

A Multivariate Assessment of Climate Change Effects on Nesting Behaviour, Feeding Ecology, and Temperature-Dependent Sex Determination of Olive Ridley Turtles in Eastern India

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Abstract: Odisha has a coastline of 480 kms and has 6 coastal districts along the coast. Odisha is well known for the mass nesting of the Vulnerable species according to IUCN Red List - Olive Ridley Turtle(s) also known as Arribadas having a scientific name *Lepidochelys olivacea*. The key nesting sites in Odisha include Rushikulya (Ganjam), Devi River mouth (Puri), and Gahirmatha (Kendrapara). As the Olive Ridley turtles are already classified as vulnerable species, they also face several challenges such as climate change impacts- sea erosion, rising sea levels, warming temperatures, pollution, anthropogenic interference, illegal overfishing due to which the species face habitat degradation. Before the pandemic hit (2019) (CoVid-19) there was a significant decline in the numbers of arribadas visiting the nesting site due to pollution and anthropogenic disturbance but the reduced human activity due to lockdown played a major role for the species to return to their nesting sites. This paper examines the threats of climate change and anthropogenic interference on Olive Ridley Turtles, emphasizing their ecological importance and discussing the conservation strategies to mitigate the extinction risks of these vulnerable species.

Keywords: Olive Ridley Turtles, Arribadas, Temperature dependent (TSD), Climate Change Impacts, Odisha, Coastal Ecosystems, Conservation efforts

1. Introduction

Olive Ridley turtles known as “Arribadas”, “*Lepidochelys Olivacea*”, “Pacific Ridley turtles”, these species are named according to the color of its shell- an olive-green hue. They are well known for their mass nesting in the whole world, mainly found in the warm waters of Pacific, Atlantic and Indian Ocean with Gabon (eastern Atlantic Ocean); Mexico; Costa Rica and Odisha and Andaman Islands (India) being the

nesting sites. In Odisha these species are found in three locations Rushikulya (Ganjam), Devi River moth (Puri) and Gahirmatha (Kendrapara). According to research and IUCN Red List, these species – Olive Ridley Turtles are listed as “Vulnerable species” under the IUCN Red list of threatened species 2008 (1). According to Shankar et al., it was reported that sightings of Arribadas have occurred almost every year from 1975 and reported to be ranging from 100 to 800000 nesting turtles and Odisha is the single largest nesting sites with a major population of these species (2).

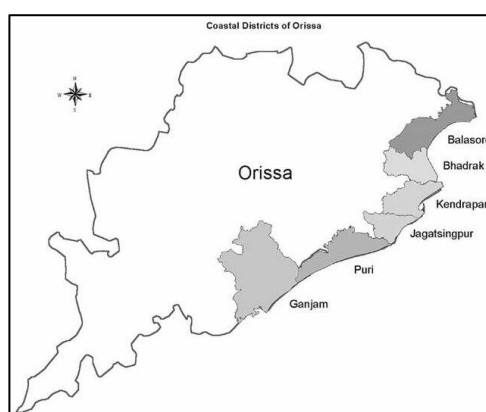


Image 1: (a) depicting India and Odisha; (b) Coastal districts of Odisha (Chittibabu, 2004)

Olive Ridley Turtles discovered by Henry Nicholas Ridley (1887), these species were named after their olive-green carapace and discoverer's name. Adult female typically

measures 55-60 cm and weighs 40-50 kg, while the hatchlings weigh 28 grams and measure about 4 cm. Their limbs are modified into flippers like limbs efficient for swimming (3)



Image 2: (a) Baby Hatchlings emerging towards sea; Source: Odisha Bytes; April 2019; (b) Adult Olive Ridley turtle visiting the nesting site to lay eggs; Source: Self Clicked Photos, February 2025

The food intake of these species mainly includes plants and animals such as algae, lobster, crab, tunicates, shrimp and fish so they are in list of omnivore/ carnivore. As a specialty of all marine animals/ mammals these species also reach surface to breathe. Adult females' turtles return to land areas/ beach/ rookery to lay their eggs in sand, the only behavior of arribada that differs from other tortoise/ turtle(s) is that they migrate great distance for nesting and in mass and large numbers. The life span of these species is not determined but they have a long lifespan. The Olive Ridley turtles reach their maturity around 14 years of age. The mass nesting period of these species is recorded during the months of November to March, peak time being January to March. More than 60000 females visit offshore from ocean to lay eggs over a period of 5-7 days. The eggs incubate for 45-50 days after which the hatchlings emerge and make their way to the ocean. (4)

Females almost nest every year, one to three times a season laying approximately 100-150 eggs in pits dug before laying eggs. Only one in thousand hatchlings survive and these species take 25-30 years to mature and on attaining maturity the females return to the same beach where they were born to lay their own eggs. These turtles migrate hundreds and thousands of kilometers for mating and nesting in the early breeding season (23).

