Nesting and hatching behaviour of Olive Ridley Turtles
*Lepidochelys olivacea* (Eschscholtz, 1829) (Reptilia: Cryptodira: Cheloniidae) on Dr. Abdul Kalam Island, Odisha, India

P. Poornima

26 April 2021 | Vol. 13 | No. 5 | Pages: 18122–18131
DOI: 10.11609/jott.6878.13.5.18122-18131
Nesting and hatching behaviour of Olive Ridley Turtles
*Lepidochelys olivacea* (Eschscholtz, 1829) (Reptilia: Cryptodira: Cheloniidae) on Dr. Abdul Kalam Island, Odisha, India

P. Poornima

Divisional Forest Officer, Bhadrak Wildlife Division, Bhadrak, Odisha, India.
poornimapandian4@gmail.com

Abstract: This paper reports the nesting, impact of lunar phase and rainfall on mass nesting, hatching, and hatchling behaviour of *L. olivacea* in Dr. Abdul Kalam Island, Bhadrak District, Odisha. The study site is a well-known rookery for this species. A study of 15 mass nesting events between 2003 and 2020 using Rayleigh’s test indicated that the onset of mass nesting was not uniform across a lunar month, but was most intense towards the beginning of the fourth quarter moon (mean lunar day = 22.44). Also, rainfall and mass-nesting data from 2015 to 2020 revealed that ≥3.2 mm rainfall in February delayed mass nesting from the second fortnight of February to the end of the first fortnight of March. Sporadic nesting continued after hatching commenced in May, and continued until the end of May 2020, with an average of three turtles nesting each day. At night, a cohort of hatchlings from individual nests emerged synchronously. Before emergence they remained a little beneath the sand surface in airy-shallow pits. During hatchling emergence these pits fill with sand, leaving depressions described as "emergence craters" in recent literature on *L. olivacea*. To study hatchling emergence 30 such craters were examined in May 2020, and the numbers of emerged hatchlings per cohort varied from 28 to 182. Of 30 craters examined, 28 were circular and two were elliptical, with diameters varying between 10 and 26 cm. Pearson’s correlation coefficient between the numbers of emerged hatchlings and crater diameter was 0.38. Hatchlings took 17 min 22 sec (SD= ±5min 30 sec) on average to reach the sea from a mean distance of 34.6m.

Keywords: Arribada, Bhadrak District, cohorts, emergence crater, hatchling emergence, moon phase, sporadic nesting.
INTRODUCTION

The Olive Ridley Sea Turtles *Lepidochelys olivacea* are the second smallest sea turtles in the world next to the Kemp Ridley *Lepidochelys kempii* (Van Buskirk & Crowder 1994). *Lepidochelys olivacea* have a circumtropical distribution and occur in India, Mexico, Costa Rica, and the Arab Peninsula, further to coastal Africa along the warm tropical and subtropical waters of the Indian and Pacific Oceans (Pritchard 1997; Pritchard & Mortimer 1999). They do not migrate from one ocean to another but move between the oceanic and neritic zones within the same ocean (Plotkin et al. 1995).

*Lepidochelys olivacea* populations are well known for ‘arribada’ (a Spanish term, meaning ‘arrival by sea’) wherein 1000s of pregnant turtles arrive at the same beach site to lay their eggs and nest for the next few days. The mass nesting sites for *L. olivacea* include Costa Rican and Mexican beaches (Pritchard 1997) and the Odisha coast (Bustard 1976) along the Pacific and Indian Ocean, respectively. In Odisha, Gahirmatha Wildlife Sanctuary in Kendrapada District (Bustard 1976), the Devi River mouth in Puri District (Kar 1982) and Rushikulya in Ganjam District (Pandav et al. 1994) are the three principal nesting sites for *L. olivacea*. Among these, Gahirmatha Wildlife Sanctuary is the largest known nesting centre for *L. olivacea* (Bustard 1976) with 1–8 lakh turtles nesting per year (Pattnaik et al. 2001).

Breeding and nesting of *L. olivacea* occur through the year in Costa Rican and Mexican coasts, with mass nesting in the rainy months of July–December (Hart et al. 2014), mostly during the third quarter moon (Plotkin 1994). In the Odisha coast mass nesting occurs in the dry months of January–March (Dash & Kar 1990). In Gahirmatha Wildlife Sanctuary in particular, breeding of *L. olivacea* starts in November and mass nesting occurs in January–March (Behera et al. 2010). *Lepidochelys olivacea* have the ability to delay nesting in response to heavy rainfall, because high moisture level in the beach sand reduces hatching success in the nest (Plotkin et al. 1997). The numbers of turtles participating in mass nesting are variable (Pattnaik et al. 2001). Sporadic nesting by a few individuals of *L. olivacea* along the eastern coast of India from North 24 Parganas District to Kanyakumari (21.638°N, 89.075°E) between December and April are common (Pandav & Choudhury 2000; Tripathy et al. 2008). After 45–50 days of incubation, the hatchlings return to the sea in April.

