



Maldivian Manta Ray Project

Ari Atoll | Annual Report 2018

*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 globally healthy marine ecosystems.

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 4,600 different individual reef manta rays, from more than 60,000 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 over 380 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 second in a series presenting data collected by the Manta Trust's Maldivian Manta Ray Project (MMRP) in the geographical atolls of Ari, Rasdhu, and Thoddu (administratively, Alifu Alifu and Alifu Dhaalu Atolls) between January and December 2018.

Ari Atoll is a very large (2,259 km²) complex atoll, consisting of 91 islands, and is the 18th largest geographical atoll in the world. Rasdhu Atoll is much smaller (62km²) and is defined as an oceanic faro, as it consists of six islands with only a few channels along the atoll's outer rim. Thoddu Atoll is the smallest of the three (5km²) and is an oceanic platform reef, not a true atoll. It consists of the single island of Thoddu and has no lagoon system. All three atolls are part of the northern section of the central Maldives archipelago; Thoddu Atoll is located 10 km north of Rasdhu Atoll, which is located 8.5 km to the northeast of Ari Atoll. Analysis throughout the report refers to this combined area as the Ari Atoll Region (AAR).

The AAR has a year-round presence of reef manta rays (*Mobula alfredi*) and whale sharks (*Rhincodon typus*), with both planktivorous species following the seasonal movement of their food across the atolls with the changing South Asian Monsoons. The high chance to see these charismatic megafauna species, along with easy accessibility to Malé, has resulted in the AAR becoming one of the most popular tourist destinations in the Maldives. The high tourist presence in the region means that the majority of data collected by the MMRP, including in 2018, came from engaged citizen scientists. These tourists, dive guides,

snorkel leaders, and marine biologists have submitted many photo identification (photo-ID) images to the MMRP. The year 2018 also served as the first time that the MMRP was able to continuously survey manta rays on both the eastern and western sides of Ari Atoll, leading to a much better understanding of the region's manta population.

Key findings include a total of 2,066 sightings of 550 individual reef manta rays, recorded at 37 different sites in the AAR in 2018. Reef manta ray sightings continued to follow an increasing trend, with more sightings reported and more individual manta rays recorded in 2018 than any single year prior. This is likely due to the continued increase in survey effort throughout the region by the MMRP and supporting resorts and liveaboards. As only 9% of the individuals sighted were new to the Maldives population in 2018, and 82% have been re-sighted in the Maldives, it is likely that the vast majority of manta rays in the AAR have now been recorded.

Reproductive activity was observed quite frequently in the AAR in 2018, with 30% of all mature females seen pregnant in 2018; this is close to the 31% seen in 2017, and much higher than recorded in previous years. In addition, 17 new manta pups, or 2018 "young of year", were recorded in the AAR, which is more than ever recorded in a single year prior. Courtship behaviour peaked in the region in January and October, supporting the nationwide trend of bi-annual courtship seasons.

Reef manta rays are highly mobile species, often travelling hundreds of kilometres throughout the Maldives. Due to its central location and close proximity to other atolls, forty-four percent ($n=606$) of AAR reef manta ray population has been sighted outside of the region, compared to only 29% of the total recorded Maldives' reef manta ray population ($n=4662$). Indeed, reef manta rays from the AAR have been re-sighted in 16 different geographical atolls.

Manta rays are an incredibly important economic resource to the Maldives, bringing tens of thousands of divers and snorkellers to the country each year, and generating millions of USD for the economy annually. This is especially true in the AAR, with more tourists and tourist boats recorded by the MMRP in 2018 than in any year prior. Extensive tourism studies conducted by the MMRP and the Maldives Whale Shark Research Programme (MWSRP) show that unregulated tourism can have a negative impact on marine

megafauna. The Manta Trust and the MMRP continued to disseminate their 'How to Swim with Manta Rays' tourism code of conduct in 2018 to as many involved tourism operators as possible. Operators and tourists will continue to be equipped with the tools and information they need to make their excursions as sustainable as possible.

Efforts to conserve the natural heritage of the AAR and manage the increasing human impacts upon the environment are encouraging, providing much to look forward to in 2019 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. 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

Seasonal variance and weather patterns within the Maldives are dictated by the South Asian Monsoon. The fluctuating monsoons (seasons) play an important role in determining manta ray distribution and, thus, an understanding of the monsoons is critical to the analysis of manta ray sightings in the AAR.

The South Asian Monsoons are characterized by their winds, which blow consistently and reverse direction seasonally. The Maldives Northeast Monsoon, or Iruvai, generally runs between December and March, and the Southwest Monsoon, or Hulhangu, between May and October; the months of April and November tend to serve as the transitional periods between the changing seasons. However, the monsoons sometimes change earlier or later than normal. The Southwest Monsoon tends to be characterized by higher levels of rainfall and cloud cover, and stronger wind speeds resulting in rougher seas.

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 atoll systems of the Maldives, rising 2,000 meters off the sea floor, act as a barrier to the oceanic currents, displacing the water as it flows around and through the atolls, creating areas of

deep-water upwelling along the leeward side of each atoll. These upwellings bring nutrient rich water within reach of the sun, enabling the photosynthetic phytoplankton to flourish, which, in turn, generates a bloom of zooplankton that feeds on the phytoplankton. Zooplankton is the food source for manta rays and whale sharks, and tends to be concentrated in specific areas by the movements of lunar currents into and out of the atolls, via numerous channels. These sites are where we are most likely to observe feeding planktivorous megafauna and, in the case of reef manta rays, where these animals frequent cleaning stations in close proximity to their plankton-rich feeding areas.

The manta rays migrate seasonally to utilize feeding and cleaning areas on the monsoonal down-current edge of the atolls. Therefore, research efforts are focused on the western edges of the atolls during the Northeast Monsoon and on the eastern edges during the Southwest Monsoon. Within the AAR, these seasonal changes of zooplankton and manta ray abundance are observable in Ari Atoll. However, due to the differing topographies of the oceanic faro of Rasdhu Atoll, and the oceanic platform reef of Thoddu Atoll, manta sightings at these atolls do not follow as closely the same seasonal patterns observed throughout the larger, more complex, atoll systems of the archipelago.

STUDY PERIOD & SAMPLING METHODOLOGY

Sampling Methodology

Manta ray sightings data in the AAR was obtained via photo identification (photo-ID) and was collected throughout the AAR both by full-time 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-ID of an individual manta ray on a given day in a certain location. Surveys were conducted in-water, both on SCUBA and via snorkelling, with sightings recorded at 72 different sites in Ari, Rasdhu, and Thoddu Atolls across all survey years. Twenty of these sites were classified as key aggregation sites due to higher (>50) number of manta ray sightings (Fig. 1).

During each survey performed by the MMRP researchers, individual manta ray sightings were documented via photo-ID. In addition, researchers collected data on location, manta ray numbers and behaviour, environmental variables (including wind speed, current direction, and plankton density), and anthropogenic factors (including number of divers/snorkellers, number of boats, and number of paying guests). Data was collected on all surveys, regardless of whether manta rays were sighted or not. Citizen scientists in the AAR recorded data only on surveys resulting in a confirmed manta ray sighting. In addition to submitting sighting photos to the MMRP for identification purposes, citizen scientists noted the trip location, manta ray sighting time, and the manta's prevalent behaviour.



Ari Atoll

● Thoddu Atoll

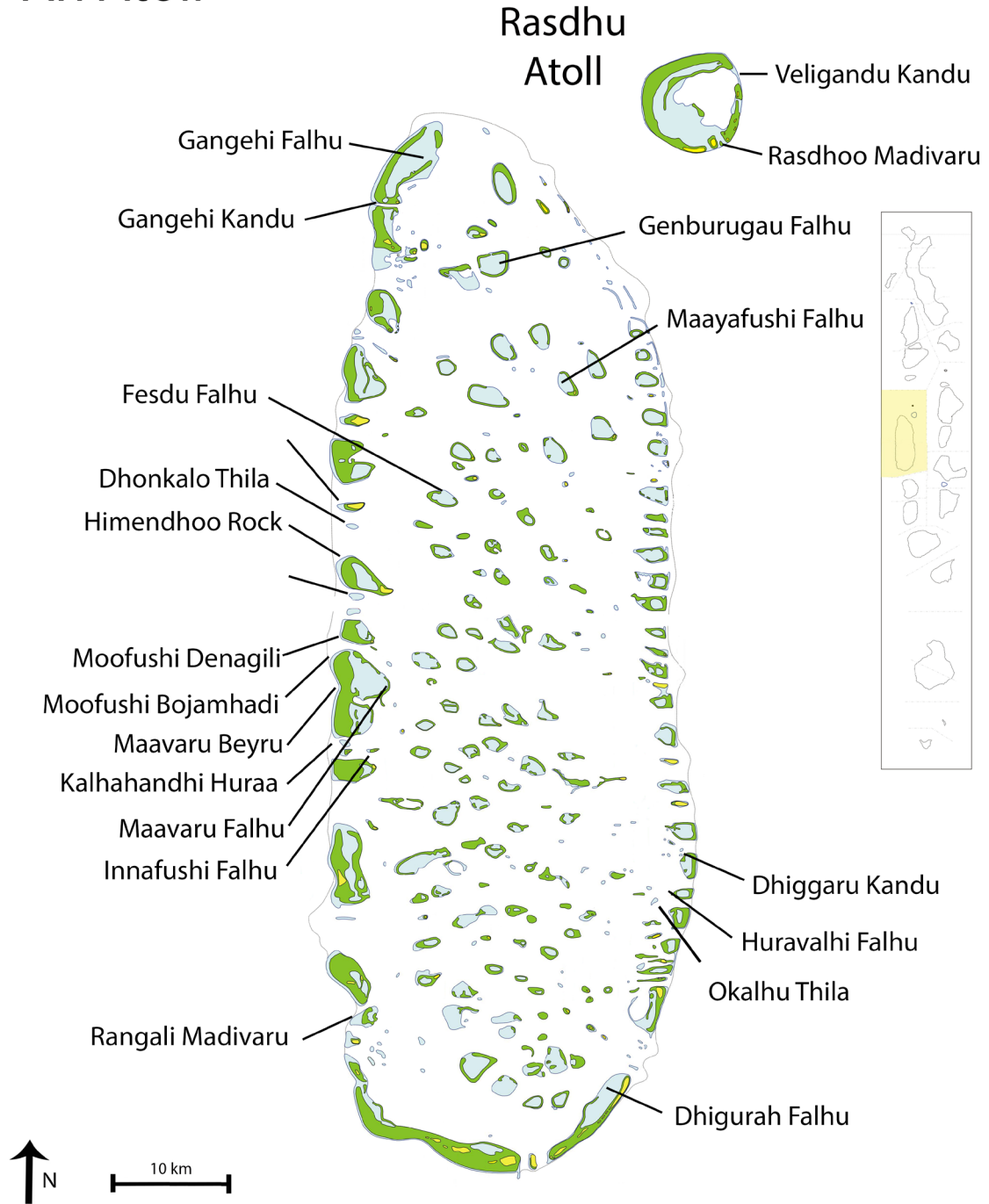


Figure 1: Map of the Ari Atoll Region (AAR) showing twenty of the key reef manta ray (*Mobula alfredi*) aggregation sites within the three geographical atolls (Ari, Rasdhu, and Thoddu). Also shown in the inset box is the AAR in relation to the rest of the Maldives Archipelago.

2018 Study Period

During 2018, the MMRP researchers performed a total of 403 surveys, the highest number of annual surveys completed since the MMRP established permanent research bases in the AAR (Fig. 2). From January until April, the MMRP had researchers based in three locations in Ari Atoll (Athurugau Island, Thundufushi Island, and Vilamendhoo Island). After the MMRP bases closed in west Ari Atoll at Athurugau and Thundufushi Islands, research was conducted solely from the east at Vilamendhoo Island, with 2018 serving as the first full year of consistent survey effort in the east of the atoll during the Southwest Monsoon.

Throughout the year, the MMRP researchers carried out surveys on as many days as conditions and logistical operations allowed. The 403 surveys were completed on 183 days at 27 sites, and all surveys were accompanied by resort guests. Manta rays were sighted on 59% ($n=236$) of all survey trips, with photo-ID data collected on 48% ($n=192$) of surveys.

From January until mid-April, survey effort focused on the western Ari Atoll manta aggregation sites: Maavaru Falhu ($n=33$), a manta ray feeding site, Moofushi Bojamhadi ($n=20$) and Kalhahandi Huraa ($n=43$), both manta cleaning stations, and Rangali Madivaru ($n=70$), where both feeding and cleaning manta rays were encountered. During mid-April, survey effort moved to focus on the manta ray aggregation sites in southeast Ari Atoll. Surveys were performed at Dhiggaru Kandhu ($n=58$) and Huravalhi Falhu ($n=35$) through to November. Both of these aggregation sites are home to reef manta ray feeding sites and cleaning stations. With the beginning of the Northeast Monsoon in December, surveys were again performed in west Ari Atoll at Rangali Madivaru ($n=8$). Throughout 2018, surveys were also conducted at the feeding site of Dhigurah Falhu ($n=43$) in southern Ari Atoll. Periodic SCUBA and snorkel surveys were also conducted in the South Ari Marine Protected Area (SAMPA), with a dual focus of manta ray and whale shark sightings.