Temperature Dependent Sex Determination

Temperature dependent sex determination (TSD), a term that is an interesting biological mechanism observed in many of the reptile species that includes Olive Ridley Turtles. The sex of the hatchlings is not determined genetically like mammals, but the sex is determined by the temperature of the sand where the eggs are incubated. Temperature of sand during incubation part plays an important role in determining the gender of hatchlings such as warmer temperature leads to more female hatchlings whereas cooler temperature leads to more male hatchlings. Generally warmer temperature approximately above $\sim 29-30^{\circ}\text{C}$ results predominately female hatchlings whereas cooler temperatures below $\sim 28-29^{\circ}\text{C}$ results in male hatchlings. A small fluctuation in temperature can greatly impact the sex ratio of male - female hatchlings of that batch. With climate change this natural phenomenon is disrupted by posing threat in balancing and threatening the future population of these species (23).

2. Literature Review

Odisha, a maritime state in India has a coastline stretching 480 km, that is bounded by West Bengal in Northeast,

Jharkhand in the North, Chhattisgarh in the West, Andhra Pradesh in the South and Bay of Bengal in the East. Odisha is located between $22^{\circ}33'49''$ N latitude to $17^{\circ}48'9''$ N latitude and $87^{\circ}28'58''$ E to $81^{\circ}22'59''$ E longitude with six coastal districts including Ganjam, Puri, Jagatsinghpur, Kendrapara, Bhadrak and Baleshwar consisting of different beach(s) and other coastal features like creeks, mudflats as well as wildlife sanctuary, rivers, mangroves, one of India's largest brackish water lagoon, major ports and major nesting sites for olive ridley turtles (24).

Out of the 480 km of Odisha's coastline mass nesting of the olive ridley turtles are mainly found in 3 major regions of Odisha- Rushikulya, Gahirmatha and Devi River mouth. According to Chattopadhyay *et al*, 50% of the total world population of olive ridley turtles' visits Odisha major nesting places during the peak nesting season (23).

Chattopadhyay *et al*, reports that the turtles travel 100s to 1000s of kilometers from their feeding to breeding ground and mostly the turtles return to the natural beach where these species were originally born to lay their eggs as adult female turtles. Normally the turtles lay all their clutches within 0 – 10 km during the breeding season but in some cases these species travel a long distance for nesting. The beach selection of these species for laying eggs should have the following characteristics: a) the beach must be accessible from the sea, b) should be high to prevent eggs from the high tides, c) prefer slopy, wide, moist sand that allows easy digging of nest, d) Low light areas as they are dependent on natural light, e) return to the same beach where they were born, f) less interaction with human interference to ensure safe access and nesting (23)

According to studies as soon as the hatchlings emerge from their nests, they are highly vulnerable during this period as they are drawn instinctively towards brightest horizon, that is the natural light of moon and stars on the ocean but artificial lighting such as from nearby roads, buildings and tourism activity often distracts the hatchlings leading them away from the sea, making them easy prey for birds, crabs, dogs jackals, fish and many others. (5) With that pollution on beach due to anthropogenic activities such as plastic waste and debris can obstruct their path or entangle them leading to death of many. These problems cause many of the hatchlings to wander inland, being trapped or dying due to dehydration, exhaustion and predation with that rising temperature and climate change also plays its part for increasing the mortality of these species. These species also face threat during their migratory route,

habitat and nesting beaches due to involvement of anthropogenic activities, exploitation of beaches for ports and tourist centers. These species are extensively poached for their meat, shell, leather and eggs though it is banned under CITES Appendix I. (WWF) (6). Combining all these factors results in a high mortality rate with a tiny fraction of hatchlings surviving adulthood.