Hatching within a nest is synchronous (Spencer et al. 2001) and emergence occurs through group-digging behaviour customarily described as ‘social facilitation’ (Carr & Hirth 1961). The emergence of hatchlings from a single nest occurs in 1–4 cohorts over a few days, with the first cohort having the largest number of hatchlings (Rusli et al. 2016). Before emergence, hatchlings rest in an air-filled pit in sandy soil and during emergence, the surface sand sags into the pit (Salmon & Reising 2014), leaving a depression described as ‘emergence crater’ (Bishop et al. 2011). Hatchling emergence in *L. olivacea* has been studied using various methods. Among them, the numbers of hatchlings leaving the emergence crater (Burney & Margolis 1998) is considered a reliable index of hatching emergence. After emergence, the hatchlings crawl radially out of the crater and the crawl marks are used in describing hatching emergence (Bishop et al. 2011).

Hatchlings emerge nocturnally (Mrosovsky 1968) and move towards negative surface gradient (Salmon et al. 1992). Also, hatchlings exhibit positive phototaxy. Since the sea surface reflects moon light better than the land surface, they move seawards (Mrosovsky & Shettleworth 1968). Artificial illuminations placed on the land distract the seaward movement of hatchlings (Tuxbury & Salmon 2005). In the absence of artificial illumination, disorientation in hatchling movement is high on new moon days (Salmon & Witherington 1995).

*Lepidochelys olivacea* populations have declined in many countries due to various reasons: collection of eggs (Arauz 2000), destruction of nesting beaches (Pandav & Choudhury 1999), trapping of adults (Fretey 2001), intensive fishing practice using trawlers and banned nets (Pandav 2000), diseases (Herbst 1994), and global warming (Hays et al. 2003) are a few significant ones. The IUCN Red List of Threatened Species has evaluated *L. olivacea* under ‘Vulnerable’ category (Abreu-Grobois & Plotkin 2008).

In Gahirmatha Wildlife Sanctuary, mass nesting was delayed between February and March 2020 probably because of sporadic rainfall in February (3.2mm). Also, the nesting period (14–20 March 2020) coincided with waning phase of the moon. These observations prompted further study exploring the effect of certain environmental variables, viz., lunar phase and rainfall on mass nesting and hatching behaviour of *L. olivacea*. Although the nesting and hatching behaviour of *L. olivacea* have been reasonably well explored in Gahirmatha (Dash & Kar 1990; Silas et al. 1985; Pandav 2000; Behera et al. 2010), little information exists pertaining the influence of lunar phase and rainfall on mass nesting, and behaviour of hatchlings post emergence.

Therefore, I proceeded with this study keeping the
following objectives in focus: (1) mass nesting and its relation with lunar phase, (2) effect of rainfall on mass nesting, (3) the duration of sporadic nesting, (4) the patterns in hatchling emergence and emergence craters, and (5) behaviour of hatchlings post emergence.

MATERIALS AND METHODS

Study Area

Dr. Abdul Kalam Island (previously Wheeler Island, 20.753°N, 87.072°E) falls under the Gahirmatha Wildlife Sanctuary, managed by the forest department of the state of Odisha (Figure 1). The Gahirmatha Beach is 2.4 km long with varying widths. The average annual temperature is 27°C and the average annual rainfall is 1,530mm. *Ipomoea pescaprae* (Convolvulaceae) and *Suaeda maritima* (Amaranthaceae) usually occur abundantly on the sandy shoreline.

Methods

Hatchlings from each nest dig synchronously upwards in cohorts, forming emergence craters on the sand surface. The hatchlings gradually leave the craters and reach the surface, beginning their movement towards the sea. The number of emerged hatchlings per cohort was determined through visual observation of emergence from such craters. During the hatching period, 2–7 May 2020, 30 craters were sampled randomly and each crater was observed from 20.00h to 06.00h, and the numbers of hatchlings emerging from each crater were counted. From each crater, the movements of the first 5–10 hatchlings to the sea were observed individually and the time taken by each of them was measured using a stopwatch. The overall shape of each crater was measured for the diameter using measuring tapes. The

![Figure 1](https://example.com/figure1.png)

**Figure 1.** Study area: (a) Bhadrak District (marked) in Odisha map | (b) Bhadrak coast (marked area in ‘a’) | (c) Bhadrak coast showing the Dr. Abdul Kalam Island (marked area in ‘b’) | (d) Gahirmatha beach in Dr. Abdul Kalam Island (marked area in ‘c’). Source: odishaassembly.nic.in, censusindia.co.in and earth.google.com.
nesting data of *L. olivacea* for 2003–2020 were obtained from the archives of the Rajnagar Wildlife Division Office, Kendrapada. The rainfall data of Dr. Abdul Kalam Island for 2015–2020 were obtained from the nearest meteorological office of Dhamra Port Company Limited, Dhamra, Bhadrak District, Odisha.

