



**Maldivian  
Manta Ray Project**

**BAA ATOLL | ANNUAL REPORT 2020**

*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 5,000 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 over 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

Since 2007, the Maldives reef manta ray (*Mobula alfredi*) population in Baa Atoll has been continuously studied by the Maldivian Manta Ray Project (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 (SW) 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 2020 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. It is important to note that due to the COVID-19 Pandemic and subsequent disruptions to the research base in Baa Atoll, the MMRP team survey effort was limited during May – July 2020. This report also presents data on various tourism and education activities conducted within Baa Atoll during 2020.

The MMRP, with outside contributions, conducted 1,205 reef manta ray surveys on 184 days in 2020. Of the 184, 147 survey days occurred during the Southwest Monsoon between the 13<sup>th</sup> May and the 30<sup>th</sup> of November 2020. Key findings of the MMRP in Baa Atoll during 2020 include a total of 5,471 sightings of 562 individual manta rays. Of these individuals, each manta ray was observed on average 9.7 times. The mean daily number of reef manta ray sightings per survey day between May and November in 2020 was 25, with a peak in daily manta ray sightings seen during the month of November ( $n=66$ ). A Residency Index (RI) was calculated to gauge the extent of movement

amongst those frequenting the region. The RI for 2020 (5.1%) represented an increase from 2019 (3.8%) and is the highest RI recorded since the MMRP's inception. The total number of sightings ( $n=4,644$ ) and number of individual manta rays ( $n=521$ ) recorded in Hanifaru Bay MPA in 2020 increased by 61% from 2019 records.

As of the end of 2020, the reef manta ray population demographics of Baa Atoll constitutes 53% females ( $n=1,129$ ), 46.5% males ( $n=984$ ), and 0.5% ( $n=9$ ) of individuals for which the sex could not be determined. Of these Baa Atoll manta rays ( $n=2,122$ ), 46% ( $n=980$ ) have also been seen in at least one other atoll in the Maldives. Of the 100 new reef manta rays added to the MMRP database from across the Maldives in 2020, 27% ( $n=27$ ) were documented in Baa Atoll during the Southwest Monsoon, a decrease from the previous year ( $n=42$  in 2019).

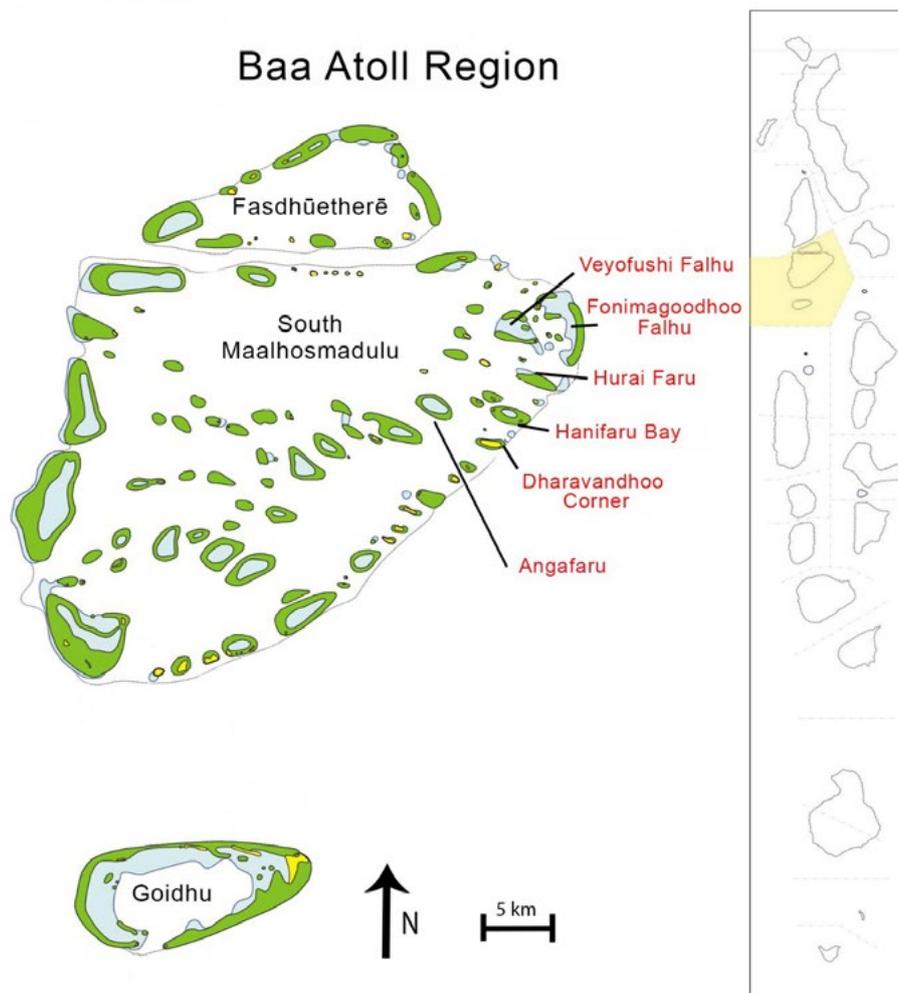
The number of pregnancies recorded in Baa Atoll ( $n=6$ ) was less than 80% of the observed pregnancies in 2019 ( $n=29$ ). In addition, nine females were recorded with fresh reproductive wounds but not visibly pregnant. Of the six pregnant females observed, all were recorded in the later stages of gestation (3<sup>rd</sup>–4<sup>th</sup> trimester).

