

Impact of artificial illumination on sea-finding behavior of Olive ridley sea turtle at Gahirmatha rookery, Odisha



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Report submitted to the

**Directorate General of Lighthouses and Lightships
Ministry of Shipping**

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Olive ridley hatchlings getting attracted to light (Bivash Pandav)

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Acknowledgement

This study was undertaken at the request of the Directorate of Lighthouses and Lightships. We thank the Chief Wildlife Warden, Government of Odisha for giving us the necessary permits to carry out field research along the Odisha coast. Our sincere gratitude to Shri Kedar Swain and S. Mishra, Divisional Forest Officers of Mangrove Forest Division (Wildlife), Rajnagar and Berhampur Forest Division respectively for providing us logistic support while carrying out field work for the study. We thank Director, WII and Dean, Faculty of Wildlife Sciences, WII for their support and encouragement. Shri Rajashekar Bandi volunteered his services and painstakingly collected valuable data for us at Gahirmatha and Rushikulya. We thank Shri Suvendu Behera, Range Forest Officer, Gahirmatha Marine Range for his support at Gahirmatha. We specifically like to thank our field assistants: Dambaru Behera, Bipro, Kalia, Mahendra, and Magada for their untiring support during field work.

In an undisturbed environment, the brighter horizon on the seaward side provides a cue to both nesting sea turtles as well as their hatchlings to find their way to the sea (Mrosovsky and Kingsmill, 1985). Any kind of artificial illumination near the nesting beaches are known to alter the sea finding behavior of nesting turtles, as well as their hatchlings. Studies carried out on sea turtles at various nesting sites across the world have shown the adverse impact of artificial illumination on the sea finding behavior of marine turtles (McFarlane 1963, Witherington & Bjorndal 1991, Witherington 1992, Peters & Verhoeven, 1994, Tripathy et al. 2003, Sella et al. 2006, Karnad et al. 2009). Artificial illumination near the nesting beaches impacts adult sea turtles by disrupting nest site selection, abandonment of the nesting process and disruption of sea finding ability following unsuccessful nesting. Hatchling sea turtles emerge from the nests at night and are strongly attracted to visible light sources near the beach. Consequently, hatchlings move toward the source of artificial illumination and away from the sea.

Sea turtles use multiple visual cues to find their way to the sea, of which intensity, wavelength, background illumination and landward silhouettes are important factors (Witherington & Bjorndal 1991, Witherington 1992, Godfrey & Barretto 1995, Salmon & Witherington 1995, Tuxbury & Salmon 2005). While background illumination and landward silhouettes reduce the relative effects of coastal artificial light, light of low wave length, and high intensity tend to increase a hatchling's probability of disorientation (Lohmann et al. 1997). However response of hatchlings to intensity and wavelength of light show species specific differences (Witherington & Bjorndal 1991). Variation in the response to artificial illumination at the population level may also be possible.

Orientation of turtles, hatchlings in particular, away from the sea result in considerable mortality (McFarlane 1963). Increasing thrust on coastal development is likely to amplify hatchling mortality due to light pollution. Therefore, finding suitable measures to minimize the impact of light pollution is vital especially when light pollution is probably one of the problems that can be solved with relative ease if the developmental agencies are committed to conserving sea turtles.

The nesting beach at Gahirmatha is considered to be the largest rookery of olive ridley sea turtle (*Lepidochelys olivacea*) in the world (Bustard 1976). As recent as 1990s, the nesting beach at Gahirmatha was considered to be extremely remote. However, with the establishment of a missile test range in the mid-1990s and the Dhamra port in mid-2000, the surroundings of mass nesting site at Gahirmatha has been subjected to considerable change. Artificial

