



Maldivian Manta Ray Project

LAAMU ATOLL | ANNUAL REPORT 2019

*Conservation through
research, education, and collaboration*

- The Manta Trust





WHO ARE THE MANTA TRUST?

The Manta Trust is a UK and US-registered charity, formed in 2011 to co-ordinate global research and conservation efforts around manta rays. Our vision is a world where manta rays and their relatives thrive within a globally healthy marine ecosystem.

The Manta Trust takes a multidisciplinary approach to conservation. We focus on conducting robust research to inform important marine management decisions. With a network of over 20 projects worldwide, we specialise in collaborating with multiple parties to drive conservation as a collective; from NGOs and governments, to businesses and local communities. Finally, we place considerable effort into raising awareness of the threats facing mantas, and educating people about the solutions needed to conserve these animals and the wider underwater world.

Conservation through research, education and collaboration; an approach that will allow the Manta Trust to deliver a globally sustainable future for manta rays, their relatives, and the wider marine environment.



MALDIVIAN MANTA RAY PROJECT

Formed in 2005, the Maldivian Manta Ray Project (MMRP) is the founding project of the Manta Trust. It consists of a country-wide network of dive instructors, biologists, communities and tourism operators, with roughly a dozen MMRP staff based across a handful of atolls.

The MMRP collects data around the country's manta population, its movements, and how the environment and tourism / human interactions affect them. Since its inception, the MMRP has identified over 4,942 different individual reef manta rays, from more than 70,000 photo-ID sightings. This makes the Maldivian manta population the largest, and one of the most intensively studied populations in the world. The MMRP has also identified over 710 different individual oceanic manta rays.

The long-term and nationwide data collected by the MMRP has allowed researchers to record and identify key patterns within this population over time. Not only does this invaluable information improve our understanding of these animals, but it informs their ongoing management and protection both in the Maldives, and around the world.



OUR PARTNERSHIP WITH SIX SENSES LAAMU

For years, Six Senses Laamu has contributed to the research efforts of the Manta Trust and the MMRP, through external submissions of manta ray ID photos. In 2014, a closer partnership began to blossom, with the Manta Trust launching an exciting five-month pilot project in Laamu Atoll. The project focused on investigating the nearby manta aggregation site at Hithadhoo Corner. The pilot phase was so successful that the Manta Trust team were invited back in 2015, this time for an extended period of nine months.

In 2016, a full 12-month partnership between both parties was born, and since then the project has gone from strength to strength. The Manta Trust's MMRP now has a permanent presence on the island, working closely with the resorts' resident marine biologists and sustainability manager, to raise awareness surrounding the unique, yet vulnerable marine environment of Laamu Atoll.



Photo by Marteyne van Well

EXECUTIVE SUMMARY

This report is the sixth of its kind in a series that presents data collected by the Maldivian Manta Ray Project (MMRP) on Laamu Atoll's manta ray (*Mobula alfredi* and *Mobula birostris*) populations from January through December 2019. The MMRP has been collecting data on manta rays in the Maldives consistently since 2005; however, data for Laamu Atoll only dates back to 2012, a short time after Six Senses Laamu opened in 2011. The Manta Trust are incredibly proud and grateful to continue to have Six Senses Laamu as one of the MMRP's Key Regional Partners.

Laamu Atoll supports year-round manta ray sightings with the highest numbers of sightings historically recorded between the months of May to June and October to November each year. Two primary aggregation sites have been identified, Hithadhoo Corner in the south of the atoll, and Fushi Kandu in the Northeast. Following increased manta ray sightings reports at Maabaidhoo Kandu in January 2019, the MMRP expanded monitoring efforts to include this location as another potential manta aggregation site requiring regular surveillance throughout the year. Both Hithadhoo Corner and Fushi Kandu are characterised by large cleaning stations which support frequent cleaning behaviour and seasonal courtship activities. At Maabaidhoo Kandu, cleaning has been observed over an area of high coral cover at the reef drop-off. However, there have also been anecdotal reports of manta rays utilising a well-defined cleaning station within the channel.

In 2019, surveys ($n=557$) were conducted on a total of 327 days by either the MMRP, Six Senses Laamu staff or citizen

scientists from outside the resort. This was the highest number of days surveyed since the start of research in the atoll. Key findings in 2019 include a total of 450 sightings of 80 individual reef manta rays, recorded over ten sites. While overall sightings in 2019 decreased, sightings during the Northeast Monsoon (December – March) were higher than average ($n=156$). Hithadhoo Corner continued to support the highest number of sightings throughout the region ($n=357$), followed by the Northeastern channels of Fushi Kandu and Maabaidhoo Kandu ($n=53$). The number of sightings recorded at secondary sites in 2019 ($n=40$) was higher than the average recorded in previous study years.

Of the 80 individuals recorded, each manta ray was observed on average 5.63 times. The mean number of manta ray sightings per survey was 0.8 in 2019, with a peak in sightings per survey occurring during June, at 1.7 manta rays per survey. As with previous years, a Residency Index (RI) was calculated to gauge the extent of movement amongst those frequenting Laamu Atoll. The RI for 2019 (1.72) was at its lowest (2.65 in 2018) to date.

As of 2019, the population demographics of Laamu Atoll constitutes 59% female ($n=78$), 40% male ($n=53$), and 1% ($n=1$) for which sex cannot be determined. Overall, 58% ($n=76$) comprise adult individuals, 40% ($n=52$) juveniles and 3% ($n=4$) are considered sub-adult. Of the population known to Laamu ($n=132$), 93% ($n=123$) have been re-sighted and only 14% ($n=19$) have been seen in another geographical atoll of the Maldives.

In 2019, six individuals were identified as new to the Maldives database, and one individual, new to Laamu Atoll, was previously recorded in another atoll (Huvadhu). This number was lower than the new individuals observed in Laamu Atoll in 2017 (n=9), but comparable to that noted in 2018 (n=6). In 2019, there were seven pregnancies recorded, less than recorded in 2018 (n=11). Of the individuals recorded as pregnant in 2018, nine were re-sighted in 2019, and three were recorded as pregnant in two consecutive years. Courtship behaviour was minimal, with only 15 sightings throughout 2019 (n=11 for 2018), and no period of the year offered particularly high sightings

of the behaviour (courtship season) as had been observed in 2016 and 2017.

Research projects in 2019 included photo-ID surveys, stereo video photogrammetry, contactless underwater ultrasound scanning, remote underwater video cameras, and interviewing fishermen in the local community. Outreach led to the development of digital materials to support sustainable tourism in Laamu Atoll, increased citizen science submissions, education sessions within the community, and the identification of potentially three new manta ray aggregation sites in the atoll.

MONSOONS & LAAMU ATOLL

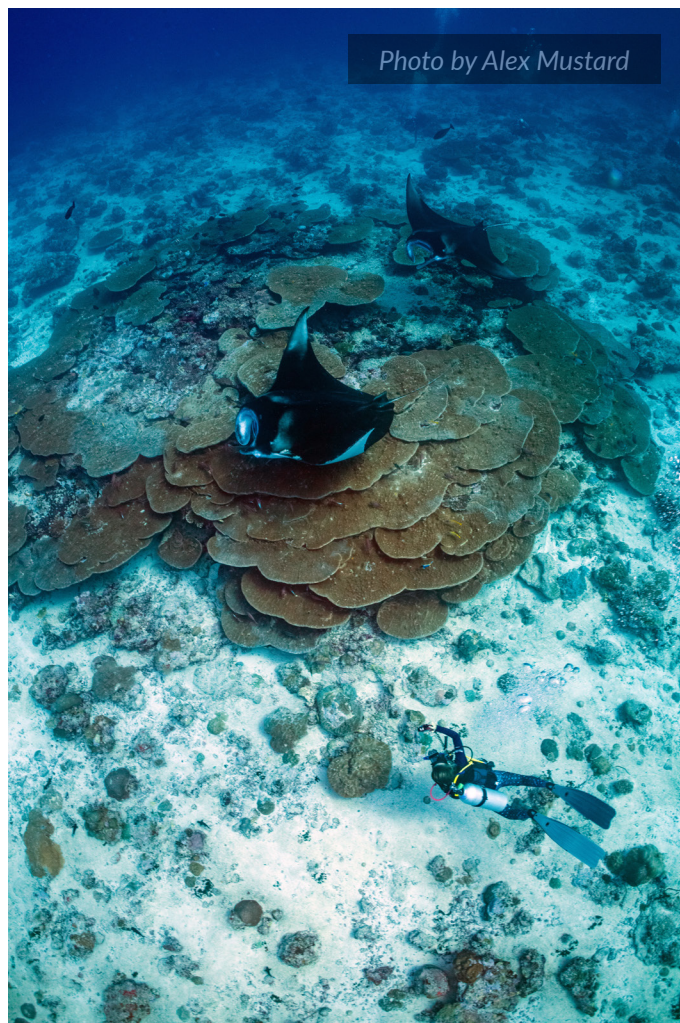
The South Asian Monsoon heavily influences weather patterns in the Maldives. There are two defined monsoons (seasons) in the Maldives, characterised by wind speed and direction. The Northeast Monsoon (*Iruvai*) runs from December to March, while the Southwest Monsoon (*Hulhangu*) runs from May to October. April and November are classified as transition months; here, wind speed and direction can be highly variable.

As the winds change with each monsoon, so do ocean currents. The islands and atolls within the Maldives act as barriers to these currents, creating regions of deep-water upwelling which drives nutrient-rich water to the surface. This increases the production of phytoplankton and drives subsequent blooms of zooplankton - the primary food source of manta rays.

The central and northern atolls of the Maldives are “double-chained”, with numerous channels dividing the fringing reefs. These characteristics cause plankton to accumulate on either the western or eastern sides of atolls depending on the monsoon, and manta rays migrate accordingly to take advantage of the varying abundances of their zooplanktonic food. Between periods of feeding, manta rays often utilise cleaning stations to clean and engage in other social interactions.

Located at the southernmost tip of the central Maldives, the topography of Laamu Atoll differs from that of the more northern atolls (Fig. 1). Laamu Atoll does not form part of a double chain, and few (seven) channels break the outer reef. While Laamu Atoll experiences strong oceanic currents, water movement through the atoll is restricted, and no clear seasonal manta ray migration pattern has been documented.

Hithadhoo Corner, located near the southern edge of Laamu Atoll, has historically supported year-round manta sightings, with peaks at the start and end of the Southwest Monsoon. Fushi Kandhu, located on the northeastern edge of the atoll, appears to be used primarily during the Southwest Monsoon (Fig. 1). Both sites have well-defined cleaning stations and support cleaning and courtship behaviours.



Laamu Atoll

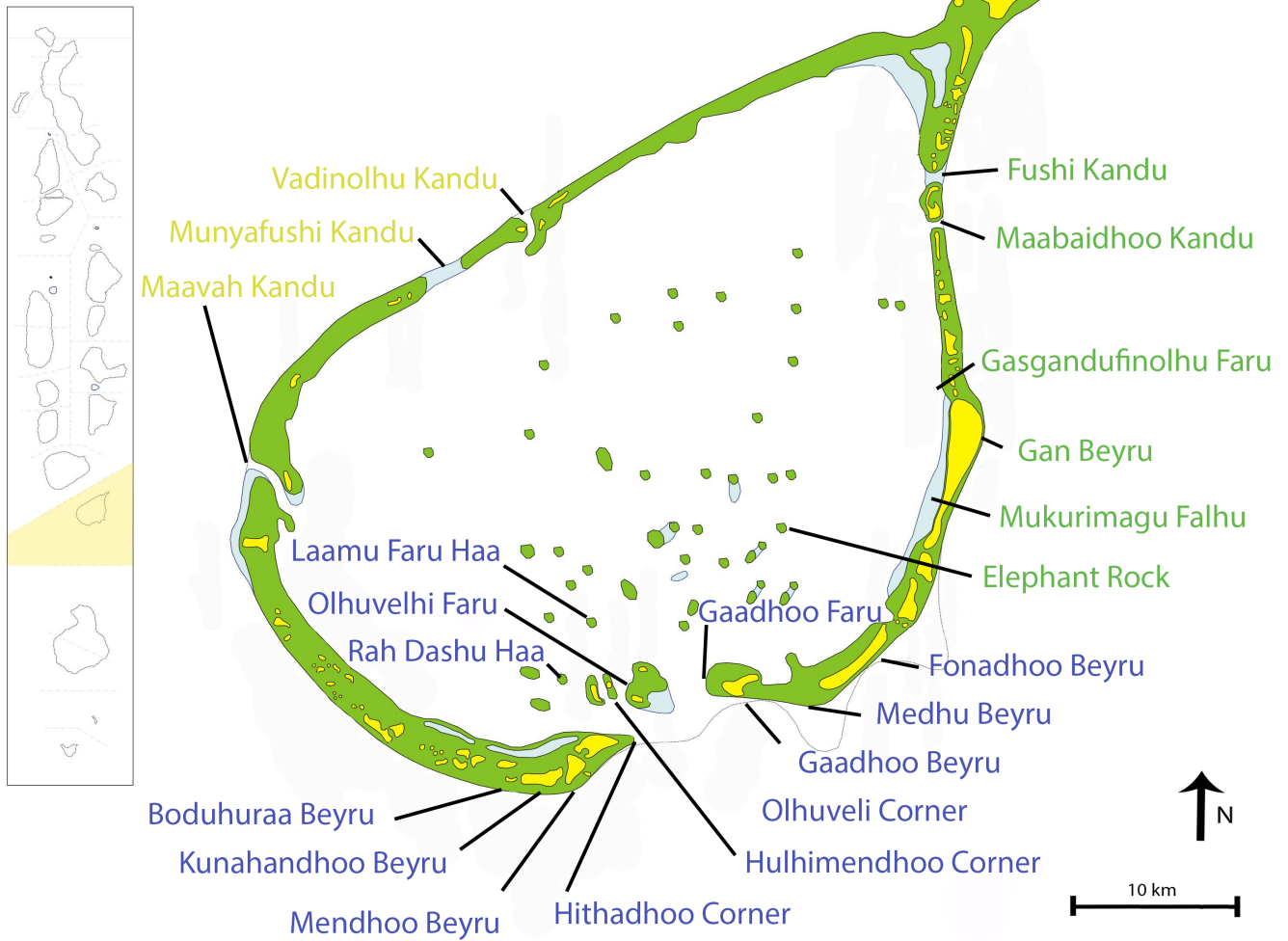


Figure 1: Map of Laamu Atoll showing the twenty-two locations in the atoll where reef manta rays (*Mobula alfredi*) have been observed (2014-2019).

STUDY PERIOD & SAMPLING METHODOLOGY

Throughout the Maldives, the MMRP records sightings of manta rays through photographs of the unique ventral spot patterns of individuals. Since 2013, the majority of sightings data on the local manta population in Laamu Atoll has been collected by the MMRP researchers ($n=3,589$). However, sightings have also been submitted by resort partners and guides ($n=80$), and outside contributors including guests ($n=49$). For this report, a sighting is defined as a confirmed photo identification (photo-ID) of an individual manta ray on a given day at a specific location (survey site).

