INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE

ISSN: 2067-533X Volume 7, Issue 4, October-December 2016: 1105-1126 www.ijcs.uaic.ro

REPRODUCTIVE BIOLOGY AND CONSERVATION OF OLIVE RIDLEY AT THE RUSHIKULYA ROOKERY OF ODISHA, INDIA

Basudev TRIPATHY*

Zoological Survey of India, M-Block, New Alipore, Kolkata – 700 053, West Bengal, India

Abstract

A study of the reproductive biology and conservation of the Olive Ridley Lepidochelys olivacea was undertaken at the Rushikulya rookery along the Odisha coast in 2002-2005. The distribution of Olive Ridley sea turtles in the nearshore waters of the Rushikulya rookery was studied. Solitary and arribada population of Olive Ridley at the rookery was monitored. Data on adult mortality, predation of eggs and juveniles, beach erosion and Casuarina plantation along the beach were enumerated. The maximum offshore area utilized by turtles is 57.92sq.km and mating takes place at a depth of 16-28m and 2 to 5km from the shore. The number of turtles counted on the beach was 11024, for which curved carapace measurements of egg laying females were recorded as 67.16 ± 3.65cm. Sporadic nesting was documented from December to April with a peak in March, and no major intermediate nesting in between. The mass nesting census differs greatly compared to the figures projected by the monitoring agency. Multiple nesting by individual and inter-seasonal shift in movement of turtles from the Rushikulya rookery was confirmed. Fishing practices are not found to infuence breeding activities. Mortality was low at Rushikulya compared to rest of the Odisha coast. However, other anthropogenic pressures, viz. plantation, erosion and illumination, have emerged as visible threats at Rushikulya.

Keywords: *Olive Ridley; Reproductive patch; Arribada; Incubation; Orientation; Illumination; Rushikulya; Odisha*

Introduction

The world's most abundant sea turtle is perhaps the least understood biologically. Much of our understanding of the signature behaviour of Lepidochelys olivacea, the arribada is speculative. How these aggregations form and whey this behaviour evolved continue to be a mystery [1]. The annual migration of Olive Ridleys to the same breeding area year after year and where fishing intensity is high puts them at risk of entanglement and drowning in fishing nets [2-4]. Males and females migrate to the breeding grounds and aggregate close to the shore near the mass nesting beaches. Sea turtle biologists have defined this assemblage of Olive Ridleys as Reproductive Patch [5, 6]. According to Richard and Hughes [7], Plotkin et al. [8], Kalb et al. [9] and Kopitsky et al. [10], this reproductive patch is composed of mature reproductive males and females engaged in courtship and mating. Odisha, a state in India along the eastern coast, harbours three such major congregation sites, viz. Gahirmatha, Devi and the Rushikulya rookery [11-13].

* Corresponding author: tripathyb@gmail.com

While much of the sea turtle conservation efforts in Odisha have focused on protecting nesting beaches, the protection of offshore habitats has been overlooked, since enforcement requires expensive logistic support. But given that turtles spend most of their life at sea, it is imperative that conservation efforts be effective in this habitat as well. The lack of information on the distribution and abundance of sea turtles in the offshore habitat is a major obstacle to providing adequate protection for sea turtles in coastal waters. Knowledge of the spatial and temporal use of the breeding habitat is critical for designing proper conservation and management plans for Olive Ridleys. Instead of promoting total protection of a large marine area, which would likely be prohibitively resource-demanding, precise knowledge of the areas used by the turtles should be obtained through monitoring during the breeding and non-breeding seasons. This will ensure that the animals are protected efficiently without resorting to blanket restrictions on fishing activities or other activities along the coast.

Between January and May every year, these turtles congregate in the coastal waters of Odisha and nesting takes place either in solitary or in great simultaneous aggregations (mass nesting) where up to 100,000 females come up the beach to lay their eggs, also popularly known as an arribada. a Spanish term meaning mass arrival [14]. Besides solitary nesting all along the coast of Odisha, more than a hundred thousand turtles are believed to nest annually at *Gahirmatha* [11] and tens of thousands nest at other two locations, i.e. Devi and the Rushikulya rookery [12, 15]. In spite of its biological importance, solitary nesting has never been evaluated adequately in many important nesting rookeries [16]. Although some information is available on solitary nesting of *L. olivacea* at Gahirmatha and Devi rookery [17], there is little or no information on solitary nesting activities at the Rushikulya rookery. Similarly, the mass nesting events at the Rushikulya rookery have not yet been monitored properly; current data are from anecdotal accounts [12] and the imprecise census by the Odisha State Forest Department due to improper statistical techniques [17-19]. The Odisha State Forest Department has reported mass nesting at this rookery every year since 2001, but accurate estimates of the number of nesting turtles in arribadas are not available in the absence of a standard technique for mass nesting census [18, 20]. The IUCN/SSC Marine Turtle Specialist Group (MTSG) has recommended for use of strip transect method for estimating the arribada on mass nesting beaches, on the basis of successful experiment by *Valverde and Gates* [21].

Unlike most marine turtles that migrate among their breeding ground and foraging areas, Olive Ridley turtles resemble nomadic migrants that swim hundreds of thousands of kilometres over vast oceanic stretches [22-24]. Knowledge of Olive Ridley turtle migrations is fragmentary throughout most of the species' range. Along the northern Indian Ocean, Olive Ridley turtles migrate to the Indian coast each winter (i.e., in October/November) to "breed" and nest on suitable beaches. Sparse or anecdotal evidence suggests that females migrate and perform inter-rookery movements during the breeding and nesting season along Odisha coast [25]. Hence, additional knowledge of the locations and temporal use of Odisha's nesting grounds by Olive Ridley turtles will help us evaluate the extent of habitat loss and large-scale mortality of turtles in the offshore waters.

Similar to other long-lived species, the Olive Ridley turtles are also prone to population decline because of slow intrinsic growth rate coupled with anthropogenic pressure. Degradation, transformation and destruction of natural conditions at nesting beaches from coastal developments continue to threaten the long-term survival of many Olive Ridley rookeries. Olive Ridleys are victim of several threats along the coast and natural and anthropogenic pressure at Rushikulya rookery are mounting year after year.

Except at Gahirmatha, there is no information on reproductive activities of turtles in the coastal waters of Odisha. Present study consists preliminary observations on the offshore distribution of turtles as they congregated for reproduction off the Rushikulya rookery in Odisha. Environmental parameters that might influence the offshore distribution and reproductive congregations were also examined. Over the past decade, more than 100,000 dead turtles have been reported along the Odisha coast due incidental and accidental fishing related casualties in the sea. Whether this mortality has an impact on the population size of *L. olivacea* is yet to be known [26]. In this paper, in light of its importance, the sporadic nesting and mass nesting census of *L. olivacea* at the Rushikulya rookery was evaluated using standard techniques recommended by the MTSG to ascertain the actual arribada nesting population of turtles at this rookery and compare this figure with estimates from the Odisha State Forest Department. The traditional method of studying turtle migration is to tag the females on their flippers while they are nesting and record where these tagged turtles are subsequently recaptured [27]. Multiple recaptures during nesting documents the migratory capability of sea turtles and nesting site fidelity. The present study adopts this method to examine the spatio-temporal spread of the nesting turtles along the Odisha coast. Reproductive homing and inter-rookery movements of Olive Ridley turtles at the Rushikulya rookery was evaluated. Apart from offshore fishing related mortality, *Casuarina* plantation, beach erosion, artificial illumination and predation of eggs and hatchlings affects the animal directly through the loss of nesting habitat or indirectly through changes in the thermal profiles of the beach at Rushikulya. Through this study, various threats to the Olive Ridley turtles at this rookery were evaluated and suitable conservation measures suggested for protection of the Olive Ridley turtles and their offshore and onshore habitats at the Rushikulya rookery of Odisha coast.

Materials and Methods

Study area

The study was carried at Rushikulya rookery which is the mass nesting beach and adjacent coastal waters near Rushikulya estuary. The Rushikulya river estuary is a shallow tidal estuary, which opens into the Bay of Bengal near Ganjam town. The estuary mouth is connected with the southern sector of the Chilka lagoon through a man-made channel known as the Palur channel. The Palur channel runs parallel to the nesting beach for 8km. The physiographic features of the estuarine environment have undergone many recognizable changes since the last two-decade [28]. The irregular floods in river Rushikulya leading to formation of new mouths on several occasions.

The southernmost rookery of Olive Ridley in Odisha near the mouth of river Rushikulya was discovered in March 1994 [12]. The mass-nesting beach is located on the sand spit along the northern side of Rushikulya River mouth. The rookery is situated 320km south of Gahirmatha mass nesting beach (Lat. 19º 22’ N and Lon. 85º 02’E; Fig. 1). Turtle nesting at this rookery takes place along a stretch of ~ 5km immediately north of Rushikulya River mouth from the village Purunabandha (1km north of the Rushikulya River mouth) to Kantiagada village. The beach is more or less flat with scattered sand dunes of 1-2m high. The average beach width is 80m above the high tide line, though at some places, the extent of beach is more than 150m.

The extended sandy beach adjacent to north of the Rushikulya river mouth has been proved as a favourable site for mass nesting of Olive Ridley turtles at least since its discovery. However, with the change of the beach topography, the mass nesting has shifted towards further north up to four kilometres from the earlier nesting area. Remarkable changes such as development of a typical lagoon like structure, comparably lowering of wave action and beach gradients and enormous growth of vegetation on the beach has taken place in the old nesting beach. The new nesting beach located between the Gokhurkuda and Kantiagarha village, two kilometres north of Rushikulya river mouth. The new nesting site which is relatively flat and subjected to minimum human interference being away from the fish-landing centres.