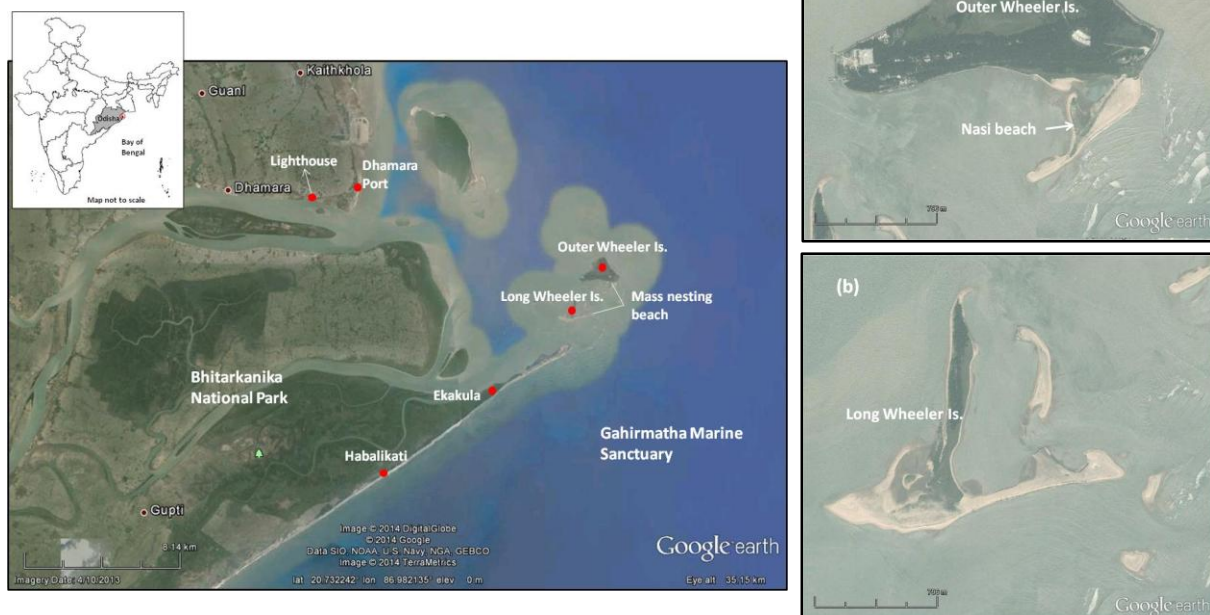
illumination arising from these establishments as well as other associated coastal developments has been the cause of concern for turtles nesting at this rookery as well as the hatchlings emerging from this nesting beach at Gahirmatha. The impact of this illumination on sea turtles has never been investigated. Our lack of understanding of this issue often impedes associated developmental activities, which may or may not impact sea turtles using Gahirmatha rookery.

Considering the lack of information on impact of artificial illumination on sea turtles using Gahirmatha rookery and based on the request of Directorate General of Lighthouses & Lightships, Ministry of Shipping, Government of India, the Wildlife Institute of India took up a study with the following objectives:

- I. To study the impact of artificial illumination on nesting sea turtles using the Gahirmatha rookery.
- II. To assess the level of disorientation by turtle hatchlings and suggest measures to minimize this.

This study was carried out at the Gahirmatha turtle rookery over a period of three months from March to May 2014, which coincided with the peak nesting of the olive ridleys in the area. Located at the Maipura river mouth in northern Odisha, the rookery is 15 km away from the Lighthouse proposed to be setup and the Dhamra Port. The olive ridley mass nesting at the Gahirmatha rookery primarily occurs on two islands Long Wheeler and Nasi, which are a part of the Wheeler group of islands (Figure 1). These two islands once located south of the current location were part of the mainland beach stretch extending as a single long sand-spit. During a cyclonic storm in 1989 the sand spit got dissociated from the mainland beach forming the two islands, and later in 1998 got fragmented further. As a result, the space available for turtles to nest has drastically reduced over the years. Studies on morpho-dynamics of this rookery have revealed that the islands are under severe stress due to erosion (Prusty et al., 2000). The Nasi nesting beach currently exists as a short 1 km beach extending from the Outer Wheeler Island as a sand-spit, which island houses a Defense establishment. Most parts of the Outer Wheeler Island are armored with concrete blocks and shielded with dense *Casuarina* plantation. The turtle nesting on the Long Wheeler Island primarily occurs on a 2 km beach stretch on the seaward side. As part of this study the mainland beach stretch extending from Ekakula to Habalikati, about 10 km in length was also surveyed. This beach is shielded by dense *Casuarina* plantation and mangrove vegetation along a major part of the 10 km stretch.

Figure 1. The olive ridley mass nesting at the Gahirmatha site located at the Maipura river mouth primarily occurs on the Nasi beach (a) and on the Long Wheeler Island (b).



The Rushikulya turtle rookery located 300 km south of the Gahirmatha site was also visited during the study. This site was selected as a control site as there is a lighthouse currently in operation there. This lighthouse is located close to the Prayagi village and is about 10 km from the northern end of the Rushikulya mass nesting beach (Figure 2). Arena experiments to document hatchling turtle orientation in response to the light from the lighthouse were conducted at this site during the study.