For each survey, information was collected on the location,

manta ray numbers, behaviour (e.g. cleaning, courtship, feeding, cruising), duration of encounters, environmental variables (including wind direction, current direction, and plankton density), and anthropogenic factors (including the number of divers/snorkellers and the number of boats). Most data were collected while scuba diving due to the depth of aggregation sites. In 2019, the overall survey time was increased through the use of remote underwater video cameras (RUV), primarily at Hithadhoo Corner. These did not impact the total number of survey days as they were deployed between dives.

For this report, a survey is defined by time spent at a single location each day. If multiple dives or snorkels took place at a single site with only a short surface interval (approx. 60 minutes), it was considered a single survey. If more than two dives took place with an extended surface interval between (i.e. morning and afternoon dives), these were counted as separate surveys. Survey days refers to the number of days when surveys were conducted in the atoll irrespective of location. There were additional reports of manta ray sightings received in 2019. However, only

surveys conducted in-water were analysed for this report.

Before April 2015, MMRP researchers were not based in Laamu Atoll during all 12 months of the year, and therefore, data was not recorded on all dives to the manta aggregation sites. For this reason, averages where survey effort could be accounted for, only include data between 2016 through 2019. Where possible, data has been standardised for survey effort to provide comparable results by both months and years.

2019 Study Period

In 2019, all surveys conducted by Manta Trust and Deep Blue Divers at the primary aggregation sites of Hithadhoo Corner and Fushi Kandu were recorded regardless of whether manta rays were observed during the dive. Following reported manta ray sightings at Maabaidhoo Kandu in early January 2019, the MMRP began joining guest dives to this location, and Maabaidhoo Kandu became a new site for regular monitoring in 2019. Reports were also received from Emperor Divers Laamu on dives at Fushi Kandu and Maabaidhoo Kandu between April and November, irrespective of if manta rays were recorded. For

all other locations, surveys were only recorded if manta rays were present, or if MMRP staff participated in the dive.

In 2019, surveys were undertaken ($n=557$) on as many days ($n=327$) as conditions and logistical operations allowed (Fig. 2). Data was collected on the manta ray population through a combination of dedicated research dives ($n=334$) and snorkels ($n=9$), Six Senses Laamu (SSLM) manta excursions with guests ($n=335$ dives and seven snorkels), remote underwater video camera deployments ($n=68$), and survey data collected from contributors outside the resort ($n=42$).

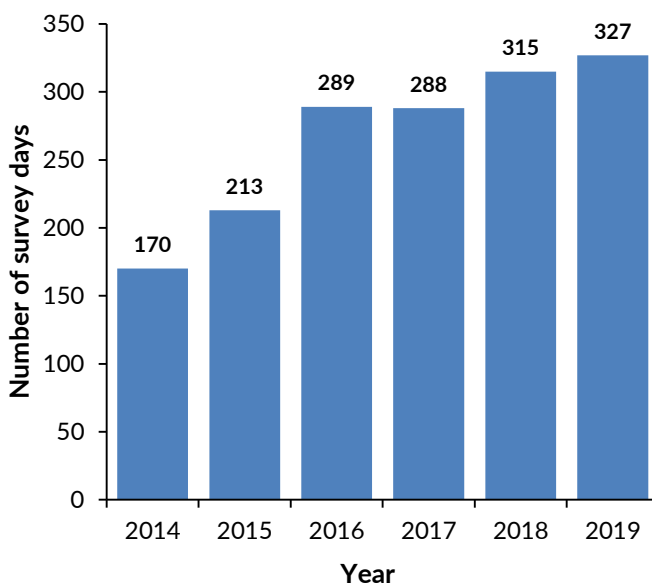


Figure 2: Number of days that surveys were undertaken in Laamu Atoll annually.

Hithadhoo Corner and Fushi Kandu continued to be the two primary survey sites, with data collected from Hithadhoo Corner on 272 days, and Fushi Kandu on 81 days in 2019 (Fig. 3). Before 2019, data was only available for Maabaidhoo Kandu on one day in 2017, and one day in 2018. With increased reporting from outside contributors and visits by Deep Blue Divers, data was recorded for this site on 28 days during 2019. Survey effort by the MMRP at this location prior to 2019 was minimal. Therefore, this is the first year the site has been considered a potential aggregation site. Given the proximity and location of Maabaidhoo Kandu to Fushi Kandu (approximately two kilometres), these two sites have been grouped as the Northeastern Channels for further discussion of environmental trends and sightings patterns.

Three potential manta ray aggregation sites (Hulhimendhoo Corner, Gasgandufinolhu Faru, and Mukurimagu Falhu) were identified in 2019. The MMRP has now collected

reports of manta ray sightings from 22 sites in the atoll, and confirmed sightings from 14 locations (Fig. 1 and Table 1). Regular monitoring of these sites in future is necessary to determine the reliability of these locations for supporting manta ray sightings.

Overall, manta rays were encountered on 37% (n=263) of all dives (n=708), and identification photographs were recorded during 80% (n=210) of dives with manta rays. Manta rays were observed on 50% (n=34) of the remote underwater video camera deployments. Snorkelling surveys were usually only recorded when manta rays were sighted. Manta rays were observed on 95% (n=18) of the snorkel surveys (n=19), with confirmed identification photos collected for 58% (n=11) of the surveys. These figures are not reflective of snorkelling conducted across Laamu Atoll, and it remains rare to see manta rays while snorkelling in the atoll.

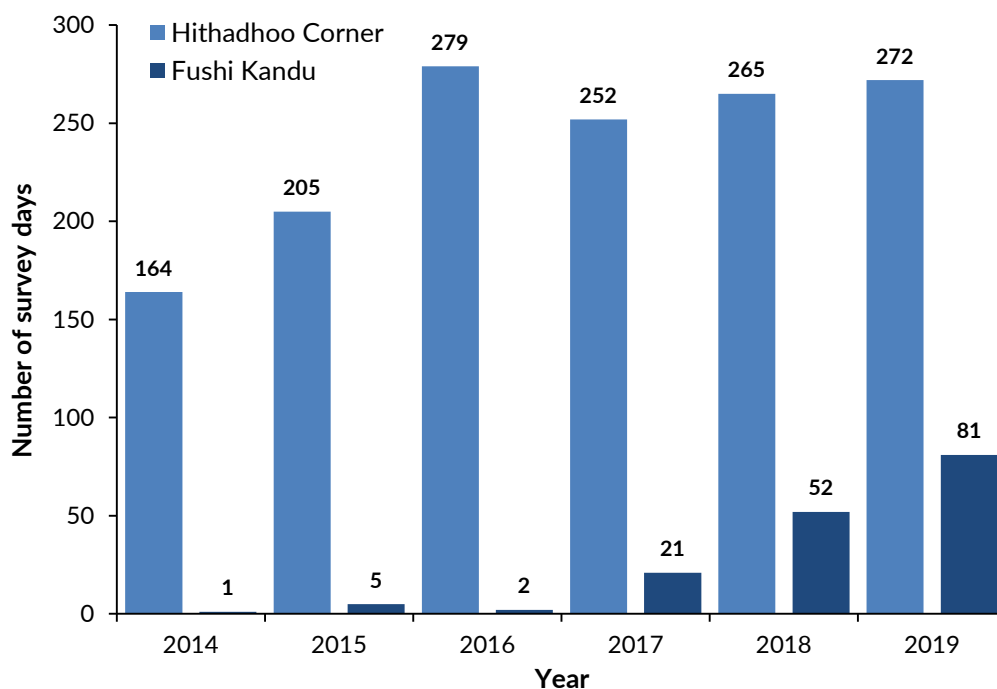


Figure 3: Number of days where surveys were conducted at Hithadhoo Corner and Fushi Kandu in Laamu Atoll annually.

Table 1: Twenty-two sites in Laamu Atoll where reef manta rays (*Mobula alfredi*) have been observed; grouped by their geographical location within the atoll. * Indicates primary study site. + Indicates that the site was newly identified in 2019.

Group	Site Name	Reef Type	Location
1	Boduhuraa Beyru	Outer Reef	Southwest
	Kunahandhoo Beyru	Outer Reef	Southwest
	Mendhoo Beyru	Outer Reef	Southwest
	Hithadhoo Corner*	Channel	South
	Olhuveli Corner	Outer Reef	South
	Hulhimendhoo Corner+	Inner Reef	South
	Olhuveli Faru	Inner Reef	South
	Gaadhoo Faru	Inner Reef	South
	Rah Dashu Haa	Inner Reef	South
	Laama Faru Haa	Inner Reef	South
	Gaadhoo Beyru	Outer Reef	Southeast
	Medhu Beyru	Outer Reef	Southeast
	Fonadhoo Beyru	Outer Reef	Southeast
2	Mukurimagu Falhu+	Lagoon	East
	Elephant Rock	Inner Reef	East Central
	Gan Beyru	Outer Reef	East
	Gasgandufinolhu Faru*	Inner Reef	East
	Maabaidhoo Kandu	Channel	Northeast
	Fushi Kandu*	Channel	Northeast
3	Vadinolhu Kandu	Channel	Northwest
	Munyawushi Kandu	Channel	Northwest
	Maavah Kandu	Channel	West

SIGHTING TRENDS

Oceanic Manta Rays

Oceanic manta ray (*Mobula birostris*) sightings in Laamu Atoll remain rare. However, three sightings were reported - one confirmed by photo ID - in 2019. The three sightings were reported in March, April and June; however, only the individual sighted in June was photographed. Twelve oceanic manta rays have been identified in Laamu Atoll since 2014, at five different sites. The MMRP is working to increase our understanding of this species through research

conducted in Fuvahmulah and Addu Atolls, where oceanic manta rays are sighted seasonally in much larger numbers than in other regions of the Maldives. The team in Laamu Atoll will continue to monitor for this species throughout 2020. The remainder of this report refers solely to reef manta rays (*Mobula alfredi*); any subsequent reference to manta rays refers only to this species.

Reef Manta Rays

Since 2012, a total of 3,864 sightings of reef manta rays have been recorded in Laamu by full-time MMRP researchers, citizen scientists and remote underwater cameras. Between 2015 and 2018, numbers of confirmed sightings remained consistent, ranging between 694 and 739 sightings per year (Fig. 4). In 2019, there was a significant decline in the number of manta ray encounters with only 450 confirmed sightings (Fig. 4); the lowest recorded figure since the

establishment of a permanent research base in Laamu Atoll. The mean number of sightings per survey further decreased from 2018, with an average of just 0.8 (Fig. 4). Tourism levels remain low in the atoll, and survey effort was consistent with previous years. Therefore, the decrease in sightings is not likely linked to an increased presence of divers and possible human disturbance.

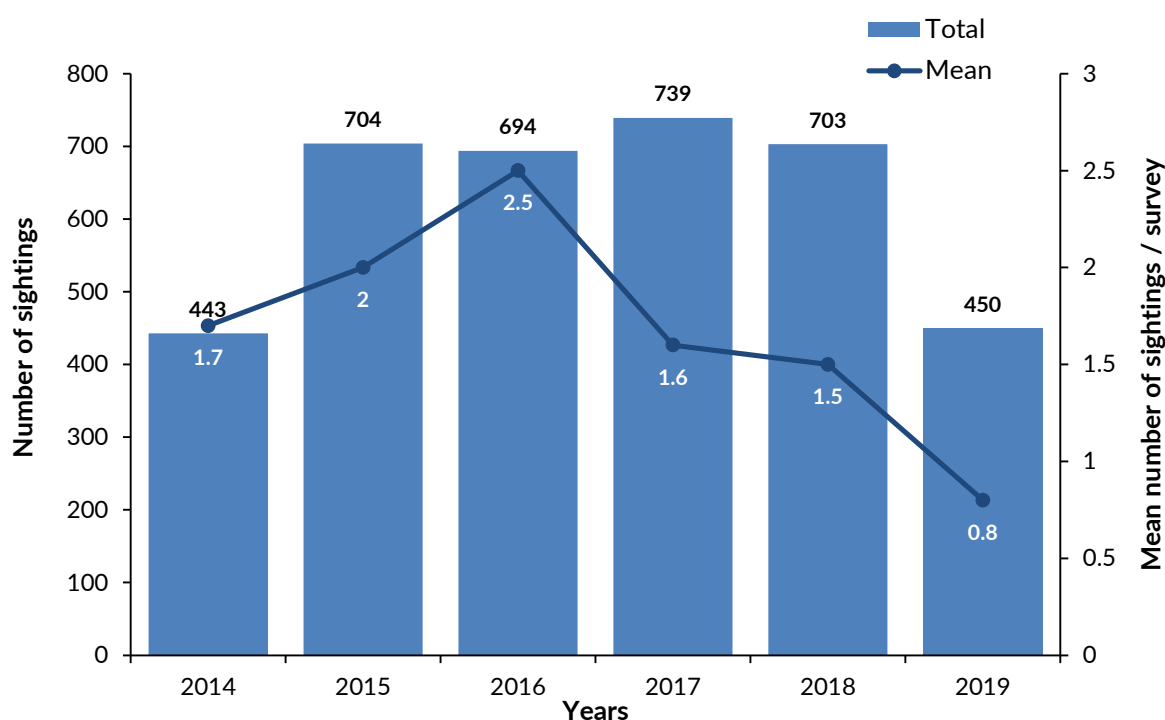


Figure 4: Annual sightings of reef manta rays (*Mobula alfredi*) in Laamu Atoll, and the mean number of sightings per survey for each year (2014-2019).

Sightings trends in Laamu Atoll have been relatively consistent between 2014 through 2018, with peaks in sightings typically recorded at the start and end of the Southwest Monsoon (Fig. 5). In 2019, sightings did not follow this trend. Peak sightings occurred at the onset of the Northeast Monsoon (January, $n=61$) and again during the change between the Northeast and Southwest Monsoons (April-June, $n=200$) (Fig. 6). Sightings recorded in other months of the year were notably lower than average, with the exception of March ($n=33$), which had higher than average sightings (Fig. 6). Interestingly, in 2019, the month of March represented the period during which the MMRP team recorded the highest level of manta ray surface feeding activity ever documented in Laamu Atoll. This above average sightings count documented in March

also coincided with high concentrations of zooplankton which were noted along the southwestern barrier reef of the atoll; likely the result of more consistent north-easterly winds which were recorded during this time. Moreover, manta ray sightings in October and November, historically recognised as months for increased courtship activity, were significantly lower than average ($n=23$ and $n=18$, respectively), and may be linked to changes in environmental conditions influencing reproductive activity.

The majority of sightings were recorded at Hithadhoo Corner (79%, $n=357$), and at the Northeastern Channels (12%, $n=53$). However, there was an increase in sightings at secondary locations (nine percent, $n=40$) in 2019.