A conspicuous feature of the Rushikulya beach is the absence of Casuarina plantation in the old nesting area and dense Casuarina plantation in the new nesting stretch. The natural beach vegetation on the sand dunes includes psammophytes such as Sea morning glory (*Ipomea pescaprae*), Feathertop (*Spinifex littoreus*), *Gisekia phranacoides* and Indian waterbluet

(*Hydrophylax maritima*). On the beach, exotic and invasive species like Prickly pear (*Opuntia* spp.*)*, Swallow-wort *(Calotropic gigantia),* Sleeping grass (*Mimosa Pudica*) can be seen. Besides, species such as Bermuda grass (*Cynodon dactylon),* Screw pine (*Pandanus fascicularis)* and Casuarina (*Casuarina equisitfolia*), which grows in patches in some parts. The backwater of the river Rushikulya fringed by Cashew (*Anacardium occidentale*) and Coconut (*Cocos nucifera*) which extended to four km northwards along the nesting beach.

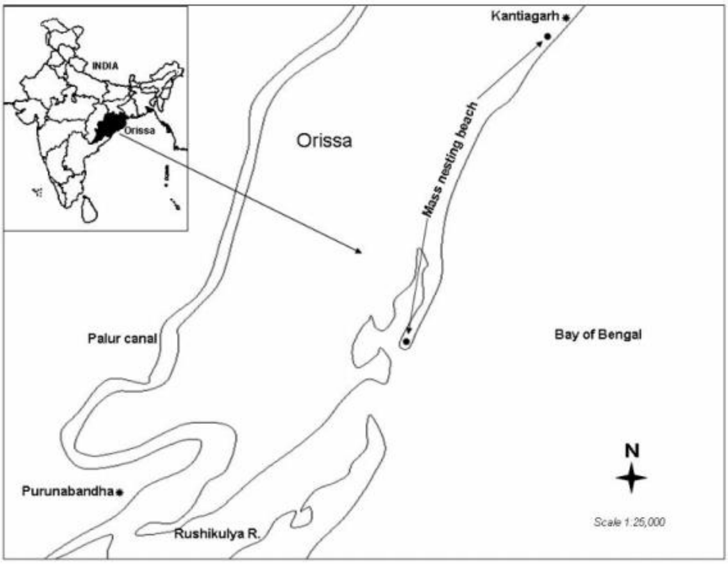

Fig. 1. Map of Rushikulya sea turtle rookery.

The offshore waters of the Rushikulya rookery in shallow. The continental shelf in this region is ~3000 sq.km and does not exceed 30m even at an inshore distance of 10km. The climate is hot and humid throughout the year except from December to January. The tides are semi-diurnal (Survey of India, Tide Time Table) and the average seawater salinity is ~ 27PPT and temperature varies from 18 to 43ºC [29]. The wide changes in the physico-chemical properties of seawater are the result of unique geo-meteorological conditions at Rushikulya rookery.

Human settlements near the mass-nesting beach include the fishing villages of Purunabandha and Palibandha, and the major fish landing centres are Gokhurkuda, Kantiagarha and Nuagaon. Unlike the northern Odisha coast, the majority of coastal dwellers here are Nolias *(*fishermen migrated from Andhra Pradesh) artisanal fishermen engaged in sea going or estuarine fishing. Among the different types of fishing gear, drift/gill nets are most popular in this part of Odisha [30]. Monofilament nets are abundantly used for fishing in the nearshore waters of the rookery.

At present, this rookery and its near shore coastal waters does not come under any Protected Area management. Gopalpur (20km north of Rushikulya) is being developed as a sea port. Recently the Reliance Petroleum and the Indian Oil have identified the offshore waters (~75km from the seashore and inside the sea) of the rookery for major oil exploration. Near Arjipalli, the Indian Rare Earths Limited mines the beach for sand. There are abandoned prawn farms that are immediately behind the nesting beach. A chloro-alkali plant situated on the right bank of the Rushikulya River, which discharges effluents directly into the estuary. The Ganjam Township as well as the National Highway No.5 is just a kilometre away from the mass-nesting beach. During night high illumination on the beach occurs due to these establishments.

Detailed methodology for field work

Distribution and dynamics of reproductive patch in Olive Ridley off Rushikulya: The present study was carried out in the coastal waters off Rushikulya (19º 22'N, 85º 02'E; Fig. 2).

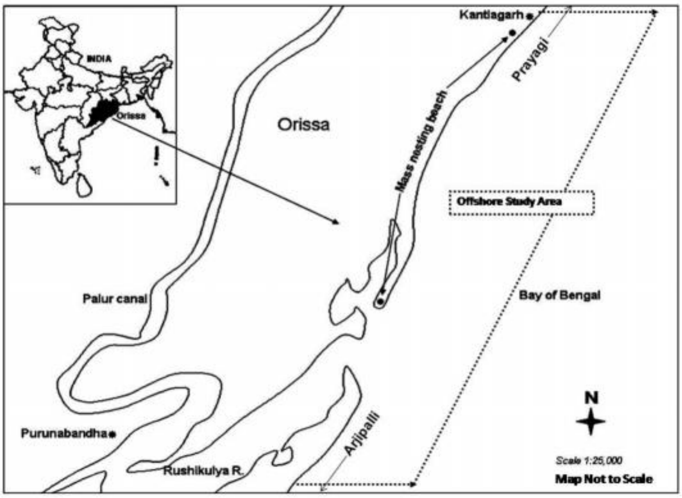

Fig. 2. Map of Rushikulya sea turtle rookery and offshore waters.

The water off Rushikulya is shallow and the continental shelf extends over ~3000km^2. Depth does not exceed 30m even at 10km offshore. The fieldwork was carried during the breeding season (November–March) using a small-motorized boat powered by a 5-hp outboard motor at an average speed of 7km/h and within a distance of 10km from the shore between the villages Prayagi and Arjipalli (extending ~25km from north to south of the nesting beach) and covering an area of ~250km^2 in the offshore waters. Turtle abundance was estimated using line transect methodology. Line transects (25×10km) were laid perpendicular to the coast on alternate days at random locations between 9:00 and 15:00 h. Average speed of the boat was maintained at 5km/h for consistency among transects. When a turtle was observed at the sea surface, the bearing and radial distance of sighting was recorded using a handmade angle board, magnetic compass and a laser range finder (Bushnell Yardage Pro 1000 Range Finder). As laser does not reflect off the water surface, sighting of turtles far away from the track line was considered accurate. Program distance was used to fit the transect data. Three models *viz*. Uniform-Cosine/Polynomial, Half Normal-Cosine/Polynomial and Hazard Rate-Cosine/Polynomial were tested on the distance data. Model with the lowest Akaike's information criterion value (AIC) was the UNIFORM WITH COSINE adjustments with order 1, 2 which provided the best fit for the data. The estimates however did not differ much between various models tested.

The distribution of the turtle mating pairs and the size of the '*reproductive patch*' were estimated using the same transects. Radial distance and bearing were recorded for each sighting using the range finder and a GPS (Global Positioning System, Garmin 12; Garmin Inc). Locations of turtle mating pairs observed very close to the boat (< 25m) were estimated visually. Environmental conditions *viz*. Beaufort Sea State, sun, time, depth (with a Portable Sounder (Speedtech Instruments; SM-5 Depthmate Portable Sounder; Range: 6–79m), air temperature and sea surface temperature (with a digital multi-thermometer (Mannix/Interstate) were monitored during the transect surveys to determine their influence on detectability and turtle mating behaviour in the offshore water. To minimize the chance of missed sightings, field surveys were conducted only when sea conditions were at Beaufort Sea State Scale 0 and 1. The turtle sighting locations were plotted on GIS map to project distribution of turtles during the breeding season. The turtle mating pair locations were projected to Universal Transverse Mercator and the extent of distribution was obtained by drawing a minimum convex polygon (MCP) around the sighting points. CALHOME, Adaptive Kernel and ARC-GIS (ARC-INFO 9.0 & ARC-VIEW 3.2) were used for Home Range Analysis. The offshore environmental data from mating locations were computed using descriptive statistics and SPSS software.

Assessment of solitary and arribada nesting of Olive Ridleys at Rushikulya: For systematic coverage, the entire stretch of nesting beach was divided into 100m segments and was marked with wooden poles. To monitor nesting activities, patrolling was done by foot every night between 17.00 and 7.00 h from November to April for two seasons. Sea turtles are known to nest along the Rushikulya rookery towards the end of December (Basudev Tripathy, personal observation) and therefore the chance of missing out of some crawls during the nesting season is minimal. Turtle crawls onto the beach were classified into nesting and non-nesting types based on crawl mark pattern and sign of nest [31]. There is no standard classification of solitary nesting or arribada nesting based on the number of nests per night. However, keeping the beach length of the study area (~5km) in mind, the author classified night with less than 20 nesters/km (~4 nests/km) as solitary nesting, nesting densities of 20 to 99 turtles/km were considered intermediate nesting, while those with 100 (20 nests/km)or above turtles as arribada nesting. A modified strip transect method was used to estimate the mass nesting at the Rushikulya rookery [32]. This method was effective in arriving at an estimate of the number of nesting females, with a mean, variance and confidence intervals that provide rigorous statistical support for the results. A 20m strip transect was laid at every 100m segment of the nesting beach. Only egg-laying females (turtles in oviposition) within the strip were counted on hourly intervals starting with the first individual ascending the beach in the evening until morning when there were no nesting activities.