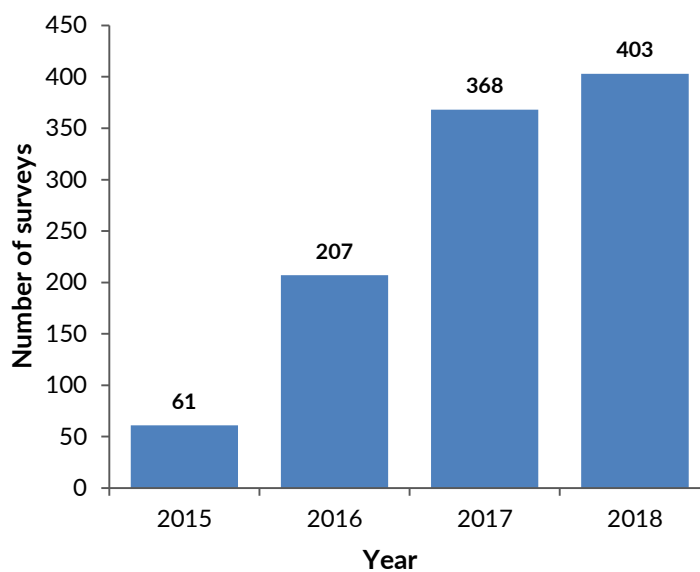


Figure 2: Number of surveys undertaken annually by the Maldivian Manta Ray Project in the Ari Atoll Region.

REEF MANTA RAY POPULATION

Sighting Trends

A total of 10,131 sightings of reef manta rays have been recorded across the AAR between 1992 and 2018. Of those sightings, 2,066 were recorded in 2018, which showed an increase over previous years, likely a result of increased survey effort (Fig. 3). When sub-divided by geographic atoll, the majority of sightings were recorded in Ari Atoll ($n=9,577$), followed by Rasdhu Atoll ($n=530$), and with the fewest sightings recorded in Thoddu Atoll ($n=24$). This trend remained consistent in 2018, with 1,808 sightings reported from Ari Atoll, 251 from Rasdhu Atoll, and seven from Thoddu Atoll.

For the last few decades, the AAR has had a heavy tourism presence through local resorts, guest houses, and liveboards. The MMRP has relied upon the support from this large tourism sector for many manta encounter reports submitted via citizen scientists and local operators. In 2018, 41% of reef manta ray sightings were recorded by MMRP researchers, while the remaining 59% came from citizen scientists. This trend, with the majority of sightings reported by citizen scientists, has remained consistent throughout the MMRP's study time in the AAR, even after the MMRP had permanent researchers based in the region.

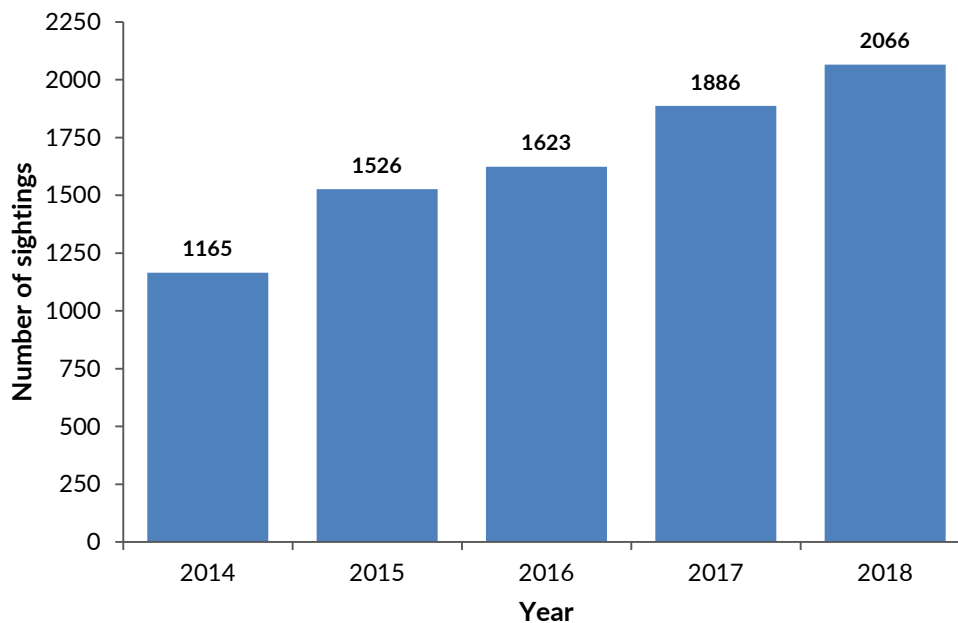


Figure 3: Total annual sightings of reef manta rays (*Mobula alfredi*) in the Ari Atoll Region.

In 2018, monthly reef manta sightings were at their lowest in August and September, with more sightings recorded during the first three months of the year (Fig. 4). This was biased by the much higher survey effort in early 2018, when the MMRP had three researchers regularly surveying the manta population. Therefore, the data collected by the MMRP in 2018 was used to standardise sightings by survey effort (Fig. 5). The standardised data showed three peaks in manta sightings in February, July, and October, as well as three months with low numbers of sightings in April, August, and December. The decrease in sightings

during April and December was expected, as these months encompass the seasonal monsoon changes; the drop in sightings during the month of August was likely due to variations in local environmental conditions. Sightings peaked during the Northeast Monsoon months of February and March, with two smaller secondary peaks during the Southwest Monsoon from June to July, and again between September and November. These peaks coincide with periods of expected high productivity, which are believed to occur one or two months following the stronger winds associated with the seasonal transition periods.

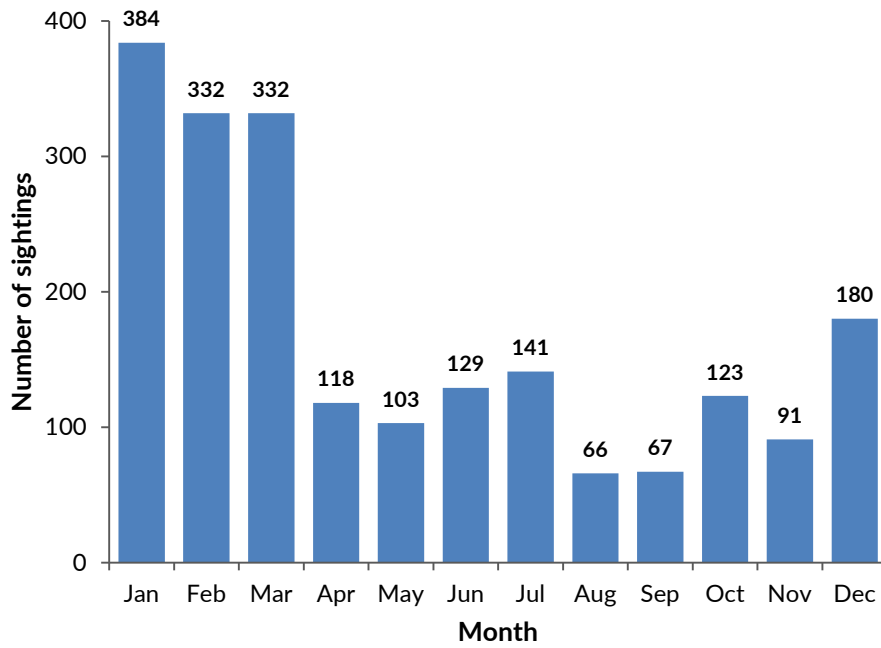


Figure 4: Monthly sightings of reef manta rays (*Mobula alfredi*) in the Ari Atoll Region in 2018.

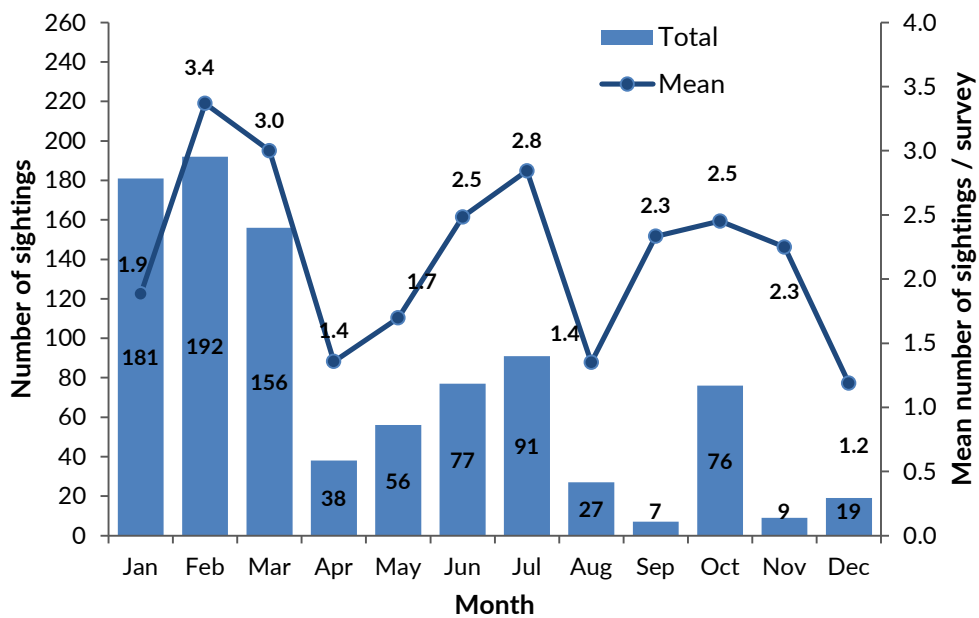


Figure 5: Total monthly sightings of reef manta rays (*Mobula alfredi*) recorded by the Maldivian Manta Ray Project’s researchers in the Ari Atoll Region and the mean number of sightings per survey (2018).

Population Demographics

The current recorded population of reef manta rays in the AAR is 1,368 individuals, 29% of the total recorded Maldives population ($n=4,662$). Divided geographically, Ari Atoll has a population comprising 1,261 individuals, Rasdhu Atoll has 150 individuals, and Thoddu Atoll has 15 individuals. Fifty-four (54%) of these individuals have been recorded in more than one atoll.

The AAR reef manta ray population is split almost evenly by sex, with 670 (49%) females and 688 (50%) males. The remaining 10 individuals (1%) were not able to be clearly sexed (Fig. 6). Sixty-two percent ($n=846$) of the regional population are adults and 37% are juveniles ($n=512$). Without knowing the sex of the ten unknown individuals, their maturity status could not be determined (Fig. 6).

A total of 550 individuals (12% of the overall Maldivian population) were sighted in the AAR in 2018, which is the largest number of individuals sighted within a single year (Fig. 7). Nine percent ($n=50$) of these individuals were new to the Maldives reef manta ray population (Fig. 7). This was the lowest percentage of new individuals sighted annually, which was expected, as more of the total population is added to the database each year. To date, 82% ($n=1128$) of the region's reef manta ray population ($n=1368$) has been re-sighted in either the AAR or elsewhere in the Maldives, suggesting that the MMRP has recorded a vast majority of the individuals that visit the AAR. Of the 50 new individuals recorded, 17 (33%) were estimated to be "young of the year" (YoY), based on their small disc widths measuring approximately 1.5 metres.

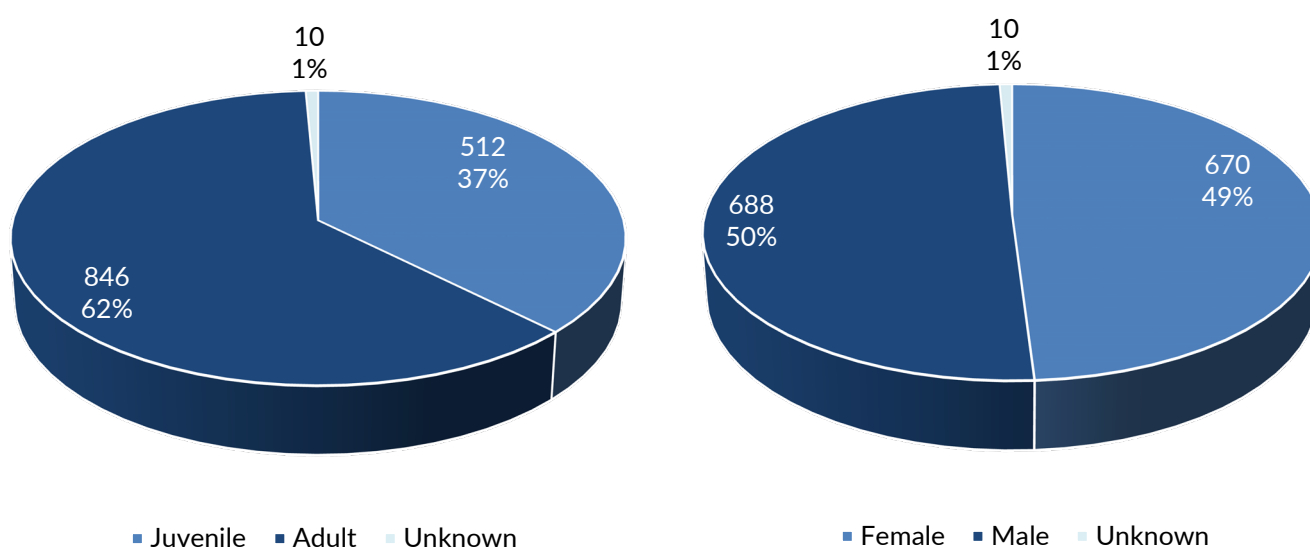


Figure 6: Demographics of the Ari Atoll Region's reef manta ray (*Mobula alfredi*) population ($n=1368$).

