



Maldivian Manta Ray Project

LHAVIYANI 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 Maldives manta population the largest, and one of the most intensively studied populations in the world. The MMRP has also identified nearly 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.

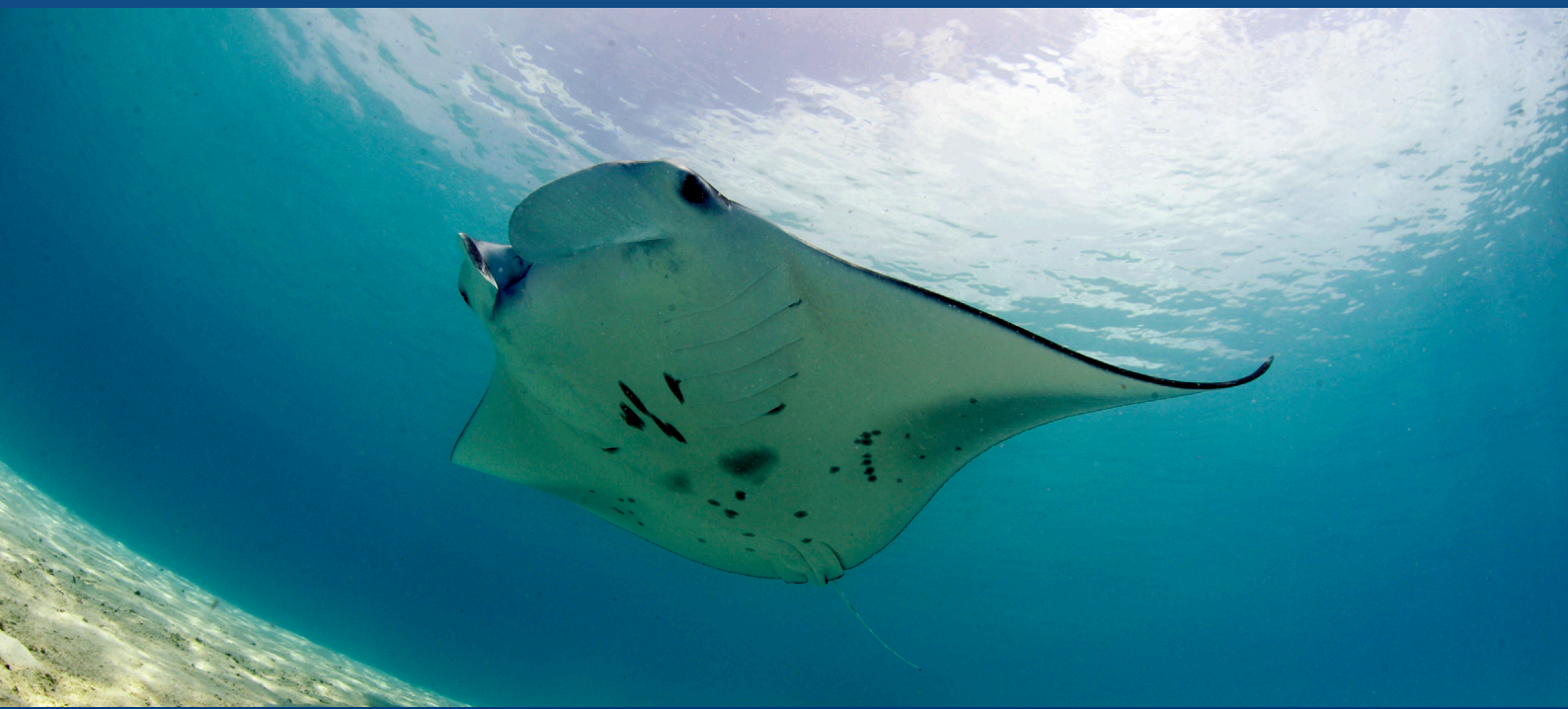


THE CONSERVATION CHALLENGE

In the last two decades, manta and mobula rays have faced increasing threats from both targeted and bycatch fisheries, due in part to a growing trade in Asia for their gill plates. The gill plates are what these rays use to filter zooplankton from the water. In Traditional Asian Medicine, it is believed these gill plates will filter the human body of a variety of ailments when consumed in tonic. There is no scientific evidence to support this claim.

Unregulated and badly managed tourism is also negatively affecting manta rays, while climate breakdown, reef degradation and pollution is reducing the manta's food supply and suitable habitat.

Manta and mobula rays are particularly vulnerable because of their aggregating behaviour and conservative life-history; they grow slowly, mature late in life, and give birth to few offspring. These traits make it very easy to wipe out entire populations in a relatively short period of time. With protection in place, populations are still slow to recover.



EXECUTIVE SUMMARY

This report is the third of its kind in a series that presents data collected by the Manta Trust's Maldivian Manta Ray Project (MMRP) on Lhaviyani Atoll's reef manta ray (*Mobula alfredi*) population from January through December 2019.

Reef manta rays are sighted in Lhaviyani Atoll year-round, but are recorded more frequently toward the end of the Southwest Monsoon (Oct-Nov) and during the Northeast Monsoon (Jan-April). During these months, favourable environmental conditions created by the monsoon winds generate an abundance of phytoplankton and zooplankton, which in turn influences manta ray abundance locally.

The MMRP conducted reef manta ray surveys on 190 days throughout 2019. Key findings of the MMRP in Lhaviyani Atoll during 2019 include a total of 360 sightings of 124 different manta rays; the highest number of sightings recorded in any survey year. Of these individuals, each manta ray was observed on average 2.9 times. The mean daily number of reef manta ray sightings for 2019 was 1.9, with peaks in daily manta ray sightings seen during the months of January to February, and October. A residency index (RI) was calculated to gauge the extent of movement amongst those frequenting the region. The RI for 2019 (1.19) was higher than 2018 (1.11).

As of 2019, the population demographics of Lhaviyani Atoll constitutes 51% females ($n=208$), 48% males ($n=198$), and 1% ($n=5$) of individuals for which the sex could not be determined. Overall, 51% ($n=210$) comprise adult individuals, 48% ($n=199$) juveniles, and the maturation

stage for the remaining 0.5% ($n=2$) of the population could not be determined. Of these Lhaviyani Atoll manta rays ($n=411$), 92% ($n=347$) have been re-sighted, and 41% ($n=168$) have been seen in at least one other geographical atoll in the Maldives.

Of the 280 new reef manta rays added to the MMRP database from across the Maldives in 2019, 7% ($n=19$) were documented in Lhaviyani Atoll. This is a slight decrease from the previous year ($n=29$, in 2018). Furthermore, the number of pregnancies recorded in Lhaviyani Atoll during 2019 was fewer than in 2018 ($n=5$), with a total of three pregnancies. Of the three pregnant females observed, only one individual was recorded in the later stages of gestation (3rd- 4th trimester).

Efforts to conserve the natural heritage of Lhaviyani Atoll and manage the increasing human impacts upon the environment are encouraging, providing much to look forward to in 2020 and beyond. However, it is crucial that active research into manta rays and other marine life continues in order to monitor the effects of both tourism and environmental change. Manta rays are an incredibly important economic resource for the Maldives, bringing tens of thousands of people to the country each year to dive and snorkel with them, generating millions of USD for the economy annually. Being able to pinpoint the reasons for any observed trends in, or threats to, the Maldives manta ray population is crucial for the ongoing management and protection of these animals.

UNDERSTANDING THE MONSOONS

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 Lhaviyani Atoll. The monsoons, which dictate the weather in the Maldives, are characterised by their winds, which blow consistently and reverse direction seasonally. The Maldives Northeast Monsoon, or Iruvai, runs from December to March, while the Southwest Monsoon, or Hulhangu, runs from May to October each year, with the months of April and November acting as transitional periods of change between the two seasons. The Southwest Monsoon is typically characterised by more rain and cloud cover, along with reduced underwater visibility and rougher seas.

The strong monsoonal winds create oceanic currents which 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 to the surface, 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 we are likely to observe feeding planktivorous megafauna. 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. Due to the seasonal migration patterns of the manta rays, research efforts are focused on the west side of the atolls during the Northeast Monsoon, and on the east during the Southwest Monsoon. Both monsoons attract reef manta rays to the surface waters of Lhaviyani Atoll. However, sightings tend to peak towards the end of the Southwest Monsoon and during the Northeast Monsoon.

STUDY PERIOD & SAMPLING METHODOLOGY

Manta ray sightings data in Lhaviyani Atoll was collected by both regional MMRP researchers and citizen scientists (tourists, local dive guides, snorkel leaders, and marine biologists). Individual manta rays that were sighted in the water were documented by photographing the unique spot patterns on their ventral surface, allowing for identification of individuals. In the context of 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). Surveys were conducted in-water, both on SCUBA and via snorkelling, with sightings recorded at 31 different sites across all years.

During each survey performed by MMRP researchers, individual manta ray sightings were documented via photo-ID, and data on the location, manta ray numbers, and predominant behaviours were recorded. Details on environmental variables (including wind speed, current

direction, and plankton density), and tourism data (including number of divers/snorkellers, number of boats, and number of paying guests) were also noted during each survey. Surveys were collected on all trips, regardless of whether manta rays were sighted or not.

Between 2004 and 2016, prior to the establishment of a full-time MMRP researcher in Lhaviyani Atoll, data on manta ray sightings were collected mostly through citizen science. Tour guide operators, dive instructors and tourists would look for manta rays on both full and half day surveys. These surveys were also conducted in-water on SCUBA, or while snorkelling. Prior to 2010, only surveys resulting in a confirmed manta ray photo-ID sighting were recorded. It is unknown how many surveys were conducted annually prior to 2010. However, thereafter all data has been standardised for survey effort where possible to produce comparable results between, and within, years.

2019 Study Period

During 2019, Manta Trust researchers conducted a total of 202 surveys on as many days that conditions and logistical operations allowed ($n=173$), at 28 different sites. Four of these sites were classified as key aggregation sites due to higher numbers of individual manta rays sighted in these locations across the study year (Fig. 1).

