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Observations on the mortality of olive ridley sea turtles (*Lepidochelys olivacea*) and associated factors along Ganjam coast, east coast of India

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The Odisha coast along the east coast of India is home to three mass nesting sites (Gahirmatha, Devi and Rushikulya) and several sporadic nesting sites for olive ridley sea turtles. The coastline in the Ganjam district of Odisha has more than nine beaches that report olive ridleys (*Lepidochelys olivacea*) nesting, including one mass nesting site *i.e* the Rushikulya estuary. To develop a better understanding of beach habitat conditions along the Ganjam district's 60-km-long coastline, a survey was conducted and data on the extent of olive ridley mortality, associated threats (both direct and indirect), and factors affecting habitat loss, were collected. The survey was carried out entirely on foot between March and April 2020, visiting nine separate sites three times each. Dead turtle carcasses were seen on only seven out of the nine beaches. The major threats observed were fishing activities and predation; while plastic contamination, topographical changes (shifting in Rushikulya river mouth), vehicular movements, and artificial lighting were the factors associated with habitat degradation. The highest incidences of mortality were caused by fishing activity. In addition, maximum turtle mortality was seen at lower elevations (3 – 6 m above MSL) as compared to beaches with higher elevations. The current survey on olive ridley turtle mortality is the first of its kind along the Ganjam coast and the findings underscore the importance of solidifying conservation efforts on the olive ridleys' habitat.

[**Keywords**: Ganjam coast, Mortality, Olive ridley, Rushikulya, Threats]

Introduction

The Leatherback (*Dermochelys coriacea*), Loggerhead (*Caretta caretta*), Green turtle (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*), and Olive ridley (*Lepidochelys olivacea*) are the five species of marine turtles found in the Indian subcontinental waters[1]. All five species of marine turtles are placed under Schedule-I of the Indian Wildlife Protection Act (1972)[2], which provides the highest level of protection, by prohibiting hunting, poaching, and egg destruction[3]. Despite their widespread global distribution, the Olive ridleys are classified as vulnerable by the IUCN. The Olive ridleys, which are known for their mass nesting near the Rushikulya estuary in Odisha[4], are the most abundant species to nest along India's eastern coast. Gahirmatha, Devi and Rushikulya Rookery are three major arribada (mass nesting) sites for Olive ridleys in Odisha; Gahirmatha is the largest among the three sites[5]. While mass nesting of Olive ridleys at the Rushikulya rookery in Odisha's Ganjam district has been discovered in the year 1994 by Pandav *et al*.[6]. Sporadic nesting can be observed throughout the coastline of the Ganjam district. The turtle congregation in near-shore waters along the Odisha coast starts in early November[7], and the breeding activities take place during the next five to six months, *i.e*. up to April[3]. The breeding activities take place in three phases, *i.e*. pre-breeding phase (migration of turtles to Odisha coast, congregation in near-shore waters), breeding phase (mating, nest site selection, egg-lying and hatching), and post-breeding phase (venturing of hatchling to near-shore waters successfully).

Olive ridleys' population has been reportedly decreasing over the last several decades, which is primarily attributed to their low intrinsic growth rate associated with natural and anthropogenic stresses[8]. Turtle mortality is primarily caused by fishing-related practices such as entanglement in fishing nets and being thumped by the fishing vessels, primarily by trawlers[5] as well as through predation by stray dogs[9]. The decrease in the adult breeding population in nesting sites will eventually lead to a population decline in turtles[8]. The Olive ridley turtle population in Odisha has decreased considerably in the previous two decades[11,12]. Between 2007 and 2010, 13,443 dead turtles were recorded at the Gahirmatha mass

nesting site, with the majority of deaths ascribed to fishing practices[13]. Earlier studies on Olive ridleys in Rushikulya estuary and elsewhere in Odisha focused primarily on their nesting population distribution[14], nesting pattern[15], beach fidelity, and mortality (only in Rushikulya estuary area in Ganjam district[6,8]), other aspects such as offshore population, mating pairs, the extent of trawling in near-shore waters, stranding and coastal developments have also been studied[3]. However, there has been no comprehensive scientific investigation of the region's Olive ridley mortality. In this regard, the current survey is an initial attempt to ascertain the extent of Olive ridley mortality along the Ganjam district's entire coastline and the associated causative factors.