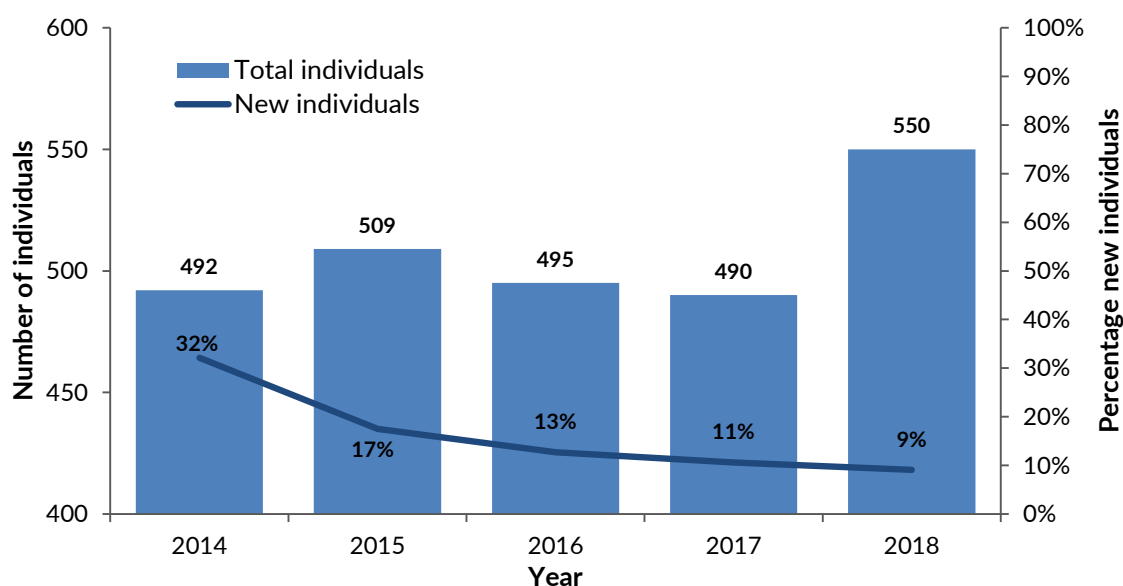


Figure 7: Total number of individual reef manta rays (*Mobula alfredi*) sighted annually in the Ari Atoll Region, and the percentage of those individuals that were newly recorded.

Reproductive Fecundity

In recent years, the MMRP has observed an increase in reproductive fecundity, with higher numbers of pregnant females and new-born pups sighted throughout the Maldives. A total of 79 individual female manta rays in the AAR were recorded pregnant between 1992 and 2018, with the largest number of pregnant females recorded in 2018 ($n=29$) (Fig. 8). This represented 30% of all adult females sighted in the AAR in 2018 ($n=98$), and was very similar to the pregnancy rate of 31% of all adult female sightings in the region in 2017. However, with a gestation period of approximately one year, 11 of the females recorded pregnant in 2018 were first reported pregnant in 2017. Much lower pregnancy rates were recorded in previous years, with a small peak in observed pregnancies in 2007 and 2008 when 22% and 21% of the adult females sighted were observed pregnant, respectively. Overall, 23% ($n=310$) of the AAR manta population are mature females; the 79 individuals with at least one recorded pregnancy represent only 25% of the overall population of adult females. This low reproductive rate, even with the peaks seen in recent years, indicates a low fecundity for reef

manta rays, and reinforces the importance of establishing effective conservation methods to minimize population decline.

Over the last four years (2015-2018), increased numbers of manta pups, or YoY, have been recorded. A high of 17 YoY individuals recorded in the AAR in 2018 represents only 3% of all individuals recorded that year in the region. Lower numbers were recorded in previous years with 11 YoY in 2017, 11 in 2016, 14 in 2015, and two in 2014, representing 2%, 2%, 3%, and <1% of individuals sighted per year, respectively. Only two pups were recorded in the AAR prior to 2014. This increase in sightings of young manta rays is likely attributed to greater research effort, the discovery of manta aggregation areas frequented by juveniles, and the higher number of pregnancies recorded in 2015, 2017, and 2018. With continued research in the AAR, we hope to gain a better understanding of site usage by these young individuals, and develop insight into reproductive periodicity, and factors influencing recruitment rates.

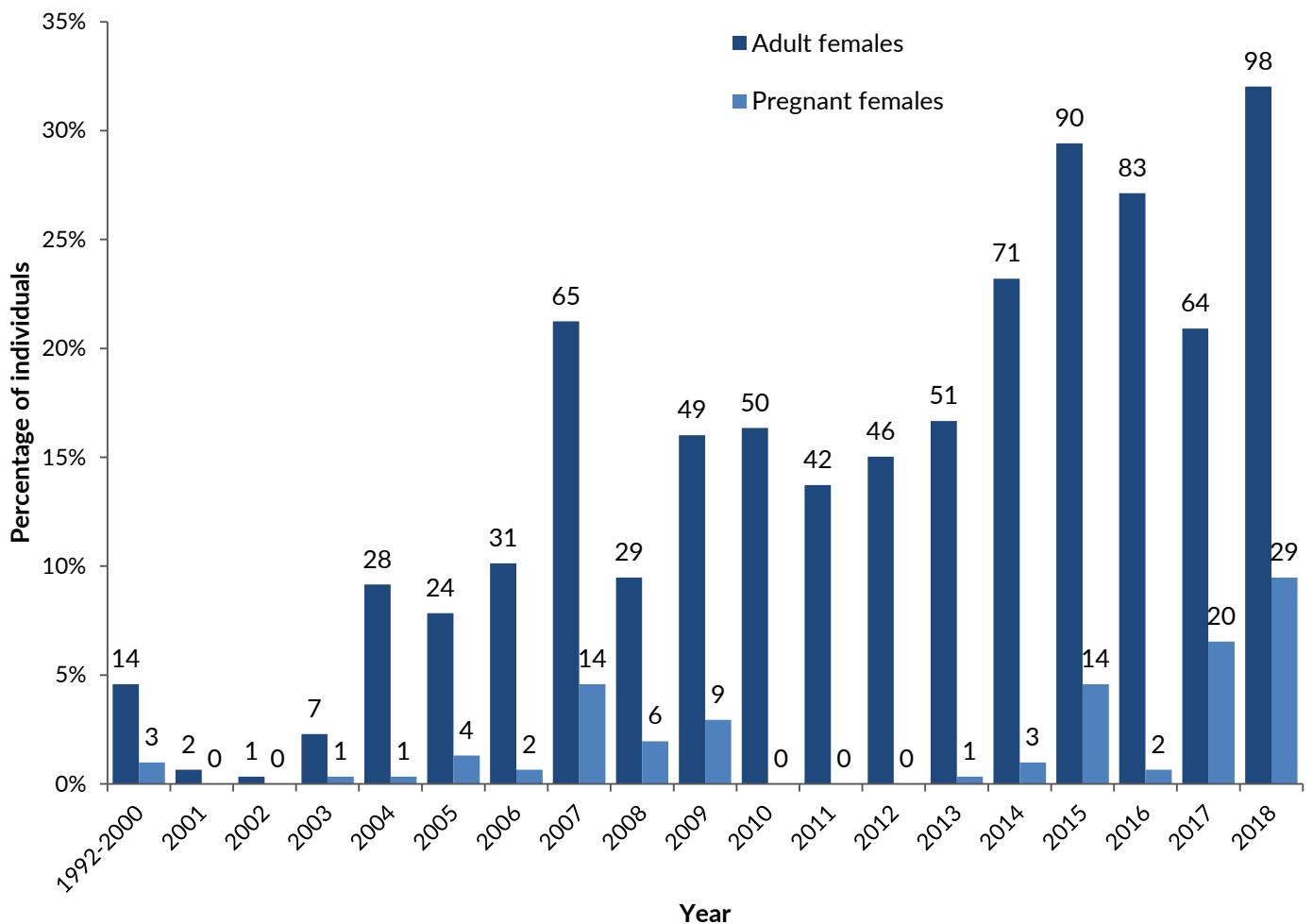


Figure 8: Percentage of the Ari Atoll Region's adult female reef manta ray (*Mobula alfredi*) population ($n=306$) sighted annually, and the percentage of those females that were recorded pregnant in the same year. Actual numbers above bars.

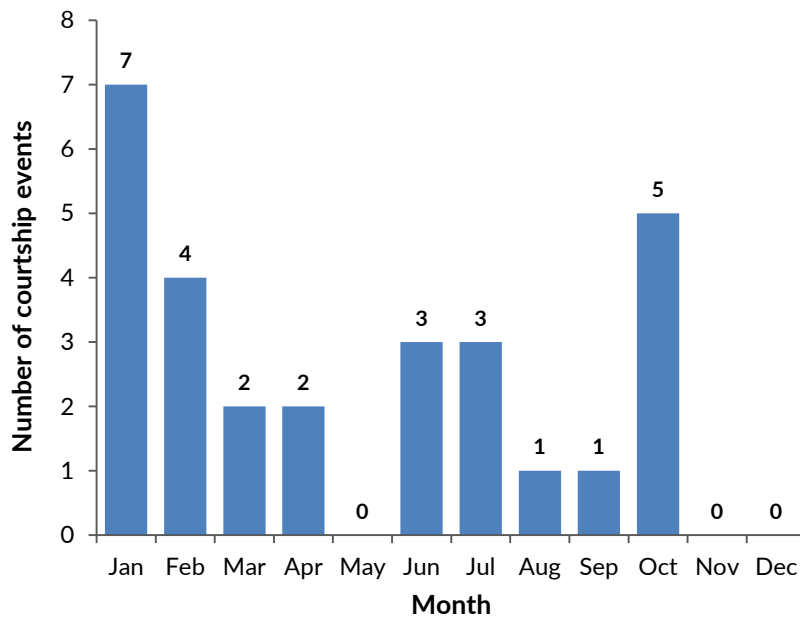


Figure 9: Total number of reef manta ray (*Mobula alfredi*) courtship events recorded throughout the Ari Atoll Region (2018).

Throughout the Maldives, juvenile and adult manta rays have been observed frequenting different aggregation areas; juveniles tended to be found in sheltered lagoon areas whilst adults were typically seen at cleaning stations and feeding areas in channels and along outer reefs. It is likely that the juvenile manta rays prefer the relative safety provided by shallower, sheltered waters within the atolls. Of the 17 YoY recorded in 2018, seven were seen at Dhigurah Falhu and four at Maayafushi Falhu, leading us to believe these are two important aggregation areas for juvenile manta rays in the AAR. Both sites are heavily visited by tourist boats and, due to their importance to the region's young reef manta ray population, are key sites to conserve and manage boat traffic and human presence at.

Manta ray courtship and mating behaviour typically peak at certain times of the year throughout the manta rays' global range. Cleaning stations tend to be the focal point of manta courtship behaviour, allowing researchers and knowledgeable citizen scientists to observe and record this behaviour. During 2018, 28 courtship events were recorded, with some of the first reports of courtship recorded during the Southwest Monsoon, due to the establishment of the MMRP's first research base on the eastern side of Ari Atoll (Fig. 9). Courtship activity peaked in January and October, with seven and five events recorded, respectively. These peaks in courtship activity coincided with the transitional period between the monsoons, matching the general timing of courtship activity recorded throughout the Maldives.

Atoll Residency

Throughout 2018, each individual manta ray was sighted, on average, 3.76 times, which was slightly lower than the 3.85 sightings per individual recorded in 2017, but higher than previous years (Fig. 10). The percentage of reef manta rays seen more than once in the AAR in 2018 was equal to that in 2017, with a 62% re-sighting rate (Fig. 10). Because these rates came from sightings recorded by both citizen scientists and MMRP researchers, they did not account for survey effort and might show bias. Therefore, a Residency Index (RI) was calculated for 2016, 2017, and 2018 using sightings and survey data collected by the MMRP researchers. The RI is based on the ratio between the number of days each individual was sighted and the

total number of surveyed days, in order to determine how often each individual was seen per survey day throughout the year. For example, a RI of 3% means that, on average, each individual was sighted on 3% of the total surveyed days. Within the AAR, the RI in 2018 was 1.59%, which was slightly higher than that calculated for 2017 (1.56%), but slightly lower than the RI for 2016 (1.68%) (Fig. 11). This likely reflected the increase in the number of manta aggregation sites surveyed due to the expansion of the MMRP's project coverage in eastern Ari Atoll. It could also have been related to the slightly less favourable conditions in 2017 and 2018, due to the lower recorded wind speeds in these two years compared to 2016.