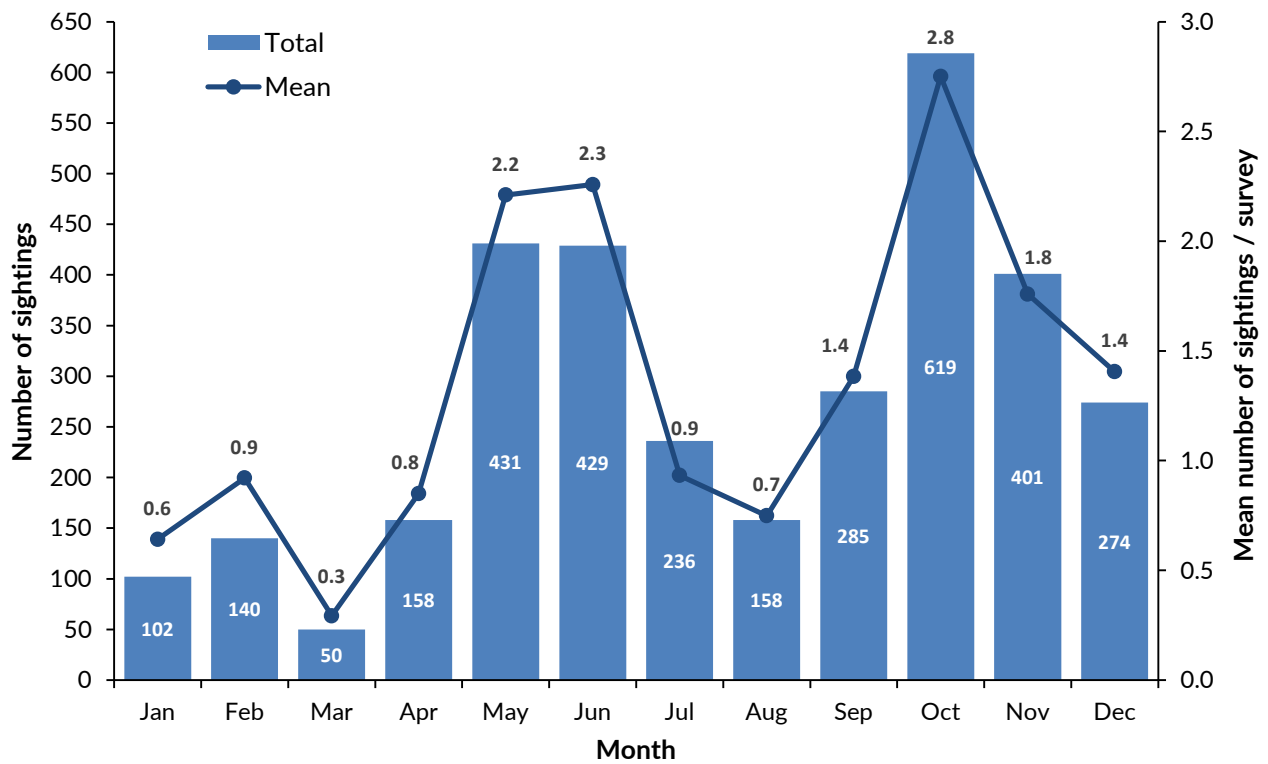


Figure 5: Monthly sightings of reef manta ray (*Mobula alfredi*) in Laamu Atoll (2014-2018) and the mean number of sightings per survey.

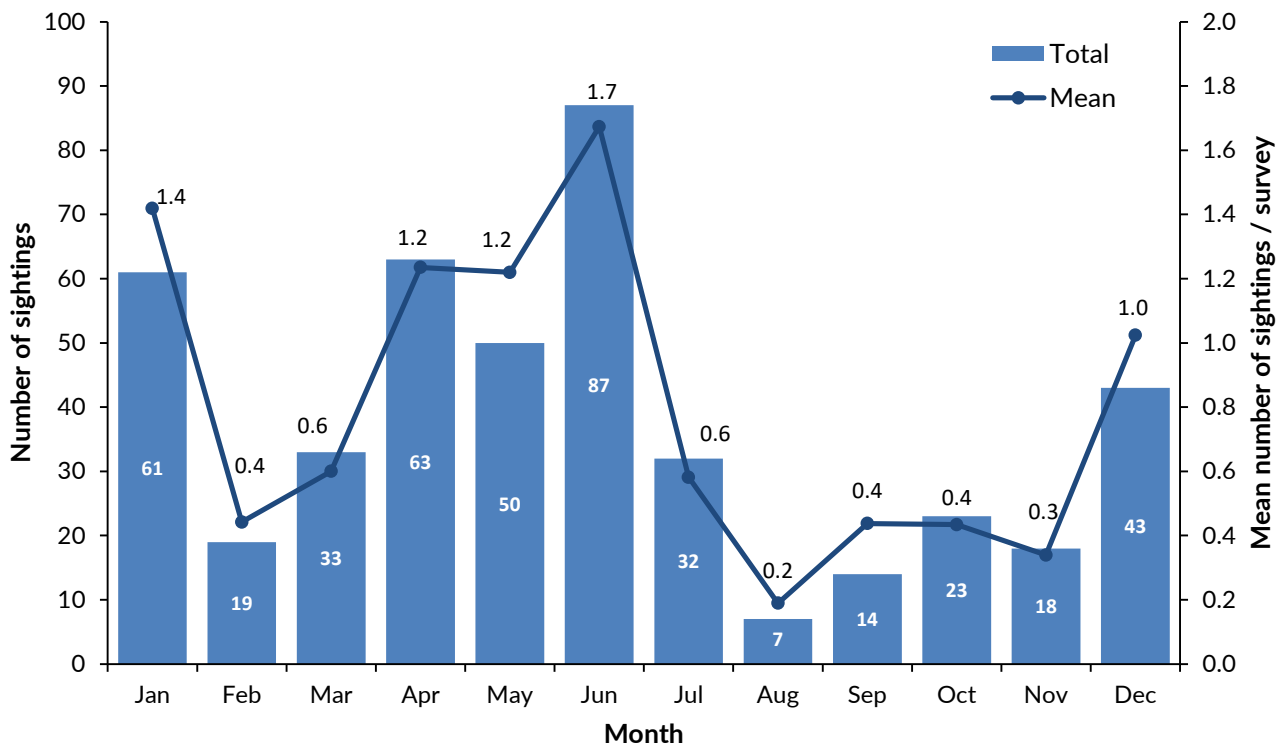


Figure 6: Monthly sightings of reef manta rays (*Mobula alfredi*) in Laamu Atoll (2019) and the mean number of sightings per survey.

Hithadhoo Corner

Consistent with the overall reduction in sightings for the atoll, sightings at Hithadhoo Corner saw a steep decline in 2019 ($n=357$). When accounting for survey effort, a drop in the mean number of sightings per survey day was also apparent ($n=2.27$ and $n=1.31$, in 2018 and 2019

respectively) (Fig. 7). Peaks in sightings were recorded at Hithadhoo Corner in January, April-June and December 2019, with the highest numbers of individuals also recorded during these months (Fig. 8).

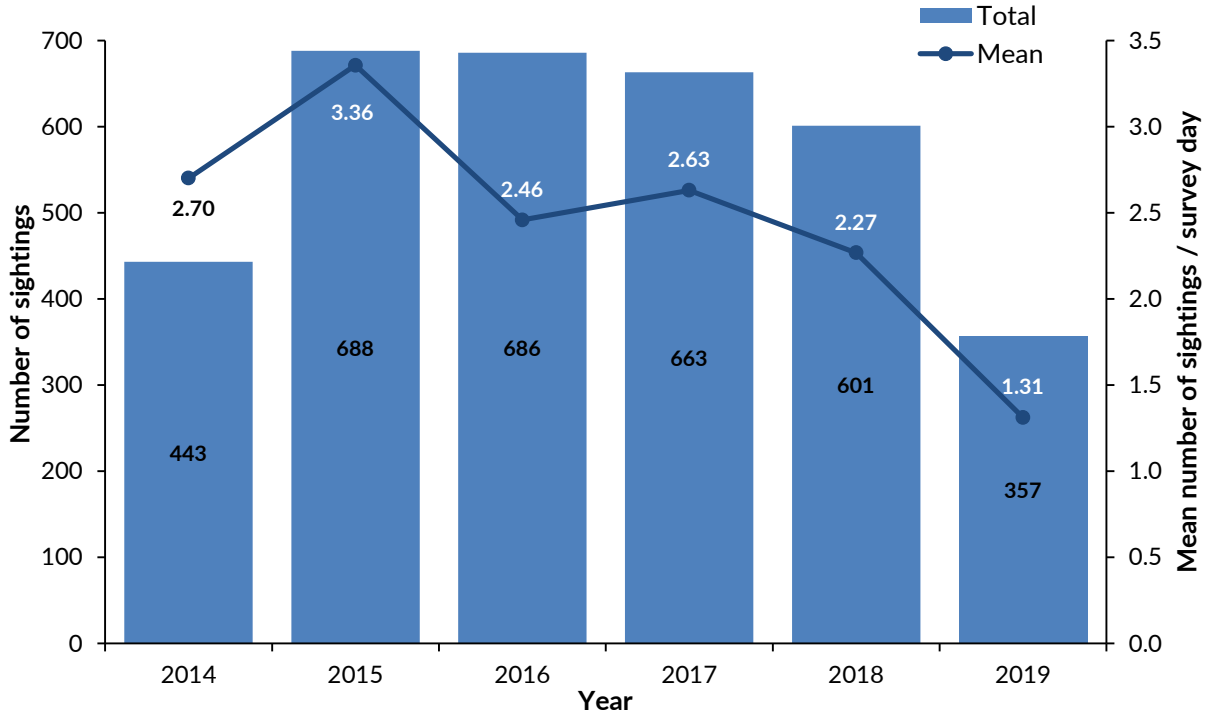


Figure 7: Annual sightings of reef manta rays (*Mobula alfredi*) at Hithadhoo Corner in Laamu Atoll and the mean number of sightings per survey day.

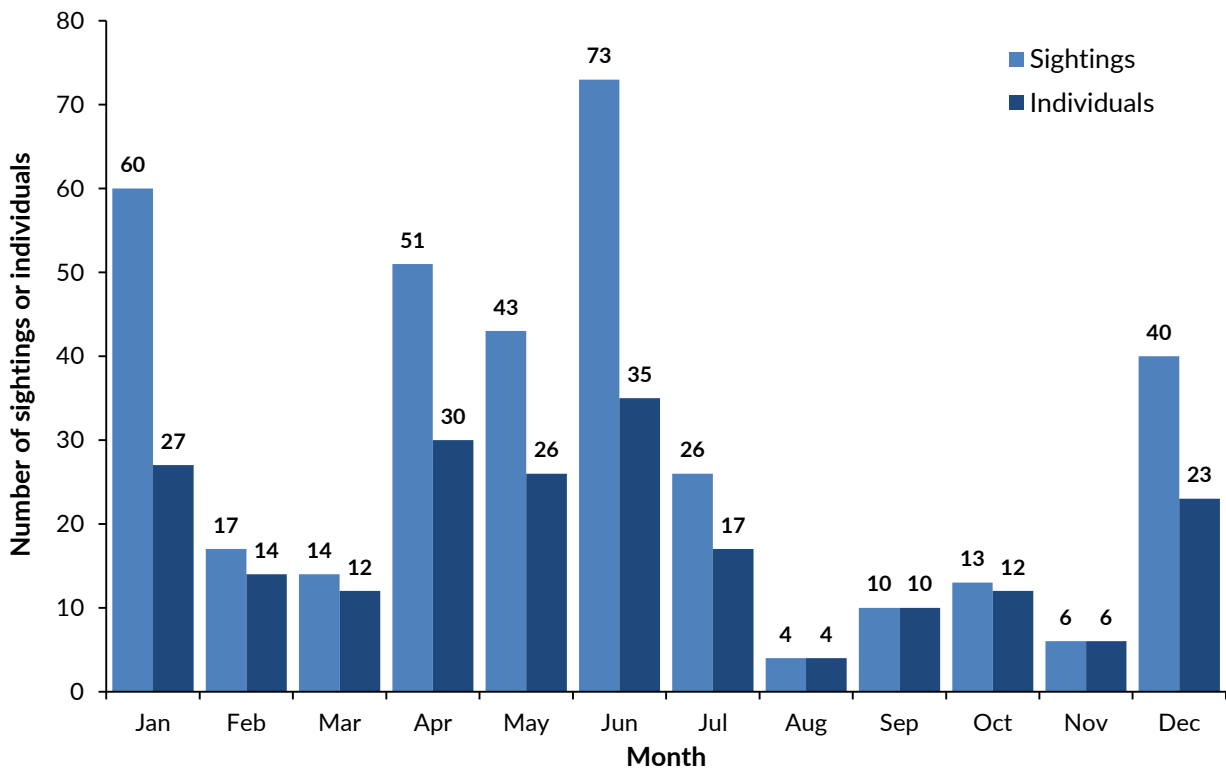


Figure 8: Monthly sightings and the number of individual reef manta rays (*Mobula alfredi*) recorded at Hithadhoo Corner in Laamu Atoll (2019).

Twenty-four percent (n=86) of sightings recorded at Hithadhoo Corner in 2019 were associated with cruising behaviour, a marked increase from previous years (Fig. 9). Researchers also noted a decrease in the amount of time manta rays spent at cleaning stations. The average encounter duration (n=10.79 minutes) was significantly shorter in 2019 than in previous years (Fig. 10). These observations may indicate that individuals were cleaning

elsewhere, possibly at sites which presented better feeding opportunities nearby. These observations may also indicate that the manta rays passing through the site were less likely to stop at these social aggregation sites because of a lack of reproductive opportunities in 2019. Changes in environmental conditions may offer more favourable conditions elsewhere, or reduce drivers of cleaning station use.

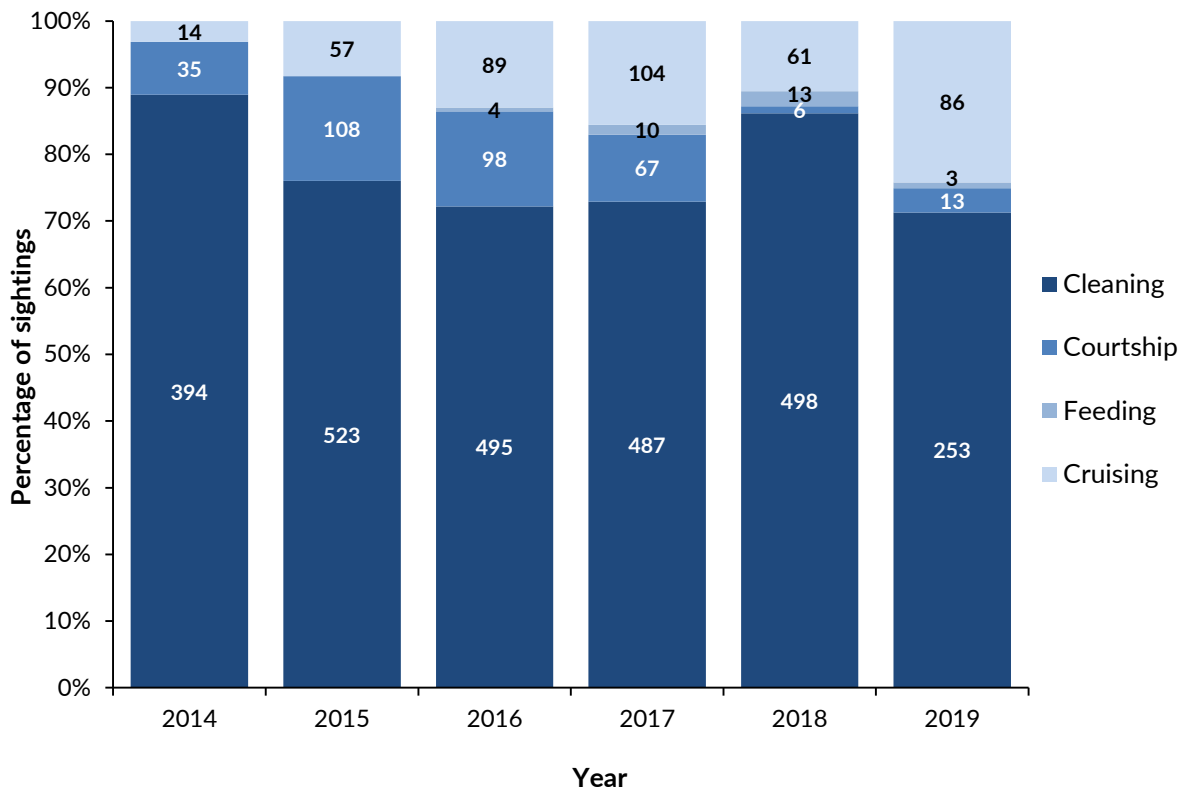


Figure 9: Predominant behaviour recorded during each reef manta ray (*Mobula alfredi*) sighting at Hithadhoo Corner in Laamu Atoll annually. Actual number of sightings above bars.