The lunar days corresponding to the starting of each mass nesting were obtained from keisan.casio.com (CASIO Computer Co Ltd, 2020, Tokyo, Japan). The lunar days were then converted into angular data for using Rayleigh’s test, which was done using MS Excel 2019 to verify uniformity in the occurrence of onset of mass nesting across a lunar month. The correlation between variables in the scatter plot was calculated using Pearson’s correlation. Photographs of nesting and hatching were made using a COOLPIX P1000 (125X Optical Zoom Camera, Nikon Corporation, Tokyo, Japan).

**RESULTS**

**Mass nesting (Arribada) and Lunar phase**

Mass nesting of *L. olivacea* revealed that 407,204 individuals laid eggs between 14 and 20 March 2020 (Table 1). Maximum numbers (n= 98,700) nested on 17 March (fourth day) and the minimum (n= 3,600) on 20 March (seventh day) (Table 1). Mass-nesting data obtained from Rajnagar Wildlife Division for 2015–2020 revealed that a maximum of 664,897 individuals nested in 2018 and a minimum of 51,995 in 2016 (Table 2).

Rayleigh’s test was done to determine if the onset (in lunar days) of 15 mass nesting events between 2003 and 2020 (Table 3) was non-uniformly distributed across a lunar month. Results indicated a highly non-uniform distribution (n= 15, r= 0.504, z= 3.81, z_{critical}= 2.945, α= 0.05) with a mean lunar day of 22.44 (i.e., the onset of mass nesting is at the beginning of fourth quarter moon).

**Nesting period and rainfall**

Mass nesting and the rainfall data for 2015–2020 (Table 4) were analysed in conjunction to study the impact of rainfall on nesting. When the rainfall in February was less than 3.2mm, mass nesting occurred in the last fortnight of February or in the first week of March. When the rainfall increased ≥3.2mm in February, mass nesting was delayed to the end of the first fortnight of March; however, rainfall in the first week of March did not delay mass nesting further, since the nesting season for *L. olivacea* ended in March.

**Sporadic nesting**

Sporadic nesting of *L. olivacea* at Gahirmatha started from the second fortnight of December 2019 and continued after mass nesting from 14–20 March to 1–10 May 2020. Between December and February, an average of 15 individual females of *L. olivacea* nested per day. The numbers increased to 40 per day for a week prior to and after mass nesting. During hatching (2–7 May), an average of three turtles nested on the beach every day.

| Day       | Population numbers |
|-----------|---------------------|
| 14 March  | 10,076              |
| 15 March  | 68,311              |
| 16 March  | 98,135              |
| 17 March  | 98,700              |
| 18 March  | 95,541              |
| 19 March  | 32,841              |
| 20 March  | 3,600               |
| **Total** | **407,204**         |

| Year | Population numbers |
|------|---------------------|
| 2015 | 413,334             |
| 2016 | 51,995              |
| 2017 | 603,962             |
| 2018 | 664,897             |
| 2019 | 450,949             |
| 2020 | 407,204             |

| Numbers of hatchlings per cohort |
|---------------------------------|
| Crater diameter (cm)            |
| 0                               |
| 2                               |
| 4                               |
| 6                               |
| 8                               |
| 10                              |
| 12                              |
| 14                              |
| 16                              |
| 18                              |
| 20                              |
| 22                              |
| 24                              |
| 26                              |
| 28                              |
| Numbers of hatchlings per cohort |
| Crater diameter (cm)            |
| 0                               |
| 2                               |
| 4                               |
| 6                               |
| 8                               |
| 10                              |
| 12                              |
| 14                              |
| 16                              |
| 18                              |
| 20                              |
| 22                              |
| 24                              |
| 26                              |
| 28                              |
| Numbers of hatchlings per cohort |
| Crater diameter (cm)            |
| 0                               |
| 2                               |
| 4                               |
| 6                               |
| 8                               |
| 10                              |
| 12                              |
| 14                              |
| 16                              |
| 18                              |
| 20                              |
| 22                              |
| 24                              |
| 26                              |
| 28                              |
Hatchling emergence

The hatchlings dug through the sand above synchronously to emerge from their sandy nests. At the time of emergence, usually after sunset, an emergence crater formed on the sand surface due to synchronous, collective, digging effort by a single cohort of *L. olivacea* from a nest. These craters lasted for 7–10 days and eventually were either eroded or filled up with sand spread by wind. The hatchlings reached the surface gradually with the hatchlings present near the surface pushed by emerging hatchlings below in the crater. On reaching the surface they spread themselves radially in different directions, but moved towards the sea.

