OLIVE RIDLEY
PROJECT

Research Report and Proposal:
Study of Maldivian Sea Turtle Nesting Populations via Nesting Surveys & Nest Excavations

Introduction and previous work

The Olive Ridley Project (ORP) has been working towards strategically monitoring sea turtle activity in the Maldives since 2013 with the aim to identify, evaluate and protect sea turtle nesting areas in the country. The establishment of a long-term dataset will be part of the necessary framework for the evaluation of population trends and thus the establishment of conservation efforts.

Our nesting research started based on opportunistic citizen-science data collection of nesting activity in the country. The data collection process was formalised as part of the TurtleWatch Maldives program designed by the Marine Research Centre, and led to a first publication in 2017 (Hudgins et al. 2017). Consistent data collection including nest content analysis post hatching was established in 2017 in all locations with ORP biologist and veterinary staff on site. In subsequent years the collected data was used in various reports, e.g., the country chapter for the IUCN Marine Turtle Specialist Group Annual Regional Report (Ahmed et al. 2019, 2020, 2021) and respective technical reports from ORP (latest: Afeef et al. 2021, Gervolino et al. 2022). Additionally, the ORP Nesting Protocols developed in 2021 in consultation with the Environmental Protection Agency of the Maldives (EPA) were further improved and updated, with a latest version available from October 2023 (Annex III), which can support the effort of standardising data collection methods throughout the country, and which are shared with interested parties.

Country Wide Overview

We have been collecting data in the Maldives since 2017 with the goal of understanding nesting seasonality, regional distribution of nests, and hatching success. With the data collected by our Biologists in Lhaviyani since November 2017 and in Laamu since 2018, supplemented by citizen science contributions nation-wide, we are finalising a summary of nesting activity in the Maldives from 2018-2022. The findings to an international scientific audience at the 41st International Sea Turtle Symposium in Cartagena, Colombia, in March 2023. The respective manuscript to be handed in for peer review has been held back from last year to include 2022 in the reporting period and therefore strengthen the overall analysis. We are aiming to hand this in for peer review in the coming months.

2018-2022 Overview

We have recorded a total of 1110 incidents of nesting activity between January 2018 and December 2022, out of which 657 were true nests and 453 nesting attempts or false crawls. The majority of the nests were laid by green turtles and the data was distributed between ten atolls (**Fig. 1**). The highest number of nests have been recorded in Laamu, Noonu, Baa and Lhaviyani (**Fig. 2**). The large number of nests and false crawls from N. Medhufaru and Budufushi were predominantly reported in 2022 since we had two team members stationed on Medhufaru who ensured regular monitoring. Overall, Noonu atoll is now the atoll with the second highest number of nests recorded over the five year period, indicating that it might be a critical nesting spot. Preliminary findings from 2023 suggest that nesting activity is always comparatively high in Noonu, despite regular annual variation. This is a first hint that while N. Medhufaru was not included in the initially designated nesting hotspots nationwide by the Ministry of Fisheries in 2006; it might deserve to be included.

A more detailed analysis of green turtle nesting was conducted, due to the low number of nests recorded of other species. Our findings clearly indicate that there is no distinct nesting season in the Maldives for green sea turtles as nesting happens all year round (**Fig. 3**). We do, however, observe a clustering of nests towards the middle of the year during the Southwest monsoon season. This is typically the monsoon season with the higher amount of rainfall. Sea turtle nesting season also coincides with the rainy season in other parts of the world (Hart et al. 2018, Patrício et al. 2019). Our data shows a potentially high variability between different atolls (**Fig. 4**) and different years (not shown), further emphasising the lack of a distinct nesting season.

From 2018-2022, 34 nesting female green turtles were identified with the help of photo identification (Jean et al., 2010). Out of these, 16 individuals were observed during multiple

years. The remigration interval varied between 18 months and five years, with an average of three years, which is in agreement with other observations for this species (see for example Hughes 1995, Troëng & Chaloupka 2007). On average, females were observed laying 1.4 clutches of eggs per year. This rather low number is most likely an artefact due to females not being observed for every clutch that they have laid. To avoid this, intensive night time beach monitoring would be required, a task which is only feasible with a larger dedicated team performing consistent night time patrols, which is challenging to implement due to the geographical and logistical constraints of the monitoring area.

The hatching success rate of green turtle nests in the Maldives continues to remain high compared to reports from most other rookeries (see Hirth 1997 for a summary, other examples Fowler 1979, Broderick et al. 2001, Turkozan et al. 2011, Comer Santos et al. 2017, Calderón Peña and Azanza Ricardo 2021), as pointed out in the last permit report. The prevalence of congenital malformations also continues to be low, compared to the prevalence reported in other studies (see Bárcenas-Ibarra et al. 2015 for a review). A more detailed description of abnormalities and malformations observed will be prepared in the coming year.