Materials and Methods

Study area

Most of the Odisha's 476.4 km long coastline is bestowed with sandy beaches that are suitable and conducive for sea turtle nesting. Ganjam, Odisha's southernmost coastal district, comprises around 12.5 % of the state's total coastline (60 km) and is bordered on the north by Chilika Lake and the south by the Bahuda river estuary extending to Andhra Pradesh. Ganjam's coastline is characterized by a variety of landforms, including sand dunes, estuaries (Rushikulya and Bahuda), and other features like *Casuarina* plantations and fish landing centers. The coastal stretch of the district is largely protected by the *Casuarina* plantation, an intervention by the State Government to mitigate the impacts of tropical cyclones that hit the coast on regular basis. Several fish landing sites, which contribute to the livelihood of local fishermen are located along this coastal region. There are a total of 28 fishing villages and 20 fish landing centers in this region[16], with 12 fish landing centers in the present study area. Around 20 % of the population of total fishing households in Odisha belongs to the Ganjam district. Depending upon the topography and availability of resources, the whole Ganjam district coast was divided into nine beaches and stretches (along this region - North-South direction), *i.e*. Prayagi, Bateswar, Podampetta-Puranabandha, Rushikulya Estuary-Nalia Nuagan, Arjyapalli, Gopalpur, Golabandha-Markandi, Ramayapatana, and Bahuda estuary-Pati Sonapur (Table 1). The topographical and geological characteristics of four locations (Podampetta-Puranabandha, Rushikulya Estuary-Nalia Nuagan, Golabandha-Markandi, and Bahuda Estuary-Pati Sonapur) were so close that the stretch between two beaches was considered to be one contiguous stretch. However, all nine locations are marked in Figure 1 for better understanding.

Coastal sand dunes are a common landform in the study area. Casuarina plantations, fish landing centers, industrial complexes such as Grasim Industries, Odisha Sands Complex (OSCOM), and Gopalpur port, as well as two estuaries, the Rushikulya and Bahuda River estuaries, are other notable features along the coast. Field surveys were carried out between March and April 2020, with a minimum of three visits to each of the nine sites at different times. The survey was conducted on foot, with the researchers walking along a stretch of beach and recording the number of dead Olive ridley turtles, the distance travelled, topographic features, geo-coordinates (using a handheld GPS), photographic evidence (using a DSLR camera), and other activities in and around the locations where dead turtles were observed. The length, width, elevation, area of each stretch of beach, the distance travelled, the survey effort in hours were recorded, and the encounter rate was estimated. Since Olive ridleys are known to prefer river mouths or estuaries[3], the survey in two estuarine locations (Rushikulya and Bahuda estuaries), was replicated five times for a total survey effort of 08 hours and 7.50 hours, respectively. In

Table 1 — A snapshot of site characteristics and dead turtles seen on the site

Sites	Length (km)	Width (km)	Area (km²)	Survey effort (hrs)	Encounter rate (per km)	# Dead turtles
Prayagi	5.00	0.06	0.30	05:00	1.20	6.00
Bateswar	2.70	0.05	0.13	03:00	1.85	5.00
Podampetta-Puranabandha	3.58	0.17	0.60	04:00	4.46	16.00
Rushikulya estuary-Nalia Nuagan	8.00	0.14	1.12	08:00	1.50	12.00
Arjyapalli	3.35	0.03	0.11	03:45	0	0
Gopalpur	6.22	0.03	0.18	07:00	0	0
Golabandha-Markandi	5.33	0.05	0.26	06:10	0.93	5.00
Ramayapatana	4.16	0.06	0.27	05:00	0.72	3.00
Bahuda estuary - PatiSonapur	6.43	0.06	0.38	07:50	0.62	4.00

