Conservation and Management of olive ridley sea turtle (Lepidochelys olivacea) in Orissa, India

Principal Investigator
B. C. Choudhury

Researcher
Bivash Pandav

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

This report is an out come of the Wildlife Institute of India's research project entitled "An ecological analysis of critical sea turtle habitats in Orissa for the development of a scientific sea turtle management strategy". Field work for the research project was carried out between 1995 and 1999. During this project nearly 13,000 olive ridley sea turtles were tagged in different parts of Orissa coast and their movements were monitored. Death of more than 46,000 adult olive ridleys were documented during this study.

Citation: Pandav, B. and B. C. Choudhury (2000). Conservation and management of olive ridley sea turtle (*Lepidochelys olivacea*) in Orissa. Final report. Wildlife Institute of India

Contents

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

This report is an outcome of Wildlife Institute of India's (WII) sea turtle research program in Orissa. We express our sincere gratitude to Mr. S. K. Mukherjee, Director, WII for all his advice, support and constant encouragement. We thank him for providing proper guidance and an absolutely wonderful working atmosphere.

The Orissa Forest Department gave the necessary permission to carry out fied work along the coast. We thank the Chief Wildlife Warden, Orissa for the same. The Divisional Forest Officers (Mr. Ashish Mohapatra, Mr. B. N. Nayak and Dr. P. R. Karat) and the Assistant Conservator of Forests (Mr. Arun Mishra, Mr. Manoj Mahapatra and Mr. Kedar Swain) of Mangrove Forest Division, Raj Nagar provided all sorts of support while carrying out field work at Gahirmatha.

Funds to carry out the tagging program came from the Norwegian Agency for Development (NORAD) through the M. S. Swaminathan Research Foundation (MSSRF), Chennai. We thank Dr. R. J. Ranjit Daniels and Dr. Hemal Kanvinde of MSSRF for their support while carrying out the field work.

We had a fantastic team assisting us throughout the Orissa coast in carrying out the field-work. Kalia, Subhas, Madhu, Siria and Sarbeswar at the Gahirmatha camp; Tuku, Tulu, Deva, Bishnu and Bichitra at Devi mouth camp; and Rabi, Damburu and Gouranga at the Rushikulya camp have spent many sleepless nights, looking for turtles to tag and counting the dead turtles. It would have been next to impossible for us to carry out this work without all their support. We also deeply appreciate the help of all the research assistants, Sushant, Basu, Arjun, Majumdar, Banu and Dipani during this work.

Drs. D.D. Pandav and Sova Das provided their whole hearted support in all aspects while carrying out field work in Orissa. We greatly acknowledge their unconditional support in carrying out this piece of work in Orissa. At WII Mr. Panna Lal, Mr. Virendra Sharma and Mr. Veerappan helped us a lot in drawing the maps and in finalizing the lay out of the report.

And finally, watching the armada of turtles ascending a remote speck of beach in hundreds of thousands was the most exhilarating experience in our life. We thank these ancient animals for giving us this privilege.

ABSTRACT

Olive ridley sea turtle (*Lepidochelys olivacea*) nests in low densities all along the east-coast of India. However, the most important nesting beaches lie in Orissa where the mass nesting occurs. Three of the world's six known major mass nesting beaches of olive ridley occur in Orissa. The three mass nesting beaches in Orissa at Gahirmatha, Devi River mouth and Rushikulya together support a significant portion of the world's olive ridley population. Although the nesting population at Gahirmatha has been the focus of several studies over the past two decades, little is known about the turtles at the other two rookeries in Orissa. This study aimed at monitoring the turtle population all along the Orissa coast and addressing certain key issues related to their conservation.

The off shore aggregations of olive ridleys in the coastal waters off Gahirmatha as well as the nesting populations at the three rookeries were studied during 1995 – 1999. 1,767 olive ridley mating pairs were captured in the coastal waters off Gahirmatha of which 1,657 males and 1,616 females were double tagged using monel metal flipper tags. On the beach, 10,327 nesting females were tagged during the study. This study reveals that straight carapace lengths of males and females at Gahirmatha are 66.2 ± 2.9 cm and 66.7 ± 2.4 cm respectively. When compared with sizes from other populations it seems clear that average lengths of carapaces and range of sizes obtained in this study are larger than other geographical regions. Both male and female olive ridleys showed strong fidelity to breeding ground. Upon remigration ridleys tagged at Rushikulya rookery re-laid their eggs within 100 to 300 m of their previous nests with a range of 0 to 1,000 m. Nesting females also showed some degree of movement between nesting beaches, both within as well as between nesting seasons. The range of such inter-rookery movement of olive ridley in Orissa varied from 35 to 320 km (n = 6). Recovery of 14 tagged turtles from Sri Lanka and three from South Tamilnadu (Gulf of Mannar) provides a clue about the non breeding areas of olive ridleys nesting in Orissa. One year remigration intervals were the commonest for ridleys of both sexes with the second and third year intervals are correspondingly less common. Tag recovery from dead turtles washed ashore the Orissa coast also showed considerable movement in the coastal waters off Orissa.

The location of olive ridley mating pairs, sighted during the study, in the coastal waters off Gahirmatha were recorded and the extent of distribution was obtained by drawing a Minimum Convex Polygon around the turtle locations. Mating pairs were found to be aggregated in an area of 52.58 sq. km (100% MCP) in the coastal waters off Gahirmatha and the area of maximum utilisation was 27.52 sq. km (90% Harmonic Mean). All the sightings of mating pairs recorded during the study were within 5 km of the coast line. All the observed mating took place within a depth of 20 meters. Turtles nesting in Orissa showed a distinct temporal pattern of nesting with most of the nesting taking place during neap tidal nights. A drastic change in beach profile was observed at the Nasi rookery, Gahirmatha during the study. In total, 34,469 and 77,208 eggs were examined respectively at Gahirmatha and Rushikulya rookery to determine the incubation success. The mean percentage hatching success and emergence success at Gahirmatha vried from 47.7 to 94.4 and 39.8 to 84.3 respectively. Similarly, the mean percentage hatching success and

emergence success at Rushikulya varied from 83.8 to 97.01 and 69.78 to 96.1 respectively. The overall man hatching success of the nests in the whole period of study were 63.5 ± 30.4 (range = 0 to 100, n = 277 nests) and 95.01 ± 7.03 (range = 39.7 to 100, n = 600 nests). A significant difference in hatching success ($F = 304.137$, $df = 1$, $p < 0.001$) as well as emergence success ($F = 282.127$, $df = 1$, $p < 0.001$) was observed between Gahirmatha and Rushikulya.

Of the two mass nesting beaches (Gahirmatha and Rushikulya) regularly monitored during the study, extensive beach erosion was observed at the Nasi rookery, Gahirmatha. Beach erosion resulted in loss of almost 59% of the total nesting area at Nasi rookery, Gahirmatha. The dis-orientation of turtle hatchlings at Rushikulya was prevalent at Rushikulya rookery. During the study, the Orissa coast witnessed an exponential increase in number of dead turtles. In total 46,219 adult olive ridleys were counted washed ashore the Orissa coast during the study. All the dead turtles counted during the study were adults. The number of dead turtles counted in the survey sectors showed a strong correlation with the number of mechanised fishing vessels operating in their respective coastal waters.

The findings of this study strengthen the case for establishing a net work of protected areas for sea turtles along the Orissa coast. This study proves the fact that olive ridleys in Orissa use more than one beach for nesting during the same as well as subsequent breeding season. Based on the movement of turtles between nesting beaches and in the coastal waters off Orissa obtained during this study it is proposed that the entire sea turtle population visiting Orissa coast should be considered as a single conservation unit. Therefore protection of all the three mass nesting beaches as well as their coastal waters are extremely crucial for the survival of sea turtles in Orissa which could well be a single population. Further the analysis on incubation success data strengthens the importance of smaller rookeries like Rushikulya.

The large-scale mortality of adult turtles in Orissa recorded during the study is a matter of utmost concern and need to be addressed immediately. The need for strengthening the patrolling in offshore waters where turtle congregation occur and the use of Turtle Excluder Device are some of the steps suggested that needs to be taken up immediately. Turtle congregations like that in the coastal waters off Gahirmatha need to be located along rest part of the Orissa coast so that adequate protection can be provided to the turtles in the offshore waters. Keeping in view the intensity of artificial illumination at Rushikulya rookery, the use of low intensity lights are suggested to mitigate the problem. Finally this study recommends a continuous monitoring of the turtle population in Orissa which is undoubtedly under great threat.

INTRODUCTION

1.1. PROJECT BACKGROUND

The olive ridley sea turtle (*Lepidochelys olivacea*) nests in varied densities along the entire east coast of India. However, the most important nesting beaches are located in Orissa, where the mass nesting occurs. Three of the world's six known major mass nesting beaches are located in Orissa. A significant portion of the world's olive ridley population that migrates every winter to the Indian coastal water nests at the three rookeries; Gahirmatha, Devi River mouth and Rushikulya along the Orissa coast.

The Gahirmatha beach was the first of Orissa's nesting beaches to be made known to the scientific and conservation community in mid 1970's by the FAO/UNDP crocodile project (Bustard, 1976). Substantial nesting has been recorded at this site with over 100,000 turtles in most years and over 600,000 turtles in peak years (Dash and Kar, 1990). The rookery near the mouth of river Devi is located 100 km south of Gahirmatha. Though this rookery was discovered in 1981 (Kar, 1981), the management and scientific community did not monitor this site till mid 1990's. In 1993-94, the Wildlife Institute of India (WII) in collaboration with the wildlife wing of the Orissa Forest Department carried out a status survey of olive ridley sea turtle and its nesting habitats in Orissa (Pandav et al., 1994a). This survey led to the discovery of the third sea turtle rookery near the mouth of river Rushikulya along southern Orissa coast (Pandav et al., 1994a, b). This survey also monitored and documented the continuation of olive ridley mass nesting of much lower intensity along the sea coast near Devi River mouth.

Fig. 1.1 Olive ridley is the smallest and most numerous among all sea turtles. This species commonly occurs all along the Indian coast

The survey by Pandav et al. (1994a) documented a distinct pattern of olive ridley nesting along the Orissa coast with the mass nesting first starting at Gahirmatha followed by arribadas at Devi and Rushikulya rookeries, almost after a month of nesting at Gahirmatha. However, it was not clear whether the Gahirmatha population after commencement of first mass nesting are dispersing to nest in Devi and Rushikulya rookeries, or the populations nesting at Devi and Rushikulya are two different ones. It was also not clear whether large number of ridley nest every year at Devi and Rushikulya rookeries or not.

The three sea turtle mass nesting beaches along the Orissa coast collectively support a nesting population of probably more than half a million olive ridleys (Pandav et al., 1994a) and this number is comparable to the collective number of other three large scale rookeries of olive ridleys located in the Pacifics. In this context, the Orissa coast is extremely important for olive ridley conservation and can also be termed as a place of globally important ecological site. Due to lack of proper coastal zone protection guidelines and effective management policy, the sea turtle mass nesting beach at Devi River mouth has been altered by Casurina plantations (Pandav et al., 1994). Construction of fishing jetties in the vicinity of Gahirmatha nesting beach has also drawn world wide attention in the early 1990s.

Fig. 1.2 Hundreds of thousands of olive ridleys nest in most years at Gahirmatha. Discovered in 1974, Gahirmatha is considered to be one of the largest nesting sites of sea turtles in the world.

From the mid 80's till now the olive ridley sea turtle population in Orissa has become the focus of world wide attention because of their large scale mortality due to mechanised marine fishing activities. Significant mortality of breeding male and female olive ridley along the Orissa coast have been documented during the mid 1980's (Silas et al. 1983). However, systematic survey of mortality of olive ridley all along the Orissa coast was taken up only after 1993. During the survey undertaken by WII, large scale mortality of olive ridley was documented all along the Orissa coast (Pandav et al. 1997).

In this background the present project was undertaken by the WII during the year 1995-96 to 1998-99 to collect reliable information on olive ridley biology and ecology and information on its habitat and other associated factors to develop a management strategy and action plan for the olive ridley sea turtles along the Orissa coast. The principal aims of the study were (i) to examine the distribution of olive ridley sea turtle and (ii) to study the population dynamics of the nesting turtles along the Orissa coast. In addition, information on threats to the olive ridley population along the Orissa coast, their migration and movement patterns were also planned to be collected so as to develop a realistic management strategy.

1.2. GOALS AND OBJECTIVES OF THE STUDY

The overall goal of this project was to provide scientific information that is needed for developing and implementing the long-term conservation and management of the olive ridley sea turtle population in Orissa. The specific objectives of the study were as follows:

i. To study the distribution of olive ridley sea turtle population along the Orissa coast.
ii. To enumerate the olive ridley nesting population and study the population dynamics at the rookeries in Orissa.
iii. To make regular annual survey of sea turtle nesting beaches along Orissa coast and in the off-shore waters in order to find out their extent of dispersal in the off-shore waters during breeding season.
iv. To monitor causes and levels of incidental catch of sea turtles by off-shore fishing operations and finding ways and means of reducing the mortality.
v. To study the impact of fish landing centres near important sea turtle nesting beaches along Orissa coast and based on the above
vi. To develop an effective eco-friendly management policy for the proper management of sea turtle population and their nesting habitats along the Orissa caost.

1.3. THE PROBLEM OF SEA TURTLE CONSERVATION

Marine turtles had their origin during the rise and reign of dinosaurs. Most of the air-breathing marine reptiles such as ichthyosaurs and plesiosaurs went extinct by the end of the Cretaceous era, but sea turtles tenaciously survived and flourished up until very recent times. But today their numbers are drastically reduced to the point that all seven remaining sea turtle species are considered either globally threatened or endangered. Undoubtedly, human interference is the major cause of this collapse. The challenges that sea turtles now face from human impacts affect every stage of their life cycle. Green and olive ridley turtles have been harvested in large numbers especially for meat. The

Fig. 1.3 Unlike many other marine life forms sea turtles are air breathers, at regular interval a sea turtle surfaces to breathe. Forcing the sea turtles to stay under water for more than an hour results in death.

hawksbill turtle has been hunted exclusively for tortoiseshell. International trade on tortoiseshell has played a prominent role in the depletion of 80% of the global hawksbill population in the last hundred years (Meylan and Donnelly, 1999). All species are hunted for leather, oil and their eggs. In some cases, egg collection alone has been implicated in the demise of entire population.

Incidental capture in fishing gear has also caused significant mortalities of marine turtles, especially in shrimp trawls, drift nets, large mesh set nets and long lines. Incidental capture in shrimp trawls has been implicated in population declines in the USA and Mexico (National Research Council, 1990), and Australia (Limpus and Reimer, 1994). In some areas, ingestion of plastic and other debris has been identified as a significant cause of mortality (Lutcavage et al., 1997). Mining of beach sands and urbanisation near nesting habitats have destroyed many marine turtle nesting beaches. The inexorable spread of beach development eats away natural sea turtle nesting habitats. Artificial illumination resulting from these developmental activities is detrimental to sea turtles because it disrupts critical behaviours, including nest-site choice and the nocturnal sea-finding behaviour of both hatchlings and nesting females (Witherington, 1992). Companion animals and pets attracted to trash and food remains left by humans can have a devastating impact on the sea turtle nesting beaches. Nesting depredation by feral dogs, wild pigs, jackals, foxes, coyotes and coatis can destroy up to 100% of nests (Stancyk, 1982).

There is ample evidence that human activity is seriously affecting once abundant sea turtle populations (Lutcavage et al., 1997). In order to be biologically effective, conservation programmes must be firmly based on knowledge of how and to what extent humans are jeopardising the survival of turtles. In order to be accepted both politically and practically, conservation programs must also recognise the economic forces behind the disturbing influences. These are different in different countries and implementing conservation measures are part of a complex process. Nevertheless, action is urgently required to halt the decline of sea turtles and turn the situation around. Otherwise, the extinction of local populations and even some species is inevitable.

1.4. STATUS OF KNOWLEDGE ON OLIVE RIDLEY SEA TURTLE

The olive ridley is the smallest of all marine turtles with adults measuring about 65 cm long (Straight Carapace Length) and weighing 30-55 kg. It is widely distributed throughout the tropics, with the exception of the Gulf of Mexico, and populations of highest densities are found in the northern Indian and eastern Pacific Oceans. Olive ridley is considered to be the most abundant sea turtle in the world mainly due to its enormous nesting aggregations in India, Mexico and Costa Rica (Pritchard, 1997). Among the sea turtles, members of the genus *Lepidochelys* (*L. olivacea* and *L. kempii*) have the habit of forming huge nesting aggregations - a phenomenon popularly referred as *"arribada"* (Spanish for arrival). During the breeding season ridleys congregate in extremely large numbers in favourable coastal waters and resort to synchronised nesting involving thousands of individuals in suitable nesting beaches. Within the ridley's nesting ranges, arribadas occur at only a limited number of beaches. The largest nesting sites of this species are located along Bay of Bengal (Gahirmatha, Devi and Rushikulya) in eastern India (Pandav et al., 1994) and Costa Rica (Nancite and Ostional), and Mexico (La Escobilla) in the Pacifics (Valverde et al., 1998). While important feeding grounds for the Pacific population include the stretch between Panama and Equador (Meylan, 1982), feeding grounds of northern Indian olive ridley population had remained unidentified.

Fig. 1.4 Olive ridleys are known to undertake long distance migration between breeding ground and foraging areas. Mating starts soon after their arrival in the breeding grounds. Mating pair like this are a common sight off the mass nesting beaches in Orissa during every winter.

Olive ridley usually migrates along continental shelves and feeds in shallow coastal waters. It is usually seen in large flotillas travelling between breeding and feeding grounds mainly in the eastern tropical Pacific and the Indian ocean (Pitmann, 1990; Marquez, 1990; Dash and Kar, 1990). Regarding remigration interval, the genus *Lepidochelys* is an exception among marine turtles as certain individuals from both the species of *Lepidochelys* are known to migrate annually (Dash and Kar, 1990).

Courtship activities of olive ridleys have not been frequently observed (Marquez, 1990). Mating occurs in shallow coastal waters off nesting beaches (Richard and Hughes, 1972; Dash and Kar, 1990; Plotkin et al., 1996; Ram, 2000; this study) and along migratory routes (Kopitsky et al., 2000). However, the absence of oceanic aggregations indicates absence of any definitive oceanic breeding grounds (Plotkin et al., 1996). Reproductive aggregations of olive ridleys off the nesting beaches have recently been studied at Nancite (Kalb, 1999) and Gahirmatha (Ram, 2000; and this study). Multiple paternity in the ridleys have been documented (Hoekert et al., 1999). After the mating season, males return to their foraging areas (Plotkin et al., 1996) where as the female turtles head towards nesting beaches.

Nesting takes place almost a month after mating. Individual females arrive for nesting throughout the season on both arribada and non-arribada beaches. A day or two of increased nesting activity typically precedes an arribada. Although the arribada event itself is very well documented, it is not known what exactly controls the timing or synchronisation of arribadas. Environmental factors such as heavy rainfall and strong on shore wind have been documented to influence the arribada (Cornelius and Robinson, 1986; Dash and Kar, 1990; Plotkin et al., 1997). In the Americas, arribadas in olive ridley occur at comparatively fixed intervals (2-4 weeks) round the year, with the largest occurring in the autumn rainy season (Pritchard, 1969). In contrast, the ridleys in Orissa show a distinct pattern of nesting at Gahirmatha with the arribada taking place normally twice and occasionally thrice in a year during late winter and early summer (Dash and Kar, 1990). Olive ridleys typically nest two times per season in successive arribadas (Cornelius, 1986; Dash and Kar, 1990). During the inter-nesting period, the ridleys do not necessarily stay in large groups and are capable of re-establishing themselves as a group during a subsequent nesting emergence (Plotkin et al., 1995). After the last nesting of the season a female olive ridley leaves the inshore waters for the feeding ground (Plotkin et al., 1991).

Olive ridley arribadas occur, or have occurred, on beaches in India, Mexico, and Costa Rica, with smaller arribadas taking place in Nicaragua and Surinam. No arribadas have been observed in Surinam since 1972 (Reichart, 1993) and three of the four arribada populations in Mexico no longer exist (Clifton et al., 1982). Today, the largest reported arribada nesting population of olive ridleys occur at the nesting beaches in Orissa, along the Bay of Bengal (Bustard, 1976; Dash and Kar, 1990; Pandav et al., 1994). Arribada nesting also occurs at the mouth of river Devi (Kar, 1982) and the mouth of river Rushikulya (Pandav et al., 1994b), 100 and 320 km south of Gahirmatha respectively. There are currently five olive ridley arribada beaches along the Pacific coast of the Americas, two in northern Costa Rica, two in southern Nicaragua, and one in southern Mexico. Playa Esobilla in the state of Oxaca, Mexico is currently known to support the largest population of arribada nesters in the western hemisphere.

1.5. THE OLIVE RIDLEY SEA TURTLE AND ITS NESTING HABITATS IN ORISSA - A review of available literature


Fig. 1.5 Hawksbill occasionally occurs along the Devi river mouth in Orissa.

Four species of sea turtles: olive ridley, hawksbill, green and leatherback are reported to occur in the coastal waters off Orissa (Dash and Kar, 1990, personal observation). However, the nesting of only one species, the olive ridley has been confirmed so far. The remaining three species are extremely rare in the coastal waters off Orissa.

Scientific research on sea turtles started in Orissa a little over two decades ago. But even this has largely remained confined to the world's largest known olive ridley rookery at Gahirmatha (Bustard, 1976; Kar, 1980; Kar and Bhaskar, 1982; Silas et al., 1983; Silas et al., 1984; James et al., 1989; Dash and Kar, 1990). The first artificial hatching of eggs collected from Gahirmatha and Konark coasts was carried out in 1974 and 1975 (Biswas et al., 1977). Bustard (1976) first reported the large scale nesting of olive ridleys at Gahirmatha. After the discovery of Gahirmatha rookery, the Orissa Forest Department in 1976 started monitoring the nesting population. Then initiated a tagging program in 1978 at Gahirmatha. Nearly 15,000 ridleys were tagged at this rookery between 1978 and 1985 (Dash and Kar, 1990). Whereas many of the tagged turtles have been recovered while nesting in Gahirmatha during subsequent nesting season, there were very few recoveries outside Orissa. The study by Dash and Kar (1990) extensively deals with the nesting biology of Gahirmatha population. Olive ridleys arrive in the coastal waters off Orissa by late October and early November. Mating takes place in the shallow coastal waters off Gahirmatha during November and December followed by sporadic and mass nesting from January to April. An estimated half a million ridleys lay their eggs during the arribadas at Gahirmatha, which usually takes place twice in a season (Dash and Kar, 1990).

While most of the studies on sea turtles in Orissa concentrated on the Gahirmatha nesting population, little attention was paid to other sea turtle nesting beaches existing along Orissa coast. Kar and Bhaskar (1982) reported exploitation of sea turtle eggs from the beaches near Astaranga, Chandrabhaga and Gopalpur-on-sea in Orissa indicating nesting of sea turtles in these areas. Biswas (1982) has mentioned sea turtle nesting at the southern end of Puri beach and also on the sea beach near Chandrabhaga. Silas et al. (1983) have marked most part of Orissa coast south of the Gahirmatha rookery as sea turtle nesting grounds. However, none of these authors have given any clue about the intensity of sea turtle nesting in these areas or elsewhere on the Orissa coast. A second mass nesting ground of olive ridley in Orissa was discovered near the mouth of river Devi in 1981 (Kar, 1982). Due to lack of proper survey and regular monitoring, no further information was available from this area till 1993. Pandav et al. (1994a) confirmed the continuation of sea turtle mass nesting of much lower intensity at this rookery. Most of the nesting ground at this rookery was lost because of Casuarina plantation on the beach (Pandav et al., 1994a). Almost after two decades of the discovery of Gahirmatha, a major rookery of olive ridley was identified near the mouth of river Rushikulya along the southern Orissa coast (Pandav et al., 1994 a, b).

The illegal capture and transport of olive ridleys from the nesting beaches of Orissa to Calcutta and other markets were reported by Kar and Bhaskar (1982) and by Silas et al. (1983). Although the Gahirmatha nesting beach is well protected by Orissa Forest Department, the coastal waters off Gahirmatha is still subjected to intense commercial fishing activities (Pandav et al., 1994a). Large scale mortality of olive ridleys due to incidental capture in fishing nets during the nesting season at Gahirmatha has been well documented (Kar, 1980; Silas et al., 1983; Dash and Kar, 1990; Pandav et al., 1997). The number of dead turtles getting washed ashore the Orissa coast is on the rise and a record high of 13,500 dead ridleys were recorded along Orissa coast during 1997-98 breeding season (Pandav and Choudhury, 1999). The offshore aggregation of ridleys in Orissa has been a subject of very few studies. Recently Ram (2000) has estimated the distribution and abundance of olive ridleys in the off shore region of Gahirmatha Marine Sanctuary.