Since 1993, records of marine turtle strandings on coast of Odisha have been kept as a part of ongoing sea turtle research program of the wildlife institute of India. The entire coast of Odisha stretching about 480 kms have been divided into nine survey sectors (Pandav et al; 1994) (R Chandrana, January 2017) and each of these sectors are walked once every two weeks during the breeding season (November to April) (7) (8).

Shifts in Olive Ridley Turtle(s) Nesting Sites

Mass nesting of Olive Ridely turtles was observed in 9 sectors of Odisha coastline - Chandipur, Gahirmatha, Hukithola, Jatadhar, Devi River mouth, Nuanai, Chilika, Rushikulya, Bahuda, but as of today the most important sectors observed are - Gahirmatha, Devi River mouth and Rushikulya. Climate change plays a significant role with increasing surface and ocean temperatures that affect the hatchlings ratio and overall marine health. Sea level rise and coastal erosion lead to beach shrinking and the nesting grounds are washed off, directly making it difficult for the female olive ridley turtles to access the safe nesting zones.

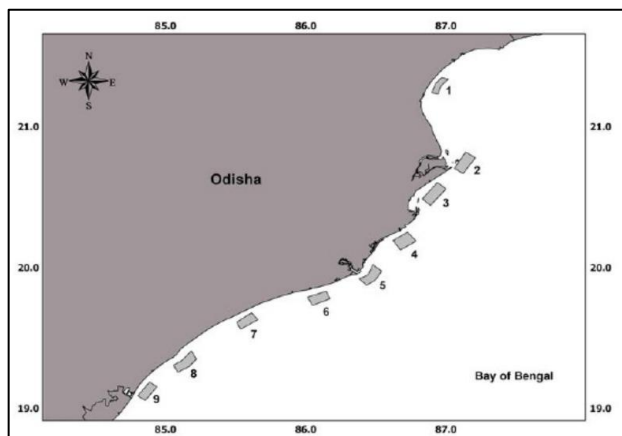


Image 3: The above image shows nine sampling locations along Odisha Coast; Image source: CMPA technical Report Series 07; January 2017

Odisha geographically is vulnerable to cyclonic events every now and then, due to which the nests are destroyed and alter the coastal ecosystem. Human interference involves coastal development that includes infrastructure projects, ports and construction projects that lead to habitat fragmentation and loss of nesting areas. Use of intensive fishing activities in the areas increases mortality and accidental catch of turtles. Pollution on beach or nesting sites due to tourism activities or

population influx creates physical obstruction for the female turtles and emerging hatchlings. Artificial lightings from nearby areas disorients turtles as these species totally depend(s) on natural moonlight for their pathway to navigate between sea and shore. These factors altogether play a major role in reducing the number of mass nesting sites, posing a serious threat to the species and its long-term survival and has reduced the sites from 9 to 3 active nesting sites in Odisha.

In early 2000s Gahirmatha was one of the major spots for the mass nesting but due to coastal pollution and erosion the mass nesting shifted to Rushikulya and with proper conservation techniques, banning of fishing activities during the peak season and reduced interference during the peak season has resulted in highest number of mass nesting of Olive ridley turtles in this season, 2025 that was approximately 700000 olive ridley turtles laid eggs.

Mortality of Olive Ridley Turtles (OLR)

In the early 1990s, there was an increase in the number of dead Olive Ridley turtles being washed ashore was observed by conservationists. During the last past data, it was estimated that approximately 100,000 dead olive ridley turtles were reported on these beaches (25). Those dead turtles washed offshore were measured, sexed, marked with white paint on their carapace to avoid repeat counting's during surveys. In the year 1993-94 season, a total of 5282 dead turtles were recorded (Pandav *et al*, 1994; Pandav *et al*; 1997) (9). Since then, more than 30000 Olive Ridley turtles stranding were documented in Odisha. Mortalities are also caused due to illegal activities like fish catching and illegal trawling. In the 1997-98 season illegal trawling was recorded of approximately 13575 Olive Ridley turtles. The coastal waters of these four sectors- Gahirmatha, Paradeep, Kujang and Devi were recorded the major strandings and highest levels for shrimp trawling. (5) The illegal gill net and trawl fishing in offshore waters due to incidental catch of Olive Ridley turtles also is responsible for the increase in the mortality rate of these species. (Pandav, 2000a, Rajagopalan *et al.*, 2001) (10) (11). The nesting's in Gahirmatha declined for some years due to intense offshore fishing activities, unsuitable beach conditions such as overcrowding, pollution, overfishing, and beach erosion. (4) climate change, involvement of anthropogenic activities, beach erosion, industrialization and urbanization continue to threaten the long- term survival of Olive Ridley turtles rookeries (Tripathy and Rajasekhar, 2009) (12) in 1997-98 season the sharp decrease in size of arribadas and decline in population caused an approximate mortality of at least 100000 since 1994, and 10000-15000 turtles per every year since 1999 (Pandav 2000; Shankar *et al.*, 2004b) (13) (Pandav and Choudhary, 1999) (14) (Wright and Mohanty, 2001) (15). Climate change directly impacts ocean circulation, hampering the migratory routes of the turtles and altered ocean currents impacts health, food availability and reproduction. Increase in cyclonic activities destroys the nest that will lead to habitat loss, beach erosion leads to destruction and reduction of nesting sites.

