to tremendous marine algae pastures (Norris 1975, Pacheco-Ruiz and Zertuche-Gonzalez 1996a; 1996b) and invertebrate populations (Brusca 1980). Gastric lavage and fecal analysis has demonstrated that black turtles in this region feed predominantly on the red algae *Gracilarioposis laminoformis* (Seminoff *et al*. 1998). In addition, a variety of marine invertebrates have been recovered in diet samples (Seminoff *et al*. 2000). Telemetry data demonstrate that black turtles spend large periods in deep water areas void of marine algae, yet the actual patterns of microhabitat and feeding selection are not well known due to our inability to monitor their interactions with benthic features.

The objective of this study was to increase our understanding of black turtle ecology in this Gulf of California feeding habitat. Specifically, through CMC deployment in a variety of areas in the bay our goal was to determine what food resources and habitat types were most commonly utilized by black sea turtles. This knowledge will be highly useful as we begin to develop conservation strategies for this endangered species in the region.

Methods

Turtle capture was facilitated with the use of entanglement nets (100 m x 8 m, mesh size = 50cm stretched). Nets were regularly monitored during each netting trial to prevent drowning mortality. Upon capture, straight carapace length (SCL), weight, and other physical data were recorded, and diet samples collected (Forbes and Limpus 1993). All turtles were released at site of initial capture within 24 hours. CMCs were programmed to begin video and data acquisition approximately one hour after release.

Black turtles were tracked continuously during deployments with the use of radio and sonic telemetry. Researchers stayed within visual range of turtles during the deployments, but took special care to prevent disturbance to the study animals. Surfacing positions and times were recorded for correlation with CMC data and calculation of swim speed, headings, and distances.

Upon recovery of the unit, all data were downloaded to a lap-top computer by the Windows based program *LiteShow* and videos were dubbed to a master tape from which data analysis tapes were later produced.

Results

A total of 8 black turtles were deployed with carapace mounted cameras. Upon release, most turtles exhibited an ‘escape’ response lasting 30 to 40 minutes. This behavior was characterized by erratic breathing and steady offshore movement. As deployments progressed, turtle movements slowed, breathing patterns became more regular, and deep dives became more common. A comparison demonstrated that post-release swim speeds of CMC-equipped turtles were consistent with those from radio/sonic tagged turtles (two sample t-test, p=.94).

CMC deployments yielded a total of 19.98 hours of underwater video footage. Average video length was 2.85 hours (n=7). Upon detachment, CMC recovery usually occurred within 5 minutes. On two occasions, weather conditions prevented immediate recovery (BLA 220, BLA 340). In both cases, units were retrieved the following day.

Sea temperature and dive profiles were successfully recorded in 6 deployments. The data indicate that all turtles commonly traversed sea temperature gradients. Sea temperatures decreased with depth and distance from shore. Dive data revealed 4 dive types: near-surface , mid-water, short benthic , and extended benthic. Maximum submergence time was 27.68 minutes, maximum dive depth was 28 meters (BLA 340).

CMC footage showed black turtles utilize benthic and mid-water areas of the mid-bay zone. There was a positive correlation between bottom time and feeding activity as the only animals that foraged were those that spent extended periods associated with the benthic habitat. Further, these turtles showed affinity to patches of yellow-polyp black corral (*Antipathes galapagensis*). On multiple occasions, turtles appeared to ‘cruise’ along the sea floor and stop upon encountering a patch of *A. galapagensis.* Turtles often settled directly within the branches of this soft coral. On two occasions turtles apparently foraged on unidentified epibionts adhered to the coral. Away from coral patches, CMC video footage revealed consumption of solitary tube worms (*Bispira* spp) anchored in the sandy benthos (BLA 343). Though less common, video footage also revealed mid-water foraging. On two occasions, turtles consumed medusas (Scyphozoa) while swimming at depths of 15 and 17 meters.

No deployments resulted in movement into shallow water (<5m) marine algae pastures and no consumption of algae was documented.

Discussion

The integration of carapace-mounted cameras into current studies near Bahia de los Angeles has enabled us to develop a more well rounded understanding of black sea turtle ecology. Prior to this study it had been determined through surface-based radio and sonic telemetry that black turtles regularly traversed the study area, utilizing both peninsular and insular marine habitats. However, feeding selection and habitat use in the mid-bay zone separating these nearshore habitats was unknown.

Our findings indicate that deep water benthic habitats and mid-water zones are an important component of the Bahia de los Angeles feeding area. The consumption of benthic tube worms is particularly interesting due to the fact that presence of these items in lavage and fecal samples was previously considered to be incidental. Moreover, the association with black coral patches explains the presence of fragments of this deeper water species in gastric lavage and fecal samples. The consumption of the benthic tube worms and affinity to *A. galapagensis* provides substantial evidence that deeper water portions of the mid-bay zone are important for black turtles.

In addition to adding insight to diet samples, CMC video footage was successful in documenting food items not previously recovered in diet samples. In the case of the mid-water consumption of medusas, this is the first documentation of black turtle feeding on such items in the Gulf of California. The significance of this finding is enhanced by the fact that the gelatinous nature of medusas make them highly difficult to recover with either gastric lavage or fecal sampling.

The lack of algae consumption was likely due to the fact that upon release turtles swam immediately offshore, away from algae pastures. An alternate explanation is that black turtles feed predominantly at night in algae pastures. Though telemetry data suggest such a pattern, the short duration of the CMC deployments prevented the monitoring of feeding once turtles returned to these shallow water areas.

Conservation of the black sea turtle will require extensive knowledge on which to base management decisions and the use of carapace-mounted cameras is a new approach at collecting such information. As we continue to integrate CMC use into long-term studies we aim to improve this technology, making CMCs less intrusive and bettering our data acquisition potential. Specifically, new innovations in housing design and advances in the video system will increase the reliability and amount of data gathered. In doing so we will better our ability to provide insight to many aspects of black sea turtle ecology.

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Subsamples of Egg Measurements: Can 14 Years of Data Collection Still be Presumed Significant?

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Identifying patterns of egg sizes and the factors influencing it are critical to the understanding of reproductive investment, ecological strategy and reproductive potential of populations (e.g. Smith and Fretwell, 1974). These, in turn are fundamental to the application of suitable population management approaches, (e.g. Heppell, 1998). It is, therefore, important to identify trends and variation both within and between populations. Subsamples of population parameters, such as egg size, are routinely made throughout biological research, as it is often impossible or impractical to record data on each 'unit'. The size of a sample is frequently dependent upon the logistical abilities of the researchers, the methods of data collection and the time available.

Data on egg diameter (mm +/-0.1) from *Caretta caretta* have been collected during oviposition on the island of Kefalonia for 14 years. Reviewing the data from the last five research seasons (1994-1998) has shown that a spread of subsample sizes have been collected but are concentrated towards the intended maximum: 5 eggs (1994- 1996), 10 eggs (1997-1998). Irrespectively, these subsample sizes typically represent a very low proportion (%) of, and are therefore used to describe, the entire clutch (**Fig. 1**).

During the 1998 season a single (doomed) nest, comprising 83 eggs, was excavated for relocation. Upon excavation all eggs from the nest were measured according to the protocols used in routine measurements during oviposition. These data were assessed to the routine characterization (14 years 1985-1998) of a clutch based on a subsample. The highest and lowest possible means at each respective subsample size establish limits for a range (**Fig. 2**) of potential means that could be obtained assuming a random extraction of the subsample from the population (all eggs in the clutch). This range decreases as the size of the subsample increases and accounts for a larger proportion of the population. The highest value of this range represents the difference of the means from the 2 largest and 2 smallest eggs. The corresponding standard errors (SE) for each of the highest and lowest possible means at each respective subsample size also become more constrained towards a common value as a greater proportion of the clutch (subsample) is accounted into the subsample. Both these parameters approach a relatively conformative level at approx. 16-20 eggs.

The trends suggest that small subsamples, e.g. 5-10 eggs most commonly employed by the KMTP, represent a relatively high probability that a derived mean will not reflect the true mean. A more accurate minimum subsample size should reflect the point at which the SE becomes constrained. The above assessment is based on a random extraction of a subsample from a nest. A study by Hays *et. al.*, (1993) on *Chelonia mydas* has demonstrated that egg size is influenced by its respective position in the clutch. They report that egg size decreases from the start to the end of the clutch oviposited. Therefore, the most accurate mean (based on a subsample) would incorporate a spread of eggs from the entire clutch. This appears to have been rarely achieved during the fourteen years of data collection by the KMTP since measurements are stopped once the intended maximum is achieved. This typically occurred during large clutch oviposits which would imply a bias since the end of the clutch is not sampled adequately. Conversely, subsampling which starts late in oviposition would not include the initial, larger eggs of the clutch. Data concerning the actual position of each subsampled egg within the entire clutch are not available from these 14 years of assessment by the KMTP, and although a basic linear regression between egg size and consecutive subsample number from the clutch

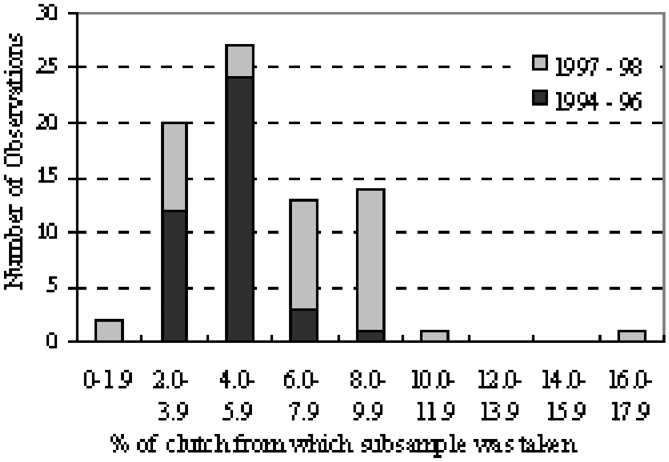

Figure 1. Histogram representing frequency of number of eggs (subsample size) measured as a fraction (%) of the total number of eggs from each respective clutch. Bars are split into 2 year groupings (see text). n=78.

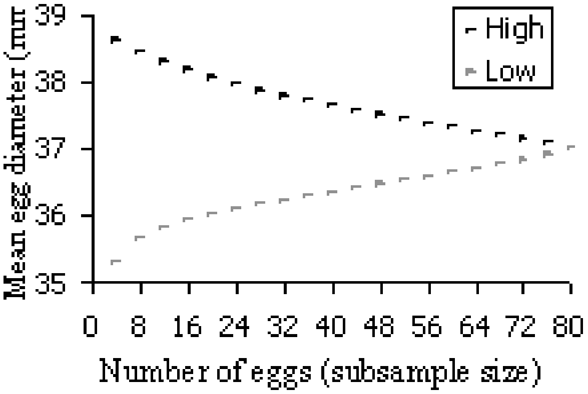

Figure 2. Distribution of mean egg diameter (millimetres: mm) at each respective subsample size. Means are given as highest and lowest possible values attained for a random subsample.

yields a negative slope, it is not statistically significant. This appraisal, however, cannot be fully conclu-sive until we are sure that such observations by Hays *et. al.* (1993) translate to other species, in this case *C. caretta*.

The analysis described here is only representative of one reproductive investment from one female; however, it is known that the sizes of eggs in each clutch varies within and between clutches (e.g. Frazer & Richardson 1985 a, b) and species (Van Buskirk & Crowder 1994). Ultimately, if differences exist in clutch variability within and between females, populations or species, do we need to consider alternate [sub]sampling strategies? Reproductive biology has remained a focus of a large proportion of sea turtle research throughout the past fifty years, but we are still at a point where our most basic assessments are not necessarily aiding the advancement of science, or our understanding, in the most efficient direction. The KMTP has been collecting data concerning the reproductive characteristics of *C. caretta* for 14 years, however, we must answer more questions before determining if it is accurate (and to what degree), and therefore applicable.

Conclusions

The size of the subsampling 'unit' routinely employed to characterize the mean size of egg diameter for the entire clutch is important where a random sampling approach is employed. This observation may have less significance when considering that marine turtles can exhibit a pattern of egg sizes between the beginning and end of oviposition. In either case, it suggests that subsampling procedures employed by the KMTP have not accounted for a proportion of this natural variability, and estimates will contain a degree of error. Further work is required to quantify this variability within and between individuals, populations and species since (future) alternate subsampling strategies may be required. Most fundamentally, this example underlines the importance of the consideration of a methodology before and particularly throughout its application.

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Biotelemetry of Leatherback Sea Turtles (*Dermochelys coriacea*): A Novel In-Water Attachment Method for Transmitters

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Techniques for applying biotelemetry devices to leatherback sea turtles are limited to onshore application and do not allow researchers the opportunity to track males or females beyond one year post nesting. A dart and pole spear were developed to apply devices to in-water leatherbacks in areas where they aggregate or to incidentally captured turtles that can be released alive from commercial fisheries. The dart was tested on nesting leatherbacks and found to remain secure for periods of 9-13 days. A satellite transmitter was fitted to a buoy made of syntactic foam and applied to an in-water leatherback using the dart and pole arrangement. The transmitter remained attached to the turtle for six days before being removed when it was snagged on floating debris or pulled away by a copulating male.

Introduction

Leatherback turtles (*Dermochelys coriacea*) are the most widely distributed of reptiles occurring throughout tropical and temperate oceans of the world (Pritchard, 1980; Carr 1952). Movements of leatherbacks are poorly known as researchers have relied on flipper tag recoveries to describe migratory destinations and philopatry of free-ranging individuals. Recently, satellite telemetry has been successful at monitoring leatherback movements and gathering behavioral data (Eckert 1997, Keinath and Musick, 1993). The advantages of satellite telemetry over other tracking techniques include long-term data acquisition without the need for vessel support. Movements of leatherbacks within one year of nesting have been successfully monitored (Eckert, 1997) although there is no information on movements of male, subadults or those of females during subsequent years at sea. This is due to limitation in attachment including longevity and researchers inability to attach tracking instrumentation once the turtle has left the nesting beach.

Methods of attaching biotelemetry equipment to turtles include adhesive (Beavers *et al*., 1992), harnesses (Keinath and Musick, 1993; Eckert, 1997) or through a hole drilled in the carapace (Dizon and Balazs, 1982). The method chosen for attaching devices depends on the size, behavior, potential future growth and catchability of the species, as well as the characteristics of the environment and the principal study objectives (Boarman *et. al.*, 1998). Anchor holes and harnesses have been used most frequently with leatherbacks as most adhesives do not adhere well to their carapace. These techniques require that the leatherback is stationary and on land for application to be completed.

Darts have been used to attach instrumentation to marine mammals (Croll *et al*. in press) and fish (Block *et. al*.,1998) and are placed in muscle tissue or in blubber that protects vital organs. Leatherbacks are unique among marine turtles in that their carapace is rubbery, four cm thick and constituted mainly of tough, oil-saturated connective tissue (Eckert, 1993). This provides them with protection from the environment and offers anchorage for attaching devices using a dart.

Seasonal aggregations of leatherbacks occur within 10 km of Kei Kecil Island, Indonesia (Suarez and Starbird, 1996). The people of Kei are skilled at approaching and spearing leatherbacks, which they have done for centuries (Aglionby, 1993). Most hunting is done from October-November during the local calm period when 50-75 male and female leatherback sea turtles may be taken annually (Suarez and Starbird 1996). The abundance of leatherbacks around Kei Island and the unique hunting ability of Kei people provide an opportunity to test application of biotelemetry equipment using a dart.

Leatherbacks are listed as endangered species worldwide and recent trends indicate that the population in the Pacific and perhaps the world is declining (Spotila 1996; Eckert, 1997). Conservation efforts should focus on filling gaps in our knowledge of this species and there have been few studies on leatherback behavior while in the pelagic environment. The objective was to test a method of applying biotelemetry equipment to leatherbacks using a pole spear and dart and then to use this method to apply a satellite transmitter to a turtle while they are in the water.

Methods

Four mock biotelemetry buoys containing no devices were attached to post nesting leatherbacks as they moved from their nests to the water. A pole spear (three m, Stan's Skin & SCUBA, San Jose, CA) equipped with darts (four cm long) was used for application. Darts were made of stainless steel (3 mm, Condor Manufacturing, Cambell, CA) and had monofiliment line (50 lb. tensile) attached to the barbs and to magnesium links which were set to corrode after 14 days. This insured that the dart would be free to completely disengage from the turtle after two weeks or if the package became snagged on floating debris. Buoys were attached to darts using stainless steel line (one m) which had magnesium links (20 days) attached in-line to insure release. Buoys were made of syntactic foam (Floatation Technologies, Biddeford, Mass.), were cylindrically shaped (12 cm X 4 cm) and rounded on each end to reduce drag. Darts were applied 10-cm from the posterior end of the carapace on the right side of the peduncle.

A satellite transmitter (200 grams, Telonics, Mesa, Arizona) was housed in a buoy made of syntactic foam. The buoy (25 cm X 10 cm) was designed for stability at the surface and to minimize hydrodynamic drag as it was pulled behind the turtle. Marine epoxy (10-min Evercoat 660 , San Diego, CA) was used to secure the transmitter inside the buoy. A saltwater switch on the end of the transmitter turned it off while underwater to conserve battery life. The buoy and transmitter were mounted on an aluminum pole spear which was balanced to jab or throw up to five m. A tether (0.5 m) attached the dart to the buoy and was made of coated stainless-steel line. Two in-line magnesium links insured that the buoy would be released within 30 days and a link attached to the barbs of the dart insured its release after approximately 20 days. A 1.0 m rope was attached to the end of the pole spear for retrieval following application.

A leatherback turtle was located on the surface near Kei Kecil Island, Indonesia. The turtle was approached to within 2 m and the pole spear was used to apply a dart and satellite package. The transmitter provided information on position only and data were accessed via computer and modem daily.

Results

Four darts and two mock buoys were retrieved from nesting leatherbacks as they returned to the nesting beach on days nine, 11, 12 and 13 of their internesting periods respectively. Two buoys had been broken off tethers although darts remained as they had been originally attached. Darts were found to be in good condition and firmly anchored. Exit wounds created by the removal of darts (diameter=0.5 cm) were no larger than the original entry wound. Penetration (2.5-3.0cm) remained in the connective tissue of the carapace and each dart protruded approximately one cm from the surface of the carapace. Fourteen-day magnesium links holding barbs in place were nearly gone upon retrieval.

A dart and buoy containing a ST-10 satellite transmitter were successfully attached to the rear third of the carapace of a female leatherback turtle around Kei Island, Indonesia. Following application the turtle was tracked for five days. On the sixth day the buoy and transmitter disengaged from the turtle and floated to the surface. It was retrieved ten km from where the package had been applied. The line leading to the barbs of the dart had been broken although the buoy and tether were in their original condition.

Discussion

Mock buoys that broke free from turtles may have been snagged on debris, pulled by the rear flipper of the turtle they were attached to or by a copulating male. Tethers were one meter long and allowed buoys to trail 0.75 m behind the turtle where their rear flipper could have come in contact with the buoy. Breaks in the tether arrangement occurred where a ferrule was used to secure the tether to the darts. This attachment point proved weaker than the line running to the barbs of the dart and two or three ferrules should be used in future studies to insure that tethers do not break and darts disengage when force is applied to the buoy. The length of tethers should allow the buoys to rise to the surface when the turtles surfaces and short enough to avoid entanglement with the rear flippers or floating debris (i.e. <1.0 m). Length of a tether will also depend on the point of attachment of the dart since leatherbacks rear carapace is partially submerged upon surfacing.

Wounds caused by darts did not increase in size despite 9-13 days at sea and darts remained within the cartilaginous layer of the carapace (<3 cm depth). Leatherbacks have been encountered with penetrating billfish wounds to a depth of six cm in their carapace and despite this they have nested and showed sign of healing following removal (Eckert, 1994; P. Pritchard, pers. comm., 1999). All four leatherbacks darted with mock buoys returned to successfully nest after their internesting periods and showed no sign of altered behavior. Although the effect of secondary infection could not be evaluated, wounds caused by darts did not compromise leatherback function or behavior during this study.

A satellite transmitter applied using a dart stayed attached for six days and disengaged when it became snagged on floating debris or was pulled by a copulating male turtle. Leatherbacks have been seen copulating in the area in which the transmitter was applied and 26% of those taken around the Kei Islands are male (Suarez and Starbird, 1996). Male leatherbacks use their front flippers to hold themselves in place often grappling at the carapace of the female (Godfrey and Barreto, 1998). This movement could have resulted in the removal of the dart and buoy from the female they were attached too.

Development of a system to apply tracking equipment to leatherbacks while in water may provide opportunity to study open-water movements including those of subadults and males. It may have special application for tracking incidentally captured leatherbacks or for those that can be approached in oceanic areas where they aggregate. Buoys can be designed to house an assortment of biotelemetry equipment including time-depth-recording devices, satellite, radio or sonic transmitters. Information on diving behavior could be acquired by applying buoys equipped with time-depth-recording devices, radio transmitters and timed releases for retrieval at a predetermined time. This technique has been successful in studies of marine mammals (Croll *et. al*., in press). Pop-up satellite transmitters (Microwave Telemetry, Inc., Columbia, Maryland) have been used successfully on pelagic animals (Block *et. al*., 1998) and may provide another opportunity to researchers interested in the behavior of sea turtles.

Commercial fisheries such as drift gill, set net and longlines have been found to incidentally take leatherback sea turtles (Balazs and Pooley ,1994; Wetherall *et al*., 1993) and have been implicated in the decline of major leatherback nesting beaches around the world (Eckert, 1997; Chan *et al*., 1988). Leatherbacks are commonly found alive when entangled in longlines and may be set free although subsequent mortality may result from hook wounds, internal bleeding or entanglement. Applying a dart with tracking equipment to turtles following entanglement could lead to information on mortality or migration following encounters with commercial fisheries.

Aggregations of leatherbacks around Kei Island and in the coastal areas of the United States (Starbird *et al*., 1993; Lazell, 1980) and Europe (Pritchard pers. comm., 1999) may represent groups of individuals using migratory corridors or foraging areas. Aggregations such as these could greatly increase the vulnerability of the entire population since it is more susceptible to localized threats. Conservation efforts should seek to learn as much as possible about the habits of leatherbacks in areas that are found to be focal points of populations. Application of biotelemetry equipment using darts would increase our understanding of leatherback behavior in these areas. These types of studies along with those focusing on movements in areas of fisheries conflict should enhance the prospects for effective international conservation of this species.

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Differential Global Positioning System (GPS) as a Tool for Studying Nesting Distribution on a Florida Sea Turtle Nesting Beach

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Highly accurate global positioning systems (GPS) when integrated with geographic information systems (GIS) can be very effective tools when evaluating nesting distributions along sea turtle nesting beaches. A Trimble Pro-XL™ real-time, differentially corrected GPS unit with sub-meter accuracy was used during the 1997 and 1998 nesting seasons in Juno Beach and Jupiter, Florida (USA) as part of a five year fishing pier impact study conducted by the Marinelife Center of Juno Beach in cooperation with the Palm Beach County Department of Environmental Resources Management. The data collected includes the locations of nests and aborted nesting attempts per species, and beach features such as rock outcroppings, vegetation lines, dune walkovers, traffic lights, and high profile trees. The data recorded for each turtle crawl also included the date, its relative location (per predetermined 100 meter "zone"), distance to the toe of the dune, and distance to the most recent high water line. The GPS files were then exported to an ArcView GIS™ program using Pathfinder Office™ software. Any desired data, such as nest success, depth, temperature, etc., can then be integrated with the GPS data for each recorded nest. The ArcView GIS™ software enables the user to perform any number of queries to examine nesting and/or false nesting densities and success in relation to any desired parameter or beach feature, including roads, light sources, and coastal development projects. This program also allows the visualization of changes in nesting densities and/or success in relation to changes in beach character due to natural or man-made impacts. Limitations to the use of these systems for nesting research include their high purchase cost, the advanced nature of the software, and the occasional interruptions of satellite signals. Our experience has indicated that GPS/GIS systems may prove to be the most effective mapping tools available for evaluating nesting distribution and assessing short and long-term impacts to sea turtle reproductive success.

Southeast Fisheries Science Center Marine Turtle Tagging Program: Tagging Data Management

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The Cooperative Marine Turtle Tagging Program (CMTTP) has operated at the National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center (SEFSC) since 1980. Program goals were to establish a clearinghouse for data on all flipper tags, prevent duplication of tags, facilitate exchange of tag data, and archive and collate data on all tag series. In response to those needs the CMTTP has catalogued all NMFS tagging data and assists tagging programs worldwide in the exchange and dissemination of tag data and tag related information. However, recent advances in tag technologies and data management have prompted a review of program policies and protocols.

The use of Passive Integrated Transponders (PIT) in sea turtle research has generated new concerns over locating PIT tag owners and the return of tag recapture data. Critical long-term tag recapture data may be collected after completion of a tagging project, therefore policies regarding the use of tag data and tag ownership have been developed. With these measures, and increased coordination between researchers, tag programs, and government agencies, we can continue to close the gaps in our knowledge of sea turtle biology. The policies and protocols set forth by the CMTTP are applicable to sea turtle researchers for the design and/or management of tag databases.

Managing Relocated Sea Turtle Nests in Open-Beach Hatcheries. Lessons in Hatchery Design and Implementation in Hillsboro Beach, Broward County, Florida

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Sea turtle hatcheries are used worldwide and represent the most common of conservation and management methods aimed at enhancing dwindling sea turtle populations. Hatcheries are typically nest relocation sites on relatively high, dark beaches where nests can safely incubate in large numbers. Several studies examined their efficiency and/or the risks to nests on land (Stancyk *et al.* 1980, Hopkins *et al.* 1982, McMurtray 1986). However, few studies examined the consequences to hatchlings entering the ocean from hatcheries (Glenn 1996, Wyneken *et* al. 1996).

Nests are relocated to hatcheries to increase the numbers of hatchlings reaching the water especially in developed areas, and those exposed to photopollution, erosion, egg poachers, and natural nest predators. However, hatcheries can short-circuit the safe-guards that turtles normally employ as part of their reproductive strategies, specifically:

Spatial safeguards: Generally females do not cluster their nests at one site (with the exception of some *Chelonia mydas*; Carr and Carr 1972, Mortimer and Portier 1988). Spreading nests over space (several beaches) reduces local risks.

Temporal safeguards: Depending upon species, females may nest 2-8 times/ season and deposit nests at 10-14 day intervals. Temporal "spreading" reduces the impact of a one-time, catastrophic event.

Predator "swamping": Large numbers of hatchlings emerge simultaneously from each nest. By entering the water together, hatchlings reduce their individual probability of being consumed by a predator ("predator swamping"). This advantage only occurs when predator densities are low. Hatcheries short-circuit these reproductive strategies by clustering the turtles' reproductive effort in a circumscribed area making it easy for both terrestrial and aquatic predators to locate prey.

In Broward County, Florida there is relatively little beach left undeveloped. Sea turtles (primarily *Caretta caretta* and *Chelonia mydas*, with a few *Dermochelys coriacea* and *Eretmochelys imbricata*) utilize the beach as nesting habitat. Because so little beach is safe for incubation, many nests are relocated (68.8% in 1998). Our study was designed to assess hatchery related risks to hatchlings, and to minimize those risks once hatchlings entered the water.

Approach

(I) Reduce prey density: We increased the number of hatchery locations, thus spreading the total number of relocated nests over more beach area. Each hatchery contained few nests.

(II) Change the temporal availability of prey: We relocated nests to one hatchery for a short period, then to another. Thus emergences from any hatchery occurred episodically (rather than continuously).

(III) Monitoring: We completed in-water surveys, and did extensive fishing from shore, to identify predators and estimate their numbers.

(IV) We followed hatchlings as they swam off shore to determine their probabilities of survival from natural (control) and hatchery sites.

Results

Predators and Potential Predators: Fish identifications were based upon Robins *et al.* (1986) and Humann (1992). Squid were identified according to Humann (1994). Documented (**Table 1**) predators were (i) fish we captured whose gastro- intestinal tracts contained hatchlings, or (ii) fish species that we observed eating hatchlings (i.e., mangrove snappers, Crevalle jacks, and tarpon). Mangrove snapper was the most common predator captured by hook

Table 1. Documented hatchling predators.

Common Name	Specific Name
Blue Runner	*Caranx crysos*
Great Barracuda	*Sphyraena barracuda*
Mangrove Snapper	*Lutjanus griseus*
Hardhead Catfish	*Arius felis*
Red Grouper	*Epinephelus morio*
Tarpon	*Megalops atlanticus*
Reef Squid	*Sepiateuthis sepiodea.*

and line; tarpon was most frequently observed eating hatchlings as we followed turtles off shore. During the last year of the study we observed a reef squid (*Sepiateuthis sepiodea*) capture a hatchling.

Survival Assays: Forty (of 152) hatchlings followed off shore in front of hatcheries were taken by predators within 15 minutes; 16 were taken within the first 3 minutes. In total, 26 turtles were taken in front of the oldest (18 yr) hatchery. Only 7 hatchlings (5%) were taken in front of three new hatcheries during their first year of use. Most of these were captured while crossing a nearshore reef.

Conclusions

No site is completely safe. Risk was reduced where nests were less concentrated (e.g., control sites). We chose control sites over sandy bottoms. Sites adjacent to reefs, where predators were more abundant, were more "dangerous" for hatchlings.

(1) Waters adjacent to turtle hatchery sites have higher concentrations of predatory fish than non-hatchery sites.

(2) Sites which are normally less "attractive" to fish, may remain unattractive even if used for a hatchery, provided that the number of nests placed at that location is kept low (approximately one nest every 2 linear meters of beach).

(3) Lowering nest density and hence, decreasing the spatial and temporal concentrations of hatchlings in the water can reduce the aquatic predator risk.

(4) Changing the placement of hatchery sites in consecutive years may reduce the predation risk.

Recommendations

We make the following recommendations, based upon our study.

(1) *When relocating nests, choose hatchery locations carefully*.

(2) Don't put hatcheries adjacent to reefs and inlets; place hatcheries where fish densities are low. Structured habitats concentrate more fish.

(3) Structure hatcheries so that continuous emergences of hatchlings don't occur.

(4) Pro-active approaches, where hatcheries are in use, should include "scouting" for future (next year's) low predator sites during times when hatchlings are entering the water.

(5) *Monitor nest relocation sites continuously to be aware of changing conditions*. Reefs may become exposed providing new habitat for predatory fish and invertebrates. Predator concentrations may change from year to year, so vigilance is important.

(6) *Hatcheries do not absolve the need to correct problems that cause or contribute to turtle population declines*. Hatchery use addresses just one component of the problem: hatchling numbers leaving the beach. They do not contend with the conflicts in habitat use that still need to be solved.

When hatcheries are used, if space, time, reef location, and site history are not considered, then hatchery use becomes nothing more than a halfway technology (Frazer, 1992).

Acknowledgments

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CONSERVATION PROGRAMS AND PROGRESS

The Sea Turtle Program of X'Caret, the Eco-Archeological Park, in Quintana Roo, Mexico

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Along the coasts of the state of Quintana Roo, Mexico are the principle nesting areas for loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) turtles. In 1998, there were 1033 loggerhead and 1053 green nests. Since 1991, X'Caret has participated in various sea turtle conservation activities in the Mexican Caribbean. In 1998, we continued a sea turtle conservation program on the central coast of Quintana Roo, that the defunct Centro de Investigacíones de Quintana Roo (CIQRO) started. This presentation is a description and the results of our conservation work on the beaches of Quintana Roo during 1998. We also review the living tag program in the Eco-Archeological Park of X'caret.

Enchanting a Community with Sea Turtles: A Model Inspired by Archie Carr

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Throughout history there have been those few scientists who, transcending the limitations of scientific discourse, have presented their scientific experience as adventure. Archie Carr, among Darwin and Gould, was a scientist of this tradition. For decades, Carr's writings have charmed and informed scientists and enthusiasts alike with the life of sea turtles, the object of his infatuation and, in essence, his life's work.

This poster presentation will give an account of a community conservation model that is guided by the inspiration of Archie Carr. An analysis of Carr's *So Excellent a Fishe* will identify the principles that have led a group of volunteers on a small barrier island to successfully involve the community in sea turtle conservation. In one season the community of Folly Beach (<40 nests), was transformed from a community of relative indifference to one of engaged interest and cooperation regarding the well-being of sea turtles. A group of five volunteers and one biologist gained the cooperation of local agencies, organizations, residents, and tourists in protecting nesting turtles, incubating clutches, and emerging hatchlings.

In the tradition of Archie Carr, this group mythologized sea turtles and engaged the community while imparting facts and modeling appropriate responses in an effective interweave of involvement. As a result, with an addition of only 3 nests, an increase of over 1100 hatchlings was achieved (55%). In addition, corporate sponsorship has now been secured. This model, based on Carr's intuition and science, will be explained, including goals for the future.

Utilizing Research and Education to Enhance Public Awareness for Sea Turtle Conservation on A Northwest Florida Barrier Island

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The Apalachicola National Estuarine Research Reserve (ANERR), a joint effort between NOAA and the Florida Dept. of Environmental Protection, is one of 23 research reserves nationwide. ANERR has been involved with sea turtle nest monitoring in Franklin County since 1990 through the Florida Marine Research Institute's (FMRI) statewide monitoring program (Meylan *et al.*, 1995). The barrier island beaches in the Apalachicola area (**Fig. 1**) support some of the densest concentrations of nesting loggerhead sea turtles in northwest Florida with rare occurrences of green and leatherback sea turtle nests (ANERR, 1998; Calleson *et al.*, 1998; Edmiston *et al.*, unpubl.). Nesting data for 1998 indicated a record high 656 total crawls (**Fig. 2**) investigated for ANERR's beaches coincident with heightened staff effort, increased public awareness, and a possible rise in sea turtle nesting density (Edmiston *et al.*, unpubl.).

Of the islands that Reserve staff monitor, St. George Island presents, perhaps, the most difficult management problem. The documentation of sea turtle crawls has increased 69% over the last 4 years on St. George Island. This island is currently faced with the pressures imposed by residential development and tourism, thus creating increased risks to sea turtle adults and hatchlings as a result of artificial beachfront lighting. Prior to the 1997 season, the maximum number of reported hatchling disorientation

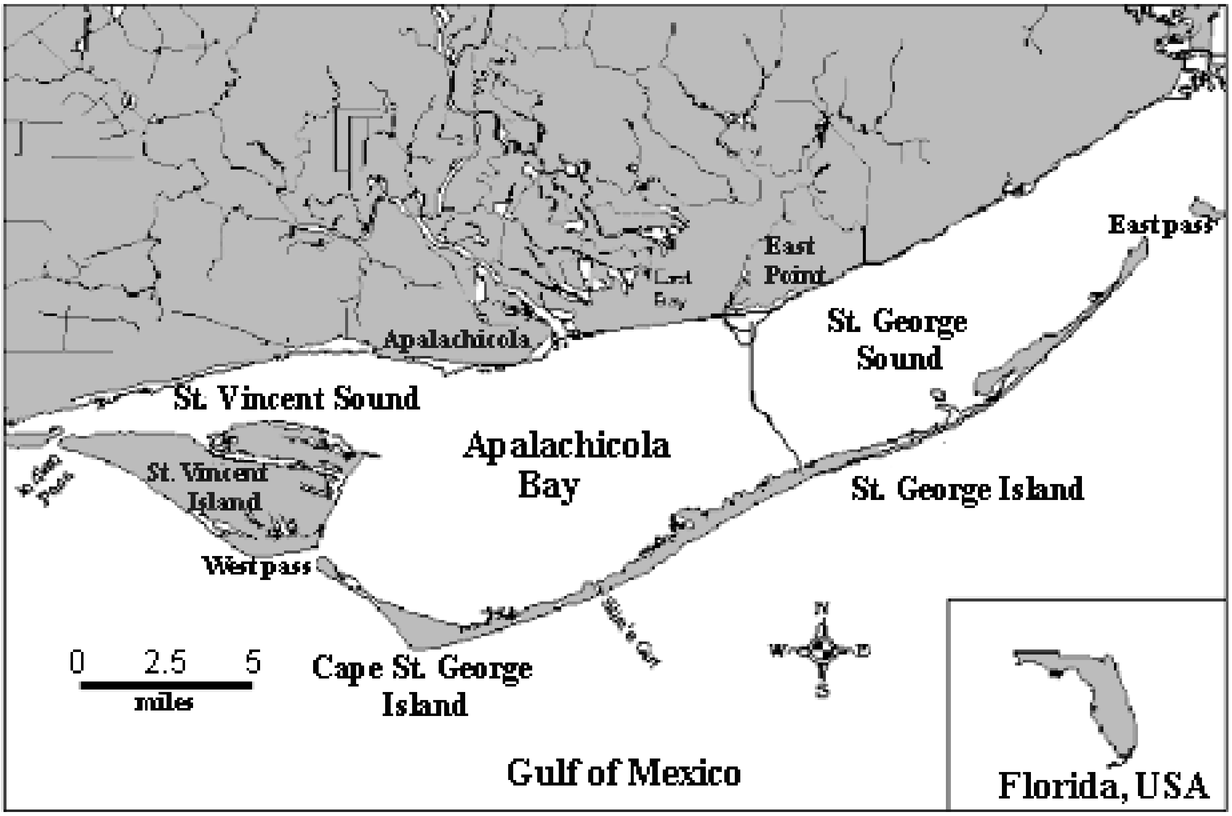

Figure 1. The Apalachicola Bay system.

events per year was 5. However, in 1997, ANERR biologists were faced with 37 documented events as well as 27 reported disorientations that occurred in 1998 prior to Hurricanes Earl and George. As a result of the threats imposed by artificial beachfront lighting and the encroaching development, Reserve staff targeted public education as the focus of their sea turtle conservation efforts.

Public Education Efforts

Prior to and during the sea turtle nesting season, ANERR staff distribute brochures to local realtors to post in beach rental units, encourage educational spots on the local radio station, contribute information to local newspaper articles, work with Florida Power Corporation (the local utility company) to get problem street lights turned off for the season, and remind private homeowners and renters to keep beachfront porch lights off in the vicinity of nests that are close to hatching. A variety of educational materials (including light switch covers and educational signs for public access areas) have been designed, produced, and distributed on St. George Island. A light switch cover depicting hatchlings, season duration, and hours to keep lights off was developed by a Reserve volunteer and modified and purchased by Florida Power for distribution to beach-front houses prior to the 1998 nesting season. Distribution was a collaborative effort between ANERR staff, St. George Island realtors, Florida Power Corporation, and a local Boy Scout troop.

To further educate the public, Reserve staff designed a billboard to remind St. George Island residents and visitors

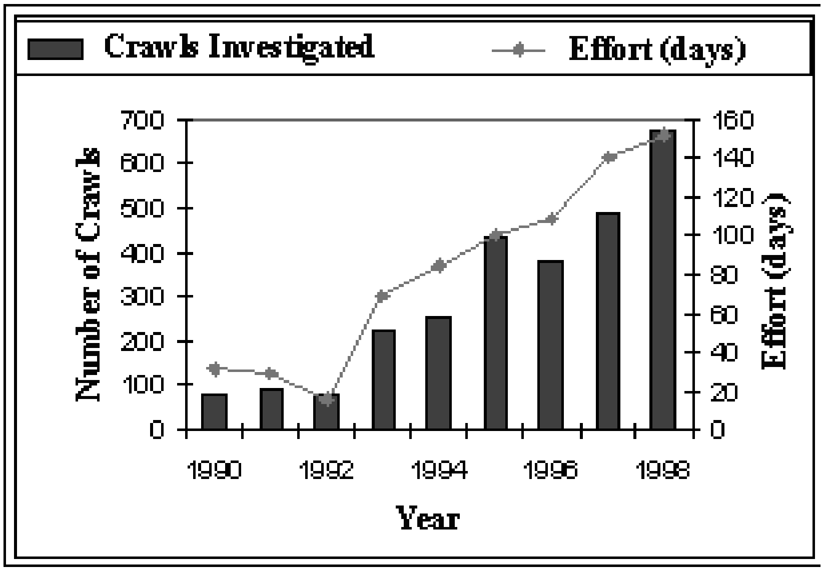

Figure 2. Total number of crawls investigated for each year plotted against effort. (Effort is defined as the number of days in which staff either performed a regular patrol or responded to a report of a crawl.)

to keep beachfront lighting to a minimum during the turtle nesting season. This community-funded billboard was a cooperative effort between ANERR and the Friends of the Reserve organization (ANERR's citizen support group), Bay Media Services, Billy Rob signs, Franklin County, Oyster Radio 100.5 FM, and the St. George Island Civic Club.

A doorhanger has also been designed which will be used for the 1999 nesting/hatching season to notify and educate homeowners/renters at houses with problem lighting. The doorhangers as well as sea turtle signs for the island's major access points were paid for by a concerned island resident who donated money to the Friends of the Reserve for sea turtle conservation. However, the most aggressive tactic to combat the lighting problem was the cooperation of a local attorney (Barbara Sanders), the island's civic club, Reserve personnel, the Franklin County Commission, Florida Power, and the USFWS to formulate a lighting ordinance for Franklin County. The passage of this ordinance on June 16, 1998, was monumental since it represented the first for northwest Florida.

Discussion

Public awareness of nesting activity has increased locally due to education efforts by the Reserve and other entities such as the USFWS and the Florida State Parks. While the Research staff at the Reserve conducts the majority of the sea turtle nest monitoring, the Education section incorporates sea turtle information into their programs, which educate thousands of people of all ages about the coastal ecosystem. The liberal use of lectures, newspaper articles, public service radio spots, flyers, brochures, and on-site interpretive efforts provide many of the contacts the Reserve depends on for reporting turtle crawls, nests, strandings, and hatchling disorientations. The Reserve's public education efforts have undoubtedly contributed to both increased crawl and disorientation reporting. Thus, observed increases in nesting or disorientations should be evaluated conservatively with the consideration of several key variables: increased public awareness, elevated staff and volunteer efforts, encroaching development, and a possible increase in nesting density.

The Reserve's efforts should be facilitated by the development of pertinent educational materials and the implementation of the Franklin County lighting ordinance. The collaborative efforts of the Reserve with those of community leaders, residents, and visitors will hopefully lead the hatchlings that emerge from St. George Island nests on a more "directed" path toward survival and will be essential to their recovery. The emphasis placed on sea turtle conservation and the cooperative effort of Research and Education personnel will help to ensure that sea turtles continue to nest on Franklin County beaches for many years to come.

Acknowledgements

The authors would like to express their appreciation to the ANERR for providing staff time to monitor and protect nesting sea turtles and hatchlings on the barrier islands of Franklin County and for their commitment to the monitoring and protection of endangered species within the Reserve. In addition, special thanks to our volunteers, local residents, and visitors to Franklin County for their awareness with regards to sea turtle nesting and conservation. Their reports pertaining to nesting adults and hatchling emergence are vital to ANERR's research efforts. The authors would also like to thank Barbara Sanders, Thom Lewis, Alan Pierce, the Franklin County Commission, and the residents and homeowners of Franklin County for their roles in the passage of the lighting ordinance.

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Conservation of the Sea Turtles in Gandoca Beach, Gandoca/Manzanillo National Wildlife Refuge, Costa Rica

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The work reported here was carried out from February to September, 1998, on Gandoca Beach, located in Limón Province, along the southeastern Caribbean coast of Costa Rica. Each year this beach serves as a nesting site for four species of sea turtles which, prior to 1985, had been exploited indiscriminately. In that year, the community of Gandoca, government authorities and ANAI began joint efforts to conserve the nesting colonies through a collaborative process that would also contribute to an improvement in the quality of human life in Gandoca. The most abundant species at Gandoca Beach is the leatherback turtle, which nests primarily between February and September.

The main objective was to conserve the nesting rookery of *Dermochelys coriacea* at Gandoca Beach, and induce efforts to conserve it on neighboring beaches, especially in northern Costa Rica and along Panama's north coast. Conservation was effected through nocturnal patrols every night during the nesting season. Whenever a turtle was encountered, its nest was camouflaged or its eggs were relocated to a more secure site or to one of two hatcheries constructed on the beach. A total of 599 leatherback nests, 43 green turtle nests and 38 hawksbill turtle nests were counted; 162 leatherback females were observed. The destiny of these nests was as follows: 29.8% were relocated to one of the hatcheries; 22.0% were relocated on the berm of the beach above the high tide line; 27.8% were camouflaged in situ; 10.0% were left untouched; 9.6% were lost to poachers; and less than 0.5% were donated to poor families of the community. Thus 612 nests of all species (90% of the total) were successfully protected from loss to poachers or erosion by the sea. Only 25% of the natural nests survived, principally due to erosion and depredation. The rate of hatching of eggs in the surviving natural nests on the beach was 71% (30%-90%), equaling a 17.75% hatchling success rate; the same rate in the hatcheries was 43.28% and varied from 0 to 98%. We liberated a total 6,400 hatchlings from the hatcheries; 16,400 are estimated to have successfully hatched from nests outside the hatcheries. A total of 449 volunteers and visitors assisted for periods of 1 week to 5 months; 63% of the volunteers were lodged in houses in the community, thus providing an alternative economic use of the turtle resource. This activity produced an income of $16,406 U.S. for the community, plus a total of $41,400 of other direct and indirect income generated by the project (local salaries, extra food and drink purchases, guide services, transport, and others). We were able to demonstrate that the volunteer program produced four times more income in the community than would have been realized if 100% of the eggs had been harvested and sold on the black market. In addition, the distribution of these newly generated economic resources has been more just and equitable, resulting in notable improvements in the quality of life, buying power and future economic potential for families near the coast.

The donors who provided critically needed support are Frankfurt Zoological Society-Help for Threatened Wildlife, PROARCA-Costas, World Wildlife Fund, The Nature Conservancy, People Trust and Tropica Verde.

The Turtle Islands Integrated Conservation and Development Project (ICDP): A Collaborative Government and NGO Approach for Management

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The Philippine Turtle Islands are a significant green turtle rookery in Asia. Unlike the Sabah Turtle Islands which are entirely protected by law, Baguan is the only Philippine island declared a marine turtle sanctuary. The other five islands support a sizeable human population that engage in the marine turtle egg trade. The Philippine Government, through the Pawikan Conservation Project (PCP), Protected Areas and Wildlife Bureau of the Dept. of Environment & Natural Resources (PAWB-DENR), implemented MNR Administrative Order No. 33 which allows the residents of the Turtle Islands to collect 60% of the eggs produced on four of the islands: Taganak, Lihiman, Langaan and Great Bakkungan.

In 1996, a Memorandum of Agreement between the DENR and World Wildlife Fund-Philippines paved the way for the Turtle Islands Integrated Conservation and Development Project (TIICDP) which aims to enhance the participation of local communities in sea turtle conservation while providing economic opportunities to eventually wean them from turtle egg collection.

This paper presents the initial activities undertaken in the Turtle Islands in preparation for the implementation of the Integrated Conservation and Development Project.

Information and Education Communications Program

The PCP conducts ecological tours for elementary and high school students in the Turtle islands. The students are given the chance to observe the activities and operations undertaken on Baguan Island. They are allowed to tag turtles, dig the eggs for transplantation to the hatcheries and release hatchlings to the wild. Short lectures are given and films on marine wildlife conservation are shown. However, bringing the children to Baguan Island depends on the weather conditions and availability of transportation to ensure the safety of the students.

In September 1996, Dalaw-Turo (DT)[a] trainers and facilitators from PAWB-DENR conducted a week-long training course that focused on familiarizing and preparing key persons to disseminate information on marine conservation. Lectures were given on marine wildlife conservation and problems/issues that beset conservation in the area. The participants were given lessons on how to develope materials to address the issues/problems raised. Also, several acting workshops were held to further enhance their creativity in developing Information and Education Communications (IEC) materials, flexibility in dealing with various types of audience and to develop as better communicators.

[a] vernacular for "Visit-Teach". Dalaw-Turo is an environmental education and awareness program of the DENR

After training, the IEC materials that were developed were presented to the community. These included environmental games and skits, interpretative talks on various topics, and brochures and posters. The beneficiaries of the IEC were appreciative and responsive to the activities of the trainees as manifested in the attendance and participation of the community during the presentation.

The DENR through its Gender and Development Program allocated some funds for the setting-up of a reading room for the residents of the Turtle Islands. WWF and PCP have solicited book donations for the reading room. Today, the facility is used not only by the students but also the grade and high school teachers. Some WWF staff also act as tutors in the area.

Establishment of Turtle Islands as a protected area

As previously mentioned, Baguan is the only island established as a marine turtle sanctuary. Notwithstanding the fact that the other islands are equally important as turtle habitats, the PCP worked for its inclusion as one of the ten priority sites of the Integrated Protected Areas System (IPAS). Presently, these sites are being managed by the Conservation of Priority Protected Areas Project (CPPAP), a foreign-assisted project of the DENR with funding support from the Global Environmental Facility B World Bank. The establishment of the area as the Turtle Islands Wildlife Sanctuary under Republic Act No. 7586 or the National Integrated Protected Areas System (NIPAS) Act of 1986 will enhance the conservation and protection of not only the sea turtles, but also the diverse species of flora and fauna.

The PCP is currently assisting the CPPAP Office in the preparation of documents needed for the establishment of the area as a wildlife sanctuary.

Bio-physical Studies in the Turtle Islands

This study aimed at gathering relevant data on the various ecosystem components of the islands, which include geophysical characteristics (climate, oceanography, landscape and topography, geology) and inventory of the marine and terrestrial flora and fauna. A GIS-based information manage-ment system is being developed to store and map information to assess opportunities and constraints for the sustainable development of the island's resources and to illustrate development alternatives. A long-term monitoring program is also being developed to ascertain the islands' ecological integrity. The results of the study were incorporated in the management plan being prepared for the Turtle Islands.

Livelihood Program

Aside from turtle egg collection, dynamite and cyanide fishing prevails in the Turtle Islands. To address the situation, WWF's Endangered Seas Campaign supported a project that introduced the Turtle Island residents to environmentally, friendly alternative sources of income with the goal to reduce dependence on egg collection and to eliminate the use of illegal fishing methods.

A research assessment and relevant training were conducted. A cooperative was formed to operate an alternative livelihood enterprise and credit was provided for a boat to be used and managed by the cooperative. The female members of the cooperative also requested assistance for the establishment of a mini-grocery store.

However, the project has had its share of failures. This was mainly due to a number of fundamental differences between some of the basic principles of a cooperative system and the existing societal patterns in the area (Cola, 1998). This predicament was seen as an opportunity to reassess the approach in undertaking developmental initiatives in the area.

In 1998, WWF-UK and the Dept. of International Development of UK supported the Integrated Conservation & Development Program (ICDP) approach proposed for the Turtle Islands. The first step was to conduct a comprehensive social analysis that included an in-depth social study, institutional assessment, and gender and stakeholders analysis. The results of the analysis are currently used as the basis for the development of an effective strategy to alleviate the social economic condition of the community. The study revealed that sea turtle egg collection is a significant source of livelihood, but not a critical source of income as initially perceived.

Eco-tourism Guidelines for the Turtle Islands

At one time, the Turtle Islands was subject to a media blitz that captured the interest of businessmen to develop the islands as a tourism destination. This prompted the PCP, WWF and the Dept. of Tourism to work together to draft eco-tourism guidelines for the area. The primary considerations were the fragile condition of these very small island ecosystems and the destruction of the important habitats of the turtles. The draft Administrative Order and accompanying Manual is presently with the Office of the DENR Secretary for review and approval.

Also, WWF contracted consultants to draft the Turtle Islands Eco-tourism Development Plan to attain rational utilization of the islands' resources for recreation and conservation.

Conclusions and Recommendations

The initiatives of the DENR through the Pawikan Conservation Project has been successful in its mandate to conserve sea turtles from a biological point of view. However, given the limited resources made available to the PCP, the social and economic concerns of the community are not addressed. This collaboration between the DENR and WWF-Philippines is an attempt to fill in the gap towards an ICDP. As we progress in our efforts, it is now becoming evident that ICDP requires more than the participation of the DENR and WWF-Philippines. The strengthening of the municipal and barangay[b] as a functional institution should be facilitated by this collaboration. A functional relation-

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[b] community or village

ship among the stakeholders especially the local governments and community is a prerequisite for the implementation of ICDP. Such an environment will pave the way for addressing the following issues and concerns:

-Setting the conservation agenda of the community specifically for the Mapun & Tausug communities

-Capability building for local governance

-Negotiate with national government agencies to install social services, access (transportation) and infrastructure

-Enhance provision of health services and sanitation facilities

-Enhance existing livelihood activities to lessen dependency on egg collection

-Provide income opportunities for women to enhance economic productivity and control population growth

-Rationalize tenurial and land classification

-Improve the educational system with more follow-up activities in line with intensifying environmental education in the Turtle Islands. This will help to fully achieve people's participation especially in promoting the community-based livelihood project of the TIICDP.

The implementation of an ICDP is a slow and tedious process, and will require 10 to 20 years to attain its goals. All sectors of society must do their part to achieve this balance of conservation and development.

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Uruguay: Turtle Country?