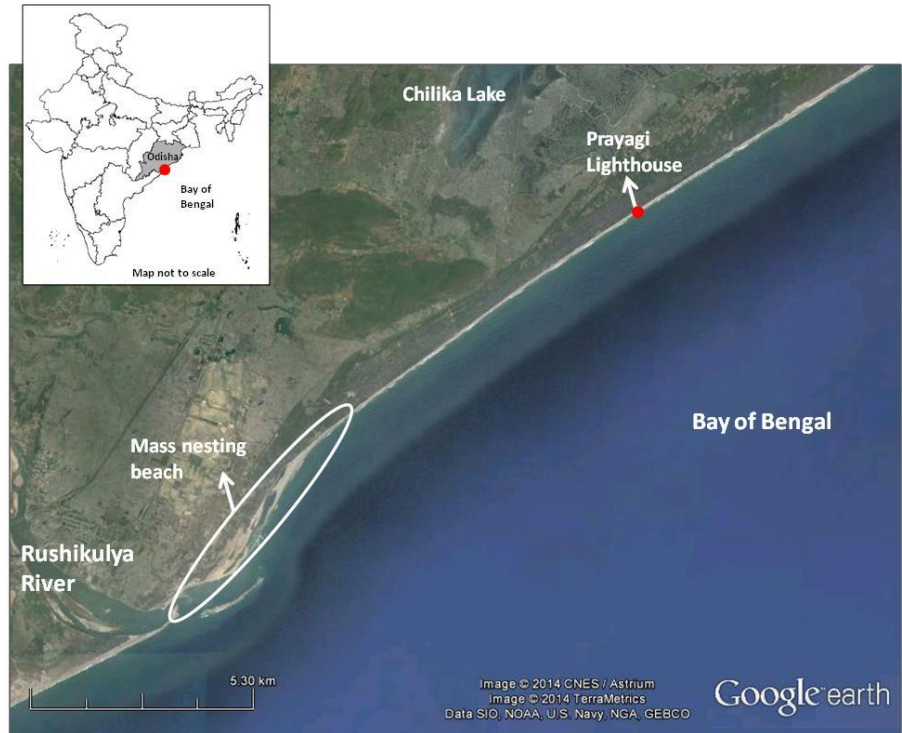


Figure 2. The Rushikulya rookery located in southern Odisha where olive ridley mass nesting occurs along a 4 km beach stretch. About 12 km south of this nesting beach is the Gopalpur Port and about 10 km north is the Prayagi lighthouse

Beach mapping and Photo-pollution characterization: The nesting beaches were mapped using the track-lines obtained through a hand held GPS by walking along the high tide line. Similar tracks were also obtained by walking along the contours of the beach vegetation and the *Casuarina* plantations. This was then mapped using GPS software (GPS TrackMaker, Version 13.9). In order to understand the beach dynamics during the study period, the mapping was carried out once every month soon after the peak high tide phase. For characterization of photo-pollution the beach available for turtle nesting was divided into 200 m segments, where a simple count of the number of visible lights at the center of each segment along with information on intensity (very bright, bright and faint) and colour of light was recorded.

Nesting Distribution: In order to locate turtle nests, three people walked the Long Wheeler Island and the Nasi beach totaling a length of 3 km on a daily basis between 0600 to 0800 hr. Beach surveys were also carried out along the 10 km mainland stretch extending from the Ekakula sand-spit to Habalikati. However, due to logistic constraints and especially that the Ekakula-Habalikati beach could only be approached by boat after an hour's boat journey surveys there could only be made once every week. Also, forest staff reported sporadic nesting by turtles to be only few than the mass nesting beaches. Using a hand held GPS, the location of the turtle nests observed were recorded and whether active or predated was noted. The turtle nests recorded were later plotted on a map of the nesting beaches to understand the spatial distribution of the nests. And, whether nest distribution was related to photo-pollution of the beach stretch.

