

# Olive Ridley Sea Turtle Movement in Relation to Oceanographic Parameters in India

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**Abstract-** The movement of Olive Ridley sea turtle in coastal region and their nesting behavior in India were studied with relation to oceanographic parameters during 2003 to 2007. The impact of oceanographic parameters including the potential environmental influences on the movements and nesting; we compared in west and east coast with remotely sensed variables including sea surface temperature (SST), sea surface current (SSC), surface chlorophyll concentration (Chl-a), sea surface height (SSH) and mixed layer depth (MLD). The movement at west and east coast observed, including the oceanic migration for pelagic and nesting mass that increased gradually from west coast to southward and then towards to northward direction with mass nesting in east coast of Orissa. The movement results due to potential mean surface Chl-a concentration of 3 mg m<sup>-3</sup> with threshold limitation of mean surface temperature at 25 °C at east coast of Orissa. Although the mean surface Chl-a and SST maintained in west coast there was distinctly variation in MLD, WSC with SSH characteristics. In contrast present study revealed the favorable oceanographic condition for mass nesting of Olive Ridley at east coast of Orissa. However the anthropogenic impact has declined the nesting population in later during 2006 and 2007.

**Keywords-** Sea turtle, Olive Ridley, Oceanographic parameters, Movement, Nesting

## I. INTRODUCTION

Out of seven species of sea turtle in the world the five species which have been reported: from Indian waters the Olive Ridley (*Lepidochelys olivacea*), the Leatherback (*Dermochelys coriacea*) the Hawksbill (*Eretmochelys imbricata*), the Loggerhead (*Caretta caretta*) and the Green (*Chelonia mydas*). All the species are distributed and nested along the west and east coast and islands of India, but Olive Ridley species are found its dominant and largely distributed than other in India, mass nesting takes place on the east coast of Orissa: Rushikulya river mouth, Devi river mouth and Gahiramatha and in west coast nesting occurs in Gulf of Kutch, Jamnagar and Gulf of Khambat. In Maharashtra Olive Ridley nesting has been reported in Gorai, Kihim, Manowrie, Versova and the beach between Ambolga and Vetye in Ratnagiri district. In Goa coast Morjim and Galgibag; and Kozhikode district in Kerala. Sporadic nesting of Olive Ridley has been recorded in Tamil Nadu, Andhra Pradesh and in Sundarbans in West Bengal. Olive Ridley turtles are globally considered as Endangered in IUCN Red List [17] and its large nesting in world occurs in Costa Rica and Mexico in the eastern Pacific and in the state

of Orissa, an east coast of India [30]. In western Indian Ocean, Olive Ridley turtles nest along the east coast of Africa [11], Pakistan [3] and Gujarat, India [18]. Olive Ridley also nests in other south East Asian countries [19].

Olive Ridley turtles, including other species of sea turtles act as navigator and most impressive in travel to long distance between their feeding and nesting habitats from hundred to thousand kilometer [1]. They frequently travel in open sea areas, where the sea currents are likely to favor their movement patterns [21]. The navigational pattern indicates the result based on certain oceanographic parameters like SST and SSC and hence they perform in geomagnetic cues [20] from western to eastern of the coast particularly in India where they come for mass nesting. The spatio-temporal distribution in east and west coast and the resultant track has been reported with satellite telemetry yields due to several oceanographic parameters such as SSH, SST, SSC including the prey dependent of their marine taxa and the chlorophyll integrated with remotely sensing data influences largely to the sea turtle habitat [5]. The dynamic process such as SST and Chlorophyll fronts in area interface has been affected strongly with different water bodies in respect to surface as well column primary and secondary productivity and their impact status as prey aggregation also influences the movements of sea turtles [24]. Each individual influential parameters and the relationship between them is inadequately understood for their mechanism linked for movements [9].

In the Eastern Tropical Pacific Ocean (ETP) the complex topography and substantial spatio-temporal variability due to oceanographic characteristics [10] and the oceanic water in this region contain much nutrient enrichment for biological hotspots area for soiling of the marine organisms including sea turtle [27]. The area with variability of oceanographic conditions coupled with the biological hotspots regions provides ideal opportunity of aggregation of marine organism including turtles. In India, a few Olive Ridleys nest in northern Andhra Pradesh [32] Tamil Nadu [4], and the Andaman and Nicobar islands [2]. Never the less, the single most important breeding area for Olive Ridleys in the eastern part of Orissa near Rushikulya river mouth, Devi river mouth and Gahiramatha. Olive Ridley (*Lepidochelys olivacea*) turtles are found for breeding in Orissa, off the coast along the Bay of Bengal, between October and May. They migrate mass from the Indian Ocean south of Sri Lanka with the onset of winter. Based on evidence from tag, describe the breeding migration of Olive Ridley turtles taking a northerly course through the