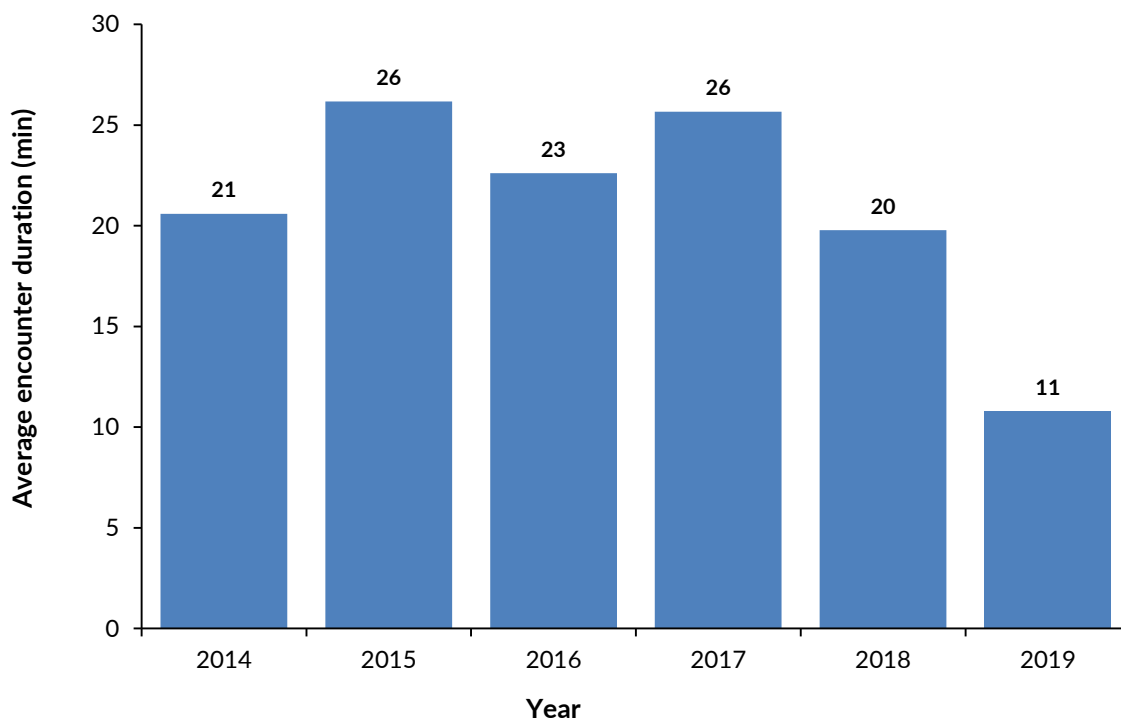


Figure 10: Average duration (min) of reef manta ray (*Mobula alfredi*) encounters recorded by divers at Hithadhoo Corner in Laamu Atoll annually.

Five percent of confirmed sightings in 2019 were recorded by both a MMRP researcher and an RUV during the same survey, whereas 13% (n=56) were solely captured by the RUV system. Interestingly, the MMRP documented the return of two individuals to Hithadhoo Corner in 2019. Bananarama (MV-MA-0035) - a large female known to travel between Laamu, Baa and Raa that had not been recorded since 2017 - was photographed in Laamu Atoll in February, and Charlotte (MV-MA-2971) - an individual that had not been sighted since February 2016 - was recorded on a RUV at Hithadhoo Corner in December

2019. Both Bananarama and Charlotte were sighted on just one occasion, highlighting the likelihood that other visiting individuals may have been missed during 2019, and during previous years.

The increase in cruising behaviour (during which, the capture of a photo-ID is most difficult), shorter average encounter duration, and significant proportion of sightings captured only on an RUV, suggest that some photo-IDs were likely missed, particularly of individuals that visited the site infrequently.

Northeastern Channels

In 2018, Fushi Kandu was identified as a second key aggregation site based on preliminary surveys conducted in previous years. Despite increased surveys, there were fewer confirmed sightings (n=39) in 2019 and researchers have since recorded a sharp decline in sightings per survey (1.8 in 2018, to 0.6 in 2019) (Fig. 11). At nearby Maabaidhoo Kandu, there were only 14 confirmed sightings, however sightings per survey was slightly higher at 0.7. To calculate sightings per survey at these sites, the approximate number of manta rays observed was used when there were no confirmed sightings, as data for these sites remains limited.

In 2019, 28 individuals were collectively recorded from 53 confirmed sightings from the Northeastern channels (Fig. 12). An increase in confirmed sightings (n=28) was observed from April-June, coinciding with the peak period for sightings (n=200) at Hithadhoo Corner. A second peak (n=10) for the Northeastern Channels was observed in November. However, sightings were at their lowest for Hithadhoo Corner in November (n=6). Historically, when both sites were surveyed (2017, 2018) peaks in sightings coincided (Fig. 13). This was observed at the start of the Southwest Monsoon. However, the peak was minimal.

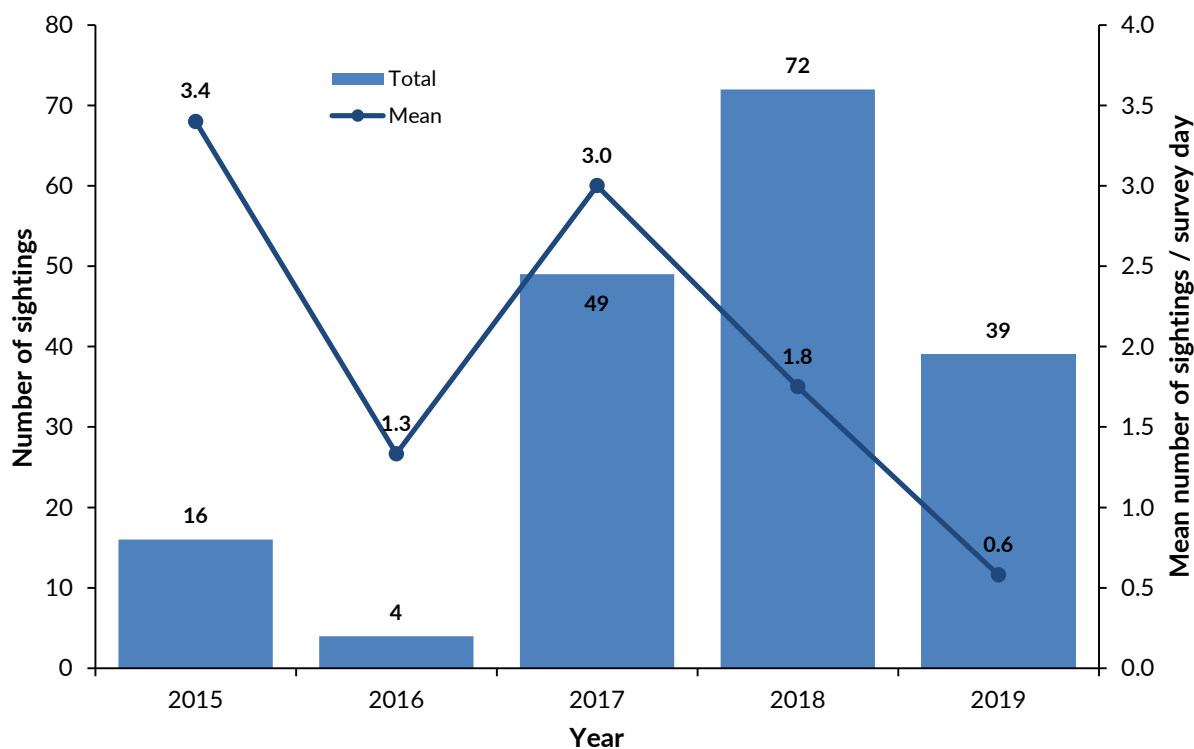


Figure 11: Annual sightings of reef manta rays (*Mobula alfredi*) at Fushi Kandu in Laamu Atoll, and the mean number of sightings per survey day.

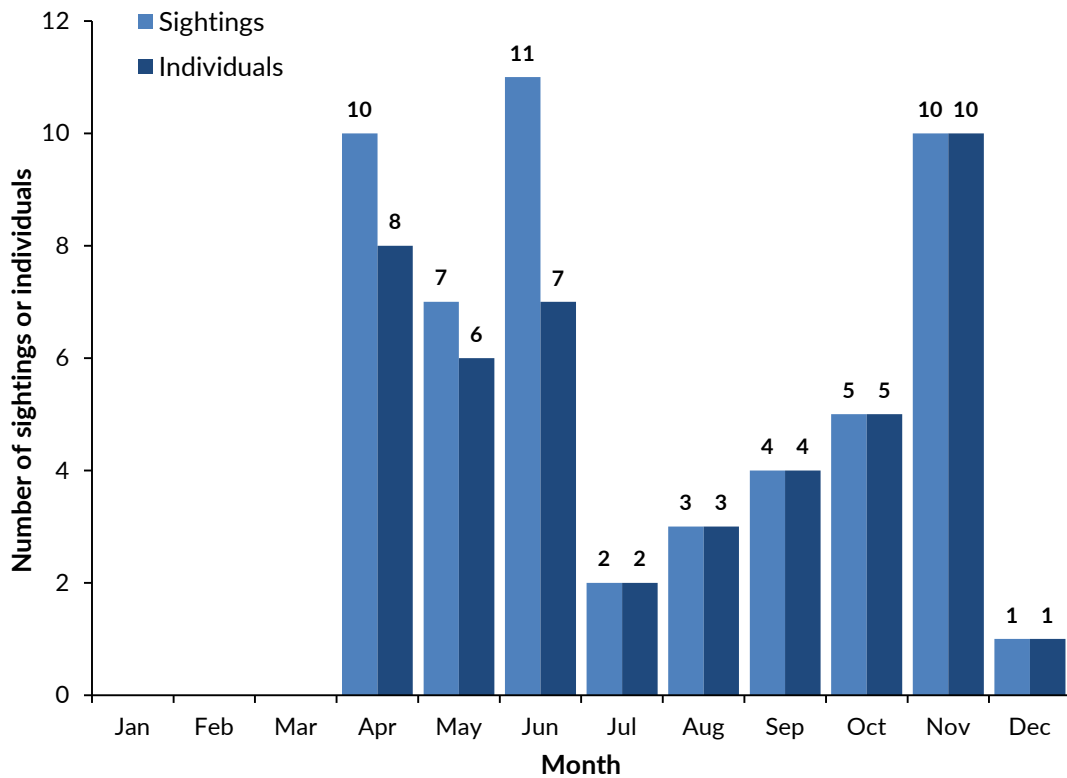


Figure 12: Monthly sightings and the number of individual reef manta rays (*Mobula alfredi*) recorded at Fushi Kandu and Maabaidhoo Kandu in Laamu Atoll (2019).

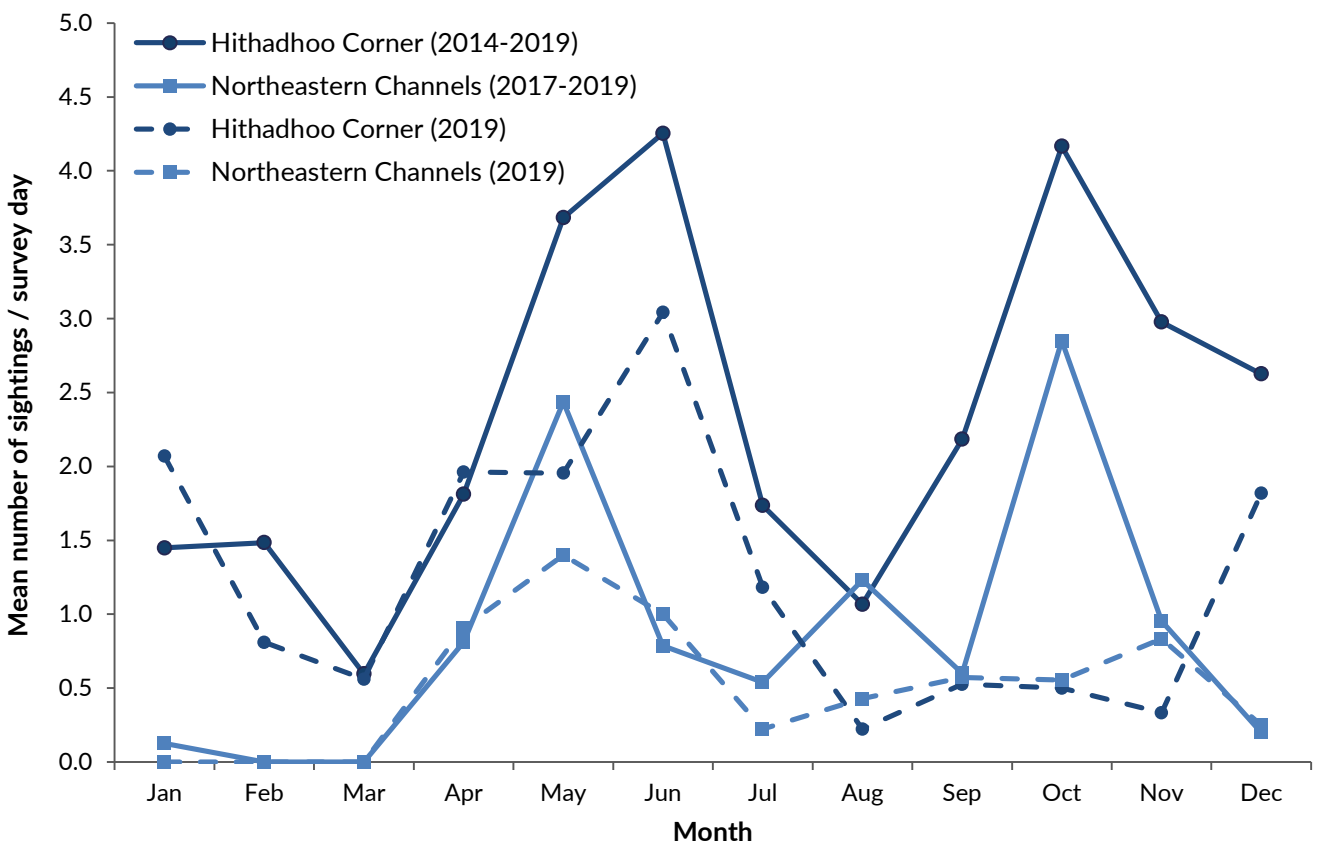


Figure 13: Mean number of reef manta ray (*Mobula alfredi*) sightings per survey day at Hithadhoo Corner and the Northeastern Channels in Laamu Atoll.

