Manta TRUST

Maldivian Manta Ray Project

BAA ATOLL | ANNUAL REPORT 2019

Conservation through research, education, and collaboration

- The Manta Trust

MALDIVIAN MANTA RAY PROJECT

WHO ARE THE MANTA TRUST?

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

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

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

MALDIVIAN MANTA RAY PROJECT

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

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

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

THE CONSERVATION CHALLENGE

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

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

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

EXECUTIVE SUMMARY

Since 2007, the Maldives reef manta ray (*Mobula alfredi*) population in Baa Atoll has been continuously studied by the MMRP. Reef manta rays and whale sharks (*Rhincodon typus*) frequent Baa Atoll each year to feed on the abundant zooplankton prey that results from the productive Southwest Monsoon conditions. Worldwide recognition has consequently been gained by Baa Atoll for being one of the most reliable places to see, and swim with, these planktivorous megafauna.

Details on the ecology, population dynamics, and movements of Baa Atoll's reef manta rays throughout 2019 are provided in this report. 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 within Baa Atoll during 2019.

The MMRP, with outside contributions, conducted reef manta ray surveys on 200 days in 2019. Of the 200, 192 survey days fell between 1st May and the 30th November 2019. Key findings of the MMRP in Baa Atoll during 2019 include a total of 4,423 sightings of 589 individual manta rays. Of these individuals, each manta ray was observed on average 7.5 times. The mean daily number of reef manta ray sightings between November and May in 2019 was 22, with a peak in daily manta ray sightings seen during the month of September (*n*=31). A Residency Index (RI) was calculated to gauge the extent of movement amongst those frequenting the region. The RI for 2019 (3.8%) represented a decrease from 2018 (4.2%), the highest RI recorded since the MMRP's inception. The total number of sightings (*n*=2,874) and number of individual manta rays (*n*=483) recorded in Hanifaru Bay MPA in 2019 decreased from 2018 records.

As of 2019, the population demographics of Baa Atoll constitutes 53% females (*n*=1,116), 46% males (*n*=972), and <0.5% (*n*=9) of individuals for which the sex could not be determined. Of these Baa Atoll mantas (*n*=2,097), 50% (*n*=1,057) have also been seen in at least one other atoll in the Maldives.

Of the 280 new reef manta rays added to the MMRP database from across the Maldives in 2019, 15% (*n*=37) were documented in Baa Atoll during the Southwest Monsoon, a decrease from the previous year (*n*=52 in 2018).

The number of pregnancies recorded in Baa Atoll (*n*=29) more than halved compared to 2018 (*n*=59). In addition, 14 females were recorded with fresh reproductive wounds but not pregnant. Of the 29 pregnant females observed, 76% (*n*=22) were recorded in the later stages of gestation (3rd - 4th trimester).

In 2019, the Baa Atoll Marine Education Programme, 'Moodhu Madharusaa', continued to raise awareness about manta and devil rays, and the importance of the marine environment. The second Manta Festival was held in Eydhafushi, which brought together multiple organisations and the local community to clean up the local beaches, spread knowledge of the ocean, and showcase environmentally themed performances and artwork.

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.

Weather patterns within the Maldives are largely dictated by the South Asian Monsoon. This monsoon has two seasons, characterised by their winds, which blow consistently and reverse their direction seasonally. May through October is recognized as Hulhangu, while December-March is known as Iruvai. Hulhangu and Iruvai refer to the Southwest and Northeast Monsoon respectively. The months of November and April are transitional periods of change between these two distinct seasons. 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 like 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 filter feeding megafauna such as manta rays and whale sharks. During the Southwest Monsoon, high wind speeds generate strong currents, which in turn create more upwelling. The daily movement of water through channels into the atolls is driven by these strong currents and 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, transform into hotspots for large aggregations of zooplanktivorous megafauna.

STUDY PERIOD & SAMPLING METHODOLOGY

The MMRP conducted surveys (*n*=1,847) to locate manta rays in Eastern Baa Atoll between the 5th May and the 28th November 2019 on as many days as possible, where the weather conditions allowed. MMRP surveys were carried out either by observers (*n*=1,629) or Remote Underwater Video systems (*n*=218). Full day survey trips were conducted on 157 days within a 214-day time-frame (May-November), or 73% of the possible monitoring period. Surveys were conducted at Hanifaru Bay, one of five 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 Marine Protected Area (MPA), was more limited than in years prior to 2011.

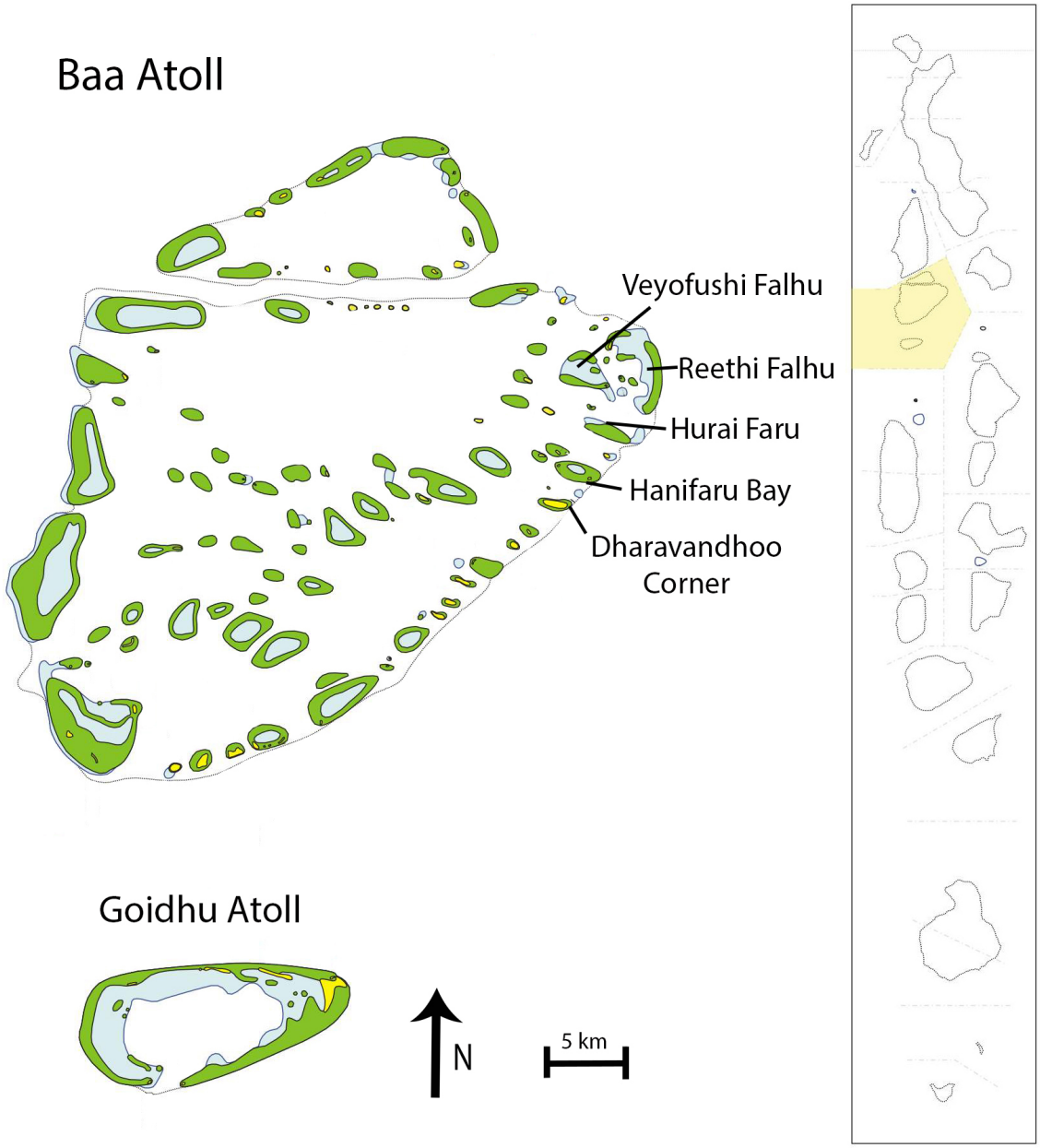


Figure 1: Map of the Baa Atoll region showing five of the key reef manta ray (*Mobula alfredi*) aggregation sites within eastern Baa Atoll, and the region in relation to the rest of the Maldives Archipelago (shaded orange).

In addition to the data collected by the MMRP, surveys (*n*=516) were also conducted by external parties. The photographs submitted by outside contributors accounted for all sightings data outside of May through November. Supplementary to the 157 survey days carried out by the MMRP, external parties conducted surveys which resulted in reef manta ray sightings on a further 43 days in 2019.

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. The results presented in this report also include sightings submitted to the MMRP by external parties. All recorded surveys were accounted for when standardising for survey effort for submissions by external parties.

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 a given day at a specific location.

MANAGEMENT CHANGES & INITIATIVES

Following the groundwork set by the 2012 government management plan, sustainable tourism practices and strict regulations are continuously being enforced within the Hanifaru MPA. These include, but are not limited to; tourist and boat limits, SCUBA 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 2019, 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 have resulted in estimated revenues of $30,000 USD for the Biosphere Reserve's Baa Atoll Conservation Fund. Such regulations and management initiatives are vital to ensure the efficacy of Hanifaru MPA in conserving the Maldives manta ray population, by minimizing the harmful ramifications arising from human-manta ray interactions.

Hanifaru Marine Protected Area including Hanifaru Island (bottom), Hanifaru Lagoon (central left), and Hanifaru Bay (right).

REEF MANTA RAY SIGHTING TRENDS

Baa Atoll Region

In 2019, a total of 4,423 reef manta ray sightings were recorded in Baa Atoll. The data shows a decrease (8.2%) in reef manta ray sightings compared to the previous year (*n*=4,816 in 2018). However, 2019 data represents a substantial increase (38%) in comparison to 2017 (*n*=2,723). Furthermore, the number of sightings documented in Baa Atoll during 2019 is the third highest on record (*n*=4,852 in 2015) (Fig. 2). Monthly breakdowns of these sightings in 2019, standardised for survey effort, show a general increase in average daily sightings from May to September (Fig. 3). Manta ray sightings peaked in September (*n*=31, average number of sightings per survey day), with subsequent months showing a marked decrease in manta ray sightings (Fig. 3).

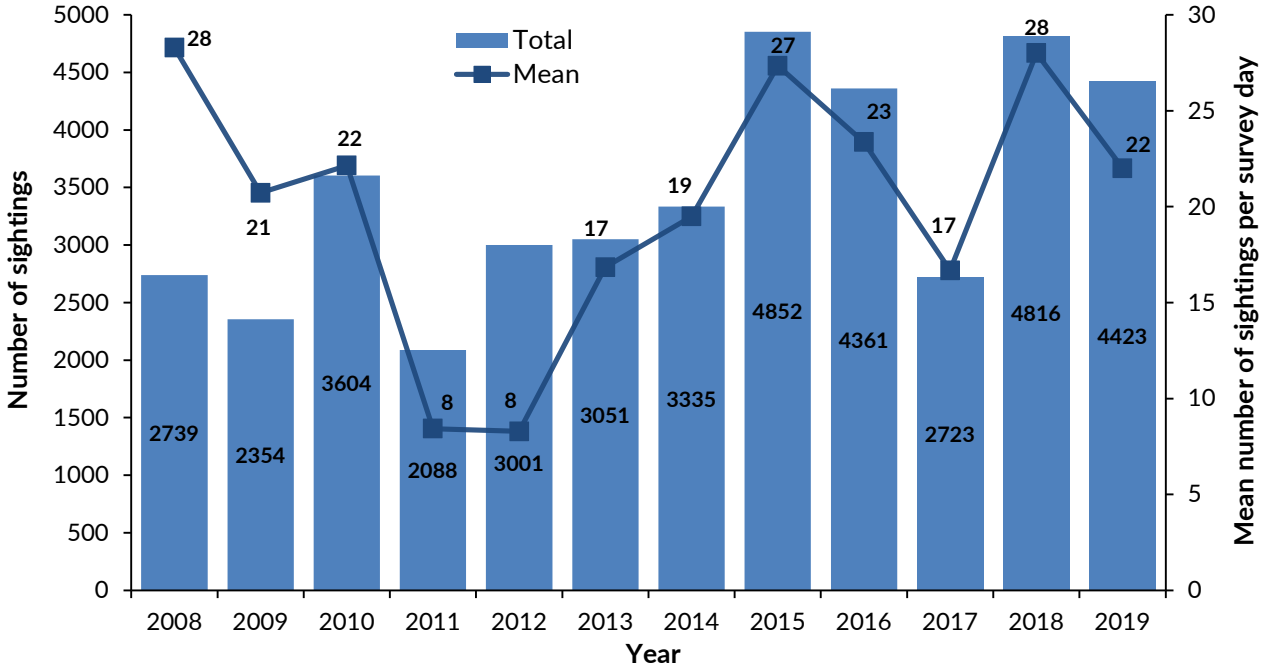


Figure 2: Annual sightings of reef manta rays (*Mobula alfredi*) in Baa Atoll, and the mean number of sightings per survey day.