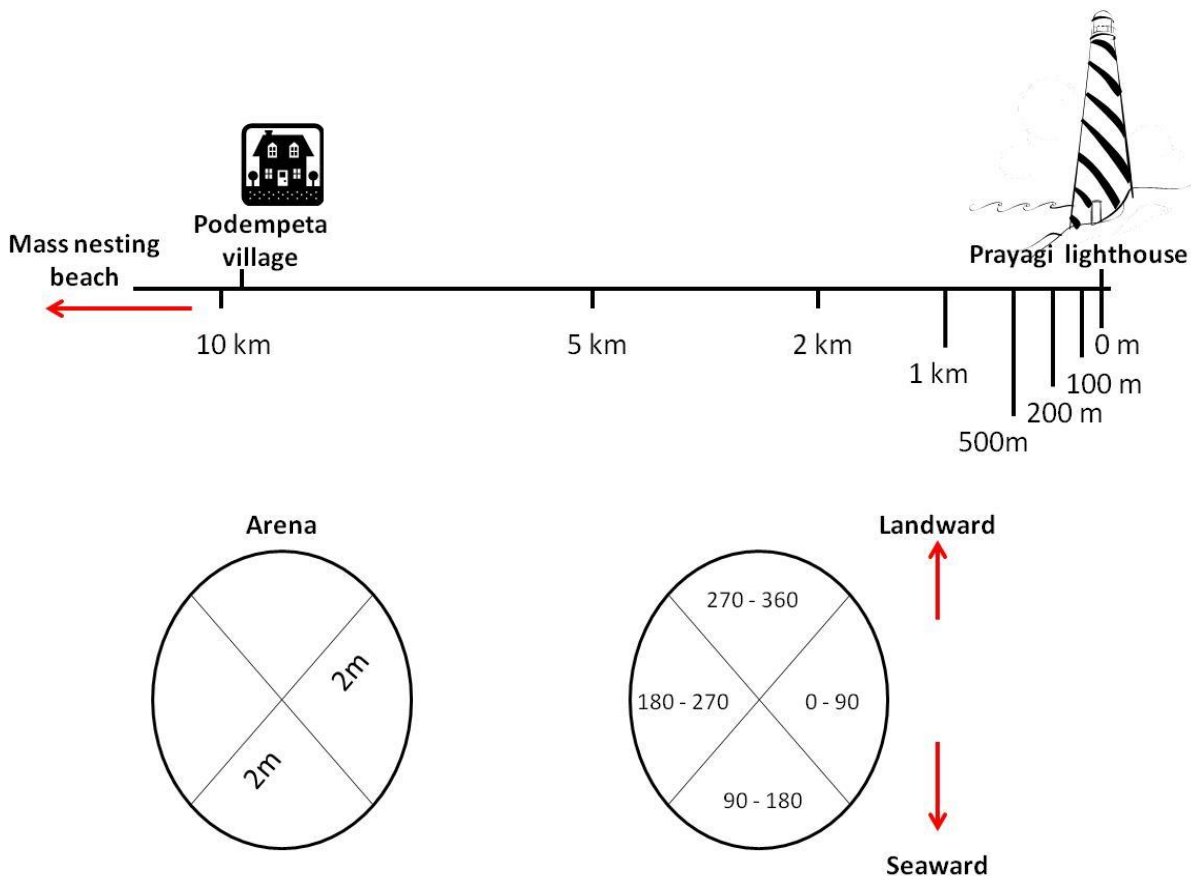
Arena Experiments: To study hatchling turtle disorientation a simple set of experiments were carried out at different locations along the beach with varying light conditions. An arena with a radius of 2 m was marked on the beach in which hatchlings were released at the center, and then their direction of movement was recorded. The circular arena was divided into four quarters: 0°- 90°, 90°- 180°, 180°- 270° and 270°- 360° (Figure 3), and the number of hatchlings exiting out of the arena in the respective quarter were noted. To determine the extent of hatchling disorientation at each location conditional probabilities were calculated as below:

$$\text{Conditional probability of hatchling disorientation} = \frac{\text{Disorientation of hatchlings at an arena location}}{\text{Disorientation of hatchlings at all arena locations}}$$

For this study, arena experiments were carried out at varying distances from the Prayagi lighthouse at the Rushikulya site (Control site) on two nights during the mass hatchling emergence. The locations ranged in distance from close to the lighthouse to 100m, 200m, 500m, 1km, 2km, 5km and 10km (Figure 3). At each of these locations three trials using 10 hatchlings in each were carried out, and the same was repeated the following night, which totaled an overall 48 trials. Hatchlings used in the experiment were only those collected from nests in which hatchlings were found just below the surface of the sand waiting to emerge. This was to avoid hatchlings that may have already been imprinted or disoriented. Further, hatchlings were only collected from nests located along the periphery of the mass nesting beach, and close to the vegetation line so as to avoid any form of disturbance.

On an average, 40-50 hatchlings were placed in plastic buckets that had a layer of wet sand at the bottom and was covered with a black cloth. The buckets with the hatchlings were then quickly transported by foot to the different locations where the arena experiments were carried out.

Figure 3. Shown here are the eight different locations of varying distances from the Prayagi lighthouse where arena experiments to study hatchling turtle disorientation was carried out. Each arena was of 2 m radius and divided into four quarters to record orientation of the hatchlings



An overall total of 400 hr were spent surveying the three beaches in the Gahirmatha rookery that included approximately 35 surveys of the 10 km Ekakula to Habalikati beach, 70 surveys of the Long Wheeler Island and about 60 surveys of the Nasi beach during the study. Since the base camp was located in the Long Wheeler Island, beach surveys there were carried out more frequently than the other nesting beaches.