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Sea turtle research has existed for more than half a century. During this time it has focused on countries where sea turtles nest. Due to the geography and climate, Uruguay does not have nesting populations of sea turtles. Countries like Canada (James and Harvey-Clark, 2000) and Chile (Brito, 1994), which also lack nesting populations, have started significant research projects based on the incidental capture of sea turtles in their fisheries. Understanding the mortality in these fisheries is important for the conservation of declining nesting populations like the Pacific leatherback (*Dermochelys coriacea*) (Eckert & Sarti, 1997).

Four sea turtle species can be found in Uruguyan waters: the green (*Chelonia mydas*), loggerhead (*Caretta caretta*), leatherback (*D. coriacea*) and olive ridley (*Lepidochelys olivacea*). Very little is known about these populations since most studies where done using museum and stranding specimens, and sight reports.

Uruguayan biologist Federico Achaval, who has worked with sea turtles for more than 35 years, recently reported on the incidental capture of these reptiles in the Uruguyan fisheries. Likewise, more stranding reports have appeared on individuals with unknown causes of death.

A key report was done by Dr. Jack Frazier 15 years ago, which prompted questions such as: What are sea turtles doing in Uruguay?; Where are they from?; and Why is there only one population class (either juveniles, subadults or adults)? On the brink of the 21st century, these questions are still without an answer. This is because for a long time there was a lack of interest among Uruguayan researchers and biologists. Without information about their migrations, population genetics, feeding grounds and condition of the individuals, we can not answer these questions. Therefore it is very important to start research projects that correct this situation and to work with other countries. Since sea turtles understand no political boundaries, international cooperation is essential for their conservation.

Thanks to the support of Mexican biologist Laura Sarti, it was possible to start training Uruguayan biologists in 1996. They worked as volunteers in the leatherback monitoring program she directs and had their first direct contact with sea turtles. This can be the start of the formation of future sea turtle specialists in Uruguay.

Even though no species nest on Uruguayan beaches, there's one thing for sure: they die there, so, in that way Uruguay is turtle country.

Acknowledgements

We wish to thank Biol. Laura Sarti for the support and opportunity that she gave us; Biol. Hedelvy Guada for the impulse to study South American sea turtles; the David and Lucile Packard Foundation for economic support and Biol. Ana. R. Barragan for assistance with translations.

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Use of Satellite Telemetry Technology to Enhance Research and Education in the Protection of Loggerhead Sea Turtles

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Gray's Reef National Marine Sanctuary (GRNMS) utilizes satellite transmitters to monitor adult and juvenile loggerhead behavior and movement in the South Atlantic. Satellite telemetry technology has contributed significantly to the study of the offshore Georgia loggerhead sea turtle population that has been declining in recent years. In a joint effort with WhaleNet, GRNMS has implemented experiences for collaborative learning to foster interdisciplinary education and environmental awareness. WhaleNet establishes Internet communication amongst students, researchers, and educators from around the world for use of GRNMS loggerhead sea turtle satellite data. These efforts enhance interest in science and mathematics; and raise awareness for the protection of loggerheads and their offshore habitat. Use of research and education, along with advanced satellite technologies and telecommunications increases loggerhead sea turtle protection awareness, develops an interest in science, and improves skills in problem solving and critical thinking.

X'Cacel-X'Cacelito: Importance of Vegetation for Marine Turtle Conservation

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The inlets of X'cacel-X'cacelito constitute important nesting sites for *Caretta caretta* (loggerhead) and *Chelonia mydas* (green) in the Mexican Caribbean. At the moment their conservation is threatened due to the implementation of tourist projects. The vegetational mosaic that is found in these inlets contributes to the good operation of the coastal ecosystem. This work describes and evaluates the different types of vegetation.

The 165 hectares of land include 13 vegetal associations of which the seasonal dry forests and mangroves are the best examples. Its good state of conservation agrees with a high floristic wealth, presently estimated to consist of 213 species, including 21 endemic (9.8%) and 26 (12.3%) of Antillean affinity. The forests main structural components are species of palms *Pseudophoenix sargentii* "Buccaneer Palm" (Kuka), *Thrinax radiata* "Thatch Palm" (Chit) and *Coccothrinax readii* (Nakax) which are considered threatened or under special protection by the national and international ecological norms. Because these forests are only found in a single strip of 13 km, and are already fragmented and damaged by the new tourist developments in the region, it is important that along with the population of turtles, conservation strategies are followed to avoid the deterioration of this already reduced ecosystem.

We would like to thank the David and Lucile Packard Foundation for the financial support to attend the 19th Annual Sea Turtle Biology and Conservation Symposium.

VIII Short Course on Sea Turtle Biology and Conservation in Sucre, Venezuela

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Sea Turtle Courses have been held in Venezuela since 1992 with more than 150 participants to date. Most participants have been from Venezuela, but three have been from Uruguay and Argentina. Each year, since 1995 we have invited a foreign instructor in order to provide a regional point of view for participants and to establish further cooperative efforts; they include specialists from Colombia, Mexico and Puerto Rico.

Methods and Results

The VIII Course on Sea Turtle Biology and Conservation was held between July 20 to 26, 1998. It was held for the first time at a sea turtle nesting beach: Puy Puy (Peninsula de Paria, Sucre State, northeastern Venezuela). We had a total of 12 participants: three from the Universidad Simon Bolivar, four from the Universidad de Oriente-Nucleo Nueva Esparta, two from the Universidad Central de Venezuela, one from the Instituto Universitario de Tecnologia de Yaracuy, and one from the Univ. of Florida. The participants received publications about sea turtles and other environmental education materials.

The main instructors were Hedelvy Guada, Carlos Diez and Vicente Vera and the course assistant was Marco Garcia (Universidad Central de Venezuela). A valuable cooperative effort for sea turtle research has developed between Puerto Rico and Venezuela, since Carlos Diez invited four of the participants to be trained in his hawksbill turtle project at Isla Mona.

The course was sponsored by WIDECAST, PROVITA, the British Petroleum Conservation Programme, SARPA-MAC, Universidad de Oriente-Nucleo Nueva Esparta, Fundacion Thomas Merle, Fundacion Proyecto Paria and the Dept. de Recursos Naturales y Ambientales of Puerto Rico.

The Perspectives for 1999

The “IX Course on Sea Turtle Biology and Conservation” in Venezuela has been organized for mid June, 1999, again at Puy Puy beach. We are again seeking a foreign instructor for the course, as well as Spanish speaking participants from countries other than Venezuela.

After the 1999 course, we will provide a different forum to some of the more than 150 persons trained in Venezuela, where they will be able to get updated information on advanced sea turtle conservation techniques. Hence, the first “Workshop on Sea Turtle Biology and Conservation in Venezuela” will be held at the end of 1999 or early 2000. The proposed site is the School of Applied Marine Sciences of the Universidad de Oriente-Nucleo Nueva Esparta Nucleous (Boca del Rio, Isla de Margarita, Nueva Esparta State).

Acknowledgments

The auspices of the course were WIDECAST, PROVITA, the British Petroleum Conservation Programme, SARPA-MAC, Universidad de Oriente-Nucleo Nueva Esparta, Fundacion Thomas Merle, Fundacion Proyecto Paria and the Dept. de Recursos Naturales y Ambientales of Puerto Rico.

The presentation of this poster at the “19th Annual Sea Turtle Symposium on Sea Turtle Biology and Conservation” at South Padre Island, Texas was made possible through the kind efforts of Dr. Karen Eckert (WIDECAST) and W. Jay Nichols (Univ. of Arizona). Travel support was received from the Columbus Zoo (Powell, Ohio), the David and Lucile Packard Foundation and the Universidad Simon Bolivar.

Restoration of Hawksbill Turtle Nesting Habitat at Kealia Beach, Maui, Hawaii

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This project was initiated as a result of the vehicular death of a nesting, hawksbill sea turtle (the second in three years) on a State Highway, at the head of Ma‘alaea Bay, Maui, Hawaii. A meeting of government agencies, conservation groups, and concerned citizens was organized by the U.S. Fish and Wildlife Service to discuss the turtle mortality problem associated with rapidly eroding sand dunes and the off-road vehicle trails connecting the highway and beach. The group agreed to pursue restoration of the degraded coastal dunes and establish a barrier to keep vehicles off the beach and disoriented turtles off the road. An interim step in this restoration process was installation of a sand drift or “dune restoration” fence which serves the purposes of rebuilding dunes and protecting turtles. Kealia Beach is now protected from off-road vehicles, and nesting hawksbills are prevented from wandering onto the highway. By preventing further vehicle induced erosion of the beach and disturbance of protective ground cover, the wood slat and wire restoration fence is allowing the sand dunes to rebuild themselves. Revegetation efforts by volunteers are underway along the severely impacted former roadways that bisect the dunes, and interpretive signs explain the project to the public. Although a more permanent barrier to vehicles is needed along this beach, and much work remains to be done to restore quality nesting habitat, this project has been successful in preventing additional hawksbill mortalities and has involved the community in restoration of their coastline.

Using Wild Captures of Sea Turtles in New York State to Predict the Magnitude of Annual Hypothermic Events

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The study examined the feasibility of predicting the annual magnitude of a cold-stunning event for sea turtles from the number of turtles caught in pound nets during that same year. Data on sea turtles that frequent Long Island waters have been collected for incidental pound net fishery captures since 1987, and for cold-stunned turtles since 1979. Data on captures and cold-stunnings were broken down by year and for the three species observed: loggerhead (*Caretta caretta)*, green (*Chelonia mydas*) and Kemp’s ridley (*Lepidochelys kempii*). Statistical analyses were run from 1987 through 1997. Total pound net captures were not significantly correlated with total cold-stunned turtles for each year (r=0.36). The total number of pound net captures per year was correlated to the number of cold-stunned loggerheads for that year (r=0.52). Additionally, the number of loggerheads caught in pound nets was correlated to the number of cold-stunned loggerheads (r=0.63). The number of cold-stunned loggerheads was significantly correlated to the annual number of sea turtles stunned (r=0.87). Analysis also demonstrated that the number of Kemp's ridleys caught in pound nets correlated to the number of cold-stunned loggerheads (r=0.62). The relationship of captured loggerheads, cold-stunned loggerheads, and total cold-stunned seems to provide an indication of the magnitude for a given year's cold-stunning. Since only one large cold-stunning year (1995 n=81) could be included, and the second (1985 n=53) had to be excluded as no pound net capture program existed, caution should be used at this time in interpreting these results.

Portable Environmental Education Kits in Greece: Their Philosophy, Design and Use

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Portable environmental education kits started to appear in Greece in 1990. Most subjects were drawn from nature sciences. The sea turtle was the subject of the first kit. Most kits were, and still are, designed by environmental organizations. Portable kits were firstly used by NGOs in promoting their specific objectives. Gradually kits were known to teachers and with the help of formal environmental education, which was established in 1992, they became one of the main tools in Environmental Education. The Ministry of Education in Greece promotes them to schools and educators of all levels may use them in accordance to their backgrounds and abilities, deploying further motivation and incentives for children.

Citizen Initiated Beachfront Lighting Ordinance to Protect Marine Turtles in Franklin County, Florida, USA

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Lighting ordinances for the protection of marine turtles often meet strong opposition from local citizens, businesses, and government agencies. Only 15 of Florida's 35 coastal counties have enacted lighting ordinances for marine turtle protection. Franklin County was the first county to pass a lighting ordinance for the protection of marine turtles in Northwest Florida (NWFL). Efforts in several nearby counties have failed. A partnership between a motivated local attorney, a citizen group and interested state and federal agencies brought together the desire and expertise to draft and pass Franklin County Ordinance No. 98-11, "Lighting Ordinance for Marine Turtle Protection of Franklin County, Florida" (ordinance). We report the details of our efforts in hopes that it facilitates similar ordinances in other locations.

Study Area and Problem

The beaches of Franklin County support nesting populations of loggerhead (*Caretta caretta*) and occasionally green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) sea turtles. Single family, vacation rental properties occupy much of the developed beaches in Franklin County. Lighting that illuminates the beach and dunes is common. Lewis *et al* (1996) identified beachfront lighting as a growing threat to marine turtles in NWFL. Beachfront lighting surveys conducted by ANERR and USFWS staff (unpubl. reports) have documented many sources of artificial lighting that could negatively impact nesting and hatchling marine turtles. This growing problem was demonstrated in 1997 when hatchling disorientation increased nearly ten-fold on St. George Island (Summers *et al.*, 2000). Lewis *et al.* (1996) and Summers *et al.* (2000) suggest adoption of a lighting ordinance to help remedy problems created by artificial beachfront lighting.

Ordinance Passage

Several factors were instrumental in the successful passage of the ordinance. The ANERR and to a lesser extent the USFWS have established a long history of sea turtle public education and awareness programs in the area. The residents, visitors, business community, and commissioners of Franklin County have a positive attitude about marine turtle conservation because of these efforts. Witherington and Martin (1996) provided a model lighting ordinance for marine turtle protection. This model needed only minor modifications to suit the needs of Franklin County. Lastly, a hatchling disorientation event motivated local attorney and President of the St. George Island Civic Club, Barbara Sanders, to seek a solution to hatchling disorientation in Franklin County. This event catalyzed the formation of a partnership that brought together the legal and environmental expertise that culminated in the passage of the ordinance.

The St. George Island Civic Club spearheaded the ordinance issue with the assistance of the resource agencies. An informal survey of local business owners and residents met with overwhelming support. We received guidance from the county planner on how to proceed and then approached the County Commission. We were pleased that the County Commission showed support and a willingness to proceed. The process to pass an ordinance is set by statute. We reviewed several existing ordinances and spoke with groups that had attempted to pass ordinances and failed. With guidance from the Florida Department of Environmental Protection (FDEP) we modified Witherington and Martin's model ordinance to fit the needs of Franklin County. Several drafts were reviewed and modified in an attempt to use the least restrictive methods necessary to protect marine turtles. We presented the final draft to the County Commission and a public hearing on the ordinance was advertised and held. The only significant discussion centered around the fact that Florida Power Corporation did not have a rate schedule for the low-pressure sodium (LPS) vapor lamps that are required by the ordinance. We reached a compromise to allow non-compliant lighting until the year 2002, as long as the lighting has a cutoff feature and shield. The County Commission felt this would give Florida Power Corporation enough time to get a rate schedule for LPS lights. Overall, Florida Power Corporation has been very supportive of conservation measures to protect marine turtles and they agreed to the compromise. The County Commission voted and passed the ordinance on 16 June 1998.

Passage of this ordinance sets standards for both new and existing artificial light sources, seaward of the Coastal Construction Control Line, that provides the highest level of protection for nesting marine turtles and their hatchlings. Before granting any building permit for coastal construction, the Franklin County Planning and Building Department (FCP&BD) shall determine that all proposed development complies with the ordinance. Lighting shall not be changed without first obtaining a permit from the County. Such permits will only be issued when the proposed lighting plan complies with the ordinance. Anyone who submits an application for coastal construction activities will be informed of the existence of and the requirements of the ordinance.

The FDEP and the Florida Marine Patrol have authority to enforce the ordinance. Violators will be notified by the FCP&BD about the ordinance. The notice will describe the violation and will include a lighting brochure from DEP and a copy of the ordinance. The violation will be corrected immediately or punished as a misdemeanor. The penalty upon conviction is a fine not to exceed $500, imprisonment not to exceed 60 days or both. Each day of any such violation shall constitute a separate and distinct offense.

Public education will remain an important part of marine turtle conservation in Franklin County. Efforts are underway to assure that people are aware of and understand the ordinance. The residents, visitors, business community, and commissioners of Franklin County were very supportive of the ordinance. We hope this support continues and marine turtles find a suitable nesting environment in Franklin County for many years to come.

Acknowledgements

We would like to acknowledge the staff of the Apalachicola National Estuarine Research Reserve, Florida Power Corporation, the St. George Island Civic Club, the Franklin County Commission, and Allan Pierce for their contributions to the passage of Franklin County Ordinance No. 98-11, "Lighting Ordinance for Marine Turtle Protection of Franklin County, Florida". We also thank Sandra L. MacPherson and Charlotte Chumney for reviewing a draft of our manuscript.

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Proposals for the Conservation of Marine Turtles on the Island of Boavista (Republic of Cabo Verde, Western Africa)

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Sea turtles are considered to be a potential high-value natural resource for the Republic of Cape Verde. Five species inhabit waters of this archipelago, where they feed and/or reproduce. *Caretta caretta* is the most common species, nesting on the islands of Sal, Boavista, Maio and São Vicente. *Eretmochelys imbricata* is only seen as juvenile stages, with some, non-confirmed, references about breeding activity in this area. *Dermochelys coriacea*, *Lepidochelys olivacea* and *Chelonia mydas* are also occasionally sighted.

The recently discovered nesting population of *Caretta caretta* on Boavista island has not yet been properly assessed. However, it seems to be one of the most important populations in the Atlantic Ocean.

The conservation of sea turtles at Boavista is affected by two major problems, due to the vulnerability of the nesting females when emerging from water:

- Direct exploitation of nesting females and their clutches by local people.
- Natural predation by the abundant ghost crab (*Ocypode quadratus*).

Several management and scientific actions must be accomplished in the short term, in order to preserve the Boavista population as a promising ecological and tourist resource. This strategy could serve as a model for the conservation of other Caboverdean marine turtle populations.

Human Pressure

Direct human exploitation is a significant threat to all sea turtles. These animals are intentionally caught in the sea by fishermen and slaughtered on the beaches when the females emerge to lay their eggs. Turtle meat and eggs are consumed, whereas the shells (and other by-products) are sold as decorative items (for the tourist trade).

The number of nesting *C. caretta* at Boavista appears to be declining year by year, due to an increasing human pressure.

Natural Predators

The ghost or sand crab (*O. quadratus*) is one of the most important recognized predators of both developing eggs and hatchlings. It inhabits Boavista beaches in great numbers, digging deep galleries to gain access to the turtle clutches. During the incubation period, they prey upon eggs, reducing the hatching success. The predatory activity of crabs also facilitates the development of opportunistic bacterial infections within the clutch. Moreover, these crabs may also feed on hatchlings either in the own clutch or on the way of the small turtles to the sea.

Proposals for the Conservation of Marine Turtles in Cape Verde

1. Creation of a Biological Reserve on Boavista Island: Priority must be given to the protection of the most important nesting areas. *A priori*, 'Biosphere Reserve' appears to be a suitable conservation term to define these sites, since it includes those areas with a high natural value that can be used by the islanders to increase their economical status (or income). The limits of a first reserve (on Boavista) could be established covering the eastern half of the island.

2. Continuous monitoring and tagging campaigns of sea turtles and their clutches. A continuous tagging program, already started in the 1998 breeding season, is important to complete the knowledge of nesting turtles on Boavista island. Some of the targets of this proposal are to determine the population size and rate at which it declines due to human activities and natural predators, and the improvement of hatching success. In this regard, the development of an incubation program, transferring vulnerable clutches to safer areas, is intended to improve hatchlings' survival rate. Finally, it could be feasible to establish new nesting colonies on those beaches, that were abandoned because of a severe predatory pressure, using hatchlings resulting from the mentioned incubation program.

3. Vigilance of beaches and reinforcement of conservation laws. New protection measures must be added to the existing legislation to impede or, at least, reduce the capture of sea turtles and their eggs. First of all, it is essential an intensive vigilance at beaches during nesting season, especially those included in the proposed natural reserve, since they host the major number of turtles. Besides, they have been the most exploited in recent years. Second, compensatory measures must be offered to local people in order to assure a gradual replacement of this traditional food resource, since it should not be forgotten that some human nucleus lack of enough protein sources in their diet.

4. Status of marine turtles on other islands from Republic of Cape Verde. First of all, it is necessary to complete the distribution of all marine turtle species that inhabit this archipelago. On the other hand, taking into account that the turtle population is declining due to human consumption, research should be addressed to discover new nesting colonies of *C. caretta* and other species. Maio, Sal, or Santa Luzia are the islands that *a priori* might be candidate to host marine turtles, since they have suitable beaches Some bibliographical references appear to confirm this fact.

5. Education program. It is essential to implement an education program with the aim of making Cabo Verdean people aware of the cultural and economical importance of preserving this significant natural resource. This program should contemplate the following subjects:

- The production of TV reports and advertisements directed to local people.
- The elaboration and delivery of educational leaflets at schools, on the importance of preserving marine turtles and the littoral environment.
- To offer information talks at every island to sensitize islanders to the need for reinforcing (or managing) this natural resource.
- Likewise, a cooperative link between local NGOs and other community projects should be agreed to develop environmental education programs.

6. Use of ecological resource. The need for the local inhabitants to stop capturing the marine turtles must be compensated for by offering valid choices to improve their living conditions. The turtles as a source of income through ecological tourism has already been tested in several places in the world, so it can be considered as unfailing. At the same time, this activity will increase substantially the tourist attractiveness of the archipelago, and so the standard of living for Caboverdeans.

Historical Report of the Sea Turtle Nesting Beaches in the Municipality of Santa Teresa, Carazo, Nicaragua

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This presentation intends to provide a historical report of sea turtles visiting the shores of the Santa Teresa municipality in Carazo, Nicaragua and the actual organization of the Environment Commission and Natural Resources with the Subcommission of the Wildlife Refuge "Chococente".

Our municipality is in brotherhood with Wisconsin and is well related with the Univ. of Wisconsin and has good relations with the Community Conservation Consultants of Gays Mills, Wisconsin. They are interested in helping us with environmental education in the communities inside and outside of the Wildlife Refuge of Chococente. For that we have informed Dr. Robert H. Horwich of the importance of the Sea Turtle Symposium in South Padre Island, Texas and how the Community Conservation Consultants can work with sea turtles and our communities in Chococente.

As Mayor of the municipality of Santa Teresa, I am able to increase (due to the new law of Municipality Autonomy) our natural protected areas in the municipality.

The best place to learn about sea turtles and the way to solve any forthcoming problems with the development of eco-tourism is this sea turtle symposium in Texas.

Marine Turtle Holding Facilities in Florida: Strategies for Management with a Five Year Synopsis

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There are currently 21 instate facilities and one out-of-state facility permitted by the Florida (FL) Dept. of Environmental Protection (FDEP) to hold marine turtles for educational display (loggerheads only), research, or rehabilitation of sick and injured animals. From 1994 through 1998, a total of 4,665 turtles were held in these facilities. Approximately 70% (2,038) of those held in captivity due to illness or injury were rehabilitated and released, 2.5% (74) are still undergoing rehabilitation and 27% (800) were unable to be recovered and either died or were euthanized. If hatchlings are excluded from the data, the success rate of rehabilitation and release drops to approximately 47%.

Approximately 6.8% (38) of the animals currently in captivity are not releasable; this includes those turtles that have severe disabilities or those whose genetic origin does not match Florida's populations. Three percent (17) are currently in captivity for educational purposes and 70% (391) are being held for research purposes.

All facilities holding turtles for rehabilitation, educational display, or research must comply with FDEP's guidelines for such activities and be permitted in accordance with the FL Marine Turtle Protection Act (FL Statute 370.12) and the FL Administrative Code for permits for collection and possession of indigenous marine organisms for scientific, educational or conservation purposes.

Table 1. Number of Marine Turtles Maintained at Permitted Facilities 1994 through 1998.

# of Turtles	Rehabilitation	Education	Research	Permanently Disabled	Other*	Total
Released	2,038	29	1,020	3	96	3,186
That Died	800	6	84	7	20	917
Still in Captivity	74	17	391	13	67	562
Total #	2,912	52	1,495	23	183	**4,665**

*Other includes: pre-act animals, captive-reared animals (except those used in research), animals with unknown or non-Florida origins, and animals whose status changed while in captivity (e.g. acquired as a stranding then transferred to another facility for educational display).

Guatemalan Sea Turtle Conservation Report

Colum Muccio
Association Rescate y Conservacion de Vida Silvestre (ARCAS), Wildlife Rescue and Conservation Association,
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Sea turtle conservation in Guatemala is a highly uncoordinated, decentralized and under-funded activity with a variety of actors operating independently of each other. The strategy used is almost exclusively that of hatcheries maintained on a shoestring budget, manned by unskilled locals and relying entirely on voluntary donations by local egg collectors. There has been very little research conducted and there has been no systematic analysis of turtle populations or conservation strategies on a national level.

Taking these realities into account, the present research was conducted with the goal of:

1) Collecting and analyzing existing sea turtle data in Guatemala and organizing it in a way that it can be used in national and regional analyses and policy-reform efforts;

2) Determining the total Guatemalan nesting population by conducting crawl counts on selected beaches thereby establishing a baseline for future research;

3) Evaluating the effectiveness of current hatchery techniques and offering recommendations for improvement;

4) Based on the analysis of the data collected in this project, develop a series of policy recommendations or a sea turtle recovery action plan for Guatemala.

Although not entirely conclusive and acknowledging the need for additional research, this study suggests that sea turtle conservation efforts in Guatemala are seriously insufficient and current rates of sea turtle egg utilization are far from sustainable. According to our estimates, of the 2,150,000 olive ridley eggs laid on the Pacific coast of Guatemala, only 1.3% are being "saved" and incubated in hatcheries.

The Guatemalan government, under its recent privatization drive, has withdrawn support to sea turtle conservation activities. Nonetheless, only with coordinated action on a national political level can serious sea turtle conservation activities be carried out.

The Sea Turtle and its Social Representation in the Wayuu Indigenous Culture, Zulia State, Venezuela

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While conducting the project "Diagnosis on the Current Situation of the Marine Turtles in the Gulf of Venezuela", the cultural role that marine turtles play within the Wayuu ethnia was studied. This ethnia constitutes one of the most numerous and representative indigenous groups of Venezuela. They are settled in the Guajira Peninsula, in northwestern Venezuela, which is a shared territory with Colombia. They are generally dedicated to shepherding, commerce and fishing. Within their cosmovision, marine turtles are intimately related to fertility. They believe that the consumption of marine turtle meat and blood has an effect on their masculine vitality. This, along with the flavor of the meat, greatly increases the demand for marine turtles. They also believe that dreaming of turtles is related to sexual activity. It is common to observe turtle craniums in the branches of fruit trees with the purpose of accelerating the process of fructification. The great majority of natives are not acquainted with the danger of extinction of the marine turtles. Through a deeper knowledge of the Wayuu culture, it will be easier to elaborate strategies of informal education that allows a real valuation of the resource.

Preliminary Investigation of Loggerhead (*Caretta caretta*) Nesting after the Removal of Australian Pines (*Casuarina equisetifolia*)

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Australian pines were introduced to Florida during the early 1900's, for protection against wind and storms (Craighead, 1971). Their shallow root system make the trees more susceptible to the effects of storm winds and erosion than native coastal plants. When they fall they often obstruct access to beaches by gravid female sea turtles (Reardon, 1998; Schmelz and Mezich, 1988). In March of 1998, Rookery Bay National Estuarine Research Reserve, Florida Department of Environmental Protection, began a large-scale restoration project to remove live Australian pines and snags from Key Island. Key Island is a 12 km primary barrier island off the coast of Naples, FL, and historically has been a significant nesting ground for loggerheads (Ryder and Addison, 1997).

The Conservancy of Southwest Florida has been monitoring nesting activity on Key Island since 1983. Prior to each nesting season, the island was marked off in 500 foot increments, which enabled nests and false crawls to be paced off to the nearest marker. A numerical location was recorded for each loggerhead emergence. Areas of beach that were inaccessible due to fallen Australian pines were also documented each year. During the 1998 nesting season, Rookery Bay and the Conservancy began plotting the location of nests and false crawls via Global Positioning System (GPS), in order to document the affect of Australian pine removal on sea turtle nesting.

The results of the 1998 nesting season were as follows: there were 284 nests and 404 false crawls, of these, 36 nests and 128 false crawls were in areas that had been previously inaccessible due to Australian pines. Rookery Bay and the Conservancy plan to continue these efforts over the next few years and compare future data to the historical data previously collected by the Conservancy.

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A Strategy for Raising Public Awareness and Inviting Local Participation: The Example of Stavros, The Green Turtle in Lakonikos Bay, Greece

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Achieving acceptance and local participation has been shown to play an important role in species conservation on a worldwide basis. Conservation efforts that are limited to forming necessary legislative measures, without first establishing bonds and raising awareness within the local community, are less likely to be successful in the long term.

Following 15 years of experience, the Sea Turtle Protection Society of Greece (STPS) has developed a strategy for approaching local communities with the objective of raising public awareness and invoking local participation in sea turtle conservation. The STPS strategy includes interacting with different levels in society: 1) school children through specially prepared environmental education programmes, 2) fishermen through incidental catch monitoring and public awareness programmes, and 3) the local government and authorities.

This strategy is currently implemented in Lakonikos Bay in a project funded by the European Commission (LIFE-Nature) and the Ministry of Environment. The case of Stavros, a juvenile green turtle, that was released in Lakonikos Bay, after having been treated at the Sea Turtle Rescue Centre in Glyfada, is a prime example of how such a strategy can aid in changing people's attitudes and finally motivate them to partake in nature conservation.

The Cooperative Agreement for the Conservation of Sea Turtles of the Caribbean Coast of Costa Rica, Nicaragua and Panama

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Trilateral negotiations for the adoption of the "Cooperative Agreement for the Conservation of Sea Turtles of the Caribbean Coast of Costa Rica, Nicaragua and Panama" commenced in December 1997 in San José, Costa Rica, and were completed in March 1998 in Panama City, Panama. Additional revisions were made to the document at Nicaragua's request, during the final review process by the environmental authorities and the chancelleries in each nation. The finalized cooperative agreement was signed on 8 May 1998 in San Jose, Costa Rica, following the inaugural ceremonies of new Costa Rican President Miguel Angel Rodríguez as the first order of business of his government. President Ernesto Pérez Balladares of Panama and President Rodríguez both expressed their intentions to collaborate for the protection of the sea turtle resources shared by their nations. President Arnoldo Alemán of Nicaragua did not attend the signing ceremony and to date, no explanation for Nicaragua's refusal to sign the agreement has been provided to the parties. Efforts are underway to fund and commence implementation of the agreement in Panama and Costa Rica, and attempts to re-engage Nicaragua in the cooperative agreement are being promoted. The new agreement calls for the Parties to establish a regional system of protected habitats based upon the biological requirements of sea turtles specific to these three countries, including nesting beaches and marine habitats. Implementation and enforcement duties are assigned to a nine-member Regional Committee, with representatives from the civil sector and from environmental and fishery sectors of the government agencies.

Rationale

The ability of sea turtles to migrate great distances across the oceans is well documented. Tags returned from turtles using the beaches of Costa Rica and waters of Panama, Costa Rica and Nicaragua have been recovered from throughout the western Atlantic Ocean. Evidence for the shared use of the beaches and waters of Panama, Costa Rica and Nicaragua is particularly compelling.

Adult green turtles (*Chelonia mydas*) that migrate through the waters of Bocas del Toro Province, Panama, feed in the waters of Miskito Cays, Nicaragua and nest at Tortuguero, Costa Rica. Panama provides the courtship stations, developmental habitat and a migratory corridor for green turtles; Costa Rica provides the nesting beach; Nicaragua provides developmental habitat and adult foraging range. The three countries also share populations of other species of endangered sea turtles, such as the hawksbill (*Eretmochelys imbricata*) and the leatherback (*Dermochelys coriacea*).

History - The San Jose Agreement Of 1969

Discussions concerning the need for trilateral cooperation in green turtle management can be traced back to 1969, and the "Tripartite Meeting on the Green Turtle." This meeting brought together high level fisheries officials from the three countries to discuss the findings of Dr. Archie Carr and his colleagues concerning the importance of all three countries to the survival of the green turtle. The meeting concluded that harvesting of turtle eggs and adults from the beaches and marine areas in all three countries was jeopardizing the species and called for: (1) a suspension of green turtle exploitation for commercial or industrial purposes for a period of three years pending the development of a management plan for the sustained yield of the species; (2) a prohibition of all trade in green turtles, their parts and their eggs, for a period of three years; (3) the establishment of a control mechanism in each country to achieve the objectives of this agreement; and, (4) making all information about status of green turtle populations and their habitats available to the Maritime Fishery Services of the participating countries and to conduct annual meetings to evaluate this information and make recommendations.

A draft agreement was prepared and signed by Costa Rica and Panama. The countries did not formally adopt this agreement due to Nicaragua's concerns for its effect on the construction and operation of turtle processing plants on the Atlantic coast, until this activity was stopped by CITES legislation in 1976.

In the interim, the biological justification for regional cooperation has continued to grow as researchers have developed the data to demonstrate the interdependency of this shared population of green turtles on the beaches and marine areas of each country through one or more stages of its life history. At the same time domestic trade and subsistence uses of sea turtles along the Caribbean Coast have presented new threats to the continued existence of the green turtle, as well as the hawksbill and leatherback populations that inhabit all three countries.

Summary of the New Cooperative Agreement

The new Cooperative Agreement for the Conservation of Sea Turtles of the Caribbean Coast of Costa Rica, Nicaragua and Panama provides a framework for a coordinated and systematic multinational approach to the conservation of sea turtles. It is based on the premise that these nations share the responsibility for certain sea turtle populations that cannot be managed independently.

The Agreement calls for the Parties to establish a regional system of protected habitats based upon the biological requirements of sea turtles specific to these three countries, including nesting beaches and marine habitats. Implementation and enforcement duties are assigned to a Regional Committee with representatives from the civil, environmental and fishery sectors of each nation. The environmental sector in Costa Rica was given the responsibility of establishing a permanent office and providing two full-time officials for the implementation of the agreement.

In order to maintain its focus on regional habitat protection and management, the agreement defers to CITES and to the Inter-American Convention for the Protection and Conservation of Sea Turtles (the Salvador Convention) with respect to issues concerning turtle excluder devices (TEDs) and international trade. The Agreement will serve as a subregional mechanism for implementation of the recently concluded Salvador Convention as well as the Convention on the Conservation of Migratory Species (the Bonn Convention).

Some of the important components of the new agreement are as follows:

Regional Committee for the Conservation of Sea Turtles of the Western Caribbean. The Committee is given the responsibility of implementing the agreement. The Committee will establish and oversee an Executive Secretariat which will carry out the functions outlined in the agreement. The fund-raising capability of the Executive Secretariat shall be developed.

Regional Management Plan. The Parties shall prepare a Regional Management Plan which shall propose a coastal and marine protected area system for the effective protection of sea turtles in all phases of their life cycle. The Plan will also include an agenda for research priorities and standardized monitoring protocols, as well as stipulations for sustainable use of the species taking into account the population biology of sea turtles and the socioeconomic aspects of sea turtle stakeholders.

Obligations to Conserve Habitats. The Parties will identify the nesting beaches and marine habitats of importance to sea turtles in the three nations and list them in annexes to the agreement. Once listed, the Parties must establish legal and administrative instruments to manage these habitats.

Provisions for Sustainable Use. Will be considered in the regional management planning process, which will include public participation mechanisms.

Research, Training and Environmental Education. The Parties must facilitate research and dissemination of results required for the management and conservation of sea turtles. The Parties shall also facilitate training programs on sea turtle management at the regional level, and shall promote socioeconomic investigation in communities for the purpose of seeking viable alternative economic income sources and reducing pressure on the resource.

*Monitoring and Compliance***.** The agreement requires each Party to establish national legislation that will guarantee compliance with the terms of the agreement, and to collaborate to ensure compliance at the regional level. There are also provisions to include sea turtle conservation in school curriculums and to publish and distribute educational materials about sea turtles.

Coordination and International Cooperation. The agreement allows other countries to become Parties, and it promotes the adoption of laws and regulations in non-party states that conform to those stipulated in the agreement. International cooperation for technology transfer and experience exchange is encouraged.

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Sea Turtle Conservation by Community Groups in South Carolina, USA

CHARLES TAMBIAH AND MEG HOYLE

in collaboration with: *Cape Romain National Wildlife Refuge, Edisto Beach State Park, Folly Beach Turtle Watch, Friends of Hunting Island State Park, Fripp Island Volunteers, Harbor Island Volunteers, Huntington Beach State Park, Kiawah Island Loggerhead Turtle Nesting Program, Myrtle Beach State Park, Seabrook Island Turtle Patrol, South Carolina United Turtle Enthusiasts (SCUTE), Isle of Palms and Sullivans Island Turtle Team, USCB Center for Coastal Ecology/Pritchards Island, and Waites Island Sea Turtle Project*

The coast of South Carolina, USA, is an important nesting area for sea turtles. In 1981, volunteers participating in the Sea Turtle Salvage and Stranding Network also began protecting turtle nests that were in danger of depredation or inundation. These volunteers gave rise to a series of community and volunteer based projects that collaborate with the South Carolina Department of Natural Resources (SCDNR) to monitor nesting beaches. In 1997, 19 projects managed 50% of the South Carolina coastline and 67% of all nests laid in the state. The data collected by the projects are used by SCDNR to continue its successful sea turtle research and management program. The projects rely on public participation to accomplish their activities and a majority of the projects consist entirely of volunteers. Over 700 people participated in sea turtle projects during the 1998 turtle season. Beyond the standardized methods used in the biological monitoring of sea turtle nests, each project has developed its own approach to facilitating voluntary participation and environmental education. The successful efforts by these projects provide a prime example of community and volunteer participation in conservation and collaborative management. This paper recognizes the invaluable contributions made by these projects and provides information on their organization, volunteer participation, challenges and recommendations, and future plans and needs.

Area Description

South Carolina has 303 km of coastline with a variety of coastal habitats used by sea turtles. Loggerhead sea turtles (*Caretta caretta*) are the primary species nesting in the state. Loggerhead nesting in South Carolina accounts for 56% of the total nesting by the northern subpopulation of loggerheads (TEWG 1998). Nesting by greens (*Chelonia mydas*), leatherbacks (*Dermochelys coriacea*), and Kemp's ridleys (*Lepidochelys kempii*) is a rarity, but has occurred. An estimated 3007 nests were laid per year in the state from 1995-1997. Nesting begins in May and can last until early September.

Projects

Fourteen projects participated in a community participation survey. Their responses are summarized in this paper.

Projects collaborate with state and federal agencies, municipalities and county administrations, community organizations, and universities.

Project objectives include: 1) sea turtle population recovery and habitat protection; 2) monitoring nesting and nest activity; 3) conservation education and community/ visitor outreach; 4) community participation; 5) fund raising; and 6) political activism.

Project activities include: 1) nest relocating, marking and protecting; 2) controlling predators; 3) monitoring hatching; 4) inventorying nests; 5) monitoring beach lighting and ordinance enforcement; 6) monitoring strandings; 7) managing and restoring habitat/landscape; 8) collecting data; 9) education and research; 10) producing reports and educational materials; 11) publicizing activities; 12) sponsoring community workshops and volunteer gatherings; 13) producing and selling products, ranging from brochures to t-shirts; and 14) participating in Lights Out and Beach Sweep campaigns.

Project Organization

Community members initiated 43% of the responding projects, while the rest were initiated by the government/ other persons. Over time, management of these projects shifted to 50% community/volunteer operated and 50% government/university operated. The structure of the projects varies to include volunteers, as well as part and full-time employed staff. Some projects are operated from the home, while others have offices. Paid staff constitute only 3% of total project participants and are found in 43% of the projects. Annual budgets for equipment, mailings, product manufacturing, salaries, and transportation range from US$ 0-74,478. Funds and materials for project activities are collected through state agencies, municipalities, corporate and private donations, association contributions and membership dues, and product sales and hospitality services.

Volunteer Participation

Projects average 69 volunteers per season and involved over 700 people statewide. Volunteers constitute 97% of all project participants. Though many volunteers are retired, projects also include full-time employed and self-employed individuals as well as students. Volunteers are recruited mainly by word of mouth, but are also found through local media publicity, community meetings, and public programs. New volunteers account for an average of 29% of the project participants. The majority of the projects have a high percentage of repeat participants.

Training in sea turtle crawl identification, working with nests and hatchlings, data collection, project objectives, public education, and other site specific activities are conducted by experienced volunteers and SCDNR staff. Approximately 60 project participants attend an annual one-day training workshop organized by SCDNR and about 11 participants attend the International Sea Turtle Symposium.

Challenges and Recommendations

Each project faces its own unique challenges and creates it own solutions. Some recurring *challenges* involve 1) educating visitors: short stay visitors require an on-going education campaign; 2) training volunteers: scheduling convenient meeting times can be difficult, subjective decisions (ie. which nests to relocate) are hard to teach; 3) recruiting volunteers, especially on beaches with high nesting numbers; 4) maintaining volunteer enthusiasm on beaches with low nesting numbers; 5) solving conflicts within projects and with the public; and 6) soliciting funding. *Solutions* to these challenges include 1) more active publicity campaigns to recruit volunteers, educate the public, and solicit funding; 2) training videos for new volunteers; and 3) better communication within and between organizations.

Future Plans and Needs

In the future, the projects plan to give increased attention to 1) local lighting ordinances; 2) education, communication and publicity; 3) new products; 4) political activism; and 5) funding opportunities.

The needs identified by the projects include 1) educational videos and slide shows for the public and a training video for project participants; 2) on-site training and more topic specific training, such as on stranding protocols and management of the public (converting interactions into educational opportunities); 3) training and information for local emergency and police personnel; 4) an "eco-friendly" educational sea turtle flyer and informational signs; 5) a newsletter with articles by project leaders; 6) data summaries and activities from neighboring locations; 7) increased collaboration for nesting season preparations, local research, community interaction, and fund-raising; 8) greater publicity of community and volunteer participation; and 9) basic sea turtle related equipment, supplies, and literature.

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Local Community Protection of Green Sea Turtle Nesting Beaches of Alto Lucero, Veracruz, Mexico

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The Alto Lucero beaches, in Veracruz, Mexico are visited by a large number of turtles during June of each year. Consequently, the number of humans present increases with the objective of hunting them. This was the principal reason for the formation of the community protection group for sea turtles, with the major objective to avoid the sea turtle slaughter. It has not been an easy task, because there is not the necessary infrastructure to perform many needed activities, like a motorcycle to survey the beaches. Even so these beaches have been protected for three years with excellent results.

The Alto Lucero beaches (25 km) are located on the Gulf of Mexico in the central part of Veracruz State, near to the "Laguna Verde" nuclear power plant.

The participation of the community inhabitants near the nesting beaches has played an important role in their conservation. During the past three years, the communities near the nesting beaches participated in an educational program with the objective of stopping the turtle slaughter while the inhabitants of these communities cooperated in green turtle protection. At the same time they are provided with economical alternatives in order to get resources for their subsistence and stop the slaughtering of the turtles.

In 1998, the Alto Lucero city hall provided the "Santander" and "El Ensueno" community protection groups with economical resources since they had developed productive projects, like aquaculture, with the end objective of obtaining sufficient resources for their subsistence. The financial aid was with the condition that the community will continue to protect the green turtle at Alto Lucero beaches.

The first author would like to thank the David and Lucile Packard foundation for funding his participation in the 19th Annual Sea Turtle Symposium.

Figure 1. Localization of field work.

The Sea Turtle Stranding and Salvage Network at the Aquarium of the Americas, New Orleans, Louisiana, U.S.A.

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The Aquarium of the Americas (AOA) is working in a cooperative effort with National Marine Fisheries Service (NMFS) to protect the five species of sea turtles found along the Gulf of Mexico: *Caretta caretta, Chelonia mydas, Dermochelys coriacea, Eretmochelys imbricata* and *Lepidochelys kempii.* The Sea Turtle Stranding and Salvage Network program is funded through grants and the Audubon Institute. Aquarium staff and volunteers participate in routine beach surveys. Surveyors scan the beaches of Port Fourchon, Elmer's Isle, and Grand Isle for stranded turtles. Low altitude flights with the Coast Guard Auxiliary assist in surveying beaches that aren't accessible by land. The information we gather, along with other surveys that the NMFS compiles, aids in assessing the status of turtle populations. These stranding reports can initiate NMFS action to involve fishery gear modification and increased law enforcement at beach areas to further protect sea turtles.

In addition to routine beach surveys, the AOA has permits for stranded sea turtle rehabilitation. With the efforts of staff members and our full-time veterinarian, the aquarium has successfully rehabilitated and released over 13 sea turtles since 1992.

The AOA reaches many visitors each year. We present various conservation education programs that discuss the importance of sea turtles to our fragile ecosystem. We hope efforts like these will aid in preserving and protecting sea turtles and our rich natural resources.

The Protection of the Sea Turtles in the Tourist Developments: the Mayan Riviera and Mayan Coast in Quintana Roo, Mexico

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The tourist developments on the coast of Quintana Roo, Mexico are mainly in 2 areas: The Mayan Riviera previously known as the Tourist Corridor "Cancun – Tulum", and in the southern part of the state on the Mayan Coast (MC). On beaches along the Mayan Riviera loggerhead (*Caretta caretta)* and green turtles (*Chelonia mydas)* nest. On the beaches of the Mayan Coast, in addition to the loggerheads and greens, the hawksbill (*Eretmochelys imbricata)* and the leatherback (*Dermochelys coriacea)* also nest. The description of the threats of the tourist developments in the Mexican Caribbean are discussed in different reports. These reports also describe the different sea turtle protection programs along the coast.

The Territorial Ordinance (TO) is an instrument of environmental planning, designed to orient the geographic location of the productive activities as well as the uses of the environmental resources. The first TO applied in Mexico is in the area of the Tourist Corridor (Diario de la Federación, 1991), 120 km long and with the plan to construct more than 40,000 hotel rooms. The other TO is for the Mayan Coast which is 135 km long, with 117, 234 hectares.

Work Description

The present work is a description of the protection of the sea turtles in the tourist developments Maya Riviera (MR) and Mayan Coast (CM) in Quintana Roo, Mexico.

Area of Study

The state of Quintana Roo is located on the eastern coast of the Yucatan Peninsula. The MR includes the coastal strip from the city of Cancún to Tulum. The tourist development of the Costa Maya, includes the coastal strip from Punta Herrero (in the Biosphere Reserve of Sian Ka´an) to Xcalak.

Methods

Two road trips were made, visiting the tourist developments along the coast, one in May and another in October of 1998. In addition, the ecological orderings in process were reviewed: TO of Cancún - Tulum, June of 1994, and the Mayan Coast, 1998

Results and Discussion

Riviera Maya: Data of the Secretary of Tourism indicates that Cancún has 22,000 hotel rooms, and the following in construction: Puerto Cancun with a projection of 7,000 more rooms. The MR has 5,000 rooms and 7,000 rooms in construction throughout the coast.

The most important nesting beaches: In February, 1998, construction began on the 450 room Doña Isabel hotel on Aventuras DIF beach. The actions to protect the sea turtles in the environmental impact study for this hotel are not known.

Chemuyil beach, sold by the state government for tourist development is surrounded by a fence. It is not known if authorization was obtained for this development.

The beach X´cacel-X´cacelito was decreed by the state government a sanctuary for sea turtles in February of 1998. In 1996 the National Institute of Ecology (INE) gave the concession to work sea turtles to Xcaret for X'cacel - X'cacelito. Since February of 1998 the Sol Melia hotel group has had controlled the access to the beach. The federal authorities determined the land use of the rest of the area, based on the documents: "The Management Plan of the Sanctuary X'cacel-X'cacelito" and "The Study of the Environmental Characterization".

Costa Maya: In 1998, the first TO of the MC was evaluated, the proposal was rejected by some sectors of society because the TO would have allowed the building of up to 30,000 hotel rooms. The local community wants a low intensity development. This study considers the sea turtle protection in the nesting and forging areas near the coast.

According to FIDECARIBE data, 12 sites of lodging (with 72 rooms) can be found along this area of the coast and a large rustic dock in the community of Ubero. In October, 1998, the construction of 40 rooms started for the Hotel Posadas at Playa Angel. Eventually there will be 150 rooms. The same errors of the MR are repeated; such as, building megaprojects on fragile beaches, filling in mangroves and leveling of the coastal dunes.

In both TO some measures of protection for the sea turtles are considered, based on the indications of Raymond (1984) and the local sea turtle specialists. Nevertheless, in our observations along the MR, 85% of beaches present tourist developments and alterations to the nesting areas. Also we observed that there are tourist megaprojects in areas adjacent to nesting beaches. In these areas we observed artificial beaches (sand mixed with limestone).

The MR presents greater modification of the coastal dune than the CM, with more sand extraction, construction without the preoccupation to eliminate lights on adjacent nesting beaches and areas; fragmentation of the ecosystems. In addition, a greater number of rustic wharves and structures for recreational activities within the water. It also lacks an urban management plan, the growth of Playa del Carmen is 30%, one of the highest in Mexico. There is a need for the evaluation of growth and social impacts in the following coastal communities: Puerto Morelos, Playa del Carmen, Akumal, Chemuyil, and Tulum.

In the book by Botello *et al*. 1996 there are several analyses of the environmental legislation of the coastal zone, from the perspective of laws, territorial ordinances, environmental impact studies, and the frame of international reference. For the suitable handling of the coastal zones in Mexico, the legal aspects are insufficient, given the complexity of the ecological problems, the diverse productive activities, and development plans.

In Mexico, several judicial ordinances exist for the prevention and control of the deterioration of the marine resources. Nevertheless, remarkable deficiencies with respect to the expedition and application of these for the coastal region in general are observed (Saavedra - Vázquez 1996). In Quintana Roo, the representatives of the three levels of government (Federal, State and Municipal), research centers, scientists with ecological knowledge and natural resource management experience, conservation groups, and the representatives from civil and private associations signed the TO (June 1994). In 1998, the agreements are not fulfilled, with the sale of the main nesting beaches, and the state decree of the Sanctuary of Sea Turtles in X'cacel. This puts in risk the reserve because of the bad studies that have been done and the developments that have arisen overnight in the region.

In many environmental impact studies of the region the turtle camps financed by the developers are thought to mitigate the problem of tourist development. For example at Puerto Aventuras, there were initially turtles and a turtle protection program, then the beach was completely modified through development. Now the turtle camp is financed by the investors, even though nesting is no longer observed. Another example is Cancún, where the problem is organization, the few nests recorded in certain hotel zones do not allow guests from other hotels to see the nesting process. There are more than 60 hotels on the strip and there is no coordination for the protection of the turtles (to diminish the light intensity in the season of turtles, etc.). The slogan of the hotel keeper is first the security of the tourists. The importance of these Atlantic ocean sea turtle populations and the complexity of protecting turtles on the coast of Quintana Roo, requires the integral protection of the main nesting beaches and an effective program of protection for the sea turtle.

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CONSERVATION CONCERNS

Towards Averting the Doom's Day Imminent for Olive Ridleys: Indigenizing the Turtle Excluder Device and Reforming the Gillnetting Practice along the Orissa Coast of India

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The unprecedented mass mortality of olive ridley sea turtles along the coast of Orissa coupled with the discontinuance of mass nesting at Gahirmatha, the world's largest rookery for olive ridleys, over the last 3 years is ascribed by most of the surveyors to the illegal and reckless practice of mechanized trawling and gill netting in the inshore waters during the turtles' breeding season. The deployment of the armed fleet of Indian Coast Guard along with personnel from the Forest & Fisheries Department of the Orissa Government, the notification of Gahirmatha as a Marine Sanctuary, repeated directives from the High Court, and continued existence of a host of enactment and regulations- all at a huge expense to the State treasurer - have proved futile, nay, in some cases counterproductive in checking the mass killing of the sea turtles along the Orissa coast. While each of the concerned Departments of the Government is busy passing the buck, and the tension between the government and the fishing communities escalates each passing day thereby benefiting neither, the problem of the Orissa coast remains yet to be addressed.

The fishing communities, being as they are the primary users of the marine resources, could prove to be the most dependable watch and ward agent for the protection and sustainable management of the endangered and threatened biodiversity including sea turtles, provided the government has a clear and sincere strategy for their real involvement. However, such community involvement is conspicuous by its absence along the Orissa coast, to the detriment of not only the innocent sea turtles, but also the legally bound Government, and the fishing communities themselves.

Two simple and inexpensive reforms, namely an indigenous Turtle Excluder Device and mesh regulation of the gill nets, though conceived and worked on since 1996 by the Government are still not in effect, due to the typical bureaucratic manner of handling a highly sensitive and complicated cause like protecting the sea turtles. Had these reform measures been translated into reality in a timely manner, they could have prevented the ongoing catastrophic massacre of olive ridleys from ever happening and thereby saved the image of a bio-rich India from its further disgrace before the international community.

Trawlers operating along the Orissa coast

The total number of trawlers registered within Orissa is 913. Of those, 115 are deep sea trawlers. The deep sea trawlers operate primarily from New Fishing Harbor of Paradip, while a few come from Paradip, Astarang, Dhamara, and Chandipur harbors. However, in addition to the registered ones, there are about 200 unregistered trawlers operating along the Orissa coast, and about 100 trawlers of different sizes fishing in the inshore waters of Orissa coast from the neighboring states of Andhra Pradesh and West Bengal.

The trawling community (which were a part of the Workshop-cum-Demonstration on TED held jointly by Orissa Fisheries Department and Project Swarajya in November 1996 in collaboration with NMFS (USA) agreed to the unanimous resolution, which called for developing an indigenous model of TED suitable for Indian fishermen's craze for mixed catches of shrimp & fish. In a number of subsequent dialogues held intermittently thereafter with the various trawlers' associations, the latter have also expressed their explicit approval for the kind of TED which would be effective for their traditional mixed catch while allowing the release of the turtles. A locally made TED is estimated to cost only Rs 1,000 to 3,000 (US$ 25 to 75 approximately). The Orissa Chief Wildlife Warden announced in a meeting of trawlers, fishermen and NGOs held on 20th October, 98 that they would provide 1000 TEDs (now called TSD- Turtle Saver Device) before the commencement of the nesting season in December, yet there is still neither an indigenous model of TED nor the supply of 1000 TEDs free-of-cost or subsidized to the trawlers of Orissa coast.

