MONITORING SEA TURTLES IN INDIA 2008 – 2024

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MONITORING SEA TURTLES IN INDIA

2008 – 2024

FOREWORD

Sea turtles are long-lived and late maturing species and, hence, changes in their demography take place over years or decades. Their life history, where individuals migrate to nesting beaches every few years and lay a variable number of clutches, results in huge variation in the number of nests laid on a particular beach each year. Together, this means that sea turtle populations have to be tracked for decades to determine if they are increasing, decreasing or stable.

The pioneers of sea turtle biology and conservation recognised this need for long-term monitoring of populations. Archie Carr set up the first monitoring programme for sea turtles in Tortuguero in the 1950s. Soon after, others like George Balazs in Hawaii, George Hughes in South Africa, and Robert Bustard and Colin Limpus in Australia followed suit.

In India, the earliest monitoring programme was initiated by Rom Whitaker in Chennai in the early 1970s. Soon after, Robert Bustard visited Odisha and initiated monitoring of the mass nesting beaches at Gahirmatha with Chandrasekhar Kar, a research fellow with the forest department. There have been many important projects since in Odisha including by the Wildlife Institute of India (WII) on tagging and tracking olive ridley turtles. Satish Bhaskar's extensive surveys provided a baseline of information for much of the Indian coast, particularly the Andaman and Nicobar and Lakshadweep Island, following which the Madras Crocodile Bank Trust (MCBT) initiated monitoring of leatherback turtles on Great Nicobar Island.

Starting in the 1980s, the forest departments has set up hatcheries in many states. In addition, a range of NGOs have worked along India's coast, providing valuable data with some, like the Students Sea Turtle Conservation Network (SSTCN), having monitored sea turtles since the 1980s.

While previous projects provided a platform, none had endured beyond a few years especially at key nesting beaches such as those in Odisha and in the islands. To fill this gap, Dakshin Foundation initiated long-term monitoring of olive ridley turtles at Rushikulya, Odisha and leatherback turtles on Little Andaman Island in 2008. These serve as index beaches for tracking the health of the population and include a range of offshore and nesting studies. A few years later, we initiated monitoring of the foraging population of green turtles in the Lakshadweep Islands.

Together, these provide data that can be used to understand trends in populations and predict the future impacts of climate change. They can also guide policy and determine conservation actions. In particular, they can help devise strategies that are inclusive of local communities towards long-term benefits for turtles, ecosystems and people.

Kartik Shanker

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INTRODUCTION

The mainland coast of India as well as its two island groups (the Andaman and Nicobar Islands, and the Lakshadweep Islands), serve as nesting grounds for four species of marine turtles including olive ridley (*Lepidochelys olivacea*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*) and hawksbill (*Eretmochelys imbricata*) turtles[1,2,3]. The loggerhead turtle (*Caretta caretta*) is occasionally found in the coastal waters of the mainland coast[4,5].

Olive ridley turtles are the most abundant species in India, with two rookeries of global significance in Odisha on the east coast. These are the only major mass nesting or *arribada* rookeries outside Central America[6] and are believed to be the ancestral source of contemporary global populations[7]. Apart from these rookeries, olive ridley turtles are also known to nest solitarily in large numbers in Andhra Pradesh[8], Tamil Nadu[9,10], and the Andaman and Nicobar Islands[11,12,13], and in smaller numbers on the west coast of India. A small mass nesting beach has emerged recently in the Middle Andaman Islands.

Nesting leatherback populations in India are currently restricted to the Andaman and Nicobar Islands, especially Great and Little Nicobar Islands. These populations are of global significance as they are amongst the largest in the Indian Ocean region[14]. Leatherbacks are also known to nest in smaller numbers in the Andaman group of islands[11], particularly Little Andaman Island[15].

Green turtles nest on the mainland coast of Gujarat, the Andaman and Nicobar Islands, and the Lakshadweep Islands[3]. Recent studies have focused on the foraging ecology of green turtles in the lagoons of the Lakshadweep Islands[16,17]. Herbivory from increasing green turtle numbers there has led to significant declines in seagrass meadows, resulting in impacts on bait fish populations, which has caused conflict with local fishing communities[18].

Hawksbill turtles nest mainly in the Andaman group of islands with some sporadic nesting occurring in Nicobar and the Lakshadweep Islands[3]. They are, however, frequently observed foraging in reef systems in the Andaman and Nicobar Islands, and the Lakshadweep Islands.

The Indian coastline, offshore waters, and reef ecosystems are important habitats for marine turtles in the region. However, threats from coastal development projects, offshore oil and gas exploration, mining, construction of new ports, vessel traffic in their habitats, and interactions with fisheries continue to impact populations. Depredation by feral dogs and take of eggs still occur, but have been mitigated to a great extent through conservation projects.

FIVE DECADES OF MARINE TURTLE RESEARCH IN INDIA

Some of the earliest research on marine turtles in India was initiated in the 1970s by H.R. Bustard along with the State Forest Department of Odisha[19,20]. From 1975 to 1980, the Odisha Forest Department, led by C.S. Kar, carried out research and monitoring programmes on olive ridley turtles at Gahirmatha, tagging more than 10,000 nesting turtles[21]. This continued into the 1980s when a second mass nesting site was discovered at Devi[22]. Several research programmes were initiated during the 1990s, notably by the Wildlife Institute of India (WII) in Odisha, which led to the discovery of the mass nesting site at Rushikulya[23]. As part of these projects, several thousand nesting turtles were tagged; additionally, mating pairs in the offshore waters of Gahirmatha were tagged for the first time in India[24].

Prior to this, with support from the Madras Crocodile Bank Trust (MCBT), Satish Bhaskar surveyed most of the Indian coast, including Gujarat[2,25], the Lakshadweep Islands[2,26], the Andaman and Nicobar Islands[27], Goa, Andhra Pradesh, and Kerala[2]. His extensive surveys, including of many remote sites in the Andaman and Nicobar Islands, provided a wealth of information for the region[11,28,29]. Nationwide surveys were carried out in the early 2000s by various agencies, supported by the Government of India-United Nations Development Programme Sea Turtle Project (GoI-UNDP Sea Turtle Project), coordinated by WII, and then by the United Nations Environment Programme-Convention on the Conservation of Migratory Species of Wild Animals, coordinated by MCBT[30].

Studies on the post-nesting migrations of olive ridley turtles in India were initiated by WII and the Odisha State Forest Department. Over the last decade, WII has deployed more than 60 satellite transmitters on olive ridley turtles in Odisha. The studies have revealed that while some of the turtles remain in the offshore waters of Odisha, many others migrate to Sri Lanka and the Gulf of Mannar[31,32,33,34].

Studies by WII and the Centre for Cellular and Molecular Biology (CCMB) also examined the molecular genetics of sea turtles along the mainland coast and islands of India. It was found that the olive ridley turtles on the east coast of India are genetically distinct from global populations, and even differ significantly from the adjacent population in Sri Lanka[6,35]. The study suggested that the Indian olive ridleys and Kemp's ridleys could be remnants of a global population which was otherwise extirpated following climatic changes before and after the closure of the Isthmus of Panama. Thus, the Indian Ocean region may have served as a source for ridley recolonisation following the extirpation of populations in other ocean basins.

Following the surveys by Satish Bhaskar, the Andaman Nicobar Environment Team (ANET) initiated monitoring of the leatherback nesting beach at Galathea, Great Nicobar in 2001, which involved tagging and monitoring leatherback turtles. However, these beaches were destroyed by the 2004 tsunami and many other important nesting beaches were also severely affected[36]. These beaches have since reformed, and nesting numbers have returned to pre-tsunami levels[37].

Research on green and hawksbill turtles has been minimal up to this point, primarily due to their low abundance and limited distribution range in India. Past studies have primarily focused on nesting surveys[27], but in the last decade, the Nature Conservation Foundation (NCF) has been studying the effects of increased herbivory by green turtles on seagrass meadows in the lagoons of the Lakshadweep Islands and as well as consequent conflict with fishers[38].

SAVING SEA TURTLES FOR HALF A CENTURY

Marine turtle conservation programmes were initiated in Odisha and Chennai (then Madras) in the early 1970s. While the Odisha programme was coordinated by the State Forest Department, the turtle hatcheries in Chennai were first operated by the Madras Snake Park, followed by the Central Marine Fisheries Research Institute (CMFRI) and Tamil Nadu Forest Department. Since 1988, the hatchery has been operated by an NGO, the Students' Sea Turtle Conservation Network (SSTCN)[39].

Over the last couple of decades, several local groups have become active in sea turtle conservation along the Indian coast including Prakruti Nature Club (PNC) in Gujarat and Sahyadri Nisarga Mitra (SNM) in Maharashtra, both along the west coast[40]. PNC was started by daily wage workers of a cement company and has become quite prominent for its work on sea turtles and whale sharks, winning several awards and accolades. SNM can be credited with initiating the turtle festival at Velas,which brings income to local communities through tourism, which is now being replicated by the state government in other coastal villages of Maharashtra. Theeram, a community effort in Kolavipalam, Kerala is no longer active, though other organisations such as Green Habitat are active in the state[41]. Other groups are also active along this coast.

On the east coast, the SSTCN, now over 35 years old, remains active in Chennai in Tamil Nadu and continues to play a role in involving students and citizens in an urban conservation programme[42], while the TREE Foundation works at a few sites along the same coast engaging communities in sea turtle rescue and conservation[43]. In Andhra Pradesh, the Visakhapatnam Society for the Prevention of Cruelty to Animals (VSPCA) has been involved in beach protection and building awareness. Several small groups continue to operate at the mass nesting beaches in Odisha.

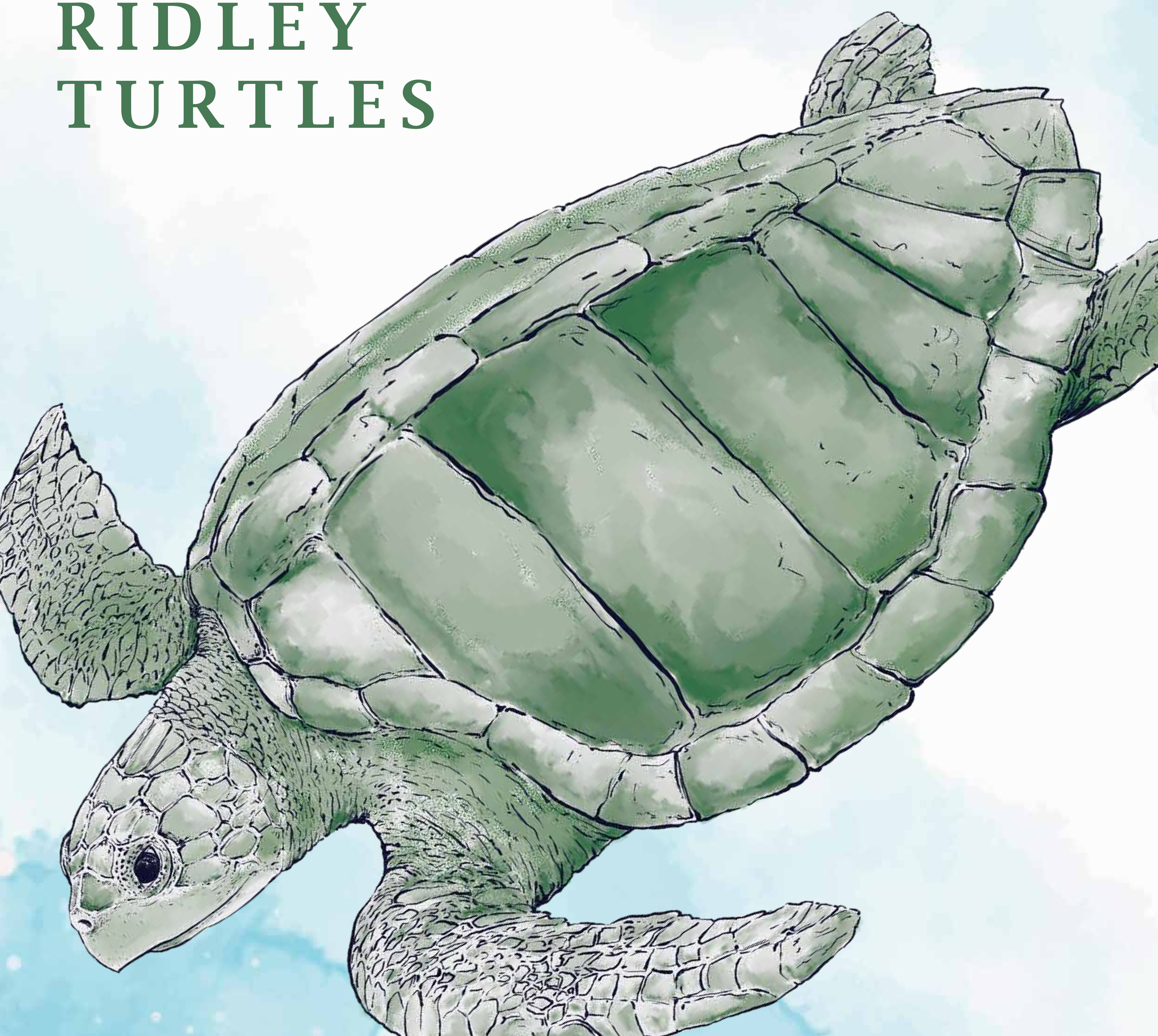
A national marine turtle network called Turtle Action Group (TAG) was formed in 2009 to bring greater synergy and collaboration to marine turtle conservation efforts. The network includes the various organisations mentioned above, as well as several sea turtle biologists and conservationists. Dakshin Foundation supports the activities of the network as well as the Odisha Marine Resources Conservation Consortium (OMRCC) by assisting with coordination, raising funds, conducting workshops, and building capacity.

Over the last 30 years, the number of both governmental and non-governmental institutions, agencies, and individuals engaged in marine turtle research and conservation, has increased greatly. Nonetheless, there remains a dire need for fostering more dialogue, collaboration, and coordination, both within and between government and non-government agencies, to ensure effective participation.

DAKSHIN'S LONG-TERM PROGRAMMES

For long-lived species such as sea turtles, long-term monitoring of nesting and foraging populations is vital to detect biologically significant trends and patterns. Towards this, in collaboration with the Indian Institute of Science (IISc) and the state forest departments, Dakshin Foundation initiated research and monitoring programmes in the late 2000s for olive ridley turtles in Odisha and leatherback turtles in the Andaman and Nicobar Islands. In Odisha, the programme monitors offshore populations, sporadic nesting, arribadas, mortality, hatching success, and sex ratios at the Rushikulya beach. In the Andaman and Nicobar Islands, we conduct long-term monitoring and tagging of leatherback turtles in Little Andaman Island accompanied by periodic surveys of the entire island group, including the Nicobar Islands. In the Lakshadweep Islands, Dakshin Foundation has monitored green turtles and their foraging habitat in the lagoons of several islands.

OLIVE RIDLEY TURTLES



Olive ridley turtles (*Lepidochelys olivacea*) are the smallest and the most abundant of all sea turtle species. Olive ridleys are widely distributed around the globe in tropical regions of the Pacific, Atlantic, and Indian Oceans. They are categorised as 'Vulnerable' in the IUCN Red List and fall under Schedule I of the Indian Wild Life (Protection) Act, 1972. They are known to inhabit open oceanic waters and feed on different marine organisms at various trophic levels. Olive ridleys are omnivorous and largely feed on jellyfish, crustaceans, and fish but they are also known to feed on algae. Ridley turtles are famous for their unique synchronised mass nesting strategy called arribada (meaning 'arrival' in Spanish). During these mass nesting events, hundreds of thousands of female turtles nest together on a beach within just a few days. Large olive ridley arribadas occur only in Central America and on the east coast of India. The east coast population of olive ridleys in India is especially interesting as it is considered to be genetically distinct and the ancestral source of olive ridleys around the globe.

PROJECT SUMMARY

Since 2008, Dakshin Foundation and the Centre for Ecological Sciences, Indian Institute of Science, Bangalore, in collaboration with the State Forest Department have monitored olive ridley turtles in Odisha. The primary objective of the programme is to monitor their nearshore and nesting populations at the index site, Rushikulya. This includes monitoring the offshore population during the breeding season to determine spatial and temporal variation in abundance and distribution, assessing population trends, and measuring hatching success to determine reproductive output. In Rushikulya, the impact of climate change on the sex ratios of hatchlings is also assessed. As the hatchlings that emerge from mass nesting events likely influence most of the recruitment into the population, skewed sex ratios from these events could impact the long-term survival of the population.

KEY FINDINGS

Since 2008, mass nesting events have occurred almost every year at Rushikulya with >100,000 - 200,000 turtles being recorded in many years. This suggests that the ridley population in this region is either stable or increasing. However, the mean incubation temperatures of the nests often exceeded pivotal temperatures, thereby resulting in female-biased hatchling sex ratios in some years.

