



Maldivian
Manta Ray Project

BAA 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 a globally healthy marine ecosystem.

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

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



MALDIVIAN MANTA RAY PROJECT

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

The MMRP collects data around the country's manta population, its movements, and how the environment and tourism / human interactions affect them. Since its inception, the MMRP has identified over 4,650 different individual reef manta rays, from more than 60,000 photo-ID sightings. This makes the Maldives manta population the largest, and one of the most intensively studied populations in the world. The MMRP has also identified nearly 700 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

The MMRP has been continuously studying the Maldives reef manta ray (*Mobula alfredi*) population in Baa Atoll since 2006. Baa Atoll is frequented by reef manta rays and whale sharks (*Rhincodon typus*) each year to feed on the abundant zooplankton prey that results from the productive Southwest Monsoon conditions. Consequently, Baa Atoll has gained worldwide recognition for being one of the most reliable places to see, and swim with, these planktivorous megafauna.

This report provides details on the population dynamics, ecology and movements of Baa Atoll's reef manta rays throughout 2018. However, the majority of the presented results focus on data collected during the intensive survey period, which took place during the months of May through November. Furthermore, this report discusses various tourism and education activities conducted by the MMRP within Baa Atoll during 2018.

The MMRP conducted reef manta ray surveys on 158 days between 15th May and the 26th November 2018. Key findings of the MMRP in Baa Atoll during 2018 include a total of 4,816 sightings of 679 individual manta rays. Of these individuals, each manta ray was observed on average 7.1 times. The mean number of reef manta rays sighted per day during the main survey period was 26, with a peak in daily manta ray sightings seen during the month of September. A Residency Index (RI) was calculated to gauge the extent of movement amongst those frequenting the region. The RI for 2018 (4.2%) was higher than 2017 (3.2%), and is the highest RI recorded since the MMRP's inception.

The total number of sightings ($n=3,838$) and number of individual manta rays ($n=606$) recorded in Hanifaru Bay MPA in 2018 were much higher than in 2017.

As of 2018, the population demographics of Baa Atoll constitutes 54% females ($n=1,092$), 46% males ($n=941$), and <0.5% ($n=10$) of individuals for which the sex could not be determined. Of these Baa Atoll mantas ($n=2,043$), 46% ($n=938$) have also been seen in at least one other atoll in the Maldives.

Of the 226 new reef manta rays added to the MMRP database from across the Maldives in 2018, 24% ($n=52$) were documented in Baa Atoll during the Southwest Monsoon, this is a large increase from the previous year ($n=16$, in 2017).

The number of pregnancies recorded in Baa Atoll during 2018 was the highest number ever recorded in a single season, with a total of 59 pregnancies and a further 25 females recorded with fresh reproductive wounds. Of the 59 pregnant females observed, 64% ($n=38$) were recorded in the later stages of gestation (3rd- 4th trimester).

In 2018, the Baa Atoll Marine Education Programme continued to raise awareness about manta and devil rays and the importance of the marine environment, culminating in the first ever Manta Festival – a very successful jubilee, aimed to inspire the youth and engage the local community in marine environmental conservation.

UNDERSTANDING THE MONSOONS

Understanding the effects of the Maldives Southwest Monsoon is inherently vital to understanding why Baa Atoll has such an abundance of marine megafauna, such as manta rays and whale sharks.

The Maldives weather is dictated largely by the South Asian Monsoon. This monsoon has two seasons, which are characterised by their winds, which blow consistently and reverse their direction seasonally. The two seasons in the Maldives run from May-October, the *Hulhangu*, and from December-March, the *Iruvai*. The *Hulhangu* is also referred to as the Southwest Monsoon, while the *Iruvai* is the Northeast Monsoon. The months of November and April are transitional periods of change between the two. An increase in rain and cloud cover, along with reduced visibility and rough seas, is typical of the Southwest Monsoon.

The strong winds created during the Southwest Monsoon generate oceanic currents which flow from the southwest

towards the northeast. The Maldives' 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, kick-starting the food-chain and providing plentiful zooplankton prey for the manta rays and whale sharks. During the Southwest Monsoon, high wind speeds generate strong currents, which in turn create more upwelling. The movement of water through channels into the atolls is driven by these strong currents and the lunar tides. The atolls, as well as the reef systems within them, act as plankton funnels and traps that accumulate high densities of planktonic life. Baa Atoll, and specifically Hanifaru Bay, amass vast amounts of zooplankton during the Southwest Monsoon, and therefore attracts large aggregations of zooplanktivorous megafauna.



STUDY PERIOD & SAMPLING METHODOLOGY

The MMRP conducted surveys to locate manta rays in Eastern Baa Atoll between the 15th May and the 26th November 2018 on as many days as possible, where the weather conditions allowed. Full day survey trips were conducted on 158 days within a 214-day time-frame (May–November), or 74% of the possible monitoring period. Surveys were conducted at Hanifaru Bay, one of four key

manta aggregation sites, and a dozen other sites around the eastern border of Baa Atoll (Fig. 1). In comparison to previous years, existing management measures (see section below) meant that accessibility to the main study site, Hanifaru Bay Marine Protected Area (MPA), was more limited than in years prior to 2011.

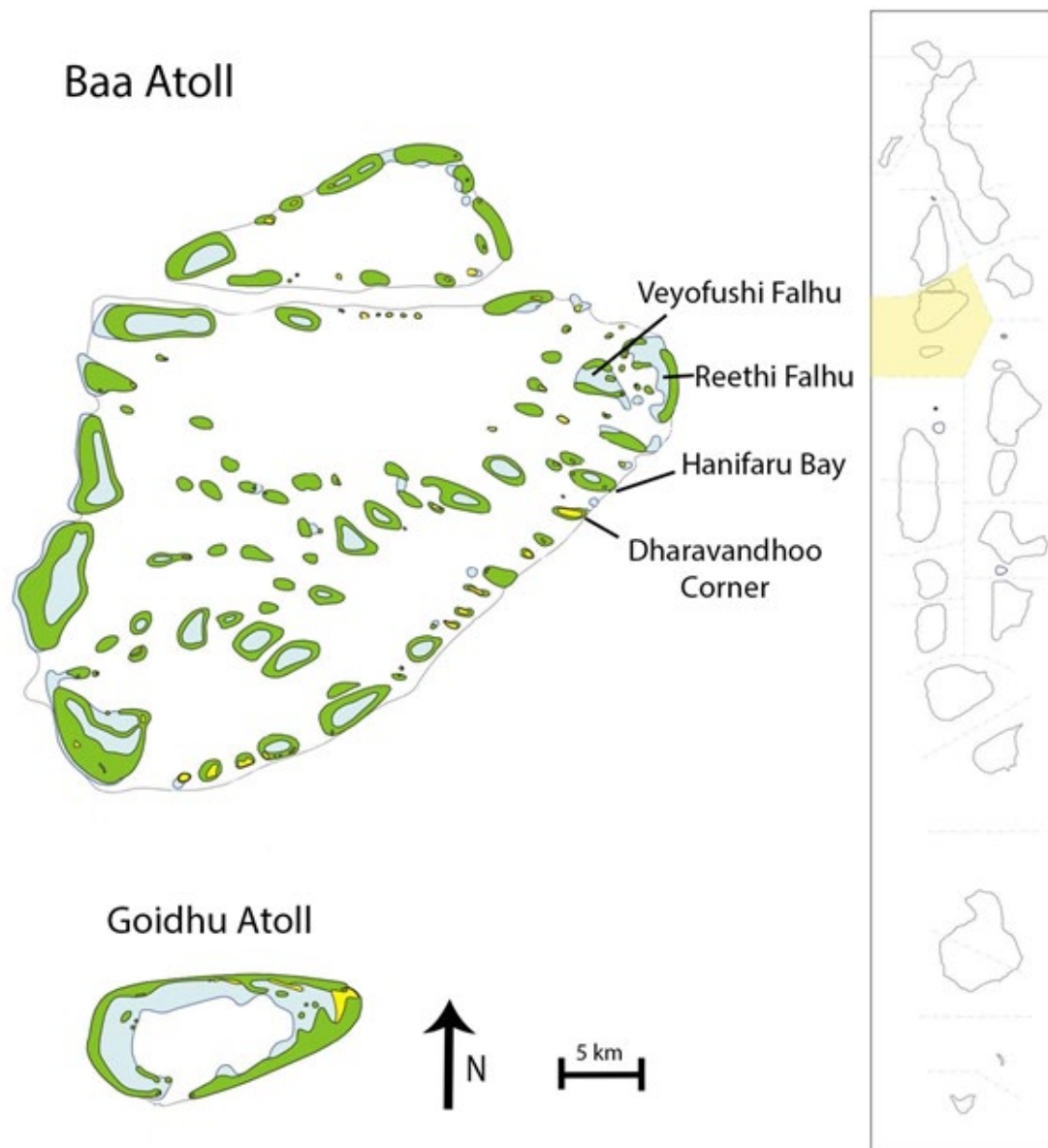


Figure 1: Map of the Baa Atoll Region, showing four of the key manta aggregation sites within eastern Baa Atoll, and the region in relation to the rest of the Maldives Archipelago (shaded yellow).

In addition to the data collected by the MMRP, surveys (n=12) were also conducted by external parties. The photographs submitted by outside contributors accounted for all sightings data outside of May through November. In addition to the 158 survey days carried out by the MMRP, external parties conducted surveys which resulted in reef manta ray sightings on a further 12 days.

To ensure comparable results, data was standardised where possible to account for changes in sampling effort spatially and temporally. All surveys undertaken by the MMRP team were recorded, whether manta rays were sighted or not. However, unlike the MMRP, complete survey records were not available for external sighting submissions, therefore

only positive manta ray sighting surveys could be accounted for when standardising for survey effort for external party sightings data.

During each survey conducted by the MMRP; location, wind speed, wind direction, and multiple other environmental variables were collected, along with manta ray abundance and behaviours (feeding, cruising, cleaning, etc.). Individual manta rays were documented in-water by photographing the unique spot pattern on their ventral surface. For the purpose of this report, a sighting is defined as a confirmed photo-ID of an individual manta ray on any given day.

MANAGEMENT CHANGES & INITIATIVES

Following the groundwork set in 2012 by the Maldives government's management plan, sustainable tourism practices and strict regulations are continuously being enforced within Hanifaru Bay MPA. These include, but are not limited to; tourist and boat limits, SCUBA diving and fishing bans, scheduled alternation of entrance days between liveaboards and resort boats, speed limits, and specified use of entrance and exit routes. To be qualified as a Hanifaru Bay guide, and therefore escort guest tours inside the MPA, the guide must first pass an exam. Furthermore, all guides are required to hold first aid and divemaster qualifications, at a minimum, before qualifying as a Hanifaru Bay guide.