Of the 132 individuals known to Laamu Atoll, 95% ($n=126$) have been sighted at Hithadhoo Corner, and 40% ($n=53$) at the Northeastern Channels. There are only four individuals that have been sighted at either Fushi Kandu or Maabaidhoo Kandu, and not at Hithadhoo Corner; two of which were new to the atoll this year. Since the majority of the individuals sighted at the Northeastern Channels have also been sighted at Hithadhoo Corner, the most plausible theory remains that Fushi Kandu and Hithadhoo Corner represent key aggregation sites of a single population within Laamu Atoll. Individuals likely move along the outer atoll reef (including Maabaidhoo Kandu) to travel between these sites.

Total sightings since 2015 remain low from the Northeastern Channels ($n=196$). However, 79% ($n=155$) of all sightings were recorded during the Southwest Monsoon and 19% ($n=38$) during the transition between seasons. Few sightings ($n=3$) were recorded during the Northeast Monsoon.

The seasonality at Fushi Kandu and Maabaidhoo Kandu is consistent with observations from the MMRP's study sites in the central atolls, whereby eastern sites experience higher numbers of sightings during the Southwest Monsoon and western sites during the Northeast Monsoon. This indicates that there may be a more significant correlation between monsoons and sightings than was previously thought.

Secondary Sites

Eighty-six reef manta ray encounters were reported at an additional ten survey sites in 2019. Of these, 40 sightings (27 individuals) were confirmed through photo-IDs. These sightings ($n=40$) constituted more than 9% of the total sightings in 2019, and 43% of all sightings ($n=93$) recorded at secondary sites in Laamu since 2014. In 2019, 62% ($n=25$) of sightings from secondary locations were of feeding, 20% ($n=8$) of cruising behaviour, 12% ($n=5$) of cleaning, and 5% ($n=2$) of courtship.

Of the confirmed sightings recorded at secondary locations between 2014 and 2019, 91% ($n=85$) were along outer reefs on the southern edge of the atoll, and 9% ($n=8$) were recorded at inner reef sites. It appears as though there may be some seasonality to the sightings on the southern edge of the atoll, with these increasing during the Northeast Monsoon. Data remains limited and additional research is needed to determine if sightings in these areas are linked to environmental conditions.

There were confirmed sightings for the first time at Gasgandufinolhu Faru and Hulhimendhoo Corner in 2019 (Fig. 1). The MMRP had previously heard anecdotal reports of manta rays near Gasgandufinolhu Faru, however the site has never been formally surveyed by the team. With sightings reported on four separate days between April, June and July, there is a possibility this site could serve as a feeding aggregation site. Located near Gasgandufinolhu Faru, Mukurimagu Falhu was a site of additional manta activity in 2019. Since October, a manta pup has been spotted feeding in the shallow waters near the beach of Gan. The pup was spotted on numerous occasions between November and December 2019. However, a photo-ID has not yet been captured.

This area of the atoll is not visited by Deep Blue Divers and it is logistically challenging to visit for research given the distance from the resort. It is highly recommended that surveys be increased at Gasgandufinolhu Faru in future, particularly between the months of April and July.

Environmental Influence

Throughout the Maldives, site usage by manta rays has been linked to wind direction, which changes with the South Asian Monsoon. Research in Laamu Atoll has been ongoing since 2014, but the wind has never been considered as a key variable in determining site use, as Hithadhoo Corner was the only aggregation site identified until 2018, and the site supports year-round encounters.

A preliminary analysis of the data since 2014 on the approximate number of manta rays observed at a site in relation to wind direction revealed that sightings at Hithadhoo Corner have generally been recorded under all wind conditions, but typically peak when winds are blowing

from the southwest and west (Fig. 14). At the Northeastern Channels of Fushi Kandu and Maabaidhoo Kandu, sightings also peak when winds are from the southwest (Fig. 14). Very few sightings have been recorded at Fushi Kandu or Maabaidhoo Kandu during the Northeast Monsoon; which suggests these sites may be used more seasonally, but surveys remain limited for these locations. In other areas of the atoll, there may be correlations, particularly on the southern outer edges of the atoll where sightings peaked when winds were from the northeast (Fig. 14). While topography may be somewhat different in Laamu Atoll to the more northern atolls, site usage in the atoll appears to still be heavily influenced by wind direction. Understanding

the influence of wind in the atoll is important as it allows the MMRP to prioritise survey areas depending on the prevailing wind direction and monsoon. Data on sites away from Hithadhoo Corner remains limited and further

research is needed during both monsoons to determine the environmental influence on sightings trends at these locations.

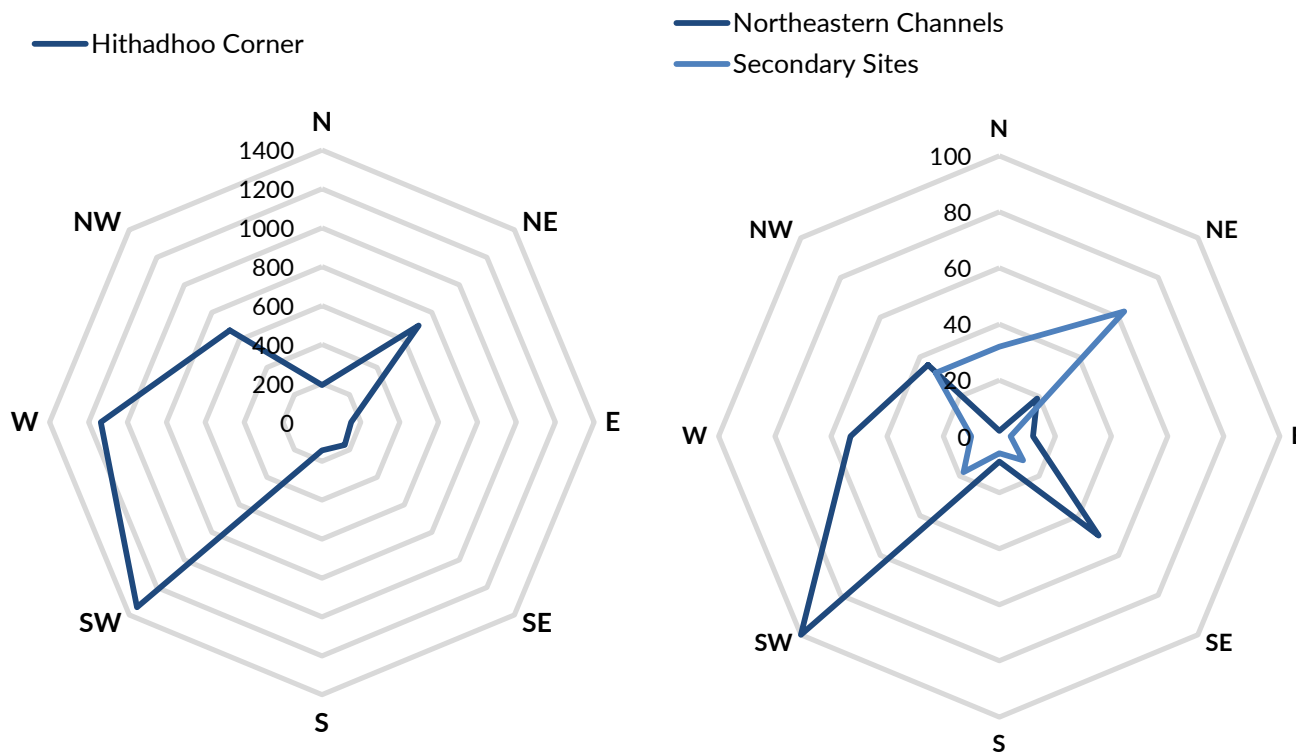


Figure 14: Number of reef manta ray (*Mobula alfredi*) sighting records in relation to the prevailing wind direction at Hithadhoo Corner, the Northeastern Channels, and at all the combined secondary sites in Laamu Atoll (2014-2019).

POPULATION DEMOGRAPHICS

As of 31st December 2019, 132 individual manta rays (78 females, 53 males, and one individual of unknown gender) have been identified in Laamu Atoll, comprising 2.7% of the known Maldives population. At study locations further north, the ratio of female to male manta rays observed is roughly 50:50. By contrast, Laamu Atoll supports a female dominated and predominantly adult population (Fig. 15). This is to be expected as the majority of sightings in Laamu Atoll occur around cleaning stations, which are commonly visited by adult manta rays, and are typically dominated by females which invest more time in cleaning than male individuals. If more feeding sites, and juvenile aggregation areas are identified within Laamu Atoll, the population demographics are likely to more closely reflect the national average.

Of the 132 known individuals, 80 (61%) were photographed in 2019, a slight decrease from records in previous years (Fig. 16). Seven new individuals were recorded in Laamu Atoll (six new to the Maldives), which remained consistent with the numbers of new individuals recorded in past years (Fig. 16). Six of the seven individuals were identified as male (one adult, two sub-adults, and three juveniles) and the sex of the seventh individual remains unconfirmed.

Between 2015 and 2018, the percentage of males sighted has remained consistent at 40-41% per year. This year, 45% ($n=36$) of individuals sighted were male, and 54% ($n=43$) were female. This shift in the ratio was due in part to the new males identified, but may have also been the result of below-average sightings of female manta rays.

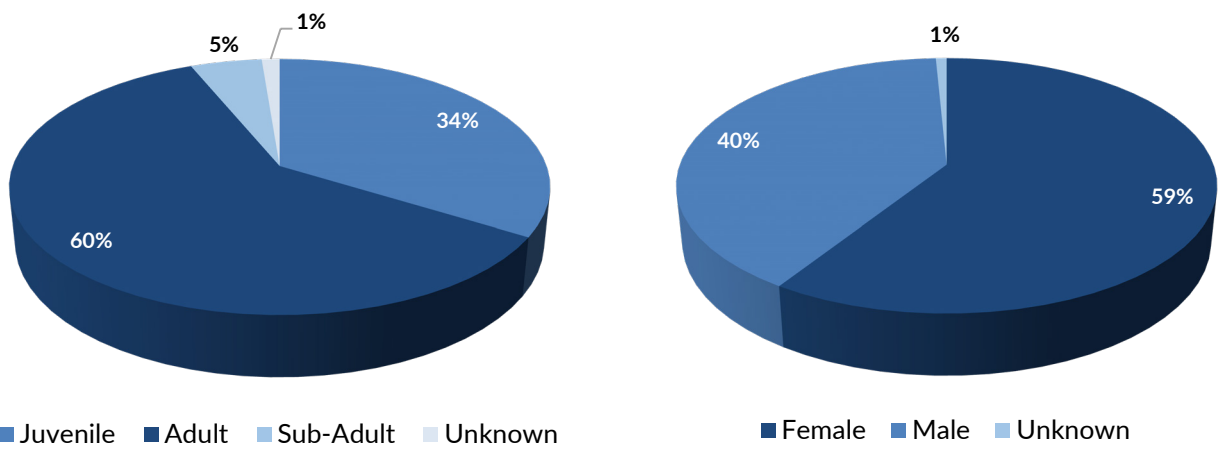


Figure 15: Demographics of the Laamu Atoll reef manta ray (*Mobula alfredi*) population (n=132).

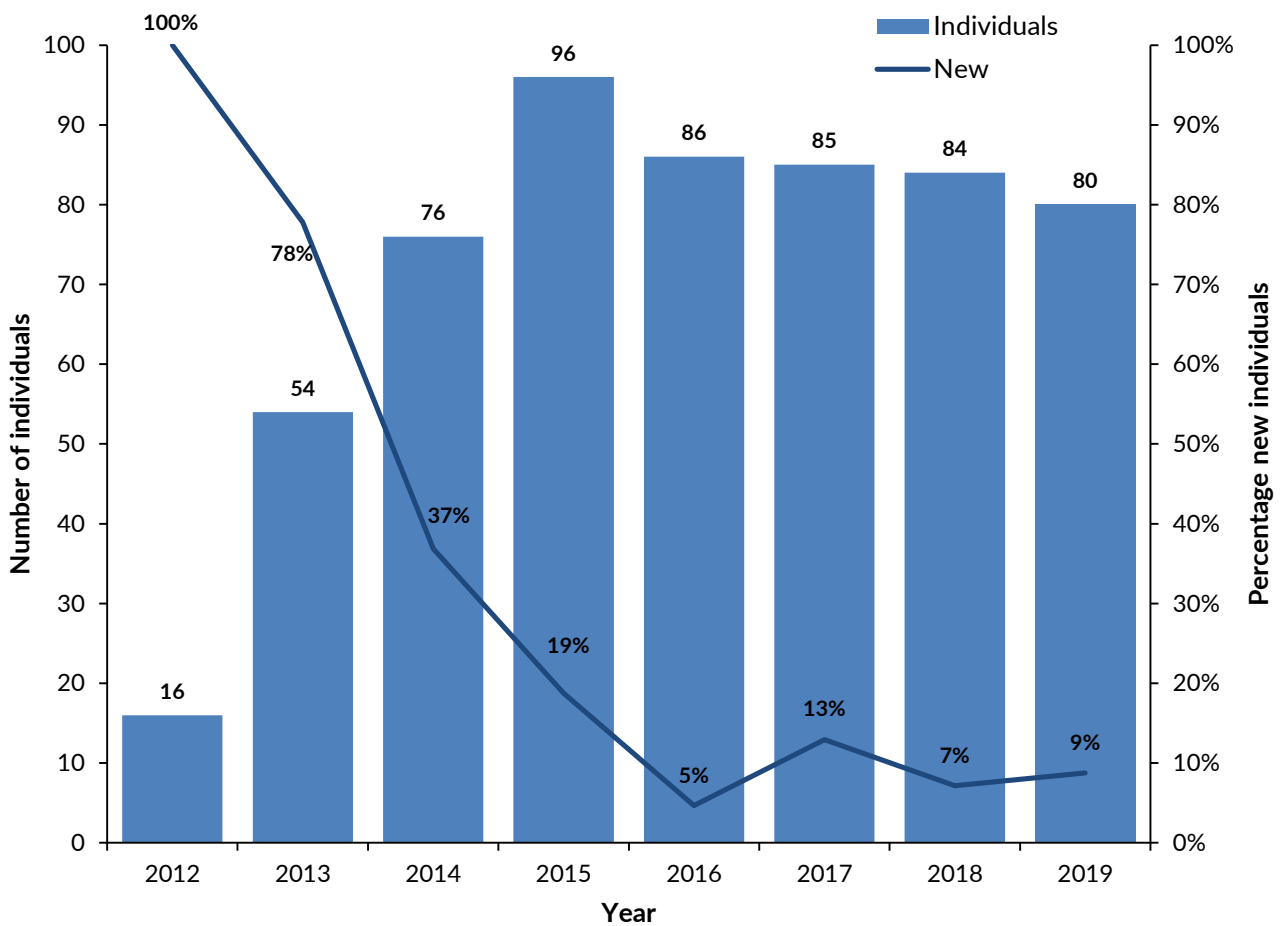


Figure 16: Number of reef manta rays (*Mobula alfredi*) sighted annually in Laamu Atoll and the percentage of those individuals which were newly recorded.