The numbers of hatchlings emerging from the 30 observed individual craters were 2,763. The maximum and minimum numbers of emerged hatchlings per cohort were 182 and 18 with an average of 92.1 hatchlings per cohort. The craters were mostly circular (93.3%) and occasionally elliptical (6.7%). The crater diameter varied between 10 and 26 cm (n= 30). Pearson’s correlation indicated a low but positive correlation (0.38) between the numbers of emerged hatchlings per crater and crater diameter. Therefore, when the number of emerging hatchlings per cohort increases, the crater diameter also tends to increase.

Movement of hatchlings towards sea

As soon as the hatchlings emerged, they moved towards the sea. The pace and direction of movement varied among individuals. Time taken by 280 hatchlings from 30 emergence craters to reach the sea indicated that the minimum time taken was 6 min 12 sec and the maximum was 35 min 9 sec. The average time taken by hatchlings to reach the sea from a mean distance of 34.55m was 17 min 22 sec. (SD= ± 5 min 30 sec).

**DISCUSSION**

Mass nesting and lunar phase

Previous reports on the numbers of mass nesting *L. olivacea* individuals at Gahirmatha Wildlife Sanctuary

### Table 3. Date of initiation of 15 arribada events and corresponding lunar days, 2003–2020.

| Sno | Year | Date of initiation of arribada | Lunar days (out of 29.53 days in a lunar month) | Sno | Year | Date of initiation of arribada | Lunar days (out of 29.53 days in a lunar month) |
|-----|------|-------------------------------|-----------------------------------------------|-----|------|-------------------------------|-----------------------------------------------|
| 1   | 2003 | 28Feb                         | 26.8                                          | 9   | 2013 | 17 March                      | 5.4                                           |
| 2   | 2007 | 11Feb                         | 23.1                                          | 10  | 2015 | 12 March                      | 21.3                                          |
| 3   | 2009 | 20Mar                         | 23.2                                          | 11  | 2016 | 03 March                      | 23.7                                          |
| 4   | 2010 | 24Feb                         | 10.2                                          | 12  | 2017 | 22 Feb                        | 25.3                                          |
| 5   | 2010 | 19Mar                         | 2.4                                           | 13  | 2018 | 04 March                      | 16.4                                          |
| 6   | 2011 | 26Feb                         | 21.2                                          | 14  | 2019 | 26 Feb                        | 21.4                                          |
| 7   | 2011 | 20Apr                         | 16.7                                          | 15  | 2020 | 14 March                      | 19.6                                          |
| 8   | 2012 | 15Mar                         | 22.3                                          | -   | -   | -                            | -                                              |

Source of mass nesting data: Archives of Rajnagar Wildlife Division, Kendrapada, Odisha Forest Department.

*—First mass nesting | **—Second mass nesting.

### Table 4. Yearly rainfall and mass nesting data for Gahirmatha Beach, Dr Abdul Kalam Island, 2015–2020.

| Year | Rainfall in 1–15 February (in mm) | Rainfall in 16–28 (29) February (in mm) | Rainfall in 1–15 March (in mm) | Rainfall in 16–31 March (in mm) | Period of mass nesting |
|------|----------------------------------|----------------------------------------|--------------------------------|--------------------------------|------------------------|
| 2015 | 0                                | 3.2                                    | 0                              | 10.8 (29th)                    | 12–19 March            |
| 2016 | 20.4                             | 5.5                                    | 3.7                            | 1                              | 3, 12–20 March (46 turtles on March 3rd) |
| 2017 | 0                                | 0                                      | 0                              | 18.2                           | 22 Feb–1 March         |
| 2018 | 0                                | 0                                      | 0                              | 0                              | 4–13 March             |
| 2019 | 0                                | 1                                      | 1                              | 1.8                            | 26 Feb–5 March         |
| 2020 | 6.4                              | 6.0                                    | 7.8                            | 10 (20th, 22nd, 23rd)          | 14–20 March            |
indicate varying annual numbers (Bustard 1976; Kar & Bhaskar 1982; Silas et al. 1985). The data for 2015–2020 also revealed that numbers of turtles differed every year with 51,995 turtles in 2016 and 6,64,897 in 2018. It is possible that the variation was due to changes in productivity in their foraging areas, because females needed sufficient nutrients to support their migratory and reproductive activities (Valverde et al. 2012). Also, an increase or decrease in hatching rates over many years may result in varying adult population participating in arribada (Cornelius et al. 1991). Beach exchange, where Olive Ridleys move to another beach for nesting, mortality in nets (Valverde et al. 1998) also affects the nesting population numbers. The exact reason for variation in the number of individuals in mass nesting, however, requires further study.