Data was primarily collected by two Manta Trust researchers who were based at Hurawalhi Resort throughout the year. In addition to MMRP survey data, this report utilises data from a further 41 surveys which were undertaken and submitted by external contributors, which include local non-governmental organisations (NGOs), resort dive and water sports staff, as well as citizen scientists. With a total of 243 surveys from Manta Trust and outside submitters combined, 2019 had the second highest survey count in the atoll since records began (Fig. 2), second only to 2010

($n=258$). Overall, manta rays were sighted on 60% ($n=147$) of all survey trips ($n=243$), with ID photographs collected on 50% ($n=122$) of surveys.

From January until July, survey effort focused on the western Lhaviyani Atoll manta aggregation sites: Veligadu Falhu ($n=57$), Felivaru (Thila and Kanduru) ($n=61$), Dhanifaru ($n=38$), and Kanifushi Falhu ($n=23$); all sites known to be manta ray feeding areas. During August, survey effort moved to focus on the manta aggregation site in the northeast of Lhaviyani Atoll (Fushifaru Kanduru), which is a manta cleaning station and feeding area. From August until November, a total of 76 surveys were conducted at this site. With the beginning of the Northeast Monsoon in December, surveys were again performed in the northern and western manta aggregation sites of Lhaviyani Atoll; including Dhanifaru ($n=12$), Kanifushi Falhu ($n=8$), and Felivaru ($n=8$).

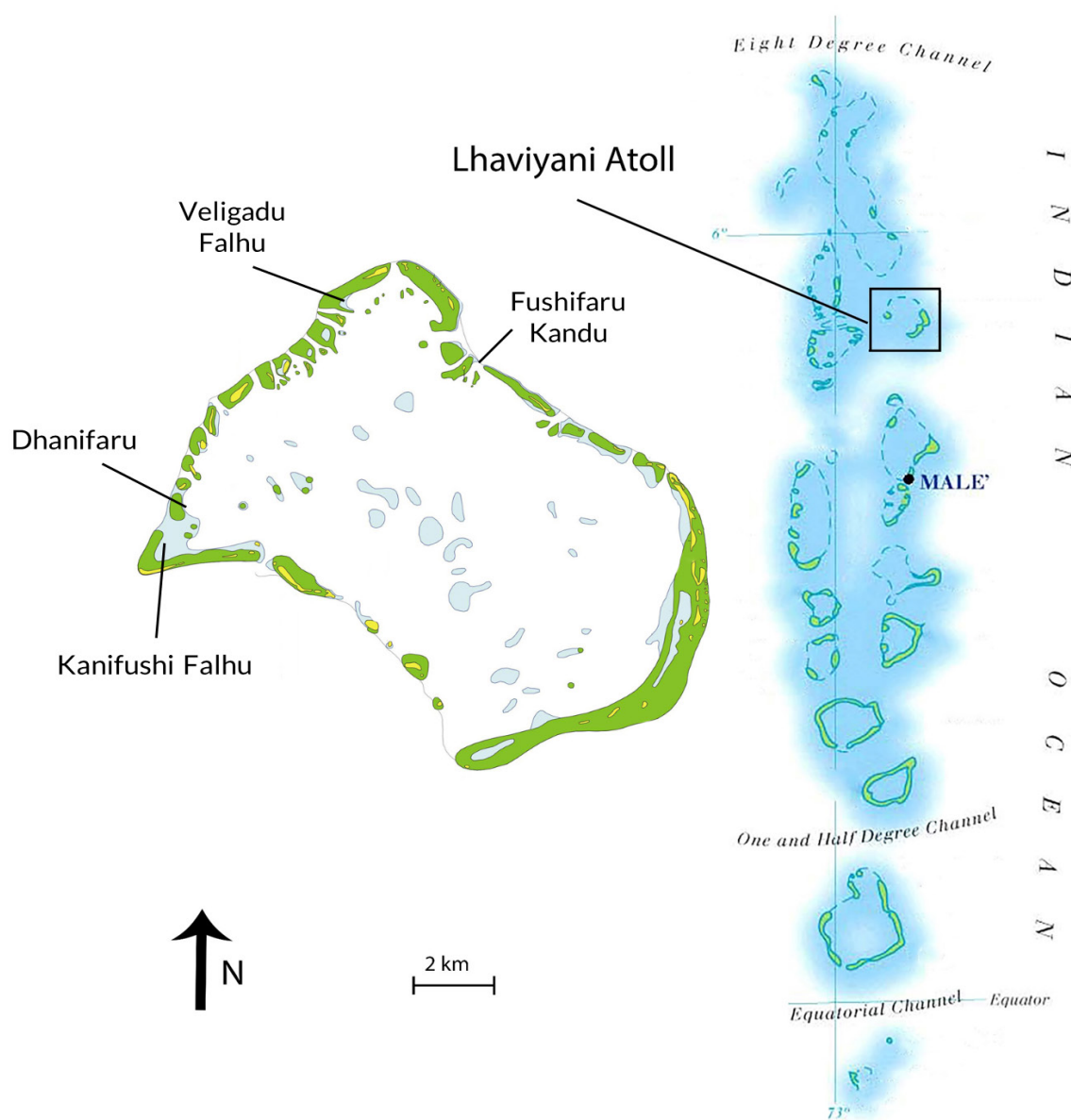


Figure 1: Map of Lhaviyani Atoll showing four sites which accounted for the highest number of reef manta ray (*Mobula alfredi*) sightings in 2019. Also shown is Lhaviyani Atoll (black box) in relation to the rest of the Maldives Archipelago.

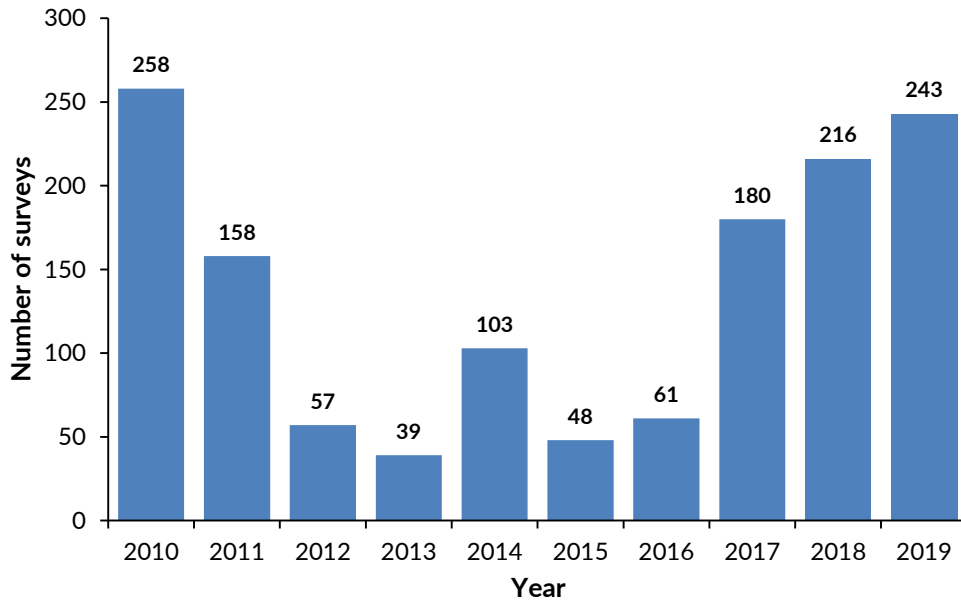


Figure 2: Number of surveys conducted annually in Lhaviyani Atoll.

REEF MANTA RAY POPULATION

Sightings

A total of 2,037 reef manta ray sightings have been recorded in Lhaviyani Atoll between 2004 through 2019, with 1.4 mantas sighted per survey on average between 2010 and 2019 (when survey data was recorded) (Fig. 3). During 2019, there were 360 sightings of 124 different reef manta ray individuals in Lhaviyani Atoll, which made 2019 the year with the highest number of manta ray sightings since data

collection started in 2004 – the second highest being in 2010 when 333 sightings were recorded (Fig. 3). The large number of sightings in 2019 was likely related to the high level of survey effort by the two permanent Manta Trust researchers based at Hurawalhi Resort, which accounted for 77% (n=277) of the sightings recorded in 2019.

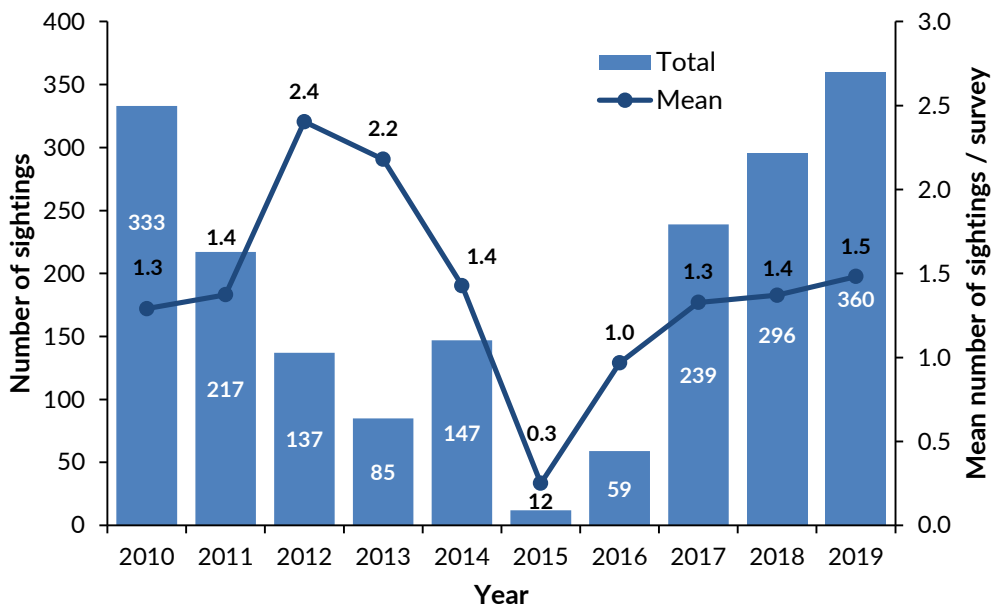


Figure 3: Annual sightings of reef manta rays (*Mobula alfredi*) in Lhaviyani Atoll, and the mean number of sightings per survey.