TSD- What is New ?

Five or four vertical metal bars are used, unlike the seven in the Georgia Jumper (**Fig. 1**), to allow wider space between the bars for both shrimp and fish to pass through into the net bag while allowing only large species such as turtles, dolphins and sharks to escape. Second, upper placement of the exit hole with a flap shall enable only the large and powerful animals like turtles to wriggle out from the hole while allowing the rest to go into the net). The TSD has been designed by Mr. Rakhal Mishra, Deputy Director of Fisheries, Orissa in consultation with the trawlers.

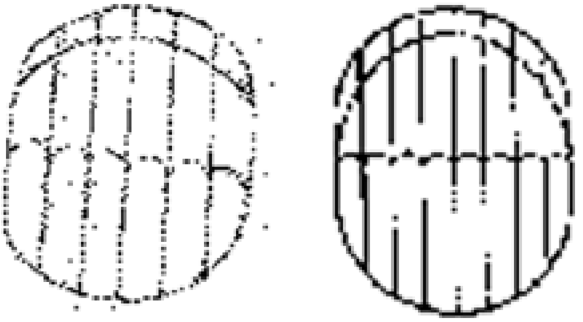

Figure 1. The indigenous model only has 4 or 5 vertical bars as compared to the standard Georgia jumper with 7 vertical bars.

Gill Netting

The next major culprit for the mass killing of sea turtles is the gillnetters (**Fig. 2**) and this situation has been handled even worse by the Government machinery. Except the occasional sermons and circulars by the officials of the Forest & Fisheries Departments, no concerted effort has been made so far to get together the inshore fishing gillnetters to demonstrate how the smaller monofilament mesh in their gillnets could effect a change in favour of marine turtles and other endangered species while saving their nets from the damage caused by incidental entanglement.

The typical gillnetters or fishing crafts in Orissa are known as Dingi, Catamaran, Botali, Nawa, Naha, Choat and Dug-out. The total number of registered gillnets operating in Orissa is almost 11,613. However, there are also numerous unregistered gillnetters, whose exact figures are yet to be determined. The average length of such crafts ranges from 28' to 48'. Earlier gillnetting was done by traditional boats, but following the implementation of motorization scheme by the Government, so far nearly 3500 traditional craft have been motorized through promotion and subsidy by the Government. This aside, the mechanized gillnetters of 38' to 48' OAL are also operating. The gill nets are made up of Nylone HDPE (High Density Polyproplin Ethiline) net of mesh size varying from 1" to 6". The twines used are mono- or multifilament. The mesh size of the gillnet depends on the size of the species to be caught during the different seasons. Therefore a gillnetter contains a minimum of 4 sets of different sized mesh nets. The Over All Length (OAL) of a gillnet varies from 1000' to 6000'. The big gillnetters are operated by 68 HP to 11O HP engines, while the Beach Landing Crafts (BLC) or other mechanized boats by 6.5 HP to 16 HP engines.

As a consequence of such top-down approach by the government towards turtle protection with no involvement of the fishing communities, the latter have developed and perfected their own brand of gorilla warfare, that is a peculiar game of 'hide and seek' with the coast guards, forest guards and fisheries personnel so as to pursue their ' bread & butter' by hook or crook.

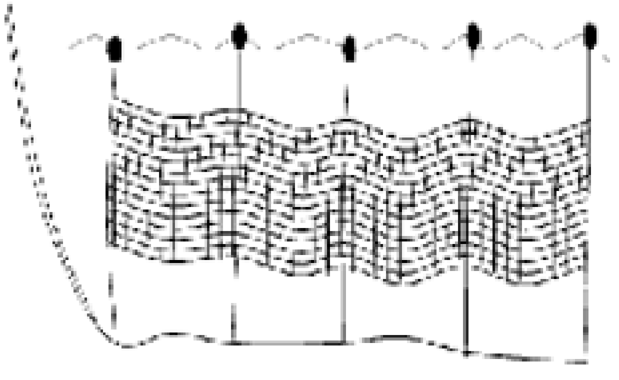

Figure 2. A typical gill or drift net.

A Gill Net or Drift Net

Such a policy which is prima facie beneficial neither to turtles nor to the fishing communities, if allowed to continue would inevitably result in turtles altogether disappearing and the corresponding degeneration of the marine ecosystem of Orissa coast. It is imperative therefore on the part of the Government to recast their present turtle protection policies in the light of the critical need for involving the representatives of the local trawling and fishing communities and NGOs active among them with a view to ensure the sustainable management of the vulnerable brackish water and marine ecosystem of Orissa coast as a whole, of which the olive ridleys and other endangered species are essential links. Such a positive and holistic policy, would prove immensely assuring not only for the sea turtles but also for the fishing communities who are the real custodians of the sea and its vast-but-depleting biodiversity.

Acknowledgment

Mr. R.S. Mishra, Deputy Director Fisheries, Orissa for his key role in innovating the Turtle Saver Device. Mr. Herbert Lingham of UNDP-GEF Small Grants Programme, India, for supporting the Project on popularizng the TED. Dr. C.S. Kar, Research Officer, Dept. of Forests, Orissa for his scientific information on Sea turtle behaviour in Orissa coast. Travel support to the 19th Annual Symposium on Sea Turtle Biology and Conservation was provided by the David and Lucile Packard Foundation.

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Human Predation on Marine Turtles in the Archipelago of Cape Verde, Western Africa

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Deliberate take of marine turtles and their eggs occurs worldwide. Turtle meat and eggs may constitute a seasonal protein source in some developing countries. The shells, the stuffed bodies and other by-products are often destined for the tourist trade. This activity has been known in Cape Verde for a long time; fishermen catch turtles in the sea, though it is on the beaches where the number of captures is much higher.

The island of Boavista hosts an important population of *Caretta caretta* which, waiting for further studies, may represent one of the most significant populations in the Atlantic Ocean. It is essential to quantify the pressure exerted by the barely 4,000 inhabitants of Boavista on the sea turtle population before implementing a conservation strategy designed to reduce the loss of reproductive females.

Methodology

Several interviews were held with local people at different islands of this archipelago over the last few years (1996-1998). The goals were to gauge the present intensity of captures, to know the different hunting techniques, and to evaluate the supposed decline of populations, using as an indicator the rough volume of captures during the last years. It is important to note that some information provided by islanders did not appear to be very reliable.

Simultaneously, there were beach surveys aimed at quantifying the number of slaughtered turtles, attending to the amount of remains onshore, and trying to observe hunting activity *in situ*.

Additionally, local markets were searched for turtle meat and decorative items (carapaces, stuffed animals, etc.).

Results and Discussion

The beaches closer to villages were likely intensively exploited in the past, simply because they were more accessible to people. Thus, on Boavista Island live individuals or, even, turtle remains are barely found on the beaches adjacent to human populations, though they are said to have been very abundant. On the beach of Chaves, near Rabil, remains are absent and, at present, only a few turtles appear to be nesting in this area. On the beaches of Calhau and Curralinho, near Povoaçao Velha, it occurs the same as mentioned above. Finally, on the beach of Bõa Esperança, near Sal-Rei and Bofareira, as well as on the beach of Canto, near three villages located on the northeastern shore, there still exists some reproductive activity, and sea turtle hunting and egg harvesting are not so intensive as at other points of the islands.

On the contrary, both nesting turtles and carcass remains are found in a relatively large number on the beaches distant from the villages located between the Ilheu of Baluarte and the Ilheu of Curral Velho (**Fig. 1**).

The over-exploitation of sea turtles on the most accessible beaches has likely led to the depletion of nearly all these nesting populations in the last decades. As a result of this, hunts have extended to more remote areas that still host an important number of specimens.

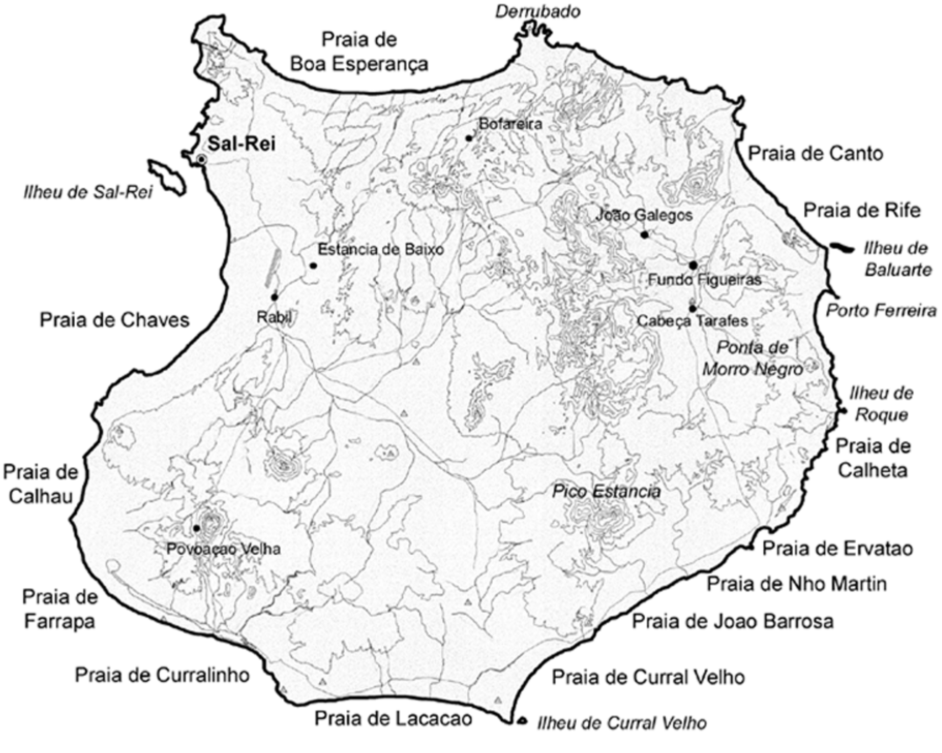

Figure 1. Map of Boavista showing the main beaches and villages.

Accidental Capture of Sea Turtles by the Fishing Fleet Based at Madeira Island, Portugal

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Pelagic stage loggerhead sea turtles (*Caretta caretta*) are seen in large numbers at Madeira and Azores archipelagos (Portugal) and originate almost exclusively from US nesting beaches. The areas around these archipelagos might prove to be the most important developmental habitat for North Atlantic loggerheads. Fishing activities based at the Archipelagos are likely to impact the turtles. Madeira Island harbors 538 registered fishing vessels, most of which are very small, and employs about 1150 fishermen. Fishing activities mostly cover local consumption.

We quantified the effect of the various fishing activities on the turtles by questioning fishermen, by quantifying their catch at the local harbor and by distributing onboard datasheets. Deep pelagic longlines targeting black-scabbard fish (*Aphanopus carbo*) had the greatest impact on the turtles. Using Catch per Unit Effort values, we estimate an annual take of slightly over 500 turtles by this activity. The effects of the other fishing methods are discussed.

Effects of Hurricanes on Sea Turtle Nests and Incubation Temperatures at Gulf Islands National Seashore Florida District

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Gulf Islands National Seashore's (GUIS) Florida district averaged 37 nests per year from 1994 to 1998. The leading cause of nest failure and hatchling mortality was nests flooded by tropical storms and hurricanes. Since 1994, five hurricanes and three tropical storms caused complete mortality of 27% of nests on GUIS beaches. Additional nests had reduced hatching success as a direct result of the storms. Beach location of each nest, storm intensity, and storm location were factors determining which nests were lost or damaged.

Surviving nests experienced significant decreases in incubation temperature. In 1997, temperature loggers were buried next to nine nests, six of which were affected by Hurricane Danny. Average sand temperatures during incubation ranged between 26.2°C and 28.6°C. Hurricane Danny reduced sand temperatures two to three degrees for up to three days depending on nest location. Temperatures did not return to pre-hurricane levels for up to five days. Nests located at the vegetation line had the highest sand temperatures and were least affected by hurricanes.

In 1998, five nests had three temperature loggers placed within the nest chamber. Probes were located at the top, middle, and bottom of each nest. Average middle of nest incubation temperatures ranged between 27.4°C and 30.1°C. Hurricane Earl affected two nests with temperatures falling up to eight degrees due to flooding. Additional loggers representing common nesting sites recorded temperature drops up to five degrees. Temperatures at the vegetation line recovered within two days of the hurricane while mid-beach temperatures did not return to pre-hurricane levels for over a week.

Preliminary data may indicate a male biased sex ratio in GUIS hatchlings. Hurricanes may increase this male bias by cooling nests during incubation. While sea turtle populations have long survived the effects of hurricanes, the combination of these storms with increased human related threats could reduce small nesting populations beyond recovery.

Sea Turtles Found in Waters off Chile

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Although there is no nesting in Chile, four species of sea turtles are occasionally encountered in Chilean waters, which represents the southernmost limit of their ranges. Information compiled from museum specimens, published accounts, personal communication, and personal observation since 1884 indicate that leatherbacks, olive ridleys and green turtles are the most common, while loggerheads are rare. However, no systematic study has been done, and we suspect that sea turtles may be more abundant than previously thought. Sarti *et al.* (1995) have suggested that the South American driftnet fisheries have played a significant role in the decline of eastern Pacific nesting populations of leatherbacks in the 1980s. Frazier and Brito-Montero (1990) suggest that the Chilean swordfish fishery continues to have an impact. Only four of the leatherbacks recovered from Chilean fishing vessels between 1988 and 1991 had been tagged on nesting beaches in Costa Rica and Mexico (Brito-Montero 1995). Additional information can now be obtained using molecular genetics to determine stock origin of untagged turtles.

Concern over this recent decline of Pacific leatherbacks has led to a new international initiative between the U.S. National Marine Fisheries Service (NMFS), the Subsecretaria de Pesca (SUBPESCA), the Chilean National Fisheries Service (SERNAPESCA), and the Instituto de Fomento Pesquero (IFOP) to determine the origin of sea turtles caught incidentally in Chilean fisheries. To date, small skin biopsy samples have been obtained from 2 leatherbacks, an olive ridley, and one loggerhead caught by fishing vessels in Chilean waters. Preliminary genetic analyses using mitochondrial DNA (mtDNA) and microsatellites suggest that one of the leatherbacks is from a population nesting in the western or Indian Pacific, and that the second leatherback is of eastern Pacific origin. This is the first evidence that leatherbacks of western Pacific origin occur in waters off Chile, confirming transoceanic migration to forage areas in the eastern Pacific in the southern hemisphere. In the case of loggerheads, since there is no nesting in the eastern Pacific, it is likely that genetic analysis will confirm that the loggerheads encountered off the coast of Chile are of Australian nesting stock. In addition, seven green turtles have been sampled from an aggregation found in coastal waters near a power plant at Mejillones in northern Chile (**Table 1**), and genetic analysis is in progress. Future work will focus on quantifying the incidental take of artisanal and commercial fisheries in Chile, and on genetic analysis of samples taken from extensive museum collections throughout Chile.

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Table 1. Sea turtles sampled for genetic ID in Chilean waters, including animals captured by a commercial longline vessel on the high seas between June and December 1998 and an artisanal vessel in 1997, as well as green turtles tagged and released near a power plant in northern Chile.

Species	Date	Location	Length (CCL)	Source
Dermochelys	21-Feb-97	33° S ? ° W	--	Fishery bycatch
Dermochelys	01-Jun-98	31° S 78° W	143 cm	Fishery bycatch
Lepidochelys	12-Jul-98	33° S 77° W	77 cm	Fishery bycatch
Caretta	03-Dec-98	29° S 79° W	71 cm	Fishery bycatch
Chelonia	18-Jan-99	23° S 70° W	71 cm	Forage area study
Chelonia	04-Feb-99	23° S 70° W	46 cm	Forage area study
Chelonia	04-Feb-99	23° S 70° W	57 cm	Forage area study
Chelonia	04-Feb-99	23° S 70° W	50 cm	Forage area study
Chelonia	04-Feb-99	23° S 70° W	59 cm	Forage area study
Chelonia	04-Feb-99	23° S 70° W	65 cm	Forage area study
Chelonia	04-Feb-99	23° S 70° W	78 cm	Forage area study

Incidences of Marine Turtle Mortality along the Mediterranean Coast of Egypt

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The entire Mediterranean coast of Egypt was surveyed to determine the location of marine turtle nesting sites during the period May to September 1998. During this survey many marine turtle corpses were found washed ashore. This paper documents the number, species, size classes and location of all dead turtles found during the survey. The Mediterranean coast of Egypt is approximately 1000 km in length and is naturally divided in to western, central and eastern regions. The western region extends from the town of El Salum on the Libyan border to the port of Alexandria; the central, or Nile Delta, region extends from Alexandria to Port Said; and the eastern, or Sinai, region extends from Port Said to the town of Rhafa on the Israeli border. Approximately two thirds of this coastline consists of sandy beach that may potentially be suitable for marine turtle nesting. During 1998, 616.5 km of the Mediterranean coastline of Egypt was surveyed by foot patrols. The location of all the dead turtles found was accurately recorded using a global positioning system (GPS). The curved carapace length (CCL) of each corpse was measured, if possible the species was identified and the cause of death determined. The distribution of dead turtles was then mapped (**Figs. 1 - 3**).

A total of 54 turtle corpses were found during the 1998 survey of the Mediterranean coast. Loggerhead, green and leatherback turtles were all represented (**Fig. 4**). Most of the dead loggerhead turtles (*Caretta caretta*) found were subadult or young adults with a CCL in the 51 - 75 cm range (**Fig. 5**). The majority of green turtles (*Chelonia mydas*) found were also subadults with CCL in the range of 26 - 50 cm (**Fig. 5**).

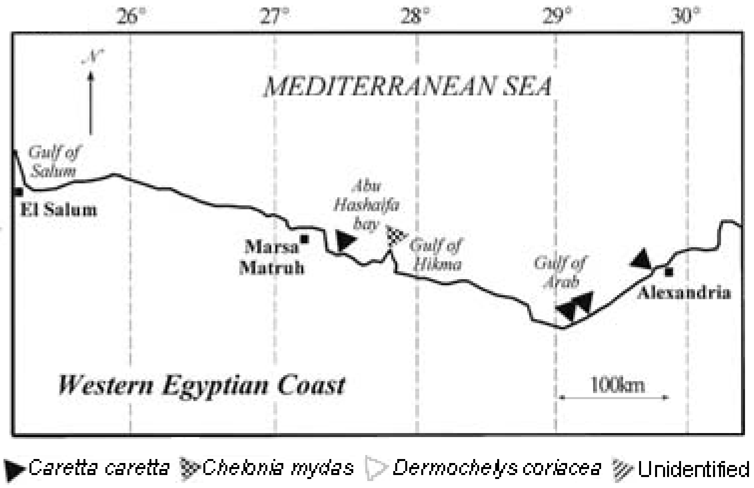
Western Region - Only 5 turtle corpses were found along the 249.3 km of coastline surveyed (density 0.020/km), 4 loggerheads and 1 green. Most of the corpses were located in the eastern part of the region towards Alexandria (**Fig. 1).**

Central Region - A total of 23 dead turtles were found along the 166.5 km of coastline surveyed in this region (density 0.138/km), 18 loggerheads, 1 green and 4 unidentified. The majority of the corpses were concentrated in the vicinity of the Rosetta branch of the River Nile (**Fig. 2**).

Eastern Region - A total of 26 dead turtles were found along the 200.7 km of coastline surveyed (density 0.129/km), 16 loggerheads, 6 greens, 1 leatherback (*Dermochelys coriacea*) and 3 unidentified. Turtle corpses were found along the entire length of the coast in this region, but were most highly concentrated in the westerly section (**Fig. 3**).

The majority of turtle corpses found were concentrated in the areas just east of Alexandria and Port Said. It is likely that large congregations of turtles are feeding on, and in, the extensive meadows of sea grass, *Posidonia oceanica,* that lie just off shore in these regions (Mostafa *et al.* 1990). Also, along the coast of the Sinai, east of Port Said, there is a small marine turtle rookery (Clarke *et al.* 1999), attracting adult females to the area. Most of the dead turtles found were subadult or young adults, probably not yet of reproductive age. The loss of a high number of prereproductive individuals could have severe consequences for the survival of the population as a whole. Subadults die before they have replaced themselves in the population. The ultimate result of the disproportionate loss of a large number of subadults is a decline in the population. However, it is also possible that the corpses of smaller, lighter individuals are more readily transferred onto the beaches by oceanic currents resulting in a biased sample. This requires further investigation.

In most cases the cause of a turtle's death was difficult to ascertain, however in several cases it was obvious that death had resulted from



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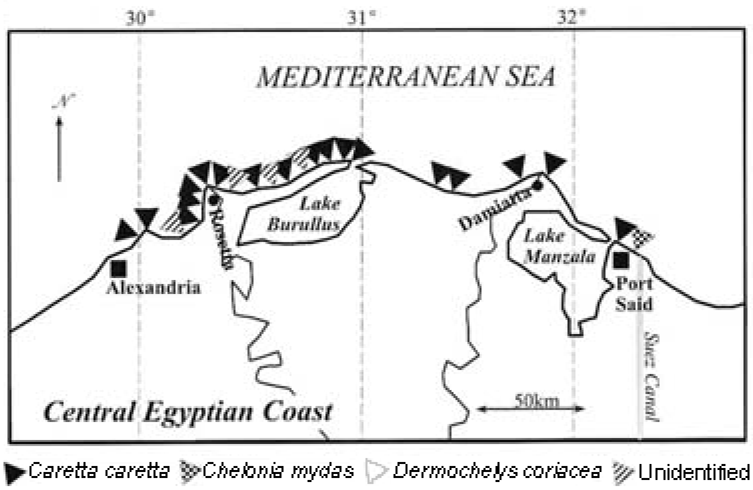

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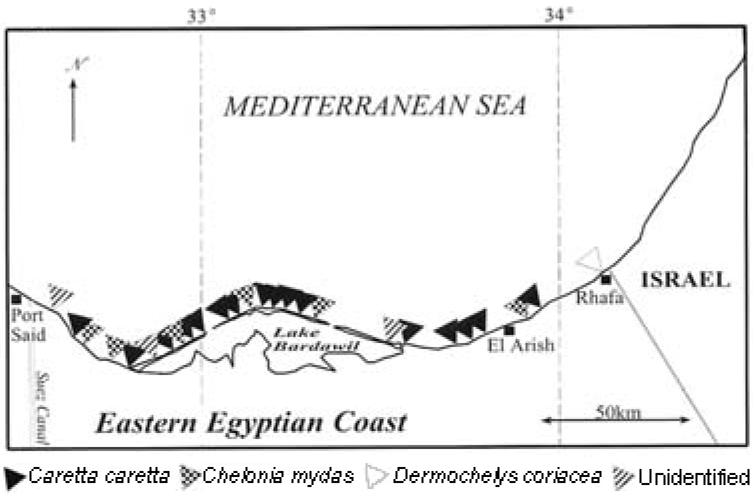

Figure 3.

entanglement in fishing line. Evidence was also found during the survey that marine turtles are still being utilized as a human food source in Egypt. These observations support the contention of Laurent (1996) who reports that several thousand turtles may be slaughtered in Egypt each year for human consumption.

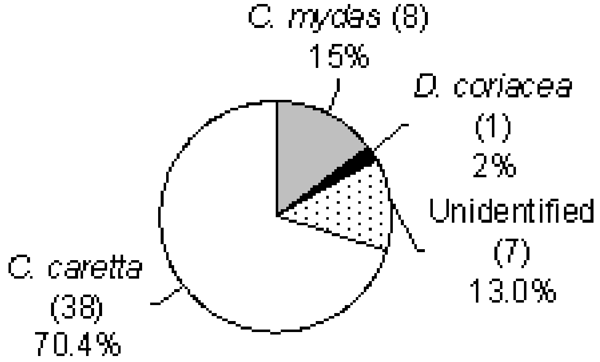

Figure 4. A total of 54 turtle corpses were found during the 1998 survey of the Mediterranean coast.

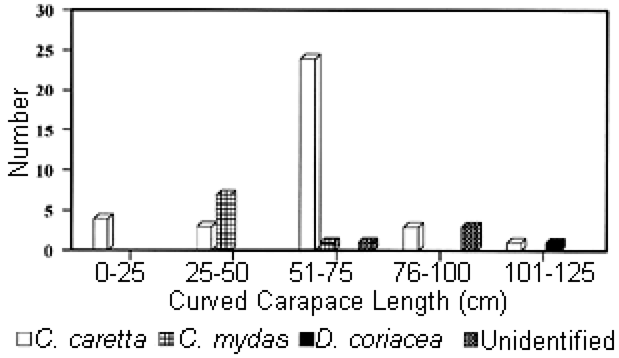

Figure 5. Curved carapace length of stranded turtles.

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The Effect of Beach Nourishment on Loggerhead Nesting and Reproductive Success at Sebastian Inlet, Florida.

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Beach nourishment is now common on the East Coast of Florida, including beaches that are major loggerhead (*Caretta caretta*) nesting grounds. Despite guidelines, nourished and natural beaches are clearly different in many respects. Recent studies at Sebastian Inlet, Florida have found significantly smaller grain sizes, higher moisture content and higher shear resistance when compared to a natural beach (Parkinson and White, 1992; Cornelisen, 1996). Nourishment may reduce loggerhead nesting success (the proportion of nests over total crawls) by impeding gravid females and it may reduce reproductive success by the alteration of the nest microclimate. Many studies have already shown that nourishment scarps can reduce nesting success (Raymond, 1984; Nelson and Dickerson, 1989; Ryder, 1993; Steinitz, *et al.*, 1998), but none have shown significantly reduced reproductive success (Raymond, 1984; Nelson *et al.* 1987; Broadwell, 1991; Burney and Mattison, 1992; Ryder, 1993; Steinitz, *et al.*, 1998). The beach profile may also be affected. Wood (1998) recently showed that nest site selection in loggerheads was related to the beach slope. Since nourished beaches can have disrupted beach profiles (Raymond, 1984), reproductive success can be reduced in nests deposited too close to the water or too close to the dune. The objective of this study was to compare nest totals, false crawl totals, nest placement, nest depth, days to emergence, reproductive success and egg fates between an old renourished beach, a recently nourished beach and a natural (control) beach at Sebastian Inlet, Florida in 1996, 1997 and 1998.

The study sites were each 200 meters and located near Sebastian Inlet, which is approximately 25 kilometers south of Melbourne Beach, Florida, USA (28.0°N, 80.5°W). The south (S) study site was last renourished in 1993. The south treatment (ST) study site was first nourished in 1997. The control (C) study site had never been nourished and was considered free of inlet influence (Venanzi, 1992). These study sites were traversed on foot each day at dawn from 1 May until 31 August and every third day after that until 15 September. We recorded cross-shore distances for all nests and false crawls to the tide line and top of the dune. In 1997 and 1998, we used a clinometer to measure slopes. We inventoried nests four days after hatchling emergence or at 60-70 days post-laying if we did not see the emergence. Since disturbances made comparisons problematic, we did not include any raccoon depredated or washed out nests in our reproductive success analysis. In 1997, we measured nest depths. During nest inventories, we opened all unhatched eggs and categorized them as "infertile type", addled (undifferentiated early development), embryo, fetus, pipped dead or unknown (ghost crab depredated). We categorized both the live and dead hatchlings that did not emerge from the nest as dead in the nest (DIN). We defined reproductive success (emergence success rate or ESR) as (hatched eggs - dead in the nest) / total eggs X 100.

In all three years, we found the number of nests and false crawls were significantly different between study sites (**Table 1).** A reduction in nesting success at south treatment in 1997 was due to the formation of a permanent nourishment scarp approximately 0.5-1.5 m high. In 1998, the Sebastian Inlet Tax District constructed a gentler beach profile by knocking down the winter scarp and nesting success improved. Mean nest distances to the top of the dune were not significantly different in 1996, but they were in 1997 and 1998 (**Table 1**). Most nests at south treatment were placed close to the water or in the dune vegetation. There were no significant differences in slope at nests in 1997 (**Table 1**), suggesting that females selected similar slope increases, but at varied cross-shore locations. The number of days to incubation was significantly different only in 1998. In addition, nest depths were significantly shallower at south treatment in 1997 probably due to increased compaction.

This was the first study, of which we are aware, that reproductive success (ESR) was significantly reduced in nourished substrates (**Table 1**). The reduction was seen primarily in many eggs that were arrested early in development. The increased sand moisture content may have impeded gas exchange across the eggshell (Packard *et al.* 1977; Ackerman, 1991), and resulted in decreased success (McGehee, 1990). In 1998, there were no significant differences in ESR. Interestingly, the lack of rainfall that year may have introduced better incubation conditions at the nourished beaches.

Physical data collected by researchers at Florida Tech continued to show these nourished beaches exhibited significantly smaller grain size, higher moisture content, lower temperature and higher shear resistance values (Parkinson and Magron, 1997; Magron pers. comm., 1999). These attributes were probably responsible for much of the data reported herein. However, other variables such as inlet influences and water table levels may have also contributed to the results reported. It is important to remember that these results were specific to the locations studied and problems such as nonrandom raccoon predation and lack of additional control sites persisted.

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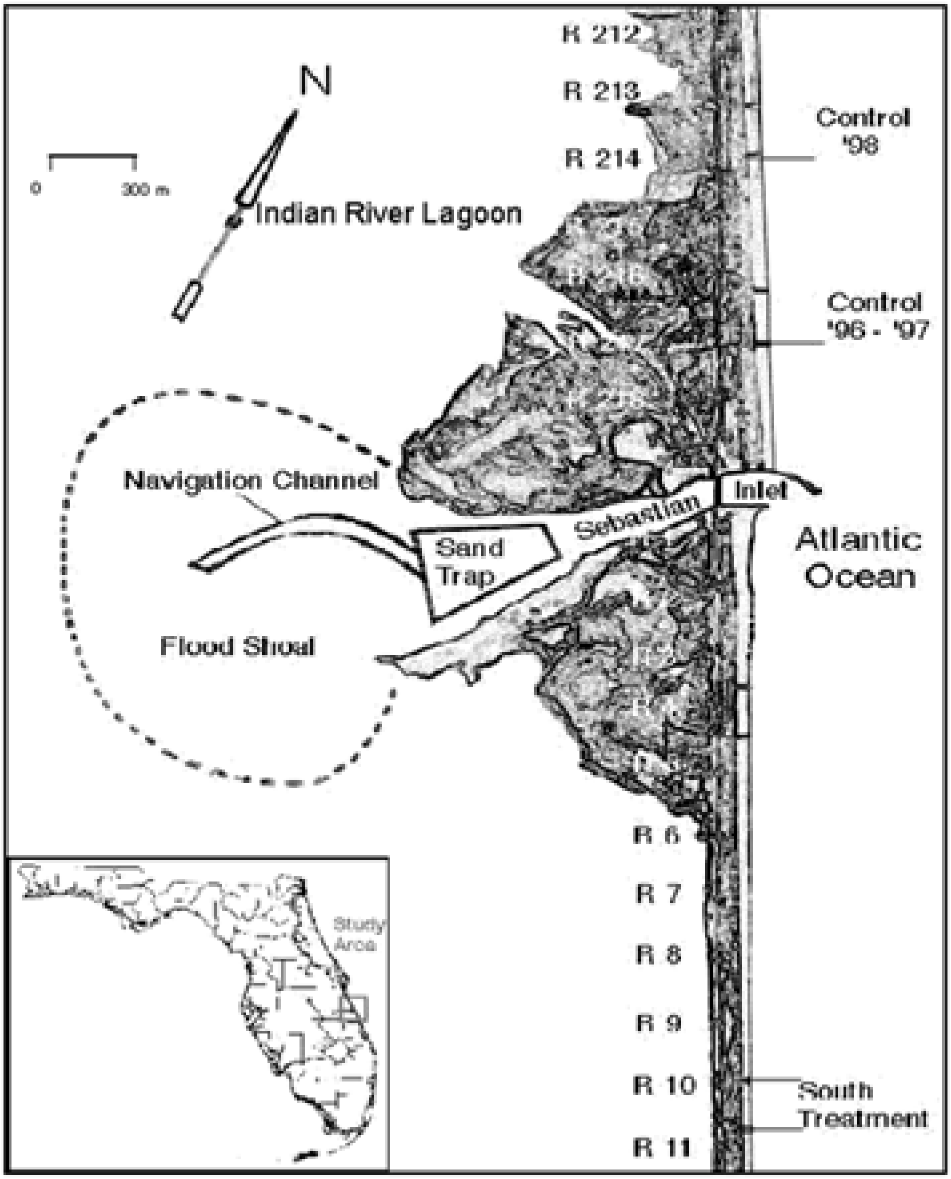

Figure 1. Control, south and south treatment study sites at Sebastian inlet, East-Central, Florida, USA.

Table 1. Totals, means and statistical tests between control, south and south treatment study sites in 1996, 1997, and 1998. Multiple comparisons with the same letter are not significantly different at the 0.05 level. ns=not significant. N/A=not available. TOD=top of the dune.

Parameter	**test**	**C**	**S**	**S. T.**	**P-value**	**C**	**S**	**S.T.**	**P-value**	**C**	**S**	**S.T.**	**P-value**
# of Nests	x^2	83	57	63	p=0.023	90	46	12	p<0.001	96	50	43	p<0.001
# of FC		100	26	49		67	54	41		188	56	56	
Nest Dist TOD	K-W	5.3	4.4	4.0	ns	5.3^a	7.7^b	11.6^b	p=0.007	5.6^{ab}	8.3^b	4.8^a	p=0.002
Slope at nests	K-W	N/A	N/A	N/A	N/A	7.8	7.9	6.3	ns	9.6^a	7.1^b	9.2^a	p<0.001
FC Dist TOD	K-W N/A	N/A	N/A	N/A	N/A	4.9^a	10.6^b	18.5^c	p<0.001	2.4^a	12.5^b	7.2^c	p<0.001
Slope at FC	K-W N/A	N/A	N/A	N/A	N/A	8.6	10.5	6.9	ns	8.9^a	7.3^b	6.4^b	p<0.001
Nest Depth	K-W	N/A	N/A	N/A	N/A	57.4^a	56.4^a	51.2^b	p=0.001	N/A	N/A	N/A	N/A
# Inventoried		53	44	40		50	42	15		73	46	22	
Days to Emergence	ANOVA	53.0	52.3	53.8	ns	53.0	52.8	54	ns	49.0^a	50.7^b	51.3^b	p=0.002
Clutch Size	ANOVA	109.7	107.1	106.1	ns	106.6	110.5	104.2	ns	107.9	117.6	110.0	ns
ESR	K-W	77.3^a	51.4^b	52.5^b	p<0.001	76.7^a	50.3^b	50.6^{ab}	p=0.015	71.2	66.7	59.9	ns

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Traumatic Causes of Stranding in Marine Turtles in Florida

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Between 03/05/97 and 05/14/98, 20 marine turtles (12 *Caretta caretta,* 7 *Chelonia mydas*, and 1 *Lepidochelys kempi*) that had been stranded along the east coast and southwest coast of Florida received complete postmortem examinations. In 8 turtles the primary disease process found at necropsy was related to trauma. Seven of these turtles were alive at the time of stranding, but died shortly thereafter. Clinical signs included flotation problems, lethargy, emaciation, and heavy encrustation of shell with barnacles. Lesions of impact injury (2 green and 2 loggerhead turtles) included fractured and/or perforated carapace; fractured vertebrae and/or osteomyelitis, resulting in hind flipper denervation muscle atrophy; coelomitis; and multicentric inflammation. A loggerhead turtle with fish hook injury presented with a nylon line exiting from the mouth and wrapped around the flippers. The fish hook had lodged in the trachea, resulting in tracheal necrosis. In a green turtle that swallowed a fishing line with lead weights, the intestine was imbricated and dilated, resulting in obstruction. In another green turtle found entangled in a lobster pot buoy rope, there was congestion and indentation of tissues around the neck and trachea, associated with fibrinonecrotic tracheitis. In a Kemp's ridley that allegedly drowned, there was pulmonary congestion and interstitial edema, but no excess fluid in the pulmonary air spaces and no other underlying life-threatening lesions. The exact cause of death of this turtle could not be determined. The cause of death in the other turtles was septicemia.

It could not always be determined whether traumatic injury was the sole cause of the demise of the turtles or if systemic disease predisposed certain turtles to traumatic injury. For instance, in the three loggerhead turtles the concentrations of several toxic metals were elevated relative to other turtles in the study, including (ranges reported in ppm): arsenic (5.5-13 in liver; 7.7-16 in kidney); cadmium (3.9-9.9 in liver; 34-53 in kidney); mercury (0.55-1.0 in liver); and lead (1.6 in one kidney). Hepatic (8.7 ppm) and renal (1.4 ppm) lead concentrations were elevated in the green turtle with intestinal foreign body, resulting in renal necrosis. In most instances, the sequela of trauma were insidious.

Introduction

Since 1980, data have been collected on marine turtle strandings in Florida coastal waters, including total numbers of annual strandings, the number of each species stranded, and the condition of the carcass at the time of stranding (Data source: Florida DEP, Florida Marine Research Institute, Sea Turtle Stranding and Salvage Network database). Some of the reported causes of stranding and death in Florida and elsewhere included boat trauma, predation, drowning and a variety of diseases, including fibropapilloma, parasitic diseases and herpesvirus infection.[1] Other factors cited as being responsible for the population declines include: 1) pollution; 2) death of turtles in drift nets, gill nets, and trawls; 3) loss of food resources; 4) loss of nesting habitat; and 5) capture of turtles by humans or other predators for food or other turtle products.[1] The cause of declines may be multifactorial or due to cumulative effects of these factors.

Necropsies of fresh carcasses can provide valuable data on causes of illness and death of the various species and populations of turtles[2], and can provide a better understanding of how marine turtles respond to a variety of disease conditions. Necropsy of recently deceased wild marine turtles is a key approach in determining the causes of disease, stranding and mortality in this group of animals. As part of an ongoing collaborative study with Florida DEP, recently deceased marine turtles are collected and submitted to the Univ. of Florida for necropsy, isolation of microbial pathogens, and toxin analyses. The overall goal of this project is to determine the actual and potential causes of illness or death by gross and microscopic examination of tissues and by conducting evaluations for bacterial and fungal pathogens, environmental toxins and parasites. In this presentation, we focus on strandings associated with traumatic causes, including boat impact injury, foreign body (fish hook and line) injury, entanglement in rope, and drowning.

Objectives

1. Determine causes of illness or death of recently deceased stranded wild marine turtles from all parts of Florida coastal waters using standardized postmortem analytic techniques.
   - Focus on traumatic causes of turtle strandings.
2. When feasible, isolate and identify bacterial, fungal and/or viral pathogens in body cavities or tissues; determine the concentrations of toxic metals in liver and kidney; and determine the degree of parasitic infestation.
3. Identify predisposing factors that might lead to traumatic injury.

Materials and Methods

A total of 20 turtles (12 *Caretta caretta*, 7 *Chelonia mydas,* and 1 *Lepidochelys kempi*) stranded along the east coast and southwest coast of Florida between 03/05/97 and 05/14/98 were received for complete necropsy. Included in this group were 8 turtles (4 *Chelonia mydas,* 3 *Caretta caretta*, and 1 *Lepidochelys kempi*) that sustained traumatic injury, resulting in stranding and/or death. This group of trauma victims included 7 females ranging from 1.3 kg (Kemp's ridley) to 141 kg, and a 20 kg male loggerhead turtle; straight midline carapace length ranged from 28 to 104 cm. All but the drowned turtle were alive at the time of stranding, but died shortly thereafter. Clinical signs included flotation problems, lethargy, emaciation, dehydration, hind limb atrophy and paralysis, and heavy encrustation of shell with barnacles. One turtle presented with a long fishing line exiting from the mouth and wrapped around the flippers. Another turtle was entangled in a rope, which encircled a front flipper and the neck area. Shell fractures were evident in some turtles.

To ensure freshness of the carcass, most necropsies were conducted within 24 hours after death. Prior to necropsy, survey dorsoventral radiographs of the carcass were obtained. All major organ systems of the turtles were characterized grossly and histologically. The plastron and skull were removed and tissues were collected from the trachea, lung, spleen, thymus (if present), integument, shell, heart and great vessels, liver, pancreas, kidney, urinary bladder, intestine, reproductive tract, skeletal muscle, brain, thyroid, adrenals, eye and associated infraorbital structures, bone, and bone marrow. Sections of liver and kidney were collected and stored at -20°C until analyzed for toxic metals. Tissue sections (approximately 0.5 cm wide) from the above organs were fixed in neutral buffered 10% formalin for 24-48 hours, embedded in paraffin, sectioned at 5-6 mm, stained with hematoxylin and eosin and as necessary, with a variety of special stains. Swab specimens of choanae, distal intestine and grossly inflamed tissues were obtained for bacterial or fungal isolation. For recovery, enumeration and identification of helminth parasites, gastrointestinal contents were recovered, washed free of ingesta through a series of 50- and 100-mesh screens, and suspended in an illuminated glass plate.

Concentrations of the following metals and minerals were determined on portions of liver and kidney: selenium, copper, iron, arsenic, mercury, chromium, cadmium, lead, manganese, zinc, molybdenum, phosphorus, barium, tin, magnesium, vanadium, sodium, cobalt, calcium, and nickel. Metal analyses were conducted in the USDA National Veterinary Services Laboratories, Ames, Iowa. With the exception of mercury and selenium, metals were analyzed by inductive coupled plasma emission spectroscopy (ICP). Mercury concentration was determined by cold vapor atomic absorption spectrophotometry and selenium concentration was determined by gas liquid chromatography/electron capture detection (GLC/ECD).

Results

Lesions of impact injury (2 green and 2 loggerhead turtles) included fractured and perforated carapace; fractured vertebrae and osteomyelitis, resulting in hind flipper denervation muscle atrophy; coelomitis; and multicentric inflammation. Internal lesions were colonized by a variety of bacteria. The cause of death in these turtles was bacterial septicemia. In a loggerhead turtle with fish hook injury, the fish hook had lodged in the larynx, resulting in laryngeal and tracheal necrosis. In a green turtle that swallowed a fishing line with lead weights, the intestine was imbricated and dilated, resulting in obstruction and ulceration. Hepatic (8.7 ppm) and renal (1.4 ppm) lead concentrations were elevated, resulting in renal necrosis. In another green turtle found entangled in a lobster pot buoy rope, there was excoriation around sites of entanglement, and congestion and indentation of tissues around the neck and trachea. The cause of death was fibrinonecrotic tracheitis, not asphyxiation. In a Kemp's ridley that allegedly drowned after being trapped against an underwater intake valve, there was pulmonary congestion and interstitial edema, but no excess fluid in the pulmonary air spaces and no other underlying life-threatening lesions. The exact cause of death of this turtle could not be determined.

In the three loggerhead turtles, the concentrations of several toxic metals were elevated relative to other turtles in the study, including (ranges reported in ppm): arsenic [5.5-13 in liver (study range=1.0-18); 7.7-16 in kidney (study range=<1.0-23)]; cadmium [3.9-9.9 in liver (study range=0.89-29); 34-53 in kidney (study range=0.97-73)]; mercury [0.55-1.0 in liver (study range=0.12-2.9)]; and lead [1.6 in kidney of one turtle (in most turtles in this study, renal and hepatic lead concentrations were <0.5)]. Hepatic (8.7 ppm) and renal (1.4 ppm) lead concentrations were elevated in the green turtle with intestinal foreign body, resulting in renal necrosis.

A loggerhead turtle with impact injury and the green turtle that was entangled in a rope had intestinal parasite counts greater than 1000. The most numerous parasites were *Orchidasma amphiorchis* in the loggerhead and *Microscaphidium reticulare* in the green.

Discussion

Of all the traumatic causes of stranding and death identified in this study, the most difficult cause to verify was drowning. If turtles trapped under water hold their breath and asphyxiate without inhaling water, then definitive diagnosis of drowning on postmortem examination must be based on something other than finding seawater in the trachea or lungs. Perhaps drowning should be considered as a differential cause of death in recently deceased turtles when no other life-threatening lesions or toxins can be found at necropsy. This applies only to fresh carcasses, as autolysis could certainly mask lesions. In this study, the hallmark of impact injury was the presence of a fractured shell or spine, resulting in bacterial septicemia or paralysis. A variety of aerobic bacteria were isolated from lesions, suggesting that bacterial infection was a secondary event. Although bacteria were found on microscopic examination, aerobic bacterial culture of the liver sometimes failed to recover an organism, indicating the likelihood of an anaerobic bacterium. The absence of inflammatory or denervation lesions may preclude a diagnosis of impact injury (for example, in a drowned turtle that was struck afterward by a boat). The discovery of internalized or entangled fishing line or rope material in a stranded turtle provided a strong clue to the cause of stranding.

Even with overwhelming evidence of trauma, the cause of stranding of some of the turtles may have been multifactorial. Study of diseases of free-ranging species that inhabit potentially polluted environments would be incomplete without addressing the impact of environmental toxins, including toxic metals. While there are minimal data on the toxic effects of heavy metals in marine turtles, heavy metals can cause debilitation or death in other wildlife species.[3] A number of potentially toxic heavy metals have been found in turtle tissues.[4-6] In most cases, metal concentrations were determined in tissues other than liver and kidney, so that comparisons cannot be made with the concentrations of metals in our study. In a study of green turtles with fibropapillomas, cadmium concentrations overlapped with those in our study, but arsenic concentrations were at the low end of our range.[6] Concentrations of arsenic, cadmium, lead and mercury at the high end of our range are considered high or toxic in one or more wild and domestic animal species.[3,7]

Heavy infestations of helminth parasites may also contribute to debilitation in marine turtles[8,9] and predispose them to traumatic events. Two turtles had gastrointestinal parasite counts greater than 1000. In the loggerhead turtle, there was a fibrinonecrotic and ulcerative enteritis, which was probably unrelated to the impact injury. Unfortunately, intestinal autolysis in the green turtle precluded determination of the significance of the apparently high parasite count. Turtles also had varying degrees of spirorchidiasis.

In conclusion, traumatic injury may result in death, but often not immediately. The sequela may be insidious, resulting in localized infection or septicemia with multicentric visceral inflammation. Fractures may heal, but trauma to the spinal cord can leave a turtle permanently paralyzed. Swallowed fish hooks can cause severe damage if the esophagus is penetrated. Lead weights attached to swallowed fishing line can cause lead toxicity. Techniques to definitively identify drowned turtles need to be identified. Finally, it is possible that factors such as metal toxicity or heavy endoparasitism can debilitate and predispose turtles to traumatic injury.

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Obstacles Associated with Sea Turtle Nesting in Biscayne National Park

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Biscayne National Park is located in extreme southeast Florida, and comprises the northernmost Florida Keys. The islands represent one of the only undeveloped areas in the Florida Keys. Sea turtle nesting was first documented within the park in 1980. Loggerheads and Hawksbills are the only confirmed sea turtles nesting within the park, although green and leatherback nesting may occur. Biscayne National Park receives approximately 18.75 nests, and 22.0 false crawls per year, covering 3.67 km.

Biscayne National Park represents a unique nesting ground for sea turtles. The islands of the park are made of coral limestone, and are surrounded by pinnacle rock at the intertidal zone, hampering movement by adult and hatchling sea turtles alike. Trash washing on the "beaches" is a constant problem. Limited access makes beach cleanup difficult. Trash material that washes ashore include a significant amount of lobster trap line, large pieces of lumber, derelict vessels, and metal drums.

Coastal vegetation on the islands consists of mangroves, shrubs, grasses, and vines. The majority of turtle nests occur among this vegetation. Crawl identification is difficult in these areas. Crawl tracks are frequently unidentifiable, and nesting attempts are difficult to discern. Due to logistical difficulties raccoons often reach nests before it is possible to screen them. Raccoon predation is heavy; however, predation control is limited to protecting nests with screens.

Pinnacle rock, debris, and small beaches with coral rubble and coarse carbonate sand are the major obstacles to nesting in the park. Despite marginal nesting habitat the park annually records 52.2% hatching success.

Impact Assessment of Upland Source Beach Nourishment on the Physical Environment of a High-Density Marine Turtle Nesting Beach, Sebastian Inlet, Florida, USA.

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This report describes the impact of a nourishment project on the coast of East Central Florida from which fill material was derived from an upland sand mine. In this region, the physical characteristics of upland and marine sands are considerably different. Many of these distinctions are known to influence marine turtle nesting and reproductive success. In this study, the sand mineralogy is a concern as the upland sand is depleted of carbonate sediments. Carbonate content on the Impact beach decreased of 33% in this particular study.

Introduction

In Florida, beach nourishment is the preferred shoreline protection against erosion. In the past, numerous projects have thus been undertaken using traditional methods of offshore and coastal sand dredging. However, the coast of East Central Florida is historically known to lack sufficient quantities of traditional marine-derived beach-quality sand to meet the ever-growing demand imposed by coastal urbanization and communities seeking permits for erosion control (Stauble, 1991). A visible effort is now being invested on evaluating new sources (i.e. upland, international imports) (Williams and Rendigs, 1995).

In this study, an upland sand source has been used for nourishment and it has not yet been ascertained what effects this new sand source might have on marine turtle nesting and reproductive success. Beach nourishment volume is expected to increase exponentially in the future (Valverde, 1996) so it is critical to seize upon the potential new effects of upland sources on nesting beach physical conditions. This study is timely since the future of beach nourishment on the coast of East Central Florida can be predicted to utilize many projects derived from upland sand sources.

Methods

The study sites (see **Fig. 1** on pg. 223) were surveyed one year prior to upland sand nourishment (1996) and the two post-nourishment years (1997-98). Beach nourishment (200,000 yd^3 of upland Pleistocene sand) occurred during the winter of 1996-97. After sand placement, the beach was graded in 1997 according to DEP regulations and it was then regraded prior to 1998 nesting season in order to reduce scarping created by adjustments in the nourishment profile.

Physical monitoring of the beach was conducted monthly during each nesting season (May through October). Assessment of the beach physical environment consisted of surveying physical parameters that were known to directly affect the nesting and reproductive success of marine turtles (i.e. shear resistance, moisture content, sand temperature, sand texture, and sand composition). Each beach study site was monitored along four transects and sampled at three cross-shore stations: (1) toe of the dune, (2) mid-backshore, and (3) spring high water level. For each station, two samples were collected respectively at -30 cm and -60 cm from which a single mean value was calculated to represent the station. The collaborative team of UCF, under the direction of Dr Llewellyn Ehrhart, conducted biological monitoring.

The impact assessment analysis was conducted by utilizing a statistical method called BACI (Before and After Control/Impact) (Underwood, 1991), and it consisted of two parts: (1) 1996 versus 1997, and (2) 1996 versus 1998.

Results and Discussion

On both post-nourishment years (1997 and 1998), alterations on the Impact beach are clearly demonstrated throughout the beach physical environment (**Figs. 1 to 3**) as well as the marine turtle nesting and reproductive success (Ehrhart and Herren, 1996, 1997; Ehrhart and Herren, pers. Comm., 1998). Statistical analysis of each individual physical parameter illustrates the same results as significant differences appear among pre- and post-nourishment years (P-values ranging from <0.001 to 0.047). Physical parameters are then clearly identified to influence the marine turtle nesting and reproductive success. Altered shear resistance and sand grain-size of the Impact beach have significantly reduced nesting success. Emergence/hatching success and days to emergence have also significantly changed with wetter, cooler and finer-grained conditions of the Impact beach.

According to Parkinson and White (1993), beaches on the coast of East Central Florida have a 45 to 50% carbonate content as the region is located within a siliciclastic to carbonate transitional zone (Parkinson and White, 1993). In 1997, the carbonate content on the Impact beach decreased from 35 to 2% (**Fig. 4**) since the upland mine (subject to long-term chemical weathering) was completely exhausted of carbonates. That is to be considered, as quartz (siliciclastic sediment) is known to influence heat conductivity. Incubation temperature can be then altered which in turn could have significant impacts on sex ratio or incubation duration (Mrosovsky and Provancha, 1998).

From 1997 to 1998, the negative biological impact was distinctly reduced while the alterations on physical parameters remained constant. Yet, when comparing both statistical analyses (1996 vs. 1997, and 1996 vs. 1998), significant differences prevailed but the P-values increased demonstrating a recovery trend over time. That trend can also be verified on the compositional ternary diagram (**Figs. 1** and **4)** as the carbonate content recovered over the post-nourishment years. The 1998 mechanical regrading action (reducing scarp formation) must have generated the recovery (allowing higher female emergence on the beach) but natural processes must also have been a factor (as the beach is continuously reworked by wind or wave actions). Natural recovery was clearly shown as "spring-high water level" stations (closer to wave action) had the highest degree of recovery when compared to the rest of the cross-shore stations. However, the natural processes are of slower recovery rate when compared to the use of engineering action.

