Maldivian Manta Ray Project

LAAMU ATOLL | ANNUAL REPORT 2018

Conservation through research, education, and collaboration

- The Manta Trust

www.mantatrust.org
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 4,650 different individual reef manta rays, from more than 60,000 photo-ID sightings. This makes the Maldivian manta population the largest, and one of the most intensively studied populations in the world.

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.
This annual report is the fifth of its kind in a series that presents data collected by the MMRP on Laamu Atoll’s manta ray populations throughout the year. We are incredibly proud and grateful to continue to have Six Senses Laamu as one of the MMRP’s Key Regional Partners.

The MMRP’s earliest data on these species from the atoll goes back only seven years. The first confirmed manta sightings were recorded by dive staff at the newly opened Six Senses Resort in 2012, and although tourism activity has increased in recent years, the majority of the data collected on the atoll’s manta population has come from the MMRP staff. The primary reef manta ray (Mobula alfredi) aggregation site within Laamu Atoll, Hithadhoo Corner, supports consistent year-round manta sightings. However, over the course of our partnership with Six Senses Laamu, manta rays have also been sighted at an additional 19 sites within the atoll. Of these additional sites, Fushi Kandu in particular is another important aggregation area for reef manta rays within Laamu atoll.

Hithadhoo Corner is a biodiverse channel, where reef manta rays aggregate to clean, engage in courtship behaviour, and occasionally feed at the surface. Working with the Six Senses Resort in Laamu, the Blue Marine Foundation (BLUE) has also determined that Hithadhoo Corner is an aggregation site of high importance for groupers. To further understand the importance of this site as a biodiversity hotspot, the Maldives Underwater Initiative (MUI) team will be extensively surveying the area throughout 2019.

Working together with BLUE and the MUI team, the Manta Trust hopes to provide the Maldives government with the necessary evidence to designate Hithadhoo Corner and Fushi Kandu as Marine Protected Areas (MPAs).

Key findings of the Manta Trust in Laamu Atoll across 2018 include 703 sightings of 84 individual reef manta rays (64% of the atoll’s recorded population). Six new reef manta rays were identified in Laamu during 2018, all of which were new to the national database, increasing the total known population of reef manta rays in Laamu to 125. Of the 125 reef manta rays known to Laamu, 63% (n=79) are female and 37% (n=46) are male. Sixty percent of the population in Laamu are adults (n=33 females and 42 males). Only two individuals (both male) are considered to be sub-adults, while the remainder are juveniles (n=48). Of the known juveniles, 46 are female, and only two are male. The total number of sightings between 2017 and 2018 remained relatively consistent (739 sightings of 85 individuals in 2017). However, when standardised for survey effort and compared to previous years, there was a minor decrease in sightings in 2018 from 2017, and the number of manta rays observed per survey day was similar to that observed in 2016. Courtship activity decreased atoll-wide in 2018, with only 11 confirmed sightings of individuals engaged in courtship behaviour during the entirety of the year. While courtship declined, the number of pregnant individuals recorded in the atoll was at its highest since records began (2012), with 27 sightings of 11 visibly pregnant individuals.
Located in the south of the Maldives, Laamu Atoll (Fig. 1) spans 48 km from north to south, and 35 km across at its widest. The atoll has a deep central lagoon (average 60 m), surrounded by over eighty relatively large islands, including Gan, the largest island in the country at 8 km in length, situated along the eastern edge of the atoll. Given the large islands and connecting causeways along a vast portion of the barrier reef, there are very few channels (n=7) that break the fringing reef. The limited channels in the atoll’s rim make the current dynamics and water flow through Laamu less dynamic than the more open central and northern atolls of the Maldives.

The fluctuating monsoons (seasons) within the Maldives play an important role in determining manta ray distribution. Therefore, understanding the South Asian Monsoon is critical to interpreting the sightings of manta rays in Laamu Atoll. The strong monsoonal winds create oceanic currents that flow either from the northeast towards the southwest (Northeast Monsoon), or from the southwest towards the northeast (Southwest Monsoon). The Maldives’ islands and atolls, rising 2,000 metres from the sea floor, act as a barrier to these currents, displacing the water as it flows through and around the atolls, creating deep-water upwelling. These upwellings bring nutrient rich water within reach of the sun’s rays, enabling photosynthetic phytoplankton to flourish, and generating a bloom of predatory zooplankton that feed on the phytoplankton. Zooplankton is the prey of manta rays and, as strong lunar currents flow through the channels, the concentrated zooplankton is so abundant that the Maldives’ waters support the world’s largest known population of reef manta rays. It is at these sites where the biodiversity and abundance of all marine life in the Maldives is at its highest. Manta rays tend to frequent cleaning stations that are in close proximity to their plankton-rich feeding areas, and thus, will migrate seasonally to utilise feeding areas and cleaning stations on the monsoonal down-current edge of the atolls where these seasonal productivity hot-spots occur.