January - October 2023 Overview

Up to 15th of October 2023 we have recorded 234 nests nationwide, with the highest nesting activity recorded in Noonu and Baa atoll. Nesting data has been collected from Noonu, Raa, Baa, Lhaviyani, North Malé, Shaviyani, and Laamu with support from citizen scientists.

We continued monitoring the temperature of nesting beaches this year, with temperature loggers deployed in Laamu, Lhaviyani, and Noonu. Temperature loggers have been placed next to 21 nests in total since the beginning of monitoring. Further data will be collected in preparation for a statistical analysis of the recorded temperature data, which we plan to carry out in the next year (minimum of ten nests per location with collected data).

Similar to 2022, sudden severe storm surges influenced nesting beaches during the middle of the calendar year, with beach inundation occurring in June to August. Due to the unpredictable nature of storm surges, three nests on L.Olhuvelhi and six in N.Medhufaru were flooded despite our best efforts to conduct nest relocations on time.

Successful relocations were conducted for a total of twelve nests, as per the protocol under EPA permit number EPA/2023/PS-SP/02. Relocations were carried out as soon as the special permit was issued and training of the relevant staff members could be insured. A detailed analysis of

hatching success in relocated vs natural nests is currently being carried out and will be shared with the EPA with the respective permit report.

Spotlight: L.Gaadhoo Nesting Overview

Since January 2023, ORP and EPA have conducted consistent nesting surveys of L. Gaadhoo. 91 nests, and 70 false crawls have been recorded up till October 2023. We also began collecting excavation data from Gaadhoo - 13 nests have been excavated opportunistically, with a median hatching success rate of 94.8%.

Proportion of poached nests by year is visualised in Annex II.

Atoll Overview (alphabetical order)

Charts displaying 2023 all nesting activity per atoll **(Fig. 5)** and per month in **(Fig. 6)** are available in Annex III.

Baa

In 2023, we recorded 29 incidents of nesting activity in Baa, with 24 true nests in total. Ten nests were laid on Dhuni Kolhu, five on Avani & Fares, two on Hanifaru and The Westin Miriandhoo Maldives, and one true nest in Amilla, Dhigufaru, Landaa Giraavaru, Maalhos, and Soneva Fushi respectively. The ORP team monitored the nests on Dhuni Kolhu and Amilla directly and received citizen science reports from the others. While the majority of the nests were laid by green turtles, one hawksbill nest was observed on Amilla and Dhuni Kolhu each.
The hawksbill turtle that nested on Dhuni Kolhu on September 12th has been known to ORPs photo ID database since 2014. The turtle dubbed ‘Lola’ has a curved carapace length of 79cm. She is usually spotted foraging on the house reef of the island or on the reef of B.Muthaafushi. This is the first instance of a turtle known from the foraging population of the Maldives to also be observed nesting in the country.

Additionally, one olive ridley nest was seen hatching on Dhuni Kolhu in March 2023. This is the 11th olive ridley nest recorded in the Maldives since the beginning of our records, and the first on Dhuni Kolhu after a nesting attempt which was observed in February 2019.

Laamu

A total of 37 true nests and 54 false crawls were recorded in Laamu this year. Nesting activity was recorded on Olhuveli, Gaadhoo and Hulhimendhoo, with the most activity still occurring on the hotspot beach of Gaadhoo (23 true nests, 35 false crawls). There were 13 true nest observed on Olhuveli and 19 false crawls. A true nest was unexpectedly observed on Hulhimendhoo during a daytime excursion to the island. Regular nest monitoring on Olhuveli and Gaadhoo was carried out by the ORP Sea Turtle Biologist as well as the Sea Turtle Ranger.

Nesting activity was observed in all months of the year except for July. Median hatching success rate was 89.2% across all nests. Six nests on Olhuveli had a hatching success rate of less than 15% (see **Table 1** below). Two of those nests were flooded despite relocation efforts and two nests showed damage from infiltrating roots. Three of the six nests had less than 60 eggs in total, which is a very small clutch size for green turtles with a usual average clutch size between 100 and 120. This potentially indicates that the nutritional or health status of the nesting female might not have been ideal. In addition to that, one of the six nests also presented a cluster of four embryos with severe congenital malformations (including albinism, kyphosis, anophthalmia), again hinting at potential underlying genetic or physiological issues.

Table 1: Details of six nests with unusually low hatching success rate observed at L.Olhuvelhi.

Nesting date	Emergence date	Excavation date	Nest ID	Emergence success %	Hatching success %	Notes
07-Jan-23	04-Mar-23	11-Mar-23	O2023N01	6.0	6.0	Root damage
10-Jan-23	15-Mar-23	18-Mar-23	O2023N02	6.9	6.9	Root damage
21-Feb-23	None emerged	23-Apr-23	O2023N04	0.0	10.2	Possible flooding
31-May-23	None emerged	23-Aug-23	O2023N09	0.0	0.0	All eggs discoloured
11-Jun-23	None emerged	23-Aug-23	O2023N10	0.0	5.5	Flooded
08-Aug-23	Emergence not witnessed	14-Oct_23	O2023N11	3.9	5.1	Congenital malformation

Nest excavations could be carried out on Gaadhoo for the first time this year. Interestingly, all nests examined showed an incredibly median high hatching success rate of 94.8%. This high success rate again confirms the importance of Gaadhoo as a sea turtle nesting location where despite beach erosion and accumulation of marine debris any nests laid can make a significant contribution to the turtle population.