Beach mapping

All three nesting beaches at the Gahirmatha rookery were mapped during each month of the study. The Long Wheeler Is. beach along the seaward side extended to a length of about 2 km, while the Nasi beach measured only 900 m in length (Figure 4). Both these island beaches were found to be highly dynamic across the months with large scale reduction in the nesting area due to tidal inundation and submergence. The Long Wheeler beach was reduced to less than 30% in May from what it was in March 2014. The Nasi beach also underwent similar loss of turtle nesting area with about 55% remaining in May (Figure 5). Further, major parts of the beach were also low lying and as a result the ideal nesting habitat available was largely reduced.

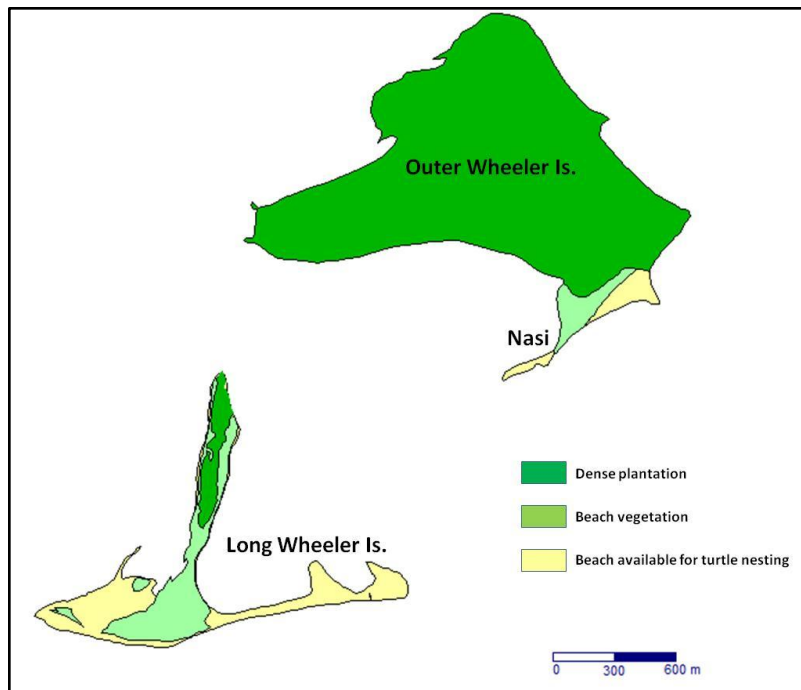
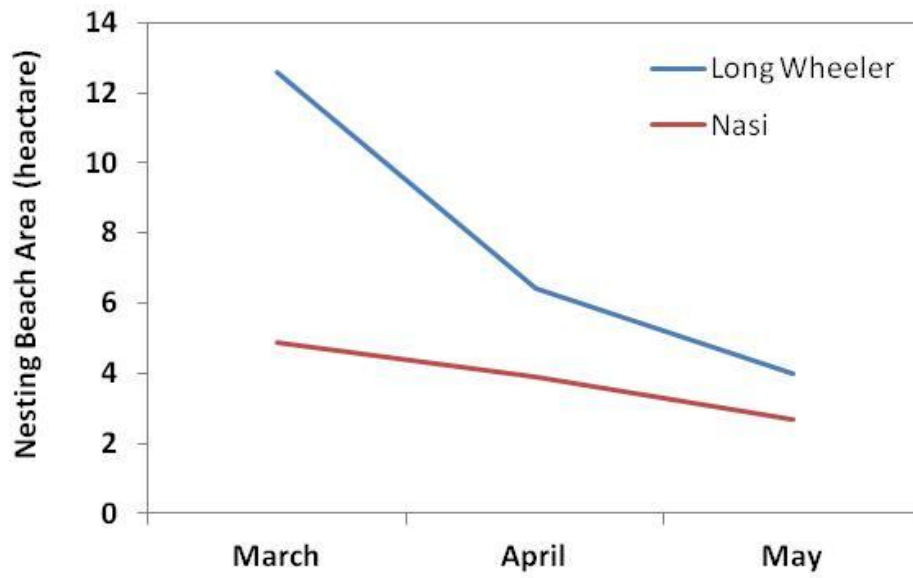


Figure 4. The two island nesting beaches were olive ridley mass nesting occurs at the Gahirmatha rookery. The island beaches that exist currently are highly reduced to what they were in the past.