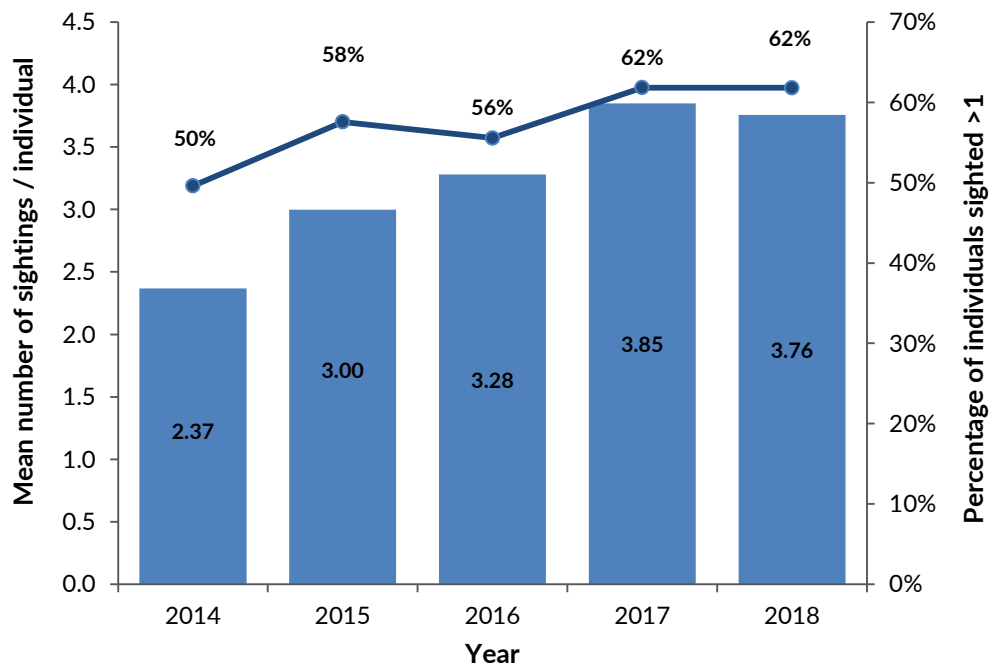


Figure 10: Mean number of sightings per individual reef manta ray (*Mobula alfredi*) in the Ari Atoll Region, and the percentage of individuals sighted on multiple occasions during the same year.

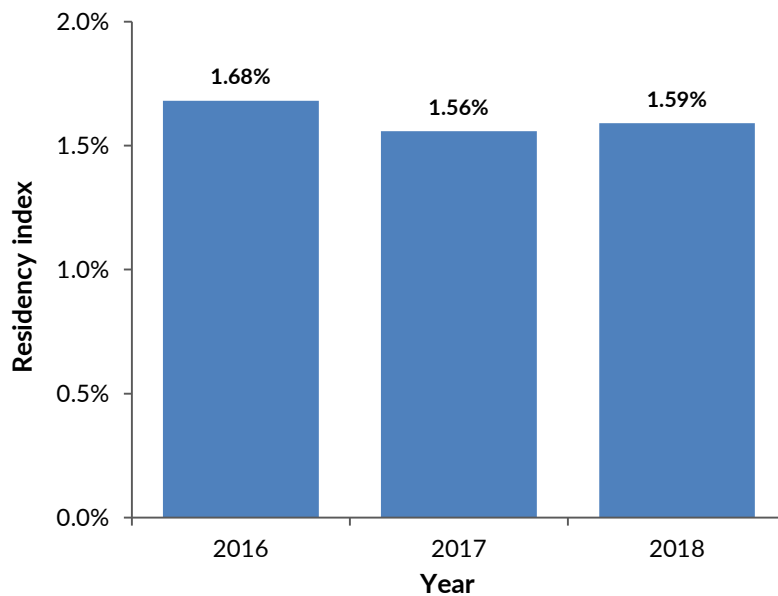


Figure 11: Annual Residency Index (RI) of the reef manta rays (*Mobula alfredi*) recorded by the Maldivian Manta Ray Project's researchers in the Ari Atoll Region. RI is calculated as the average of each individuals' residency score (=number of times sighted annually divided by the total number of surveys).

Intra Atoll Migrations

Reef manta rays in the Maldives migrate seasonally, moving between the eastern and western sides of the atolls with the changing South Asian Monsoon. As detailed in the previous AAR report, sightings in Ari Atoll have shown the same seasonal movement patterns as the country's other large atolls, with reef manta rays visiting the western aggregation sites during the Northeast Monsoon (December-March) before returning to the eastern aggregation sites during the Southwest Monsoon (May-November). Reef manta ray sightings in Rasdhu Atoll tend to peak during the Northeast Monsoon. However, the only manta aggregation sites (and channels) in the atoll are on the eastern and southern edges of the atoll. It is likely that, due to this small atoll's unique geography, with no channels on the western side of the atoll, the manta rays are utilizing cleaning stations in the channels nearest to their feeding areas, which are likely most productive during the Northeast Monsoon.

Manta ray sightings often show variance within each season, with manta sightings reported earlier in the season at some aggregation sites, and later in the season at others,

especially in those aggregation areas frequented by adult manta rays (Figs. 12 & 13). During the Northeast Monsoon, sightings typically occur on the western side of the atoll, with Gangehi Kandu, Moofushi Bojamhadi, Kalhahandhi Huraa, Rangali Madivaru, and Veligandu Kandu most active (Fig. 1). In 2018, sightings at Gangehi Kandu peaked earlier (January) in the Northeast Monsoon than those at Rangali Madivaru (March), with the peak at Moofushi Bojamhadi between the two (February), while Kalhahandhi Huraa showed consistent sightings between January and March (Fig. 12). As the seasons began to shift again at the end of the year, sightings were already recorded in December at Veligandu Kandu, Gangehi Kandu, and Moofushi Bojamhadi, with fewer sightings at Rangali Madivaru and no sightings recorded at Kalhahandhi Huraa (Fig. 12). When compared to previous years, this trend remains consistent at both Moofushi Bojamhadi and Rangali Madivaru (Figs. 14 & 15). However, due to a lack of consistent sightings data at Gangehi Kandu, Kalhahandhi Huraa, and Veligandu Kandu, it was not possible to compare 2018 data to previous years at these sites.

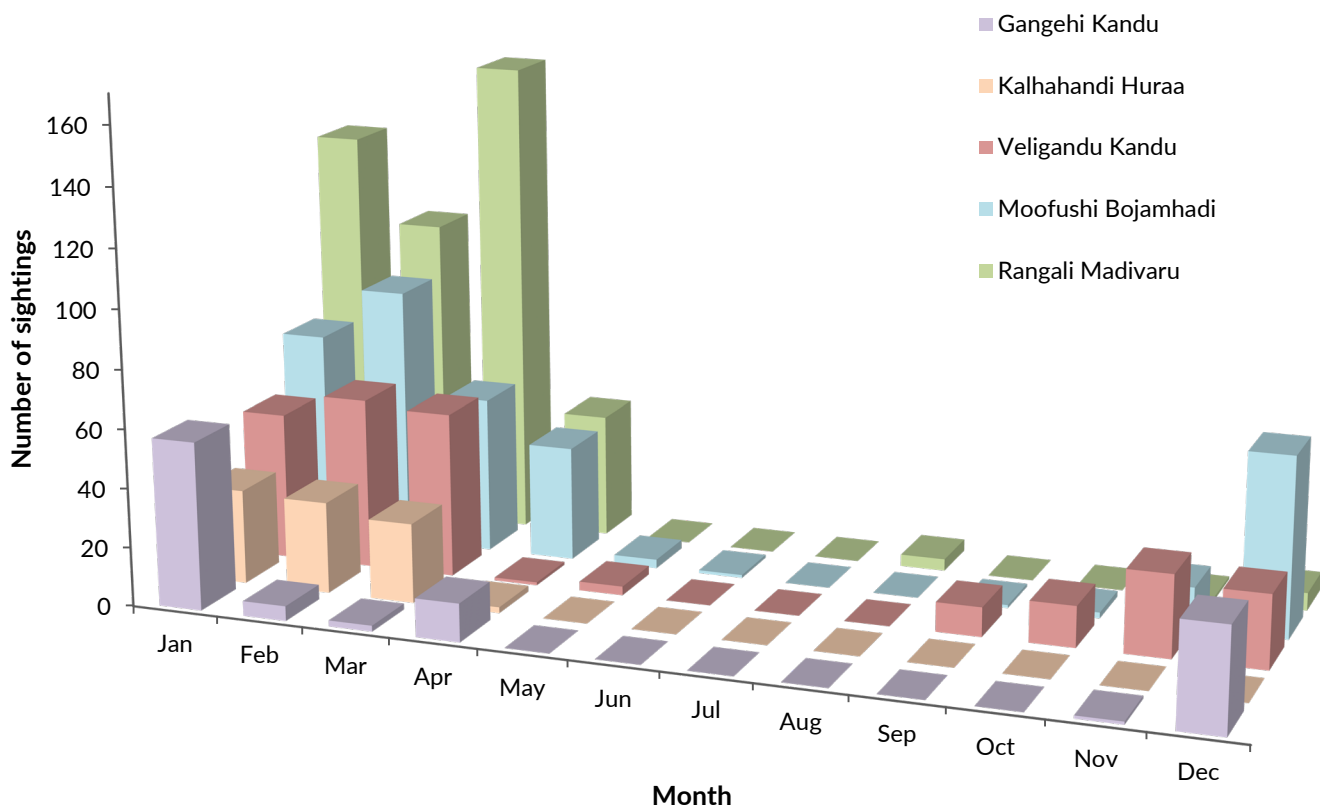


Figure 12: Intra-annual variations in sightings of reef manta rays (*Mobula alfredi*) during the Northeast Monsoon at five key adult aggregation sites in the Ari Atoll Region (2018).

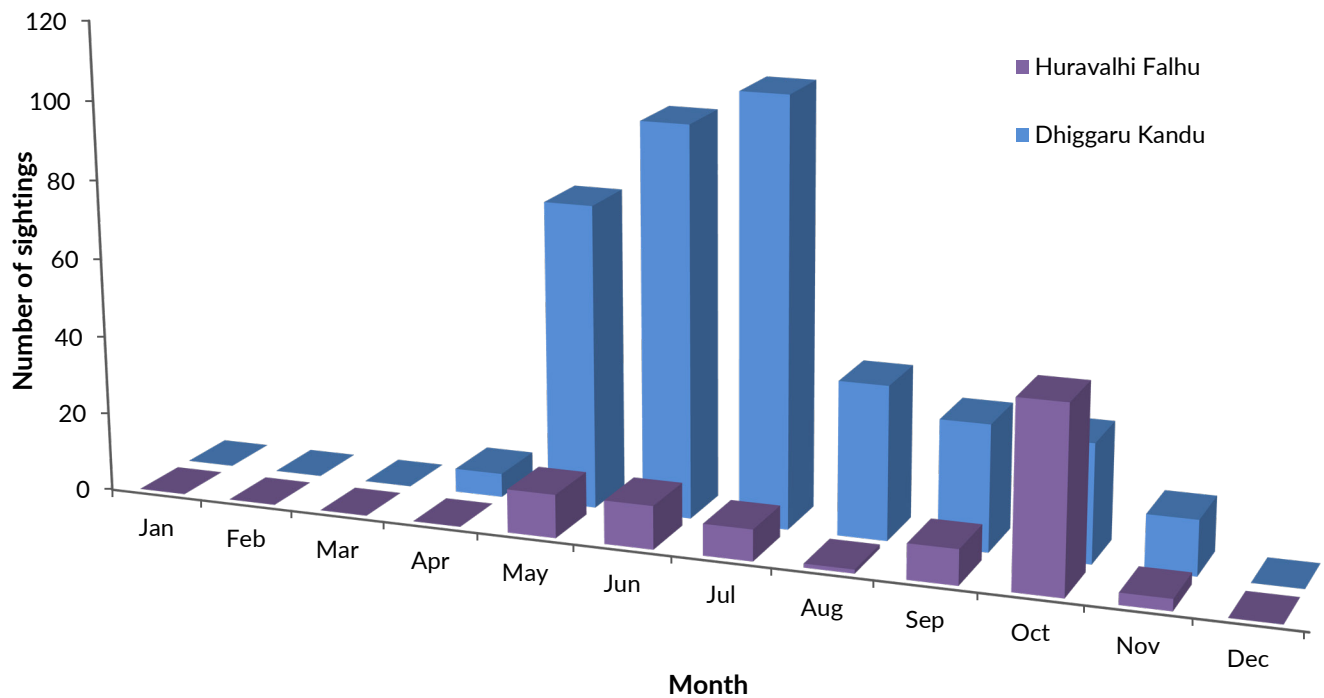


Figure 13: Intra-annual variations in sightings of reef manta rays (*Mobula alfredi*) during the Southwest Monsoon at two key adult aggregation sites in Ari Atoll (2018).

