Nest Site Selection and Effects of Anthropogenic Changes To the Rushikulya Nesting Beach, Orissa on Olive Ridley Sea Turtles

Dissertation submitted to the Saurashtra University, Rajkot in partial fulfilment of Masters Degree in Wildlife Science (2009)

By

M.Muralidharan

Supervisors

Dr. K. Sivakumar

&

Prof. B. C. Choudhury

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Certificate

This is to certify that Mr. M. Muralidharan has carried out an original piece of research in partial fulfilment of his M.Sc (Wildlife Science) Degree of the Saurashtra University, Rajkot. The topic of his dissertation is "Nest Site Selection and Effects of Anthropogenic Changes to the Rushikulya Nesting Beach, Orissa on Olive Ridley Sea Turtles". The investigations were carried out in the Wildlife Institute of India, Dehradun under our supervision from November 2008 to June 2009. We hereby certify that this work has not been submitted for any degree of any university.

Dr. K. Sivakumar
Supervisor

Prof. B. C. Choudhury
Co-Supervisor

Date:
Place: Dehradun

Wildlife Institute of India, Post Bag #18, Chandrabani
Dehradun – 248 001, Uttarakhand, India.
Ph.: +91 135 2640111 – 15
Fax: +91 135 2640117, Email: wii@www.gov.in

Contents

Certificate of Originality 2

Contents 3

List of Tables 5

List of Figures 6

Acknowledgements 7

Abstract 11

I. Introduction 14

I. 1. Nest Site Selection in Individual Olive Ridley Sea Turtles (*Lepidochelys olivacea*) at Rushikulya, Orissa, India. 15

I. 2. Hatchling orientation of Olive Ridley turtles at different photic regions of Rushikulya. 17

I. 3 Distribution pattern of turtle nest predators at Rushikulya. 19

II. Background 21

III. Study Area 23

IV. Methodology

IV. 1. Nest Site Selection 27

IV. 2 Hatchling Orientation 28

IV.3 Nest Predator Presence and Activity 30

V. Statistical Analysis

V. 1. Nest Site Selection 32

V.2. Hatchling Orientation 32

V.3. Nest Predator Presence and Activity 33

VI. Results

VI. 1. Nest Site Selection 35

VI. 2. Hatchling Orientation 40

VI. 3. Nest Predator Presence and Activity 44

VI. 3. i. Fortnightly Index 44

VI. 3. ii. Monthly Index 46

VI. 3. iii. Segment-wise Monthly Index 47

VII. Discussion

VII. 1. Nest Site Selection 48

VII. 2. Hatchling Orientation 49

VII. 3. Nest Predator Presence and Activity 50

VIII. Conclusions and Conservation Implications 53

IX. References 55

List of Tables

Table IV. 2. A: Arena Characteristics 28

Table IV. 3. A. Segment Characteristics 31

Table VI. 1. A: Bonferroni post-hoc multiple comparisons between means of nest (0) characteristics to sites along nesting crawl for soil pH. 37

Table VI. 1. B: Bonferroni post-hoc multiple comparisons between means of nest (0) characteristics to sites along nesting crawl for soil moisture 38

Table VI. 1. C.: Bonferroni post-hoc multiple comparisons between means of nest (0) characteristics to sites along nesting crawl for beach slope. 38

Table VI. 1. D. : Bonferroni post-hoc multiple comparisons between means of nest (0) characteristics to sites along nesting crawl for soil temperature. 39

Table VI. 2. A.: Orientation results of different arenas 41

Table VI. 2. B: Watsons-F test results between arenas 42

Table No. VI. 3. a. Fortnightly Predator Presence 45

Table No. VI. 3. b. Monthly Predator Presence 46

Table No. VI. 3. c. Segment-wise Predator Presence 47

List of Figures

Fig 1. Major rivers of the Orissa Coast 25

Fig 2. Map of Rushikulya Rookery 25

Fig. 3. Rushikulya Mass Nesting Beach, Orissa, India 26

Fig. IV. 2. A. Schematic representation of arena's placed beach 29

Fig IV. 3. A. Track Plot Locations 31

Fig. VI. 1. A. Mean slope (angular °) for sites along nesting crawls of Olive Ridleys 36

Fig. VI. 1. B. Mean Temperature (°C) for sites along nesting crawls of Olive Ridleys 36

Fig. VI. 1. C. Mean pH for sites along nesting crawls of Olive Ridleys 37

Fig. VI. 1. D. Mean soil moisture content for sites along nesting crawls of Olive Ridleys 37

Fig VI. 2. A. Orientation results of Hatchlings in Different Arenas 43

Fig. VI. 3. a. Fortnightly Predator Presence 45

Fig. VI. 3. b. Monthly Predator Presence 46

Fig. VI. 3. c. Segment-wise Predator Presence 47

Acknowledgements

In the entire process of writing my thesis, this section has proved to be the most difficult to complete. The number of people involved in the entire process of formulating the proposal for the study, guiding me through my field work and the final writing of the thesis are immense. I am indebted to everyone who provided their moral as well intellectual support in the completion of this work. In case I missed out on any names in this section this due to the entire mentally draining process of completing this work and not due lack of consideration for their inputs.

First, I would like to thank my supervisors Dr. K. Sivakumar and Prof. B. C. Choudhury for the unconditional support and guidance throughout this initial phase of research work I have embarked on at the end of this M.Sc. here at the Wildlife Institute of India. The Dean and Director of the institute for administering and supporting this entire program of the M.Sc. in wildlife sciences.

Dr. Basudev Tripathy was a constant source of information regarding the entire history of his working at the site at Rushikulya and provided immense loads of intellectual information as well as anecdotal tit-bits about the area. His continuing interest in this field and incredible sense of humour were always heartening to me since I reached to the field station as a naïve researcher alone in a strange land.

R. Suresh Kumar is one of the biggest guiding factors behind this entire topic of olive ridleys and the Rushikulya site ever since the time of my induction into the institute (actually since I met him when I had appeared for my interview while applying for the course). The uncountable hours of discussion with him regarding various aspects of wildlife sciences as well roaming in the rains in the institute behind the tricarinates of campus are unforgettable. He deserves an especially special thanks from my side for this piece of work.

Back to the field in Orissa, I am grateful to the Orissa Forest Department (OFD) for granting me permission to work at the Rushikulya rookery. I am thankful to Mr. S. C. Mohanty, ChiefWildlife Warden, Dr. Chandra Sekhar Kar, Research Officer, DFO's of Chilka & Berhampur and Range Officers, Chilka Wildlife Division (OFD) for their logistic and administrative support during the field work.

At the Rushikulya rookery, the Purunabandha villagers especially, my assistants Vipro and Tukna Rao who were a constant source of amusement during the long and lonely walks on the beach at night. Others include Dambru, Shankar, Madhu, Surendra, Rabi, Mittu, Mohinder and Judishtara for their help throughout the entire study including setting up of my tents searching for poles to support and also for a couple of rides back to the base camp on their cycles during the early days of work. Jangmaya, Sriramlu and Kedar the boatmen from Gokharkuda for the long boat transects along with Sajan.

Back at the base camp Sajan John for his company during the entire stay and also for putting up with my cooking after his long and tiring offshore transects. Adith from Chennai who was a refreshing new source of movies and serials from his hard disk when he arrived for his work kept the mind occupied during the extremely mundane days without work. Finally in Adith there was new company in walking the beach through the entire period beginning from the extremely gruelling days of the mass nesting count of turtles.

Other constant flow of people into the camp including Karthik Shanker, Aarthi, Sudarshan, Divya, etc kept the pace of activity flowing with fresh and new ideas and other nonsensical things to discuss over food. Karthik Shanker especially, for patiently listening to all my ideas and discussion regarding expected outcomes.

Back in WII every faculty member who taught us deserve special credit for helping me to reach this level of understanding in this particular field. Qamar and Jhala sir for helping to pound in some knowledge regarding statistics within this hard head of mine. Karthik sir for his talks on the different aspect associated with the field of research and in keeping ourselves updated with the field of science in todays world. Dr. Ramesh for his patience in listening to every little nuance of my field work and issues with my data. The hostel full of encouraging seniors and friends who welcomed us all back with their extended helping hands for every aspect of the work. Dada (Upamanyu), Bibek, Merwyn etc especially helped in relaxing our minds when the workload was overwhelming.

Back with the gang of classmates in WII there were several hours of discussions/arguments on best possible ways of writing analysis over tea, dinner and anywhere we could all park ourselves and talk about the exciting new areas that we had worked in. Sartaj and Rekha were the biggest sources of inspiration for me with their calm demeanour and patient discourses with me when there were problems along the way in the analysis and writing. Sahas for his constant work ethic which kept the rest of us on our toes in trying to keep up with his pace. Datta and his mom for rescuing us every now and then from the hostel to feed us in his house and for his lessons on being meticulous. Asif, Chandan and Sabita for their quiet and unassuming hardworking skills which made me pull up my socks a little higher in trying to maintain their levels of working. Sumithra of course last but definitely not the least for her constant presence around and cheering me up with her happiness and constant source of joy.

Other friends from back at home and senior from the msc especially Deep, Pranav, Mousumi and Abishek the real pillars behind my work all in all through the times of painful proposal writing, defense, days of boredom in field, data sorting and analysis and countless times of proof-reading and comments at every level of draft written. This thesis is almost a part of their resume as well as mine.

My friends from the old days of graduation and others from Chennai who sat through and patiently listened to me ramble endlessly about my work and turtles even though they had no clue what I was talking about. Last and most importantly, my family members; mom, sister, grandmother, uncles and aunts in Chennai for their continual support in joining this course without whose blessings I would be nowhere.

Finally a special mention to the advancing communication systems in today's world and to mobile phones for making the world so much more smaller especially at times of extreme loneliness when all you had to do is push a few buttons and talk to familiar and comforting voices. Sumithra paid the brunt of most of this effect and talks counting back to when the whole class would meet at WII after our field work and of the funny experiences happening every now and then at each persons study area. This made me feel at home with all the field sites of my classmates whenever I talked to them about their work and the areas they were at.

Abstract

The Olive Ridley sea turtle Lepidochelys olivacea is known to nest both sporadically and in arribada's in the Indian coastline. Of the three mass nesting sites on the Orissa coast, the Rushikulya rookery has been considered as a key factor in maintaining the future populations of the Ridley's in the Indian coast. Though several studies have been carried out on various ecological aspects of the species along the Orissa coast this study looked into a finer scale of behavioural patterns exhibited by the females while selecting the nesting sites. Other aspects that are looked into in detail in this study included the various impacts of anthropogenic activities near the nesting habitat of the turtles including the impact of nest predators.