MONITORING OLIVE RIDLEY TURTLES IN ODISHA

The east coast of India is known for wide, sandy beaches and numerous river deltas. The coastline is home to several thousand traditional fishers and is also a major nesting ground for olive ridley turtles. Although the species occurs throughout the Indian coast, they are most abundant off the coast of Odisha. The rookeries here likely play a critical role in the long-term survival of the east coast population as a whole.

Mass nesting was formally recorded by H.R. Bustard in 1974 in Gahirmatha[19] though there are historical records of large-scale egg trade. In the subsequent decades, two other sites, Devi and Rushikulya, were discovered[22,23], though no arribadas have occurred at the Devi rookery since the late 1990s. Currently, major arribadas in India take place at Gahirmatha and Rushikulya, while a smaller arribada with a few thousand turtles has been recently discovered at Cuthbert Bay in the Andaman and Nicobar Islands[13].

Olive ridley turtles that breed off the Odisha coast are known to have varying post-nesting migratory patterns. Most turtles migrate to the deeper parts of the Bay of Bengal or south to the Gulf of Mannar and Sri Lanka, while some are known to stay in the coastal waters off the east coast of mainland India[31,32,34].

There are numerous threats to this population ranging from incidental bycatch in fisheries to intensive coastal development adjacent to the rookeries[6]. There is also growing concern about the impacts of climate change on the species. Like many reptiles, sea turtles exhibit Temperature-dependent Sex Determination (TSD). As a result, increasing temperatures could eventually lead to skewed sex ratios, reduced hatchling performance and increased embryonic mortality[44,45,46].

There has been considerable research on olive ridley turtles in Odisha over the last few decades. Particularly noteworthy are C.S. Kar's research in Gahirmatha in the 1970s which included the monitoring and tagging of nesting females, and Bivash Pandav's research in Gahirmatha in the 1990s where he surveyed offshore populations and tagged mating pairs[31,32]. He also tagged nesting females at multiple nesting beaches showing inter-rookery movement. Subsequent research by Basudev Tripathy and Suresh Kumar focused on nesting and offshore populations at Rushikulya[33,34].

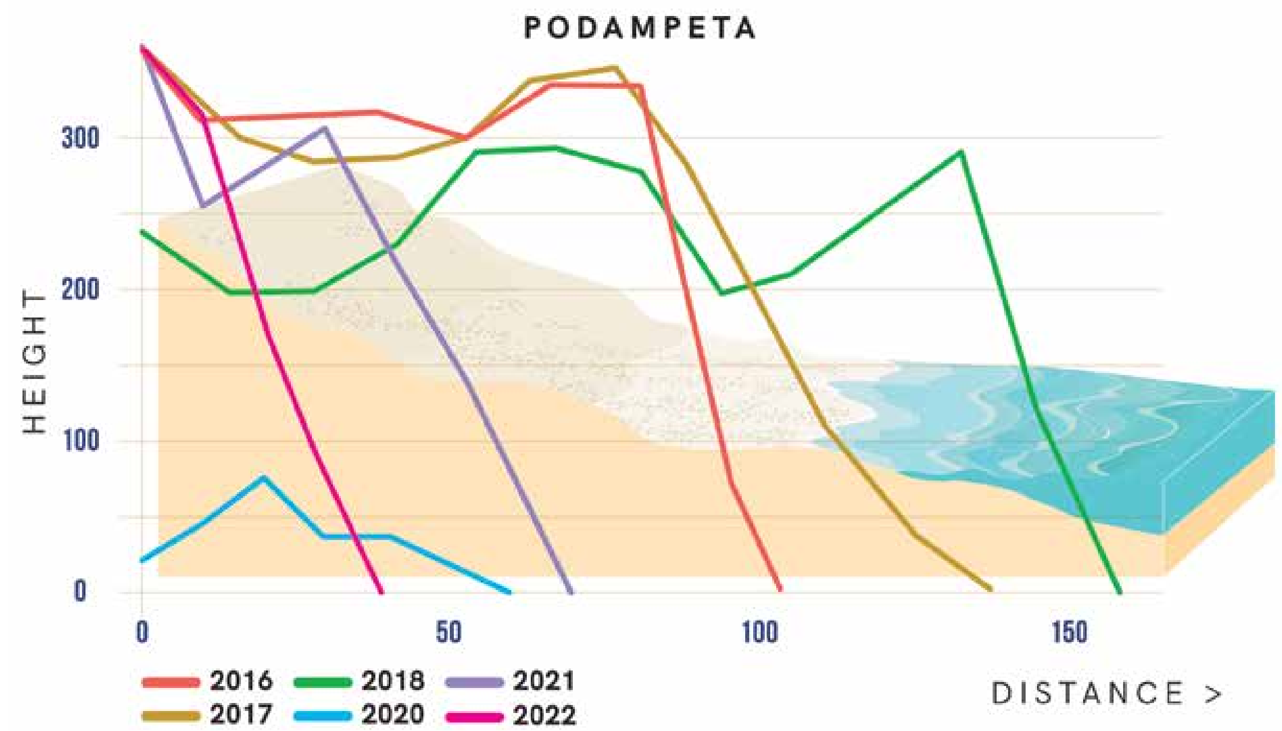
Building on this work, Dakshin Foundation initiated a long-term monitoring programme at Rushikulya in 2008, which is currently the longest-running study on olive ridley turtles in India. Here, we provide a brief overview of the programme and a summary of the results.

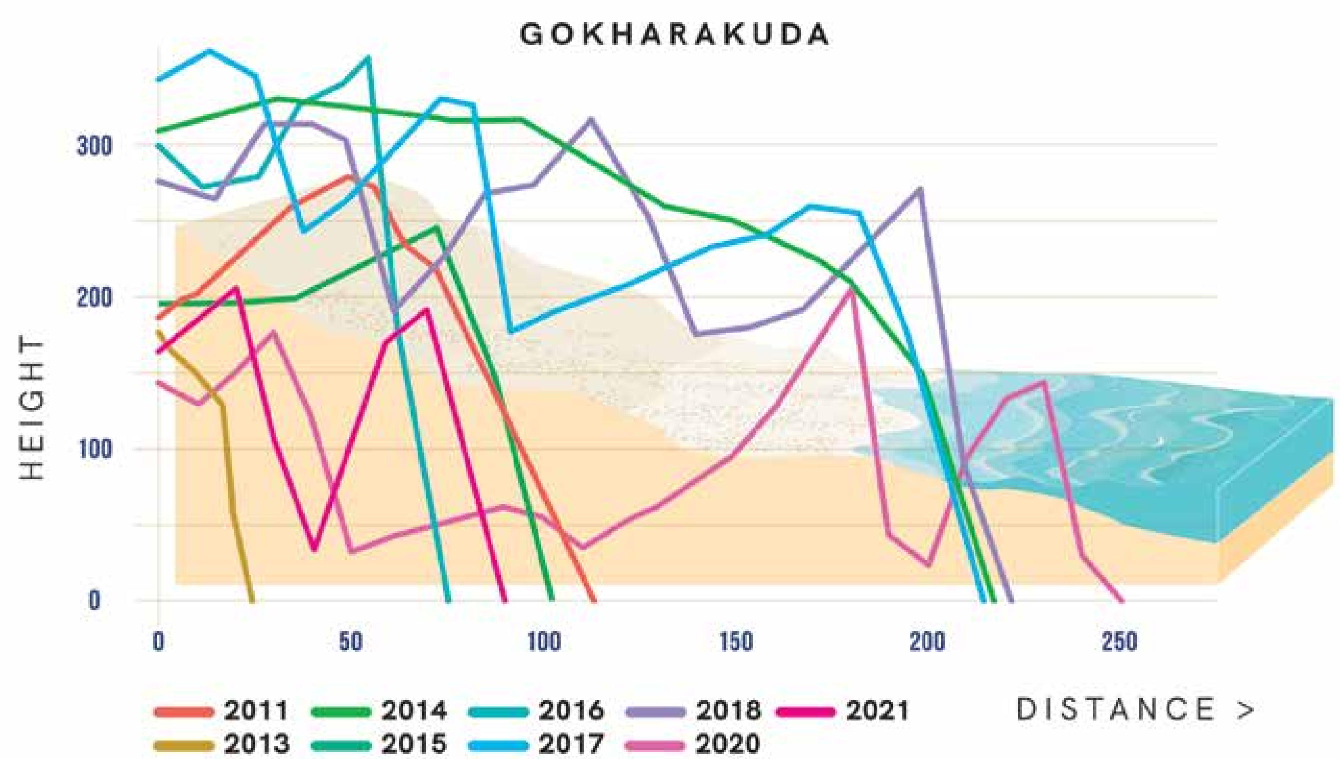
Figure 1. Olive ridley mass nesting rookeries in Odisha. Dakshin's monitoring site is located at Rushikulya.

SHIFTING SANDS

The beaches along the east coast of India, particularly those near river mouths, experience significant annual fluctuations due to regular processes of erosion and accretion. These spatial dynamics are influenced by strong winds during the northeast monsoon, as well as by periodic cyclones, resulting in drastic variation in beach morphology between years. In Rushikulya, the nesting beach extends 4 km north of the river mouth. Monsoon flooding that usually occurs after the nesting season leads to erosion of the nesting beach. During some years, the river mouth cuts through the beach, leading to the formation of one or more sand bars which offer new nesting habitats.

Monitoring these periodic changes in the beach morphology has shown that different sections of the beach undergo varying levels of change in slope and width both within and across years. Beach sections closer to the river mouth are more dynamic than those further away. Although the effect of this variability on nesting intensity is still unclear, the dynamic nature of the beach potentially influences nest site selection and hatching success.





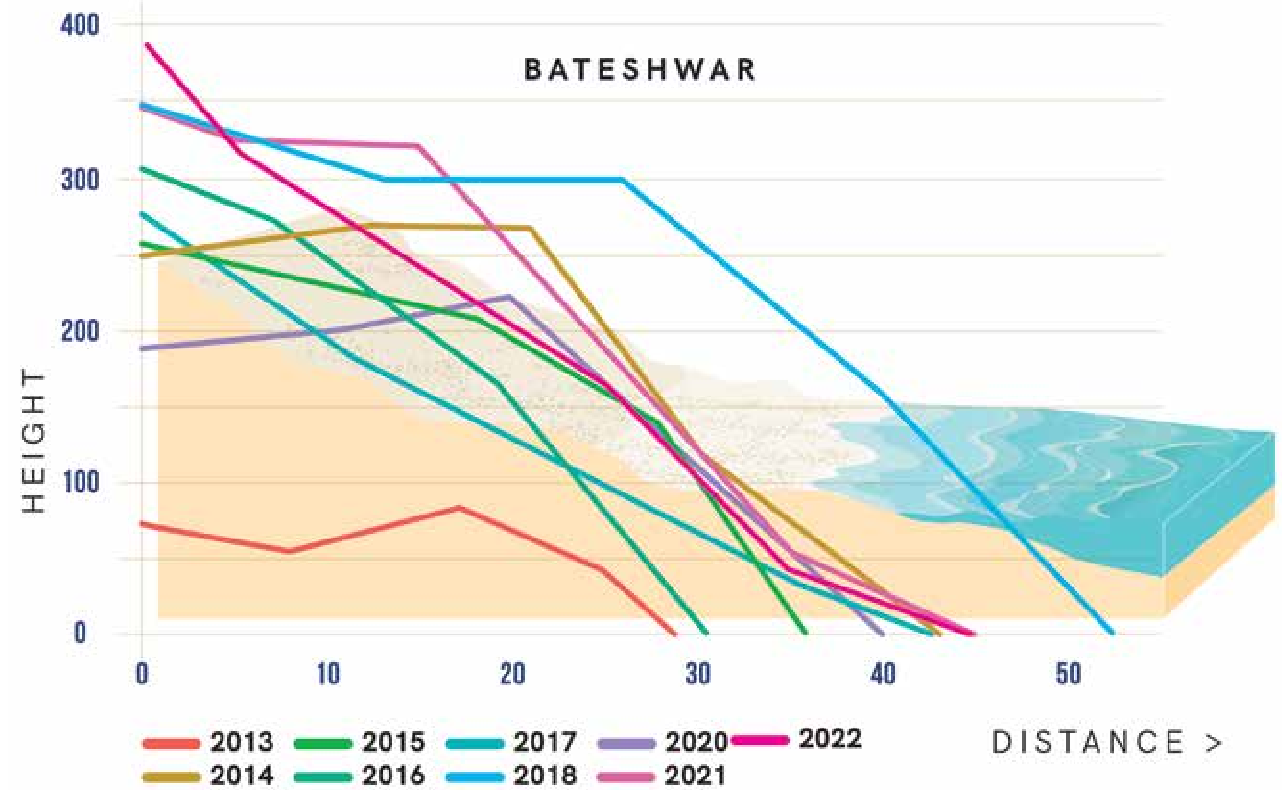


Figure 2. Variations in beach height in different sections of the nesting beach at Rushikulya, Odisha.

AGGREGATING IN NEARSHORE WATERS

Olive ridley turtles forage in pelagic waters but migrate to nearshore waters during the breeding season. Male and female olive ridley turtles migrate to Rushikulya around November, with males arriving before females. Mating takes place in the nearshore waters of Rushikulya and males return to their foraging grounds after mating. Female olive ridley turtles remain in the nearshore waters until they complete nesting.

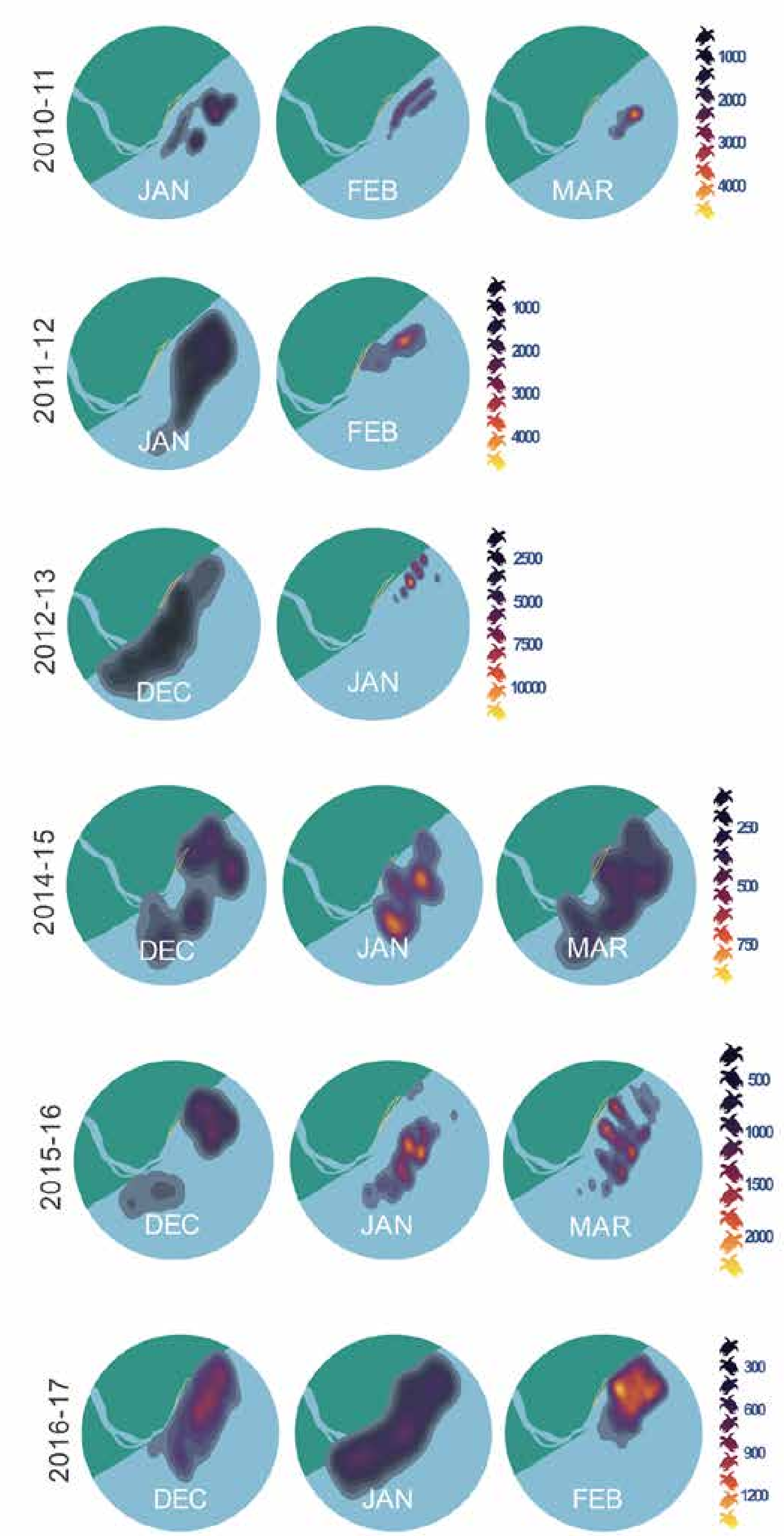
The breeding season of olive ridley turtles on the east coast coincides with the peak fishing season, which has led to large-scale mortality due to incidental capture, particularly in trawlers. The spatio-temporal overlap also results in increased interactions with other fishing craft such as gill nets. Monitoring offshore turtle densities is, therefore, critical for formulating management strategies to protect turtles in offshore waters without disrupting fishing activities, especially for small-scale fishers.