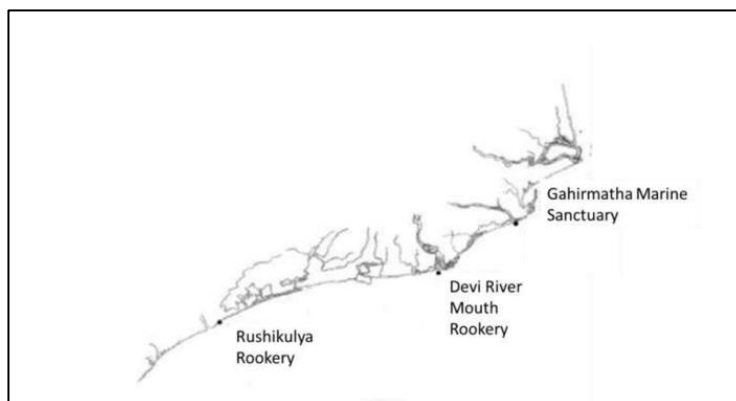


Image 4: The 3 main important nesting sites along Odisha Coast where Olive Ridley turtles are recorded the most; Image Source: (Modified after Shridhar 2005)

In the early 2000s the nest counts in Rushikulya increased from 25000-50000 per season to over 150000 in that decade, the numbers were increasing and decreasing according to the report by Research Matters (26).

In 2007 to 2010 an increase of nests was observed such as in 2007 - 39000 nests were observed, in 2009 - 120357 nests were reported, in 2010 - 344260 nests were reported whereas in 2008 no arribada was observed (28). According to a report by WWF dated 19th March 2010, that was stated by Forest Department recorded approximately 186000 female turtles nested in Gahirmatha (27).

According to study and research the sightings of Olive Ridley turtles from the year 2000 till recent are mentioned below: During the year 2000- 2015 Gahirmatha observed a total of approximate 200000 to 300000 turtles annually but significant decline in numbers was observed for several years due to factors such as climate change, pollution, beach erosion, cyclone but during the Covid lockdown due to zero human interference, clean beach, no pollution led to approximate 700000 turtles sightings across Gahirmatha and Rushikulya rookery. Currently in this year 2025 it was recorded that neatly 700000 Olive Ridley turtles arrived at Rushikulya beach for nesting, because of some conservation efforts, local support that included fencing the 9 km nesting site and regular patrolling along the rookery. According to reports and Down-to-Earth reports, Gahirmatha observed the sightings of 741000 Olive Ridley turtles in the year 2001, and being the highest till date. In 2022-23 Gahirmatha witnessed an approximate of 300000 Olive Ridelys where Rushikulya drew blank, but this year Rushikulya saw sightings as the nesting area in Gahirmatha declined over the years due to beach erosion and turtles heading towards Rushikulya. (16) (The New Indian Express, 2 March 2025)

According to a study conducted by Zoological Survey of India (ZSI)- Pune, Gahirmatha sanctuary has shifted a staggering 14 km northwards over the last three decades due to severe factors such as climate change, increased human activities and coastal erosion (TOI, April 14, 2024) (17)