Situated much further south in the Indian Ocean than the majority of the nation’s 26 geographical atolls, Laamu Atoll is less influenced by the South Asian Monsoon, resulting in more consistent localised upwelling, and reduced monsoon driven migratory behaviour of the atoll’s reef manta ray population. However, despite the year-around occurrence of reef manta rays in the southern channels of Laamu Atoll, the local manta population does still undertake seasonal migration behaviour within the atoll, and across to the more northern atolls.
Reef manta rays have been recorded at twenty sites throughout Laamu Atoll (Fig. 1). However, the vast majority of sightings have been recorded at just two primary aggregation sites (Table 1). Given its close proximity to the resort and reliable reef manta ray sightings, Hithadhoo Corner has been a primary study area for the MMRP in Laamu Atoll for the last five years, and has provided a wealth of information to this project. At this site, there are five distinct coral bommies (primarily *Porites sp.*) that provide habitat for three species of cleaner wrasse (*Labroides dimidiatus*, *L. bicolour*, and *Thalassoma amblycephalum*). These fish species play an important ecological role and interact with teleost fishes, sharks, manta rays, and sea turtles to clean their skin of any parasites or dead tissue. The large coral bommies and cleaner wrasse that occupy the habitat identify Hithadhoo Corner as a ‘cleaning station’. Fushi Kandu, a channel located in the northeast of Laamu Atoll, has a distinct coral bommie that has also been identified as a cleaning station, situated at approximately 15 metres in depth. Increased survey effort during 2017 and 2018 has allowed the MMRP to determine that this is another important aggregation site for manta rays in Laamu Atoll. Situated 30 kilometres from Six Senses Laamu, this site is logistically challenging to survey regularly. In 2017, the MMRP began joining guest dives to the area for research. In 2018, increased resort guest diver visitations to this site, and several dedicated research trips, allowed much greater survey effort.

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*Table 1: Twenty sites in Laamu Atoll where reef manta rays (*Mobula alfredi*) have been observed; pooled into four regions for comparative analysis based on their geographical position. *Indicates key manta aggregation site, and primary research location within the atoll.*
Since the project began in 2012, manta rays have been occasionally sighted along the outer reef edges of Laamu Atoll. The fringing reefs of the islands on the outer atoll are characterised by reef drop-offs to depths of approximately 24-28 metres, where there is a plateau of coral or sand before an additional drop off too much greater depths. In 2018, the MMRP increased its survey effort along the southern and eastern edges of the atoll to determine if any of the reefs may serve as potential aggregation sites for manta rays. Through partnerships with the MUI team and Deep Blue Divers, the MMRP has also received information on manta ray sightings at additional sites beyond our study locations, and from known aggregation sites when the Manta Trust team were not present. This data will prove valuable in determining where to increase survey efforts in 2019.

**STUDY PERIOD & SAMPLING METHODOLOGY**

Since 2014, survey effort by the MMRP team in Laamu has increased annually, with surveys being conducted regularly at Hithadhoo Corner, and when possible, at distant sites within the atoll. Throughout 2018, survey effort across Laamu continued to increase, with extra submissions from Six Senses staff, resort guests, and Deep Blue Divers all contributing to the database (Fig. 2).

For this report, a survey is defined by the time spent at a single location each day. If multiple SCUBA dives or snorkels took place at a single location with only a short surface interval (approx. 60 minutes), this total period was considered a single survey. If more than two dives/snorkels took place with an extended surface interval between (i.e., morning and afternoon dives), these surveys were logged separately. Survey days refer to the number of days where surveys were conducted in the atoll irrespective of location. To account for changes in sampling effort, where possible, data from all years was standardised to give comparable results.

In 2018, surveys (n=509) were conducted on as many days (n=315) as conditions and logistics allowed throughout the year (Fig. 3). Surveys were primarily conducted on SCUBA due to the depth of manta aggregation sites in Laamu Atoll. However, when surface feeding was reported or observed between dives, surveys were conducted by snorkelling (n=14). The research took place through a combination of dedicated research dives (n=398), remote underwater video camera deployments (n=8), and during resort manta excursions that included guests (n=214). For all surveys including guests at known aggregation sites, the Manta Trust’s MMRP staff briefed guests on the code of conduct for diving with manta rays, and how staff would record identification photographs (photo-IDs) if mantas were present during the dive.