The median number of incubation days has fluctuated over time **(Fig. 7)**, in 2021 was 58 days, rising to an all time peak of 65 days incubation in 2022. A median of 58 days was observed during 2023 nesting season.

Temperature loggers were deployed next to 9 nests in 2022 and 8 nests in 2023 to collect beach temperature data during the incubation period.

Lhaviyani

Nest monitoring in Lhaviyani was challenging in 2023 due to changes in staff in the ORP team as well as in any previously contributing citizen scientists. Nevertheless, 15 instances of nesting activity were observed, including six true nests laid on Kuredu, two true nests in Maabinhura and one in Dherofinolhu. None of the nests were flooded, even though one of them had to be relocated. Unfortunately, no excavation data is available for this year.
No new nesting activity has been recorded since our staff has returned to the atoll in May 2023.

North Malé

In 2023, we recorded 1 true green turtle nest in Reethi Rah, with a hatching success rate of 43.4%. In addition to that, two hawksbill nests were reported from the Fari Islands in June, one from Patina and one from Ritz Carlton. The hawksbill turtle that nested on Patina, struggled with the hard substrate, which led to 21 of the 147 eggs being crushed during the nesting process. The remaining eggs were left for incubation and hatched in August with a hatching success rate of 81%, as reported by Patina's resident marine biologist. The nest on Ritz Carlton was laid in the vegetation and protected from interference by the resident marine biologist. No excavation was carried out.

Noonu

Until October 15th in 2023 there had been 263 nesting incidents resulting in 96 true nests. 77 nests were reported by our biologist in Medhufaru, with an additional 17 on N. Bodufushi and two on N. Orivaru from a citizen scientist report. The overall nesting activity was very similar to 2022, with slightly more false crawls and slightly less true nests overall, indicating a very stable nesting population despite the usual variation to be expected between individual nesting seasons and years.

Three nests on Medhufaru had to be relocated due to being at risk of immediate flooding. Six nests flooded during spring tides and unprecedented high waterlines.

Excavation data was collected when hatched nests are found during survey walks on the nesting beach. A total of 37 nests were excavated so far. A technical analysis of nesting data will be conducted at the end of the year.

Raa

In 2023, 43 instances of nesting activity were recorded in Raa atoll, with 28 true nests reported in total. The nests were found on the following islands: eight on JOALI BEING, eight on Reethi Faru, four at Vandhoo, three on Maamunagau, two nests from Cora Cora, and one on Fenfushi, Joali Maldives, Murahvandhoo and at The Standard Huruvalhi respectively. All of these nests were laid by green turtles, except for one nest on The Standard Hurvualhi and Joali Maldives Muravandhoo each, which were laid by olive ridley turtles.

No flooding of nests was recorded and no nests had to be relocated. Total median hatching success for green turtle nests in the atoll was 90%. No information is available for the olive ridley turtle nests.

Shaviyani

Since being stationed in Shaviyani atoll in 2023 there have been 40 instances of nesting activity recorded on Gaakoshibee island with a total of 15 true nests. Two nests were relocated due to being at risk of flooding, with a hatching success of 89.17% and 72.73% respectively. There are five occasions of abnormal development observed in embryos and hatchlings: 1) albinism & supernumerary scutes, 2) kyphosis, 3) missing scutes, 4) supernumerary scutes, 5) vertebral scutes fused together. A detailed report on nesting data will be provided at the end of the year.

Future

The aim of the research project is to continue the established long-term time series for the evaluation of population trends, comparison of nesting seasons between different atolls and years, and the estimation of the length of reproductive cycles of individual females in the Maldives.

Additionally, it is our aim to further support emerging new research groups together with the EPA through the sharing of knowledge, the publication of findings and the constant reevaluation and updating of published guidelines.

We reevaluated our aim to publish the analysis of our data from Maldives for 2018-2021 to include the full year 2022. Details will be prepared for Laamu, as in previous years, for Shaviyani, and also for Noonu, to cover the first two full years of consistent nest monitoring by our team in

the atoll. Publications will include non-peer-reviewed reports, as well as peer-reviewed manuscripts in relevant journals.

We will also be conducting an analysis on nesting beach temperature with data collected across atolls, if enough data is available. We are working on the installation of weather stations to monitor localised weather conditions including rainfall in the two main nesting areas Laamu and Noonu atoll.

We will continue to work on the establishment of using drone images for the documentation of changes in coastlines and beach profiles. Due to the placement of our research team on resort islands, this has proven to be a challenging endeavour, balancing the needs of all parties.