coastal waters off Tamil Nadu and Andhra Pradesh prior to their arrival in Orissa [7], and spend considerable amount of time in the shallow waters of the continental shelf of Orissa. They ported large concentrations of Olive Ridley turtles in the coastal waters of Sri Lanka migrating northwards during September and November [23] and [8], however, very little is known about the nesting movements of Olive Ridley turtles at west coast of Gujarat Maharashtra, Goa may be is in the present study to locate the reason and oceanographic parameters which favors much in east coast of the India. Although the enormous study have been observed in their distribution, migration, breeding, nesting in southern Orissa coast and their movement from southwest to northwest, the actual cause and scene behind due to any physico-chemical, biological or physical processes which are responsible for their changes in habitat rookery at Orissa coast are still unknown. The present study analyzed based on satellite imagery cover wider area of west coast to east coast of India finding the qualitative parameters like SST, MLD, SSC, SSH and Chl-a.

## II. MATERIAL AND METHODS

Six study sites were selected from west and east coast of India for the nesting population during 2003 to 2007. Three sites from west coast of Goa, Gujarat and Maharashtra, three sites from east coast of Tamil Nadu, Andhra Pradesh and Orissa and one site of Andaman and Nicobar Island far from east coast respectively (Fig.1). These sites were selected based on their nesting population during available record on density wise in the Indian coast.



Fig. 1 The Solitary Represents the Sites Location for Moment and Nesting during 2003-2007

Each study site surveyed monthly from September to November in west coast and from December to March in east coast during 2003 to 2007 for recording turtle nesting population. Data on nesting was based on tracks found on the beach. The data collected from the various stakeholders with respect to coastal area conservation especially the forest and fisheries departments, NGOs, educational institutions; subject experts and fishermen were contacted for information and their participation. Nesting intensity for the locality of the region at the states was calculated based on average nesting during the period separately during west and east coast. The number of nesting during the two different time period at west and east coast was estimated following methods.

$$N = n \cdot d \cdot t \dots\dots\dots (i)$$

Whereas  $N$  = total nesting,  $n$  = average nesting,  $d$  = number of regions and  $t$  = duration (total days in time period). The nesting population of the sea turtle Olive Riddleys also estimated and presented by the various authors and the principal sources of different state of Orissa State Forest Department during the observation period. They estimated the nesting and variance which were derived using the method [33] as follows:

$$\text{Estimating of Nesting} = \frac{\text{Total Area available for nesting (m}^2\text{)} \times \text{Duration of arribada (min)} \times \text{Sum total of egg laying counted/Width of the transect (m)} \times \text{number of sampling periods} \times \text{sum of lengths of all transects (m)}}{\text{averageduration of oviposition (min.)} \dots\dots\dots (ii).$$

The oceanographic parameters of the physico-chemical such as SST, MLD, SSH and SSC including biological parameter of Chl-a were under taken for trekking the potential fishing zones where the Olive Ridley directly or indirectly depends on physiological behaviour and migration for nesting along the coast. All the datasets are analysed from 2003 to 2007 based on data available during nesting population along the coast. The satellite derived data of the following parameters were extracted available on Modis, AVHRR Path finder-5, OSCAR and Quick SCAT. The SST and WSC are extracted from NASA data available in PODAAC-ESIP with  $4\text{ km} \times 4\text{ km}$  resolution during January 2003 to December 2007. The Chl-a are extracted from ocean colour radiometry Visualization and Analysis assimilated monthly global products. The Chl-a extracted from the interface that is designed for visualization and analysis of the Ocean Biology Processing Group (OBPG) Modis monthly global  $4\text{ km} \times 4\text{ km}$  resolution data products that available in GIOVANNI from NASA. To generate a time-averaged area plot, the data values for each grid cell in the user-specified area are averaged over the user-specified time range. The average value of the data parameter for each grid cell is plotted and displayed. Averaging in this case is a linear operation. Multichannel SST products have been constructed operationally from the five and six channel Advanced Very High Resolution Radiometer (AVHRR) by NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) since late 1981. Versions 5.0 and 5.1 of the data set are a collaborative effort between NOAA's National Oceanographic Data Centre (NODC), the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences (RSMAS), and NASA's Physical Oceanography Distributed Active Archive Centre (PO.DAAC). Current speed measures how far the water surface moves in one second. The current direction tells the direction of flow (eastward =  $0^\circ$ , northward =  $90^\circ$ , southward =  $-90^\circ$ , westward =  $\pm 180^\circ$ ). The current direction is also shown on each map by the black arrows. Current convergence measures how strongly the current flows towards or flows away from a location. A positive convergence of water indicates flow inwards to a location and is evidence of downwelling (surface water forced to lower depths). A negative convergence indicates flow outwards and is evidence of upwelling (deeper water rising to the surface). Ocean surface currents also play a larger role in influence weather patterns not only along the coast but inland as well. As