The offshore waters of Odisha are monitored using boat transects during the breeding season. Double-oberver boat transects are carried out every month to understand changes in the distribution and size of the aggregations across the nesting season. We have observed that the size and location of these aggregations vary both within and between seasons. The number of turtles in offshore waters also varies between years, providing important insights into population trends. A shift in turtle aggregations in nearshore waters, moving closer to the coast, may also indicate the onset of mass nesting.

Notably, the abundance of turtles in offshore waters does not correlate with the size or occurrence of arribadas. The main aggregations form a very small part of the total designated no-fishing zone, which suggests that these zones need to be rationalised for more efficient protection of turtles with minimal impacts on small-scale fishing[47].

The monitoring of nearshore aggregations is particularly important as it can help in devising spatial protection measures. The turtle congregation zones along the Odisha coast are also commercially important areas of fishing for the local communities. Mapping the distribution of turtle aggregations can help demarcate more nuanced fishing and no-fishing zones in nearshore waters. This can help regulate the intensity of mechanised fishing along the coast and reduce mortality due to incidental capture in gill nets and trawlers without impacting small-scale fishing communities. These activities can be carried out in collaboration with fishers to enable wider stewardship of Odisha's olive ridley turtles.

The main aggregations form a very small part of the total designated no-fishing zone, which suggests that these zones need to be rationalised for more efficient protection of turtles with minimal impacts on small-scale fishing.



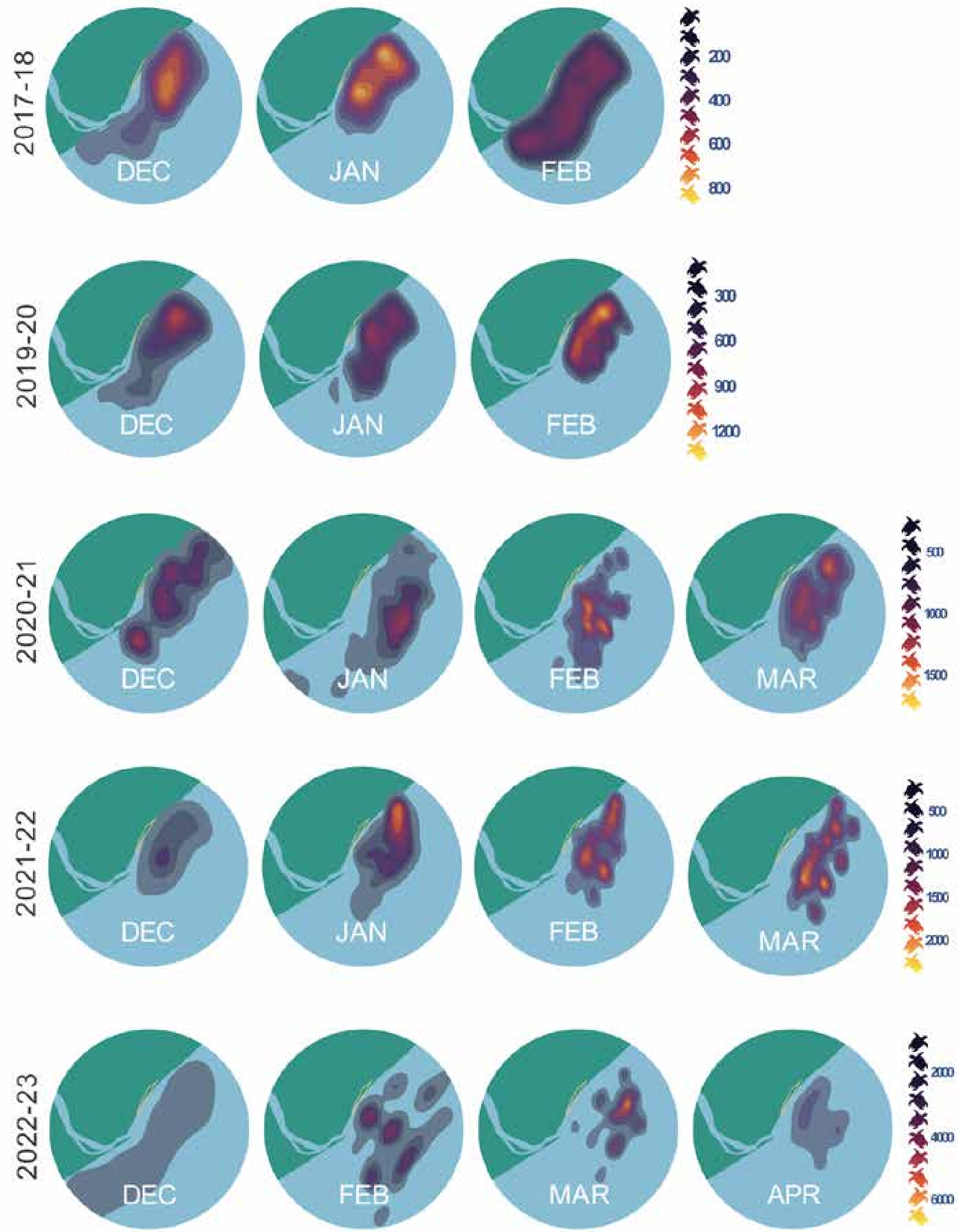


Figure 3. Nearshore breeding aggregations of olive ridley turtles along the Rushikulya coast.

COUNTING TENS OF THOUSANDS OF TURTLES

The arribada or mass nesting of olive ridley turtles usually occurs once or, rarely, twice each nesting season at both Gahirmatha and Rushikulya. Olive ridleys on the Odisha coast have shown inter-rookery movements during the nesting period, sometimes nesting in an arribada at both the rookeries within the same season[33].

At Rushikulya, mass nesting occurs on a 4 km beach stretch extending north of the river mouth. These mass nesting events in Odisha last anywhere between 2-10 days.

Since 2008, Dakshin has been monitoring the mass nesting population through a standardised census protocol. The number of turtles nesting in arribadas is estimated using a strip transect method[48]. Arribadas have occurred every year in Rushikulya since 2004 except in 2007, 2016, 2019, and 2021. Two mass nesting events in 2018 occurred two months apart. Although rare, nesting during the day has also been observed during some arribadas. Estimates of the number of nesting turtles at arribadas over the last decade indicate an increasing trend at this rookery.

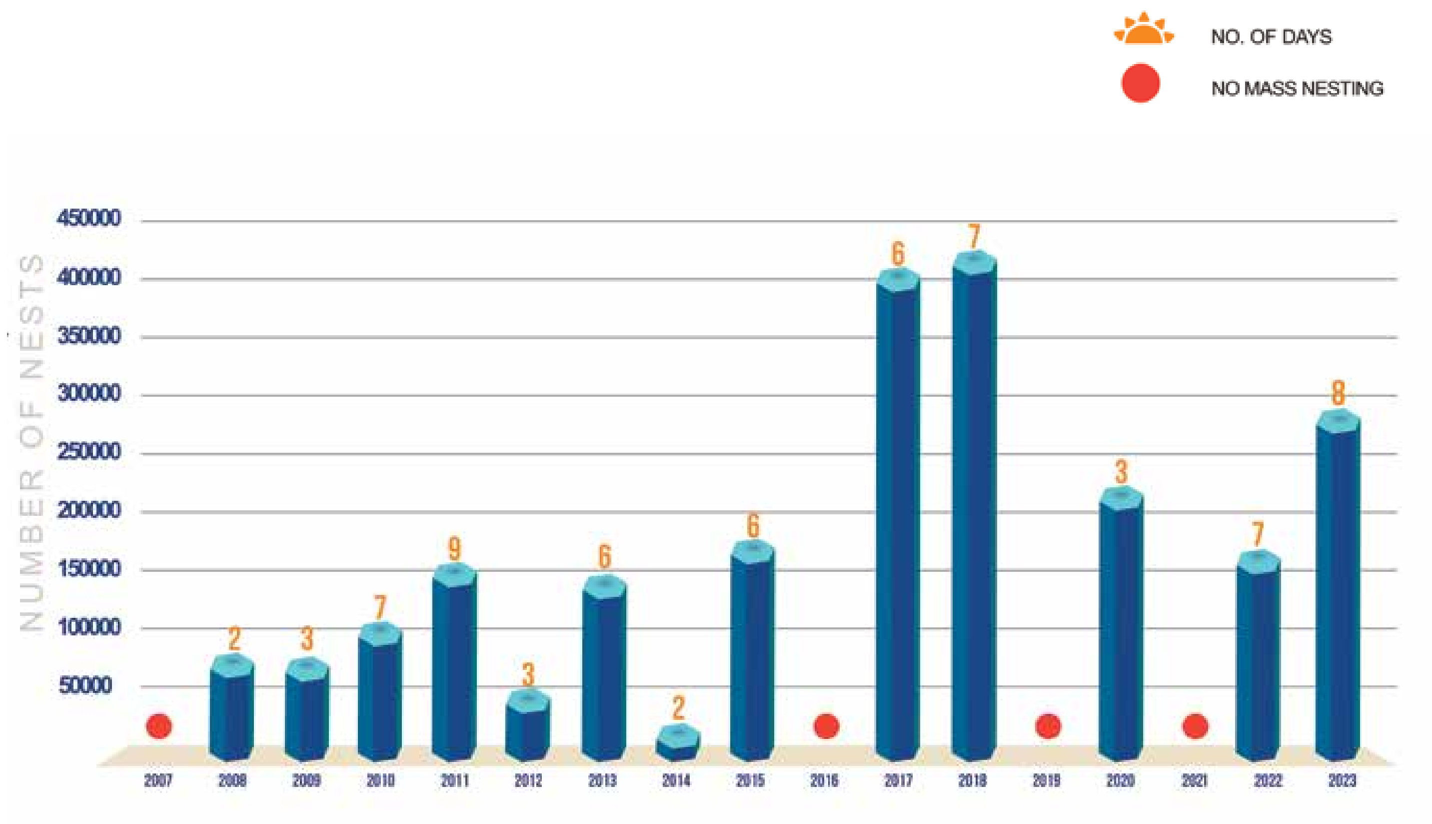


Figure 4. Estimated number of nesting turtles during arribadas (numbers above bars indicate the duration of arribada in days) at Rushikulya, Odisha.

Estimates of the number of nesting turtles at arribadas over the last decade indicate an increasing trend at the Rushikulya rookery.

HATCHING SUCCESS

The survival of sea turtle eggs varies across different beaches. Many factors such as temperature, beach quality, and moisture can influence the success of olive ridley nests. Changes in the nesting beach due to erosion and accretion lead to a periodic overhaul of the beaches at Rushikulya. When new beaches are formed, the microbial load from previous arribadas is washed away, which results in higher hatching success[49].

The nests at Rushikulya have shown a higher hatching success than other arribada nesting beaches around the world over the last decade[50,51,52]. Hatching success is also higher in wild nests than those relocated to hatcheries. The overall hatching success was 82% and 64% in wild and hatchery nests, respectively. The proportion of hatchlings that emerged (emergence success) was 78% and 53%, respectively.

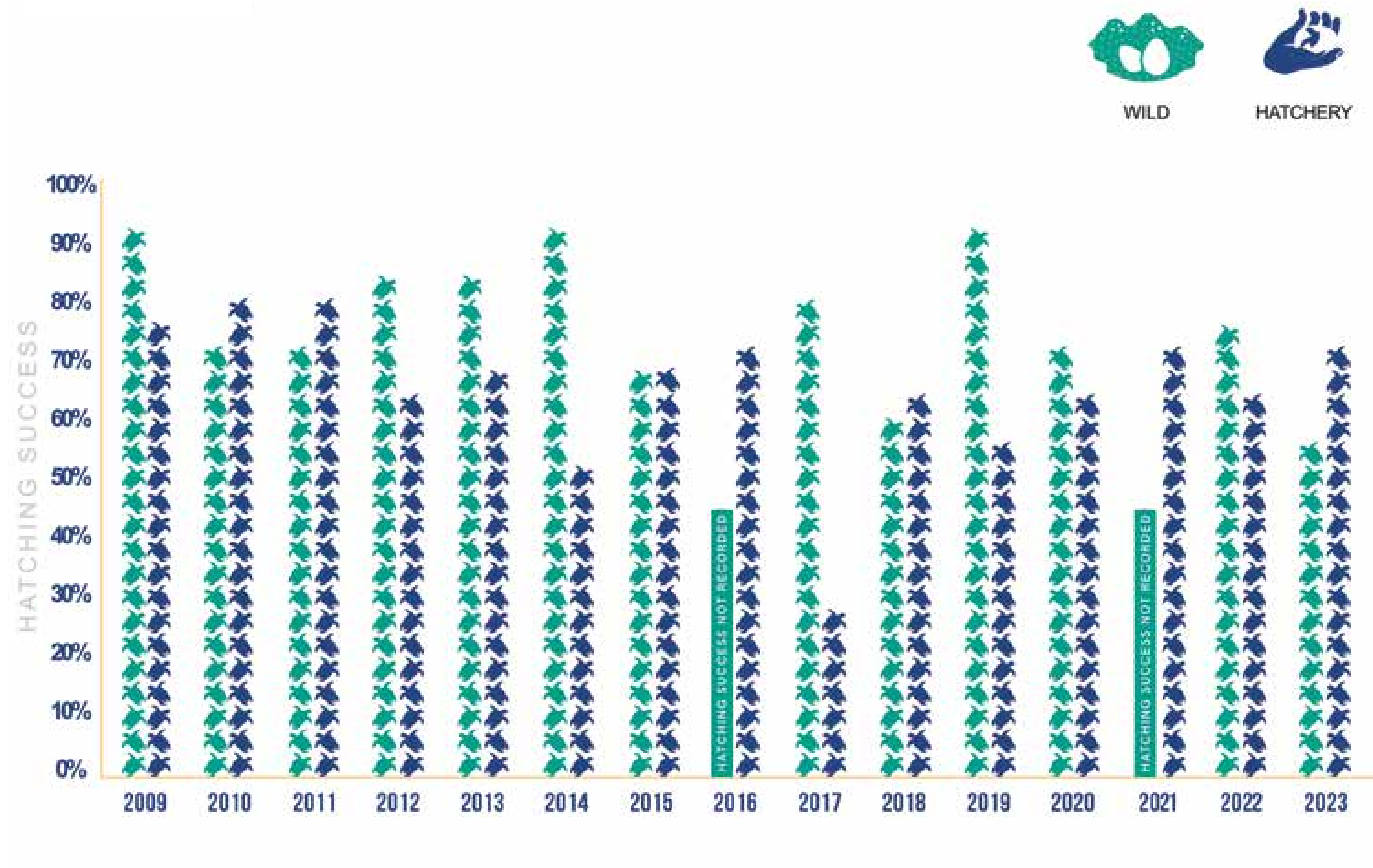


Figure 5. Hatching success of wild and hatchery nests at Rushikulya, Odisha.

CLIMATE CHANGE AND SEX RATIOS

As global temperatures rise, sea turtle populations might become increasingly feminised[44,53]. Rushikulya, being one of the largest mass nesting rookeries in India, contributes significantly towards hatchling recruitment. Estimating the sex ratios of hatchlings produced at this rookery is, therefore, useful for understanding the future impacts of climate warming.

Over the last 15 years, we have been monitoring nest temperatures and hatchling sex ratios at the Rushikulya rookery. Determining hatchling sex through gonad histology helps monitor the primary sex ratios of both solitary and arribada nests. This data has been instrumental in establishing the pivotal temperature of the population. Sex ratios at Rushikulya are skewed towards females but not to the extent seen in certain global sea turtle populations[44,54]. The hatchling sex ratio from arribadas at Rushikulya was found to be about 71% female on average. While some years had extremely female-biased sex ratios due to high nest temperatures, a few years produced male-biased sex ratios.

Our ability to accurately determine sex ratios is limited by the kind of data we can collect at the rookery. Nevertheless, with additional temperature data, we aim to employ embryo growth models to examine the long-term trends in sex ratios of hatchlings from arribadas at Rushikulya.