Methodology

All methods will be applied as detailed in the ORP Nesting Protocols 2023 (Updated October 2023, Annex III).

Beach surveys: Islands will be surveyed for nesting females in the evenings and for new nests in the mornings by ORP and by trained resort staff (e.g., security performing regular island checks in general). In case a nesting turtle is encountered, the ORP Biologist will be on site to ensure that the nesting female is not disturbed.

Nesting data: Nesting females will be approached for data collection only after they have finished digging the nest cavity and started laying eggs. Only red light will be used during the night around nesting females. Light use will be kept to a minimum. Females will be photographed (Photo-ID) and their carapace length will be measured. If the female is observed nesting, the number of eggs will be counted. A GPS point will be taken at the location of the nest, and track measurements will be taken. Where nesting beach temperature research is being conducted, the temperature logger will be buried close to the nest at the estimated mid-depth of the egg chamber. The temperature logger will be collected during nest excavations.

Excavations: After a nest hatches naturally, permit-holders will excavate the nest about 48 hours after the last hatchlings have emerged. Live hatchlings found in the nest will be allowed to run down the beach into the ocean together. Dead hatchlings, unhatched eggs, and eggshells will be counted in order to determine the total number of eggs laid and hatching success. Excavating nests will allow us to accurately determine hatching success and identify embryos with congenital malformations.

Database management: Metadata will be entered into a database for each nesting attempt or true nest. These include: date, time, location (GPS), observers name, track width, true nest or false crawl. If the turtle was observed nesting: number of eggs, curved carapace length (CCL) or straight carapace length (SCL) of the nesting female, ID-photos and any additional information pertaining to the encounter.

Data sharing: Data will be shared with the EPA along with any Maldivian Government agency as required along with the larger community of biologists in the Indian Ocean and International Sea Turtle community through various means (reports, presentations and publications).

Drone monitoring: Changes of nesting beaches will be monitored with monthly drone surveys on islands Biologists are based on, to understand the tidal patterns and become better prepared for predicting and documenting the need for nest relocations. The aim is to document beach erosion events. Flight paths over nesting beaches will be chosen in cooperation with the respective resort and will include fixed landmarks for referencing of the captured images. In case of adverse weather events with sudden beach erosion, additional drone flights will be scheduled.
The drone flights will be conducted by trained resort personnel - e.g., marketing team or photography group on each island - under the guidance of the respective biologist to ensure consistent flight paths.

Research Area

Maldives - nationwide
Nest excavations will only be conducted on:

Atoll	**Name of island**	**Resort based on island**
Shaviyani	Gaakoshibee	Fairmont Maldives Sirru Fenfushi
Noonu	Medhufaru	Soneva Jani
	Budufushi (Chicken Island)	(uninhabited)
Raa	Bodufushi	Joali Being
Baa	Dhuni Kolhu	Coco Palm Dhuni Kolhu
	Finolhas	Amilla Resort and Residences

Lhaviyani	Kuredu	Kuredu Island Resort
	Jehunuhura	(uninhabited)
	Masleggihura	(uninhabited)
	Kanuhura	Six Senses Kanuhura
North Male’		One&Only Reethi Rah
Laamu	Olhuveli	Six Senses Laamu
	Gaadhoo	(agricultural island under the company AgroNat)

Team members

The ORP team contributing to the project consists of members currently working in the country, who will be the primary data collectors in the field, as well as senior team members coordinating the project, curating data and overseeing the publication process.

Field team

Neus Segura	Sea Turtle Biologist, Fairmont Maldives, *Shaviyani*
Sarah Patman	Sea Turtle Biologist, Soneva Jani, *Noonu*
Abdulla Iyaan Ahmed	Sea Turtle Biologist Intern, Soneva Jani, *Noonu*
Shah Rasheed	Sea Turtle Biologist, Joali Being, *Raa*
Tristan Neto	Veterinary Nurse, Coco Palm Dhuni Kolhu, *Baa*
Adam Athif Mohamed	Marine Turtle Rescue Centre Intern, Coco Palm Dhuni Kolhu, *Baa*
Maria Izurieta	Sea Turtle Biologist, Kuredu, *Lhaviyani*
Afrah A. Sathaar	Sea Turtle Biologist, Six Senses Kanuhura, *Lhaviyani*
Philippa Darbyshire-Jenkins	Sea Turtle Biologist, One&Only Reethi Rah, *North Male’*
Julian Gervolino	Sea Turtle Biologist, Six Senses Laamu, *Laamu*
Mohamed Ziyan	Sea Turtle Biologist Intern, Six Senses Laamu, *Laamu*

Coordinators

Dr. Stephanie Köhnk, Senior Project Scientist
Jane Lloyd, Database Administrator
Dr. Martin Stelfox, CEO & Founder
Fathimath Isha Afeef, Maldives Project Manager