The observed sporadic nesting turtles crawled an average of 47.39 m from the waterline before nesting (Range = 10.7(102m, SD = 21.0481, n = 70). Tests were conducted to check for the possibility of whether turtles were actively choosing their site of oviposition while compared to random placement over varying distances. Beach slope and soil temperature were not found to be significantly different from the nesting sites (Slope – $F = 1.289$, Temperature – $F = 2.241$, $df = 8$ $P>0.05$) while compared to sites along the track of the nesting turtles, whereas pH and moisture were found to be significantly different from the nest-site to all sites prior to them (pH – $F=37.640$, Moisture – $F = 44.208$, $df = 8$ $P<0.05$). This shows the possibility of both pH and slope to be amongst the possible proximate cues used by a turtle in deciding a final nest. The effects of beach lighting on the disorientation of turtle hatchlings at this site has already been studied at various levels and this study re-affirms the results of the previous studies by including the effects of lighting acting upon various distances away from the water-line as well as different photic

conditions present along the beach and from the adjoining villages. With areas near the villages showing maximum disorientation while compared to areas shielded from light by *Casuarina* plantations.

Associated human activities near the Rushikulya rookery could also act in supporting and maintaining populations of certain animals (feral dogs, jackals), which have had an increased threat to turtle nests. The plantation of *Casuarina* adjoining the nesting beaches could also act in providing refuge to such predators apart from the known effect of changing the geomorphologic profile of the beach. These predators are known to be able to thrive even in marginalised habitats sustaining their numbers near human occupied areas. These plantations may thus also be aiding an artificial boom in their numbers thus having an increased impact of their predation on turtle nest while compared to natural levels of predation loss.

A Passive Tracking Index (PTI) for the predator presence and activity observed a minimum presence before the mass nesting which increased immediately after the commencement of the mass nesting. Protective chain link fencing laid across sections of the beach flanked by *Casurina* to reduce the predator pressure in these areas may not have proven to be completely successful as high activity was still observed in the weeks following the mass nesting.

Any developmental projects along the rookery areas should consider its potential impact on the nesting turtles and hatchlings. Illumination and plantations along the rookery could be harmful to the nests as well as hatchlings, which can be avoided or minimised for the successful conservation of Olive Ridley in the Indian Ocean.

I. Introduction

Seven species of sea turtles representing two families, Dermochelyidae and Cheloniidae are the only living members among the turtles (Lutz and Musick, 1997). These seven species include the largest among the turtles, the leatherback (*Dermochelys coriacea*) and the smallest, the olive ridley turtle (*Lepidochelys olivacea*). The other five species are the hawksbill turtle (*Eretmochelys imbricata*), green turtle (*Chelonia mydas*), loggerhead turtle (*Caretta caretta*), kemp's ridley (*Lepidochelys kempii*) and flatback turtle (*Natator depressus*).

Amongst the seven, five species of sea turtles have been reported from Indian waters, viz. leatherback turtle, hawksbill loggerhead, green turtle and the olive ridley (Kar and Bhaskar, 1982). Barring the loggerhead turtle, all the other four species are known to nest along the mainland and Bay Islands of India (Kar and Bhaskar 1982, Biswas, 1982; Shanker and Choudhury, 2005; Tripathy, 2005).

The olive ridley turtle is a circumglobal species, widely distributed throughout the tropics, with the exception of the Gulf of Mexico, and appearing in the highest densities in the northern Indian Ocean and eastern Pacific Ocean (Márquez, 1990; Reichart, 1993; Ernst *et. al.,* 1994). This species is well known for its synchronous nesting behaviour, also known as *arribada* (Spanish for "arrival") in which several hundred thousand of female olive ridleys nest *en-masse*. A significant portion of the world's olive ridley population nests along the Orissa coast of India. Besides sporadic nesting all along the Indian coastline and its Bay

Islands, the Orissa coast harbours three major *arribada* sites (Gahirmatha, Devi and the Rushikulya rookery).

The southern most *arribada* site along the Orissa coast; the Rushikulya rookery was discovered in 1994 (Pandav *et al.* 1994), and is approximately 5 km long beach located immediately north of the Rushikulya river mouth (Fig 1) from Purunabandha to Kantiagada village. Like the Gahirmatha site, mass nesting at the Rushikulya rookery has also been regularly recorded (Fig. 2). The Rushikulya rookery currently has the most consistent record of *arribadas* in the last decade along with fewer dead adults washing ashore. Thus, this site is considered by many as to contribute significantly to the future populations of the olive ridley turtle in the Indian Ocean (Shanker *et al.* 2003, Tripathy 2005).

I. 1. Nest Site Selection in Individual Olive Ridley Sea Turtles (*Lepidochelys olivacea*) at Rushikulya, Orissa, India.

Nest-site selection behaviour is a maternal effect that contributes to offspring survival and variation in offspring that are subject to natural selection (Kolbe and Janzen 2002). Nest-site selection can be defined as the placement of eggs by females at sites that differ from random sites within a delimited area. Site selection often results in non-random patterns of organism distribution, which are assumed to be the result of natural selection (Martin 1998). Evaluating the nest-site selection offers a tangible way to track habitat selection during an important life-history event with implications for offspring and maternal fitness.

The olive ridley turtle is known to nest along the Orissa coast beginning from December till late April varying in numbers from solitary to *arribada* (Pandav 2000). Nest-site selection in sea turtles can be divided into three phases: beach selection, emergence of the female, and nest placement. Beach selection and emergence probably depend largely on offshore cues and beach characteristics (Mortimer 1982). Whereas, final nest placement is most likely largely dependant on the physical conditions of the beach at that that point of time at which the female emerges onto the shore. Nest-site placement in sea turtles plays an important role in the reproduction, since conditions inside the nest and in its surroundings directly or indirectly affect recruitment of offspring [incubation period, survival of hatchlings, hatchling size, hatchling growth, and sex determination] (Wood and Bjorndal, 2000).

Little is known about proximate cues that sea turtles may use for nest-site selection (Hendrickson, 1958; Carr and Ogren, 1960; Carr *et al.*, 1966). The genera *Caretta, Chelonia, Eretmochelys*, and *Lepidochelys* have a fixed behaviour pattern before selecting nest-sites that includes pressing their heads into the sand as they ascend the beach, perhaps to monitor microhabitat characteristics to assess potential nest-sites (Hendrickson, 1958; Carr and Ogren, 1960; Carr *et al.*, 1966). Sand characteristics that turtles may evaluate in this manner include temperature, moisture, texture, etc. Studies have also indicated that sea turtle nest-sites are not randomly distributed; moreover they do not indicate, which characteristic or characteristics may be the cues (Hays and Speakman, 1993).

Nest placement in sea turtles have implications beyond nest success as variable external environments can influence gas, water exchange and the temperature experienced by eggs.

During incubation, these microenvironmental factors influence developmental rate, offspring size, offspring sex, locomotor speed, thermoregulation behaviour, and growth rate (Mrosovsky and Yntema, 1980; Ackerman, 1997; Kolbe and Janzen, 2002;Wood and Bjorndal, 2000).

The olive ridley population in the Orissa coast have been studied at varying levels through the years and certain aspects of their life history have also been documented (Pandav 2000; Tripathy 2005). These studies have also looked into the aspects of nesting characteristics, offshore distributions, migratory pathways, etc. However, there is no detailed information on nest site selection of this species in relation with micro-environments.

I. 2. Hatchling orientation of Olive Ridley turtles at different photic regions of Rushikulya beach, Orissa, India

Generally, sea turtle hatchlings emerge from their nests at night and have been known to be positively phototropotactic, orienting themselves towards the brighter horizon. This orientation behaviour is critical in the sea finding abilities of the hatchlings (Mrośovsky, 1972). Under natural circumstances when hatchlings leave the nest, the landward horizon is often elevated and darkened by vegetation, and the view toward the sea which is lower and usually brighter.

Experiments by Mrosovsky (1972) led to the hypothesis that hatchlings find the sea by orienting toward the brighter seaward horizon. Though, other studies (Parker, 1922). Limpus

(1971) also show that hatchlings also to respond to objects (bushes, dunes, trees and/or their silhouettes) which darken the view and elevate the horizon toward shore (found that hatchlings moved away from elevated horizons, even if that took them toward a night sky darker than the sky in other directions. These results suggest that turtles find the ocean by orienting away from landward horizons, not toward cues located out to sea.

Previous studies on hatchlings orientation in Rushikulya have looked into this aspect and observed high levels of disorientation due to the presence several lighting factor present (Karnad et al 2009, Tripathy 2003, Pandav 2000). However, there was no study conducted to look at the orientation of hatchlings at the various sections of the nesting beach having different levels of illuminations in the background. In this connection, this experiment was carried out, so that the different levels of management actions can be taken at different sections of beach to handle such events especially due to the overwhelming numbers of hatchlings emerging.

I. 3. Distribution pattern of nest predators in Rushikulya.

Predation is a critical threat to many endangered species and predation losses can have an increased deleterious impact due to the compounding effects of habitat loss (Engeman *et al* 2003). Sea turtle nests in particular are vulnerable to such impacts as there is no protection to the nest once the female has nested. At Rushikulya, the main nest predators of Olive ridley nests are feral dogs, golden jackals, striped hyenas, etc which are able to detect these nests with their strong olfactory senses. These nest predators have been observed to subsist on this seasonal "bounty" of turtle nests and have also been noticed to increase in numbers and move in towards the mass nesting sites as the nesting season progresses (Tripathy 2005). These predators in general are difficult to observe because of their nocturnal or secretive behaviour and thus an appropriate index can provide us with necessary information to track changes in their population with time and geographical constraints about their activity.

Previous studies have observed that the extensive plantations of *Casuarina equisitifolia* along the Indian coast line laid across as a cyclone barrier may also be providing a refuge to marginalized predators such as feral dogs. These predators have been known to be a major threat to nest survival, accounting for nearly 90-100% predation of the turtles nesting sporadically earlier in the season (Pandav 2000, Tripathy 2005).

As nest depredation has been noted to impact nest survival at varying degrees, and predation by the associated predators seems to vary along the nesting season of turtles. This has been noted to impact most of the early nesters.

Here, I look into the patterns of nest predator activity and distribution along the mass nesting beach of Rushikulya from the commencement of the turtle nesting season in December through the period of mass nesting, which took place in mid February 2009 till the mass emergence of hatchlings in April 2009. This can also enable us to look into patterns of the predator presence through the season to identify areas of predator invasion into the nesting beach as the season progresses

II. Background

Though, the olive ridley populations in the Orissa coast have been studied at varying levels through the years (Pandav 2000, Tripathy 2005) and certain aspects of their life history have been documented. These studies have mainly looked into the aspects of nesting characteristics, offshore distributions, migratory pathways, off-shore mortalities etc. Active site selection has been noted anecdotally in many of these studies and the onshore cues which determine the choice made by the female needs further investigation. The disorientation of hatchlings due to the anthropogenic presence near the coastline incidentally causing harm by causing an artificially lighter horizon or due to specific wavelengths of light dispersed by their household lights (Tripathy *et al* 2003,Karnad 2008).