For each dive, environmental variables, such as wind direction, cloud cover and sea state, were recorded alongside information about the manta rays at the site (e.g. pregnancies, injuries). The behaviour of the observed manta rays, and the number of divers at any given location, were also recorded. For guest dives, additional data was collected on the number of guests and interactions between manta rays. This data contributed to a Maldives-wide study on the diving code of conduct for manta rays. During all dives, the research team photographed the ventral pattern of individual manta rays whenever possible. For the purposes of this report, a sighting is defined as a confirmed photo-ID of an individual manta ray on a given day at a single location.
Survey effort at Hithadhoo Corner remained high in 2018, with data collected at this site on 265 days of the year (Fig. 4). In 2017, Fushi Kandu was only surveyed on 21 days over nine months. However, as this site has now been identified as an important aggregation area for manta rays, survey effort increased in 2018, resulting in visitations on 52 days throughout the year (minimum of once a month) (Fig. 4).
Oceanic manta rays (*Mobula birostris*) are rarely observed in Laamu atoll, with only eleven sightings in the atoll to date. No oceanic manta rays were observed in the atoll during the 2018 survey period. As the more offshore of the two species in the Maldives, oceanic manta rays are rarely observed by divers in the Maldives. The remainder of this report will refer only to the reef manta ray population in Laamu Atoll.

### Sightings & Population Size

At the end of 2018, the recorded reef manta ray population was 125 individuals. In 2017, there was a slight increase in recorded sightings from previous years. However, in 2018 sightings returned to similar levels recorded in 2015 and 2016 (Fig. 5). In 2018, there were 703 sightings of 84 individual reef manta rays recorded (Fig. 6). The number of individuals observed each year has remained relatively consistent since 2016, and only six of the 125 individuals recorded in Laamu Atoll have only been sighted once. This high re-sighting of individuals (95%), and only the occasional sightings of new individuals in Laamu Atoll, strongly suggests that the majority of the adult population in this area has likely been identified (Fig. 6).

A monthly breakdown of sightings over the course of 2018 show two clear peaks in sightings; May/June and again in October/November (Fig. 7). These peaks are consistent with sightings recorded in previous years (Fig. 8). The highest number of sightings recorded in a single month since the start of this research programme occurred in May 2018 \((n=153)\). Changes in the frequency of sightings are likely to be linked to fluctuations in the availability of the manta ray’s food near to key aggregation sites, and the reproductive activity of the population (discussed in more detail below).

![Figure 5: Total annual sightings of reef manta rays (*Mobula alfredi*) in Laamu Atoll (2014-2018).](image-url)
Figure 6: Total annual number of individual reef manta rays (*Mobula alfredi*) sighted in Laamu Atoll (2014-2018) and the percentage of new individuals during each year.

Figure 7: Total number of confirmed reef manta ray (*Mobula alfredi*) sightings during each month of 2018 in Laamu Atoll.
With more than 4,650 reef manta rays identified by the MMRP in the Maldives at the end of 2018, the Laamu Atoll population (n=125) represents only a small portion (2.7%) of the total. At study locations further north, the ratio of female to male manta rays observed is roughly 50:50, whereas in Laamu Atoll, the majority (63%) of the population is female (Fig. 9). Throughout the Maldives, female manta rays generally display higher site fidelity to cleaning station habitats than males. The same applies to adults over juveniles (Fig. 9). Given that the project’s primary study sites are both cleaning stations (Hithadhoo Corner and Fushi Kandu), these female and adult sample biases are not unexpected.

Of the eighty-four reef manta rays observed in 2018, 61% were female (n=51) and 39% were male (n=33) (Fig. 10). This sex ratio is almost identical to what was observed in 2017, when 85 individuals were observed (33 males and 52 female). Furthermore, these figures are consistent with the overall female:male ratio in the atoll throughout the study period 2014-2018. Overall, 60% of the population in Laamu is considered to be adult (33 females and 42 males), and 38% is juvenile (46 females and two males). Only two individuals, both male, are sub-adult (Fig. 9).
Maturation demographics have remained similar across years; with 24 adult females, 31 adult males, and 29 juveniles observed in 2018 (Fig. 10). Of the 703 sightings recorded within the atoll during 2018, only 194 sightings were of adult females, with the majority of sightings being of adult males ($n=259$). Males are often believed to visit cleaning stations to search for a mate, but with the low level of courtship behaviour observed in 2018 (see section below), this male visitation bias was somewhat unexpected, because generally adult females utilise these sites more frequently. However, the remainder of sightings were comprised of juvenile manta rays ($242$ female sightings and $8$ male sightings), and of these, $146$ sightings were of females of size class 3 ($270 – 310$ cm disc width), signifying they are close to maturation. When combined, size classes 3 and 4 (adult) females ($n=65$) comprise the largest demographic group ($65\%$) within the recorded Laamu Atoll population.