In 2018, Environmental Protection Agency (EPA) rangers were again on site to maintain the rules and regulations of Hanifaru Bay MPA. This act has resulted in a decrease of infractions and a well-maintained schedule of alternating tourism days. The regular collection of tourism entry fees for entrance into the bay resulted in estimated revenues of at least \$30,000 USD for the Biosphere Reserve's Baa Atoll Conservation Fund in 2018. Such regulations and management initiatives are vital to ensure the efficacy of Hanifaru Bay MPA in conserving the Maldives manta ray population, by minimizing the harmful ramifications arising from human-manta ray interactions.



REEF MANTA RAY SIGHTING TRENDS

Baa Atoll Region

In 2018, a total of 4,816 reef manta ray sightings were recorded in the Baa Atoll Region (the geographical atolls of Maalhosmadulu Dhekunuburi and Fasdhuetherē; hereafter referred to as Baa Atoll). The data shows a substantial increase (43%) in reef manta ray sightings in comparison to the previous year ($n=2,723$ in 2017). Furthermore, the number of sightings documented in Baa Atoll during 2018 is one of the highest on record, second only to data collected

in 2015 ($n=4,852$) (Fig. 2). Monthly breakdowns of these sightings in 2018, standardised for survey effort, show an increase in sightings from May to September, the largest of which occurred between May and June (Fig. 3). Manta ray sightings peaked in September ($n=49$, average number of sightings per survey day), with subsequent months showing a marked decrease in manta ray sightings (Fig. 3).

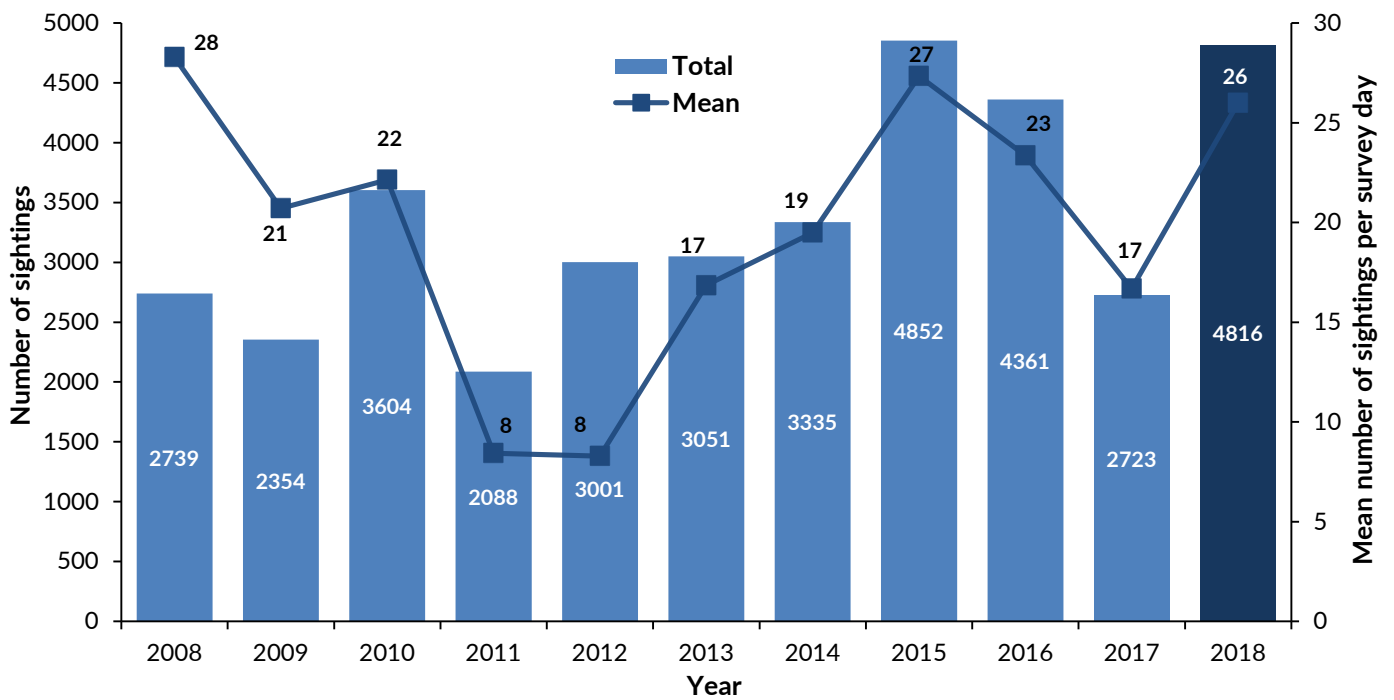


Figure 2: Total annual sightings of reef manta rays (*Mobula alfredi*) in Baa Atoll, and the mean number of sightings per survey day.

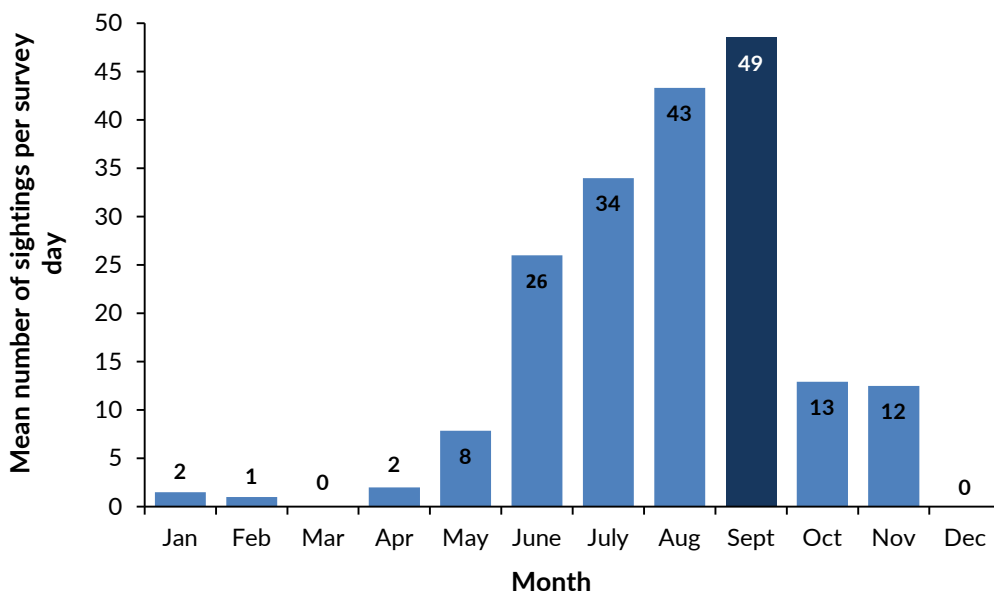


Figure 3: Mean number of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll during 2018.

During 2018, a total of 679 different individual reef manta rays were recorded in Baa Atoll. This accounts for 15% of the total recorded Maldives population ($n=4,671$); an increase from 2017 ($n=553$) (Fig. 4). Throughout 2018, each manta ray was observed on average 7.1 times; the highest since this research programme began in 2008 (Fig. 4). Similarly, during the intensive survey period in 2018 (May-November), where 4,808 sightings of 676 individuals were recorded, each individual manta ray was also sighted

on average 7.1 times. Monthly, the average number of sightings per manta ray increased from May to September, followed by a sharp decrease thereafter (Fig. 5). In 2018, the mean daily number of reef manta ray sightings during May to November ($n=26$) was significantly higher than in 2017 ($n=17$).

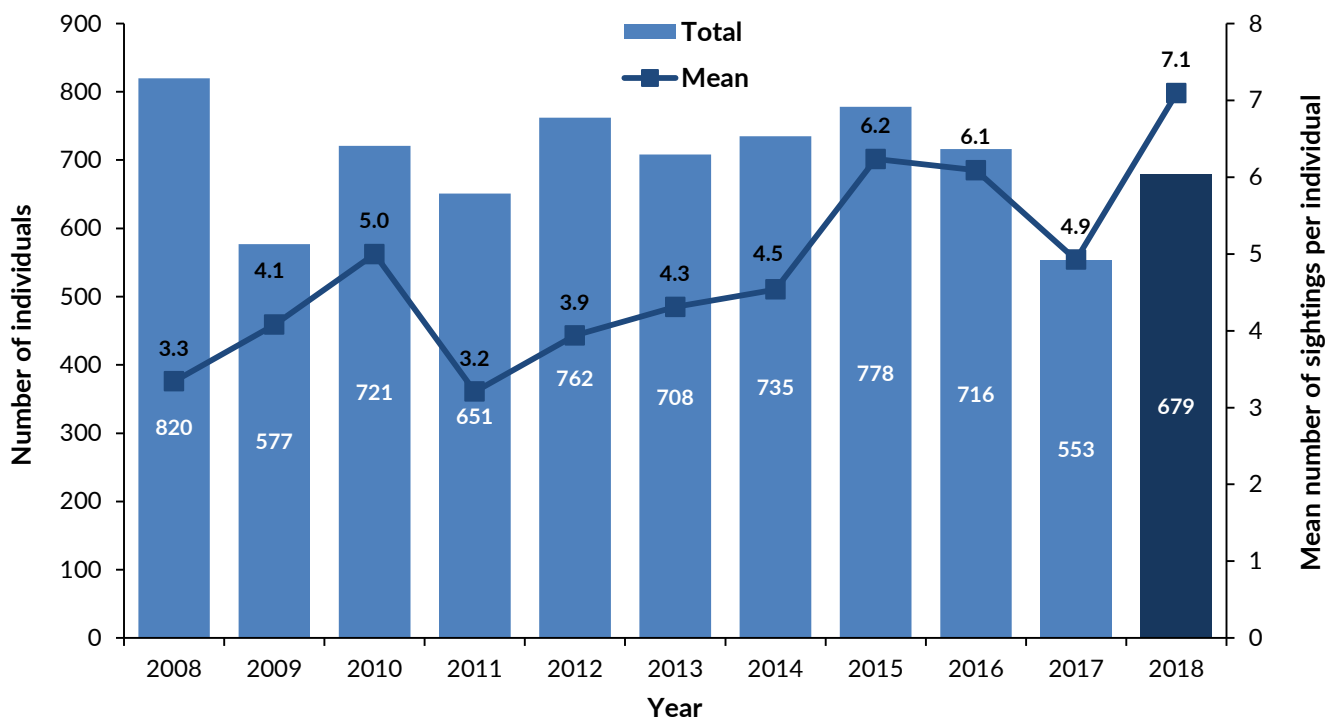


Figure 4: Total annual number of individual reef manta rays (*Mobula alfredi*) sighted in Baa Atoll, and the mean number of sightings per individual.