The formula below was used for computation of the mass nesting data [21]:

$$\text{Estimate of nesting} = \frac{A \times H \times N}{W \times t \times L \times h} \qquad (1)$$

Where:

A	=	Total available nesting area (in m^2)
H	=	Duration of arribada (in minutes)
N	=	Total of number of egg laying turtles
W	=	Width of the transect (in m)
T	=	Number of sampling period (in days)
L	=	Total of length of all transects (in m)
H	=	Average time spent by turtles for egg laying (in minutes)

Size of female *L. olivacea* was determined by the measurement of curved carapace length (CCL) at the time of egg lying. Each turtle was measured down the midline from the nuchal notch to the posterior carapace tip using a flexible measuring tape and values were rounded to the nearest 0.5cm.

Beach fidelity and inter-nesting movements of Olive Ridleys at Rushikulya: The author was involved in tagging programme on turtles along Odisha coast through Wildlife Institute of India in which he had tagged females on both of the front flippers using monel tags (National Band and Tag Co., Newport, KY, USA) marked WG/WR & serial number and a return address – “WII, PB 18, Dehradun 248001, India” on the reverse side [32] from 1995 to 2002. The author along with volunteers from local villages collected the recapture data on tagged turtles from the nesting seasons (December to May) of 2002-03 to 2004-05. Each night volunteers conducted hourly patrols. When they encountered a turtle, data on the tag number, date, place and nature of nesting (arribada/solitary) was recorded. Subsequently, original tag data records compiled by WII was compared with the tag information gathered through recapture on the beach.

Natural and anthropogenic threats to Olive Ridleys at Rushikulya Rookery: The entire beach was monitored by foot once in a fortnight throughout the breeding season from November to April (2003-04 and 2004-05). Dead turtles washed ashore were marked on their carapace with synthetic paint to avoid duplication during subsequent counts. These stranded turtles were sexed using external characteristics. Curved Carapace Length (CCL) (anterior point at midline/nuchal scute to the posterior tip of the supra-caudal) and Curved Carapace Width (CCW) were measured for all the dead turtles following standard procedures suggested. Predation on turtle eggs (nest predation) was documented for each breeding season from November to April. This study focused on the entire six km beach from the Rushikulya river mouth to Kantiagarh village. Signs of nesting on the beach were monitored every morning based on crawl marks. Turtle tracks do not always reliably distinguish true nests from pits where a female has come ashore, dug, but not laid. However, predation of eggs in the nest is a direct evidence of nesting. For some nests it was possible to record exactly the interval between egg laying and fresh predation. For others, a minimum interval from the date of nesting i.e., date at which the nest was found to the date of predation was recorded. Predation was determined by one or more of the following characteristics: paw prints on the sediment, sand thrown in one or more directions with a wide opening of the nest, egg shells scattered around the nest site and visually witnessing the predator in action[5]. Data were collected regularly from the beginning of sporadic nesting at the rookery till hatching. For the purpose of computing, nest predation of sporadic and arribada nests were calculated separately.

The beach profiling was done for the entire six km stretch beach on a fortnight basis from November to April following standard procedures suggested. At every 100m point a permanent landmark was fixed. These points were marked with a concrete pole/sandbag for subsequent monitoring. Beach width was measured perpendicular from the high tide line (HTL) to the permanent land mark.

The formula used for calculating the available nesting beach was as follows.

$$\text{Width of the beach } l = a \pm b \qquad (2)$$

Where, b is the width of beach from its earlier fortnight observation (a).

Finally, area available for nesting (N) was calculated as average beach width (l) x total length of the beach.

The various sources of illumination close to the nesting beach that might have some impact on turtles and their hatchlings were documented. The impact of *Casuarina* plantation on the nesting adults and hatchling were also taken into consideration by direct observations on their movement behaviour during breeding season.

Results and Discussions

Distribution and dynamics of reproductive patch in Olive Ridley off Rushikulya: In the 36 days of offshore field surveys, 222 line transects (average = 6 transects/day) covering approximately 307km (an average of 1.4km/transect) resulted in 942 sighting of single turtles. The number of turtles observed varied from 1 to 21 turtles/transects. Uniform cosine model with two adjustment terms fitted best (p = 0.122) with a minimum AIC value. The ESW (effective strip width) was 43.75m and the estimated surface density was 35.067 turtles/km^2 (CV = 11.22%). The Encounter rate for surfacing turtles was estimated to be 3068/km. A total of 353 mating pairs were recorded in an area of 264.1km^2 (100% MCP) in the coastal water off Rushikulya. The area of maximum utilization by turtle mating pairs was 57.92km^2 (90% MCP,

Fig. 3). The Adaptive Kernel value did not differ much in comparison to the MCP (Table 1, Fig. 3).

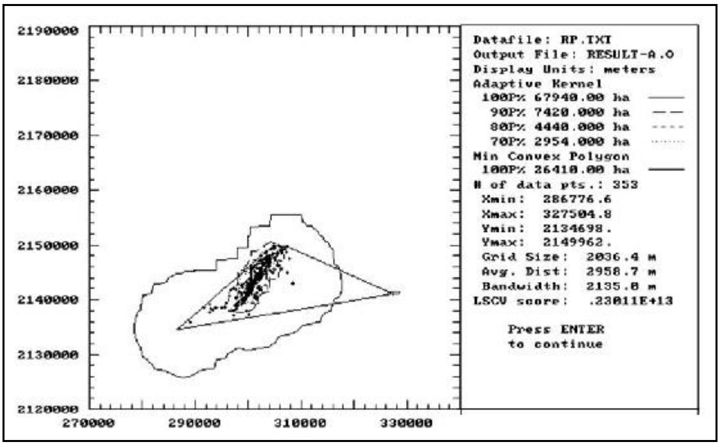

Fig. 3. Core area of mating congregation of olive ridley turtles off Rushikulya rookery

Table 1. Habitat utilization by turtle mating pairs in the sea (n=353)

Estimator	100%	90%	75%	50%
Minimum Convex Polygon	26410.00 ha	5792.00 ha	4005.00 ha	1504.00 ha
Harmonic mean		8188.00 ha	3483.00 ha	1604.00 ha
Adaptive Kernel		7420.00 ha	3602.00 ha	1808.00 ha
Average distance between points = 2958.7 m				

Turtle mating pairs were sighted from as close as 100m to 8km from shore and > 95% of the sighting were within 5km from shoreline. The majority of the mating congregation (85%) was observed in front of the Rushikulya nesting beach or towards northern side of the river mouth. The depth at which turtle mating observed was between 16m and 28m with maximum at 19–20m ($\bar{x}$ = 26.66m; Fig. 4). Sea surface temperatures were between 21.2°C to 26.8°C with a mean of 24.06°C for the entire area surveyed. Turtle mating pair sightings were poor during morning (up to 10.00h) but increased with the time of the day and a rise in sea surface temperature, and decreased after a peak between 12:00 hrs and 13:00 hrs (n = 353; Fig. 5).

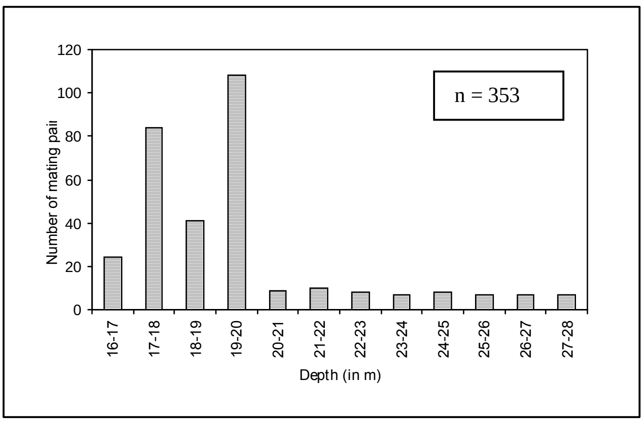

Fig. 4. Turtle mating pair sighting at different depth at sea.

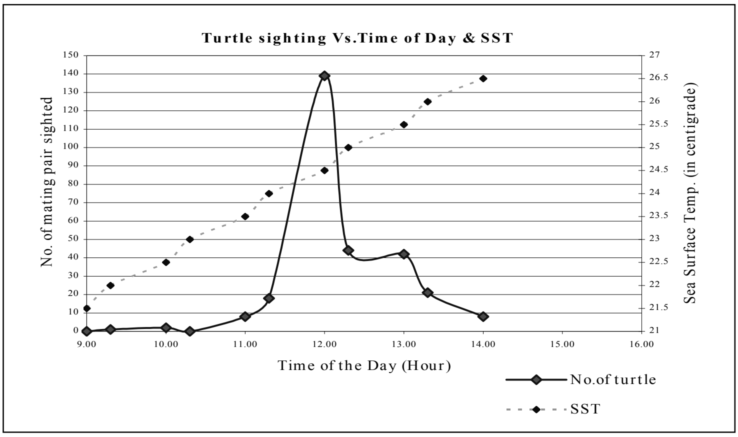

Fig. 5. Turtle mating pair sighting and time of the day.

Assessment of solitary and arribada nesting of Olive Ridleys at Rushikulya:

Of the 568 nests observed during the 2003–04 nesting season between December 2003 and April 2004, 45.2 % of the nesters were intermediate nesters, with rest being sporadic nesters (Table 2). Similarly, during the 2004–05 nesting season, intermediate nesting was calculated to be 33.3% (Table 2). There was a distinct pattern of solitary nesting observed at Rushikulya rookery, with a peak in activity during March for both the season (Fig. 6). A total of 15 and 20 transects with 20m width and 100m length were established for counting turtles in arribadas during 2004 and 2005 respectively (Table 3). During 2005, the topography of the beach changed drastically and mass nesting was extended from the estuarine mouth and 2km northward, and therefore, five more transects were laid. Although arribada took place twice during 2004 (February 9–10 and March 10–13), the February arribada could not monitored due to logistic constraint and hence the census was done only for the March 2004 arribada. During four days of peak nesting in March, a total of 23,461 turtles were estimated to have nested in arribada. However, the 2005 arribada was larger and was estimated to be 86,688 nesting individuals in two nights when censuses were carried out (Table 4).