Maturation status in manta rays can be determined by the presence of mating scars or visible pregnancies in females, or by the enlargement and calcification of claspers in males. If visual features are not apparent, the size and historical sightings records of individuals can also be considered to estimate maturation. If an individual was estimated or measured to be at, or larger than, 320 cm disc width

in females or 270 cm disc width for males, they were considered as adults. Research on measuring manta rays is currently being conducted in Laamu Atoll as part of a PhD study. A follow-up report on this PhD research will be available in July 2020. More information about measuring manta rays is also available in the project activities report.

Maturation demographics in 2019 remained similar to previous years. Sixty percent of individuals sighted in 2019 were adult manta rays ($n=48$) (Fig. 17). Demographics of the overall population appear relatively consistent. However, since 2016, there has been a steady increase in the proportion of juveniles sighted in Laamu Atoll, and a steady decrease in the proportion of adults sighted (Fig. 18). This may be the result of young recruits utilising the study sites after a period of population fecundity. It

could also indicate that the study sites in Laamu Atoll are utilised more by adults when conditions are favourable for courtship. Another possibility is that research effort in recent years has diversified focus to collect data from more varied manta aggregation sites, opportunistically capturing younger individuals in the process which are less likely (less often) to frequent the adult cleaning stations at sites like Hithadhoo Corner.

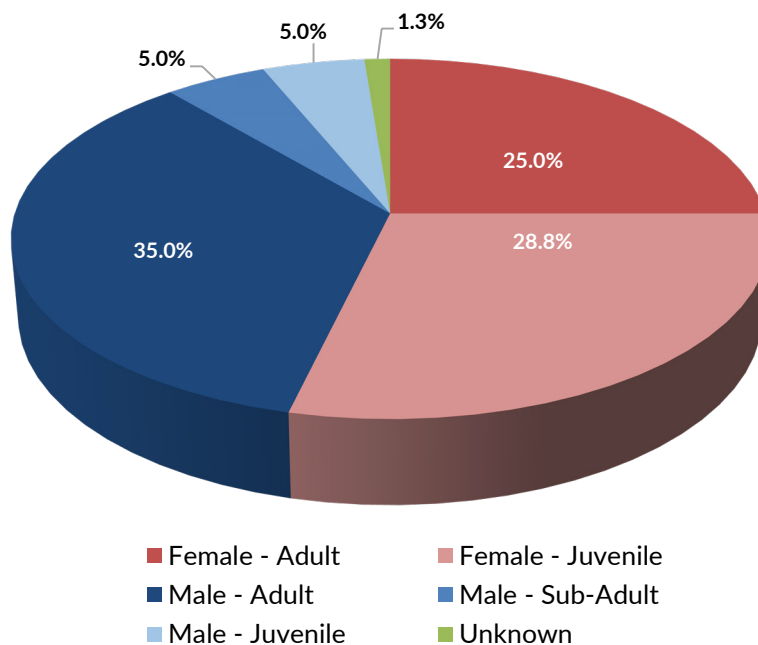


Figure 17: Demographics of the Laamu Atoll population of reef manta rays (*Mobula alfredi*) sighted in 2019.

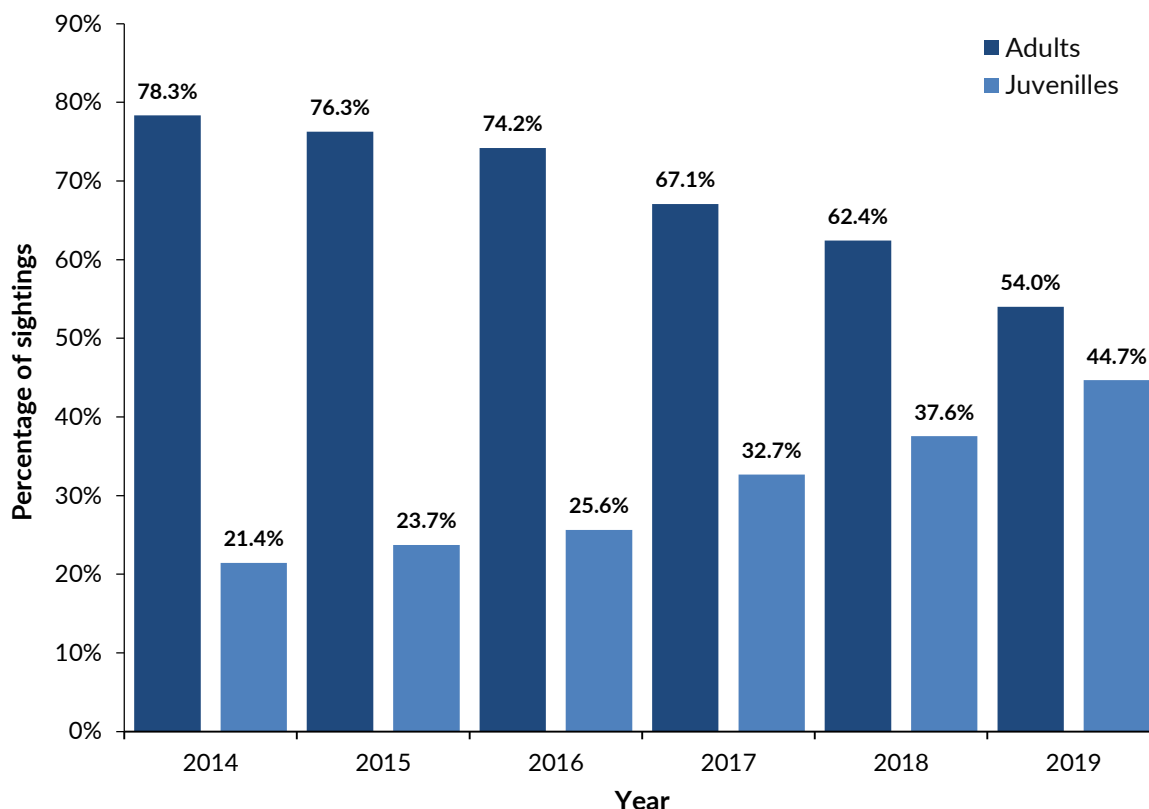


Figure 18: Percentage of confirmed sightings of juveniles and adult reef manta rays (*Mobula alfredi*) in Laamu Atoll between 2014 and 2019.

MIGRATION & RESIDENCY

The population of reef manta rays in Laamu Atoll is small yet highly resident. Individuals show high site fidelity and are rarely sighted elsewhere in the Maldives. Given the decrease in sightings, yet the similar number of individuals sighted (Fig. 16), the number of sightings per individual was lower in 2019 than in previous years (an average of 5.63 sightings per individual in 2019, compared to an average

of 8.12 sightings per individual between 2015 and 2018). The proportion of manta rays observed on more than one occasion (81%) was the lowest recorded since 2015 (Fig. 19). This suggests that the manta rays of Laamu Atoll were spending more time away from the identified study sites, utilising habitats unknown to the Manta Trust, most likely still within the atoll.

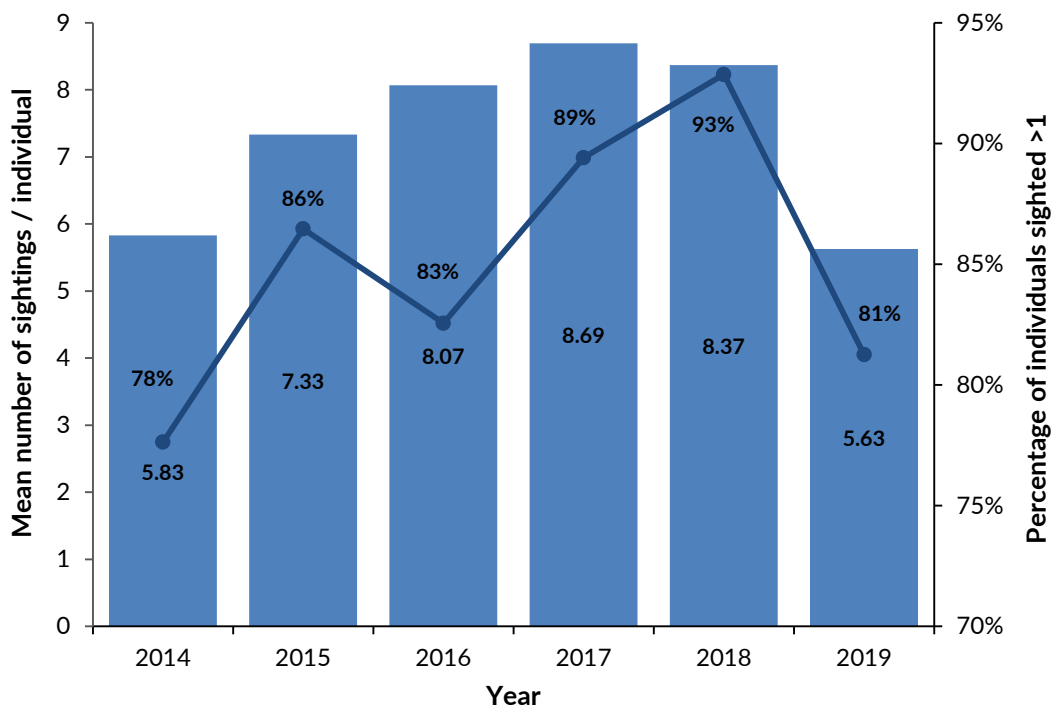


Figure 19: The mean number of sightings per individual reef manta ray (*Mobula alfredi*) annually in Laamu Atoll and the percentage of those individuals sighted more than once.

To account for variations in survey effort, an average Residency Index (RI) was calculated for each year based on the ratio between the number of times each individual was sighted and the total number of surveyed days (e.g. an RI of 3% means that, on average, each individual was sighted on 3% of the total surveyed days). Prior to 2019, average RI in Laamu Atoll ranged from 2.6% to 3.4%. In 2019, the RI dropped to 1.7% (Fig. 20). Changes in RI can be linked to environmental fluctuations or changes in survey effort in a given year. The number of survey days in 2019 was consistent with previous years; therefore, the decrease in residency is likely due to environmental or behavioural changes rather than variation in survey effort.

exhibited more transient behaviour in 2019, perhaps searching for more favourable conditions elsewhere. To date, 14% ($n=19$) of Laamu Atoll's population have been recorded elsewhere (Fig. 21).

In 2019, seven individuals were recorded outside of Laamu Atoll; three of which were recorded both in Laamu Atoll and elsewhere (Ari, Baa or Thaa). It is important to note that this low level may be a reflection of low survey effort and few reported sightings in nearby atolls. It could also indicate that individuals are not travelling outside Laamu Atoll, and may be using habitats yet to be identified by the MMRP.

While we cannot determine the exact movements of individual manta rays, it appears that the population

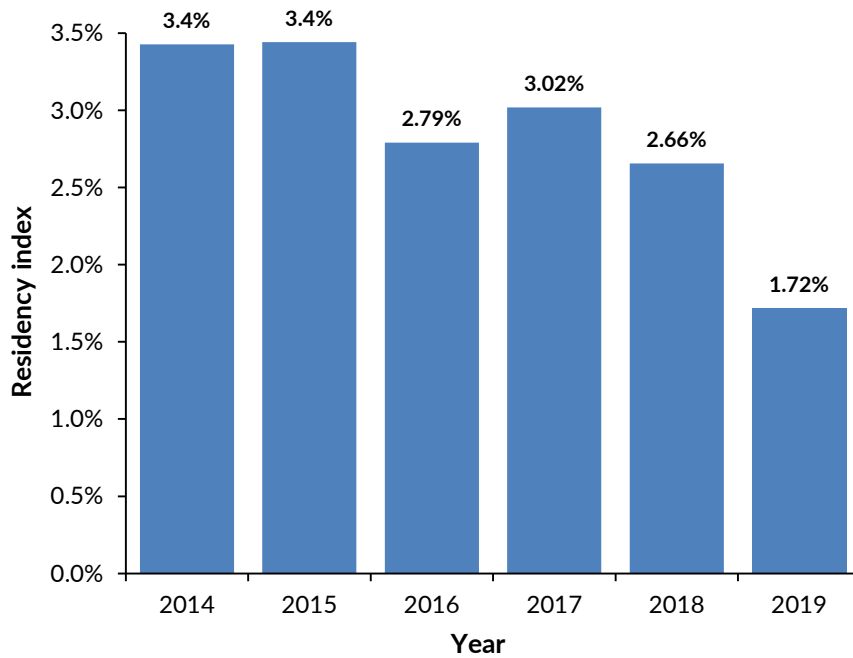


Figure 20: Annual Residency Index (RI) of the reef manta rays (*Mobula alfredi*) sighted annually within Laamu Atoll. RI was calculated as the average of each individual’s residency score (equal to the number of times sighted annually divided by the number of surveyed days in the atoll).

To determine if manta rays are utilising additional sites, it is necessary to increase survey effort in unexplored areas of Laamu Atoll. Increasing numbers of exploratory dives presents logistical challenges and this would mean a decrease in dives at Hithadhoo Corner. However, decreased sightings at crucial aggregation sites provide significant justification. This should be accompanied by increased outreach to liveaboard operators and dive centres in Laamu Atoll in the hope of obtaining additional sightings updates from study sites.

While some individuals were recorded to have travelled from Laamu Atoll in 2019, one juvenile male (MV-MA-4459) was recorded having travelled to Laamu Atoll from Huvadho Atoll, the closest atoll to the south (148 km away). This male was sighted three times in 2019. This was the first recorded sighting of an individual from Huvadho Atoll in Laamu Atoll, and it may suggest that other individuals are also visiting this region of the Maldives.