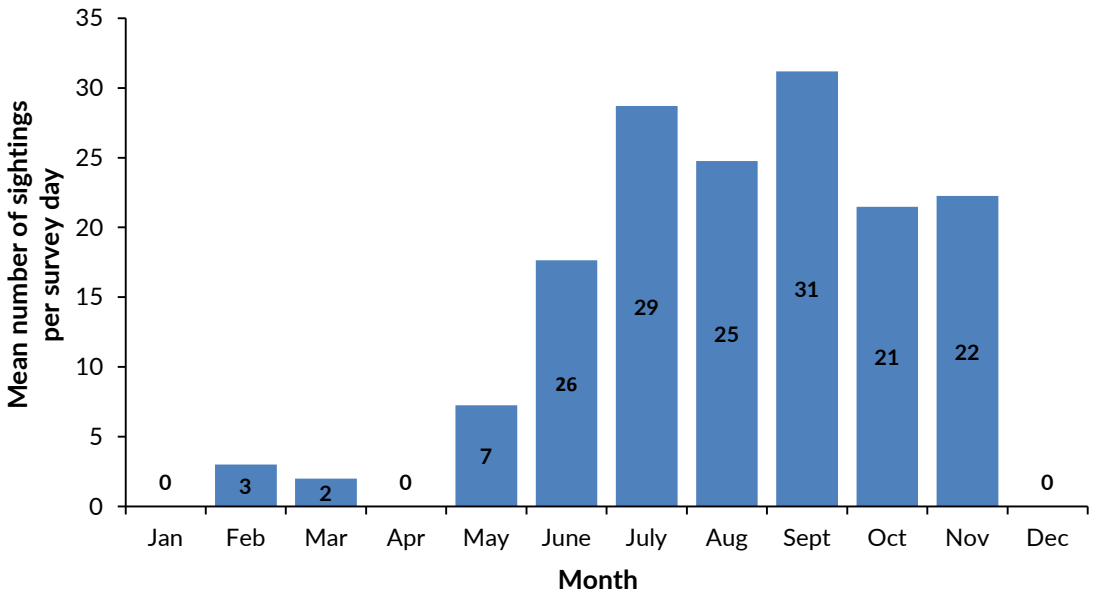


Figure 3: Monthly breakdown of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll during 2019.

During 2019, a total of 589 different individual reef manta rays were recorded in Baa Atoll. This accounts for 12% of the total recorded Maldives population (*n*=4,942); a decrease from 2018 (*n*=679) (Fig. 4). Throughout 2019, each manta ray was observed on average 7.5 times; the highest since this research programme began in 2008 (Fig. 4). Similarly, during the intensive survey period in 2019 (May-November), where 4,405 sightings of 582 individuals were recorded, each individual manta ray was also sighted on average 7.6 times. Monthly, the average number of sightings per manta ray increased from May to July, then remained consistent through to November (Fig. 5). In 2019, the mean daily number of reef manta ray sightings during May to November (*n*=22) was slightly lower than in 2018 (*n*=26).

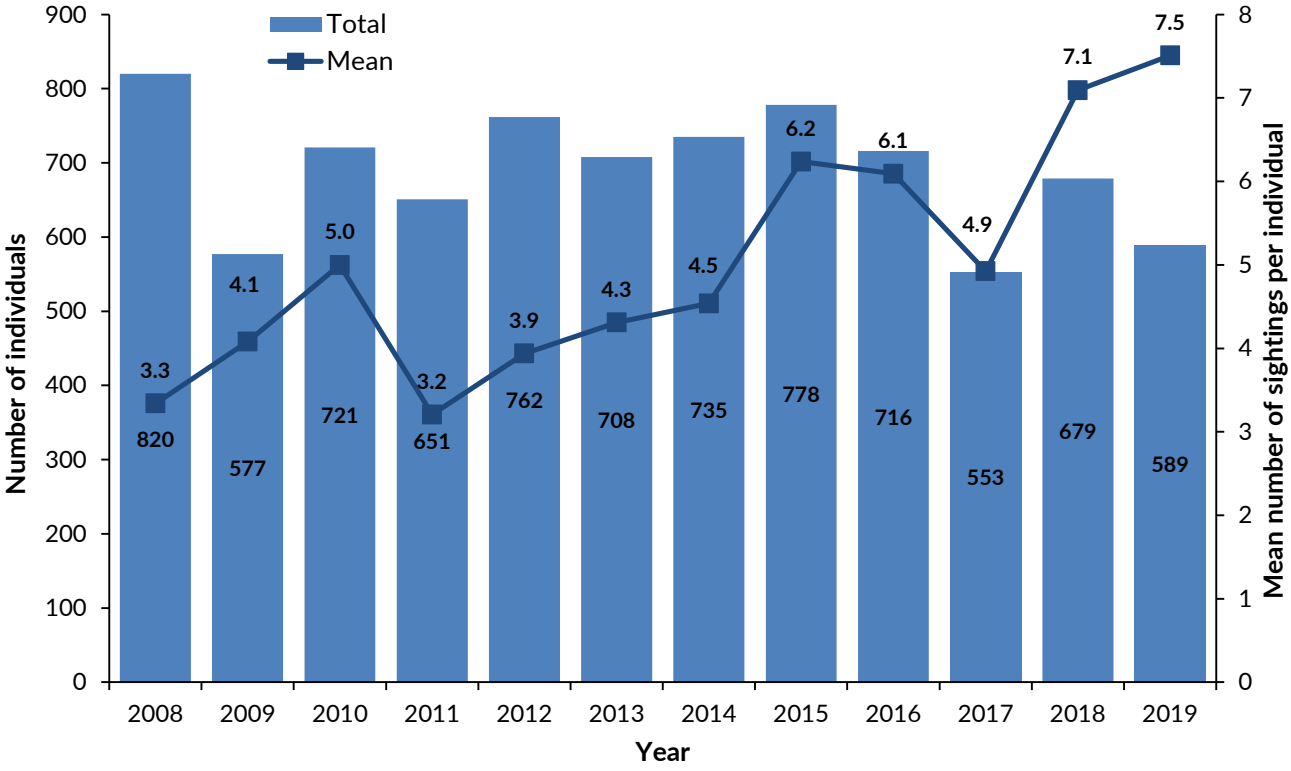


Figure 4: Annual number of individual reef manta rays (*Mobula alfredi*) sighted in Baa Atoll, and the mean number of sightings per individual.

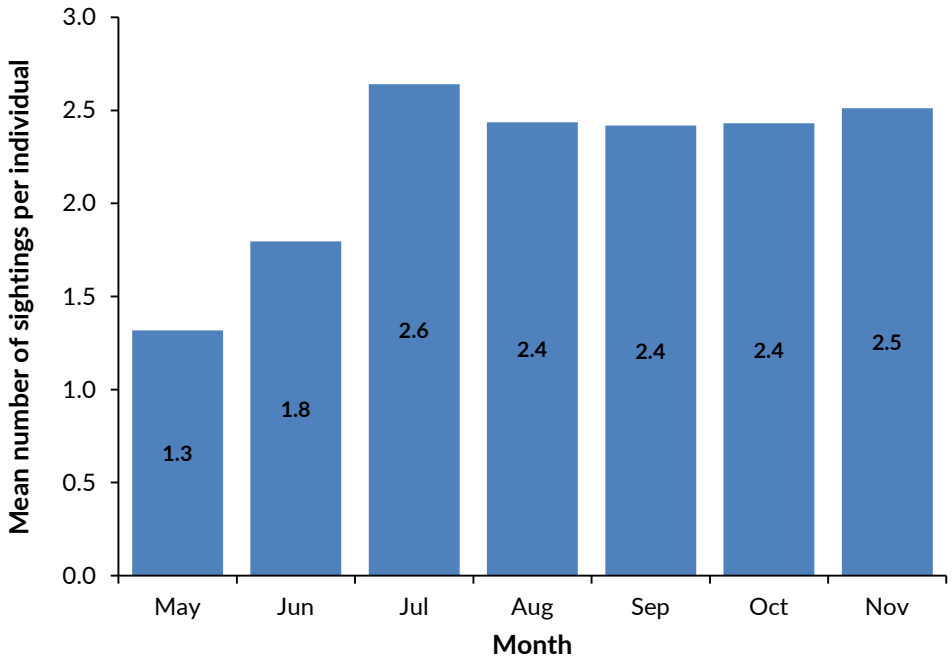


Figure 5: Mean number of sightings per reef manta ray (*Mobula alfredi*) during each month of intensive surveying in 2019.

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 2019 (3.8%) was slightly lower than in 2018 (4.2%) (Fig. 6). Monthly breakdowns show that the RI was lowest during the month of June (6.4%) but increased substantially during the month of July (8.5%) and remained consistently high throughout the study period, with the highest peak noted in November (9%) (Fig. 7). Although lower than 2018, the RI recorded in 2019 is still relatively high in comparison to previous years, potentially indicating a less transient population and a continued high abundance of localised plankton, the manta ray's food source.

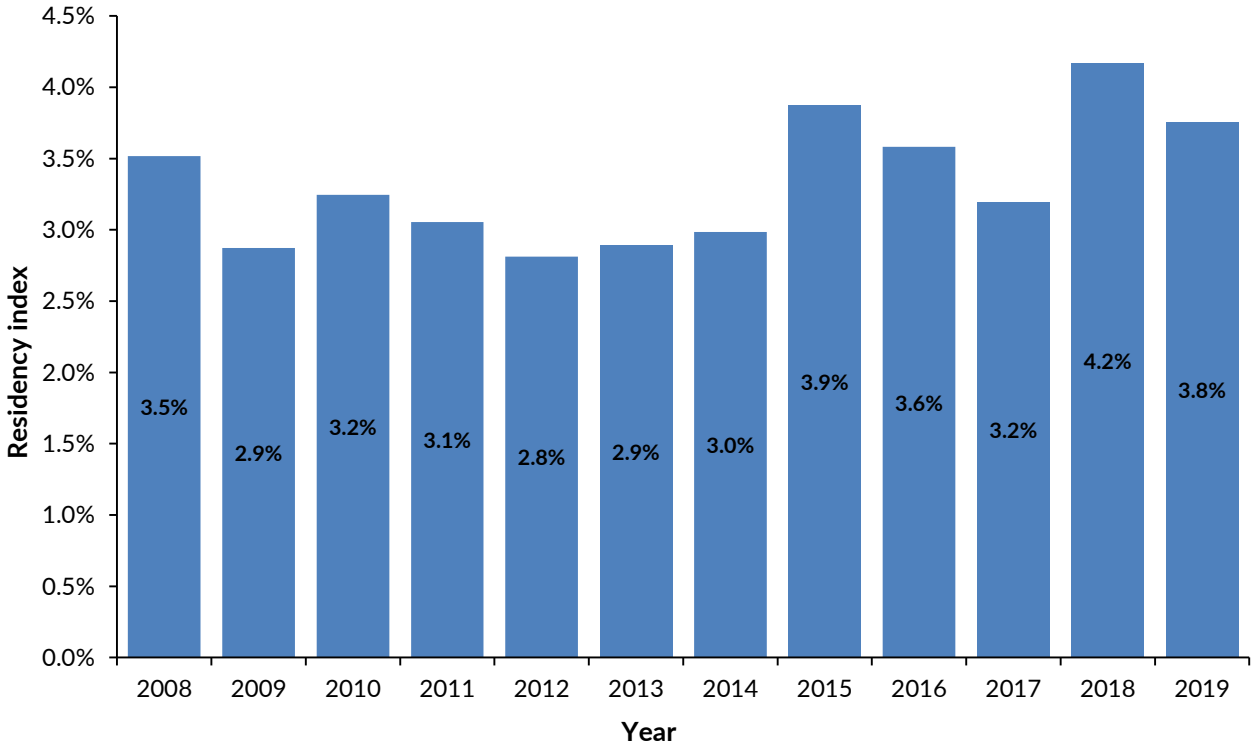


Figure 6: Annual Residency Index (RI) of the reef manta rays (*Mobula alfredi*) in Baa Atoll. RI is calculated as the average of each individuals' residency score (= number of times sighted annually divided by the total number of survey days).

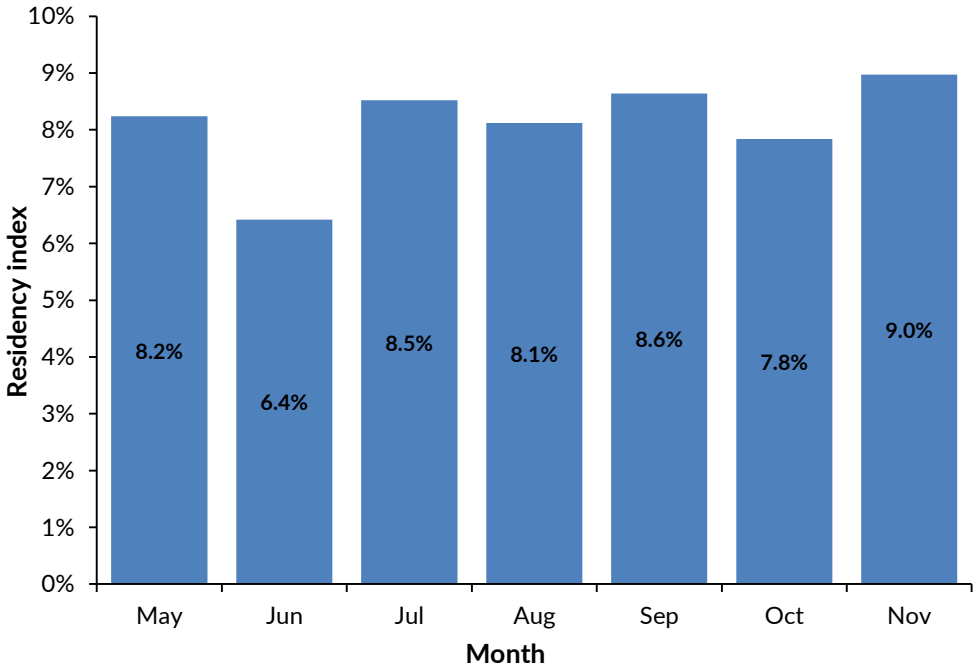


Figure 7: Residency Index of reef manta rays (*Mobula alfredi*) for each month of intensive surveying in Baa Atoll during 2019.