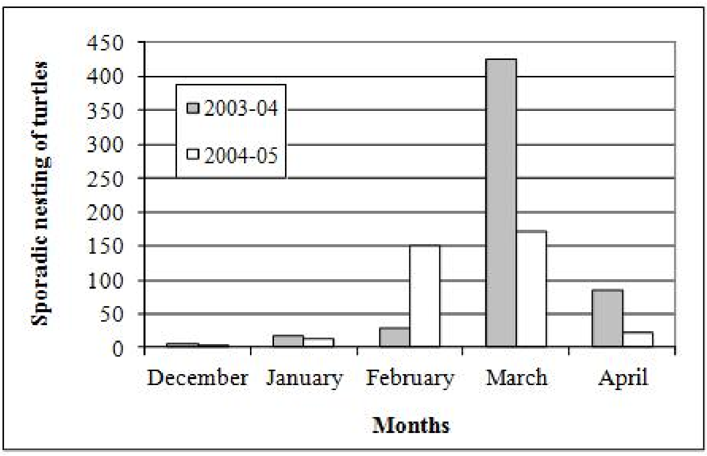

Fig. 6. Month-wise turtle nesting at the Rushikulya (2003-04 and 2004-05).

Table 2. Sporadic nesting of olive ridley turtles at the Rushikulya rookery

Month	2003-2004		2004-2005	
	No. of sporadic nesting (No. of nights)	No. of intermediate nesting (No. of nights)	No. of sporadic nesting (No. of nights)	No. of intermediate nesting (No. of nights)
November	5 (5)	0	0	0
December	6 (5)	0	2 (2)	0
January	17 (8)	0	12 (3)	0
February	30 (22)	0	31 (6)	119 (6)
March	166 (21)	258 (9)	170 (29)	0
April	86 (14)	0	23 (10)	0

Table 3. Sporadic nesting of olive ridley turtles at the Rushikulya rookery

Month	2003-2004		2004-2005	
	No. of sporadic nesting (No. of nights)	No. of intermediate nesting (No. of nights)	No. of sporadic nesting (No. of nights)	No. of intermediate nesting (No. of nights)
November	5 (5)	0	0	0
December	6 (5)	0	2 (2)	0
January	17 (8)	0	12 (3)	0
February	30 (22)	0	31 (6)	119 (6)
March	166 (21)	258 (9)	170 (29)	0
April	86 (14)	0	23 (10)	0

Table 4. Estimates of arribada (nesting number) of 2004 and 2005 nesting season

Date	Number of nesting turtle ($\bar{X}$)	Lower confidence interval (95%)	Upper confidence interval (95%)	Standard Error
2004				
10th March 2004	4262	3534.10	4990.03	364.36
11th March 2004	12434	11270.86	13598.10	507.45
12th March 2004	4362	4227.10	4297.10	273.25
13th March 2004	2503	2204.03	2802.86	149.80
Total (4 nights)	23561	21236.09	25688.09	
2005				
14th March 2005	44466	42017.33	46915.99	7379.48
15th March 2005	42222	40444.45	44001.99	6129.67
Total (2 nights)	86688	82461.78	90917.98	

Nesting females in arribadas at the Rushikulya rookery had an average CCL of 67.163.65cm (n = 515; min: 60.8, max: 73.61), a value slightly greater than that of the solitary nesters at 66.024.34cm (n = 335; Mann Whitney = 505, p = 0.0004). No significant differences in CCL existed for arribada of February and March 2004 (Kruskal-Wallis χ^2 = 6.9, p = 0.2412) and also between 2004 and 2005 season (Kruskal-Wallis, χ^2 = 5.80, p = 0.1225).

Solitary nesting emergence of *L. olivacea* is known to occur almost every month along rest the Odisha coast [11]. However, solitary nesting is found in greater numbers during January to May, indicating that this is the main nesting season for this species [26]. Although year round sporadic nesting is not known from the Rushikulya rookery, this study confirms sporadic nesting of Olive Ridley turtles at the rookery between December and April, with a peak in March and is identical to other sea turtle rookeries along the Odisha coast. Temperature, weather condition, physiography of nesting beaches and the adjacent sea, conditions of tide, temperature and surface current circulation all play an important role in determining female nest selection [26]. However, this study could not incorporate the above variables at the Rushikulya rookery due to logistic constraints. Unlike Gahirmatha and Devi (Basudev Tripathy, personal observation) where sporadic nesting is almost continuous for the entire season (> 10 turtles/night), at Rushikulya rookery, sporadic nesting is irregular, with nesting intensity increasing before the commencement of the arribada. During the other nights, there is either no nesting or low sporadic nesting (< 5 turtles/night). However, it is likely that the females emerging on nights with intermediate levels of nesting are responding to arribada cues (cue such as southerly strong wind, cloudy weather and strong wave action in the sea) and are truly arribada nesters. What actually comprises solitary or arribada nesting must also be evaluated in light of the total population for a given beach [11]. During the present study, there was no major intermediate nesting events observed at the Rushikulya rookery except for nine nights in 2004 February and six nights during 2005 March, when nesting per night was over 100. However, it is likely that these turtles were early arribada nesters, since the arribada commenced in the rookery few days later.

At the Rushikulya rookery, although arribadas were reported for many years, precise mass-nesting censuses have not been carried out. The Odisha Forest Department report estimates the number of turtles during the arribada every year, but the methods used are unpublished and unavailable (estimated by Odisha State Forest Department; Table 5). Furthermore, it is not clear that methods are standardized, unbiased and therefore comparable. The State Forest Department staffs counts all female turtles that remain on the beach during arribada. However, during arribada emergence, many turtles do not deposit their eggs (~30–40%) and hence are not part of true nesting population. While estimating nesting arribada population, this factor greatly affects the population size estimation and leads to bias. In the past 25 years, a variety of approaches and methods have been used to estimate female populations at arribada beaches of Odisha (reviewed by *Shanker et al* [18]). The present study estimated very low nesting populations during arribadas (using the standard technique as suggested by the IUCN/MTSG [21] compared to the figures projected by the Odisha state forest department (Tables 4 and 5). While projection of a large nesting figure attracts attention, particularly to the national and international media and conservation communities at large, it may results in the downgrading of this species in the Indian Wildlife (Protection) Act and IUCN's Red List.

Table 5. Estimates of arribada at the Rushikulya rookery by Odisha Forest Department and other researchers (1994-2005)

Year	Nesting estimate	*Date of arribada*	Reference
1994-1995	2,00,000	14 - 16 March 1995	*Pandav et* al. (1994)
1995-1996	?	06 - 08 March 1996	- do -
1996-1997	?	31 January – 3 February 1997	B. Pandav (Personal Observation)
1997-1998	?	20 – 23 March 1998	- do -
1998-1999	-	No arribada	-
1999-2000	-	No arribada	-
2000-2001	1,59,000	26 Feb – 4 March 2001	-
2001-2002	-	No arribada	-
2002-2003	2,08,000	09 – 14 March 2003	Odisha state forest department
2003-2004	2,01,000	10 – 15 March 2004	- do -
2004-2005	?	15 – 18 February 2005	- do -

In recent years (at least between 1996 and 2000), a small but significant decrease in curved carapace length (CCL) of female Olive Ridley Sea Turtles has been documented [12, 5]. Similarly, the average CCL of females at Gahirmatha from 1978 to 1985 were larger than those measured during 1996–2000 [11, 26]. The present study found that arribada nesters are significantly larger than the solitary nesters, with a mean CCL being 1.14cm greater, but was within the range. The decrease in size class (as compare to 1996–2000) was not detected during the current study, but this could be due to a small sample size, the lack of sufficient data, and a less accurate measuring technique (measuring tape for CCL *Vs* metallic calipers for SCL).

Beach fidelity and inter-nesting movements of Olive Ridleys at Rushikulya: During the beach monitoring for three nesting seasons (2002-03 to 2004-05), 1070 tagged turtles were recaptured during arribadas. A total of 609, 318 and 143 tagged turtles were recaptured during the 2002-03, 2003-04 and 2004-05 seasons respectively (Table 6). Of the 3080 turtles tagged on arribada and solitary nesters between 1996-1999 and 1331 tagged in 2002, only 1070 female turtles were recaptured during the study; 988 (92.3%) in arribadas and 82 (7.7%) as solitary nesters. Of the 988 tags recaptured during arribadas, as many as 88.7 % nested at least once on the beach during the same year. A total of 9.7% nested twice in the same season at the rookery and 1.47 % turtles nested three times within a season (Table 7). The inter-nesting period within a season ranged from 20 to 25 days (22.09±0.58, n = 32). We observed only one turtle (tag number WR 25013L, 25014R; replaced with 33233 in 2002) that ascended onto the beach four times in the same season, and it actually nested on two of these occasions. We tagged this turtle on 02 February 1997 and on two earlier occasions, *Pandav* (unpublished data) recaptured it at this rookery (i.e. 13 March 1999) and then on 24 March 2002. Among year recaptures (2003-2005) occurred four times. A total of 90 turtles nested in at least two consecutive years. This led us to calculate remigration intervals of 11 months and 21 days to 8 years and 12 days.