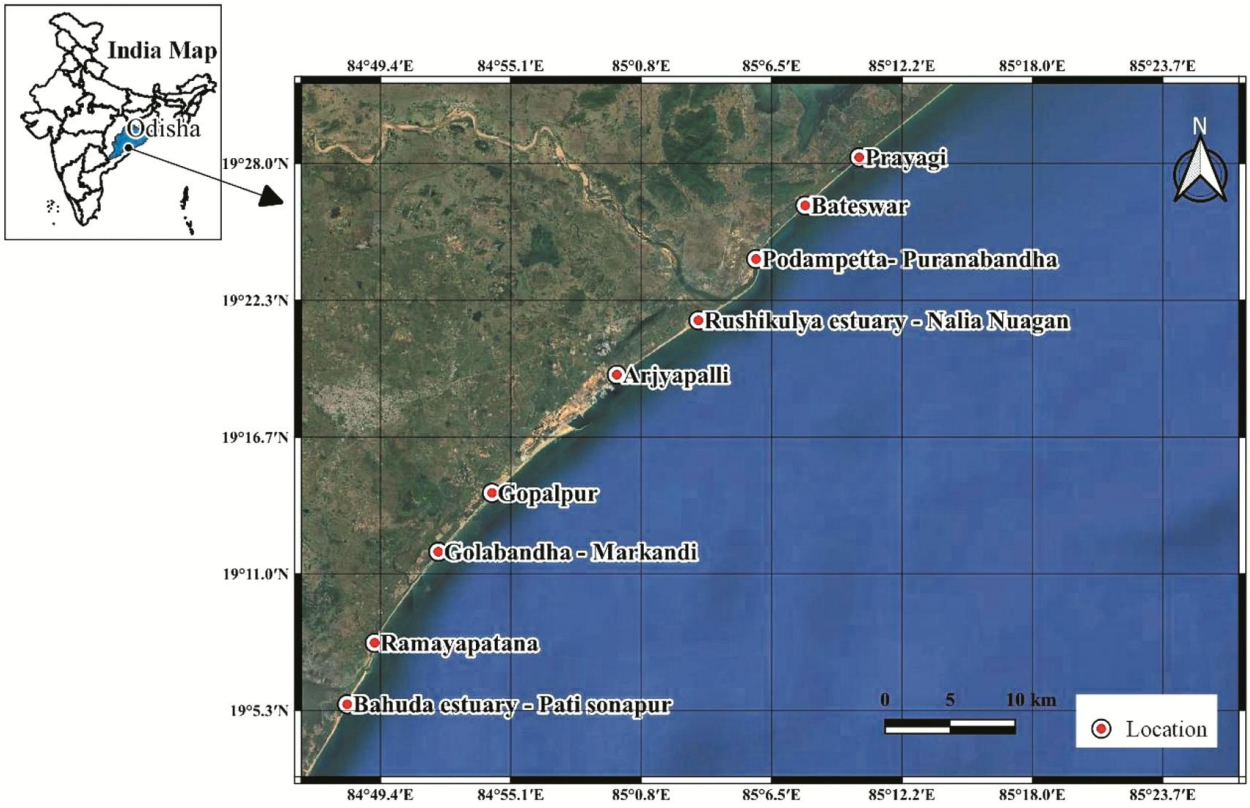

Fig. 1 — Study area map with survey locations

total, 49.05 hours of survey were conducted in all the nine locations. Threats that could contribute to turtle mortality, such as stray dogs, proximity to fishing villages, artificial lighting at night and marine debris (especially plastics), were noted and considered for analysis and interpretation. For ease of understanding, data segregation, and interpretation, the beaches were considered as fishing beaches where, fishing-related activities such as the presence of fishing boats, fish drying, and fishing net drying were seen. The plastic pollution was estimated in each of the beaches following a random sampling methodology by placing three 1×1 m^2 quadrats randomly beyond the swash mark on the landward side. The encounter rate (ER) of dead turtles was calculated following the formula ER = n/(l * t).

Where, n = no. of dead turtles, l = length of the beach surveyed (km), t = no of times surveyed.