Hanifaru Bay (Marine Protected Area)

In trend with previous observations at the atoll level, the total number of sightings (*n*=2,874), and number of individual reef manta rays (*n*=483), recorded in Hanifaru Bay MPA in 2019 were slightly lower than in 2018 (*n*=3,838 and 606 respectively) (Fig. 8). Monthly breakdowns reveal a steady increase in the average number of manta ray sightings per survey day at Hanifaru Bay in 2019 from May to August (*n*=8 and 21 respectively) (Fig. 9), with the greatest number of individuals seen in August (*n*=259). It should be highlighted that there were no recorded sightings during 2019 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 29th July 2019 saw the greatest number of individuals recorded on a single day during the year, with a total of 116 confirmed individual reef manta rays identified from Hanifaru Bay.

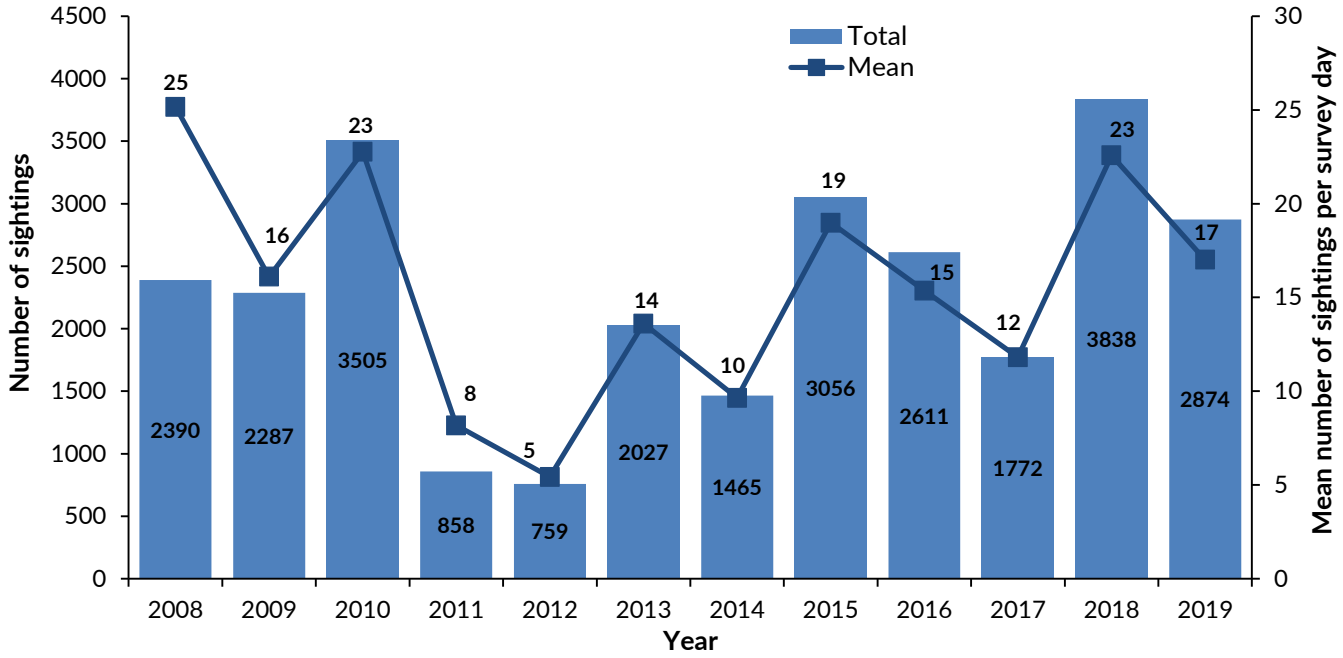


Figure 8: Annual sightings of reef manta rays (*Mobula alfredi*) in Hanifaru Bay, and the mean number of sightings per survey day.

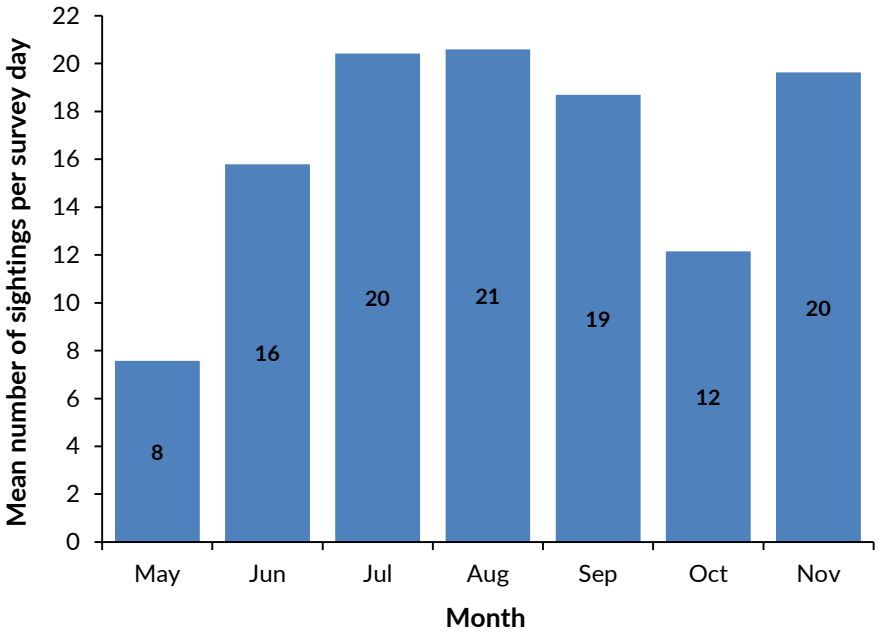


Figure 9: Average number of reef manta ray sightings (*Mobula alfredi*) recorded per survey day inside Hanifaru Bay during each month of intensive surveying in 2019.

Angafaru (Marine Protected Area)

The Angafaru MPA includes Angafaru, Angafaru Falhu, Dhonfanu Thila, and Dhigu Thila. In previous years, the total number of sightings recorded in this area was relatively low with minimal peaks in 2014 and 2016 (*n*=64 and 52 respectively). Total sightings in 2019 were significantly higher than previous years (*n*=209) (Fig. 10). When standardising the data by number of days this area was surveyed, 2019 shows an increase in the sightings per day (*n*=2) from 2018 (*n*=1). Monthly breakdowns of average sightings per day revealed an increase in July (*n*=2) and a significant peak in September (*n*=10), all other months had an average of zero sightings (Fig. 11). It should be noted that the majority of sightings were recorded during mass feeding events at Angafaru Falhu on September 12th and 13th (*n*=68 and 58 respectively). The occurrence of mass feeding activity demonstrates the ecological importance of the Angafaru MPA and highlights the need to effectively manage and monitor this area closely in years to come.

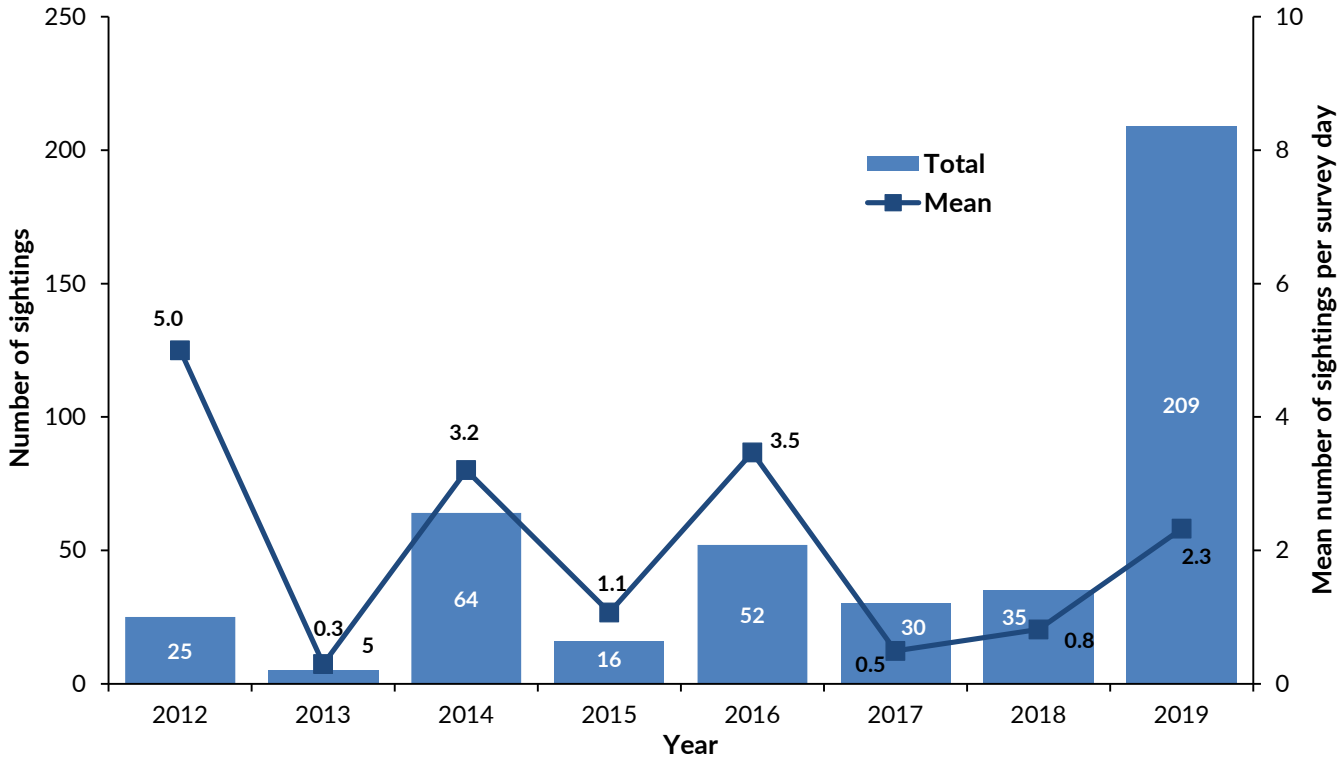


Figure 10: Annual sightings of reef manta rays (*Mobula alfredi*) in the Angafaru MPA, and the mean number of sightings per survey day.