While there is a certain degree of inter-annual variation across all study years, a general trend in sightings throughout the year can be observed. Sightings in Lhaviyani Atoll tend to peak annually during the months of January to March, then decrease between April and September, followed by a second peak during the months of October to December (Fig. 4). Reef manta ray sightings in 2019 followed a similar trend, with two main peaks in January/February and October (Fig. 5).

The seasonally observed sighting peaks reflect intra-annual variation in site use by reef manta rays around Lhaviyani Atoll. Movements of manta rays around Lhaviyani Atoll are largely influenced by the monsoons of the Maldives (seasons), which drive productivity and, ultimately, variation of manta rays' zooplankton food source in different locations throughout the year. Four key aggregation sites have been previously identified as having the highest number of sightings across study years (2004-2019); Veligadu Falhu, Fushifaru Kandu, Dhanifaru, and Kanifushi Falhu (Fig. 1).

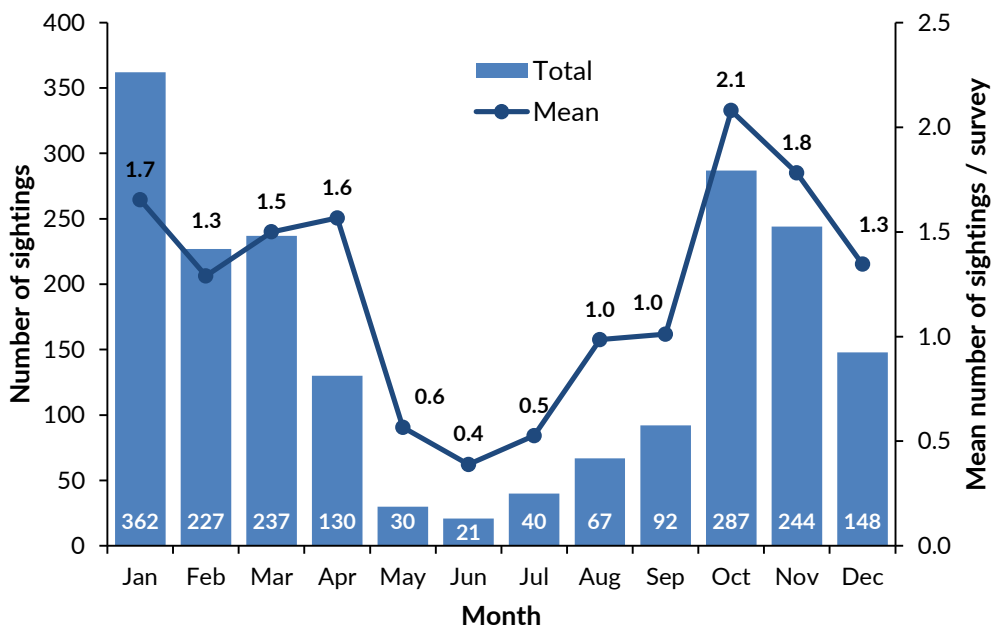


Figure 4: Monthly sightings and mean number of sightings per survey of individual reef manta rays (*Mobula alfredi*) recorded in Lhaviyani Atoll (2010-2019).

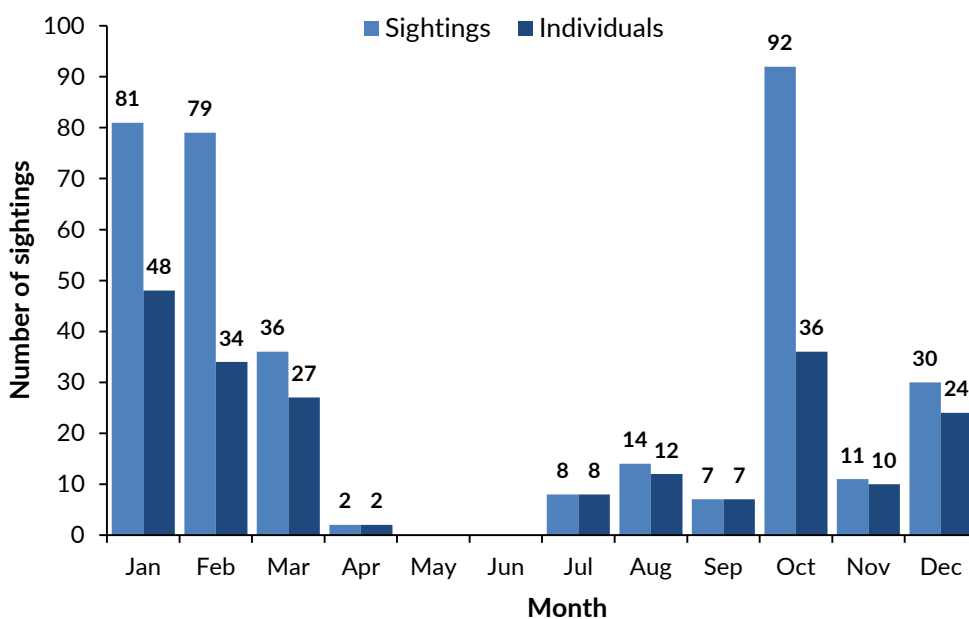


Figure 5: Monthly sightings and the number of individual reef manta rays (*Mobula alfredi*) recorded in Lhaviyani Atoll (2019).

In 2019, sightings peaked at Veligadu Falhu in January/February, and at Dhanifaru and Kanifushi Falhu in December (Fig. 6). Veligadu Falhu accounted for the highest number of reef manta ray sightings in Lhaviyani Atoll in 2019 ($n=143$), while Dhanifaru and Kanifushi Falhu had 23 and 18 recorded sightings, respectively (Fig. 7). It seems that manta rays sighted at these three locations took advantage of localised abundances in zooplankton, as the majority of individuals were recorded while feeding. Visitations to these three sites coincided with the Northeast Monsoon, which drives productivity and food availability in the western areas of atolls within the Maldives between December and March each year.

On the eastern side of Lhaviyani Atoll, sightings peaked at Fushifaru Kandu in October (Fig. 6), where manta rays predominantly exhibited cleaning ($n=56$) and feeding ($n=31$) behaviour. This coincided with the end of the Southwest Monsoon, which drives increased food availability in the eastern areas of atolls within the Maldives between May and October each year. Further, towards the end of the season, and during the transitional period between the Southwest and Northeast Monsoons, it is typical for manta rays throughout the Maldives to engage in increased cleaning, courtship, and mating activity, with cleaning stations acting as a focal point for these behaviours.

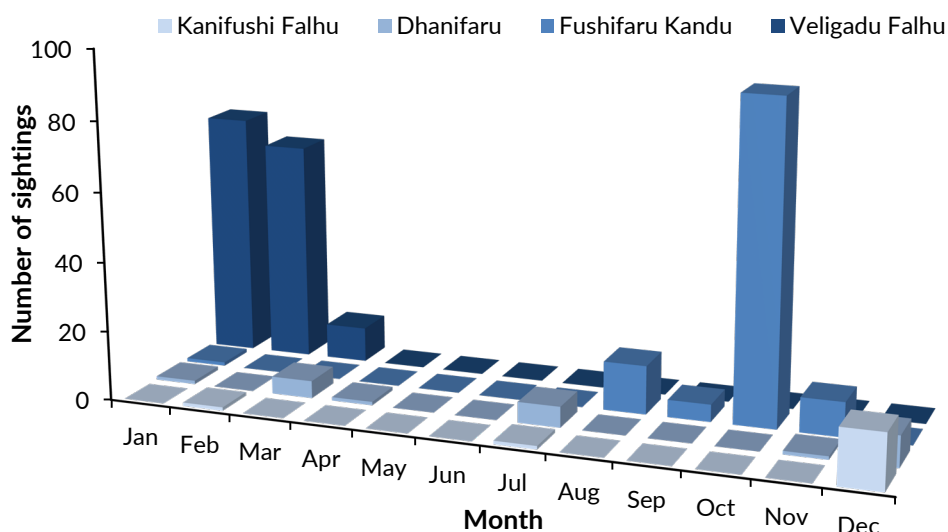


Figure 6: Monthly sightings of reef manta rays (*Mobula alfredi*) at four key aggregation sites in Lhaviyani Atoll (2019).

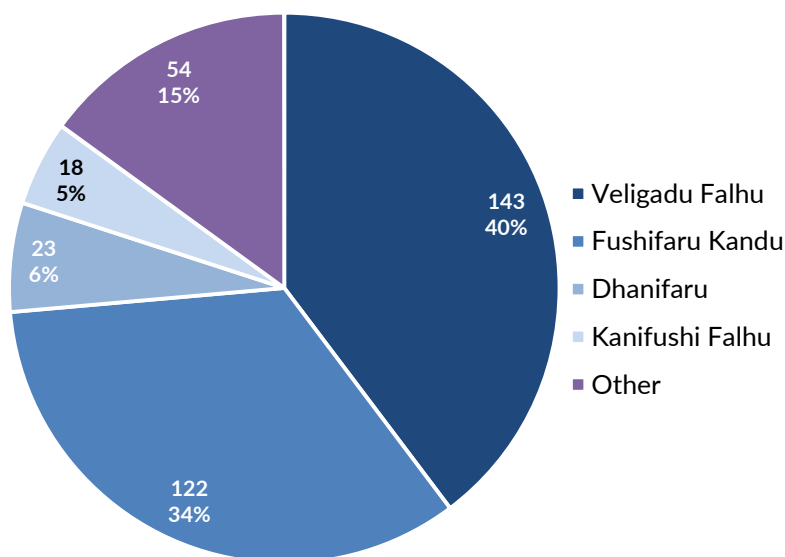


Figure 7: Proportion of total reef manta ray (*Mobula alfredi*) sightings ($n=360$) recorded at the study sites in Lhaviyani Atoll (2019).