STUDY AREA

The geographical limits of Orissa extend from 17° 31' to 20° 31' N and from 81° 31' to 87° 30' E, covering an area of roughly 1,56,000 sq. km. The present study was conducted along the entire 480 km coast line of Oirrsa, stretching from west of the Subarnarekha River mouth, near Udayapur village bordering West Bengal, to the salt marshes of Ichhapuram in Andhra Pradesh. The coastline traverses six districts in Orissa - Balasore, Bhadrakh, Kendrapara, Jagatsinghpur, Puri and Ganjam. The major rivers here are Subarnarekha, Budhabalanga, Brahmani, Baitarani, Mahanadi, Devi and Rushikulya. Several smaller rivers such as Hansua, Kadua, Kushabhadra, and Bahuda also drain into the Bay of Bengal in Orissa.

2.1. THE CLIMATE ALONG ORISSA COAST

The climate along the Orissa coast can be classified into three distinct seasons - a mild winter (November to February) with the temperature varying from 18.5 - 28.5°C; a hot summer (March to mid June) with the temperature varying from 25.6 - 43°C and a rainy season (mid June to October) with the temperature varying from 25.5 - 34°C. The average annual rainfall varies from 1200 mm to 2680 mm. The number of rainy days per year varies from 55 to 97. The sea surface temperature varies from 20 - 33.3°C. The tides along the coast are semi-diurnal type.

Orissa receives most of its rainfall from the southwest monsoon that passes over the state between June and September. The depressions caused in the Bay of Bengal because of this southwest monsoon results in severe cyclonic storms during May and October. The entire coastal Orissa is prone to such cyclonic storms. During such cyclones the low-lying areas along the coast get inundated by tidal waves resulting in heavy loss of life (human and livestock) as well as property. In the past Orissa coast has had severe cyclone disasters. A severe cyclonic storm battered Orissa in 1971, claiming more than 10,000 human lives. However, the super cyclone of October 1999, was the most disastrous of all known cyclones that the Orissa had experienced in the past. The wind speed during the October 1999 super cyclone was of the highest intensity with speed averaging around 260 km/hr. As a consequence, most parts of the Orissa coast was badly affected by this storm, causing heavy casualty and devastation in the coastal districts.

2.2. THE COASTLINE

The State Gazetteer published in 1990 classifies the Orissa coast as a bulit-up coast. The Orissa coast bulges out in the central portion, from Brahmagiri on Chilka lake to Dhamra, where Mahanadi, Brahmani and Baitarani river systems form a combined delta. While between Dhamra and the Subernarekha River mouth, the coast is concave in shape as no major river pushes the shoreline into the Bay of Bengal. The Rushikulya river in the south and the Budhabalanga and Subarnarekha rivers in the north have very little or no delta formation. The sand spits at the mouth of Chilka lake, the Devi mouth and on the left bank of Mahanadi River mouth are the best examples of this. At the Mahanadi River mouth, the complex spit with a number of hooks are formed due to offshore long current and the strong south-west current during the monsoon when the load discharge in the Mahanadi is at its maximum.

The characteristics of Orissa's coastline also explain the general absence of bays and inlets here. The lone Hukitola bay off Jambu has been formed as a result of the huge complex spit to the north of the Mahanadi estuary. There are only three islands off the Orissa coast - Outer Wheeler Island, Long Wheeler Island, and Coconut Wheeler Island off Dhamra and Maipura River mouths. All these three islands are depositional in nature.

2.3. THE COASTAL VEGETATION

The most prominent natural beach vegetation found all along the Orissa coast is composed of psammophytes or sand binders which cover the sand dunes and help in controlling soil erosion. The commonest natural beach vegetation encountered along Orissa coast are *Ipomea pescaprae*, *Spinifex littoreus*, *Launea sarmentosa*, and *Gisekia pharnacoides*. The coast of Orissa also harbours several patches of mangrove formations - on the Mahanadi estuary, Brahmani-Baitarani confluence, and near the mouths of rivers Devi, Dhamra, Budhabalanga, and Subarnarekha. Banerjee and Rao

Fig. 2.1 Open beaches with scattered sand dunes were once a common feature along the Orissa coast.

(1990) have described the mangroves of the Mahanadi and Brahmani-Baitarani deltas in detail. Mangroves on the Devi estuary, despite the conducive conditions for their growth, are in a degraded state (Patnaik et al., 1990). *Avicennia officinalis*, *Sonneratia apetala*, *Excoecaria agallocha* are also seen here in stunted formation along with few other species such as *Acanthus illicifolius* and *Achrostichum aureum*. The long stretches of mudflats along Balasore coast, north of Dhamra are covered by *Avicennia marina*, *A. alba*, *Sesuvium protulacastrum* and *Suaeda maritima*. Remnants of mangrove vegetation are seen near the mouth of Budhabalanga river. Mangroves also occur in the small deltaic formations near the mouth of river Subarnarekha.

Fig. 2.2 Most part of Orissa coast has now been planted with *Casuarina*. Plantation of *Casuarina* has drastically altered the natural beach profile along Orissa coast.

However, the most conspicuous feature of the coastal vegetation in Orissa now is the Casuarina plantation. Casuarina was planted in mid 1970s to prevent beach erosion and to act as a barrier against cyclonic storms. Cashew (*Anacardium occidentalis*) has also been planted extensively behind the Casuarina belt, particularly in Puri and Ganjam districts.

2.4. THE CONTINENTAL SHELF ALONG ORISSA COAST

The coast line north of Dharmra River mouth is characterized by long stretches of inter tidal zones. The continental shelf along this stretch is shallow and the maximum width of the inter tidal zone varies up to 4 km. The continental shelf along the entire 35 km coast is also very shallow and does not exceed 20m even at an off-shore distance of 7 km. The continental shelf south of Paradeep becomes steep and the south Orissa coast is characterized by a narrow and steep continental shelf. The total continental shelf area of Orissa is estimated to be 23,830 sq. kms of which 29% lie in the depth zone 0 – 20 m and 36% in 20 – 50 m depth zone (Anon, 1997).

2.5. MARINE FISHING AND FISHERMEN

Orissa has a long coastline, yet the marine fishing activities here are dominated by migrating fishermen from West Bengal (between West Bengal-Orissa border to Paradeep) and Andhra Pradesh (between Konark to Andrha Pradesh border). The marine fishing by the native Oriya fishermen is minimal. During the early 1990s as part of the Bay of Bengal Program, most of the traditional crafts were replaced with fibre glass boats with out-board motors. Mechanized fishing along Orissa coast is characterized by trawl and gill net fishing. The northern part of Orissa coast is subjected to heavy mechanized fishing activities. Some of the major fishing bases such as Kashaphala, Balaramgadi, Dhamra, and Paradeep are located along this part. Mechanized gill netters from neighbouring West Bengal also fish in this area. Most fishing in the coastal waters south of Konark is carried out by traditional Telgu fishermen. Trawlers from Andhra Pradesh often come and fish along the southern Orissa coast.

Fig. 2.3 As part of the Bay of Bengal programme most of the traditional crafts are now replaced by fibre glass motor boats with out board motors.

2.6. SEA TURTLE NESTING ALONG ORISSA COAST AND THE SURVEY SECTORS

Four species of sea turtles - leatherback, green, hawksbill and olive ridley have been recorded to occur in Orissa (Dash and Kar, 1990; this study). However, the nesting of only one species, olive ridley, has been confirmed so far in Orissa (Pandav et al., 1994). Nesting of olive ridleys take place along the entire coastline south of Dharmra River mouth. Pandav et al. (1994) provides a detailed account of sea turtle nesting intensity along the entire Orissa coast (Figure 2.1).

During the present study, the coastline between mouth of river Dhamra and mouth of river Bahuda was surveyed periodically to document the number of dead turtles washed ashore. The coastline along this stretch was divided into seven survey sectors (Figure 2.2) on the basis of major geomorphological features such as river mouths, sand spits, bays, and other coastal landmarks.

Sector I - Gahirmatha coast (35 km). This includes the coastline between mouth of river Dhamara and Hansua as well as the three Wheeler Islands and Udabali Island.

Sector II - Paradeep coast (12 Km). This includes the coastline between Paradeep port and the mouth of river Jatadhara.

Sector III - Kujang coast (40 km). This includes the coastline between mouth of river Jatadhara and river Petaphutei.

Sector IV - Devi Coast (30 km). This includes the coastline between mouth of river Devi and river Kadua as well as the Akashdia and Robert Islands.

Sector V - Puri coast (60 km). This includes the coastline between mouth of river Kadua and the mouth of Chilka Lake near Brahmagiri.

Sector VI - Chilka coast (60 km). This includes the coastline between the mouth of Chilka Lake and mouth of river Rushikulya.

Sector VII - Ganjam coast (45 km). This includes the coastline between mouth of river Rushik ulay and Dankur village bordering Andhra Pradesh.

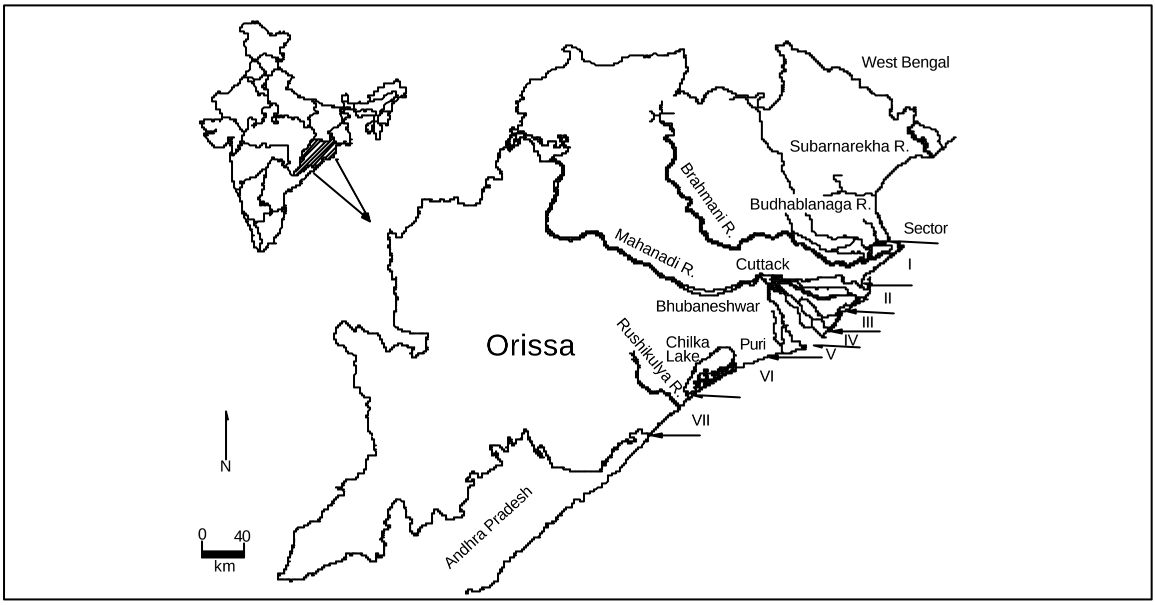


Fig. 2.4 For systematic coverage of the coast line, the Orissa coast was divided into the above seven survey sectors.

2.7. THE INTENSIVE STUDY AREAS

The present study focuses mostly on the olive ridleys nesting at the three mass nesting beaches in Orissa: Gahirmatha, Devi River mouth and Rushikulya. Although, nesting olive ridleys were tagged near the Chinchiri mouth, Barunei and Chilka mouths, bulk of the tagging was carried out at the three rookeries in Orissa.

The Gahirmatha rookery

Fig. 2.5 The Gahirmatha beach after its fragmentation in 1989. The 3.8 km long Nasi Island continued to host sea-turtle mass nesting after 1990.

In 1974 Dr. H. R. Bustard first made aware to the conservation community the importance and potential of Gahirmatha beach for sea turtle nesting during a survey of the crocodiles for the FAO-UNDP project. He observed that Gahirmatha might be the largest rookery for any sea turtle in the world and an important one for the olive ridley (Bustard, 1976). Based on his recommendations, the rookery was included as a part of the Bhitarkanika Wildlife Sanctuary (WLS) in April 1975. The 35 km coastline between mouth of river Maipura and Barunei formed the eastern boundary of Bhitarkanika WLS. When discovered in 1974, the mass nesting was taking place in a 10 km stretch from mouth of river Maipura till Habalikhati (Dash and Kar, 1990). The mouth of river Maipura was characterised by a three kilometre long sand spit. During a cyclonic storm in 1989, this sand spit got dissociated from the mainland and the mass nesting beach was reduced to a 3km long island (Nasi, Figure 2.3a). The Nasi Island is devoid of any tall vegetation and is characterised by small sand dunes of 1-2 ft high. Between 1990 and 2000 significant geo-morphological changes have taken place at this Nasi Island. Over the past decade the Nasi Island has moved nearly 5 km northwards. Studies on morphodynamics of this rookery have revealed that they are under severe stress due to erosion (Prusty et al., 2000). In 1998, the Nasi Island got fragmented into two parts and since then it has been subjected to further fragmentation resulting in a drastic reduction in space available for the turtles to nest (Figure 2.3b). These islands have presently broken into four parts, two of which are no longer suitable for turtle nesting.

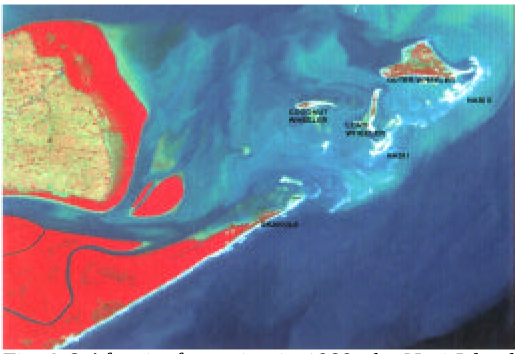


Fig. 2.6 After its formation in 1989, the Nasi Island has been subjected to further fragmentation. This has drastically reduced the area available for sea turtles to nest.

The coastal waters off Gahirmatha was declared a wildlife sanctuary in September 1997 for protecting the olive ridley sea turtle both in its nesting habitat and near shore waters.

The Gahirmatha Marine Wildlife Sanctuary (GMWS) encompasses an area of 1435 sq. km, 1408 sq. km of which are coastal waters while rest constitute mangrove forests, mudflats and sand spits. The core area of the park is ~725 sq. km. and the buffer area is ~709 sq. km. Courtship and mating of olive ridley takes place in a shallow bay, 4 km south of the Nasi group of islands near the mouth of river Maipura in the core area of GMWS. The continental shelf in this region is shallow and does not exceed 20 m up to an off shore distance of 7 km. Mating pairs of olive ridley were captured and tagged in this area of approximately 72 sq. km during the present study.

The Devi River mouth rookery

The mass nesting of olive ridleys near the mouth of river Devi was first reported in 1981 (Kar, 1982). However, after 1981 the nesting population at this rookery remained unmonitored for more than a decade. Pandav et al. (1994) reported the continuance of mass nesting at this rookery. The mass nesting at this rookery takes place on an island located between the mouth of river Devi and Petaphutei. Over the years much of the nesting area at this rookery has been lost to Casuarina plantation. Mass nesting was recorded only once during the present study. Nearly 25,000 turtles nested here in a newly accreted sand bar (Robert Island) from 13 to 17 March 1997. While this island has now submerged, a newly formed four km long sand spit on the southern side of Devi River mouth appears to be an ideal nesting ground for sea turtles. After the 1999 super cyclone this sand spit has become an island (Pandav, 2000; Figure 2.4a). The sea turtle nesting activity at this island is yet to be documented.

Fig. 2.7 The sand bars near Devi river mouth are frequented by olive ridleys for nesting.

The Rushikulya rookery

The rookery near the mouth of river Rushikulya (19° 22' - 19° 24' N latitudes and 85° 02' - 85° 05' E longitude) is located 320 km south of Gahirmatha along the southern Orissa coast. The mass nesting beach at Rushikulya is located on a sand spit on the northern side of the river mouth (Figure 2.4b). The Rushikulya river opens to the Bay of Bengal near Ganjam town. The estuary near the river mouth is connected with the Chilka lake through a man made canal locally known as Palur canal or the French Canal. The

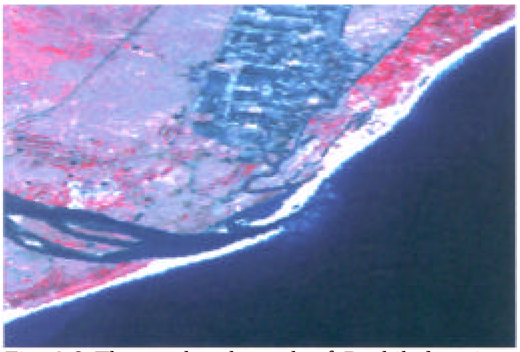


Fig. 2.8 The sea beach north of Rushikulya river mouth has emerged as one of the major mass nesting areas of olive ridley in India.

topography of the estuary has undergone many recognizable changes during the past one decade. During 1989 flood, a barrier sand spit has separated the low ridges of the estuary running almost parallel to the mainland after the formation of a second mouth facing the Potagada village. The old mouth near Gokharkuda village has subsequently been filled up by sand. At present an expanded sandy beach has developed on this old river mouth. The backwater of Rushikulya river estuary runs parallel to the nesting beach for a distance of one kilometre northward, thus forming a lagoon on its own. This lagoon is now connected with the Chilka lake through the Palur canal.

The occurrence of sea turtle nesting at Rushikulya and the availability of turtle eggs in the locality were first reported by Panigrahy et al. (1990). Of late this extensive sandy beach near Rushikulya river mouth has been identified as a major nesting ground of olive ridley (Pandav et al., 1994 a, b). 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*. One of the conspicuous features of this beach is the absence of Casuarina plantation, which is otherwise common along the rest of the Orissa coast. Human settlements near the beach include two fishing villages viz. Purunabandha and Palibandha. The major fish landing centres here are Gokharkuda, Kantiagada and Nuagan. The other features of this area are the presence of abandoned prawn fields behind the nesting beach and presence of a chloro-alkali chemical plant, which discharges effluents directly to the estuary.

THE DISTRIBUTION OF OLIVE RIDLEY SEA TURTLE POPULATION AND THEIR DYNAMICS IN ORISSA

Four species of sea turtles; olive ridley, hawksbill *Eretmochelys imbricata*, green *Chelonia mydas*, and leatherback *Dermochelys coriacea* were recorded during the course of this study. Juvenile hawksbill were recovered stranded near the sea coast near Devi River mouth on three occasions and a juvenile green turtle was recovered from a monofilament gill net at the Rushikulya rookery during the study. The only leatherback recorded during the study was found dead and washed ashore the Gahirmatha coast. As evident from this study, occurrence of sea turtles other than olive ridley in Orissa are extremely rare.

The coastal waters of the Bay of Bengal along the state of Orissa are an important breeding ground for the olive ridley sea turtle. It supports one of the largest nesting populations for the species (Bustard, 1974; Dash and Kar, 1990) and has witnessed enormous arribadas over the past decades. Although the nesting population at Gahirmatha has been the focus of numerous studies over the past two decades (Dash and Kar, 1990; James et al., 1991; Mohanty-Hejmadi and Sahoo, 1994), only scanty information exists on the ridley population using Rushikulya and Devi rookeries in Orissa. The studies mentioned above have quantified the Gahirmatha nesting population whereas information on the breeding population and their distribution in the offshore waters has been lacking. The lack of such fundamental information precludes further understanding of several facets of the biology of the species in concern. The sea turtle research community recognises such gaps exist in our understanding of marine turtle populations and of their life histories (MTSG, 1995). As part of this study, investigation was carried out on the distribution olive ridley population congregating in the coastal waters off Gahirmatha and the turtles nesting at Gahirmatha, Rushikulya and Devi rookeries.

A significant number of olive ridleys congregate in the offshore waters of Orissa to copulate and nest. This phenomenon is also characteristic of other species where much smaller assemblages of turtles have been observed in courtship areas very close to nesting beaches (C. mydas: Northern Australia – Limpus, 1993; Aldabra – Frazier, 1971; Sarawak – Hendrickson, 1958). Knowledge on the distribution, location and temporal use of such breeding grounds is important because sea turtles that assemble there for reproductive activities become extremely vulnerable to exploitation. This chapter describes the distribution and dynamics of one such off-shore aggregation of olive ridley near the Gahirmatha rookery. Because of constraints in resources and logistic problems the offshore distribution study was carried out only near Gahirmatha rookery and not along other rookeries off Orissa coast.

In order to study the distribution of turtle population using the three rookeries in Orissa, a tagging program was initiated at the beginning of this study. Tagging has been widely used in sea turtle research to obtain information on reproductive biology and movements (Balazs, 1999). Tagging provides information on site fidelity and movement between breeding sites apart from long distance movements.

Tagging of olive ridley was first initiated in French Guyana during late 1960s (Pritchard, 1973). Olive ridleys have been tagged extensively along the pacific coast of Mexico and Costa Rica (Marquez et al., 1976; Cornelius, 1982). In India the first long term tagging program on olive ridley was initiated by Orissa Forest Department in 1978 at the Gahirmatha rookery. Nearly 15,000 ridleys were tagged at this rookery between 1978 and 1985 (Dash and Kar, 1990). This tagging program has provided substantial information on the reproductive ecology of the ridleys at Gahirmatha rookery (Dash and Kar, 1990). However, the scope of this tagging study was restricted only to the Gahirmatha population and it is yet to reveal any information on the tagged turtles using other beaches in Orissa for nesting. Apart from understanding the biology of ridleys using

Fig. 3.1 A small metal tag attached to the fore flipper helps in identifying individual sea turtles. Each of these tags bear an unique number with a return address inscribed on it.

Devi and Rushikulya rookeries, the present tagging program intended to study the biology of male olive ridleys visiting the Orissa coast as well as fidelity of both males and females to a breeding ground and movement pattern between the nesting beaches.

2.1. METHODS

2.1.1. Onshore Studies

2.1.1.1. Nesting beach monitoring – For systematic coverage, the nesting beaches at the three rookeries were divided into 100-m segments. The segments were marked with either wooden poles or with cemented pillars. Patrolling by foot was carried out every night during the nesting season (January to April) at the rookeries to monitor turtle activities. Turtle crawls on the beach were classified into nesting and non-nesting types. A nesting crawl was characterized by the presence of a nest pit. In contrast, the non-nesting crawls lacked a nest pit and the turtle had returned back to sea without nesting. The turtle encountered during night patrolling were tagged immediately after they had completed the process of egg laying.

At Gahirmatha rookery, beach width was recorded at fortnightly interval at every 100-m segment. A fiberglass tape was used to measure the beach width. Beach width here refers to the extent of beach available between the high tide line of the sea and the high tide line of the estuary.

2.1.1.2. Enumeration of nesting females during arribada - In the past twenty five years from 1976 to 2000, various groups of researchers, state forest department officials and non governmental organizations have been involved in monitoring of arribada events in Orissa (Dash and Kar, 1990; Mohanty-Hejmadi and Sahoo, 1994; Chadha and Kar, 1999; Mohanty-Hejmadi, 1999; Shanker and Mohanty, 1999). Consequently, a variety of approaches and methods have been used for the estimation of turtle nesting at arribada sites in Orissa, and the reliability of these estimates has been doubted by marine turtle biologists.

During this study, four mass nesting events were observed (one at Devi mouth and three at Rushikulya). However, no precise estimates are available for these arribadas. Olive ridley turtles were censused during the arribada between March 25 – 31, 1999 at Nasi II island, Gahirmatha. Seventeen strip transects were established every 100 meters over the entire length of the beach. Each 20 metre wide transect was demarcated by wooden poles and extended from the high tide mark to the riverine end of the island i.e. over the effective nesting area. Turtles laying eggs in this 20 metre transect were counted every hour from 6 pm till 6 am in each strip from March 25-29, 2001. During this period, mass nesting also occurred on Nasi I, the adjacent island. Though the beach was not censused, the area and period of nesting was documented. Estimates of nesting and variances were derived using equations from Valverde and Gates (1999).

2.1.1.3. Estimation of incubation success - Determining incubation success provides data fundamental to conservation of sea turtles. These data are essential because they assist in understanding the suitability of the beach to act as an incubation system and the general health of nesting population. In order to examine the hatching success of sea turtle eggs at the three rookeries in Orissa, the nests were excavated after 4-6 days of emergence of hatchlings. Depth of the nest from the beach surface to the top of the first egg in the chamber was recorded for each excavated nest. The contents of the excavated nests were categorized as follows:

1. Hatched egg shells (H). Only shells that make up more than 50% of the egg size were taken into account and shell fragments were not considered while counting the number of hatched eggshells.
2. Live in nest (LIN). Live hatchlings that were left among shells and not those in neck of nest.
3. Dead in nest (DIN). Dead hatchlings that had left their shells and were found inside the nest.
4. Embryonic death (ED). Eggs that remained unhatched after the lapse of incubation duration were cut open and examined. The unhatched fertile eggs were further classified into three categories based on the extent of embryonic development.