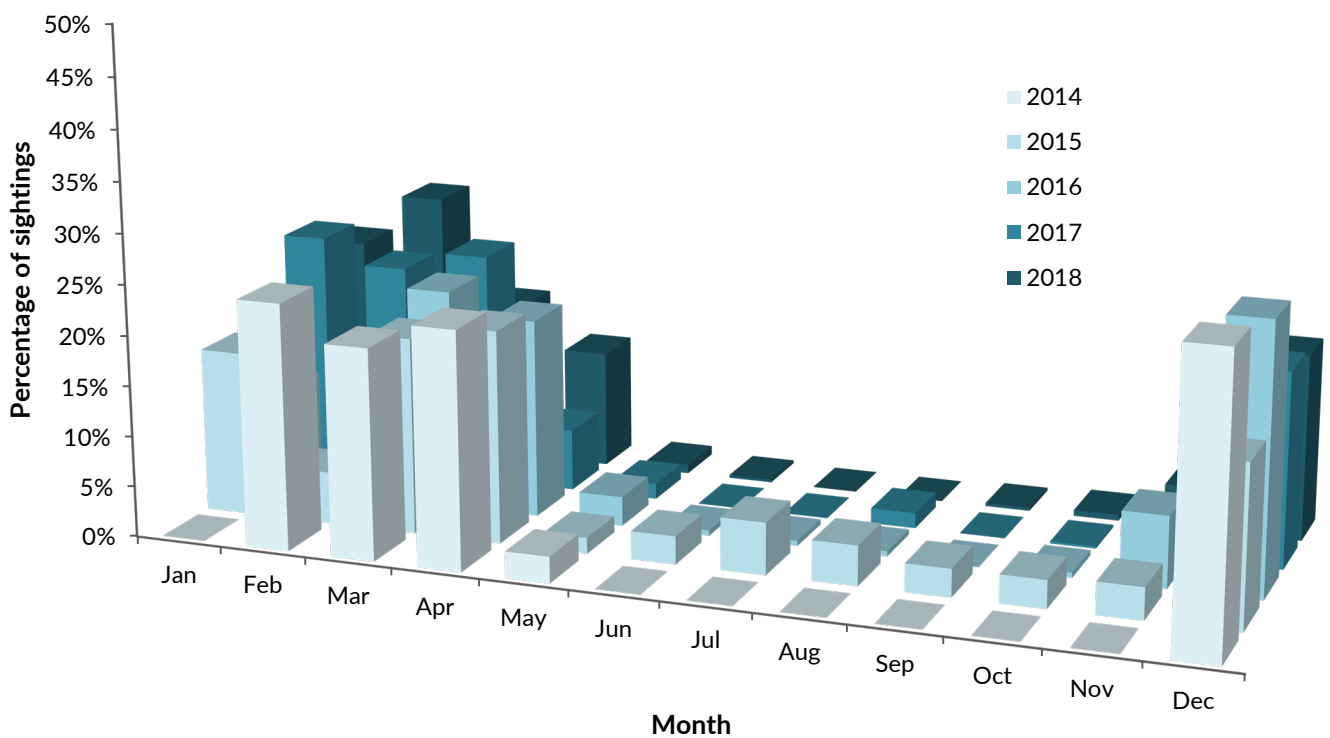


Figure 14: Intra-annual variations in sightings of reef manta rays (*Mobula alfredi*) at Moofushi Bojmhadi in Ari Atoll (2014-2018).

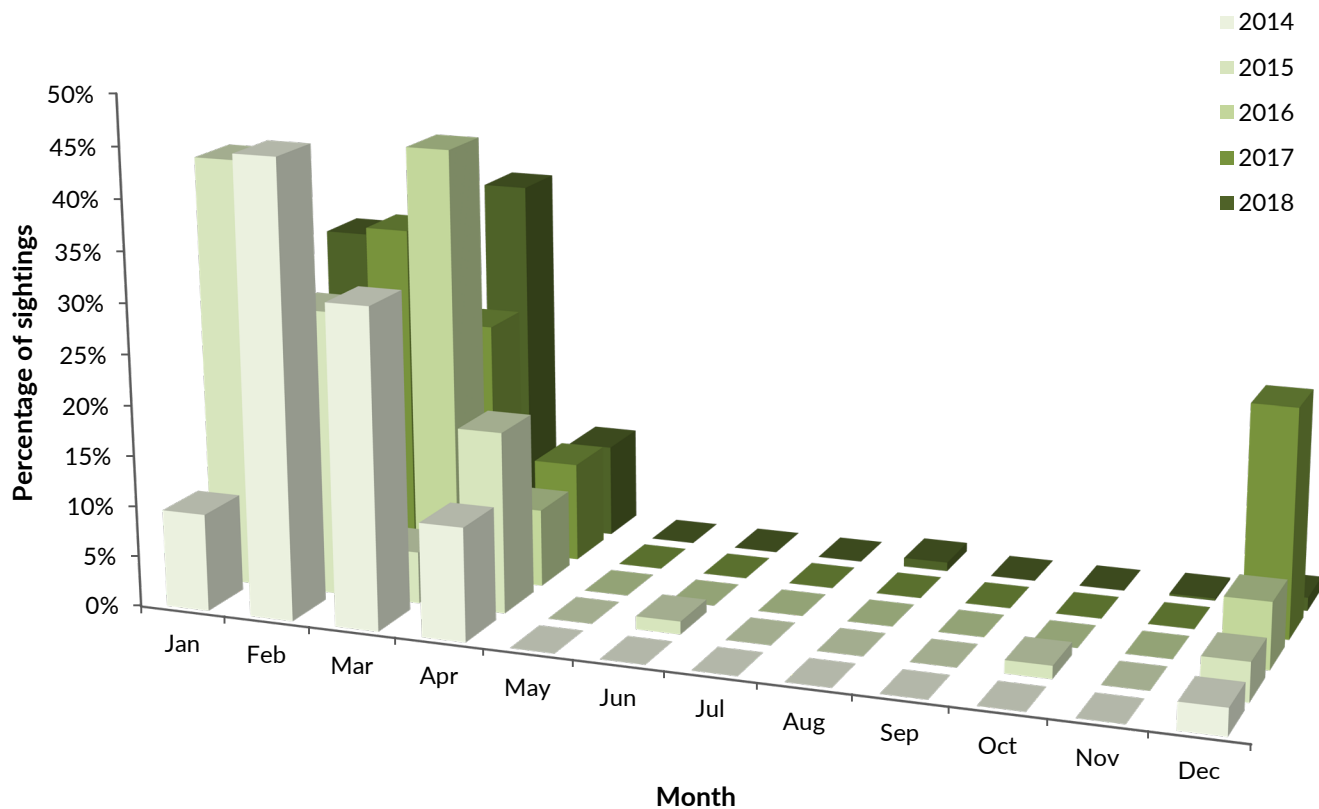


Figure 15: Intra-annual variation in sightings of reef manta rays (*Mobula alfredi*) at Rangali Madivaru in Ari Atoll (2014-2018).

During the Southwest Monsoon, the cleaning stations at Dhiggaru Kandu and Huravalhi Falhu, located on the eastern side of the atoll, are more active (Fig. 1). Manta sightings were recorded in much higher numbers at Dhiggaru Kandu early in the season (May-July) before slowly declining in number from August onwards (Fig. 13). On the other hand, sightings at Huravalhi Falhu peaked in October, with much lower sightings reported in the other months of the Southwest Monsoon (Fig. 13). The variance in site utilisation within seasons is most likely based on small-scale fluctuations in environmental conditions, especially changes in tidal current direction but may also be biased by survey effort. However, further annual analysis is required to determine the regularity of these movements and gain a better understanding of the driving factors behind this variation.

Both within and between seasons, less variation is seen at juvenile dominated aggregation sites (Fig. 16). In 2018, Dhigurah Falhu showed peaks in manta sightings between June and July, and again between October and December. However, manta rays in this region were sighted during

both the Northeast and Southwest Monsoons. No clear trends could be identified at Genburugau Falhu, likely due to the MMRP's reliance upon citizen scientist submission from this site, and the relative lack of sightings reported in 2018. Both of these sites are large, but sheltered lagoons, providing good habitat for juvenile manta rays. The more consistent year-round sightings noted here are likely due to the juvenile's habitat preference for these locations and this remains consistent with historical sightings data across the years. Manta sightings at Fesdu Falhu peaked during the Northeast Monsoon, while sightings at Maayafushi Falhu peaked during the Southwest Monsoon. These areas are unique as most sightings are artificially stimulated through the use of powerful floodlights situated on liveboards which attract large concentrations of zooplankton at night, which in turn attract the manta rays to feed. The MMRP is reliant upon citizen scientist submissions in these areas, so it is not possible to determine whether trends show true seasonal movements or a change in the frequency of visitors, and floodlight usage, in these areas.

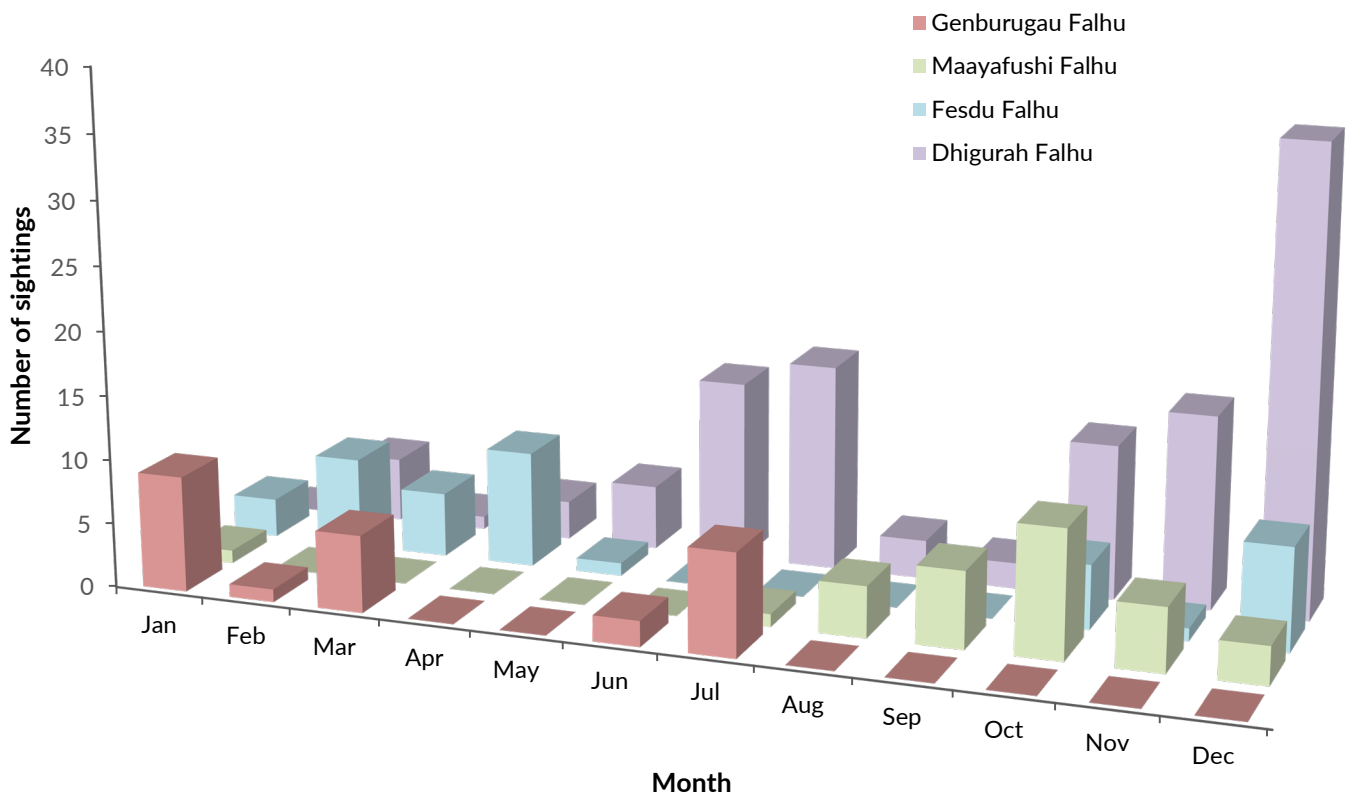


Figure 16: Intra-annual variations in sightings of reef manta rays (*Mobula alfredi*) at four key juvenile aggregation sites in Ari Atoll (2018).

Inter Atoll Migrations

Due to its central location and close proximity to other atolls, forty-four percent ($n=606$) of AAR reef manta ray population has been sighted outside of the region, compared to only 29% of the total recorded Maldives' reef manta ray population ($n=4662$). Manta rays from the AAR have been re-sighted in 16 different geographical atolls, with the highest number of re-sightings in Baa Atoll ($n=349$), followed by North Male Atoll ($n=139$) (Fig. 17). After these two atolls, the larger number of re-sightings were recorded in atolls in the central areas of the country, close to the AAR (Fig. 17). This is likely due to a combination of shorter distances and shallower water between atolls (~300m), providing fewer physical barriers for migration, and greater levels of MMRP survey effort in those areas. However, some longer migrations were also recorded from the individuals in the AAR. Research efforts in 2018 enabled the recording of the first manta sighted previously from Addu Atoll in the AAR; Errol (MV-MA-2609) was recorded twice in Ari Atoll during 2018, travelling a distance of about 500 km north from Addu Atoll.