POPULATION DEMOGRAPHICS

During 2019, 33 new reef manta rays were identified in Lhaviyani Atoll, bringing the total recorded population to 411 individuals. The sex ratio of this population is almost even; with 51% females ($n=208$) and 48% males ($n=198$), while sex could not be determined for the remaining 1% of individuals ($n=5$). Age demographics are similarly even; juveniles account for 48% of the population ($n=199$), and adults 51% ($n=210$), while maturity could not be determined for the remaining 0.5% of individuals ($n=2$) (Fig. 8). Maturity was defined by the presence of mating scars and visible pregnancies in females, and by the enlargement and calcification of claspers in males. Furthermore, if an

individual was estimated to be at, or larger than, the known size at maturation for this species in the Maldives (320-330 cm disc width for females, 270-280 cm disc width for males), adult status was also assigned. All other individuals were classified as juveniles.

Overall, 70% ($n=286$) of the atoll's population have been sighted more than once in Lhaviyani, and 84% ($n=347$) have been re-sighted either in Lhaviyani or elsewhere in the Maldives. This suggests that the vast majority of reef manta rays that frequent this region have now been discovered.

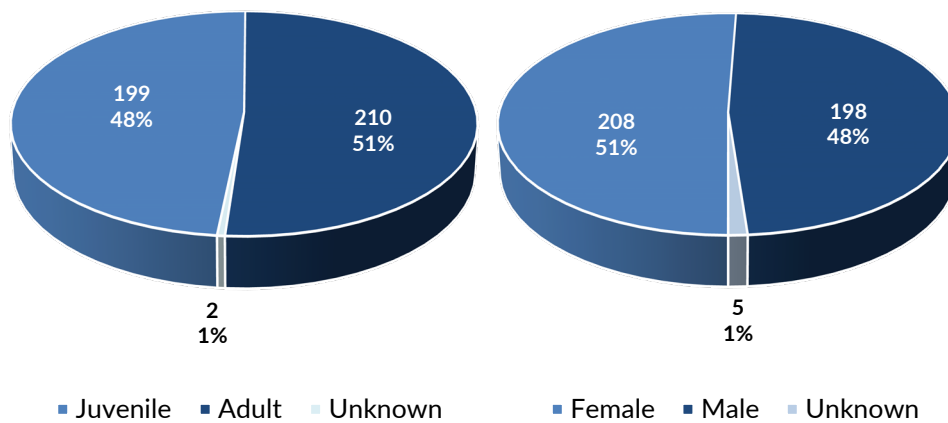


Figure 8: Demographics of the recorded Lhaviyani Atoll reef manta ray (*Mobula alfredi*) population ($n=411$).



The proportion of newly-sighted individuals decreased from 2018 to 2019 (Fig. 9), accounting for 27% of individuals sighted, compared to 40% the previous year. A downward trend in newly-sighted individuals is to be expected as years pass and more data has been collected, and sightings of new manta rays become less frequent.

Fushifaru Kandhu, Dhanifaru, and Veligadu Falhu were the locations where the largest proportions of 2019's new reef manta rays were first sighted, accounting for 30%

($n=10$), 18% ($n=6$), and 15% ($n=5$), respectively; this was fairly consistent with locations of overall manta sightings in 2019 (Fig. 7). The majority (76%) of new manta rays were juveniles ($n=25$).

Of the 33 new manta rays, 18 individuals had never before been recorded by the Manta Trust, while the remaining 15 had been sighted elsewhere in the Maldives previously. Of the manta rays that were previously unrecorded, three were estimated to be pups born that year.

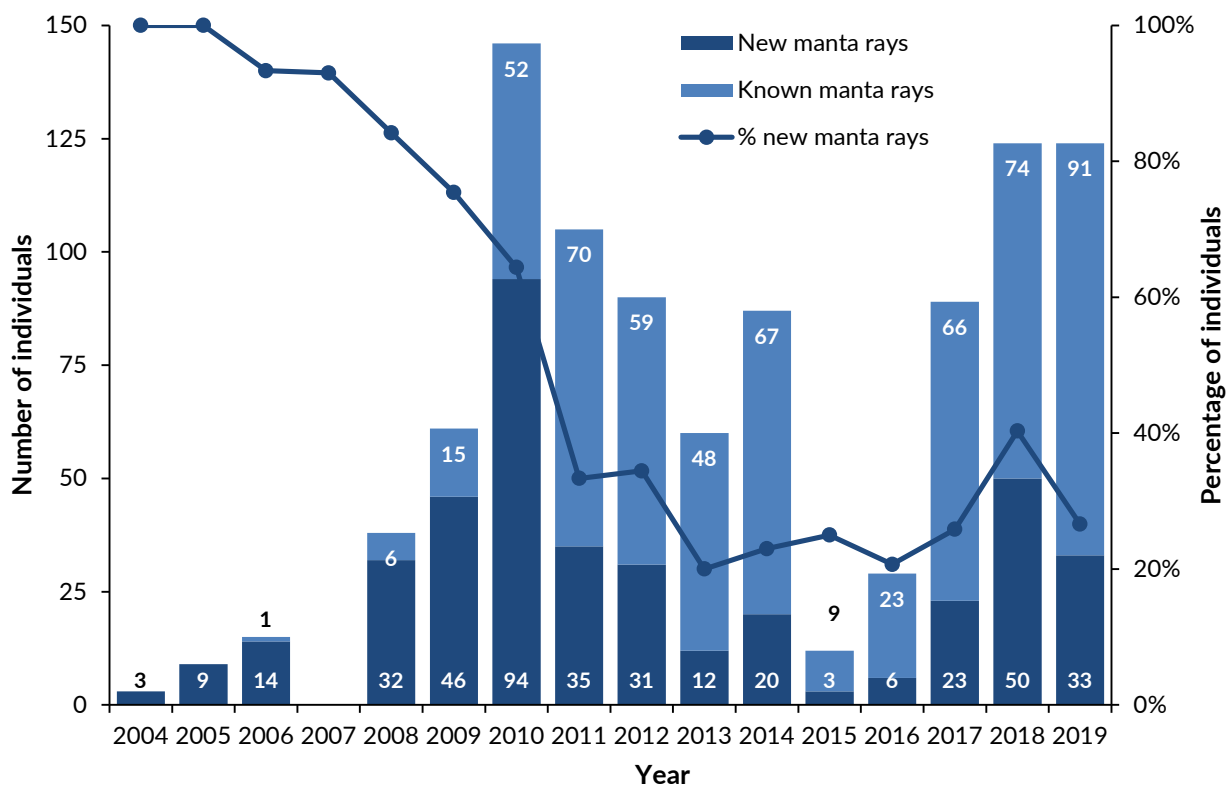


Figure 9: Number of reef manta rays (*Mobula alfredi*) sighted annually in Lhaviyani Atoll, and the proportion of those individuals which were newly recorded.

MIGRATIONS & RESIDENCY

Of the 411 reef manta rays that have been sighted in Lhaviyani Atoll across all study years, 41% ($n=168$) have been recorded by the MMRP in other atolls across the Maldives. Naturally, inter-atoll migrations are most common between atolls which are geographically closest to Lhaviyani Atoll. As of 2019, 105 individuals in the Lhaviyani

population have been recorded in Baa Atoll, 32 in Raa Atoll, 29 in Thiladhunmathi Atoll, and 23 in Ari Atoll (Fig. 10). Each manta ray sighted within Lhaviyani Atoll population tends to exhibit strong site fidelity, with 88% of individuals only recorded in one ($n=243$) or two ($n=117$) atolls (Fig. 11).

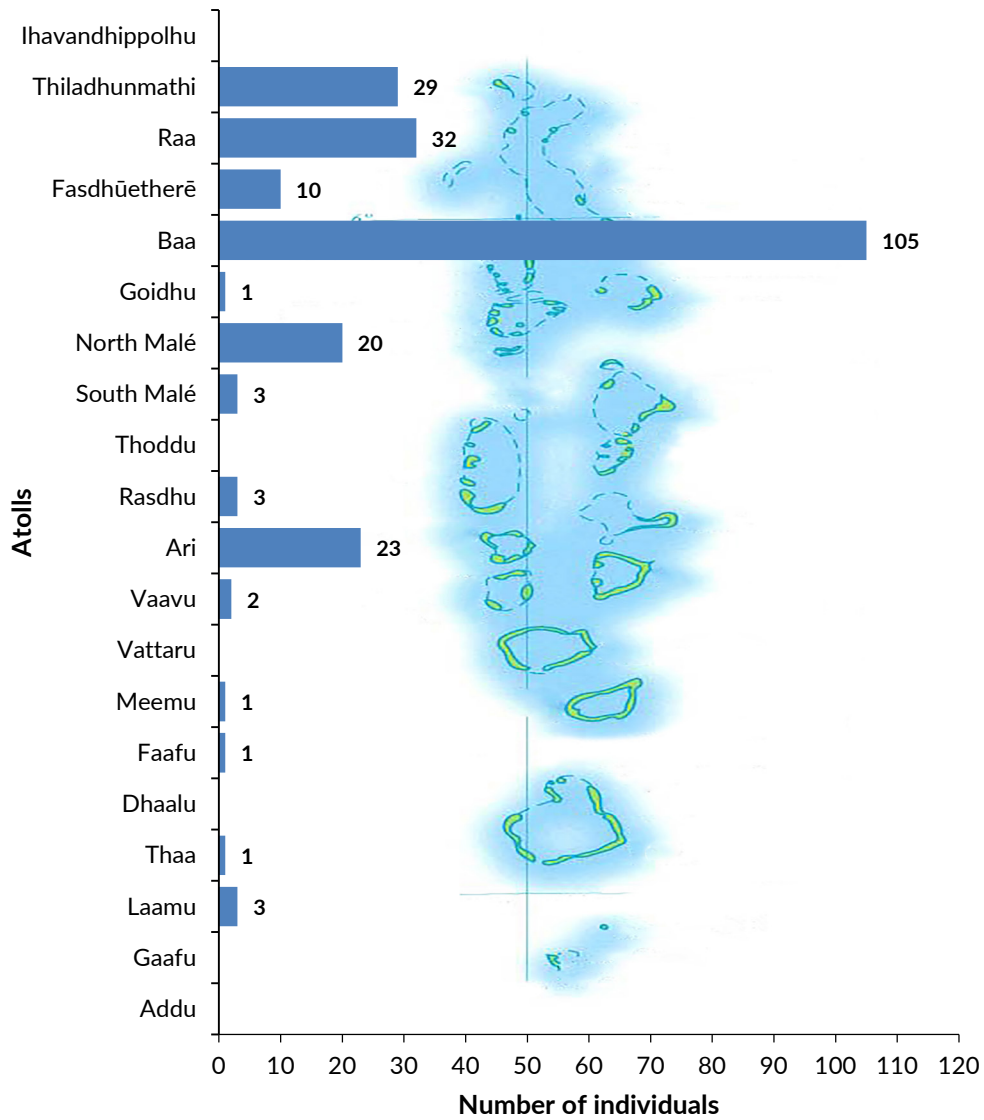


Figure 10: Number of reef manta rays (*Mobula alfredi*) ($n=168$) from within the Lhaviyani Atoll population ($n=411$) which have been recorded in other atolls throughout the Maldives Archipelago. Note - some individuals have been sighted in more than one atoll outside Lhaviyani Atoll.