At Gahirmatha, the onset of mass nesting occurred at the beginning of the fourth quarter moon. Rayleigh’s test showed a highly non-uniform distribution of onset of mass nesting across the lunar month with a mean lunar day of 22.44 days. According to Silas et al. 1985, mass nesting occurred on 7th day after the full moon in Gahirmatha, i.e., after 20.77 days. In Ostional Beach, Costa Rica, mass nesting usually began in the fourth quarter moon with mean lunar days of 23 (Bezy et al. 2020). In Mexico, mass nesting coincided with the third quarter moon (Plotkin 1994). In Ghana, a majority of L. olivacea nesting occurred in third quarter, which could be due to less light because of waning moon, and thus to avoid predators (Witt 2013). Another possible advantage of nesting during waning moon was greater prey availability post-nesting (Pinou et al. 2009) because L. olivacea feed primarily on crabs, which are nocturnal (Shaver & Wibbels 2007).

Nesting period and rainfall

In Gahirmatha, rainfall (≥3.2mm) in February 2020 delayed mass nesting of L. olivacea from February to first week of March 2020. High sand moisture content due to rainfall is indicated as a reason for reduced hatching success in the nest chamber (Packard et al. 1977). In the eastern Pacific Coast, L. olivacea individuals delayed nesting during extreme rainfall (>50 cm) (Plotkin et al. 1997), but not during normal precipitation levels (9cm) (Coria-Monter & Duran-Campos 2017) because arribadas coincided with rainy seasons in the eastern Pacific (Cornelius 1986). Whereas in Gahirmatha, even modest rainfall (3.2mm) delayed the mass nesting, because nesting occurred in dry periods in Odisha (Dash & Kar 1990). Since the nesting season of L. olivacea ended in March (Behera et al. 2010), there was no further delay in nesting beyond second week of March 2020 despite rainfall in the first week.

Sporadic nesting

Sporadic nesting of L. olivacea occurred almost every month along the Odisha coast, but more frequently between February and April (Dash & Kar 1990). Sporadic nesting occurred mainly between December and May
Nesting and hatching behaviour of Olive Ridley Turtles on Dr. Abdul Kalam Island

Poornima

Image 1. Nesting ground for arribada of Olive Ridley turtles: a—arribada in the early morning (05.00h) | b—a female clearing the surface sand for nesting | c—a female turtle in oviposition (laying eggs) | d—hatchlings emerging from the emergence crater | e—emergence craters on the sand surface | f—an individual L. olivacea hatchling | g—hatchlings moving towards the sea | h—hatchlings entering the sea. © Poornima P.
Nesting and hatching behaviour of Olive Ridley Turtles on Dr. Abdul Kalam Island

Poornima

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 April 2021 | 13(5): 18122–18131

Between December and February, an average of 15 L. olivacea individuals nested sporadically. The numbers increased to 40 per day for a week prior to and after mass nesting (14–20 March). In Gahirmatha, more than 10 turtles arrived for sporadic nesting per night (Tripathy 2008). Our observations in Gahirmatha match with those of Tripathy (2008) till April 2020 but the numbers of turtles nesting sporadically in May 2020 was, on an average, only three per night.

Hatchling emergence

Mrosovsky (1968) and Witherington et al. (1990) observed that the emergence of L. olivacea hatchlings onto the sand surface was predominantly nocturnal. The hatchlings emerged only after sunset and before sunrise, in Gahirmatha as well. After synchronous hatching from the nests, hatchlings exhibited group-digging behaviour to reach the sand surface (Hendrickson 1958; Carr & Hirth 1961). At Gahirmatha, this behaviour was prevalent in all the nests observed. Final emergence by hatchlings on to the sand surface created emergence craters (Bishop et al. 2011) due to collapse of the cavity in which hatchlings were present (Salmon & Reising 2014). Also, the hatchlings emerged in cohorts of 1–4 from a single nest, over a period of 4–8 days, with the first cohort having maximum number of hatchlings (Rusli et al. 2016). At Gahirmatha, every time a cohort of hatchlings from a nest emerged, an emergence crater formed on the surface, which lasted 7–10 days before being either eroded or filled up with sand by wind.

The minimum and maximum number of hatchlings from individual craters (per cohort) were 18 and 182, respectively, with an average of 92.1 hatchlings. These numbers represent the emergence per cohort. Therefore, the maximum egg count per nest (clutch size) found in Gahirmatha was ≥182 considering the mortality in the nest and mortality during emergence. Whereas, Kumar et al. (2013) observed maximum egg counts of 168. The craters were mostly circular (93.3%) and occasionally elliptical (6.7%). Their diameters varied between 10cm and 26cm. There was a low but positive correlation (0.38) between numbers of hatchlings per crater and respective crater diameter, as per Pearson’s correlation.