Conclusions

This study clearly demonstrates the significant impact of upland nourishment on the physical environment of the beach, which in turn directly affects the nesting and reproductive success of marine turtles. The upland nourishment impact can be credited to be identical to traditional impact, but sand mineralogy (known to influence sex ratio or incubation duration) of beach has severely changed with placement of upland fill material. So further investigation is to be taken on sand mineralogy in order to determine how biologically significant such changes can be on the marine turtles. Natural recovery of the altered beach takes place after nourishment. For future projects of this kind, beach profile regrading is recommended (at least for the 2 years after impact) in order to accelerate assimilation of beach alterations. Other parameters such as water table and sand color should be looked at.

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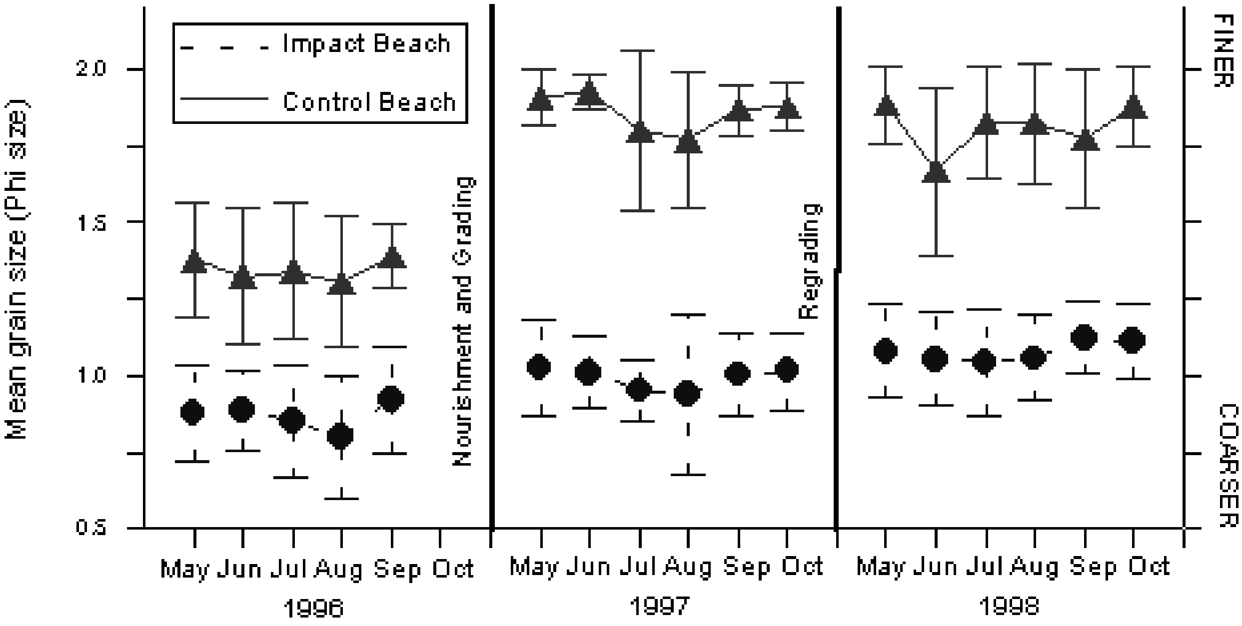

Figure 1. Mean grain-size before (96) and after (97-98) nourishment. Error bars are standard deviations. Impact beach became finer. Note how std. dev. (or sorting) increases in 1998 demonstrating recovery as grain population gets more naturally diversified.

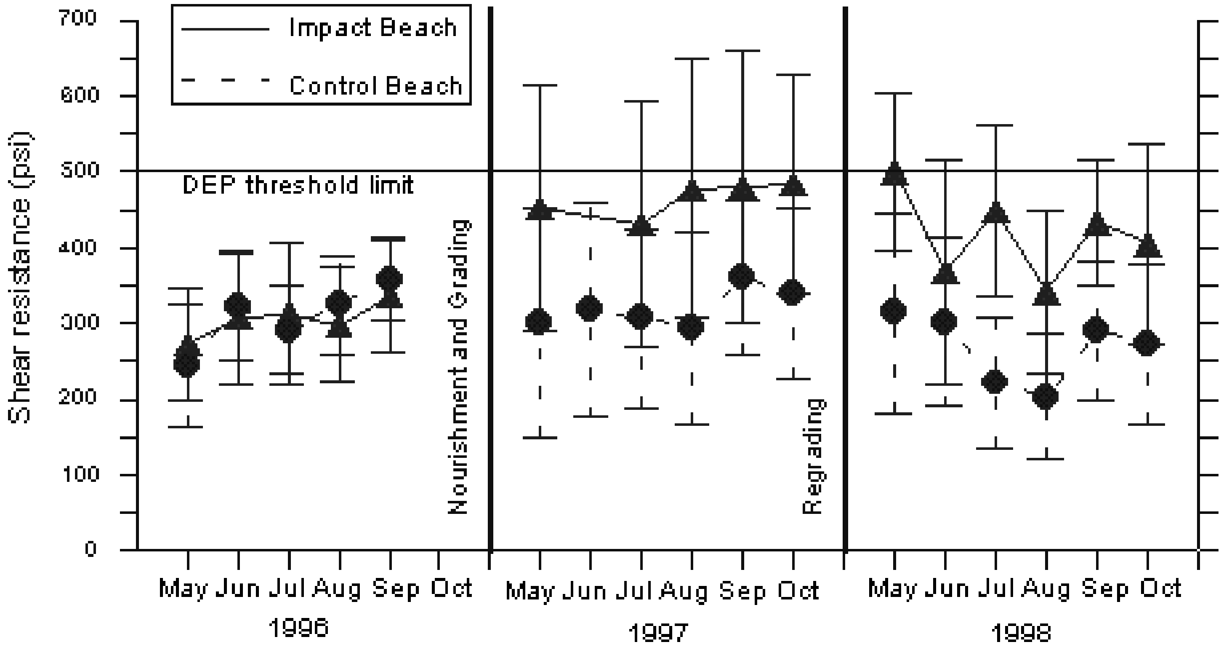

Figure 2. Shear resistance before (96) and after (97-98) nourishment. Error bars are standard deviations. Nourishment project increased resistance values but they remained below the maximum threshold limit. In 1998, values slightly decreased following regrading action.

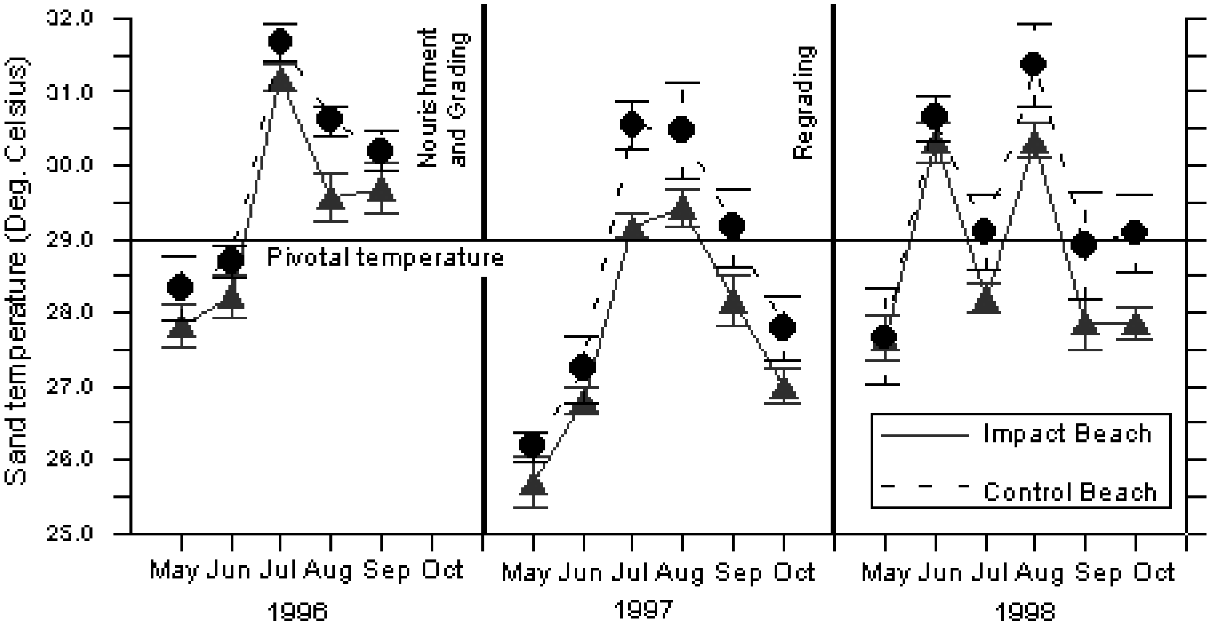

Figure 3. Sand temperature before (96) and after (97-98) nourishment. Error bars are standard deviations. A 1°C decrease was observed during both mid-season and after nourishment. Note the strong seasonal variation in July 1998 due to large amount of rainfall on sampling day.

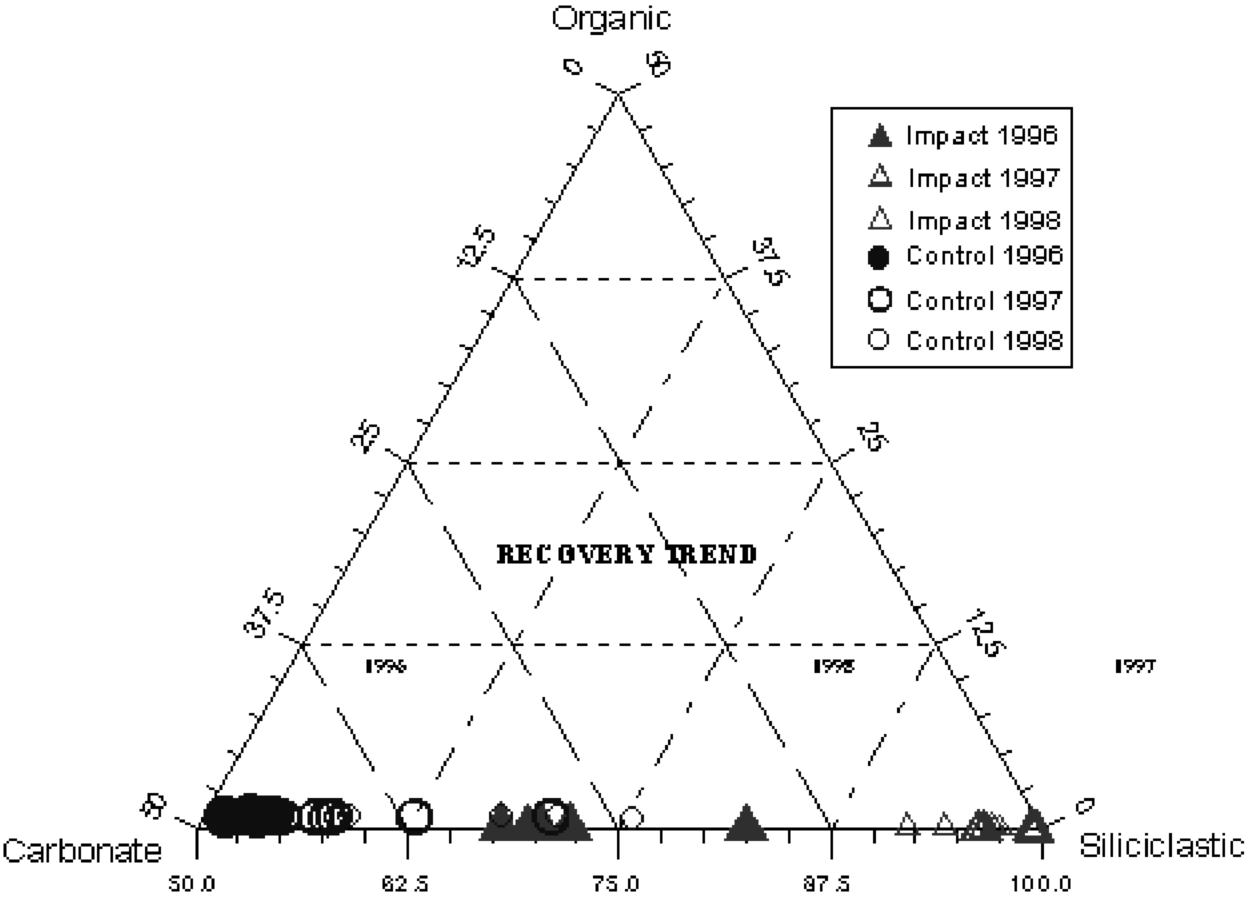

Figure 4. Ternary diagram of sand composition (organic, carbonate, siliciclastic content) before (96) and after (97-98) nourishment. Control beach values (circles) remained relatively similar. The carbonate content of Impact beach (triangles) decreased from 1996 to 1997, while in 1998 it recovered slowly. Recovery trends occur on the siliciclastic-carbonate equilibrium as the natural ratio is around 50:50.

What Is Coastal Armoring and How Can It Affect Nesting Sea Turtles in Florida?

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There are many types of coastal armoring. Some of these, such as jetties and breakwaters, are placed offshore to stabilize inlets and divert the natural flow of sediment to trap sand on beaches. Others, such as bulkheads, seawalls, and revetments, are placed onshore, parallel to the shoreline, to separate the land area from the water. Sand bags and geotextile tubes are buried on beaches to hold the sand in place. Combinations of these and other types of armoring can be found all along the Florida shoreline. Although the impact of coastal armoring on sea turtle nesting habitat is poorly understood, structures continue to be erected on turtle nesting beaches. Data summarized in 1996 show that 23% of Florida's east coast and 14% of the west coast were armored with some type of armoring structure. In a 1990 study, the Florida Division of Beaches and Shores reported that armoring was concentrated in 5 areas of the state and predicted that most future armoring would likely occur along the primary nesting beaches for sea turtles in Florida. The Florida Dept. of Environmental Protection has compiled data that show that coastal armoring structures can influence turtle nesting by blocking access to desirable nesting sites, interfering with nesting behavior and even trapping nesting females. In order to address the coastal armoring issue, the problems of inappropriate coastal development must be emphasized over the method of erosion control.

Human Impact on Loggerhead Sea Turtles in the Western Mediterranean with Emphasis on Debris Ingestion

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Anthropogenic debris and fishery activities are two important and increasing threats for marine turtles. In most diet studies with these species, anthropogenic debris are reported, sometimes with high frequency (den Hartog & van Nierop, 1984; Plotkin *et al*., 1993). The ingestion of debris may cause ulcers, injuries, intestinal obstructions and physiological alterations, resulting in the death of the animal (Hutchinson & Simmonds, 1991; Schulman & Lutz, 1992). Bjorndal *et al*. (1994) also highlighted the adverse health effects derived from the absorption of toxic agents such as tar and oil, or those released from the decomposition of plastics, some of which are known to produce immunosuppressive effects (Hutchinson & Simmonds, 1991). Part of the anthropogenic debris, such as hooks, fishing lines and pieces of nets come from fishing activities.

In the Western Mediterranean there is an important interaction between turtles and fisheries, especially from June to September (Camiñas & de la Serna, 1995), causing high mortality. Also thousands of loggerheads (*Caretta caretta*), mostly subadults, are caught by the swordfish longline fishery at Mediterranean Spanish coasts, specially at the Balearic sea, every year, (Aguilar *et al*., 1992).

In the present study, we analyzed the presence, abundance and type of anthropogenic debris found in loggerhead sea turtles in relation to turtle size and sex. We also studied the interactions with fisheries and the effects on turtles.

Material and methods

Fifty-four illegally caught loggerhead sea turtles that had been seized by Spanish authorities in Barcelona, Spain, were analyzed. Place of capture was not stated, however we may assume that it was the Spanish Mediterranean (Tomás, 1997; Aznar *et al*., 1998). Necropsies were conducted at the Autonomous Univ. of Barcelona. CCL, CCW, and weight were measured and found to be positively correlated. The sex of 52 of the turtles was determined by examination of the gonads. Stomach and gut contents were analyzed at the Univ. of Valencia. Anthropogenic debris, and other items, were separated and analyzed. The importance of debris and the types was expressed by the frequency of its occurrence. It was not possible to weigh the wet mass of the contents.

Debris ingestion was compared between two groups: A: CCL>40 cm; and B: CCL<40 cm. The turtles of the second group are considered juvenile according to Dodd (1988). A Chi-square analysis was tested to compare debris ingestion between sizes (N=54) and sexes (N=52). Since comparison, by this test, between size groups did not fit Conover's (1980) assumption, we calculated 95% confidence intervals for the frequencies (binomial distribution).

Results

All the analyzed turtles were under 70 cm CCL (mean CCL=49.4 ± 8.98 cm). Of the 54 turtles found, 42 (77.78%) had debris in the digestive tract with large amounts present in 17 and extremely large amounts present in 4 of them (**Table 1**). However, high quantities of prey items were also detected in the guts of 3 of the latter 4 (Tomás, 1997), probably suggesting that these very high quantities of debris were not sufficient to obstruct the digestive tracts. Plastic was the most frequent item, varying greatly in shape, consistency and color.

Eight turtles in size group A and 34 (73.91%) turtles in size group B had debris in their digestive tracts. There were

27 males (mean CCL 46.79±9.27 cm, mean weight 15.28±10.02 kg) and 25 females (mean CCL 53.21±7.33 cm, mean weight 22.56±10.2 kg). Regarding differences by sexes, 67.86% of the males and 87.5% of the females had debris. The Chi-square tests (with continuity correction) did not show significant differences in debris ingestion between the size groups (P^2=1.3861, P=0.2391) or sexes (P^2=0.6991, P=0.4031). Confidence intervals for the frequencies of occurrence of debris in size groups, were 63%-100% and 59%-86%, resp.

Table 2 shows the external injures observed on the seized turtles and their percentage of occurrence. Wounds caused by nets were not detected.

Table 1. Number of turtles and percent occurrence of the different debris type found in loggerheads seized at Barcelona (N=54).

Type of Debris	Turtles (%)
plastics	38 (70.37)
tar	15 (27.28)
paper	2 (3.7)
Styrofoam	2 (3.7)
wood fragments	9 (16.67)
seabird feathers	7 (12.96)
hooks/monofilament fishing line	5 (9.26)
others	3 (5.56)

Table 2. Percentage of occurrence (%) and number of turtles with external injuries found in loggerheads seized at Barcelona (N=54).

External Injuries	Turtles (%)
Ulcers and injuries at mouth	4 (7.41)
Impacts on carapace	8 (14.81)
Scratches on skin	2 (3.7)
Ulcers on skin	3 (5.56)
Injuries caused by epizoa	1 (1.85)
Cut in plastron	1 (1.85)

Discussion

The CCLs of the Western Mediterranean turtles were below the lower size limit recorded for adults by Dodd (1988). However, nesting Mediterranean populations of *C. caretta* (Eastern and Central Mediterranean beaches) have been reported to reach the sexual maturity at 60 cm CCL (Demetropoulos & Hadjichristophorou, 1995). According to the criteria of all the authors mentioned above, 37 out of the 54 turtles should be classified as subadult. The turtles of group A could be classified as juvenile (Dodd, 1988), but according to the prey found in their guts (Tomás, 1997) they seem to frequent benthic and neritic habitats, and are therefore probably between the juvenile and subadult stage. The larger turtles might be classified as subadults and adults, depending on the authors mentioned, but some loggerhead sea turtles with CCL between 60-70 cm recently stranded in Valencia coasts (Spanish Mediterranean) appeared with their secondary sexual characteristics not developed (unpublished data). So, we can assume that the larger turtles of our analysis probably were sexually immature too.

Anthropogenic debris and other items, like seabird feathers and fragments of wood, are often found in the digestive tracts of marine turtles (Plotkin *et al.*, 1993). In agreement with a previous study (Bjorndal *et al.*, 1994), we did not find significant differences between the two size groups. However it has been suggested that the smaller sea turtles have a high probability of ingesting floating debris, due to their pelagic habitat and diet. The presence of pelagic prey in the stomachs of size group B turtles (Tomás, 1997), despite the characteristic benthic diet of subadults, is in agreement with the high percentage of debris occurrence. No significant differences were found between sexes. However, Bjorndal *et al.* (1994) found significant differences, but they argue that those may be consequence of sample size.

Several authors attribute the presence of debris to the fact that turtles confuse them with prey, especially plastics with jellyfish (Mrosovsky, 1981; Plotkin *et al.*, 1993; Demetropoulos & Hadjichristophorou, 1995). Schulman & Lutz (1992) confirmed that marine turtles, when hungry will ingest debris. However, den Hartog & van Nierop (1984) argued that the shape of the prey was not important to leatherback sea turtles (*Dermochelys coriacea*) since they feed on any floating or slow-swimming object. We observed debris with a high variety of consistencies, shapes and colors. Furthermore, we found feathers, pieces of wood and terrestrial insects. All these items would suggest that these turtles behave similarly to the leatherbacks in the den Hartog & van Nierop (1984) study.

Loggerhead sea turtles may tolerate high amounts of debris, and apparently can expel it. In fact, one turtle was observed with debris at its rectum and high quantities of prey in the gut, and three turtles had heavy amounts of debris mixed with prey items. However, debris ingestion may result in poisoning, due to absorption of decomposition products of plastics (Hutchinson & Simmonds, 1991).

Regarding external injuries, we found four turtles with wounds at the beak and the mouth cavity. These injuries may have had a hook-line origin. Deep injuries on skin might also be caused by hooks. Impacts on carapace might be due to motorboats (propellers) and fishing-boats. However, some of these injuries might be caused *postmortem* when handling the turtles. The presence of hooks and fragments of fishing line and some external injuries in some of the turtles, show the interaction between this species and the Swordfish longline fishery. This and other fisheries are known to have a strong impact among Western Mediterranean loggerhead populations (Aguilar *et al.*, 1992; Camiñas & de la Serna, 1995).

Acknowledgments

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Saving X'Cacel for the Sea Turtles

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Where is X'cacel? What turtles nest there?

X´cacel is located along the eastern coast of the state of Quintana Roo, Mexico (in the Yucatan Peninsula) 112 km south of Cancún by way of the Puerto Juárez - Chetumal highway, in the tourist corridor Cancún - Tulum. It is the most important loggerhead and green sea turtle nesting beach in Mexico, with more nests per km (160 nests / km) than any other beach in Mexico. The area includes 156 hectares of land and 155 aquatic hectares.

Why is X'cacel important?

The consequence of the disappearance of X'cacel's green turtles would entail a 22% loss of mtDNA diversity in Atlantic populations, while the loss of the loggerheads would mean a loss of 30% of mtDNA diversity in the Atlantic populations.

X'cacel was one of the few publicly accessible beaches along the coast of Quintana Roo. Almost without exception, where beach development has taken place the area is closed to public access. X'cacel was the site of environmental education activities for local people as well as national and international tourists for over 10 years until last February. During the sea turtle season (May to October) groups of people were taken out onto the beach under biologists supervision and allowed to observe the nesting turtles or the release of hatchlings.

The area is home to approximately 40 other endangered species and various endangered ecosystems. The dominant type of vegetation (the low forest with *Pseudophonenix sargentlii*) is unique in all of the state of Quintana Roo. Some of the plant species considered threatened or in danger of extinction are: *Pseudophoenix sargentii*, *Thrinax* *radiata*, *Bravaisia tubiflora, Acacia dolichostach* and mangrove (*Rhizofora mangle, Avicennia germinans, Laguncularia racemosa*) and *Conocarpus erecta*. Within the species of fauna: *Crocodylus moreleti, Boa constrictor, Kinosternon creaseri, Rhinoclemmys areolata* and A*cacia dolichostachya*. The fish found in X'cacel's cenote (natural sink hole filled with water) are endemic and are unique to the area. Scientists say that the fish of the X'cacel cenotes justify by themselves that the place has special protection.

What is the conservation situation?

In the ecological management plan for the Cancún-Tulum corridor, published June 9, 1994 in the Mexican Official Newspaper, there is a special recommendation to designate X'cacel and X'cacelito as an especially fragile zone, including the marine area and the adjacent continental area up to the Chetumal-Puerto Juárez federal highway. This special and obviously very important recommendation, for some reason, was not considered when the Protection Zone limits were defined.

In February of 1998 the governor of the state of Quintana Roo announced the sale of every inch of X'cacel to 5 hotel developers. Until then, X'cacel had been protected and more than 10 years of conservation and research had been done on the beach.

Also in February of 1998 the state of Quintana Roo declared the area from the 60 meter isobath to 100 meters up the beach as a preserve. This was just a public relations move meant to calm the storm after the sale of X'cacel was announced.

In the meetings on the tourist corridor the environmentalists proposed to change the land use of the area from the "reserve" (100 meters up the beach) to the highway from "conservation" (allows the construction of up to 10 rooms per hectare) to "protection" (prohibits all construction).

In May of 1998 GEMA filed a lawsuit against the parties responsible for the damage to the palms protected under Mexican law. During the first visit by the inspectors from the Attorney General of the Environment's (PROFEPA) office, the investors did not see the damage done where the borderlines were cut!! In June 1998 Greenpeace in Mexico City filed a lawsuit against Sol Melia for the destruction of the protected palms and mangrove. PROFEPA went to X'cacel with local environmentalists to look at the whole area. Neither GEMA or Greenpeace have received a final response.

A technical commission was formed to exclusively study X'cacel. In this commission, representatives from the investors, environmentalists, academics, and the government were present. In the first meeting, February 15, 1999, they analyzed the management plan for the "reserve" at X'cacel done by The University of Quintana Roo (UQROO). El Colegio de la Frontera Sur (ECOSUR) presented a technical opinion of the management plan which coincides with the opinion of the environmentalists and specialists in the management of natural areas. ECOSUR's evaluation of the management plan for the "reserve" includes the following comments: A band of land only 100 meters wide would not be a practical protected area, it would be too vulnerable in ecological terms, the border effects would be very intense, as well as habitat fragmentation, contamination, and the invasion of undesirable species. In the long term, with the changes in sea level and the water table, the organisms would not have any possibility of adapting by moving because of the tourist and urban development that will encompass the reserve. ECOSUR also states that "because of the importance of maintaining the quality of the phreatic water, extremely sensitive to any transformation of the landscape, and to guarantee ocean water quality, the reserve should be extended, at least, to include the Cancún-Tulum highway."

The National Institute of Ecology (INE) proposed that ECOSUR evaluate the environmental characterization done by ECORED, the environmental consulting company, that was hired by the investors to do a environmental characterization of X'cacel. ECOSUR's evaluation found various deficiencies in ECORED's document, including the lack of information about the marine and fresh water ecosystems and the omission of information on the hydrology. Despite the problems, they agreed with the suggestions to preserve the area, as raised in the document.

In the last technical commission meeting the environmentalists told the investors that they, "had not bought a piece of property, they had bought a problem." Another set of studies conducted for potential investors in 1991 concluded that the area was fragile. The academics of the Yucatan Peninsula who participated in the management plan for the tourist corridor Cancun-Tulum in 1994 recommended special handling for X'cacel and considered it ecologically important.

During meetings of the technical commission, the investors have been offered alternatives: 1. That their investment be returned. 2. The state government helps them build in another part of the state. 3. The federal government gives them a tax break in exchange for the land.

After receiving the academic opinion from the technical commission INE will analyze all the information and determine the fate of X'cacel.

There are many groups in Mexico and abroad who are fighting to protect X'cacel; such as the Caribbean Conservation Corporation, Centro de Derecho Ambiental Mexicano (CDAM), Earth Island Institute's Sea Turtle Restoration Project, Friends of the Earth - The Netherlands, GEMA, Global Response, Greenpeace Mexico and Spain, Grupo de los Cien, National Audubon, Society Oceanic Resource Foundation, Rainforest Information Centre, Sierra Club, and many others.

Protests have been held in Cancun, Quintana Roo, and Mexico City, Mexico; San Antonio and Dallas, TX, and San Francisco, CA, USA; London, England, etc.

Letters have been written by several groups, such as The Audubon Society (which had 48 co-signers), a group from UMAN, the National Autonomous University in Mexico City, "Science in X'cacel", plus thousands of individuals. Signatures have also been collected on petitions and sent to Mexican Government officials.

What you can do to help:

PLEASE fill out a postcard, and add yourself to the paper or on-line petition! We also encourage you to let the Mexican Government officials know your thoughts on the sale and development of X'cacel. And write letters to the Sol Melia hotel chain which is buying the largest section of the beach.

For more information contact the authors or visit the following web sites:

http://www.cpsc.ucalgary.ca/~robertof/xcacel/
http://www.seaturtle.org/xcacel/letter.shtml
http://www.globalresponse.org/index/gra1098.html
http://cccturtle.org/act-now/xcacel.htm
http://www.earthisland.org/strp/xcacel.html
http://www.tortoise.org/news/1998s34.html
http://www.student.wau.nl/~jellef/herpdigest/hdindex.html
http://www.turtledisaster.org/
http://www2.netcom.com/~harveys/Turtles1.html
http://www.milieudefensie.nl/earthalarm/engframe.htm
http://www.audubon.org/local/latin/

DISEASE AND REHABILITATION

Persistent Infectivity of Chelonian Herpes Viruses after Exposure to Artificial Seawater

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Recent data have shown the association of a unique herpesvirus with fibropapillomatosis (FP) of green, loggerhead, and olive ridley turtles. This herpesvirus is a candidate for the etiology of FP. The mechanism of FP transmission is unknown. Herpesviruses are known to maintain their infectivity under many different conditions. If herpesviruses are stable in seawater, the FP-associated herpesvirus may be transmitted by mechanisms other than by direct contact between turtles.

These studies were designed to test the stability of a Chelonian herpesvirus (LET: lung, eye, trachea virus isolated from a green turtle) in artificial seawater. Another herpesvirus, strain HV2245, isolated from the European tortoise, *Testudo hermanni*, was also tested. Both herpesviruses were dialyzed against aerated artificial seawater (osmolality=1000 mmol/kg; specific gravity=1.026; pH=7.8) at room temperature (23°C). Viruses were dialyzed against culture medium as a negative control. Virus titers (TCID50) were determined after 10 days incubation on TH-1 (terrapene heart) cells. After 48 hours of exposure to seawater, LET virus showed approximately a one log 10 TCID50 reduction in infectivity as compared to the culture medium control. HV2245 virus showed no reduction in titer.

These data indicate that Chelonian herpesviruses may retain their infectivity for extended periods of time in a marine environment. The FP-associated herpesvirus could not be included in this study because it has not yet been cultured. However, these data suggest that the FP-associated herpesvirus may also be stable in marine habitats.

Aural Abscesses in Green Turtles (*Chelonia mydas*)

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Aural abscesses of the middle ear are a common clinical illness seen in chelonians. Although the exact cause cannot be definitively stated, most appear to be the result of several predisposing factors. As a result, the turtle tends to be immunosuppresed with secondary opportunistic infections. A variety of organisms have been isolated from these aural abscesses.

Signs of aural abscesses appear as unilateral or bilateral inflammation with firm to semi-firm swelling of the space between the skin and the tympanic membrane. Using general and local anesthesia, the skin is incised, the abscess is evacuated and the area is painted with iodine. The turtle is treated with local and systemic antibiotics until healing has occurred.

The Distribution of Stranded Green Turtles with Fibropapillomas in the Eastern United States, 1980-1998

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Using data collected by the Sea Turtle Stranding and Salvage Network , we examined the distribution of stranded green turtles (*Chelonia mydas*) with fibropapillomas in the eastern United States from 1980 through 1998. Although green turtles stranded from Texas to Massachusetts, those exhibiting fibropapillomas were restricted to central and southern Florida (south of 29° latitude). The percent occurrence of fibropapillomas among stranded green turtles was associated with the extent of shallow-water areas. Along the west coast and the very southern tip of Florida (where the coastline is adjacent to a wide continental shelf and/or large bays), tumors were reported in almost 50% of stranded green turtles. Along the southeast coast of Florida (where the continental shelf is narrow and there are no large lagoons), tumors were reported in only about 6% of stranded green turtles. Along the eastern coast of central Florida (where the continental shelf widens and lagoons become common), tumors were reported in almost 13% of stranded green turtles. Additionally, green turtles that stranded adjacent to inshore waters were more likely to have fibropapillomas than those that stranded adjacent to offshore waters. This was especially true along the east coast where 25.3% of stranded turtles along inshore waters had tumors, whereas only 5.5% of those along offshore waters had tumors. Tumors were evident in stranded green turtles of all sizes but were most commonly found in those with a curved carapace length of between 30 and 80 cm. Despite some fluctuations, the occurrence of tumors documented among stranded green turtles in Florida increased from 5 - 10% in the early 1980's to 25 - 30% in the late 1990's. The increasing incidence of tumors was especially evident within the smallest size class (30 - 39.9 cm), possibly indicating that green turtles recruiting to central and south Florida nearshore environments (at a size of 25 - 30 cm and free of tumors) are developing the disease more quickly.

Papillomas in Kemp's Ridley Turtles

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According to tagging data collected at the Kemp's ridley marine turtle field station at Rancho Nuevo, Mexico a record of ridleys presenting signs of abnormal growths similar to fibropapillomas has been compiled. Observations based on this data indicate recaptures of several papilloma turtles after two years. Records dating from 1985 indicate only one observed case of tumors on ridleys. Upon further observation tagging data collected from 1990 to the present indicate a slight increase in the number of infected turtles.

Cutaneous Papillomas of Green Turtles: A Morphological and Immunohistochemical Study in Brazilian Specimens

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Eleven juvenile green turtles (*Chelonia mydas*) from the Atlantic ocean, Brazil with multiple cutaneous papillomatosis were examined. Histologically, the papillomas exhibit stromal hyperplastic proliferation and epithelial proliferation. These lesions exhibit nuclear features suggestive of viral infection. Severe nuclear pleomorphism was also observed in all cases with epithelial proliferation. Nuclear halo of the large type was present in the cases with epithelial proliferation; in these cells, nuclear features are frequently dyscariotic, without inclusion. All fibropapillomas examined were negative for papillomavirus group-specific antigens (BPV) and herpesvirus group-specific antigens (HSV1 / HSV2) by the peroxidase-antiperoxidase technique.

Introduction

Fibropapilloma in captured adult green sea turtles was first described by Lucke (1938) and Smith and Coates (1938), over 50 years ago. They observed that papillomas were distributed over the dorsal cervical region, axillary regions of the hindlimbs, eyelids and conjunctivae.

Since then the number of green turtles with papillomas seems to have increased. Of one hundred green turtles captured in the Indian River Lagoon System of east central coastal Florida, U.S.A, before 1982 none displayed this lesion, but 30 of 57 (57%) captured from 1982 to 1986 showed this proliferative arrangement. Similarly, Balazs (pers. comm.) observed that, in 1985 and 1986, tumors were present in 35% of all stranded turtles recovered from the Hawaiian Islands.

Previous work by Sundberg *et al*., failed to identify papillomavirus antigens in reptilian species; but recently, Jacobson *et al*. described an association between Herpes virus and fibropapillomas in green turtles; microscopic evaluation (H.E.) revealed areas of ballooning degeneration of epidermal cells associated with eosinophilic intranuclear inclusions. Electron microscopy analysis showed that these inclusions consisted of virus-like particles measuring from 77 to 90 nm. Envelopment of these particles was observed at the nuclear membrane and mature enveloped particles measuring 110 to 120 nm were present in the cytoplasm. Morphology, size, and location of the particles were compatible with those of the family Herpetoviridae.

The present study focused on features of cutaneous papillomatosis lesions of green sea turtles. Lesions were examined morphologically (H.E) and immunohistochemically. An attempt to characterize the etiological agent using a polyclonal antibody for bovine papillomavirus (BPV) and monoclonal antibodies to herpes simplex virus (HSV) 1 and 2 is also reported.

Materials and Methods

Samples of multiple cutaneous papillomatosis of 11 green turtles from the Atlantic ocean were examined at the Dept. of Pathology of the Veterinary Medicine and Animal Science Faculty of São Paulo Univ., Brazil, and Pathology Div. of Adolfo Lutz Institute, Brazil.

These turtles, from the coasts of São Paulo, Espírito Santo and Bahia States, were juveniles weighing around 10kg.

Fragments of papillomas were fixed in 10% formalin buffered solution, processed according to routine histological methods, and sections of 5 µm thickness were stained with hematoxylin-eosin (H.E.), for light microscopic examination.

Fragments of lesions were fixed in 10% formalin and embedded in paraffin. 4 µm sections were submitted for immunohistochemical study. The protocol used was described by Hsu *et al.* (1981). After deparafinization, sections were treated with 3% hydrogen peroxide solution to block endogenous peroxidase activity. Incubation with polyclonal antibodies anti-papillomavirus (DAKO B580) and polyclonal antibodies anti-Herpes Simplex I (DAKO B114) and anti-Herpes Simplex II (DAKO B116), obtained from rabbits, were performed at 4ºC for 18 hours. Subsequently, biotinyled goat anti-rabbit immunoglobulin (VECTOR BA1000) was added, and incubated at 37ºC for 30 minutes. The amplification of the reaction was obtained with avidin-biotin-peroxidase complex (VECTOR PK4000) and incubated at 37ºC for 30 minutes. All incubations were concluded with two PBS washings of 5 minutes each. 50 mg% diaminobenzidine (Sigma D5637) and 0.1 % H_2O_2 in PBS were used as chromogen substrate and Harris Hematoxylin in the counter staining.

Results

Papillomas were distributed over the dorsal cervical region, axillary regions of the hindlegs, eyelids and conjunctivae, and ranged from 0.5 cm to 10 cm in diameter. These formations involved all soft integumentary tissue, but were particularly numerous in the axillary and inguinal soft tissue adjacent to both forelegs and hindlegs (**Fig. 1**).

The smallest recognizable lesions were slightly raised, light-brown in color, oblong in shape and had rough surfaces. In the major lesions, the surfaces were verrucous often ulcerated. Upon gross evaluation all cases exhibited, dispersed on the papillomatosis formations, trematode infections. These appeared, in paraffin sections, as elliptical structures enveloped by a chestnut-brown capsule, surrounded by macrophagic giant cells present in the interstitial area of the proliferative tissue.

The major part of the papillomas exhibit stromal (conjunctive) hyperplastic proliferations, and other epithelial proliferations.

These lesions when compared with that of human papillomavirus lesions exhibit nuclear features suggestive of the viral infection which was observed in all cases with epithelial proliferation. Two cases with stromal hyperplasia showed a discrete epithelial proliferation associated with cytological evidences of the viral infection. Severe nuclear pleomorphism, not seen in all cases with predominantly conjuntive hyperplasia, was also observed in all cases with epithelial proliferation. Nuclear halo of the large type, similar to the human papillomavirus koilocyte, was present in the cases with epithelial proliferation; in these cells, nuclear features are frequently dyscariotic, without inclusion (**Fig. 2**).

All fibropapillomas examined were negative for papillomavirus group-specific antigens (BPV) and herpes virus group-specific antigens (HSV1/HSV2) by the peroxidase-antiperoxidase technique.

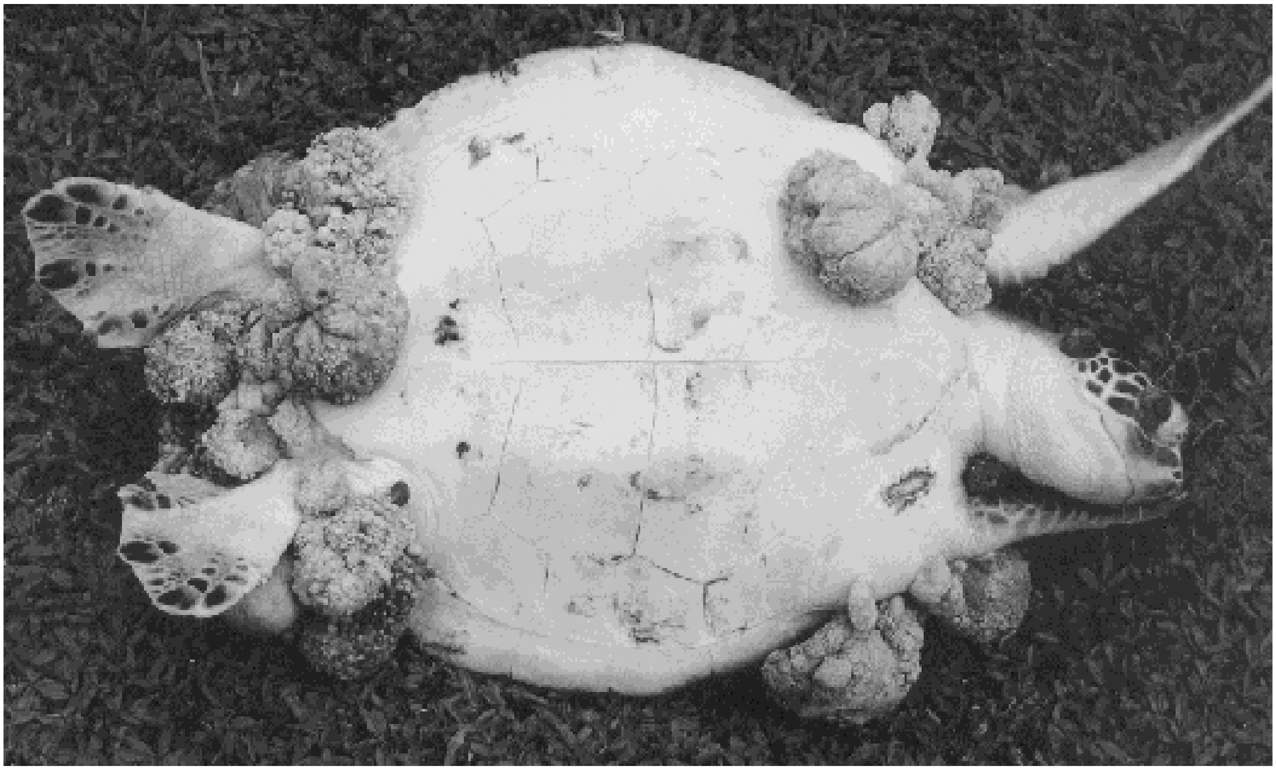

Figure 1. Green turtle fibropapillomas are particularly numerous in the axillary and inguinal soft tissue adjacent to both forelegs and hindlegs.

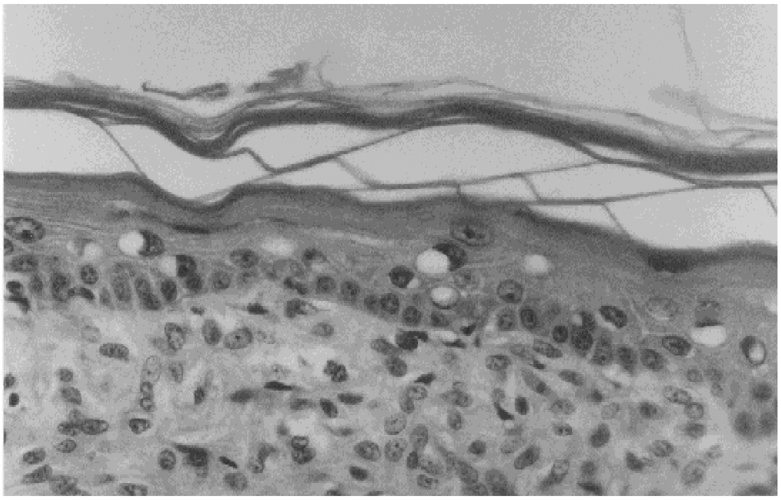

Figure 2. Microscopic lesion of the fibropapilloma (coloration HE and x165.)

Discussion

The proliferative cutaneous lesions of the green turtles from this report were consistent with previous works which described fibropapillomas of green turtles from Florida (Lucke, 1938; Smith and Coates, 1938). The lesions had some morphological similarities with cutaneous fibropapillomas of mammals, i.e., epithelial hyperplasia marked proliferation of the dermal collagen and koilocytotic-like atypia, a cytopathological feature of productive papillomavirus infection (Koss and Durfee, 1956; Sundberg, 1984). Immunohistochemical and ultrastructural investigations failed to detect the viral particles.

Herpesvírus has also been found in papilloma lesions of a wide variety of vertebrates, including the European green lizard, *Lacerta viridis* (Raynaud and Adrian, 1976), African elephants, *Loxodonta africana* (Jacobson, Sundberg, Gaskin, Kollias and O' Banion, 1986), and green turtle, *Chelonia mydas* (Jacobson, Buergelt, Willians and Harris, 1991). The involvement of herpes virus as a primary agent of these lesions is, until now, uncertain. Except for its demonstration by indirect immunofluorescence or through the observation of intranuclear amphophilic inclusions in paraffin sections, there's no evidence of the activity of this virus in papillomatous lesions.

The occurrence of papillomas in dysjunct populations of green turtles, and the increased numbers of affected turtles in the Atlantic Ocean suggest that it may be caused by an infectious disease or by environmental influences such as chemical or physical pollution.

Further studies are required in order to explain the etiology and biological behavior of these papillomatous lesions.

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Trends in Fibropapillomatosis among Green Turtles Stranded in the Hawaiian Islands, 1982-98

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In the Hawaiian Islands, immediate management considerations are often instrumental in necessitating a response to stranded sea turtles. These factors may include 1) carcasses occurring along coastlines with high human use, especially recreational, 2) the public's concern for threatened and endangered species, and 3) humane aspects when turtles strand alive as injured, diseased, or near death and therefore in need of medical attention. For sea turtle scientists, however, strandings of dead or even live turtles offer an array of special research opportunities that are impossible or difficult to pursue by other avenues. The Southwest Fisheries Science Center conducts research of sea turtles in support of the National Marine Fisheries Service (NMFS) strategic goal to recover protected species. An integral component of this research in Hawaii includes a stranding and salvage program started in 1982. This activity is carried out in partnership with the State of Hawaii Dept. of Land and Natural Resources, the NMFS Southwest Region Pacific Islands Area Office, and the Univ. of Hawaii - JIMAR and Marine Option Program. Reports of strandings from the public, as well as from county, state, and federal personnel on six major inhabited Hawaiian Islands (Kauai, Oahu, Maui, Molokai, Lanai, and Hawaii) form the basis for initiating a response to collect data and/or acquire the turtle.

The primary objective of the stranding research program is to obtain information relevant to the epidemiology of the tumor-forming disease known as fibropapillomatosis (Balazs and Pooley, 1991). This sickness has emerged as a significant issue for sea turtles and their habitats at certain sites worldwide including Hawaii, Florida, Barbados, Australia, and the Pacific coasts of Mexico and Costa Rica. In addition to epidemiological data, strandings in the Hawaiian Islands provide valuable specimens for disease-related research involving histopathology, virology, parasitology, bacteriology, immunology, molecular genetics, diagnostic testing, and forage utilized by turtles at discrete coastal habitats. Biological samples are also collected for sex determination and skeletochronology to estimate age for use in computerized sea turtle simulation models developed by the Southwest Fisheries Science Center.

Some of the important findings of Hawaiian green turtle (*Chelonia mydas*) stranding research over a 17 year study period (1982-98) are as follows:

- Annual strandings have significantly increased from 10-20 cases in the early 1980’s to 200-300 cases in the late 1990’s (**Fig. 1**).
- The number of turtles in the Hawaiian population has significantly increased over the same period at both the nesting colony and in coastal foraging pastures.
- Of the 2377 recorded strandings, 75% have been on Oahu where 75% of the 1.2 million human population resides. Oahu comprises 15% of the 1200 km of coastline of the inhabited Hawaiian Islands.
- Dead turtles make up 65% of the strandings and 35% involve live turtles.
- Fibropapillomatosis and spirorchidiasis are major causes of strandings, as determined by hundreds of necropsies by veterinary researchers Drs. Thierry Work and Alonso Aguirre (Aguirre *et al*., 1998; Work and Balazs, in press).
- Annual prevalence of fibropapillomatosis among stranded turtles has significantly increased over 17 years and has remained consistently high, ranging from 47-69% during the past decade (**Fig. 2**).
- Strandings occur evenly throughout all months of the year with no seasonal variation. No variation exists in the monthly percent occurrence of tumored turtles.
- Strandings have decreased on Maui since a record high of 46 in 1996, but annual tumor prevalence (78-88%) remains the highest for any island. For the 17 year study period, 13% of the 2377 cases have been on Maui, making this island the second highest for strandings.
- The west (Kona-Kohala) coast of the Island of Hawaii remains virtually free of fibropapillomatosis.
- The juvenile size-class (>35cm post-pelagic to 65cm in straight carapace length) comprises the majority of stranded turtles and this group also has the highest occurrence of tumors.

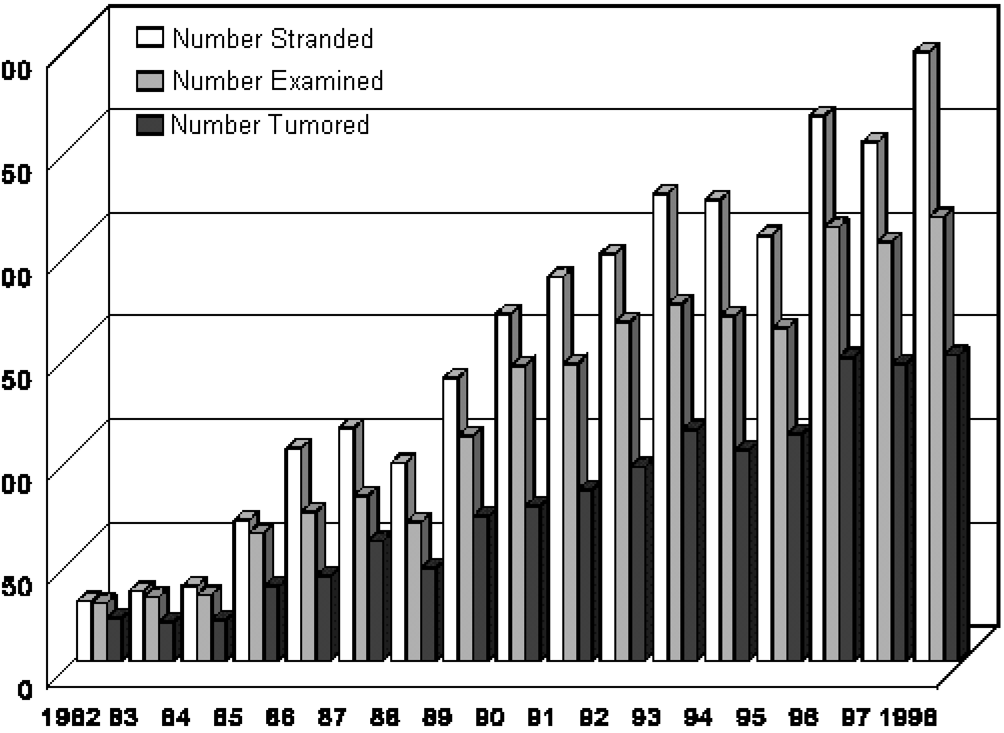

Figure 1. Annual trend for green turtle strandings in the Hawaiian Islands, 1982-1998 (N=2,377).

- Tumored turtles have a sex ratio significantly biased to females.
- Based on a defined scoring system, the severity of tumored turtles among annual strandings has significantly increased since 1990 (**Fig. 3**; Work and Balazs, p. 243).
- Oral tumors, and oral and eye tumors in combination, are highly prevalent in stranded turtles and their annual occurrence has significantly increased since 1990 (**Fig. 4** and **5**). Internal (visceral) tumors have also significantly increased since 1990. Turtles with internal tumors always have external tumors.
- The manifestation of oral tumors with glottal invasion is a unique and especially damaging aspect of fibropapillomatosis in the Hawaiian Islands. No cases of oral tumors have been reported in Florida.

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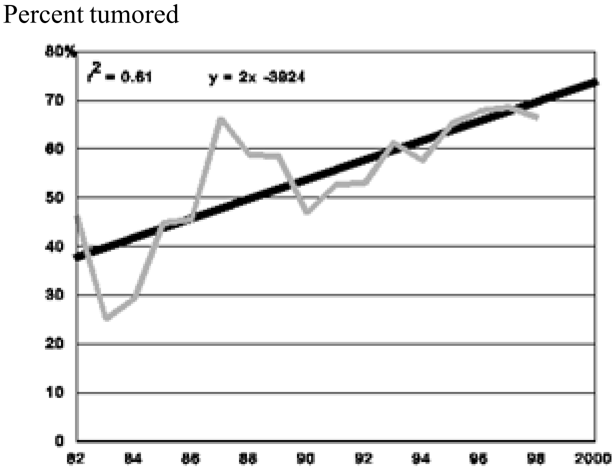

Figure 2. Annual trend for tumored green turtle stranded in the Hawaiian islands, 1982-1998 (N=2,377).