Figure 5. The mass nesting beaches of Long Wheeler and Nasi underwent large scale beach reduction across the months of study due to tidal inundation and submergence



Nesting distribution

Mass nesting did not occur at the Gahirmatha rookery this year and only sporadic nesting was observed, while mass nesting occurred at the Rushikulya rookery from 12 to 15 February 2014. At the Gahirmatha rookery a total of 305 sporadic nests were recorded during the study, with the maximum recorded at the Nasi beach followed by Long Wheeler and the mainland beach (Table 1). Further, the maximum turtle nesting was observed during the month of April with 165 nests. The Nasi beach is primarily where mass nesting occurred in the previous years and the high sporadic nesting observed there during the study is likely a result of site-fidelity by the nesting turtles. The Nasi beach also had high turtle nest predation by feral dogs coming from the establishment in the Outer Wheeler Is. Close to 50 % of the sporadic nests recorded in this beach were lost to predation. The forest staff eradicated all the feral dogs from the Long Wheeler Is. and as a result there was no nest predation by large vertebrates. In case of the mainland beach the relatively few sporadic nests recorded were all predated except for few by feral dogs and Wild Boar *Sus scrofa*. Many of the nests in the Nasi and Long Wheeler Is. that escaped predation were subsequently lost to tidal inundation and beach erosion.

Table 1. Details of the sporadic nests recorded during March to May 2014 at the three nesting beaches of the Gahirmatha rookery

Month	Number of sporadic nests recorded			Total
	Mainland	Long Wheeler	Nasi*	
March	13	15	88 (16)	116
April	26	50	89 (52)	165
May	4	5	15 (13)	24
Total	43	70	192 (81)	305

* Number of sporadic nests predated at the Nasi beach is given in parentheses

Nest distribution was also observed to be concentrated in few segments of the Nasi and Long Wheeler beach. Of the five segments in Nasi one segment close to the Outer Wheeler Is. alone had 108 of the 192 nests recorded there. This is mainly because this beach segment was much wider and higher, and did not influence tidal inundation (Figure 6a). Similarly, in the Long Wheeler Is. three out of the 10 segments there had 41 of the 70 nests recorded there (Figure 6b). These segments were closer to the sea front and had a wide and relatively higher nesting beach.

Figure 6. Sporadic nest distribution in the (a) Nasi beach showing a higher concentration in segments closer to the outer wheeler Is., (b) Long Wheeler Is. showing higher concentration in segments closer to the sea front

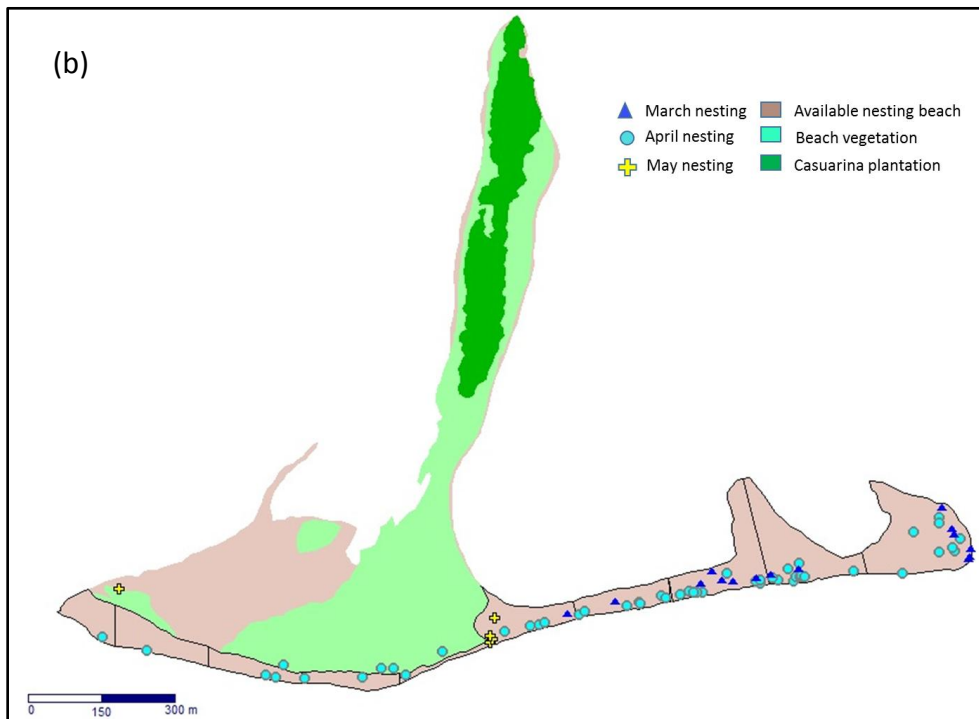
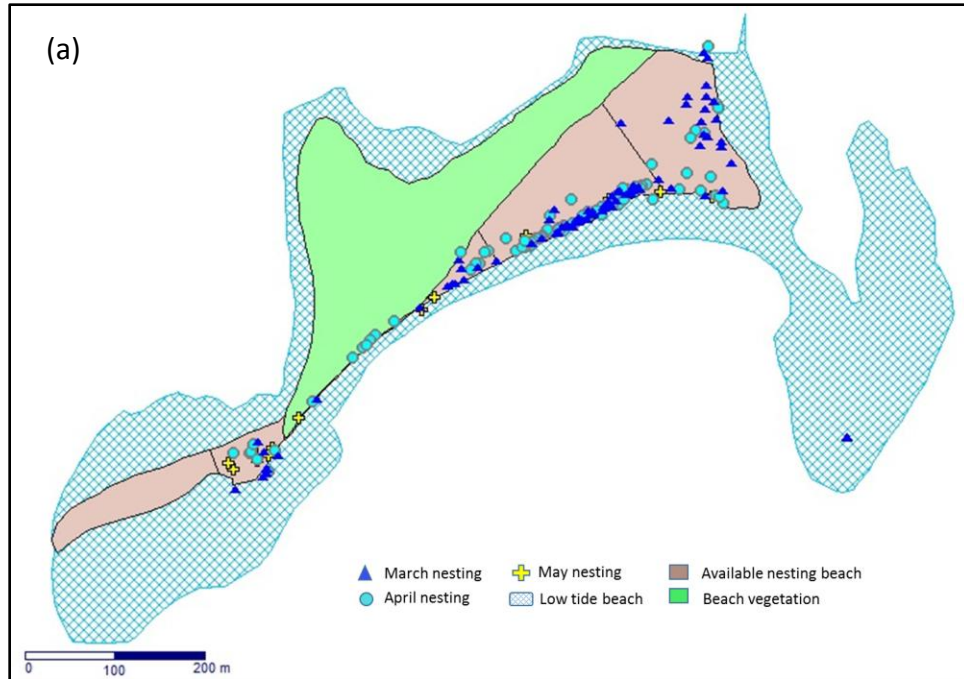