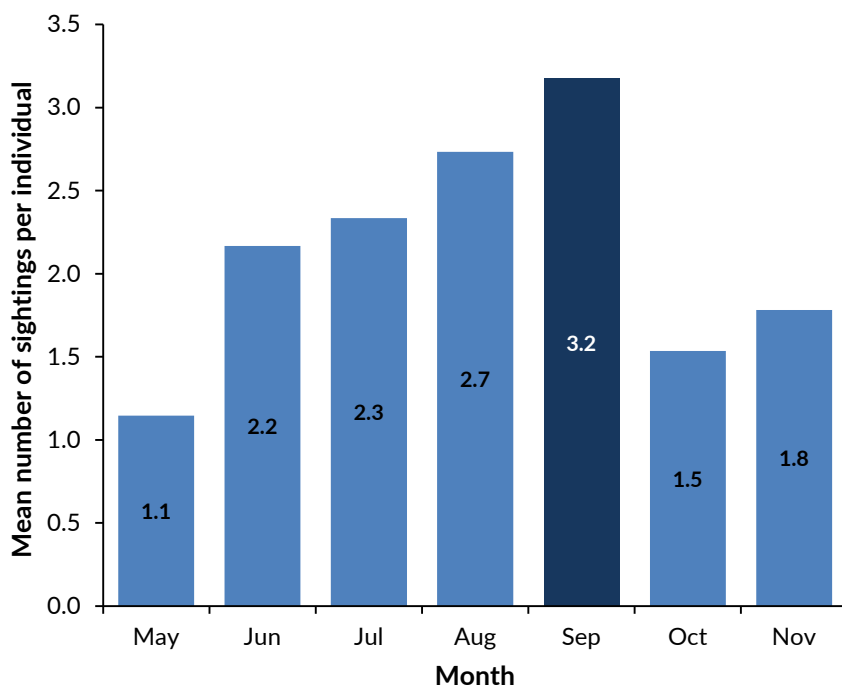


Figure 5: Mean number of sightings per reef manta ray (*Mobula alfredi*) during each month of intensive surveying in 2018.

To account for survey effort, a Residency Index (RI) was calculated for each month based on the ratio between the number of days each individual was sighted and the total number of surveyed days (e.g. a RI of 5% means that, on average, each individual was sighted on 5% of the total surveyed days). The RI for 2018 (4.2%) was significantly higher than 2017 (3.2%), and is the highest RI recorded by the MMRP to date (Fig. 6). Monthly breakdowns show

that the RI was highest during September (11.7%), with smaller peaks at the start and end of the survey period (May and November respectively) (Fig. 7). The high RI recorded in 2018 may indicate a less transient population in comparison to other years, potentially highlighting an increase in the localised abundance of plankton, the manta ray's food source.

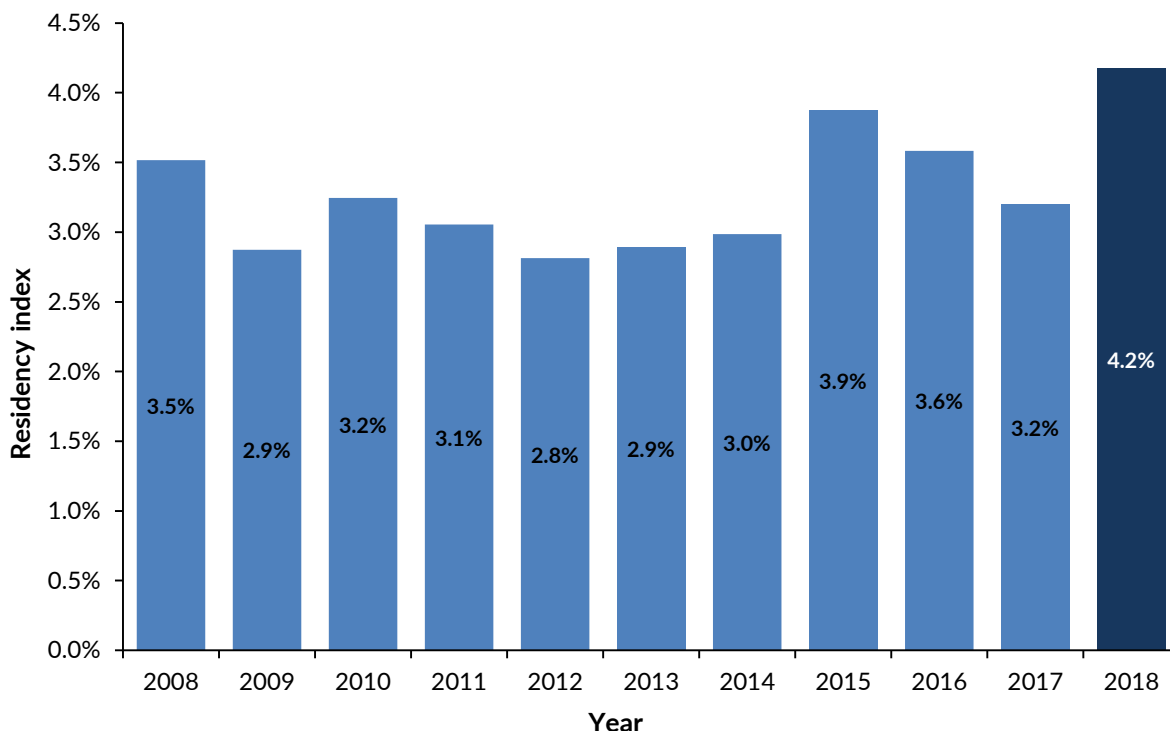


Figure 6: Annual Residency Index (RI) of the reef manta rays (*Mobula alfredi*) in Baa Atoll. RI is calculated as the average of each individuals' residency score (= number of times sighted annually divided by the total number of survey days).

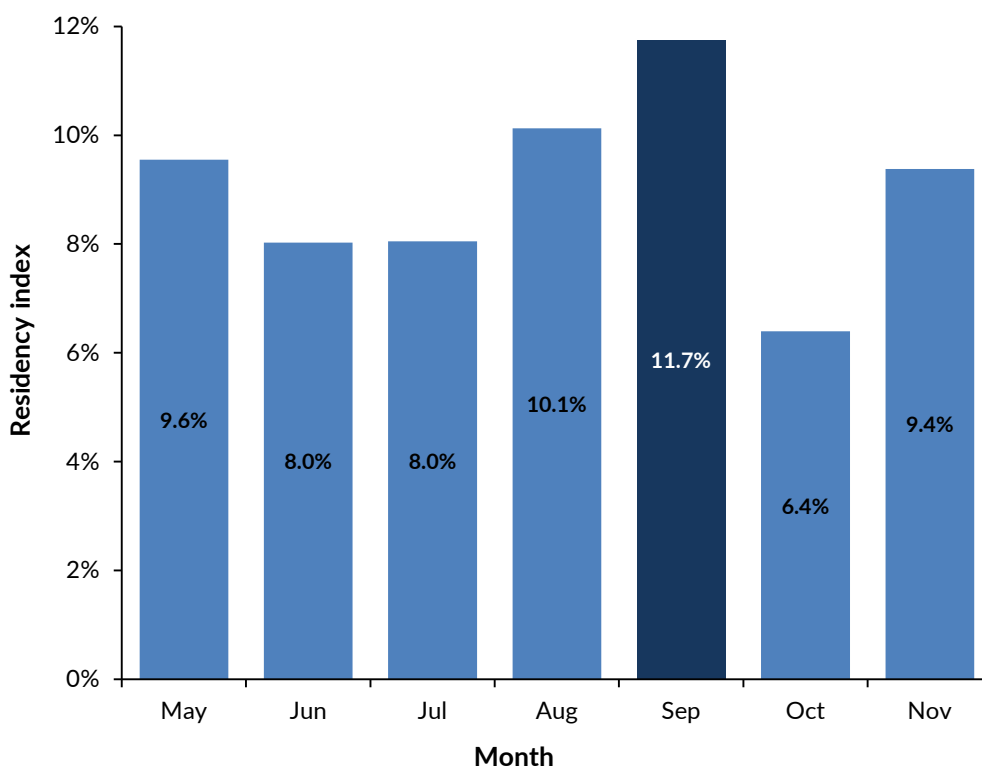


Figure 7: Residency Index of reef manta rays (*Mobula alfredi*) for each month of intensive surveying in Baa Atoll during 2018.



Hanifaru Bay (Marine Protected Area)

In a repetition of the trends observed at the atoll level, the total number of sightings ($n=3,838$), and number of individual reef manta rays ($n=606$), recorded in Hanifaru Bay MPA in 2018 were much higher than in the majority of previous study years (Fig. 8). Monthly breakdowns reveal a steady increase in the average number of manta ray sightings per survey day at Hanifaru Bay in 2018 from May to September (14 to 54 respectively) (Fig. 9), with the greatest number of individuals seen in August ($n=387$). It should be highlighted

that there were no recorded sightings during 2018 of reef manta rays at Hanifaru Bay outside of the MMRP survey period (May-November), indicating that the Maldives reef manta ray's arrival at Hanifaru Bay is linked with the onset of the Southwest Monsoon. The 9th September 2018 saw the greatest number of individuals recorded on a single day during the year, with a total of 180 confirmed reef manta rays identified from Hanifaru Bay.

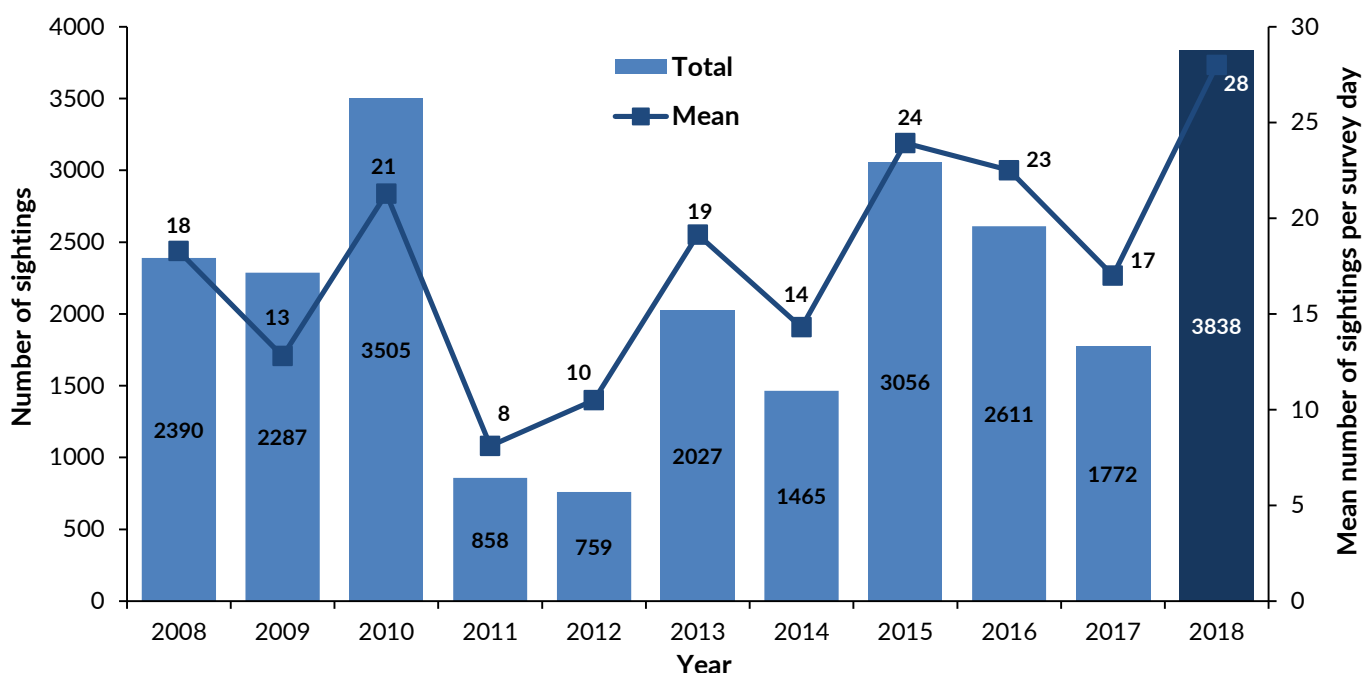


Figure 8: Total annual sightings of reef manta rays (*Mobula alfredi*) in Hanifaru Bay, and the mean number of sightings per survey day.