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ANNEX I - Figures

NESTING ACTIVITY OVERVIEW 2018-2022

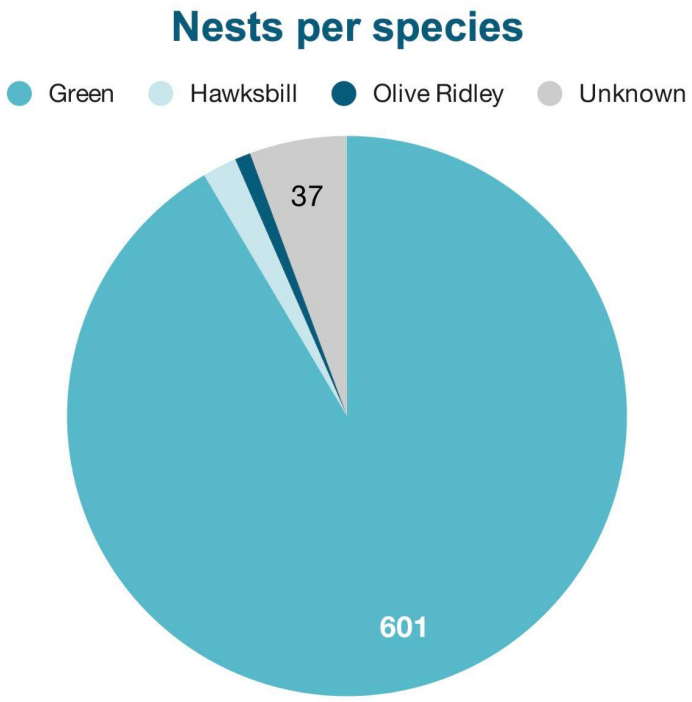

Fig. 1: Reported nests per species in the Maldives in 2018-2022. Vast majority of nests on record are green turtle nests.

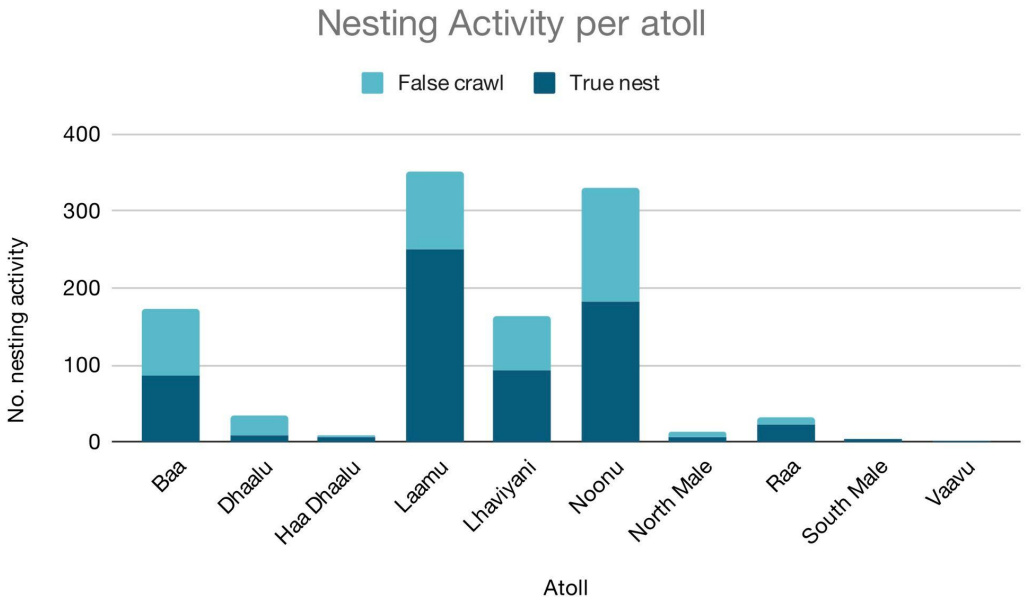

Fig. 2: True nests and false crawls recorded for all species per atoll in 2018-2022. Highest number of nests were recorded in Laamu and Noonu atoll.