evidence continues to mount that human activities are warming the atmosphere, it becomes imperative that we understand the role that the ocean and its surface currents play in shaping weather and climate.

The Tropical Ocean Surface Currents - OSCAR data set extracted from PO.DAAC site mirror those available via the National Oceanic and Atmospheric Administration (NOAA) site. The surface currents are computed directly from the gridded surface topography and surface wind analyses. This employs a straightforward linear combination of geostrophic and wind-driven (Ekman) motion. The technique is tuned to best represent the geostrophic motion of the WOCE/TOGA 15 m drogued drifters relative to the surface wind stress. Geostrophic velocities are computed with sea level gradients derived from satellite sea surface height analyses. Sea Surface Height: Positive values, indicated by the warmer colours such as yellow and red indicate higher sea surface heights, cooler colours, corresponding to negative values indicate lower sea height. Values are in millimetres.

### III. RESULTS AND DISCUSSION

The survey and reports in the west and east coast, the data was collected from the fisheries department, environment and forest department, various NGOs and the stakeholders for the nesting of Olive Ridley turtles, which shows their mass nesting mostly at arribadas preferably in near river mouth [31]. The results has been observed through the mass nesting at near river mouths in Orissa are known [25]. The mass nesting at near river mouth has been observed within a few kilometres near northern and southern part of Andhra Pradesh [32]. The observation also compared the river mouths at coastal region of both in west and east coast, where we found rivers and its influences were least at west coast than east coast. The rivers at west coast was surveyed fewer and smaller in length and intensity of river flow, sedimentation and nutrient load causing coastal rich vegetation was lesser than east coast. The surveys result the densities of mass nesting at Orissa near river mouths (Table 1) were higher, and no data was collected the real relationship between nest density and distance of river mouth. However, based the result collected the mass nesting beaches were occur in Orissa within the estimated of 5km of river mouth [25]. In other coast except Andaman and

TABLE 1: the Various Nesting Population of Olive Ridley in an Indian Coast during (2003-2007)

Year	Gujarat	Maharashtra	Goa	Tamil Nadu	Andhra Pradesh	Andaman & Nicobar Islands	Orissa
2003	732	50	45	67	1,551	1173	4,44,000
2004	1200	35	29	50	1,302	-	3,23,000
2005	-	31	20	62	-	1333	4,65,000
2006	985	36	37	-	1,279	1027	1,46,000
2007	-	62	-	53	978	-	1,80,000

Nicobar, the nesting shows in similar characteristics at beaches near river mouth estimated within 5 km radius but the nesting potential was very less (Table 1). This indicated clearly the geomagnetism characteristics of Orissa coast and the morphology with oceanographic parameter influences at the coast. The nesting densities increases from west to southern coast and then gradually towards the northern coast of Orissa through nesting beaches of Rushikulya, Devi and

Gahiramatha river mouth of Rushikulya, Chandrabhaga and Baitarani river respectively. The results show the east coast of Orissa was one major arribada during 2003 to 2007, whereas the small arribadas at west coast were reported. The maximum was during the period of 2003 to 2005 followed by 2006 to 2007 in Orissa. Next to Orissa the nesting shows it's maximum in Andhra Pradesh, Andaman & Nicobar islands with consistence and in Gujarat 2004 followed by 2006 and 2003 during study period, in contrary, lesser nesting was found in Maharashtra, Tamil Nadu and Goa (Table 1).

The SST played major role in distribution and nesting movement of the Olive Ridley turtle at west and east coast. The SST ranges from 22 to 32 °C in west coast and varies from 28 to 32 °C in east coast. The SST front was observed much in west than east coast. This results the movement of foraging habitat and nesting of Olive Ridley assumed from west south bound to east north bound (Fig.2). It suggests that SST fronts may only be important if the associated temperatures are within an optimal range. Considering the movement between west and east coastal zones, they encountered substantially in different oceanographic condition. Oceanographic variables in waters at coastal region had significantly different values for SST, Topography, Mixed layer, Current and Chl-a concentration.