   Early embryonic death (EED) - Eggs showing signs of blood vessel formation or small embryo without pigmentation.

   Mid embryonic death (MED) - Eggs containing a small embryo with pigmented eyes but unpigmented body measuring approximately 10-30 mm from head to tail.

   Late embryonic death (LED) - These included eggs with fully developed embryos as well as the dead ones that had pipped their head from the eggshell.

5. Unfertilized egg (UFE) - Unhatched eggs without visible embryos or blood formation were classified as infertile eggs.

After categorizing and counting the contents of the nest, the number of eggs in the clutch was determined using the formula:

Clutch Size = H + ED + UFE

Incubation success was determined in two stages, which involved calculation of hatching success and emergence success. Hatching success refers to the number of hatchlings that hatch out of their eggshell and emergence success refers to the number of hatchlings that reach the beach surface. Both hatching success and emergence success were calculated as follows:

Hatching success (%) = (H ÷ Clutch size) × 100

Emergence success (%) = {[H - (LIN + DIN)] ÷ Clutch size} × 100

2.1.2. Offshore Studies

2.1.2.1. Extent of distribution of mating pairs – Mating pairs were actively searched from morning to evening during November to January in the coastal waters off Gahirmatha. The search effort was continued as long as pairs were present. Efforts were discontinued only when no pairs were detected for more than two kms. In order to determine the size and extent of this reproductive aggregation in the coastal water, latitude and longitude of each capture and sighting was recorded using a hand held Global Positioning System (Garmin Inc.). These locations were then plotted on a bathymetric map of the area obtained from the Chief Naval Hydrographer, India at Dehradun to determine the extent of distribution of ridley mating pairs.

The extent of distribution was obtained by drawing a minimum convex polygon (MCP) around the turtle locations. This is a simple method for calculating the area enclosed by a set of locations (Bekoff and Mech, 1984). The peripheral locations of the points are connected in such a way that internal angles of the polygon do not exceed 180 degrees. Another method, the harmonic mean (HM) was used to obtain an area of maximum utilization. The harmonic mean is a non-parametric estimator. It determines distribution by estimating the probability of use at any given location within the home range. The above mentioned methods are traditionally used to determine the home range of radio tagged animals, but the concept can also be applied to assemblages of certain groups such as the present one. The locations were converted from degree decimals to UTM for home range analysis (MCP and HM) in the program CALHOME (Kie et al., 1994). The capture and recapture locations of male and female olive ridleys in the same mating season were plotted in ARCVIEW and a line was drawn between both the capture and recapture points to depict the movement of olive ridleys during the mating season in the coastal waters off Gahirmatha.

2.1.3. Tagging

The tagging operation carried out over three nesting seasons of November to May during the year 1996 to 1999 comprised of two phases: capture and tagging of ridley mating pairs in the coastal waters off Gahirmatha and on the beach tagging of nesting females.

2.1.3.1. Capture and tagging of olive ridley mating pairs - The offshore aggregations of olive ridleys were studied along Gahirmatha nesting beach. The sheltered bay just south of the mass nesting beach where mating pairs congregate was selected as the intensive study area. The coastal waters in this area was scanned for ridley mating pairs. As pairs became visible, they were approached by a motor boat and captured. All captures were done using an indigenously developed hand held triangular scoop of bamboo trap loosely fastened to the side of the boat (Plate). As the boat approached the pair, the leading edge of the trap was lowered to a depth of a meter below the water surface. When contact was made with the pair, the net was drawn out of water scooping the pair out, and fastened to the side of the boat. Each individual was picked up by its fore flippers and placed on a rubber tyre for measurement and tagging. For each individual captured, following variables were measured: curved carapace length and width (CCL, CCW), straight carapace length and width (SCL and SCW), plastron length and width (PL, PW) and weight (Plate). Other information recorded includes presence and severity of scars and the manifestation of secondary sexual characters in adult turtles. All the turtles captured were double tagged. Once tagged the turtles were returned to the

Fig. 3.2 The indigenously developed triangular trap was found to be very effective in catching sea turtle mating pairs.

sea along the side of the boat. The entire operation would be carried out within five minutes, per individual capture.

2.1.3.2. Tagging of nesting females - On the beach tagging of nesting olive ridleys was carried out at the five sites mentioned in the study area during January to May over three seasons. The nesting beach at all the three rookeries in Orissa was divided into permanent 100 m segments with wooden or concrete poles and each of these beach segments were patrolled every night by foot through out the nesting season to look for nesting sea turtles. Turtles encountered during the night patrolling were tagged immediately after they completed the process of egg laying. Tags were applied on the fore flippers, through, or immediately adjacent to, the most proximal large scale on the trailing edge of the front flipper (Plate). This is defined as the axillary tagging scale and has been the recommended position for tagging sea turtles (Limpus 1992). While tagging, parameters such as date of tagging, segment of the beach where the turtle was tagged, and wherever possible the CCL and CCW were recorded. All the turtles were double tagged to minimise tag loss and to find out the tag loss correction factor. The self-piercing, self-locking Monel tags (style 49) by means of a specific tag applicator supplied by the manufacturer was used for tagging the turtles. The standard Monel tags used extensively in marine turtle research were obtained from the National Band and Tag Company, Newport, USA.


Fig. 3.3 Tags are applied on the fore flipper as close to the body as possible so as to minimise tag loss.

2.1.3.3. Recapture of tagged turtles - The mating pairs captured in the coastal waters, the nesting turtles on the beach and the dead sea turtles washed ashore along the Orissa coast were searched for presence of tags on their flippers. Upon recapture, the date and place of recapture, in case of a nesting female the segment of the beach where the turtle was recaptured and the morphological measurements were recorded.

2.2. RESULTS

ONSHORE STUDY

2.2.1. Nesting beach monitoring

Ridleys in Orissa showed a distinct temporal pattern of nesting with most of the nesting activity taking place during neap tidal nights. A great variation in the number of turtles nesting at the three rookeries was recorded during the study. For two consecutive seasons in 1997 and 1998 the arribada failed to occur at Gahirmatha. Proportion of nesting crawls to that of non-nesting crawls also showed considerable variation during the study period (Figure 4.5). Whereas 84.3% of the turtles (n = 800) emerged during 1996 nesting, only 13.6% of the crawls (n = 362) monitored in 1998 resulted in nesting. A drastic change in the width of the nesting beach was also recorded at Gahirmatha during the study period. Whereas the average beach width ± S.D. was 140.56 ± 32.92 m. in 1996 it got reduced to 82.44 ± 54.13 m. in 1998 (Figure 4.6).

Figure 2.1. Proportion of nesting vs. non-nesting olive ridley crawls recorded during the study at Nasi rookery, Gahirmatha.

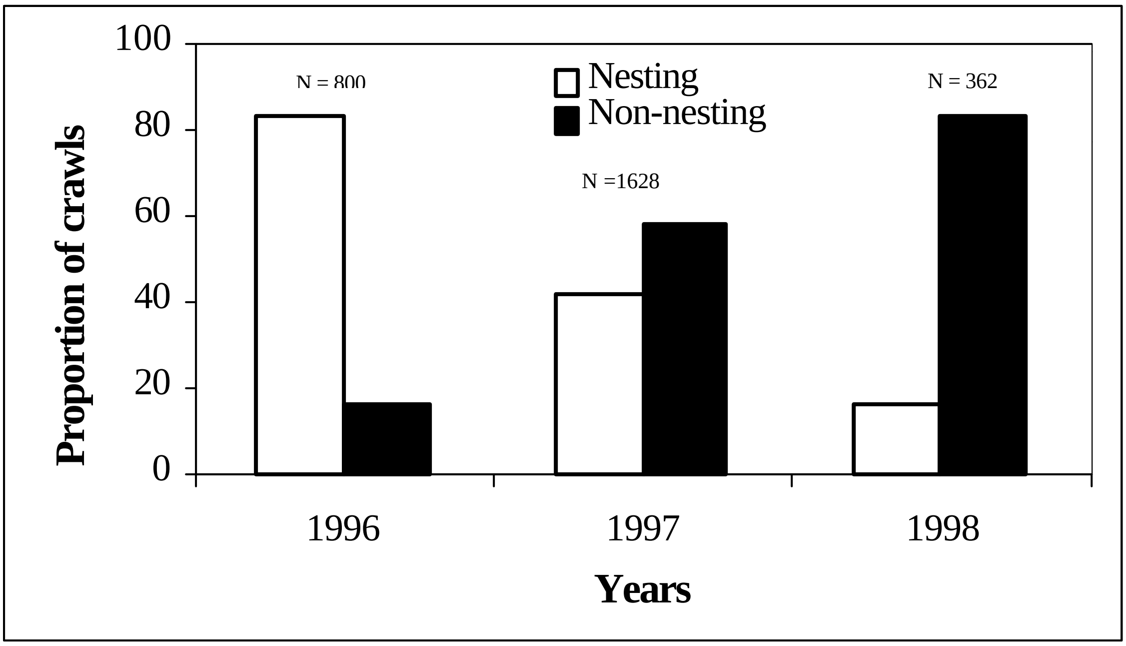
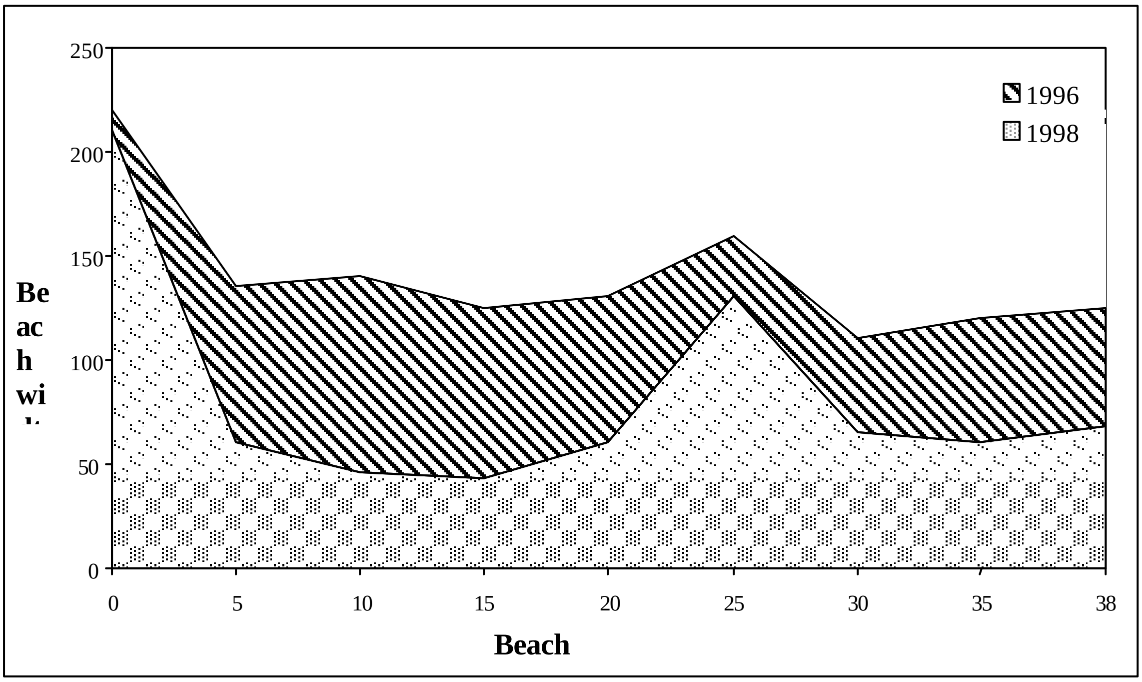


Figure 2.2. Changes observed in beach width at Nasi rookery, Gahirmatha during 1996-1998.



2.2.2. Enumeration of nesting females during arribada

Mass nesting occurred over five days on the two Nasi group of islands in Gahirmatha during March, 1999. Nesting occurred over the entire length of the beach on Nasi II Island (1.7 km) and was localized to 700 metres of beach on Nasi I Island. During four days of peak nesting, 125,500 to 145,500 olive ridley turtles were estimated to have nested on Nasi II Island (Table 2a). Nesting was extrapolated to the first day (when sampling was not carried out). Based on available information on duration of nesting and area available on Nasi I Island, nesting was estimated by extrapolating densities of nesting of Nasi II Island on the same days (Table 2b). The toatal nesting during this event is estimated to be ~ 180,000 clutches.

Table 2a: Estimates of nesting numbers during four days of peak nesting in March 1999

Day	Mean	Lower Confidence limit	Upper Confidence limit	Coefficient of Variation
1	51981	44436	59525	7.26 %
2	55182	48599	61765	5.96 %
3	17053	15127	18978	5.65 %
4	10850	8924	12775	8.87 %
Combined	135066	124549	145583	3.89 %

Table 2b: Extrapolation of total nesting numbers in March 1999 in Gahirmatha (Based on length of beach on Nasi 1 (1/3 length of Nasi 2)

Date	Nasi 1		Nasi 2	
	Day	**Night**	**Day**	**Night**
March 24-25, 1999				High sporadic
March 25-26,1999		Sporadic	Nesting (??)	*17,000*
March 26-27, 1999		Sporadic	Nesting (??)	51981
March 27-28, 1999	Mass nesting (4PM-6AM)	*18394*		55182
March 28-29, 2001		*5684*		17053
March 29-30, 2001		*3616*		10850

2.2.3. Incubation success

Because of failure of nesting during 1997 and 1998, incubation success at Gahirmatha rookery was calculated for three nesting seasons (1995, 1996 and 1999). The incubation success at Rushikulya rookery was calculated for four seasons (1995 to 1998). Incubation success data for 1999 at Rushukulya rookery is not available for analysis in this study because of failure of mass nesting at this rookery. Average clutch size for all excavated nests at Gahirmatha and Rushikulya rookeries were 124.4 ± 20.9 (range = 55 to 177, n = 277) and 127.9 ± 19.2 (range = 66 to 199, n = 600) respectively. In total, 34,469 and 77,208 eggs were examined respectively at Gahirmatha and Rushikulya rookery to determine the incubation success (Table 2c). A great variation in incubation success was observed at Gahirmatha compared to that of Rushikulya. The mean percentage hatching success and emergence success at Gahirmatha varied from 47.7 to 94.4 and 39.8 to 84.3 respectively (Table 2d). Compared to Gahirmatha, Rushikulya showed a higher rate of hatching as well as emergence success. The mean percentage hatching success and emergence success at Rushikulya varied from 83.8 to 97.01 and 69.78 to 96.1 respectively (Table 2d). The overall mean hatching success of these nests in the whole period of study were 63.5 ± 30.4 (range = 0 to 100, n = 277) and 95.01 ± 7.03 (range = 39.7 to 100, n = 600) for Gahirmatha and Rushikulya respectively.

Univariate analysis of variance carried out on hatching success showed a significant variation between Gahirmatha and Rushikulya ($F = 304.137$, $df = 1$, $p < 0.001$). The hatching success between the nesting season during the study period at both the rookeries were also significantly different ($F = 225.637$, $df = 6$, $p < 0.001$). The overall mean emergence success for the excavated nests during the study were 54.9 ± 30.8 (range = 0 to 100, n = 277) and 92 ± 10.9 (range = 18.2 to 100, n = 600) for Gahirmatha and Rushikulya respectively. Univariate ANOVA carried out on emergence success between Gahirmatha and Rushikulya showed a significant difference during the study ($F = 282.127$, $df = 1$, $p< 0.001$). Similarly the emergence success between the nesting seasons during the study period at both the rookeries were also significantly different ($F = 242.544$, $df = 6$, $p < 0.001$).

Table 2c. Fate of the eggs excavated at Gahirmatha and Rushikulya rookeries to determine the incubation success during 1995 - 1999.

Rookery	% eggs hatched	% LIN	% DIN	% EED	% MED	% LED	% TED	% UFE	N
Gahirmatha	63.6	6.3	6.9	1	0.5	25.9	27.4	9	277 nests (34,469 eggs)
Rushikulya	95.3	1.3	1.8	0.1	0.08	1.52	1.7	3	600 nests (77,208 eggs)

Table 2d. Incubation success of olive ridley nests at Gahirmatha and Rushikulya rookeries during 1995 – 1999. HS = Hatching Success, ES = Emergence Success, S.D = Standard Deviation.

Rookery	Year	Mean % HS ± S.D.	Range	Mean % ES ± S. D.	Range	# Nests excavated	# eggs counted
Gahirmatha	1995	47.7 ± 30.8	0 to 99.2	39.8 ± 30.3	0 to 98.3	77	10,059
	1996	94.4 ± 7.5	60.6 to 100	84.3 ± 14.5	33.7 to 100	67	8,661
	1999	57.2 ± 26.1	3.7 to 100	48.9 ± 27.2	0 to 100	133	15,736
Rushikulya	1995	85.94 ± 9.1	65 to 97.7	69.8 ± 14.9	46.6 to 96.4	17	2,055
	1996	96.04 ± 3.6	77.4 to 100	92.1 ± 8.3	49.2 to 100	173	21,860
	1997	97.01 ± 2.9	75.6 to 100	96.1 ± 3.3	75.6 to 100	346	45,381
	1998	83.8 ± 13.9	39.7 to 99.3	75.4 ± 18.4	18.2 to 96.6	64	7,452

2.2.4. Courtship and mating

Olive ridleys arrive in the coastal waters off Gahirmatha by early November and immediately upon their arrival mating pairs become visible in the coastal waters. Mating pairs are observed till mid February with peak mating taking place between 20 December and 10 January in the coastal waters off Gahirmatha. During the offshore capture of mating pairs for tagging, presence of mating triplets, quadruplets as well as male-male pairs of olive ridleys were observed in the coastal waters off Gahirmatha. In total 43 male-male pairs were observed over three breeding seasons. The male-male pairs were commonly encountered during early part of the mating season with 83% of the captures made in December and showed a declining trend during later part of the breeding season (Figure 2.3). Multiple mating of same male and female turtles with different partners was observed during the present study. An analysis of within season recaptures of breeding males and females revealed that males remained sexually active for a longer period (up to 50 days) compared to that of females (Figure 2.4). Some of the females tagged while mating in the coastal waters off Gahirmatha were subsequently recaptured nesting at Nasi group of islands in the same breeding season. The females were recaptured nesting after an average of 86.6 days (S.D. = 23.3 days, range = 35 to 113 days, n = 17) of being captured while mating (Appendix).

Fig. 3.4 Although mating pairs were common, triplets and quadruplets consisting of two to three males mounted over one female was often encountered in the coastal waters off Gahirmatha.

Figure 2.3. Fortnightly distribution of male – male pairs in the coastal waters off Gahirmatha. A total of 43 such pairs were captured during the study.

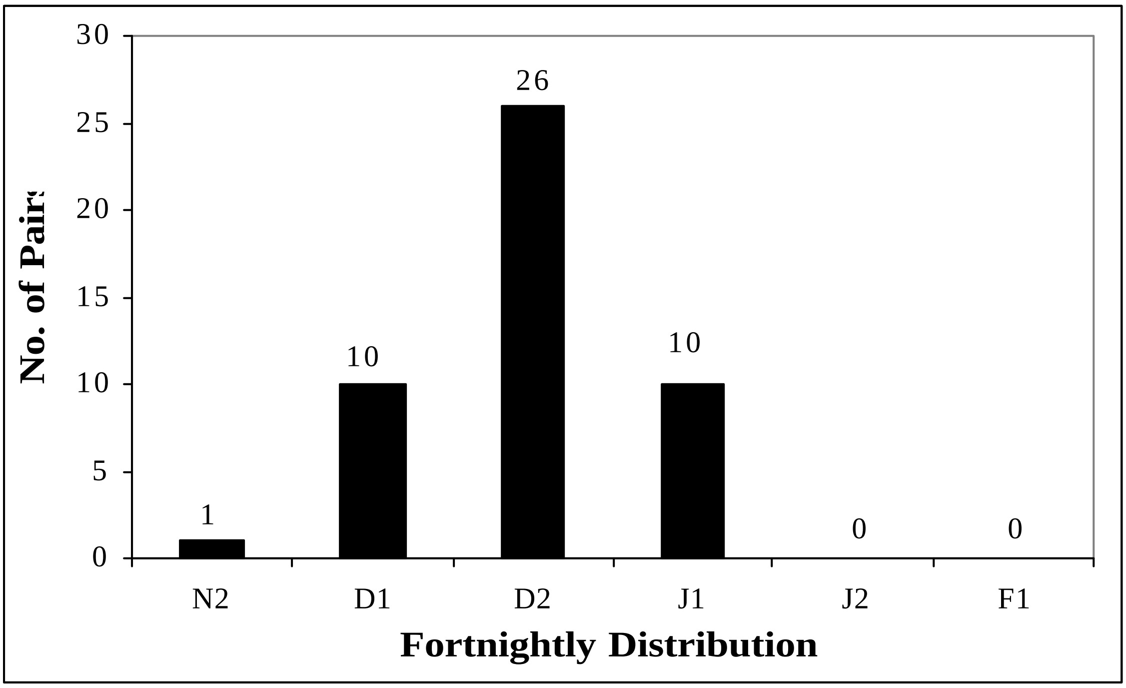
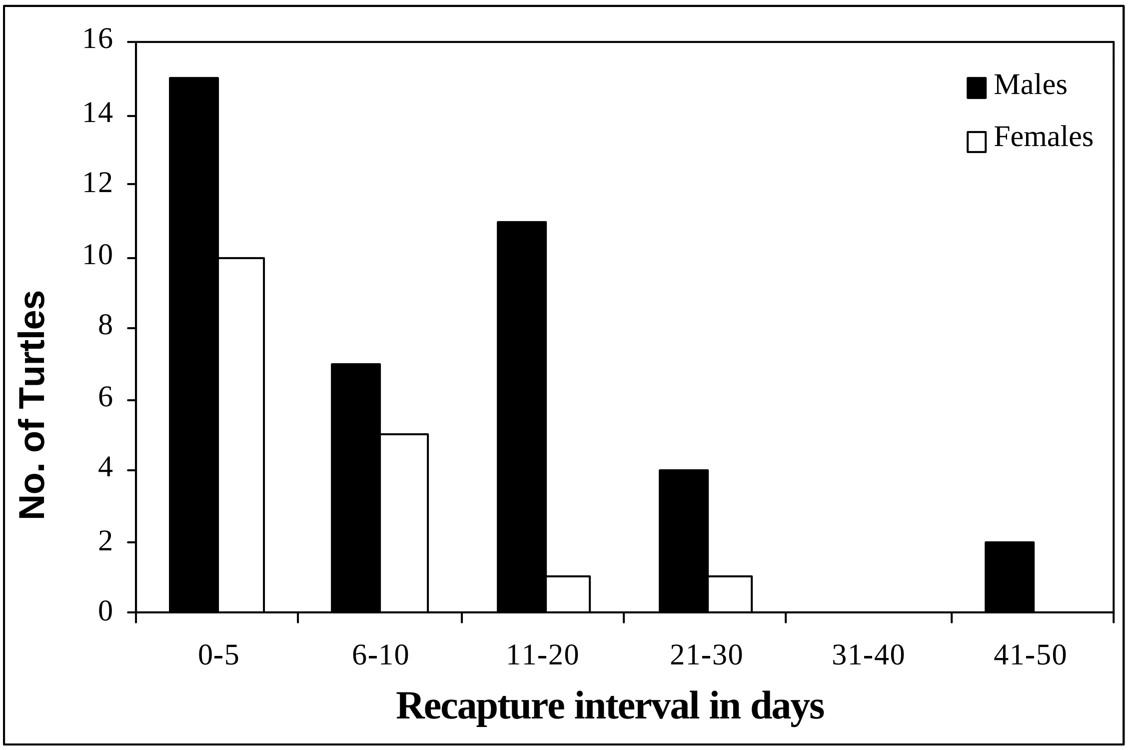


Figure 2.4. Within season recapture of male and female olive ridley sea turtle in the coastal waters off Gahirmatha.



2.2.5. Distribution of mating pairs

In total 85 surveys were made in the coastal waters off Gahirmatha and locations of 563 turtle mating pairs were taken to ascertain the breeding aggregation in the area. However, since the program CALHOME does not entertain more than 500 locations for home range analysis, only 450 randomly selected points were considered in the present analysis to determine the extent of aggregation (Figure 2.5). Mating pairs were found to be aggregated in an area of 52.58 sq. km (100% MCP) in the coastal waters off Gahirmatha and the area of maximum utilisation was 27.52 sq. km (90% HM, Table 2e). All the sightings of mating pairs recorded during the study were within 5 km of the coastline. All the observed mating took place within a depth of 20 meters.