During 2018, a total of 113 sightings of 78 individuals were recorded at Gangehi Kandu in north-western Ari Atoll. This population appears more transient than the AAR population as a whole, with 64% ($n=50$) of individuals

seen in more than one atoll. Interestingly, of those 50 individuals, 70% ($n=35$) were seen in Baa Atoll. The manta rays recorded in Baa Atoll by the MMRP take advantage of the high productivity in the east of this atoll during the Southwest Monsoon, but much less is known about the whereabouts of these individuals during the rest of the year. These recent sightings in the AAR, and the high overlap in number of individuals sighted in both Gangehi Kandu and Baa Atoll, suggest many of them migrate south to northern Ari Atoll. For example, Bryce (MV-MA-1128) and Juno (MV-MA-0623), are two manta rays which are regularly sighted in Baa Atoll during the Southwest Monsoon, particularly in Hanifaru Bay. In 2018, these two individuals were the most commonly seen manta rays recorded in Gangehi Kandu, with seasonal migratory trends beginning to become evident between North Ari Atoll and Eastern Baa Atoll (Fig. 18). Hanifaru Bay is situated within a marine protected area (MPA) of Baa Atoll's UNESCO Biosphere Reserve, where these rays are afforded greater protection. However, to ensure nationwide protection for these highly migratory and vulnerable species, much more key manta ray habitat must be protected and effectively managed throughout the archipelago.

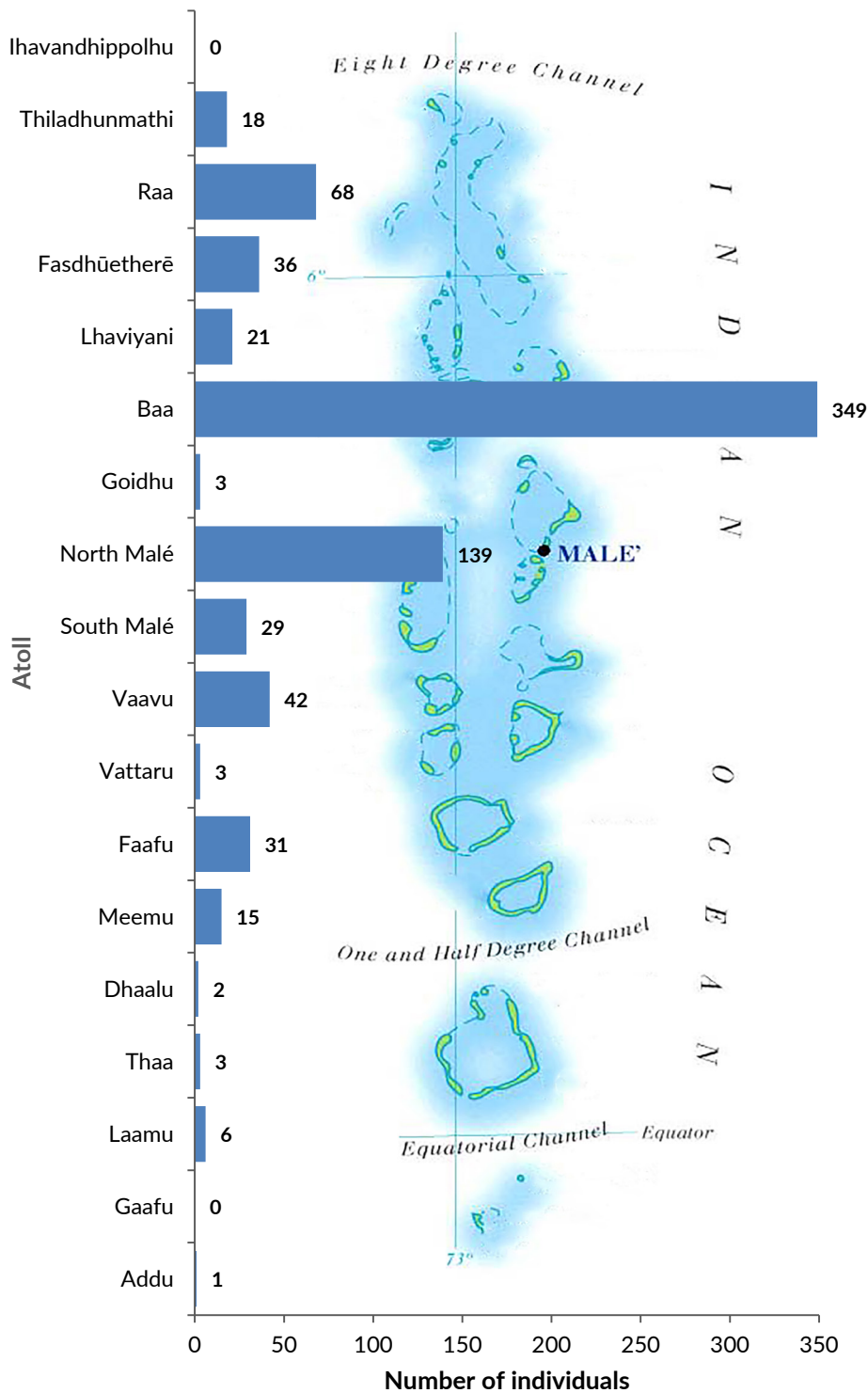


Figure 17: Number of reef manta rays (*Mobula alfredi*) ($n=606$) from within the Ari Atoll Region population ($n=1368$) which have been recorded in other atolls throughout the Maldives Archipelago. Note - some individuals have been sighted in more than one atoll throughout the Maldives Archipelago.

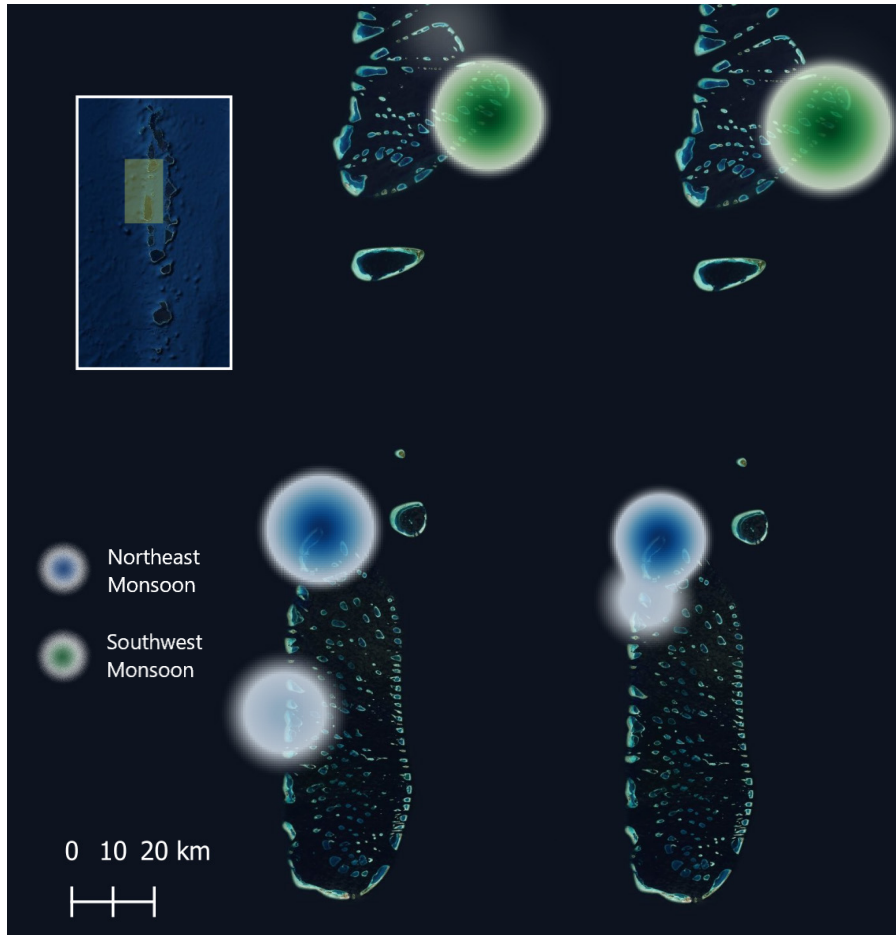


Figure 18: heatmap of the sightings of the reef manta rays (*Mobula alfredi*) MV-MA-1128 ($n=157$) (left) and MV-MA-0623 ($n=147$) (right) in Ari and Baa Atolls (2005-2018).

Sub-lethal Injuries

In 2018, a total of 34 new injuries were recorded on individual manta rays within the AAR. Of these injuries, 58% ($n=11$) were anthropogenic in origin. Most anthropogenic injuries were caused by fishing line ($n=8$), followed by boat strike ($n=2$), and net entanglement ($n=1$). This pattern remained consistent between both sexes and between juveniles and adults (Fig. 19). All newly recorded injuries from natural causes were predatory bites ($n=8$), and the cause of 44% ($n=15$) of new injuries could not be determined. Of the individuals sighted in the AAR in 2018, 55% were adults and 58% of new injuries were recorded on adult manta rays. The slightly higher number of new injuries recorded on adults may be partially due to the higher number of sightings of adult individuals, and partially related to the habitat usage of adult individuals. Adult reef manta rays tend to feed and clean in channels and along outer reefs, where they are more exposed to predators, and where more fishing activity takes place, leaving them more vulnerable to injuries.

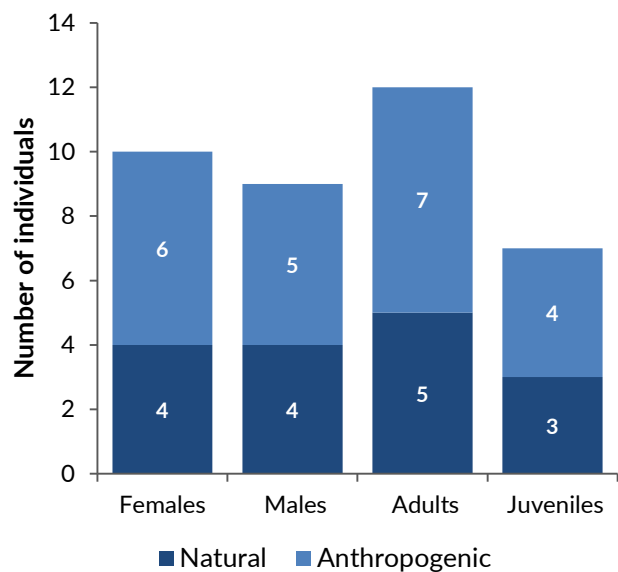


Figure 19: Demographic variations in the number of new sub-lethal injuries ($n=34$) recorded in 2018 on reef manta rays (*Mobula alfredi*) within the Ari Atoll Region population ($n=1368$), and likely injury origin (natural or anthropogenic).

Lethal Injuries

Sadly, the MMRP received a report on 17th March 2018 that a deceased manta had been discovered on the shallow, top reef of the manta aggregation area at Rangali Madivaru. The manta was identified as Aude (MV-MA-2830), a mature female who was first known to the MMRP in 2012, and had been sighted a total of 30 times, with several injuries sustained over her lifetime. It is highly unusual to find the body of a deceased manta. The initial reported sightings of the manta's body showed no clear signs of injury of either natural or anthropogenic origin, with predators having already fed on parts of the corpse by the time the image below was taken. Prior to this report, Aude had been sighted eight times during 2018 at Rangali Madivaru, including some involvement in courtship behaviour just a few weeks earlier. In addition, the citizen scientist report of the sighting of the deceased individual included photos

and video of one male manta circling the body of the deceased individual. This behaviour had not been recorded previously, but was speculated that, in combination with Aude's recent involvement in courtship behaviour and a recent scar typical of mating, it might indicate that she died during courtship or mating, or from the associated stress. However, the Rangali Madivaru area is a popular tourist destination with heavy boat traffic, including over the shallow top reef where the deceased manta was first observed, so boat strike cannot be ruled out as a possible cause of death. Although we cannot confirm the manta's cause of death, it is important to note that further management of manta aggregation areas, especially with regards to boat traffic, can help to eliminate the possibility of further lethal or sub-lethal injuries.



This manta, MV-MA-2830 (Aude), was found dead on the shallow reef crest at Rangali Madivaru in Ari Atoll at the start of the year. © Katie Burkart.

ENVIRONMENTAL VARIABLES

Environmental conditions, especially wind and current strength, have a strong influence on the seasonal abundance of zooplankton, which in turn influence manta abundance. On a smaller scale, lunar tidal current strength and direction strongly influence the manta's movements, behaviour, and habitat use.