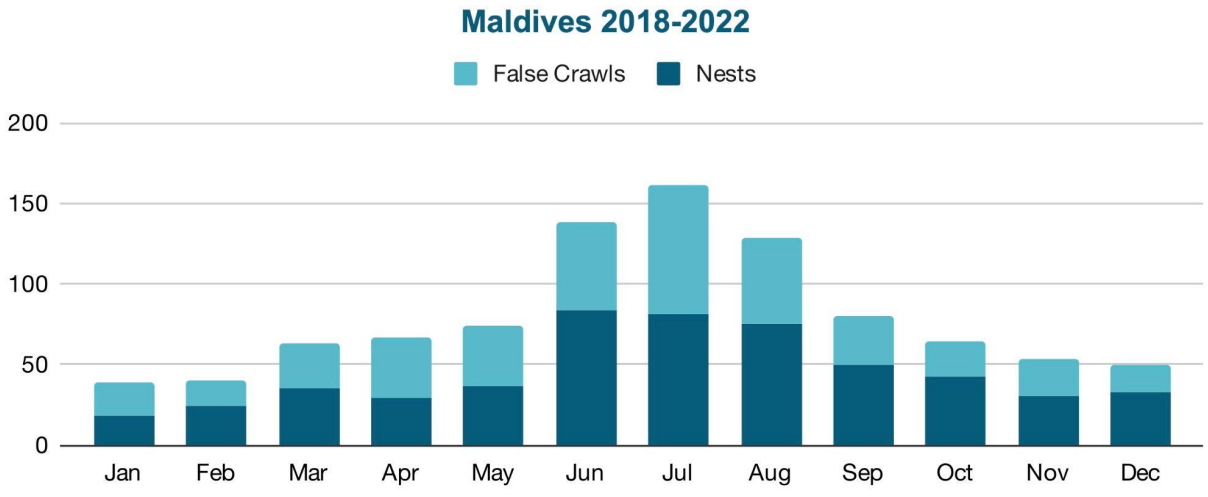

Fig. 3: Nesting Seasonality

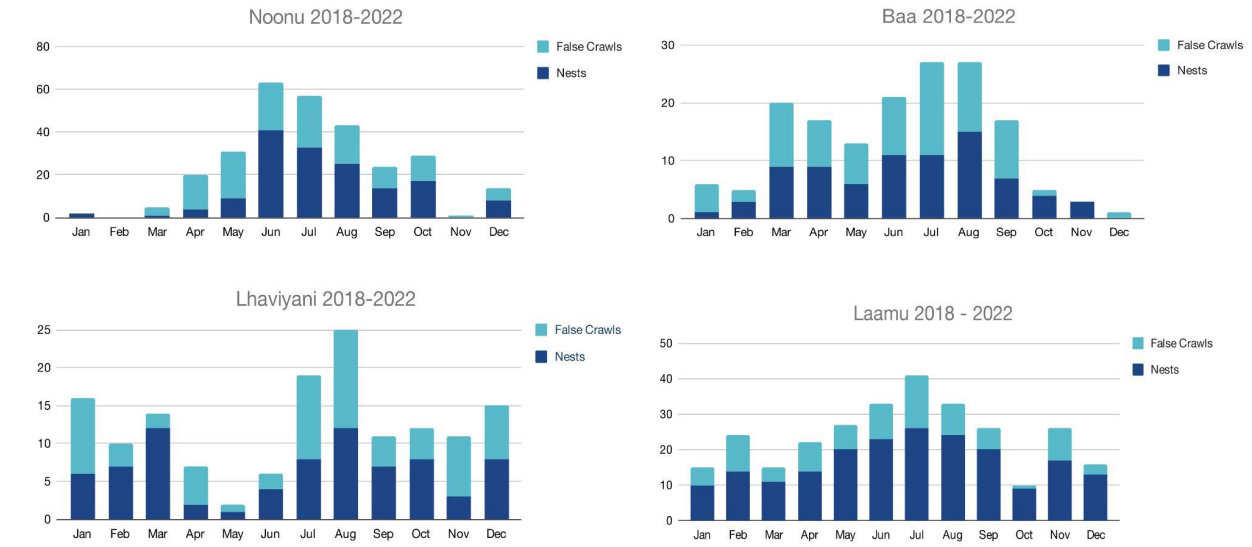

Fig. 4: Nesting seasonality per atoll, using the example of the three atolls with the most recording nesting activity.