Table 2e. Area of utilizatiion by mating pairs in the coastal waters off Gahirmatha calculated using Minimum Convex Polygon (MCP) and Harmonic Mean (HM) methods at different levels.

Estimator	100%	90%	80%	75%
Minimum Convex Polygon	5258 ha			
Harmonic Mean		2752 ha	1904 ha	1649 ha
Average distance between points: 1042 m				

Capture and recapture locations of 12 turtles in the coastal waters off Gahirmatha were plotted to find out the movement of individual turtles in one breeding season (Figure 2.6). Males and females were recaptured copulating after an interval of 10 minutes to 48 days and 25 minutes to 28 days respectively (Appendix). The average distance covered by males during this period was 1.99 ± 1.51 km (range = 0.16 to 4.02 km, n = 8). Although the sample size is small, females were found to cover slightly longer distance compared to the males in the breeding area off Gahirmatha. The average distance covered by females during this period was 2.64 ± 1.72 km (range = 1.06 to 4.84 km, n=4).

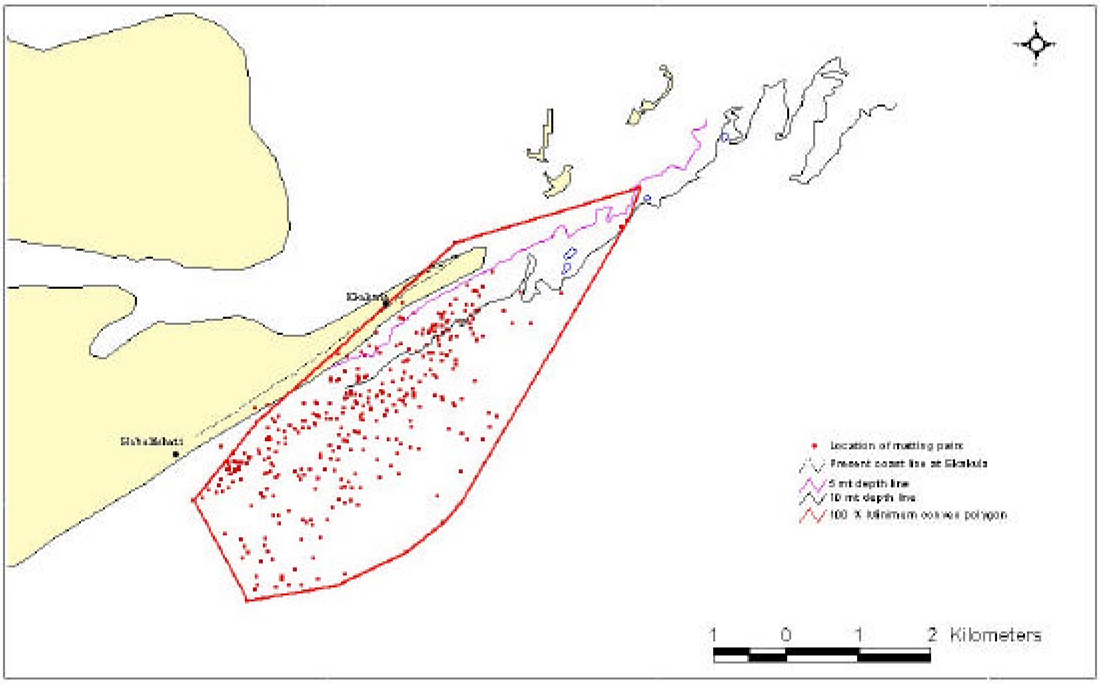


Fig. 3. Area of utilization (100% MCP) by olive ridley sea turtle mating pairs in the reproductive patch off Gahirmatha during 1997-98 mating season.

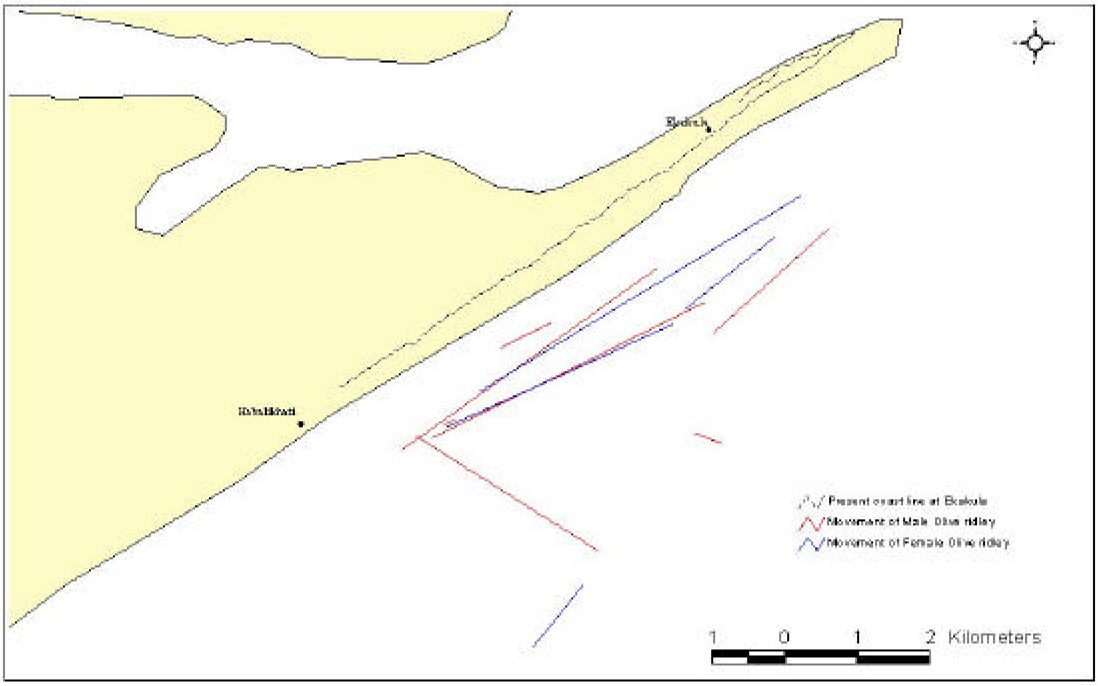


Fig. 3. Movement of male (n=8) and female (n=4) olive ridley sea turtles in the reproductive patch off Gahirmatha during 1997-98 mating season

2.2.6. Tagging

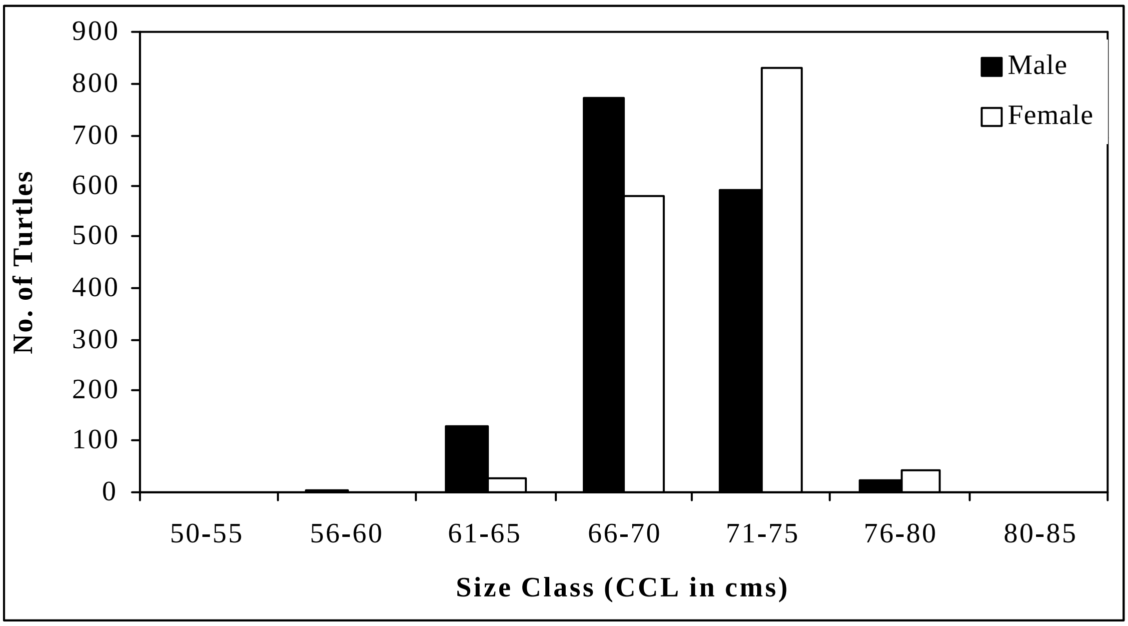
In total, 329 hours were spent in off shore tagging operation during the year 1997 and 1999, and over a period of 85 days 1,767 mating pairs of olive ridleys were captured of which 1,657 males and 1,616 females were tagged. On the beach 10,327 nesting females were tagged at the five tagging sites in Orissa between January 1997 and May 1999.

2.2.6.1. Morphometrics of the ridleys captured during the study - The measurements obtained during these captures reveal frequency of size classes of turtles present in the offshore waters off Gahirmatha. The size distribution of breeding males and females is summarised in Table 2f and Figure 2.7.

Table 2f. A four year comparison of straight carapace length (SCL in cm) of breeding male and female olive ridley from mating aggregations off Gahirmatha. * Source – Ram (2000)

	Year	Mean	S.D.	Range	N
Male	1996-97	67.3	2.5	55.3-73.3	182
	1997-98	67.1	2.65	55.6-74.6	534
	1998-99	65.2	2.91	49.0-73.8	690
	1999-2000*	65.5	2.54	61.6-77.7	90
Female	1996-97	67.1	2.5	54.7-74.9	183
	1997-98	67.04	2.32	52.3-73.6	350
	1998-99	66.3	2.44	58.8-72.6	692
	1999-2000*	66.1	2.16	61.9-71.8	85

Figure 2.7. Size class (CCL) of breeding male and female olive ridleys captured while mating in the coastal waters off Gahirmatha during 1997-99.



When annual samples of breeding turtles are pooled for all years, the males captured during the study had a mean (± S.D.) CCL of 69.9 cm ± 2.9 cm (range = 51.0 to 79.0 cm, n = 1,529), SCL of 66.2 cm ± 2.9 cm (range = 49.0 to 74.6 cm, n = 1,407) and PL of 49.6 cm ± 2.3 cm (range = 38.3 to 79.0 cm, n = 1,660). The breadth measurements of males were CCW of 68.0 cm ± 2.7 cm (range = 47.8 to 78.3 cm, n = 1,527), SCW of 58.0 cm ± 2.3 cm (range = 48.5 to 72.0 cm, n = 1,407) and PW of 49.7 cm ± 2.3 cm (range = 38.0 to 68.9 cm, n = 1,660).

The females captured during the study had a mean (± S.D.) CCL of 71.2 cm ± 2.5 cm (range = 61.2 to 82.0 cm, n = 1,484), SCL of 66.7 cm ± 2.4 cm (range = 52.3 to 74.9 cm, n = 1,374) and PL of 53.9 cm ± 2.3 cm (range = 40.7 to 63.6 cm, n = 1,628). The breadth measurements of the females were CCW of 69.3cm ± 2.5 cm (range = 54.3 to 78.3 cm, n = 1,484), SCW of 58.2 cm ± 2.2 cm (range = 49.0 to 69.3 cm, n = 1,374) and PW of 52.1 cm ± 2.4 cm (range = 40.6 to 60.0 cm, n = 1,628).

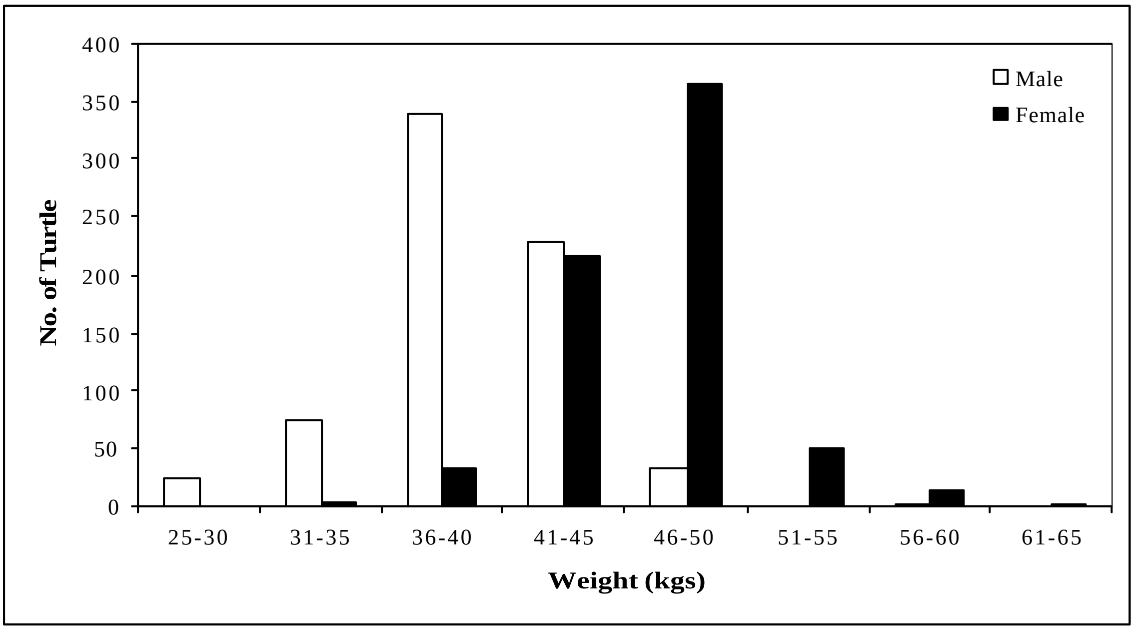
The mean curved carapace length of both sexes together was 70.5 cm ± 2.8 cm (range = 51.0 to 82 cm, n = 3,013) and the mean straight carapace length was 66.5 cm ± 2.7 cm (range = 49 to 74.9 cm, n = 2, 781). The sizes in comparison with other populations of olive ridley are given in Table 2g.

Table 2g. Comparison of carapace lengths between different geographic populations of olive ridley.

Location	SCL (cm)	Range (cm)	N	Source
Gahirmatha	66.5	49 – 74.9	2,781	This study
Oxaca, Mexico	62.9	52.5 - 73	1,203	Marquez et al. (1976)
Guerrero, Mexico	63.5	52 – 73.5	253	-do-
Michoacan, Mexico	63.1	60 - 67	13	-do-
Colima, Mexico	64.3	60 - 68	19	-do-
Sinaloa	62.2	55 - 69	190	-do-
Nancite, Costa Rica	63.6		942	Cornelius & Robinson (1985)

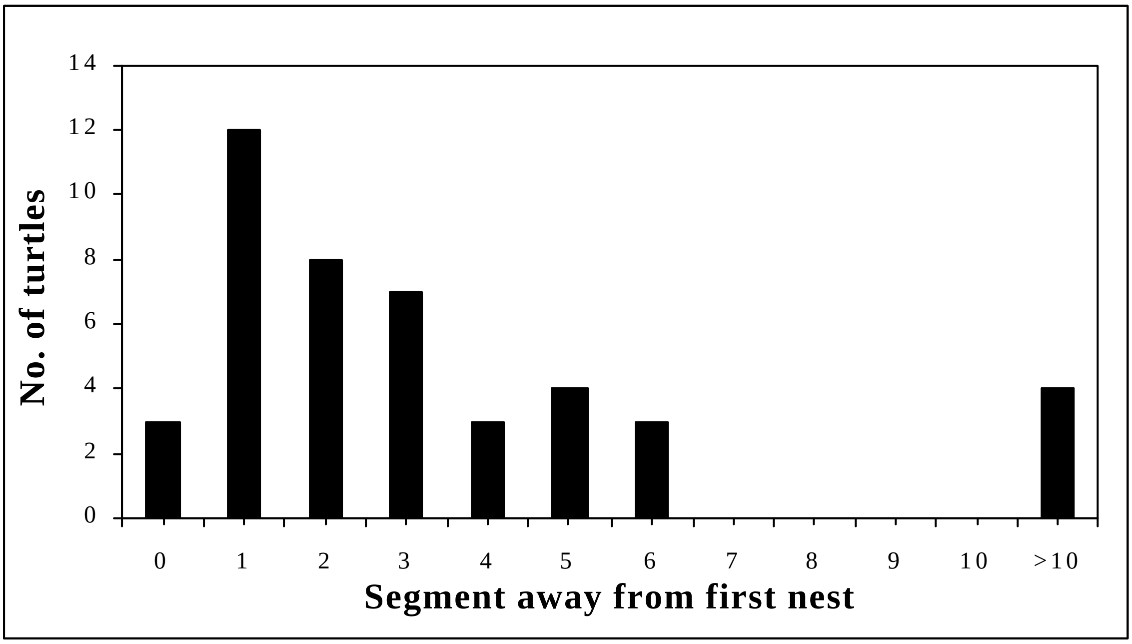
The females captured during the study were heavier than the copulating males. The weight frequencies of males and females courting in the coastal waters off Gahirmatha are represented in Figure 2.8. Mean (± S.D.) weight of males and females were 39.7 kg ± 4.0 kg (range = 25 to 56 kg, n = 702) and 47.1 kg ± 3.9 kg (range = 32 to 62 kg, n = 670) respectively.

Figure 2.8. Weight frequency of breeding male and female olive ridleys capture in the coastal waters off Gahirmatha during 1997-99.



2.2.6.2. Nest site fidelity and movement between the nesting beaches - During the course of this study, the beach profile at Gahirmatha and Devi River mouth witnessed rapid changes. The nesting beach at Gahirmatha (Nasi rookery) was fragmented into two widely separated islands and the Robert Island near the Devi River mouth where most of the turtles were tagged in March 1997 arribada got submerged during the subsequent breeding season. This rapid change in beach profile made it impossible to compare the place of nesting (segment of the beach) between years for nest site fidelity analysis. Therefore, only recaptures made at the Rushikulya rookery is being considered in this chapter for nest site fidelity analysis. Turtles recaptured at Rushikulya rookery showed a higher degree of nesting site fixity during the present study. Of the 519 turtles tagged in February 1997 arribada at Rushikulya rookery 44 were recaptured in the March 1998 arribada at the same rookery. Ridleys generally re-laid their nests within 100 to 300 m of their previous nests with a range of 0 to 1,000 m (Figure 2.9).

Figure 2.9. Nest site fidelity of olive ridley sea turtle upon remigration at Rushikulya rookery.



Ridleys tagged at nesting beaches in Orissa also exhibited movement between two rookeries. Two of the turtles tagged during the arribada at Rushikulya rookery on 2 and 3 February 1997 (Tag No. WR25417, WR25418 and WR25793, WR25794) were recaptured while nesting in another arribada at Robert Island near Devi River mouth on 17 March 1997. One of the turtles tagged during the arribada at Robert Island on 14 March 1997 (Tag No. WG23444 and WG23445) was subsequently recaptured while nesting at Nasi rookery on 16 April 1997. An estimated 300 turtles had nested at Nasi rookery on the same night. Besides these inter-seasonal movements between the rookeries, ridleys in the present study also exhibited intra-seasonal shift in nesting beaches. Two of the turtles tagged at Nasi rookery on 2 April 1997 (WG01484 and WG01485) and 14 April 1997 (WG01912 and WG01913) were recaptured while nesting on the sea beach near mouth of river Baunsagarha on 22 April 1998 (35 km away from Nasi). Similarly one of the turtles tagged near Chilka mouth (WG20020 and WG20021) on 30 March 1997 shifted its nesting beach and was recaptured while nesting at Rushikulya rookery during the arribada on 23 March 1998. The distance range of these inter-rookery movements of olive ridley in Orissa varied from 35 to 320 km (n = 30, Table 2h).

Table 2h. Details of beach exchange by olive ridley sea turtle between the three sea turtle rookeries and sporadic nesting beaches in Orissa. A total of 30 turtles were recorded straying between nesting beaches in Orissa and the distance of this movement varied from 35 to 320 km. AA = Arribada-Arribada, SA = Solitary-Arribada, SS = Solitary-Solitary

Date of tagging	Place of tagging	Turtle	Date of recapture	Place of recapture	Distance between the sites	Nesting type	Remarks
02.02.1997	Rushikulya	WR25417	17.03.1997	Devi Mouth	220 km	AA	Within season
03.02.1997	Rushikulya	WR25793	17.03.1997	Devi Mouth	220 km	AA	Within season
14.03.1997	Devi Mouth	WG23444	16.04.1997	Gahirmatha	100 km	AA	Within season
30.03.1997	Chilka Mouth	WG20020	23.04.1998	Rushikulya	60 km	SA	Between season
02.04.1997	Gahirmatha	WG01484	22.04.1998	Chinchiri	35 km	SS	Between season
14.04.1997	Gahirmatha	WG01912	22.04.1998	Chinchiri	35 km	SS	Between season
23.03.1998	Rushikulya	WR28045	14.03.2000	Gahirmatha	320 km	AA	Between season
17.03.1997	Devi Mouth	WG06264	14.03.2000	Gahirmatha	100 km	AA	Between season
07.04.1999	Barunei	WG12891	18.03.2000	Gahirmatha	40 km	AA	Between season
25.02.1999	Agar Nasi	WG21853	19.03.2000	Gahirmatha	40 km	SA	Between season
23.03.1998	Rushikulya	WR29309	03.02.2001	Gahirmatha	320 km	AA	Between season
03.04.1999	Barunei	WG02875	06.02.2001	Gahirmatha	40 km	SA	Between season
23.03.1998	Devi Mouth	WG06706	06.02.2001	Gahirmatha	100 km	AA	Between season
07.04.1999	Barunei	WG12837	06.02.2001	Gahirmatha	40 km	AA	Between season
27.03.1999	Agarnasi	WG02953	06.02.2001	Gahirmatha	40 km	SA	Between season
23.03.1998	Rushikulya	WR27659	06.02.2001	Gahirmatha	320 km	AA	Between season
14.03.1997	Devi Mouth	WG23947	26.02.2001	Rushikulya	220 km	AA	Between season
31.03.1999	Gahirmatha	WG24875	26.02.2001	Rushikulya	320 km	AA	Between season
14.03.1997	Devi Mouth	WG23753	26.02.2001	Rushikulya	220 km	AA	Between season
31.03.1999	Gahirmatha	WG24667	26.02.2001	Rushikulya	320 km	AA	Between season

Date of tagging	Place of tagging	Turtle	Date of recapture	Place of recapture	Distance between the sites	Nesting type	Remarks
28.03.1999	Gahirmatha	WG24425	27.02.2001	Rushikulya	320 km	AA	Between season
31.03.1999	Gahirmatha	WG24657	27.02.2001	Rushikulya	320 km	AA	Between season
14.03.1997	Devi Mouth	WG23506	01.03.2001	Rushikulya	220 km	AA	Between season
30.03.1999	Gahirmatha	WG24386	01.03.2001	Rushikulya	320 km	AA	Between season
14.03.1997	Devi Mouth	WG23250	01.03.2001	Rushikulya	220 km	AA	Between season
14.03.1997	Devi Mouth	WG23464	01.03.2001	Rushikulya	220 km	AA	Between season
30.03.1999	Gahirmatha	WG24702	01.03.2001	Rushikulya	320 km	AA	Between season
14.03.1997	Devi Mouth	WG23970	02.03.2001	Rushikulya	220 km	AA	Between season
17.03.1999	Devi Mouth	WG06146	26.02.2001	Rushikulya	220 km	AA	Between season
08.04.1997	Chilka Mouth	WG20026	26.02.2001	Rushikulya	60 km	SA	Between season

2.2.6.3. Tag recoveries from dead turtles washed ashore - More than 45,000 dead adult olive ridleys washed ashore the Orissa coast during the entire study period were counted, out of which 85 dead turtles were found with tags. Of the 85 dead tagged turtles, three were recovered after three season intervals (Mean ± SD = 1040 ± 21.1 days, range = 1016 to 1054 days), 28 were recovered after two season intervals (Mean ± SD = 710 ± 33.4 days, range = 661 to 760 days), 39 were recovered after one season interval (Mean ± SD = 338 ± 46.4 days, range = 248 to 483 days) from the date of tagging. The remaining 15 dead tagged turtles were recovered during the same season (Mean ± SD = 24 ± 16.6 days, range = 7 to 52 days). Recovery of tagged turtles showed evidences of movement of olive ridleys between the nesting sites in Orissa.

2.2.6.4. Migration -Prior to their arrival along Orissa coast in early November, olive ridleys are known to follow a coastwise northerly course i.e. turtles cross the coastal waters off Tamil Nadu and Andhra Pradesh and arrive in Orissa (Dash and Kar 1990). However, little is known about the post-nesting movements of ridleys using the Orissa coast and the existing literature is completely silent about the return migration of ridleys.