**Photogrammetry**

In 2016, Dr. Mark Deakos visited Laamu Atoll to measure the reef manta ray population using a paired laser system in collaboration with the MMRP. During his visit in that year, he measured 26 reef manta rays to establish baseline measurements against which growth could be compared. In 2018, Dr. Deakos returned to Laamu Atoll and measured 23 reef manta rays, nine of the same individuals from 2016. The MMRP team in Laamu will continue measuring manta rays using a stereo-video system that was introduced in 2018. By measuring the local manta population, it is hoped that in-depth observations on the maturation and growth rates of this slow growing species can be obtained, and important life history parameters defined.
Throughout 2018, each manta was observed on average 8.37 times, a very slight decrease from 2017 (average 8.69 sightings per individual) but still higher on average than observations in most previous years (Fig. 11). The proportion of manta rays observed on more than one occasion in 2018 was 93%, higher than in all previous years (Fig. 11).

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 days 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). The RI in 2018 (2.66) was lower than the RI in 2017 (3.02), but was comparable to the RI observed in 2016 (2.79) (Fig. 12). Changes in the residency index may be due to environmental fluctuations in the atoll (food availability, reproductive activity, environmental conditions) or potentially due to increased survey effort at sites outside known aggregation locations, which may have led to reduced sightings of individuals per survey day.

Reef manta rays encountered in Laamu Atoll are not often recorded in other atolls of the Maldives, supporting the theory that the atoll’s population is predominantly resident, with high levels of site fidelity. Only 15 individuals from Laamu Atoll’s total population (n=125) have been recorded elsewhere in the Maldives (Fig. 13). Given the high site fidelity of the population, local protection for the key aggregation sites in the area is necessary to ensure conservation of the population in the future.
Figure 13: Number of reef manta rays (Mobula alfredi) (n=15) from the Laamu Atoll population (n=125) which have been recorded in other atolls throughout the Maldives Archipelago. *Some individuals have been sighted in more than one atoll outside Laamu Atoll.
Given its proximity to Six Senses Laamu and the reliability of year-round sightings, Hithadhoo Corner remains the project’s primary study area for reef manta rays in Laamu Atoll. In 2018, there was a slight decrease in the number of sightings (n=601) at Hithadhoo Corner in comparison to previous years (Fig. 14). While the number of sightings is lower than in previous years, the decrease in sightings may be attributed to fluctuations in monthly survey effort (Fig. 15). The peak months for sightings at Hithadhoo Corner continued to be May/June and October/November. However, the mean number of manta sightings likely decreased as survey effort increased during historically quieter months (March/July), and decreased during peak periods to survey other aggregation sites, such as Fushi Kandu.

When standardised for survey effort, the average number of confirmed sightings per day at Hithadhoo Corner decreased slightly from 2.54 in 2017 to 2.26 in 2018 (Fig. 16). These averages do not take into account missed opportunities for photo-ID data collection from either outside contributors, or the MMRP team in Laamu Atoll. Therefore, the number of manta rays sighted each day may be slightly higher than is shown here.

**Hithadhoo Corner**

![Figure 14: Total annual sightings of reef manta rays (*Mobula alfredi*) at Hithadhoo Corner in Laamu Atoll (2014-2018).](image)

![Figure 15: Total number of survey days at Hithadhoo Corner in Laamu Atoll during 2018 (bars). The lines show the total number of days surveyed at Hithadhoo Corner during 2017, and the mean number of days surveyed (2014-2018).](image)
During three months in 2018, the mean number of manta rays sighted per day was greater than five, higher than has been observed during most of the study period (2014-2018) (Fig. 17). The only other month during which this has been higher was in October 2017. Despite the higher than average sightings during four months of the year, the remaining eight months of the year saw lower than average sightings per day.

Figure 16: Average number of reef manta rays (*Mobula alfredi*) sighted per survey day at Hithadhoo Corner, Laamu Atoll (2014-2018). *The figure for 2014 is not representative of the entire year as MMRP researchers were not on site for the first part of the year, and multiple encounters were reported where photographs were unavailable.*

Figure 17: Average number of reef manta rays (*Mobula alfredi*) sighted each survey day per month at Hithadhoo Corner in Laamu Atoll (2018), and the mean number sighted across all study years (2014-2018).
Of the 77 individual manta rays recorded at Hithadhoo Corner in 2018, 86% of individuals (n=66) were recorded at Hithadhoo Corner on more than one occasion (Fig. 18). These re-sighting rates are similar to the previous study years, suggesting similar residency rates at this site over the study period. Despite this high re-sighting rate, it is equally important to note that 45 individuals (58%) were recorded less than five times at the site during 2018 (Table 2), highlighting that the majority of the reef manta ray population which visits this site spend a considerable amount of their time elsewhere. When taking the entire Laamu Atoll population into account between 2014 and 2018 (n=125), 79% of the population has been sighted on more than one occasion at Hithadhoo Corner. Only four individuals known to the Laamu Atoll population have not been sighted at Hithadhoo Corner (2014-2018).