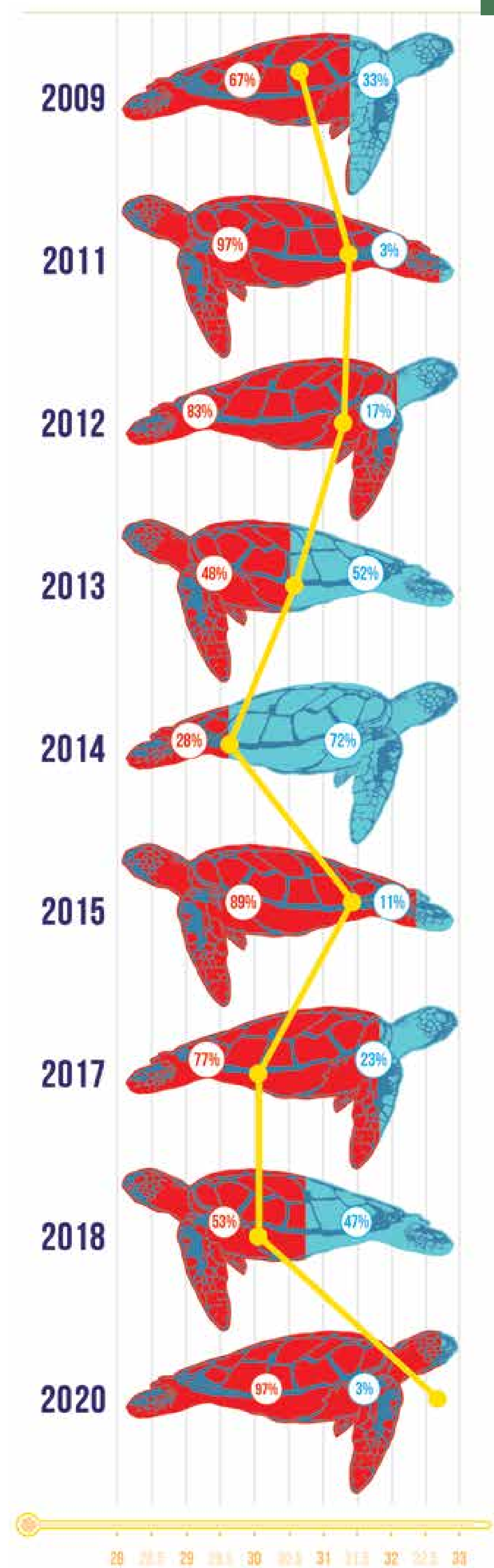


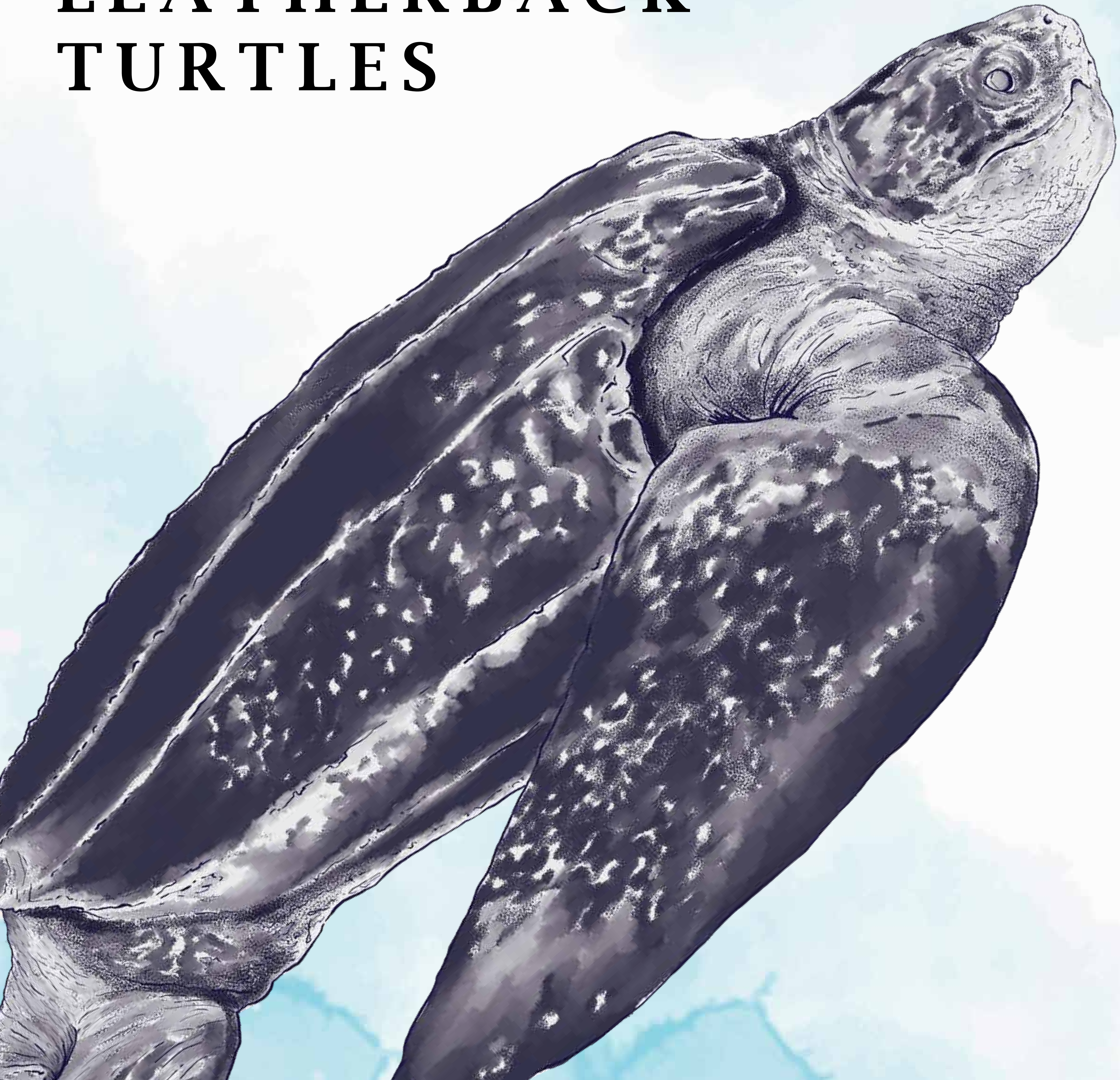
Figure 6. Hatchling sex ratios in arribadas at the Rushikulya rookery, Odisha.

FUTURE DIRECTIONS

Historically, the east coast population of olive ridley turtles has experienced significant declines due to direct harvesting of both eggs and adults. Industrialization exacerbated these declines, as mechanized fishing led to large-scale mortality. Over the last two decades, the population has shown signs of recovery, attributed to a combination of conservation measures and the resilience of the population. However, the population continues to face threats from fishing, coastal development, and climate change. It is, therefore, crucial to monitor the population, both on land and at sea, to ensure their continued recovery and long-term survival. Odisha is home to two of the largest mass nesting sites in the world and threats experienced by the population in the nearshore waters and at the these sites would drastically affect the survival and viability of the regional population.

Given the global significance and conservation priority of the population, long-term monitoring of olive ridley turtles in Odisha is essential to understand population status, assess the impacts of climate change, and observe changes to nesting habitats. Since climate change impacts take time to manifest, it is crucial to conduct longitudinal studies to assess population change over time. Conservation initiatives for the protection of olive ridley turtles in Odisha need careful consideration of the social consequences for local fishing communities. This calls for devising measures that prioritise the protection of high-density areas rather than large-scale spatial restrictions or fishing bans. It is, therefore, important to devise and facilitate dynamic approaches to sea turtle conservation. In addition to continuing long-term monitoring, the programme intends to initiate and strengthen dialogue among stakeholders with collaboration among various departments, organizations, and local communities.

LEATHERBACK TURTLES



Leatherback turtles (*Dermochelys coriacea*) grow over six feet in length and are the only extant species of the family *Dermochelyidae*. They are the largest of all sea turtle species, weighing > 500 kg, and feed solely on a diet of jellyfish. They are known for their leathery carapace and, unlike other sea turtle species, lack bony shells. They have the widest distribution of the seven species of sea turtles and are found in both tropical and temperate waters in the Atlantic, Pacific, and Indian Oceans. The leatherback is listed as 'Vulnerable' globally in the IUCN Red List of Threatened Species and is under Schedule I of the Indian Wild Life (Protection) Act, 1972.

PROJECT SUMMARY

The research and monitoring programme on leatherback turtles was initiated in 2008 by Dakshin Foundation and the Centre for Ecological Sciences, Indian Institute of Science, Bangalore, in collaboration with ANET and the Andaman and Nicobar Forest Department. The programme was launched in Little Andaman Island with a focus on long-term monitoring of nesting trends, post-nesting, migratory patterns and genetic studies. Rapid surveys of other important nesting sites in the Nicobar Islands are also conducted regularly.

KEY FINDINGS

The nest monitoring programme in the South and West Bay beaches of Little Andaman Island shows that there is a steady increase in leatherback nesting in the region. Telemetry studies conducted from 2011 to 2014 reveal that leatherback turtles from Little Andaman travel across the Indian Ocean during their migrations, with some ranging as far east as Western Australia, and others as far west as Mozambique and Madagascar. Over 150 turtles have been tagged with Passive Integrated Transponders (PIT) tags as well as flipper tags in the last 15 years.

In the Nicobar Islands, surveys conducted in 2016 and 2019 show that, after the 2004 Indian Ocean earthquake and tsunami, all the important nesting beaches have re-formed and continue to support nesting. The beaches of Great and Little Nicobar Islands continue to exhibit the highest nesting in the region, with over 1000 nests per season. The population appears to be stable, with some inter-annual variation. It remains the most significant population of nesting leatherbacks in the northern Indian Ocean.

MONITORING LEATHERBACK TURTLES IN THE ANDAMAN AND NICOBAR ISLANDS

There has been concern over the decline in nesting populations of leatherback turtles throughout the world, especially in the Pacific[55]. In Asia, Malaysian rookeries have undergone a well-documented decline from approximately 10,000 nests per year in the 1960s to less than 20 nests per year in the 2000s[56]. It is, therefore, imperative to understand the nesting trends of leatherback turtles in the Andaman and Nicobar Islands, their foraging habitats, migratory routes and the threats they face across their range.

Though there were records of leatherback turtles from the Indian mainland in the early 1900s[3], the nesting population is now entirely restricted to the Andaman and Nicobar Islands[36]. The first leatherback nest was reported by Satish Bhaskar in Rutland Island in 1978, and surverys between 1978 and 1995 established Little Andaman Island, Little Nicobar Island, and Great Nicobar Island as key leatherback nesting sites[27,28,57]. In 2000, Harry Andrews of ANET and MCBT initiated a monitoring programme at Galathea, Great Nicobar Island. Subsequent surveys and monitoring indicate that the nesting population of the Andaman and Nicobar Islands is globally significant, supporting over 1000 nests per season[14,37]. Currently, these are the only sites (in addition to one in Sri Lanka) that host a significant nesting population between Southeast Asia and South Africa[37].

Given the lack of knowledge about this population, long-term monitoring of leatherback turtles was initiated in 2008. This programme is now part of the 'Long-term monitoring of coastal and marine ecosystems of the Andaman Islands' project under the Long-Term Ecological Observatories (LTEO) programme of the Ministry of Environment, Forest and Climate Change (MoEFCC). Little Andaman Island receives significant nesting at two beaches, namely the South Bay nesting beach, 4 km long, on the southwest tip of Little Andaman Island and the West Bay nesting beach, 7 km long, located north of the Tothibue River.

The South Bay nesting beach was monitored through daily night surveys from 2008–2011. Since 2011, night surveys have been constrained due to the large river mouths (Benyabol and Tothibue) and the presence of saltwater crocodiles. Though opportunistic night surveys were conducted at South Bay between 2011 and 2020, the beach is regularly surveyed only during the day. Since the establishment of the West Bay monitoring camp in 2010, our monitoring and tagging efforts have been concentrated there through daily night surveys.

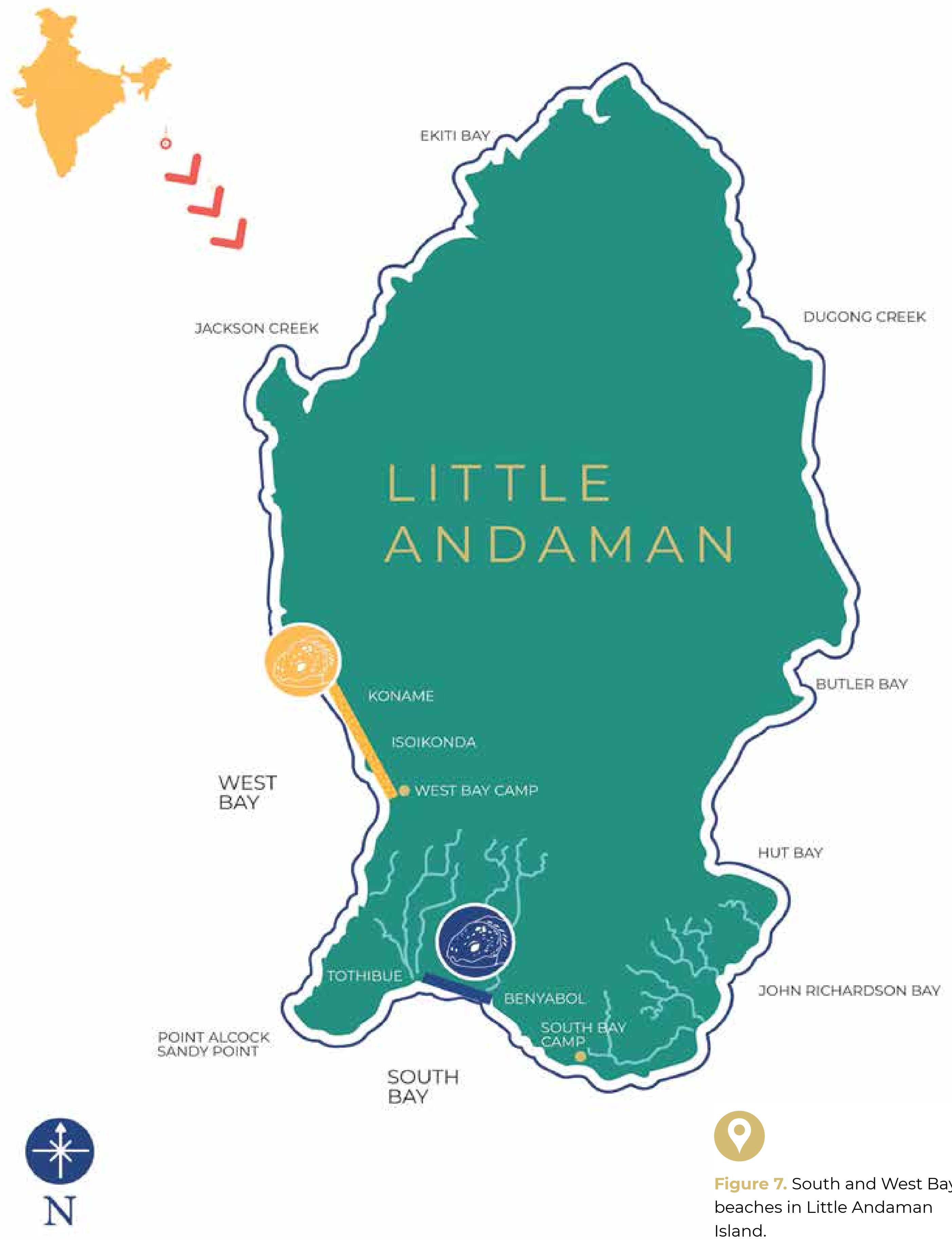


Figure 7. South and West Bay beaches in Little Andaman Island.

POPULATIONS TRENDS

Leatherback nest monitoring at the South and West Bay beaches indicates that nesting has recovered substantially after the 2004 tsunami and is stable with periodic fluctuations. In the 2014–2015 and 2017–2018 seasons, nesting was low at both South and West Bay. The highest nesting figure of 274 nests was recorded in 2018–2019. However, such fluctuations are natural and occur due to variations in reproductive cycles[58], food supply, environmental conditions, and mortality at different stages in their life history[59,60].

During the monitoring period, 156 leatherback turtles were tagged with external and PIT tags. Turtles showed an average re-nesting interval of 15 days. The mean Curved Carapace Length (CCL) observed was 158 cm and the mean Curved Carapace Width (CCW) was 115 cm, with the largest turtle measuring 187 cm CCL and 121 cm CCW in West Bay.