Table 6. Recapture of tagged Olive Ridley Turtles (*Lepidochelys olivacea*) at the Rushikulya rookery

Year of Tagging	Turtles Tagged (n=4411)	Turtles Recaptured (n = 1070)			
		2003	2004	2005	Recapture rate (%)
1997	518*	38	12	8	10.79
1998	2063*	158	52	32	8.50
1999	499*	63	36	18	4.26
2002	1331	350	218	73	20.7
Total	4411	609	318	143	8.04

*****Data from Pandav and Choudhury (2000)

Table 7. Recapture of tagged Olive Ridley Turtles at the Rushikulya rookery (2002-03 to 2004-05)

Parameter	2003	2004	2005	Total
No. of turtles encountered at least once on the beach	439	296	105	840
No. of turtles encountered twice on the beach	65	11	16	92
No. of turtle encountered thrice on the beach	12	0	2	14
No. of turtles encountered four times on the beach	1	0	0	1

During the study period, the beach profile was dynamic and underwent rapid changes. However, in 2004, the main beach became fragmented into many smaller submerged islands bordering a lagoon over the traditional mass-nesting beach. This change of beach profile shifted the mass nesting ground 2km northward from the Gokhurkuda fish-landing center, formerly the extreme northern end of nesting of the rookery (Fig. 7).

The change in beach profile during the study period could have confounded any specific comparisons of segments of the beach for nest site fidelity study. Therefore, we only considered tag recaptures for nest site fidelity analysis. Of the 4411 turtles tagged at Rushikulya rookery (1997-2002), we identified 609 recaptures during March 2003 arribada at the same mass nesting beach and during 2004, we captured 318 turtles of which 128 turtles tagged in 1997-1999 and 190 turtles in 2002. Turtles tagged in Gahirmatha were recaptured at Devi and Rushikulya and vice-versa (Table 8). Although inter-rookery movement of Olive Ridley turtles in Odisha occurs [25], and turtles tagged in Odisha arose in Sri Lanka, this study revealed tag returns of turtle tagged further abroad. A nesting female Olive Ridley Turtle arrived during the arribada on 11th March 2004 with a metal carapace tag on its right marginal scute (Tripathy, personal communication). It is presumed that this turtle was tagged somewhere in the Philippines during the 1980s (Database of PAWIKAN Conservation Project, Government of Philippines) but the exact location cannot yet be confirmed. While monitoring mass nesting, we found 136 tagged turtles during the February 2004 arribada that nested during the subsequent arribada in March 2004.

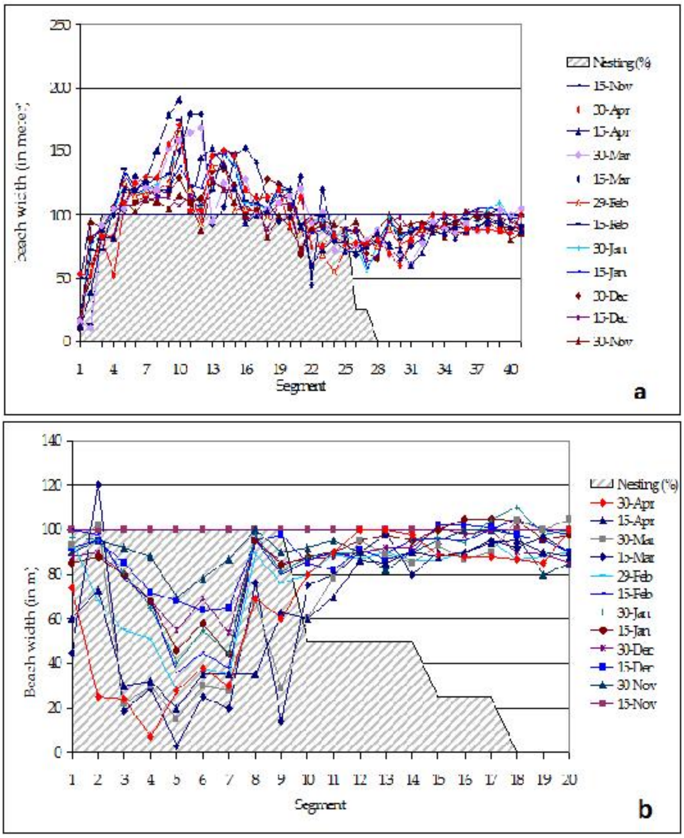

Fig 7. Beach profile of Rushikulya rookery : a - during 2003-04 sea turtle nesting season and b - during 2004-05 sea turtle nesting season.

Table 8. Details of beach exchange by Olive Ridley Turtles (*Lepidochelys olivacea*) between the sea turtle rookeries and sporadic nesting beaches in Odisha, India.

Date of tagging	Place of tagging	Turtle tag ID	Date of recapture	Place of recapture	Distance between the sites (tagging and capture;km)
24-04-1999	Devi	WG 6910	09-03-2003	Rushikulya	220
17-03-1999	Devi	WG 6326	09-03-2003	Rushikulya	220
06-12-1998	Gahirmatha	WG 5176	10-03-2003	Rushikulya	320
30-03-1997	Chilka	WG 20020	09-03-2003	Rushikulya	60
22-12-1998	Gahirmatha	WG 13061	10-03-2004	Rushikulya	320
07-01-1998	Gahirmatha	WG 04901	11-03-2004	Rushikulya	320
22-01-1998	Gahirmatha	WG 13062	11-03-2004	Rushikulya	320
17-03-1997	Devi	WG 06142	17-02-2005	Rushikulya	220
30-03-1997	Chilka	WG 20020	17-02-2005	Rushikulya	50
17-03-1997	Devi	WG 6146	17-02-2005	Rushikulya	220

Natural and anthropogenic threats to Olive Ridleys at Rushikulya Rookery: During November-April of 2003-04 and 2004-05, 92 and 108 dead Olive Ridley turtles were counted respectively. By the end of November 2003, two dead turtles were counted along this coast, After December the number of dead turtles started increasing (Fig. 8).

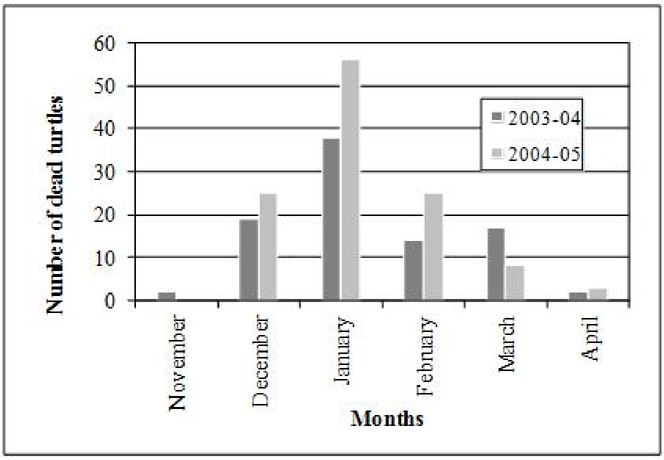

Fig. 8. Month-wise dead olive ridley turtles washed ashore along the Rushikulya rookery.

Of the total dead turtles that were sexed, 37 (18.2%) were male, 134 (66.6%) were female and 30 were unidentified carcasses. There was no significant difference in size between male and female dead turtles (two-sample t-test, $p > 0.05$) (Table 9; Fig. 9). During 2003-04 season, the nesting beach underwent remarkable changes. Considerable changes in beach profile were observed due to heavy natural erosion, and as a result more than 60% of the nests were washed along with the wave. In contract, there was little change in beach geomorphology during 2004-05. Although the beach stretch beyond Gokhurkuda village suffered from erosion, there was no egg loss, it was so because mass nesting of 2005 was confined to beach immediate north of the Rushikulya river mouth (segment #3-8) and there was no inundation of beach along this stretch during 2004-05 season. The data on nest predation by non-human predators at the Rushikulya rookery shows a difference in predation level in both the years. While 71.69% and 83.53% of the sporadic nests were predated during 2003-04 and 2004-05 season respectively (Fig. 9), the level of predation to arribada nests was as low as 8.32% and 2.62% for these years. All the sporadic nests were found excavated by jackal, hyena and or feral dogs as evidenced from direct sightings and their footprints. The mean interval between nest laid and predation was 5.8 days. Of the 74 nests where egg laying was observed during night, it was attacked later on the same night. On an average 48.43% of eggs in the nests (range 6 to 120 eggs) were found damaged by the predators. March and April months were the peak predation period for both the years. Hatchlings of turtles on the beach were found predated by feral dogs (*Canis familiaris*), house crows (*Corvus splendens*), Brahminy kites (*Haliastur indus*) and Brown-headed gulls (*Larus ridibundus*) mostly during early morning hours. On the beach, ghost crab (*Ocypoda ceratophthalma*), also a predator was found to be the common. Of the 45 nests of 2003-2004 that were randomly observed, orientation data was collected from 4865 hatchlings. Of these, 78.24% (±5.55 SE) hatchlings showed orientation towards sea, while only 21.76% (±4.38 SE) moved towards landward side of the beach. However, orientation of hatchlings towards land (towards the source of light) was very high during the 2004-05 season (90.59%; n = 6094) and only very few hatchlings moved towards the sea (9.24%). Majority of the hatchlings were seen crawling towards the land attracted by artificial illuminations from the Chloro-alkali plants and the nearby townships ($\bar{x}$ = 83.94±26.5 SD).

Table 9. Size measurements of male and female olive ridley turtles stranded on the beach along the Rushikulya rookery, Orissa coast.