Necessary care was taken to avoid sampling bias, *viz*., capturing photographic evidence, marking of carcasses, and recording geo-coordinates. Furthermore, the mortality density (time-averaged) was calculated as the number of dead turtles seen per

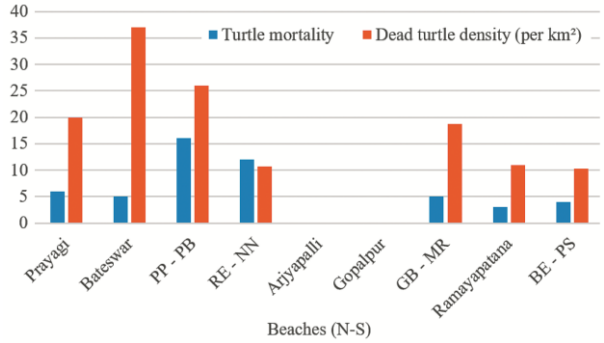

Fig. 2 — Observed turtle mortality in different locations (Site codes: PP-PB: Podampeta – Puranabandha, RE – NN: Rushikulya Estuary – Nalia Nuagan, GB – MR: Golabandha – Markandi, BE – PS: Bahuda Estuary – Pati Sonapur)

km^2 of beach surveyed per visit to get a good understanding of turtle mortality. The variation in turtle mortality on fishing vs non-fishing beaches were compared using the Mann-Whitney U test at α = 0.05 level.

Results and Discussions

During the two months of the survey in March-April 2020 (coincides with turtle breeding season), 51 dead turtles were seen in all nine sites (Fig. 2). The

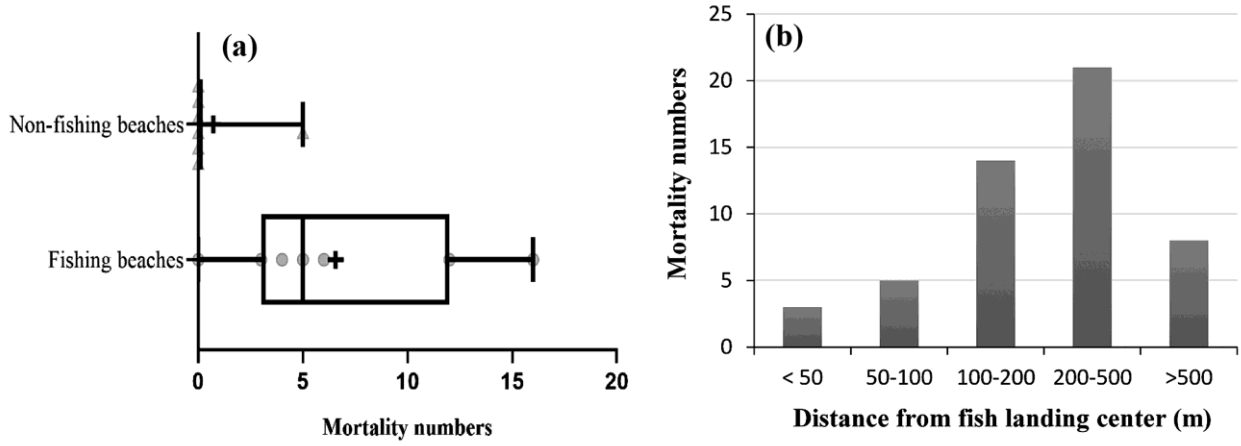

Fig. 3 — Spatial observations of turtle mortality: a) Fishing vs non-fishing beaches; and b) Distance from fish landing center

majority of these dead turtles (82.35 %) were found between 200 – 500 meters from the fish landing centers (Fig. 3). Five of the dead sea turtles exhibited struck marks on their carapaces, resembling a possible propeller hit (Fig. 4), and two were observed entangled in fishing nets. The drift/gill net is the most often used form of fishing in the Ganjam district's Chatrapur and Rangailunda blocks, followed by hooks, lines and boat seines. The most popular fishing techniques used by the fisherman community in Chikiti and Ganjam blocks are drift/gill nets and hooks and lines. The mortality rates differed significantly between fishing and non-fishing beaches (Mann-Whitney U test: $Z = 6.50$, $P = 0.017$), with the mortality number of turtles on fishing beaches being much greater than those on non-fishing beaches (Fig. 3). The high rate of mortality around fish landing centers shows that fishing practices might be playing a significant role in turtle mortality. Olive ridley sea turtle mortality is comparable along Odisha and Andhra Pradesh's beaches, with the bulk of deaths attributed to fishing practices[3]. This high death rate could be a result of accidental catch in fishing gears[5], and the presence of commercial fishing trawlers in shallow waters[22]. Gopi *et al.*[22] in their study observed that most of the accidental capturing-related mortality in the turtles occurs within five km from the shore and within a depth of 10 fathoms (= 18 meters). Fishing activity was observed at all the nine locations in the present study area. Further, previous surveys have reported the fishery-related mortality of Olive ridley turtles to the extent of ~ 100,000 in one decade and around 10 – 15000 every year[11,12,17].