Long distance tag recapture data from this study suggests that female turtles move southward along the coast after the commencement of nesting season. One of the turtles tagged on 13 March 1997 during the arribada at Robert Island rookery (Tag No. WG22081 and WG22082) was subsequently recovered 324° off Kalmunai coast and about 22 nautical miles from the beach off Kalmunai, eastern Sri Lanka on 27 April 1997. The straight-line distance (as the crow flies) between Robert Island and Kalmunai is roughly around 1,900 km. So far, there have been 22 long distance recoveries of the ridleys tagged in Orissa (Appendix). Of the 22 long distance recoveries five are from the Gulf of Mannar, south Tamil Nadu and the remaining are from Sri Lanka (Figure 2.10). Ridleys tagged at all the three mass nesting beaches as well as in the coastal waters off Gahirmatha have been recaptured from Sri Lanka.

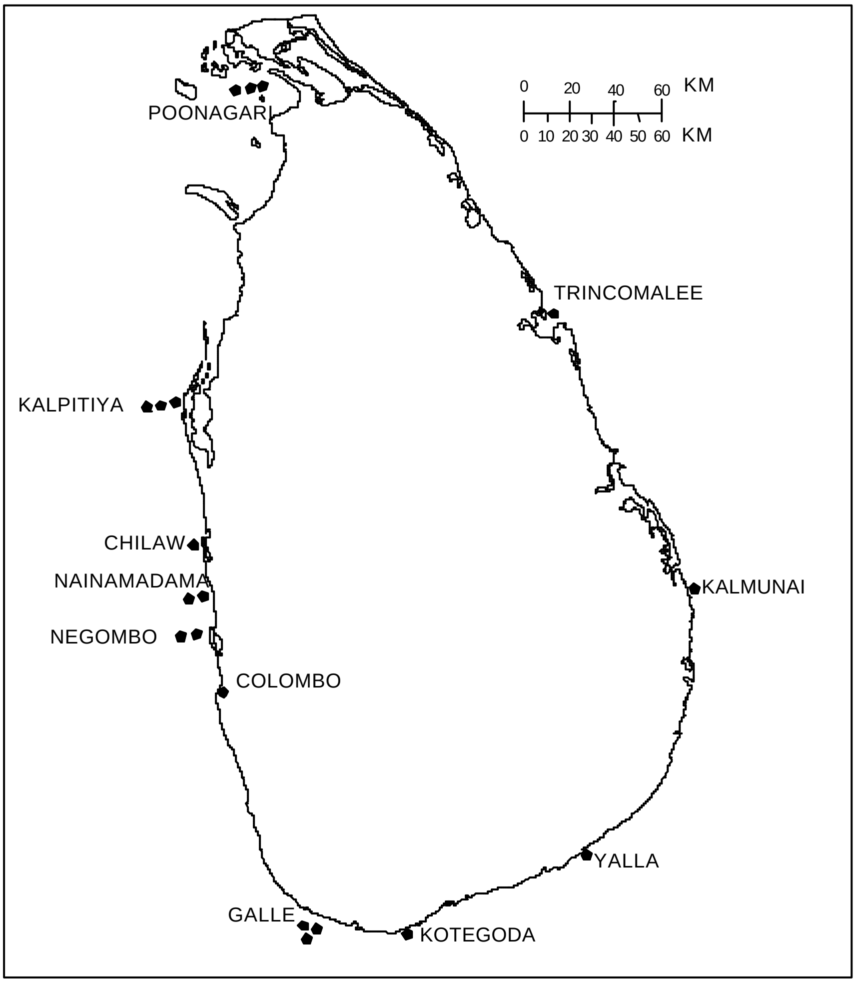


Fig. 3. Recovery sites of tagged olive ridley sea turtles from coastal waters off Sri Lanka

2.2.6.5. Remigration interval - During the present study some males have been recorded in courtship activity in subsequent breeding season and all such recaptures were made in the coastal waters off Gahirmatha where they had been originally captured while courting in a previous year. For the males recorded mating in subsequent years, mean remigration interval was 0.99 years (S.D = 0.06, range = 0.86 to 1.14 years, n = 28). Females recaptured offshore were returning after an interval of 1.01 years (S.D = 0.05. range = 0.96 to 1.09 years, n = 5).

Remigration intervals for nesting turtles tagged at Gahirmatha and Rushikulya rookeries between 1997 and 2000 are shown in Table 2i. In total 193 and 98 recoveries were made at Gahirmatha and Rushikulya respectively during the above period. The remigration pattern of olive ridleys shows that one year remigration intervals were the commonest (64.8% and 74.5% respectively for Gahirmatha and Rushikulya), and the second and third year remigration intervals were correspondingly less common (25.4% & 9.8% for Gahirmatha and 22.4% & 3.1% for Rushikulya). Those turtles which remigrated annually to Rushikulya rookery showed a mean remigration interval of 1.07 years (S.D = 0.06, range = 0.96 to 1.13 years, n = 73). Similarly, the turtles nesting annually at Gahirmatha showed a mean remigration interval of 0.97 years (S.D = 0.03, range = 0.92 to 1.14 years, n = 193).

Table 2i. Recapture of tagged turtles at Gahirmatha and Rushikulya rookeries during 1997 - 2000.

Beach	Nesting Season	# of turtles tagged	# of turtles recovered in different nesting seasons			
			1997	1998	1999	2000
Gahirmatha (Nasi)	1997	571		8	35	19
	1998	93	-	-	9	14
	1999	4851	-	-	-	108
	2000	-	-	-	-	-
Rushikulya	1997	518	-	41	19	3
	1998	2063	-	-	28	3
	1999	499	-	-	-	4
	2000	-	-	-	-	-

2.3. DISCUSSION

Olive ridleys on the shore:

Olive ridleys have been reported to exhibit distinct temporal pattern of nesting. Marquez et al. (1976) correlated Mexican arribadas with the phases of the moon; emergences usually take place during the waning quarter when tidal amplitude is low. Dash and Kar (1990) have also recorded nesting of ridleys during neap tidal nights. Spring tidal days are marked by high variation in tide. Tidal variation during neap tidal days is minimal and sea remains relatively calm, thus providing an easy access to the nesting beach. This could have been the possible reason behind the distinct temporal patterns of nesting exhibited by ridleys in Orissa. The significant relationship between moon phase and nightly nesting densities is important for sea turtle conservation program. Surveys to find out nesting intensities of olive ridleys along Orissa coast can be effectively planned during neap tidal days. Intense artificial lighting on the beach-front that disorients the nesting females and the emerging hatchlings ought to be controlled during these periods at rookeries like Gahirmatha and Rushikulya.

During normal nesting season when beach formation is proper, Gahirmatha witnesses a high proportion of nesting emergences. During peak nesting years in 1982 and 1983, Dash and Kar (1990) recorded low percentage of non-nesting emergences (9.4 to 13.1 %). During the present study when beach formation was proper in 1996, only 15.7% of crawls resulted in non-nesting emergences. However, with the reduction in beach width during 1997 and 1998, most part of Gahirmatha rookery was subjected to frequent tidal inundation. The beach remained wet for most part of the nesting season. Wet beach condition because of excessive rainfall or tidal inundation is known to adversely affect the survival of post-ovipositional eggs (Ragotzkie, 1959; Kraemer and Bell, 1980). The high proportion of non-nesting emergences (86.4%) recorded in 1998 when most part of the nesting beach was wet indicated the unsuitability of beach condition for turtle nesting.

Barring the March 1999 arribada at Gahirmatha, standardized methods have not been used in Orissa to estimate turtles nesting in arribadas. This makes the estimates of large arribadas in Orissa a suspect. None of the published reviews of nesting in Orissa (Dash and Kar, 1990; Mohanty-Hejmadi and Sahoo, 1994; Chadha and Kar, 1999; Mohanty-Hejmadi, 1999) makes any mention of methods used in the counting of turtles or estimation. One unpublished report describes a stratified strip (100m) transect used to count turtles in Gahirmatha in 1985 (Mishra and Kar, 1986). However, none of them has been published in peer reviewed publications, and estimates published in these books and reports by different authors do not in fact match. Furthermore, the absence of an estimate of variance is felt acutely.

Enumeration of turtles carried out in this study during 1999 arribada at Gahirmatha emphasized on the count of only ovipositing turtles. Counting of only ovipositing turtles is specifically important since many turtles are likely to strand several times before nesting successfully in an arribada. In Gahirmatha, the nesting beach got fragmented in 1989 and was subjected to frequent tidal inundation, leading to multiple strandings before nesting, especially during arribadas. Hence it is very likely that earlier figures reported for Orissa overestimate the number of turtles to an unknown degree each year. The census in March, 1999 suggests that less than 200,000 turtles nest during major arribadas in Gahirmatha.

Compared to the Rushikulya rookery, nests placed at Gahirmatha show considerable variation in incubation success. The overall mean hatching success at Gahirmatha during this study (63.5%) is considerably lower to that of findings of Dash and Kar (1990). In five nesting seasons from 1981 to 1985, Dash and Kar (1990) estimated the overall mean hatching success to be 87.72%. Incubation success in sea turtles is believed to be influenced by a number of interacting ecological factors such as sand temperature, sand particle size, water content and salinity (Miller, 1985). Wet beach condition as a result of excessive rainfall has been documented to adversely affect the survival of post-ovipositional eggs of olive ridleys at Nancite, Costa Rica (Ragotzkie, 1959; Kraemer and Bell, 1980). High moisture content in the beach sand reduces the hatching success by inhibiting or reducing gas exchange between egg clutch and its surroundings (Packard et al., 1977; McGehee, 1990) or by promoting fungal growth on the egg shell (McGehee, 1990). As the results of this study indicates. Gahirmatha has shown over the years a decline in the hatching success of eggs laid during the arribada. This decline in hatching success at Gahirmatha could be possibly due to the changes in nesting beach profile. Over the years the nesting beach at Gahirmatha has been severely fragmented. The Nasi group of islands over the years has witnessed a drastic reduction in the length and width of the nesting area. Moreover, the nesting beach at Gahirmatha during this study were subjected to frequent tidal inundation and most part of the beach remained wet through out the incubation duration. This could have played a major role in reducing the hatching success at this rookery.

The low incubation success at Gahirmatha and a higher rate at Rushikulya could possibly be because of the major differences in the physical characteristics of the two beaches. The beach is wider, three tired, free of tidal inundation and the turtle nests are spread out at Rushikulya rookery. Consequently, destruction of nests by subsequently emerging nesting females during the arribada is much less at Rushikulya. In comparison, the narrow nesting stretch restricted on both sides by Maipura estuary keep the turtles on a finite beach at Gahirmatha. Extensive destruction of nests by turtles takes place during arribada at Gahirmatha, promoting microbial proliferation in the nesting beach. Microorganism proliferation is thought to result from the increased amount of egg derived organic matter found in the arribada beaches as a direct consequence of nest destruction by other nesting turtles, as well as predators, beach erosion and high tides (Cornelius et al., 1991). All the factors that promote microbial proliferation in the nesting beach are prevalent in Gahirmatha. Due to the limited size of nesting area at Gahirmatha, nest disturbance increases as the nesting density increases during the subsequent nights of an arribada. Estimating that 25% of 300,000 nests (of ca. 100 eggs each) were destroyed by turtles during the 1999 arribada at Gahirmatha, and if the average mass of the eggs is 32.6 g (Reichart, 1993), then about 244 metric tons of organic matter were added to the beach that year as a consequence of nest disturbance by other nesting females. This figure increases significantly if embryos that die during different developmental stages are included.


Fig. 3. The low lying nesting beach at Nasi was subjected to frequent saline inundation thus considerably reducing the hatching success of turtle eggs laid in it.

Turtle eggs require an optimal respiratory environment to develop properly (Ackerman, 1980). Given the tremendous amount of decomposing organic matter from the many broken eggs and the frequent tidal inundation at Gahirmatha, the level of oxygen available for the development of embryos may not be optimal. Thus, it is conceivable that high embryonic mortality at Gahirmatha could be due to a large extent to low availability of oxygen brought about by the massive decomposition of organic matter and by frequent tidal inundation during the incubation period. A similar reason for the low hatching success of nests laid during arribada at Nancite, Costa Rica has been provided by Valverde et al. (1998).

In comparison to Gahirmatha, the incubation success at Rushikulya is extremely high. The beach at Rushikulya is wide, turtle nests are spread out and moreover its three-tier structure (low, medium and high beach) is free of frequent tidal inundation. The ideal condition of egg development at Rushikulya is reflected in terms of low embryonic mortality (1.7%, Table 4.3). Although Rushikulya receives smaller number of nesting turtles in comparison to Gahirmatha, its potential in terms of a stable and more productive beach cannot be ignored. Considering the rapid fragmentation and erosion of nesting habitats of olive ridleys at Gahirmatha, stable beaches like Rushikulya can play a vital role in sustaining a viable population of ridleys in future.

Olive ridleys in the off shore waters:

Courtship and mating has been least studied in sea turtles. Information available on sea turtle courtship and mating are mostly anecdotal. Ehrhart (1982) tabulated 15 studies, which provide the foundation for the current understanding of courtship and mating in sea turtles. Sea turtles have a promiscuous mating system. Mounted pairs have been reported in the open ocean, along migratory pathways, in aggregations and off nesting beaches (Richard and Hughes, 1972; Cornelius, 1986; Pitman, 1990; Meylan and Meylan, 1994). Unlike the Costa Rican mass nesting beaches of olive ridley, where mating pair assemblages appear to be minimal (Kalb, 1999), Gahirmatha witnesses a huge congregation of mounted pairs off the nesting beach at the beginning of breeding season. Similar observations have been made for green turtles where the main courtship area occurs within sight of the nesting beaches (Central Pacific: Balazs, 1980, 1983; Northern Australia: Bustard, 1972; Aldabra Atoll: Frazier, 1971). Balazs (1980) tagged the courting turtles and demonstrated that they included the same females that were nesting on the adjacent islands, usually within 2 km of the courtship sites.

Although most of the turtles that breed off the Gahirmatha coast use the Nasi group of islands for nesting, few of them have been recorded to nest as far south as Chinchiri (35 km). Three of the females tagged at Devi River mouth and one female at Rushikulya have also been recorded in courtship activities in the offshore waters of Gahirmatha during subsequent breeding seasons. These tag recoveries indicate the possibility that at least some of the mounted females disperse from courtship sites to distant rookeries within the region (Chinchiri, Devi and possibly Rushikulya), and not necessarily to the closest one. Limpus (1993) observed similar movement of female green turtles and noted that turtles courting in lagoonal areas of Heron Reef (Southern Great Barrier Reef) dispersed from courtship sites to rookeries that lie within 92 km without nesting at Heron Reef. Meylan et al. (1992) reported movement of 240 km in female green turtles from a courtship aggregation off Bocas del Toro, Panama to the Tortuguero rookery in Costa Rica. The few tag recoveries during this study only provide a clue that turtles nesting in different rookeries in Orissa are possibly using the courtship area off Gahirmatha. Further tagging and monitoring at the courtship area in Gahirmatha will provide definite answers on the use of this area by the turtles nesting in the near by rookeries (Devi, Rushikulya).

Males probably arrive earlier in the breeding season and females are present in less numbers during this period (Dash and Kar, 1990). Because of scarcity of females during early part of breeding season, males actively compete with each other to copulate with the females. Presence of male-male pairs as well as the triplets (two males mounted on a female) and quadruplets (three males mounted on a female) in the initial part of mating season seems to indicate the scarcity of females during this period.

A female sea turtle exhibits a receptive period, or "heat", for about 7 to 10 days and males appear to be sexually active for about one month (Wood and Wood, 1990; Limpus, 1993). Recapture of tagged turtles during the mating season in this study also shows a similar period of receptivity for both female and male olive ridleys. Results of this study also augment the findings of several genetic studies that indicate promiscuous mating in sea turtles (Limpus, 1993; Owens, 1980).

Approximately two weeks after mating the ovulation starts and the first nesting typically occurs about two weeks after ovulation, although longer intervals are possible in the ridleys (Owens, 1980; Wood and Wood, 1980). During this study females were recaptured nesting within an interval of 35 to 113 days of mating, corroborating Owens (1980) that nesting is followed almost four weeks after mating. However 15 out of 17 recaptures were obtained after an interval of 60 days or more (Table 4.1). As ridleys are known to lay more than one clutch per season (Dash and Kar, 1990), all these recaptures could be of the turtles that are nesting for the second time during the season.

Olive ridley sea turtle is well known for its huge breeding assemblages both on the nesting beach as well as in the offshore waters during mating and prior to the commencement of arribada. Kalb et al. (1992) have defined assemblages of olive ridleys located just off the nesting beaches as the "reproductive patch". Their study revealed that individuals within the patch are reproductively active and transitory during the breeding period. However, nothing more is known about the dynamics within such a patch. During the present study the reproductive patch at Gahirmatha was located just south of the nesting beach and with the progress of the nesting season this patch gradually shifted north and prior to the commencement of arribada the patch was located right in front of the nesting beach. This study reveals that maximum area covered by the reproductive patch during the mating season at Gahirmatha was 52.58 sq. km. (100% MCP) and most of the mating was concentrated over an area of 27.52 sq. km. (90% HM). The extent of off shore distribution seems to be consistent with observations off Nancite where individuals in the reproductive patch although transitory were found within 5 km off shore during the breeding period. The mating pairs at Gahirmatha tend to occur in much shallower waters than do other species of sea turtles. The reproductive patch off Nancite was aggregated at a depth of 40 - 130 feet (Kalb, 1999) but the Gahirmatha patch during mating season is located in an area of less than 60 ft deep. This is because of the shallow nature of the continental shelf in the region.

The exact reason why the ridleys aggregate in such shallow near-shore waters at Gahirmatha is unknown. Factors such as availability of food in the area, river effluents and near-shore current pattern may play a role in the aggregation of turtles off Gahirmatha. However, the fact that turtles aggregate in huge numbers in the offshore waters during the breeding season is of considerable importance from management point of view. The Gahirmatha Marine Sanctuary spreads over an area of 1400 sq. km. and there is only one patrolling vessel to protect this entire area. Because of lack of effective patrolling, mechanized fishing is rampant within the sanctuary limit. The adverse impact of mechanized fishing is reflected in terms of high sea turtle mortality along the Gahirmatha coast (Dash and Kar, 1990; Pandav and Choudhury, 1999; also discussed in detail in Chapter III). Keeping a vigil on the entire marine sanctuary with one patrolling vessel is certainly not feasible. Result of this study shows that ridleys during the breeding season are not randomly distributed throughout the marine sanctuary. And rather, they occur in certain patches. One such reproductive patch located during the mating period in this study covers a maximum area of 52.58 sq. km. Locating such reproductive patches and providing adequate protection to these congregations will definitely reduce fishing pressure in these areas. Instead of diluting the patrolling effort throughout the sanctuary with just one vessel, the management can concentrate on intensifying the patrolling effort in such reproductive patches, thereby reducing the turtle mortality in the area.

Tagging Sutides:

It is a well-known fact that many species of marine turtles undertake long distance migration between their foraging areas and nesting sites with a high degree of accuracy. Recent genetic studies have demonstrated that breeding sea turtles return to their region of birth (Bowen et al., 1992; Gyrius and Limpus, 1988). After returning to their region of birth and selecting a nesting beach, sea turtles tend to re-nest in relatively close proximity. During subsequent nesting attempts within that nesting season, a small percentage will utilise more distant nesting sites in the general area or within a few hundred kilometres (Bjorndal et al., 1985; Limpus et al., 1984; Limpus et al., 1992). Results of this tagging study on the nest site fidelity concurs with that of Dash and Kar (1990) on olive ridleys at Gahirmatha, Bosc and Le Gall (1986) on green turtles and Chaves et al. (1996) on leatherback, *Dermochelys coriacea*, at Playa Langosta, Costa Rica. Like the olive ridleys in Orissa, green and leatherback were also found to have re-laid their nests usually less than 300 m and often within 100 m of the previous nests with a range of about 600 m to 1,100 m.

Earlier tagging studies on olive ridley have also recorded the movement between nesting beaches with a range of 85 km (Schulz, 1971; n = 3) to 160 km (Meylan, 1982; n = 1). Compared to these studies, the movement of olive ridley between nesting beaches in Orissa seems to be the longest for the species recorded so far. Eckert et al. (1989) recorded similar movements between nesting beaches for leatherback sea turtle with a range of 30 to 110 km. Bjorndal et al. (1983) reported the distance between intra-seasonal re-nesting attempts of 38 loggerheads ranged up to 290 km. Other records of intra-seasonal nesting movements suggest that loggerhead turtles are capable of moving long distances, but the proportion of individuals doing so is low (Limpus, 1985). Movement of olive ridleys between nesting beaches has also been observed between the two mass nesting sites in Costa Rica; Nancite and Ostional. Between 1980 and 1984, a total of 29 Ostional ridleys were observed at Nancite and 35 Nancite turtles were recorded at Ostional (Cornelius and Robinson, unpubl. Report; cited in Valverde et al., 1998). This dynamic movement between beaches is remarkable and may represent an exception to the natal homing hypothesis as applied to green turtles (Bowen et al., 1992). It is possible that beach exchange is part of a complex phenomenon that olive ridleys use to colonise or even move to another beach altogether. So far, in Orissa we have six instances where the ridleys have shifted their nesting beach. Continuous monitoring at these nesting beaches in Orissa is essential to determine the degree of such movements between nesting beaches. Further, some of the turtles that were tagged while nesting at Devi River mouth were recaptured mating at Gahirmatha. The turtles that mate at Gahirmatha have also been recorded to nest as far south as Chinchiri (25 km) and some have been recovered 100 km south. This seems to be consistent with the findings for male green turtles (Fitzsimmons et al., 1997) that there is some degree of male mediated gene flow in this population although the population structure seems to be quite weak (Shanker et al., 2000). Monitoring the coastal waters off the nesting beaches can also provide substantial information on movement of olive ridleys between sites in Orissa.

The recovery of dead tagged turtles along Orissa coast during this study also gives some understanding of their movement in the coastal waters off Orissa. Till January 2000, 13 of the 3079 nesting females tagged at Rushikulya rookery were found dead in Orissa. Of the 13 tagged turtles, one was found washed ashore near Satbhaya village along the Gahirmatha coast and the remaining 12 were found in the coastal stretch between Paradeep and Devi River mouth. The distance between the place of tagging and the place of recovery of dead turtles varied from 200 to 320 km. Similarly four of the turtles tagged at Gahirmatha rookery were subsequently found washed ashore in the coastal stretch near Devi River mouth (approximately 100 km south of Gahirmatha). Recovery of dead turtles away from their place of tagging strengthens the view that there exists certain degree of movement of sea turtles in the coastal waters off the mass nesting beaches in Orissa. The same turtles that are using the Rushikulya rookery for nesting are also frequenting the coastal waters off Devi River mouth, Paradeep and Gahirmatha. This is again substantiated with the fact that ridleys in Orissa are using more than one beach for nesting. Although mortality of sea turtles near the Rushikulya rookery is minimal, turtles tagged at the same rookery have been recovered dead near Devi River mouth, Paradeep and Gahirmatha. The coastal waters in these areas are subjected to heavy commercial fishing activities and densities of dead turtles washed ashore in these areas are extremely high. Therefore providing adequate protection to sea turtles in the coastal waters off Gahirmatha and Devi is not only crucial for the turtles nesting in these areas but also for the turtles using the Rushikulya rookery.

SEA TURTLE MORTALITY IN ORISSA
- ABIOTIC & BIOTIC FACTORS

Sea turtles are killed by various animals and environmental phenomena. Predators, erosion, and inundation by rain or tides destroy nests and eggs. After hatching turtles of all ages, both at sea and on land are consumed by predators. They are also subjected to debilitating parasites and diseases (George, 1997) and are killed by various abiotic factors, including hurricanes (Limpus and Reed, 1985) and thermal stress (Meylan and Sadove, 1986; Witherington and Ehrhart, 1989). Quantitative accounts of sea turtle mortality in the wild are few. Natural mortality of sea turtles has been studied well during the egg and hatchling stages, including the brief period when hatchlings emerge from the nest and make their way down the beach to the water.

Many species, from ants to jaguars, prey on sea turtles. Excellent reviews by Hirth (1971), Stancyk (1982), and Dodd (1988) categorize predators by the life stage of sea turtles on which they prey. Eggs and emerging hatchlings are some times killed when a nesting female of either the same or a different species digs into their nest. Bustard and Tognetti (1969) described this activity as a density dependent mortality factor and this phenomenon is highly prevalent in mass nesting species like olive ridley (Cornelius, 1991; Valverde et al. 1998). Other biotic and abiotic factors that cause mortality in sea turtles include invasion of plant roots in the turtle nests (Witherington, 1986), beach erosion and tidal inundation (Whitmore and Dutton, 1985; Eckert, 1987).