In 2020, the Baa Atoll Marine Education Programme, 'Moodhu Madharusaa', continued to raise awareness about manta and devil rays, and the importance of the marine environment. Although COVID-19 interrupted planned operations of Moodhu Madharusaa, early 2020 saw a successful rollout of multiple theory classes, snorkelling lessons and field trips with Kamadhoo School, Baa Atoll.

# THE BAA ATOLL REGION

Geographically, the Baa Atoll Region (BAR) is comprised of three geographical atolls: South Maalhosmadulu, Fasdūetherē, and Goidhu (administratively and collectively, Baa Atoll) (Fig. 1). South Maalhosmadulu Atoll is a very large (943 km<sup>2</sup>) complex atoll, consisting of 60 islands and sandbanks, nine of which are inhabited and another dozen host resorts. The lagoon depth reaches a maximum of 49m and the channels separating the islands along the atoll's outer reef are mostly wide and deep. Fasdūetherē Atoll is much smaller (134 km<sup>2</sup>), has only 12 islands/sandbanks separated by wide channels and a shallow lagoon (34 m max.). Goidhu is the smallest of the three geographical

atolls (111 km<sup>2</sup>), with just four well vegetated islands and a few islets and sandbanks, it is considered an oceanic faro. Goidhu Atoll has a shallow lagoon (37m max.) with only one natural channel break in the south of the atoll, resulting in limited water flushing between the inner lagoon and outer reef. All three atolls are part of the northern section of the central Maldives archipelago; Fasdūetherē lies just 1km to the north of South Maalhosmadulu and the two atolls are separated by a shallow channel (Kudarikilu Kandū). Goidhu Atoll is located 12 km to the south of South Maalhosmadulu Atoll. Analysis throughout the report refers to this combined area as the Baa Atoll Region (BAR).



**Figure 1:** Map of the Baa Atoll Region showing the three geographical atolls (in black), six of the key reef manta ray (*Mobula alfredi*) aggregation study sites (in red), and the region in relation to the rest of the Maldives Archipelago (shaded yellow).

# UNDERSTANDING THE MONSOONS

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Understanding the effects of the Maldives Southwest (SW) 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 – October is recognized as *Hulhangu*, while December – March is known as *Iruvai*. *Hulhangu* and *Iruvai* refer to the Southwest and Northeast (NE) 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, the lunar phases and 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. Eastern Baa Atoll, and specifically Hanifar Bay, is often inundated with vast amounts of zooplankton during the Southwest Monsoon, and therefore, transforms into a hotspot for large aggregations of zooplanktivorous megafauna.



# STUDY PERIOD & SAMPLING METHODOLOGY

The Maldivian Manta Ray Project (MMRP) conducted surveys ( $n=983$ ) to locate manta rays in Baa Atoll between May 13<sup>th</sup> and 30<sup>th</sup> of November 2020 on as many days as possible, where the weather conditions allowed. MMRP surveys were carried out either by observers ( $n=881$ ) or Remote Underwater Video systems ( $n=102$ ). Full day survey trips were conducted on 134 days within a 214-day timeframe (May – November), or 63% of the possible monitoring period. Surveys were conducted at Hanifaru Bay, one of six 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. Outside the Southwest (SW) Monsoon, the MMRP conducted an additional 16 surveys on 13 days.

In addition to the data collected by the MMRP, surveys ( $n=206$ ) were also conducted by external parties over the entire year of 2020. The photographs submitted by outside contributors accounted for a majority of the sightings data outside of May – November. Supplementary to the 147

survey days carried out by the MMRP, external parties conducted surveys on 120 days. This resulted in reef manta ray sightings on an additional 37 days, bringing the total survey period to 184 days during 2020.

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, tourism information and multiple environmental variables were collected in addition to manta ray abundance and observed 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. This implementation of the management plan has resulted in a decrease in infractions and a well-maintained schedule. The regular collection of tourism fees for entry into the Bay have also resulted in significant annual revenues to manage the site and to contribute to the Biosphere Reserve's Baa Atoll Conservation Fund. These regulations and management initiatives are vital to ensure the efficacy of Hanifaru MPA in conserving the Maldives manta ray population by mitigating the harmful ramifications arising from human-manta ray interactions.