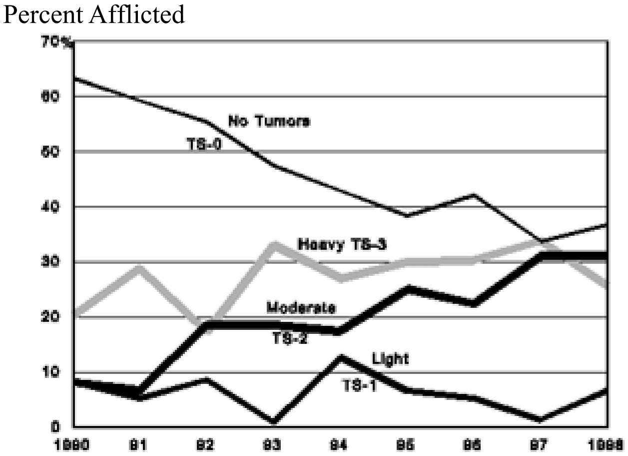

Figure 3. Tumor severity trends of stranded green turtles necropsied in the Hawaiian Islands, 1990-98 (N=677)

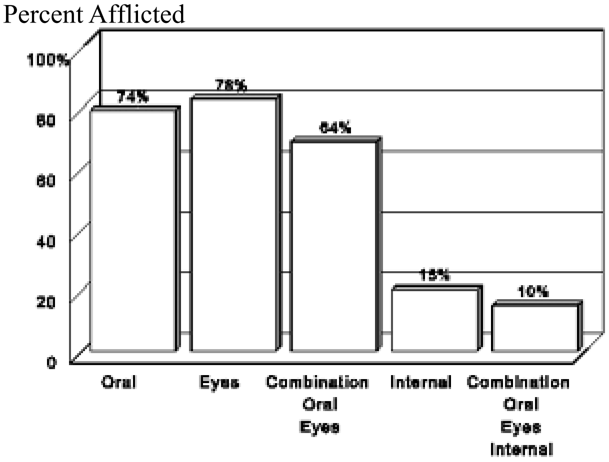

Figure 4. Location of tumor affliction for green turtles stranded and necropsied in the Hawaiian Islands, 1982-1998 (N=677).

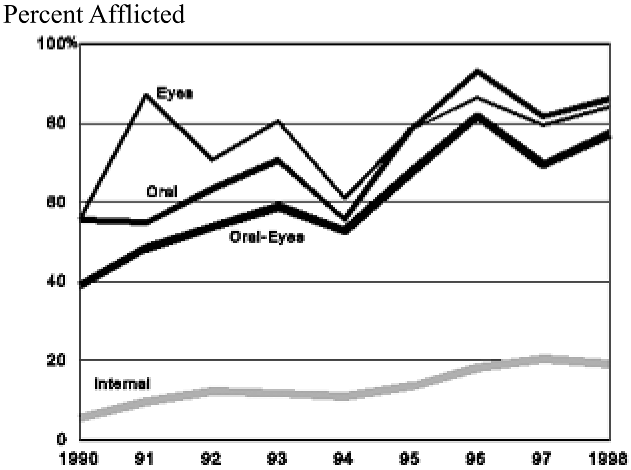

Figure 5. Anatomic trends of tumor affliction for green turtles stranded and necropsied in the Hawaiian Islands, 1990-98 (n=677).

Prevalence and Phylogeny of Herpesvirus Sequences from Normal and Fibropapilloma Tissues of Green and Loggerhead Turtles Sampled at Moreton Bay, Australia

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Fibropapillomatosis of sea turtles is a recently emerging disease and likely represents a new viral epizootic (Balazs, 1991; Casey *et al.* 1997; Herbst, 1994; Quackenbush *et al.*, 1998). We have identified turtle herpesvirus (THV) DNA sequences that are associated with fibropapillomas from green (*Chelonia mydas*), loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) turtles from Hawaii, Florida, and Costa Rica, respectively (Quackenbush *et al.*, 1998). We now report the nucleic acid analysis of fibropapillomas and normal tissues from green and loggerhead turtles sampled in June 1998 at Moreton Bay, Australia. There is a strong correlation (93%) of the turtle herpesvirus DNA polymerase gene with fibropapillomatosis as measured by PCR. DNA sequence analysis has allowed for the phylogenetic positioning of these geographically distinct viral isolates and further confirms herpesviruses as etiologic agents in the genesis of fibropapillomatosis.

Methods

Consensus sequence PCR amplification and cloning of amplicons: Biopsies of tumors and normal skin were collected from green and loggerhead turtles captured from Moreton Bay, Australia (Aguirre *et al.*, this volume). Tissues were homogenized and DNA prepared as previously described. One mg of DNA isolated from various tissues was subjected to PCR amplification with turtle-specific herpesvirus primers (GTHV1: 5' TGTCTGGAGGTGGCGGCCACG 3', GTHV2: 5' GACACGCAGGCC AAAAAGCGA 3', for cloning GTHV2 and GTHV3: 5' AGCATCATCCAGGCCCACAA 3' were used). The PCR mixture consisted of 20 mM Tris-HCl (pH 8.3), 2 mM MgCl2, 50 mM KCl, 2.5% DMSO, 200 mM of each dNTP, 10 pmol of each primer, and 2.5 units of Taq DNA polymerase (Gibco BRL, Gaithersburg, Maryland). All samples were denatured at 94°C for 5 min and then amplified for 30 s at 94°C, 30 s at 62°C, 30 s at 72°C for 35 cycles followed by 5 min at 72°C for one cycle. Fifteen ml of each PCR amplification reaction was separated on a 2% agarose gel. PCR products were gel purified with a Qiaex II gel extraction kit (Qiagen, Inc., Chatsworth, Calif.) according to the manufacturer's instructions and cloned into pCR2.1 TOPO (Invitrogen, Carlsbad, Calif.). Automated sequencing was done with an ABI 373A automated sequencer (Applied Biosystems, Inc. Foster City, Calif.) at the Biotechnology Resource Center at Cornell University.

Results

Detection of herpesvirus pol sequences in green and loggerhead turtles: To determine if fibropapillomas from Australian green and loggerhead turtles contain a herpesvirus, DNA was extracted and subjected to PCR using the specific GTHV primers. A total of fifteen tumors were assayed from 13 green and 2 loggerhead turtles. Similarly, uninvolved skin from 13 tumor bearing and 27 non-tumor bearing turtles were also assayed. The results are presented in **Table 1**.

Table 1. Detection of turtle herpesvirus sequences in Australian green and loggerhead turtles.

Green turtles	**N**	**No. positive (%)**
Fibropapillomas	13	12 (92)
Skin from tumor positive turtles	11	5 (45)
Skin from tumor free turtles	14	3 (21)
Loggerhead turtles		
Fibropapillomas	2	2 (100)
Skin from tumor positive turtles	2	0 (0)
Skin from tumor free turtles	13	2 (15)

There is a high prevalence of herpesvirus associated with fibropapillomatosis in both the Australian green (92%) and the loggerhead (100%) turtles. Histologically normal skin samples from fibropapillomatosis positive green turtles also shows a significant level of herpesvirus positivity (45%). There were not enough loggerhead skin samples from fibropapillomatosis positive turtles for a valid comparison in this category. However, some skin samples from fibropapillomatosis free green and loggerhead turtles at Moreton Bay were also herpesvirus infected, 21% and 15% respectively.

Cloning and sequence analysis of green and loggerhead pol amplicons: To further evaluate the specificity of the PCR positive signals, especially with fibropapilloma samples, amplicons from both green and loggerhead tumors were cloned and sequenced. The amino acid sequence derived from the 483 bp fragments of the two herpesvirus DNA polymerase genes was aligned with the turtle herpesvirus sequences from the Hawaiian green, Florida green, Florida loggerhead, and Costa Rican olive ridley samples. The Australian green has a unique amino acid substitution of a (L) leucine to (S) serine but is otherwise identical to the Hawaiian green. Similarly, the Australian loggerhead is identical within this region to the Hawaiian green. Interestingly, as previously reported the Florida green and Florida loggerhead turtles were also shown to be identical within this region (Quackenbush *et al*., 1998).

Conclusion

In this study we used a PCR assay with turtle specific primers, designed to amplify a region of the DNA polymerase gene of herpesviruses that contains highly conserved amino acid motifs, to identify herpesvirus sequences that are etiologically associated with fibropapillomatosis of Australian green and loggerhead turtles. To date, turtle herpesvirus sequences are detected in green, loggerhead and olive ridley fibropapillomas, suggesting the presence of newly identified turtle herpesviruses as the causative agents of disease. We now extend these data to include a geographically unique population of turtles.

We conclude that:

Turtle herpesviruses are etiologically associated with fibropapillomatosis of green and loggerhead turtles at Moreton Bay, Australia.

PCR amplification, cloning and sequence analysis show that the Australian turtle herpesvirus are most similar to the Hawaiian turtle herpesvirus.

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Quantification of Tumor Severity and Hematology in Green Turtles Afflicted with Fibropapillomatosis in the Hawaiian Islands

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In this study hematologic status was related to the severity of tumor affliction in green turtles (*Chelonia mydas*) with fibropapillomatosis (FP). In July 1997 and July 1998, 108 free-ranging green turtles were captured and bled at Palaau, a coastal foraging area on the island of Molokai where FP is endemic (Balazs *et al*., 1998). Blood was analyzed for hematocrit, estimated total solids, total white count and differential (Work *et al*., 1998). Based on earlier work (Balazs, 1991), each turtle was assigned a subjective tumor score indicating the severity of FP as follows: TS0 - no visible external tumors, TS1 - lightly tumored, TS2 - moderately tumored, and TS3 - heavily tumored. Individual tumors were graded into four size classes (A=<1cm, B=1-4cm, C=>4-10cm, D=>10cm) and tumor scores were assigned based on the number of tumors in each class.

There was a progressive increase in monocytes and a decrease in all other hematologic parameters except heterophils and total white counts as tumor score increased. These data indicate that tumor score can relate to physiologic status of green turtles afflicted with FP and is a useful field tool for monitoring and reporting the severity of the disease in this species.

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POPULATION STATUS AND BEACH STUDIES - AFRICA

The Reproductive Biology of *Caretta caretta* on the Island of Boavista (Republic of Cabo Verde, Western Africa)

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Nesting areas of *Caretta caretta* are well-known in the western Atlantic (Sternberg 1981; Márquez 1990) and the Mediterranean (Brongersma 1981; Bowen *et al.* 1993; Margaritoulis 2000). With respect to the Atlantic coast of Africa, the information available regarding the abundance and distribution of marine turtle species and the location of their possible breeding and foraging areas remains scarce and, often, unreliable (Fretey 1998).

The occurrence of *C. caretta* in the Cape Verde archipelago, although already known, has been more accurately defined with the finding of an apparently important nesting population on Boavista island. Here we present preliminary data on its reproductive biology. In the subsequent abstract the distribution of sea turtles within Cape Verde will be discussed.

Materials and Methods

From July to September 1998, the shores of Boavista island were regularly surveyed. Most of the effort focused on the eastern beaches since all evidence (turtle remains, tracks on the sand, interviews held with local people) indicated that they supported the largest nesting populations (Fretey 1998, and references therein).

The beaches were patrolled almost every night. On their return to the sea, the animals were restrained and double-tagged on their forelimbs, using monel metal tags labeled with an official inscription of the Cape Verde Government and an identification number. A Passive Integrated Transponder (PIT) tag was inserted into the intramuscular region of the right forelimb. PIT tags contain an individual code consisting of 10 digits. Morphological data were also collected before release (only 7 specimens were weighed). In case of egg-laying, the location of the clutch was marked with a visual marker, and the eggs were counted, measured and weighed. Diurnal patrols were also carried out on the less visited beaches, looking for tracks and clutches.

Due to the preliminary character of this study, detailed information on the incubation period and hatching success were not recorded. Because of the large extension of the beaches and the logistics available at particular times and places, total cover of the study area was not possible.

Results

During the sampling period, 92 nesting females were tagged on Boavista and a total number of 142 emergences were recorded, including recaptures.

The female activity appears to start in mid June (the first record of an emergence occurred on June 21st) and likely extends up to late October (last emergence was recorded on October 21st). On the sampled beaches, the activity was most pronounced in August.

Emergences occurred more often on the eastern beaches of the island. The most activity appeared to occur on Ervatão beach, decreasing as one moved north or south away from that site. Based on data collected at Ervatão beach, 54.6% of the emergences resulted in a nest, whereas the other 45.4% were non-productive.

Turtles nesting on Boavista shore are relatively small [77.1 cm straight carapace length (SCL) and 66.3 kg in weight] compared to those of the eastern populations of the USA [>90 cm SCL (see Le Buff, 1990)]. South African populations (see Bjorndal *et al.* 1983) are more similar in size. However, the Mediterranean population of Cyprus is even smaller in size [< 70 cm SCL (Broderick & Godley 1996)] (**Table 1**).

Table 1. Average, standard deviation (SD), sampling size (N), and Range, of straight carapace length (SCL), straight carapace width (SCW), weight, clutch size, and egg size of *C. caretta* nesting females in Boavista.

	Mean	SD	N	Range
SCL (cm)	77.1	5.3	85	63-96
SCW (cm)	60.7	3.7	83	54-74
Weight (kg)	66.3	6.5	7	56.6-74.7
Clutch size	90.6	16.2	80	60-137
Egg diameter (mm)	39.5	1.6	60	32.2-42.7
Egg weight (g)	35.6	4.1	47	26.8-44.8

At Boavista clutch size ranged from 60 to 137 eggs with an average of 90.5 (**Table 1**). There was a positive correlation between clutch size and female size ($F=38.69$, $p<0.0001$, $N=38$).

The eggs are practically spherical with an average diameter of 39.7 mm ($SD=1.50$, $N=27$) and weight of 36.1 g ($SD=4.62$, $N=22$). There with no significant differences between the largest and smallest ($t=-0.16$, $p=086$, $N=27$) nor between the first and the last, though the later eggs were slightly larger ($t=-1.70$, $p=0.09$, $N=27$).

Discussion

A continuing effort in the future may provide further information to make a more accurate estimate of the *C. caretta* population size at Boavista, as well as provide new insights into the biology of this species in Cape Verde.

The continuation of the tagging campaign, which started during the 1998 breeding season, and a thorough assessment of the sea turtle take and egg harvest will be essential to evaluate the population dynamic. The islanders take a large number of turtles.

Boavista beaches vary remarkably in length, energy and slope; nesting females don't appear to show any preference for specific types. The rate of non-nesting emergences is quite similar to that recorded in other Atlantic populations (e. g., Le Buff 1990). Morphological data and nesting behavior of Boavista turtles are not much different from those documented in populations already known (see e. g., Carr 1995).

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Distribution of Marine Turtles in the Archipelago of Cape Verde, Western Africa

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Cape Verde archipelago (14°48'-17°18'N, 22°42'-25°18'W) is located 500 km off the West Coast of Africa. It includes ten islands and several small islets of volcanic origin. The insular character of Cape Verde, its distance from the continental shore compared to other East Atlantic islands, the water temperature, and the sea currents by which it is affected, make it an important biological area, especially from a bio-geographical point of view. The presence of sea turtles in these islands is evident. However, as in many eastern Atlantic populations, references have always been scarce and not very reliable. It is still unknown whether different species nest in this zone. Here we present preliminary data on the distribution of sea turtles in this archipelago, and their nesting sites.

Methods

First of all, numerous bibliographical references concerning the presence of sea turtles in the archipelago were reviewed, bear in mind that many of them were never confirmed (**Table 1**). The bibliography was contrasted with direct observation of marine turtles in the sea and on the beaches from 1996 to 1998. At the same time, different beaches were surveyed to verify the female reproductive activity through recognition of turtle tracks on the sand. Moreover, human predatory activity was assessed by quantifying the remains of slaughtered turtles on the shores.

Results

Dermochelys coriacea. Isolated sightings by fishermen and some non-confirmed references about nesting on Boavista.

Eretmochelys imbricata. It is the second most common species. Only juvenile stages, up to 45 cm in Straight Carapace Length, were observed. The occurrence of the species has been confirmed on the following islands: São Vicente, Santiago, Sal, Boavista and Maio. References not confirmed about nesting.

Lepidochelys olivacea. References related to the islands of Sal and São Nicolau mention stranded animals. References not confirmed about nesting in Maio.

Chelonia mydas. Only small-sized shells from unknown origin have been reported as decorative ornaments. A doubtful record of nesting activity on Santa Luzia island.

Caretta caretta. Its the most widespread species in the archipelago. Its presence is practically confirmed on every island, and their nesting populations remain established in Sal, Boavista, Maio, and São Vicente. References not confirmed in Santa Luzia and Santiago.

Conclusions

Five species of marine turtles are regularly sighted in Cape Verde. *C. caretta* is likely the most abundant species in these islands. Its nesting areas are located on the islands of Sal, Maio, São Vicente and Boavista. *E. imbricata* (only juvenile stages were observed), *C. mydas* (despite the many previous references citing its occurrence in this archipelago), *L. olivacea* (only a few stranded animals have been recorded), and *D. coriacea* (although some Caboverdeans argue that it may reproduce in the islands), are not noted to breed here (or appear not to breed in this area). *C. Caretta* is particularly abundant along the eastern coast of the island. Although deeper studies on this matter are lacking, Boavista could host the largest nesting population of loggerheads in the whole archipelago, accounting for one of the most significant populations in the Atlantic Ocean.

Table 1. Bibliographical review of the existing data about marine turtles in Cape Verde.

	Caretta caretta	
Rochebrune (1884)	-	-
Bocage (1896)	São Vicente	Juvenile (nesting?)
Angel (1937)	Sal, São Vicente	-
Bertin (1946)	-	-
Loveridge & Williams (1957)	Sal, São Vicente	-
Bannerman & Bannerman (1968)	-	-
Schleich (1979)	Boavista	Human predation
Groombridge (1982)	Boavista	Human predation
Dodd (1988, 1990)	-	Nesting area?
Hazevoet & Hafkens (1990)	Boavista (Curral Velho)	Nesting area
Márquez (1990)	-	Nesting area?
Gawler & Agardy (1994)	-	Nesting area?
Jouvenet (in Fretey 1998)	-	Nesting area?
	Lepidochelys olivacea	
Márquez (1990)	-	Nesting area?
Agardy (1992)	-	-
Chelonia mydas		
Robert (1721)	-	-
Rochebrune (1884)	São Vicente	-
Loveridge & Williams (1957)	São Vicente	-
Parsons (1962)	Santiago, Fogo	-
Parsons (1962)	Sal, Boavista, Maio	Nesting area
Bannerman & Bannerman (1968)	-	-
Brongersma (1981)	-	Improbable
Sternberg (1981)	-	Nesting area
Groombridge (1982)	-	Nesting area
Márquez (1990)	-	Nesting area
Gawler & Agardy (1994)	-	Nesting area
Bonin (1996)	-	-
Jouvenet (in Fretey 1998)	Sal, Boavista (Morro Negro)	Nesting area
	Eretmochelys imbricata	
Loveridge & Williams (1957)	Fogo	-
Maigret (1977)	-	Human predation
Schleich (1979)	-	Human predation
Brongersma (1981)	-	-
Marques (1990)	-	Nesting area
Groombridge (1993)	-	-
Gawler & Agardy (1994)	-	Nesting area
Jouvenet (in Fretey 1998)	Sal, Boavista (Morro Negro)	Nesting area
	Dermochelys coriacea	
Agardy (1992)	Boavista (Santa Monica)	Nesting area
Jouvenet (in Fretey 1998)	Boavista	-

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Sea Turtles in the South of Bioko Island (Equatorial Guinea), Africa

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Bioko (Equatorial Guinea) is a volcanic island in the Gulf of Guinea on the west coast of Africa (**Fig. 1A**). South Bioko, under the influence of high mountains, is one of the rainiest areas in Africa and the World (Pérez del Val, 1996). The island has 150 km of mainly rocky coast (Butynski & Koster, 1989). Only at the south of the island are there large black sandy beaches surrounded by non-altered rain forest and very difficult access area.

There is scarce information about the nesting activity and population size of sea turtles in Bioko, despite their well known presence (Butynski & Koster, 1989; Castroviejo *et al.*, 1994; Butynski, 1996). Four species nest at South Bioko: the green turtle (*Chelonia mydas*), the leatherback (*Dermochelys coriacea*), the olive ridley (*Lepidochelys olivacea*) and the hawksbill (*Eretmochelys imbricata*).

Traditionally, sea turtles have been exploited in Bioko for food (meat and eggs), especially by South Bioko people, or to obtain ornamental objects. In 1995, the Spanish NGO Asociación Amigos de Doñana, within the project Conservación y Ecodesarrollo del sur de la isla de Bioko, began to protect the area and the marine turtle nesting beaches. In this study, we tried to evaluate the population size for the sea turtle species nesting at South Bioko during two surveyed seasons (1996/97 and 1997/98).

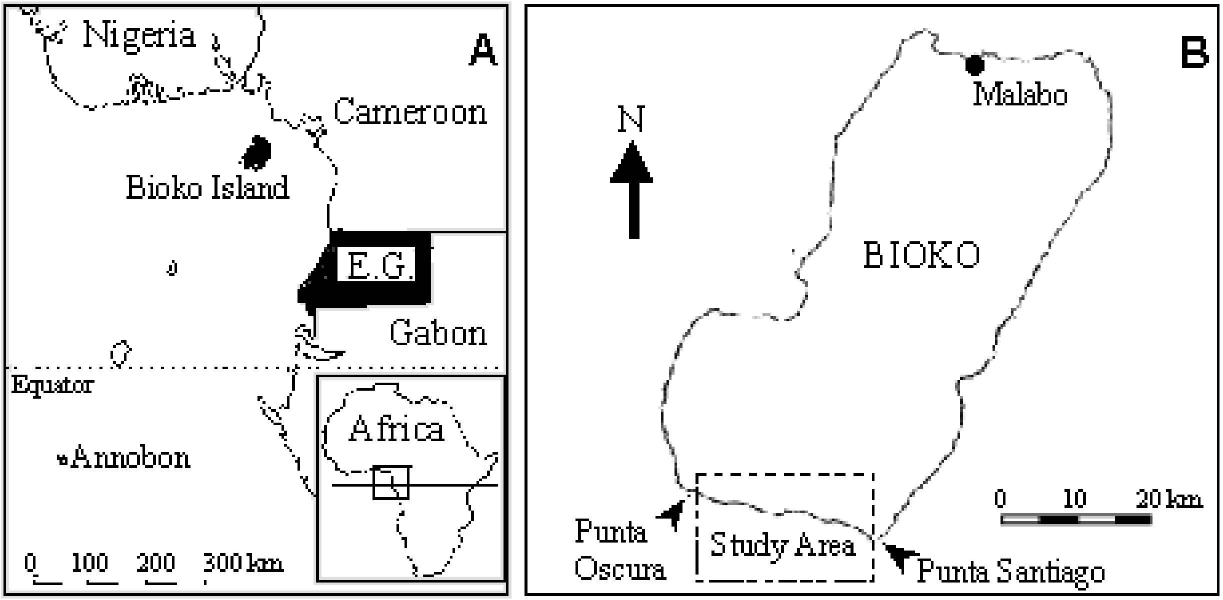

Figure 1. A: Equatorial Guinea (shadowed areas: Bioko, Annobón and Continental Equatorial Guinea: E.G.), indicating the location of Bioko Island in the West coast of Africa . **B:** Bioko Island with the study area, that includes all the monitored beaches, and their geographic limits (Punta Oscura and Punta Santiago).

Moreover, we will describe the nesting season (start, maximum and decline) and study the beach preferences for the different species. In the following abstract we discuss the nesting success of the green turtle at Bioko.

Material and Methods

The study area is situated between the Punta Oscura cape and Punta Santiago cape (between 8°28'E-3°16'N and 8°40'E-3°3'N) in South Bioko (**Fig. 1B**). There are 19,346 m of beaches separated by rocky areas. These beaches are suitable for the nesting turtles. Access to the beaches was only possible by walking or motorboat.

Several studies, focusing on census, reproductive biology and predation, were carried out in the last two nesting seasons (1996/97 and 1997/98) by Asociación Amigos de Doñana and the University of Valencia (Spain), and with the collaboration of the people from the only village of this area, San Antonio de Ureca.

The beaches were monitored from 7th October 1996 to 15th April 1997 and from 15th September 1997 to 7th March 1998, surveying approximately 95% of the nights. The study area was divided into 6 zones: four western beaches (A, B, C, and D) and two eastern beaches (E, F), the two groups separated by a long rocky area. Four person teams monitored each beach with three surveys performed each night. During each survey turtle tracks were counted, turtles measured and tagged, and their nesting activity recorded.

To estimate the green turtle population we divided the total number of nests by the mean number of nests per female (Le Gall *et al.*, 1986). We studied beach preferences by the number of emergences, the density (emergences/beach length) and percentage of each species per zone.

Results

Table 1 shows the CCL mean and range for these four species. **Table 2** indicates that the most abundant species was *C. mydas*, then *D. coriacea*. Adult female populations of the *L. olivacea* and *E. imbricata* are smaller.

The primary nesting season, extending from November until March for the four species (Castroviejo *et al.* 1994), coincides with the dry season at the island. However the full nesting season is longer and varies between species. One green was recorded on the beach 13th July. Other green turtles primarily visited the Western beaches during August and the first half of September. In the same season, the first leatherback arrived the 28th September, the first olive ridley the 21st September, and the first hawksbill 3rd of December (in the 1996/97 season the first hawksbill arrived 13th December 1996). The number of nesting females decreased very quickly at the end of February, although turtles, mostly greens, continued arriving sporadically until the beginning of April (**Fig. 2** and **3).**

Besides the number of emergences and nests per species, **Table 2** shows the number of turtles tagged and recaptured at least once. No turtles tagged in the first season were observed the following year. A decrease was observed in green turtle and hawksbill nesting populations, in comparison to an increase in leatherback and olive ridley populations, during the second nesting season. Leatherback turtles were predominant on the eastern beaches during the first nesting season, but were considerably more active on the Western Beaches the following year (zone A) (**Table 3**). Green turtles were predominant at the Western beaches and scarce at the Eastern ones (**Table 3**).

The internesting interval was estimated to be 12-14 days. When a female was not observed nesting for 24-28 days, it was assumed that she nested during the interim. In this way, the identity of unobserved nesters was determined. It was estimated from the 1996/97 data that each female deposited an average of 3.06±1.88 (range: 1-10, N=195) clutches.

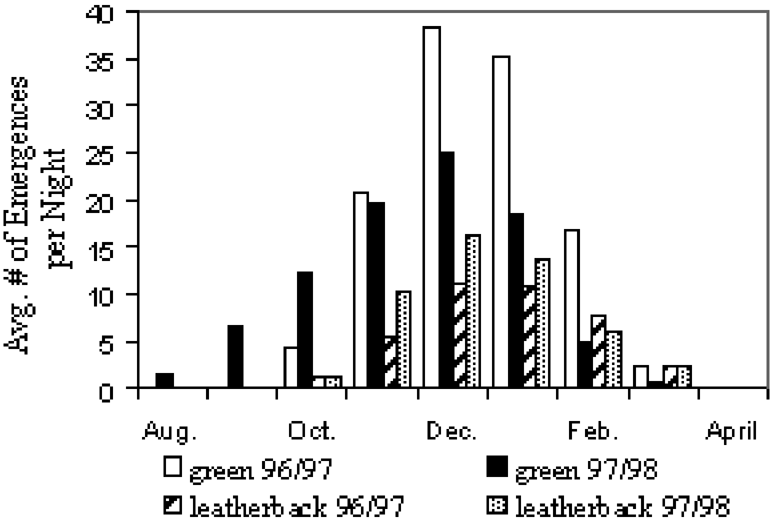

Figure 2. Mean activities per night for green (*Chelonia mydas*) and leatherback turtles (*Dermochelys coriacea*) during the 1996/97 and 1997/98 seasons.

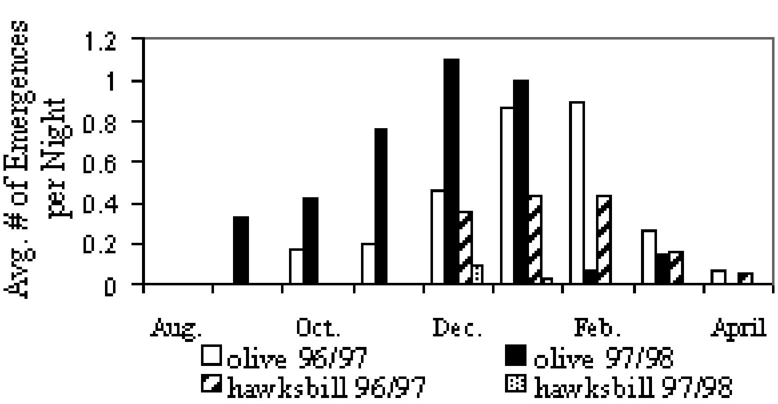

Figure 3. Mean activities per night for olive ridleys (*Lepidochelys olivacea*) and hawksbills (*Eretmochelys imbricata*) during the 1996/97 and 1997/98 seasons.

Table 1. CCL (curve carapace length) mean (SD) and range (cm) for the four species nesting at South Bioko during the two nesting seasons surveyed (1996/97 and 1997/98).

Species	1996/97			1997/98		
	Mean (SD)	Range	N	Mean (SD)	Range	N
C. mydas	99.56 (7.47)	70-117	1396	100.79 (5.9)	79-118	779
D. coriacea	156.06 (14.87)	120-200	458	159.46 (14.13)	130-209	266
L. olivacea	75.32 (6.75)	60-89	29	74.81 (7.55)	63-90	16
E. imbricata	78.38 (5.68)	72-91	13	84		1

Table 2. Results of the 1996/97 and 1997/98 surveys on South Bioko (Equatorial Guinea) nesting beaches. The last two columns show the number of tagged turtles recaptured at least once after having been tagged.

Species	Emergence		Nests		Tagged turtles		Recaptured	
	96/97	97/98	96/97	97/98	96/97	97/98	96/97	97/98
C. mydas	3380	2620	1671	1257	193	15	114	7
D. coriacea	1125	1441	862	1170	17	4	8	2
L. olivacea	83	108	57	85	3	1	0	0
E. imbricata	41	4	20	3	2	0	1	0

Table 3. Number of emergences, density (number of emergences/beach length in meters) and percentage (%) of *Chelonia mydas* and *Dermochelys coriacea* in the 6 zones of the study area (A-D are western beaches, E & F are eastern beaches). The zone column includes the beach length in meters.

		Emergence		Density (emer./m)		%	
Zone	Species	1996/97	1997/98	1996/97	1997/98	1996/97	1997/98
A	*C. mydas*	1170	996	0.734	0.625	34.19	38.12
(1593 m)	*D. coriacea*	58	173	0.036	0.109	5.23	11.96
B	*C. mydas*	1183	930	0.418	0.329	34.57	35.59
(2827 m)	*D. coriacea*	52	54	0.018	0.019	4.69	3.73
C	*C. mydas*	95	52	0.028	0.015	2.78	1.99
(3441 m)	*D. coriacea*	2	8	0.0006	0.002	0.18	0.55
D	*C. mydas*	792	432	0.23	0.125	23.14	16.53
(3446 m)	*D. coriacea*	209	203	0.061	0.059	18.85	14.03
E	*C. mydas*	23	5	0.008	0.002	0.67	0.19
(2881 m)	*D. coriacea*	190	212	0.066	0.073	17.13	14.65
F	*C. mydas*	159	198	0.031	0.038	4.65	7.58
(5158 m)	*D. coriacea*	598	797	0.116	0.155	53.92	55.08

Discussion

Hirth (1997) indicated the presence of less than 500 green turtle nests per season in South Bioko. Leatherbacks, olive ridleys and hawksbills have been reported nesting there (Castroviejo *et al*., 1994) but this has never been evaluated. We were not able to estimate the population sizes for these three species because of the low numbers of turtles tagged. But the total number of nests indicates that South Bioko is an important nesting area for the leatherback sea turtle, much more than for the olive ridley and the hawksbill. Furthermore, leatherbacks can nest occasionally far away from their habitual nesting beach (Girondot & Fretey, 1996), hampering the estimation of their population from the mean number of nests per turtle in this area. For the green turtle, we estimated the adult female population assuming that nesting occurred at regular 12-14 day intervals between the first and last observed emergence of each turtle (Le Gall *et al.*, 1986; Hirth, 1997). Using the mean number of nests obtained from the tagged turtles, we estimated that around 546 green turtles nested at South Bioko during the 1996/97 season. This method is properly applied to the green turtles because of their high degree of nest site fidelity (Miller, 1996). Hirth (1997) proposed an average of 3.3 clutches per season (rank: 1-9, N=21 samples), while Le Gall *et al.* (1986) proposed a value of 2.8 nests per season, estimated in a similar green turtle nesting area. The estimated number of nesting green turtles in South Bioko would be around 506 and 381 for the 1996/97 and 1997/98 seasons , respectively, using the Hirth (1997) value, and 597 and 449 in 1996/97 and 1997/98, respectively, using the Le Gall (1986) value. In any case, our data and estimations show higher populations than previously recorded.

We can see in **Table 2** that the leatherback turtle is more efficient than the other species, having the lowest ratio of emergences to nests-1.3 and 1.23 in 1996/97 and 1997/98, respectively. In contrast, the green turtle shows rates of 2.05 and 2.08 in 1996/97 and 1997/98, respectively.

Table 3 indicates that green turtles prefer to nest on the Western beaches. In spite of being the shortest beach, zone A shows a surprising number of emergences and nests. We can see also the preference of leatherbacks for the Eastern beaches. The Western beaches are narrower and shorter, with steeper slopes, than Eastern beaches. The latter have very shallow slopes and a very wide and sandy intertidial zone, being almost completely covered during high tide, specially zone E. These conditions seem to be adequate for leatherbacks, with their larger size and weight and soft carapace and skin. In opposition, the physical conditions of the Western beaches (A and B), including the presence of rocks in the intertidial zone, are adequate to species with higher nest site fidelity, such as the green turtle or the hawksbill, which use the rocks to orient (Hughes, 1974 in Mortimer, 1995). Zone C had the least activity because it is almost completely stone. The increase of leatherbacks in zone A in the second nesting season might be due to the physical changes in this beach, especially the widening of the intertidial zone.

Despite the existence of laws to protect marine turtles, they are still captured in Equatorial Guinea. Since 1995, the study area has been delimited as a reserve, decreasing the number of captures and the poaching of nests. Protection efforts must be enhanced, especially at the southern end of the island. The protection of these beaches is important because of the high nesting activity and the number of species arriving. These two factors classify this locality as one of the most important marine turtle nesting areas in Central Africa.

Acknowledgments

The presentation of this work was possible thanks to a travel grant awarded by the Symposium Overseas Travel Fund and the David and Lucile Packard Foundation. We wish to thank Ramón Castelo, coordinator of the Proyecto de Conservación y Ecodesarrollo del sur de la isla de Bioko conducted by the Asociación Amigos de Doñana, for his great help at the study area. We wish to express our gratitude to the economic collaboration of the project ECOFAC (from the European Union) and the collaboration of the Equatorial Guinea authorities (specially the Ministry of Fisheries and Forest) and the people of Ureca. We also wish to thank the aid of Dr. Mercedes Fernández with the ms. First author has been supported by a grant of the Conselleria d'Educacio i Ciencia of the Generalitat Valenciano.

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Preliminary Data on Green Sea Turtle, *Chelonia mydas*, Nest Success at South Bioko, Equatorial Guinea, Africa

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The green turtle (*C. mydas*) has been reported from South Bioko, Equatorial Guinea (Castroviejo *et al.*, 1994). Studies at these beaches during the last two nesting seasons, 1996/97 and 1997/98, have indicated that this is a very important nesting area for the green turtle. This species is threatened in this country because adults and eggs are taken for human consumption. Poaching of nests has been common at these beaches for years because marine turtles are one of the few resources available to the people of San Antonio de Ureca, the only village on South Bioko. Over the last few years the Asociación Amigos de Doñana (Spanish NGO) has attempted to protect the marine turtles of South Bioko and to reduce the poaching of nests. To improve these conservation efforts, it is necessary to know both the status of the nesting population and all aspects of the green turtles' reproductive biology.

We studied the nest and hatching success of the green turtles nesting on one beach of South Bioko during two nesting seasons. Furthermore, we tested several factors in order to know their effect on hatching success. This is the first study on reproductive biology of marine turtles in this area.

Materials and methods

This study was carried out on Moraca-Tudela beach (1593 m long), the western most of approximately 20 km of marine turtle nesting beaches on South Bioko. This black sand beach is located in an isolated area, surrounded by non-altered forest, and is only accessible by walking along the coast. This beach has the highest green turtle nesting activity in the area.

Two nesting seasons were surveyed: 1996/97 and 1997/98. Practically, all of the nests were marked with a stick the day they were laid and the location recorded (open beach, along the border of vegetation or in the vegetation). A total of 212 nests were dug up: 131 in 1996/97 and 85 in 1997/98. Nests were excavated approximately 16 days after the first hatchling emerged.

For each nest we counted the total number of eggs, empty eggshells, yolkless eggs, non-viable eggs, the number of hatchlings dead in eggs and the number of hatchlings dead in the nest. The hatching success was calculated by counting hatched egg shells, as in Whitmore and Dutton (1985), and without counting the yolkless eggs, according to the Dutton and McDonald (1995) assumption. Duration of incubation was calculated as the number of days between the day the nest was laid and the day of the first emergence (Godfrey *et al.*, 1996). We also measured the depth (from the surface to the bottom of the chamber) of several nests and the distance from the nests to the high tide line. A Mann-Whitney test was used to compare the two seasons. Spearman correlations were calculated between hatching success and the rest of measured variables. A Kruskal-Wallis test was used to evaluate the hatching success in the three nesting zones (Sokal and Rohlf, 1981).

Results

Table 1 shows the descriptive statistics of the variables obtained from the nests in the two surveyed seasons. Differences in eggs number per nest between seasons were not significant, but showed a low P value (Us=4571.5, P=0.0591). Differences in hatching success and duration of incubation between seasons were significant (Us=4103.5, P=0.0031 and Us=2027.0, P=0.007, respectively). No significant correlation was found between hatching success and the following variables: egg number, incubation during both seasons, and the distance from nests to high tide line, during the 1997/98 season. A significant correlation was found between hatching success and the distance to the high tide line in 1996/97 (P value=0.011, a=0.05). Hatching success seemed to be higher for the nests placed in the middle of the beach than along the edge or in the vegetation for both seasons, but only during the first season were the results statistically significant (P value=0.0159, a=0.05, N=112) (**Fig. 1**).

Of 131 nests studied in 1996/97, 43 (32.82% were predated with four being completely destroyed. Ghost crabs (*Occipode* sp.) predated 21 of the nests, including the four completely destroyed. Several species of ants appeared in 18 of the nest excavated. Eight nests were predated by diptera larvae, monitor lizards *(Varanus niloticus*), and several species of mammals. We also detected 38 nests predated in the second season, 31 by ghost crabs. Several nests were predated by more than one species.

Table 1. Mean and standard deviation, range and sample size (N) of the variables obtained from the nests excavated in the two nesting seasons surveyed in Moraca beach (South Bioko, Equatorial Guinea).

	Season	Mean (SD)	Range	N
Egg number	1996/97	104.59 (31.93)	14 -192	127
	1997/98	112.39 (31.29)	25 -188	85
Hatching Success (%)				
	1996/97	65.25 (25.28)	---	127
	1997/98	74.68 (21.64)	---	85
Duration of Incubation (days)				
	1996/97	66.66 (11.02)	51 -107	70
	1997/98	61.77 (6.73)	47 - 86	78
Distance between Nest and High Tide Line (m)				
	1996/97	10.72 (6.29)	1.5 - 45	113
	1997/98	7.65 (3.88)	0 - 21	82
Nest Depth (cm)				
	1996/97*	---	---	--
	1997/98	60.72 (9.79)	35 - 80	78

*Not measured

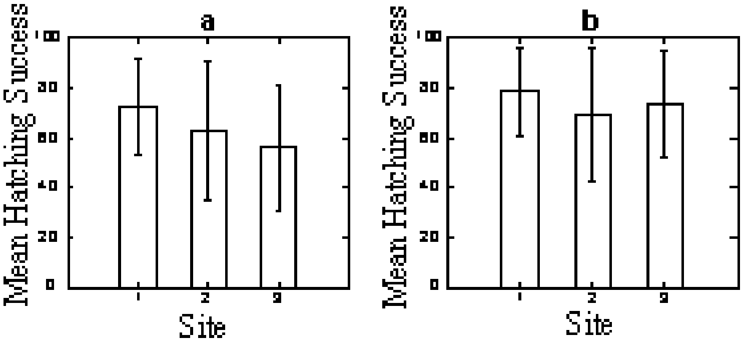

Figure 1. The mean hatching success for nests excavated at Moraca-Tudela beach during the two surveyed seasons: **a**: 1996/97 season (1=beach (N=31), 2=border (N=41), 3=vegetation (N=40)); **b**: 1997/98 season (1=beach (N=20), 2=border (N=16), 3= vegetation (N=46)).

Discussion

The mean clutch size of South Bioko green turtles, for the two seasons surveyed, was lower than that reported by Hirth (1997) for other Atlantic and African-Indian Ocean nesting areas. This difference may be due to sample size. Few studies have been carried out on hatching success in natural nests (see Hirth, 1997). The differences in hatching success for the two seasons might be due to the low sample size of the second season. The mean duration of incubation, especially for the first season, was longer than in other studies reported in Hirth (1997), probably due to the very high rainfall in South Bioko. 1997/98 was a less rainy season, which could explain the shorter incubation period during that season. Due to statistical differences in egg number and hatching success distributions between the seasons we analyzed them separately.

Hewavisenthi (1994) reported an inverse relationship between hatching success and clutch size in a hatchery. Our correlation between these two variables, in natural nests, was highly non-significant. Just the distance to the sea seems to have some effect on hatching success**.** However, these factors may have no effect separately, but jointly. Furthermore, other factors related to the environment, may also have effect on hatching success. Further analysis needs to be made on this aspect. The lower hatching success in the vegetation area may be due to plant roots that can perforate the eggs, the higher humidity, and less sunshine in the vegetation area. Sand seems to be a preferred site for nest placement by this species on this beach (unpublished data). However, we may suppose that green turtles could nest in the vegetation area, despite the negative conditions, to avoid the predation by crabs or the destruction of their nests by the nesting activity of other turtles, especially leatherbacks, at the same beach.

Poaching of sea turtle nests is habitual along South Bioko beaches, but not on Moraca beach during the last two seasons because of its status as a protected area. Nest success at this beach depended on predation, environmental, and physical conditions. Only ghost crabs, and probably ants, may have an important effect on nest and hatching success. Furthermore, crabs may facilitate the access of other predators, like insects, to the nest chamber.

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The presentation of this work was possible thanks to a travel grant awarded by the Symposium Overseas Travel Fund and the David and Lucile Packard Foundation. We wish to thank Ramón Castelo, coordinator of the "Proyecto de Conservación y Ecodesarrollo del sur de la isla de Bioko" conducted by the Asociación Amigos de Doñana, for his great help at the study area. We wish to express our gratitude to the economic collaboration of the project ECOFAC (from the European Union) and the collaboration of the Equatorial Guinea authorities (specially the Ministry of Fisheries and Forest) and the people of Ureca. We also wish to thank the aid of Dr. Mercedes Fernández and Dr. J.A. Balbuena with the manuscript. First author has been supported by a grant of the Conselleria d'Educacio i Ciencia of the Generalitat Valenciano.

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POPULATION STATUS AND BEACH STUDIES: EUROPE AND ASIA

Demography of a Green Turtle Population Nesting on Enu Island, Aru – Indonesia

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Enu is an uninhabited island located off the coast of the southeast Aru mainland and is considered to be one of the major nesting grounds for green turtles in Indonesia. The island is part of the SE Aru Marine Reserve, which encompasses an area of 114,000 ha of highly diverse and rich ecosystems. This area has been internationally recognized for its importance as nesting and foraging grounds for marine turtles, primarily *Chelonia mydas* and *Eretmochelys imbricata*. Due to intensifying fisheries activities, increasing commercial turtle harvests and limited conservation activities in the past, the turtle populations are seriously threatened. In cooperation with WWF-Indonesia and a number of other institutions this project aims to formulate a set of conditions required to maintain a healthy turtle population on the Enu rookery as well as on the extensive feeding grounds.

For a conservation plan to be effective in the long-run, a consistent set of data on various aspects of local turtle biology is needed. Very little is known about the SE Aru turtles. Long-term monitoring and tagging activities were initiated to investigate the current status of both populations. Initial activities focused on nesting turtles. In former days both green and hawksbill turtles frequented most of the islands that now make up the Aru Tenggara Marine Reserve (**Fig. 1**). Nowadays only Enu Island is visited by green turtles throughout the year. Hawksbills are only encountered on rare occasions. The rookery is vulnerable due to continuing poaching and egg collecting activities, due to a high level of beach erosion and relatively low nesting success. The following paper presents preliminary results of a 5 month survey that was conducted in 1997.

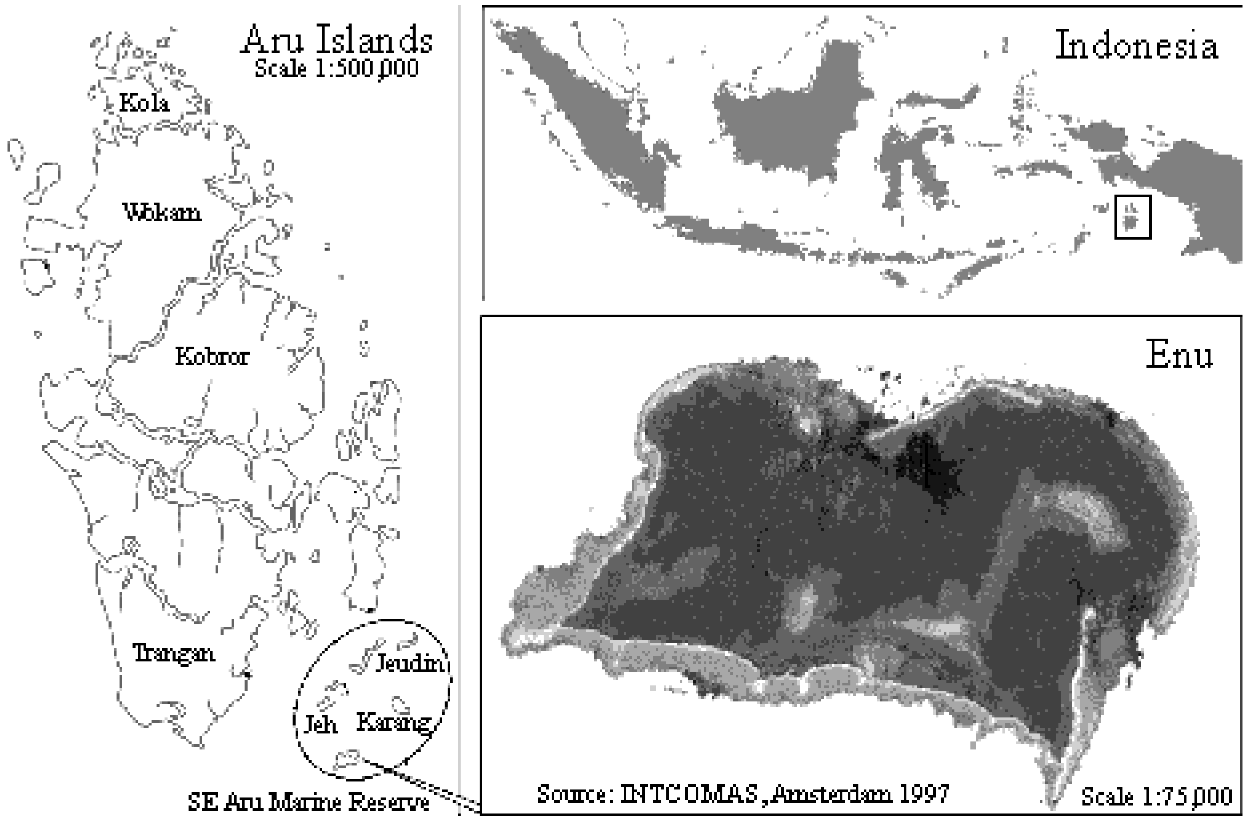
Methods

The entire nesting area along the west and south coast of Enu (7.6 km) was patrolled nightly to count tracks and nesting females, record recaptures and monitor poaching activities. When nesting females were encountered, flipper tags were applied and curved carapace length (CCL) and width (CCW) were measured. At daytime hatched nests were excavated and eggshells counted. The degree of development was studied in unhatched eggs.

Results

Over a period of 18 weeks a total of 282 turtles were tagged with a mean recapture rate of 2.6. During this period 3504 tracks were counted. Considering each track to be a nesting attempt, less than 15% of all tracks resulted in a successful nest (**Fig. 2 and 3**).

Presumably a peak occurs in the year-round nesting cycle of the Enu nesting population between December and



Source: INTCOMAS, Amsterdam 1997

Figure 1. Map of study area.

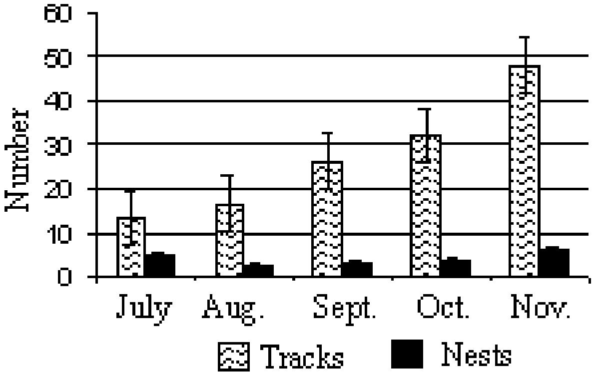


Figure 2. Monthly average of tracks and nests.

March. Most nests were made on the southeastern beach during the east monsoon but a shift of nest concentration to the west beach is assumed during the west monsoon (based on earlier counts and interviews with fishermen). The high number of unsuccessful nesting attempts (75%) was attributed primarily to difficulties in digging in the coarse coraline beach substrate (32.5% of all unsuccessful cases). Another 21 % had to be attributed to the inaccessibility of steep floodwalls, which are regularly formed along the entire stretch of the beach. Poaching, on several occasions, also prevented turtles from making a nest. Enu Island offers shelter for fishing boats during rough weather. At night the crews roam the beaches in search of turtles or freshly laid eggs for consumption. Poaching is almost nonexistent (< 1%) during research and turtle conservation activities on the island.

Curved carapace length (CCL) varied between 84.3 and 117.3 cm, with an average of 102.5 cm. The incubation period for nests laid between July and November varied from 48 to 65 days with 58 the average (n=40). Hatching success averaged 85.2% (n=91), based on counts of empty eggshells. Hatchlings measured 4.7 cm on average and weighed 22 g (random samples of 50 nests).

Remarkable observations

- Of the 282 tagged turtles, only 3 were hawksbills.
- 2 turtles tagged in Australia were caught near the reserve.
- Of the approximately 70 turtles tagged on Enu in 1993, only 1 individual was recaptured in 1997

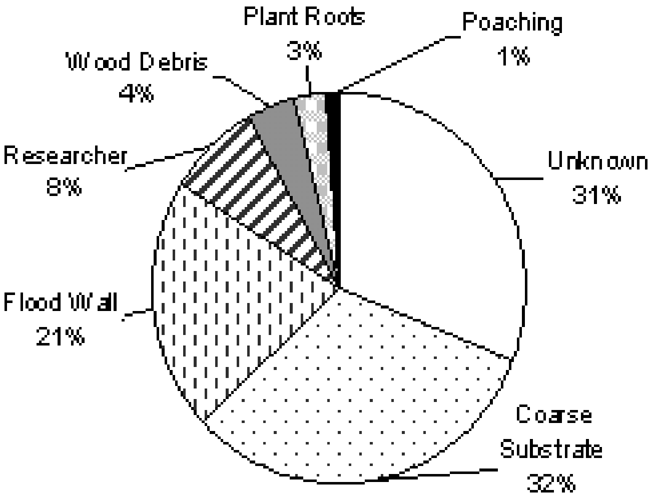


Figure 3. Causes of unsuccessful nesting attempts

The future of marine turtle research & conservation in Aru

Since the implementation of the Marine Turtle Research Aru project in 1997, research and conservation activities have been continued and are still ongoing;

- Continuation of beach monitoring activities for both conservation and scientific purposes.
- Study on the effect of different substrate compositions on hatching and emerging success of green turtle nests on Enu.
- Study of nest loss due to beach erosion, inundation, predation and other disturbances.
- Quantitative and qualitative study of foraging preferences of green turtles and their distribution on the SE Aru seagrass beds.
- Analysis of DNA sequences to investigate the origin of the feeding population and to establish whether or not the nesting population is a discrete population.
- Further activities focus on biodiversity studies of the SE Aru reserve, socioeconomic studies of local communities, infra-structural and co-operational networks and fisheries activities in the Arafura Sea.

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Potential Loggerhead Sea Turtle (*Caretta caretta*) Nesting Beaches along the Southern Coast of Croatia

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Two species of marine turtles reproduce in the Mediterranean basin: the loggerhead turtle (*C. caretta)* and the green turtle (*Chelonia mydas*). Thanks to numerous efforts, the primary Mediterranean nesting areas are today well known, and recently reviewed (Laurent, 1998).