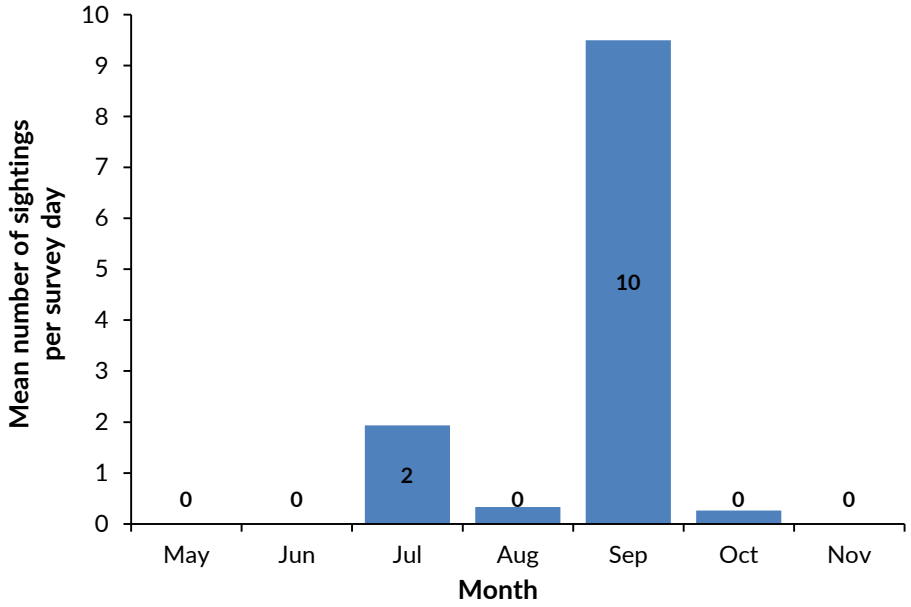
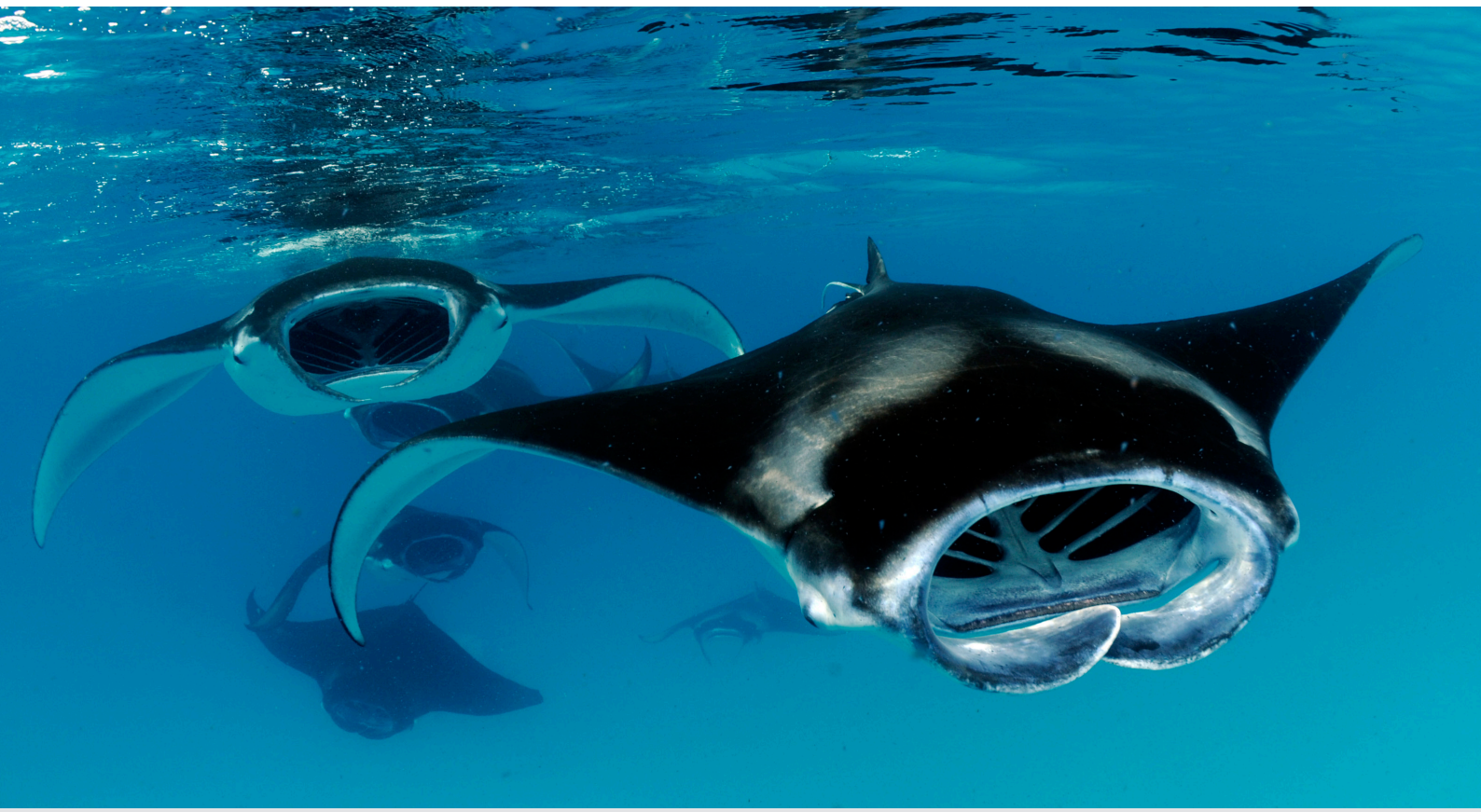


Figure 11: Average number of reef manta ray (*Mobula alfredi*) sightings recorded per survey day in the Angafaru MPA during each month of intensive surveying in 2019.

Population Demographics

The total number of individual reef manta rays which have been recorded in Baa Atoll during the last decade is 2,097, almost half (42%) of the Maldives reef manta ray population (*n*=4,942). As of 2019, population demographics of Baa Atoll constitute 53% females (*n*=1,116), 46% males (*n*=972) and <0.5% individuals for which the sex could not be determined (*n*=9). Of these manta rays recorded in Baa Atoll (*n*=2,097), 50% (*n*=1,057) 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. 12). This highlights the importance of Baa Atoll as a core aggregation site for the Maldives manta ray population during the Southwest Monsoon.



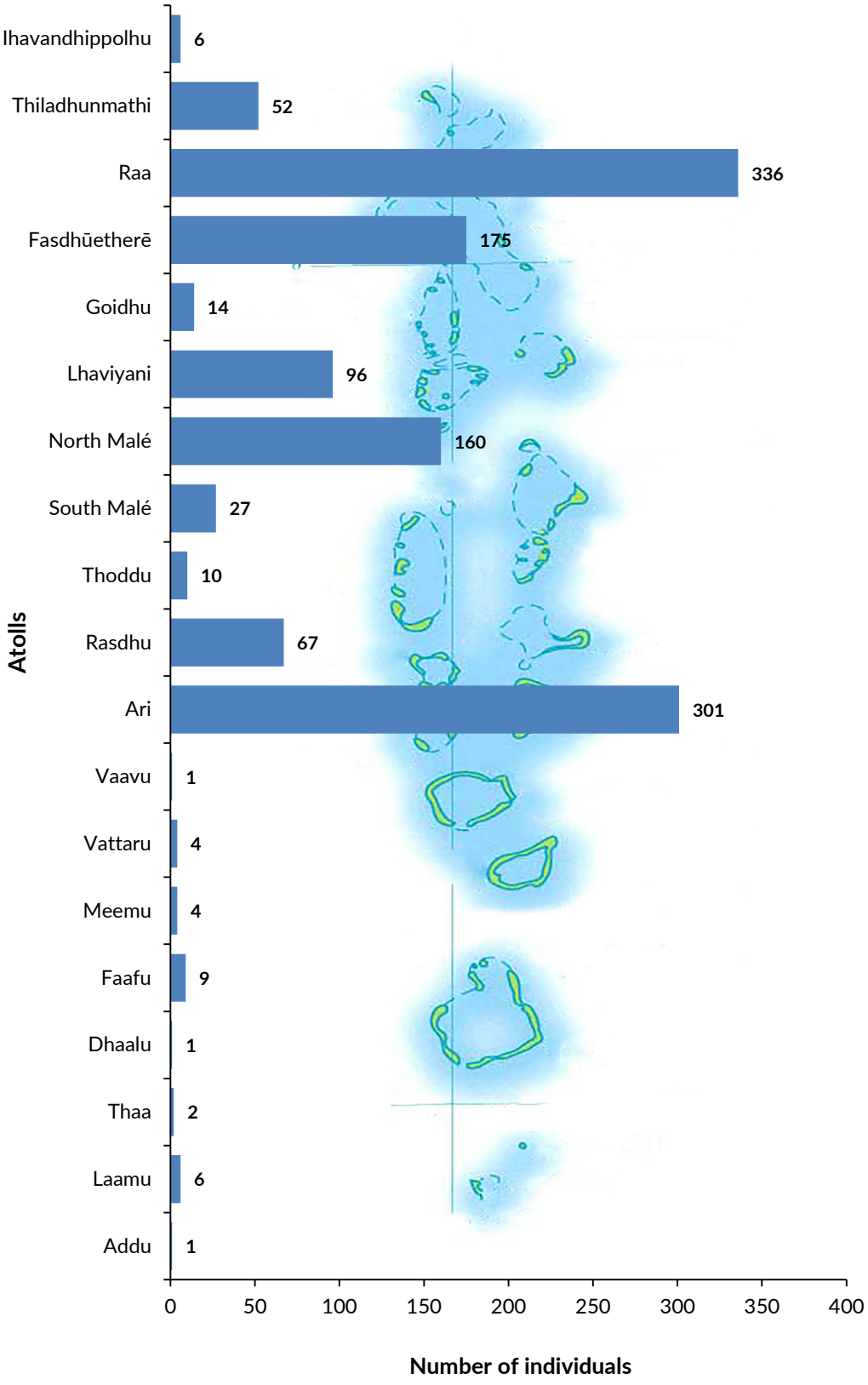


Figure 12: Number of reef manta ray (*Mobula alfredi*) individuals (*n*=1,057) from among the Baa Atoll population (*n*=2,097) which have been recorded in other atolls throughout the Maldives Archipelago.
* Many of these cross-atoll individuals have been observed in more than two atolls.

Throughout May to November, a total of 385 adult and 197 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 recorded month of the sampling period, there were more sightings of female juvenile manta rays than their male counterparts. Similarly, the ratio of adult female and male manta ray individuals favoured females throughout May to November, with the exception of August and September, when males were more frequently sighted by 2.8% and 0.2% respectively (Fig. 13). The relatively high number of sightings and small difference in the ratio between males and females during this time may highlight favourable conditions in August and September for adult manta rays. The peak in adult male manta ray sightings occurring in July may be correlated with an increase in reproductive activity. The frequency of courtship behaviour was recorded at least 20% (*n*=6) higher in July than any other month. 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 manta rays at focal reproductive sites at specific times of the year.

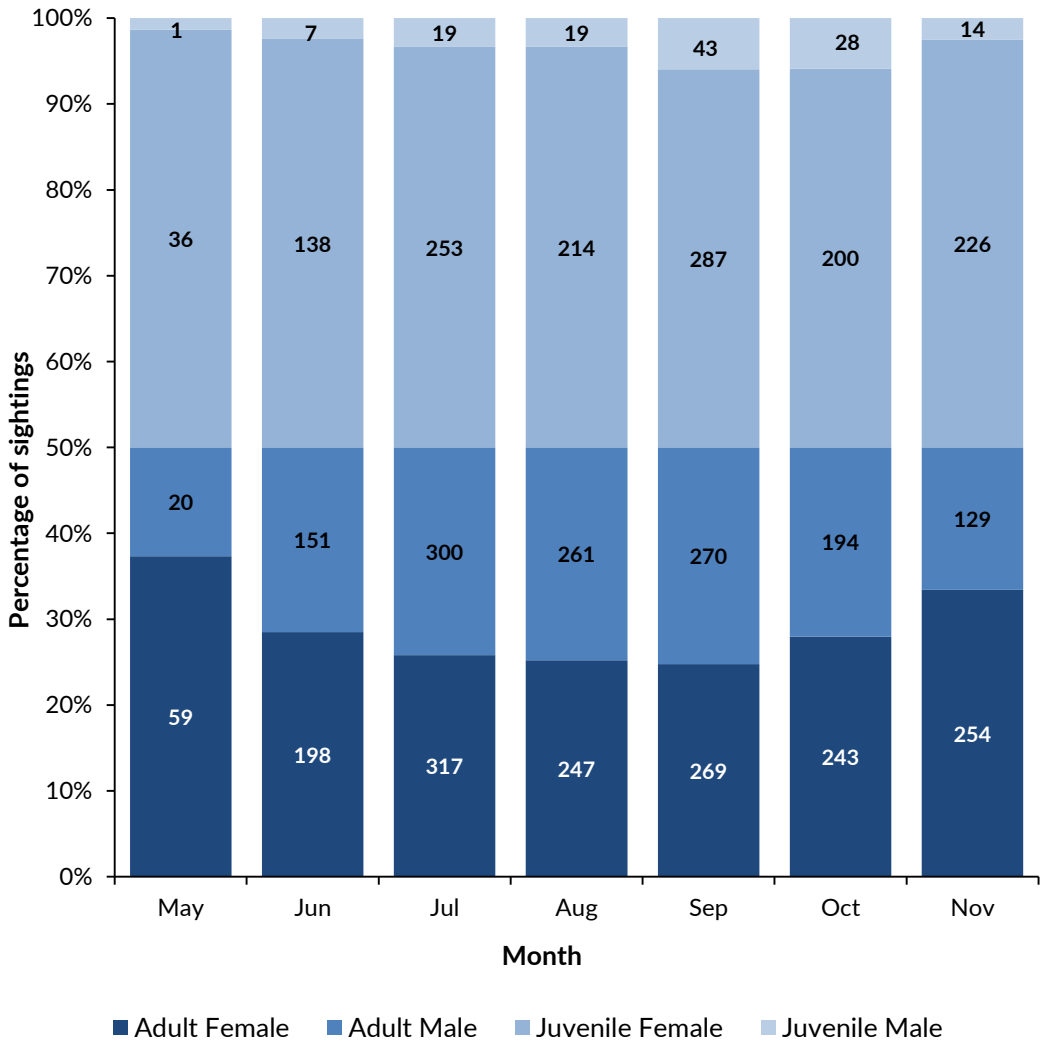


Figure 13: Reef manta ray (*Mobula alfredi*) sightings distribution categorised by maturation status during each month of intensive surveying effort in Baa Atoll in 2019. *Actual numbers within bars.*

POPULATION RECRUITMENT

A total of 280 new individual reef manta rays were documented across the Maldives during 2019, a population recruitment of approximately 6% from the previous year (2018, *n*=4,662). As of 2019, the Maldives reef manta ray population was comprised of 4,942 individuals. Of the 280 new individuals added to the MMRP database, 15% (*n*=42) were documented in Baa Atoll during 2019, demonstrating a slight decline from the previous year (2018, *n*=54) (Fig. 14).