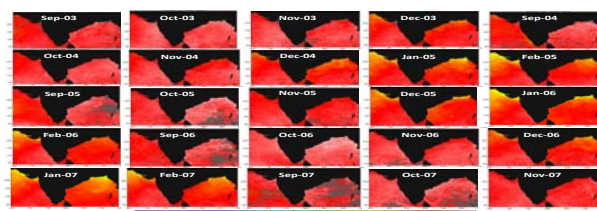


Fig. 2 Monthly Sea surface Temperature (SST) Variation in an Indian Coast during (2003-2007)

The significance difference in mean surface Chl-a concentration at west coast of ( $4.5 \pm 3.3 \text{ mg m}^{-3}$ ) and east coast of ( $3 \pm 2.5 \text{ mg m}^{-3}$ ) despite the consistency in coastal water during September to November and December to February respectively, suggests Chl-a concentration may have influenced turtles for pelagic movement and nesting habitat in these two coastal zones (Fig.3). With respect to thermal environment the Olive Ridley observed mass nesting with SST of  $\leq 25^\circ\text{C}$  and mean SST along turtle's movement was  $\geq 2^\circ\text{C}$  warmer in offshore than that for their coastal movement (Fig.2). The result has revealed the similar movement characteristics in green turtles with thermal response of  $24^\circ\text{C}$  and moves with  $2^\circ\text{C}$  at oceanic offshore region than coastal region in Galapagos Islands.

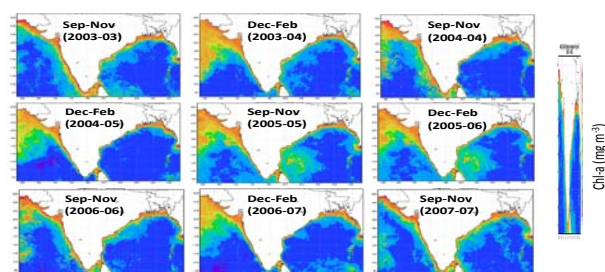


Fig. 3 Monthly Average Chlorophyll a (Chl-a) Concentration at Study Site during (2003-2007)



In respect of Chl-a concentration distribution along west and east coast, the result reflects the intensity of Chl-a concentration maximum of  $10 \text{ mg m}^{-3}$  with the ranges from 1 to  $10 \text{ mg m}^{-3}$  in west coast and  $0.7$  to  $10 \text{ mg m}^{-3}$  in east coast. However the spreading area covered by west coast is about 1200 km from centre location (78E) to coastward from west side, which was much than the east coast is about 900 km from (78E) to eastward coast as shown in (Fig.2). This shows the Chl-a concentration represent primary production is higher in west coast than east coast. But the foraging and nesting movement in east coast is higher than west coast, indicates the secondary production of various zooplankton, small fishes to large one biomass may be assumed much at east coast than west coast as seen the primary production is being consumed much at east coast for their high population [12] and the reason the Olive Ridley depend their preferable prey on secondary production greater in east than west coast. This has also been reflected from the survey, where the industrial growth and anthropogenic activity and threaten of their nesting and young lives is much at west than east coast. The well MLD resulted in east coast, which is absolutely negligible in the west coast. The MLD magnitude during September to November and December to February respectively in west and east shows in (Fig.4).

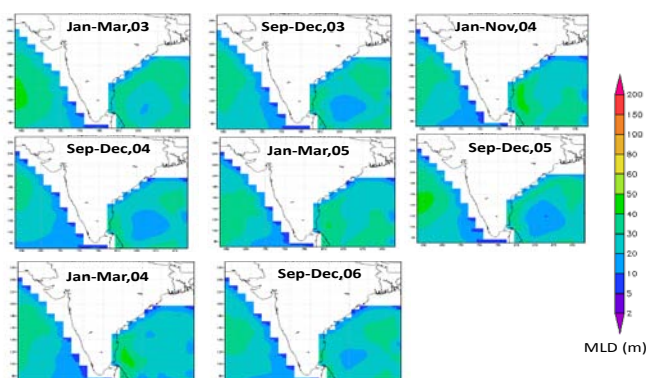


Fig. 4 Variation of Mixed Layer Depth (MLD) at Study Site during (2003-2007)