# REEF MANTA RAY SIGHTING TRENDS

## Baa Atoll Region

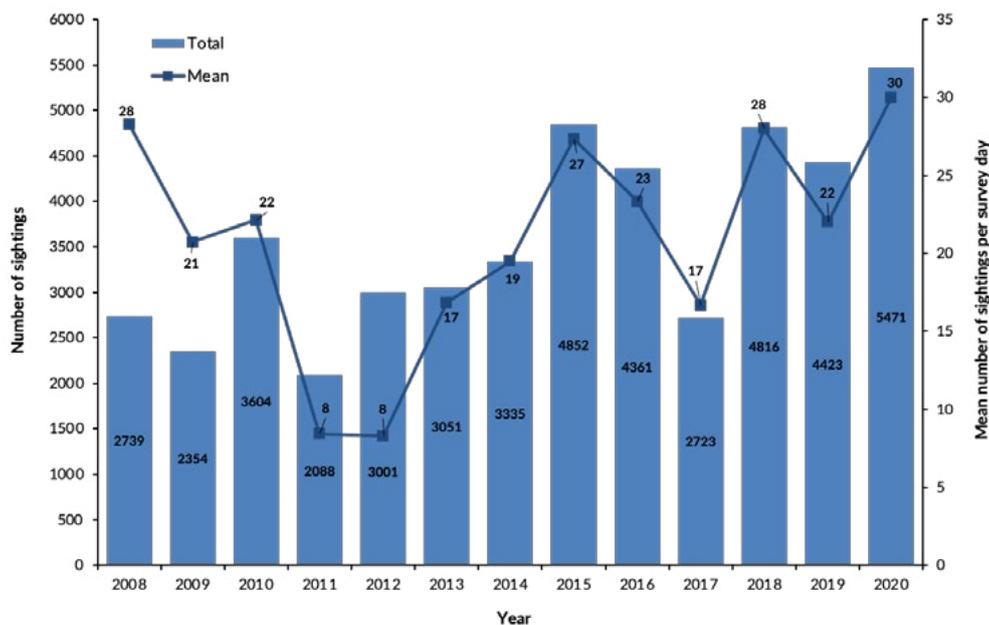
In 2020, a total of 5,471 reef manta ray sightings were recorded in Baa Atoll (Fig. 2). The data shows an increase (23.7%) in reef manta ray sightings compared to the previous year ( $n=4,423$  in 2019). The number of sightings documented in Baa Atoll during 2020 is the highest on record following previous years of high sighting numbers in 2015 ( $n=4,852$ ) and 2018 ( $n=4,816$ ) (Fig. 2).

Monthly breakdowns of these sightings in 2020, standardised for survey effort, show a general increase in average daily sightings from May to November (Fig. 3). Manta ray sightings peaked in November ( $n=66$ , average number of sightings per survey day), with the other months showing a marked decrease in manta ray sightings (Fig. 3). The mean number of reef manta ray sightings per survey day was 25 for the monitored Southwest Monsoon months of May – November. In comparison to past years, the mean sightings rate for the 2020 Southwest Monsoon was higher than in 2019 ( $n=22$ ) and similar to 2018 ( $n=26$ ).

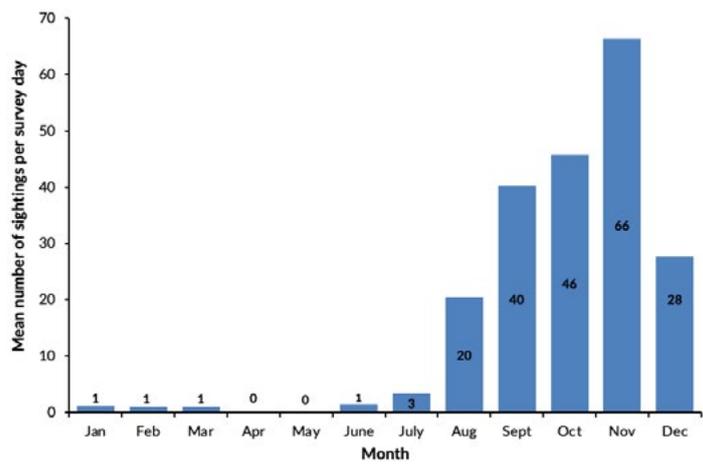
During 2020, a total of 562 different individual reef manta rays were recorded in Baa Atoll. This accounts for 11.1% of the total recorded Maldives population ( $n=5,042$ ) a slight decrease from 2019 ( $n=589$ ) (Fig. 4). Throughout

2020, each manta ray was observed on average 9.7 times; this resighting statistic is the highest recorded since this research programme began in 2008 (Fig. 4). Similarly, during the intensive survey period in 2020 (May – November), where 5,031 sightings of 550 individuals were recorded, each individual manta ray was also sighted on average 9.1 times. Monthly, the average number of sightings per manta ray increased from May to November, remaining consistent through September and October (Fig. 5).

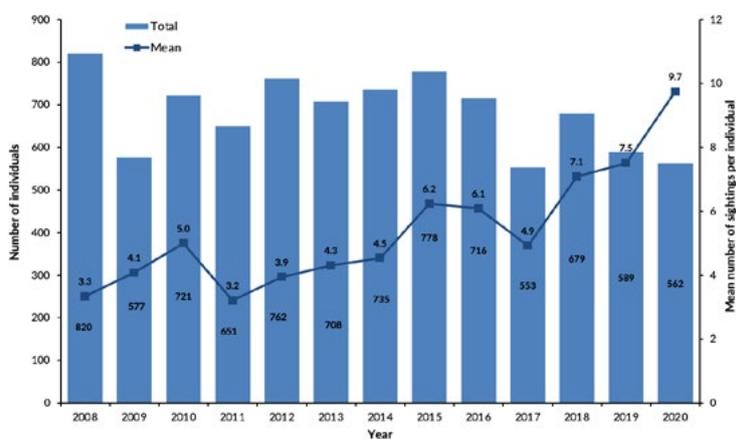
To account for survey effort, a Residency Index (RI) was calculated for each month based on the ratio between the number of days each individual was sighted and the total number of surveyed days (e.g., a RI of 5% means that, on average, each individual was sighted on 5% of the total surveyed days). The RI for 2020 (5.3%) was higher than in 2019 (3.8%) (Fig. 6). Monthly breakdowns show that the RI was lowest during the month of June (6.1%) but increased substantially throughout the study period, with the highest peak noted in November (15.9%) (Fig. 7). The high RI recorded in 2020 is potentially indicating a less transient population and sustained high abundance of localised plankton, the manta ray's food source.