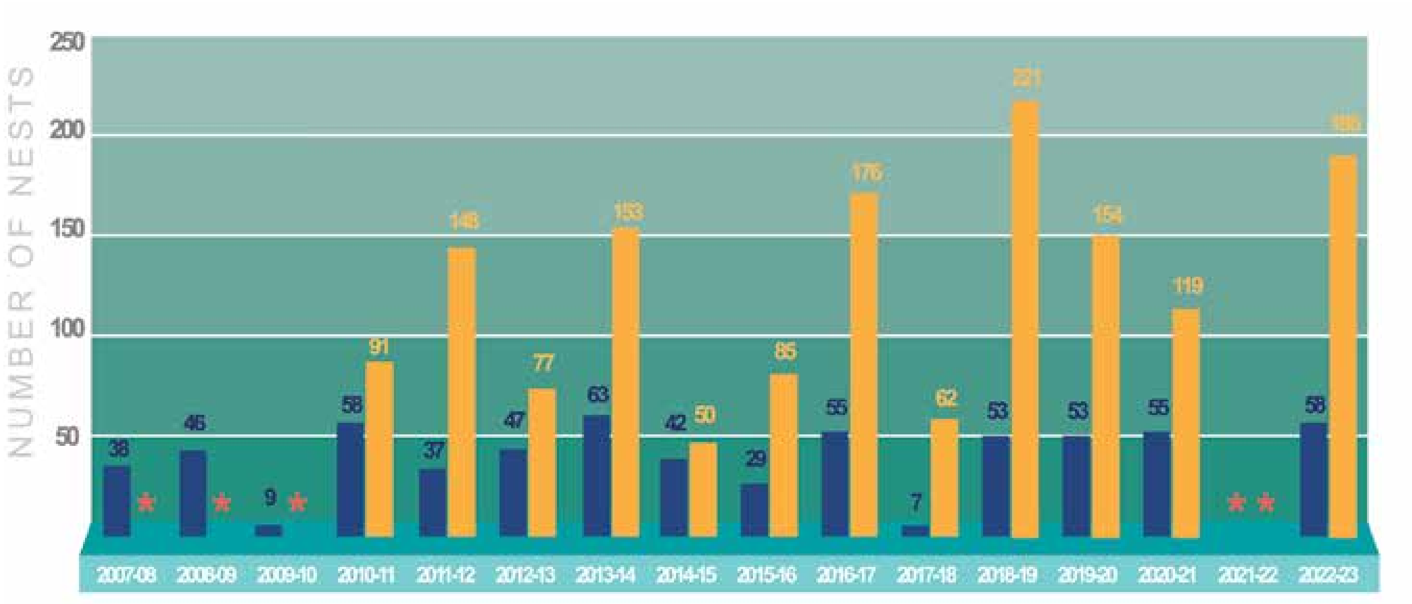


Figure 8. Leatherback turtle nesting in South and West Bay, Little Andaman Island.

PELAGIC PATHWAYS

Between 2011 and 2014, ten female leatherback turtles were tagged with Platform Transmitter Terminals (PTT), model Kiwisat 202 (specially designed for leatherback turtles by Sirtrack Wildlife Tracking Solutions Ltd.), at West Bay, Little Andaman Island to track their migratory paths to their foraging sites[61]. The PTTs were surgically attached to the carapace of nesting females using the direct attachment method[62,63].

After nesting, most tagged leatherback turtles started their migrations by heading south of the Andaman and Nicobar Islands. Once out of the Bay of Bengal, the turtles dispersed in varied paths in the southeast and southwest Indian Ocean. Five turtles travelled southeast towards the coastal waters of Indonesia and northwestern Australia and four turtles travelled southwest towards the eastern coast of Africa, with one turtle travelling 13,237 km to the coast of Madagascar and Mozambique. One transmitter failed to transmit any location data. The first turtle tagged on 4th January 2011 (PTT #103333) travelled southeast, reaching the Timor Sea (7312 km), the furthest a leatherback was tracked in the eastern Indian Ocean, before transmission stopped (Figure 10). Two turtles (PTT #113336, tagged on 5th January 2014 and PTT #113337 tagged on 8th January 2014) travelled southwest to the southeastern coast of Africa, with the first turtle reaching Madagascar in 395 days, swimming 12,328 km. During the inter-nesting period, PTT #113337 travelled to the northwest coast of the Andaman and Nicobar Islands and remained in the Andaman Sea for several weeks post-nesting, before heading southwest, reaching the western coast of Mozambique in 266 days (Figure 10; Table 1). Four turtles re-migrated and nested on West Bay beach after an interval of 4-6 years (Table 1).

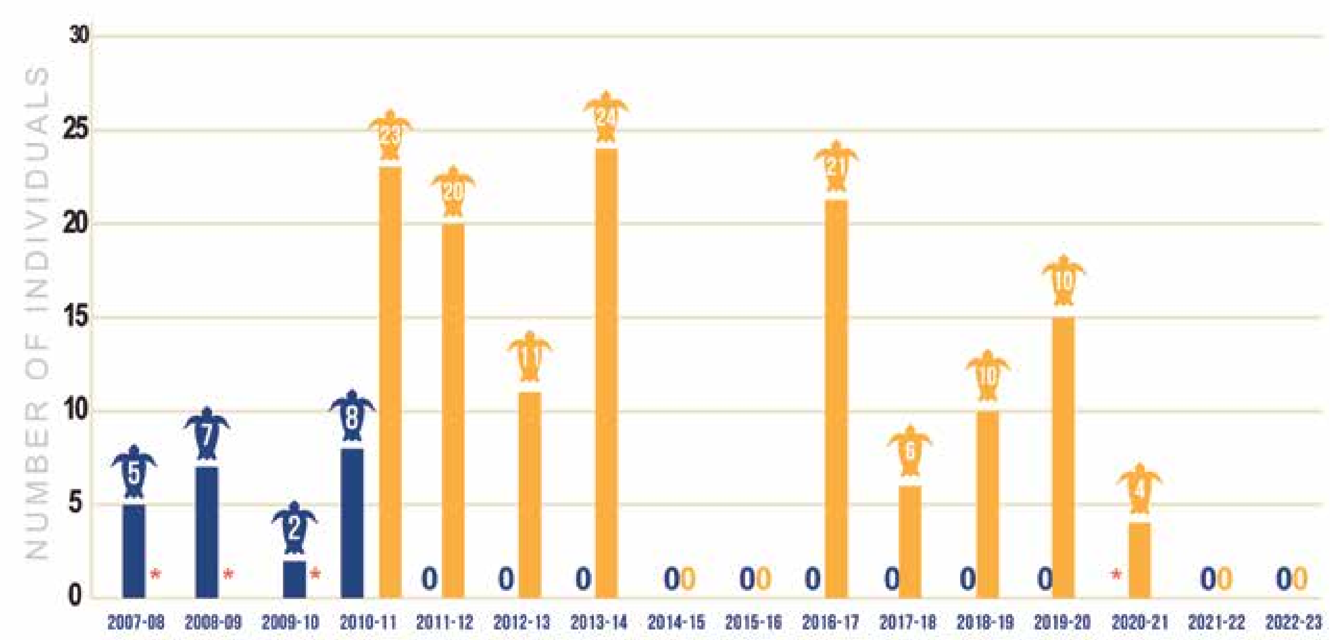


Figure 9. Leatherback turtle tagging data for South and West Bay, Little Andaman Island.

SOUTH BAY
WEST BAY
* DID NOT MONITOR

TURTLE ID	# DAYS TRANSMITTED	TOTAL DISTANCE TRAVELLED (KM)	AVERAGE DISTANCE PER DAY (KM)
103333	179	7,312	40.85
103334	69	1,077	15.6
103335	92	4,600	50.0
113332	183	6,998	38.24
113333	51	2,690	52.75
113334	0	0	0
113335	125	6,713	53.7
103402	77	4,634	60.2
113336	395	12,328	31.2
113337	226	13,237	49.8

Table 1. Satellite telemetry data of 10 female leatherback turtles tagged in West Bay, Little Andaman, from 2011-2014.

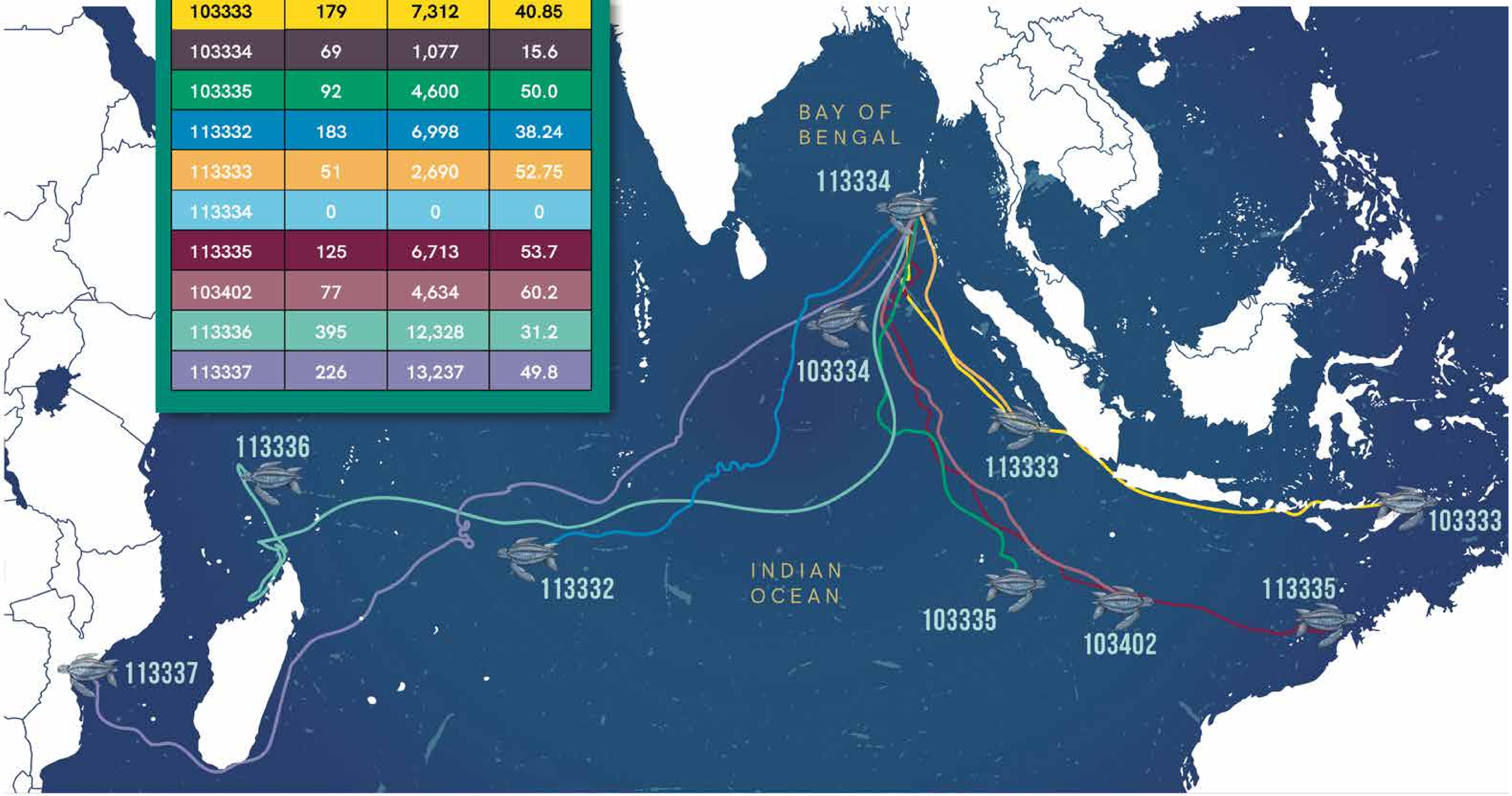


Figure 10. Map of the post-nesting migratory route of leatherback turtles nesting in Little Andaman.

ACROSS THE NICOBAR

Opportunistic and full-season surveys over the last four decades indicate that the most important nesting sites for leatherback turtles continue to be in Great and Little Nicobar Islands. In 2016, a survey carried out by Dakshin Foundation in collaboration with the Andaman and Nicobar Forest Department in the Nicobar group of islands indicated high nesting at previously reported nesting sites[37]. The important nesting sites include Galathea, Alexandria, and Dagmar Bay on Great Nicobar Island and Kiyang, Muhincohn, and Bahua on Little Nicobar Island. Over 94% of the leatherback turtle nests found in the Nicobar group of islands were restricted to Great and Little Nicobar Islands[37]. A subsequent survey conducted in 2019 in the Great and Little Nicobar Islands revealed that all the important nesting beaches in the region have formed again. Though the profiles of these beaches have changed from the pre-tsunami period, they continue to be favourable for leatherback turtle nesting.

SURVEY YEAR	2016	2019
GREAT NICOBAR ISLAND	775	819
LITTLE NICOBAR ISLAND	229	234
BAMBOOKA ISLAND	0	*
CAR NICOBAR ISLAND	0	*
CHOWRA ISLAND	0	*
KAMORTA ISLAND	6	*
KATCHAL ISLAND	57	*
NANCOWRY ISLAND	1	*
TERESSA ISLAND	0	*
TILLANCHONG ISLAND	0	*
TREIS ISLAND	0	*
TRINKET ISLAND	0	*

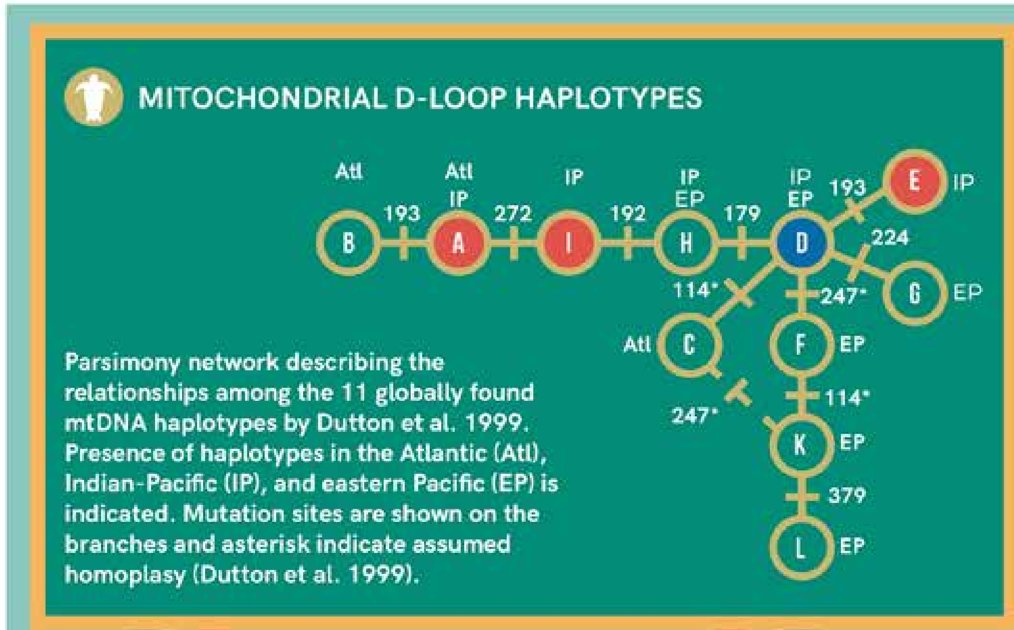
LOCATION · NO. OF NESTS · * DID NOT SURVEY

Table 2. Records of leatherback turtle nests in Great and Little Nicobar Islands.

GENETIC STRUCTURE

Given the significance of this population in the region, we studied the population genetic structure of the nesting population. We found four of the 11 reported global haplotypes (from 131 samples) namely *I, A, E* & *D* in the Great Nicobar leatherback turtle population.

More recently, in 2015, a preliminary analysis of samples from Little Andaman Island found three haplotypes (*I, A* and *E*) in eight samples. These results confirm previous findings that the leatherback population in the Andaman and Nicobar Islands is not very distinct from those found in the Indo-Pacific region[65].



HAPLOTYPES	LITTLE ANDAMAN	GREAT NICOBAR
I	1	13
A	5	57
E	2	37
D	0	24
TOTAL	8	131

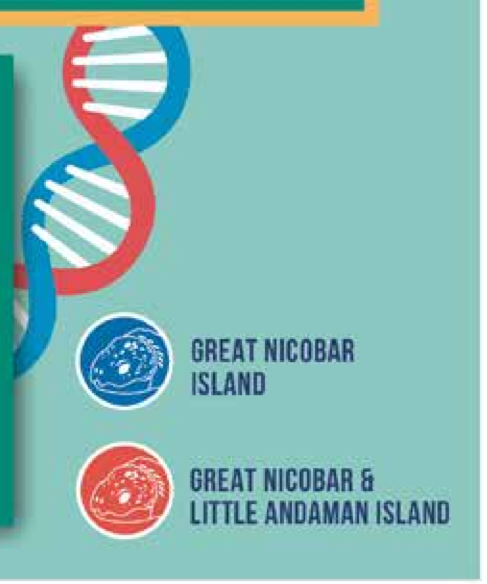


Figure 11. Genetic structure of the leatherback turtle nesting population in the Andaman and Nicobar Islands[64].

Table 3. Mitochondrial d-loop haplotypes seen in leatherback turtles in Little Andaman and Great Nicobar Islands.

FUTURE DIRECTIONS

Globally, some leatherback turtle populations have declined as a result of targeted take (of eggs and adults) and have required intervention at nesting sites for complete protection. In the Andaman and Nicobar Islands, the leatherback turtle population remains resilient with little intervention, as almost all the important nesting sites fall within protected areas with very little human disturbance. Nonetheless, leatherback turtle eggs and hatchlings are still depredated by monitor lizards, crabs, birds, and wild pigs, which are native to these islands. Although recent trends suggest that the population is resilient, permanent alterations to beaches could have a significant impact on nesting in the Andaman and Nicobar Islands. Therefore, these nesting sites must continue to be protected from large-scale developmental projects.