Table 1: Year wise mass nesting with numbers

Sr No.	Year	Mass Nesting (no's)
1	2000 – 2001	1,59,000
2	2001 – 2002	35,000
3	2002 – 2003	2,08,000
4	2003 – 2004	74,890
5	2004 – 2005	89,300
6	2005 – 2006	1,98,794
7	2006 – 2007	74,000
8	2007 – 2008	1,80,426
9	2008 – 2009	59,000
10	2009 – 2010	89,000
11	2010 – 2011	1,34,000
12	2011 – 2013	65,000
13	2014 – 2015	78,000
14	2015 – 2016	3,10,000
15	2016 -2017	3,70,000
16	2017 – 2018	4,82,000
17	2019 – 2020	3,23,000
18	2020 – 2021	No mass nesting
19	2021 – 2022	5,50,000
20	2022 – 2023	6,37,000
21	2023 – 2024	3,01,000
22	2024 – 2025	7,00,000

Source: Chattopadhyay et al, and ETV Bharat

The above data highlights the trends in mass nesting of Olive Ridley Turtles across Odisha. In 2025 Rushikulya site recorded the highest number of nesting. Probably, CoVid-19 lockdown also saw improvement in nesting success, as reduced human interference, minimal beach pollution and fishing Activity lead to positive turtle sightings and survival rates.

Importance of Olive Ridley Turtles

Considered as incarnation of God (Kurma/ Kachchappa Avatar- 2nd avatar of Lord Vishnu in Dashavtar) in Hindu mythology; The turtles have been swimming in the ocean for over 100 million years predating dinosaur's era; an integral part in maintaining the marine ecosystem; eggs of OLR when predated or unhatched, provide vital nutrients to coastal beach eco system, supporting plants and other wildlife; nesting beaches creates habitats for coastal species contributing to coastal biodiversity; in Odisha, the OLR are a part of local heritage and conservation identity.

Olive Ridley Turtles Survival Before and After Conservation Efforts

According to Tripathy and Rajasekhar, (2009) the population of Olive ridleys along the coastline of Odisha was significantly declining in 2000s due to human interference. Some other factors such as increase in industrialization, urbanization, coastal infrastructural development, climate change impacts contributed to the degradation and declination of critical nesting sites. With that Coastal erosion also played a major part by washing away the good fertile nutrient beaches that reduced the safe space for nesting, threatening the survival of these species. In addition to that, Casuarina plantation along the shore hampered the natural beach landscape making it unsuitable for turtle nesting. Furthermore, artificial lighting near the coast disorients the hatchlings who refer to the natural light of moon and starts towards the sea and brings them offshore and other activities such as fishing, accidental turtle entanglement also increases the mortality rate of these species. These factors altogether pose a threat to Olive Ridley turtles.

Conservation Efforts for Olive Ridley Turtle(s)

Olive Ridley Turtles, Fondly Known as Arribadas, Face Major And Significant Threats Due To Various Factors Such as Climate Change, sea level rise, extreme weather events, pollution, human interference, below mentioned are some key efforts for conservation of these species:

- A common man named- Rabindranath Sahu, who is the founding head of Rushikulya Sea Turtle Protection Committee (RSTPC) that was made in 1990 but formally formed in 1996, made a team and educated and sensitized the communities about these vulnerable species and slowly more people joined his team and were involved in the conservation and preservation of these species. During the nesting season to save more turtles from death their team collect some eggs and shift those collected eggs to some specially made hatcheries on the beach for survival, with that they also help the predators stay away by regular patrolling on the beach during the peak season. 25 years back these turtles' meat, eggs, and shells were sold but due to these initiatives now the community is also aware about these species and help in the efforts to conserve the turtles. (Down To Earth, May 2020) (19)
- Dr. Bivash Pandav, a wildlife biologist did pioneer research on Olive Ridley turtles that brought global attention to the significance of mass nesting sites along the Odisha coast. He has been associated with Wildlife Institute of India (WII) and as a part of research has tagged around 15000-20000 Olive Ridley turtles. He also emphasized on banning fishing activities along the 5-6 km of the nesting area of turtles during the peak season. (Nature InFocus, May 2018) (20)
- Operation Kachappa (since 1998)- a collaborative approach by Wildlife Society of Orissa (WSO) and Odisha Forest Department, NGOs, and UNDP for the protection of Olive Ridley turtles involved improving patrolling, collecting data on turtle mortality, monitoring, enforcement against illegal fishing and conducting awareness programs by building public support for conservation and fighting legal battles in court. It received immense support from the national and state media (15).