Sea turtle mortality associated with human activities far exceeds to that of natural mortality. Human induced activities have resulted in the world-wide decline of most species of sea turtles. Today their numbers are drastically reduced to the point that all seven sea turtle species are considered either threatened or endangered. The challenges that sea turtles face from human activities impact every stage of their life cycle, from loss of nesting beach and foraging habitats to mortalities on the high seas and coastal waters through intense mechanised fishing activities (NRC, 1990; Lutcavage et al., 1997). Anthropogenic activities have been a major reason behind the decline in the number of olive ridleys. Direct harvest of adult turtles and their eggs from nesting beaches have resulted in the collapse of some of the major nesting congregations of olive ridley sea turtles in Mexico in recent times (Cliffton et al., 1982; Green and Oritz-Crespo, 1982). The nesting population of ridleys in Orissa has recently been the focus of attention of national and international community because of the large-scale mortality of adult turtles. Uncontrolled mechanised fishing in areas of high sea turtle concentration has resulted in large scale mortality of adult sea turtles during the last two decades in Orissa (James et al., 1989; Dash and Kar, 1990; Pandav et al., 1994; Pandav et al., 1997; Pandav and Choudhury, 1999).

Clearly, a complete analysis of all natural and human activities that adversely impact the survival of olive ridleys in Orissa is beyond the scope of this chapter. In this chapter the mortality of olive ridleys in Orissa are dealt in three stages: loss of post ovipositional eggs laid during the arribada as a result of beach erosion; mortality of olive ridley hatchlings as a result of artificial illumination near nesting beaches and the mortality of adult olive ridleys in the coastal waters off Orissa related to mechanised fishing activities.

3.1. METHODS

3.1.1. Quantification of egg loss because of beach erosion

As mentioned in chapter 4.1.2, for systematic coverage the nesting beaches were divided into 100m segments. With the commencement of arribada, the total beach width (a) and width of the total nesting stretch (n) was measured at each of the 100m segments using a fibre glass tape. Total nesting stretch refers to the extent of turtles nesting (perpendicular to the high tide line of the sea) at each of the 100m segments. Average of the total nesting stretch was multiplied into the total length of the beach to find out the total area used by turtles for nesting (N).

Erosion of the nesting beach is a common phenomenon in Orissa after March. By March the arribada gets over at the nesting beaches in Orissa and hence beach erosion results in loss of large number of turtle eggs. To find out the extent of beach lost because of beach erosion, the total beach width after erosion (b) was again measured at the same points during the hatchling emergence period.

The loss of beach area (l) was calculated for each segment by subtracting the beach width after erosion from the total beach width at the time of nesting.

$$l = a - b$$

The average loss of beach width (l) was multiplied into the total length of the beach to find out the total area lost (L) because of beach erosion.

L = Average of l x total length of the beach

Percentage of total nesting area lost (NAL) because of beach erosion was calculated by dividing the total area lost with total area used by turtles for nesting.

$$\% NAL = (L \div N) \times 100$$

3.1.2. Quantification of orientation of hatchlings

Under natural condition, the sea turtle hatchling after emerging from the nest moves directly towards the sea. However, presence of artificial lights near the nesting beach disrupts the sea finding behaviour of the hatchlings. In the presence of artificial lights the hatchlings get disoriented and instead of moving toward the sea they tend to move towards the source of artificial illumination. Of the three mass nesting beaches in Orissa, background of Rushikulya rookery is brightly illuminated because of the presence of chemical factories and the township. To quantify the orientation of olive ridley hatchlings at Rushikulya, a circular plot of one-meter radius was drawn from the centre of the nest where the hatchlings were observed to emerge from the nest. The circle was divided into two equal parts, one facing the land ward side and the other facing the sea. A pit of 15 cm deep was dug around the periphery of the circle and the pit on land ward side was separated from the seaside by placing two cardboards. The hatchlings falling into both sides of the pit were counted to find out their orientation.

3.1.3 Quantification of adult turtle mortality along Orissa coast

The coastline, south of the Gahirmatha rookery till the mouth of Bahuda River bordering Andhra Pradesh was monitored to document the sea turtle mortality during this study. To enable systematic coverage, the coastline was divided into seven survey sectors based on major geographical features, such as estuaries, sand spits, bays and other coastal landmarks (refer Figure 2.2). Three teams consisting of nine members covered these eight survey sectors by foot once in a fortnight throughout the breeding season

(November till April). A total count of the dead turtles washed up in each sector was carried out during fortnightly surveys. Dead turtles were marked on their carapaces with white paint to avoid repeat counting during subsequent surveys. The turtles were sexed, using external characters. Males were characterised by the presence of a long tail, which extends much beyond the posterior end of the carapace, and the strongly curved claw on the fore flipper. Females had shorter tails extending little beyond the post central, with a small and pointed claw on the fore flipper. In case of decomposed turtles, the claw character on the fore flipper was used to determine the sex. Highly decomposed specimens with no visible external characters were classified as turtles of unknown sex. Curved Carapace Length (CCL) was measured from the nuchal notch to the tip of the post central. Curved Carapace Width (CCW) was measured at the widest part of the shell. All measurements were taken in centimetre.

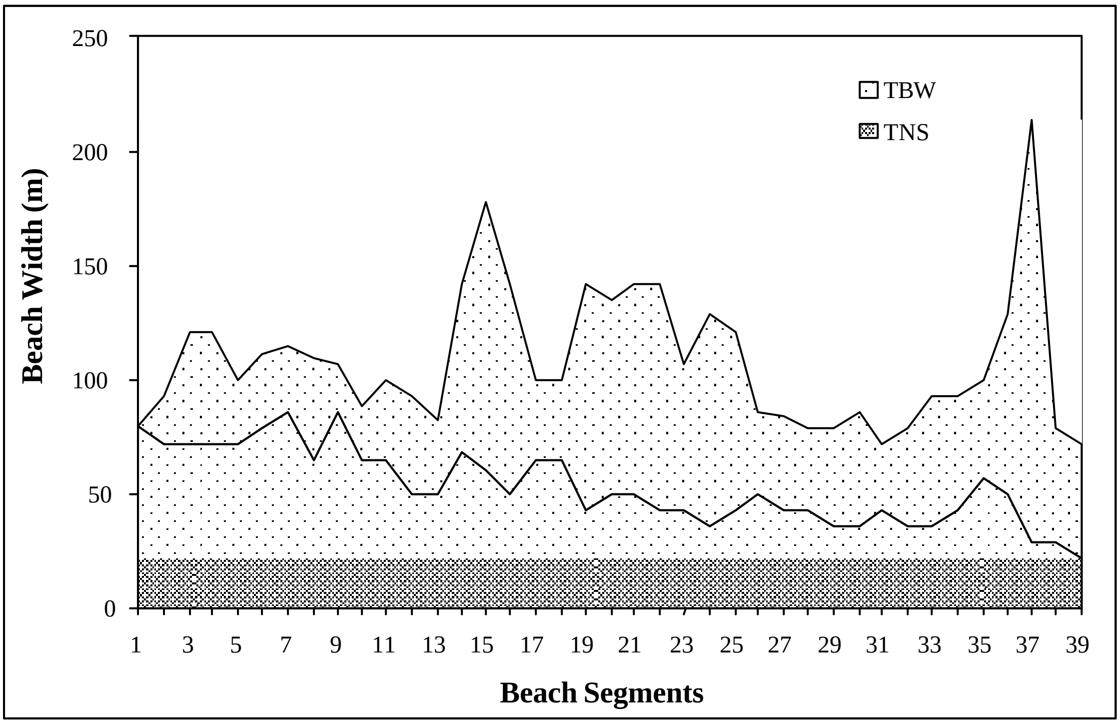
3.2. RESULTS

3.2.1. Egg loss due to beach erosion

Of the two mass nesting beaches (Gahirmatha and Rushikulya) regularly monitored during the study, beach erosion was minimal at Rushikulya. Most of the turtles at Rushikulya nested in the mid beach area which was free of beach erosion. Because of the shifting nature of the beach at Gahirmatha, heavy erosion was noticed at this rookery during the study (Plate). Although the beach width at Gahirmatha varied from 71 to 213m during the 1995 arribada, most of the turtles nested within 50m of the high tide line (Figure 3.1). The total area used by turtles for nesting at this rookery was estimated to be 0.206 sq. km during this arribada. Of this total nesting area 0.122 sq. km was estimated to have been lost because of beach erosion resulting in the loss of almost 59% of the total nesting area. The post-arribada period at Gahirmatha during 1995 breeding season therefore witnessed a heavy loss (>50%) of the post ovipositional eggs (Plate).

Fig. 4.1 (a & b) With the onset of south ward wind, the beach erosion starts in Orissa. As a result of beach erosion the nests get exposed thus resulting in the loss of extremely large number of eggs.

Figure 3.1. Spatial pattern of olive ridley nesting at Nasi rookery, Gahirmatha during 1995 arribada. TBW = Total Beach Width, TNS = Total Nesting Stretch



3.2.2 Disorientation of the hatchlings

Hatchlings at Rushikulya showed extremely high degree of disorientation (Plate). A total of 105 nests were sampled at Rushikulya rookery and 13,921 hatchlings were counted to determine their orientation during the 1997 breeding season. 91.4% of the hatchlings fell in the pit facing the land ward side. The nesting beach at Rushikulya is backed by sand dunes and creeping grasses. The disoriented hatchlings after straying form the sand dunes enter into the creeping grasses and get badly entangled in them. The hatchlings that remain stuck in the creeping vegetation either get predated by various avian predators or die because of desiccation.

3.2.3. Mortality of adult olive ridleys in Orissa

During the study duration, the Orissa coast witnessed an exponential increase in the number of dead turtles with every passing season and reached an all time high in 1997-98 when 13,575 dead olive ridleys were washed ashore. In total, 46,219 dead olive ridleys were counted during the periodic surveys over six breeding seasons in Orissa. 41% of this mortality occurred in the 35kms stretch of Gahirmatha coast (Figure 3.2). All the turtles counted during the study were adults (Figure 3.3). Mean CCL ± S.D. for dead females and males counted were 67.9 ± 2.8 cm (range = 54.5 - 78.4 cm, n = 1066) and 67.2 ± 2.6 cm (range = 52.5 - 76.4, n = 1025) respectively. Mean CCW ± S.D. of dead females and males were 66.9 ± 2.6 cm (range = 54.4 - 77.8, n = 1055) and 66.2 ± 2.5 cm (range = 56.3 - 75.3, n = 989) respectively.

The sex ratio of the dead turtles washed ashore the Gahirmatha coast was analysed for three breeding seasons (1996-97 to 1998-99). In total, 12,376 dead turtles were counted in Gahirmatha coast during the above period of which percentage of males were 36.5, percentage of females were 55.6 and indeterminate individuals constituted 7.9%. Except for the 1996-97 nesting season, a higher percentage of males were observed during initial part of the breeding season (November to February, Figure 3.4).

Figure 3.2: Dead olive ridley turtles washed ashore the Orissa coast during 1993 to 1999.

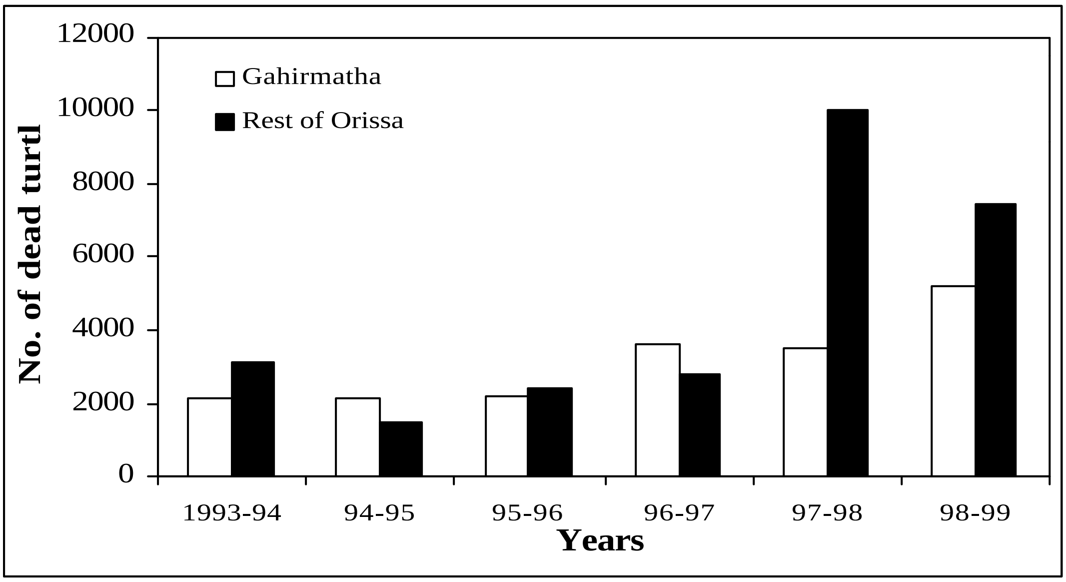


Figure 3.3. Size class (CCL) of the dead olive ridleys washed ashore the Orissa coast during the study (1995-1999).

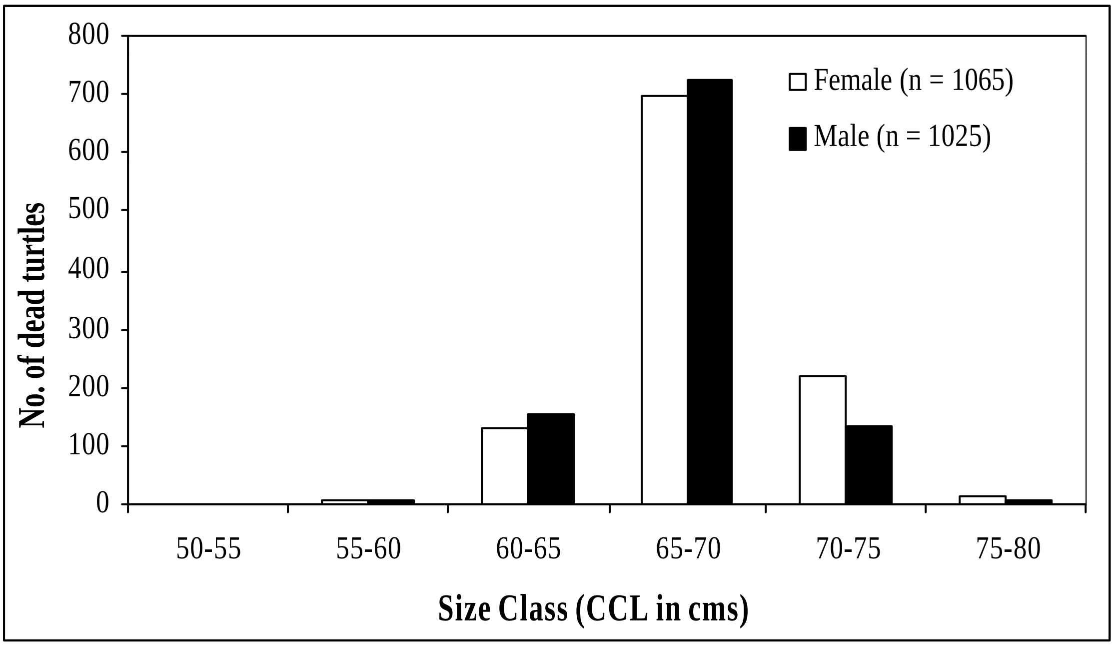
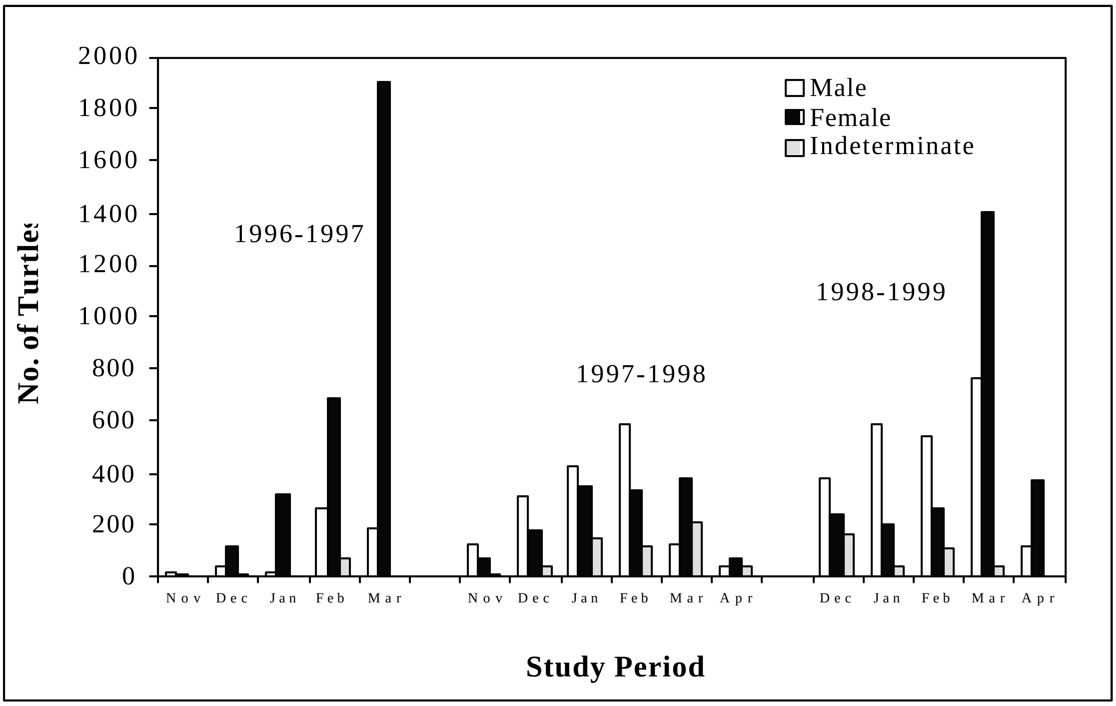
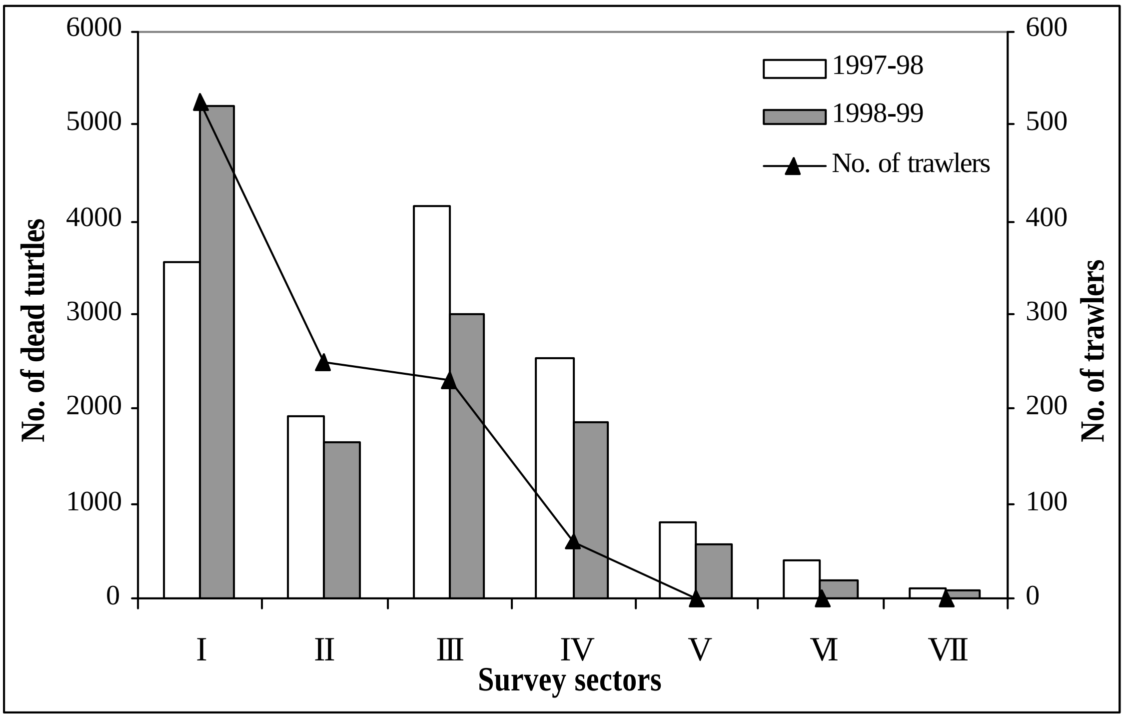


Figure 3.4. Sex ratio of the dead olive ridleys washed ashore the Gahirmatha coast during 1996 – 1999.



A sector wise analysis of dead turtles washed ashore, showed that most of the dead turtles were concentrated in the Gahirmatha and its adjoining coast lines. The majority (89.6% and 93% respectively in 1997-98 and 1998-99) of the dead turtles were recorded on the coast near Gahirmatha, Paradeep, Kujang, and Devi (Sector I to IV, Figure 3.5). The number of dead turtles in these survey sectors show a strong correlation with the number of mechanised fishing vessels (trawlers and multi-filament gill netters) operating in their respective coastal waters (Figure 3.5). Although, no quantitative information was collected on the rate of capture of sea turtles in fishing nets and the resulting mortality during the study, the frequent observations of large scale entanglement of olive ridleys in fishing gears (Plate) support the argument that mechanised fishing operation is the major reason behind this large scale mortality of olive ridleys in Orissa.

Figure 3.5. Intensity of trawling and number of dead olive ridleys washed ashore in different survey sectors along the Orissa coast during 1997 - 1999.



3.3. DISCUSSION

As mentioned in Chapter II (section), over the years considerable morphological changes of the nesting beach has taken place at Gahirmatha. The nesting beach at Gahirmatha (Nasi Island) is shifting northwards every year and loss of nesting habitat after the arribada is considerable (Prusty et al., 2000). In almost every nesting colony, some nests are lost to erosion accretion, and tidal inundation. The extent of egg mortality varies widely among beaches, years, and species. Nests deposited on shifting beaches are more susceptible to destruction from erosion. Almost 40-60% of the nests of leatherbacks laid on shifting beaches are reported to have been lost because of beach erosion (Surinam: Mrosovsky, 1983; Whitmore and Dutton, 1985; Guianas and St. Croix: Eckert, 1987). Beach erosion have been attributed to destroy 3-25% of the loggerhead nests deposited each year on two barrier islands in South Carolina in 1980-82 (Hopkins and Murphy, 1983). Although erosion of the beach is a natural process, it can greatly be influenced by human interference. Human interference with natural processes through coastal development and associated activities has resulted in accelerated erosion rate in some localities and interruption of natural shoreline migration (NRC, 1990). In this context planting Casuarina during mid 1970's has extensively modified the shoreline along the Gahirmatha coast. Plantation of Casuarina on natural sand dunes has resulted in the stabilisation of the dunes thereby affecting the natural process of shore line formation along this coast. It is presumed that this may have resulted in the rapid erosion of shoreline along Gahirmatha coast.

The other possible reason behind the accelerated beach erosion along Gahirmatha coast could be a result of the changes in off-shore current pattern. As evident in the satellite imageries, there are huge gyre formations off Gahirmatha coast (Indian Institute of Remote Sensing, Personal Communication). Waves generating from these gyres are coming and colliding with the Gahirmatha coast with great force, thereby resulting in erosion of the nesting beach. However, further studies are required to understand the dynamics of beach formation or erosion in these areas so that proper predictions can be made regarding the fate of the nesting beach.

Extensive research elsewhere have demonstrated that emergent hatchlings principal cues for finding the sea are visual responses to light (Daniel and Smith, 1947; Ehrenfeld and Carr, 1967; Witherington and Martin, 1996; Lohmann et al., 1997). Artificial beach front light

Fig. 4. Both nesting females as well as turtle hatchlings are extremely sensitive to artificial illumination. Even a small flash light can disorient thousands of hatchlings

from buildings, street lights, vehicles and other sources has been documented to disorient the turtle hatchlings (McFarlane, 1963; Philibosian, 1976; Ehrhart, 1983). As evident from the results of the present study, extremely large numbers of hatchlings get disoriented after emerging from the nest at Rushikulya rookery. The source of illumination at this rookery are the nearby town ship and the chemical factories located near the Rushikulya estuary. Although the lights are not directly visible to the nesting beach, the background glow associated with intensive inland lights is clearly visible from the nesting beach. This brighter horizon on the land ward side disorients the turtle hatchlings. The results of disorientation at this rookery are mostly fatal. As hatchlings head toward the wrong direction or meander along the beach, their exposure to predators and likelihood of desiccation are greatly increased. Disoriented hatchlings get entrapped in vegetation and large numbers of hatchlings have been found dead behind the nesting beach at Rushikulya.