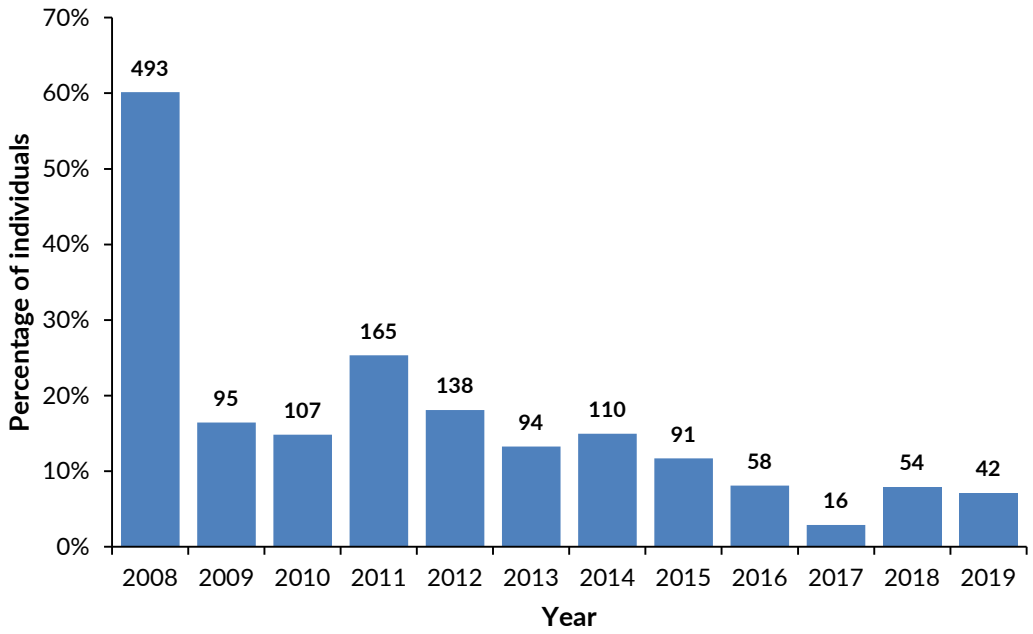


Figure 14: Proportion of the total reef manta rays (*Mobula alfredi*) sighted annually in Baa Atoll which were newly sighted individuals. Actual number of new individuals above bars.

Of the 37 new manta rays sighted in Baa between May and November; 4% were adult manta rays (*n*=7), and 96% were juveniles (*n*=30). Seven 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 amongst the identified pups were as follows; 43% female (*n*=3), 57% male (*n*=4).

The decrease in newly identified manta ray individuals during 2019, follows the general downward trend of the proportion of newly sighted individuals throughout previous years (Fig. 14). As more data is collected over the years by the MMRP, the number of new individuals (especially adults) becomes less frequent, suggesting that most of the Baa Atoll (and indeed the Maldives) reef manta ray population has been recorded and identified.

REPRODUCTIVE FECUNDITY

This report marks the seventh 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 2019 decreased from the previous year (*n*=59 in 2018), with a total of 29 individuals recorded as pregnant, and a further 14 females recorded with fresh reproductive wounds but not pregnant. Furthermore, the proportion of pregnancies recorded among Hanifaru Bay's core population of mature female reef manta rays in 2019 has decreased since peaking in 2017. Of the 50 individuals that comprise of Hanifaru Bay's core adult female population, 52% were sighted in 2019, and less than half (31%) of these individuals were visibly pregnant. In comparison, over half (60%) of this core population was sighted in 2017 with 53% of individuals recorded as pregnant, followed by a decline to 54% of the core 50

sighted with 44.4% of individuals pregnant in 2018 (Fig. 15). This gradual decline in the sightings of the core 50 females annually since 2013 is likely a result of natural mortality.

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 29 pregnant females observed in Ball Atoll during 2019, 76% (*n*=22) were in the later stages of gestation (3rd or 4th trimester) when first sighted.

The decline in pregnancies during 2019 highlights the importance of continuing and increasing the protection of the species and its habitats in a changing environment. Overall manta rays display slow reproductive rates, which, on average, show only 19% 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.

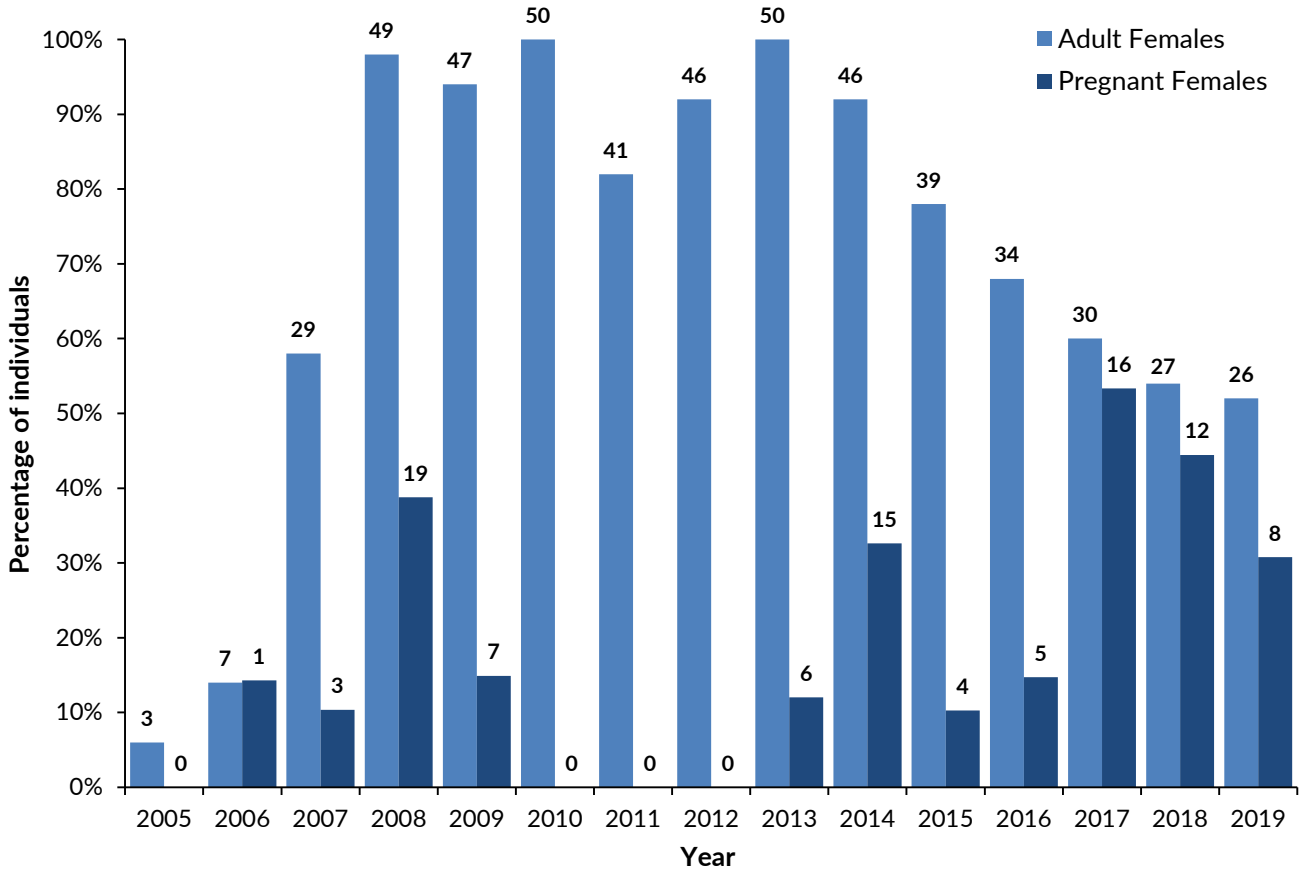


Figure 15: Percentage of Hanifaru Bay's core adult female reef manta ray (*Mobula alfredi*) population (*n*=50) sighted annually, and the percentage of those females which were recorded pregnant in the same year. *Actual numbers above bars.*

WHALE SHARK SIGHTING TRENDS

In Baa Atoll, whale sharks often inhabit the same feeding grounds as reef manta rays and are regularly sighted together along shallow reefs throughout the Maldives. In 2019, there were 22 whale shark sightings of 12 different individuals recorded in Baa Atoll between May and November (Fig. 16). Of these 12 individuals, 33.3% (*n*=4) were new to the Maldives Whale Shark Research Programme's database. Monthly breakdowns reveal that the first sighting occurred in July (*n*=1), while the greatest number of sightings in 2019 were recorded during the month of August, followed closely by September (*n*=12, *n*=8 respectively) (Fig. 17). Interestingly, the MMRP recorded the highest number of manta ray sightings in July (*n*=890), followed by September (*n*=873), suggesting that the prevailing conditions noted from July through September were most favourable for these planktivorous creatures. Within Hanifaru Bay, July and August marked the peak in manta ray sightings (*n*=592, *n*=556 respectively), while August additionally marked the

peak of whale shark sightings in the bay (*n*=2) (Fig. 18). Overall, whale shark sightings in Hanifaru comprised of 18% (*n*=4) of the total sightings. It should be highlighted that like the reef manta rays, there were no recorded sightings during 2019 of whale sharks at Hanifaru Bay outside of the MMRP survey period (May-November), indicating that the arrival of these megafauna to Hanifaru Bay is linked with the onset of the Southwest Monsoon. Although 2019 revealed a slight decline in sightings throughout Baa Atoll of 12% from 2018 (*n*=25), we remain optimistic that 2020 will reveal stability within the population.

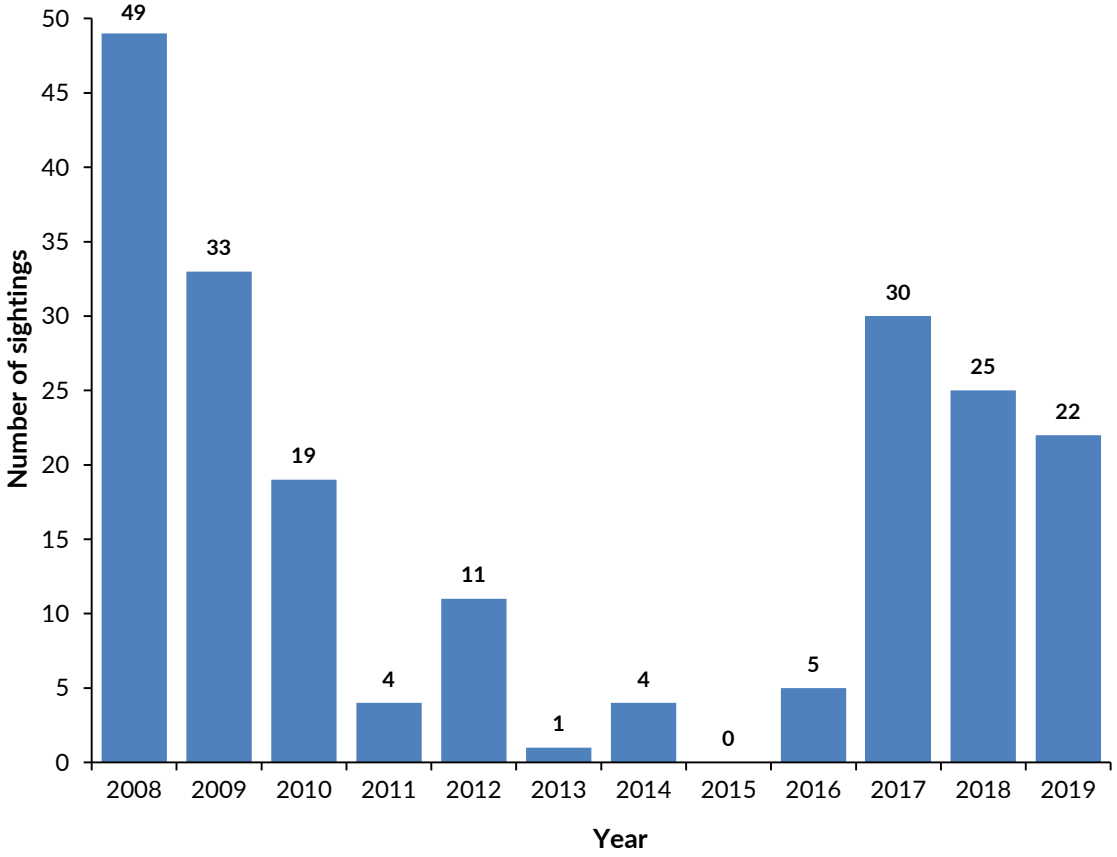


Figure 16: Annual sightings of whale sharks (*Rhincodon typus*) in Baa Atoll.

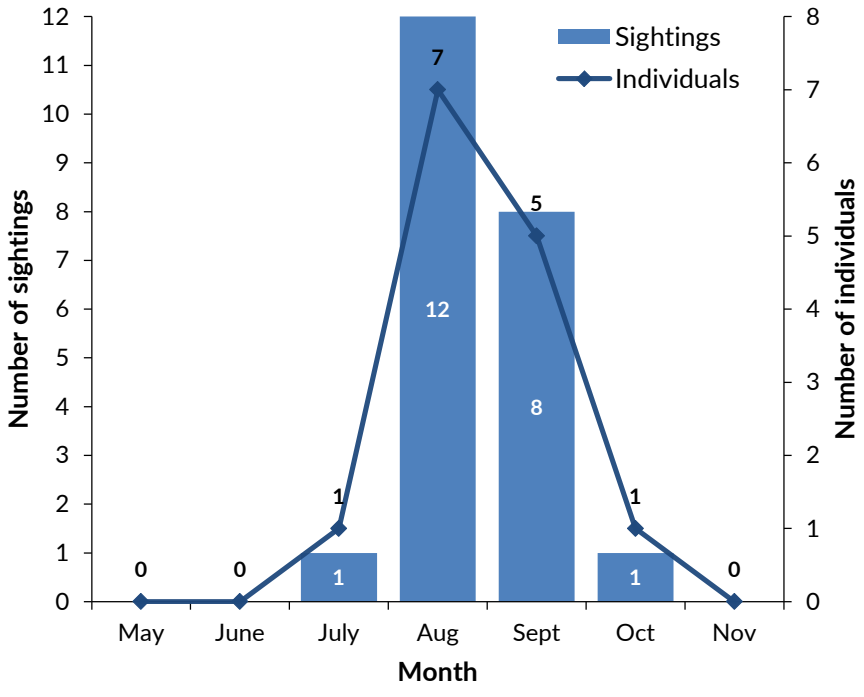


Figure 17: Whale shark (*Rhincodon typus*) sightings in Baa Atoll during 2019, and the total number of individuals recorded each month.

