Monitoring green turtles (*Chelonia mydas*) and developing conflict mitigation measures for the conservation of seagrass meadows in the Lakshadweep Islands

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Project Report

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Introduction

Monitoring green sea turtle (*Chelonia mydas*) populations and their behaviour is crucial to assess population trends, associated risks, and potential declines (Roos et al. 2005). These population abundances and behaviours are, in turn, influenced by several abiotic and biotic factors that require equal assessments to determine patterns. Foraging plays a crucial role in controlling changes in abundances as it is required for an individual's growth, reproductive maturity, success, and consequently, survival. As for most organisms, green turtle foraging and associated behaviour are dependent on quality and availability of forage (Bjorndal 1997; Seminoff et al. 2002) as well as different environmental conditions such as tides, temperature, risk of predation, geography, etc. (León and Bjorndal 2002; Burgett et al. 2018). Since most of a turtle's lifetime is spent foraging at its foraging ground(s), it is imperative to monitor and understand the spatial use of foraging grounds, foraging choice, and feeding patterns to devise conservation and management plans (Seminoff et al. 2003).

Of the seven extant sea turtle species, green turtles undergo drastic ontogenetic change as they shift diets from omnivorous as juveniles to predominantly herbivorous as adults (Chaloupka & Limpus 2001; Arthur et al. 2008). This shift in the diet also induces a change in habitats: the juvenile stage is mostly oceanic, while the adult stage is spent mostly in neritic waters. These neritic habitats are rich in marine flora, such as seagrass and algae, which form the main part of an adult green turtle diet. In addition to marine flora, green turtles also consume invertebrates (see Bjorndal 1997) and some populations have also exhibited spongivory (Russell et al. 2011). In their foraging behaviour, they also show dichotomy where some populations show fidelity to their foraging grounds (Moran and Bjorndal, 2005), whereas others show specific preferences towards the type of forage. This indicates that green turtles show behavioural plasticity with regards to their foraging and can adapt to a changing environment to replenish their energy reserves.

Fig 1. Shallow lagoons such as these provide the perfect environment for seagrass and algal species to thrive and in turn, support fishes, invertebrates, megafauna, and humans.

In the Indian subcontinent, green turtles are mainly found in Gujarat, the Andaman & Nicobar Islands and the Lakshadweep Archipelago, with rare observations of juveniles in other coastal states (Tripathy & Choudhury, 2002; Giri & Chaturvedi, 2003; Kale 2014). Of these, the Lakshadweep islands serve as effective foraging grounds for green turtles (Tripathy et al. 2002, 2007; Kelkar et al. 2013a). The seagrass and algae rich lagoons of the Lakshadweep islands cater to the adult diet of the green turtles. Previous studies have shown that green turtle numbers were observed to have increased in some island lagoons in the last decade (Arthur et al. 2013). While the exact reason for this increase has not been ascertained, islanders believe that a ban imposed by the Government on turtle hunting is the primary cause. However, this increase has led to the seagrass meadows being overgrazed in some of the lagoons. Studies on the seagrass communities elucidated that green turtles mainly feed on *Thalassia hemprichii* and even *Cymodocea rotundata* in the lagoons (Lal et al. 2010). Their overgrazing also caused a change in seagrass species composition and consequently, led to a shift in species dominance from *Thalassia*-dominant meadows to *Cymodocea* dominating the seagrass communities. Moreover, it was observed that a drastic loss in these seagrass species caused a reduction in the associated fish species (Kelkar et al. 2013a, 2013b; Arthur et al. 2013). As the fish numbers fell, it adversely affected fishers and their subsistence, and hence, they harboured negative feelings towards green turtles resulting in a perceived conflict (Arthur et al. 2013).

Past studies on green turtles in the Lakshadweep islands have focused mainly on their nesting and effects of herbivory (Bhaskar 1978; Kelkar et al. 2013a, Lal et al. 2010, Tripathy et al. 2007). While extensive studies were conducted to understand changes in seagrass communities and the resultant conflict, there was no information on the changes in abundance of green turtles in different island lagoons and its implications. Therefore, we monitored the distribution and changes in green turtle abundance within three island lagoons, their dietary composition, and conducted experiments to check for improvements in seagrass species that were known to form a predominant part of the green turtle diet.

Objectives:

1) To monitor green sea turtle demography and distribution
2) To determine the green turtle diet
3) To implement mitigation methods to reduce the fisher-turtle conflict
4) To explore techniques for the recovery of seagrass communities and dependent fauna

Study sites

The Lakshadweep Archipelago is situated approximately 200km off the west coast of India in the Arabian Sea. The Archipelago is made up of 12 atolls and 36 islands of which 10 are inhabited. Most of these islands are oriented Northeast-Southwest and are characterised by shallow lagoons on the west and reef flats on the east. The shallow lagoons provide perfect seagrass and algal habitats that support a large number of fish and invertebrate species. Juveniles and adults of the endangered green turtle and critically endangered hawksbill turtle (*Eretmochelys imbricata*) have been observed to use these habitats for feeding and resting purposes.

Based on past studies and recent observations, Agatti, Kadmat, and Kalpeni were selected for this study (Fig. 2). The turtle densities in Agatti and Kadmat were reported to be high in the early-2010s (Kelkar et al. 2013a), while recent reports suggested that Kalpeni has a high abundance of turtles. Agatti was also the first island to report of fisher-turtle conflict caused by the reduction of commercially important fish due to loss in seagrass resources (Arthur et al. 2013).

Fig 2. Maps of the three study sites

Methods

Objective 1: To monitor the green sea turtle demography and distribution

To actively monitor sea turtle movement within its foraging ground, a tagging program was planned. It was to be initiated after acquiring necessary animal handling permissions from the Ministry of Environment, Forest and Climate Change (MoEFCC), India. For this purpose, turtles were to be captured using nets and subsequently tagged on the trailing edge of each front flipper, on the first scale distal to the axilla, using Inconel© tags. Besides, photographic identification was to be used by capturing photos of any unique feature on the turtle's head or carapace to aid identification, in case of tag loss. Sea turtle growth was to be measured by collecting morphometrics during the tagging exercise. For this purpose, curved carapace length (CCL) was to be recorded using a flexible tape. The CCLs give a measure of turtle size class which helps determine the structure of a population. However, as the animal handling permits did not come through, we altered our methods and employed transects to record turtle abundance and distribution in different strata.

Green turtle numbers were recorded by using transects- 9, 12, and 12 transects in the lagoons of Agatti, Kadmat, and Kalpeni respectively (Fig. 3). The transects were drawn to cover the northern, central, and southern parts of the lagoons and over different strata such as reef, mid-lagoon, and near shore. These transects were 1km in length and were surveyed by an observer standing at the bow of the boat observing a belt of 5m on either side as the boat traversed at 8km/hr. The surveys were conducted during high tide as tides were observed to influence turtle presence in the lagoons.