As nest depredation has been noted to impact nest survival at varying degrees, it has been noted that this case of predation by the associated predators seem to vary along the nesting season of turtles (Tripathy 2005, Engeman *et al* 2003, 2005). The early nesters in the season seem to be paying the brunt of the predator activity as most of these nests are easily tracked by the predators and suffer heavy losses (Eckrich 1995). Thus, it is necessary to look into patterns of the predator presence through the season to identify areas of predator invasion into the nesting beach as the season progresses

In the following context the Present study focuses on three different aspects pertaining to Olive ridley ecology

(1) looking into the behaviour of the nesting females in making active choices while choosing site for nesting upon coming ashore,

(2) observations of hatchling disorientation in the various sections of the beach at Rushikulya with respect to the lighting conditions associated with human activity

(3) temporal and spatial distribution patterns of the nest predators along the entire nesting season of the olive ridleys.

Three main hypothesis were chalked down for testing in each of the three chapters:

Hypothesis 1.

Olive ridleys emerging from the sea place their nests at randomly placed distances away from the water.

Hypothesis 2.

The orientation of hatchlings is similar across the entire beach stretch of Rushikulya.

Hypothesis 3.

The turtle nest predators are distributed equally across the entire beach stretch of Rushikulya and their abundances are similar throughout the entire season.

III. Study Area:

The Rushikulya mass nesting site was discovered in 1993-94 during a status survey of olive ridley sea turtle and its nesting habitats in Orissa conducted by the Wildlife Institute of India (WII) in collaboration with the wildlife wing of the Orissa Forest Department (Pandav *et al.*, 1994a, 1994b). This site is at the mouth of the Rushikulya River in the state of Orissa (Fig 1).

The mass nesting beach historically has been a sand bar along the northern side of the Rushikulya river mouth (Fig. 2) found 320 km south of the Gahirmatha rookery (19°22'56.30N, 85°05'0.23E - 19°24'35.74N, and 85 ° 05' 59.48E). Tidal action along with siltation and flooding of the river causes the beach profile to vary both seasonally and annually. Due to the tidal action and the sand deposition, this year the sand spit has become a part of the mainland beach. The Rushikulya rookery currently has the most consistent record of arribadas in the last decade along with fewer dead adults washing ashore. Hence, it is considered to contribute significantly to future populations of the olive ridley turtle in the Indian Ocean (Shanker *et al.* 2003, Tripathy 2005).

The nesting beach is characterised by 3-4 ft high, scattered sand dunes with sparse natural beach vegetation. Natural vegetation on the beach includes psammophytes such as *Ipomea pescaprae*, *Spinifex littoreus* and *Hydrophylax maritima* (Pandav *et al.*, 1994a). Dense plantations of *Casuarina equisitifolia* have been planted backing the beach along the entire Orissa Coast. This is also present along certain portions of the Rushikulya beach (Fig 3). These plantations have also been suggested to possible act as effective light barriers against hatchling disorientation (Karnad 2009).

Human settlements near the beach include three fishing villages viz. Purunabandha Gokharkuda and Kantiagada (Fig. 3). All these villages are electrified and act as sources of external lights, which are considered to be the major factor affecting the seaward orientation of the sea turtle hatchlings.

The plantations of *Casuarina equisitifolia* backing the nesting beach have also been observed to support populations of nest predators such as the golden jackal (*Canis aureus),* striped hyena (*Hyaena hyena),* and feral dogs which cause considerable damage to the early sporadic nests on the beach as well as feed upon carcasses which get washed ashore.

Figure 1. Major rivers of the Orissa Coast

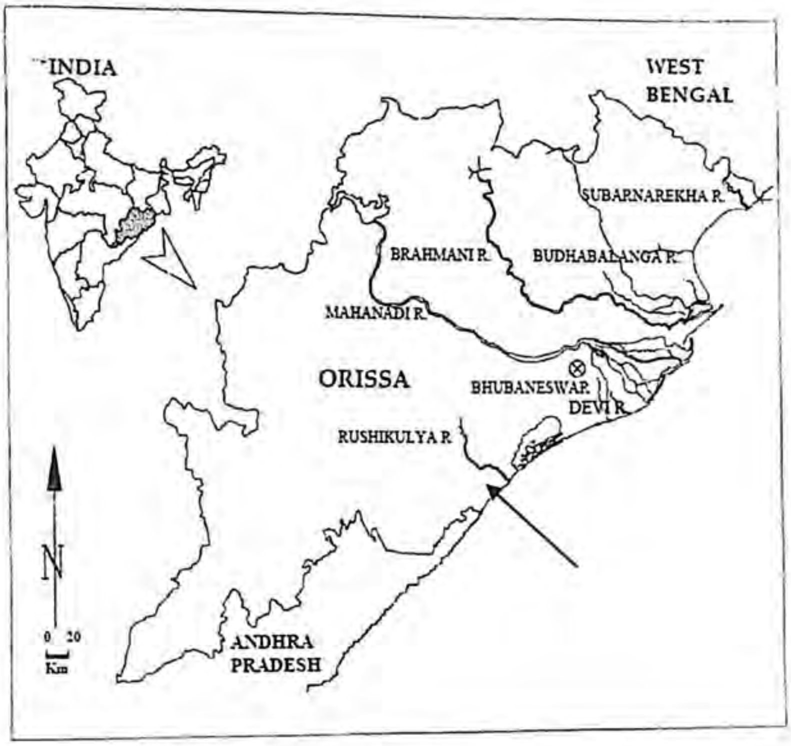


Figure 2. Map of Rushikulya Rookery

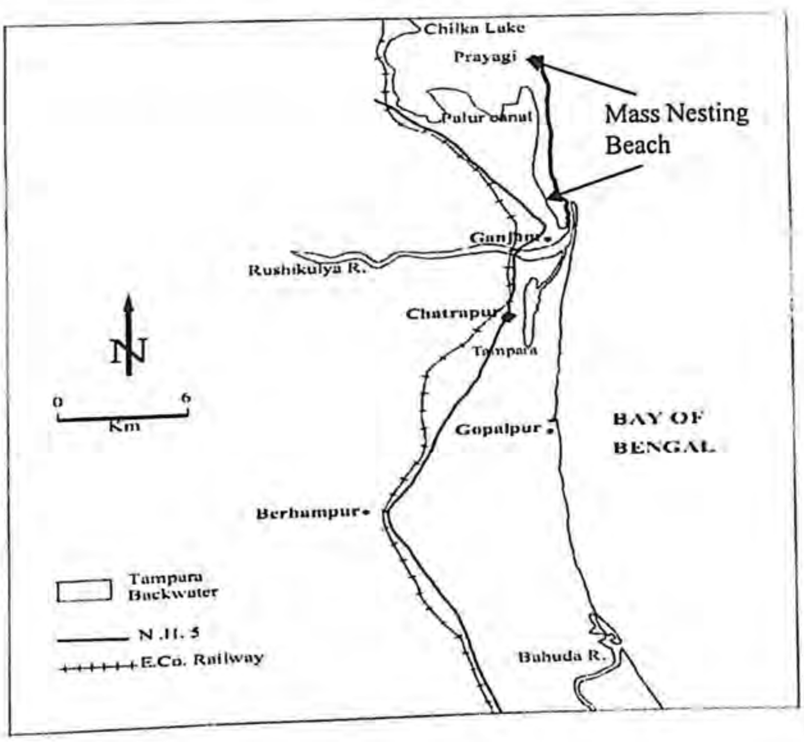
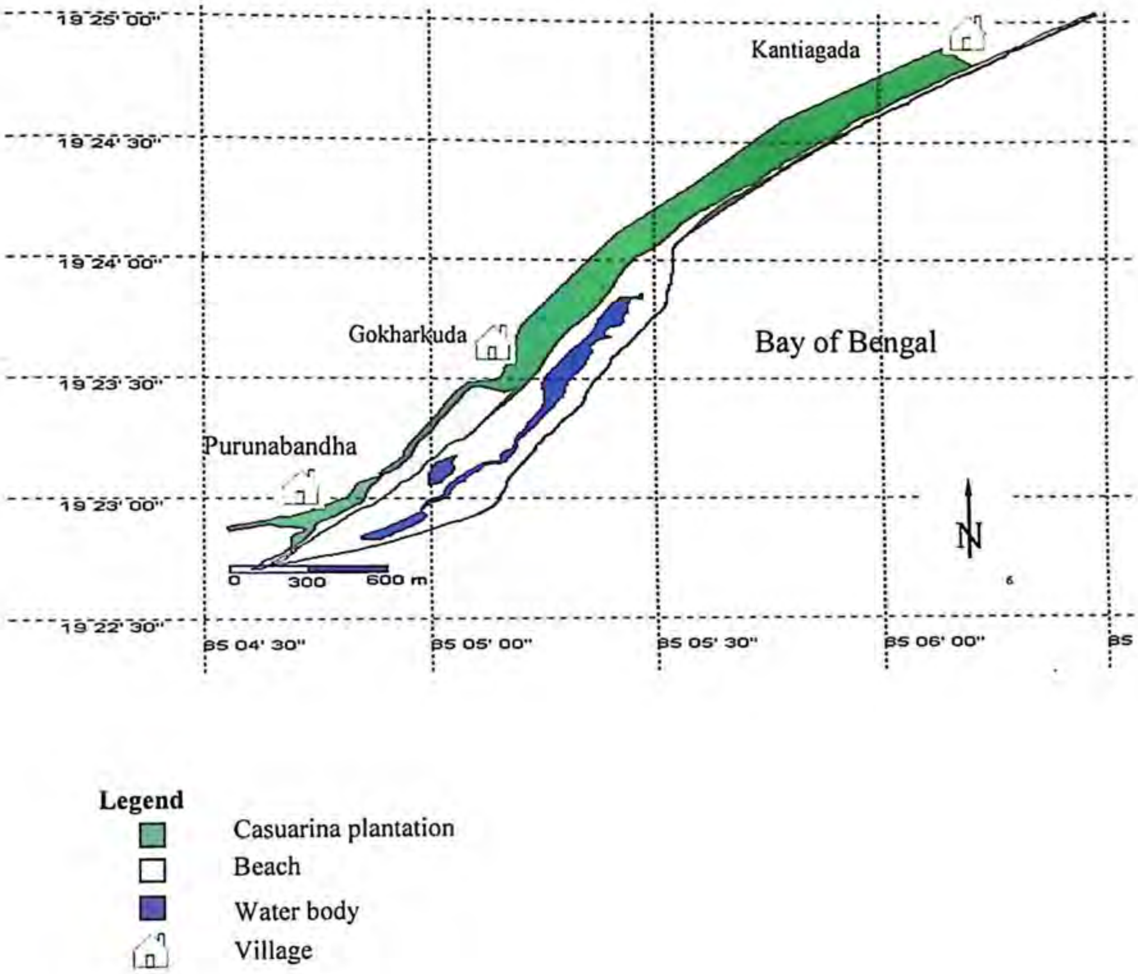


Figure 3. Rushikulya Mass Nesting Beach, Orissa, India



IV. Methodology:

IV. 1. Nest Site Selection:

Nesting turtles, which were observed emerging from the sea were studied from a safe distance without disturbing the individual. Upon the turtle arriving at a suitable nest site and the commencement of oviposition, necessary observations such as soil moisture, pH, temperature and slope of the beach were taken at 10 m intervals beginning from the point of emergence at the water line leading up to the final oviposition site. All data was collected taking care not to disturb the nesting female.