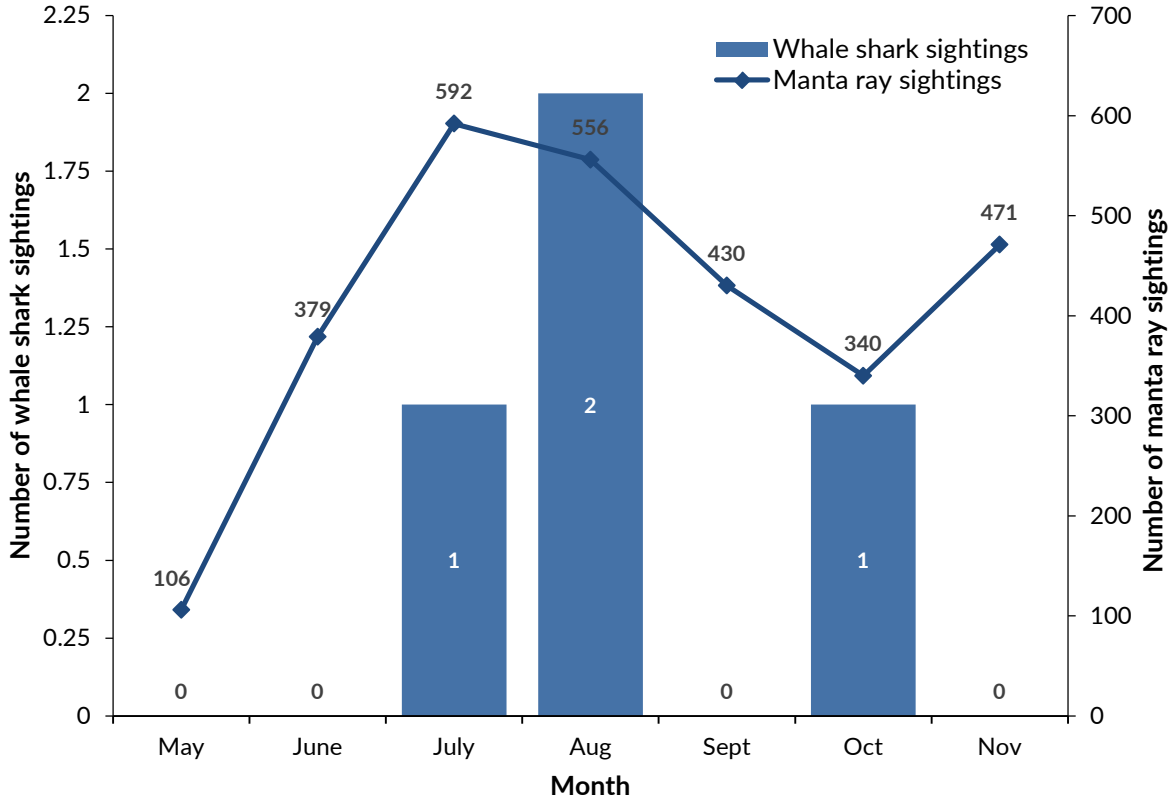


Figure 18: Monthly whale shark (*Rhincodon typus*) and reef manta ray (*Mobula alfredi*) sightings recorded at Hanifaru Bay, Baa Atoll in 2019.

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. In the years preceding 2019, May (which marks the start of the Southwest Monsoon) typically demonstrates characteristically high wind speeds. In 2019, maximum wind speeds were recorded in June at 17.3 km/h. The months of May through August showed little variation before declining to 12.2 km/h in November 2019. In turn, average manta ray sightings per survey day steadily increased throughout May and July before reaching a final peak in September (n=31) following the stronger monsoonal winds noted early in the season (May-August) (Fig. 19). Data from previous years indicate cyclical trends where average manta sightings tend to increase one or two months following an increase in average wind speeds. 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. This cyclic trend is therefore likely due to the time it takes between increased primary productivity and the blooms of zooplankton to occur. The average wind speed observed in 2019 was 14 km/h, lower than 2018 (18 km/h) (Fig. 20). Across all years, generally, when the annual wind speed increases, so do the average number of manta ray sightings (Fig. 20). This hypothesis may explain the decrease in the average number of sightings per day from 2018 as the average wind speed of the 2019 Southwest Monsoon similarly declined from 2018.

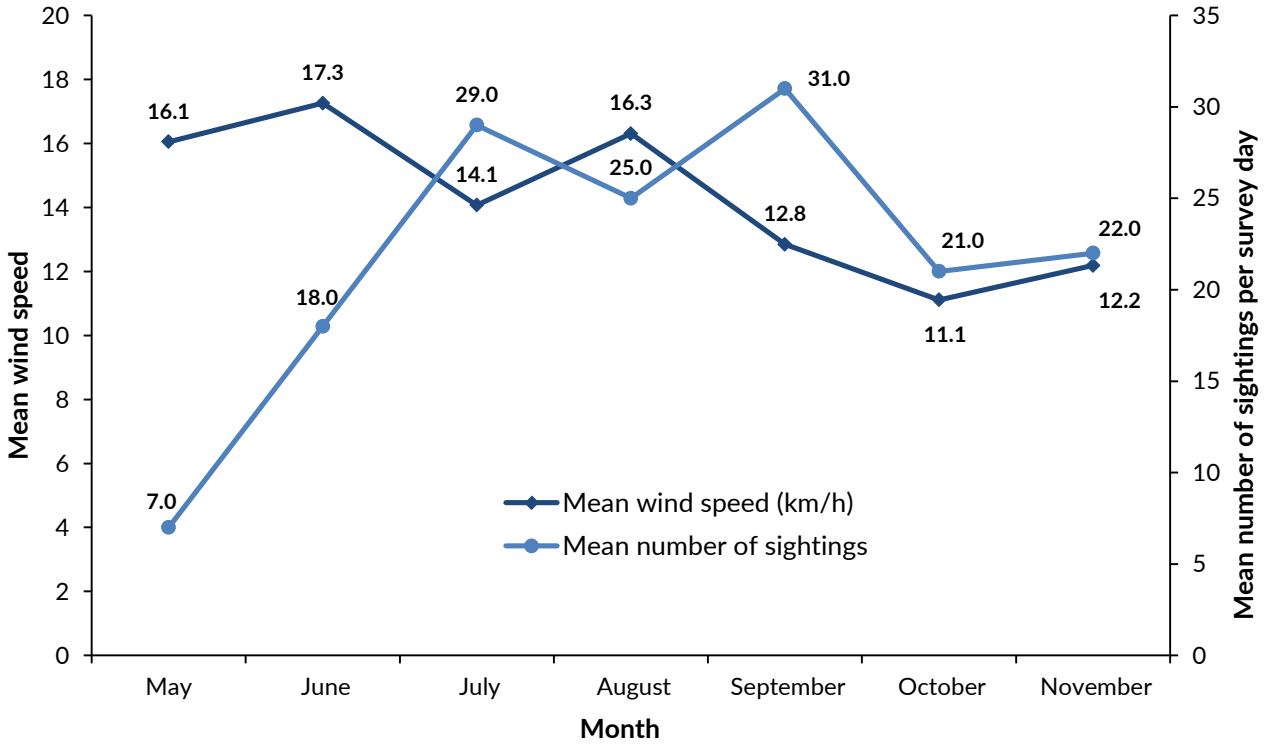


Figure 19: Mean monthly wind speed (km/h) and mean number of reef manta rays (*Mobula alfredi*) sightings per survey day in Baa Atoll (2019).

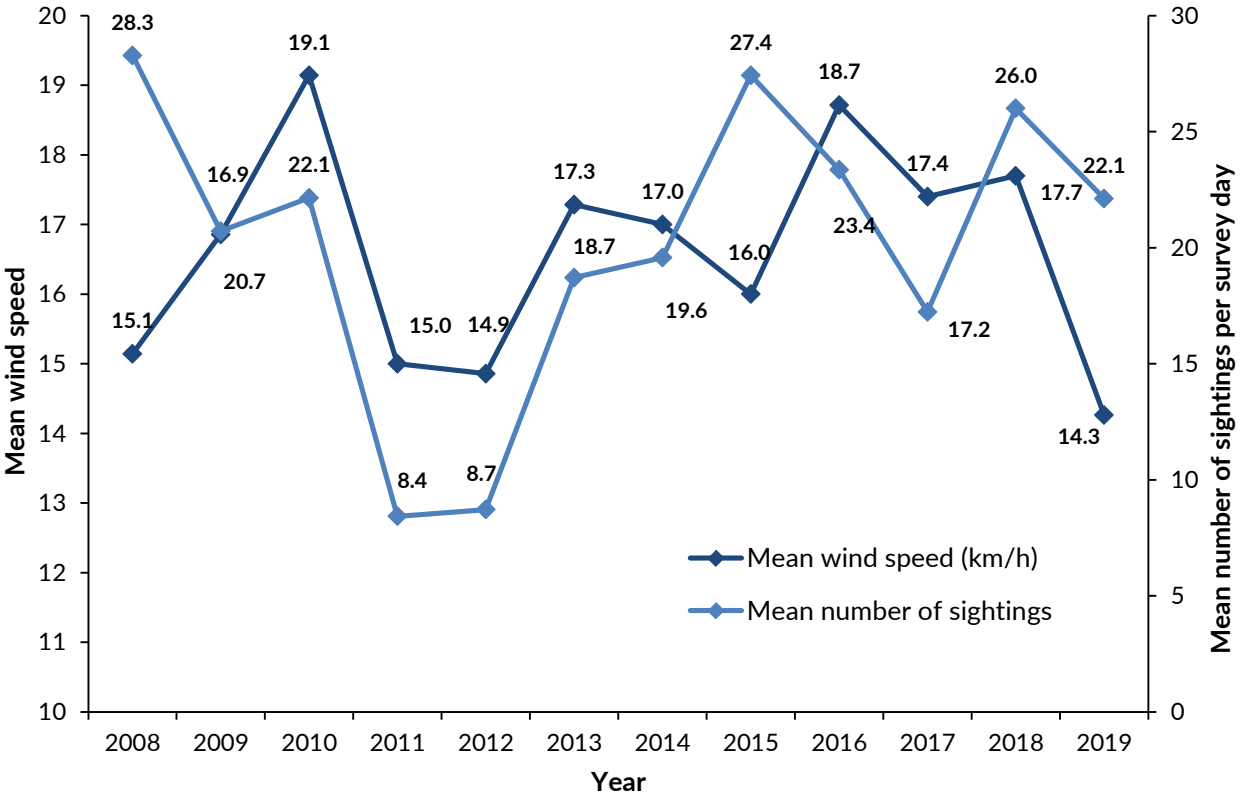


Figure 20: Mean annual wind speed (km/h) and the mean number of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll.

At the beginning of 2019, a local Vantage Vue weather station was deployed at the Four Seasons Resort on Landaa Giraavaru to log fine scale changes in weather conditions for the region. Wind directions recorded from the Vantage Vue station reveal variability throughout May to November (Fig. 21). Directions were classified into 8 main directions combining multidirectional winds into their main category (i.e. WSW winds were classified as westerly). As expected during the Southwest Monsoon, winds coming in from the general west direction dominated from May to September contributing to 44%-56% of wind direction readings during this time (Fig. 21). The beginning of the season (May and June) were marked with distinctly high westerly readings followed by a decrease during July, August and September. Although westerly readings from August were consistent with July, the percentage of readings from the southwest direction increased in August by 12% from the previous month. In comparison, average manta ray sightings per survey day increased substantially during the beginning of the season. Average manta ray daily sightings decreased from July (*n*=29) to August (*n*=25). However, with a greater contribution of winds from the southwest and west (64%) in August, average sightings increased once again subsequently reaching a final peak in September (*n*=31) (Fig. 21). As a force acting in combination with increased wind speed, wind directions dominating from the west and the southwest may additionally influence the favourable conditions which result in an increase in manta ray sightings.

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. Larger climatic phenomenon such as the Indian Ocean Dipole (IOD) and the El-Niño Southern Oscillation (ENSO) are likely to be connected to these fluctuations as both have been 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. These observations should be considered seriously because of the negative economic consequences they can have, regardless of cause and ecological ramifications. Not only will manta ray tourism be directly affected by these trends, 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.