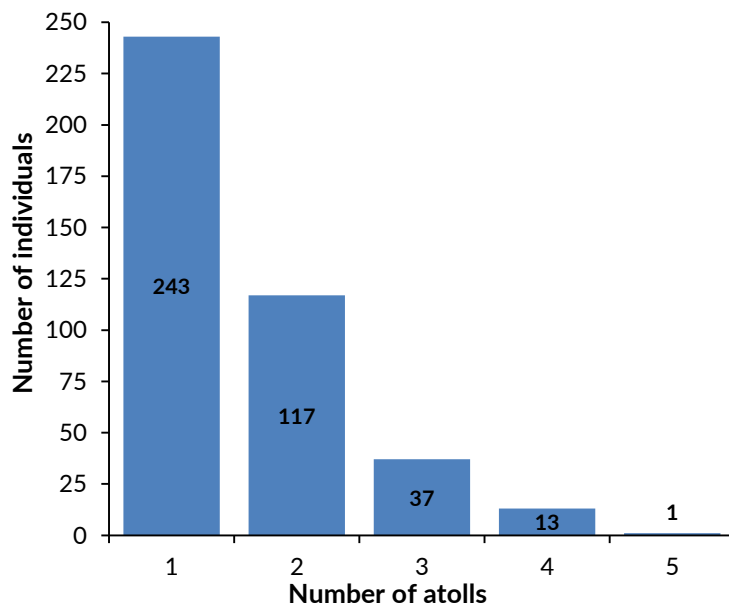


Figure 11: Number of geographical atolls each individual reef manta rays (*Mobula alfredi*) in the Lhaviyani Atoll population ($n=411$) has been recorded within.

In 2019, individual reef manta rays were sighted 2.9 times each on average (Fig. 12). When survey effort is accounted for, residency index (RI) indicates that each manta ray was recorded on 1.2% of total surveys in 2019, one of the lowest indices recorded in recent years (Fig. 13). The low

residency of manta rays in Lhaviyani in 2019 is likely the result of high survey effort, as RI is inversely correlated with number of surveys (Fig. 14), and a reflection of more transient behaviour, with manta ray movements likely dictated by more favourable conditions elsewhere.

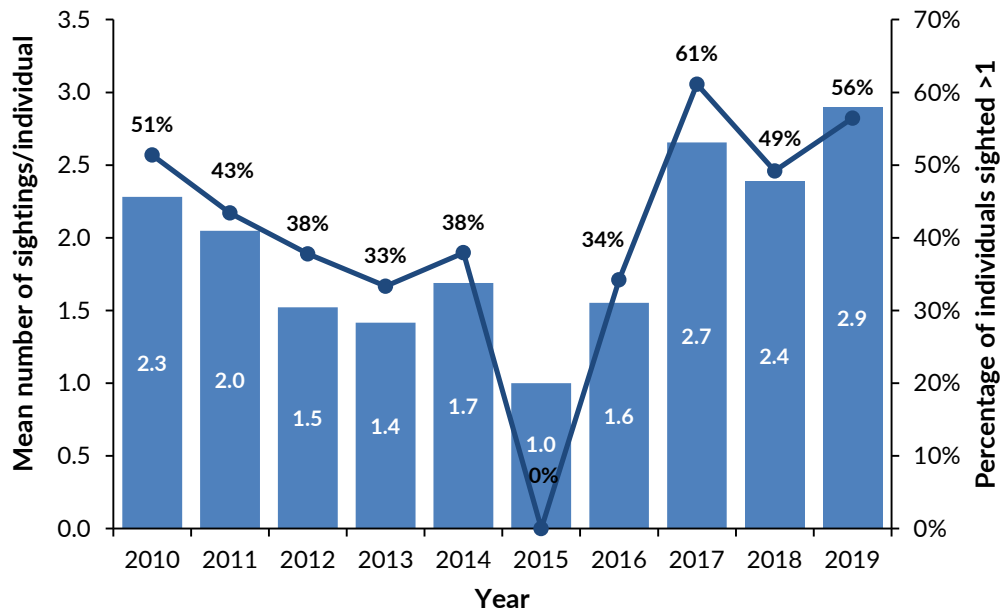


Figure 12: Mean number of sightings per individual reef manta ray (*Mobula alfredi*) in Lhaviyani Atoll, and the percentage of individuals sighted on multiple occasions during the same year.

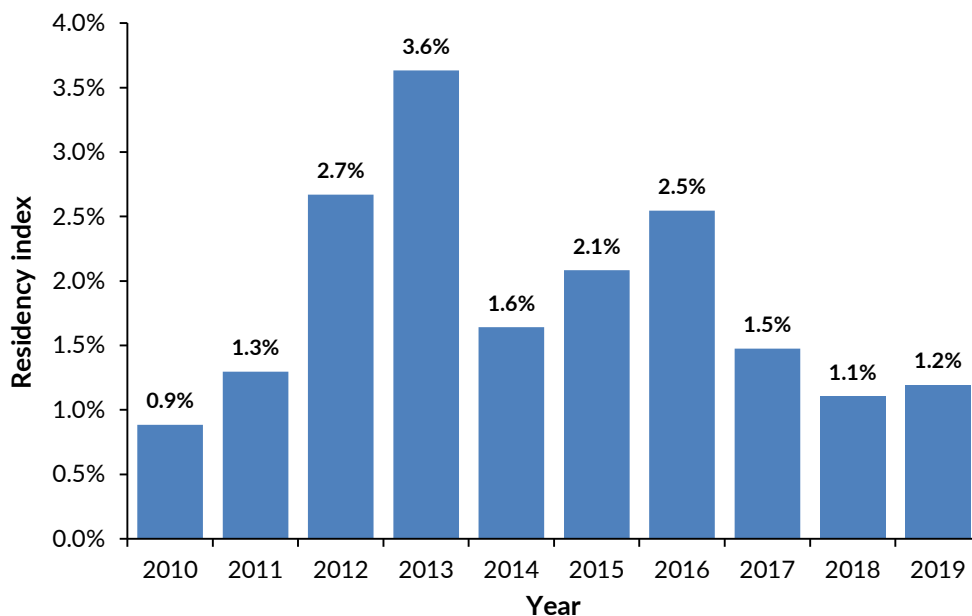


Figure 13: Annual residency index (RI) of reef manta rays (*Mobula alfredi*) in Lhaviyani Atoll. RI is calculated as the average of each individuals' residency (number of times sighted annually divided by the total number of surveys).

Within Lhaviyani Atoll, fidelity of reef manta rays to different aggregation sites varies between individuals. Four key hotspots have been identified (as described previously); Dhanifaru and Kanifushi Falhu (both sheltered lagoons to the west of the atoll), Fushifaru Kandu (a key cleaning station to the northeast), and Veligadu Falhu (an elongated sandbank to the northwest). Of the manta rays that frequent these four key sites ($n=372$), 47% ($n=176$) have been recorded at one of the locations only, indicating variation in site preference among individuals. Indeed, these sites appear to be utilised by different age and sex demographics within the population (Fig. 15). Across study years, Dhanifaru and Kanifushi Falhu were

visited by a relatively large proportion of juvenile manta rays, which may be due to the fact that young individuals tend to prefer more sheltered lagoon areas. Meanwhile, the majority of those individuals recorded at Fushifaru Kandu and Veligadu Falhu were adults. Furthermore, while Dhanifaru and Veligadu Falhu were favoured slightly by males, 61% of individuals sighted at Fushifaru Kandu were female. The preference of mature manta rays, particularly females, to Fushifaru Kandu is unsurprising, given that adults commonly visit cleaning stations which act as focal points for courtship activity, and are typically dominated by females which invest more time in cleaning than males.

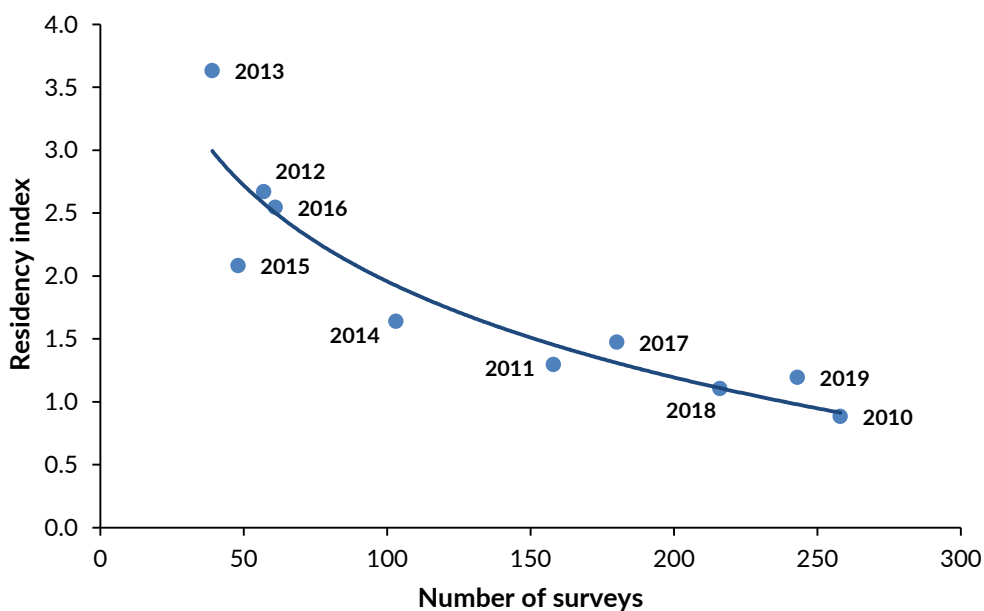


Figure 14: Relationship between the number of surveys conducted and the residency index of reef manta rays (*Mobula alfredi*) recorded within a study year in Lhaviyani Atoll (2010-2019).