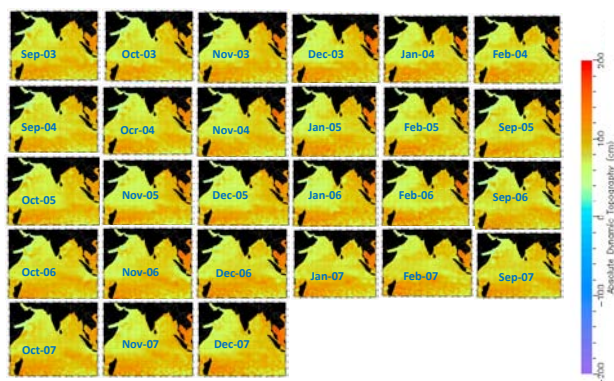


Fig. 5 Variation of Dynamic Topography (SSH) in an Indian Coast during (2003-2007)

The depth maintained 5 to 30 meters, in contrary zero depth at west coast within 300 km from the location (78 E) from west side in west coast, where it is clearly predominant in the east coast. In addition the topography of the study area

supports the explanation of favourable nesting site for the Olive Ridley in east coast than west coast. The absolute dynamic topography varies largely in east coast i.e. 50 to 150 cm, whereas it varies only 50 to 100 cm at the west coast (Fig.5), suggests the higher depth profile in east than west coast. This reflects the mass nesting at the east coast of Orissa, as suitable environmental condition for Olive Ridley.

The near surface current velocities were observed in September-November and December-February for corresponding west and east coast for pseudo-eulerian field and the turtle movement. This shows the visual comparison the average current velocities and directions respect to the turtle movements. The surface current shows in the west coast i.e. 0.3 to 0.6 meter/sec in comparison the larger current of 0.5 to 0.8 meter/sec was observed in the west coast. This reflects higher current system as suitable for pelagic movement of Olive Ridley throughout study period in east coast (Fig.5). An important consequence of nesting population dynamics is that reserves may be able to support self-sustaining populations. Instead, the nesting habitat to them may originate from somewhere else likely from western side to eastern side perhaps many kilometres away. Table-2 shows potential areas of dispersal including seven sites under the Arabian and Bay of Bengal and is based on the assumption that the nesting drift partially passively on ocean currents. This suggests the adult Olive Ridley can potentially be carried very long distance from places from western coast to eastern coast (Fig.6).

TABLE 2: Distribution of Olive Ridley (*Lepidochelys olivacea*) in an India and Adjacent Coast.

Sl No	Region	Presence (P)	Nesting (N)	Foraging (F)	Reference
1	Andaman & Nicobar Islands	P	N		Andrews et al., 2006
2	Thailand	P	N	?	Aureggi et al., 2004
3	Bangladesh	P	N	?	Rashid and Zahirul. 1998; Islam, 2002a,b; Sarker, 2004; Rashid, 2006
4	India, East coast (Gahirmatha + Rushikulya + Devi River mouth)	P	N	F	Bhaskar, 1981; Kar & Bhaskar, 1982; Shan-ker & Choudhury, 2006; Tripathy et al., 2003; Bhupathy and Saravanan, 2006; Shanker, 2003
5	India, West coast	P	N	?	Kar & Bhaskar, 1982; Shanker & Choudhury, 2006; Sunderraj et al., 2006
6	Myanmar	P	N	?	Thorbjornarsson et al, 2000; Shanker and Pil-cher, 2003
7	Sri Lanka	P	N	F	Dattatri & Samarajiva 1983; Hewavisenthi, 1990; Amarasooriya and Jayathilaka, 2002; Kapurusinghe, 2006; De Silva, 2006

The remarkable features of the Olive Ridley movements in surface water respect to the current pattern clearly shows due to the differential magnitude of the current speed and the life stage. It has been observed in the hatchling loggerhead turtles the influence of the current which largely effect to the development stage and hence the distribution in ocean basins merely driven by the current system [6]. Similar results could assume in the east coast of Orissa where the Olive Ridley after nesting have immediate favourable current system for movement and reason they prefer. However in adult stage they