All readings were taken immediately adjacent to the tracks made by the female so that sampling of the characters were not influenced by the sand which was disturbed by the female while crawling ashore, thus providing a condition similar to the characters which were probably assessed by the female when she came ashore to nest.

Soil pH and moisture data were collected using a DM-15 soil and pH tester (Takemura Electric Works Ltd.), sub-soil temperature was collected using a digital temperature probe and beach slope was taken with a Brunton Cadet Pocket Transit with a protractor reading from -90° to +90° in 2° increments was placed on the beach and used as a clinometer.

IV. 2. Hatchling Orientation:

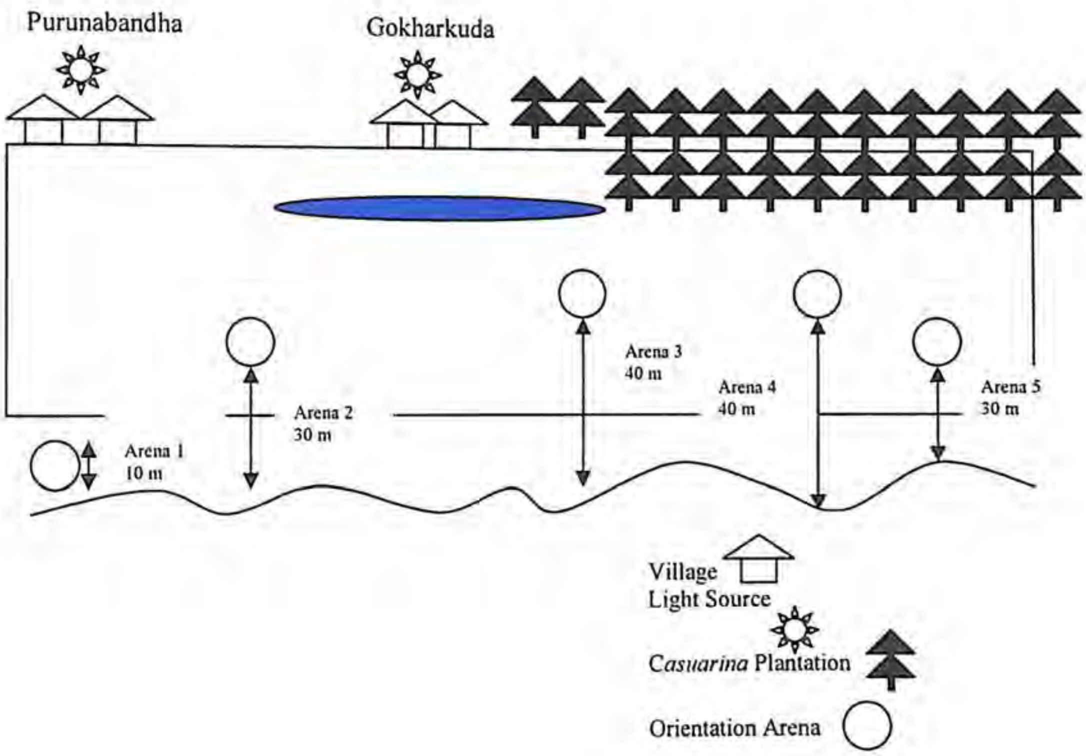
Orientation arenas were set up (Kamel 2004), which consisted of a circular arena of four metres in radius and divided into eight equal segments and a pit at the centre simulating the conditions of a naturally emerging nest pit. Five arenas were placed in different visually classified photic regions of the beach according to the presence of village lights, distance from vegetation and distance from the tide line (Table IV. 2. A, Fig. IV. 2. A). For each arena, while 270°-90° represented the landward half of the arena, 90°-270° represented the seaward half. All experiments were conducted between 20:00h and 03:00h under a clear sky when the lunar phase was nearing full.

Table IV. 2. A: Arena Characteristics

Arena Id	Distance from tideline (m)	Distance from vegetation (m)	Light conditions	Remarks
Arena 1	10	No tall vegetation visible from beach	Purunabandha village lights and highway lights clearly visible 1Km away	Maximum photic region of beach. Adjacent to Rushikulya river mouth. Average beach width ~100m
Arena 2	30			
Arena 3	40	~250	Faint glow from Gokharkuda village and distillery visible	Wide portion of beach ~150m width. 2 km from arena 1, 2. Faint glows from different light sources visible.
Arena 4	40	50	No external light source visible.	Minimal photic conditions. Backing plantation acting as effective light barriers against factors affecting arena1, 2, and 3. Least beach width ~60m. 3 km away from arena 1 and 2.
Arena 5	30	50		

Freshly emerged naïve hatchlings were chosen for the orientation tests and placed in the centre of the arena in the pit and covered with loose sand to simulate the conditions of a natural emergence. 50 hatchlings were used in each arena.

Fig. IV. 2. A: Schematic representation of arena's placed beach



IV. 3. Nest Predator Presence and Activity:

Track plots were laid across the entire study area distributed at intervals of ~250m (Fig IV. 3. A). The plots were ~2m x 3m in area and discreetly marked by wooden stakes at the corners and the sand was smoothed to provide a good tracking base. A total of 20 track plots were laid uniformly across the 5km stretch of beach to monitor the presence of the various nest predators. All the plot locations were recorded using a GPS (Garmin GPS 72). The same locations were observed for the entire study period (Map 1).

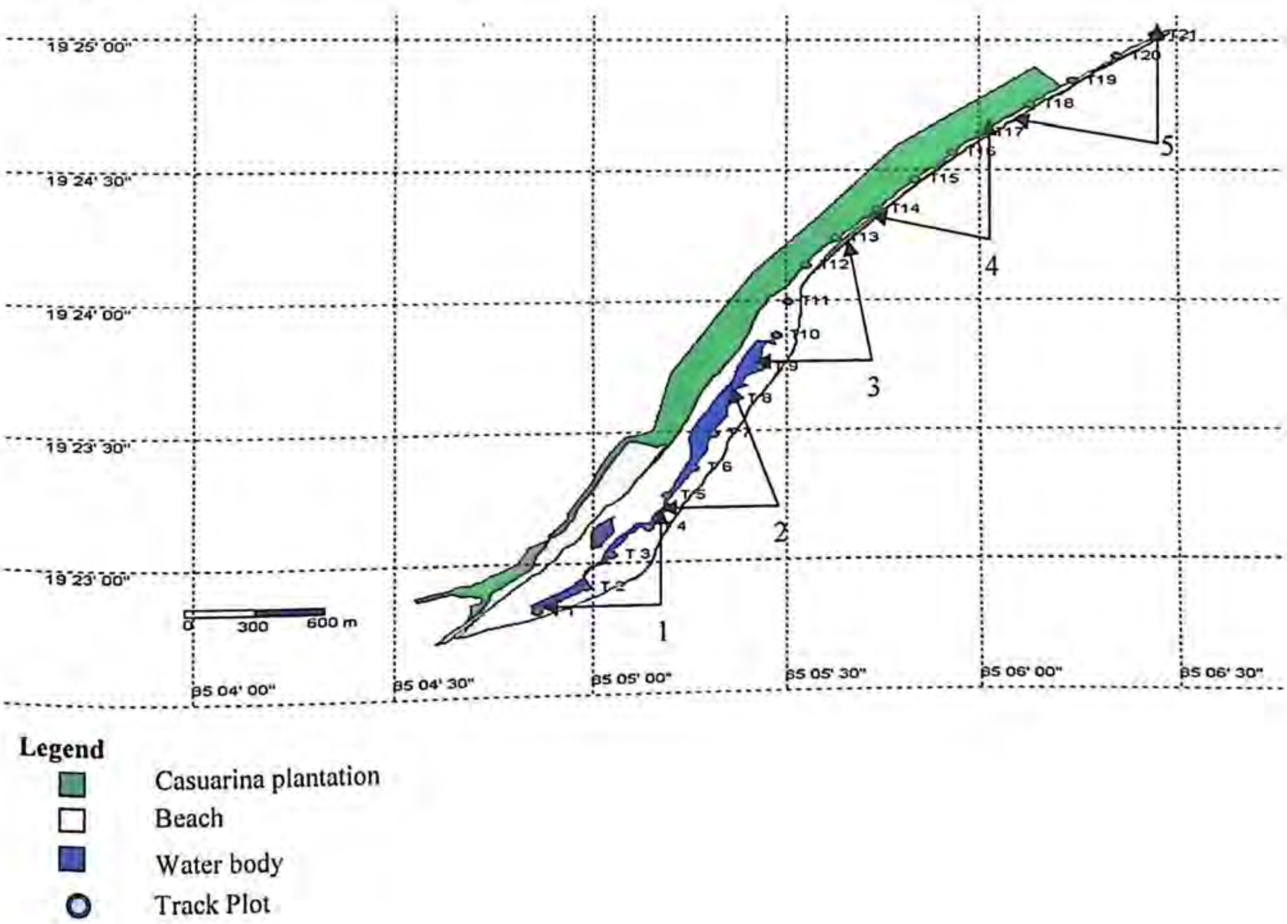
As most turtle nesting and nest predation events occurred during the dark, the plots were laid during the previous evening and checked for predator spoor after a 12 hour interval. Due to the difference in the sand compactness in various sections of the beach accurate identification of the different canid species was difficult, thus, tracks of all species were pooled together as a similar entity. Each monitoring event was repeated on a weekly basis thus providing adequate temporal replicates through the entire nesting season.

Nest predator abundance and activity along the beach was calculated using the Passive Tracking Index (PTI) developed by Engeman *et al* (2003). Furthermore, the beach was spatially classified into five 1km segments based on the adjoining habitat characteristics (Table IV. 3. A).