Apart from a few records of *C. mydas*, *C. caretta* is the only species regularly present in the Adriatic Sea. Besides data on fisheries bycatch and possible existence of overwintering and feeding areas in the Adriatic Sea (Argano *et al.*, 1992; Lazar, 1995; Lazar & Tvrtkoviƒ, 1995, 1998; Gerosa & Casale, 1998), there are some reports of *C. caretta* on shore in Croatia (Lazar & Tvrtkoviƒ, 1995). *C. caretta* may be the only marine turtle species to nest on these shores. Sporadic cases of loggerhead nesting have been recorded along the Italian Adriatic coast (Basso, 1996), and thus it is possible that nesting could occur on the Croatian coast of the Adriatic sea. This research was performed within the Action Plan for the Conservation of the Mediterranean Marine Turtles, adopted within the framework of the Mediterranean Action Plan of UNEP.

Materials and Methods

The beach survey was carried out along the southern part of the Croatian Adriatic coast, and included the coastal region between cities of Split and Dubrovnik, and the coasts of seven major islands (olta, Bra…, Hvar, Vis, Kor…ula, Lastovo and Mljet) and surrounding islets (**Fig. 1**). According to climatic characteristics, this part of the Croatian coast, belonging to the eumediteranean region, may be suitable for the nesting of loggerhead turtles. A speedboat was used to survey the islands and islets, while the coast between Split and Molunat was checked by car. The composition of the coast (rocky coast, or beaches) and every beach (gravel or sandy) was recorded. As gravel beaches and short sandy beaches washed by the sea are not suitable for nesting, their dimensions were just estimated. This study was carried out between July 1st and August 8th 1997.

Special attention was given to dry sandy beaches greater than 10 m width with a homogeneous sand layer deeper than 50 cm deep , i.e. "physically suitable beaches". On such beaches the following data were collected:

- beach dimension (length/width), and geographic coordinates (*Garmin GPS 12XL Personal Navigator)*;
- sand samples were taken for *texture* analysis (by dry sieving through a series of sieves, according to *Wentworth*'s scale);
- plant species were identified and photo-documented for vegetation community analysis;
- beach pollution and photo-pollution was noted;
- human beach use (tourism impact) was estimated according to the number of people and tourism infrastructure on the beach.

Field research activities also included morning patrols (July 2-6) on the beaches in Saplunara Bay and in Blace Bay (Island of Mljet), as well as temperature measurements of the sand surface and at a depth of 50 cm, by two digital thermometers, for three days (July 4-6), between 9 a.m. and 9 p.m. Every evening thermometers were taken out, and dug in again next day.

Results and Discussion

Of the 960 km of the entire southern Croatian coast that was inspected, 940 km (97.9%) was found to have a rocky shore. Both sandy and gravel beaches combined accounted for only about 20 km of coast. The majority of the beaches were classified as gravelly (including fine gravel beaches and pebble beaches) with a total length of about 18 km of the coast inspected. Only about 1.7 km of sandy coast were found, forming 18 sandy beaches. Thirteen small, narrow (less than 10 m wide), sandy beaches often completely washed by the sea do not present suitable sites for marine turtle nesting, and were excluded from further analysis.

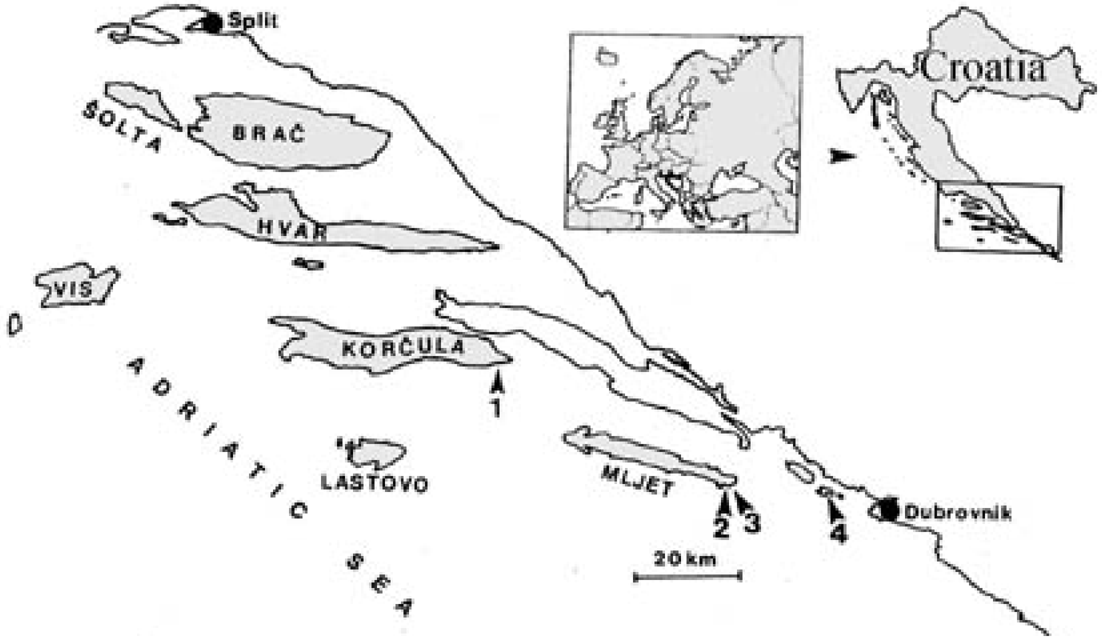

Figure 1. Map of surveyed area (rectangle on southern Croatia), with position of "physically suitable" beaches/bays (1-Prñina Beach, Kor…ula Island; 2-Saplunara Bay with Saplunara II Beach and Saplunara III Beach; 3-Blace Beach; 4- unj Beach, Lopud Island).

From these results it appears that the southern Croatian coast is generally not suitable for loggerhead nesting.

Despite the general unsuitability of the southern Croatian coast for marine turtle nesting, 1040 m of sandy shores (5 beaches in total) seem physically suitable for loggerhead egg deposition (**Fig. 1**). The suitability of those five beaches from different parameters which influence beach selection by nesting loggerhead females (Mortimer, 1995) is discussed below.

1) Beach dimension. Two of the five "physically suitable" beaches in southern Croatia are less than 100 m long (Prñina Beach-90 m and Saplunara III Beach-70 m), while the remaining three beaches are 180 m (Saplunara II Beach), 200 m (unj Beach) and 500 m (Blace Beach). Analysis of sand layers on Blace Beach indicates only the eastern 200 m is suitable. The dimensions of all five beaches do not represent an elimination factor for loggerhead nesting, since deposition still takes place on smaller beaches (Mortimer, 1995).

2) Beach sand.

- *Mechanical structure (Texture).* Analysis has shown no overriding importance of grain size in a turtle's choice of nesting beach (Mortimer, 1995). The five larger sandy beaches shows a major fraction of small- and medium-grained particles, so they can be classified as fine sandy beaches, suitable for marine turtle laying.
- *Sand temperature*. Temperature is the most important factor in limiting the geographic range of sea turtle rookeries (McGehee 1979). Temperature measurements of the sand at a depth of 50 cm on Saplunara II Beach averaged 25.3°C. A mean maximum peak of 29.0°C (**Fig. 2**) may be explained by the penetration of hot air while a probe was being installed into the sand layer every day. Nevertheless, the average temperature could be considered as satisfactory for loggerhead egg development. According to temperature conditions on Saplunara II Beach, an incubation period of about 80 days may be expected (Uchida & Kajihara, 1977; McGehee 1979). Considering the average sand temperature, the hot and dry climate with a period of about 79 clear days, the nesting season should theoretically start in June, and should last only a month.

3) Beach vegetation. The presence of beach vegetation seems to increase the desirability of a beach as a nesting site (Mortimer, 1995). On all five sandy beaches typical Mediterranean dune vegetation, represented by the *Agropyretum mediterraneum* association, was found. Sandy dunes (0.3-2 m high) were recorded only on beaches at Mljet Island. Backings of beaches at Korƒula Island and at Lopud Island are composed of a high red soil layer (about 2m high on Prñina Beach, and about 10m high on unj Beach).

4) Human impact. The heaviest tourist exploitation was recorded at Prñina and unj Beaches. At Prñina, a Beach Club was found, with a light-show facing the sea and 218 people on the beach. unj beach was surveyed early in the morning, so far fewer people were present. Along the beach about 50 sun umbrella stands were counted and a restaurant was located behind the beach, but it was not directly visible from the beach. In Saplunara Bay human activity was less visible. This may be explained by the presence of a military base until 1990. However since then, tourism has developed and illegal buildings are very visible today. The most undisturbed beach was isolated Blace Beach.

In terms of beach dimensions and characteristics, five beaches on southern Croatian islands are classified as "physically suitable" for loggerhead nesting. Human modifications differentiate these beaches, emphasizing the sandy beaches on Mljet Island as less exploited by tourism, and therefore more suitable for loggerhead nesting. During interviews with the inhabitants of Saplunara Beach the irregular presence of marine turtle tracks on Saplunara II Beach and on Blace Beach were reported, although no tracks were found during morning patrols. As emergences may result in false crawls, observation of tracks does not confirm any actual nesting of loggerheads on Mljet. However, according to the unconfirmed interview in one Croatian newspaper, turtle eggs were in the past used for domestic consumption on Mljet Island (Lazar & Tvrtkoviƒ, 1998).

It is certain that the southern Croatian coast lacks a loggerhead nesting population. However, the data on the physical suitability of some beaches for occasional loggerhead egg-laying, together with observations of marine turtle tracks by inhabitants of Saplunara Bay, point to emergences by individual specimens, and the possibility of individual and exceptional loggerhead nesting on Mjet Island. Interaction of temperature condition (ranged in bottom values for natural egg development, causing a long incubation period and short nesting season), low number and small beaches may explain the lack of regular loggerhead nesting activities in the surveyed area.

Acknowledgements

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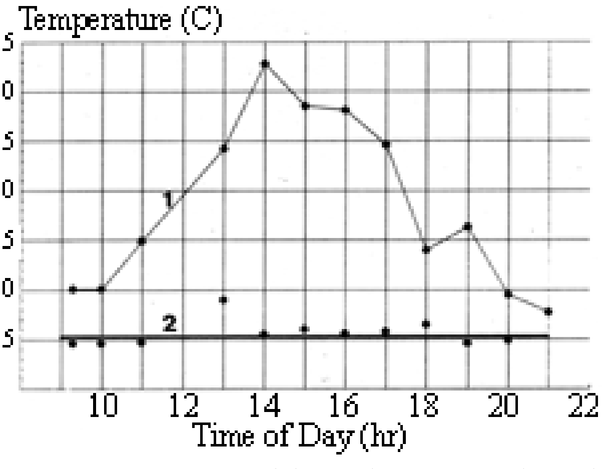

Figure 2. Measurement of the sand temperature in Saplunara II Beach throughout day. 1-Average fluctuation of sand temperature on the surface. 2-Average temperature (25.3°C, SD: 0.6°C) of sand at a depth of 50 cm.

and Technology of Croatia (Project 183005: *Fauna of Adriatic Island of Croatia*) and Ministry of Development, Croatia. Plant community analysis was conducted by Dr.Vladimir Hr√ak and Ms. Nata√a Janev (Dept. of Botany, Faculty of Sciences, Zagreb). Analysis of sand texture were carried out by Dr. Marta Crnjakoviæ (Dept. of Mineralogy and Petrography, Croat. Nat. His. Mus.), while maps were made by Mr. Branko Jalñiæ. Participation in the 19th Symposium was made possible by international travel grant from the David and Lucile Packard Foundation, and the Symposium Organizing Committee, for which we are deeply grateful. Project report can be ordered at the address: RAC/SPA, B.P. 337, 1080 Tunis CEDEX, Tunisia.

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Tagging Studies on Olive Ridley Sea Turtles in Orissa, India

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Three of the world's few remaining mass nesting or "arribada" sites for olive ridleys, *Lepidochelys olivacea, are* found in Orissa State, along the eastern coast of India. A significant portion of the world's olive ridley population nests at these three rookeries (Gahirmatha, Devi mouth and Rushikulya). Whereas the nesting population of Gahirmatha has been monitored since 1977, little information exists on the remaining two rookeries. Keeping this in view, the Wildlife Institute of India initiated a long term tagging and monitoring program along the Orissa coast in November 1996. Some of the major objectives of this tagging program were to map the movement of olive ridleys in the coastal waters of Orissa, to determine their migratory route and to collect biological information on the nesting turtles. Financial support for this program came from the Norwegian Agency for Development Cooperation (NORAD) through the M.S. Swaminathan Research Foundation, Madras, India.

Olive ridleys were tagged in Orissa over three seasons (1997-99). The tagging methods used were: capture and tagging of sea turtle mating pairs in the offshore waters and tagging of nesting females on the beach. Offshore tagging was carried out during the mating season (November to mid-January) and was restricted to the sheltered bay of roughly 30 sq. km, immediately south of Gahirmatha rookery. We used a mechanized boat and an indigenously developed triangular trap to capture the sea turtle mating pairs. On the beach tagging was carried out at five sites along the Orissa coast (including the three rookeries and two sporadic nesting beaches) during January and May. The beach was patrolled on foot every night and turtles encountered were double tagged immediately after they completed egg laying. Tags were applied on the fore flippers, close to the large scale on the proximal rear edge, immediately adjacent to the axilla. We used self-piercing, self-locking Monel tags (style 49).

In total 329 hours were spent during 85 trips to sea with 1,767 ridley mating pairs captured of which 1,657 males and 1,616 females were tagged. A total of 5,328 nesting females were tagged at five sites along Orissa coast during 1996-97 and 1997-98 breeding season.

Results from our tagging study suggest a greater degree of nesting site fidelity in olive ridleys using the Rushikulya rookery. Ridleys generally placed their nests within 100–300 m of their previous nest with a range of 0 to 1,000 m (n=44). Ridleys tagged at nesting beaches in Orissa exhibited movement between the rookeries. Two of the turtles tagged during an arribada at Rushikulya rookery on 2 and 3 February 1997 were recaptured while nesting in another arribada at Robert Island near Devi river mouth (220 km north of Rushikulya) on 17 March 1997. One of the turtles tagged during the arribada at Robert Island on 14 March 1997 was subsequently recaptured while nesting in a minor arribada at Gahirmatha (100 km north of Devi mouth) on 16 April 1997. The range of inter-rookery movement obtained during the present study varies from 35 to 220 km (n=6). Tag recoveries obtained from nesting sea turtles at Rushikulya suggest that the period between nesting is nearly annual (1.1 years, n=57). Males recaptured during offshore tagging at Gahirmatha also exhibited an annual cycle (range 319-373 days, n=28). There have been only three international recaptures of the turtles tagged in Orissa. All three recaptures were from the eastern coast of Sri Lanka (range 1,800-1,900 km). These three tag recaptures suggest that ridleys move southward along the coast after the commencement of nesting season.

Acknowledgements

The information presented in this paper was collected as part of Wildlife Institute of India's sea turtle research program in Orissa. We thank the Packard Foundation and the Barbara Delano Foundation, USA for providing travel assistance to participate in the symposium.

Nesting Activity of Olive Ridleys, *Lepidochelys olivacea* (Eschscholtz), at Important Breeding Habitats of Andhra Pradesh Coastline, India

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Along the east coast of India, olive ridleys (*Lepidochelys olivacea*) nest in significant numbers (Arribada) at Gahirmatha Beaches and Rushikulya River mouth in the state of Orissa. During the winter months (December to March), breeding populations of olive ridleys, migrating from the Indian Ocean, traverse along the coasts of Tamilnadu and Andhra Pradesh States to reach the mass nesting sites in Orissa. During this migration many of these turtles stop and nest along the northern coastal areas of Andhra Pradesh. A status survey was conducted to assess the nesting activity of olive ridleys along the 286 km coastline from Godavari River to Vamsadhara River nearer to Rushikulya River of Orissa.

To estimate the nesting frequency and nest density, the entire coastline was divided into five major zones. In each zone the nesting activities were estimated by counting nesting crawls, freshly deposited nests, disturbed nests and successfully hatched nests. The density of nests and nesting frequency were very high on sandy spits at major river mouths and on remote islands in the vicinity of mangrove forests of the River Godavari in zone I and the Vamsadhara River of zone V. The remaining zones (II, III & IV) had medium density in less disturbed areas and the lowest along urban beaches.

Introduction

Olive ridley sea turtles have a world wide distribution ranging from the Pacific and South Atlantic Oceans to the Indian Ocean (Carr, 1952). It is one of the five endangered species of sea turtles found in Indian Ocean and was placed in Schedule I, of the Indian Wildlife (Protection) Act in 1972. Their largest rookery is on the east coast at Gahirmatha in the state of Orissa along the Northern Indian Ocean (Bay of Bengal) (Kar and Das, 1984).

In the winter months (December to March) olive ridleys migrate from the Indian Ocean along the coasts of Tamilnadu and Andhra Pradesh in order to reach their mass nesting (Arribada) sites in Orissa. During migration many of the turtles select nearby suitable coastal habitats for their nesting activity (Kar, 1983). This type of sporadic nesting has been gradually increasing in recent years along the Northern coastal areas of Andhra Pradesh at the larger river mouths (Godavari, and Vamsadhara) and on remote beaches where human interference is minimum.

Study Area

The coastline from Godavari River along the Southern point to Vamsadhara River of the Northern end [16°20'-18° 25' latitudes and 81°35'-84°10' longitudes], nearer to Orissa's coast, was monitored to assess the status of olive ridley nesting activity (**Fig. 1**). This 286 km coastline has a very diverse shore, ranging from rocky to shallow sandy shores in the northern part with several extensions of hill ranges projecting into the sea, while the southern side has a shallow shore line of sand dunes. For conducting the survey the study area was divided into five major zones :

Zones	Coastline status (km)	Geographical features	Field stations
I	14 No habitation	Riverine habitats w/ mangrove vegetation	Hope Island Sacramento shoals
II, III, IV	246 Rural and semi-urban	Sandy & shallow rocky coast line	Uppada, Pentakota Dibbapalem, Visakhapatnam, & Kalingapatnam
V	26 Partial habitation	Riverine sand dunes	Nagavali & Vamsadhara

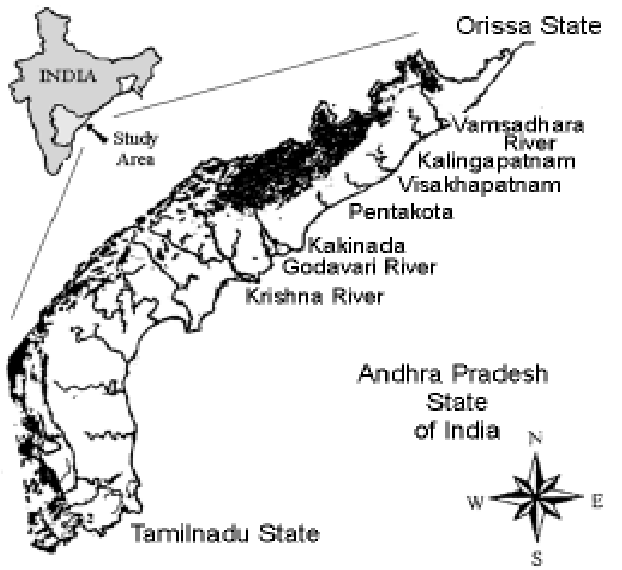

Figure 1. Study area showing the northern coastline of Andhra Pradesh.

River Godavari (Zone 1) divides at the Southern point into two major channels, the Vasishta and Gautami Godavari. Between these two river channels, a network of creeks and streams flows through muddy flats occupied by extensive mangrove forests. In addition to the mangrove swamps, the mouth of Gautami Godavari has a number of intertidal shallow zones, sandy spit deposits (Hope Island) and Sacramento shoals. Zones II, III & IV have sandy and rocky shores mostly occupied by humans (agriculture, plantations, aquaculture and salt farming). Some of the areas in these zones are occupied by major industries and fishing harbors (Kakinada, Visakhapatnam and Kalingapatnam). At the northern end of Vamsadhara River [Zone V] is a shoreline of sand dunes with casuarine plantations in the background.

Observations

Since this coastline provides an important nesting habitat for olive ridley sea turtles, survey work was carried out from January to March, 1997 and 1998. Nesting activity and density of nests were estimated by counting nesting crawls, freshly laid nests and nests disturbed by predators or humans and were classified into the following categories

- Nest Crawl (NC) - well defined body pit with evidence of digging
- Crawl Tracks (CT) - evidence of digging but no nesting
- False Crawl (FC) - U or V turn without making any nesting attempt and
- Nest opened by predator or human (NOP) with no crawl track,

Olive ridley nesting activity begins in early January and continues until the end of March, with the peak nesting season during February. Olive ridleys used the fine sandy shores with gradual slopes, often bordered by small patches of ground vegetation. These nesting places are mainly dominated by grasses and creepers; *Spinifex littoreus; Ipomea pescaprae* and shore plant, *Pandanus fascicularis*.

The frequency of nesting varied between the different habitats: riverine, sandy beaches, and rocky shores. The highest density (25.68 nesting crawls/km) was observed along the 14 km shoreline of Hope Island and Sacramento Shoals of the Godavari River. The 26 km shoreline at Vamsadhara River was the next densest with 8.76 crawls/km. The remaining 286 km of shoreline recorded the lowest nesting crawl density of 3.76 crawls/km (**Table 1** and **2**).

Table 1. Nesting activity of olive ridleys at different zones of the study area during January to March, 1997 and 1998.

Year	Zones	Types of nesting Crawls CT	FC	NC	NOP	Total	Density of crawls /km Shoreline
1997	I	68	25	189	65	347	24.78
	II, III, IV	190	64	480	136	870	3.53
	V	40	21	83	65	209	8.03
1998	I	52	34	214	72	372	26.57
	II, III, IV	217	90	513	166	986	4.00
	V	50	32	73	92	247	9.50

Table 2. Nesting density of olive ridleys at the study area during January to March, 1997 & 1998.

Years	Zones	Nests Freshly laid	Nests Disturbed	Total Nests	Nest Density per (Km)
1997	I	189	65	254	⊕20.00
	II, III, IV	480	136	316	⊕2.0
	V	83	65	118	> 5.0
1998	I	214	72	286	> 20.0
	II, III, IV	513	166	379	⊕2.0
	V	73	92	135	> 5.0

Discussion

Only olive ridleys were found during the present survey. Ridleys seemed to prefer river mouths of mangrove forests which is a favorite habitat for crabs, prawns and other invertebrates of which they depend for their food (Frazier, 1985). Similarly the Godavari River mouth and its mangrove forests attracted a large number of breeding olive ridleys. It was evident from the studies that the Godavari River mouth and Vamsadhara riverine habitats are strategic sites for the nesting olive ridleys, after Mahanadi and Rushikulya river mouths of Orissa.

A few decades ago there was very little nesting activity (an average nesting density of 2 nests/km) in these sporadic habitats, (Bhaskar, 1983 and Subba Rao *et al.*, 1987). One of the main reasons for the decreasing nesting activity at the major rookeries (Gahirmatha and Ekakulansi beaches) of Orissa is the high biotic interference (Pandav *et al.*, 1994) and frequent changes in the topography of the nesting areas which has caused some of the nesting population to search for other suitable habitats. Godavari Mangroves with its shallow shore environments (Hope Island and Sacramento Shoals) along with the Vamsadhara river habitats attract a large number of turtles to nest. Thus these sites are recommended for the Integrated Protected Area

Management Systems (IPAMS) of Andhra Pradesh Forest Department to strengthen the conservation of these nesting habitats of olive ridleys in this region.

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Leatherback (*Dermochelys coriacea*) Nesting on the North Vogelkop Coast of Irian Jaya, Indonesia

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The north Vogelkop coast of Irian Jaya is one of the world's major nesting areas for the leatherback (*Dermochelys coriacea*). Given the drastic declines of nesting populations in Malaysia and most recently, of the largest Pacific leatherback population in Mexico (Chan and Liew 1996; Sarti and Eckert 1996), these Indonesian rookeries may be the last remaining large leatherback population in the Pacific, with 3,000-5,000 nests reported annually. However, monitoring of these beaches has been inconsistent in recent years, and differences in timing and methods used in different beach censuses conducted between 1981 and 1996 make it difficult to determine current population trends.

Leatherback nesting on this coast is concentrated on the beaches of Jamursba Medi (18 km) during April-October and on War-Mon (4.5 km) during November-February. These dynamic beaches are located 30 km apart, and have nearshore water depths of >3,000 meters. Nesting was first reported along this coast in 1979 (van der Zon and Mulyana), and an aerial survey conducted in 1981 confirmed high density leatherback nesting of >4,000 nests (Salm *et al*. 1982). Subsequent nesting surveys were conducted in 1984-1985 and 1993-1996 (Bhaskar 1985; Nababan and Bakarbessy 1996; Starbird and Suarez 1994).

We have compiled and reanalyzed the available information from these previous leatherback nesting surveys conducted on Irian Jaya in the early 1980's and compared them with census data collected between 1993 and 1996. We have corrected for inconsistencies in census methods, and applied confidence limits to the data in order to better understand the status and trends of this nesting population.

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POPULATION STATUS AND BEACH STUDIES: SOUTH AMERICA

Reproductive Biology and Conservation Status of the Loggerhead Sea Turtle (*Caretta caretta*) in Espírito Santo State, Brasil

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Five species of sea turtles nest in Brazil: loggerheads *(Caretta caretta*), green turtles (*Chelonia mydas*), hawksbills (*Eretmochelys imbricata*), olive ridleys (*Lepidochelys olivacea*) and leatherbacks (*Dermochelys coriacea*). The loggerhead is the most common species nesting on Brazilian continental beaches with about 80% of the nests belonging to that species. The area from the north of Espírito Santo State(19°40'S) to the contiguous extreme south of Bahia State(18°20'S) is the second largest nesting area for loggerheads in Brazil (the north of Bahia State is the largest). In Espírito Santo State, apart from Trindade Island (1200 km offshore, which has a relatively large green turtle nesting colony), loggerheads account for approximately 95% of sea turtle nests.

Projeto TAMAR (TArtaruga MARinha), the National Sea Turtle Conservation Program of Brazil, is affiliated with IBAMA (Brazilian Institute of Environment and Renewable Natural Resources, a branch of the Brazilian government) and co-managed by Fundação Pró-TAMAR, an NGO. Projeto TAMAR began its activities in 1980 and now has 21 stations along the Brazilian coast and oceanic islands, monitoring both nesting beaches and feeding areas. Projeto TAMAR started working in Espírito Santo State in 1982, initially at Comboios beach, and is gradually extending its activities throughout the state. Currently, Projeto TAMAR maintains 5 stations in Espírito Santo, monitoring 194 km of nesting beaches. Besides beach monitoring, Projeto TAMAR carries out environmental conservation and educational activities with the coastal communities.

This poster presents data regarding the loggerhead nesting biology in Espírito Santo using data gathered from the 1991/1992 season through the 1996/1997season. A full analysis of these data, including bibliographic references, will be published elsewhere.

Marine Turtle Identification in French Guiana: Why, Where and How?

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The leatherback identification program began at the end of the 1960s in French Guiana. Many different methods have been used: plastic tags, titanium tags, Monel tags, PIT tags, photo-identification and branding. In total, more than 50,000 tags have been put on leatherbacks whereas the estimated number of females is much lower. Although it initially yielded important information the tagging program quickly became what Mrosovsky called the *tagging reflex*, because of the lack of objectives.

In 1998, a new identification program began in French Guiana. The first step of this program was to clearly identify why, where and how leatherback identification should be performed in this region.

Why ?

The first question we asked was not why identify, but what data do we need to improve our knowledge and the conservation of this species. Identification is a suitable tool to perform some of the needed studies such as:

The delimitation of the leatherback population nesting in the Guianas. The coast of the Guianas (North of Brazil, French Guiana, Suriname, and Guyana) is the most important nesting zone for *Dermochelys coriacea* in the world (Spotila *et al.*, 1996). *Ya:lima:po* beach, in the western part of French Guiana, has a large majority of the leatherback nesting activity in this region (Girondot & Fretey, 1996). The recent and important decline of French Guiana leatherback populations (**Fig. 1**) is alarming for this already endangered species (Chevalier *et al.*, 1999). However, the frequent natural destruction of beaches in the Guianas causes turtles to shift their nesting sites and could mask another phenomenon at a larger geographic scale. Indeed, the shifting already documented involved beaches of French Guiana and Suriname but are suspected of occurring in other nearby countries.

The estimation of population size and trends. Another alternative to the hypothesis advanced to explain the decline of the French Guiana leatherback population is that rather than the number of females declining the number of nests per female is decreasing since the trend is evaluated in number of nests per year. An identification program will help to establish the number of females per year which is the true index with which to characterize population trends.

The search for the life stage at the origin of the present decline. The reasons for the actual decline are not well

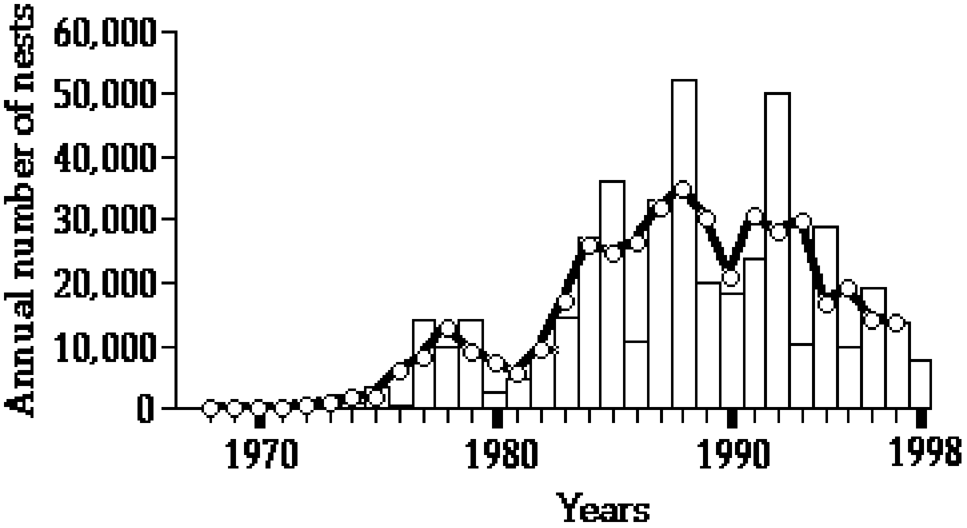

Figure 1. Annual number of leatherback nests on *Ya:lima:po* beach (histogram bars) and 3-point moving average (line).

identified but may rest with specific age cohorts. This study will help us to focus the conservation actions on the primary potential problems for the population. Thanks to this program it will also be possible to recalculate the baseline data on leatherback nesting ecology in the Guianas and to compare them with those from other nesting sites.

Where ?

We need to characterize the area where collaboration on both scientific and conservation programs is needed. The first step is to clarify the relationships between nesting beaches in this region using the results of tagging and genetic studies. Therefore the identification program should be performed first on a large scale to establish the most appropriate scale to study and conserve the Guianese population. In 1998, a new identification program began in French Guiana (Chevalier & Girondot, 1999) and will begin in 1999 in Suriname. Contacts have been made in Guyana and Brazil for similar projects.

How ?

We studied the intra and inter-seasonal retention rate for Monel tags located on the rear flippers which was the method used in French Guiana for the last 15 years. The daily tag retention rate during the first nesting season was 0.9983 (**Fig. 2**). The expected cumulated tag retentions after two and three years using this daily tag retention rate was 0.25 and 0.17 respectively (**Fig. 3, curve A**). However, the observed values are 0.75 and 0.55 respectively (**Fig. 3, points**), which are significantly different than the expected ones ($p<0.0001$ for both). The best fit to the observed data with a constant daily tag retention rate at sea is obtained with 0.9996 (**Fig. 3, curve B**). However, this curve does not fit to the observed cumulated tag retention rate. Finally, the best fit is obtained when the daily tag retention rate decreased with time (**Fig. 3, curve C**), a classical phenomenon called « tag senescence » (Nichols and Hines, 1993). In conclusion, tags are poorly retained just after the tagging, then the retention rate is higher at sea but decreased with time. After three years, which is close to the mean internesting season interval, around half of the tags are lost. This tag loss rate lead to an important bias in the nesting ecology studies (**Fig. 4**).

Therefore, we changed the identification method and have used PIT tags since 1998. Although some leatherbacks had already been PIT tagged in the neck in French Guiana in 1995 and 1996 (Girondot & Fretey, 1996), the need for standardization in identification methods and the good

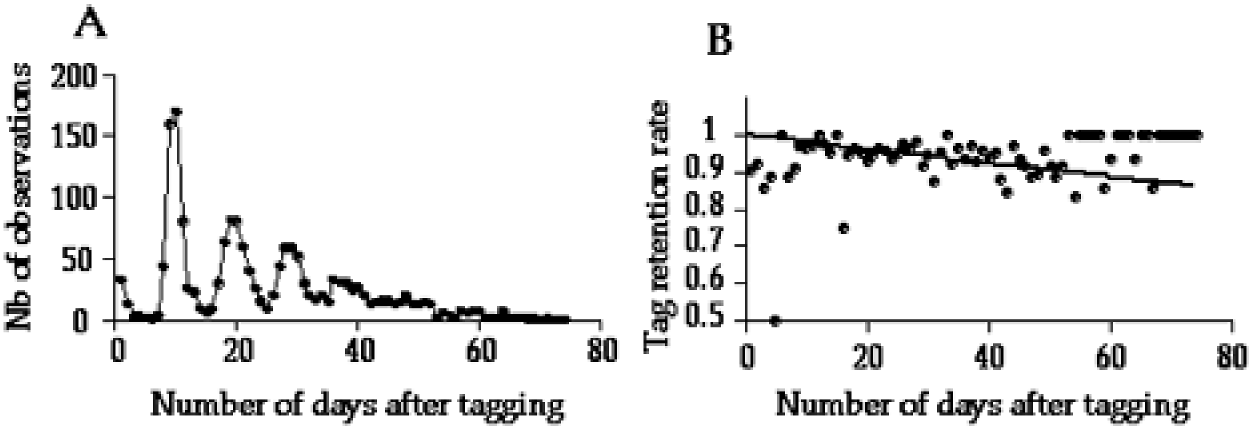

Figure 2 : Intra-seasonal retention rate of Monel tags at rear flipper location. Points are observed data (A, B) and the regression line in (B) corresponds to the best fit using ponderation by the number of observations.

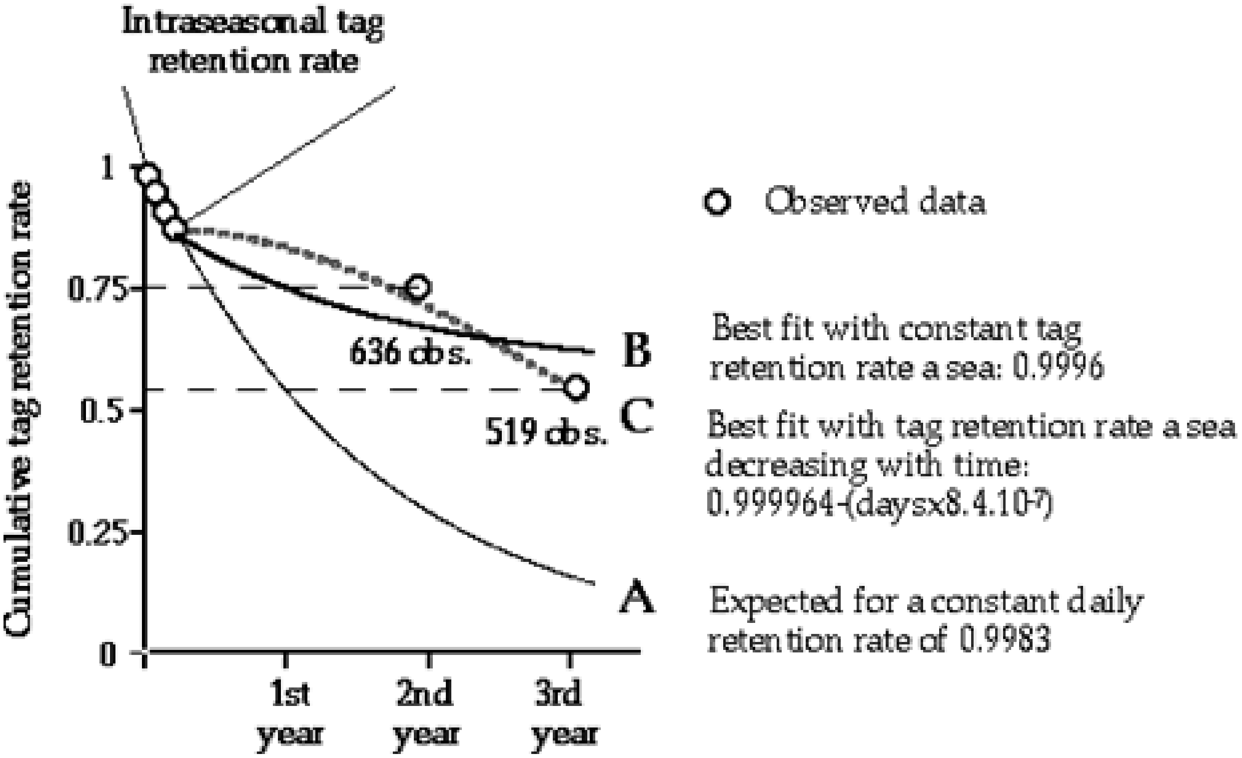

Figure 3. Long-term Monel tag retention rate on the rear flipper.

retention rate observed at other nesting beaches (Mac Donald & Dutton, 1996) lead us to PIT-tag females in the right shoulder (Dutton & Mac Donald, 1994). TROVANs material was chosen because of its storage capacity which is very useful on high density nesting beaches like *Ya:lima:po* beach.

The fact that PIT tags can't be read as easily as Monel tags, is not a problem since we have already gotten tag returns from most of the North Atlantic Ocean (**Fig. 5**). The next step in order to study the migration of these leatherbacks is telemetry, not a tagging program.

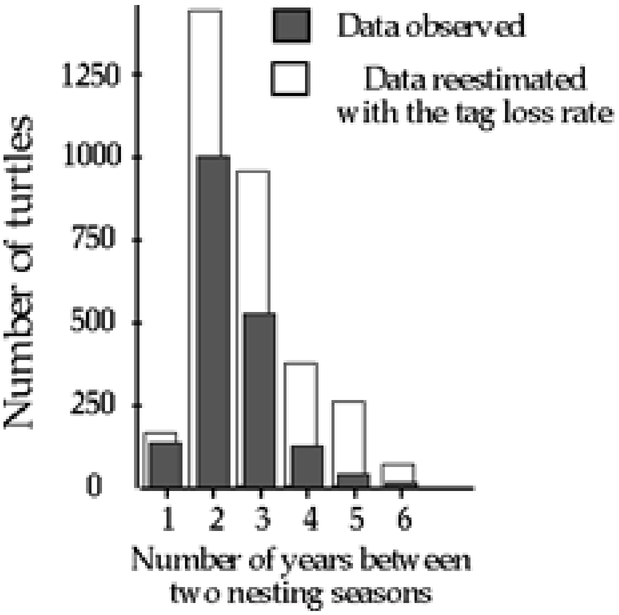

Figure 4. Comparison of the internesting season interval for leatherbacks in French Guiana, based on observed data and reestimated data with the tag retention rate.

Conclusion

This identification program is a part of larger conservation program focused on the marine turtles of the Guyana Shield region (Swinkels *et al.,* 1999). In this region, collaboration between the different countries of the Guianese nesting zone is certainly the only suitable way to face the alarming decline of leatherback turtles.

Acknowledgments

We would like to thank all of the organizations involved in the KAWANA campaign for the protection and study of marines turtles in French Guiana and particularly the DIREN of French Guiana, the WWF-France, Kulalasi, and the Amana nature reserve. We also would like to thank the people and organizations involved in the collaboration between the different sea turtles programs in the Guianas. We address a special thanks to the Biotopic Foundation for their primordial contribution in the actual collaboration dynamic and to the WWF for the preparation of the marine turtle part of the Guiana Shield program. Attendance at the symposium has been possible thanks to the help of the Symposium Overseas Travel Fund and the David and Lucile Packard Foundation. We also want to thank the Amerindian community of *Awa:la- Ya:lima:po* for their hospitality to researchers and turtles for more than 20 years. We thank Ariane Burke (Univ. of Manitoba, Canada) for her help with the English version of this text.

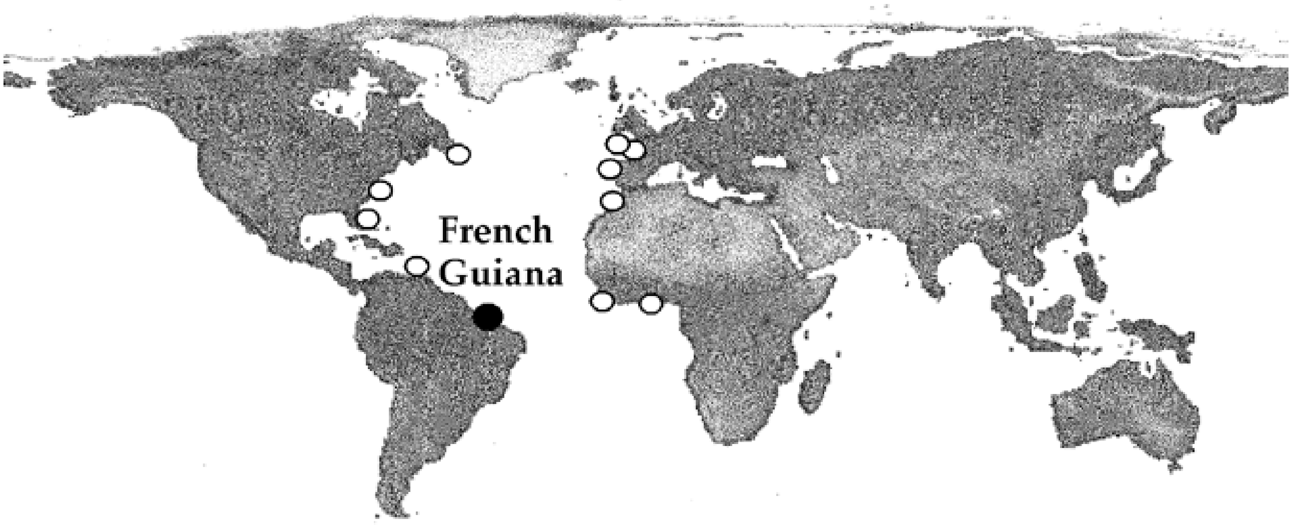

Figure 5 : Distribution leatherback tagged in French Guiana and recovered elsewhere in the Atlantic. White points are the position where Leatherbacks tagged in French Guiana have been caught.

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Study of a Bimodal Nesting Season for Leatherback Turtles (*Dermochelys coriacea*) in French Guiana

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Between April and July, the beaches of the Guianas host the most important population of *Dermochelys coriacea* (Spotila *et al.*, 1996) of the world. A second nesting season, much shorter and with less nests than the main one, occurs around December but had never been clearly characterized. French Guiana and Suriname are, as far as we know, the only nesting sites where leatherback turtles present two nesting seasons per year. The first goal of this study was to check the presence and describe the *small* nesting season. We also wanted to study the nesting ecology of the leatherbacks nesting during this season, the relationship between those turtles and other nesting groups, and the presence of a *small* nesting season for other marine turtle species.

Material and Methods

To study this *small* nesting season :

- the number of leatherback nests was counted every day from the 20th May 1986 to the 9th August 1987 on *Ya:lima:po* beach.
- from late December 1992 to early January 1993 Girondot reported the nesting activity on *Ya:lima:po* beach. However, counts were not performed on a daily basis.
- from late November to the end of January, several aspects of the *small* nesting season were studied. The number of nests was counted daily on *Ya:lima:po* beach and Cayenne Island beaches. Several other nesting beaches in French Guiana and Suriname were surveyed. Each leatherback observed nesting was identified with a PIT tag and blood was sampled for genetic studies.

Results

The *small* nesting season is specific to leatherbacks. The green turtles and the olive ridley turtles, also nesting in the Guianas, are not present during the December and January nesting season.

On *Ya:lima:po* beach, the main nesting beach of the Guianas (Girondot & Fretey, 1996), around 700 leatherback nests were laid in the 1986-87 *small* nesting season (**Fig. 1**). The repartition of the nestings present a clear bimodal annual pattern. During the 1998-99 *small* nesting season less than 40 nests were counted in *Ya:lima:po* (**Fig. 2**). This decline is certainly at least partly due the displacement of nests to other nesting beaches for example in Cayenne Island (38 nests) (**Fig. 2**). Farez, or the Spit in Suriname (**Fig. 3**), but it mainly corresponds to a global decrease in all nesting zones of the Guianas (Chevalier & Girondot, 1999). The trend of the number of leatherback nests during the main and the *small* nesting seasons appears quite close, at least the important decline for the early 1990s (**Fig. 4**). The origins of both declines are still unknown, but the driftnets of the industrial fisheries occurring in the Maroni river estuary are the main suspects (Chevalier *et al.*, 1999).

Discussion

Since the turtles observed during this study had not been tagged prior to capture, the origin of the leatherbacks nesting during the small nesting season is unknown. Therefore, many questions remain :

- What are the relationships between the leatherbacks nesting in the *small* nesting season and during the main one? Do they have the same distribution area at sea?

- Are there relationships between the leatherbacks nesting in the *small* nesting season in the Guianas and the leatherbacks nesting at the same period in Brazil?

To try to answer these questions, a study of the mitochondrial DNA of 8 leatherbacks observed during the 1998-99 *small* nesting season will be performed soon. The study of this *small* nesting season will continue during the next few years to understand the unusual nesting ecology of the leatherbacks of the Guianas.

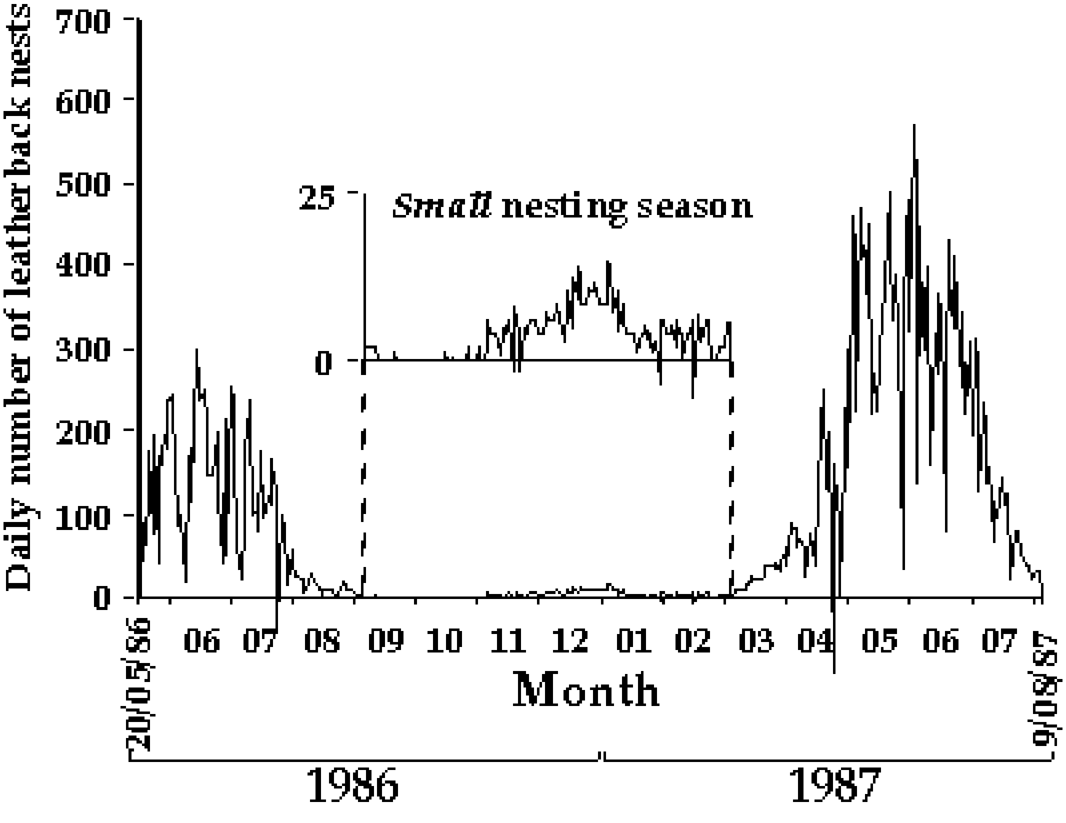

Figure 1. Number of leatherback nests on *Ya:lima:po* beach from May 1986 to August 1987.

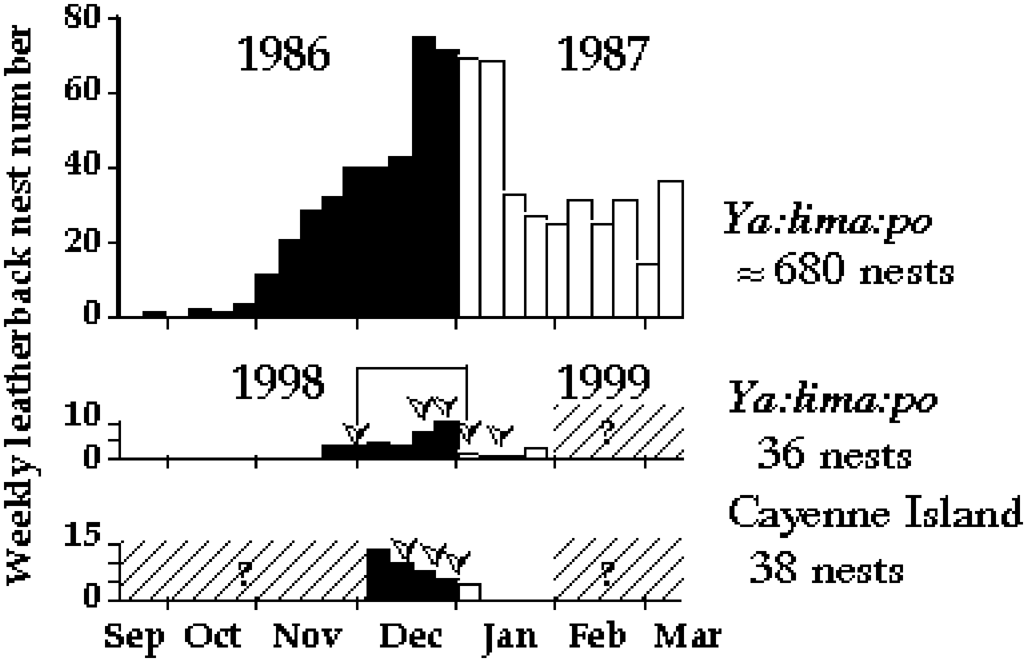

Figure 2. Number of leatherback nests per week during the *small* nesting season on the beaches of *Ya:lima:po,* in 1986-87 and 1998-99, and Cayenne Island in 1998-99. Arrowheads correspond to the leatherbacks observed and PIT tagged. The 2 joined arrows represent the turtle seen twice. (?) are weeks without data.

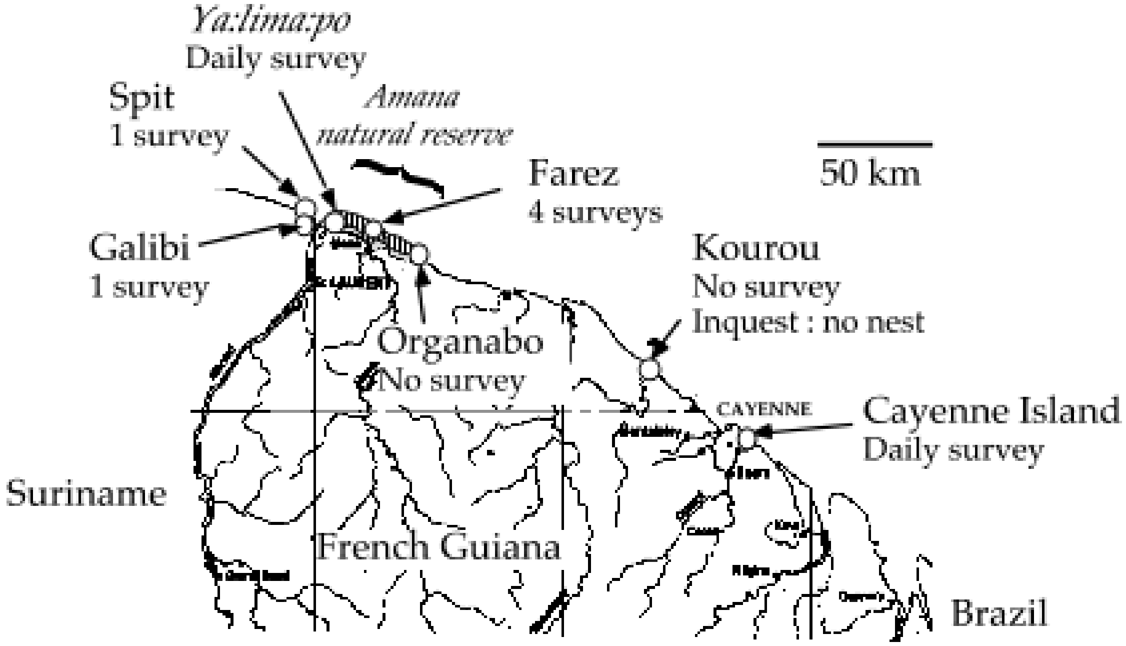

Figure 3. The nesting beaches of French Guiana and east Suriname during the 1998 main nesting season and the number of leatherback nests observed during the 1998-99 *small* nesting season surveys. (Results of beach surveys: Farez: 19 Nov. 98-1 nest, 6 Dec. 98-7 nests, 10 Dec. 98-13 nests, and 20 Dec. 98-10 nests; Galibi: 11 Jan. 99-1 nest; and Spit: 11 Jan. 99-1 nest)

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We would like to thank everyone involved in this study, particularly the DIREN of French Guiana, Kulalasi, and the Amana Nature Reserve. We also want to thank the Amerindian community of *Awa:la-Ya:lima:po* for their hospitality. Attendance at the symposium was made possible by the Symposium Overseas Travel Fund and the Packard Foundation. We thank Ariane Burke (Univ. of Manitoba, Canada) for her help with the English version of this text.