Photo-pollution characterization

About 30 visible lights were counted from the five 200 m segments in the Nasi beach, and all of these lights were located in the adjoining Outer Wheeler Is. The number of lights visible from each of the segments varied. Many of these lights were flood lights located all along the water edge. The light emanating from these fixtures did not fall directly on the nesting beach. On select days a large glow created by very high intensity lights in the Outer Wheeler Is. was visible (Figure 7). From the Long Wheeler Is. a lot more lights of varying intensities were visible, which included the lights from the Outer Wheeler Is. and the distant lights from Dhamra Port and the surrounds. On the mainland beach stretch lights were only faintly visible close to the river mouth, and elsewhere no artificial illumination on the beach stretch was visible.

Whether the number of visible lights on a beach stretch influenced the turtle nesting could not be clearly known. Even though at the Nasi beach higher sporadic nesting was recorded in segments where there was relatively less number of lights visible like in segment 4 and 5 (Table 2). However, this could also be because the nesting habitat available in segments 4 and 5 were much better than the other segments. In the Long Wheeler Is. and the mainland beach no such relationship between visible lights and sporadic nesting could be determined.

Table 2. A comparison of number of visible lights and number of sporadic nesting recorded at the Nasi beach

Beach Segment	Number of visible lights	Number of sporadic nests recorded
1	28	0
2	22	24
3	13	23
4	5	108
5	2	37



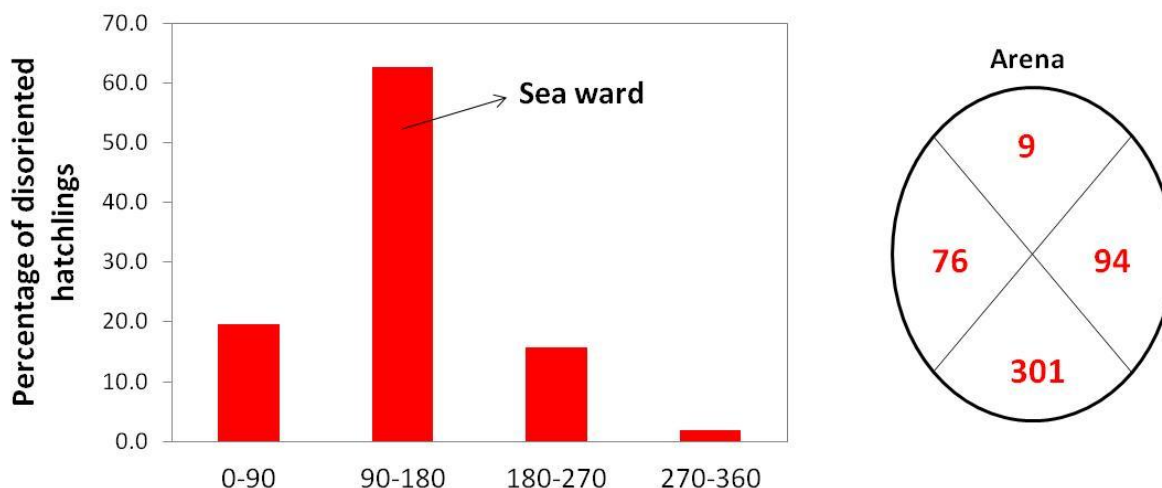
Figure 7. Very high intensity lights resulting in a large glow over the Outer Wheeler Is. visible from the Nasi mass nesting beach.