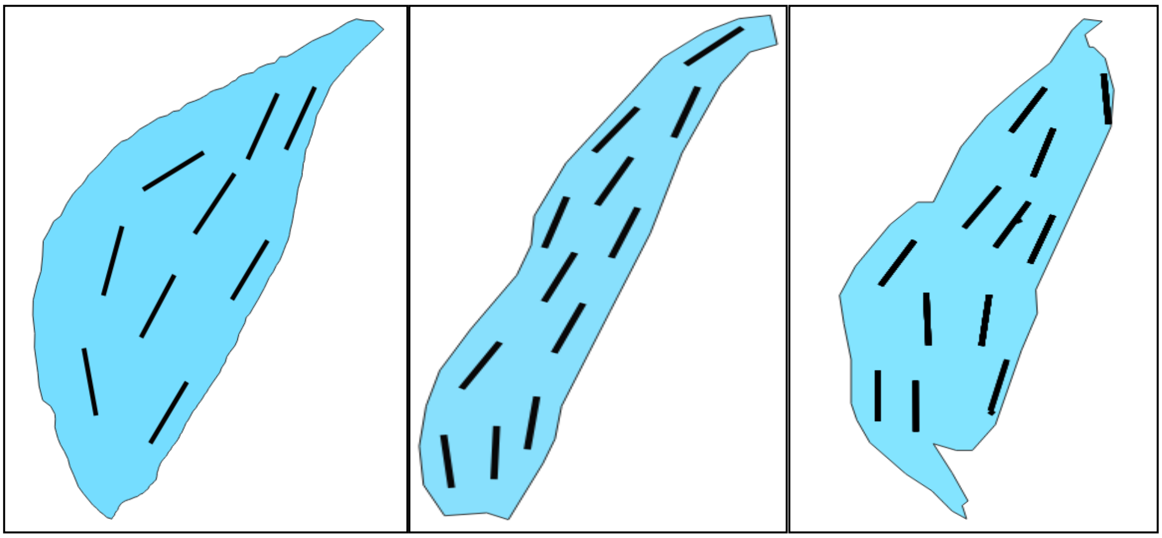

Fig 3. Line transects to detect turtle presence in Agatti, Kadmat and Kalpeni lagoons respectively

In addition, a LoRa GPS telemetry system will be designed and developed by Arcturus Inc. in collaboration with Dakshin Foundation. It will be deployed for the first time on green turtles in the Lakshadweep archipelago. These tags will cost 10-15% of that of commercially available GPS tags and can be expected to surpass financial constraints due to expensive equipment needed for movement ecology studies.

The telemetry system will comprise tags equipped with high sensitivity GPS loggers, long range radio transmitters, batteries, and a salt-water switch (to mount on turtles) and hand-held receivers as well as base stations installed on land.

Specifications of LoRa-GPS telemetry system include:

a) GPS Tags:

The tags were assembled with the following specifications:

1. Microcontroller : Atmel - Atmega 1284p, 8 bit microcontroller.
2. GPS : Quectel L86 Multi-constellation high sensitivity GPS/GNSS module.
3. Radio : Ai Thinker – Ra-02 433Mhz LoRa modem with 18 dbi transmit power.
4. Battery : 3.6V High discharge – Li-ion battery.
5. Antenna : 50 ohm impedence, high gain micro strip antenna.

b) Receivers:

Base stations installed on the islands and hand-held receivers will receive the data transmitted by the tags when in range. These are the specifications for the receivers:

1. Radio : Multi-Channel LoRa Radio with bi-directional communication capabilities.
2. GPRS : 1800/1900 dual band GPRS modem. 2G enabled only.
3. WiFi : 802.11n standard WiFi stack. Built-in on the SoC.
4. Microprocessor : Espressif Systems – ESP32 SoC.
5. Antenna : 23 dbi high gain omni-directional antenna.

Testing

After assembling, the different components of the system will be tested using various scenarios to check functionality.

Objective 2: To determine the green turtle diet

Green turtle faecal samples were used to determine the contents of the green turtle diet in the Lakshadweep islands. Faeces were found either floating in the water or washed up on the beach (Fig. 4); and the samples were collected opportunistically while snorkelling or by patrolling on the beach. After collection, the samples were sun-dried to get rid of the smell and to avoid fungal growth. In the laboratory, the samples were suspended in water overnight and then separated into individual fragments for microscopic analysis. The fragments were examined using a Leica microscope (Model No: DM 1000) under 10X magnification and photographed for identification purposes. Adulyanusokol & Poovachiranon (2003) were used as a reference for seagrass identification and the unidentified fragments were identified by consulting experts in seagrass and algal biology.

Fig 4. Green turtle faeces found on the beach

Objective 3: To implement mitigation measures to reduce the fisher-turtle conflict

To monitor the extent of conflict, the number of incidences, nature, and location of conflict were to be recorded bimonthly. This was achieved by accompanying the fishermen as a participant-observer on fishing expeditions. The conflict was assessed based on parameters such as gear damage, attitudes of fishers on encountering a turtle, etc. However, after a few attempts, this method was replaced by questionnaire surveys. These were conducted with 90 fishers [30 fishers per island] to record their response upon encountering turtles. The fishers were selected using snowball sampling. Before the survey, they were informed of the intent of the survey and the project, and permission was sought to conduct the survey. Moreover, the participants had the choice to refuse to answer any or all of the questions. Permission was also obtained from participants before recording their responses. Moreover, they were informed that anonymity would be maintained while synthesising and sharing the results.

Additionally, fishing sites commonly used by the fishers were mapped using a GPS. In the case of turtle encounter/sighting, the location was marked as a turtle usage site. All the locations were marked using a handheld Garmin© eTrex GPS to get a spatial spread of the conflict areas.

Also, fishers were provided with maps of the islands to mark areas commonly used for fishing as well as regions where they sighted turtles. Data from these surveys were used to demarcate areas commonly used for fishing, foraging by turtles, and the overlap between the two.

Objective 4: To explore techniques for the recovery of seagrass communities and dependent fauna

To achieve this objective, potential natural exclusion sites and artificial exclusion cage sites were first identified using snorkel surveys. Artificial exclusion cages were employed at a few sites to check for regrowth of seagrass. Moreover, this would help observe any change in site usage by green turtles. The cages were built as per Burkholder *et al.* (2013) where exclusion was provided by a 0.5x0.5m sized rebar cage inserted in the sand. Using appropriate mesh size ensured unhindered entry for fishes while restricting turtle grazing. Additionally, control sites were allocated close to the artificial exclusion sites to check for differences in seagrass abundance and growth between the two treatments. Cages and their controls were set up in regions classified as high and low foraging risk.