Movement of hatchlings towards sea

After emergence hatchlings typically move towards negative slope gradient (Limpus 1971), which was observed in Gahirmatha. Hatchlings also typically exhibit positive phototaxy, leading them to move towards the sea since moon light is reflected more by water than land (Carr & Ogren 1960; Mrosovsky & Shettleworth 1968). These findings also match with observations in Gahirmatha. The minimum time taken by hatchlings to move one metre was 11 sec, whereas the maximum time was 2 min 4 sec. The average time taken by hatchlings to move one metre was 33 sec (SD= ±15 sec). This is less than the time taken by L. olivacea in Costa Rica, 52.4 sec (Burger & Gochfeld 2014) and Indonesia, 36–48 sec (Maulaney et al. 2012). Of 280 hatchlings, 62.5 % took 20–40 sec to move one metre. Considering the total time taken to reach the sea, minimum and maximum time taken was 6 min 12 sec and 35 min 9 sec, respectively. The average time taken by hatchlings in Gahirmatha to reach the sea was 17 min 22 sec (SD= ± 5 min 30 sec) for a mean distance of 34.55m, whereas it was 19 min 12 sec for a mean distance of 27.7m in Ostional Beach, Costa Rica (Burger & Gochfeld 2014).

CONCLUSION

The sandy beaches of Dr. Abdul Kalam Island in Gahirmatha Wildlife Sanctuary, even though geographically small in area, continue to be one of the most important nesting site for L. olivacea population in the world. Adequate measures are undertaken every year by Odisha Forest and Wildlife Department to ensure protection of L. olivacea along the Odisha coast. Further, study of environmental factors such as rainfall, lunar phase, temperature and winds on mass nesting in Odisha in general and Gahirmatha in particular, would further enhance our understanding of L. olivacea’s intricate nesting and hatchling behaviour.

REFERENCES

Abreu-Grobois, A & P. Plotkin (2008). (IUCN SSC Marine Turtle Specialist Group), Lepidochelys olivacea. The IUCN Red List of Threatened Species 2008: e.T11534A3292503. Downloaded on 07 March 2021. https://doi.org/10.2305/IUCN.UK.2008.RLTS.T11534A3292503.en

Arauz, R. (2000). Impact of high-seas long time fishery operations on shark and sea turtles populations in Economic Exclusive Zone of Costa Rica. Unpublished report, Earth Island Institute/Sea Turtle Restoration Project (STRP), Costa Rica,15pp.

Behera, S., B. Tripathy, B.C. Choudhury & S. Kuppusamy (2010). Behaviour of Olive Ridley Turtles (Lepidochelys olivacea) prior to arribada at Gahirmatha, Orissa, India. Herpetology 3: 273–274.

Bezy, V.S., F.P. Nathan, A.U. James, M.O. Carlos, G.F. Luis, M.Q.P. Wagner, A.V. Roldan & J.L. Kenneth (2020). Mass-nesting events in Olive Ridley sea turtles: environmental predictors of timing and size.
Animal Behaviour 163: 85–94.

Bishop, G.A., F.L. Pirkle, B.K. Meyer & W.A. Pirkle (2011). The foundation for sea turtle geoarchaeology and zoooarchaeology: morphology of recent and ancient sea turtle nests, St. Catherines Island, Georgia, and Cretaceous Fox Hills Sandstone, Elbert County, Colorado, Chapter 13, pp. 247–269. In: Bishop, G.A., H.B. Rollins & D.H. Thomas (eds.). Geoarchaeology of St. Catherines Island, Georgia. American Museum of Natural History Anthropological Papers 94.

Burger, J. & M. Gochfeld (2014). Factors affecting locomotion in Olive Ridley (Lepidochelys olivacea) hatchlings crawling to the sea at Ostional Beach, Costa Rica. Chelonian Conservation and Biology 13(2): 182–190.

Burney, C. & W. Margolis (1998). Technical report 1998, Sea Turtle conservation Program, Department of Natural Resources Protection, Broward County, Florida, USA, 6pp.

Bustard, H.R. (1976). World’s largest sea turtle rookery? Tiger Paper 3: 25.

Carr, A. & L. Ogren (1960). The ecology and migration of sea turtles 4: The Green turtle in the Caribbean sea. Bullletin of the American Museum of Natural History 121: 1–48.

Carr, A. & H. Hirth (1961). Social facilitation in green turtle siblings. Animal Behaviour 9: 68–70.

Coria-M, E. & E. Durán-Campos (2017). The relationship between the massive nesting of the Olive Ridley Sea Turtle (Lepidochelys olivacea) and the local physical environment at La Escobilla, Oaxaca, Mexico, during 2005. Hydrobiologia 277(2): 201–209.

Cornelius, S.E. (1986). The Sea Turtles of Santa Rosa National Park. Fundacion de Parques Nacionales, Monograph, San Jose, 134pp.