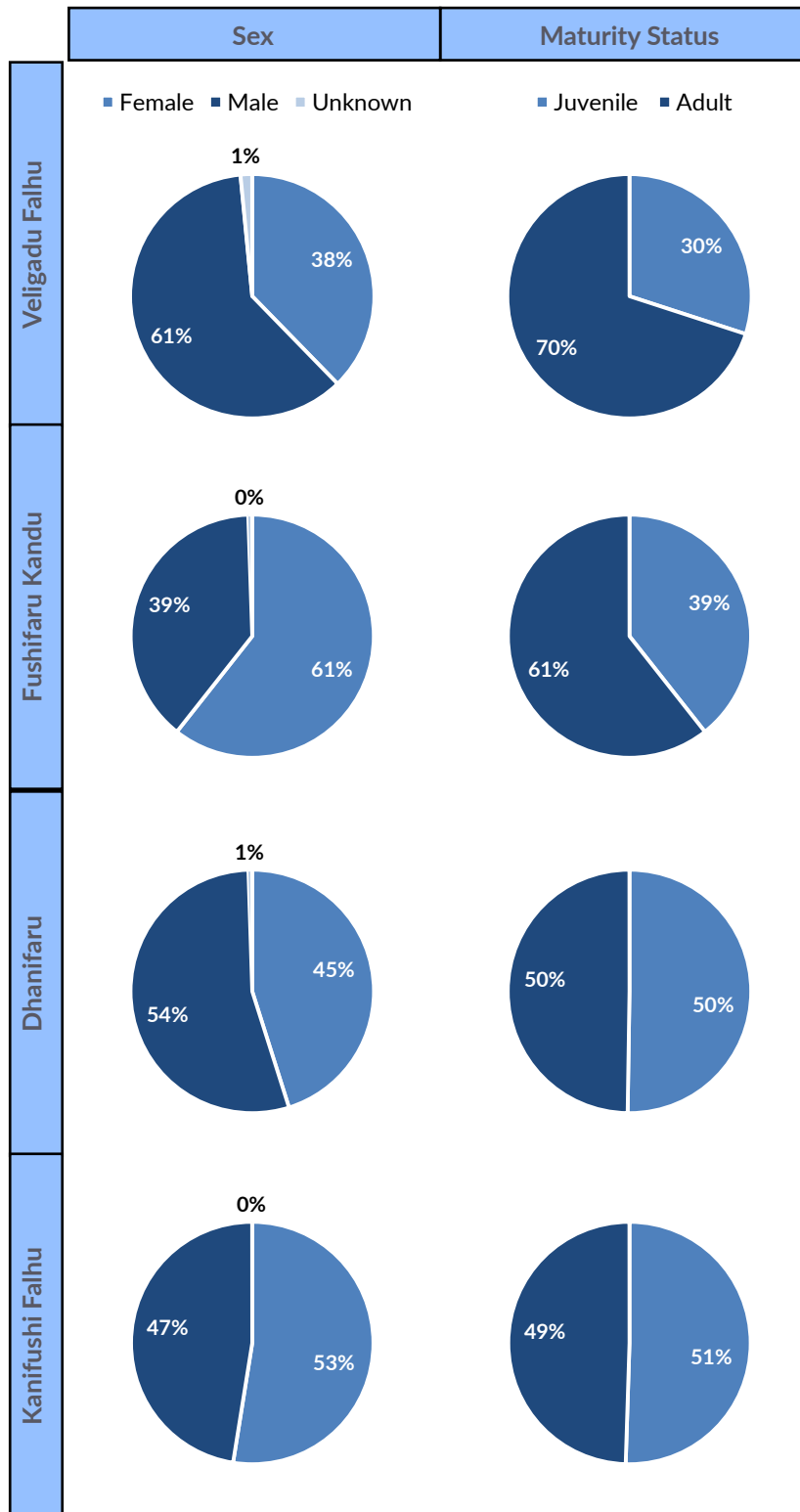


Figure 15: Demographics of the reef manta rays (*Mobula alfredi*) recorded at the four key aggregation sites in Lhaviyani Atoll (2004-2019).

Overall, these findings highlight the importance of surveying across different sites and support the protection of multiple areas around the atoll in order to protect different demographics of reef manta rays and their habitats. Of the three key sites described, only Fushifaru Kandu is currently designated as a marine protected area (MPA), with protective legislation banning fishing in 1,400 ha of the surrounding area. However, there is no enforcement or monitoring of regulations in this area, and it is not made clear what the

guidelines are for this specific area. In December of 2017, a proposal for the creation of two new MPAs at Veligadu Falhu and Dhanifaru was presented to the Lhaviyani Atoll Council by a MMRP researcher in collaboration with Naifaru Juvenile, another local NGO. The proposal was unsuccessful, however; before moving to create new MPAs within Lhaviyani Atoll, it is necessary that regulations are being enforced and monitored in existing protected areas.

PREGNANCIES & COURTSHIP

The Lhaviyani reef manta ray population comprises a total of 74 mature females, 13 of which were sighted during 2019. Of these, three were observed pregnant, making 2019 the year with the second highest number of recorded pregnancies since this study began in this atoll, together with 2008 and 2014 (Fig. 16). On average, only 14% of mature females sighted annually between 2004 and 2019 have been observed pregnant, indicating very low fecundity within the population, which is consistent with reproductive rates of manta rays elsewhere in the

Maldives. Indeed, of the 17 females that have been observed pregnant in Lhaviyani Atoll across the study period, only three individuals have been recorded pregnant more than once, one of which has been recorded pregnant in three different years (Table 1). Furthermore, there are very few records of courtship behaviour in Lhaviyani Atoll. In 2019, there were just three events; one at Veligadu Falhu in January, one at Fushifaru Kandu in October, and another at Fushifaru Kandu in November.

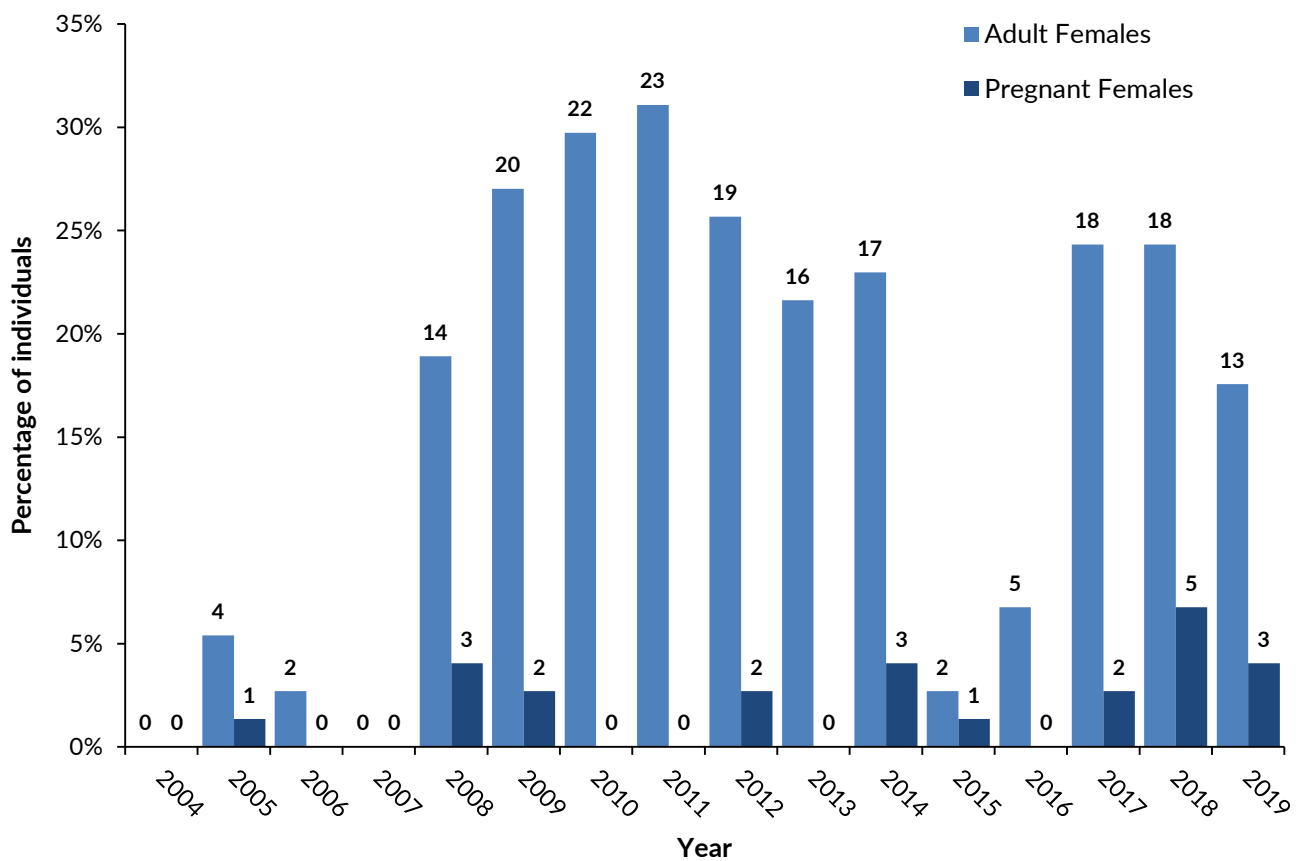


Figure 16: Percentage of Lhaviyani Atoll's adult female reef manta ray (*Mobula alfredi*) population (n=74) sighted annually, and the percentage of those females which were recorded pregnant in the same year. Actual numbers above bars.