- Project Swarajya, founded in 1988- an NGO based at Cuttack, Odisha undertook the protection of Olive Ridley turtles on the Odisha coast since 1996 (15)
- Fishing activities in coastal waters of Gahirmatha were restricted in 1993 and were completely banned in 1997 and Gahirmatha was given the status of Gahirmatha Marine Sanctuary (5).
- As baby hatchlings emerge and make their way towards ocean, they are prey to other big animals so WWF- India along with local fishermen communities actively participated to protect Olive Ridley turtles at the Rushikulya beach by creating fencing and patrolling the area by creating a safe passage for the babies towards the sea.
- Community based conservation efforts in Rushikulya where youth groups and fishermen in Rushikulya region voluntarily assist forest officials to guard nests, relocating eggs to safe hatcheries, and conducting awareness campaigns in coastal villages of Odisha.
- To reduce accidental killings of these species in India, Odisha government has made it mandatory for trawls to use Turtle Excluder Devices (TEDs), a net specifically designed with an exit cover for turtles. (WWF) (6)
- The state government has adopted Band- aid approach by banning all types of fishing activities during the nesting season and regular patrolling is also conducted so that rules can be followed. (Notification by Odisha State Government dated 31 October 2014) (18)
- Collaborative approach of Youth/ Student(s), Local communities, NGOs, Government like National Green Corps (NGC)- a program by MoEFCC, India to raise awareness and action amongst school kids and college going students through conducting eco-clubs, this program makes children understand environmental problems and solutions and involves them in hands on training to make them learn and take initiatives around their surroundings. (Environment Education Program, NGC) (21)

The above mentioned were the programs already carried out for the conservation of Olive Ridley turtles, and some efforts mentioned below can be taken during the peak season by local communities, tourist, government for the conservation of these species

- Due to urbanization and high rise buildings the natural light of moon and stars on the beach is comparatively less than the artificial light that causes distraction for the species, so during the peak season night curfews could be implemented, or using low frequency lighting along the nesting sites can be implemented to reduce the distraction and disruption during the nesting season.
- Patrolling, Protection and fencing along the nesting sites during the peak season will keep the predators away
- Regular beaches cleanup activities should be carried out before the peak season or regular intervals to collect waste, and it will create a safe space for nesting
- During the peak season, human involvement along the nesting site such as tourism activity and vehicular assessment should be banned, that will help reduce habitat disturbance.
- NGOs with the help of government can educate, sensitize the local community- kids, elders etc. about these species

and their significance will foster as sense of responsibility can build a grass root level conserving effort.

3. Conclusion

The Olive Ridley turtles are one of the most ancient species that dated to exist since the dinosaur era. These species play a major role in maintaining marine biodiversity and supporting balance of coastal ecosystems. Although they are spread worldwide in oceans but profoundly in India they are found in three major key sites along the Odisha's coastline-Gahirmatha, Rushikulya, and the Devi River mouth. Mainly these turtles rely on clean, sandy, moist and slopy beaches for successful nesting and are genetically determined by temperature of the sand- warmer temperature produces more females and cooler temperatures produces more males. Generally, the peak season of their nesting are during November to March. Over the last two decades conservation and management efforts, including beach cleanup activities, awareness activities amongst the school children(s) and coastal communities, banning fishing activities during the peak nesting season, active involvement of local fishing communities have significantly improved and nesting patterns and hatchlings survival rates. Despite the challenges such as climate change, pollution, habitat degradation, coastal erosion, this year 2025 embarked the highest number of Olive Ridley sightings at Rushikulya beach, with daytime arribadas observed. In a remarkable achievement, 2025 nesting season witnessed the arrival of approximately 700000 Olive Ridely Turtles at Rushikulya according to reports (Down To Earth, Feb 2025) (22), marking it the second highest nesting event after 2001. This success was a result of long-term conservational efforts by the Government, NGOs, Local communities all together that were regulated by fishing practices during the peak season, habitat safeguarding by involving the local communities, and awareness programs for the communities to safeguard these vulnerable species. However, to sustain and gain this for long timeline, it is essential to adopt, adapt and implement scientific preservation methods, strengthen climate resilience strategies and ensure regular involvement of local community to maintain the grass root engagement. Protecting and Conserving the Olive Ridely turtles is not just a responsibility but it a shared collaborative approach, important for sustaining the marine biodiversity and ensuring the resilience and well-being of the coastal livelihoods.

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Table Source:

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