	Curved Carapace Length		**Curved Carapace Width**	
***Sex* (n)**	**Mean ± S.E**	**Range**	**Mean± S.E**	**Range**
Males (37)	69.39 ± 0.5266	60.8 – 78.0	67.5 ± 0.6048	62.4 – 73.4
Females (134)	69.47 ± 0.6121	63.2 – 78.0	67.40 ± 0.5268	62.4 – 75.4
Unknown (30)	69.09 ± 0.6428	63.8 – 73.5	66.91 ± 0.7160	61.6 – 74.0

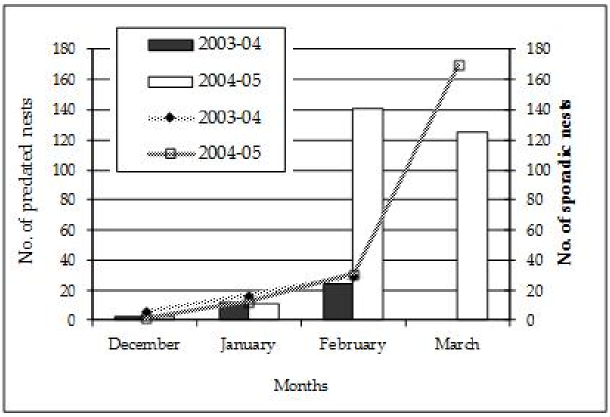

Fig. 9. Non-human predation of olive ridley nests at the Rushikulya rookery.

Although *arribadas* have not been recorded annually, there is evidence that Olive Ridley turtles congregate in the nearshore waters of Odisha from November to May every year. However, the spatial-temporal distribution of turtles during their breeding and migration is not well known. Line transects are considered one of the options for density estimation of Olive Ridley turtles at sea. The DISTANCE sampling method provides a robust estimation that can be applied effectively to estimate density of turtles at sea. Although enumerating mating pair density in an area can be used as an effective population-monitoring tool for turtles, reproductively active males are aggressive during the mating period and try to mount on many objects. *Pandav* [17] and the present study have observed mounting of three males over a female and male over male. Also, during the receptive period, females actively avoid males' courtship attempts, though the reason for such behaviour by females is not known adequately. Also, the sighting of a mating pair is closely linked with abiotic factors such as sea state, temperature, cloud cover and time of the day. In contrast, turtles on the surface can be seen anytime. They are slow to respond to the observer and thus easy to encounter in the transect line. In view of this, floating turtles bobbing their head frequently on the sea surface were considered for density estimation that provide a more precise index of the actual population in the water.

The turtle mating pairs at Rushikulya tend to occur in much shallower waters than at other rookeries for this species. *Reproductive patches* aggregated at a depth of ~50m at Nancite [8] and ~25m at Gahirmatha [6, 26]. However, the mating locations at Rushikulya are much shallower than the above. In the absence of bathymetric characteristics of the study area, however, it is difficult to infer whether turtles at Rushikulya prefer shallow areas for aggregation. The *reproductive patch* of turtles at Rushikulya were located just off the *arribada* beach and extended for a maximum of 5km from the shore. Although turtles dispersed in an area of ~250km^2, the major congregation was observed within ~60km^2. The results of the present study corroborate the findings at Gahirmatha and the Central Pacific. The *reproductive patches* observed elsewhere where Olive Ridley assemblage occurs were large aggregations located just off the *arribada* nesting beaches although *reproductive patches* known to shifts spatiotemporally. *Cornelius* and *Robinson* [33] have also observed activities of Olive Ridley turtles in the near-shore waters of Playa Nancite prior to *arribadas*. *Plotkin et* al., [8] suggested that female Olive Ridleys do not retreat offshore until they nest and this congregation close to the beach may enable them to conserve energy for nesting. However, contrary to such studies, *Kopitsky et al*., [34] suggests that Olive Ridleys are capable of mating in the pelagic zone, hundreds of kilometres from the nesting beaches, and hence there is a need for further long term observations in areas distant from the nesting beaches too. The small size of the boat did not allow us offshore survey beyond 10km. Therefore, future studies need to consider observations in the deeper waters off the coast using a bigger vessel. Similarly, it will be difficult to infer whether sea surface temperature has an influence on the mating behaviour of Olive Ridley turtles, unless long term monitoring of environmental parameters is conducted at Rushikulya rookery.

It is apparent that the solitary and arribada nesters are not different, but from the same population stock. The genetic study on Olive Ridley turtles from Odisha also supports this view [36]. Also, sporadic nests contribute equally to the population recruitment as that of arribada nesters being hatching success is higher for the later [16, 36]. Olive Ridleys along the Odisha coast are known to exhibit fidelity to their breeding as well as nesting ground [11, 37]. Nesting females are known to exhibit movement between rookeries in Odisha both within and between seasons [32, 38]. Migration and inter-rookery movement by females during the breeding and nesting season along Odisha coast has also been documented [25]. Hence, knowledge of the location and temporal use of nesting grounds of Olive Ridley turtles in Odisha is important in view of the habitat loss and large-scale mortality of turtles in the offshore waters. Therefore, along with protection of arribada nesters, it is necessary to monitor the beach and safeguard the sporadic nesters and their habitat as well.

Prior to this study, there were no proper estimates of the number of turtles that nest during arribada at the Rushikulya rookery. Our estimates show that the number of turtles could be much less than what is projected by various governmental agencies. Thus, declaration of a mass nesting population in broad terms (e.g. hundreds of thousands) without a proper assessment may result in the reduction of protection required for *L. olivacea* in their breeding ground, which is already meagre. Hence, standard and accurate techniques for mass nesting census are urgently required for additional years for monitoring the status and nesting trends of *L. olivacea* at the in Rushikulya rookery of Odisha. As evidence from the last decade of sea turtle mortality data from Odisha [26], reduction of the size class of individuals participating in arribadas [13, 35], and elimination of the older females from the breeding stock over a period of time. However, to confirm this, extensive and accurate measurements of the nesting females and clutch sizes need to be performed to determine if there is a difference/reduction in size of *L. olivacea* over the years at rookeries in Odisha, and thereby a declining of the Olive Ridley turtle population of the Indian Ocean area and or the rest of the world.

The typical internesting period (IP) for other genera of *Chelonia* is 10 to 15 days [39]. IP is usually the time between successive arribadas [40], which can occur at two to four week intervals [41, 42] but can exceed two months. We found the IP for Olive Ridley turtles at Rushikulya to be 22.09±0.58 SD days (range = 20 to 25 days). Internesting intervals range from as short as 9 days observed in *Dermochelys coriacea* [43] to as much as 66 days in *Lepidochelys olivacea* depending on environmental conditions [24, 44]. It is known that some Olive Ridley turtles may nest between arribadas as solitary nesters and nest for a shorter interval (14 days) than those nests during arribadas [5, 45]. In addition, solitary nesters have weak site fidelity [5]. One apparent difference between the *Lepidochelys olivacea* and the other species of chelonians is the ability to retain eggs for extended periods [45]. However, the mechanism of egg retention behaviour by the Olive Ridley turtle is unknown. Previous investigators reported movements by Olive Ridley turtles between nesting beaches ranging from 85km ([46], n = 3) to 160km ([47], n = 1). Our observations at Odisha are the longest reported inter-beach movements by Olive Ridley turtles (see Table 4). *Eckert et al*. [48] recorded similar movements between nesting beaches for Leatherback turtles (range = 30–110km). *Bjorndal et al*., [49] reported the distance between intra-seasonal re-nesting attempts of 38 Loggerhead turtles ranged ≤ 290km. Other records of intra-seasonal nesting movements suggest that few Loggerhead turtles travel long distances [50]. Records of inter-beach migration by Olive Ridley turtles exist for Nancite and Ostional in Costa Rica. Between 1980 and 1984, 29 Ostional Olive Ridley turtles arrived at Nancite and 35 Nancite turtles appeared at Ostional [51]. Therefore, it is possible that beach exchange is part of a complex phenomenon that Olive Ridley turtles use to colonize new areas or to colonize new beaches (thus adopt better reproductive strategy by females for survival of their offsprings [52]). Although shifts in nesting beach preference by Olive Ridley turtles is poorly understood, coastal geomorphology in the river mouth [53], topography [54], or offshore approaches [8] may influence beach selection by arribada nesters. Continuous monitoring of these nesting beaches is essential to determine the degree that such movements between nesting beaches occur.

Incidental capture of Olive Ridley turtles occurs worldwide in trawl fisheries, long-line fisheries, purse seines, gill net and other net fisheries and hook and line fisheries and considered to be serious threat to the species globally [2]. The Odisha Olive Ridley population has been subjected to high mortality in recent years; with over 10,000 turtles counted dead on the coast each year due to fishery related incidental mortality. We have documented 200 dead turtles, which is quite low when compared to the mortality figures for the entire Odisha coast for any year. Comparatively low mortality of turtles along the Rushikulya rookery could be due to the unique fishing practice in the area. Monofilament gillnets are not known to harm turtles as they are soft and turtles can easily break the webbing. In contrast, Gahirmatha and its adjacent areas are subjected to high mortality during the breeding season, where intense shrimp trawling occurs. The average sizes of dead turtles during this study were marginally smaller than those reported in 1999 and 2002. While turtle-fisheries interface at the Rushikulya rookery is least compared to other rookeries in Odisha, other problems are mounting seriously at this rookery. Apart from the proposed developmental activities (proposed ports, oil refineries, coastal industries etc.), the immediate threats to turtles here are beach erosion, *Casuarina* plantation and mortality of hatchlings due to artificial illumination.

Nests deposited on shifting beaches are more susceptible to damage due to erosion. Almost 40–60% of the nests of leatherbacks laid on shifting beaches are reported to have been lost because of beach erosion. The shifting of the Rushikulya river mouth from north to south and vice versa is known for a long time. As a result of this, there has been a substantial loss of nesting habitat at this rookery. *Dash and Kar* [55], *Choudhury et* al. [56], *Mortimer* [57] and *Cornelius* and *Robinson* [40] have suggested that heavy loss of the post ovipositional eggs could occur as a result of beach erosion at mass nesting sites. Erosion of Gahirmatha beach after the 1970's was due to *Casuarina* plants planted along the coast. Similar erosion had occurred at Rushikulya rookery in the last few years affecting the nesting beach at Rushikulya.