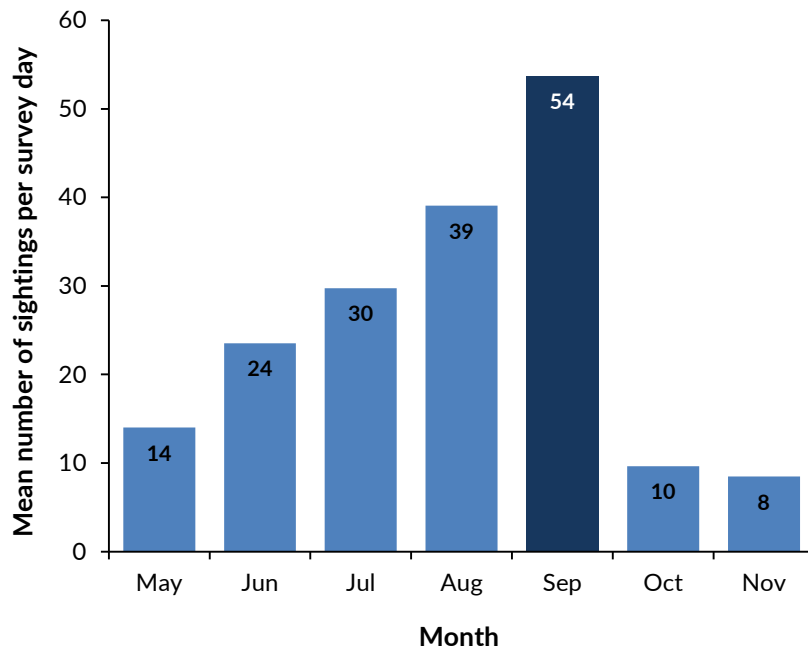


Figure 9: Mean number of reef manta ray (*Mobula alfredi*) sightings per survey day at Hanifaru Bay during each month of intensive surveying in 2018.

Population Demographics

The total number of individual reef manta rays which have been recorded in Baa Atoll during the last decade is 2,043, almost half (44%) of the Maldives reef manta ray population ($n=4,671$). As of 2018, population demographics of Baa Atoll constitute 53% females ($n=1,092$), 46% males ($n=941$) and <0.5% individuals for which the sex could not be determined ($n=10$). Of the reef manta rays recorded

in Baa Atoll ($n=2,043$), 46% ($n=938$) have also been seen in at least one other atoll in the Maldives; spanning from the very northern atoll of Ihavandhippolhu, down to the southernmost atoll of Addu (Fig. 10). This movement behaviour highlights the importance of Baa Atoll as a key aggregation site for the reef manta rays during the Southwest Monsoon.



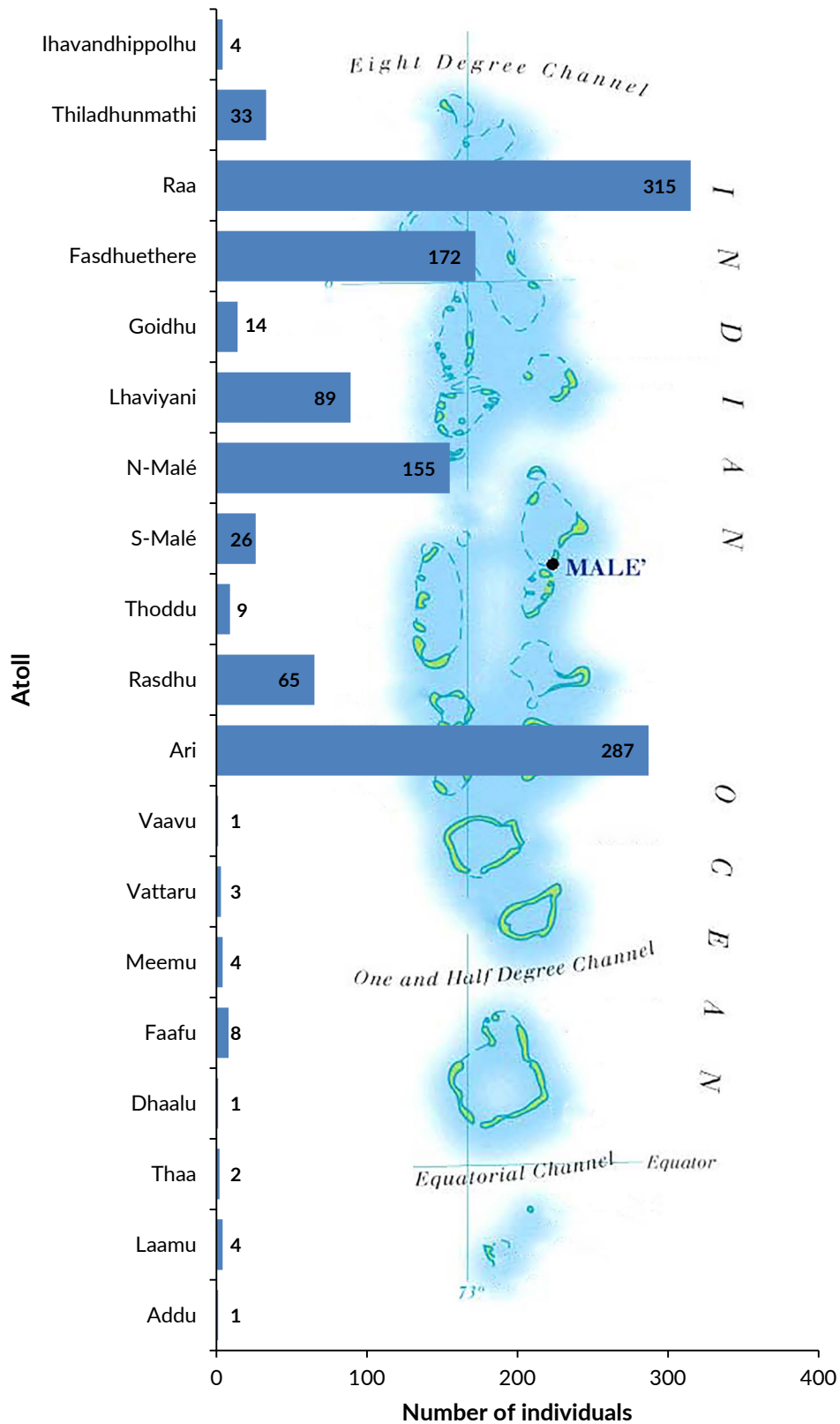


Figure 10: Number of reef manta ray (*Mobula alfredi*) individuals ($n=938$) from among the Baa Atoll population ($n=2,043$) which have been recorded in other atolls throughout the Maldives Archipelago. Note: many of these cross-atoll individuals have been observed in more than two atolls.

Throughout May to November, a total of 405 adult and 271 juvenile reef manta rays were sighted. Maturation 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, 270-208 cm disc width for males), adult status was also assigned. All other individuals were classified as juveniles.

During every month of the main sampling period (May-November) across all study years (2008-2018), there were

more sightings of juvenile female reef manta rays than their male counterparts. In contrast, the ratio of adult female-to-male reef manta ray individuals altered considerably. More adult females were sighted than adult males during the month of October, whereas the trend reversed during May and November (Fig. 11). The peak in adult male reef manta ray occurrence during these months may be correlated with an increase in reproductive activity. It is thought that during courtship, receptive females release pheromones into the water to attract a mate. These signals, and others, may result in greater aggregations of adult male reef manta rays at focal reproductive sites, like cleaning stations, at specific times of the year.

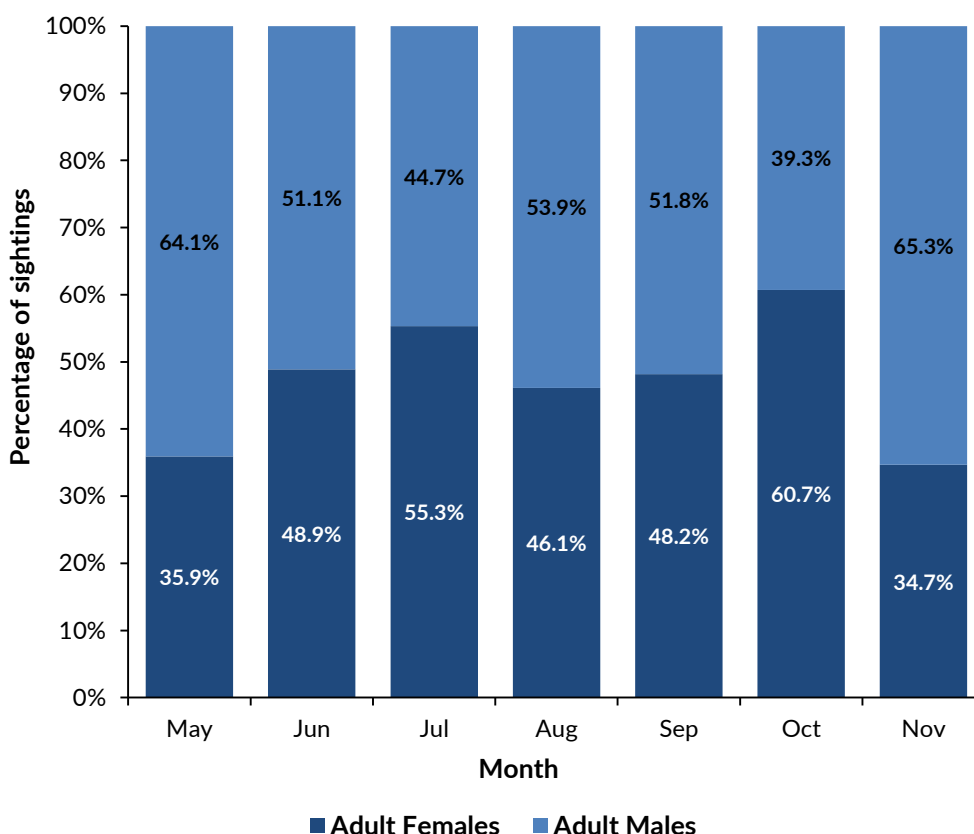


Figure 11: Mean monthly variations in the sighting demographics of adult reef manta rays (*Mobula alfredi*) in Baa Atoll during the intensive surveying periods (May-November) between 2008-2018.