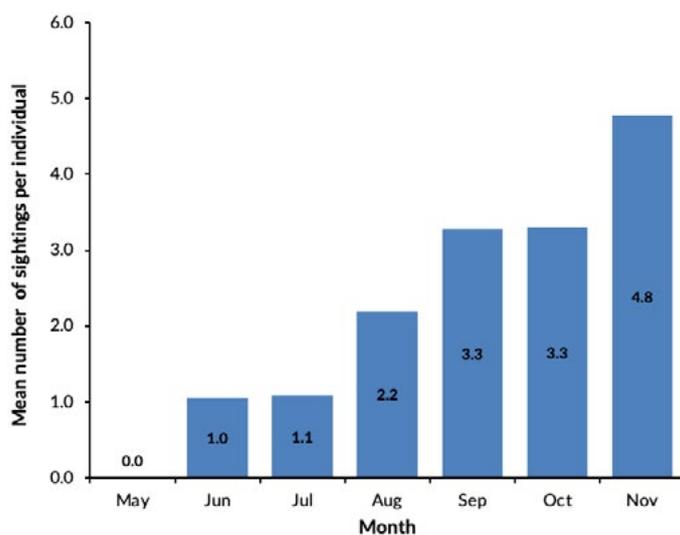
**Figure 2:** Annual sightings of reef manta rays (*Mobula alfredi*) in the Baa Atoll Region, and the mean number of sightings per survey day.



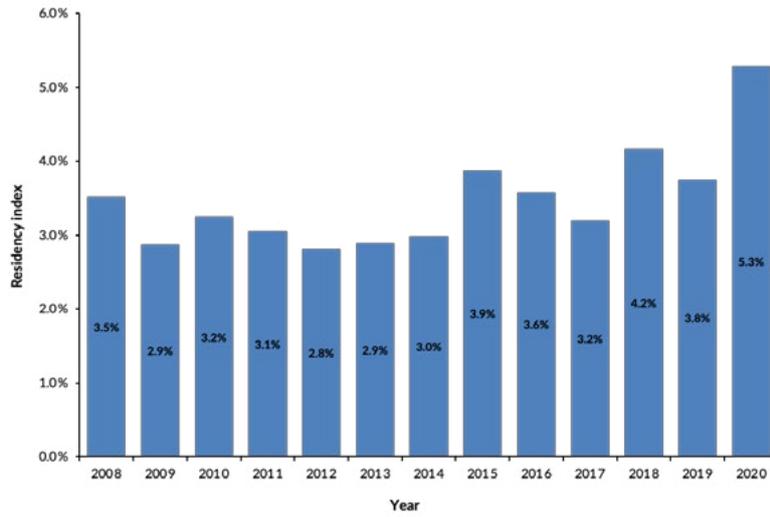
**Figure 3:** Monthly breakdown of reef manta ray (*Mobula alfredi*) sightings per survey day in the Baa Atoll Region during 2020. Actual numbers on top of or within bars.



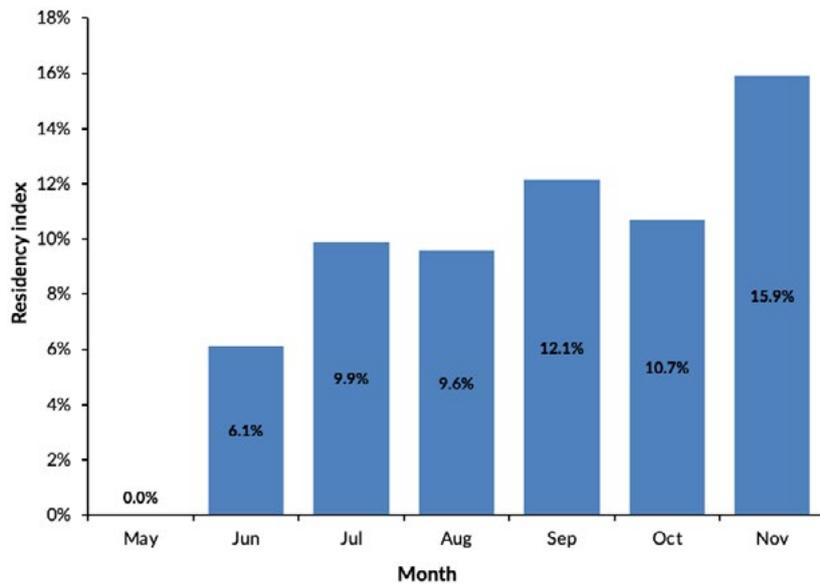
**Figure 4:** Annual number of individual reef manta rays (*Mobula alfredi*) sighted in the Baa Atoll Region, and the mean number of sightings per individual.



**Figure 5:** Mean number of sightings per reef manta ray (*Mobula alfredi*) during each month of intensive surveying in 2020.



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



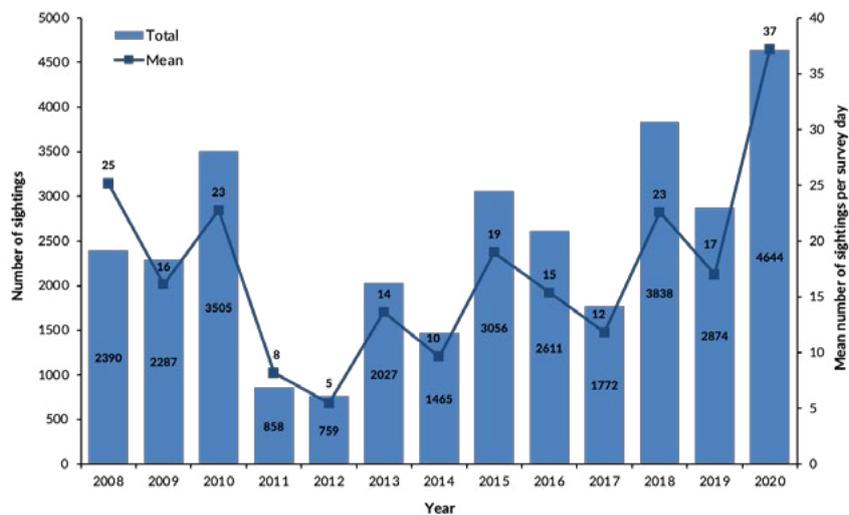
**Figure 7:** Residency Index of reef manta rays (*Mobula alfredi*) for each month of intensive surveying in the Baa Atoll Region during 2020.