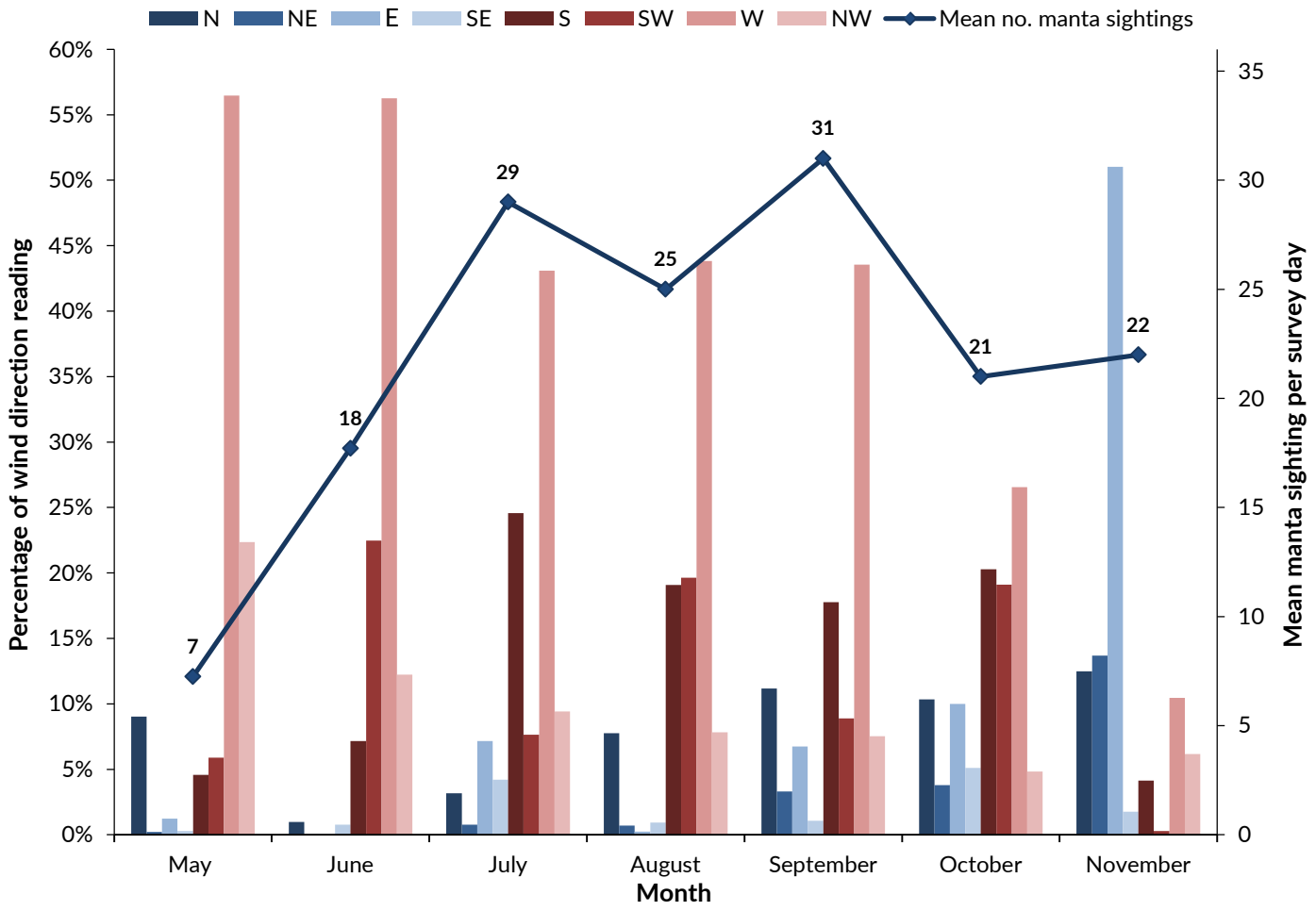


Figure 21: Monthly breakdown of the percentage of Baa Atoll wind direction readings from Vantage Vue weather station situated at Landaa Giraavaru, and the average number of reef manta ray (*Mobula alfredi*) sightings per survey day (2019).

SUB-LETHAL INJURIES

Of the 2,097 individual reef manta rays recorded in Baa Atoll, 30% (*n*=631) were recorded with sub-lethal injuries. Of those injured manta rays; 87% (*n*=551) have only one injury, 12% (*n*=73) have two recorded injuries, and seven individuals (1%) have three injuries. Fifty-seven percent (*n*=351) of recorded injuries (with known origin) resulted from natural sources, whilst the remaining 43% (*n*=261) resulted from an anthropogenic source. Demographically, instances of injuries are roughly the same between females and males, but higher in adults than juveniles. Sixty-six percent (*n*=133) of injuries recorded to juveniles are naturally caused (Fig. 22). The increased presence of injuries, anthropogenic and natural, to the adults is unsurprising, as these individuals are older and therefore likely to have encountered threats more often than juveniles during their life.

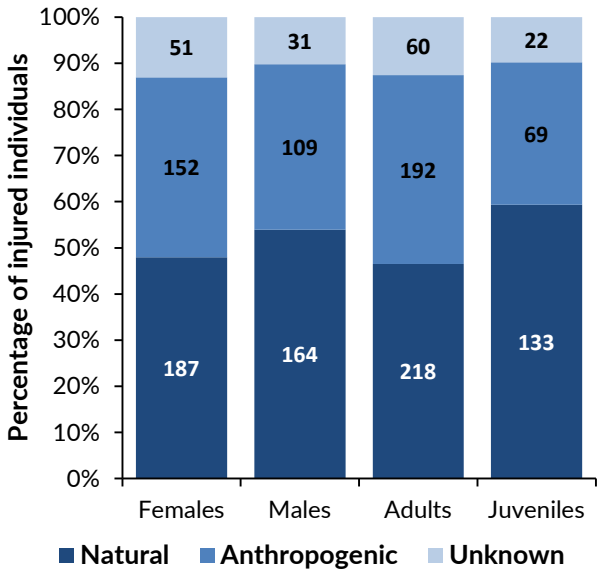


Figure 22: Demographic variations in the number of sub-lethally injured (*n*=631) reef manta rays (*Mobula alfredi*) within the Baa Atoll Region population (*n*=2,097), and likely injury origin (natural, anthropogenic or unknown). Actual number of injuries on bars.

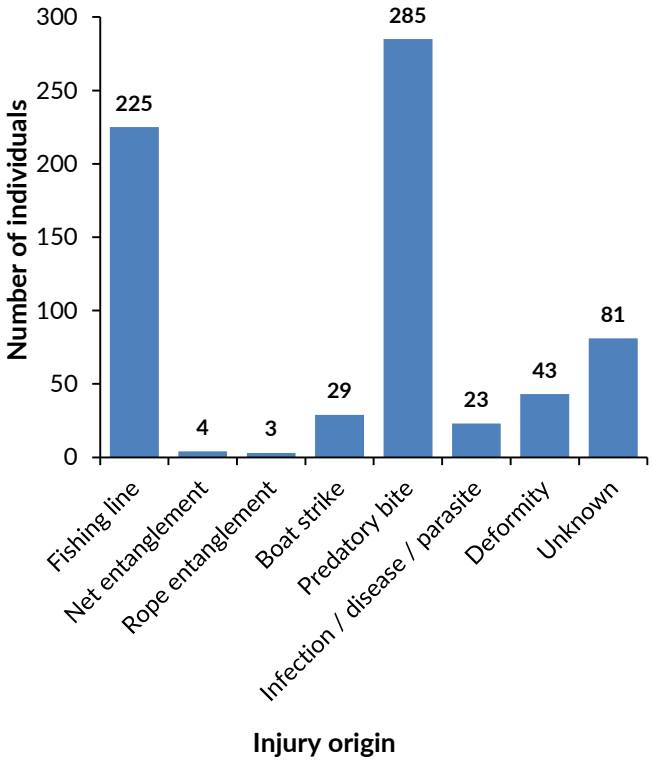


Figure 23: Variations in the likely origin of sub-lethal injuries (*n*=693) within the injured reef manta ray (*Mobula alfredi*) population of Baa Atoll (*n*=631).

Across all individuals sighted within Baa Atoll, the most common cause of injuries (for both adults and juveniles) was from predatory bites (*n*=285), followed closely by fishing line (*n*=225). Deformities, boat strikes, infections, disease, parasites, net and rope entanglement were less frequent, with *n*=43, 29, 23, 4 and 3 recorded cases respectively (Fig. 23). Of all the manta injuries recorded across four different demographics (male, female, adult and juvenile), 65-68% are inflicted upon the manta rays' pectoral fins (Fig. 24). Most predatory bites (mainly inflicted by large sharks) occur on the manta ray's anterior pectoral fin region. Manta rays cannot see well directly behind them, making them more vulnerable to predatory attacks in this area.

Manta rays that have been recorded with new injuries in 2019 follow a similar trend to that of the whole Baa Atoll population in terms of injury origin. Of all injuries (*n*=59), 49% could be identified to a specific cause (*n*=29). Most injuries were attributed equally to fishing line (*n*=10) and predatory bites (*n*=11), followed by boat strikes (*n*=3) and infection, disease and parasites (*n*=3) (Fig. 25). Of all anthropogenic threats, fishing line most greatly affects the Baa Atoll manta ray population, highlighting areas where management should be improved to protect the species in this region.

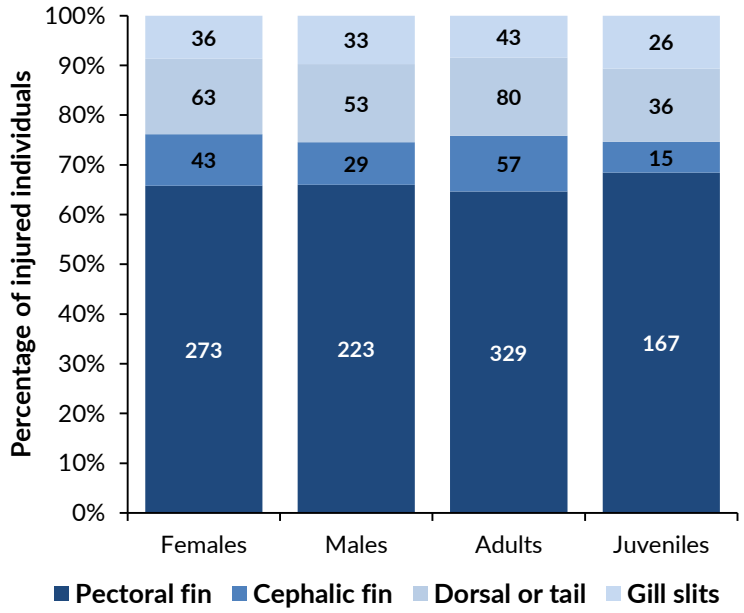


Figure 24: Demographic variations in the number of sub-lethal injuries by body area, within the injured reef manta ray (*Mobula alfredi*) population of the Baa Atoll Region (*n*=631). Actual number of injuries on bars.

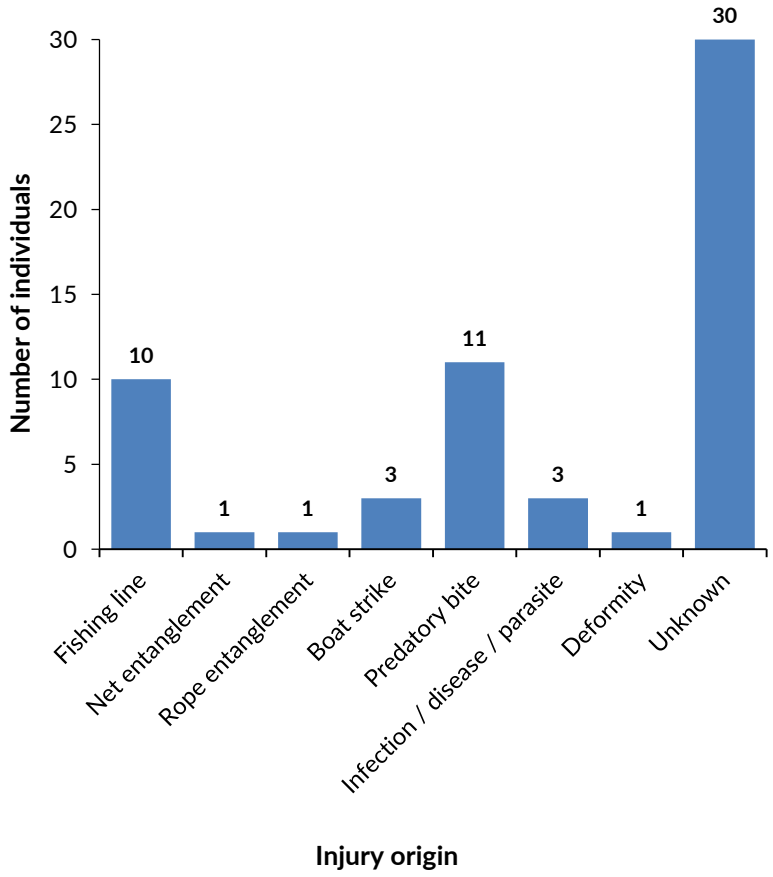


Figure 25: Variations in the likely origin of sub-lethal injuries (*n*=59) within the reef manta rays (*Mobula alfredi*) recorded injured in Baa Atoll in 2019.