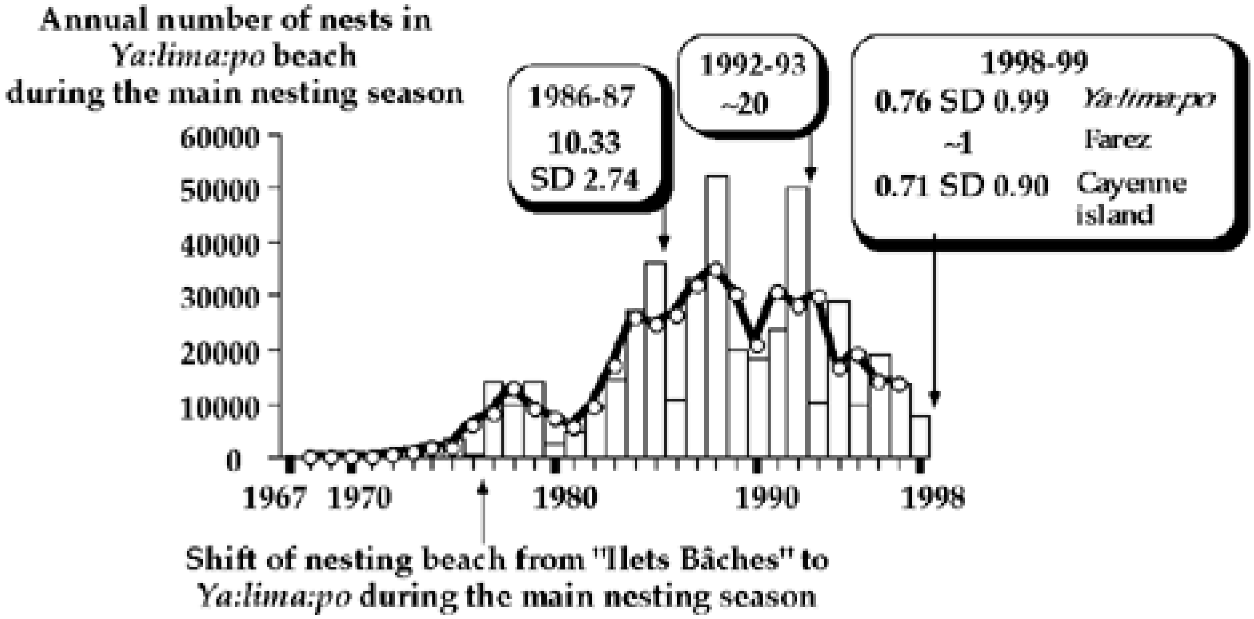

Figure 4. Evolution of the leatherback nest number per year on *Ya:lima:po* beach. Histogram corresponds to the number of nests during the main nesting season. The upper panels present the mean number of leatherback nests from the 20th December to the 10th January for the three years with data. SD indicates standard deviation.

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Preliminary Results of a Survey of Sea Turtles in the Gulf of Venezuela

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After reviewing the existing reports on the sea turtles in the Gulf of Venezuela, surveys were conducted on beaches in the Miranda, Insula Padilla, Mara and Paez Districts of Zulia State, along the west side of the Gulf of Venezuela. Some surveys were made in the daytime to observe the tracks left by the turtles and/or by hunters. Some observations were also made at night to observe nesting females. Interviews were carried out with fishermen and local inhabitants to get more detailed information on the presence and abundance of sea turtles in the area. Based on the discovery of remains (shells and skulls) a prevalence of *Chelonia mydas*, *Caretta caretta*, *Eretmochelys imbricata* and *Lepidochelys olivacea* was observed, in decreasing order. No *Dermochelys coriacea* were observed, but the interviews do indicate the presence of this species in the area. The Paez District had the highest density of turtles and turtle consumption. Intentional capture appears to be the main cause of mortality due to the presence of indigenous hunters and the commercial use of the meat and shells. The project will be extended until May, 1999.

Population Status and Beach Studies: Central America, the Caribbean, and Mexico

Seven Years (1992-1998) of Sea Turtle Research On “juan Venado” Island, León, Nicaragua

Francisco Raúl Cruz Martínez

Reserva Natural “Isla Juan Venado”, Dirección de Areas Protegidas, Ministerio del Ambiente y Recursos Naturales (MARENA)

Sea turtles and hatchlings from the years 1992 to 1998 in the Natural Reserve “Isla Juan Venado” are reported in this presentation. This reserve is protected by two communities “Las Peñitas” and “Salinas Grandes” with the leadership of the “Ministerio del Ambiente y los Recursos Naturales” (Dept. of the Environment & Natural Resources). Others involved include the Environment Commission of the Municipality of León with 33 local organizations and 4 NGOs. The sea turtle research presented includes the effects of hurricane Mitch in this Natural Reserve and along other beaches in the northwest pacific coast of Nicaragua.

Recruitment and Mortality Estimates for Female Leatherbacks Nesting in St. Croix, U.S. Virgin Islands

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The St. Croix nesting population of leatherback turtles has increased since intensive conservation and monitoring efforts began in 1981. However, it has been difficult to assess whether this is due to increased survival of adults or recruitment of new nesters, since flipper tag loss is extremely high in leatherbacks. Consistent use of photoidentification, since 1987, and PIT tagging since 1992 has supplemented flipper tags and allowed reliable identification of remigrants, even those that lose all flipper tags between nesting seasons (see McDonald & Dutton 1996), and enabled a preliminary assessment of adult mortality and recruitment in this nesting population.

For this analysis, all unidentified turtles were considered to be “new” turtles, nesting at Sandy Point for the first time, and we consider data from 1992 on to be free from significant errors due to tag loss (complete photographic coverage beginning in 1987, plus 5 year max. remigration period). Only turtles nesting from 1987-1993 that were photographed and/or PIT tagged were used for mortality estimates. Mortality was estimated from the percentage of turtles tagged in a given year that were not seen again within a minimum of 5 years. If a turtle was observed nesting elsewhere, but did not nest at Sandy Point, it was not counted as dead.

An average of 18 “new” turtles (range 11-38, sd 7.0) nested annually between 1983 and 1991, although some of these were likely remigrants that lost tags. This number increased to 27 (range 14-61, sd 15.1) from 1992-1998 (**Fig. 1**). After 1992 we identified an increasing proportion of remigrants with observed remigration intervals of 4 or 5 years. Using 5 years as the longest remigration interval for Sandy Point, we estimated mortality from 19%-49% for the adult females nesting each year (**Fig. 2**). This assumes that turtles that did not return to nest for five years had died. These may be overestimates; turtles may be nesting elsewhere, or may nest at intervals greater than 5-11 years. A few turtles originally tagged on St. Croix have nested on neighboring Puerto Rico beaches, and visa versa. However, given the widespread impact of various fisheries on leatherbacks, both at these Caribbean nesting areas, and at forage grounds and migratory corridors throughout the Atlantic, it is reasonable to expect mortality on the scale reported here. Intensive, long term saturation tagging and monitoring is required on all the key nesting beaches in the region in order to determine the accuracy of these estimates.

Our data suggest that while there has been an increase in the numbers of “new” turtles since 1992, adult female mortality (or emigration), estimated as high as 49%, is an important factor that needs to be further addressed. Continued use of PITs in a long-term tagging program that includes all the regional leatherback nesting beaches will be needed to improve estimates of mortality.

Acknowledgements

Funding was provided by the U.S. Fish and Wildlife Service, U.S. Virgin Islands Dept. Planning and Natural

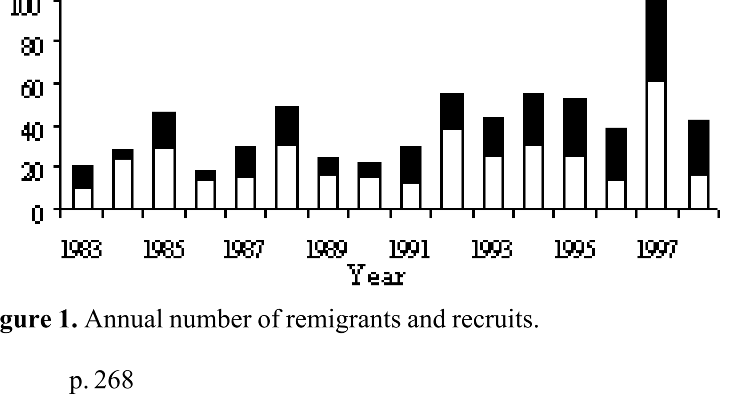

Figure 1. Annual number of remigrants and recruits.

Resources, and Earthwatch Insitute. We gratefully acknowledge Mike Evans(USFWS), Otto Tranberg (VIDPNR), Jorge Picon (USFWS), Bob Bradner, Sue Basford, Scott and Karen Eckert, Amy Mackay, James Rebholtz, Janine Ferguson, Barry Krueger, Scott Forbes, Janet Cowden, Ana Barragan, John Shih, Elizabeth Taylor and the 1,022 Earthwatch volunteers, without whom this work would not have been possible.

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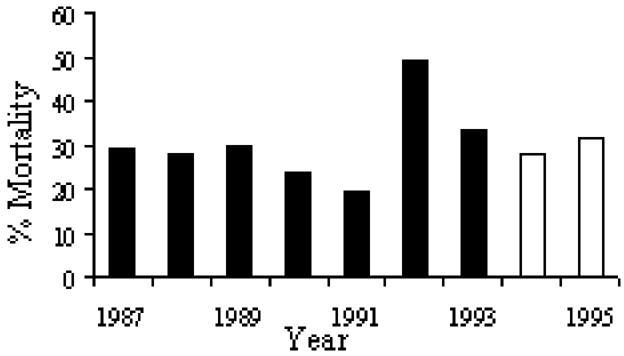

Figure 2. Adult mortality

Possible Effects of El Niño-Southern Oscillation on the Black Turtle Nesting Population at Michoacan, Mexico

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The number of female black turtles nesting annually at Colola beach on the Michoacan Pacific coast in Mexico has dramatically fluctuated from year to year since monitoring began in 1982 (**Fig. 1**). Like other sea turtle species (with the possible exception of the Kemp´s ridley), the black turtle exhibits iteroperous reproduction with a remigration cycle that varies between two to six years (Alvarado and Figueroa, 1992). Water temperature influences *Chelonia* breeding cycles by its possible effects on quality and availability of food resources (Limpus and Nicholls, 1988). Water temperatures may also affect reproductive cycles in sea turtles since higher temperatures increase metabolism and may shorten the folliclar maturation period (Márquez, 1996).

The distribution area of the black turtle is located within a region of significant interannual variability in water temperature and productivity associated with the El Niño-Southern Oscillation (ENSO) (Fiedler and Philbrick, 1991) (**Fig. 2**). Average surface temperatures in the area of the black turtle distribution range from 17-21°C in the northern feeding grounds in the Pacific Coast of Baja California, to 27 - 29°C in the southern feeding grounds in Central America (seasonal average temperatures in the period of 1960 to 1990; Fiedler, 1992). Extreme interannual variability of temperature and productivity affects the survival and reproduction of a number of vertebrates in the eastern tropical Pacific (Arntz and Fahrbach, 1996 for a review). The possible effects of the interannual variations in temperature in the eastern tropical Pacific on the number of black turtles nesting at Colola was examined.

Methods

Colola and Maruata beaches (state of Michoacan) on the Mexican Pacific are the main continental rookery for the black turtle in the east Pacific (Alvarado and Figueroa, 1992). This study was conducted along the five miles of Colola beach. This beach annually supports approximately 70% of all black turtle nesting activity in Michoacan with nesting occuring from early September to late January. The number of nests and nesting frequency were used to estimate annual female nesting densities. Nightly surveys were conducted from mid-September to mid-December for each year (1982–1997). Mean water surface temperatures for the period October-December of each year (1982–1997) were used as an index of the interannual variabilities of temperature in the eastern tropical Pacific for the study period.

Results and Discussion

A positive correlation ($r=0.62$, $df=14$, $P<0.01$) between the numbers of black turtles nesting at Colola and the water surface temperatures in the eastern tropical Pacific was found (**Fig. 3**). Cluch frequency and clutch size was not significantly varied between seasons. Except for 1995, the years of highest nesting density coincided with years of high surface temperature in the ETP (if 1995 is excluded from the analysis the correlation is stronger, $r=0.82$, $df=14$, $P < .001$) (**Fig. 1**). The strongest Niña recorded (1988) coincided with the lowest nesting density. The two year lag between ENSO effects on *Chelonia* breeding numbers reported for Australia (Limpus, 1989), was not found in Michoacan. The coincidence between nesting peaks and temperature peaks suggests a short term response of black turtles to the increment in water temperature. This short term response suggests that the effect of high temperature on nesting density is mediated through an increase in metabolic rate rather than through an increase in food availability. Contrary to what has been found for other aquatic and semi-

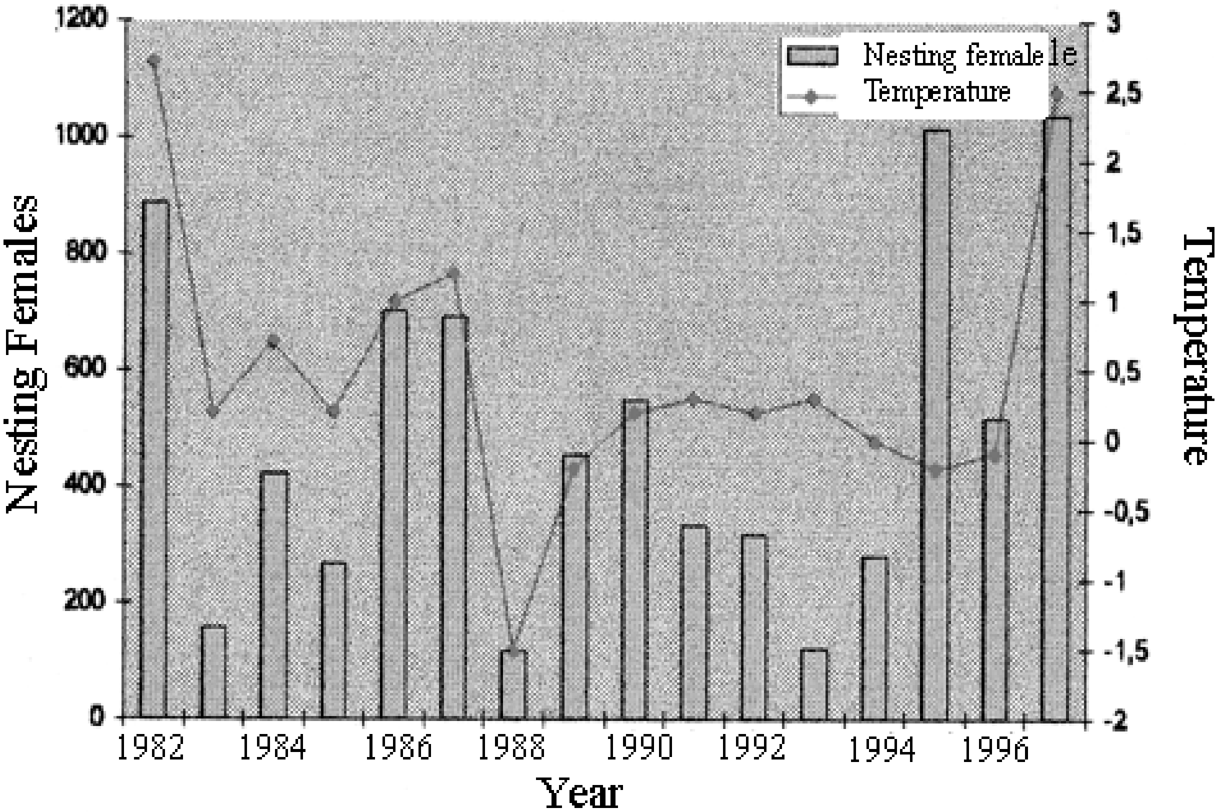

Figure 1. Numbers of black turtles nesting at Colola, Michoacan, Mexico in relation to water surface temperature in the Eastern Tropical Pacific.

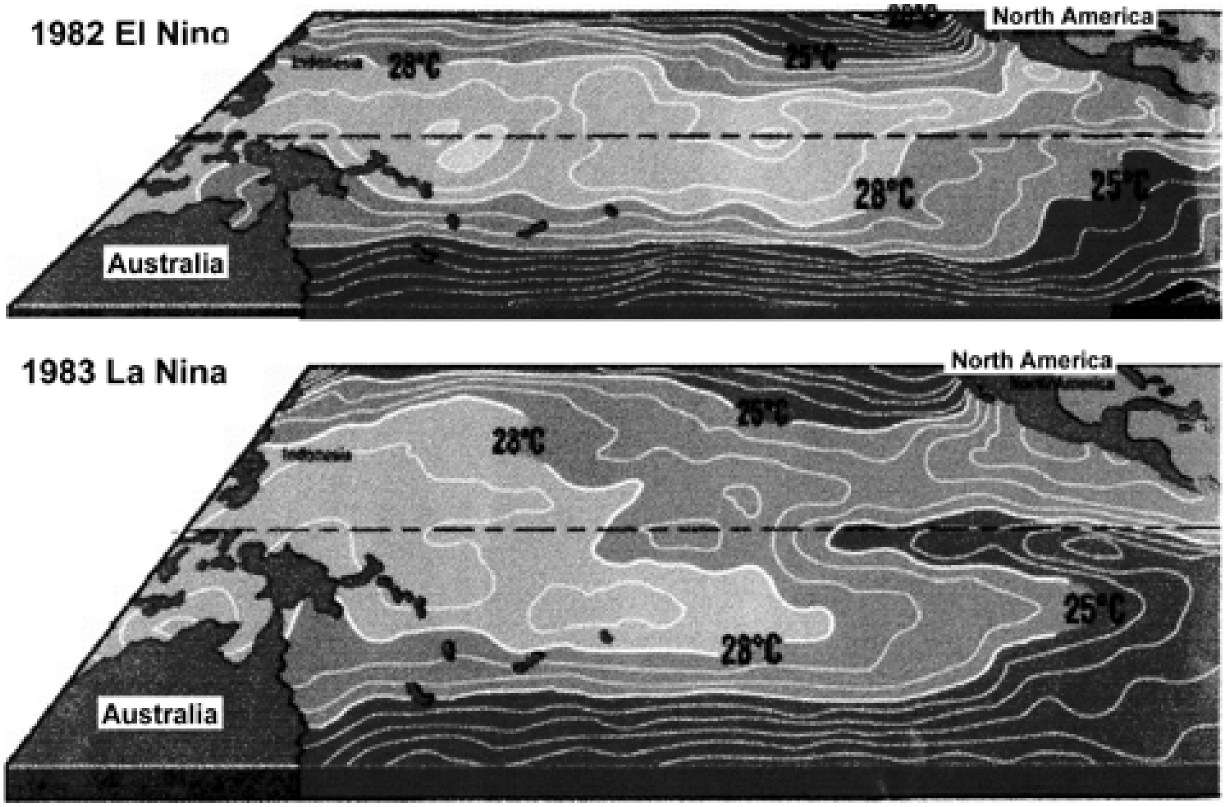

Figure 2. Southern Oscillation - sea surface temperature (Earth, 1992).

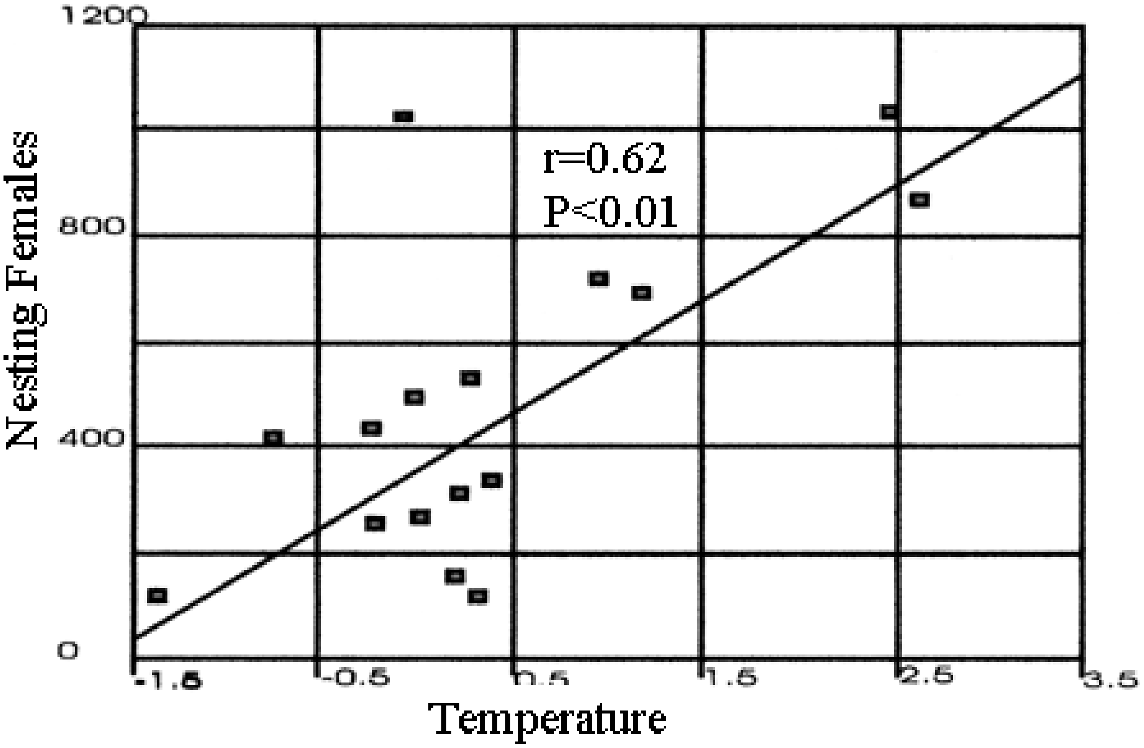

Figure 3. The relationship between water surface temperature and numbers of nesting females.

aquatic vertebrates in the ETP, the results suggest that the high temperatures associated with the ENSO have a short-term positive effect on the black turtle.

Acknowledgements

Funding for the conservation and monitoring activities of the black turtle population of Michoacan was provided by the U.S. Fish and Wildlife Service.

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Protection of Olive Ridley Sea Turtle (*Lepidochelys olivacea*) Nests and Turtle Camps along the Coasts of Michoacan and Guerrero.

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Instituto Nacional de la Pesca

Since 1996, the Instituto Nacional de la Pesca (National Fisheries Institute) in Mexico has protected, conserved, conducted research, and managed several populations of different sea turtle species along the coasts of Mexico. To evaluate the population status of the olive ridley sea turtle an annual patrol (known in Spanish as Recorrido Anual) was performed along the coasts of the states Michoacan and Guerrero. Presented in this poster were the results of the olive ridley nesting population protection for the 1998 nesting season as well as the turtle camps installed and operated by the Government, School and Productive Sectors.

Sequence of "Arribadas" of the Kemp's Ridley Sea Turtle (*Lepidochelys kempii*) at the Nesting Beaches of Rancho Nuevo, Tepehuajes and Barra Del Tordo, Tamaulipas, Mexico during the 1998 Season

MANUEL GARDUNO DIONATE, JUAN DIAZ FLORES, RENE MARQUEZ-M. AND MIGUEL A. CARRASCO AGUILA
Instituto Nacional de la Pesca

The nesting population of Kemp's ridley sea turtles (*Lepidochelys kempii*) along the coast of Tamaulipas shows signs of recovery through an increase in the abundance of nests and the nesting density at the established stations. During the 1998 nesting season, 22 "arribizones" occurred at the beach in Rancho Nuevo, 15 in Tepehuajes and 10 in Barra del Tordo. These began on April 12 and ended on June 26 with a similar reproductive behavior on the part of the nesting females on the three beaches, confirming the knowledge about "arribazones" for this species during its nesting season and the goals achieved in its recuperation.

University Project on the Study and Conservation of Sea Turtles: Preliminary Results and Future Plans

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This project is being carried out at a Cuban Biosphere Reserve called Peninsula de Guanahacabibes. Two well-known beaches, Playa Antonio and Playa El Resguardo, were studied from June to August 1998. Five groups of eight people each monitored the two sites every 15 days. The primary objectives were to study the nesting population and to gather morphological and ecological data. Fifty-three female turtles (49 green turtles *Chelonia mydas* along with four loggerhead turtles) were observed and measured.

Although it was understood that no hawksbill turtles were nesting on these two beaches, 11 juveniles were observed swimming very close to the study areas. This observation leads us to believe that the study area may in fact constitute a hawksbill feeding ground. Analysis of the local green turtle population's DNA has begun.

Acknowledgements:

I would like to express our sincere acknowledgements to all the people and institutions that provided us support for this study. Especially to David and Lucile Packard Foundation for having provided us financial support to attend the XIX Annual Symposium on Sea Turtle Biology and Conservation and the Meeting of Latin-American Specialists to be held in March in Texas, USA.

Distribution and Abundance of the Kemp's Ridley (*Lepidochelys kempii*) Neophytes at the Rancho Nuevo Nesting Beach, Tamaulipas, Mexico, during 1996-1998

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To estimate the population growth for the Kemp's ridley sea turtle population at Rancho Nuevo, México, an analysis of increments was conducted along 30.3 km of the nesting beach. Rancho Nuevo beach (23º12´Lat N, 97º47´ Long W) extends 16.8 km to the north and 13.5 km to the south of the Marine Turtle Research Station and was subdivided into 0.33 km units, each of which was composed of several zones. Every turtle that arrived at the nesting beach between April and July was recorded. The total number of females observed was 441 in 1996, 835 in 1997, and 2,149 in 1998, of which 281, 318 and 609 were neophytes, respectively. More nesting occurred between 5.4-7.5 and 9.9-16.8 km to the north and 3.5-13.5 km to the south. Turtles nested mainly in the 3rd zone on the beach profile, although some were observed in the 2nd and 4th this seems due to the beach topography. From 1996 to 1998 there was an 82% nesting increase, which indicates an increment of 97.7% in the registration of new turtles, neophytes.

Olive Ridley Nesting in Baja California Sur, México: Preliminary Observations

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Baja California Sur, Mexico provides nesting and/ or feeding habitat for five species of sea turtles. In recent years it has become an important area for sea turtle research which has focussed primarily on in-water studies of movement, habitat use and exploitation. However, leatherback and olive ridley sea turtles are known to nest on several beaches in Baja California's cape region. We present the results of nesting beach surveys for olive ridley sea turtles in the region. While these are not the most important rookeries for the species they are interesting in that they represent the northern limits of the nesting distribution and are located in high temperature, low humidity, semi-arid zones.

As the species recovers along the Pacific coast of Mexico several NGOs will continue to monitor these Baja California beaches. The region also offers opportunities for controlled ecotourism activities due to the proximity of Cabo San Lucas and San José del Cabo, both premier tourist destinations. Historically, the most important nesting sites on the peninsula have been located in the Cape Region (southern portion of the peninsula) from Bahía Magdalena to La Paz, especially Playa Migriño and Punta San Cristóbal and some beaches along the corridor from Cabo San Lucas to San José del Cabo.

Preliminary Observations

Of the seven sea turtle species that live in our seas, five inhabit the coastal waters of the eastern Pacific Ocean, these are *Caretta caretta*, *Chelonia mydas agassizii*, *Eretmochelys imbricata*, *Lepidochelys olivacea*, and *Dermochelys coriacea.* All of them are found in Mexican waters. México is considered a very important country for Pacific sea turtle conservation since it provides nesting and feeding areas along its entire coast (Márquez, 1996; Pritchard, 1997). One of the most critical regions for sea turtle conservation and research is the Baja California peninsula. In the past, several species were harvested in Baja California waters in large numbers and in recent years it has become an important region for sea turtle investigation (Nichols, 1999). Studies have mainly focussed on distribution and abundance, in-water behavior, movement, habitat use and exploitation in places like Bahía de Los Angeles, B.C. and Loreto, B.C.S. in the Gulf of California, and Bahía Magdalena and Punta Abreojos, B.C.S. in the Pacific coast.

At least two species are known to nest regularly along the southern part of the peninsula: the leatherback (*D. coriacea*) and the olive ridley (*L.olivacea*). The most important nesting sites for both species are those between Bahía Magdalena on the Pacific and La Paz in the Gulf of California (Fritts *et al*., 1982; Nichols pers. obs.; Sarti *et al.* unpublished data), an area known as the "Cape Region" (**Fig. 1**). In the last five years, nesting has increased in these areas and their protection has become the main goal of several NGO's such as ASUPMATOMA (Asociación Sudcaliforniana para la Protección del Medio Ambiente y la Tortuga Marina), whose members had protected over 250 nests and released more than 20,000 hatchlings trough these years (**Table 1**).

Table 1. Number of nests and hatchlings of olive ridleys protected by ASUPMATOMA in the beaches of Cabo San Lucas, B.C.S. during the last three nesting seasons.

Year	Nests Protected	Hatchlings Released
1996 – 1997	112	10,372
1997 – 1998	119	11,125
1998 – 1999		
Total	231	21,497

What makes these nesting areas interesting is that the rookeries are found at the northern limits of the nesting range of the species in the eastern Pacific. Other than the nesting areas in Baja California, the closest area with significant olive ridley nesting is located in Mazatlán, Sinaloa, at the mouth of the Gulf of California and major leatherback nesting beaches occur further to the south in Michoacán, Guerrero and Oaxaca. Waters that are warmer

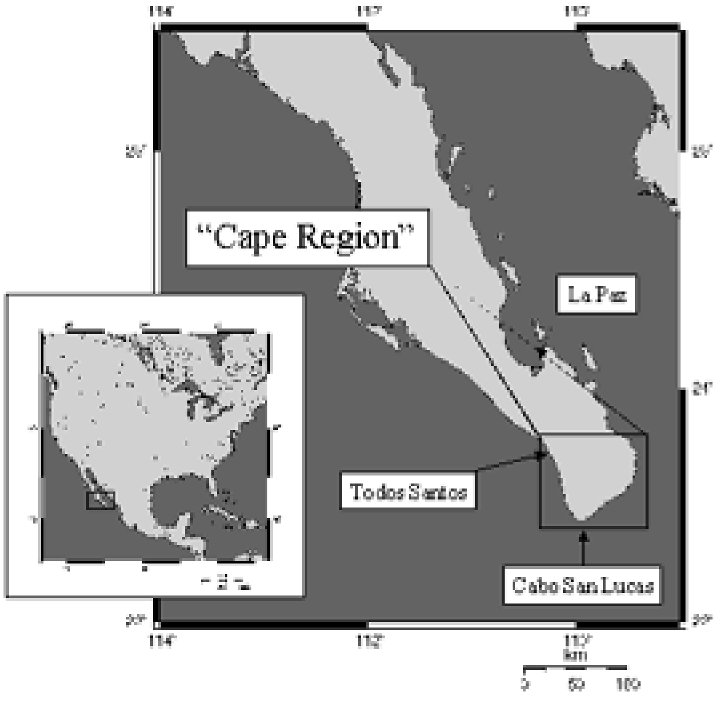

Figure 1. Regions of *Lepidochelys olivacea* and *Dermochelys coriacea* nesting in Baja California Sur, México.

than those of the outer coast of Baja California area – especially during the summer months of the year (Robinson *et al*., 1973) – bound this regions. Although other olive ridley nesting activities have been reported along the Gulf of California - one in San Felipe, B.C. (Caldwell, 1962), several in the Central Gulf (Carr, 1961a and 1961b), as well as in Bahía Kino and Puerto Peñasco, Sonora (Carr, 1967; Nichols, 1999)–they represent only sporadic observations. The physical conditions in Sinaloa and in the other important nesting sites along the Pacific coast (mainland), differ greatly from those found in the Baja California cape region.

The olive ridley nesting season in Baja California takes place during the months of July through November as it does at the other rookeries in México. Most of the nesting areas for sea turtles in México are characterized by high humidity levels caused by the summer rainy seasons, and are often located near estuaries or river outlets (Casas–Andreu, 1978). High temperature (often greater than 100 °F), low humidity, and semi-arid or desert zones characterize those nesting areas located in Baja California's Cape Region. The rainy season produces only occasional precipitation when a tropical storm or hurricane is near the coast and occasionally there are extended periods of up to 10 months without precipitation. An annual precipitation range from 70–300 mm occurs in the areas where olive ridley and leatherback nesting season is known (López-Ferreira, 1998). Evapotranspiration rates, however, are extremely high. These factors seem to be very inappropriate for turtle nesting since humidity plays a very important role in the embryonic development (Ehrenfeld, 1979), and in these areas it becomes whether scarce. However, olive ridley and leatherback sea turtles nest each year and it seems that numbers of olive ridleys are now increasing from one nesting season to the next (ASUPMATOMA, unpublished data). Apparently the turtles are able to locate suitable nesting habitat with the necessary humidity levels for egg development despite the generally high temperature and low humidity of the region. As olive ridley populations recover, this area may provide an interesting setting for studies of nest site selection and hatchling development which is now our main goal. Several questions can be asked: Do olive ridleys and leatherbacks chose nesting beaches in the areas with highest precipitation? Do they nest near arroyos and river beds, microclimates that may have higher humidity? Is nesting behavior on Pacific and Gulf beaches different due to differences in sand humidity?

In our preliminary observations, we have noted that the nesting behavior on these beaches differs from that reported by Márquez, *et al.* (1976) on other mainland México nesting beaches. Turtles nest closer to the water, on the beach platform, and therefore spend less time on the beach. We have focused our study on discovering the factor or factors that may alter this behavior since environmental conditions act directly on this subject. We expect to show results by the end of 1999.

Acknowledgments

We will like to thank The Oceanic Resource Foundation and Mrs. Lynnan Jiménez for their economic support on the presentation of this work. The people of ASUPMATOMA for sharing their information, vital for this work and for the knowledge of people. Thanks to Orso Angulo y Liza Gomez for their friendship and support, without them this work would have been so difficult, Muchísimas gracias.

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Sea Turtle Conservation Project - Humacao, Puerto Rico

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The town of Humacao is located on the southeast coast of the island of Puerto Rico. It has a shoreline of about 15km of sand beaches with rocky promontories that extend toward the sea. The Sea Turtle Conservation Project of Humacao began in 1985 under the direction of a local agency of the Dept. of Natural and Environmental Resources of Puerto Rico. In September 1996 the Sea Grant Program of the University of Puerto Rico at Humacao joined efforts with this agency to carry out the project.

Humacao's coast is used as a nesting beach by two species of sea turtles: *Dermochelys coriacea* (leatherback) and *Eretmochelys imbricata* (hawksbill). During the last three years (1996-98), nesting data has been gathered, nest management has been carried out, adults have been tagged and problems confronts the sea turtles in this place have been worked on. A total of 109 nests and 9898 liberated hatchlings have been counted for the hawksbill, while a total of 117 nests and 1988 liberated hatchlings have been counted for the leatherback.

Lamentably the sea turtles of this coast confront a series of obstacles that put in risk their survival. The main problems are light disorientation, erosion of the coast, egg robberies, and illegal fisheries. The largest problem is the tourist and residential development of the coast.

To minimize or eliminate these problems an environmental education project has been developed. This is directed to the coastal communities and developers to educate and orient them towards sea turtle conservation.

Implementation of a New Monitoring Protocol at Tortuguero, Costa Rica

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A new monitoring protocol was implemented in Tortuguero, Costa Rica, during the 1998 green turtle *Chelonia mydas* nesting season. Compared to previous years, the protocol included several new activities at the expense of decreased effort of nightly tagging.

Results from track surveys indicate that the number of green turtle nests in 1998 was one of the highest since weekly track surveys were initiated in 1971. During night patrols, a total of 1,225 green turtles were tagged, 286 green turtles with tags from previous years were encountered, and 3 green turtles (Panama 2, Mexico 1) tagged at other sites were seen. Green turtles with evidence of old tag holes or notches in at least one flipper represented 10% of newly tagged turtles. The probability of within-season inconel tag loss was estimated at 0.019.

Fibropapilloma incidence amounted to 2.1% with none of the affected turtles showing evidence of prior tagging. Carapace length (CCLmin) ± ST.D. for nesting green turtles was 103.6 ± 5.4cm and mean clutch size ± ST.D. was 108.6±20.9 eggs.

Hatching success for 196 marked nests was 62.8%, and emerging success for 193 marked nests was 60.0%. Of marked nests, 15.3% were disturbed by nesting turtles, 6.7% were illegally harvested by humans, 1.5% were depredated by natural predators, and 1.0% were depredated by dogs.

Rainfall varied from 80.9 mm per month (September) to 430.6 mm (June). Sand temperature was higher for the month with the least rainfall (September).

A total of 16,972 tourists paid US$5-US$25 per person to go on guided turtle walks at Tortuguero, during June-October. It is anticipated that these results will aid in management and increase interest in green turtle conservation on regional, national and local levels.

Acknowledgements

The monitoring program in Tortuguero was coordinated by Caribbean Conservation Corporation and implemented under a research permit from the Ministry of Environment and Energy of Costa Rica. The protocol for monitoring was developed by staff and Scientific Advisory Committee of Caribbean Conservation Corporation. Data was collected by the many research assistants and program participants whom are thanked for their hard work and long hours on the beach.

Nesting of Olive Ridley Sea Turtle (*Lepidochelys olivacea*) at Nancite Beach, Costa Rica, during 1997 Season

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Nancite beach in the Guanacaste Conservation Area is of worldwide importance for the olive ridley sea turtle (*Lepidochelys olivacea*). In 1997, we continued the year round monitoring that the Programa de Manejo y Conservacion de Vida Silvestre (Wildlife Conservation and Management Program) of the National University of Costa Rica started in 1989. The principal objectives were focused on estimating the number of arribada turtles and the number of solitary turtles that nest throughout the year. Secondary objectives were to record adults measurements, the number of nest predated, and to determine causes of mortality in adults.

In 11 months of data collection, we observed a total of 958 solitary olive ridley tracks, of which only 575 solitary turtles actually deposited eggs, the rest were false crawls. In addition to the olive ridley, 17 Pacific green turtles (*Chelonia agasizzi*) and 4 leatherbacks turtles *(Dermochelys coriacea*) were recorded as nesting at Nancite. Seven arribadas occured during the 11 months of study. We estimated the arribada populations with the transect method using the protocol developed by Gates *et al.*, 1996 (Modified Instantaneous Count Procedure) and with the traditional quadrat method established by Cornelius and Robinson (1982). There was no significant difference between the solitary sea turtle adult carapace measurement (CCL=69.9±4.3) and the arribada sea turtle adult carapace measurement (CCL=69.3±3.5) (t-test, $p>0.5$). A total of 1192 nests were predated during the period of this study, predation of rotten eggs (44.9%) was higher than that of any other stage development, followed by moderately development (16.5%) and fresh eggs (13.7%). A total of 27 dead turtles were found on Nancite from February to December 1997. Thirteen of those were presumed to be killed by crocodiles, the rest seemed be killed by shrimp boats that are frequently seen off the coast of Nancite, especially during the dry season.

Nancite is unique because it is a fully protected area where no harvesting of eggs is allowed, nevertheless, data from the last 10 years highly suggest that the nesting population in Nancite is decreasing in size (Valverde *et al.*, 1998) and the continued monitoring of the Nancite population appears essential.

Results of "Arribazones" of the Olive Ridley Turtle, *Lepidochelys olivacea,* on Escobilla Beach, Oaxaca, México in the 1998 - 1999 Season.

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An "arribazon" is when about 1000 turtles arrive at the beach at the same time to nest. It can last from a few hours to several days, and generally occurs at night (Márquez, 1990). Olive ridley sea turtles demonstrate this type of behavior and can be found on the Mexican Pacific coast.

Location and Description of the area of work

Escobilla beach is considered Mexico's most important marine turtle nesting zone and is one of the principal olive ridley nesting beaches in the world due to the number of turtles. The "arribazons" occur along a sandy, 8 km long zone at the western end of a 22 km long beach. It is delimited by the Cozoaltepec river to the west and the Lagartero river to the east. Access to the beach is at kilometer 180 of highway 200 between Pochutla and Puerto Escondido. The National Institute of Fishing through the Regional Center of Fishing Investigation in Salina Cruz started work at Escobilla in 1973. The Mexican Turtle Center took over operations in 1994.

Results

During the 1998-99 nesting season there were 6 "arribazones", with an estimated 248,063 nests (**Fig. 1**).

The 1st "arribazon" began on July 15 1998, two days before the quarter phase of the waning moon and lasted 4 days. There was an estimated 12,750 nests laid within 2.5 km. The 2nd "arribazon" started August 15, coincided with the quarter phase of the waning moon, and lasted five days. The turtles nested on 2.6 km of beach with an estimated number of 51,267 nests. The 3rd "arribazon" happened September 1-4 during the quarter of the waxing moon. There were strong south-westerly winds one day before and during the beginning of the "arribazon". It was estimated that 83,897 nests were laid on 2.5 km of beach. The 4th "arribazon" was October 14-17 (or 18) during the quarter phase of the waning moon with an estimated 83,897 nests deposited by October 16 on 3 km beach. No data were collected on the last days of the "arribazon" due to hurricane "Lester". The 5th "arribazon" occurred from November 15-21 with 42,011 nest during seven days on 2.5 km of beach during the period of the new moon (November 18). The 6th and last "arribazon" happened three days after the quarter phase of the waning moon, from January 12-15 1999, on 2.8 km of beach, with 24,059 nestings during the four day period.

Tide information according to the annual calendar of tides for the zone, was recorded for the periods of "arribazones" in order to observe the tide changes and their possible influence on the occurrence of "arribazones" (**Fig. 2**).

The 4th arribazon was the largest, while the 5th was the longest.

Discussion

66% of the "arribazones" occurred during the quarter phase of the waning moon, 17% during the waxing moon and the same percentage during the new moon phase. Nesting was concentrated on an average of 2.7 km of beach. The "arribazons" lasted from 3-7 days, with an average of 4.5 days. The interval between "arribazones" varied from 12 to 49 days with an average of 31 days.

Given an average incubation period of 45 days, there were two occasions when the "arribazon" occurred simultaneously with hatchling emergence: the 3rd "arribazon" coincide with the first hatchling emergence and the 4th "arribazon" with the hatching of the 3rd.

Five of the six "arribazones" happened with the tide below average. However the biggest one happened with high tide, but it is possible that it has been influenced by the presence of Hurricane Lester in the proximity of the nesting area.

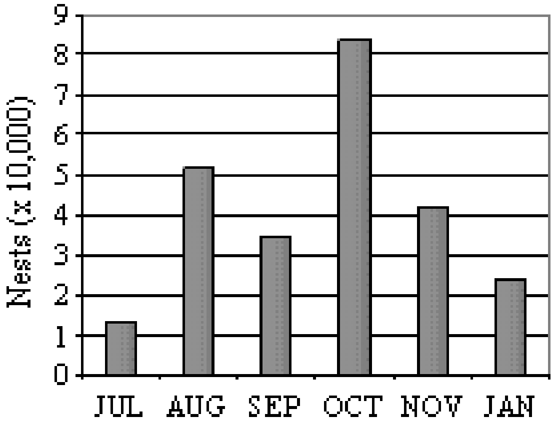

Figure 1. Nesting in "arribazones" at Escobilla beach.

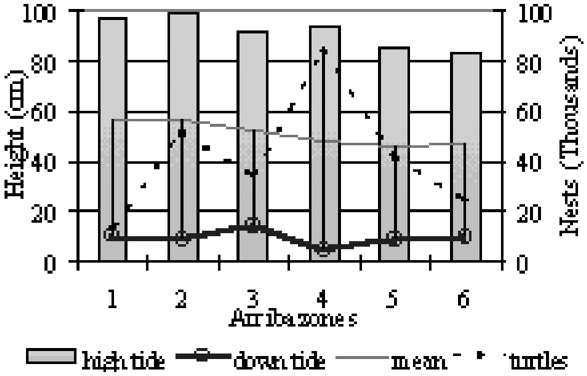

Figure 2. Relationship between tides and arribazones.

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Nesting Activity of Marine Turtles on Cape Canaveral Air Station, Florida, 1984-1998

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Federal agencies are required to protect and conserve threatened and endangered species (Endangered Species Act, 1973). In 1984 the 45th Space Wing, US Air Force, initiated a program for the conservation of nesting marine turtles in Cape Canaveral Air Station (CCAS). In 1988, CCAS was included in the Florida Dept. of Environmental Protection Index Nesting Beach Survey. In addition, agreements with the U. S. Fish and Wildlife Service (FWS) require detailed documentation of marine turtle hatchling disorientation and strict adherence to CCAS Light Management Plans. This long-term program has provided, to date, 11 years of high quality data from index nesting beaches around the State of Florida.

Study Area

The survey area comprises 21 out of 70 kilometers of federally protected beaches located at the Atlantic coastal beach along the eastern shore of CCAS. The nesting beach is bordered by Kennedy Space Center (KSC) on the north and Port Canaveral Inlet on the south. The beach is characterized by a high-energy surf zone, a gentle sloping sandy beach, and a substantial dune system. Significant accumulations of ocean-borne debris litter the beach in most areas.

Methods

Beach kilometer sections were subdivided into five 200-meter sectors and marked with PVC stakes. Nesting surveys were conducted seven days per week, beginning 1 May and ending 15 September. Surveys began at 0700 hours, using all-terrain vehicles. All new nests and false crawls were recorded daily.

A sample of loggerhead nests was marked once a week using wooden (sprayed with high-visibility orange paint) and numbered survey stakes. All green and leatherback nests were also marked and monitored throughout the season. Nest and false crawl determinations were made visually and by hand digging as needed.

Visual light shields, constructed of wood found on the beach, were erected 3-5 days before projected hatch for nests that were vulnerable to local lighting. Shielded nests were evaluated for shield effectiveness and disorientations were documented.

Predator control was accomplished by live-trapping and removal of animals from beach and inland locations. Tomahawk live traps baited with sardines were used for raccoon *Procyon lotor* control. Beach trapping was conducted by setting multiple traps in areas of intense raccoon activity and single traps at 200-meter intervals along the dune line. Trapping was conducted from 21 January - 26 February and from 20 April-7 July. Feral hogs *Sus scrofa* were also removed. Additional predation control measures included occasional screening with 4' x 4' sections of welded wire fencing.

Nest success evaluations were conducted on marked nests not previously disturbed and known to have emerged. Depredated were considered a total loss and included in the total success rate calculation.

Nests were relocated only if deposited below high tide line, in thick vegetation, out of sight of the ocean, or in a high traffic area. Movement induced mortality was reduced by relocation within 12 hours of deposition.

Results

Past and Present: The 1998 season was characterized by record numbers of nests of loggerhead *Caretta caretta*, Atlantic green *Chelonia mydas* and leatherback *Dermochelys coriacea* turtles.

The sea turtle nesting season resulted in 7,895 loggerhead, 241 green and 7 leatherback crawls of which 3,512, 104 and 7 resulted in egg deposition, respectively (**Table 1**).

Loggerhead nesting activity has showed a significant increasing trend (r^2=0.74) since the CCAS beach survey started in 1986 (**Fig. 1**). Although not significant, green turtle nesting has increased 46% since 1992. High annual variability is common in this species (**Fig. 2**). Clutch size has remained fairly constant over time (Mean=116.5, n=8 years). Twelve leatherback nests have been documented since 1993.

Depredation rates of loggerhead nests have decreased significantly from 86.4% in 1984 to 17.8% in 1998 (**Table 1, Fig. 3**).

The establishment of Light Management Plans (1991) and an extensive nest shielding effort have significantly decreased disorientation events (**Fig. 4**). There has been a reduction from 160 nests in 1990 to as few as 16 nests in 1995.

Future

The goals for the future seasons will be to increase the overall success rate of sea turtle nests deposited on CCAS by: (a) continuing the aggressive predator control program, (b) enforcing the CCAS light management program and night light surveys in conjunction with protective measures on the nests and (c) improving dune vegetation and constructing cross walks in areas prone to pedestrian disturbance.

The future for marine turtle nesting on CCAS is promising. Restoration of degraded coastal dune sites has opened up additional areas for sea turtle nesting. The

Table 1. Summary of loggerhead (top) and green (bottom) nesting activity at CCAS, FL from 1986 through 1998.

LOGGERHEAD															
Year	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Nests	668	1199	1423	1284	1562	1677	2110	2726	2356	1960	2424	2942	2799	2349	3512
NEST FATES															
Successful Emergences	27	232	567	972	1172	897	1353	2078	1467	1488	1471	1179	1726	1465	226**
% Success Rate	**4**	**19.3**	**39.8**	**75.7**	**75.0**	**53.5**	**64.1**	**76.2**	**61.8**	**76.2**	**60.7**	**40.1**	**61.7**	**62.4**	**67.26****
NEST FAILURES															
Depredated															
Raccoons	577	792	171	81	85	121	258	285	709	243	238	355	394	427	59
Feral Hogs	0	129	641	106	43	0	131	43	0	100	329	21	35	9	2**
Bobcats	0	0	0	0	0	0	0	0	0	2	8	0	0	0	0
Armadillos	0	0	0	0	0	0	0	0	0	0	73	6	69	147	0
Ghost Crabs	0	0	0	0	0	0	0	0	0	0	8	11	2	5	0
Fire Ants	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTAL	577	921	812	187	128	121	389	328	709	345	656	393	500	589	60**
% Depredated	**86.4**	**76.8**	**57.1**	**14.6**	**8.2**	**7.2**	**18.4**	**12.0**	**30.1**	**17.6**	**27.1**	**13.4**	**17.9**	**25.1**	**18.5****
Erosion/Tidal Inundation	60	43	30	78	83	282	32	86	99	29	136	195	142	76	6**
Other	4	3	15	41	60	40	55	55	48	82	124	79	368	191	23**
Unknown	0		0	6	119	337	281	179	43	16	37	1096	63	28	20

** Based on 336 marked nests.

GREEN															
Year	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Nests	0	0	10	13	6	28	23	17	55	5	54	7	45	8	104
NEST FATES															
Successful Emergences	0	0	5	10	5	n/a	14	17	36	3	34	0	24	3	74 %
Success Rate	0	0.0	50.0	76.9	83.3	n/a	60.9	100.0	65.5	60.0	63.0	0.0	53.3	37.5	71.2
NEST FAILURES															
Deprated															
Raccoons	0	0	1	0	0	3	2	0	4	0	2	0	0	0	10
Feral Hogs	0	0	4	0	0	n/a	2	0	0	0	1	0	0	0	1
Bobcats	0	0	0	0	0	n/a	0	0	0	2	0	0	0	0	0
Armadillos	0	0	0	0	0	n/a	0	0	0	0	1	0	2	0	0
Ghost Crabs	0	0	0	0	0	n/a	0	0	0	0	0	0	0	0	0
Fire Ants	0	0	0	0	0	n/a	0	0	0	0	0	0	0	0	0
TOTAL	0	0	5	0	0	3	4	0	4	2	4	0	2	0	11
% Depredated	**0.0**	**0.0**	**50.0**	**0.0**	**0.0**	**10.7**	**17.4**	**0.0**	**7.3**	**40.0**	**7.4**	**0.0**	**4.4**	**0.0**	**10.6**
Erosion/Tidal Inundation	0	0	0	1	0	n/a	1	0	4	0	5	1	1	0	1
Other	0	0	0	2	1	n/a	0	0	9	2	9	0	12	5	12
Unknown	0	0	0	0	0	n/a	4	0	2	0	2	6	6	0	6

relative lack of beachfront development and extensive shoreline armoring should secure good nesting habitat for many years. Vigilance must be maintained though, with increases in activity expected at several previously abandoned launch complexes as well as increased lighting along Port Canaveral and Cocoa Beach.

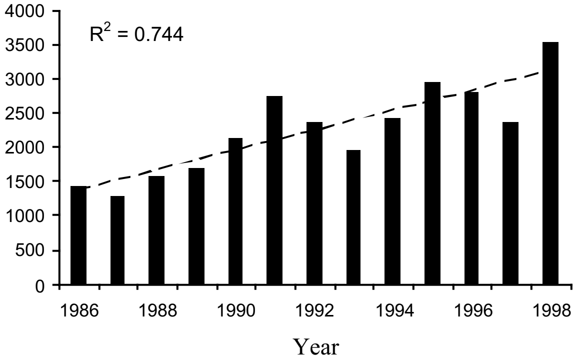

Figure 1. Loggerhead nesting activity on CCAS beaches from 1986 through 1998.