Table IV. 3. A. Segment Characteristics

Segment ID	No. of Plots	Adjoining Habitat/Village	Average Beach Width	Remarks
1	4	Purunabandha Village	~80m	Near River Mouth, Low Nesting numbers during *Arribada*
2	4	Between Purunabandha and Gokharkuda Village	~120m	Bound by stagnant water body, High Nesting during *Arribada*
3	4	In front of Gokharkuda village	~110m	Bound by stagnant water body, Medium nessting intensity during *Arribada*
4	4	Bound by Casuarina plantation	~55m	Beach immediately bound by vegetation, High nesting density during *Arribada*
5	4	Starts at Kantiagada Village and continues past the village bound by Casuarina	~90m	Village boat landing centre and immediately bound by Casuarina, Minimal nesting through the season including *Arribada*

Fig IV. 3. A. Track Plot Locations



V. Statistical Analysis:

V. 1. Nest Site Selection:

All analyses were performed with Statistical Package for Social Sciences (SPSS) V.16.0 (SPSS Inc.). Univariate General Linear Models (GLM) with one-way ANOVA was used to analyze the single-factor, between-subjects effects of soil temperature, moisture, pH and beach slope. Each factor was loaded as the dependant variable along the track taken by the nesting turtle with repeated contrasts to test for differences at each adjacent level (10 m distances from the nest). Bonferroni multiple comparison post-hoc tests between the means was performed to check for changes between each 10 m interval away from the nest.

V. 2. Hatchling Orientation:

Circular statistics (Batschelet, 1965) was used to determine the direction of orientation and the strength of direction. The mean vector length (r) indicates the consistency of orientation in a particular direction, mean direction (μ) represents the mean angle of orientation. Rayleigh's Z test (Zar 1998) was used to determine whether orientation was significant in any particular direction while compared to random. Upon observation of significant orientation, Watson's F-test (Fisher, 1993) was used to check for differences in direction between arenas. Analysis and graphs were prepared using the software Oriana version 3.00 (Kovach computing services 2009).

V.3. Nest Predator Presence and Activity:

A Passive Tracking Index (PTI) for the predator presence and activity was calculated in accordance to general index developed by Engeman *et al* (1998, 2003). This is calculated as follows:

A linear model developed to calculate the number of track sets found on the *i*th plot on the *j*th day represented as x_{ij} was used.

$$\mathbf{x_{ij} = \mu + S_i + D_j + e_{ij}}$$

Where, the term μ is the overall mean number of sets of tracks per plot per day for the area being assessed. D_j is a random effect due to the day on which an observation was be made. S_i is a random effect due to the *i*th plot with $i=1,2,3 \ldots p_j \leq$ no. of plots representing the number of plots contributing data on the *j*th day. The e_{ij} represent random error associated with each plot each day.

To assume that the tracking stations are uncorrelated, or that observation days are uncorrelated, would be biologically unreasonable in most circumstances. As most animals may roam distances greater than the inter-plot distances, and stations closer to each other may share more characteristics than ones which are more distantly separated. So the tracking stations in this framework are not assumed to be independent of each other nor are days assumed to be independent of each other, i.e. a non-zero covariance structure is assumed to exist among stations and days.

This data structure permits calculation of a passive tracking index (PTI), components of variance, and variance estimates using the methods in Engeman *et al.* (1998). The PTI is defined mathematically in linear model terminology as:

$$PTI = \frac{1}{d}\sum_{j=1}^{d}\frac{1}{s_j}\sum_{i=1}^{s_j}x_{ij}$$

The variance formula for the PTI, when the numbers of tracking plots are equal on all days is depicted as:

$$\text{var}(PTI) = \frac{\sigma_s^2}{s} + \frac{\sigma_d^2}{d} + \frac{\sigma_e^2}{sd}$$

where the σ_s^2, σ_d^2, σ_e^2 are, respectively, the components for plot-to-plot variability, daily variability, and the random observational variability associated with each plot each day. A variance component analysis (VARCOMP), using restricted maximum-likelihood estimation procedure was used to calculate the variance components using SPSS v 16.0.

The PTI was calculated across fortnights using the sampling from consecutive weeks as the second replicate of the plot for that fortnight. To calculate a monthly index measure data from four consecutive weeks were clubbed as the repeats for that month. Furthermore, to examine areas of higher predator abundance subsets of 1km segments were used to calculate an index measure for different segments of the beach.

VI. Results.

VI. 1. Nest Site Selection:

The observed nesting turtles crawled an average of 47.39 m before nesting (Range = 10.7-102m, SD = 21.0481, n = 70). These nesting crawls were used as transects to check for gradients of change in physical parameters of the nesting beach "tested" by the nesting female. The relationship of all the characters along the path can be seen in the following figures where the nest characters are represented by the point "0" and each point representing the characters 10m away from the nest along the turtles track.

Though average soil temperatures were lower near the water at the point of emergence and increased sparingly along the path till the site of oviposition there was no significant difference amongst the nesting site and point of emergence or between adjacent sites (Fig VI. 1. B). Moisture content of the soil was highest at the point of emergence and drastically reduced along the path till the nest site. Low pH was recorded along the water line and gradually decreased along the beach gradient. Beach slope was almost constant across the samples and distance along the path taken by the turtle and thus did not vary significantly from the nest site as well (Fig. VI. 1. A).

Moisture and pH showed significant differences from the contrasts of every distance away from the nest (P>0.05) (Fig. VI. 1. C, D). Temperature and slope showed no significant difference amongst the samples (P>0.05). Upon post-hoc bonferroni trials (Tables VI. 1. A, B, C, D) between each "tested" site pH and moisture showed significant difference between every site away from the nest thus showing the presence of a shift in these characters along the path of the turtle. This is significant across all the samples.

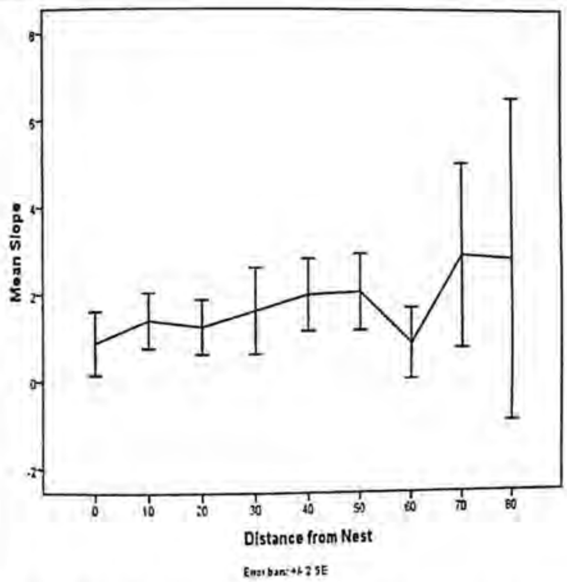


Fig. VI. 1. A. Mean Slope (Angular°) for sites along nesting crawls of Olive Ridleys. '0' refers to the nest site. Vertical bars represent standard error. (*) indicate significant difference from the nest site (GLM repeated contrasts, Bonferroni multiple comparisons post-hoc).

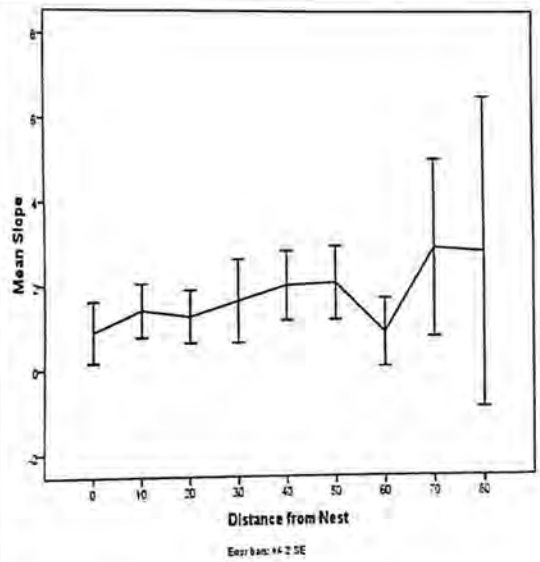


Fig. VI. 1. B. Mean Temperature (°C) for sites along nesting crawls of Olive Ridleys. '0' refers to the nest site. Vertical bars represent standard error. (*) indicate significant difference from the nest site (GLM repeated contrasts, Bonferroni multiple comparisons post-hoc).

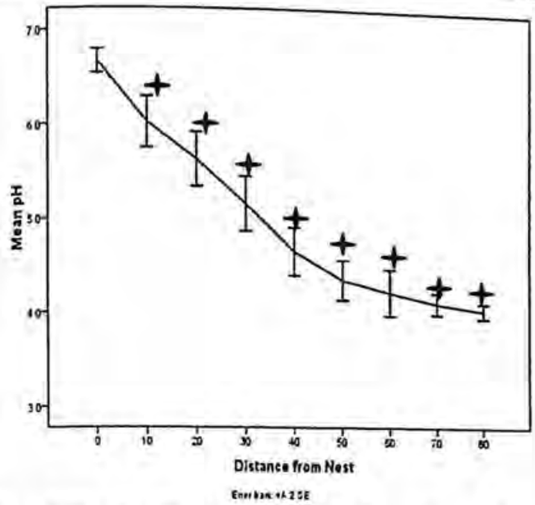


Fig. VI. 1. C. Mean pH for sites along nesting crawls of Olive Ridleys. '0' refers to the nest site. Vertical bars represent standard error. (*) indicate significant difference from the nest site (GLM repeated contrasts, Bonferroni multiple comparisons post-hoc).

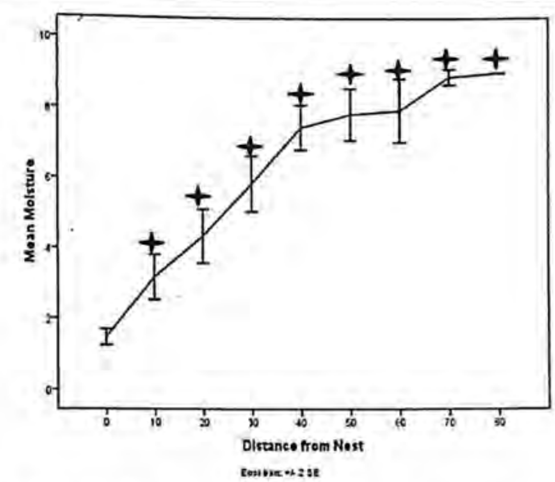


Fig. VI. 1. D. Mean soil moisture content (1 – least moisture – 9 max moisture) for sites along nesting crawls of Olive Ridleys. '0' refers to the nest site. Vertical bars represent standard error. (*) indicate significant difference from the nest site (GLM repeated contrasts, Bonferroni multiple comparisons post-hoc).

Table VI. 1. A: Bonferroni post-hoc multiple comparisons between means of nest (0) characteristics to sites along nesting crawl for soil pH.