ANNEX II - Gaadhoo

L. GAADHOO PROPORTION OF POACHED NESTS BY YEAR

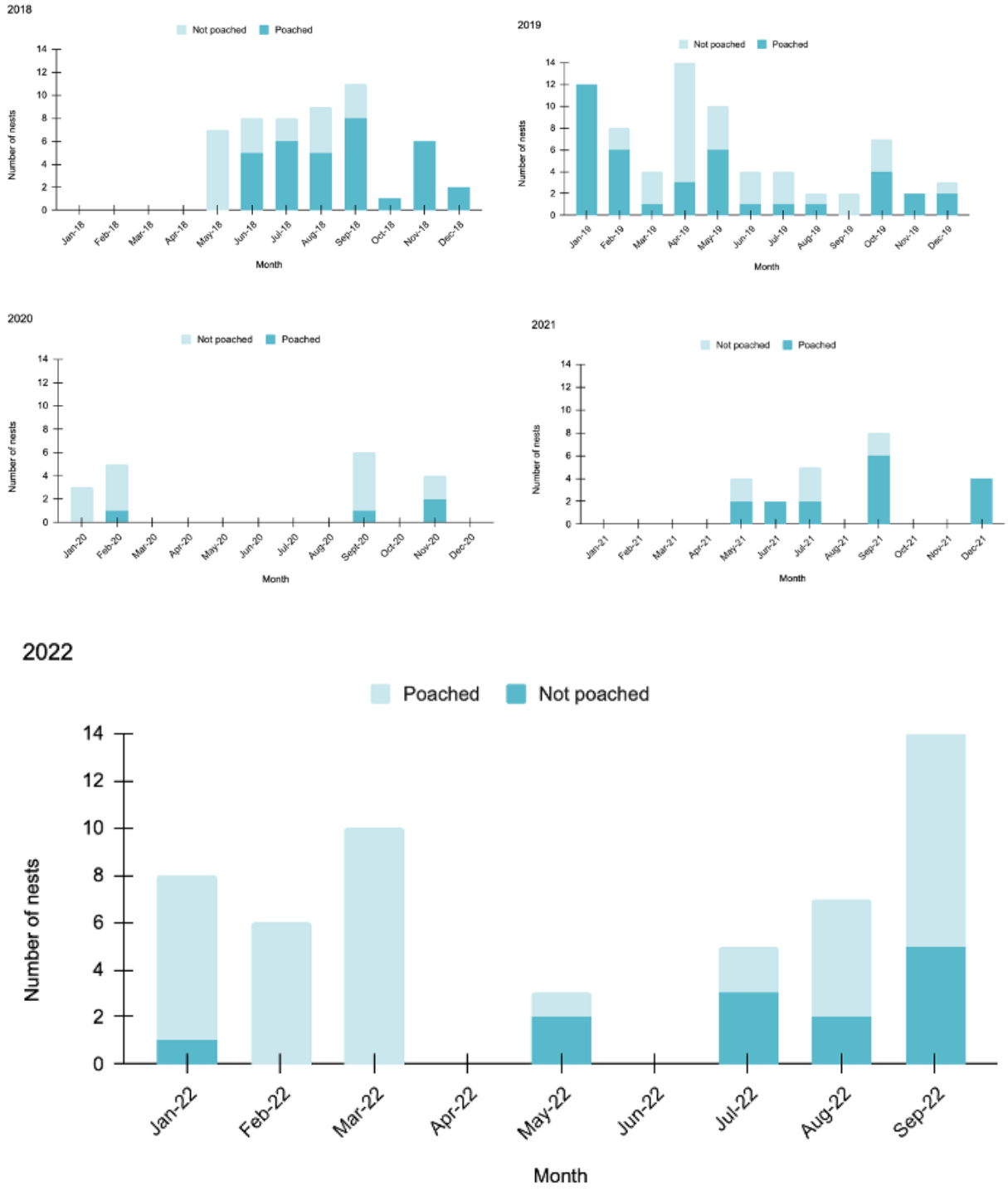

Fig 3: Proportion of poached nests in L. Gaadhoo 2018-2022.