Cornelius, S.E., M.A. Ulloa, J.C. Castro, M.M. Del Valle & D.C. Robinson (1991). Management of Olive Ridley Sea Turtles (Lepidochelys olivacea) nesting at Playas Nancite and Ostional, Costa Rica, pp. 111–115. In: Robinson, J.G. & K.H. Redford (Eds.). Neotropical Wildlife Use and Conservation. The University of Chicago Press, Chicago.

Dash, M.C. & C.S. Kar (1990). The Turtle Paradise: Gahirmatha. Interprint, New Delhi, 295pp.

Fretney, J. (2001). Biology and Conservation of Marine Turtles of the Atlantic Coast of Africa. CMS Technical Series Publication No. 6. UNEP/CMS Secretariat, Bonn, Germany, 429pp.

Hays, G.C., A.C. Broderick, F. Glen & B.J. Godley (2003). Climate change and sea turtles: a 150-year reconstruction of incubation temperatures at a major marine turtle rookery. Global Change Biology 9(4): 642–646.

Hart, C.E., C.L. Quilhóez, A.M. Gasca, A.Z. Norzagaray & F.A.A. Grobois (2014). Nesting characteristics of olive Ridley turtles (Lepidochelys olivacea) on El Naranjo Beach, Nayarit, Mexico. Herpetological Conservation and Biology 9: 524–534.

Hendrickson, J.R. (1958). The Green Sea Turtle Chelonia mydas (Linn.) in Malaya and Sarawak. Proceedings of the Zoological Society, London 130: 455–535.

Herbst, L.H. (1994). Fibropapillomatosis of marine turtles. Annual Review of Fish Diseases 4: 389–425.

Kar, C.S. (1982). Discovery of second mass nesting ground of the Pacific Olive Ridley Sea Turtles in Orissa, India. Tiger Paper 1: 5–7.

Kar, C.S. & S. Bhaskar (1982). The status of sea turtles in the eastern Indian Ocean, pp. 365–372. In: Bjornal, K. (ed.). The Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, D.C.

Kumar, S., J. Sajan, S. Kuppusamy & B. Choudhury (2013). Egg laying duration in the olive ridley turtle Lepidochelys olivacea and its relevance for the estimation of mass nesting population size. The Herpetological Journal 23: 23–28.

Limpus, C.J. (1971). Sea turtle ocean finding behaviour. Search 2: 385–387.

Maulany, R.I., D.T. Booth & G.S. Baxter (2012). The effect of incubation temperature on hatching quality in the olive ridley turtle, Lepidochelys olivacea, from Alas Purwo National Park, East Java, Indonesia: implications for hatchery management. Marine Biology 159: 2651–2661.

Mrosovsky, N. (1968). Nocturnal emergence of sea turtles. Control by thermal inhibition of activity. Nature 220: 1338–1339.

Mrosovsky, N. & S.J. Shettleworth (1968). Wavelength preferences and brightness cues in the water finding behaviour of sea turtles. Behaviour 32(4): 211–257.

Packard, G.C., M.J. Tracy, & J.J. Roth (1977). The physiological ecology of reptilian eggs and embryos, and the evolution of viviparity within the Class Reptilia. Biological Reviews 52: 71–105.

Pandav, B. (2000). Conservation and Management of Olive Ridley Sea Turtles (Lepidochelys olivacea) in Orissa, India. Final Report, Wildlife Institute of India, 61pp.

Pandav, B., B.C. Choudhury & C.S. Kar (1994). A status survey of Olive Ridley Sea Turtles (Lepidochelys olivacea) and their nesting beaches along the Orissa coast, India. Wildlife Institute of India, Dehradun, India, 48pp.

Pandav, B. & B.C. Choudhary (1999). An update on the mortality of Olive Ridley Sea Turtle in Odisha, India. Marine Turtle Newsletter 83: 10–12.

Pandav, B. & B.C. Choudhury (2000). Conservation and Management of Olive Ridley Sea Turtle (Lepidochelys olivacea) in Orissa, India. Final Report, Wildlife Institute of India, Dehradun, 70 pp.

Pattnaik, S.K., C.S. Kar & S.K. Kar (2001). A Quarter Century of Sea Turtle Conservation in Orissa. Wildlife Wing, Forest Department, Government of Orissa, Bhubaneshwar, 34pp.

Pinou, T., K.J. Pacete, A.P. Niz, L. Gall & E. Lazo-Wasem (2009). Lunar illumination and sea turtle nesting. Herpetological Review 40: 409–410.

Plotkin, P.T. (1994). Migratory and reproductive behavior of the Olive Ridley Turtle, Lepidochelys olivacea (Eschschoitz, 1829) in the eastern Pacific Ocean. PhD Thesis. Texas A & M University, College Station, Texas.