In the present study, both permanent and episodic threat factors associated with turtle mortality were

Fig. 4 — A dead olive ridley with a possible hit mark on its carapace

identified. Some of the factors such as fishing and predation can be considered direct threats, whereas, other factors *viz*., marine debris (litter), industrial development, beach erosion and vehicular movements can be indirect threats/associated factors for the declining population of turtles. In the present study, no incidences of stray dogs killing adult turtles were seen. However, stray dogs were seen feeding on the carcasses of the dead turtles on seven beaches (Prayagi, Bateswar, Podampetta-Puranabandha, Rushikulya estuary-Nalia Nuagan, Golabandha-Markandi, Ramayapatana, Bahuda estuary-Pati Sonapur). The stray dogs are known to feed on the eggs and attack the female turtles thereby killing them[11]. The present report deals with turtle mortality on the beach (through direct/indirect observation) and identifying threats. Thus, other incidences of predation of turtle hatchlings (while hatchlings emerge out from the nest pit and crawl to the sea) by stray dogs and raptors are not included in this study.

Out of nine locations, two (Arjyapalli and Gopalpur) are near industries, *i.e*. Odisha Sands Complex (OSCOM) and Gopalpur Port, respectively, which might have made the sites unsuitable for turtle nesting. Plastic litter was mostly seen on four beaches (Prayagi, Bateswar, Gopalpur, and Ramayapatana). Plastic litter can be a potential factor jeopardizing turtle survival, as the consumption of such debris can lead to gastrointestinal obstruction or perforation[23]. Additionally, four sites (Bateswar, Arjyapalli, Gopalpur, and Ramayapatana) had some form of artificial illumination emanating from local fisherman villages. Further, turtle mortality (as a factor for population decline) can be associated with habitat degradation, *viz*., contamination of beach habitats, hardening of nesting sites (through vehicular movements) and loss of (nesting ground) habitat due to beach erosion. Although vehicular movements are restricted in the nesting beaches as per relevant guidelines, many vehicles were seen plying on different beaches. Vehicular movements were high on the tourist beaches (*e.g*. Bateswar, Gopalpur, Golabandha, and Prayagi). The vehicular movements on the beach can be a factor in degrading the nesting habitats by making the substratum hard and compact, thereby rendering the beach unsuitable for egg laying[18]. In addition, three beaches i.e. Ramayapatana, Nalia Nuagan, and Podampetta-Puranabandha were actively eroding, of which Nalia Nuagan and Puranabandha were located close to the Rushikulya estuary, one of Odisha's major mass nesting sites[19]. Furthermore, the Rushikulya river mouth has been shifting over time (Fig. 5), causing further erosion and loss of nesting sites[8]. Such indirect factors might also result in turtle mortality (population decline).

A maximum number of dead turtles was found at the Podampetta-Puranabandha site which is very close to the Rushikulya estuary mass nesting site (Table 1). Such high mortality might be ascribed to the location of the sites (falling between two of the fishing villages Nalia Nuagan and Puranabandha). The location being a mass nesting site (with a very high number of nesting turtles) is ought to witness high mortality than other locations. Among all the locations, the estimated dead Olive ridley turtle density (Table 2) was highest in Bateswar and Podampetta-Puranabandha beaches