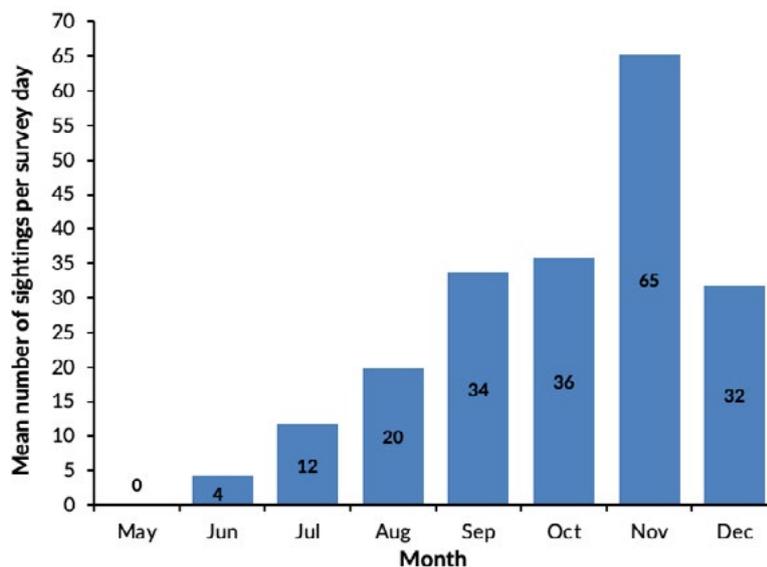
## Hanifaru Bay (Marine Protected Area)

In comparison with previous observations at the atoll level, the total number of sightings ( $n=4,644$ ), and number of individual reef manta rays ( $n=521$ ), recorded in Hanifaru Bay MPA in 2020 were substantially higher than in 2019 ( $n=2,874$  and 483 respectively) (Fig. 8). During the Southwest Monsoon period, 4,230 sightings of 515 individuals occurred. Monthly breakdowns reveal a steady increase in the average number of manta ray sightings per survey day at Hanifaru Bay in 2020 from May to November ( $n=0$  and 66 respectively) (Fig. 9), with the greatest number of individuals ( $n=406$ ) and sightings recorded ( $n=1827$ ) in November. It should be highlighted that 414 sightings of

193 individual reef manta rays occurred at Hanifaru Bay in December outside of the MMRP's main survey period (May – November), with only six of these individuals being sighted solely in December. A majority of the Hanifaru sightings (91.1%) were recorded during May – November, indicating that the Maldives reef manta ray's arrival at Hanifaru Bay is linked with the onset of the Southwest Monsoon. The 28<sup>th</sup> of November 2020 saw the greatest number of individuals recorded on a single day during the year, with a total of 215 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.



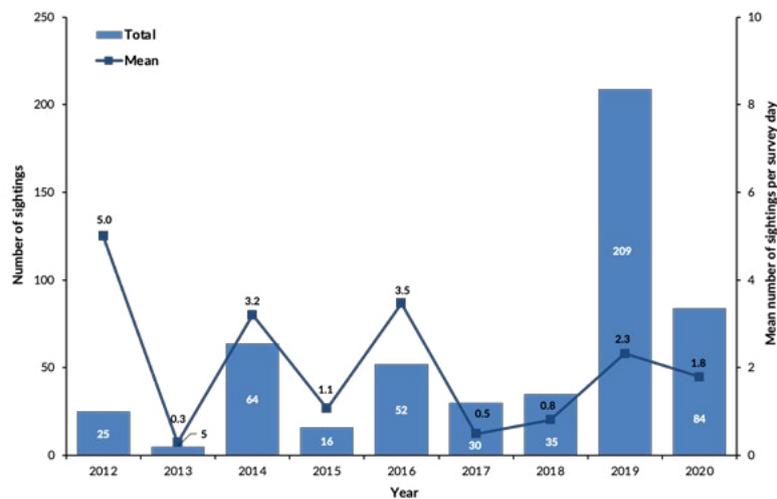
**Figure 9:** Average number of reef manta ray sightings (*Mobula alfredi*) recorded per survey day inside Hanifaru Bay during each month of intensive surveying in 2020.