REMOTE UNDERWATER VIDEO SURVEYS

Remote underwater video surveys (RUVs) are commonly used in research to monitor specific areas and their use by different marine life whilst humans are absent. In 2019, of the total 2,355 surveys conducted between May and November, 1,629 were carried out by MMRP researchers (69%), 508 were submitted by outside contributors (22%), and 218 were done using RUVs (9%). A total of 322 sightings were recorded over the 218 RUV surveys, which makes up 7% of the total sightings between May and November (*n*=4,405). Nine individuals were sighted only on the RUV surveys and not by human observation, three of which were newly identified in 2019 (MV-MA-4669, MV-MA-4742 and MV-MA-4939). The highest number of monthly sightings recorded by RUVs was 98 (in October), and the lowest was two (in May) (Fig. 26). In July and October, the average sightings per RUV was the same as the average over MMRP surveys (*n*=3 and 2 respectively), all other months the average RUV sightings were lower than the average over MMRP surveys. Out of the 14 individuals recorded engaging in courtship behaviour in 2019, six were sighted by RUVs. These sightings of courtship are not unexpected; reef manta rays often partake in courtship on cleaning stations, and RUVs are placed at cleaning stations to collect data. It is our aim to expand our understanding of site use by reef manta rays in the Maldives through further use of this non-invasive research method in 2020.

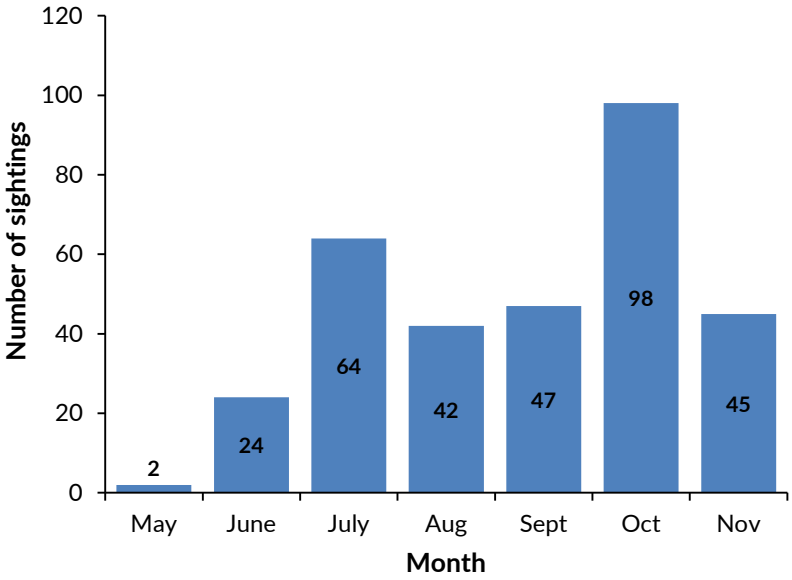


Figure 26: Monthly breakdown showing the number of reef manta ray (*Mobula alfredi*) sightings using Remote Underwater Video systems in Baa Atoll in 2019.

TOURISM ACTIVITIES

Throughout 2019, the MMRP strove to improve the sustainability of manta ray tourism activities in Baa Atoll by undertaking workshops aimed at those leading swim-with-manta-rays tourism initiatives, as well as those who are directly involved in the protection of manta rays and their environment across the Maldives. To kick off the manta ray season in May, a workshop was held for 55 tour operators and community members in Baa Atoll. Attendees came from 21 resorts, guest houses, dive centres and community councils. The primary aim of this workshop was to provide marine users with the necessary tools to conduct sustainable manta ray tourism activities; to safeguard against any negative ramifications of human-manta ray interactions and ensure the conservation of the Maldives manta ray population. The information sharing event provided education on manta ray biology, ecology, the MMRP Marine Education Program, research the MMRP conducts (including findings from the 2018 manta season), and the MMRP's citizen science and best Code of Conducts for interacting with manta rays in the water. Additionally, the Biosphere Reserve Rangers presented on Hanifaru Bay and its importance.

In contribution to a three-day workshop hosted by the Environmental Protection Agency and the Baa Atoll UNESCO Biosphere Reserve in November 2019, the MMRP and Four Seasons Landaa Giraavaru held a one-day event wherein 22 protected areas staff from throughout the Maldives were in attendance. The workshop was aimed at improving management practices, research and collaborations within marine protected areas across the Maldives. Participants included members of the Baa Atoll UNESCO Biosphere Reserve, Environmental Protection Agency, Ministry of Environment, Addu Nature Park, South Ari Marine Protected Area, and Fuvahmulah Nature Park. The event included educational presentations focusing on manta ray biology, ecology and key research findings, while highlighting the contribution of research to the function of a biosphere reserve. In addition to research efforts, the MMRP shared the importance of outreach and collaboration to the effectiveness of a protected area and long-term conservation. Following information sessions, all participants headed to Hanifaru Bay to swim with manta rays. The workshop concluded with a cross-learning session wherein protected areas staff shared and discussed the successes and obstacles they face within their management strategies and how they might implement or improve such strategies. Considering the success of these workshops, similar outreach events will be scheduled in 2020.

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, including boat speeds linked to these activities, at manta sites and other protected areas throughout Baa Atoll. Rules and regulations within Hanifaru Bay aid in the protection of these animals. However, these measures (or similar) should be implemented at other key manta ray aggregation sites in Baa Atoll. It is crucial the tourist community understand the importance of safe boating and in water best practices.

BAA ATOLL MARINE EDUCATION PROGRAMME

'Moodhu Madharusaa' or 'Ocean School' is the MMRP's flagship marine education programme. Moodhu Madharusaa aims to:

- Build a conservation-aware generation that will take stewardship of their environment.
- Inspire intergenerational change in communities.
- Equip students with skills to pursue marine-based careers.
- Increase swimming and snorkelling confidence.

The MMRP, in partnership with the Ministry of Education, spend up to 6-months with each Moodhu Madharusaa school. Students are educated about marine biology and conservation through five core modules: Marine Ecology, Coral Reefs, Marine Megafauna, Seagrass and Mangroves, and Ecosystem Conservation.

The programme promotes experiential learning, whereby students learn through a broad range of experiences. Moodhu Madharusaa prioritises snorkelling and nature exploration field trips, supported by theory classes and practical activities (Fig. 27). From designing and delivering presentations for their younger peers, to creating awareness-raising videos, and participating in a mock research conference, homework is designed to encourage intergenerational learning.

Moodhu Madharusaa has been expanding in reach since its inception in Baa Atoll in 2015. Over 160 students from five schools across two atolls have now completed the programme, and another 100 are expected to complete the programme during 2020 (Fig. 28).

During June – December 2019 sixty students from Baa Atoll Education Centre (BAEC), Eydhafushi completed Moodhu Madharusaa. The students completed over 60 hours of taught classes and fieldtrips and achieved a 70% pass rate in the final exam. Highlights included a field trip to the Olhugiri mangroves with our partner the Baa Atoll UNESCO Biosphere Reserve (BR) and preparing a stall and educational performance for the Baa Atoll Manta Festival 2019. Pre- and post-programme surveys show that the students' marine environmental knowledge increased by 19% after completing the Moodhu Madharusaa programme. Students spent 42% more-time snorkelling and exhibited improved marine environmental attitudes, pro-environmental behaviours, and swimming and snorkelling confidence. The Eydhafushi programme was a great success due to a high level of collaboration between partners and enthusiasm from the BAEC school community.

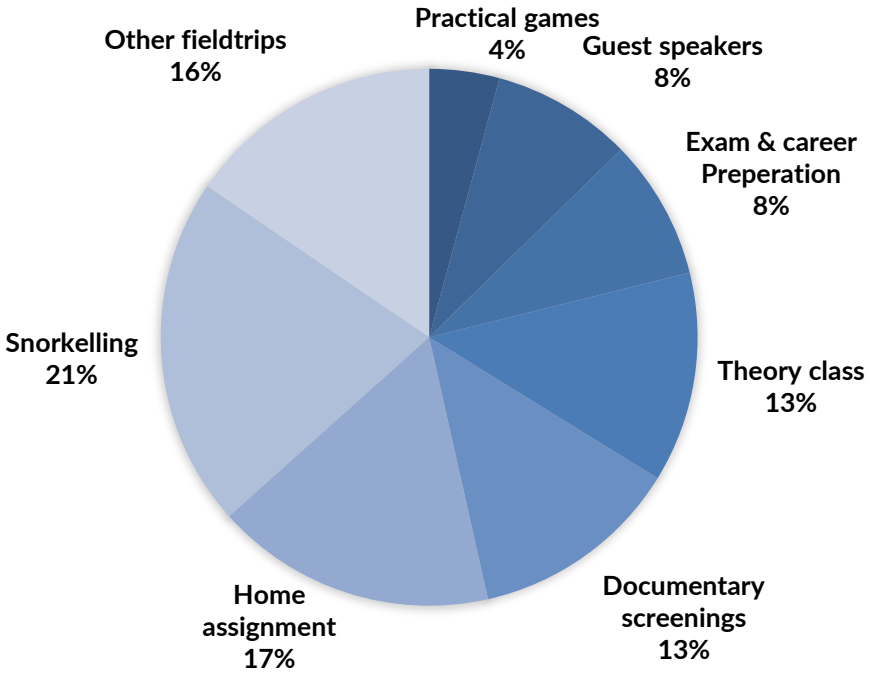


Figure 27: Percentage of time devoted to each activity which comprised the Moodhu Madharusaa Marine Education Programme.

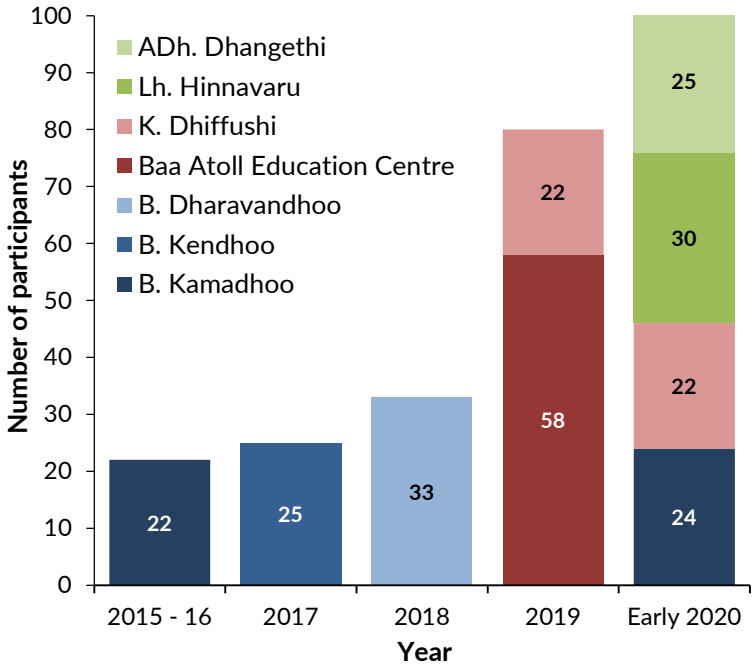


Figure 28: Number of students participating in the Moodhu Madharusaa Marine Education Programme annually on different local islands in the Maldives.

MANTA FESTIVAL

The Baa Atoll Manta Festival 2019 was spearheaded by the Manta Trust's MMRP in collaboration with the Biosphere Reserve, the Island and Local Councils, the BAEC, and the Four Seasons Landaa Giraavaru. The festival brought together fifty local and international organisations. Successful collaboration culminated in a two-day event featuring thirty marine education stalls hosted by environmental organisations, resorts and schools. Educational activities included a multi-island beach clean and waste segregation session, conservation-themed performance competition and live art competition. The community-based festival benefitted numerous Eydhafushi businesses with over 1000 people visiting from more than a dozen islands.

Prior to the festival, the MMRP and the Biosphere Reserve coordinated with local resorts to take over 200 students and teachers from 11 schools in North Male' Atoll, Raa Atoll and Baa Atoll snorkelling with manta rays inside Hanifaru Bay, many for the first time. This initiative was a great success, eliciting high engagement and enjoyment from all participants, who afterwards exhibited a new appreciation for manta rays and their conservation. The MMRP aims to repeat this with the oldest students in each school annually.

Due to excellent support from the Eydhafushi community and our collaborators. the initiatives' reach and impact increased during 2019. Moodhu Madharusaa and the Manta Festival will continue to expand and aim to include as many communities as possible in snorkelling and outreach activities during 2020.


Photo by Thoriq Abdul Rahman


Photo by Thoriq Abdul Rahman

CONSERVATION & MANAGEMENT

Baa Atoll has been globally recognised as one of 700 UNESCO World Biosphere Reserves around the globe in-part because it's an ecologically important aggregation site for manta rays and whale sharks. As such, this location is an extremely important research location for these species globally. The designation of Hanifaru MPA as a core zone within the Reserve is extremely important for the conservation of the Maldives manta ray population. Therefore, this location needs 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 access to monitor 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

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 supportive of the Manta Trust and MMRP since its inception. We hope this partnership continues to prosper for years to come.

EPA

MARINE RESEARCH CENTRE

MALDIVES GOVERMENT 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:

Beth Faulkner - BSc (Hons)
Project Manager - Baa Atoll

Kaitlyn Zerr - BSc (Hons)
Assistant Project Manager - Baa Atoll

Flossy Barraud - MSc (Hons)
Education Officer - Baa 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:

baa@mantatrust.org **info@mantatrust.org**