The South and West Bay beaches of Little Andaman Island serve as index beaches for monitoring the leatherback turtle population in the region. The monitoring programme at Galathea needs to be re-established to carry out surveys throughout the nesting season to understand long-term trends in annual reproductive output. At nesting sites where establishing monitoring camps is logistically not feasible, annual rapid surveys should be conducted at the end of each nesting season. The tagging programme needs to continue to approach saturation tagging. While we have some insights into the post-nesting movement patterns of leatherback turtles in the Indian Ocean, more satellite telemetry studies are needed, including of turtles nesting in the Nicobar Islands, to assess if there are other migratory routes taken by the leatherback turtles nesting in these islands.

GREEN TURTLES

Green turtles (*Chelonia mydas*) get their name from the colour of their fat. They belong to the hard-shelled sea turtle family *Chelonidae*. Growing up to 120 cm and weighing between 120 to 150 kg, they are the largest of the hard-shelled sea turtles. This species can be easily distinguished from other sea turtle species by the presence of a single pair of scales in front of the eyes (prefrontal scales). They have a global distribution and are found in tropical waters in all the ocean basins.

PROJECT SUMMARY

Following pilot surveys in 2011 and 2015, a long-term monitoring of the green turtle population in the Lakshadweep Islands was initiated in 2017 by Dakshin Foundation and Centre for Ecological Sciences, Indian Institute of Science, Bangalore, in collaboration with the Lakshadweep Forest Department. This programme was launched to monitor the movement patterns, distribution, and habitat use of green turtles in the Lakshadweep Islands. Over the past two decades, green turtle numbers in the lagoons have fluctuated widely, with high densities leading to a decline in seagrass meadows due to intense grazing. This reduction has adversely affected the abundance of seagrass-dependent fish, which are of great economic importance to local fisher communities, leading to conflict between the turtles and local fishers. Over the years we have monitored the distribution of seagrass meadows in the lagoons and the diet and movement ecology of green turtles to inform conservation decisions. In addition, Dakshin is developing a low-cost transmitter in collaboration with Arcturus Inc.

KEY FINDINGS

Green turtles affect seagrass meadows by reducing the density and cover of seagrass through overgrazing. Furthermore, the distribution of turtle densities over time suggests that turtles move from one island to the other once they have depleted their forage.

MONITORING GREEN TURTLES IN THE LAKSHADWEEP ISLANDS

Leading a neritic life as an adult, green turtles live in bays and along coastlines and are commonly found in areas with rich seagrass beds. Globally, they are responsible for recycling nutrients in seagrass ecosystems. Widely believed to have a strictly herbivorous diet as adults, they have also been recorded to occasionally feed on invertebrates and sponges. They nest both on small island beaches as well as on large mainland nesting beaches. In India, they are known to nest in Gujarat, the Andaman and Nicobar Islands, and the Lakshadweep Islands.

Lakshadweep is an archipelago of 36 islands with lagoons and white sandy beaches off the southwestern coast of India. These islands are the peaks and craters of massive underwater volcanoes. These inactive volcanoes form the northernmost mountains of the Chagos-Laccadive Ridge, an underwater mountain range that extends from the Northern Indian Ocean to the Central Indian Ocean. Calm, shallow lagoons protected from the ocean's swell, with coral reefs ringing the island, support diverse and teeming communities of marine life. These conditions in the lagoons are perfect for seagrass and marine algae to thrive. Extensive seagrass meadows in the lagoons serve as important nurseries and breeding grounds for a wide range of invertebrates and fishes[66].

As with most of the sea turtle research conducted along the Indian coastline, work in the Lakshadweep Islands also began with Satish Bhaskar's surveys in the 1970s. His determination to work in adverse field conditions provided baseline information on the species nesting in the archipelago. His surveys revealed that green, hawksbill and olive ridley turtles use the sandy beaches of the archipelago as nesting habitats. Green turtles were found to mainly nest in the islands of Suheli Valiyakara, Tinnakara, Bangaram, Parali, and Agatti. Hawksbill and olive ridley turtles nest on the islands of Androth, Kadmat, Agatti, Bangaram, and Tinnakara[26].

Nearly 23 years after the initial surveys by Bhaskar, Basudev Tripathy of WII conducted a survey in 2001 to assess the status of sea turtle populations in the Lakshadweep Islands[67]. This study found green turtles to be the most abundant species followed by olive ridley and hawksbill turtles. Nest encounter rates indicated that green turtles might have multiple peaks in nesting between July and February.

Green turtles are found abundantly in the lagoons owing to the availability of seagrass[67]. Historically, green turtles were were an important resource in the islands for oil that was derived from their fat. The oil was commonly used as caulk for traditional boats, especially to make the screws watertight[67]. A single green turtle would yield between 10–20 litres of oil which could cover a single boat. However, with the implementation of the Indian Wild Life (Protection) Act, 1972, and a switch to fibre boats, these animals are no longer used in the Islands.

Figure 12. Kadmat, Agatti and Kalpeni islands, Lakshadweep.

POPULATION EXPLOSION

Similar to a few other green turtle populations around the globe, the regional population in the Lakshadweep Islands began to increase in the early 2000s. This population increase of green turtles around the world and in Lakshadweep could be attributed to conservation efforts in nesting beaches and foraging habitats (in this case, Sri Lanka). Additionally, turtle numbers increased in regions where predators such as sharks were overfished[68]. The The ban on direct take of eggs and adults could also have contributed to this increase.

Nature Conservation Foundation (NCF) began systematic observational studies and experiments in 2005 to examine the impact of intense green turtle herbivory on seagrass meadows. These studies have made major contributions to a growing body of literature around the globe that elucidated the role green turtles played as herbivores in seagrass ecosystems. High densities of green turtles effectively reduced the primary productivity and growth rates of seagrasses through grazing[17]. Meadow structure, including parameters such as shoot density, canopy height, and leaf width area, was also significantly altered by intense herbivory[16]. Green turtles were found to prefer the slow-growing *Thalassia hemprichii* over the fast-growing *Cymodocea rotundata*, although they still graze on the latter. This preference mediated a shift in the seagrass community from a co-dominance of the two species to the dominance of *Cymodocea sp.*[17].

As dense aggregations of green turtles grazed down meadows to early successional stages, cascading effects rippled through the associated fish community. Seagrass fish biomass declined with green turtle herbivory[38]. Voluntary log books maintained by lagoon fishers and underwater fish surveys between 2010 and 2013 recorded a decline in seagrass fishes such as emperors and rabbitfish. However, there was an increase in pelagic fishes that have an affinity for sandy patches such as mackerels, sardines, and pompanos[38]. The decline in seagrass-associated fishes and the resultant reduction in catch have led to resentful attitudes among fishers towards the green turtles. Green turtles swimming into and damaging fishing nets have further contributed to this resentment[69].

Despite substantial evidence for the impact of green turtles as ecosystem modifiers, the ecology of the species is poorly understood in the region[16,68,70,71]. With dwindling seagrass resources in the wake of intense green turtle grazing, profuse algal growth and empty sandy patches have replaced extensive meadows in the lagoons. The feeding response of green turtles to this shift in their forage resources remains unclear. There is still little knowledge of the diet composition, foraging movements, and migratory patterns of the population of green turtles in the Lakshadweep Islands.

To address these knowledge gaps, Dakshin Foundation and Centre for Ecological Sciences, IISc began investigating the spatial ecology of green turtles in 2011. Initial pilot studies led to the establishment of Dakshin's ongoing monitoring programme in 2016[72].

Dakshin's long-term monitoring programme aims to examine trends and patterns in the spatial and feeding ecology of green turtles, map the distribution of seagrass resources in the lagoons of different islands, and understand fisher-turtle interactions towards reducing conflict. Currently the project monitors seagrass and turtle densities across four islands in the archipelago: Agatti, Kadmat, Kalpeni and Bangaram. The results from this project attempt to inform the conservation and management of green turtles and their resources in the Lakshadweep archipelago.

WHAT GREEN TURTLES EAT

As the quality and quantity of seagrass resources in the islands continue to degrade with phase-shifts to algal growth and empty sand patches in some regions, green turtle feeding responses need to be examined. Since it is difficult to make direct observations of green turtles foraging, faecal analysis provides valuable insights into their diet composition and potential dietary changes.

Green turtle faeces were collected from the beaches and lagoons, and then sun-dried. The components of the faeces were then observed under the microscope and identified. Samples from 2013 revealed a dominance of *Cymodacea sp.* shoots which reflects the shift in their diet during that time[71]. Faecal analysis from 2016, 2018 and 2019 showed shoots and leaf sheaths of both *Cymodacea* and *Thalassia* confirming previous studies on their feeding preferences[73,74]. Additionally, undigested shoots of *Halodule uninervis* were found in the faeces. Patches of *Halodule sp.* have formed and increased in Agatti and Kalpeni Islands and green turtles have been observed to feed on this seagrass species too. With the decline of their preferred forage, green turtle densities reduced drastically in particular islands. The remaining population appears to have gone through a dietary shift to begin feeding on the pioneer species of seagrass now colonising the lagoons. Seagrass rhizomes were also observed in most faecal samples. A study from Derawan Island in Indonesia suggests that this is a feeding response of green turtles in regions with scarce resources and dense feeding aggregations[75] where they dig for seagrass roots with their flippers[71].

Apart from seagrasses, an assortment of coir, coconut husk, plastic, cloth, animal remains, sponge spicules, and coral fragments were observed in the faeces. The presence of animal remains and sponge spicules indicates that they might form a minor component of the green turtle diet. Animal remains could also indicate accidental ingestion of seagrass-associated invertebrates[74].

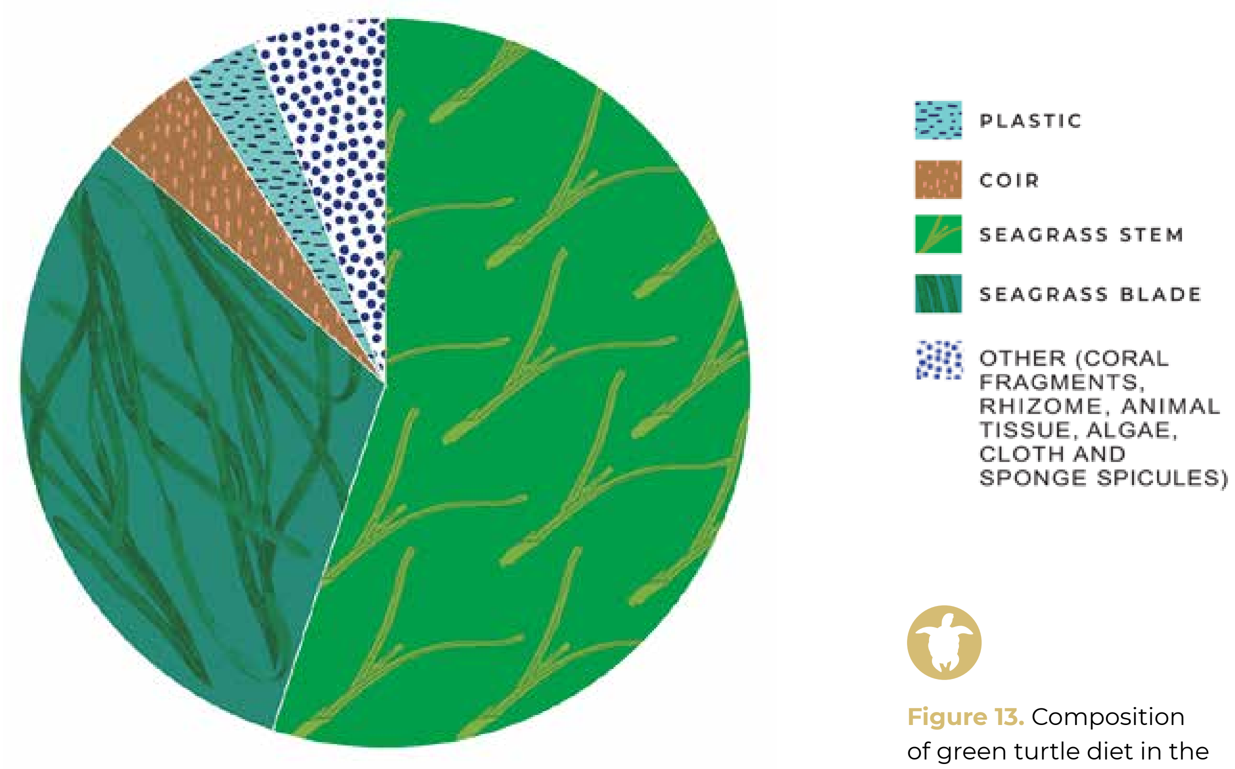


Figure 13. Composition of green turtle diet in the Lakshadweep Islands.

THE STATE OF SEAGRASS MEADOWS

High levels of green turtle herbivory reduced seagrass shoot densities across all the islands surveyed. Shoot densities had dwindled to their lowest in Agatti and Kadmat by 2018 and Kalpeni in 2019. In 2018, average shoot densities had declined by >50% in Agatti and 94% in Kadmat compared to their densities recorded in 2013. By 2019, the average shoot density in Kalpeni had declined to 5% of the density recorded in 2016. Post 2019, there has been an increase in seagrass densities across all islands except Kadmat. In 2023, shoot densities in Agatti and Kalpeni had increased to 3.2 and 16.5 times their lowest densities in 2018 and 2019, respectively.

The increase in densities recorded in Agatti and Kalpeni is due to the emergence of *Halodule sp.* and *Halophila sp.* patches. In addition, *Syringodium isoetifolium* has also been recorded at very low densities in the monitored islands. These pioneering and fast-growing species of seagrass have colonized portions of the habitat once occupied by lush meadows of *Thalassia hemprichii* and *Cymodocea rotundata*, which had been depleted to very low densities by 2016 across all the three monitored lagoons.

YEAR	AGATTI	KADMAT	KALPENI
2013	171.99 / m²	437.48 / m²	NA
2016	128.59 / m²	NA	426.16 / m²
2018	76.03 / m²	27.01 / m²	42.47 / m²
2019	99.09 / m²	35.25 / m²	20.11 / m²
2022	176.57 / m²	68.37 / m²	201.966 / m²
2023	239.86 / m²	71.46 / m²	332.48 / m²

Table 4. Seagrass shoot density (per m²) recorded in our study across islands and years.

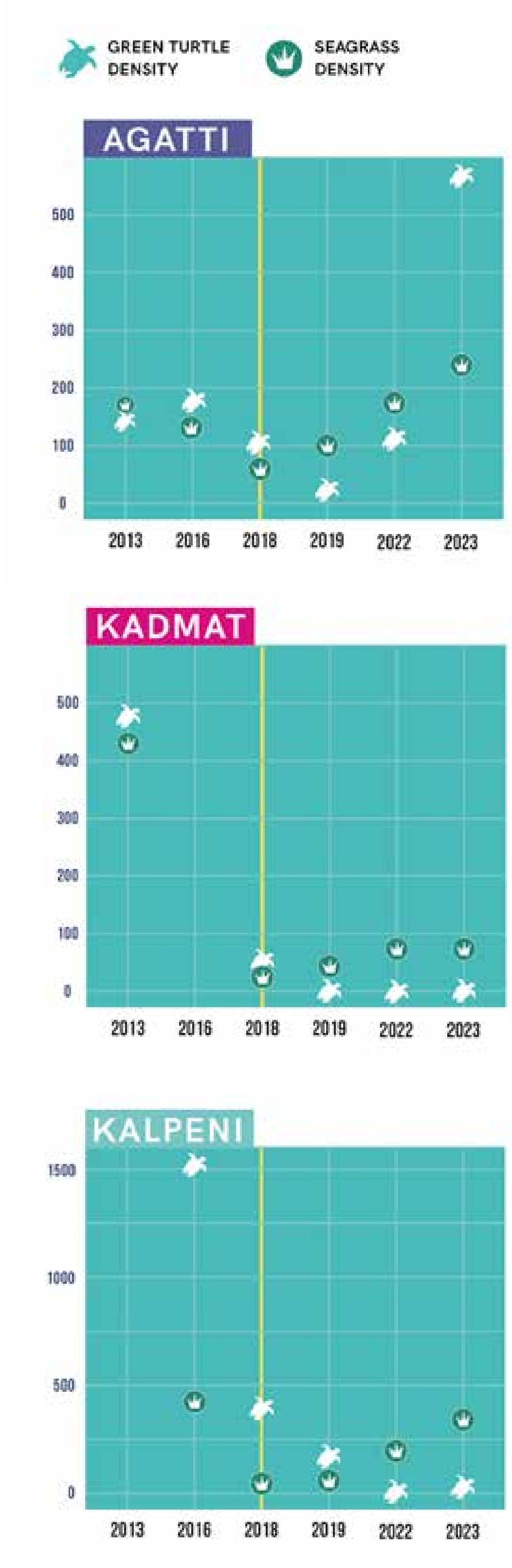


Figure 14. Changes in seagrass (per m²) and associated green turtle densities (per km²) in the archipelago over the years.