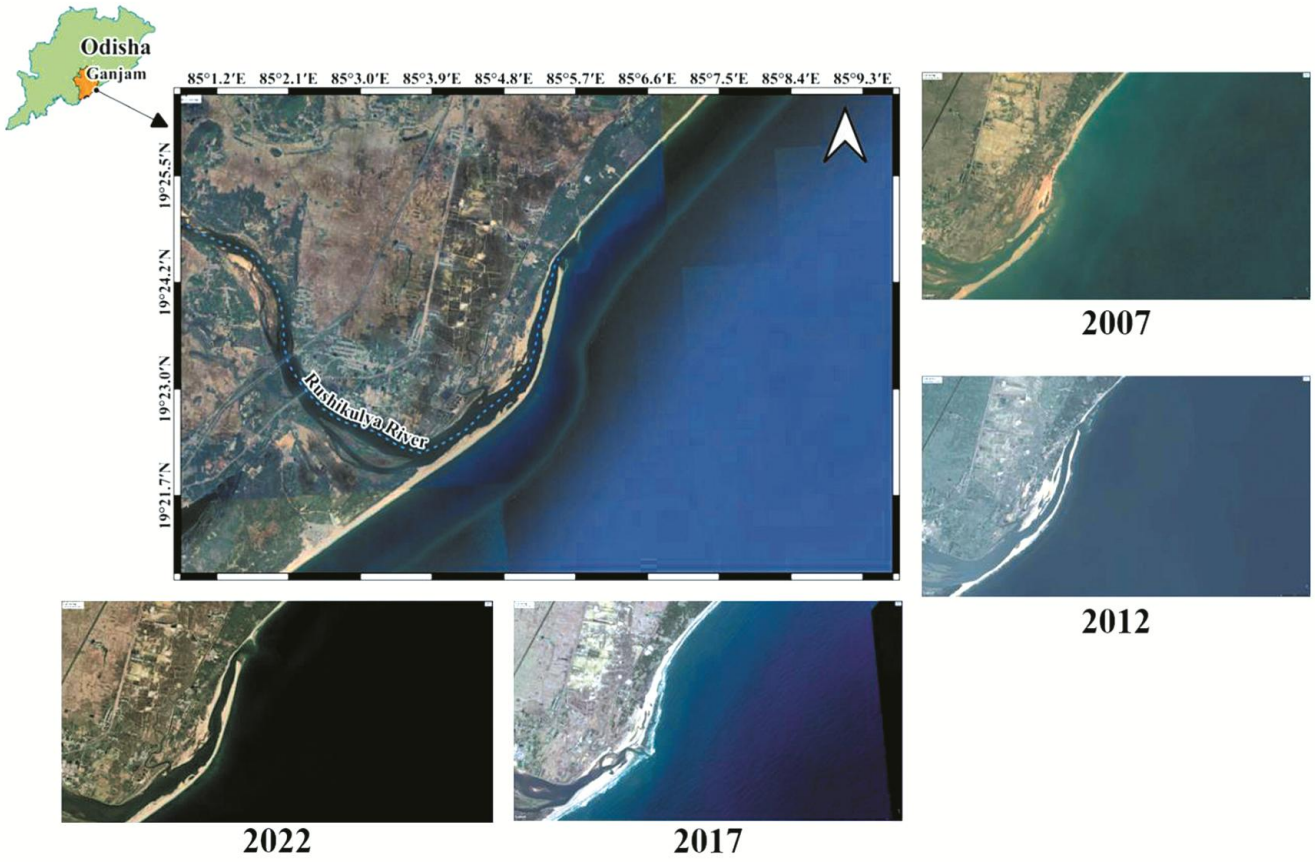

Fig. 5 — Changes in the Rushikulya river mouth during the last two decades

Table 2 — Potential threats observed during the field visits. *[If a threat was observed it is denoted as (*) and if not then denoted as (--), and this process has been done at least three times]*

Beaches (N-S)	Fishing activity	Stray dogs	Industries	Artificial lighting	Vehicles	Plastic debris	Dead turtle density (per km²)
Prayagi	* * *	-- * *	-- -- --	-- -- --	* -- --	* * *	20.00
Bateswar	* * *	* * *	-- -- --	* * *	* * *	* * *	37.00
Podampetta-Puranabandha	* * *	* * *	-- -- --	-- -- --	-- -- --	-- -- --	26.00
Rushikulya Estuary-Nalia Nuagan	* * *	* * --	-- -- --	-- -- --	-- -- --	-- -- --	10.70
Arjyapalli	* * *	* * *	* * *	* * *	-- -- --	-- -- --	0
Gopalpur	* * *	* * *	* * *	* * *	* * *	* * *	0
Golabandha-Markandi	* * *	* * *	-- -- --	-- -- --	* -- *	-- -- --	18.70
Ramayapatana	* * *	* -- *	-- -- --	* * *	-- -- --	* * *	11.00
Bahuda Estuary-Pati Sonapur	* * *	* * *	-- -- --	-- -- --	* * --	-- -- --	10.30