## Angafaru Area (Marine Protected Area)

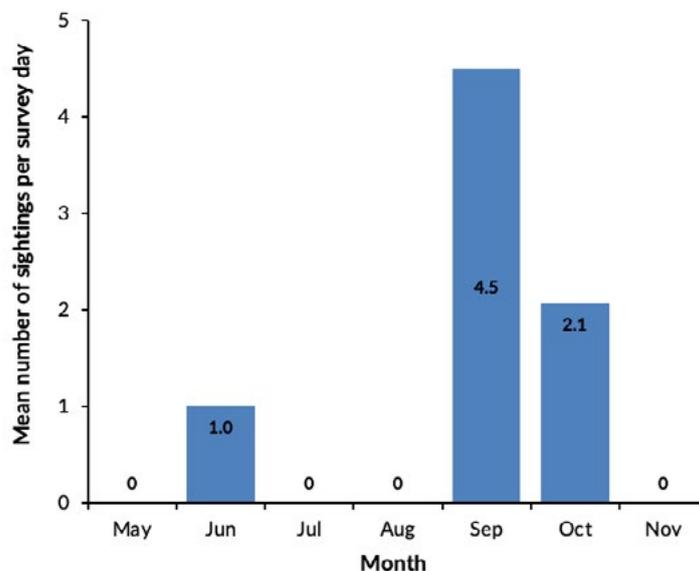
The Angafaru MPA includes Angafaru, Angafaru Falhu, Dhonfanu Thila, and Dhigu Thila. In past years, the total number of sightings recorded in this area has been relatively low with minimal peaks in 2014 and 2016 ( $n=64$  and  $52$  respectively). Although total sightings in 2020 ( $n=84$ ) were much lower than in 2019 ( $n=209$ ), both years are substantially higher than previous years (Fig. 10). A total of 77 unique individuals were observed in the Angafaru MPA during 2020.

When standardising the data by number of days this area was surveyed, 2020 shows the same number of sightings per day ( $n=2$ ) as 2019 ( $n=2$ ). Monthly breakdowns of average sightings per day revealed peaks in August ( $n=2$ )

and September ( $n=5$ ), while all other months had an average of one or zero sightings (Fig. 11). However, the majority of sightings occurred during two survey days, where 54 sightings occurred on the 26<sup>th</sup> of September in Angafaru, and 23 sightings occurred on the 29<sup>th</sup> of October in Angafaru Falhu during mass feeding events. It should be noted that most sightings in 2019 were also recorded during mass feeding events at Angafaru Falhu on the 12<sup>th</sup> and 13<sup>th</sup> of September ( $n=68$  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 2020.

## Population Demographics

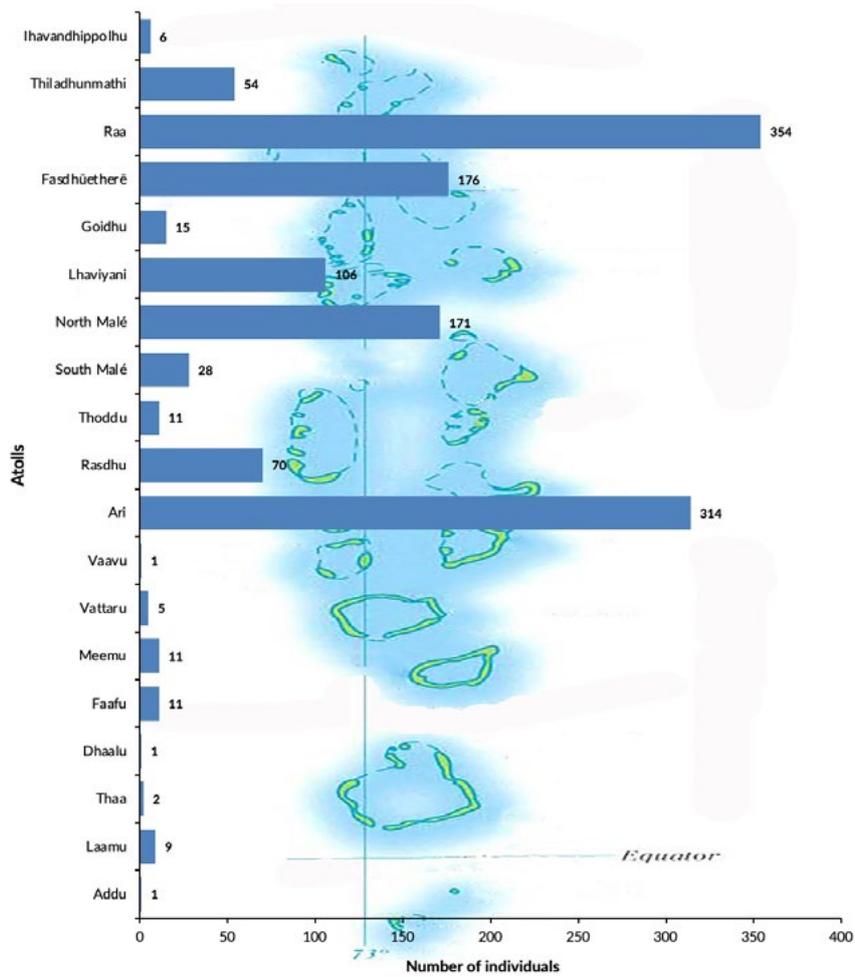
The total number of individual reef manta rays that have been recorded in Baa Atoll during the last decade is 2,122, almost half (43%) of the Maldives reef manta ray population ( $n=5,039$ ). As of 2020, population demographics of Baa Atoll constitute 53% females ( $n=1,129$ ), 46% males ( $n=984$ ) and 0.5% individuals for which the sex could not be determined ( $n=9$ ). Of these manta rays recorded in Baa Atoll ( $n=2,122$ ), 47% ( $n=980$ ) 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.

Throughout 2020, a total of 327 adult and 212 juvenile reef manta rays and 23 subadults were sighted. The sightings from 2020 consisted of 310 females and 251 males and one of unknown sex. Of these, there were 142 adult females, 168 juvenile females, 212 adult males, 16 juvenile males, and 23 subadult males. 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 – 280 cm disc width for males), adult status was also assigned. All other individuals were classified as juveniles.