One major effort during this study went in documenting the enormous number of dead turtles along the coast of Orissa. More than 46,000 dead olive ridleys were documented over six breeding seasons during this study. Except for couple of instances (Pandav et al., 1995), all the dead turtles counted were adult breeding individuals. Such high mortality is a cause for grave concern as Kemp's ridley population faced a similar problem and is the most endangered sea turtle in the world today (Pritchard, 1997). What is more alarming is the fact that all the turtles that get washed ashore are adult breeding individuals. Demographic models on sea turtles have clearly established that the reproductive value of adult breeding individuals are much more higher than compared to any other life stages of a sea turtle (Frazer, 1986, 1987; Crouse et al., 1987). Crouse et al. (1987) estimated the reproductive value of an adult breeding loggerhead turtle to be 584 times greater than that of an egg or hatchling. Considering the high reproductive value that an adult sea turtle has in a population, this large scale mortality of adult olive ridleys in Orissa is definitely alarming. It is true that no conservation effort can be successful without adequately protecting all stages in the

Fig. 4. Thousands of dead turtles get washed ashore the Orissa coast during every breeding season. Off late the mortality of adult ridleys in Orissa has reached alarmingly high proportion.

life cycle of a sea turtle, but the analyses of Crouse et al. (1987) strongly suggest that efforts to reduce mortality of adult turtles will be more effective at promoting the population growth than efforts to increase the number of hatchlings leaving the beaches. The analyses also predict that efforts to protect eggs on nesting beaches and efforts at head starting would themselves be insufficient to reverse the decline in the population without adequately protecting the breeding individuals. Because the population growth in sea turtles is most sensitive to changes in survivorship of adults, the death of large number of adult turtles in Orissa in this context is definitely a matter of grave concern.

The presence of dead or stressed turtles on the beaches has been used as an index of at sea mortalities (Murphy and Hopkins-Murphy, 1989; NRC, 1990). There are many factors that bias this index such as wind and ocean currents. Juvenile and adult turtles have a specific gravity greater than sea water and both adjust their buoyancy by inflating their lungs (Milsom, 1975). Consequently the dead turtles sink to the bottom and as a result of decomposition the animals eventually bloat and float to the surface only to sink again later. Thus probability of stranding at any given location on the beach is largely dependent on the near bottom current field (Epperly et al., 1996). Studies suggest that the number of dead turtles washed ashore represent a minimum estimate of mortality (Hillestead et al., 1978; Murphy and Hopkins-Murphy, 1989). Therefore, documentation of 46,200 odd turtles during this study is a minimum estimate for mortality of olive ridleys in Orissa. The actual number of dead turtles killed during fishing operations could actually be much higher than this count.

The primary cause for such mortality in Orissa is fishery related although other causes have been suggested by various government agencies (Pandav and Choudhury, 1999). One of the major hurdles in overcoming this problem has been the lack of quantitative information on the rate of incidental capture during mechanised fishing operations off Orissa coast. Sea turtles are caught in fishing activities around the world, especially in trawl net (Hillestad et al., 1982; Robins, 1995). Trawl captures may result in drowning of turtles or may weaken their physical condition, putting them at a greater risk of predation (Kilma et al., 1988). Drowning in trawl nets is the main cause of sea turtle mortality due to human activities in the south eastern Untied States of America (NRC, 1990), where between 5,000 to 50,000 turtles are estimated to be caught annually in shrimp trawl nets (Henwood and Stuntz, 1987). From the frequent observations in the coastal waters off

Gahirmatha during this study it is quite obvious that olive ridleys are caught in trawl fisheries in Orissa and the positive correlation between trawling intensity and adult mortality has been adequately demonstrated (refer Figure 3.5). Gahirmatha and its adjoining areas (Sector I to IV) are subjected to the highest levels of shrimp trawling in Orissa. Trawlers and gill-netters from fishing bases such as Balaramgadi, Kashaphali, Dhamara, Paradeep and Nuagada operate in the coastal waters off these four sectors. The intensity of mechanised fishing is reflected by the presence of highest number of dead turtles in these sectors.

Fig. 4. (a) & (b) While sea turtles incidentally captured during trawl fishing, gill nets are also responsible for large scale sea turtle mortality.

MANAGEMENT STRATEGIES

The concentrated mass nesting of olive ridley sea turtles in several critical localities along the Orissa coast is one of the most intensive in the world and needs to be protected. Measures must be taken up urgently to conserve this sea turtle population which is facing increasing threats to its survival. A recent study on molecular genetics of this population has come up with the finding that the Orissa population of olive ridley sea turtle may have served as the ancestral source for ridley populations across the world (Shanker et al., 2000). This greatly enhances the conservation value of this population. It is clearly of utmost importance that this large population visiting Orissa coast must be given the highest priority. Based on the findings of this study following measures are recommended to effectively manage the sea turtle population in Orissa.

5.1. ESTABLISHMENT OF A NETWORK OF PROTECTED AREAS IN ORISSA FOR SEA TURTLE CONSERVATION

Of the three mass nesting beaches of olive ridleys in Orissa only the Gahirmatha rookery and its coastal waters are given protected area status. The nesting beaches as well as their coastal waters at Devi and Rushikulya lack any kind of legal protection, making them vulnerable to human related disturbances. Tag recoveries during the present study have revealed the movement of sea turtles between the rookeries as well as their coastal waters. This study also proves that olive ridleys in Orissa are using more than one beach for nesting during the same as well as subsequent breeding seasons. Therefore, the possibility that the turtles, nesting at Rushikulya are also nesting at Devi and Gahirmatha cannot be ruled out. Hence any adverse impact on the turtles at Devi or Rushikulya rookery is ultimately going to affect the nesting population at Gahirmatha. Further, if the nesting beach at Gahirmatha continues to decline due to geographical factors, these turtles may nest at the other rookeries and it is important that these alternate-nesting beaches should be safeguarded from disturbance factors. Therefore the entire sea turtle population using Orissa coast for nesting should be considered as a single conservation unit and protecting the three mass nesting beaches as well as their coastal waters is extremely crucial for the survival of sea turtles in Orissa which could well be a single population.

Further, the analysis in section ( ) highlights the importance of smaller rookeries like Rushikulya. Although Gahirmatha undoubtedly supports the largest congregation of olive ridleys, this study reveals that the mortality of eggs is also higher there due to high intensity of beach erosion. Further, frequent saline inundations also considerably lower the rate of incubation success at Gahirmatha. Compared to Gahirmatha, nests laid at Rushikulya showed a significantly higher incubation success during this study. Considering the rapid changes in nesting habitat at Gahirmatha and the resulting lower incubation success, a stable beach like Rushikulya emerges as an important rookery that can help in sustaining a stable population of olive ridleys in the long run.

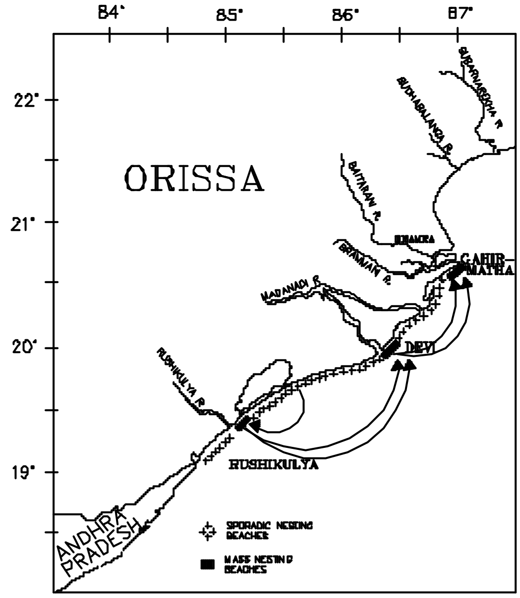


Fig. 5.1 Tag returns during the study indicated the movement of olive ridley sea turtles between nesting beaches.

The mass nesting beach at Devi River mouth, discovered in 1981, has not yet received any kind of protection measure. To make matters worse, much of the nesting ground at Akashdia Island on Devi River mouth has been lost to Casuarina plantation due to lack of proper land-use management program. It is recommended that the coastline between Kadua River mouth and mouth of river Petaphutei (which includes two islands - Akashdia and Sahana Nasi) should be declared as a protected area and proactive management strategy is required to conserve the nesting habitats of ridleys along this coast.

Similarly the Rushikulya rookery although discovered in 1994 (Pandav et al., 1994), is yet to receive any protective measure. In the absence of legal protection status, the nesting beach at this rookery has been usurped and altered by aquaculture firms. It is therefore suggested that a 20 km coastal stretch, from the Rushikulya river mouth north wards to the Malud village along Chilka coast should be declared a sanctuary.

5.2. REDUCING THE MORTALITY OF ADULT SEA TURTLES IN ORISSA

Natural mortality factors except those affecting eggs and hatchlings on beaches are difficult to alleviate. However, mortality factors that result from human activities are more amenable to management. The present study documents an extremely high mortality of olive ridleys on the coast of Orissa. A major reason behind this large-scale turtle mortality is mechanised fishing activities in areas of high sea turtle concentration.

Organised harvesting and large-scale killing of sea turtles over a prolonged time is a major cause for drastic declines in turtle populations; kemp's ridley sea turtle in Mexico is a prime example of this. No one has ever successfully managed marine turtle population at stable population levels while subjecting them to large-scale mortalities. As discussed in Chapter 3.3, the reproductive value of an adult turtle is much more higher than any other life stages. More over the fact that both male and female olive ridley remigrate annually to the same breeding area (Chapter 2.2.6.5) where fishing intensity is high, puts them at a greater risk of getting killed in the fishing nets. Therefore, the high levels of olive ridley mortality recorded during this study are a matter of utmost concern and need to be addressed without any further delay. The first step is a strict enforcement of ban on near-shore mechanised fishing and commercial fishing activities in areas of high sea turtle concentration. As discussed in Chapter 3.2.3, most of the turtle mortality in Orissa has been documented in the coastline between Gahirmatha and Devi River mouth. Undoubtedly, the coastal waters along this stretch support high sea turtle population. The Government of Orissa has declared the coastal waters off Gahirmatha a marine sanctuary and the coastal waters off Devi River mouth a no-fishing zone for certain period. Besides, the Orissa Marine Fishing Regulation Act, 1982 and Rules 1983 seek to prevent any kind of mechanised fishing within 5 km of the shoreline. However, the enforcement agencies *viz.*, the State Forest Department and the State Fisheries Department, lack infrastructure to enforce the ban on fishing in these areas. Therefore the agencies concerned, should be provided with adequate sea going vessels and personnel for strict enforcement of these bans.

Fig. 5.2 While TED has been effective in reducing trawl related mortalities, of late large scale drowning in gill nets has been a major concern.

The use of Turtle Excluder Devices (TED) in trawl nets should be made mandatory for trawlers operating in the coastal waters beyond five km from the shoreline. TEDs are essentially trapdoors, which can be attached to trawl nets and they allow large animals like sea turtles to escape from the net without significant loss of fish catch. However, use of TED alone will not bring down the turtle mortality because turtles are also caught and killed in gill nets and TEDs cannot be used in gill nets. Therefore, a combined strategy involving strict enforcement of the existing law on marine fishing and the use of TEDs, should be adopted to bring down the turtle mortality.

5.3. PROTECTION OF SEA TURTLES IN THE COASTAL WATERS

Protection of the nesting turtles and the post-ovipositional eggs on the nesting beach is a fairly straightforward option open to us. However, the real problem for the management is the protection of sea turtles in the sea where much of the problem occurs. Protecting vast stretches of coastal waters with inadequate infrastructure has been a major problem in managing the sea turtle population in Orissa. The Gahirmatha Marine Sanctuary is spread over an area of 1400 sq. km. There is only one sea going vessel with the management to patrol the entire area. Results of this study (section 2.2.5, Figure 2.5) clearly show that much of the congregation of ridleys during early part of the breeding season is confined to an area of roughly 52 sq. km. Although possibility of other reproductive congregations in the vicinity cannot be ruled out, this study has identified one big congregation. The management, instead of diluting its effort in patrolling the vast 1400 sq. km of coastal waters with just one patrolling vessel, can actually intensify patrolling in a small area such as the reproductive patch identified during this study. Such reproductive patches keep shifting with the progress of the breeding season. The management should try to locate such reproductive patches and intensify patrolling there to deter the mechanised boats to trawl/fish in the area. The exercise to identify reproductive patches should be extended to all the other parts of the Orissa coast so that adequate protection can be provided to the whole population during the breeding season.

Fig. 5.3 Unless turtle congregations in the coastal waters are provided absolute protection, turtles will continue to die in large numbers like this.

5.4. MINIMISING THE IMPACT OF ARTIFICIAL ILLUMINATION

More than the adult turtles, the turtle hatchlings were found to be strongly disoriented in the presence of artificial illumination at Rushikulya rookery. Since hatchling emergence at this rookery takes place only for 3-4 nights in a year and these dates can be predicted well in advance, the management should initiate a dialogue with the local municipal authorities and the chemical plants to put off the lights during the hatchling emergence period. Most of the background glow at Rushikulya results from the high intensity mercury vapour lamps that are used as street lamps by the municipal authorities and the chemical plants. These high intensity lamps can be replaced with lights of low intensity such as sodium vapour lamps to minimise disorientation of turtle hatchlings. A green fence, in the form of a plantation, can be raised on the higher grounds behind the mass nesting beach at Rushikulya to counter the impact of background glow. However, it should be ensured that the green fence be raised well away from the nesting beach leaving enough space for the turtles to nest.

Fig. 5.4 In order to ensure smooth return of hatchlings back to sea, artificial lights near mass nesting beaches in Orissa must be put off during the hatchling emergence period.

5.5. IDENTIFICATION OF THE EXACT NON-BREEDING GROUNDS OF OLIVE RIDLEYS NESTING IN ORISSA

Though olive ridleys spend almost six months in a year in the coastal waters off Orissa, till recently nothing was known about the area where they spend the remaining six months. Recovery of 22 turtles tagged in Orissa from Sri Lanka and Gulf of Mannar during this study indicate that this could possibly be the non-breeding grounds for the ridleys migrating to the Orissa coast every winter. Although the tagged turtles have been recovered all around Sri Lanka, most of the recoveries are made from Gulf of Mannar and the west coast of Sri Lanka. Satellite telemetry studies can provide definite answers about olive ridleys non-breeding area. However, with the existing tag returns it is clear that olive ridleys are migrating from as far south as Sri Lanka to breed in Orissa. Therefore, further surveys are needed to find the status and identify potential threats to the ridleys in these areas especially in the Gulf of Mannar.

5.6. CONTROL AND REALIGNMENT OF COASTAL CASUARINA PLANTATION

A prominent feature of coastal vegetation in Orissa is the presence of extensive Casuarina plantation. The former nesting beach at Gahirmatha and the existing nesting beach at Devi River mouth has been completely taken over by this dense Casuarina plantation. Casuarina is detrimental to the nesting of sea turtle population in more than one way. Dense Casuarina plantation causes excessive shading of the nesting beach. Studies in south western Florida suggest that nests laid in the shaded areas are subjected to lower incubation temperature which can alter the natural sex-ratio of hatchlings (Schmelz and Mezich, 1988). Casuarina with its superficial root growth and thick litter fall renders the beach unsuitable for turtles to nest. Davis and Whiting (1977) reported declines in nesting activity of loggerhead in Everglades National Park where dense strands of Casuarina took over native beach vegetation.

Fig. 5.5 No amount of legal status is going to save sea turtles in Orissa unless reckless plantations like this in some of the prime nesting habitats are immediately stopped and the planted Casuarina uprooted and removed.

Fresh plantations are still coming up very close to the high-tide line near Barunei along the Gahirmatha coast and near Devi River mouth. It is essential to put an end to the spread of Casuarina plantations towards beach-front and, in fact, recent plantations that were raised close to the high tide line should be uprooted and cleared. This study strongly recommends that Casuarina plantations should be at least 150-200 m away from the high-tide line to provide adequate nesting habitat for sea turtles. Such stipulation should ideally be extended to the entire stretch of Orissa coast.

5.7. RESEARCH IN SUPPORT OF CONSERVATION

Research on sea turtles throughout the world has contributed in a long way towards understanding their biology and managing these endangered animals. The tagging program carried out during this study indicated that there is inter-rookery movement of olive ridleys in Orissa, while the tagging of mating pairs has provided key information on reproductive biology of the species. Keeping this research as a baseline study, follow up work needs to be taken up on this species to develop further management strategies.

The sea turtle rookeries as well as the sporadic nesting beaches in Orissa need constant monitoring during the breeding season to determine the intensity of sea turtle nesting based on which detailed management program can be laid out. Regular surveys of the coast during the breeding season will also provide crucial information on sea turtle mortality. Although this study documented a high mortality of adult turtles in Orissa, there are still glaring gaps in our knowledge in understanding the root cause of the problem. No quantitative information is available on the capture rates of sea turtles in shrimp trawls or in gill nets and on their mortality rate due to such incidental capture. In order to prevent this large scale incidental capture, it is essential for the manager to know when and where turtle captures occur, at what depth majority of the captures occur and how many turtles are killed. To resolve these questions a quantitative study of incidental capture-related-mortality during fishing operations needs to be carried out in Orissa.

The largest known rookery of olive ridleys at Gahirmatha has undergone considerable changes in the recent past. The study of coastal geomorphology in this area will help in understanding the beach dynamics so that proper plans can be worked out to effectively manage the turtles nesting at this rookery. Since the olive ridleys migrating to Orissa coast do not necessarily spend the remaining part of the year within the geographical limits of Orissa or for that matter India, it is necessary to involve various governmental and non-governmental agencies across countries in the management of these long distance migrants.

REFERENCES

ACKERMAN, R.A. (1980). Oxygen consumption by sea turtle eggs during development, Physiol. Zool., 54, 316-324.

ACKERMAN, R.A. (1997). The nest environment and the embryonic development of sea turtles. In: Lutz, P.L. and Musick, J.A. (Eds.). The biology of sea turtles. New York: CRC Press, pp. 83-106.

ANONYMOUS (1997). Handbook on fisheries statistics, Orissa, 1996-97. Directorate of Fisheries, Government of Orissa, Cuttack.

BALAZS, G. (1980). Synopsis of biological data on the green turtle in the Hawaiian Islands. National Oceanic and Atmospheric Administration technical memorandum, national marine fisheries service, Southwest Fisheries Centre. No. 7: 1-141.

BALAZS, G. (1983). Recovery records of adult green turtles observed or originally tagged at French Frigate Shoals, north-western Hawaiian islands. National Oceanic and Atmospheric Administration Technical Memorandum, National Marine Fisheries Service, 36:1-42.

BALAZS, G. (1999). Factors to consider in tagging of sea turtles. In: Research and management techniques for conservation of sea turtles. Eds. K.L. Eckert, K.A. Bjorndal, F.A. Abreu-groubis and M.donnelly. MTSG publication 4: 101-110.

BANERJEE, L.K. AND RAO, T.A. (1990). Mangroves of Orissa coast and their ecology; Bishen Singh Mahendra Pal Singh, Dehra Dun; 118 pages.

BEKOFF, M. AND L.D. MECH. (1994). Simulation analyses of space use: Home range estimates, variability, and sample size. Behaviour research methods, instruments and computers. 16 (1): 32-37.

BHASKAR, S. (1993). The status and ecology of sea turtles in the Andaman and Nicobar Islands. Centre for Herpetology Publication No. ST 1/93:1-37.

BISWAS, S. (1982). A report on the olive ridley *Lepidochelys olivacea* (*E*schscholtz) [Testudines: Cheloniidae] sea turtle of Bay of Bengal; Rec. Zool. Surv. India, 79: 275-302.

BISWAS, S.; L.N. ACHARJYO; AND B.C. MOHAPATRA (1977). Observations on incubating eggs of *Lepidochelys olivacea (Eschscholtz)* from Orissa coast in natural and artificial conditions ; Science and Culture, 143: 43-45.

BJORNDAL, K. A.; A.B. MEYLAN; AND BJ. TURNER (1983). Sea turtles nesting at Melbourne beach, Florida, I. Size, growth and reproductive biology. Biological Conservation 26: 65-76.

BJORNDAL, K.A.; A. CARR; A.B. MEYLAN; AND J.A. MORTIMER (1985). Reproductive biology of the hawksbill *Eretmochelys imbricata* at Tortuguero, Costa Rica, with notes on the ecology of the species in the Caribbean. Biological Conservation, 34: 353-368.

BOOTH, J AND J.A. PETERS (1972). Behavioural studies on the green turtle (*cheloni mydas)* in the Sea. Anim. Behavior. 20: 808-812.

BOSC, P. AND J. Y. LE GALL (1986). Attachment spatial des tortues vertes *Chelonia mydas* aux plages de l'ile de Tromelin (Ocean Indien), Oceanologica ACTA 9: 489.

BOWEN, B.W.; A.B. MEYLAN; P. ROSS; C.J. LIMPUS; G.H. BALAZS; AND J.C. AVISE(1992). Global population structure and natural history of the green turtle (*Chelonia mydas*) in terms of matriarchal phylogeny. Evolution, 46: 865-881.

BUSTARD, H. R. (1972). Sea Turtles: Natural History and Conservation. (Collins, London).

BUSTARD, H.R., (1976). World's largest sea turtle rookery? Tiger Paper 3: 3.

BUSTARD, H. R. AND L. P. TOGNETTI. (1969). Green Sea Turtles: A discrete simulation of density dependent population regulation. Science, 163: 939-941.

CARR, A.F., (1983). Life lines**:** Old faithful. Animal Kingdom 1, 49-50.

CARR, A.F. AND H.F. HIRTH (1962). The ecology and migrations of sea turtles, 5. Comparative features of isolated green turtle colonies. American Museum Noviates 209: 1-42.

CARR, A.F. AND L. GIOVANNOLI (1957). The ecology and migrations of sea turtles, 2. Results of field work in Costa Rica. American Museum Novaites 1835: 1-32.

CHAVES, A.; G. SERRANO; G. MARIN; E. ARGUEDAS; A. JIMENEZ; AND J.R. SPOTILA (1996). Biology and conservation of leatherback turtles, *Dermochelys coriacea*, at Playa Langosta, Costa Rica. Chelonian Conservation and Biology. 2(2):184-189.

CLIFFTON, K.; D. O. CORNEJO; AND R. S. FELGER (1982). Sea turtles of the Pacific coast of Mexico. In: Bjorndal, K. (Ed.). Biology and Conservation of sea turtles. Washington D.C.: Smithsonian Institution Press, pp. 199-209.

CORNELIUS, S.E. (1982). Status of sea turtle population in the central Eastern Pacific. In Biology and conservation of sea turtles, ed. K. A. Bjorndal, pp. 211-219, Smithsonian Institution Press, Washington D. C.

CORNELIUS, S.E. (1986). The sea turtles of Santa Rosa National Park. San Jose: Fundacion de Parques Nacionales, Coata Rica. Monograph., 134pp.

CORNELIUS, S.E., AND D.C. ROBINSON (1985). Abundance, distribution and movements of female olive ridley turtles tagged in Costa Rica. Vida Silvestre Neotropical 1(1): 12-23.

CORNELIUS, S. E.; M. A. ULLOA; J. C. CASTRO; M. M. DEL VALLE; AND D. C. ROBINSON (1991). Management of Olive Ridley Sea turtles (*Lepidochelys olivacea*) nesting at Playas Nancite and Ostional, Costa Rica. In: J. R. Robinson And K. H. Redford (Ed.). Neotropical Wildlife use and conservation. Chicago: University of Chicago Press. Pp. 111-135.

CROUSE, D.T.; L.B. CROWDER; AND H. CASWELL (1987). A stage- based population model for loggerhead sea turtles towards the sea. Science 106:398-399.

DANIEL, R.S. AND K.V. SMITH (1947). Migration of newly hatched Loggerhead turtles towards the sea. Science 106:398-399.

DASH, M. C. AND C. S. KAR. 1990. The turtle paradise – Gahirmatha, Interprint, New Delhi, 295 pages.

DAVIS, G.E. AND M.C. WHITING (1997). Loggerhead sea turtle nesting in Everlades National park, Florida, U.S.A. Herpetologica 33: 18-28.

DODD, C. K. JR. (1988). Synopsis of the biological data on the loggerhead sea turtle *Caretta caretta* (Linnaeaus 1798). USFWS Biological-88(14). Gainsville, Florida: National Ecology Research Center. Pg. 119. Available from NTIS as PB89-109565.

ECKERT, K.A.; S.A. ECKERT; T.W. ADAMS; AND A.D. TUCKER (1989). Inter-nesting migrations by Leatherback sea turtles (*Dermochelys coriacea*) in the West Indies. Herpetologica, 45: 190-194.

ECKERT, K.L. (1987). Environmental unpredictability and leatherback sea turtle (*Dermochelys coriacea)* nest loss. Herpetologica 43: 315-323.

EHNENTELD, D.W. AND A.F.CARR (1967). The role of vision in the sea finding orientation of the green turtle *(Chelonia mydas)*. Anim. Behav. 16: 281-287.

EHRHART, L.M. (1982). A review of sea turtle reproduction. 29-38 In: Bjorndal, K.A. (Ed.). Biology and conservation of sea turtles. Smithsonian Institution Press, Washington D.C.