POPULATION RECRUITMENT

A total of 226 new individual reef manta rays were documented across the Maldives during 2018, a population increase of approximately 5% from the previous year (2017, $n=4,445$). Therefore, as of 2018, the Maldives reef manta

ray population was comprised of 4,671 individuals. Of the 226 new individuals added to the MMRP database, 24% ($n=54$) were documented in Baa Atoll during 2018, this is a large increase from the previous year (2017, $n=16$) (Fig. 12).

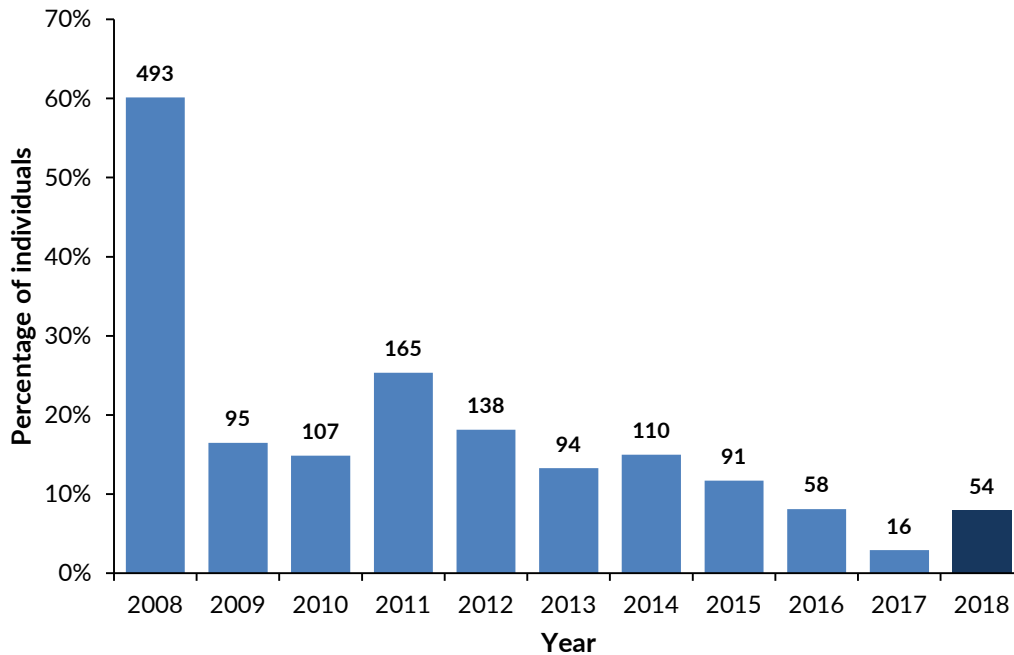


Figure 12: Proportion of the total reef manta rays (*Mobula alfredi*) sighted annually in Baa Atoll which were newly sighted individuals. Actual numbers above bars.

Of the 52 new manta rays sighted in Baa between May and November; 38% were adult manta rays ($n=20$) and 62% were juveniles ($n=32$). Eleven of the juveniles were recorded as 'young of the year', indicating that the individuals were of a small enough size to be termed a manta ray pup. The demographics were split evenly amongst the identified pups: 50% female ($n=5$); 50% male ($n=5$), and one individual whose sex could not be determined at the time of identification.

Despite the increase in newly identified manta ray individuals during 2018, the proportion of newly sighted individuals is following a general downward trend (Fig. 12). As more data is collected over the years by the MMRP, the number of new individuals becomes less frequent, suggesting that most of the Baa Atoll manta ray population has been recorded and identified.

REPRODUCTIVE FECUNDITY

This report marks the sixth year in a row that the MMRP has recorded pregnancies among the Maldives reef manta ray population. The number of pregnancies recorded in Baa Atoll during 2018 was the highest number ever recorded in a single season, with a total of 59 individuals recorded as pregnant, and a further 25 females recorded with fresh reproductive wounds. Furthermore, the proportion of pregnancies recorded among Hanifaru Bay's core

population of mature female reef manta rays in 2018 is considerably greater than that recorded in most previous years. In 2018, 50% of Hanifaru Bay's core adult female population were sighted, and more than half (52%) of these individuals were visibly pregnant (Fig. 13).

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

4-6 months (2nd trimester onward). Of the 59 pregnant females observed in Ball Atoll during 2018, 64% (n=38) were in the later stages of gestation (3rd or 4th trimester) when first sighted.

The high incidence of pregnancies reported in 2018 should not however detract from the overall very slow reproductive

rate for this species, which, on average, sees only 20% of the mature females reproducing annually. With such low fecundity it becomes vital for the survival of these animals to minimise anthropogenic and natural impacts. Effective measures include the establishment of functional MPAs and the adherence to sustainable tourism activities at key manta ray mating, cleaning and feeding sites.

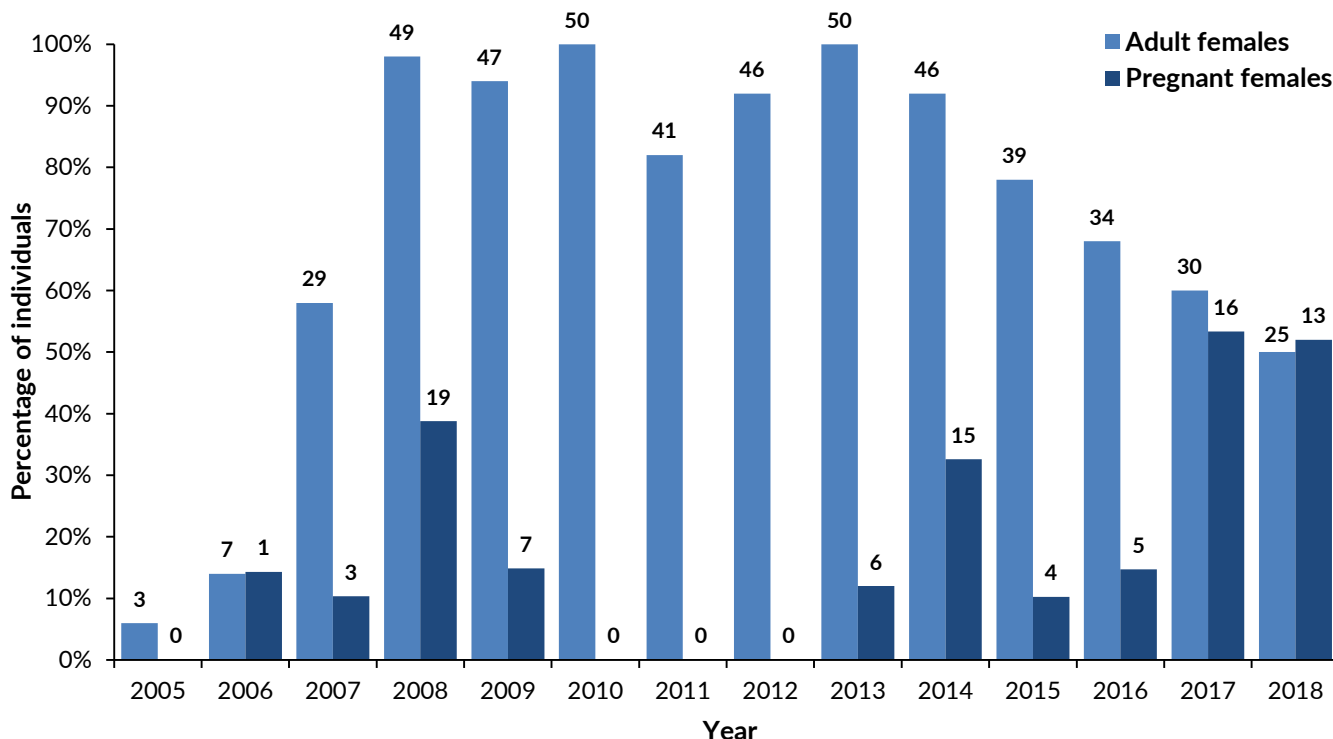
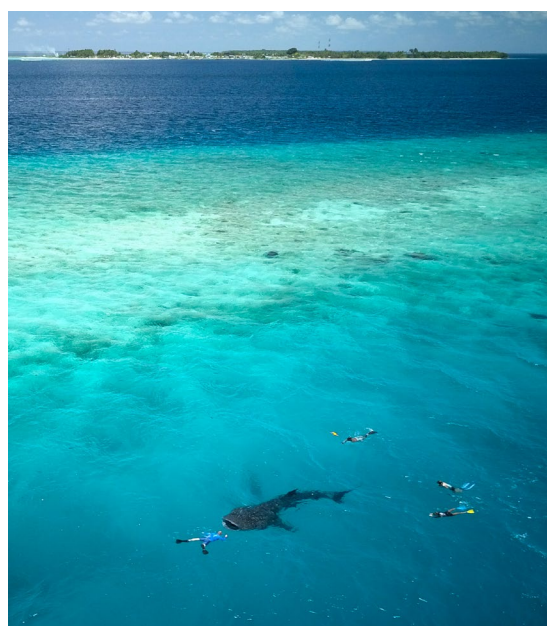


Figure 13: Percentage of Hanifaru Bay's core adult female reef manta ray (*Mobula alfredi*) population (n=50) sighted annually, and the percentage of those females which were recorded pregnant in the same year. Actual numbers above bars.