Results and Discussion

Fieldwork was conducted in April-May, 2018, and February-March, 2019. Due to a delay in obtaining entry permissions to Lakshadweep, the fieldwork period was limited to 2 months each year.

Objective 1:

The request to obtain animal handling permits from the Ministry of Environment, Forests and Climate Change (MoEFCC) is still pending. Due to this, the tagging, photographic identification, and morphometric program could not be initiated. However, the photographic identification technique has now been employed to create a database of turtle profiles with the help of professional divers based in the Lakshadweep islands.

Single observer transects in the three islands showed that fewer than 10 turtles were encountered in Agatti and Kadmat (Table 1). Of the three, Kalpeni showed a drastic reduction in turtle encounters within the year. This coincided with the observation that the seagrass density in Kalpeni had also reduced by 2019 (see 'Additional Surveys'). In addition to tides, fisher surveys indicated that weather influenced turtle presence in the lagoons with more turtles observed closer to or during the monsoons.

Overall, Kalpeni recorded a high abundance of turtles over the two years. In comparison, Kadmat had zero observations from 2019, but 1 green and 1 hawksbill turtle were seen near the reef region during snorkelling. These two species are known to occur in similar areas in different parts of the world as they do not compete for food resources due to their different diets. While green turtles are mainly herbivorous, hawksbill turtles are also known to consume sponges and soft corals (Palaniappan & Abd Hamid 2017). Similarly, in Agatti, 7 and 1 turtles were observed off the transects in 2019 and 2018 respectively.

Table 1. The total number of turtles encountered in the two study years saw a drop in the number of turtles observed in Kalpeni.

Island / Year	2018	2019
Agatti	9	3
Kadmat	5	0
Kalpeni	48	11

The reduction in turtle encounters in these islands, especially Kalpeni, suggests that these turtles could be moving from one island to another after exhausting the seagrass resources. Moreover, it seems that most of the population moves within the Lakshadweep islands for foraging, but a few turtles continue to remain in some of the islands despite sparse seagrass numbers as can be seen by the presence of turtles in Agatti and Kadmat. In non-breeding times, adults continue staying at their neritic foraging habitats (Lopez-Mendilharsu et al. 2005) and maintain specific home ranges (Hart and Fujisaki 2010; Christiansen et al. 2017; Levy et al. 2017). At the same time, green turtles are more likely to show behavioural plasticity in terms of change in foraging sites rather than a change in diet or foraging preference (Chambault et al. 2020). However, these assumptions need further investigation through tagging or satellite tracking to understand their movements and stable isotope analysis to determine the change in their diet.

Transects were also distributed within the lagoon to cover different strata categorized as near shore, reef, and mid-lagoon. It was observed that in Kadmat, turtles were mainly observed to be uniformly distributed in the three regions, while in Agatti, no turtles were observed in the reef region of the lagoon. On the other hand, turtles showed a clear preference for the mid lagoon area in Kalpeni (Fig. 5).

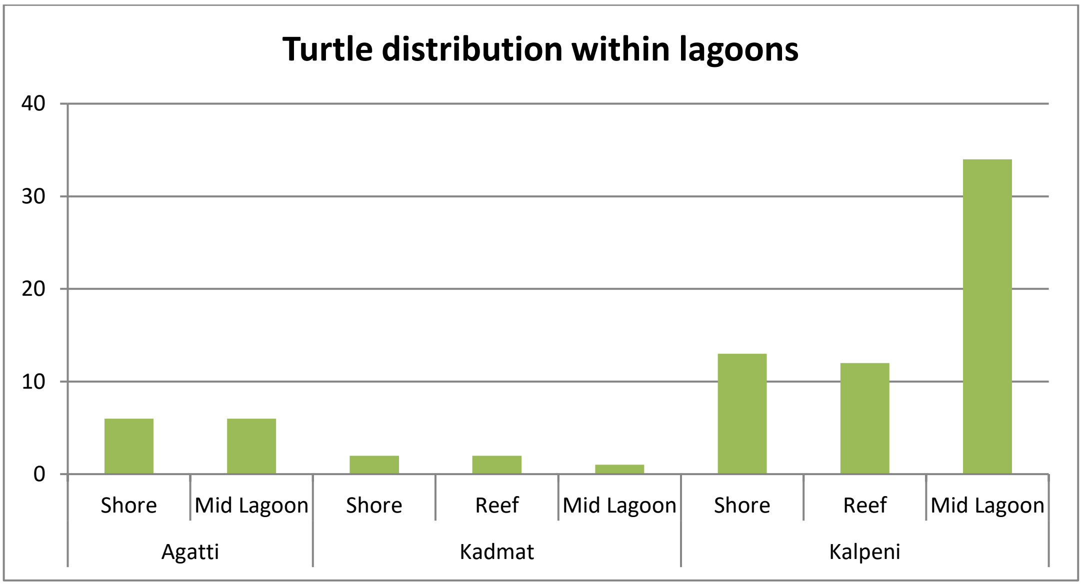

Fig 5. Distribution of turtles in Shore, Reef and mid-Lagoon areas of the islands

The firmware and hardware of the LoRa-GPS telemetry system were tested. The six GPS logger functioned well in locking geolocations and time stamps accurately. The long-range radio transmitter successfully transmitted the acquired data to a receiver station when in range. The hardware units will now be encased in a 3-D printed plastic housing and will go through tests to ensure water proofing, ability to withstand pressures and the functioning of salt water switch to switch on the logger and transmitter when a tagged individual surfaces.