SHIFTING GREEN TURTLE DENSITIES

Green turtle densities have fluctuated in the islands over the last twenty years. Studies show a steep increase from low densities in the mid-2000s to high densities of green turtles in different lagoons over the next few years. High density turtle aggregations were first reported from Agatti in 2008 and then in Kadmat and Kalpeni in 2013 and 2016, respectively. The highest number of green turtles ever recorded was in Kalpeni in 2016 with approximately 1500 turtles/km².

In Agatti, turtle densities fluctuated over the years before reducing to 33.3 turtles/km² in 2019 and increasing again to 566.6 turtles/km2 in 2023. This increase in turtle densities may be attributed to *Halodule sp.* patch formation in Agatti. A drop in turtle densities was observed in Kadmat from an estimated 485 turtles/km² in 2013 to no records between 2019 and 2023. The most dramatic increase was seen in Kalpeni with approximately 1500 turtles/km² in 2016 followed by a drastic decline to approximately 92 turtles/km² in 2019.

By 2023, the average density of turtles was low at 25 turtles/km². This decline in turtle densities in different lagoons coincided with a decline in shoot densities of their preferred seagrass species.

In general, green turtles were found to aggregate in lagoons with high shoot densities and canopy heights of seagrass. They were most likely to be present in lagoons with *Thalassia hemprichii* and in nearshore regions. Fisher surveys indicated that green turtles increased in density closer to or during the monsoons.

There seems to be a pattern in how green turtles forage in the lagoons of the islands. They appear to exhaust resources at one site before shifting to a new site[76]. Factors that trigger movement and the mechanisms of identification of a new patch are still unknown. Studying cues that lead to shifting green turtle densities can also reduce direct conflict with fishers.

YEAR	AGATTI	KADMAT	KALPENI
2013	~155.5 / km²	~485 / km²	NA
2016	~166.6 / km²	NA	~1516.6 / km²
2018	~100 / km²	41.6 / km²	~400 / km²
2019	33.3 / km²	0 / km²	91.6 / km²
2022	~111 / km²	0 / km²	~8 / km²
2023	566.6 / km²	0 / km²	25 / km²

Table 5. Green turtle densities (per km²) observed in our study across islands and years.

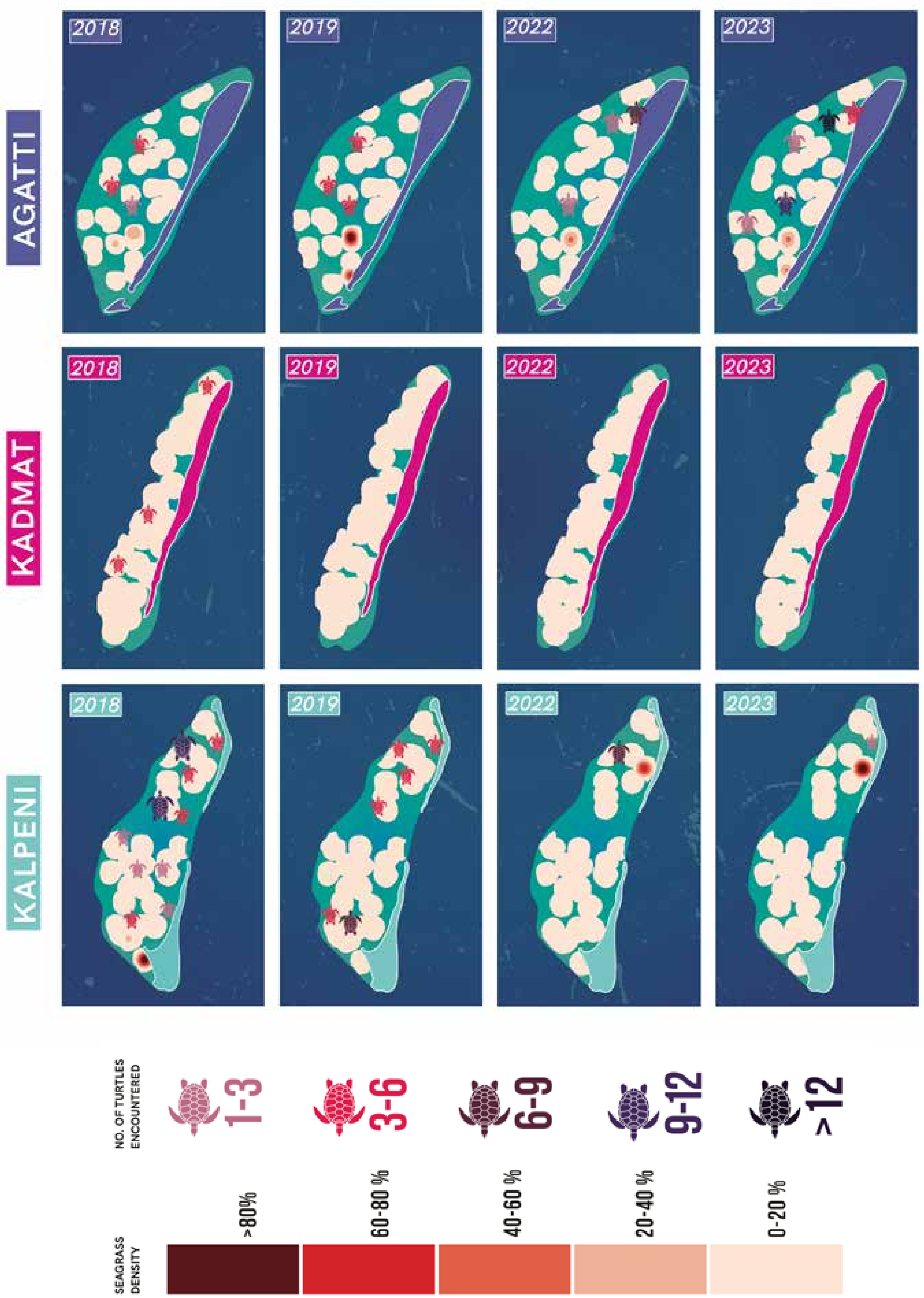


Figure 15. Seagrass density and turtle encounters in Agatti, Kadmat and Kalpeni in 2018 and 2019.

TRACKING GREEN TURTLES

Foraging movements of these marine mega-herbivores can lead to seagrass meadow extinction and trigger trophic cascades through the associated faunal communities. Hence, the internal and external drivers of green turtle movements need to be examined in depth to understand green turtle responses to environmental conditions and their interactions in a larger seascape. Based on knowledge gaps identified from our long-term monitoring programme spanning a little over a decade, we have increased efforts to study the movement ecology of green turtles using different methods.

PHOTO-IDENTIFICATION OF INDIVIDUAL GREEN TURTLES

Currently, a non-intrusive photo-identification study has been initiated in collaboration with local dive centres. In 2019, several dive professionals were provided with underwater cameras. On opportunistically sighting a green turtle on a dive, scutes on the left and right profiles of the face are photographed along with a full body photo. Based on the shape and position of the scute arrangement, a numbered ID is assigned to each individual following Jean et al. 2010. A repository of individual green turtles collected over the years can help track movement patterns and habitat preferences, and also engage the community in participatory research.

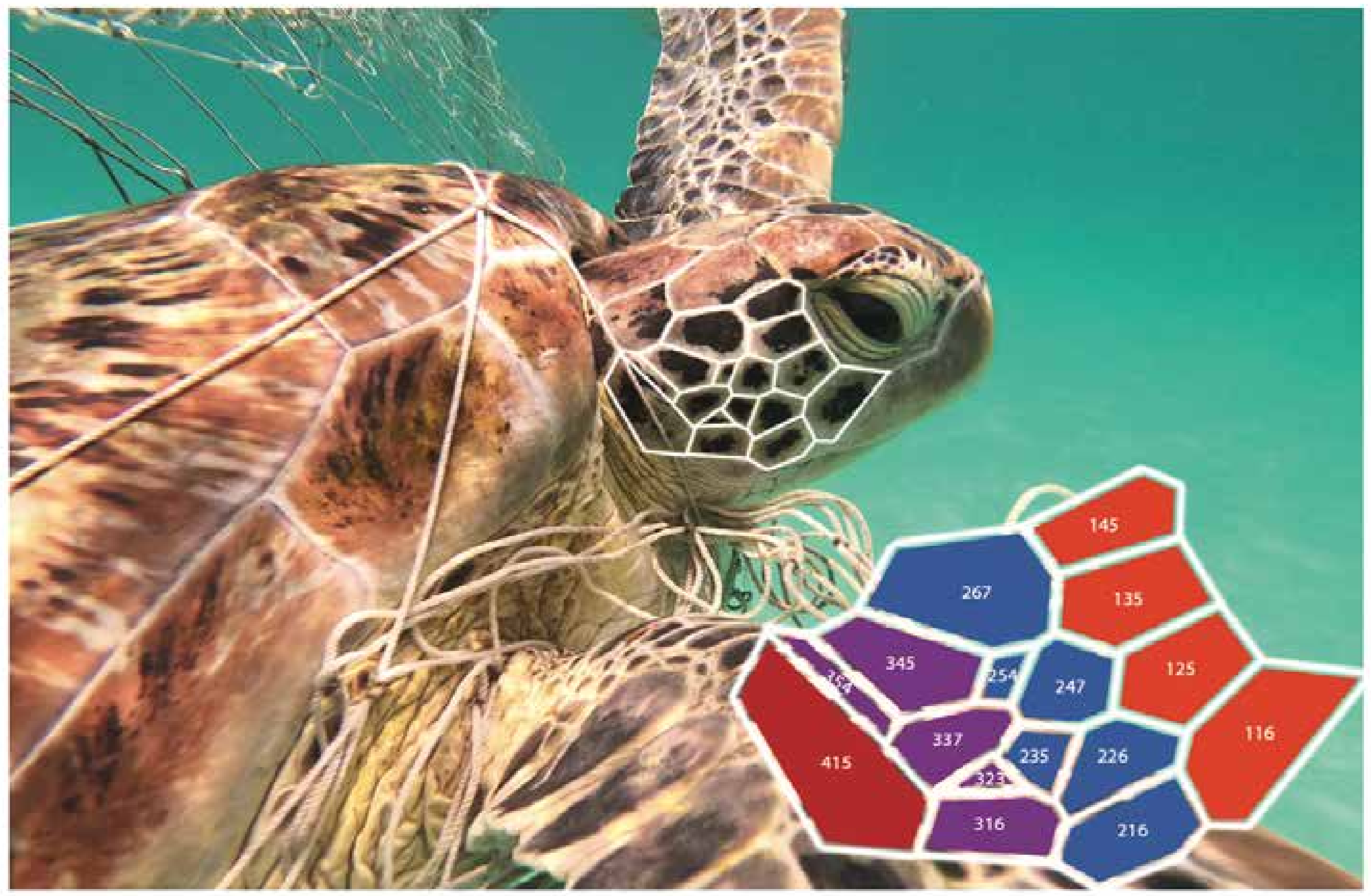


Figure 16. A numbered ID assigned to photographs of a green turtle rescued by a fisher.

INDIGENOUS GPS LORA RADIO TELEMETRY SYSTEM

Taking advantage of the high fidelity that green turtles exhibit to their foraging grounds[78], we plan to deploy an indigenously developed radio telemetry system to examine the movement ecology of green turtles in the Lakshadweep Islands. Dakshin Foundation has supported the development and testing of a GPS LoRa radio telemetry system in collaboration with Arcturus Inc. A network of receiver stations in known foraging grounds can be used to passively track tagged green turtles. The radio tag is equipped with a submergence sensor, GPS logger, and a radio transmitter. At 10-20% of the cost of commercially available telemetry systems, we aim to make this technology accessible to other researchers and research agencies. Since the telemetry system is inexpensive, a greater number of individuals can be tagged and studied, resulting in robust data that telemetry studies often lack. The knowledge generated will shed light on foraging patterns and movements in response to resource availability and environmental conditions. Informed and evidence-based management decisions can then be taken to ensure the conservation of both green turtles and seagrass ecosystems.

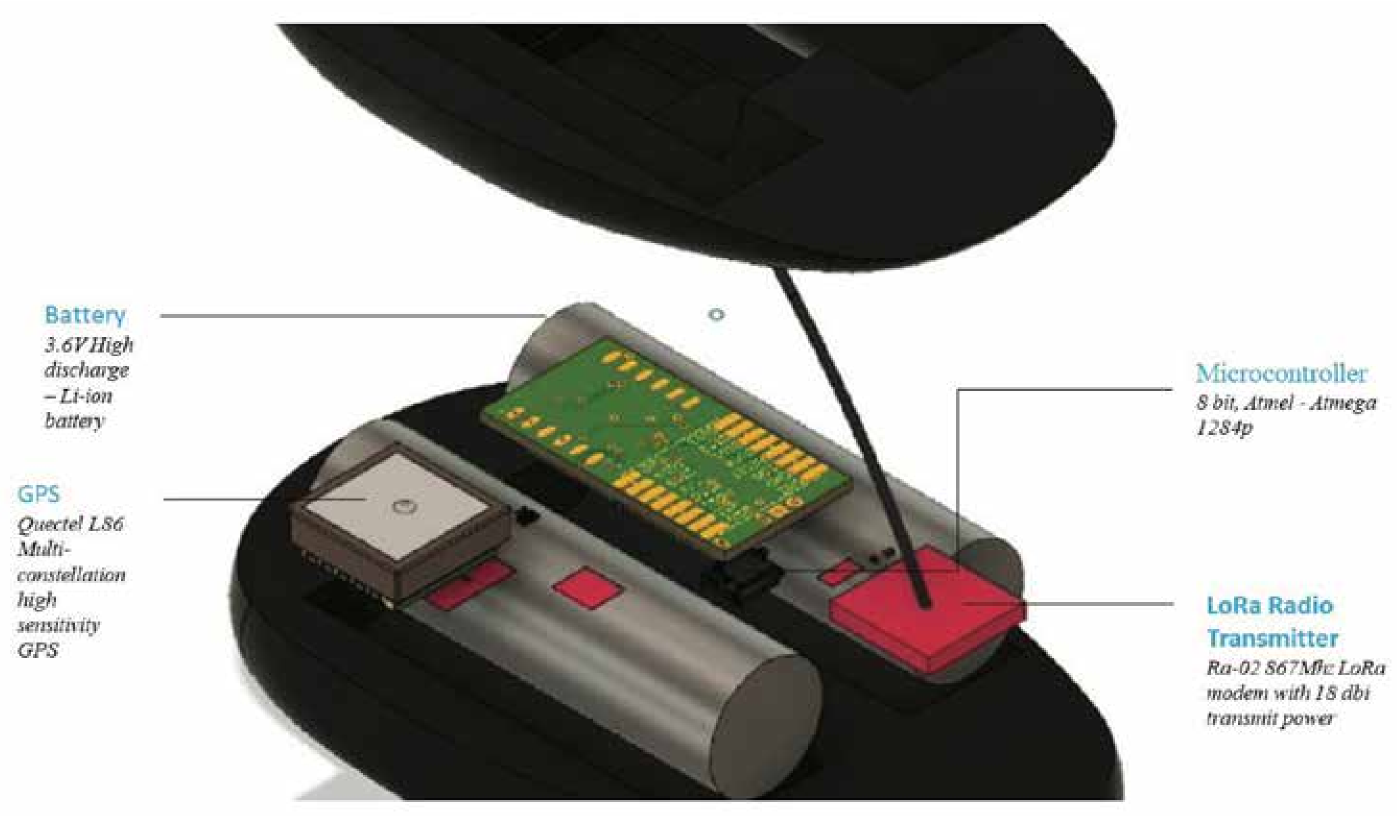


Figure 16. Components of the GPS LoRa radio tag.

FISHER TURTLE INTERACTIONS

The lagoons of Lakshadweep are important to both green turtles (as prime feeding habitats) as well as to local fishers. This results in fishers and turtles frequently crossing paths. Using researcher observations of turtles, and the areas marked by fishers as commonly used for fishing, we generated maps of the lagoons. These areas were then overlaid to identify regions of spatial overlap between fishing areas and turtle distribution.

Kadmat had fewer areas where overlap was observed because of low turtle densities. A high density of green turtles in the northern and southern regions of the Kalpeni lagoon resulted in increased overlap with fishing activities. There is a high spatial overlap in Agatti despite the low densities of turtles recorded there. This is because fishers leave their nets in the water for extended periods and sometimes overnight. Moreover, in recent times, more turtles have been observed on the eastern side of the islands due to seagrass presence, resulting in encounters with fishers. To keep the fishers informed of regions with turtle presence, the maps were distributed among them. These maps could potentially ameliorate direct fisher-turtle conflicts by informing them about regions with high turtle densities[74].

Fishers in the islands were interviewed to understand their attitudes towards green turtles, especially considering the recent increase in turtle abundance and entanglement in their fishing nets. In these surveys, most fishers responded that they would release turtles by lifting the nets so the turtles could swim away, disentangle the turtles from the nets, or simply lift them out by holding their carapaces. Some fishers have also had to cut their nets if the turtles' flippers got entangled in them. Other common responses were that turtles would break the nets and escape unnoticed. Sometimes, fishers would scare the turtles away by making a sound in the water or on their boats. Some fishers chose not to elaborate on their reactions to encountering a turtle.