WHALE SHARK SIGHTING TRENDS

In Baa Atoll, whale sharks often inhabit the same feeding grounds as manta rays and are often sighted together along shallow reefs throughout the Maldives. In 2018, there were 25 whale shark sightings of 16 different individuals recorded in Baa Atoll between May and November (Fig. 14). Of these 16 individuals, 38% (n=6) were new to the Maldives Whale Shark Research Programme's database. Monthly breakdowns reveal that the greatest number of sightings in 2018 were recorded during the month of July. Interestingly, this was also the period when the MMRP recorded the highest number of adult manta ray individuals, and could indicate that the prevailing conditions noted at this time were most favourable for these planktivorous creatures. July is also typically characterised as the 'heart' of the Southwest Monsoon - midway through the season (Fig. 15). It is eagerly hoped that 2019 will see a continued increase in whale shark encounters within Baa Atoll.



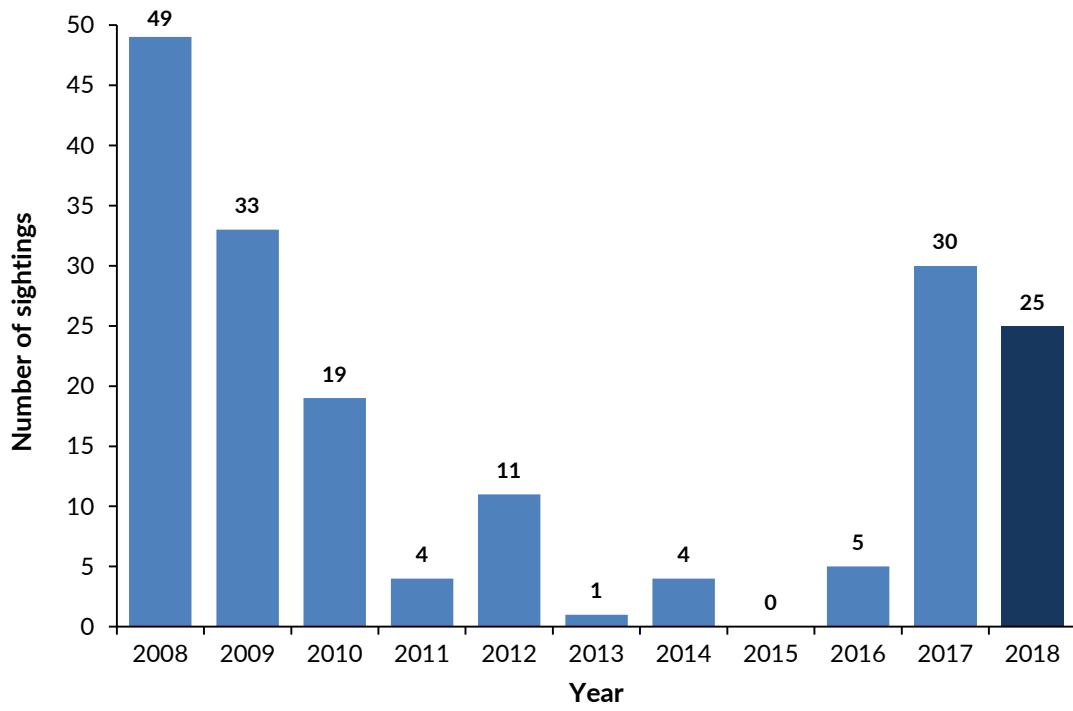


Figure 14: Total annual sightings of whale sharks (*Rhincodon typus*) in Baa Atoll.

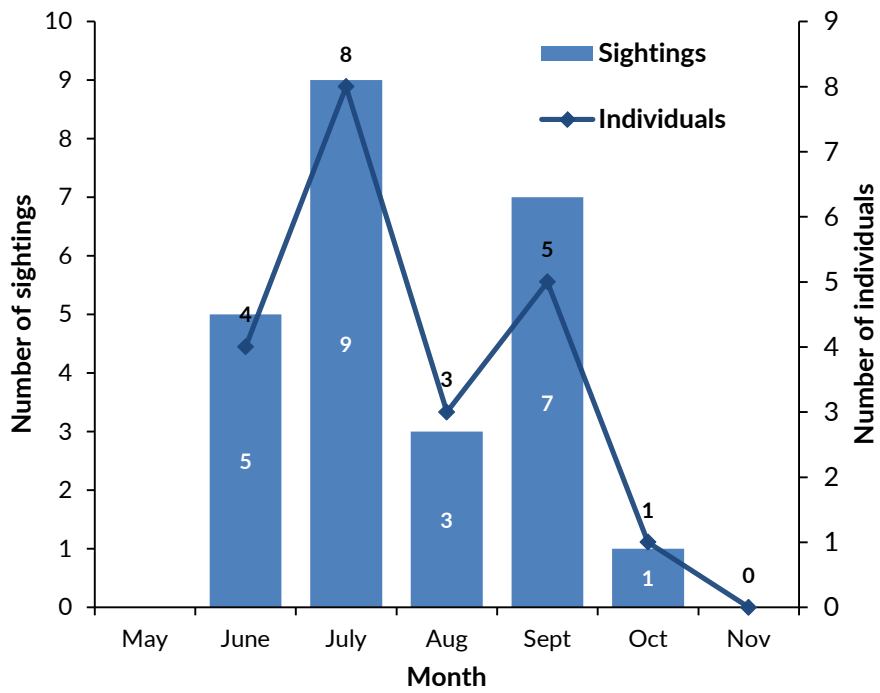


Figure 15: Whale shark (*Rhincodon typus*) sightings in Baa Atoll during 2018, and the total number of individuals recorded each month.

WEATHER & CLIMATIC VARIATION

The MMRP continued to investigate the possible correlation of environmental variables (such as wind speed and direction) and the frequency of reef manta ray sightings. The average wind speed observed in 2018 was 18 km/h, slightly higher than in 2017 (17 km/h). As in preceding years, the start of the Southwest Monsoon in 2018 was characterised by typically high wind speeds in May (23.4 km/h) (Fig. 16). This number steadily decreased as the season progressed, dropping to 11 km/h in the month of November (Fig. 16). In turn, manta ray sightings increased from May to September (Fig. 16). In contrast to 2017, but in keeping with the general trend observed by the MMRP in previous years,

2018 data shows a peak in manta ray sightings at the heart of the Southwest Monsoon (Fig. 16). September had the highest average number of manta ray sightings per survey day ($n=49$). September's high sightings number follows the stronger monsoonal winds noted early in the season (May-July). It has been previously hypothesized by the MMRP that this increase in wind speed results in more favourable conditions for zooplankton; attracting manta rays to the region (Fig. 17). Across all years, generally when the annual wind speed increases, so do the average number of manta ray sightings (Fig. 17).

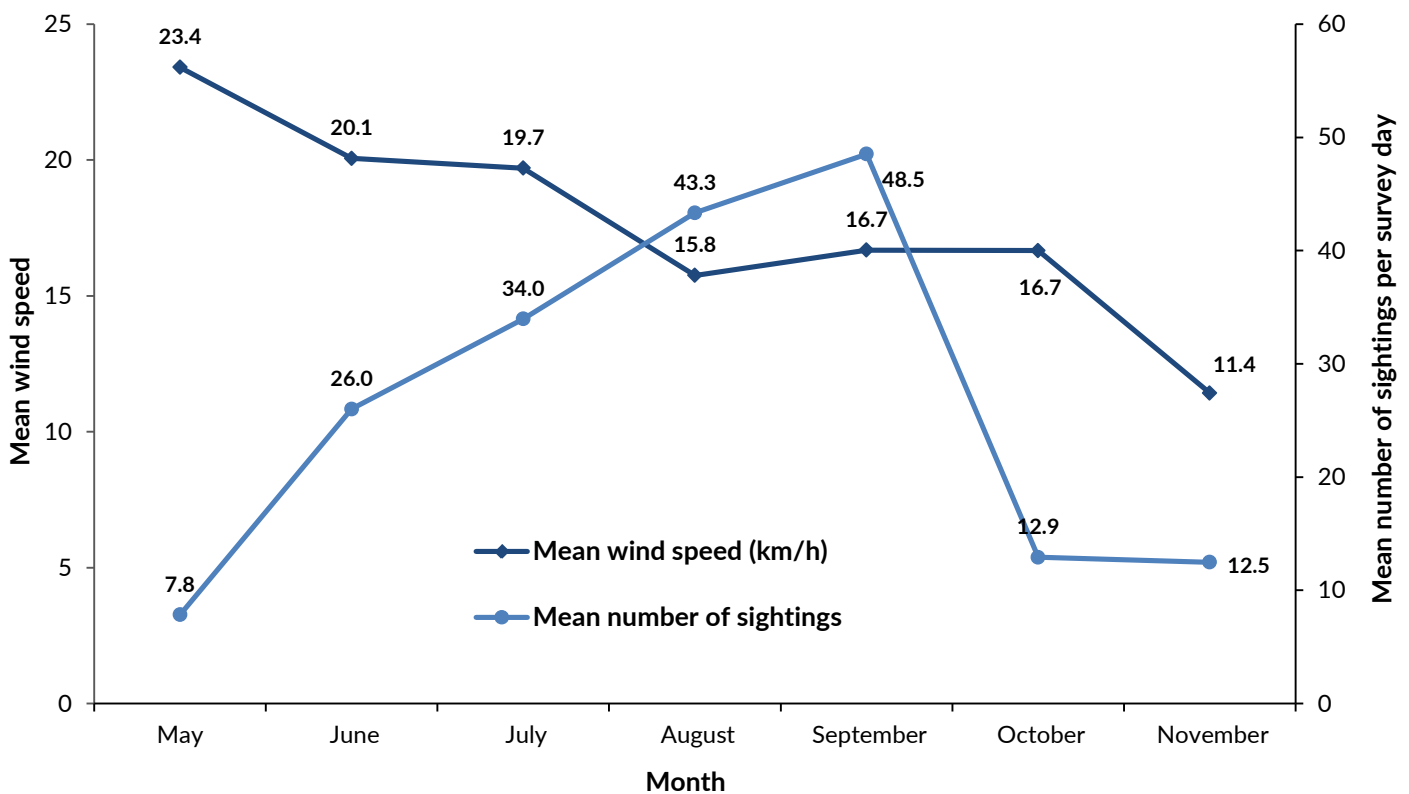


Figure 16: Mean monthly wind speed (km/h) and the mean number of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll during each month of intensive surveying in 2018.