Photo by Marteyne van Well

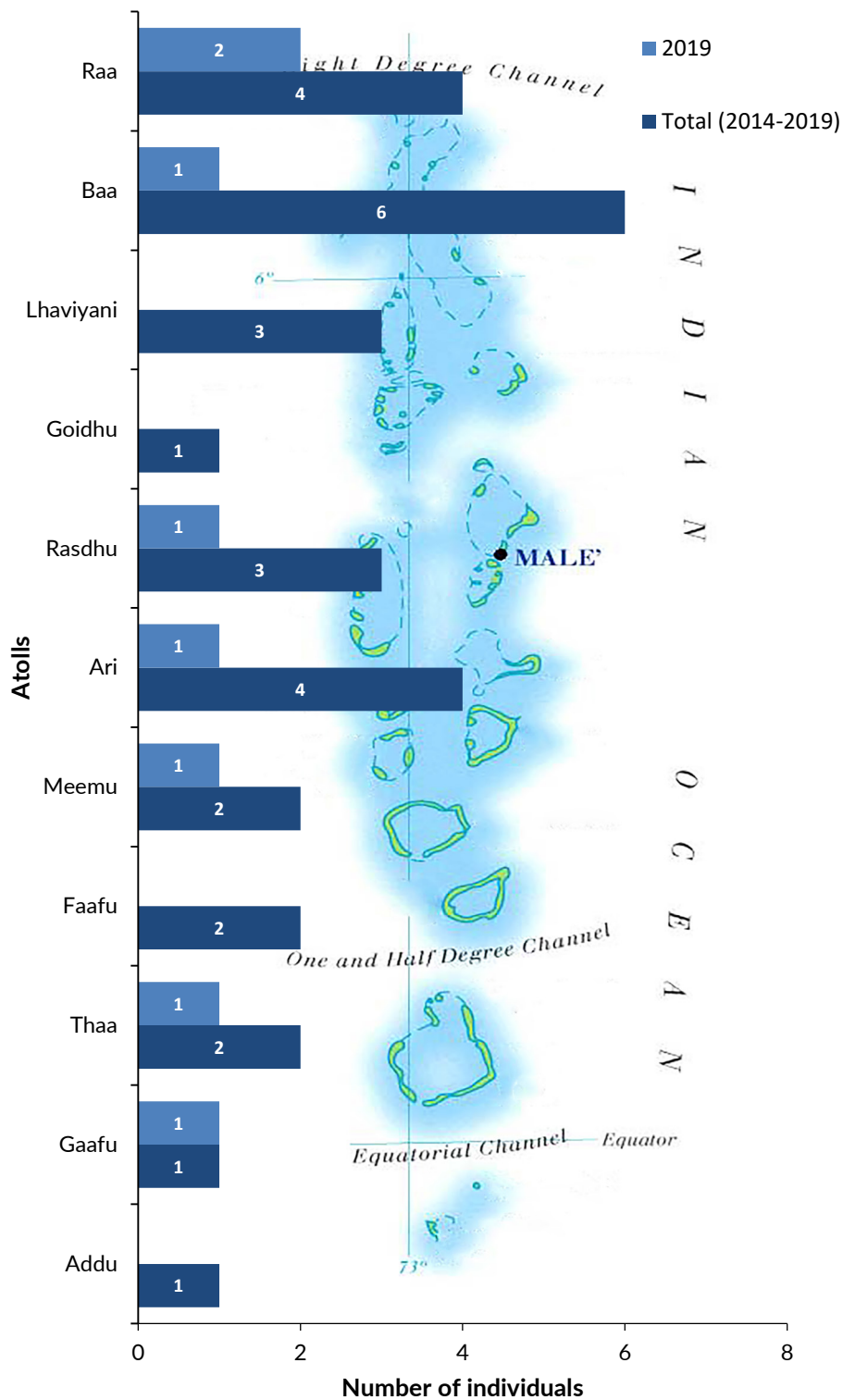


Figure 21: Number of reef manta rays (*Mobula alfredi*) ($n=19$) from the Laamu Atoll population ($n=132$) which have been recorded in other atolls throughout the Maldives. Some individuals have been sighted in more than one atoll outside Laamu Atoll.

PREGNANCIES & COURTSHIP

Prior to 2018, Laamu Atoll was considered to support a bi-annual courtship season (May-June and October-November). In 2018, courtship behaviour was minimal (11 sightings), likely due to the high number of pregnancies recorded the same year. In 2019, there was a very slight increase in courtship behaviour (Fig. 22), 15 sightings of 14 individuals. However, compared to most previous study years, instances of courtship activity were greatly reduced (Fig. 22). As a result, no seasonality to the courtship behaviour could be determined in 2019.

The gestation period of manta rays is a little over one year, and pregnancies become visible to researchers at about 4-6

months (2nd trimester onward). Of the 11 pregnant females recorded in 2018, 27% (n=3) were observed pregnant in 2019. Two individuals (MV-MA-2414 and MV-MA-2972) were recorded in the later stages of gestation (3rd-4th trimester), indicating their pregnancies were likely ongoing from the previous year. Both individuals were recorded at the end of 2019, and it appeared they had given birth in 2019. In the case of the third individual (MV-MA-3430), she was recorded with a late-term pregnancy in 2018, and then confirmed as pregnant in June 2019, signifying she likely gave birth and was pregnant for a second time in consecutive years.

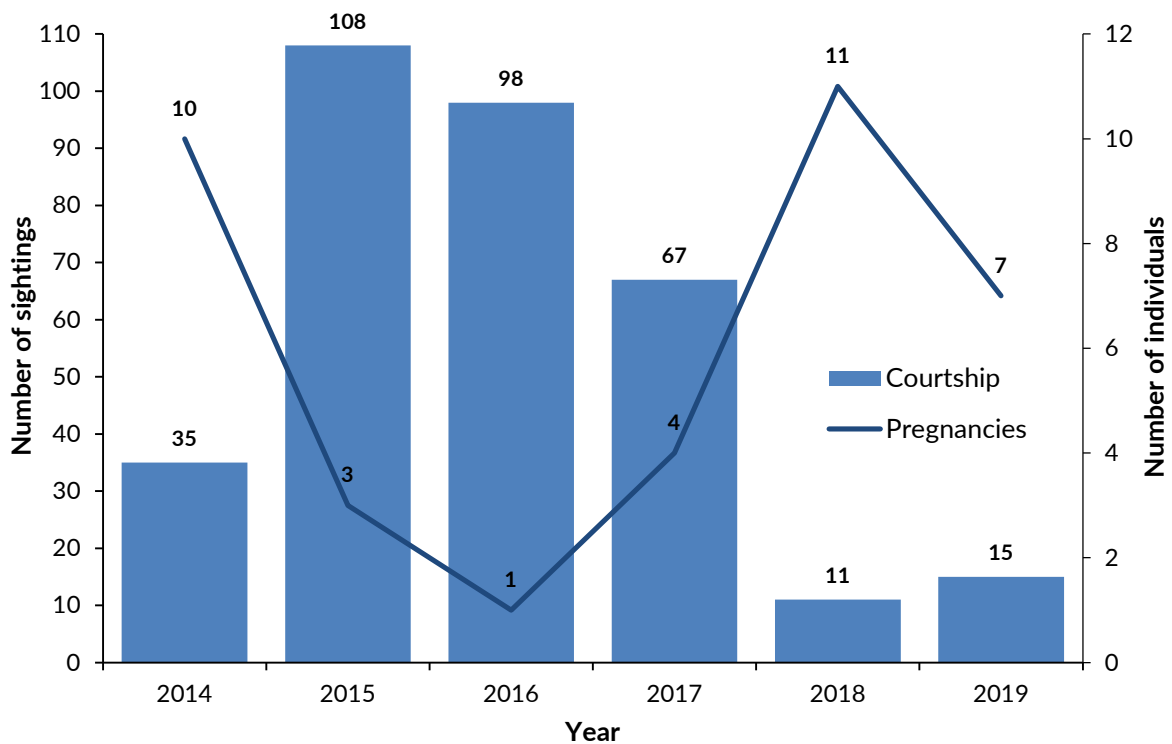


Figure 22: Number of sightings annually during which courtship was the primary behaviour, and the number of individual reef manta rays (*Mobula alfredi*) which were recorded pregnant annually.

Fifty-four percent (n=6) of the pregnant females from 2018 were sighted and no longer pregnant in 2019, suggesting they had also likely given birth. Two individuals (MV-MA-1446 and MV-MA-2930) were recorded as pregnant in 2018 but they were not sighted in 2019. Including the three individuals recorded as pregnant in 2018 (above), there were a total of seven pregnancies recorded in 2019 (Fig. 23). For two individuals (MV-MA-0258 and MV-MA-2412), 2019 was the first year in which a pregnancy was recorded. One individual (MV-MA-2810) was last recorded pregnant in 2015, while a second individual (MV-MA-2912) was

recorded as pregnant in 2014.

Of the 32 mature females known to Laamu Atoll, 84% (n=27) have been recorded on at least one occasion since 2017. Of these individuals sighted recently, 55% (n=15) were recorded as pregnant in the last two years. Given the low instances of courtship activity recorded in 2019, the high number of pregnancies recently documented, and the recovery time between pregnancies, it is likely the number of new pregnancies recorded in 2020 will be substantially lower.

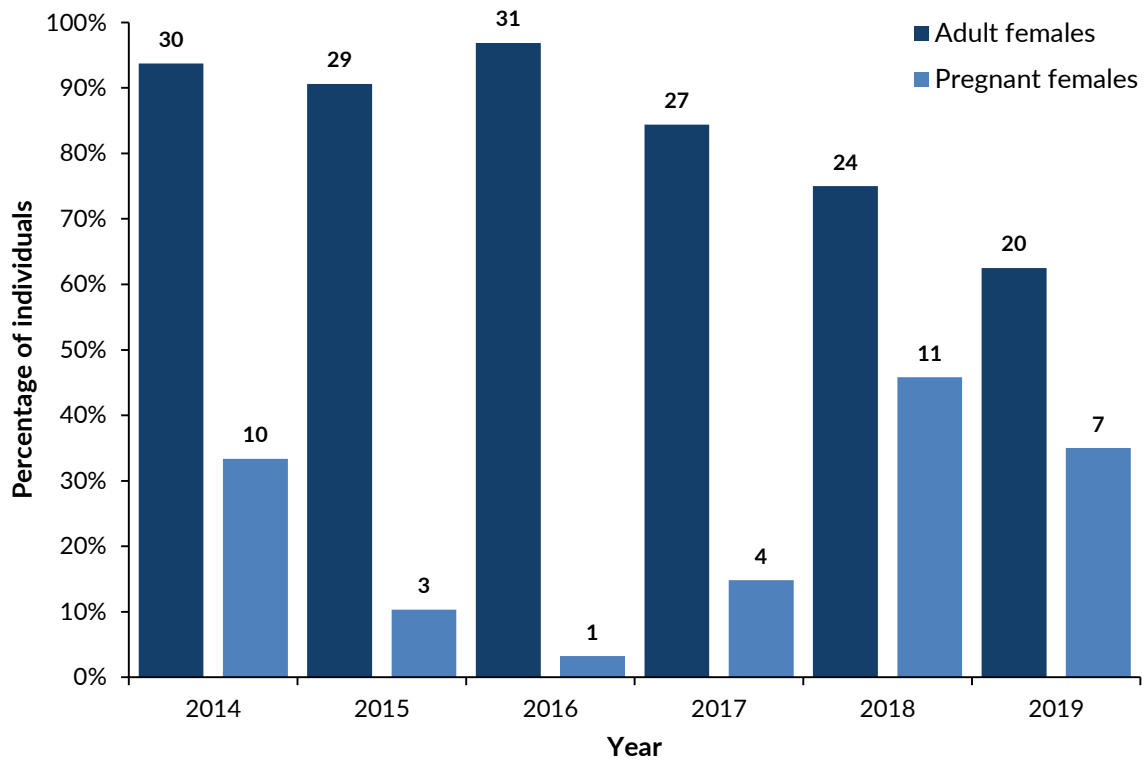


Figure 23: Percentage of the adult female reef manta ray (*Mobula alfredi*) population sighted annually in Laamu Atoll, and the percentage of those sighted females which were recorded pregnant in the same year. Actual numbers above bars.

In 2019, Six Senses Laamu, the Manta Trust, IMV Imaging, and the University of Cambridge released the first images of pregnant and non-pregnant reef manta rays using the world’s first contactless underwater ultrasound scanner. In 2019, the MMRP team at Six Senses Laamu recorded

12 scans of 10 individuals, two of which confirmed pregnancies (MV-MA-3430 and MV-MA-2972). For additional information about the ultrasound scanner, please see the press release or project activities report. An additional report will also be available in July 2020.

SUB-LETHAL INJURIES

Of the 132 identified individuals in Laamu Atoll, 35% ($n=45$) have been recorded with at least one sub-lethal injury. Forty-eight injuries have now been documented in Laamu Atoll, and 93% ($n=42$) of injured individuals have one sub-lethal injury, while 7% ($n=3$) have two sub-lethal injuries. Of these injuries, 48% ($n=23$) were of natural origin, 35% ($n=17$) of anthropogenic origin, and 17% ($n=8$) of unknown origin (Fig. 24). Of the 45 injured individuals, 73% ($n=33$) sustained injuries to their pectoral fins, 17% ($n=8$) to their head, tail or dorsal regions, 13% ($n=6$) to their cephalic fins, and 2% ($n=1$) to gill slits (Fig. 25).

Ninety-four percent ($n=16$) of anthropogenic injuries have resulted from entanglement in fishing line (Fig. 26). The majority (68%, $n=11$) of fishing line entanglements have caused injury to the pectoral fins of individuals, but there have also been injuries of concern ($n=4$) to the cephalic fins

or eye regions ($n=1$).

Only one injury consistent with a boat strike has been recorded in Laamu Atoll. The low prevalence of this injury type in the atoll is likely due to the low level of tourism and boat traffic. As tourism and boat traffic increases, particularly near the aggregation sites, operators need to be vigilant in looking for marine megafauna on the surface.

Predatory bites accounted for 78% ($n=18$) of injuries originating as a result of natural causes and interestingly, 94% ($n=17$) have been inflicted upon female manta rays. This may be coincidental, but could also suggest that predatory attacks occur near cleaning stations where female manta rays spend more of their time cleaning. Cleaning stations are typically located in channels and are therefore more exposed to large predators.

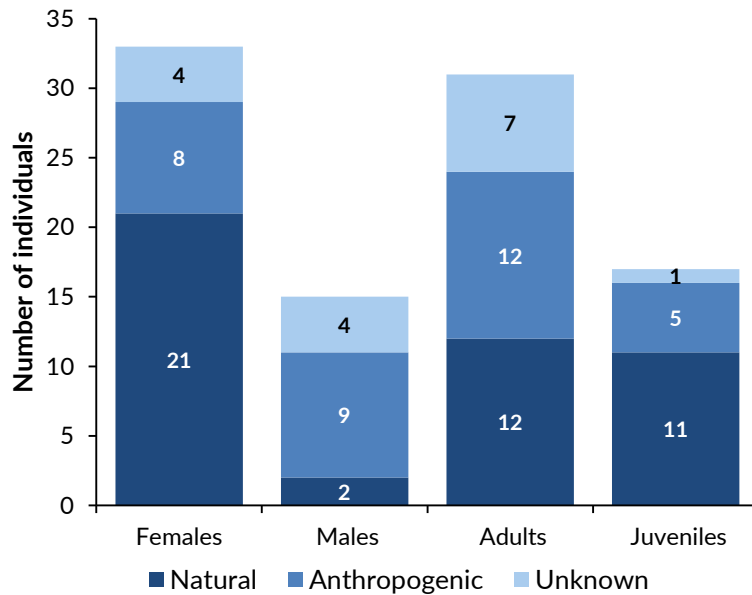


Figure 24: Demographic variation in the likely origin (natural, anthropogenic or unknown) of sub-lethal injuries ($n=48$) within the injured reef manta ray (*Mobula alfredi*) population of Laamu Atoll ($n=45$).