**Figure 18:** Mean number of sightings per individual reef manta ray (*Mobula alfredi*) at Hithadhoo Corner in Laamu Atoll (2014-2018), and the percentage of individuals sighted on multiple occasions during the same year.

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**Table 2:** Sighting frequency of individual reef manta rays (*Mobula alfredi*) at Hithadhoo Corner and Fushi Kandu, Laamu Atoll in 2018.
Four new individuals were sighted at Hithadhoo Corner during the 2018 survey period, compared to three in 2017 (additional information about the new individuals can be found later in this report). Overall, the residency index for the site decreased from 3.65 in 2017 to 2.95 in 2018, which was similar to what was recorded in 2016 at 2.96. Lower reproductive activity together with increased survey efforts elsewhere may explain the slight decrease in site residency recorded in 2018. Consistent use of this habitat by the majority of the Laamu Atoll reef manta ray population signifies that this is a crucial manta aggregation site in the atoll, and that efforts should be made to ensure the site is protected.

Fushi Kandu

Anecdotal reports of manta ray sightings and preliminary surveys in 2017 (49 confirmed sightings of 22 individuals), provided evidence to suggest that Fushi Kandu could be another key aggregation site for reef manta rays in Laamu Atoll. In 2018, research at the site increased, and 45 individuals have now been recorded at Fushi Kandu from over 141 sightings to date (Fig. 19). Given the limited amount of data we have on the site, the mean number of sightings per survey day for Fushi Kandu has been calculated using the confirmed number of sightings, and the approximate sightings when no individuals were confirmed (Fig. 20).

Figure 19: Total annual sightings of reef manta rays (Mobula alfredi) and the number of individuals sighted at Fushi Kandu in Laamu Atoll (2014-2018).

Figure 20: Mean number of reef manta rays (Mobula alfredi) per survey day at Fushi Kandu in 2017 and 2018.
Of the 125 reef manta rays known to Laamu Atoll, 45 individuals were encountered at Fushi Kandu at least once between 2014 and 2018 (Table 2). One individual sighted in 2018 was a new individual to our database. Two females sighted in previous years at Hithadhoo Corner were only observed at Fushi Kandu in 2018 (MV-MA-2816 and MV-MA-3641) and were the two most frequently sighted individuals at the site \((n=6\) and \(n=7\) respectively). A Residency Index has not been calculated for the site given the inconsistent survey effort, but we hope to be able to present these values in the 2019 report.

The sex ratio of reef manta rays in 2017 and 2018 remained consistent at Fushi Kandu with 19 females and 10 males sighted at this location in 2018. Frequent re-sightings of individuals, and use of the site by at least 36% of the Laamu residents, confirms that Fushi Kandu is an important manta ray aggregation site in Laamu Atoll. Given the inconsistency of sightings throughout the year, this site may only serve as a manta habitat during a few months of the year during the Southwest Monsoon (Fig. 20). Thus far, the evidence available suggests that peak sightings at Fushi Kandu may coincide with the peak sightings at Hithadhoo Corner (Fig. 17).

In 2015 and 2016, all observations of manta rays at Fushi Kandu were of feeding behaviour (both on the surface and during dives), but survey effort at the site was minimal \((n=6)\), thus other behaviours may have been missed. With increased survey effort at the site during 2017 and 2018, there was a change in the primary behaviour observed to cleaning (57% of confirmed sightings 2014-2018). Further research at this site is integral to understand the importance of the region and the utilisation of the habitat by reef manta rays.
Throughout the Maldives, there is a high tourist presence, and submissions of manta photo-IDs are made to the MMRP from tour operators and guests on a regular basis. While tourism in Laamu Atoll is increasing, other than staff and guests diving with Deep Blue Divers, we do not receive regular submissions of citizen science data from contributors.