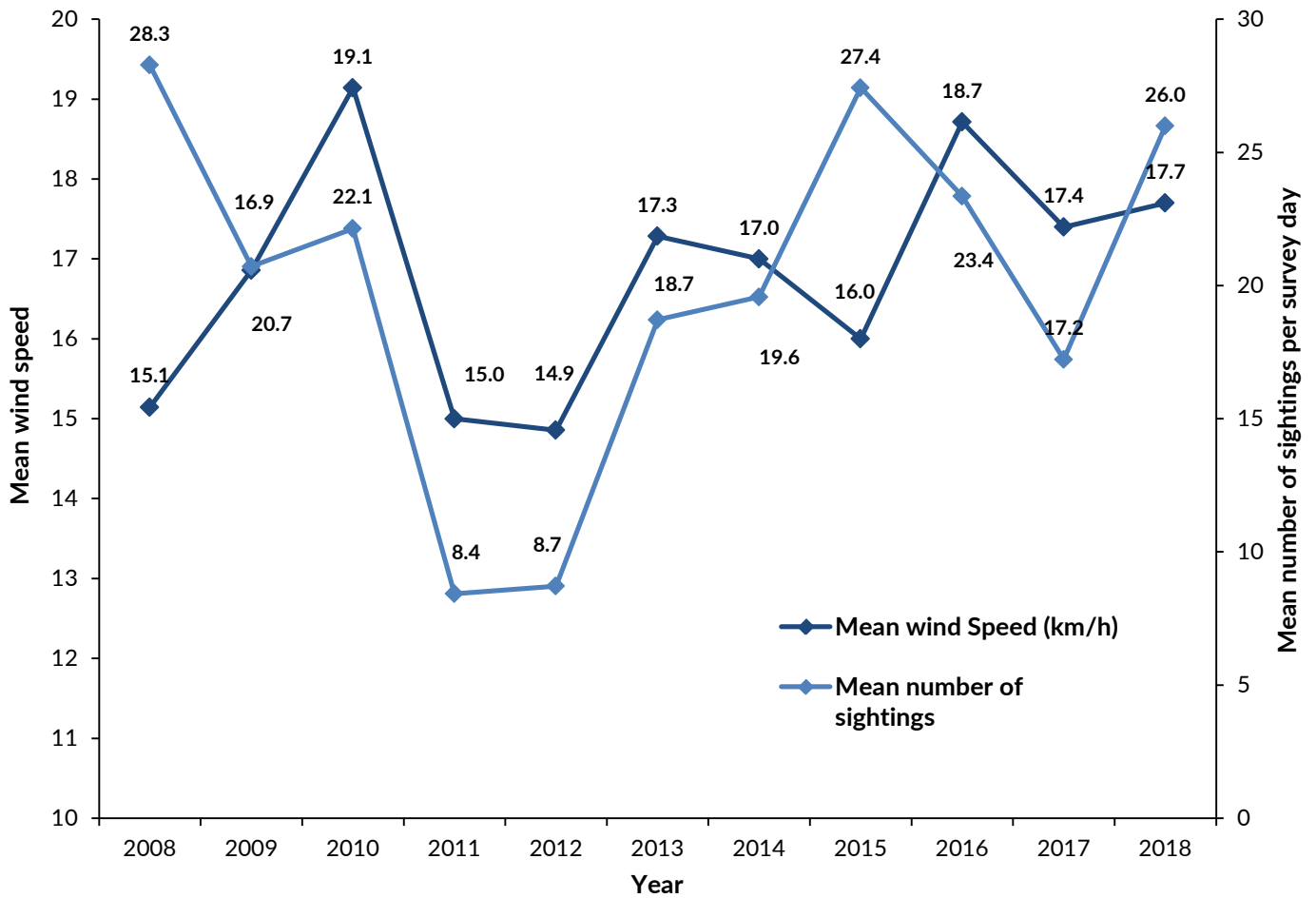


Figure 17: Mean annual wind speed (km/h) and the mean number of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll.

The fluctuation of monsoonal strength, food availability, manta ray sightings, and fecundity are likely to be part of a natural cycle of variable weather patterns which occur within the Maldives over time. These fluctuations are also likely to be connected to, and amplified by, larger climatic phenomenon, such as the Indian Ocean Dipole (IOD) and the El-Niño Southern Oscillation (ENSO); both of which are linked to the increased fluctuations in climate change recorded in the Indian Ocean in recent decades. Only on-going and consistent monitoring will elucidate the

causal drivers behind these variables, and determine what measures need to be taken to manage them. Regardless of cause, and leaving aside the ecological ramifications, these observations should be considered seriously because of the negative economic consequences they can have. Not only will these trends affect manta ray tourism directly, but also on a wider scale, they will affect the wider tourism and fishing sectors, which heavily rely upon the ocean's productivity, and therefore the strength of the monsoons.

SUB-LETHAL INJURIES

Of the 2,043 individual reef manta rays recorded in Baa Atoll, 29% ($n=600$) have one or more sub-lethal injuries. Of those injured manta rays; 89% ($n=533$) have only one injury, 10% ($n=62$) have two recorded injuries, and only five individuals (1%) have three injuries. Fifty-one percent ($n=346$) of recorded injuries ($n=672$) resulted from natural sources, 36% ($n=242$) resulted from anthropogenic

sources, whilst the remaining 13% ($n=84$) resulted from an undetermined source. Demographically, instances of injuries are similar between females and males, but higher in adults than juveniles (Fig. 18). This increase in instances of injuries to the adults is unsurprising, as these individuals are older and therefore likely to have encountered threats more often than juveniles during their life.

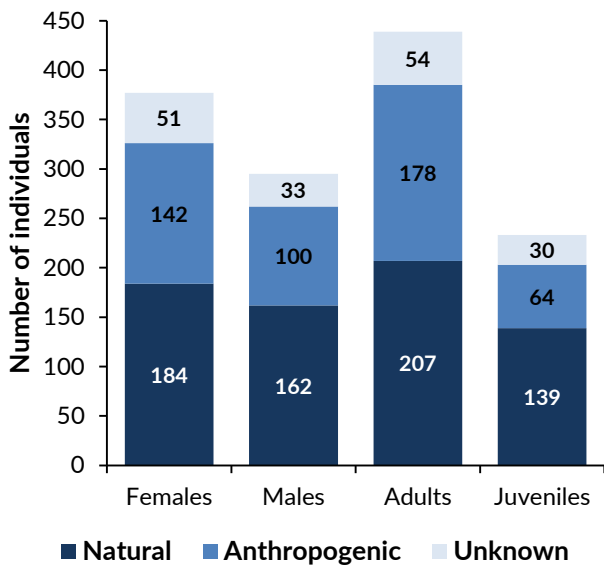


Figure 18: Demographic variations in the number of individuals ($n=600$) with natural, anthropogenic and/or unknown source injuries ($n=672$) amongst the reef manta ray (*Mobula alfredi*) population within the Baa Atoll Region ($n=2,043$).

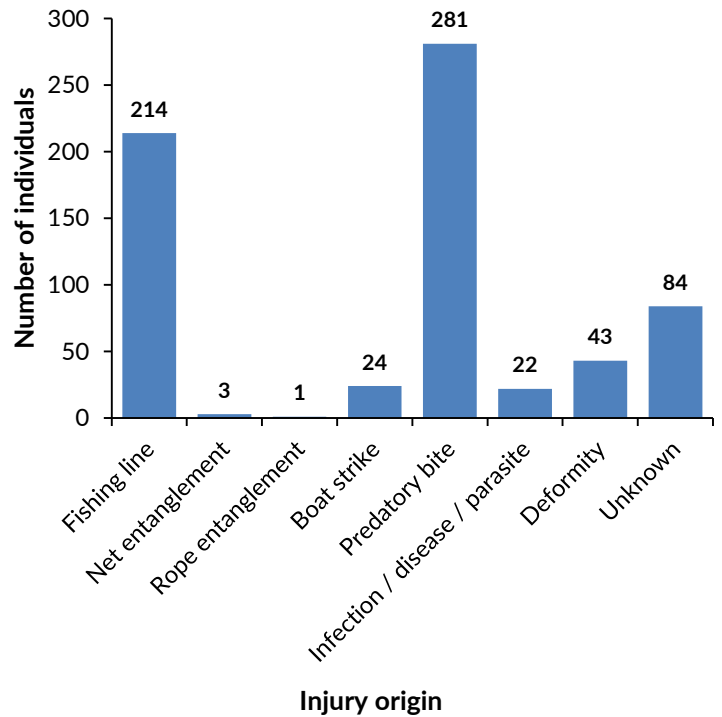


Figure 19: Total number of sub-lethal injuries ($n=672$) recorded on the reef manta ray (*Mobula alfredi*) population in the Baa Atoll Region ($n=2,043$), classified by the cause of the injury.

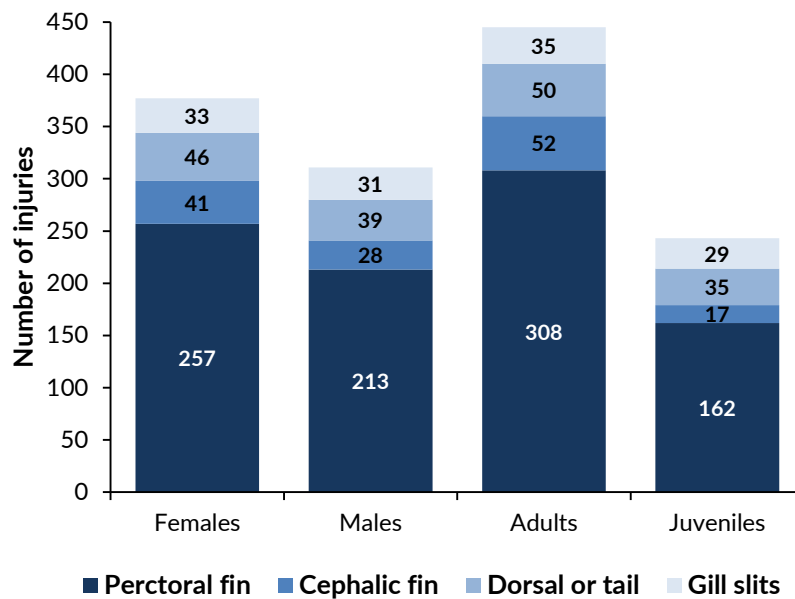


Figure 20: Demographic variations in the number of sub-lethal injuries ($n=688$), counted by body area, within the injured reef manta ray (*Mobula alfredi*) population of Laamu Atoll ($n=600$).

The most common cause of natural injury in all individuals, both adults and juveniles, were from predatory bites ($n=281$), followed by deformity ($n=37$), and infection, disease, or parasite ($n=20$). The most common cause of anthropogenic injury was from fishing line ($n=214$), followed by boat strike ($n=24$), and net or rope entanglement ($n=4$) (Fig. 19). Of all the manta injuries recorded (when counted by

body location; $n=688$), 68% are inflicted upon the mantas' pectoral fins. This proportion remains consistent between the sexes and the maturity status (Fig. 20). Most predatory bites (mainly inflicted by large sharks) occur on the manta's anterior pectoral fin region. Manta rays cannot see well directly behind them, making them more vulnerable to predatory attacks in this area.