(I) dist	(J) dist	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0	10	0.6712	0.1684	0.0030	0.1280	1.2143
	20	0.9846	0.1684	0.0000	0.4415	1.5277
	30	1.4635	0.1684	0.0000	0.9203	2.0066
	40	2.0095	0.1718	0.0000	1.4551	2.5638
	50	2.3101	0.1877	0.0000	1.7046	2.9156
	60	2.4365	0.2454	0.0000	1.6448	3.2283
	70	2.5504	0.3099	0.0000	1.5506	3.5503
	80	2.6215	0.4020	0.0000	1.3248	3.9183

Table VI. 1. B: Bonferroni post-hoc multiple comparisons between means of nest (0) characteristics to sites along nesting crawl for soil moisture

(I) dist	(J) dist	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0	10	-1.7500	0.4438	0.0036	-3.1815	-0.3185
	20	-2.7346	0.4438	0.0000	-4.1661	-1.3031
	30	-4.2500	0.4438	0.0000	-5.6815	-2.8185
	40	-5.9776	0.4529	0.0000	-7.4386	-4.5165
	50	-6.3478	0.4947	0.0000	-7.9437	-4.7519
	60	-6.4567	0.6469	0.0000	-8.5435	-4.3700
	70	-7.4081	0.8169	0.0000	-10.0434	-4.7729
	80	-7.5192	1.0594	0.0000	-10.9369	-4.1015

Table VI. 1. C.: Bonferroni post-hoc multiple comparisons between means of nest (0) characteristics to sites along nesting crawl for beach slope.

(I) dist	(J) dist	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0	10	-0.5000	0.5481	1.0000	-2.2681	1.2681
	20	-0.2692	0.5481	1.0000	-2.0373	1.4989
	30	-0.7692	0.5481	1.0000	-2.5373	0.9989
	40	-1.0769	0.5594	1.0000	-2.8815	0.7276
	50	-1.1341	0.6110	1.0000	-3.1052	0.8371
	60	0.0481	0.7990	1.0000	-2.5293	2.6255
	70	-1.9658	1.0090	1.0000	-5.2207	1.2891
	80	-1.8769	1.3085	1.0000	-6.0982	2.3444

Table VI. 1. D. : Bonferroni post-hoc multiple comparisons between means of nest (0) characteristics to sites along nesting crawl for soil temperature.

(I) dist	(J) dist	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound.
0	10	0.7818	1.4227	1.0000	-3.8354	5.3990
	20	1.6091	1.4227	1.0000	-3.0081	6.2263
	30	2.0121	1.4227	1.0000	-2.6051	6.6293
	40	4.4465	1.4455	0.0868	-0.2445	9.1376
	50	5.2238	1.6377	0.0601	-0.0910	10.5386
	60	3.2074	2.4049	1.0000	-4.5971	11.0119
	70	3.1388	2.7734	1.0000	-5.8618	12.1394
	80	4.7288	4.2085	1.0000	-8.9291	18.3866

VI. 2. Hatchling Orientation:

Results from Rayleigh's Test showed that orientation in all arenas were significantly different from random. This shows the presence of a strong orientation factor guiding the movement of the hatchlings in all the various sections of the beach. Tripathy (2003) observed largest number of disoriented hatchlings in the sections with arena 1 and 2.

In Fig.VI. 2. A. the black arrows represent the mean vector angle, and the length of the arrow signifying the mean vector length (blue arrows represent other orientation paths taken by the hatchlings). Arenas 4 and 5 showed strongest seaward orientation (r = 0.893, 0.944, μ = 198.858°, 187.747°), while arena 1 though placed within 10 m of the tide line showed weaker seaward orientation when compared to 4 & 5 (r =0.706, μ = 225°). Hatchlings from arenas 2 and 3 exhibited the maximum land ward orientation (r = 0.827, 0.725, μ =290.068°, 261.021°).

Table VI. 2. A.: Orientation results of different arenas

	Arena 1	Arena 2	Arena 3	Arena 4	Arena 5
Number of Observations	50	50	50	50	50
Mean Vector (μ)	225°	290.068°	261.021°	198.858°	187.747°
Length of Mean Vector (r)	0.706	0.827	0.725	0.893	0.944
Median	225°	270°	270°	180°	180°
Concentration	2.046	3.238	2.17	4.976	9.23
Circular Variance	0.294	0.173	0.275	0.107	0.056
Circular Standard Deviation	47.783°	35.291°	45.963°	27.23°	19.419°
Standard Error of Mean	6.741°	4.951°	6.46°	3.843°	2.745°
Rayleigh Test (Z)	24.941	34.214	26.271	39.891	44.574
Rayleigh Test (p)	1.47E-11	< 1E-12	3.89E-12	< 1E-12	< 1E-12

Watsons F Test Between Arenas:

Upon comparison for the differences in direction between arenas using Watson's F-test, arenas 4 and 5 showed least variation in the orientation (Table VI. 2. B). Arena 1 and 4 also showed very little difference in the observed orientation (although, orientation in arena 1 and 5 showed significant difference in orientation).

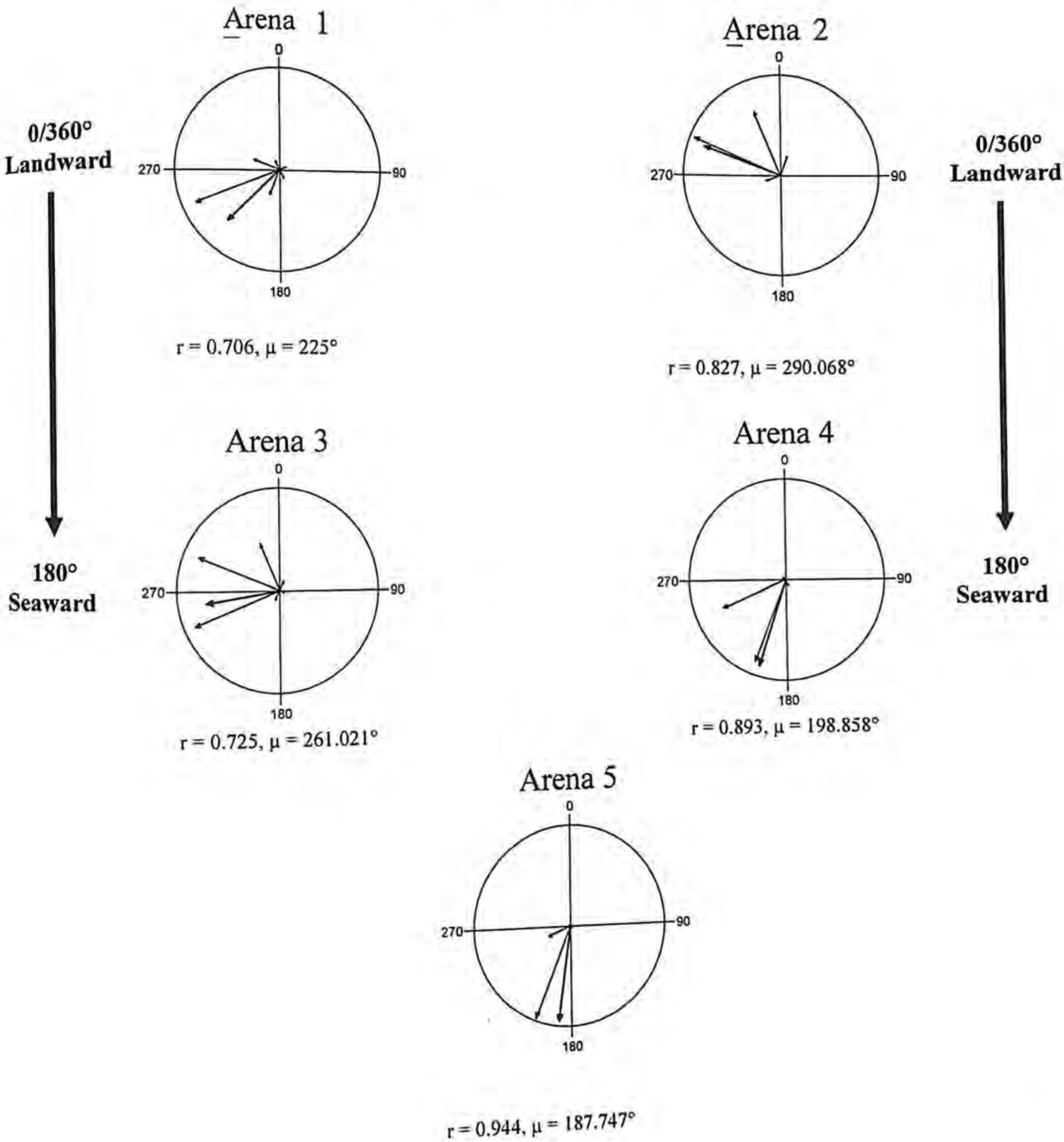
These results show the effect of lighting in different sections of the beach affecting the orientation of the hatchlings. Only arena 4 and 5 showed near perfect seaward orientation and even though arena 1 when placed at such close distance from the water didn't show an orientation as strong as the arenas placed in the darker portions of the beach.

Table VI. 2. B: Watsons-F test results between arenas

	Arena 1	Arena 2	Arena 3	Arena 4	Arena 5
Arena 1	-----	1.82E-11	2.77E-04	0.001	1.36E-06
Arena 2	57.712	-----	6.65E-04	< 1E-12	< 1E-12
Arena 3	14.229	12.363	-----	1.25E-12	< 1E-12
Arena 4	11.312	198.285	66.331	-----	0.021
Arena 5	26.493	304.133	106.443	5.5	-----

(F Values in lower half, Significance levels in upper half)

Fig VI. 2. A. Orientation results of Hatchlings in Different Arenas



(r = Mean Vector Length, μ = Mean Vector Angle,)

VI. 3. Nest Predator Presence and Activity

Predator spoor was easily detected in all the plots but due to variation in the compactness of the sand in the various portions of the beach all the canid spoor were pooled together as a single entity of a nest predator. This was done due to the difficulty in accurate identification of jackal vs. feral dog spoor, hyena presence throughout the season was found to be extremely low (4 track sets through the entire study period). As the effect of each of these predators on the survival of the nest was assumed to be equal (i.e. damage caused by any of these predators on the nest was equal), pooling the data for nest predator presence using them as a single entity is justified.