Without reducing the survey effort at Hithadhoo Corner, it is difficult to determine the importance of less surveyed habitats to the local manta population. Although still limited, citizen science submissions have increased our knowledge of manta sightings throughout Laamu Atoll, and have guided much of the increased survey effort beyond the known manta ray aggregation locations. In 2018, manta rays were sighted \( n=51 \) at eight secondary locations throughout the atoll. Before 2018, the MMRP had only four confirmed sightings between 2014 and 2017 at two secondary survey locations. We now know of 18 additional secondary sites within Laamu Atoll where reef manta rays have been observed since 2012 (Fig. 1). The majority of these observations took place along the outer reefs, from Boduhuraa Beyru to Fonadhoo Beyru during 2018 (Group 1). Mantas have been reported in this general region since 2016, and since then, 39 of the 125 individuals recorded in Laamu Atoll have been sighted there. Divers have observed manta rays using a small cleaning station at Boduhuraa Beyru (28 metres in depth), but very few sightings have been confirmed at the site. Due to the depth, all encounters have been short in duration; additional surveys of the region may provide more information on the frequency of use by the population.

Feeding behaviour is rarely observed in Laamu Atoll, and no primary sites within the atoll lagoon have been located that can be classified as surface feeding aggregation sites. Elsewhere in the Maldives, zooplankton accumulation in shallow lagoons is correlated to the monsoonal weather patterns, and manta rays are often observed feeding in these sheltered areas, especially juveniles. Recorded instances of feeding behaviour in Laamu Atoll more than doubled this year, with 24 confirmed sightings (20 individuals) feeding along the outside atoll edge, specifically at Boduhuraa Beyru and Hithadhoo West (Fig. 1). It is possible that reef manta rays may use this region when traveling to or from Hithadhoo Corner. Anecdotal reports suggest this area may serve as a consistent feeding region, and historically oceanic manta rays have also been observed feeding in the Boduhuraa Beyru region. Over the course of 2019, the MMRP hope to increase survey effort along the outer edge of the reef, and will continue to work with Deep Blue Divers staff to learn more about sightings of manta rays during guest dives.

Olhuveli Corner, part of the Six Senses Laamu’s house reef, is located just to the north of Hithadhoo Corner, and is the outer reef habitat that separates Hithadhoo Kandu from Gaadhoo Kandu. In February 2018, two individuals were recorded feeding in this area, and an additional individual was recorded by a guest at the house reef of Six Senses in October 2018 (Olhuveli Faru). These were the first confirmed individuals near Olhuveli since the start of the research project, and they provided the first confirmed record of a manta ray within the atoll lagoon.
SITE INTERCONNECTIVITY & MIGRATION CORRIDORS

Of the 25 individuals observed at secondary study sites in 2018, all except one (MV-MA-2970) was encountered at Fushi Kandu and/or Hithadhoo Corner during the year. Records of the same individuals utilising multiple sites within the atoll provides additional supporting evidence of high regional fidelity by the recorded Laamu Atoll population.

Fifteen of the eighty-four individuals recorded in Laamu Atoll this year were observed at both Fushi Kandu and Hithadhoo Corner. Two adult female reef manta rays (MV-MA-2414 and MV-MA-2911) were sighted at Fushi Kandu and Hithadhoo Corner within a two-day time span. Without the ability to track the movement of individuals using satellite tags, it cannot be determined which routes are used to travel throughout the atoll. However, given the relatively few sightings recorded from inside lagoonal reefs (sites which are regularly dived), they are probably using the outer reef edge from Hithadhoo Corner past Gan to reach Fushi Kandu. With minimal data available on migrations, it remains important that outer barrier reefs are protected as they may be key migratory corridors between aggregation sites. As feeding behaviour has been observed on the outside of the atoll, the population may also be taking advantage of plankton accumulations while traveling between cleaning stations.

CLEANING & FEEDING BEHAVIOUR

With many coral bommies that support assemblages of cleaner wrasse, Hithadhoo Corner is a cleaning station by nature; thus, the primary driver of habitat use in the region is expected to be cleaning. With additional cleaning stations at Fushi Kandu and Boduhuraa Beyru, the majority of the recorded behaviour within the atoll has been linked to reef manta ray cleaning requirements. Recorded instances of cleaning have remained relatively consistent across the study period, and in 2018, cleaning accounted for approximately 75% of the behaviour observed (Fig. 21). Cleaning was the only behaviour to be observed during incoming, outgoing and slack currents, and was observed most often during outgoing currents at Hithadhoo Corner and Fushi Kandu.

While seldom, feeding behaviour was most often observed during incoming currents (n=14). Much of the feeding recorded this year was surface feeding, but MMRP researchers also witnessed reef manta rays somersault feeding to take advantage of dense zooplankton patches at Hithadhoo Corner during outgoing currents.