have capable for the movement towards any direction preferably in straight line between coastal and distant nesting habitats as loggerhead turtles [22]; [13]. Using drifter trajectories in North Atlantic, the observation has been made the drift pattern for loggerhead turtles from beaches in Florida for role of currents that influencing the moments of turtles at coastal as well in offshore (Hays and Marsh 1997). In present study using the current pattern (Fig.6) and the current meters (data not presented) for the intensity the same approach indicates the influencing of currents for favourable nesting at Orissa coast. Never the less the movement was not regard to the currents speed in either of direction with clockwise or anticlockwise as shown (Fig.6) in present study area for nesting, otherwise the current influences after nesting for Olive Ridley during pelagic and foraging with passive drifting, which has been noticed at the east coast of Orissa. The phenomenon reveals, where the Ridelys activities to vertical foraging movements within the eddies, which formed frequently in east coast than west coast (Fig.6), transports high concentrations of prey. The similar results have been documented for loggerhead and Olive Ridley in North pacific Region [28] and the same has been supported the approach from the distribution of MLD ( Fig.4) .In addition of current and mixed layer depth and topography of dynamic condition the thermal conditions and sea surface Chl-a concentration appears to be an oceanographic variable that influenced Olive turtles movements. Oceanic migrants occurred in east coast of Orissa water with mean sea surface Chl-a of  $3 \text{ mg m}^{-3}$ ,

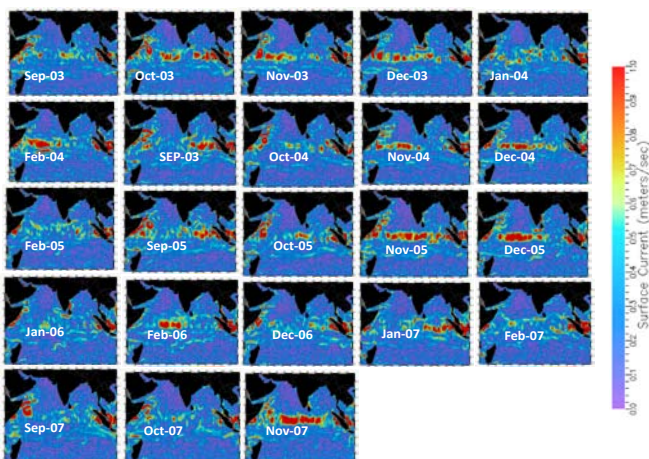


Fig.6 Monthly Variation of Sea Surface Current (SSC) at Study Site during (2003-2007)

resulted the increase of secondary production. This is consisted with several years together from satellite derived Chl-a concentration at the Orissa coast during December to February where the transition zone of chlorophyll front formed at the location for movements of Olive Ridley turtle along the coast with threshold limit of  $25^{\circ}\text{C}$  with mean MLD of 17 to 18 m and mean absolute dynamic topography 100 cm (Fig.5). The condition prevails at the location as convergence zone at east coast of Orissa is biologically important since these seasonal oceanographic condition with productivity of chlorophyll masses results increases the zooplankton with other secondary and tertiary products which constitutes important food resources along the Orissa coast

during nesting period, similar results due to this has been revealed [29] and [14]. The present result also good agreement with the prey relationship of secondary and tertiary production as gastropods and fishes etc for green turtle [15] at north pacific of Galapagos.

#### IV. CONCLUSION

The present study correlated the movement of Olive Ridley and the nesting in Indian coast using satellite data parameters. The regular movement along the coast for observing diving profiles, their transiting through location along coast could be used for information to further investigate changes in behaviour of pelagic and nesting turtles with individual influence of oceanographic parameters and their threshold limitation as discussed in above. In concern to threshold limitation the temperature  $\leq 25^{\circ}\text{C}$ , the MLD 17 to 18 m, topography 100 cm, Chlorophyll  $3 \text{ mg m}^{-3}$  and current  $0.6 \text{ m/sec}$  were indicated the ideal oceanographic parameters for the mass nesting in an east of Orissa. The majority of turtles swim to distant foraging areas that have less highly regulated and largely unmanaged exploitation of sea turtles. Hence the decline in annual number of nesting turtles has been noticed from 2003 to 2007 as discussed, suggests that consequences of these effects are apparent at the nesting beaches. However, despite this evidence of coastal nesting by Olive Ridley turtles the strategies to access oceanic prey resources remain poorly understand. To study this behaviour, we encourage additional satellite telemetry effort that employ GPS and dive profiling technology to reveal the exact location relation to oceanographic features with surfacing intervals. The conservation efforts have largely focussed on nesting beaches, representing only a fraction of marine turtle life history, but it is now essential that safeguarding the migratory corridors for coastal foraging areas. However the successful implementation of this plan will require an additional GPS and field data for more turtle biology and fisheries impacts for further validation of satellite information along with ARGOS tagged application for monitoring and tracking of the reason mass nesting in east coast of Orissa and viable solution for necessary sustainable conservation.

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