VI. 3. i. Fortnightly Index:

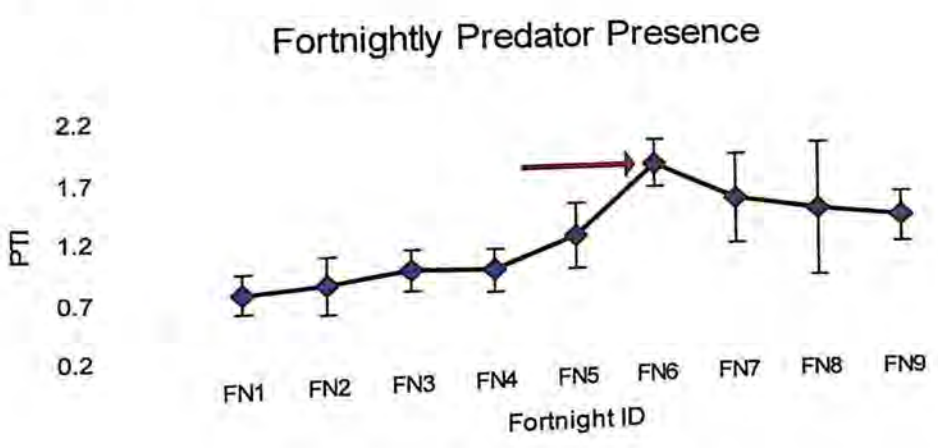
From, the index derived for fortnightly predator presence it was observed that there was minimal difference in predator presence across the first five fortnights and a slight increase in predator numbers immediately after the mass nesting between fortnight 5 and 6. Protective chain link fencing was laid across certain sections of the beach by local NGO's and the Orissa State Forest Dept. which caused clumping of predator tracks only in particular sites of the beach thus adding significantly to variance across plots which is evident from the large error estimates fortnight 7 and 8.

Predator numbers were observed to gradually reduce around the 9^{th} fortnight during the mass emergence of hatchlings (Fig. VI. 3. a). This could be due to the presence of larger numbers of feral dogs in the locality which are more diurnal in habit thus not showing in the track plots which were laid during the night.

Table No. VI. 3. a. Fortnightly Predator Presence

ID	PTI	S.E
FN1	0.75	0.168
FN2	0.8	0.252
FN3	0.9	0.184
FN4	0.875	0.175
FN5	1.15	0.279
FN6	1.75	0.204
FN7	1.425	0.39
FN8	1.325	0.575
FN9	1.25	0.222

Figure No. VI. 3. a. Fortnightly Predator Presence



FN- Fortnight ID

PTI-Passive tracking

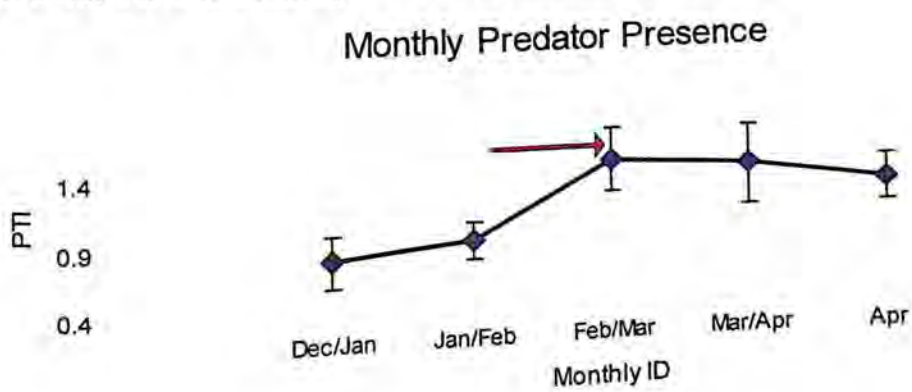
VI. 3. ii. Monthly Index:

Monthly PTI index estimates show how the predator numbers across the beach gradually increased from the times of low nesting in Dec/Jan to the period of mass nesting which occurred in mid-February and persisted till the middle of April (Fig. VI. 3. b). This shows the increase and sustenance of the predator numbers until the period of hatching. As mentioned earlier the large variances during the period after mass nesting was contributed due to presence of wire fence causing a clumping of their tracks only in particular segments of the beach. This contributed to the large variance amongst plots within days.

Table No. VI. 3. b. Monthly Predator Presence

Month	PTI	SE
Dec/Jan	0.78	0.19
Jan/Feb	0.89	0.14
Feb/Mar	1.45	0.24
Mar/Apr	1.38	0.3
Apr	1.25	0.18

Figure No. VI. 3. b. Monthly Predator Presence



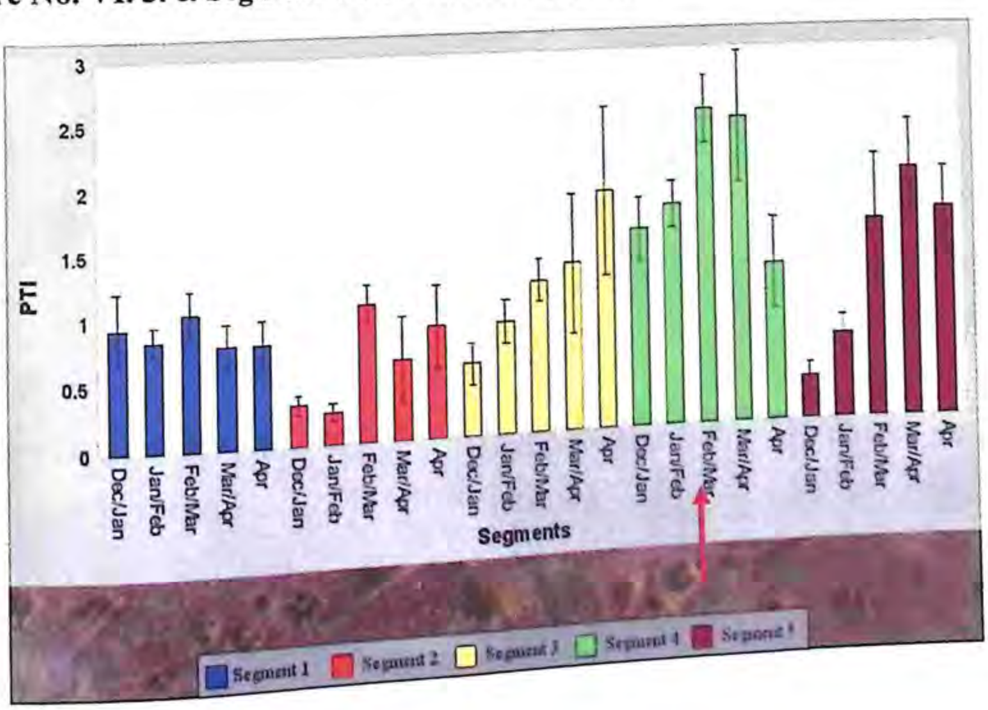
VI. 3. iii. Segment-wise Monthly Index:

Upon sub-sampling from the plots in the kilometre segments, areas of maximum usage by predators are clearly evident. Segements 3 and 4 had clearly higher predator numbers across all months with little or no overlap of error values across segments 1 and 2 (Fig. VI. 3. c). The predator numbers in segments 1 and 2 showed minimal variation across months, whereas there was a marked increase in the predator numbers during the period of mass nesting which continued till April.

Table No. VI. 3. c. Segment-wise Predator Presence

Time Period	All Points		Segment 1		Segment 2		Segment 3		Segment 4		Segment 5	
	PTI	*S.E*	*PTI*	*S.E*	*PTI*	*S.E*	*PTI*	*S.E*	*PTI*	*S.E*	*PTI*	*S.E*
Dec/Jan	0.78	0.19	0.95	0.275	0.313	0.074	0.563	0.164	1.563	0.257	0.333	0.102
Jan/Feb	0.89	0.14	0.85	0.109	0.25	0.063	0.875	0.171	1.75	0.186	0.667	0.154
Feb/Mar	1.45	0.24	1.05	0.181	1.063	0.15	1.188	0.164	2.5	0.27	1.583	0.526
Mar/Apr	1.38	0.3	0.8	0.166	0.625	0.327	1.313	0.557	2.438	0.524	2	0.382
Apr	1.25	0.18	0.8	0.187	0.875	0.319	1.875	0.667	1.25	0.368	1.667	0.333

Figure No. VI. 3. c. Segment-wise Predator Presence



VII. Discussion

VII. 1. Nest Site Selection.

The tests were conducted to check for the possibility of whether turtles were actively choosing their site of oviposition while compared to random placement over varying distances. The test results confirmed the absence of any nesting taking place in the moist portions of the sand after emergence from the water though, this may be an artefact of the linear relationship of soil moisture content to distance away from the tide-line. Wood (2000) reported slope as a significant factor influencing the nest placement in loggerheads however, this was not observed in the olive ridley's at Rushikulya, which may be due to the other physical properties of the beach in itself as it was flatter in overall comparison. pH in itself was inversely correlated to moisture and thus acted in a very similar fashion as that of soil moisture. Though, the effects of temperature on the nest environment of sea turtles have been widely studied this has not proved to be an effective measure while a turtle selects for its nest site (Ackerman 1997; Wood 2000; Karnad 2008).

The significant repeatability of nest site choice with respect to distance from the tide lines by all marine turtles suggests that this behaviour may show evolutionary inheritance. Apart from this, the degree of fidelity shown by the nesting females in returning to beaches over the years signify the level to which selection has taken place historically and fixation of the character of the natal nesting areas into the behaviour of the animal.

As Miller *et al* (2003) pointed out; while several studies have been conducted to determine the factors which discourage the nesting process as a result of lighting, beach vegetation, etc., little is known about proximate cues that sea turtles use for nest-site placement.

Since, there is no parental care involved in during the period of incubation the process of nest-site selection is considered a significant part of the maternal investment made by the female turtle. This strengthens the idea of individual females making an active effort in testing the microhabitats scale before nesting. Our study here show the that soil moisture and pH may act amongst the various potential proximate cues used by nesting turtles at Rushikulya for their final nest site selection while compared to temperature and beach slope which showed large amounts of variation in their observations thus, may not be finally be serving as a cues used.

VII. 2. Hatchling Orientation

A number of studies have reported the different factors influencing sea turtle hatchling orientation towards the sea (Mrosovsky 1972, Kamel and Mrosovsky 2004). These factors include several physical characters which attract/deter the hatchling to a particular direction. Under natural conditions upon emergence hatchlings are known to orient naturally seawards using these various cues. Previous studies in Rushikulya have looked into this aspect and observed a high level of disorientation observed due to the presence several lighting factor present (Karnad et al 2009, Tripathy 2003, Pandav 2000).

By looking at orientation of hatchlings at the various sections of the beach used by nesting females the issues regarding disorientation at Rushikulya is clearly seen. The results seen in the case of areas in the zone of maximum photic conditions indicate the extent of disorientation as hatchlings placed within 10m of the tideline were also observed to be confounded by the external lighting factors present. As expected strong landward orientation was seen when the nests are placed further away from the water in areas with maximum photopollution. Though the patterns of sea turtle nesting over the years have been observed to have moved further away into darker sections of the beach while compared to past records (Karnad et al 2009, Tripathy 2003), there are still sizeable number of turtle nests in the zones with sources of external light. As all observations here were made during a bright moonlit night where the effect of light induced disorientation is expected to be minimal the results here seem to show that the certain external sources still having a big role in affecting the seaward orientation of the hatchlings. This indicates the different levels of management required to handle such events especially due to the overwhelming numbers of hatchlings emerging.