The other factors that affect turtle eggs, juveniles and the hatchlings at Rushikulya are the non-human predation. Besides ghost crab, large numbers of nests were found predated by various mammalian species *viz*. feral dog, hyenas and jackals immediately after nesting was over. The nesting sites of sea turtles usually are islands, free from mammalian predators. Even mainland nesting populations often utilize stretches relatively free from human use and terrestrial predators. The Rushikulya rookery initially was separated from mainland by a channel, which become shallow and bridges were constructed at many places for accessing the beach for use by fisherfolk. This has allowed the mammalian predators to access the beach.

Casuarina trees have been extensively planted all along the coast of Odisha. While 50% of the mass nesting beach of Rushikulya is devoid of plantation, the rest areas are backed with dense *Casuarina* plantation. Those nests laid inside the *Casuarina* shrubs were immediately predated upon by jackals and dogs. *Casuarina* is known to be detrimental to the nesting sea turtle population in more than one way. Dense *Casuarina* causes excessive shading on the nesting beach. Studies in Florida suggest that nests laid in the shaded areas are subjected to lower incubation temperature and which can alter the sex ratio of the population. There is report of declines in nesting activities of loggerhead in Everglades National Park where dense stands of *Casuarina* took over the native beach vegetation. The Supreme Court constituted the Central Empowerment Committee of India has strongly recommended for the removal of *Casuarina* and the restoration of natural beach condition at three sea turtle mass nesting sites along the Odisha coast. Under natural condition, sea turtle hatchlings move directly towards the sea after they emerge out from the nest. However, when any kind of artificial source of light present near the nesting beach, they tend to move towards the source of light as it disrupts the sea finding behaviour of the hatchlings. The Rushikulya rookery beach is illuminated due to the presence of various artificial illumination sources which has caused disorientation of hatchlings leading to death on the beach.

Conclusions

The decade of data on Olive Ridley turtle migration and movement from Odisha suggests that they use multiple habitats for breeding and mass nesting. Thus, protection of isolated beaches is insufficient for population sustainability because Olive Ridley turtles in Odisha use multiple beaches for nesting. The genetic study on Olive Ridley turtles of Odisha supports that the populations that are nesting in Orissa could be a single population dispersed into the three rookeries along the coast rather than three different populations [35]. Therefore, it may be necessary to pool data from the three rookeries when estimating the mass nesting population in Odisha. Also, there is clearly unsustainable heavy mortality of turtles at the Gahirmatha and Devi rookeries. Therefore, equal amount of protection should be pertaining on all three rookeries of Odisha and for conservation of Olive Ridley turtles during the breeding phase. Development of suitable conservation and management plans for Olive Ridley turtles from the Odisha Coast of India will require continued tagging efforts to identify more thoroughly their demographics. The Olive Ridley turtles in Odisha are now exposed to many problems other than fishing related casualty and precautionary measures need to be taken by the wildlife and forest authority to safeguard the Olive Ridleys and their nesting habitat including the Rushikulya rookery of Odisha coast.

Acknowledgements

This study is part of the author's doctoral work on Olive Ridley turtles in Odisha. I am thankful to the Orissa Forest Department for granting permission to me for carrying out the field work. I am also indebted to Bivash Pandav, Kartik Shanker and B.C. Choudhury for their supports in various ways during field work. I am equally thankful all field personnel for assisting me in the field and help in necessary data collection.

Funding body

The above study was part of doctoral work of the author and conservation programmes undertaken by him through various sources of funding. BT would like to thank the Wildlife Conservation Society-India Programme, Bangalore for support towards studying the offshore biology, the Wildlife Trust of India for studying the nesting biology and bahaviour of olive ridley during solitary and arribada nesting at Rushikulya and the World Turtle Trust, Hono Lulu, USA for support provided for studying the incubation success and hatchlings behavior during post nesting season. He would like to place on record the help, support and permission for study provided by the Wildlife Wing of Odisha Forest Department, Bhubaneswar. The author is also thankful to the Department of Science and Technology, Government of India, New Delhi and Wildlife Institute of India, Dehradun for supporting him during and after his doctoral work. The author was supported by Zoological Survey of India, Kolkata during preparation of the manuscript.

References

[1] J. Bernardo, P.T. Plotkin, *An evolutionary perspective on the arribada phenomenon and reproductive behavioral polymorphism of Olive Ridley sea turtles (Lepidochelys olivacea)*, **Biology and Conservation of Ridley Sea Turtles**, edited by P.T. Plotkin, Johns Hopkins University Press, Baltimore, 2007, pp. 59-87.

[2] * * *, **Committee on Sea Turtle Conservation**, National Research Council (U.S.), National Academy Press, 1990.

[3] S. Behera, B. Tripathy, K. Sivakumar, B.C. Choudhury, C. Kar, *Nesting Habitat Suitability for Olive Ridley Turtles (lepidochelys olivacea) at the Gahirmatha Rookery,Odisha Coast of India*, **International Journal of Conservation Science**, 4(4), 2013, pp. 477-484.

[4] L.D. Alfaro, V. Montalvo, F. Guimaraes, C. Saenz, J. Cruz, F. Morazan, E. Carrillo, *Characterization of Attack Events on Sea Turtles (chelonia mydas and lepidochelys olivacea) by Jaguar (panthera onca) in Naranjo Sector, Santa Rosa National Park, Costa Rica*, **International Journal of Conservation Science**, 7(1), 2016, pp. 101-108.

[5] H.J. Kalb, Behavior and physiology of solitary and arribada Olive Ridley sea turtle (Lepidochelys olivacea) during the internesting period, **Ph.D. Thesis**, Texas A & M University, USA, 1999, p. 200.

[6] K. Ram, Behavioral ecology of the Olive Ridley sea turtle Lepidochelys olivacea (Eschscholtz, 1827) during the breeding period, **Masters' Dissertation**, Salim Ali School of Ecology, Pondicherry University, 2000.

[7] J.D. Richard, G.R. Hughes, *Some observations of sea turtle nesting activity in Costa Rica*, **Marine Biology**, **16,** 1972, pp. 297-309.

[8] P. Plotkin, M. Polak, D.W. Owens, *Observations on Olive Ridley Sea Turtle Behavior Prior to an Arribada at Playa Nancite, Costa Rica*, **Marine Turtle Newsletter**, **53**, 1991, pp. 9-10.

[9] H.J. Kalb, R. Valverde, D.W., Owens, *What is the reproductive patch of the olive ridley sea turtle ?*,**Proceedings of the 12th Annual Workshop on Sea Turtle Conservation and Biology**, Jekyll Island, Georgia, USA. NOAA Technical Memorandum NMFS-SEFSC, 1992, pp. 57-61.

[10] K. Kopitsky, R.L. Pitman, P. Plotkin, *Investigations on at-sea mating and reproductive status of olive ridleys, Lepidochelys olivacea, captured in the eastern tropical Pacific*, **Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation** (Editors: H.J. Kalb, and T. Wibbels), NOAA Technical Memorandum NMFS-SEFSC-443, 2000, pp. 160-162.

[11] M.C. Dash, C.S. Kar, **Turtle Paradise-Gahirmatha (An Ecological Analysis and Conservation Strategy)**, Interprint, New Delhi, India, 1990.

[12] B. Pandav, B.C. Choudhury, C.S. Kar, **A Status Survey of Olive Ridley Sea Turtle (*Lepidochelys olivacea*) and Their Nesting Beaches Along the Orissa Coast, India**, Wildlife Institute of India, Dehradun, India, 1994, p. 48.