Hatchling Orientation

The arena experiments to determine impact of artificial illumination on hatchling turtle orientation was initially planned to be carried out at Gahirmatha and Ruhsikulya rookeries. However, as there was no mass nesting at Gahrimatha and with very few sporadic nests that survived the arena experiments could not be carried out at Gahirmatha. Therefore, arena experiments were only carried out at the Rushikulya site. Mass hatchling emergence started at 1900 hr on both 6th and 7th April, with the scale of hatchling emergence being higher on the second day. Hatchlings were collected each day between 2000 and 2100 hr, and were transported quickly to different locations where the arena experiments were to be carried out. The 10 km point was at the edge of the mass nesting beach where the first set of arena experiments was conducted from 2200 hr onwards during the two days.

A total of 480 hatchlings were used in the arena experiments, and 63% of which exited the arena in the quarter 90° - 180° that significantly oriented in the direction of the sea (Rayleigh test $P < 0.001$; Figure 8). The remaining appeared to be disoriented with a small number of hatchlings heading in the landward direction (2%).

Figure 8. Orientation of the hatchlings released at the arena locations, a majority of which exited in the direction of the sea



The probability of hatchling disorientation was found to be highest at the location closest to the lighthouse though this was only about 18%. It was also observed that hatchling disorientation declined with increasing distance from the lighthouse, and beyond the 500 m location it was relatively negligible (Table 4). The hatchling disorientation at the 10 km location observed was due to the lights from the Podempeta village.

Table 4. Details of the conditional probability of hatchlings disoriented with respect to the Prayagi lighthouse at the Rushikulya site.

Distance from Lighthouse (in metres)	Number of disoriented hatchlings	Conditional Probability of hatchling disorientation
0	32	0.18
100	23	0.13
200	28	0.15
500	23	0.13
1000	16	0.09
2000	20	0.11
5000	14	0.08
10000	23	0.13
Total	179	

Increasing thrust on coastal development has resulted in an increase in intensity of artificial illumination in some of the major sea turtle nesting sites in India. The Gahirmatha olive ridley turtle rookery, once considered to be remote, has been subjected to significant developmental activities. The establishment of a missile test range in mid 1990s and the Dhamra Port in mid-2000 has significantly altered the illumination profile at Gahirmatha. While adverse impact of artificial illumination on sea finding behavior of sea turtles has been well documented (Salmon 2003), it was still required to investigate the probable impact of the proposed 45 m high lighthouse at Jyotsnamayi village near Dhamra Port on turtles at the Gahirmatha rookery. The experiments carried out at the Rushikulya site in southern Odisha clearly showed that level of hatchling disorientation declined with respect to increasing distance from the Prayagi lighthouse located there. Thus, considering the 15 km distance of the proposed lighthouse at the Jyotsnamayi village from the Gahirmatha rookery, the impact of lighting from the lighthouse on sea finding behavior of sea turtles is likely to be negligible. In support of our finding Reintsma *et al.* (2014) also found lighting from a 41 m high lighthouse at a Florida beach to have any significant impact or disrupted hatchling orientation. They attributed their findings to the relatively short “on” (5 s) to longer “off” (15 s) lighting periodicity of the lighthouse. It has also been suggested that in cases where the lighthouse to may have a possible impact on turtles, then the effective solution is to increase the duration of the “off” period. Therefore, it is recommended that the lighting periodicity (On - Off duration) be taken into account for the proposed lighthouse at the Jyotsnamayi village. Further, it is important to highlight here that a significant amount of illumination arising from Outer Wheeler Island in the vicinity of the Gahirmatha rookery was observed during the study. This is a major concern and likely has a far greater impact on sea finding behavior of sea turtles and needs to be addressed on a priority basis. Besides, our study also documented an acute loss of nesting beach and significant predation pressure on turtle nests at the Gahirmatha rookery. The latter requires removal of feral dogs from the Outer Wheeler Island and a control of the Wild Pig population. To conclude, given the findings of this study the construction of the proposed lighthouse at the Jyotsnamayi village may be permitted.

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