Small Scale

Tidal currents have the largest influence on daily zooplankton abundance within the atoll channels and lagoons, moving plankton-rich water into and out of the atolls. Manta ray movement, behaviour, and habitat use are influenced by the current direction. Both current direction and predominant manta behaviour were recorded on 269 surveys by the MMRP in 2018 (Fig. 20). As expected, feeding manta rays were more often encountered during incoming current ($n=27$), as it is normally the incoming tidal currents that bring an abundance of zooplankton from the upwellings along the atoll's outer edges. Cleaning manta rays were more often encountered ($n=66$) during outgoing currents when zooplankton was less readily available. However, variations in site topography and location type (channel, outer reef, lagoon) meant that some areas showed much stronger relationships between current direction and manta activity. For example, Rangali Madivaru and Hukurudhoo Faru are situated in close proximity to one another and, at these two sites, manta rays typically aggregate where the narrow channel meets the long outer reef. Cleaning manta rays seemed to show a strong preference for outgoing currents, with feeding manta rays showing a weaker preference for incoming currents (Fig. 21). On the other hand, Dhiggaru

Kandu is situated in the middle of a wide channel, where manta rays are typically found inside the channel away from the atoll edge. At this site, feeding and cleaning manta rays were observed at nearly equal frequencies on incoming and outgoing currents (Fig. 22).

With current direction serving as a strong influence on manta behaviour in some locations, it may be a possible driver of intra-seasonal sightings variations. Many manta sightings in the AAR are recorded by MMRP researchers and citizen scientists on cleaning stations, where manta rays are typically encountered on SCUBA. All surveys in the AAR are reliant on guest excursions, which tend to follow schedules that do not account for current variations. Due to this bias, it is possible that sightings are only recorded in areas like Rangali Madivaru at times when divers are present and currents are favourable to cleaning manta rays, whilst sightings are recorded more consistently at Dhiggaru Kandu as manta rays seem to be less influenced by tidal current movement and, thus, are more likely to be seen by citizen scientists.

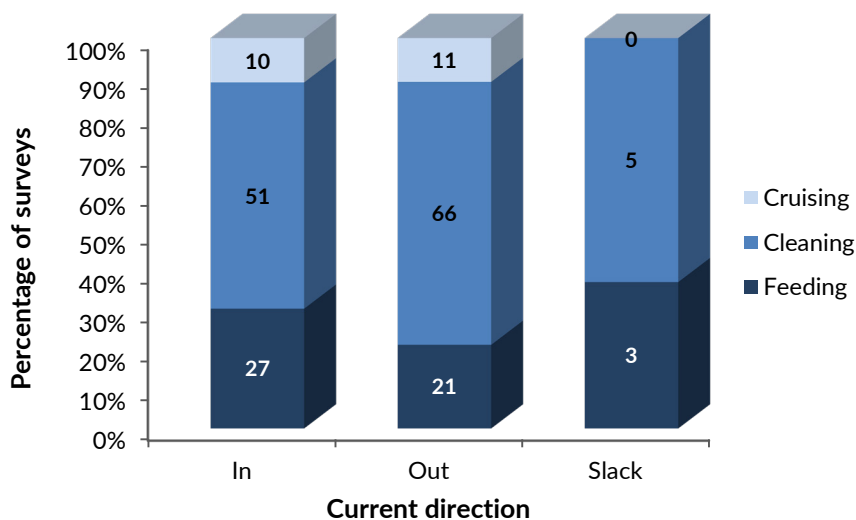


Figure 20: Changes in the behavioural activities of reef manta rays (*Mobula alfredi*) in relation to current direction (In, Out, Slack) through the channels in the Ari Atoll Region during surveys (2018) where manta rays were observed ($n=364$).

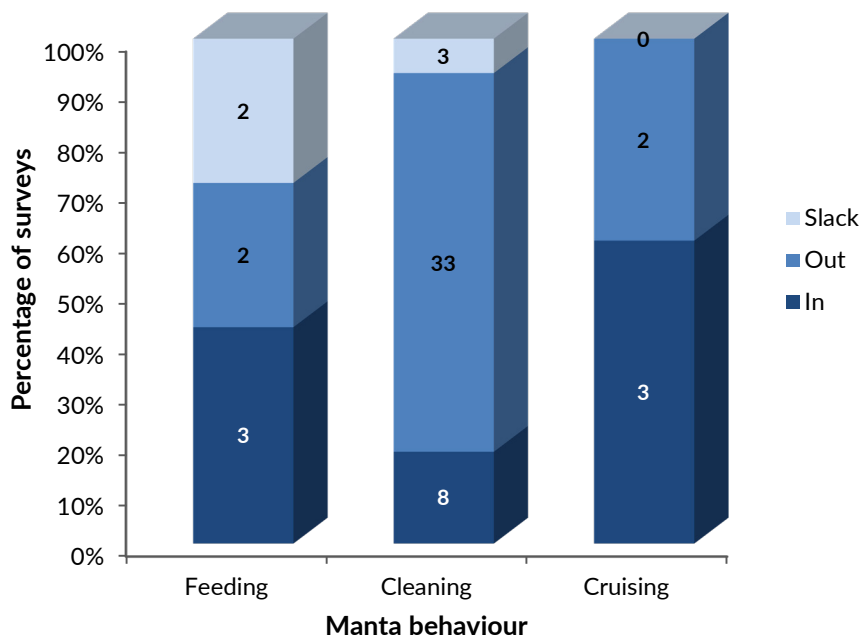


Figure 21: Changes in the behavioural activities of reef manta rays (*Mobula alfredi*) in relation to current direction (In, Out, Slack) through the channels at Rangali Madivaru and Hukurudhoo Faru during surveys in 2018 where manta rays were observed (n=71).

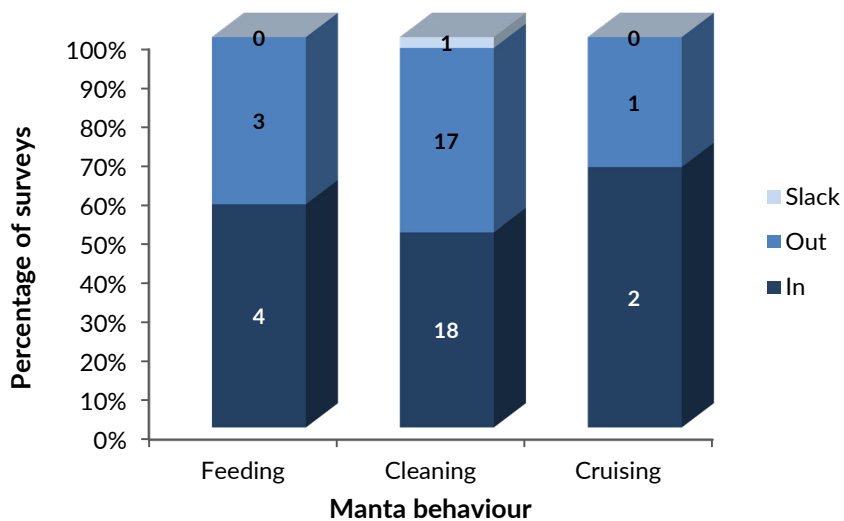


Figure 22: Changes in the behavioural activities of reef manta rays (*Mobula alfredi*) in relation to current direction (In, Out, Slack) through the channel at Dhiggaru Kandhu during surveys in 2018 where manta rays were observed (n=54).

Large Scale

Wind strength and direction strongly influences seasonal upwelling - playing an important role in determining zooplankton abundance over longer timescales, typically monthly to seasonally. Average overall wind speed in 2018 (16.0 km/h) was close to that of 2017 (16.3 km/h), but slightly weaker than 2016 (17.2 km/h). In order to look at the relationship between manta ray sightings and wind speed, data collected by MMRP researchers in 2016, 2017, and 2018 was used for analysis. Overall, a weak negative correlation ($R^2=0.03$) was found between average monthly wind speeds and daily manta sightings. However, data from 2018 showed a weak positive correlation ($R^2=0.05$) between these two variables (Figs. 23 & 24). When manta ray sightings and average wind speeds were compared on a monthly basis, manta sightings tend to increase one or two months after wind speeds increase, likely due to the time taken between increased primary productivity and the blooms of zooplankton to occur. Wind speeds in 2018

peaked in January and February, and again in May and June. Wind speeds were at their lowest in March and April, and again in November and December. In response to the peaks in wind speed, manta ray sightings were higher in February and March, and again in June and July (Fig. 25). This slight delay may also explain the lack of significant correlation when analysing monthly wind speeds and monthly manta sightings between 2016 and 2018.

Additional research effort at both the eastern and western manta aggregation sites over the next several years should help to further elucidate the relationship between food availability, the strength of monsoonal winds, and manta ray sightings. It is possible that these variables all fluctuate with long-term, natural weather cycles within the Maldives but, more concerning, these changes may also be linked to the global climate crisis.

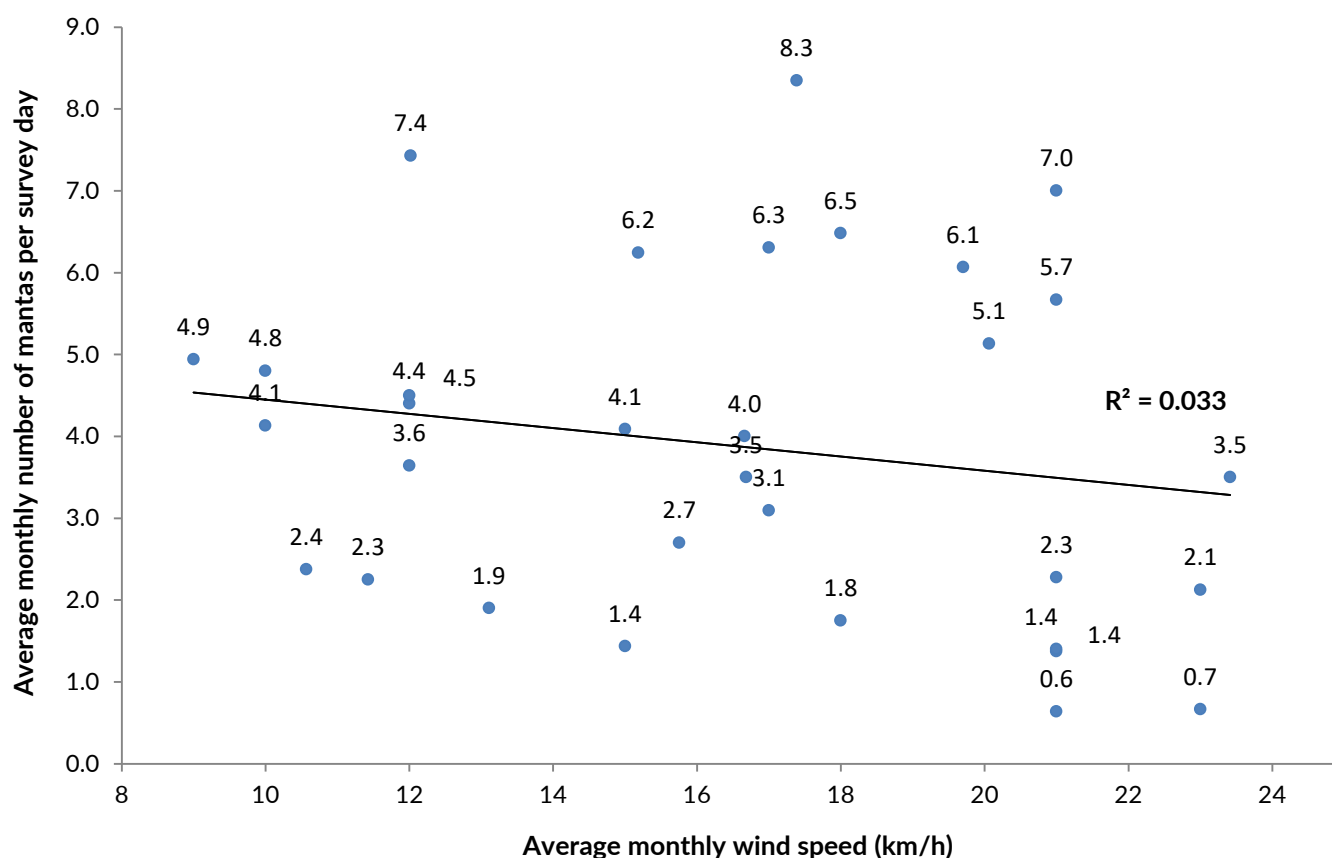


Figure 23: Mean monthly wind speed (km/h) and the mean monthly number of reef manta ray (*Mobula alfredi*) sightings recorded per survey day by the Maldivian Manta Ray Project researchers in the Ari Atoll Region (2016-2018).