Figure 21: Changes in behavioural activity of reef manta rays (Mobula alfredi) in relation to current direction (In, Out, Slack) at Hithadhoo Corner in Laamu Atoll during 2018; when manta rays were observed and current was recorded (n=252).
CURRENTS & TIDAL CYCLES

Hithadhoo Corner and Fushi Kandu are both influenced by strong oceanic and tidal currents. When standardised for survey effort between 2015 and 2018, reef manta rays were encountered at Hithadhoo Corner on 74% of dives where the current was outgoing (n=979), and on 55% of dives (n=518) where the current was incoming (Fig. 22). Data from 2014 was not included in this calculation as dives during the first part of the year were only recorded if manta rays were present. During 2018, reef manta rays were observed on 41% of dives with incoming current and 67% of dives with an outgoing current.

At Fushi Kandu between 2017 and 2018, reef manta rays were observed on 83% of dives where the current was outgoing (n=41), and on 39% of dives where the current was incoming (n=38). Only one dive was recorded where the current was slack, and mantas were encountered. Without consistent survey effort at the site each month, and over a range of currents, it cannot be determined if manta presence is necessarily correlated to current, or if there are other factors (behavioural requirements, environmental factors, seasonality) that are having a more significant influence on reef manta ray sightings at this location.

Figure 22: Current state (outgoing, incoming or slack) during surveys when reef manta rays (Mobula alfredi) were observed at Hithadhoo Corner, Laamu Atoll (2015-2018).

REPRODUCTIVE ACTIVITY & POPULATION RECRUITMENT

Courtship has been a prevalent behaviour at Hithadhoo Corner in the past, particularly during May/June and October/November during the transition months between monsoons (Fig. 23). Levels of courtship can vary seasonally, and in 2018, the MMRP recorded a steep decline in courtship behaviour at Hithadhoo Corner and across the atoll. Only 11 confirmed sightings of individuals engaged in courtship behaviour were recorded during the entirety of the year (Fig. 24). While courtship declined in 2018, an increase in pregnant female manta rays was recorded, which may be in response to the high levels of courtship (and presumed mating events) that occurred during 2015, 2016 and 2017 (Fig. 24). The number of pregnant individuals in the population in 2018 was at its highest recorded levels to date, with 27 sightings of 11 pregnant females (Fig. 25).

As discussed in previous reports, we have theorised that a reduction in pregnancies since 2014 was likely due to the...
The long gestation time of reef manta rays (thought to be approximately 12 months) and the necessary recovery time between pregnancies (it is thought manta rays are able to store sperm to delay gestations after mating has occurred). With a higher number of pregnancies recorded in 2018, the MMRP now have a record of individuals in Laamu Atoll that have been pregnant on more than one occasion since the start of the research project. Of the 33 adult female manta rays known to Laamu Atoll, 21 individuals have been recorded as pregnant on at least one occasion since 2014, and eight of those have been recorded as having multiple pregnancies. Only two of the 11 pregnant individuals were recorded at Fushi Kandu during the 2018 survey period. Being able to record subsequent pregnancies in the local population provides valuable data on the recovery time between pregnancies and health of the overall population.

![Figure 23: Cumulative number of individual reef manta rays (Mobula alfredi) engaged in courtship behaviour (2014-2018), and the total number of individuals observed engaged in courtship during 2018, in Laamu Atoll.](image)

![Figure 24: Annual sightings of reef manta rays (Mobula alfredi) engaged in courtship behaviour and the annual number of pregnant individuals in Laamu Atoll (2014-2018).](image)
New Individuals

Of the 84 individuals encountered during 2018, six were new to both the Laamu Atoll and the nationwide MMRP databases. This was a slight decrease from the number observed in 2017, when nine new individuals were recorded. No individuals from elsewhere in the Maldives were encountered for the first time in Laamu Atoll during the 2018 study period. It is likely that the vast majority of the manta ray population in Laamu Atoll has now been identified, and the number of new individuals each year will continue to be low. Henceforth, most newly recorded individuals will arise from new-born pups and transitory migrants moving into, or through, the atoll.

SUB-LETHAL INJURIES

Of the 125 known reef manta rays in Laamu Atoll, 34% (n=43) were recorded with at least one sub-lethal injury during the study period (2014-2018). A total of 47 injuries have been recorded, and 91% (n=39) of the injured individuals have one injury, while the remaining four have two recorded injuries. Of the forty-seven injuries, 47% (n=22) are thought to be from natural causes, 32% (n=15) were anthropogenic in origin, and 21% (n=10) were caused by an unknown source (Fig. 26). The majority of injuries were to the pectoral fins of reef manta rays (n=33) followed by dorsal or tail injuries (n=7) and cephalic fin injuries (n=6) (Fig. 27).