Fig 6: CAD design of the tag housing with the antenna

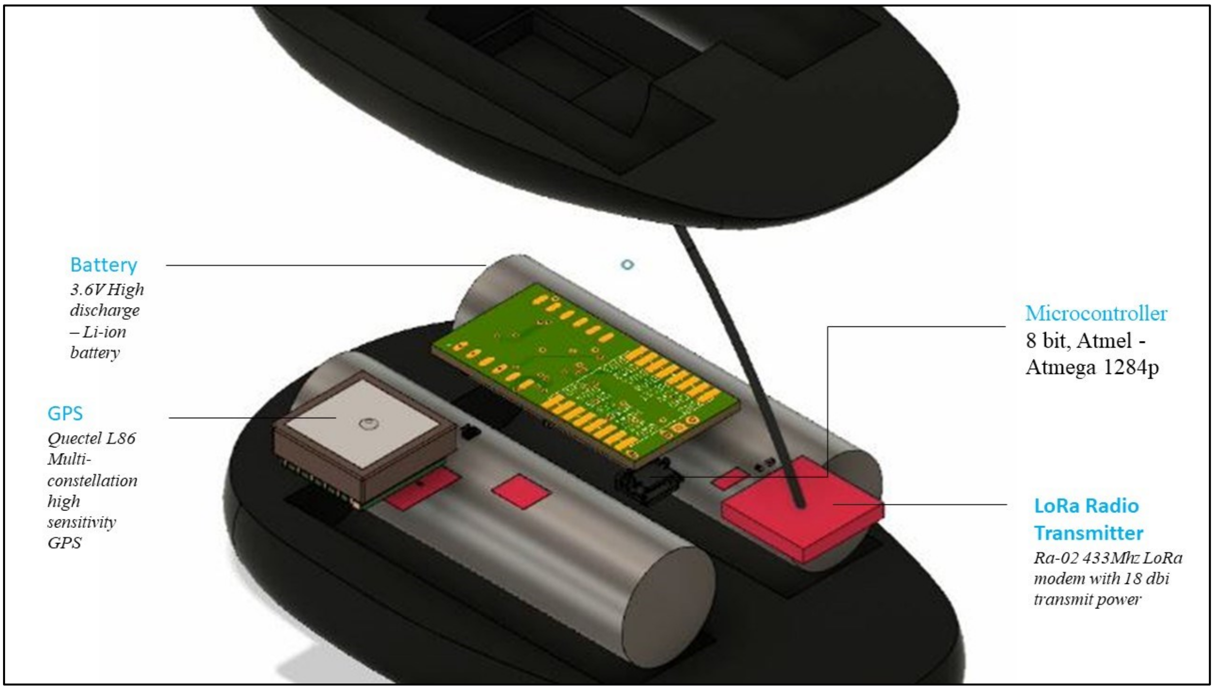

Fig 7: Components of the GPS-LoRa tag

Fig 8: Hand-held receiver to actively look for signals from tag units. The receiver can be coupled to a smartphone through Bluetooth and the data can be downloaded using a dedicated app

Objective 2:

Faecal samples were obtained mainly from Agatti and Kalpeni. Due to varying turtle presence, the faecal samples found in each island varied in the two years. After the samples were separated, the individual fragments were collected, flattened, and observed under the microscope at 40x and 10x power. While the seagrass components of the samples were easily identified, various other organic components were unidentifiable. However, some filamentous green algae (Fig. 11(b)) was found in some samples from Kalpeni island, indicating some individuals' preference towards both seagrass and algae. Cloth and plastic material were also found in the samples indicating accidental plastic ingestion by the animals (Table 10). This could be a result of poor waste management in the islands which allows the waste to make its way into the lagoons, the seagrass meadows, and consequently, into the green turtles' digestive systems. Therefore, it is necessary to address the extent of marine debris found in the lagoons and how it affects marine life.

The presence of *Cymodocea* and *Thalassia* shoots (Fig. 11(a)) and leaf sheaths (Fig. 9(a)) coincided with feeding observations from previous studies (Lal et al. 2010; Kelkar et al. 2013a); however, the presence of *Halodule uninervis* blade (Fig. 9(b)) was also detected. The segments of *Halodule* were found whole which suggests that the turtle was unable to digest the plant material. This indicates either accidental ingestion, since the leaf blades look similar to that of *Thalassia hemprichii* and *Cymodocea rotundata*, or a potential slow transition towards *Halodule* species which could suggest a diet shift. Also, there were roots and rhizomes found in many samples suggesting that green turtles employ the rare feeding strategy of digging for roots using their flippers (Christianen et al. 2014). This, in turn, indicates that the seagrass meadows of the Lakshadweep islands are potentially unable to support the green turtle population. Moreover, it calls for the need to implement strict seagrass conservation strategies to preserve the seagrass habitat as loss in rhizomes will reduce the potential for seagrass regrowth (Christianen et al. 2014).

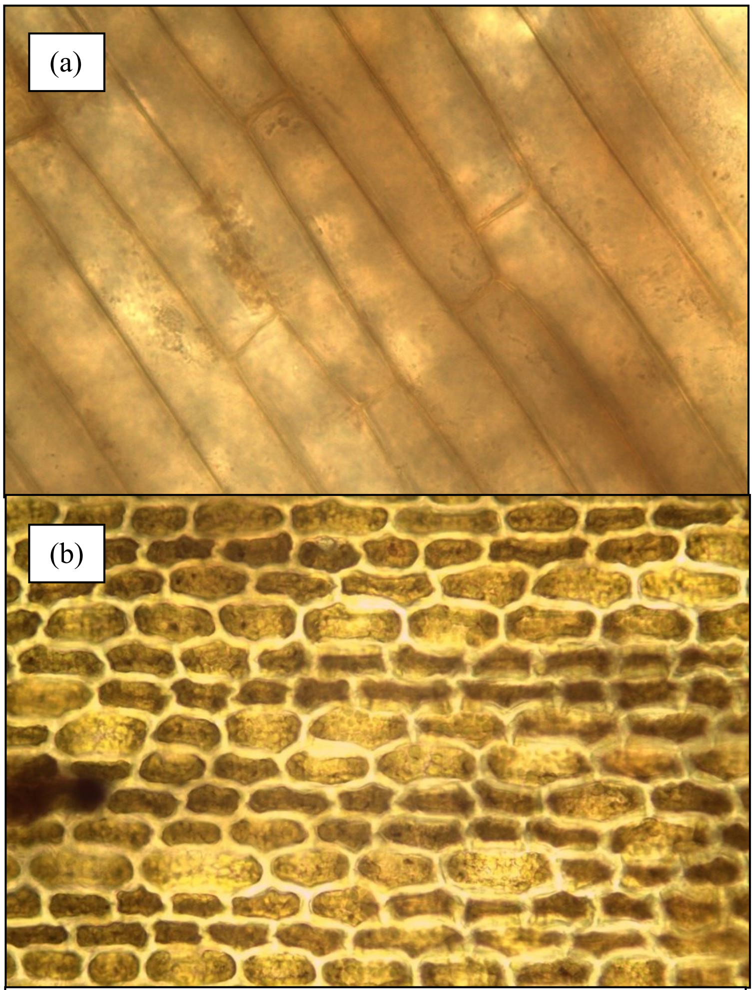

Fig 9(a). Epidermal cells of the leaf sheath of Thalassia (b). A blade of Halodule uninervis found in Agatti samples

Given below are the results collected from samples in 2018 and 2019:

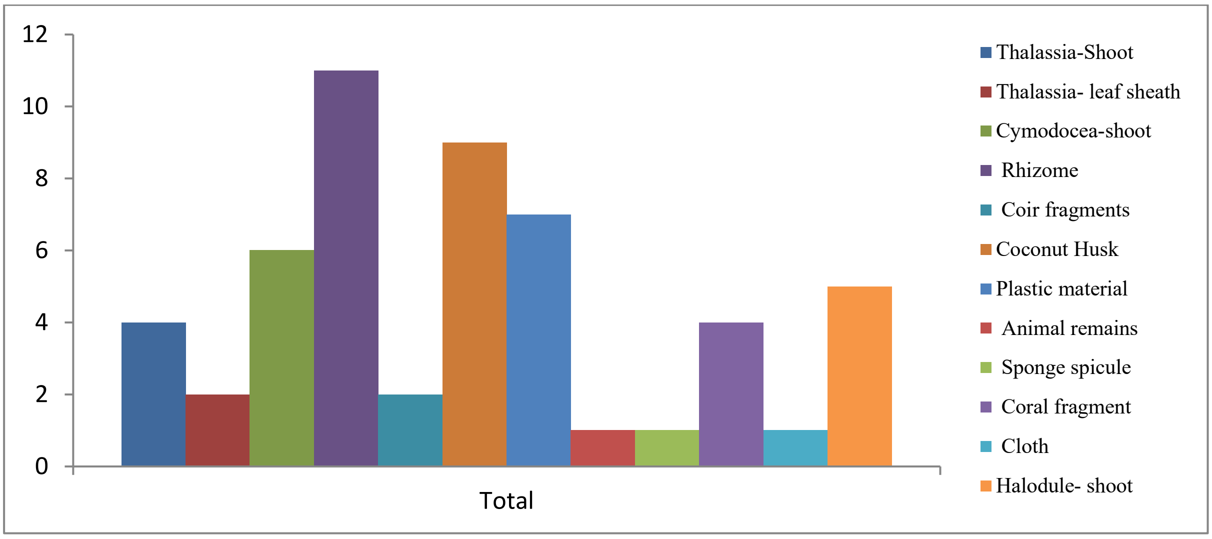

Fig 10. Contents of green turtle faecal samples

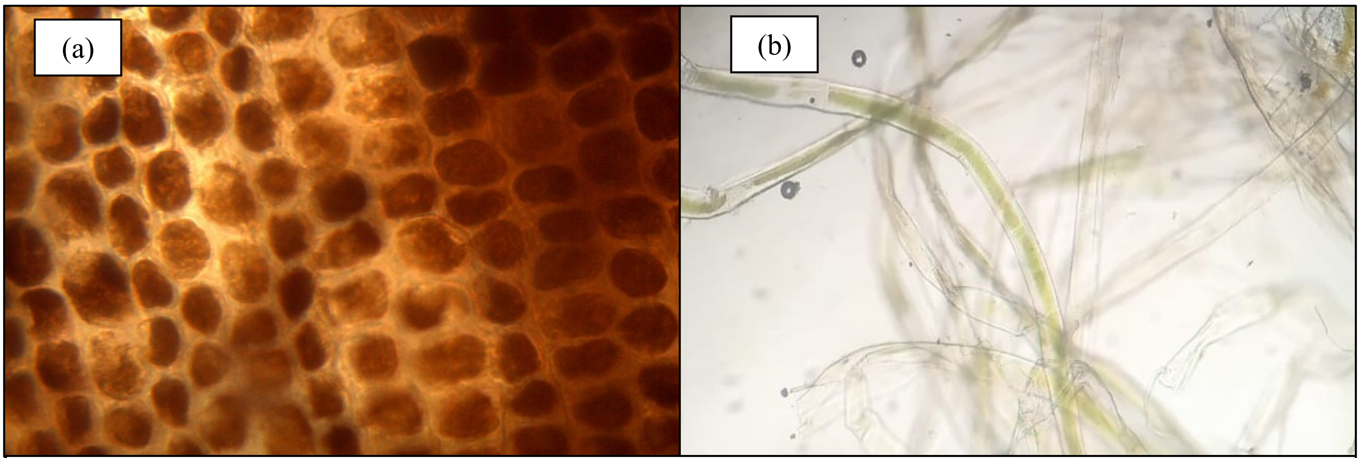

Fig 11(a). Thalassia leaf blade found in a faecal sample (b) Presence of an unidentified algal species from some Kalpeni samples.

Objective 3:

The method for this objective was altered as fishers were not comfortable having a female observer on-board while fishing. Moreover, having an observer could have affected or influenced their behaviour towards turtles on an encounter. Therefore, to understand their attitudes on encountering turtles, we conducted a questionnaire survey with 90 fishers [30 from each island]. The interviewees were selected using snowball sampling strategy.

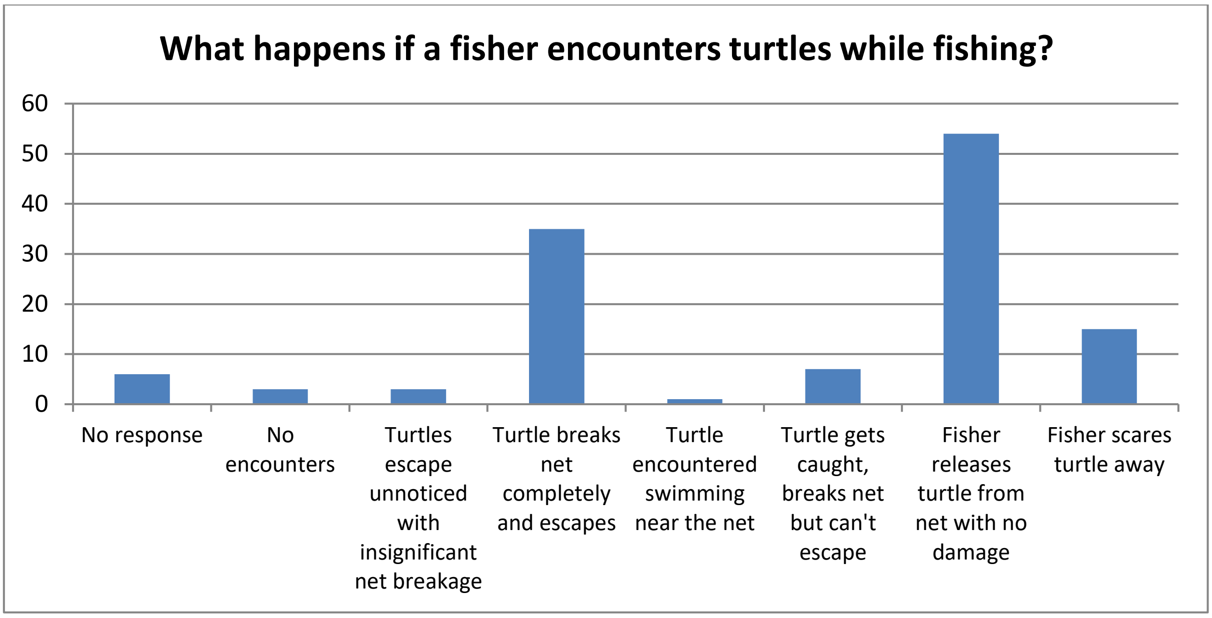

Fig 12. Responses provided by the fishermen for encounters with turtles

In these surveys, most fishers responded that they would release turtles by lifting the nets so the turtle could swim away, disentangling the turtle from the nets, or simply lifting them out by grabbing their carapace (Fig. 12). Some fishers also said that they have had to cut their net if the turtle's flippers got entangled in it. Other common responses included that turtles would break their nets and escape undetected or if seen, fishers would scare the turtles away. In order to scare turtles away, fishers said that they would hit the turtles on the carapace using sticks, make a sound in the water or on the boat, or catch turtles and tie floats/plastic bottles on their flippers to keep them from swimming towards the net. Some fishers chose not to respond or elaborate on their reactions on encountering a turtle, while others gave multiple responses.