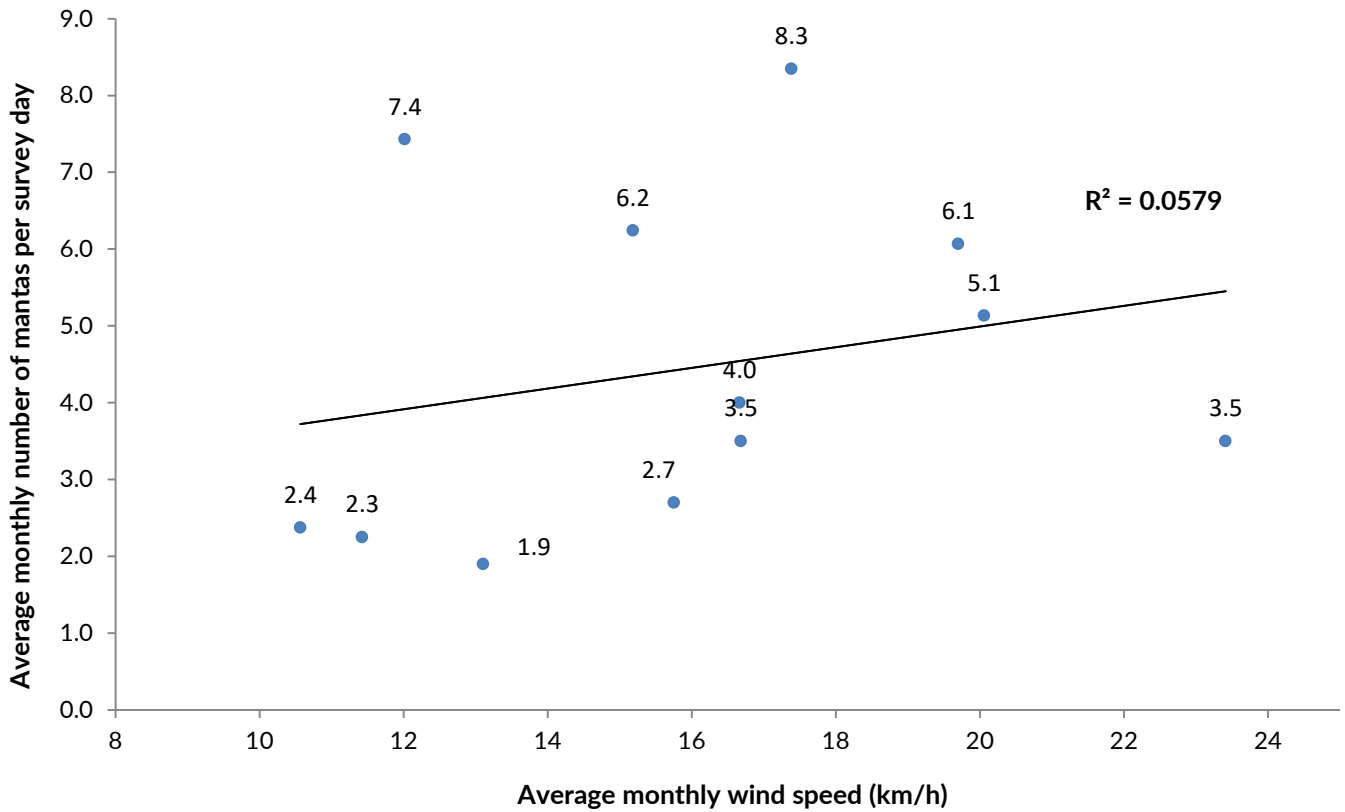


Figure 24: Mean monthly wind speed (km/h) and the mean monthly number of reef manta ray (*Mobula alfredi*) sightings per survey day by the Maldivian Manta Ray Project researchers in the Ari Atoll Region (2018).

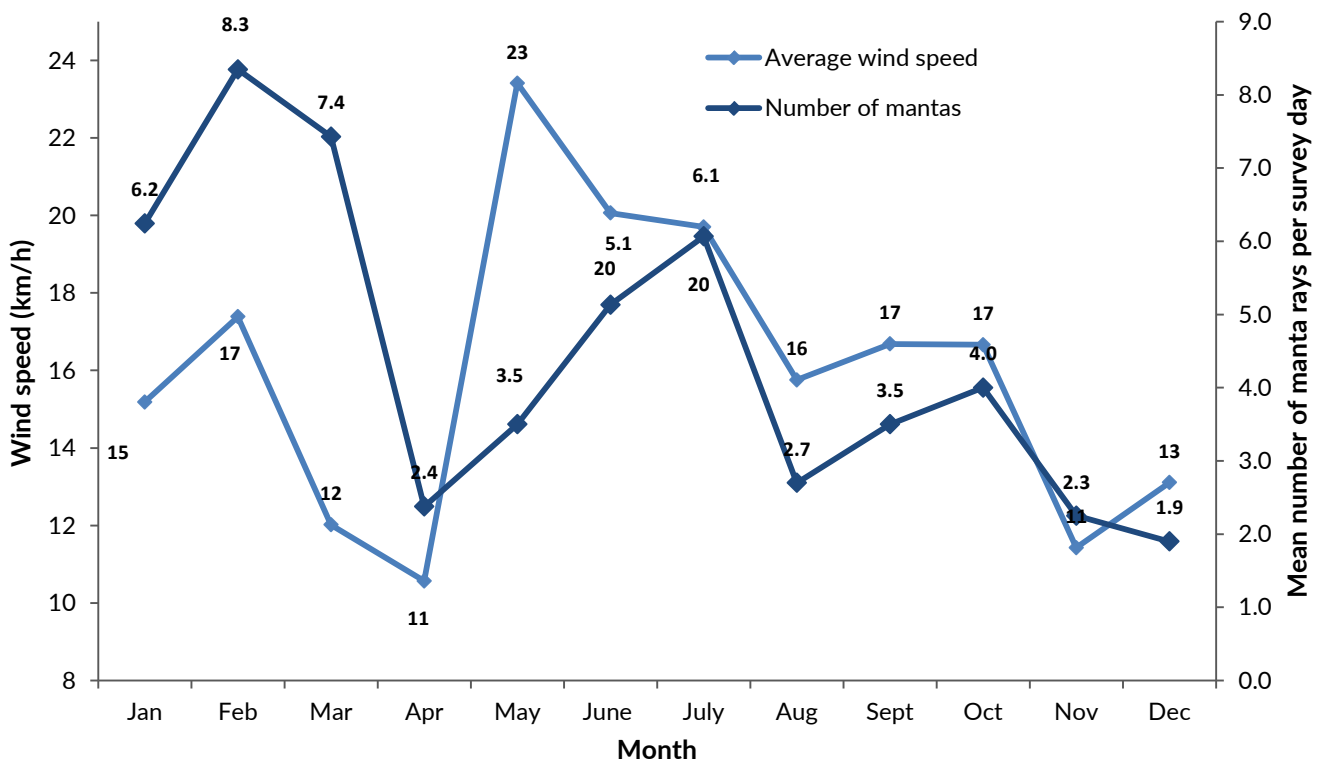


Figure 25: Mean monthly wind speed (km/h) and mean number of reef manta ray (*Mobula alfredi*) sightings per survey day by the Maldivian Manta Ray Project researchers in the Ari Atoll Region (2018).

WHALE SHARK AND OCEANIC MANTA RAY SIGHTINGS

The reef manta rays' close relative, the oceanic manta ray (*Mobula birostris*), can grow to over six metres in disc width and tend to spend much more time away from reefs in the open ocean. The vast majority of manta sightings in the AAR are of reef manta rays, with only eight oceanic manta ray sightings recorded in the region. There were no recorded sightings of oceanic manta rays in the AAR in 2018.

Whale sharks (*Rhincodon typus*) are another species of large, filter-feeding elasmobranchs, with similar life history characteristics and habitat use to manta rays. The AAR region, specifically South Ari Atoll, is host to

a semi-resident whale shark population. This region is believed to be a nursery ground for the sub-adult whale sharks which aggregate there. The Maldives Whale Shark Research Programme (MWSRP) monitor this population of whale sharks, along with the wider Maldives whale shark population. Much like manta rays, each whale shark can be identified by photo ID of its unique spot pattern. In 2018, the MMRP researchers, along with guests who accompanied them on excursions from Vilamendhoo Island, were able to contribute a total of 56 whale shark sightings to the MWSRP to support their research efforts.



MANTA RAY TOURISM

The Ari Atoll Region is one of the nation's most popular tourist destinations with numerous visitors snorkelling and diving during their stay, and many choosing this area due to their desire to encounter marine megafauna. During surveys, the MMRP collected data on anthropogenic pressure. Since 2016, the average number of boats recorded per survey has steadily increased from 1.6 in 2016, to 1.9 in 2017, to a high of 2.2 in 2018. Similarly, the average number of snorkellers and/or divers per survey has increased since data collection began, with a big jump in numbers recorded between 2017 and 2018. Nine-point seven people were recorded per survey in 2016, increasing to 12.6 in 2017, then increasing to 18.1 in 2018. There was also a steady increase in the number of guests per boat, with 4.9 in 2016, 5.8 in 2017, and 6.7 in 2018. Interestingly, the ratio of guests to manta rays during in-water surveys decreased slightly between 2017 and 2018, which is likely due to a larger number of manta rays seen per survey in 2018 than seen in 2017, rather than a decrease in tourist numbers.

The increasing tourist pressure on these important manta aggregation sites shows the importance of these areas to the Maldivian economy, and emphasizes the need for proper protection and tourism management. Manta tourism from guests based in local guesthouses, resorts, and on dive liveaboard boats generates an estimated \$15 million USD annually. However, if tourism pressure continues to increase, manta rays will be more heavily subjected to anthropogenic related injuries, such as boat strikes, and it is possible that they will be forced to abandon these disturbed aggregation areas. The Manta Trust released updates to its Best Practice Code of Conduct (CoC) in 2017, and throughout 2018 continued to distribute the CoC tools to any tourism operators, both in the AAR and throughout the Maldives, who were not previously aware of the guidelines and tools available to them. We hope to further disseminate the CoC to get all tourism operators nationwide, ideally with the support of the Maldives government.



Divers position themselves under a cleaning manta ray at Rangali Madivaru in Ari Atoll. Unfortunately, with tens of thousands of divers visiting this site annually, the impacts of these divers kicking, touching and resting on the coral degrades the reef. Some of these divers also attempt to touch or grab hold of the rays. Without stricter regulations on tourism activities, the negative impacts on these sites, and the manta rays, will continue to increase.

MANAGEMENT CHANGES & INITIATIVES

On the 8th October 2018, the Maldives government created an MPA at Rasdhoo Madivaru in the southeast of Rasdhu Atoll. The designation of this MPA is in addition to two other known manta ray aggregation sites in the AAR which are currently within MPAs: one at Rangali Madivaru and the other covering the whale shark aggregation area along the southern edge of Ari Atoll (South Ari Marine Protected Ari, or SAMPAs). Although the MPA at Rasdhoo Atoll was designated due to the presence of hammerhead sharks, the protected status of this area will also afford protection to the visiting manta rays. Rasdhoo Madivaru is a feeding area for reef manta rays, and is also the location of the only two oceanic manta sightings from Rasdhu Atoll.

Although the designation of Rasdhoo Madivaru, along with Rangali Madivaru and SAMPAs, as protected areas is an important step, they are currently only protected on paper. Without the implementation of effective management plans and on-site enforcement, these biologically and economically important areas will remain highly susceptible to the threats inherent to unsustainable tourism and fishing pressure. As tourist numbers continue to grow in the AAR, the implementation of effective MPA management along with the expansion of protected areas to other key manta aggregation sites becomes increasingly important.

ARI ATOLL MARINE EDUCATION PROGRAMME

The first Manta Trust marine education programme was conducted in the AAR in 2018. The MMRP team based on Vilamendhoo Island was able to conduct an after-school enrichment programme with students at Dhangethi School, as a part of the school's Faru Koe programme. Ten sessions were run involving students in grades six, seven, eight, and nine, and included a combination of classroom-based theory sessions and practical training through interactive games activities and field trips. The programme was run with the aim of increasing students' understanding of, and engagement with, their local marine environment, and inspiring them to work to conserve their island and local reefs. Students at Dhangethi School do not have the option in secondary school to complete courses in fisheries or marine science, making the programme the only exposure some students will have to marine conservation. Programme topics included the basic biology and ecology of Maldives marine ecosystems and locally prevalent marine megafauna,

the climate crisis understanding and awareness, waste and pollution, and conservation actions that students can implement to take care of their island environment. In addition, field trip activities (a snorkelling session and a beach clean-up) served to increase student engagement and give students a chance to see the ecosystems and issues discussed during the classroom sessions. The Manta Trust was also pleased to join the MWSRP to deliver their Moodhu Kudhin, or "Children of the Sea", environmental education programme at Dhangethi School. This programme served as a perfect addition to the ten-session programme and gave students additional in-water opportunities and the chance to learn about the MWSRP's research methods aboard their research dhoni. The MMRP is extremely grateful to the MWSRP, Vilamendhoo Island Resort & Spa, EuroDivers Maldives, and the Dhangethi School teachers, administration, students, and parents, without whom the programme would not have been possible.



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, liveaboards, 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.



This report was compiled on behalf of the MMRP and the Manta Trust by:

Emma Hedley - BSc (Hons)
Project Manager - Ari Atoll

Tam Sawers - MSc (Hons)
MMRP Project Leader

Dr. Guy Stevens
Chief Executive & Co-Founder

This document was created by:

Simon Hilbourne - MSc (Hons)
Digital Media & Communications Manager

For further information, please email:

ari@mantatrust.org

info@mantatrust.org

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