(*i.e.* 37 and 26 dead Olive ridleys per km^2). It is to be noted that intensive fishing activities were seen on these beaches and five nearby fishing villages rely on these two beaches for regular fishing activities. Earlier researchers[11,20] have confirmed that stray dogs predate on turtles during arribada (mass nesting). Stray dogs were seen on almost all the beaches (Table 2) in the present study. However, no direct observation of dogs killing adult turtles was noticed. Thus, predation by stray dogs and jackals appears to have contributed less to mortality than fishing, as no direct evidence of stray dogs and jackals attacking turtles were seen.

The surveyed beaches are located at an altitude of 0 to 17 m above MSL (Fig. 6). Majority of dead turtles were seen on lower elevations (3 – 6 m above MSL, Fig. 6), an indication that turtles prefer lower-elevation beaches for egg-laying to avoid investing more energy traversing steeper grounds. Thus, the presence of more turtles on low-elevation beaches may be the factor for higher mortality on those beaches. Further, such beaches might witness more washed corpses close to the swash mark. The sea turtle population is also endangered by various climate-induced environmental factors, *viz*., sea-level rise, and natural disasters[21], as these factors are known to degrade/destroy the nesting grounds. Further, an increase in temperature can produce a skewed sex ratio, and it can also influence the turtle's range and dietary breadth[24]. As a result, the Olive ridley turtle population, particularly the breeding population, suffers. The olive ridley population is threatened by issues more or less unique to the area, including illicit fishing, plastic litter, vehicular activity and predation.

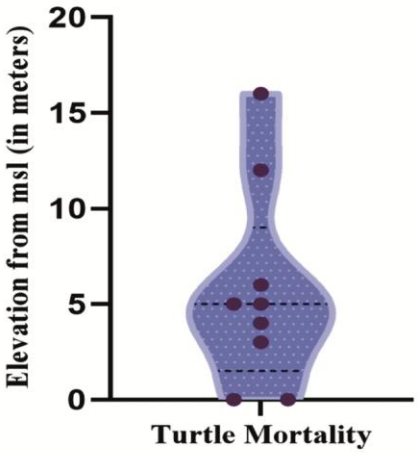

Fig. 6 — Association of beach elevation with turtle mortality

Concerned stakeholders, particularly government agencies, should take precautionary measures to protect these creatures with a participatory approach (involving the local populace). During the survey, casual interactions were held with many fisherfolks, and the majority of them were enthusiastic about assisting in the protection of Olive ridley sea turtles. Thus, all future conservation efforts must adopt a participatory approach to achieve long-term conservation goals.

Conclusion

The present study provides insights into the extent of turtle deaths on nine beaches along the Ganjam coast, east coast of India. With the observation of dead Olive ridley turtles on seven beaches, the causative and associated factors for such mortality could be fishing and allied activities, predation by

stray dogs and jackals, vehicular movements, and plastic litter. Although various regulations restricting fishing and vehicular movements are in place, necessary surveillance mechanisms need to be executed to arrest such incidences. Numerous site-specific management programs, such as regulated fishing during the turtles' breeding season, periodic debris clean-up, and prohibition of lighting near nesting sites, should be undertaken during the Olive ridley sea turtle's Arribada to minimize mortality and boost productivity. Involving the local community will help achieve long-term conservation goals. On the whole, the results of this preliminary survey highlight the importance of continuous beach monitoring to get a better knowledge of the factors that contribute to sea turtle mortality in the area.

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Conflicts of Interest

Both the authors hereby declare that there is no conflict of interest in the publication of this manuscript.

Ethical Statement

This paper presents the results of our primary field survey. No animals were captured or harmed during the study and relevant national and/or international norms were followed.

Author Contributions

SPP & BAKP designed the study. SPP carried out the field study and drafted the manuscript. BAKP supervised the whole study including editing and finalizing the manuscript.

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