Most fishers mentioned that only when thin, mesh-sized nets were used and/or the nets were left overnight or for a long period, turtles would get caught and mostly break the nets. The bigger nets were sturdy and rarely broke so the fishers would just release the turtles. Moreover, due to strict laws in place, most fishers said that they resorted to the removal of turtles from the net rather than other methods.

In addition, by 2019, most fishers in Agatti thought that turtle numbers had reduced in the lagoon; almost half the fishers in Kadmat and Kalpeni thought that the numbers had increased, while the other half thought they had decreased (Fig. 18).

Using researcher observations as well as the areas marked by fishers indicating commonly used fishing and turtle sighting areas, maps of the lagoons were generated. These areas were then overlaid and few areas were observed to have an overlap of fishing and turtle sighting (Fig. 13).

Due to a reduction in turtle numbers, Kadmat had fewer areas where an overlap was observed (Fig. 13(b)). However, due to the migratory nature of turtles, fishers still encountered turtles or turtles that would get trapped in nets. Moreover, in recent times, more turtles were also observed on the eastern side of the island due to some seagrass presence. This resulted in encounters with fishers, mainly with those who used nets.

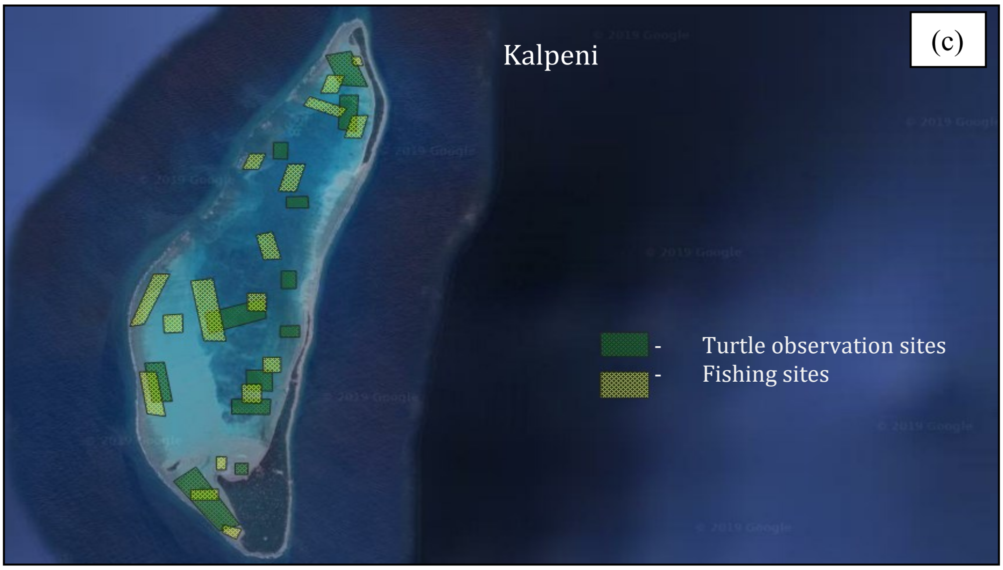

Fig 13. Areas marking fishing, turtle sightings and the overlap in (a) Agatti, (b) Kadmat and (c) Kalpeni

More areas with overlaps in fishing and turtle sites were observed in Kalpeni and Agatti than Kadmat. In Kalpeni, the main reason for the overlap was the high density of turtles in the northern and southern regions of the lagoon due to the presence of seagrass. Moreover, fishes caught as bait and other economically viable fish occur in seagrass patches which are used by fishers and turtles. resulting in frequent encounters between the two. In Agatti, despite low observations of turtle, these encounters still occur because fishers leave their nets overnight or for extended periods. Such nets end up catching turtles that are swimming through the area or resting on the lagoon floor.

As turtles move extensively within the lagoon, these encounters cannot be completely avoided especially if there is seagrass present. Moreover, due to varying densities, the number of encounters tends to vary too. Fishers also stated that the type of net plays a role in this where a thin net can be easily broken by turtles causing losses to the fishers, while a thick nets result in turtles getting caught but not tearing it.

Towards the end of this field season, these maps will be distributed to fishers- starting with those who participated in the survey- to check if avoiding areas with usage overlap reduces encounters with turtles. The success of these maps will be tested by conducting follow-up interviews in the following years.

Objective 4:

Snorkelling surveys were carried out to locate sites of natural exclusion where coral colonies served as a protective barrier for seagrass shoots. Multiple surveys were carried out in Agatti and Kalpeni; however, we could not detect any site that provided exclusion. One site in Kadmat was identified as a natural exclosure but no seagrass shoots were found there in 2019 (Fig. 14).

	
Fig 14. Thalassia shoots growing under the protection of coral in Kadmat	*Fig 15. An exclosure set up on the eastern side of Agatti*

Artificial 0.5x0.5m exclosures were set up in the lagoons to preserve seagrass species that were observed to form a green turtle diet (Fig. 15). These exclosures were set-up to protect the seagrass from green turtle grazing but to allow fishes to enter and exit the cages. These cages were mainly put over *Thalassia* and *Cymodocea* species as they were commonly observed in green turtle faecal matter [see 'Additional surveys'].

Due to the short time of the exclosure casting (2 months/year), there was no change in length or density in the seagrass shoots observed. However, the density of shoots was maintained within the exclosure while some change was observed at the control region of one of the exclosures. As most seagrass species are slow-growing, these exclosures need to be inserted for at least 5-6 months to observe a measurable change in the density as well as the length of the seagrass shoots. Moreover, to ensure that the seagrass grows undisturbed, the patches need to be maintained over a few years. This will be achieved by obtaining help from youth or fishers who would assist in maintaining the exclosures mainly during the monsoons, and till the start of next fieldwork season. Secondly, the material for the exclosures seems suitable to be used in the water; however, it requires cleaning every week at least. Therefore, different materials need to be tested in the following seasons including those that do not require frequent cleaning.