ANNEX III - Figures

NESTING ACTIVITY 2023

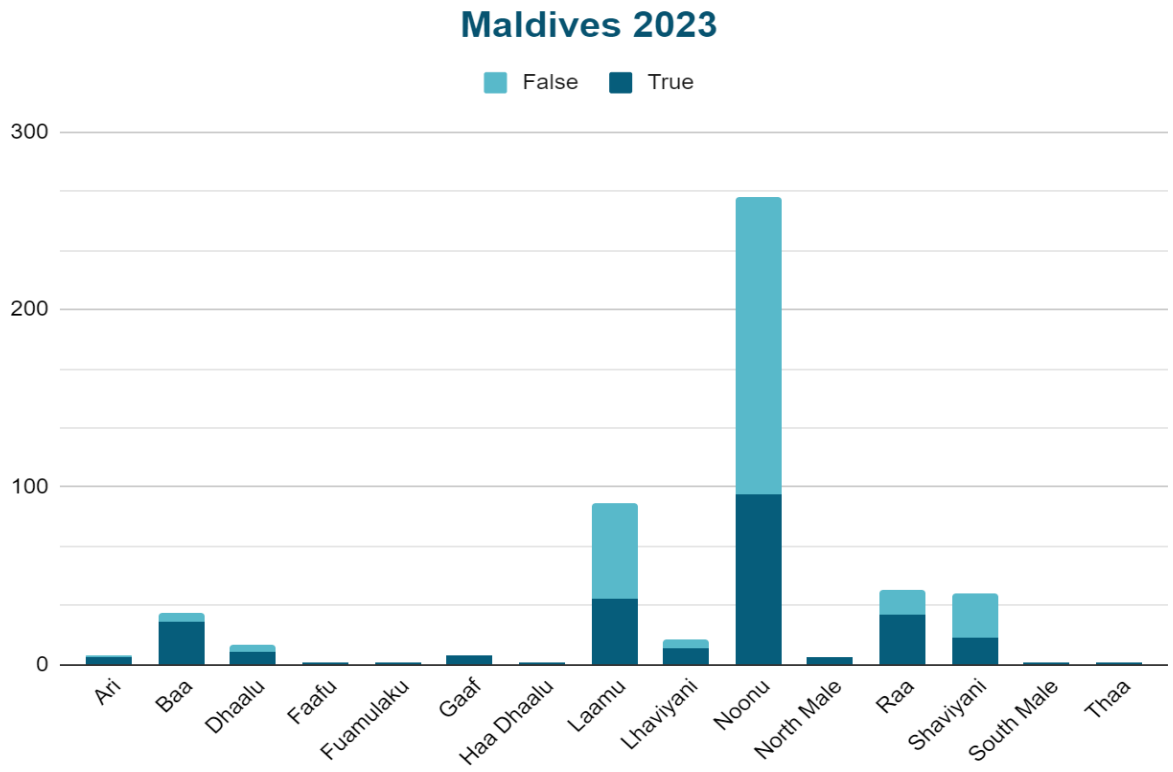

Fig. 5: True nests and false crawls recorded for all species per atoll in 2023. Highest number of nests were recorded in Noonu and Laamu atolls.

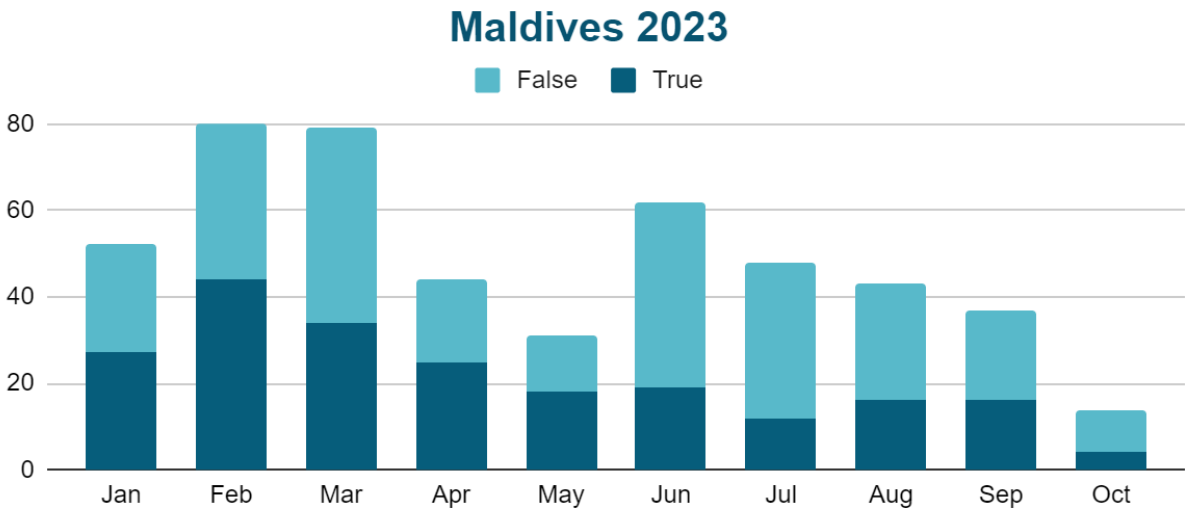

Fig. 6: Nesting seasonality 2023

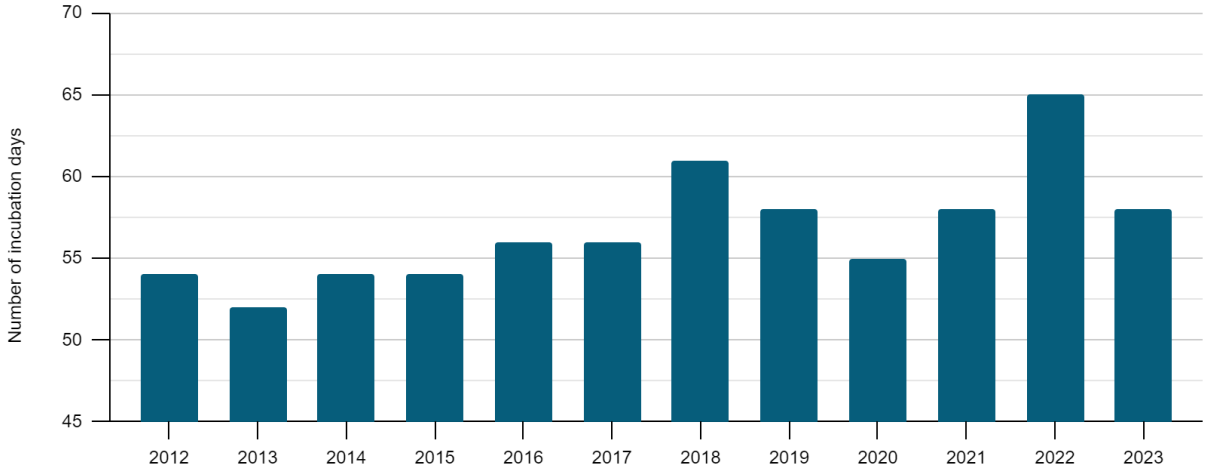

Fig. 7: Median number of incubation days for Laamu nests*

*(2013, 2014, 2015, 2016, 2017 & 2020 less than 10 nests with emergence data available).