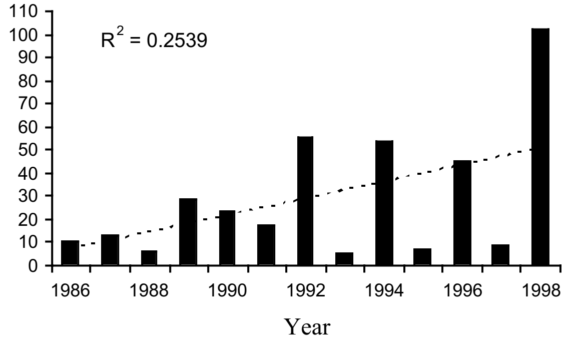

Figure 2. Green turtle nesting activity on CCAS beaches from 1986 through 1998.

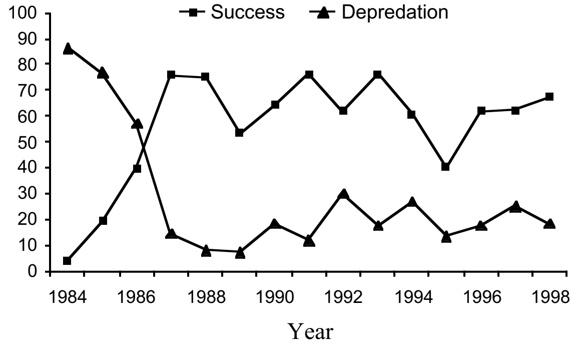

Figure 3. Loggerhead depredation and success rates 1984-1998.

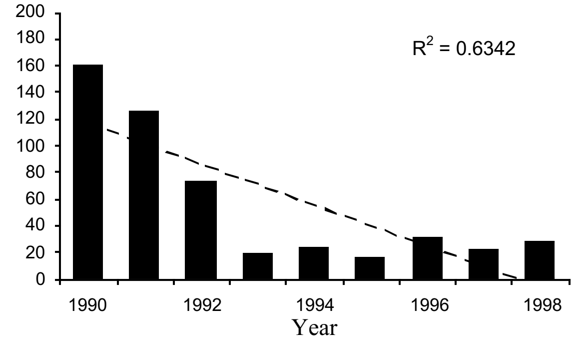

Figure 4. Disorientation events at CCAS beaches from 1990 through 1998.

An Overview of Twelve Years of Tagging Data from *Caretta caretta* and *Chelonia mydas* Nesting Habitat along the Central Gulf Coast of Florida, USA

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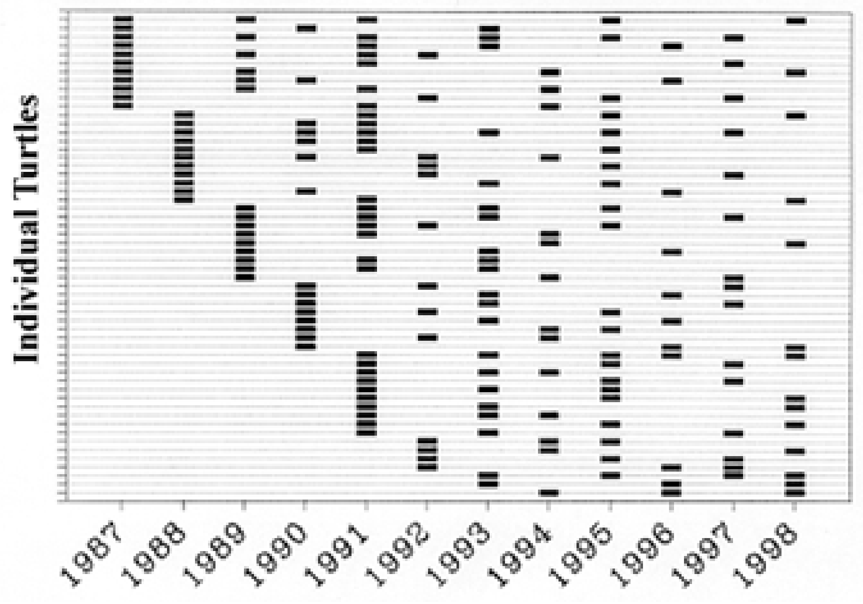
For the 12 years between 1987 and 1998 1,981 marine turtles (1,977 loggerhead and 4 green turtles) have been observed and flipper tagged on Sarasota County beaches along the central Gulf coast of Florida. Over 3,000 observations were made of these individual turtles. Two hundred forty three turtles were observed in seasons subsequent to the initial tagging. Re-nesting occurrences of special interest include four loggerhead and one green turtle flipper tagged while nesting on the Gulf coast who were resighted while nesting on the Atlantic coast of Florida (**Fig. 1**). Additionally one loggerhead initially tagged on the Gulf coast of Florida who was resighted while nesting on the Atlantic coast of North Carolina.

The yearly pattern of emerging turtles is shown in **Fig.2** for only those turtles that have been observed three or more years. The trend of nesting in alternate years is apparent. **Fig.3** shows the interval in years between the first and most recent resights. The longterm fidelity of the turtles to these beaches can be seen in this figure. Two turtles tagged in 1987 were resighted in 1998. Overall nesting on Casey Key increased during the study period (**Fig. 4**) but the number of tagged turtles resighted from previous years has remained fairly steady. Two factors may have contributed to this trend; 1) the increase in the total number of turtles nesting serves to dilute the chances of observing previously tagged turtles and 2), stringent requirements in tagging regulations limit the observers ability to observe and examine increased numbers of turtles for tags. Correlations of turtle nesting with several abiotic factors were examined. **Fig. 5** shows that incoming tide was preferred over outgoing tides in each of the study years. Moon phase showed no correlation with nesting on these beaches. Nest position on the beach (upper, mid-beach, lower) also appeared random both overall and when examining the reappearance of the same individual turtles. All nests were located at least 7m landward of the daily mean high tide line, however. A

Figure 1.

Figure 2. Pattern of appearances for turtles sighted 3 or more years.



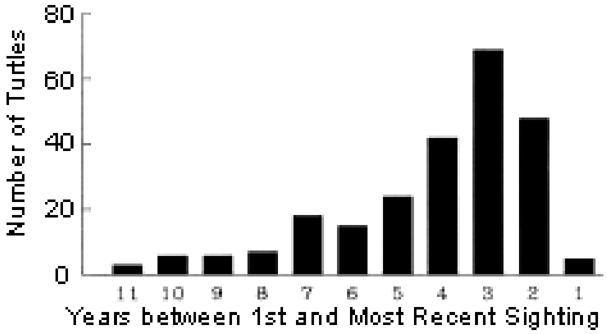


Figure 3. Interval in years between the first and most recent sightings of turtles on Casey and Manasota Keys, Fl

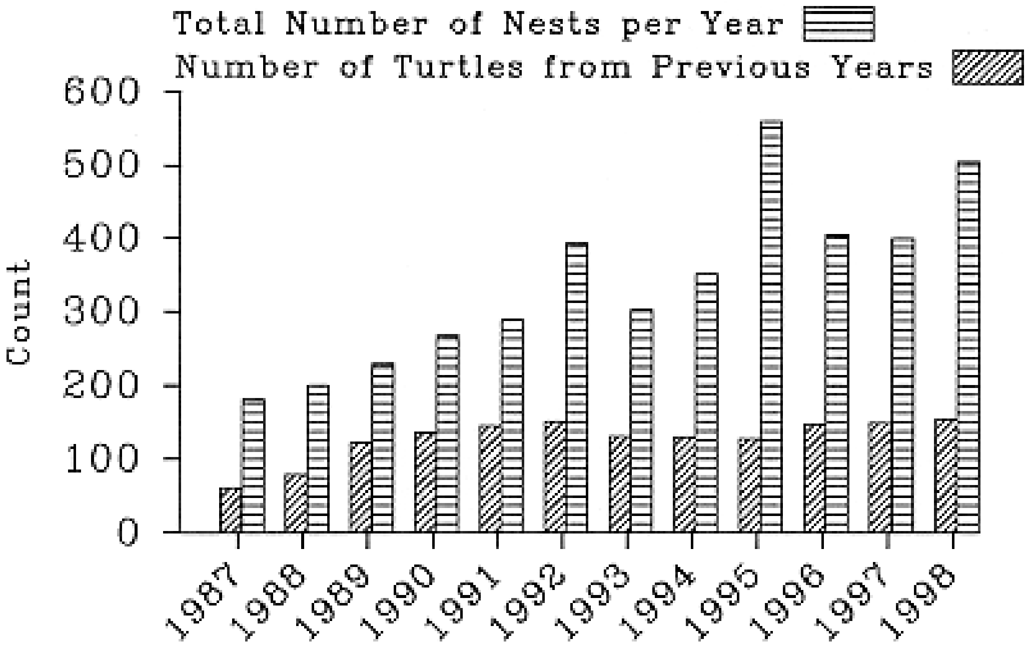


Figure 4.Total number of nests on Casey Key with the number of returning turtles tagged in previous years.

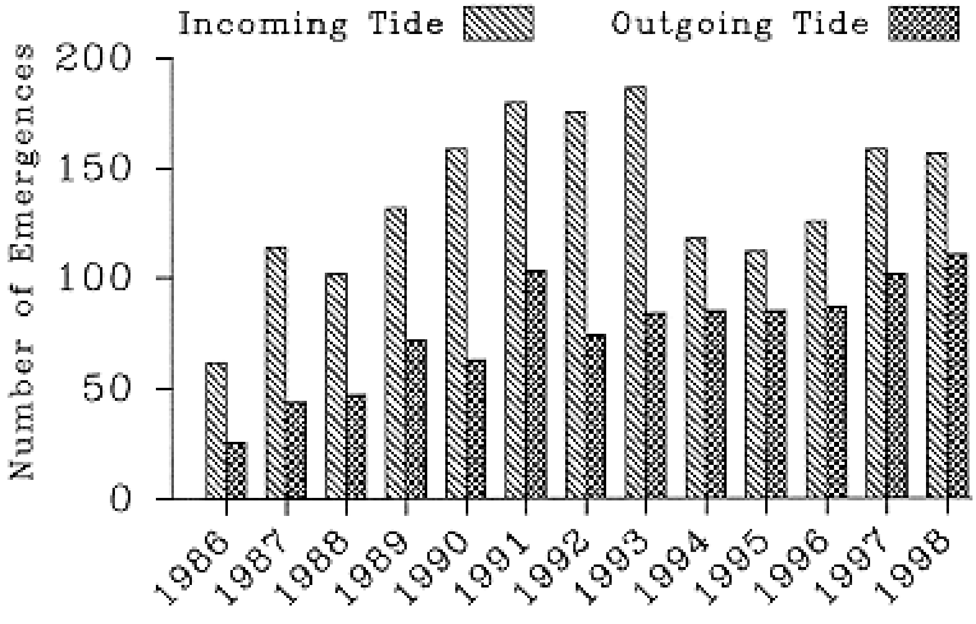


Figure 5. Yearly number of emergences observed during incoming and outgoing tides.

correlation of crawl widths and turtle widths revealed that the crawl width is not a reliable indicator of turtle size.

Acknowledgements

Information on tag returns was made available by Wendy Teas, Amy Woodhead and Lisa Csuzdi of the Miami office of the National Marine Fisheries Service; Dean Bagley and the Turtle Research Group at the Univ. Central Florida; Gerry Monahan at Camp Lejeune Marine Base, Camp Lejeune, North Carolina; Ruth Boettcher, Sea Turtle Coordinator for North Carolina; and Jim Eggers of Public Service Electric and Gas Company, Salem, New Jersey.

Kemp's Ridley (*Lepidochelys kempii*) Nesting in Florida, USA.

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The Kemp's ridley is one of the world's most endangered vertebrates. The primary nesting site of the species is Rancho Nuevo, Tamaulipas, Mexico, where the vast majority of nesting activity occurs. Secondary nesting beaches are located near Rancho Nuevo and isolated nesting events have occurred at a variety of other locations within the Gulf of Mexico, as well as on the eastern coast of the United States. We report the first confirmed nesting of a Kemp's ridley on the eastern coast of Florida (two nests in Volusia Co.) and an additional nesting event on Florida's west coast (Lee Co.). Genetic analysis of nuclear DNA showed that hatchlings from one of the Volusia Co. nests were pure *L. kempi* and not hybrids. Including the nests reported here, five *L. kempi* nests, involving three individual turtles, have been confirmed on Florida's beaches thus far. There is no evidence that these individuals were part of the Kemp's ridley head-start program, although that possibility cannot be excluded. The manuscript from which this poster was derived has been accepted for publicaiton in Florida Scientist 62(4) and should be published late in 1999. Correspondence and requests for reprints should be addressed to the first author at the Univ. of Florida. The 1999 Sea Turtle symposium is gratefully acknowledged for awarding SAJ a student travel grant.

Summary of Hawksbill Turtles (*Eretmochelys Imbricata*) Nesting on Maui, Hawaii from 1991 to 1996

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This study documents the nesting of hawksbill sea turtles on Maui, Hawaii from 1991 to 1996. Hawksbill sea turtles are distributed circumtropically and are endangered throughout their range (NMFS 1998). The state of Hawaii's population of hawksbills is critically endangered, consisting of perhaps a total of 20 to 30 nesting age females (NMFS 1998).

Prior to 1991, only anecdotal reports existed regarding the sighting of nesting or foraging adult hawksbills or hatchlings on Maui, Hawaii. Since 1991, it has become evident that hawksbills still use Maui as nesting habitat.

Attention focused on hawksbill nesting on Maui in August of 1993 when a nesting female was struck and killed by a vehicle as she attempted to cross a coastal highway to nest. A hawksbill nest was also discovered in 1993. The nest contained an estimated 209 eggs of which 153 are thought to have hatched (estimated hatchling success 73%). On three separate occasions in 1994 hawksbills were discovered on shore. Two of these turtles were freed from entangling weeds and released. The third was tagged and transported to National Marine Fisheries Service, Honolulu. In 1995, a hawksbill nest from a previous year was exposed by eroding sand dunes. Six eggs from this nest were retrieved. In 1996, a second nesting hawksbill was struck and killed (within a mile of the 1993 incident) by a vehicle while she tried to cross the highway. 134 eggs from this turtle were buried but did not hatch. Two other nests were monitored in 1996. These nests contained 148 and 191 eggs. 40 and 10 hatchlings are estimated to have emerged from these two nests, respectively (estimated hatchling success 27% and 5%, respectively). 20 hatchlings from an unidentified nest were also discovered in 1996. These hatchlings had been crushed by cars along the highway or died of dehydration after becoming entangled in non-native weeds along the roadside. One live hatchling was recovered and released.

Following the turtle fatalities in 1993 and 1996 a collaborative community and intergovernmental effort to stabilize the nesting environment, prevent turtles from reaching the highway, and monitor hawksbill nesting activity began. The backbone of this monitoring effort was a program of Dawn and Dusk Patrols. These patrols searched for signs of nesting hawksbills, monitored suspected nest sites and monitored hatchling emergence. Dawn and Dusk

Patrols have continued in subsequent years.

It became evident throughout the course of this project that a number of conservation issues existed which must be addressed in order to allow the nesting of hawksbills to continue on Maui. These problems include the presence of coastal light sources that may discourage female hawksbills from nesting in preferred habitat and may disorient hatchlings, non-native plants that could entangle hatchlings and adult hawksbills and habitat degradation as a result of coastal development. Conservation measures to help keep turtles off the highway, to encourage nesting and to reduce human impacts have been implemented.

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Green Turtles (*Chelonia mydas*) and the U.S. National Park Service Inventory and Monitoring Program

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In an effort to protect and preserve its natural resources, the National Park Service established the Natural Resource Inventory and Monitoring (I & M) program in the early 1990's. Participating National Parks are grouped regionally, forming prototype ecological monitoring programs. Buck Island Reef National Monument (BUIS NM) and Dry Tortugas National Park (DRTO) are part of the Virgin Islands-Southern Florida Cluster, Tropical-Subtropical Biome.

The Buck Island Sea Turtle Research Program is in its 11th year of nighttime research focusing primarily on the nesting activities of hawksbill sea turtles (*Eretmochelys imbricata*). Dry Tortugas Sea Turtle Monitoring Program is in its fourth year of comprehensive daytime monitoring of loggerhead (*Caretta caretta*) and green (*C. mydas*) sea turtles, with loggerheads being the primary nesting turtle in the Dry Tortugas.

Buck Island and the Dry Tortugas share an important common tie: both parks have documented green turtle nesting activity over time, including a record level of green turtle activity during the 1998 nesting season. Small in size, Buck Island (with 1.5 km of nesting beach) and the Dry Tortugas (4-5 km of beach) both host a significant concentration of green turtle nesting activity within the Southeastern United States and U.S. Caribbean territories. The documentation of this activity combined with the standardization of monitoring protocol within the I & M program provides a valuable tool for the understanding and recovery of green turtle nesting populations within these regions.

Loggerhead Turtle (*Caretta caretta*) Incubation Periods across the Florida Panhandle

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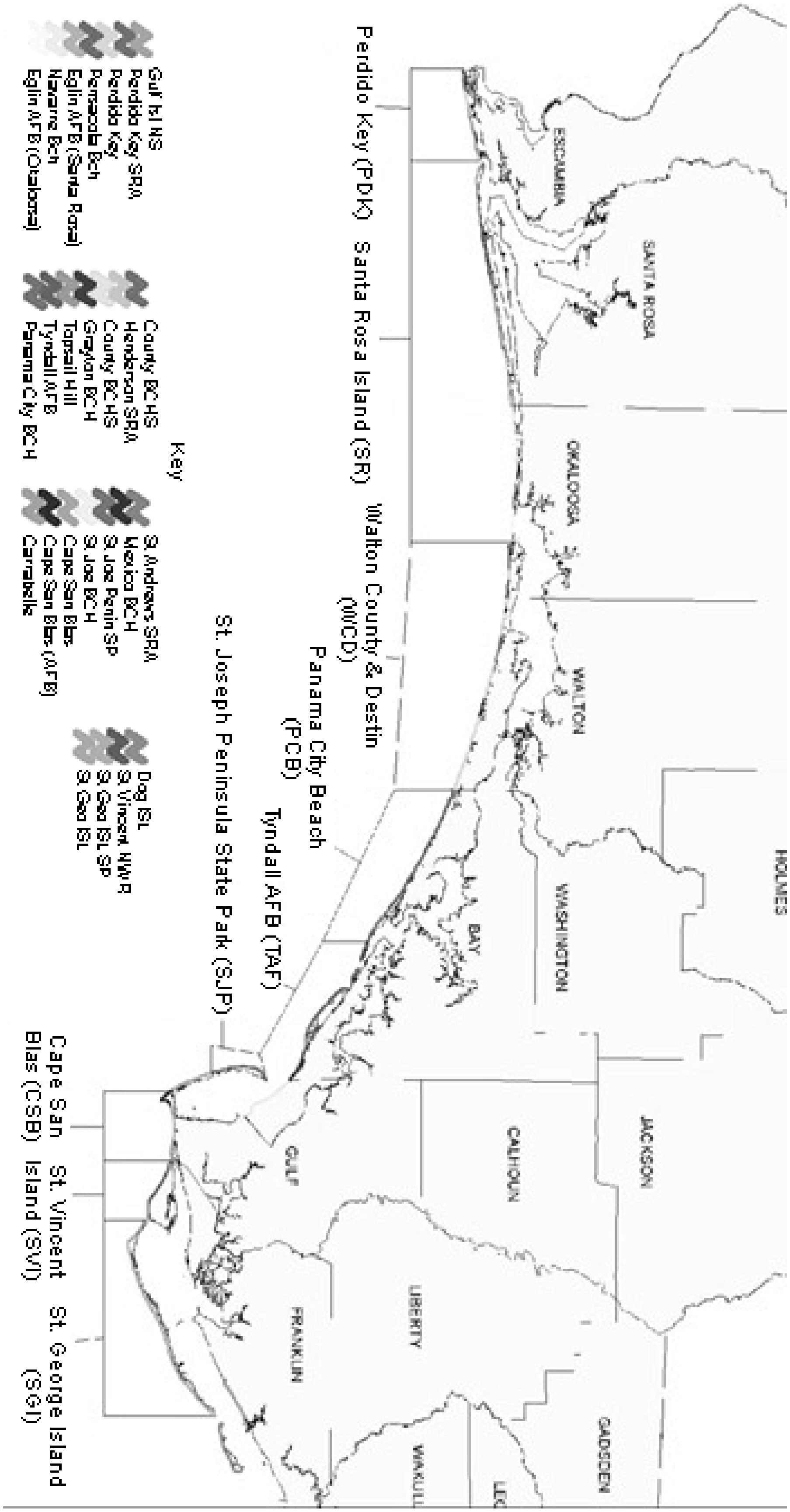
Substrate composition and geographical location interact in complex ways to influence the incubation environment for marine turtle nests. Cooler sediment temperatures can prolong the incubation period as well as influence the sex of the hatchlings (Ackerman, 1997). The geographic distribution of differences in incubation length, and implications for site-specific differences in gender due to temperature, is not well known. Such differences could be particularly important in determining hatchling survival and gender at the geographic limits of the nesting ranges of marine turtles. The loggerhead turtles (*C. caretta*) that nest in the Florida panhandle (**Fig. 1**) are a genetically distinct subpopulation (Encalada *et al.*, 1998) that may be affected by these differences.

Incubation length for loggerhead nests deposited in Panama City, Florida, (central panhandle) averaged 70 to 80 days (Watson, 1996) in contrast to the 53 to 55 day average previously reported for Florida (Davis and Whiting, 1977). Comparisons with unpublished data from neighboring beaches suggested that incubation lengths varied across the panhandle. Formal comparisons were conducted to assess the incubation period for loggerhead nests across the panhandle, from St. George Island west to Perdido Key at the Florida-Alabama border (**Fig. 1**). In particular, we asked: do incubation lengths vary with location on a gradient across the Panhandle? If such incubation length patterns exist, further studies addressing substrate temperature and sex ratios of panhandle loggerhead nests would be appropriate.

Materials and Methods

In order to document incubation lengths for loggerhead nests deposited in panhandle beaches, nests were marked and the dates deposited were recorded. Nesting surveys were conducted by organizations permitted by the state to conduct marine turtle nest monitoring (**Fig. 1**). A total of 16 organizations surveying 24 different beaches participated in this study. Beaches were combined into nine distinct geographic regions with natural boundaries such as inlets (in most cases) as endpoints.

Figure 1. Loggerhead turtle (*Caretta caretta*) nesting beaches and regions in the Florida panhandle. Regions from west to east: Perdido Key (PDK), Santa Rosa Island (SRI), Walton County and Destin (WCD), Panama City Beaches (PCB), Tyndall AFB (TAF), St. Joseph Peninsula State Park (SJP), Cape San Blas (CSB), St. Vincent Island (SVI), and St. George Island (SGI).



Incubation period was calculated from date of deposition to date of first hatchling emergence. Nests for which incubation period was recorded were chosen haphazardly. Incubation periods were compared among geographic locations utilizing the Games and Howell test of equality of means on nontransformed data (Sokal and Rohlf, 1981).

Results

Nesting data were collected from nine geographic regions (**Fig. 1**), and average incubation period across each region calculated between 1994 and 1998. Incubation length varied from 45 to 95 days across the panhandle.

The data were heteroscedastic and not normally distributed (p<0.01 in most cases, Sigma Stat v. 2.0). Transformations did not correct the distribution and/or the error variance. This effect was most likely attributable to different sample sizes among regions. Therefore, the Games and Howell test of equality of means was used to determine if differences existed between regions (Sokal and Rohlf, 1981). **Table 1** lists the pairs of regions that were significantly different at the p=0.05 level. In all cases, the westernmost beach of the pair had a longer average incubation length.

Discussion

Some western areas of the panhandle have significantly longer incubation lengths than eastern areas, though this does not hold true for all regions in all years. In 1994 and 1995, low sample sizes (due to hurricanes and other factors) may have had an impact on detecting differences between regions. The most notable exception to the pattern across all years is Perdido Key (PDK), the westernmost beach. This beach consistently has intermediate average incubation lengths that were not statistically different from any other region in any year. However, sample sizes at Perdido Key are notably small due to the low number of nests deposited. If differences exist, they may not be statistically detectable.

Table 1. Regions in the Florida panhandle exhibiting different incubation lengths at the p<.05 level, Games and Howell test of equality of means (Sokal and Rohlf, 1981). See Figure 1 for region abbreviations and locations.

1998	1997	1996	1995	1994
SRI/SJP	WCD/SVI	SRI/CSB	none	PCB/TAF
SRI/CSB	WCD/SGI	SRI/SGI		
SRI/SGI	TAF/SVI	PCB/CSB		
PCB/SGI	CSB/SVI	PCB/SGI		
TAF/SJP				
TAF/SGI				
CSB/SGI				

We are unsure at this time if these differences in incubation length are correlated with gradients in physical factors that may occur across the panhandle, such as sand temperature differences. Sand temperature is dependent upon a variety of factors: air temperature, cloud cover, precipitation, and sand color, for example. The relationships between sand temperature, nest temperature, and sex ratios are currently being analyzed directly with the utilization of buried data loggers in another part of this study (Maglothin *et al.*, 1999). If predominantly male turtles are being produced by the nests in cooler sands in the western panhandle, a smaller proportion of females may be available in the population to return to those regions of the panhandle to nest. Differing sex ratios on different nesting beaches within the panhandle population would present some unique population management challenges.

Acknowledgements

We express our gratitude to the members of the following organizations who were working together to make this project possible: U.S. Fish and Wildlife Service, Gulf Islands National Seashore, St. Vincent National Wildlife Refuge, Eglin Air Force Base, Tyndall Air Force Base, Florida Dept. of Environmental Protection (Florida Park Service, Apalachicola National Estuarine Research Reserve, and Bureau of Protected Species Management), the Univ. of Florida (Florida Cooperative Fish and Wildlife Research Unit), St. Andrew Bay Resource Management Association, the Emerald Coast Wildlife Refuge, the South Walton Turtle Watch, and the Gulf County Turtle Patrol.

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Analysis of Trends in Loggerhead Turtle (*Caretta caretta*) Nesting Densities along a Southeast Florida Beach, USA, 1990-1997

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The importance of beaches in the southeastern United States to the worldwide status of the loggerhead sea turtle has been described by Ross (1982) and Hopkins and Richardson (1984). Ross concluded that the aggregation of female adult loggerhead turtles nesting on the beaches of the southeastern U.S. is second in size only to that of Masirah, an island off the coast of Oman in the northwest Indian Ocean. The Masirah group numbers approximately 30,000 adult females, and the southeastern U.S. group numbers approximately 25,000. These two areas support the two largest loggerhead nesting aggregations in the world. Nesting densities along the beaches of northern Palm Beach County, FL are second in significance in the southeastern U.S. only to those of the Archie Carr National Wildlife Refuge in Brevard County, FL. Daily nesting beach surveys were initiated in 1989 on a 6 mile stretch of beach beginning at the Jupiter Reef Club in the Town of Jupiter and terminating at the northern boundary of John D. MacArthur Beach State Park in the Village of North Palm Beach (**Fig. 1**).

A total of 42,344 nests were constructed during the period 1990-1997, resulting in an overall average of 882 nests/mile. The beach was divided into 11 Zones of approximately 2 mile in length in conformance with the FDEP Index Nesting Beach (INB) program. The influence on nesting densities of two variables, INB Zone and Year, are examined to better understand spatial and temporal trends in nesting density during the 8 year period.

Methods

INB Zone: A simple linear regression model was used to examine the influence of INB Zone on nesting densities. Although localized variations in nesting densities within a given Zone may occur, for the purposes of this analysis we assume that the mean nesting density represents the "true" density for each Zone.

Year: The influence of Year is examined through the use of a Shewart X-bar control chart. Suppose that at each time t, $1\#t\#k$, a subgroup of n_t measurements is sampled from a Poisson process. The process subgroup at time t is denoted $\{Y_{ti}, 1\#i\#n_t\}$ with mean process $F_t = E(Y_t|X_t)$, satisfying $g(F_t) = X^T_t\beta + f(F_t - 1)$, where X_t are covariates and g is the link function $g(x) = log\, x$ for the Markov model. For a given F_t, the nesting rate Y_{ti} is an i.i.d. sample from Poisson (F_t).

Year and Zone are further examined through use of the standard Poisson regression model. The regression response variable is the number of nests/mile (Y), and the factors are INB Zone and Year. The conditional mean, denoted by F, on the main effects Year (X_1) and Zone (X_2) satisfies $g(F) = \alpha X_1 + \beta X_2 + Y$, with link function $g(F) = log(F)$ and variance defined by $Var(Y) = F$ where is the scale parameter.

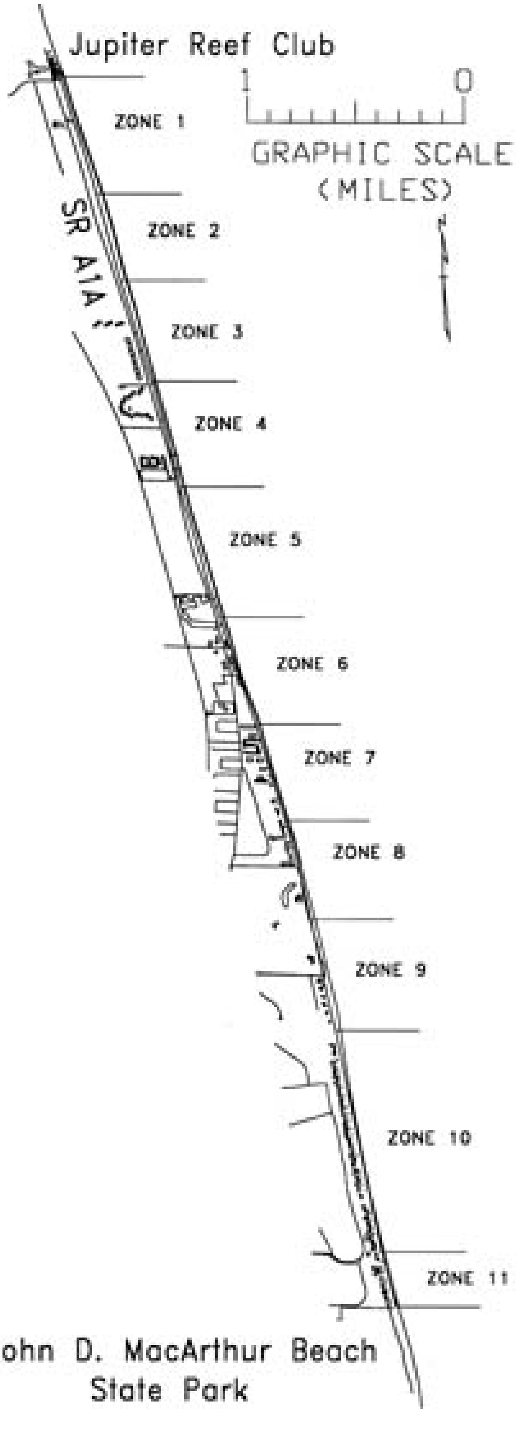

Figure 1. Index Nesting Beach Zones, northern Palm Beach County, Fl.

Results

INB Zone: Yearly plots of Zone nesting densities are shown in **Fig. 2**, and mean densities for the 8 year period in **Fig. 3**. There is an apparent increasing trend in the pattern of nesting densities from north to south along the study beach (Zone 1 through Zone 11). Nesting density is fairly linear with respect to Zone, suggesting a simple regression with predictor variable Zone. Mean nesting densities for the study period and the fitted regression line are plotted in **Fig. 4**. The regression line is described as follows: Log(Mean nests/mile)=6.600+0.030**Zone*, indicating a baseline nesting density of approximately ($e^{6.6}$) = 735 nests/mile each year, with an increase of [($e^{0.03}$-1)$e^{6.6}$] = 22 nests/mile for each successive Zone from north to south. The regression analysis demonstrated that Zone was a significant factor to nesting density (p-value=0.002). The amount of variability of the Log(Mean nests/mile) explained by Zone is approximately 66.2% (residual S.E. = 0.076).

Year: The 11 Zone time series are plotted in **Fig. 5**. Zone 11 had a very high nesting density in Year 1991. This high value appears to be an outlier when compared to other years, and is not included in the analysis. **Fig. 6** is a plot of the x-bar control chart for the time series. Year 1993 had densities falling below the lower control limit, while Year 1995 had densities exceeding the upper control limit. There appears to be a temporal cycle with nesting densities peaking every four years, and an overall increasing trend in nesting density.

Box plots of total nests for each level of the two factors, Year and Zone, are displayed in **Fig. 7**. Standard Poisson regression was then used to model the data. According to the analysis of deviance table (**Fig. 8**), it appears that both factors (Year and Zone) have a significant influence on the total nests observed. First order model plots are also shown in **Fig. 8**. The plots of observed versus fitted values show no great departure from the model.

Discussion

Many factors can influence sea turtle nesting densities along a given beach. Beach character can change significantly along both small and large temporal and spatial scales, influencing site selection by nesting females both within and between seasons. The interaction of features such as beach scarps, rock outcrops, beach berm/dune profile, dune vegetation character, artificial lighting, and other aspects of development intensity and beach character produce the environment within which nest site selection must be made at any point in time along the beach.

The study beach varied greatly in character, ranging from areas of virtually no beach front "development" (residential/commercial structures/ significant point light sources) in Zones 3 and 5 to an area of intensively developed 6-12 story condominiums situated right along the dune crest (Zones 7-9). Additionally, State Road A1A is situated immediately behind the dune crest along the entire study beach, with dune vegetation providing various amounts of screening. Traffic lights visible from the beach occur at Marcinski Rd., Juno Beach Park (Zone 4), and Loggerhead Park (Zone 5).

Approximately 2000 feet of supra- and inter-tidal rock outcrops occur in Zones 8 and 9. Outcrop profiles ranged in height from 0 to approximately 4 feet. Substantial changes in the extent and profile of these outcrops can occur both within and between nesting seasons. Direct access to the beach berm by nesting females was precluded along approximately 300 feet in Zone 8 and 1800 feet in Zone 9 in 1997. The disruption of beach access by rock outcrops likely accounts for much of the drop in nesting densities exhibited in Zones 8 and 9 (**Fig. 3**).

Regression analysis revealed that loggerhead nesting densities steadily increased from north to south in spite of the fact that beachfront development intensity was highly varied. It appears that geographic Latitude, the morphological/ environmental aspects of this segment of coastline, its proximity to the Gulf Stream and other resources, or a combination of these and other variables contribute to the substantial baseline nesting density, and increasing north-south trend in densities observed.

Nesting density patterns across years suggest a temporal cycle with densities peaking every four years, and an overall increasing trend in nesting densities. The pattern of high and low density years mirrored the trend of peaks and valleys recorded during statewide FDEP INB counts of the same period, suggesting a "synchronous" nesting pattern for the loggerhead turtle in the southeastern U.S. (**Fig. 9**). Further study will be needed to verify these patterns, as the data represent a relatively short time series.

Acknowledgements

Support for this report was provided by the Board of County Commissioners, Palm Beach County, FL, the Research Initiation Award of Florida Atlantic University, and the Marinelife Center of Juno Beach. Special thanks to all those who spent countless hours on the beach collecting the data.

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Hopkins, S.R. and J.I. Richardson. 1984. A recovery plan for marine turtles. National Marine Fisheries Service, Southeast Regional Office.

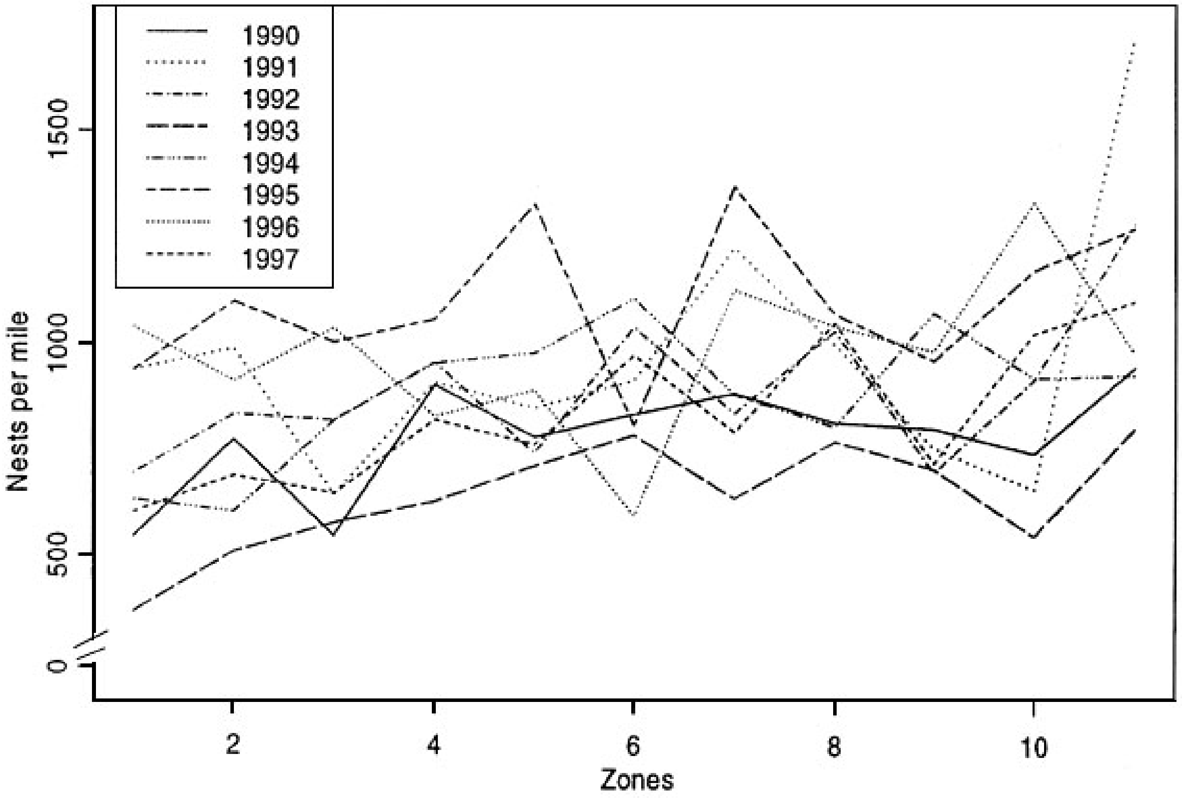


Figure 2. Yearly plots of zone nesting densities.

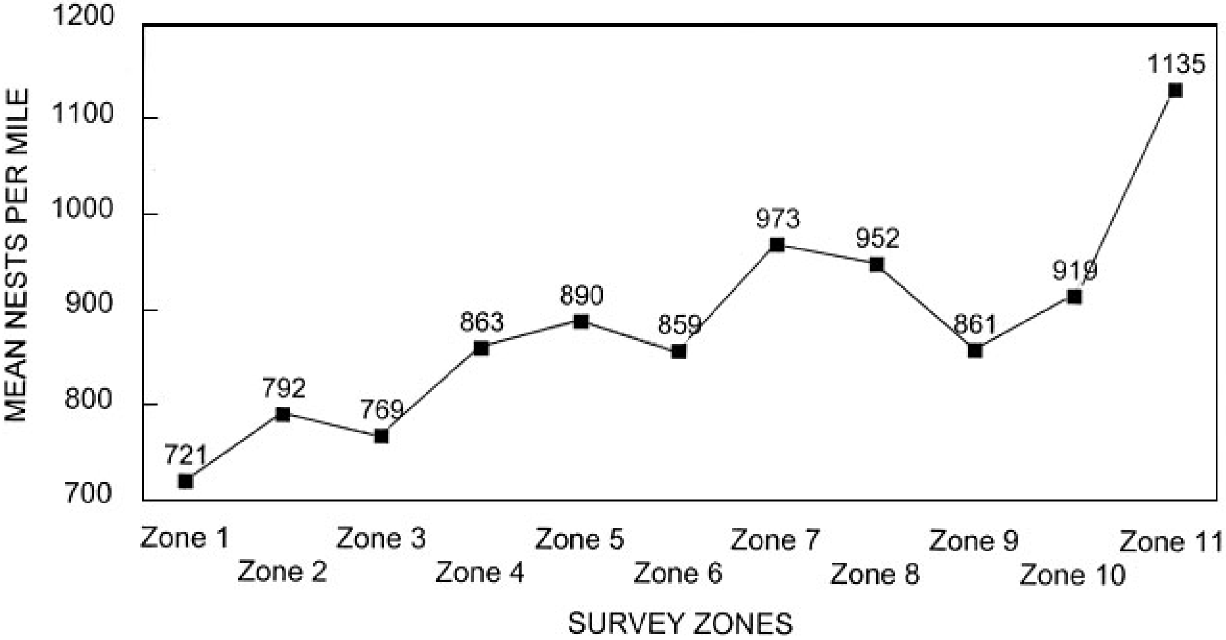


Figure 3. Mean nesting densities by zone, 1990-1997.

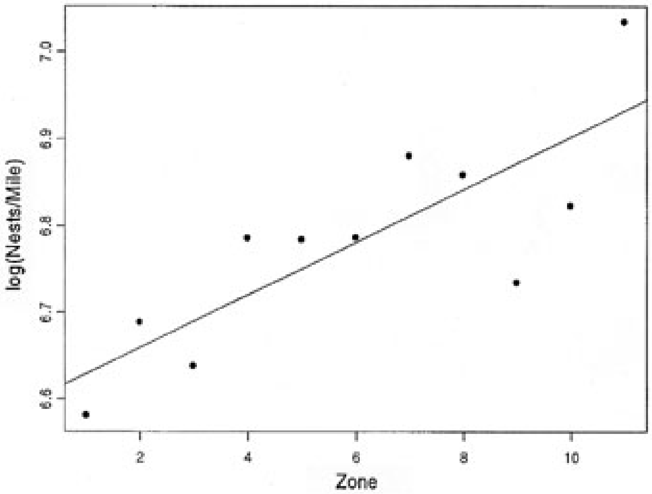


Figure 4. Plot of mean zone densities and the fitted regression line.

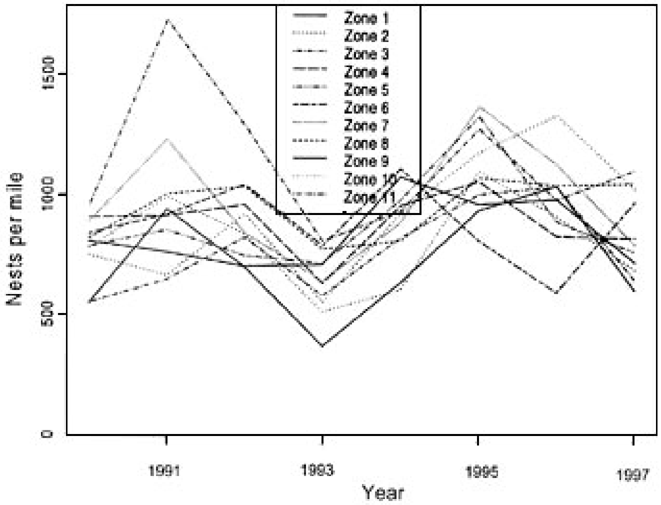


Figure 5. The 11 zone series plotted per year.

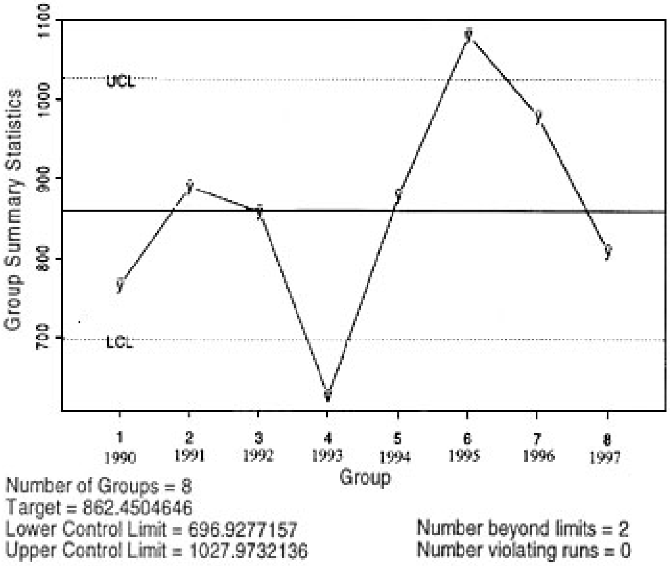


Figure 6. X-bar control chart of nesting densities for the 8 year study period.

Figure 7. Box plots of total nests and false crawls for both factors, Zone and Year (opposite page, above the horizontal line.)

Figure 8. Analysis of deviance table and first order Poisson regression model plots (opposite page, below the horizontal line.)

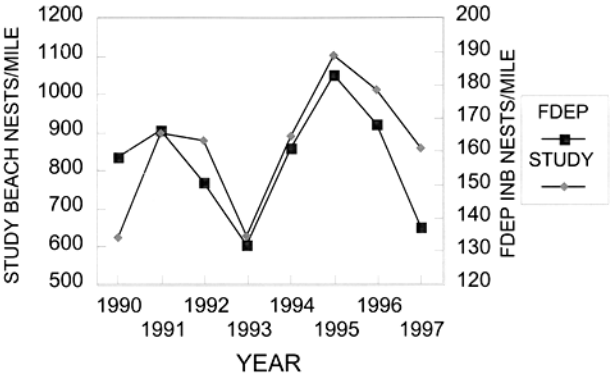
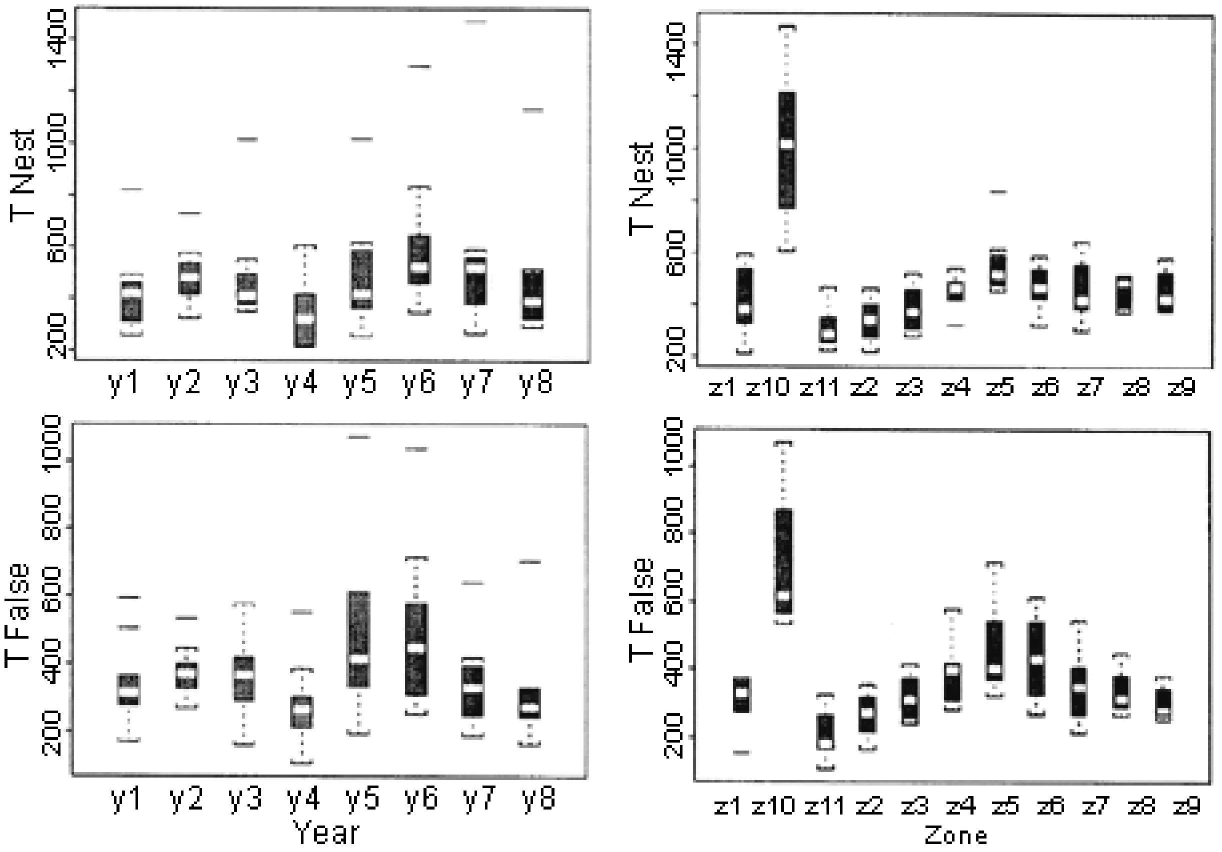
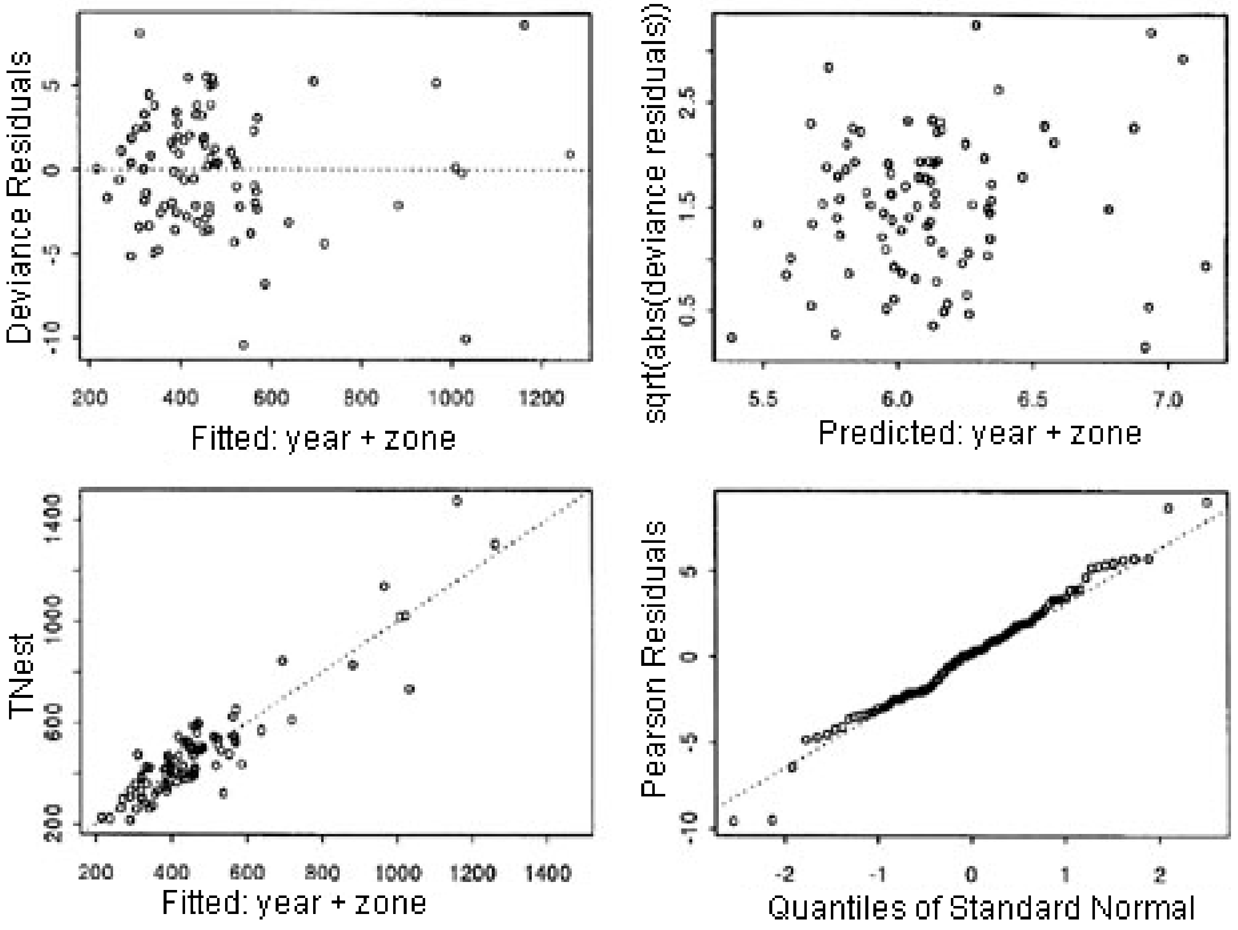


Figure 9. Mean loggerhead turtle nesting densities along the study beach and statewide FDEP Index Nesting Beaches (INB), 1990-1997.


T Nest
200
600
1000
1400
y1 y2 y3 y4 y5 y6 y7 y8
z1 z10 z11 z2 z3 z4 z5 z6 z7 z8 z9
T False
200
400
600
800
1000
Year
Zone


Deviance Residuals
-10
-5
0
5
200
400
600
800
1000
1200
Fitted: year + zone
sqrt(abs(deviance residuals))
0.5
1.5
2.5
5.5
6.0
6.5
7.0
Predicted: year + zone
TNest
200
600
1000
1400
Fitted: year + zone
Pearson Residuals
-10
-5
0
5
-2
-1
0
1
2
Quantiles of Standard Normal