EHRHART, L.M. (1983). Marine turtles of the indian river lagoon system. Fla. Sci. 46: 337:824.

EPPERLY, S.P; J.BRAUN; A.J. CHESTER; F.A.CROSS; J.V.MERRINER; P.A.TESTER; And J.H. CHURCHILL (1996): Beach strandings as an indicator of at-sea mortality of sea turtles. Bulletin of Marine Science, 59 (2): 289-297.

FITZSIMMONS, N.N.; A.D. TUCKER; AND C.J. LIMPUS (1995). Long-term breeding histories of male green turtles and fidelity to a breeding ground. Marine turtle newsletter. 68:2-4.

FITZSIMMONS, N.N.; C. MORITZ; C.J. LIMPUS; L. POPE; AND R. PRINCE (1997). Geographical structure of mitochondrial and nuclear gene polymorphisms in Australian green turtle populations and male biased gene flow. Genetics 147: 1843-1854.

FRAZER, N.B. (1983). Survivorship of adult female loggerhead sea turtles, *Caretta caretta*, nesting on Little Cumberland Island, Georgia, USA. Herpetologica, 39: 436-447.

FRAZER, N.B. (1986). Survival from egg to adulthood in a declining population of loggerhead turtles, *Caretta caretta*. Herpetologica, 42: 47-55.

FRAZER, N.B. (1987). Preliminary estimates of survivorship for wild loggerhead sea turtles, *Caretta caretta*. Herpetologica, 21:232-235.

FRAZIER, J. (1971). Observations of Sea turtles at Aldabra Atoll. Philosophical Transactions of the Royal Society of London (B). 260: 373-410.

GEORGE, R. H. (1997). Health problems and diseases of sea turtles. In: Lutz, P. L. And J. A. Musick. (Eds.). The biology of sea turtles. CRC Press, Boca Raton, Florida. Pp. 363-385.

GREEN. D. (1999). Mating behaviour in Galapagos green sea turtles. In Proc. of the 19th annual symposium on sea turtle biology and conservation, South Padre, TX.

GREEN. D. AND F. ORTIZ-CRESPO (1982). Status of sea turtle populations in the central eastern pacific. In: Bjorndal, K. (Ed.). Biology and Conservation of sea turtles. Washington D.C.: Smithsonian Institution Press, pp. 221-233.

GYRUIS, E. AND C. J. LIMPUS (1988). The loggerhead turtle, *Caretta caretta* in Queensland: breeding population structure. Australian Wildlife Research 15, 197-209.

HARRISON, T. (1956). Tagging green turtles. Nature 178, 1479.

HARRISON, T. (1958). Notes on the edible green turtle (*Chelonia mydas*). 7. Long term tagging returns. 1952-8. Journal of Sarawak Museum 8, pp. 772-8.

HARRY, J.L. AND D.A. BRISCOE (1988). Multiple paternity in the loggerhead turtle (*Caretta caretta)*. J. Heriditry. 79: 96-99.

HENDRICKSON, J.R. (1958). The green turtle, *Chelonia mydas*, In Malaya and Sarawak. Proc Zool Soc Lond 130:455-535.

HENWOOD, T.A. AND W.E. STUNTZ (1987). Analysis of sea turtle captures and mortalities during commercial shrimp trawling. Fish. Bull., 85, 813-17.

HILLESTEAD, H.O.; J.I. RICHARDSON; AND G.K. WILLIAMSON (1978). Incidental capture of sea turtles by shrimp trawlsmen In Georgia. Proc Conf Assoc. Fish Wildl. Agencies. 32:167-178.

HILLESTEAD, H.O.; J.I. RICHARDSON; C. MCVEA JR; AND J.M. WATSON JR. (1982). Worldwide incidental capture of sea turtle. In: K.A. Bjorndal (Editor) Biology and conservation of sea turtles, Second Edition. Smithsonian Institution Press, Washington D.C.

HIRTH, H. F. (1971). Synopsis of biological data on the green turtle *Chelonia mydas* (Linnaeaus 1758). FAO Fish, Synop. 85:1.1-8.19.

HOEKERT, W.E.J.; A.D. SCHOUTEN; H. NEUFEGLISE; AND S.B.J. MENKEN (1999). Multiple paternity in the olive ridley sea turtle. In Proc. of the 19th Annual Symposium on sea turtle biology and conservation, south Padre,TX.

HOPKINS, S.R. AND T.M. MURPHY (1983). Management of loggerhead turtle nesting beaches in South Carolina. Study completion report, E-1, VI-A-2, S.C. Wildlife and Marine Resource Department. 18pp.

HUGHES, G.R. (1974). The sea turtle of South Africa, 2. Investigation report of the Oceanographic Research Institute Durban 36: 1-96.

JAMES, P. S. B. R.; M. RAJAGOPALAN; S. S. DAN; A. B. FERNANDO; AND V. SELVERAJ. (1989). On the mortality and stranding of marine mammals and turtles at Gahirmatha, Orissa from 1983 to 1987. J. Mar. Biol. Ass. India, 31:28-35.

KALB, H.J. (1999). Behavior and physiology of solitary and arribada nesting olive ridley sea turtles *Lepidochelys olivacea* during the internesting period. Ph. D. thesis submitted to the office of graduate studies of Texas A & M University, USA.

KALB, H.J.; R. VALVERDE; AND D.W. OWENS (1992). What is reproductive patch of the olive ridley sea turtle ? In proceedings of the 12th annual workshop on sea turtle Conservation And Biology. Jekyll Island, Georgia. P 57-61.

KAR, C.S. (1980). The Gahirmatha turtle rookery along the coast of Orissa, India; IUCN/SSC Marine turtle Newsletter, Canada; No. 15:2-3.

KAR, C.S. (1981). Discovery of second mass nesting ground of the Pacific olive ridley sea turtle (*Lepidochelys olivacea*) in Orissa. Tiger Paper 9, 6-7.

KAR, C.S. (1982). Discovery of second mass nesting ground of the Pacific olive ridley sea turtles (*Lepidochelys olivacea*) in Orissa, India; Tiger Paper, 9 (1): 6-7.

KAR, C.S. AND S. BHASKAR (1982). The status of sea turtles in the eastern Indian Ocean; In, The biology and conservation of sea turtles; Ed: K, Bjorndal; Smithsonian Institution Press, Washington DC; 365-372.

KARL, S.A. (1995). Hybridization and taxonomy of marine turtles: Anonymous nuclear DNA sequence analyses. In: Bowen, B.W. and Witzell, W.n. (Compilers). International Symposium on Sea Turtle Conservation Genetics . Miami, F.L: NOAA Technical Memorandum NMFS-SEFSC-396,pp. 99-108.

KARL, S.A. AND B.W. BOWEN (1999). Evolutionary significant units versus geotropical taxonomy: Molecular systematics of the endangered green sea turtle. Conservation Biology. 13: 990-999.

KIE, J.G.; J.A. BALDWIN; AND C.J. EVANS (1994). Calhome- Home range analysis program U.S. Forest Service, Pacific Southwest Research Station, 2081 East Sierra Avenue, Fresno, CA 93710.

KLIMA, E.F.; G.R. GITSCHLAG; AND M.L. RENAUD (1988). Impacts of the explosive removal of offshore petroleum platforms on sae turtles and dolphins, Mar. Fish. Dev., 50,33-42.

KOPITSKY, K; R.L. PITMAN AND P.T. PLOTKIN. (2000). Physiology and behaviour of olive ridley sea turtles mating on the open ocean in the Eastern Tropical Pacific. Proceedings of the 20th annual symposium on sea turtle biology and conservation, Orlando, FL.

KRAEMER, J.E., AND R. BELL (1980). Rain-induced mortality of eggs and hatchlings of loggerhead sea turtles (*Caretta caretta)* on the Geongia Coast. Herpetologica 36: 72-77.

LIMPUS, C.J. (1985). A study of the Loggerhead sea turtle, *Caretta caretta*, in Eastern Australia, Ph. D. dissertation, University of Queensland, St. Lucia, Australia.

LI MPUS, C. J. (1992). Estimation of tag loss in marine turtle research. Wildl. Res. 19:457-69

LIMPUS, C. J. (1993). The green turtle *Chelonia mydas* In Queensland: Breeding males in the Southern Great Barrier Reef. Wildl. Res. 20: 513-23.

LIMPUS, C.J. AND D. REIMER. (1994). The loggerhead turtle, *Caretta caretta*, in Queensland : A population in decline. In: Proceedings of the Australian marine turtle conservation workshop, ed. R.James. Australian Nature Conservation Agency, pp 39-59.

LIMPUS, C.J. AND P.C. REED. (1985). Green sea turtles stranded by cyclone kathy on the South-Western coast of the gulf of Carpentaria. Aust. Wildl. Res. Vol. 12: 523-33.

LIMPUS, C.J.; A. FLEAY; AND V. BAKER (1984). The flatback turtle, *Chelonia depressa*, in Queensland: reproductive periodicity, philopatry and recruitment. Australian Wildlife Research 11, 579.

LIMPUS, C.J.; J.D. MILLER; C.J. PARMENTER; D. REIMER; N. MCLACHLAN; AND R. WEBB (1992). Migration of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles to and from eastern Australian rookeries. Wildlife Research 19, 347-358.

LOHMANN, K.J. AND C.M. LOHMANN (1996). Orientation and open-sea navigation in sea turtles. J. Exp. Biol. 1996: 73-81.

LOHMANN, K.J.; B.E. WITHERINGTON; C.M.F. LOHMANN; AND SALMON (1997). Orientation, navigation, and natal beach homing in sea turtles. In: P.L. Lutz and S.A Musick (Eds). The Biology Of Sea Turtles. CRC Press.

LUTCAVAGE, M.E.; P. PLOTKIN.; B.WITHERINGTON; AND P.L. LUTZ (1997). Human impacts on sea turtle survival. In: The biology of sea turtles. (Eds) P.L Lutz and J.A Musick. CRC Press.

LUTZ, P.L. AND J.A. MUSICK (1997). Eds. Biology of sea turtles. CRC marine science series.

MARQUEZ, M.R. (1994). Synopsis of biological data on the Kemp's ridley turtle, *Lepidochelys kempii* (Garman 1880), NOAA Tech. Memo. NMFS-SEFSC-343, Miami, FL. 91 pages.

MARQUEZ, R.; A. VILLANUEVAO; AND C. PENAFLORES (1976). Synopsis de datos biologicos sobre la tortuga golfina *Lepidochelys olivacea*. Inst. Nac. Pesca, Sinopsis sobre la Pesca, 2:1-61.

MARQUEZ, R.; A. VILLANUEVA; AND C. PENAFLORES (1976). Sinopsis de datos biologicos sobre la tortuga golfina (*Lepidochelys olivacea* Eschscholtz, 1829). INP sinopsis sobre la Pesca numero 2. Instituto Nacional de Pesca, Mexico.

MARQUEZ, R.M. (1990). Sea turtles of the world : An annotated and illustrated catalogue of sea turtle species known to date. Rome, Italy food and Agriculture Organisation, Species catalogue, FAO Fisheries synopsis, 11 (125): 81pp.

MAYOR, P.A. (1998). Nesting of the leatherback turtle (*Dermochelys coriacea)* at the Las baulas and Santa rosa National Parks and population estimations for the entire Pacific coast of Costa Rica. M.S thesis, Swiss fedrel Institute of technology (ETH), Zurich, Switzerland.

MCFARLANE, R.W. (1963). Disorientation of loggerhead hatchlings by artificial road lighting. Copeia 1963:153.

MCGEHEE, M.A. (1990). Effects of moisture on eggs and hatchling sea turtles (*Caretta caretta)*. Herpetologica. 46: 251-258.

MEYLAN, A. (1982). Sea turtle migration – Evidence from tag returns. In: Bjorndal, K. (Ed.). Biology and Conservation of sea turtles. Washington D.C.: Smithsonian Institution Press, pp. 91-100.

MEYLAN, A. AND P. MEYLAN, (1994). Description of migratory fleet of green turtles. In: Schroeder, B.A. and Witherington, B.E. (Compilers). Proc. 13th Ann. Symp. Sea Turtle Biol. Conserv. Miami, FL: NOAA Tech. Mem. NMFS-SEFSC-341, Pp107.

MEYLAN, A.B. AND S. SADOVE (1986). Cold stunning in Long Island Sound, New York. Marine Turtle Newsl. 37: 7-8.

MEYLAN, P.; A.B. MEYLAN; AND R. YEOMANS (1992). Interception of tortuguero bound Green Turtles at Bocas Del Toro province, Panama. In: Salmon, M. And J. Wyneken (Compilers). Proeecedings of the eleventh annual workshop on sea turtle biology and conservation. National Oceanic and Atmospheric Administration technical memorandum, National Marine Fisheries Service, Southeast Fisheries Center. No. 302, 74.

MEYLEN, A.B., AND M. DONNELLY (1999). Status justification for listing the hawksbill turtle (E*retmochelys imbricata)* as critically endangered on the 1996 IUCN Red list of threatened animals. Chelonian Conservation and Biology. 3(2): 200-224.

MILLER, J.D. (1985). Embryology of marine turtles. In: Gans, C, Billet, F., Maderson, P.F.A. (Eds) . Biology of the Reptilia, Vol.14, Wiley, New York, P.269-328.

MILLER, J.D. (1997). Reproduction in sea turtles. In: Lutz, P.L., Musick, J.A. (eds), The biology of sea turtles. CRC Press, Inc., Boca Raton, Florida. 432pp.; 1997, p269-328.

MILSOM, W.K. (1975). Development of bouancy control in juvenile Atlantic loggerhead sea turtles, C*arreta carreta,* Copeia 758-762.

MOHANTY-HEJMADI AND G. SAHOO (1994). Biology of the olive ridleys of Gahirmatha, Orissa, India. Bjorndal, K.A., Bolten, A.B., Jhonson, D.A., Elaazar, P.J.Compilers, Proceedings of the fourteen annual symposium on sea turtle biology and conservation. NOAA technical memorandum NMFS-SEFSC-351, 323 Pp.; 1994, P.90-93.

MOOREHOUSE, F.W. (1933). Notes on the green turtle, *Chelonia mydas*. Report of the Great Barrier Reef Committee 4 (1), pp. 1-22.

MORTIMER, J.A. AND R. BRESSON (1999). Temporal distribution and periodicity in hawksbill turtles (*Eretmochelys imbricata*) nesting at Cousin Island, Republic of Seychelles, 1971-1997. Chelonian Conservation and Biology 3, 318-325.

MROSOVSKY, M. (1983). Ecology and nest-site selection of leatherback turtles, *Dermochelys coriacea*. Biol. Cons. 26: 47-56.

MTSG. (1995). A global strategy for the conservation of sea turtles. IUCN: MTSG.24pp.

MURPHY, T.M., AND S.R. HOPKINS-MURPHY (1989). Sea turtle and shrimp fishing interactions: A summary and critique of relevant information. Washington, D.C. : Center for Marine Conservation. 60pp.

NATIONAL RESEARCH COUNCIL (NRC). (1990). Decline of the Sea Turtles: Causes and Prevention. National Academy Press, Washington DC.

NORUSIS, M.J. (1980). SPSS/PC+ for the IBM PC/XT/AT.SPSS inc. Chicago,U.S.A.

OWENS, D.W. (1980). The comparative reproductive physiology of sea turtles. Amer. Zool. 20:549-563.

PACKARD, G. C.; M. J. TRACY; AND J. J. ROTH. (1977). The physiological ecology of reptilian eggs and embryo, and the evolution of viviparity within the class reptilia. Biol. Rev. 52: 71-105.

PANDAV, B. (2000). Post cyclone situation in coastal Orissa with special reference to marine turtle conservation. Report submitted to GOI-UNDP sea turtle project. Wildlife Institute of India, Dehradun. 14 pages.

PANDAV, B. AND B.C. CHOUDHURY (1998). Olive ridley tegged in Orissa recovered in coastal waters of Eastern Sri Lanka. Marine Turtle Newsletter No. 82; 1998, p. 9-10.

PANDAV, B. AND B.C. CHOUDHURY (1999). An update on mortality of olive ridley sea turtle in Orissa, India. Marine Turtle Newsletter 83, 10-12.

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 along Orissa coast, India. Marine Turtle Newsletter 67, 15-16.

PANDAV, B.; B.C. CHOUDHURY; AND C.S. KAR (1997). Mortality of olive ridley turtles *Lepidochelys olivacea* due to incidental capture in fishing nets along the Orissa coast, India. Oryx 31:32-36.

PANDAV, B.; B.C. CHOUDHURY; AND K. SHANKER (1998). The olive ridley sea turtle (*Lepidochelys olivacea)* in Orissa: An urgent call for an intensive and integrated conservation program. Current Science vol. 75, No. 12.

PANDAV, B.; K. BANUGOPAN; D.SUTARIA; AND B.C. CHOUDHURY (2000). Fidelity of male olive ridley sea turtles to a breeding ground. Marine Turtle Newsletter (87): 9-10.

PANIGRAPHY, R.C.; R. GOUDA; S. MISHRA; AND L. NAYAK (1990). Availability of marine turtle eggs near Rushikulya river mouth, East coast of India. Indian Forester, 116: Pp 515-516.

PATNAIK, S.N.; N.K, MAHALIK; AND S.P, BHUNYA (1990). Mapping and characterisation of the wetlands along the eastern coast of Orissa; Final project report submitted to Ministry of Environment and Forests, Govt. of India; Utakal University, Bhubaneswar, Orissa.

PHILIBOSIAN, R. (1976). Disorientation of hawks bill turtle hatchlings, *Eretmochelys imbericata,* by stadium lights. Copecia, 1976: 824.

PITMAN, R.L. (1990). Pelagic distribution and biology of sea turtles in the Eastern Tropical Pacific. In: Richardson, T.H., Richardson, J.I And Donnelly, M. (Eds.). Proc. 10th Ann. Workshop Sea Turtle Biol. Conserv. Miami, FL: NOAA Tech. Mem. NMFSSEFC-278, Pp. 143-148.

PLOTKIN, P.T; D.C. ROSTAL; R.A. BYLES AND D.W. OWENS .(1995). Independent versus socially facilitated oceanic migrations of the olive ridley, *Lepidochelys olivacea.* Marine Biology 122:137-143.

PLOTKIN, P.T; D.W. OWENS; R.A. BYLES; AND R. PATTERSON. (1996). Departure of male olive ridley turtles, *Lepidochelys olivacea,* from a near shore breeding ground. Herpetologica 52 (1), 1-7.

PLOTKIN, P.T.; M. POLAK; AND D.W. OWENS (1991). Observations on olive ridley sea turtles behaviour prior to an arribada at Playa nancite. Costa Rica. MTN 53:4.

PRITCHARD, P.C.H. (1969). Studies of the sysmatics and reproductive cycles of the genus *Lepidochely*. Ph.D. Dissetation. University of Florida, Gainsville, FL.

PRITCHARD, P.C.H. (1973). International migrations of South American sea turtles (Chelonidae and Dermochelidae). Animal Behavior 21, 18-27.

PRITCHARD, P.C.H. (1997). Evolution, phylogeny and current status. In: Biology of sea turtles, Lutz, P.L. and Musick, J.A. Eds. CRC Marine Science Series.

PRITCHARD, P.C.H., AND P. TREBBAU. (1984). The turtles of Venezuela. Society for the study of amphibians and reptiles. 375 pages.

PRUSTY, B. G.; R. K. SAHOO; AND S. D. MEHTA. (2000). Natural causes lead to mass exodus of olive ridley turtles from Ekakulanasi, Orissa, Indai: A need for identification of alternate sites. In: Sea Turtles of the Indo Pacific – Research, management and conservation; ed. Pilcher, N. and G. Ismail. Academic Press, London, pp. 189-197.

RAGOTZKIE, R.A. (1959). Mortality at loggerhead turtle eggs from excessive rainfall. Ecology 40: 303-305.

RAM, K. (2000). Behavioral ecology of the olive ridley sea turtle *Lepidochelys olivacea* (Eschscholtz,1827) during the breeding period. M.Sc thesis submitted to the Salim Ali School of Ecology Pondicherry University.

REICHART, H.A. (1993). Synopsis of biological data on the olive ridley sea turtle *Lepidochelys olivacea* (Eschscholtz 1829) in the Western Atlantic. NOAA technical memorandum NMFS-SEFSC-336. Pg. 78.

RICHARD, J.D. AND G.R. HUGHES (1972). Some observations of sea turtle nesting activity in Costa Rica. Marine Biology 16: 297-309.

ROBINS, J.B. (1995). Estmated catch and mortality of sea turtles from the East coast otter trawl fishery of Queensland, Australia. Biological Conservation, 74, 157-167.

SCHMOLZ, G.W. AND R.R. MEZICH (1988). A preliminary investigation of the potential impact of australian pines on the nesting activities of loggerhead turtle. Pp 63-66 In proceedings of the eighth annual workshop on sea turtle conservation and biology held 24-26 February, 1988 at Font Fishes, North Carolina, B.A. Schroeder, Corp. NOAA-TM-NMFS-SEFC-214. Miani, Fla.: Southeast Fisheries Center, National Marine Fisheries Service.

SCHULZ, J.P. (1971). Situation report on marine turtles nesting in Surinam. pp. 68-74. In: Marine Turtles. IUCN Publications New Series, Supplementary paper 31. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland.

SCHULZ, J.P. (1975). Sea turtles nesting in Surinam. Nederlandsche Commissie Voor Internationale Natuurbescherming Mededelingen 23:1-143.

SHANKAR, K.; B.C. CHOUDHURY; R.K. AGGARWAL; AND L. SINGH (2000). Conservation genetics of the olive ridley sea turtle (*epidochelys olivacea)* on the east coast of India. A report. Wildlife Institute of India, Dehradun, India.

SILAS, E.G.; M. RAJAGOPALAN; A.B. FERNANDO; AND S.S.DAN (1983). Marine turtle conservation and management. A survey of the situation in Orissa 1981-82 and 1982-83; Mar. Fish. Infor. Serv. T & E ser., 50: 13-23.

SILAS, E.G.; M. RAJAGOPALAN; S.S. DAN; AND A.B. FERNANDO (1983). Observations on the mass nesting and immediate post mass nesting influxes of the olive ridley, *Lepidochelys olivacea,* at Gahirmatha, orissa 1984 season; Bull. Cent. Mar. fish. Res. Inst., 35 : 76-82.

STANCYK, S.E. (1982). Non Human Predators Of Sea Turtles And Their Control. In: Bjonndal, K. A. (Ed.). Biology And Conservation Of Sea Turtles. Smithsonian Institution Press, Washington, D. C. Pp. 139-152.

STEYERMARK, A.C.; K. WILLIAMS; J.R. SPOTILA; F.V. PALADINO; D.C. ROSTAL; S. J. MORREALE; M.T. KOBERG; AND R. ARAUZ (1996). Nesting leatherback turtles at Las baulas national Park, Costa Rica. Chelonian conservation and Biology 2(2): 173-183.

VALVERDE, R.A.; S.E. CORNELIUS; AND C.L. MO (1998). Decline of the Olive Ridley Sea Turtle (*Lepidochelys olivacea*) Nesting Assemblages at Nancite Beach, Santa Rosa National Park, Costa Rica. Chelonian Conservation and Biology 3:58-63.

WHITMORE, C.P.; AND P.H. DUTTON (1985). Infertility, embroyonic mortality and nest site selection in leatherback (*Dermochelys coriacea)* and green sea turtles (*Chelonia mydas)* in Surinam. Biol. Conserv. 34: 251-272.

WIBBELS, T.; D.W. OWENS; C.J. LIMPUS; P.C. REED; AND M.S. AMOSS JR. (1990). Seasonal changes in serum gonadal steroids associated with migration, mating and nesting in the loggerhead sea turtle (*Caretta caretta*). Gen. Comp. Endocrinol. 79, 154.

WITHERINGTON, B.E. (1986). Human and natural causes of marine turtle clutch and hatchlings mortality and their relationship to hatchling production on an important florida nesting beach. M.Sc. Thesis. University Of Central Florida, Orlando, Florida. 141 Pp.

WITHERINGTON, B.E. (1992). Behavioural responses of nesting sea turtles to artificial lighting. Herpetologica 48:31-39.

WITHERINGTON, B.E. AND L.M. EHRHART (1989). Hypothermic stunning and mortality of marine turtles in the Indian river lagoon system, Florida, USA. Copeia. 3: 696-703.

WITHERINGTON, B.E., AND R.E. MARTIN (1996). Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches. FMRI Tech. Rep. TR-2. Florida Marine Research Institute, St. Petersburg, Florida. 73p.

WOOD, J.R. AND F.E. WOOD (1980). Reproductive biology of captive green sea turtles *(Chelonia mydas)*. Amer. Zool. 20:499-505.