Demographically, 37% of known females (n=29) and 30% of known males (n=14) to the region have injuries (Fig. 28). When the cause of natural injuries was considered, there were distinct differences in the ratio of female to males (Fig. 28). The most common cause of natural injuries was predatory bites (n=17) (Fig. 26); with females being the most inflicted (n=16). The number of juveniles with predatory bites (n=9) was also higher than the number of adults (n=8), which could be due to the small size of individuals making them particularly susceptible to attack. Of the adult females with predatory bites, only one was recorded as relatively fresh in 2014, while the remainder have been determined from scarring, signifying that these individuals may have also been attacked earlier in their lives as juveniles. The higher prevalence of shark bites amongst the female and juvenile population may signify differences in habitat use or movement to locations where large predatory sharks are
found. A predatory bite caused one tail injury; however, most are considered natural deformities (n=4), and are observed in the form of a bent tail. Only one individual has ever been observed with natural damage to a gill; however, the exact cause was unknown.

While the majority of injuries recorded are naturally occurring, anthropogenic injuries remain a concern, particularly those resulting from fishing line entanglement. Almost all of the anthropogenic injuries seen within the atoll was caused by fishing line (n=14), followed by one instance of a boat strike (Fig. 26). Ten of the fishing line injuries resulted in damage to the pectoral fins of the individuals, four damaged or completely removed a cephalic fin, and one additionally injured the eye of an individual (Fig. 26). Injury or amputation of a cephalic fin can have negative implications on an individual's ability to feed and interact with the environment. To date, only one individual exhibits evidence of a boat strike, but as tourism and associated boat traffic within the atoll increases, boat crew and local operators need to remain vigilant to ensure that wildlife (including sea turtles, whale sharks, manta rays and dolphins) are not injured while on the surface.

![Figure 26: Total number of sub-lethal injuries (n=47) recorded on the reef manta ray (Mobula alfredi) population in Laamu Atoll (n=125), classified by the cause of the injury.](image)

![Figure 27: Demographic variations in the number of sub-lethal injuries (n=47), by body area, within the injured reef manta ray (Mobula alfredi) population of Laamu Atoll (n=43). Actual number of injuries on bars.](image)
TOURISM

Tourism activities have remained relatively low within Laamu Atoll, but a new resort is slated to open in 2019, and visits to the atoll by liveaboard vessels have increased, particularly during the Northeast Monsoon. During 2016 and 2017, in addition to our research boat, we recorded only 27 surveys where more than one boat was present at a dive site. In 2018, this figure jumped to 32 surveys where an additional tourist boat was present at the same time as either the Six Senses guest boat or the research dhoni. The maximum number of boats observed during a single trip was five, at Fushi Kandu, and the maximum number of divers recorded at Hithadhoo Corner during a dive was 24 divers. Our increase in observations of other vessels is due in part to increased surveys at Fushi Kandu, but there has also been an increase in the number of liveaboard operators visiting Hithadhoo Corner.

As tourism increases throughout the atoll, we need to be mindful of the potential negative impacts of divers on fragile habitats, and a relatively small manta ray population. The coral reef habitats that form the cleaning stations in Laamu Atoll are essential for manta tourism. Reef degradation caused by contact from divers, or anthropogenic impacts caused by development in the area, could damage key manta ray aggregation sites.

In response to growing tourism throughout the Maldives, and the lack of regulation on manta dives sites in the country, the Manta Trust developed a code of conduct for both snorkelling and diving with the species. Six Senses has used the code of conduct since its inception, and in 2018, the team in Laamu Atoll hosted a graduate student who analysed data from all the MMRP bases, and personally recorded observations of divers at Hithadhoo Corner. Prior to diving, guests were briefed on the code of conduct by a Manta Trust staff member who joined the dive and recorded any interactions where the manta ray came within ten metres of guests. The research showed that divers who remained at the sides of cleaning stations (Fig. 29), and did not approach the species within three metres, were least likely to have an impact on the natural behaviour of reef manta rays. Overall, the level of disturbance to reef manta rays by divers was relatively low, and the study provided evidence to support continued use of the code of conduct materials. Tourism operators throughout the country have access to the code of conduct materials, and the Manta Trust team will be actively encouraging liveaboard vessels in Laamu to use these materials in 2019.

Figure 28: Demographic variations in the number of individuals (n=37) with natural and/or anthropogenic injuries amongst the reef manta ray (Mobula alfredi) population of Laamu Atoll (n=125). Individuals with unknown injury types (n=6) have not been included.
Figure 29: The mean response of reef manta rays (*Mobula alfredi*) to SCUBA divers positioned on or off cleaning stations during diver-manta interactions (*n*=147) throughout the Maldives. The mean response is on an increasing scale of severity; where 1 is no reaction, and 4 is avoidance behaviour. Error bars show standard error to a 95% CI.
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 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.