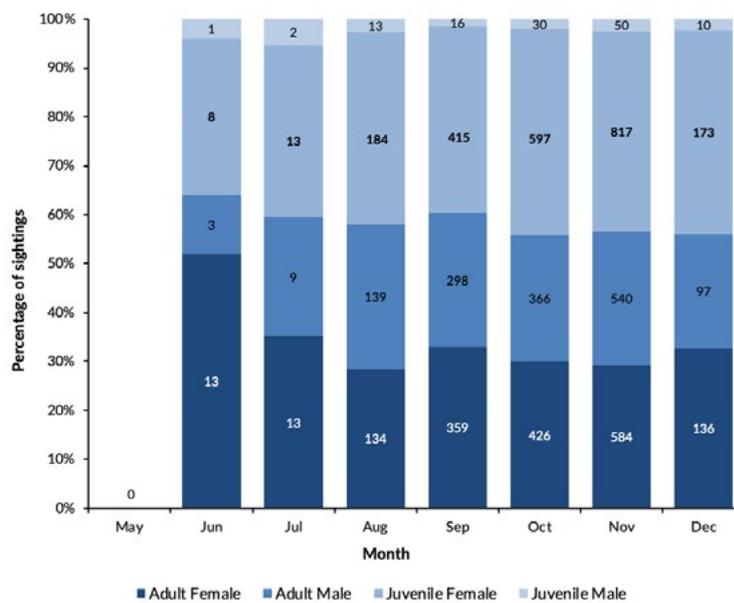
During every recorded month of the sampling period, there were more sightings of female juvenile manta rays than their male counterparts. This observation was particularly extreme during the Southwest Monsoon months of July to November and the transition month of December, with an average of five male juveniles and 160 female juveniles observed monthly. The ratio of adult females and male manta ray individuals favoured females throughout May – December (with the exception of August) (Fig. 13) but was far more evenly distributed between male and female sightings than in the juvenile cohort. The skewed ratios between sightings of juvenile females and males are a result of the much later (~5 years on average) age at maturity for female reef manta rays in the Maldives (~16 years) than the males (~11 years of age).

The relatively high number of sightings and small difference in the ratio between adult males and females during this time may highlight favourable conditions between September and November for manta rays. This peak may be correlated with an increase in reproductive activity, with courtship behaviour being recorded only during October ( $n=6$ ) and November ( $n=10$ ). 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 12:** Number of reef manta ray (*Mobula alfredi*) individuals ( $n=980$ ) from among the Baa Atoll subpopulation ( $n=2,122$ ) 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.



**Figure 13:** Reef manta ray (*Mobula alfredi*) sightings distribution categorised by maturity status during each month of intensive surveying effort in the Baa Atoll Region in 2020. Actual numbers within bars.

# POPULATION RECRUITMENT

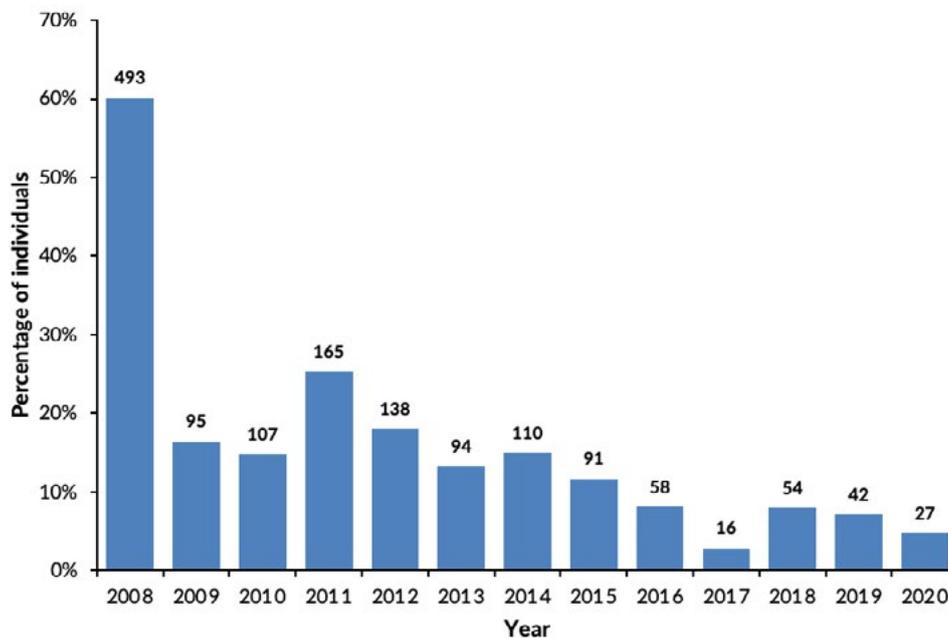
A total of 109 new individual reef manta rays were documented across the Maldives during 2020, a population recruitment of approximately 2.2% from the previous year (2019,  $n=4930$ )\*. As of 2020, the Maldives reef manta ray population was comprised of 5,039 individuals. Of the 109 new individuals added to the MMRP database, 26% ( $n=28$ ) were documented in Baa Atoll during 2020, demonstrating a decline from the previous year (2019,  $n=42$ ) (Fig. 14). One of these individuals was first identified in Maamunagau Falhu, a putative nursery site for reef manta rays in Raa Atoll, during the Northeast Monsoon and was later identified feeding in Hanifaru Bay in October.