Plotkin, P.T., R.A. Byles, D.C. Rostal & 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.C. Rostal, R.A. Byles & D.W. Owens (1997). Reproductive and developmental synchrony in female Lepidochelys olivacea. Journal of Herpetology 31(1): 17–22.

Pritchard, P.C. (1997). Evolution, phylogeny, and current status, pp. 1–28. In: Lutz, P.L. & J.A. Musick (eds.). The Biology of Sea Turtles. CRC Press, Boca Raton, Florida.

Pritchard, P.C. & J.A. Mortimer (1999). Taxonomy, external morphology, and species identification, pp. 21–38. In: K. Eckert, K. Bjornal, F. Abreu-Grobois & M. Donnelly (eds.). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/ SSC Marine Turtle Specialist Group Publ. No. 4, Washington, D.C.

Rusil, M.U., D.T. Booth & J. Joseph (2016). Synchronous activity lowers the energetic cost of nest escape for sea turtle hatchlings. Journal of Experimental Biology 219: 1505–1513.

Salmon, M., J. Wyneken, E. Fritz & M. Lucas (1992). Sea finding by hatching sea turtles: Role of Brightness, Silhouette and beach slope as orientation cues. Behaviour 122: 56–77.

Salmon, M. & B. Witherington (1995). Artificial lighting and seafinding by loggerhead hatchlings: evidence for lunar modulation. Copeia 4: 931–938.

Salmon, M. & M. Reising (2014). Emergence Rhythms of Hatching Marine Turtles: is a Time Sense Involved? Chelonian Conservation and Biology 13(2): 282–285.

Shaver, D.J. & T. Wibbels (2007). Head-starting the Kemp Ridley Sea Turtle, pp. 297–323. In: Plotkin, P.T. (ed.). Biology and Conservation of Ridley Sea Turtles. Johns Hopkins Univ. Press, Baltimore, Maryland.

Silas, E.G., M. Rajagopalan, S.S. Dan & A.B. Fernando (1985). On the second mass nesting of Olive Ridley Turtles Lepidochelys olivacea at Gahirmatha, Orissa during 1984. Proceedings of the Symposium on Endangered marine animals and marine parks 1: 234–241.

Spencer R.J., M.B. Thompson & P.B. Banks (2001). Hatch or wait? A dilemma in reptilian incubation. Oikos 93: 401–406.

Tripathy, B. (2008). An assessment of solitary and arribada nesting of Olive Ridley Turtles on Dr. Abdul Kalam Island, Orissa, India. Tropical Conservation Science 1(2): 18122–18131.
Nesting and hatching behaviour of Olive Ridley Turtles on Dr. Abdul Kalam Island

P. Poornima

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 April 2021 | 13(5): 18122–18131

Olive Ridley Sea Turtles (Lepidochelys olivacea) at the Rushikulya rookery of Orissa, India. *Asiatic Herpetological Research* 11: 134–140.

Tripathy, B., R.S. Kumar, B.C. Choudhury, K. Sivakumar & A.K. Nayak (2008). Compilation of Research Information on Biological and Behavioural Aspects of Olive Ridley Turtles along the Orissa Coast of India – A Bibliographical Review for Identifying Gap Areas of Research. Wildlife Institute of India, Dehra Dun, 8pp.

Tuxbury, S.M. & M. Salmon (2005). Competitive interactions between artificial lighting and natural cues during sea finding by hatching marine turtles. *Biological Conservation* 121: 311–316.

Valverde, R.A., S.E. Cornelius & C.L. Mo (1998). Decline of the Olive Ridley Sea Turtle (Lepidochelys olivacea) nesting assemblage at Nancite Beach, Santa Rosa National Park, Costa Rica. *Chelonian Conservation and Biology* 3(1): 58–63.

Valverde, R.A., C.M. Orrego, M.T. Tordor, F.M. Gómez, D.S. Solís, R.A. Hernández, G.B. Gómez, L.S. Brenes, J.P. Baltodano, L.G. Fonseca & J.R. Spotila (2012). Olive Ridley mass nesting ecology and egg harvest at Ostional Beach, Costa Rica. *Chelonian Conservation and Biology* 11(1): 1–11.

Van Buskirk, J. & L.B. Crowder (1994). Life-history variation in marine turtles. *Copeia* 1: 66–81.

Witherington, B.E., K.A. Bjorndal & C.M. McCabe (1990). Temporal pattern of nocturnal emergence of loggerhead turtle hatchlings from natural nests. *Copeia* 4: 1165–1168.

Witt, D.W. (2013). Tidal and lunar correlates on sea turtle emergence patterns in Ada Foah, Ghana. MSc Thesis. The Faculty of the College of Arts and Sciences, Florida Gulf Coast University, Fort Myers, Florida, USA, 36pp.