TOURISM ACTIVITIES

The number of resort and guesthouse visitations to Hanifaru Bay have significantly increased over the last seven years, however the number of liveaboard vessels visiting the MPA have remained consistent during the same timeframe. This is in part due to the implementation of an alternating schedule of liveaboard vessels and resort vessels visiting Hanifaru Bay MPA, in order to limit the number of tourists in the MPA at any one time.

Since 2012, there has been a ban on SCUBA diving in Hanifaru Bay, which has had a visible impact on the number of liveboards vessels observed in the area. Many of the liveboards that operate throughout the Maldives cater

predominantly to divers. Most of these vessels will not take the time, nor use the resources necessary, to travel to and from Hanifaru Bay MPA if they are unable to dive. These factors have significantly reduced the number of liveaboard vessels travelling to Baa Atoll since 2011 (Fig. 21). August through October proved to be the busiest months in Hanifaru Bay for liveaboard visitors (Fig. 22). The greatest number of liveaboard vessels were observed in October, when guests from 17 different vessels were recorded inside Hanifaru Bay (Fig. 22). Overall, the MMRP team witnessed guests from 34 different liveaboard vessels inside Hanifaru Bay throughout the seven-month sampling period; an increase from 2017 ($n=23$ individual vessels) (Fig 21).

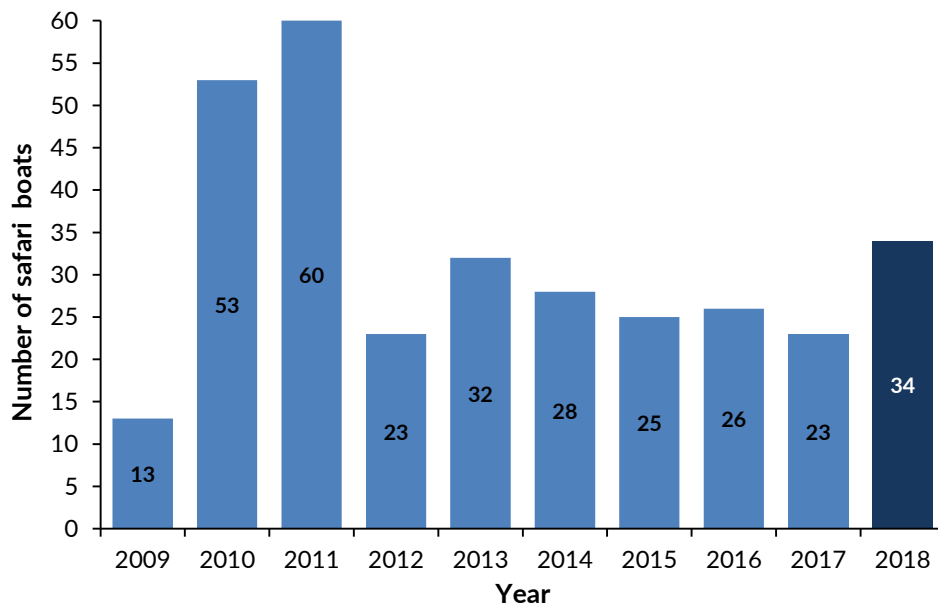


Figure 21: Total number of different safari boats (liveboards) observed from May-November each year in Baa Atoll.

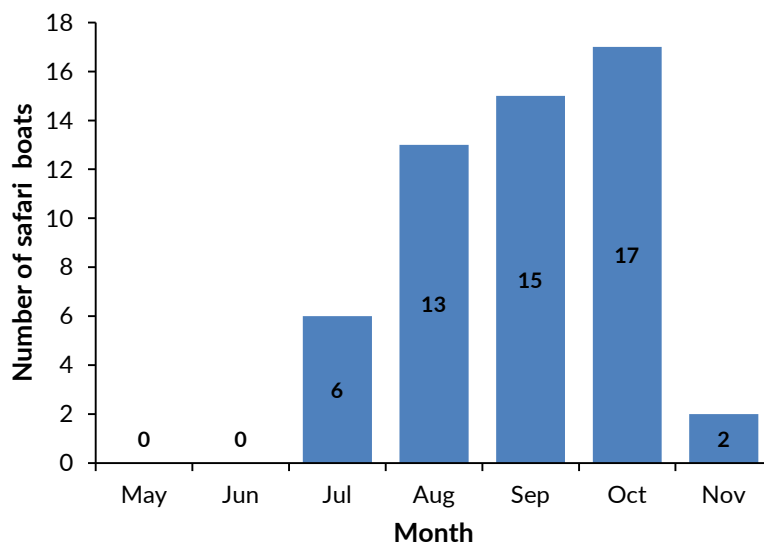


Figure 22: Total number of safari boats (liveboards) visiting Hanifaru Bay each month in 2018.

The MMRP strove to improve the sustainability of manta ray tourism activities in Baa Atoll during 2018 by organising a series of informative presentations and workshops aimed at those leading swim-with-manta-rays tourism initiatives. These information sharing events provided education on manta ray biology, ecology, the history of MMRP, the research the MMRP conducts in the Maldives, and the best Code of Conducts for interacting with manta rays. The aim was to provide marine users with the necessary tools to conduct sustainable manta ray tourism activities, to safeguard against negative ramifications of human-manta ray interactions, and to ensure the conservation of the Maldives manta ray population. The information sharing events were a success. One workshop held prior to manta season had over thirty attendees from a variety of resorts. Considering the success from 2018, a workshop has already been planned to be held at Four Seasons Landaa Giraavaru ahead of the manta ray season commencing on Thursday 23rd May 2019.

Beyond education of 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 Baa Atoll. Furthermore, as tourism and associated boat traffic within the atoll increases, boat crew and local operators need to remain vigilant to ensure that wildlife (including turtles, mantas and dolphins) are not injured while on the surface. Rules and regulations within Hanifaru Bay aid in the protection of these animals, however; disaster will continue to strike in areas not thoroughly regulated. Take for example one of the MMRP's best-known manta rays, Babaganoush. In November 2017, Babaganoush suffered a horrific boat strike injury along his dorsal surface. The propeller visibly went so far as to cut through his flesh and into his organs. Luckily, Babaganoush was able to survive this ordeal and heal exceptionally well, but the long term effects of an injury such as this are still not well known. For protection of the population, the tourist community must understand the importance of safe boating practices.

BAA ATOLL MARINE EDUCATION PROGRAMME

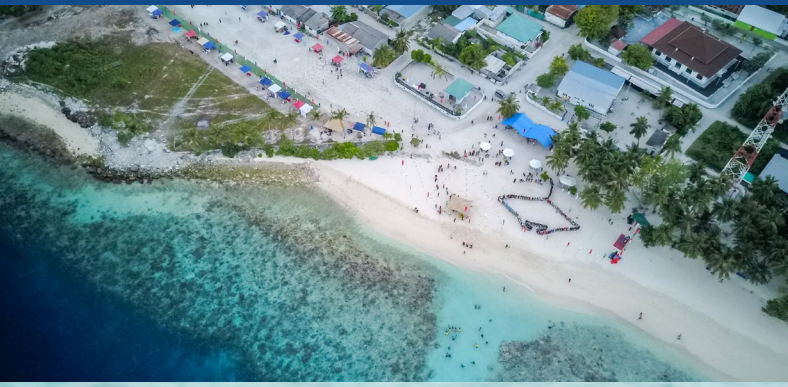
The MMRP Marine Education Programme (MEP) aims to educate groups of local school students about the environmental issues the Maldives and their own local community is faced with, and provides initiatives to tackle the problems and improve conservation. The MMRP has conducted the MEP with three schools since its inception in 2015. In 2018, thirty secondary school students from Baa Atoll School, Dharavandhoo, completed the 50-hour programme. Students studied four core modules: Maldives Marine Ecosystems, Coral Reef and Megafauna, Waste Management, and Ecosystem Conservation. Classes are divided into theory lessons with practical components and fieldtrips. There is a strong emphasis on snorkelling fieldtrips to increase student's in-water confidence and first-hand knowledge of the ocean.

The Dharavandhoo MEP spanned from July–November and culminated in the Baa Atoll Manta Festival, which took place on Dharavandhoo on 24th November 2018. The programme was a success. Students exhibited increased marine environmental knowledge, awareness and pro-environmental behaviours following the programme and achieved a 90% pass rate in the MEP exam. Many students expressed a new desire to work in the marine field, and in particular, female snorkelling confidence greatly improved. During 2019, the MEP will expand to conduct activities

with a hundred students from the Baa Atoll Education Centre, Eydhafushi.

The Baa Atoll Manta Festival 2018 was spearheaded by the Manta Trust in collaboration with the Baa Atoll UNESCO Biosphere Reserve, Island and Atoll Councils, and Four Seasons Resort at Landaa Giraavaru. The festival was the first of its kind in the Maldives and included over twenty educational stalls hosted by environmental organizations, schools and resorts. Academic presentations were given by guest speakers and NGOs, and 13 schools and 300 students participated in art competitions and snorkelling lessons. As part of the initiative, the Manta Trust coordinated the donation of 222 sets of snorkelling equipment to 13 schools across Baa Atoll. The festival successfully brought resorts, guesthouses, government agencies, NGO's and local communities together to raise awareness of marine conservation issues and initiatives across Baa Atoll and the Maldives. During 2019, the event will be repeated on a different island in the atoll and expanded.

The Manta Festival and the MEP served to bring the Manta Trust closer to reaching its goal of getting communities across Baa Atoll interested and engaged with the ocean and ocean conservation. The MMRP will expand these initiatives throughout 2019 and continue to improve ocean literacy in the area.



CONSERVATION & MANAGEMENT

With less than 700 UNESCO World Biosphere Reserves around the globe, Baa Atoll is an ecological gem for manta ray and whale shark research. The designation of Hanifaru Bay as a core zone of the Reserve is extremely important for the conservation of these threatened species in the Maldives. However, these species need continued protection and effective management practices. We look forward to future partnerships and commitments with the Maldives' Environmental Protection Agency and the Baa Atoll Biosphere Reserve Office to protect this world-renowned site.

Research within Baa Atoll's UNESCO World Biosphere Reserve must remain a top priority for all involved. Biosphere reserves help us to better understand population dynamics, conservation and management strategies, conflict prevention, and human impacts on certain species. The long-term and consistent quality of the data collected within Baa Atoll allows us to gain a deeper knowledge of manta rays worldwide. The continued and monitored access to these amazing animals is imperative to our research goals and further advancement as the leading manta ray research programme in the world.



This report was made possible thanks to



FOUR SEASONS RESORT MALDIVES AT LANDAA GIRAAVARU

As our primary supporter in Baa Atoll, the Four Seasons Resort Maldives at Landaa Giraavaru has been incredibly support of the Manta Trust and MMRP since its inception. We hope this partnerships continues to prosper for years to come.



MALDIVES GOVERNMENT AUTHORITIES

The Manta Trust is grateful for the oppertunities 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 scienteists 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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