Table 1: Annual sightings of the 17 mature female reef manta rays (*Mobula alfredi*) in Lhaviyani Atoll which have been recorded pregnant at least once. Years where the individual was observed as being pregnant are highlighted in dark blue. * MV-MA-1975 was pregnant once, spanning from 2018 to 2019.

ID	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
MV-MA-0040	1														
MV-MA-0041	1			4	2	8	4	6		2		1	6	15	12
MV-MA-0042	1			1				2	1	4			7	6	
MV-MA-0939				1		2	2	1		3	1		6		
MV-MA-1090						1								1	
MV-MA-1184				1		1	2						2	1	
MV-MA-1185				1											
MV-MA-1186				2											
MV-MA-1412					1			1		1					
MV-MA-1419					2	2									
MV-MA-1421					1		3			4			6	3	7
MV-MA-1424				1	1	4	1								
MV-MA-1975							1		2				2	3	3*
MV-MA-2798								2							
MV-MA-3161									1	1				4	
MV-MA-3162									1						2
MV-MA-3233										1					
Total Pregnancies	1	0	0	3	2	0	0	2	0	3	1	0	2	5	3

SUB-LETHAL INJURIES

During each photo-ID sighting, data on any injuries of the reef manta rays was also recorded. Within the Lhaviyani Atoll reef manta ray population, 66% ($n=270$) have no significant injuries, while the remaining 34% ($n=141$) have been recorded with sub-lethal injuries. Of those, 12 individuals had not one, but two injuries, and one individual had a superficial injury which healed and left no scarring.

Over half (61%) of injured individuals in the Lhaviyani reef manta ray population have injuries from natural origins ($n=86$), while 30% ($n=43$) have injuries caused by anthropogenic impacts. Thirteen percent ($n=18$) of injured individuals have an injury for which the origin could not be clearly identified (Fig. 17). Naturally caused injuries included infection or disease ($n=3$), deformity ($n=4$), and predatory bites ($n=82$). Injuries caused due to anthropogenic impact included boat strikes ($n=3$), injuries caused by fishing line ($n=40$), and manta rays being entangled in fishing nets ($n=1$)

(Fig. 18). Ghost nets and discarded fishing gear are regularly encountered in Lhaviyani Atoll, which may explain the large number of injuries caused by fishing lines in the region. Of the 141 manta rays recorded with injuries, 86% ($n=121$) had injuries inflicted upon their pectoral fins, 14% ($n=20$) on the tail and dorsal areas, 9% ($n=13$) on the cephalic fins, and 4% on the gill slits ($n=5$) (Fig. 19).

In 2019, eight manta rays were recorded with new injuries in Lhaviyani Atoll. Of these, two had injuries caused by anthropogenic impacts; one with scarring from a fishing line, and one with a fishing line and hook embedded in the gills. A further four manta rays had injuries from natural causes; two individuals had new shark bite injuries, one had a growth above the eye, and one had minor damage to the gills which was possibly caused by an infection. The cause of injuries on the two remaining injured manta rays could not be determined.

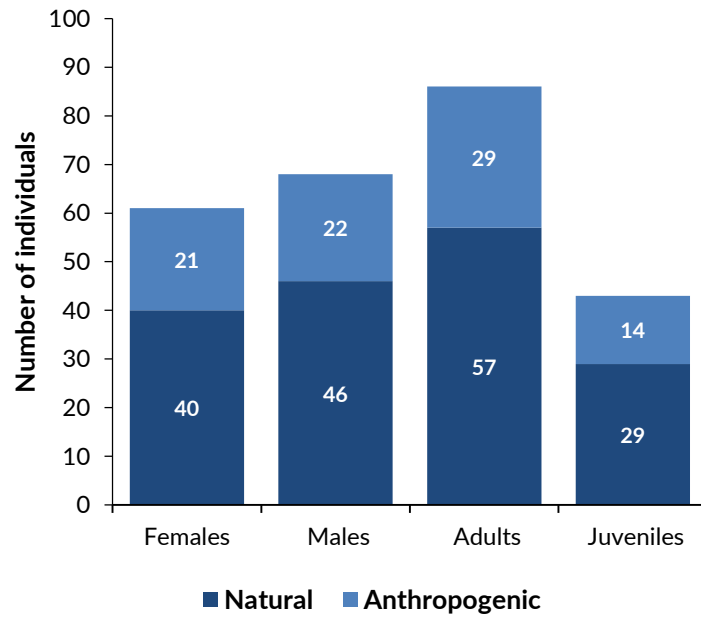


Figure 17: Demographic variations in the likely origin (natural or anthropogenic) of sub-lethal injuries within the injured reef manta ray (*Mobula alfredi*) population of Lhaviyani Atoll (n=141).

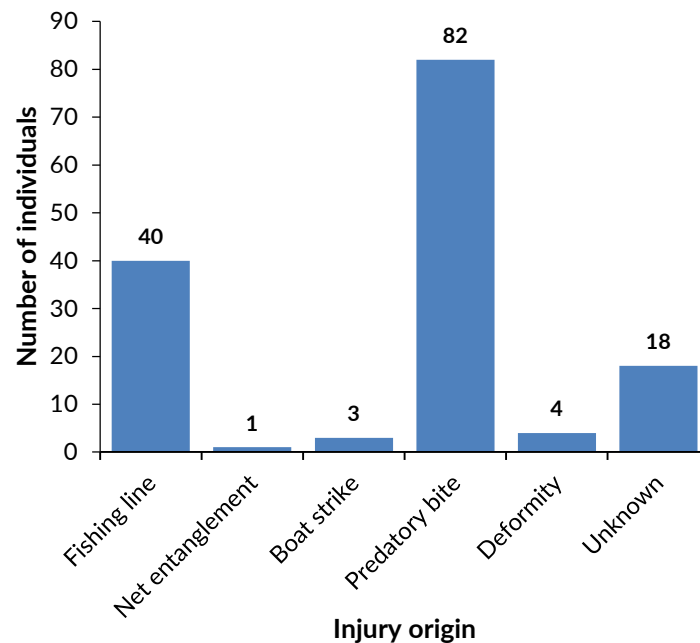


Figure 18: Variations in the origin of sub-lethal injuries within the injured reef manta ray (*Mobula alfredi*) population of Lhaviyani Atoll (n=141).

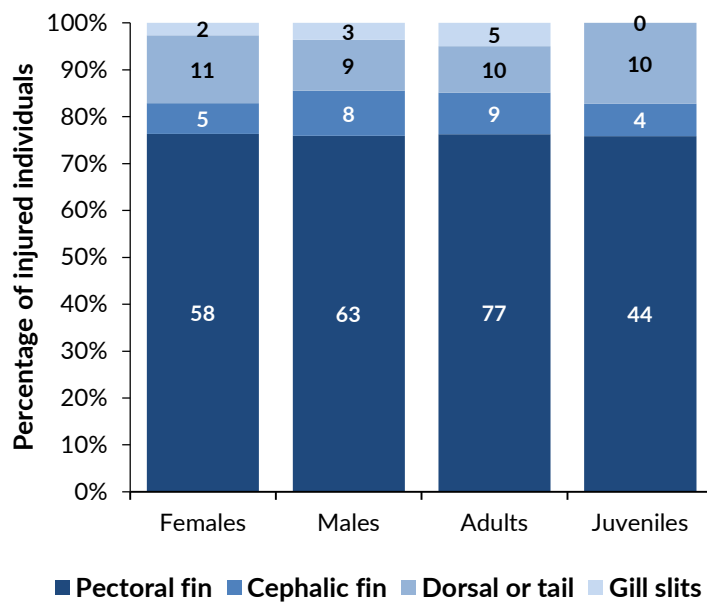


Figure 19: Variations in the location and number of sub-lethal injuries within the injured reef manta ray (*Mobula alfredi*) population of Lhaviyani Atoll ($n=141$) and their demographic variation (actual number of individuals on bars).

FATALITIES

Boat mooring and buoy lines have been widely used in the Maldives for decades. However, as the number of these lines greatly increases throughout the country due to tourism development, they are increasingly posing a serious threat to the reef manta ray population. Very sadly, one reef manta ray became entangled in such a mooring line in Lhaviyani Atoll in 2019. Since manta rays are obligate ram ventilators, meaning they need to swim constantly to “breathe”, the manta ray quickly asphyxiated and died prior to it being discovered. The individual was a juvenile female, with a disc-width of approximately 190cm, and was previously unknown to the MMRP database. The mooring line in question was poorly configured, with a large amount of slack line, in which the manta ray became entangled.

This tragic incident has highlighted the importance of ensuring that all mooring and buoy lines in the Maldives are modified to reduce the risk of manta ray entanglements. To aid these efforts, the Manta Trust has developed a few simple actions which can be taken to help prevent future manta ray entanglements, and guidance on how to respond in the event of an entanglement. These can be found on the Manta Trust website (www.mantatrust.org/resources).



Photo by Karin Nistler

ENVIRONMENTAL VARIABLES

Within Lhaviyani Atoll, site use by manta rays appears to be linked to wind direction, which changes with the monsoons. Wind direction was recorded on all surveys conducted by resident Manta Trust researchers ($n=202$) in 2019, and on 39 of the 41 surveys conducted by external contributors. Notably, north-easterly monsoon winds accounted for the largest proportion of sightings at Veligadu Falhu ($n=114$) (Fig. 20), a site on the northwest side of the atoll which is most associated with feeding behaviour. Winds of the Northeast Monsoon drive upwelling and primary productivity on the outer edge of the atoll between December and March each

year. When combined with tidal currents, this results in localised abundances of zooplankton within the western side of Lhaviyani during this time. In contrast, the majority of reef manta ray sightings at Fushifaru Kandu occurred when winds were blowing from the southwest ($n=34$), or west ($n=29$) (Fig. 20), and mostly occurred at the end of the Southwest Monsoon. During this monsoon, food availability is concentrated toward the eastern side of the atolls in the Maldives, and manta rays utilise feeding areas, as well as nearby cleaning stations as the monsoon draws to a close.