Conclusion

There is a need for detailed studies on the ecology of green turtles found in the Lakshadweep islands. Information on the aspects of green turtle biology such as changes in abundance, diet, as well as source populations that utilise these foraging grounds will be crucial to understand this population and its management to protect seagrass as well as to reduce conflict.

The change in turtle abundance at the islands every few years necessitate the implementation of a strict conflict mitigation strategy that can be replicated across islands. It has been observed that islands with high seagrass resources in the lagoon have witnessed sudden increases and then drops in green turtle abundances in a few years as the seagrass (mainly *Thalassia* and *Cymodocea)* density reduces. It indicates a need to understand the movements of these green turtles and the cues they use to find foraging grounds to determine the next potential foraging site which will be attempted next year with the use of the LoRa GPS tagging system. This information can be used to initiate seagrass preservation efforts in islands where green turtles could potentially go and to spread awareness on interactions with turtles while fishing.

Seagrass conservation needs to be undertaken in collaboration with the local community as well as government agencies. Due to strong currents, the exclosures tend to get compromised and washed away or washed up on the beach. To ensure that the seagrass can regrow without disturbance, it is crucial to engage with the island inhabitants to maintain the exclosures year-round and over years.

The fisher surveys indicated that there is a need to spread awareness about the importance of sea turtles in the ecosystem. As turtle grazing has caused a decline in seagrass numbers and consequently, decreases in seagrass associated fishes, fishers consider turtles a nuisance. To change their attitudes towards turtles, it is important to inform the community of the roles of marine megafauna and especially sea turtles in the ecosystem.

All this information will consequently feed into improving our knowledge of the green turtles from the Lakshadweep islands. As per the recent MTSG regional assessment, green turtles in this region are poorly studied (Phillott and Rees 2018), and therefore, their regional conservation status needs to be determined. Further studies will aid in devising management strategies as well as assist in global green turtle conservation assessment. Moreover, the seagrass and algal resources of the Lakshadweep islands should be considered regionally important foraging habitats for sea turtles as well as other marine species, and the conservation of these resources must be undertaken to preserve the lagoon ecosystem.

Additional surveys

To support the findings of this study, we conducted some additional exercises which included seagrass density surveys, and surveys with fishers. The purpose of this additional data was to understand the diets of the green turtles, the relation between turtle and seagrass densities, and recording local knowledge regarding turtles such as changes in their population and its causes, behaviour, consumption, and attitudes of fishers towards turtles.

a) Seagrass surveys

Seagrass surveys were conducted by randomly selecting 28 points within the lagoon and surveying the points in the four directions- North, South, East, and West. After every 8 fin strokes, a point count was taken and the substrate was checked for seagrass presence. Upon encounter, seagrass species and density were noted. These surveys were conducted to check for correlation between turtle density and seagrass density in the islands. As mentioned in Objective 2, Kalpeni showed a decrease in the number of turtles which corresponds with the reduced density of seagrass observed.

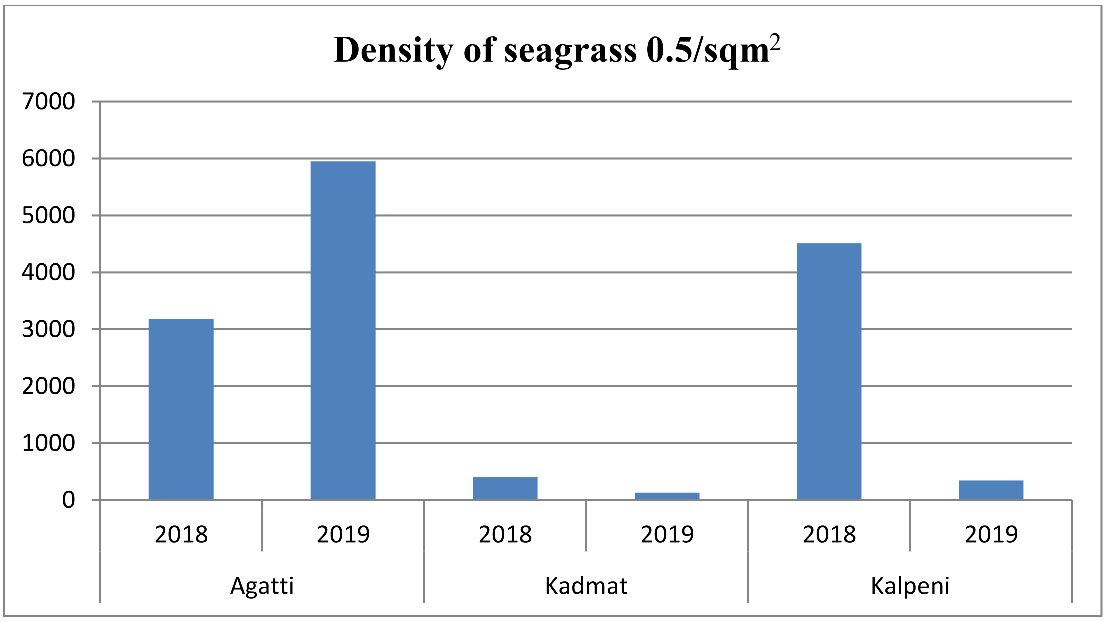

Fig 16. Changes in density of the seagrass observed in 2018 and 2019

While the decrease in Kalpeni was mainly that of *Thalassia*, a species preferred by the green turtles in the Lakshadweep islands, an increase in the number of *Halophila* shoots was observed in Agatti. Seagrass was also seen on the eastern side of all the islands. However, these were not included in the surveys. *Halodule* species was also observed in Agatti and Kalpeni; however, it was not detected during the surveys.

In addition to the seagrass on the western side of the islands, considerable amounts of seagrass were also observed on the eastern side of the islands mainly *Thalassia* and *Cymodocea* species in Agatti and Kadmat. Consequently, turtles were also observed on the eastern side, corroborated by fisher accounts of how the turtles have also moved from the western to the eastern side of the lagoons.