VII. 3. Nest Predator Presence and Activity

This study was able to identify the clear shift in predator presence across months and also areas of maximum usage. This indicates that the drastic increase in predator numbers in the area upon the commencement of mass nesting even with the protective measures taken up by the State Forest Department using chain-link fencing between plantation and nesting beach. From the pattern of predator presence in the different sections of the beach it is observed that the highest predator numbers are observed in the sections of the beach immediately flanked by *Casuarina* plantation. This is clear across all the months even during periods of low nesting (December and January).

Engeman *et al* (2005) developed a simple but effective method for monitoring predators with enough sensitivity to identifying areas of maximum racoon (*Procyon lotor*) and armadillo (*Dasypus novemcinctus*) presence which were the main nest predators at the Hobe Sound National Park and Saint Lucie Inlet Preserve State Park. With effective measures of predator removal in the area, the nest predation effects in the area was reduced to 27.7% in 2000 and to as low as 9.4% in 2002. Increased urbanization around the parks was observed to cause the increased racoon densities causing the increased levels of nest predation events.

Many previous studies in the area have talked about the increased predator presence during the periods of mass nesting as the sudden increase in food supply draws the attention of predators from the adjoining areas (Eckrich 1995). It has also been noticed that these plantations may also be providing a refuge to several of these predators (Tripathy 2005, Karnad 2009), which has been confirmed from this study. This could also be the effect of the waste disposal methods present in the three adjoining villages attracting these associated predators (jackals and feral dogs) which are known to thrive in marginalised habitats.

Apart from the well studied impacts of *Casuarina* plantations on beach geomorphology thereby affecting sea turtle nesting habitats (Chaudhari 2008), our results also provide information on the added issues regarding these plantations also providing refuge to associated nest predators. These results support the findings of Karnad *et al* (2009) regarding the necessity to provide necessary management plans in order to reduce the effects of nest predation in areas where the shelterbelt of *Casuarina* adversely affect the survival of nests with appropriate light management mechanisms to minimise the effects of hatchling disorientation as well.

VIII. Conclusion and Conservation Implications

This study focused on the behavioural aspects as well as the implications of survival and recruitment of the olive ridley turtle (*Lepidochelys olivacea*). Basic behavioural information such as the aspects of nest-site selection provide us with vital information about vital in the overall understanding of any organism's ecology.

- Such studies provide clues regarding the evolutionary history of an organism such as natural selection.

At Rushikulya, hatchlings were observed to have variable levels of landward as well as seaward orientation along the entire stretch of the beach.

- This implicates the necessary levels required to be taken in order to prevent such overwhelming levels of hatchling displacement requiring large amounts of manpower.
- This supports the role of providing appropriate light shields or barriers to prevent the effects of the photo-pollution acting upon the nesting beach.
- 'Turtle friendly' lighting can be employed in the adjoining villages to reduce their impacts on the hatchlings.

Casuarina plantations across the country have known to have various impacts on the geomorphology of beaches impacting the nesting habitats of sea turtles. At beaches with high turtle nesting densities such as Rushikulya this can also doubly affect the turtles by providing refuges to many associated marginalised predators.

- This can be looked into further while providing protection to turtle nests from predators by giving extra attention to beach areas adjoining plantations.
- Effective predator control mechanisms can be looked into such as removal/management of human associated marginalised predators such as feral dogs in such areas.
- Appropriate period for planning predator control strategies can be formalised by looking into the times at which increase in predator numbers is noticed.

Any developmental activity along the rookery areas should consider their potential impacts on the nesting turtles as well as the hatchlings.

IX. References

Ackerman, R. A. 1997. The nest environment and the embryonic development of sea turtles, p 83-106. . In : *The biology of sea turtles.* P. L. Luitz and J. A. Musick (eds.). CRC press, Florida.

Biswas, S. 1982. A Report on the olive ridley *Lepidochelys olivacea* (Eschscholtz) (Testudines: Chelonidae) of Bay of Bengal. *Record of Zoological Survey of India* 79: 275-302.

Carr, A, H. Hirth, and L. Ogren. 1966. The ecology and migrations of sea turtles. 6. The hawksbill turtle in the Caribbean Sea. *American* Museum *Novitates* 2248:1-29.

Carr, A., and L. Ogren. 1960. The ecology and migration of sea turtles, 4. The green turtle in the Caribbean Sea. Bull. *American Museum of Natural History*. 121:4-48.

Chaudhari, S., 2008. Impact of Casuarina (Casuarina equisetifolia) plantation on nesting of olive ridley (Lepidochelys olivacea) sea turtle along the Chennai– Pondicherry coast. Master's Thesis, Pondicherry University, Pondicherry.

Eckrich, C. E and D. W. Owens. 1995. Solitary versus Arribada Nesting in the Olive Ridley Sea Turtles (Lepidochelys Olivacea): A Test of the Predator-Satiation Hypothesis. *Herpetologica.* 51, 3: 349-354

Engeman, R.M., Allen, L., Zerbe, G.O., 1998. Variance estimate for the Allen activity index. *Wildlife Research.* 25, 643–648.

Engeman, R.M., R. E. Martin, B. Constantin, R. Noeld, J. Woolard. 2003. Monitoring predators to optimize their management for marine turtle nest protection. *Biological Conservation* 113, 171–178

Engeman, R.M., R. E. Martin, H. T. Smith, J. Woolard, C. K. Crady, S. A. Shwiff, B. Constantin, M. Stahl and J. Griner. 2005. Dramatic reduction in predation on marine turtle nests through improved predator monitoring and management. *Oryx.* 39, 3, 318-326

Ernst, C.H. J. E. Lovich And R.W. Barbour. 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington, D. C. 578 p.

Fisher, N.I., 1993. Statistical analysis of circular data. Cambridge University Press, Cambridge. 277pp.

Hays, G. G., and J. R. Speakman. 1993. Nest placement by loggerhead turtles, *Caretta caretta. Animal Behaviour.* 45:47-53.

Hendrickson, J. R. 1958. The green sea turtle, *Chelonia mydas* (Linn.), in Malaya and Sarawak. *Proceedings of the Zoological Society of London* 130:455-535.

Kamel, S. J. and N. Mrosovsky. 2004. Nest site selection in leatherbacks, *Dermochelys coriacea*: individual patterns and their consequences. Animal behaviour. 68: 357- 366.

Kar, C. S. and S. Bhaskar. 1982. The status of sea turtle in the eastern Indian Ocean. Pp.365-372. *In*: K. A. Bjorndal (Ed.), Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington D. C. 615 p.

Karnad, D, K. Isvaran, C. S. Kar, K. Shanker. 2009. Lighting the way: Towards reducing misorientation of olive ridley hatchlings due to artificial lighting at Rushikulya, India. *Biological Conservation*, (In Press)

Karnad, D. 2008. The effect of lighting and temperature on the eggs and hatchlings of olive ridley turtles at Rushikulya, India. M.Sc. dissertation. Manipal University, Karnataka, India

Kolbe, J. J and F.J. Janzen. 2002. Impact of Nest-Site Selection on Nest Success and Nest Temperature in Natural and Disturbed Habitats. *Ecology*. Vol. 83, No. 1, pp. 269-281.

Lutz, P. L., J. A. Musick. 1997. The Biology of Sea Turtles. Boca Raton, Florida, CRC Press, 432 p.

Márquez, R. 1990. FAO Species Catalogue: Sea Turtles of the World. An annotated and illustrated catalogue of the sea turtle species known to date in *FAO Fisheries Synopsis,* 125 (11): 81 p.

Martin, T. E. 1998. Are microhabitat preferences of coexisting species under selection and adaptive? *Ecology* 79: 656-670.

Miller, J.D, C.J. Limpus, M.H. Godfrey. 2003 Nest site selection, oviposition, eggs, development, hatching, and emergence of loggerhead turtles, p 125–143. In: *Loggerhead sea turtles* A.B. Bolten, B.E. Witherington (eds). Smithsonian Institution, Washington DC.

Mortimer, J. A. 1982. Factors influencing beach selection by nesting sea turtles, p. 45-52. In: *Biology and conservation of sea turtles.* K. A. Bjorndal (ed.). Smithsonian Institution Press, Washington, DC.

Mrosovsky, N and C.L. Yntema. 1980. Temperature dependence of sexual differentiation in sea turtles: implications for conservation practices. *Biological Conservation.* 18: 271-280

Pandav, B.; B.C. Choudhury; and C.S. Kar. 1994a. A status survey of olive ridley sea turtle (*Lepidochelys olivacea*) and their nesting beaches along the Orissa coast, India. *Report published by the Wildlife Institute of India,* Dehradun.

Pandav, B. B. C. Choudhury and C. S. Kar. 1994b. Discovery of a new sea turtle rookery in Orissa. *Marine Turtle Newsletter* 67: 15-16 p.

Pandav, B., 2000, Conservation and management of olive ridley turtles along the Orissa coast. PhD Dissertation, Utkal University, Orissa, India.

Reichart, H. A. 1993. Synopsis of biological data on the olive ridley sea turtle *Lepidochelys olivacea* (Eschscholtz 1829) in the western Atlantic. U. S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-336, 78-84 p.

Shanker K, B. Pandav, B. C. Choudhury. 2003. An assessment of the olive ridley turtle (Lepidochelys olivacea) nesting population in Orissa, India. *Biol Conserv*. 15: 149 –160

Shanker, K. And B. C. Choudhury (Ed.s) 2005. Marine Turtles of Indian Subcontinent: Status, threats and Conservation. Universities Press, Hyderabad.

Tripathy, B., Pandav, B., Panigrahy, R.C., 2003. Hatching success and orientation in Lepidochelys olivacea (Eschscholtz, 1829) at Rushikulya rookery, Orissa, India. Hamadryad 27, 213–220

Tripathy B. 2005 A study on the ecology and conservation of olive ridley sea turtle (Lepidochelys olivacea) at the Rushikulya rookery of Orissa coast, India PhD dissertation, Andhra University

Tripathy, B. 2005. Status of the loggerhead turtle in India. *Current Science* Vol. 88, 4: 535-536.

Wood, D. W, K. A. Bjorndal. 2000. Relation of temperature, moisture, salinity, and slope to nest site selection in Loggerhead sea turtles. *Copeia* 1:119–128.

Zar, J.H., 1998. *Biostatistical Analysis. 4th Edition.* Prentice Hall, New Jersey. 663pp.