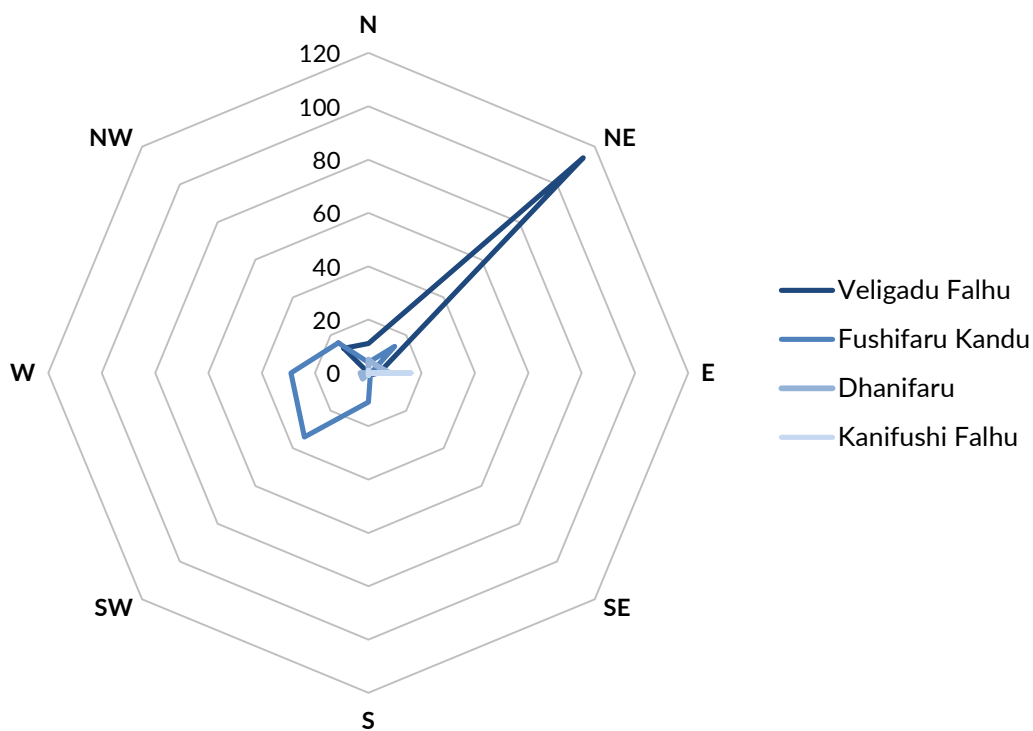


Figure 20: Number of reef manta ray (*Mobula alfredi*) sightings in relation to prevailing wind direction at four key aggregation sites in Lhaviyani Atoll (2019); obtained from surveys where wind direction was recorded ($n=241$).

In addition to wind direction, wind speed is also an important factor in influencing manta ray sightings. In 2019, sightings appeared to correlate with wind speed during the months of the Northeast Monsoon (December to March) (Fig. 21). Higher wind speeds are likely to be associated with an increase in upwelling and productivity in the region at these times, driving higher abundance of manta rays' zooplankton food source on the western side of the atoll. Sightings did not appear to be strongly associated with the prevailing

winds during the heart of the Southwest Monsoon (June – September) in Lhaviyani Atoll (Fig. 21). While it is possible that manta rays may be feeding on the eastern side of the atoll during this period, just one feeding aggregation site has so far been identified (Fushifaru Kandu), which was utilised only at the very end of the Southwest Monsoon season. Exploratory trips to identify key feeding sites along the eastern borders of Lhaviyani Atoll will continue in 2020.

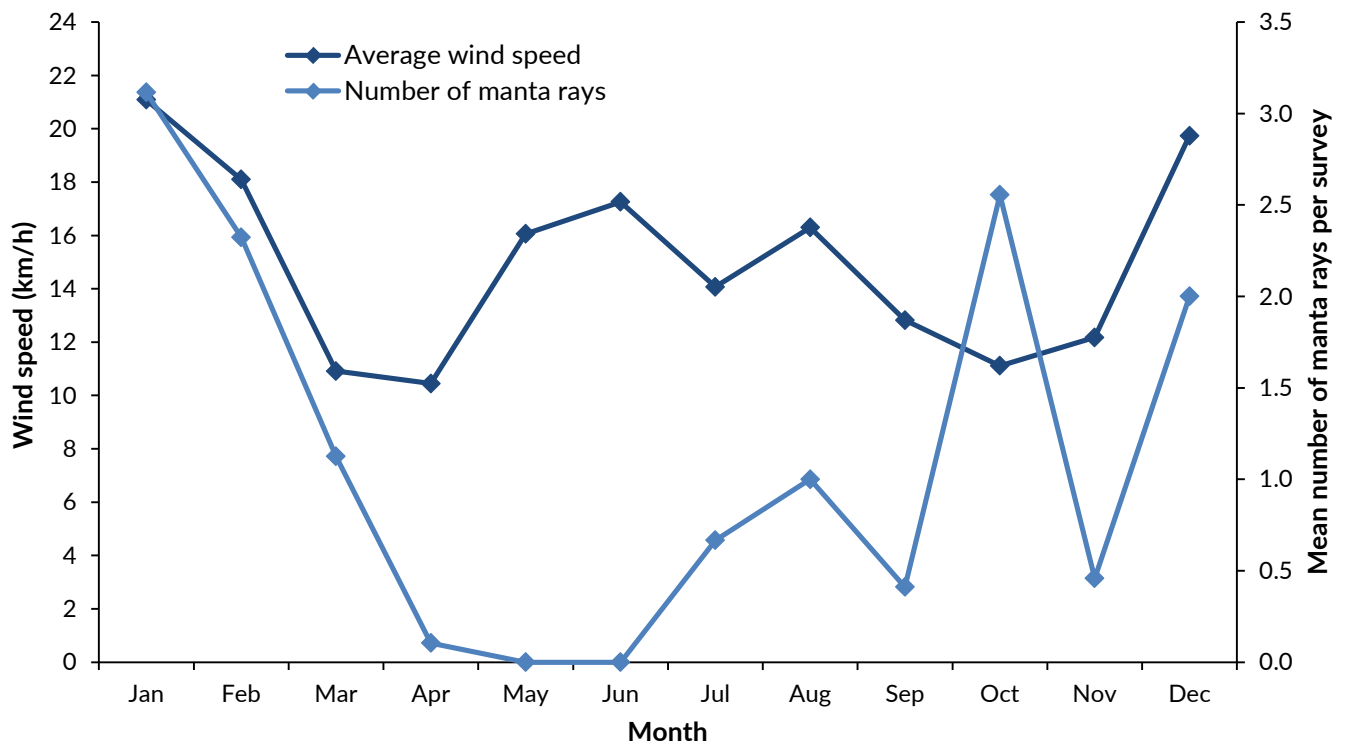


Figure 21: Monthly mean maximum wind speed (km/h) and the mean number of reef manta ray (*Mobula alfredi*) sightings per survey in Lhaviyani Atoll (2019).

TOURISM ACTIVITIES

The MMRP strive to improve the sustainability of manta ray tourism activities in Lhaviyani Atoll. In 2019, the MMRP researchers continued to collect tourism related data within the region and noticed an increase in the average number of tourist boats and snorkellers present per survey when compared to 2018 records. On average, 2.6 boats and 8.3 snorkellers were recorded per survey trip in 2019, compared to 1.1 boats and 5.6 snorkellers recorded per survey in 2018. This rise in tourism activity is likely to be related to the two new resorts opening within Lhaviyani Atoll in 2019, both of which operate daily dive and snorkel excursions.

As manta ray excursions continue to become more popular with visitors to the atoll, MMRP researchers have continued to encourage sustainable tourism practices to be administered. During 2019, the MMRP team organised a series of informative presentations and workshops aimed at those leading swim-with-manta-ray tourism initiatives. The information sharing events provided education on manta ray biology, ecology, the history of the MMRP, the research the MMRP conducts in the Maldives, and the best Codes of Conduct (CoC) for interacting with manta

rays in the water (www.swimwithmantas.org). The aim was to provide marine users with the necessary tools to conduct sustainable manta ray tourism activities, in order to safeguard against negative ramifications of human-manta ray interactions and ensure the conservation of the Maldives manta ray population. The information sharing events were a success.

Beyond educating marine users, it is crucial to the conservation of the Maldives manta ray population that there is improved monitoring of diver and snorkeller manta ray tourism activities at manta sites (and other protected areas) in Lhaviyani Atoll. Wide distribution of the CoC and the “How to swim with manta rays” (www.swimwithmantas.org) guidelines across all dive centres and live-aboard vessels that operate in Lhaviyani Atoll is becoming increasingly important, as new resorts and guest houses are opened and more tourists join manta excursions each year. All tourists who joined manta snorkel excursions or dives from Hurawalhi Resort in 2019 were properly briefed by the MMRP’s Manta Trust researcher and/or the Prodivers staff on how to behave in water.

This report was made possible thanks to



MALDIVES GOVERNMENT AUTHORITIES

The Manta Trust is grateful for the opportunities provided by the Ministry of Environment and Energy, the Ministry of Fisheries, Marine Resources and Agriculture, the Environmental Protection Agency, and the Marine Research Centre. All data was collected in accordance with the relevant permit requirements of the aforementioned governing bodies.

The Manta Trust would also like to extend a warm thank you to all the other resorts, guest houses, liveboards, dive centres and watersports teams as well as the marine biologists and citizen scientists who have supported our research and submitted sightings.

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



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 opportunities that the Manta Trust's MMRP have in the Maldives are unparalleled. Working in an area that is home to the largest aggregation of reef manta rays in the world, our research continues to expand every year. We are humbled by the thought of being able to further pursue our research programmes alongside the Maldives government. 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.



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