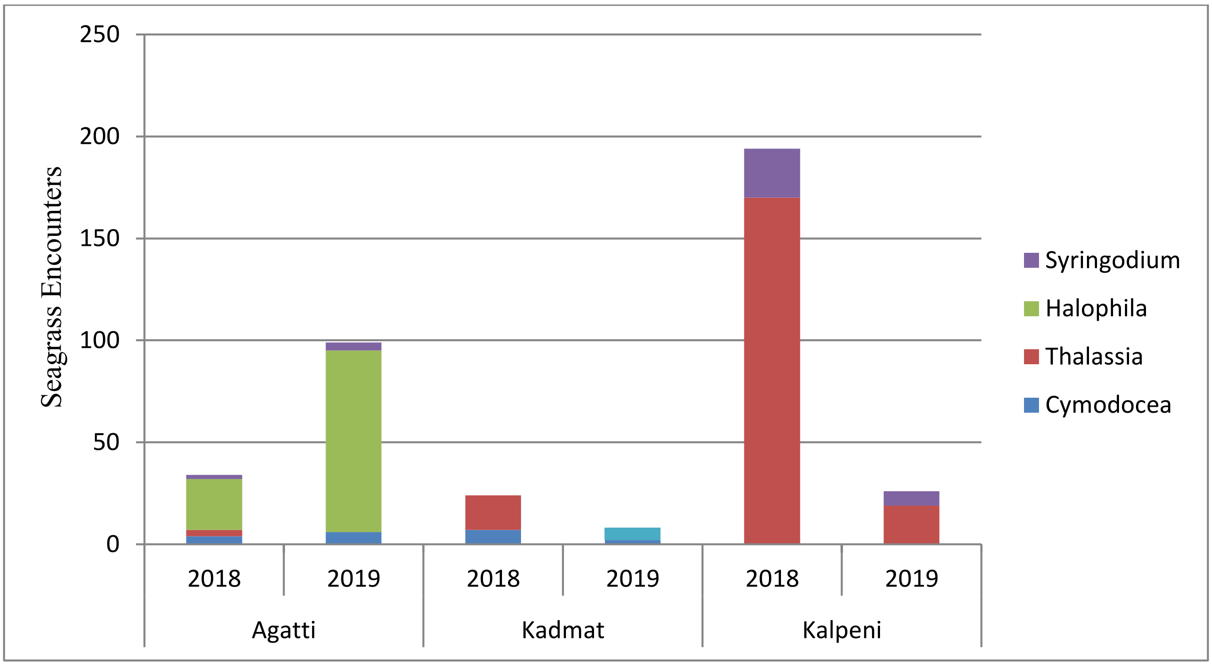

Fig 17. Seagrass species encountered in 2018 and 2019

b) Fisher surveys

Questionnaires were used to collect local knowledge of turtles. As fishers come into contact with turtles often, 30 fishers per island participated in the exercise [n= 90 fishers]. They were asked for details such as a change in turtle numbers observed, reasons for changes in their numbers, the number of species observed and their description, turtle consumption in recent times and the past, fisher encounter with turtles, etc. The results for some of the questions are given below.

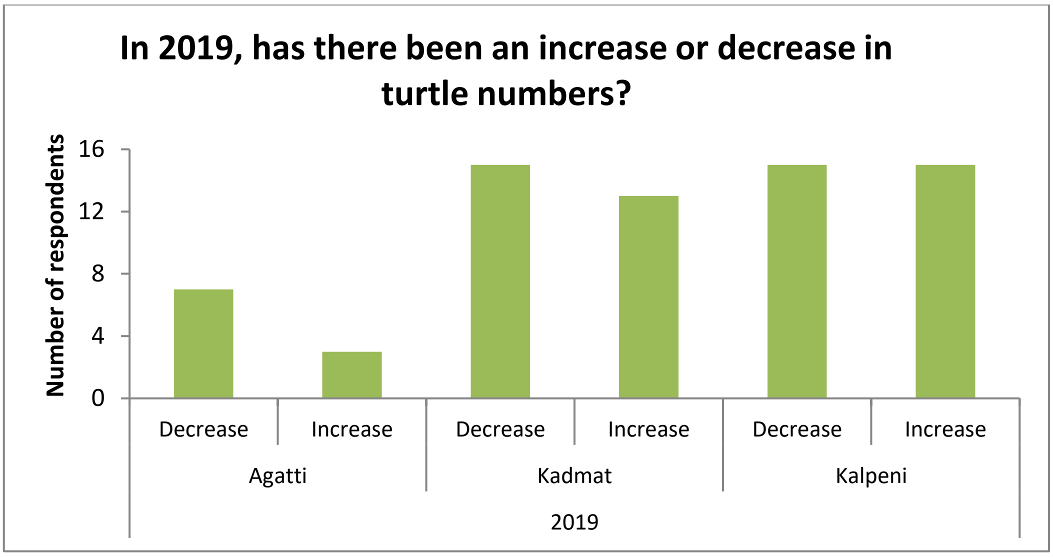

Fig 18. Responses to current turtle densities in the lagoons

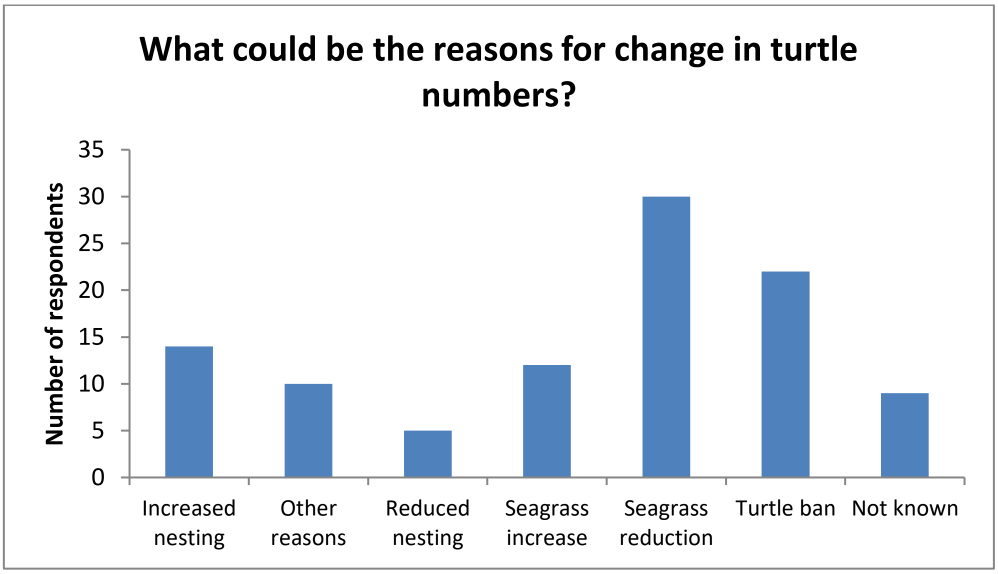

Fig 19. Responses to reasons for changes in turtle number

Caveats and constraints

The delay in obtaining animal handling permits hampered some of our objectives including tagging and photo-identification. The request is still pending at the Ministry of Environment, Forests and Climate Change, India. Delays in receiving entry permits into the islands were also a barrier and it restricted the time for fieldwork.

Due to the slow-growing nature of seagrass, we were unable to discern any measurable growth in the seagrass blades that were protected using the exclosures. Moreover, wave action during high tide and monsoons compromised some of our exclosures resulting in removal, especially of those on the eastern side of the islands where the exclosures could not be inserted properly due to rocky substrate.

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