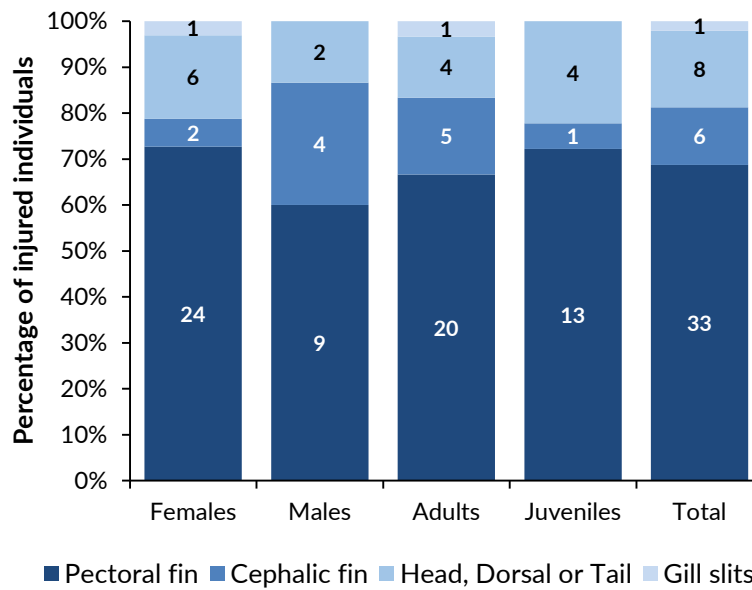


Figure 25: Variations in the location of sub-lethal injuries ($n=48$) within the injured reef manta ray (*Mobula alfredi*) population of Laamu Atoll ($n=45$). Actual number of individuals on bars.

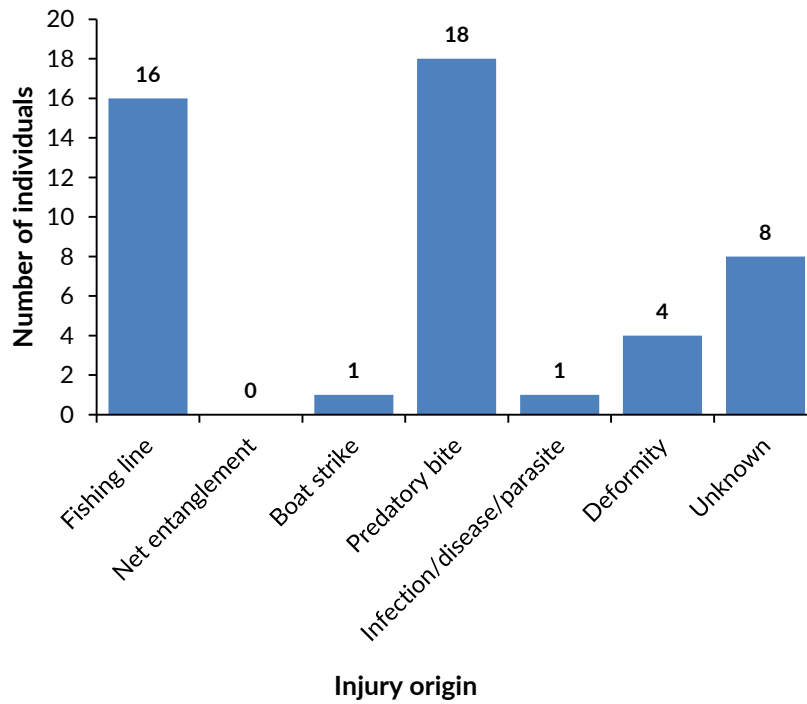


Figure 26: Variations in the origin of sub-lethal injuries ($n=48$) within the injured reef manta ray (*Mobula alfredi*) population of Laamu Atoll ($n=45$).

In 2019, there were three individuals (MV-MA-2816, MV-MA-2972, and MV-MA-4399) recorded with new minor injuries to their pectoral fins, face or eye regions, all of which appeared to be caused by fishing line. While injuries were considered superficial, there was an entanglement that could have resulted in severe injury. Calypso (MV-MA-2410) was photographed via RUV at Hithadhoo Corner in October, trailing approximately six feet of fishing line. When he was next photographed in late November, the fishing line had gone, yet he did not appear to have sustained any lasting injuries.

Despite Six Senses Laamu actively discouraging fishing at Hithadhoo Corner, and the Maldives Underwater Initiative team working hard to protect the area, fishing continues at this site. Active fishing is rarely observed. However, the MMRP removed fishing line from the reef and cleaning stations on multiple occasions. This fishing line likely originates from reef fisheries as tuna fishing takes place further offshore. Without observing individuals becoming entangled, it is impossible to determine whether fishing at Hithadhoo Corner constitutes the cause of injuries observed or whether these injuries are sustained elsewhere.

FISHERMAN INTERVIEWS

Since the MMRP's partnership with Six Senses Laamu in 2014, our work has primarily focused on in-water surveys. In 2019, the Manta Trust's Laamu Atoll team broadened its reach and conducted fishermen interviews to gather information from the local community.

Throughout the Maldives, fishermen spend a vast amount of time on the water and therefore are likely to encounter manta rays on their fishing trips. In the Maldives, the method of bait-fishing involves the use of a large light at night to accumulate plankton and attract baitfish. These lights have been known to also attract manta rays in some areas of the Maldives (e.g. Ari Atoll) as they come to feed on the zooplankton. Trials in Laamu Atoll using lights to attract manta rays took place throughout 2018 and 2019 without success.

The Laamu Atoll team conducted preliminary fishermen interviews to gain a greater understanding of current and historic manta sightings in the region and to determine whether night light trials may be more successful at different sites within the atoll. These interviews also provided a fantastic opportunity to gain knowledge about fishermen's perceptions of manta rays and manta ray conservation.

In 2019, the team conducted 31 preliminary interviews on six local islands (Hithadhoo, Kunahandhoo, Maamendhoo, Gan, Maabaidhoo and Isdhoo). The majority of fishermen ($n=29$) targeted skipjack tuna; the others targeted either reef fish ($n=1$) or yellowfin tuna ($n=1$). Ninety percent ($n=28$) of those interviewed were actively involved in fishing.

Ninety percent of fishermen (n=28) reported that they had encountered manta rays during fishing trips. Nine fishermen reported seeing manta rays during the Northeast Monsoon, three fishermen stated that they had encountered them during the Southwest Monsoon, and five fishermen reported having seen manta rays year-round. Only four fishermen stated that they rarely encountered manta rays in Laamu Atoll.

Of the 28 fishermen that reported manta sightings, 75% (n=21) reported encounters within the atoll, whereas 61% (n=17) reported encounters farther offshore (between 1-70 miles). Specific channels and sites that were reported are shown in Figure 27. Additionally, six fishermen reported manta rays between channels, along the inside of the atoll from Isdhoo to Maavah (n=5), or from Isdhoo to Gan (n=4). The area around Vadinolhu Kandu was mentioned in 25% (n=7) of interviews, and it is recommended that the reefs around this channel should be further explored. Only three fishermen reported encounters with manta rays at night lights, and each commented that such encounters were particularly rare.

Seven fishermen reported either catching a manta ray, or a manta ray becoming entangled in fishing line. Most fishermen understood that manta rays were a protected species in the Maldives; however, 51% (n=16) were unaware of the rules and regulations surrounding the species. Ninety-four percent (n=29) of fishermen agreed that manta rays should be protected and 6% (n=2) did not answer the question.

At the end of the interview, each interviewee was asked if they would be willing to contact MMRP representatives if they saw a manta ray; most were willing to share information. We are hopeful that through collaboration and information sharing, the MMRP team in Laamu Atoll can learn more about habitat usage and migration of manta rays in the atoll. In 2020, the team plan to conduct more formalised interviews on each of the inhabited islands in Laamu Atoll.

To learn more about our education and outreach programs with schools, liveboards, and community members in Laamu Atoll, please see the 2019 project activities report.

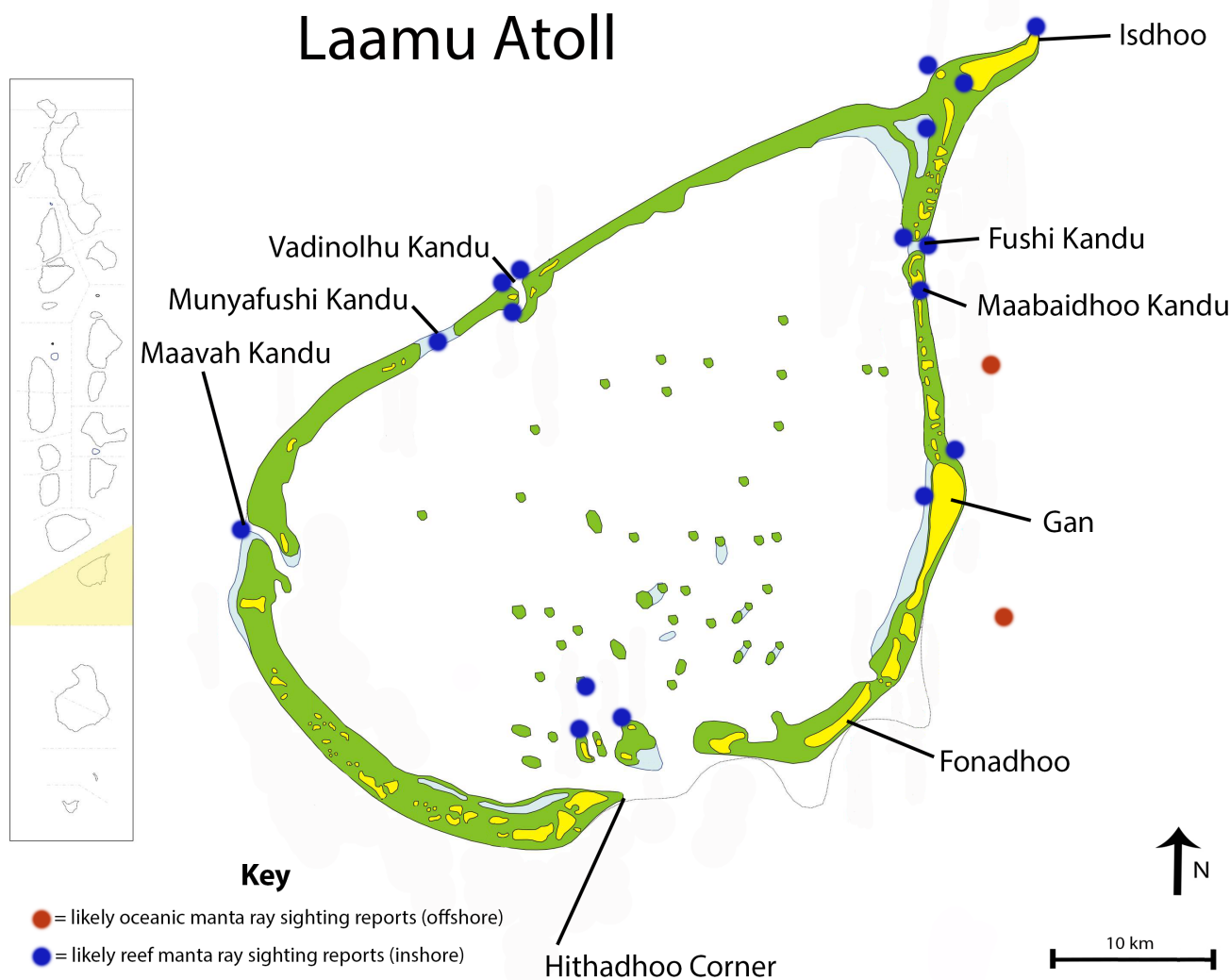


Figure 27: Locations where fishermen have reported manta ray sightings following interviews conducted throughout Laamu Atoll in 2019.

CONCLUSION

In 2019, the Manta Trust researchers recorded shifts in behaviour, encounter locations, and seasonality of manta ray sightings. The most plausible explanation for these changes could be a result of inter-annual fluctuations in the ecological needs of the population, most likely resulting from changes in environmental conditions. While sightings decreased, research remained valuable, as surveys without manta rays are equally important to understanding long-term behavioural patterns and habitat usage.

The manta ray population in Laamu Atoll remains highly resident, with few individuals known to other atolls. Despite lower than average sightings, Hithadhoo Corner continues to support year-round manta sightings - a crucial habitat for the species in this region. While it is a key aggregation site, it is likely that other sites in the atoll also support the local manta population. Comparatively little is known about manta ray sightings closer to Isdhoo, and at the western channels of the atoll. Further research should be conducted in these areas, during both monsoons, as sightings here may provide information about site usage and potential migrations within Laamu Atoll. Further study is needed, and we hope that in conjunction with community outreach and exploratory dives, we can gain additional insight into migration patterns and habitat use in the atoll.

Advances in technology and survey methodology have increased data collection, and these tools will enable us to expand our research across Laamu Atoll. Remote underwater video cameras proved their value this year,

recording more than 10% of confirmed sightings. While drone surveys have only been trialled in Laamu Atoll to date, they have enabled teams in the northern atolls to identify shallow water manta ray cleaning stations and feeding aggregations. Aerial studies will be conducted regularly in 2020 to search for new sites across Laamu Atoll.

Outreach this year allowed us to increase sightings information, encourage the use of our “swim with mantas” guidelines, and engage with community members. The team will continue to focus on engagement opportunities in 2020 through additional fisherman interviews, community sessions and liveaboard outreach.

Given the small size of the reef manta ray population, and the high site fidelity observed in the atoll, habitats in Laamu Atoll are of utmost importance to the local manta ray population. As development and tourism continues to increase in the Maldives, we need to be mindful of all potential impacts to habitats and recognise the stressors already altering the environment in the Maldives.

We remain incredibly grateful to Six Senses Laamu for supporting our research, education, and outreach initiatives. Through collaboration with the Maldives Underwater Initiative team, local stakeholders, and government agencies, it is our hope that significant areas of manta ray habitat in Laamu Atoll can be protected to safeguard this species, and to conserve the wider biodiversity and marine resources in the atoll.



Photo by Marteyne van Well

This report was made possible thanks to



MALDIVIAN MANTA RAY PROJECT (MMRP)

The MMRP is highly regarded within the scientific community. It is the largest and one of the longest running manta ray research programmes in the world. We would welcome the opportunity to continue to work with the Maldives government and our other partners for the long-term management and conservation of these species in Maldivian waters. The opportunity we have to learn about manta rays in the Maldives is unique and has many implications on a global scale for manta ray conservation.

The MMRP and the Manta Trust are happy to share with the Maldives government any data collected as part of this study.



SIX SENSES

LAAMU

SIX SENSES RESORT LAAMU

The MMRP expresses its sincere appreciation for the ongoing partnership between Six Senses Laamu Resort and the Manta Trust. Without their support, this important work would not have been possible. The Manta Trust and the MMRP are looking forward to a continued and successful partnership with Six Senses Laamu.



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