Most fishers mentioned that entangled turtles could only break nets with thin meshes. Chances of net damage increase when they are left overnight or for a long period in the water. Nets made of sturdy materials are more resistant to damage, therefore, the fishers just disentangle turtles from the intact nets. Moreover, due to strict laws in place, most fishers said that they resorted to removing turtles from the nets rather than harming them[74].

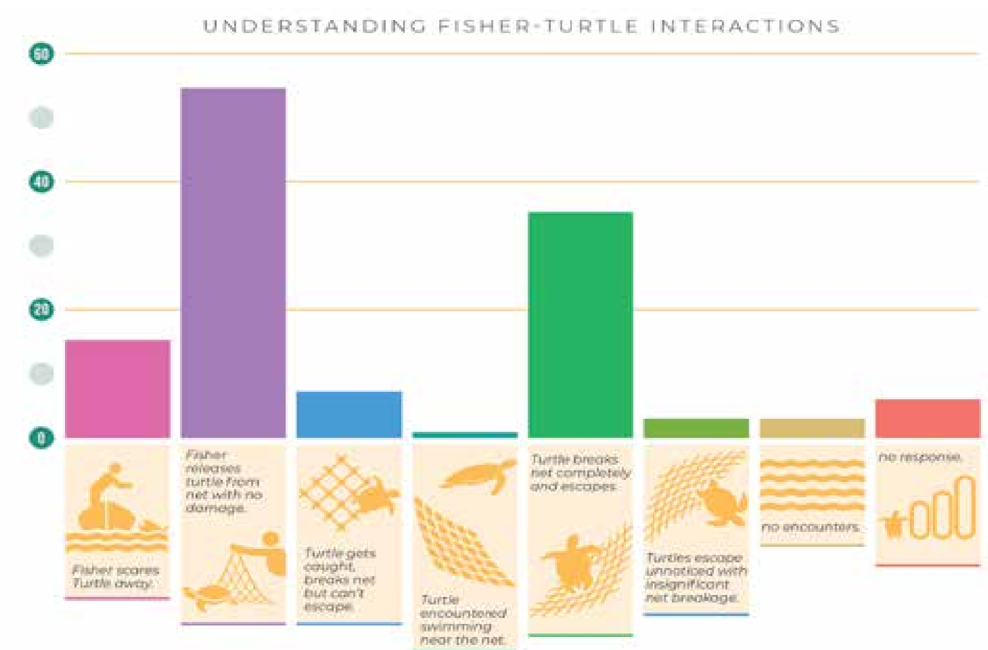


Figure 17. Understanding fisher-turtle interactions.

FUTURE DIRECTIONS

The decline in seagrass leaves this population vulnerable, and hence, it is important to monitor their movement and foraging ecology. The data collected in our ongoing project and observations from previous studies suggest that green turtles move from one island to another after depleting seagrass resources. Other potential environmental and social cues that trigger migration from one patch to another are still unknown.

Green turtles that nest in Sri Lanka have been observed to migrate to the Lakshadweep Islands[79]. Apart from this, the residency and migratory patterns of green turtles in these islands are largely unknown. Studying their movement patterns can offer insights into green turtle foraging ecology. Their plasticity in terms of foraging resources and sites can also be examined in detail with the help of these studies. Deploying animal-borne cameras can provide us with insights into their feeding patterns, as has been done in Japan and Australia.

In the future, we aim to elucidate the patterns of green turtle movements in Lakshadweep through a combination of telemetry and identification of individuals from photo and flipper tags. Our indigenously designed radio telemetry system can be used to track green turtle movements within the archipelago.

Establishing these programmes in collaboration with local communities will ensure the sustainability and viability of such programmes and can be crucial for raising awareness about threatened species.

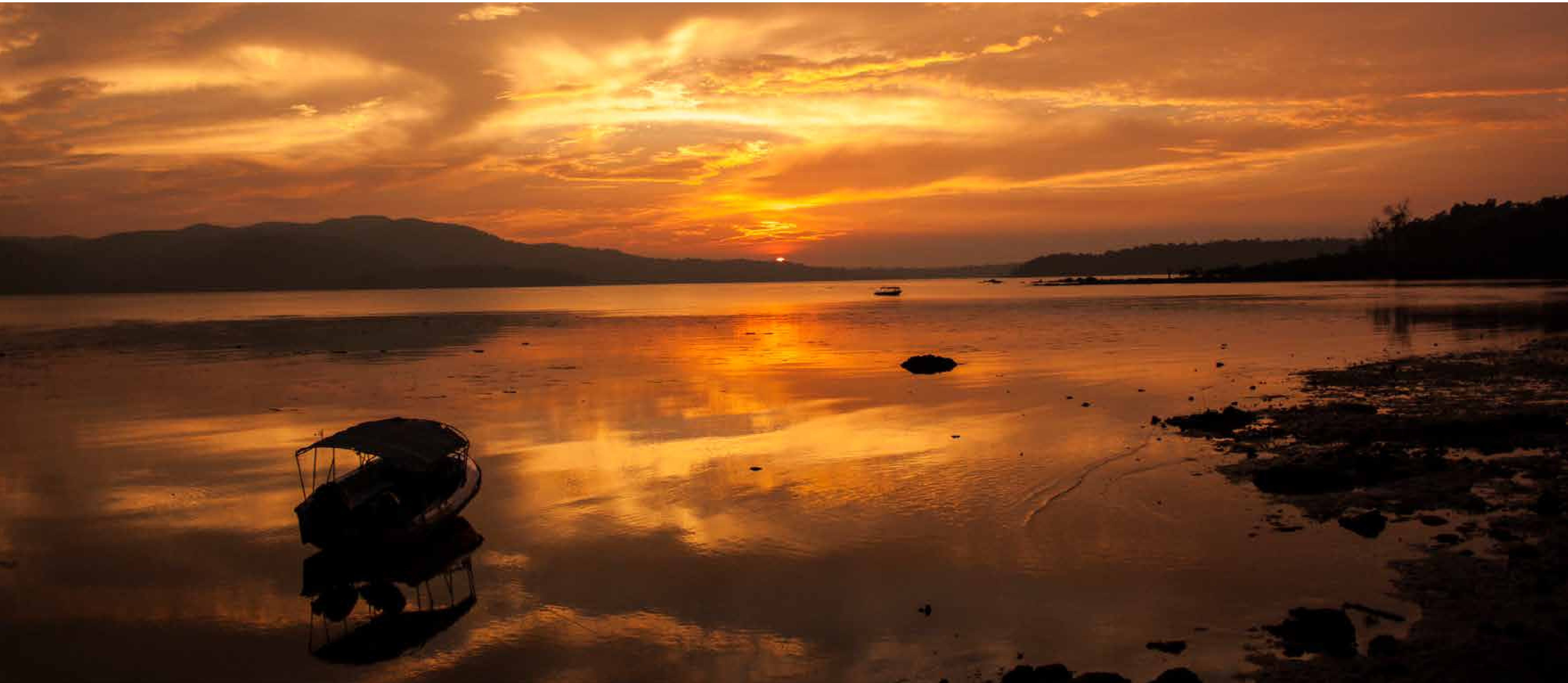
ENGAGING STAKEHOLDERS IN MONITORING TURTLES

Sea turtles mature slowly and have long generation times, making them particularly vulnerable to threats and impeding their ability to recover from rapid population declines. It is, therefore, crucial to monitor vital demographic parameters over an extended period for effective conservation and management. The long-term monitoring programmes for sea turtles in Odisha, the Andaman and Nicobar Islands and the Lakshadweep Islands are vital for obtaining reliable data on nesting trends, breeding aggregations, migratory routes, feeding ecology and other aspects of their biology at these index nesting and foraging sites.

In particular, understanding population dynamics at these index sites is fundamental to informing conservation initiatives. In India, foraging and breeding sites of various sea turtle species overlap with important commercial fishing grounds of coastal communities. As a result, the consequences of protection measures inevitably impact the livelihoods of these communities.

While the need to involve stakeholders in conservation planning and decision making is widely recognised, significant challenges remain in bringing about change on the ground. These challenges stem from differing priorities, communication barriers and resource constraints. Addressing these issues will require strategic planning and intervention from the government to promote inter-sectoral collaboration between agencies and stakeholders involved in the process.

It is particularly important to engage with and ensure the well-being of local communities that live alongside and share space with these species. Local stewardship in the monitoring and conservation of sea turtles and their habitats, promoting sustainable practices in coastal and fishing communities, and exploring alternative livelihood opportunities are crucial for safeguarding these species and the ecosystems they inhabit.



PUBLICATIONS

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Rao, C., C. Pusapati, M. Manoharakrishnan, N. Kale, A. Barnes and K. Shanker. 2023. Distribution patterns of nearshore aggregations of olive ridley turtles (*Lepidochelys olivacea*) in Rushikulya, Odisha, India: implications for spatial management measures. *Aquatic Conservation: Marine and Freshwater Ecosystems* 33(4): 1–10.

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THE ANDAMAN & NICOBAR ISLANDS

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Namboothri, N., A. Swaminathan and K. Shanker. 2012. A compilation of data from Satish Bhaskar's sea turtle surveys of the Andaman and Nicobar Islands. *Indian Ocean Turtle Newsletter* 16: 4–13.

Swaminathan, A., N. Namboothri and K. Shanker. 2011. Post-tsunami status of leatherback turtles on Little Andaman Island. *Indian Ocean Turtle Newsletter* 14: 5–10.

Swaminathan, A., S. Thesorow, S. Watha, M. Manoharakrishnan, N. Namboothri and M. Chandi. 2017. Current status and distribution of threatened leatherback turtles and their nesting beaches in the Nicobar group of islands. *Indian Ocean Turtle Newsletter* 25: 12–18.

Swaminathan, A., N. Namboothri and K. Shanker. 2019. Tracking leatherback turtles from Little Andaman Island. *Indian Ocean Turtle Newsletter* 29: 8–10.

THE LAKSHADWEEP ISLANDS

Kale, N., M. Manoharakrishnan, D.K. Bharti, M. Poti and K. Shanker. 2022. The island hoppers: how foraging influences green turtle (*Chelonia mydas*) abundance over space and time in the Lakshadweep Archipelago, India. *Endangered Species Research* 48: 1–14.

Kale, N., M. Manoharakrishnan and K. Shanker. 2021. Dietary components of green turtles in the Lakshadweep Islands, India. *Marine Turtle Newsletter* 162: 6–10.

PEOPLE

KEY FIGURES

Clockwise: Satish Bhaskar with a green turtle at Madras Crocodile Bank, 1976; Dhruvajyoti Basu, Satish Bhaskar, Romulus Whitaker and Allen Vaughan with a haul of lobsters at Mahabalipuram, 1977; Saw Paung, Harry Andrews and Saw Todi in Little Andaman Island, 1997; Olive ridley being fitted with a satellite transmitter in Devi River Mouth, Odisha, with B.C. Choudhury, C.S. Kar, Sushil Dutta, Sudhakar Kar and Jack Frazier, 2001; Romulus Whitaker, Manish Chandi and Saw John in Wandoor, 2007.

TEAM LEADERS

Kartik Shanker
Kartik was inspired to a career in ecology by an ancient reptile, a sea turtle that crawled ashore late one night in Madras. As faculty at the Centre for Ecological Sciences, Indian Institute of Science, Bangalore, he works on the ecology and evolution of frogs, reptiles, birds, and marine fauna. He has established long term research on sea turtles along the Indian coast, and more recently on sharks and rays. Kartik is a founding trustee of Dakshin Foundation and a founding editor of the magazine, Current Conservation. He is the author of the book *From Soup to Superstar*, a historical account of sea turtle conservation in India and of several children's stories including *Turtle Story*, *The Adventures of Philautus Frog*, *Moonlight in the Sea*, and *Lori's Magical Mystery*.

Muralidharan Manoharakrishnan
Murali started his career studying olive ridley turtle arribadas at Rushikulya which sparked his interest in Odisha's sea turtle conservation history. This led him to study the beaches of Odisha and eventually, other turtle species along India's coast from 2010-2022. He also worked with the TAG network on marine conservation projects in the west coast. His work at WWF-India continues to focus on engaging coastal communities to protect marine species and habitats across India.

Adhith Swaminathan
Adhith joined Dakshin Foundation in 2008 and worked on olive ridleys in Rushikulya, Odisha, for two consecutive nesting seasons before joining the leatherback monitoring programme in the Andaman and Nicobar Islands in 2010. Between 2010 and 2024, he carried out long-term monitoring in Little Andaman Island, conducted rapid surveys of the Nicobar Islands and led the leatherback programme as a Programme Officer with Dakshin Foundation.

Chandana Pusapati
Chandana joined Dakshin in 2019 after her Master's at TERI University, Delhi. As part of the olive ridley monitoring project in Odisha, she conducted onshore and offshore surveys to monitor breeding and nesting population dynamics. Currently, as a Programme Officer, she coordinates Dakshin's sea turtle monitoring projects across India. She also leads the long-term monitoring project on olive ridleys in Odisha and oversees the lab work on hatchling sex ratios.

RESEARCHERS

ODISHA

Anusha Koushik, 2007 - 2008

Divya Karnad, 2008 - 2009

Adhith Swaminathan, 2009 - 2010

Ema Fatima, 2010 - 2014

Muralidharan M, 2010 - 2022

Amrit Kumar Mishra, 2011 - 2012

Nupur Kale, 2012 - 2015

Chetan Rao, 2014 - 2020

Alissa Barnes, 2015 - 2018

Hariprasath R, 2016 - 2017

Avik Banerjee, 2018 - 2019

Mohit Mudliar, 2019 - 2020

Chandana Pusapati, 2019 - Present

Vishrutha Rao, 2022 - 2023

Rahul MS Rao, 2023 - Present

SPECIAL MENTIONS

Sajan John, 2013 - 2014

Akash Varma, 2013 - 2014

Mugdha Kulkarni, 2014 - 2015

Madhuri Ramesh, 2011 - 2017

Ridhi Chandarana, 2015 - 2018

Sadhwi Sindhura, 2015 - 2016

ANDAMANS

Devi Subramaniam, 2008 - 2008

Adhith Swaminathan, 2010 - 2024

K Irfan Ali, 2024 - Present

LAKSHADWEEP

D.K. Bharti, 2011 - 2012

Meenakshi Poti, 2014 - 2016

Nupur Kale, 2018 - 2020

Hariprasath R, 2020 - 2024

Mohammed Serfas Khan, 2023 - Present

OUTREACH COORDINATORS

Seema Shenoy, 2009 - 2014

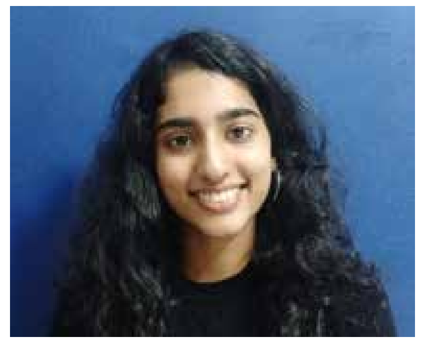
Amrita Tripathy, 2011 - 2014

Smrutica Jeetendranath, 2014 - 2014

Mallika Sardeshpande, 2015 - 2015

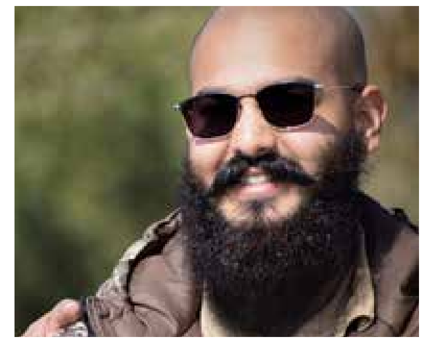
Rutuja Dhamale, 2015 - 2017

Prakriti Mukherjee, 2017 - 2019



Rhea George, 2019 - 2023

Debangini Ray, 2021 - Present



Tanuj Mark, 2023 - 2024

Vidisha M.K, 2024 - Present

FIELD STAFF

ODISHA

Dambru Behera (Late)

Madhusudan Behera

Surendra Behera

Shankar Rao

Ganapati Sahu

Bipro Behera

Mahendra Nayak

Kedar Rao

Sriramulu

Magata Behera

Judistir Behera

ANDAMANS

Sushil Lakra

Saw Berny

Saw Willy

Saw Colombus

Sabien Horo

Saw Kenik

Saw Samson

Sandeep

Saw Darius

Saw Thesorow

Saw Momong

Saw Isaac


Saw Watha


Saw Stanley


Saw John


Parimal Toppo


Suresh Kujur


Vipin Tirkey


Saw Kerry


Saw Mishap


Yakub Kerketta


Saw Thoma


Saw Tobow


Suman Kerketta


Sonu


John Lakra


Jonsan Topno


Sanjay Xess

LAKSHADWEEP


Ajmal TP


Jaffar Khan MM


Ubaidullah HUM


Jaffar Khan KK

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