[13] B. Tripathy, A study on the ecology and conservation of Olive Ridley sea turtle Lepidochelys olivacea at the Rushikulya rookery of Orissa coast, India, **Ph.D. Thesis**, Andhra University, India, 2005.
[14] P.C.H. Pritchard, Evolution, phylogeny and current status, **The Biology of Sea Turtles**, (Editors: P.L. Lutz and J.A. Musick), Boca Raton, Florida, CRC Press, 1997, pp. 1–28.
[15] C.S. Kar, *Discovery of second mass nesting ground for Pacific ridley sea turtles in Orissa, India*, **Tiger Paper, 9**(1), 1982, pp. 6-7.
[16] J.C. Castro, *Contribución de las tortugas loras solitarias*, Lepidochelys olivacea, *en el mantenimiento de esta especie*, **Tesis de Licenciatura**, Universidad de Costa Rica, 1986.
[17] B. Pandav, *Conservation and management of Olive Ridley sea turtle (*Lepidochelys olivacea*) along the Orissa coast*, **PhD Thesis**, Utkal University, Orissa, India, 2000, pp. 148.
[18] K. Shanker, B. Pandav, B.C. Choudhury, *An assessment of the Olive Ridley turtle (Lepidochelys olivacea) nesting population in Orissa, India*, **Biological Conservervation 115**, 2003, pp. 149-160.
[19] * * *, **Orissa State Forest Department**, Government of Orissa, http://www.wildlifeorissa.org.in.
[20] S.K. Pattanaik, C.S. Kar, S.K. Kar, A **Quarter Century of Sea Turtle Conservation in Orissa,** Publication of Wildlife Wing of Forest Department, Government of Orissa Publication, Bhubaneswar, 2001, p. 34.
[21] R.A. Valvarde, C.E. Gates, *Population surveys on mass nesting beaches*, **Research and Management Technique for Conservation of Sea Turtles** (Editors: K.L. Eckert, K.A. Bjorndal, F.A. Abrell-Grobois, M. Donnelly), IUCN Marine Turtle Specialist Group Publication 4, CGC, Blanchard, Pennsylvania, USA, 1999, pp. 56–60.
[22] P.T. Plotkin, *The migratory and reproductive behavior of the Olive Ridley*, Lepidochelys olivacea *(Eschscholtz, 1829) in the eastern Pacific Ocean*, **Ph.D. Dissertation**, Texas A and M University, College Station, Texas, USA, 1994, p. 241.
[23] P.T. Plotkin, R.A. Byles, D.W. Owens, *Migratory and reproductive behavior of* Lepidochelys olivacea *in the eastern Pacific Ocean*, **Proceedings of the Thirteen Annual Symposium on Sea Turtle Biology and Conservation** (Editors: B.A. Schroeder and B.E. Witherington), NOAA Tech Memo NMFS-SEFSC-341, 1994, pp. 138.
[24] Plotkin, P. T. D. C. Rostal, R. A. Byles, D. W. Owens, *Reproductive and developmental synchrony in female Lepidochelys olivacea*, **Journal of Herpetology**, **31**, 1995, pp. 17-22.
[25] B. Pandav, B. C. Choudhury, *Migration and movement of Olive Ridley Turtles along the east coast of India*, **Marine Turtles of the Indian Subcontinent** (Editors: B.C. Choudhury and K. Shanker), Universities Press, Hyderabad, AP, India, 2006, pp. 365–379.
[26] B. Pandav, B.C. Choudhury, *Conservation and management of Olive Ridley sea turtle (Lepidochelys olivacea) in Orissa*, **Project Final Report**, Wildlife Institute of India, 2000, pp. 77.
[27] H. Chavez, *Tagging and recapture of the Lora Turtle Lepidochelys kempi*, **International Turtle and Tortoise Journal, 3,** 1969, pp. 32-38.
[28] R. Gouda, R.C. Panigrahy *Monthly variation of some hydrographic parameters in the Rushikulya Estuary*, **Mahasagar**, **26**(2), 1993, pp. 73-85.
[29] R. Gouda, R.C. Panigrahy *Zooplankton ecology of the Rushikulya estuary, East coast of India*. **Journal of Aquaculture in Tropics 10**(3), 1995, pp. 201-211.
[30] U. Tietze, **Artisanal Marine Fisherfolk of Orissa: Study of Their Technology, Economic Status, Social Organization and Cognitive Patterns,** Vidyapuri, Cuttack, 1985.
[31] B. Schroeder, S. Murphy, *Population Surveys (ground and aerial) on Nesting Beaches* **Research and Management Techniques for the Conservation of Sea Turtles** (Editors:

K.L. Eckert, K.A. Bjorndal, F.A. Abreu-Grobois and M. Donnelly), IUCN/SSC Marine Turtle Specialist Group Publication No. 4. Washington, DC, 1999, pp.1-11.

[32] B. Pandav, B.C. Choudhury, *Conservation and management of Olive Ridley Turtles (Lepidochelys olivacea) in Orissa. India*, **Unpublished Report**, Wildlife Institute of India, Dehra Dun Report, 2000, p. 77.

[33] S.E. Cornelius, D.C. Robinson, *Post nesting movements of female Olive Ridley Turtles tagged in Costa Rica*, **Vida Silvestre Neotropical**, **1**(1), 1986, pp. 12-23.

[34] K. Kopitsky, R.L. Pitman, P.T. Plotkin, *Investigations on at-sea mating and reproductive status of Olive Ridleys, Lepidochelys olivacea, captured in the eastern tropical Pacific*. **Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation** (Editors: H.J. Kalb and T. Wibbels), NOAA Technical Memorandum, NMFS-SEFSC-443, 2000, pp. 160-162.

[35] K. Shanker, R.K. Aggarwal, J. Rama Devi, B.C. Choudhury, L. Singh, *Phylogeography of Olive Ridley turtles (Lepidochelys olivacea) on the east coast of India: implications for conservation theory*, **Molecular Ecology, 13**, 2004, pp. 1899–1909.

[36] B. Tripathy, B. Pandav, R.C. Panigrahy, *Hatching success and orientation of Lepidochelys olivacea (Eschscholtz, 1829) at Rushikulya rookery, Orissa, India*, **Hamadryad, 27**(2), 2003, pp. 185–192.

[37] B. Pandav, K. Banugopan, D. Sutaria, B.C. Choudhury, *Fidelity of male Olive Ridley Turtles to a breeding ground*, **Marine Turtle Newsletter**, **87**, 2000, pp. 9–10.

[38] B. Tripathy, B. Pandav *Beach fidelity and internesting movements of olive ridley sea turtles* (*Lepidochelys olivacea*) *at Rushikulya, India*, **Herpetological Conservation and Biology 3**(1), 2008, pp. 40-45.

[39] L.M. Ehrhart, *A review of sea turtle reproduction*, **Biology and Conservation of Sea Turtles,** Smithsonian Institution Press, Washington, D.C., USA, 1982, pp. 29-38.

[40] S.E. Cornelius, D.C. Robinson, *Post nesting movements of female Olive Ridley Turtles tagged in Costa Rica*, **Vida Silvestre Neotropical**, **1**(1), 1986, pp. 12-23.

[41] P.C. H. Pritchard, *Studies of the systematics and reproductive cycles of the genus Lepidochelys*, **Ph.D. Dissertation**, University of Florida, Gainesville, Florida, USA, 1969, p. 226.

[42] M.R. Márquez, O.A. Villanueva, C. Peñaflores, *Sinopsis de datos biológicos sobre la tortuga golfina, Lepidochelys olivacea (Eschscholtz, 1829),* **Instituto Nacional de la Pesca, México**, INP Sinop. Pesca 2, 1976, p. 61.

[43] D.C. Rostal, J.S. Grumbles, K.S. Palmer, V.A. Lance, J.R. Spotila, F.V. Paladino, *Reproductive endocrinology of the leatherback sea turtle (Dermochelys coriacea),* **General and Comparative Endocrinology**, **122**, 2001, pp. 139-147.

[44] P.T. Plotkin, M.K. Wicksten, A.F. Amos, *Feeding ecology of the loggerhead sea turtle* (*Caretta caretta) in the North-Western Gulf of Mexico*, **Marine Biolology**, **115**(1), 1993, pp. 1-15.

[45] D.C. Rostal, J.S. Grumbles, R.A. Byles, M.R. Márquez, D.W. Owens, *Nesting physiology of wild Kemp's Ridley Turtles, Lepidochelys kempii, at Rancho Nuevo, Tamaulipas, Mexico*, **Chelonian Conservation and Biology, 2,** 1997, pp. 538-547.

[46] J.P. Schulz, *Nesting beaches of sea turtles in west French Guiana*, **Koninkl** (Nederland Akademie van Wetenschappen – Amsterdam), **74**, 1971, pp. 396-404.

[47] A. Meylan, *Behavioral ecology of the West Caribbean Green Turtle (Chelonia mydas) in the internesting habitat,* **Biology and Conservation of Sea Turtles** (Editor: K.A. Bjorndal), Smithsonian Institute Press, Washington, D.C., USA, 1982, pp. 67-80.

[48] K.L. Eckert, S.A. Eckert, T.W. Adams, A.D. Tucker, *Inter-nesting migrations by Leatherback Sea Turtles (Dermochelys coriacea) in the West Indies*, **Herpetologica**, **45**, 1989, pp. 190-194.

[49] K.A. Bjorndal, A. Carr, A.B. Meylan, J.A. Mortimer, *Reproductive biology of the hawksbill, Eretmochelys imbricata at Tortuguero, Costa Rica, with notes on the ecology of the species in Caribbean*, **Biological Conservation, 3**, 1985, pp. 353-368.
[50] C.J. Limpus, *A study of the loggerhead turtle, Caretta caretta in Queensland*, **PhD. Thesis**, University of Queensland, Brisbane, Australia, 1985, pp. 481.
[51] S.E. Cornelius, D.C. Robinson, *Abundance, distribution and movements of Olive Ridley Sea Turtles in Costa Rica (I-V),* **United States Fish and Wildlife Service Report**, Albuquerque, New Mexico, U.S.A., 1981-1985.
[52] S. Morreale, P. Plotkin, D.J. Shaver, H.J. Kal, *Adult migration and habitat utlilization*, **Biology and Conservation of Ridley Sea Turtles** (Editor: P. Plotkin), Johns Hopkins University Press, Baltimore, Maryland, USA, 2007, pp. 213-229.
[53] G. Prusty, S. Dash, *The effect of rookery geomorphology on Olive Ridley nesting in Gahirmatha, Orissa*. **Marine Turtles of the Indian Subcontinent** (Editors: B.C. Choudhury and K. Shanker), Universities Press, Hyderabad, AP, India, 2006, pp. 384-392.
[54] A.M.J. Meijerink, *Dynamic geomorphology of Mahanadi delta*, **ITC Journal**, Special Verstappen Volume, 1982, pp. 243-250.
[55] M.C. Dash, C.S. Kar, **Turtle Paradise-Gahirmatha (An Ecological Analysis and Conservation strategy),** Interprint, New Delhi, India, 1990.
[56] B.C. Choudhury, B. Pandav, B. Tripathy, H.A. Andrews, **Sea Turtle Conservation: Eco (turtle) friendly Coastal Development,** Centre for Herpetology/MCBT, Mammalapuram, Tamil Nadu, India, 2003.
[57] J.A. Mortimer, *Reproductive ecology of the green turtle, Chelonia mydas at Ascension Island*, **Ph.D. Thesis**, University of Florida, USA, 1981.

Received: March, 21, 2015
Accepted: December, 02, 2016