Of the 23 new manta rays sighted in Baa between May and November; 14% were adult manta rays ( $n=3$ ), and 87% were juveniles ( $n=20$ ). The demographics amongst the identified juveniles were as follows; 50% female ( $n=10$ ), 45% male ( $n=9$ ), and one individual of unknown sex. Only

one individual sighted in December outside the Southwest Monsoon period was recorded as 'young of the year', indicating that this individual was of a small enough size to be deemed a manta ray pup.

The decrease in newly identified manta ray individuals during 2020, 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.

*\*Previous reports stated the population as of 2019 was 4,942; however, duplicates of individuals were discovered, resulting in the corresponding decrease in the reported 2019 population numbers in this report.*



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

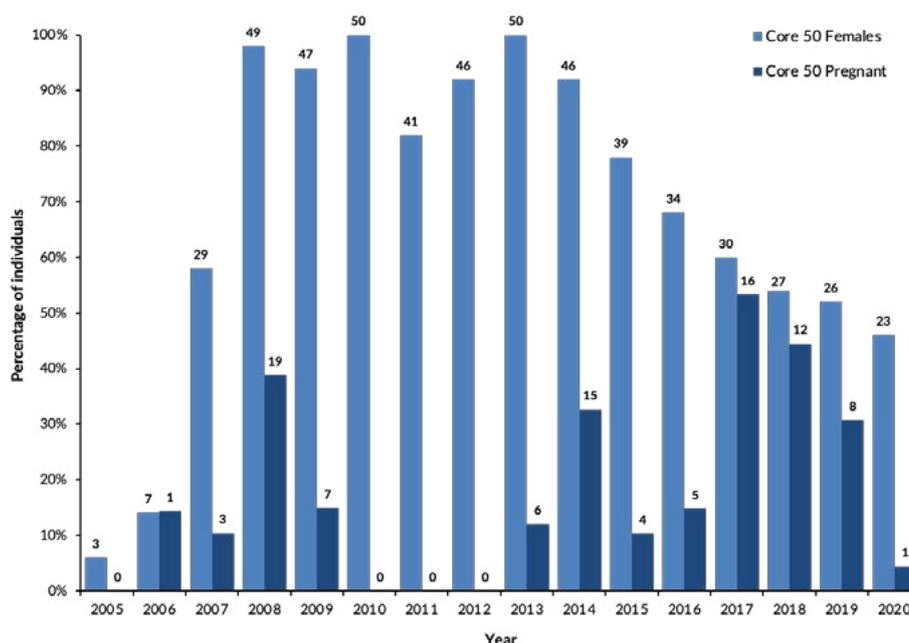
# REPRODUCTIVE FECUNDITY

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 2020 decreased from the previous year ( $n=29$  in 2019), with a total of six individuals recorded as pregnant, and a further nine 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 2020 has decreased since peaking in 2017. Of the 50 individuals that comprise of Hanifaru Bay's core adult female population, 46% were sighted in 2020, and only one (2%) of these individuals was 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 52% of the core 50 sighted with 30.8% of individuals pregnant in 2019 (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 (2<sup>nd</sup> trimester onward). Of the six pregnant females observed in Ball Atoll during 2020, all were in the later stages of gestation (3<sup>rd</sup> or 4<sup>th</sup> trimester) when first sighted. Three individuals that were classified as juveniles and had not been recorded pregnant before were observed as pregnant for the first time. An additional three juvenile females were also observed with fresh mating wounds.

The decline in pregnancies during 2020 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.

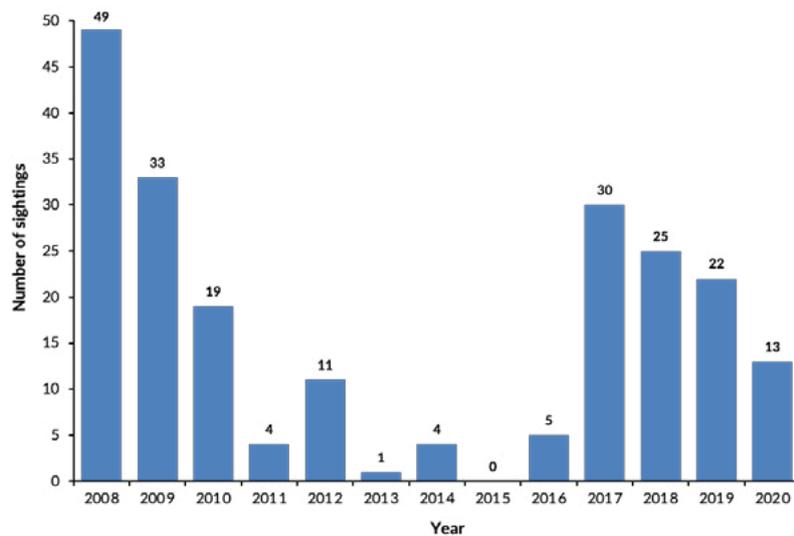
# WHALE SHARK SIGHTING TRENDS

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 2020, there were 13 whale shark sightings of 13 different individuals recorded in Baa Atoll between May and November (Fig. 16). Of these 13 individuals, only 8% ( $n=1$ ) were new to the Maldives Whale Shark Research Programme's database. Monthly breakdowns reveal that the greatest number of sightings in 2020 were recorded during the months of September ( $n=5$ ) and October ( $n=5$ ), followed closely by November ( $n=3$ ) (Fig. 17).

Interestingly, the MMRP recorded the highest number of manta ray sightings in November ( $n=1,991$ ), followed by October ( $n=1,420$ ) and September ( $n=1,088$ ), suggesting that the prevailing conditions noted from September

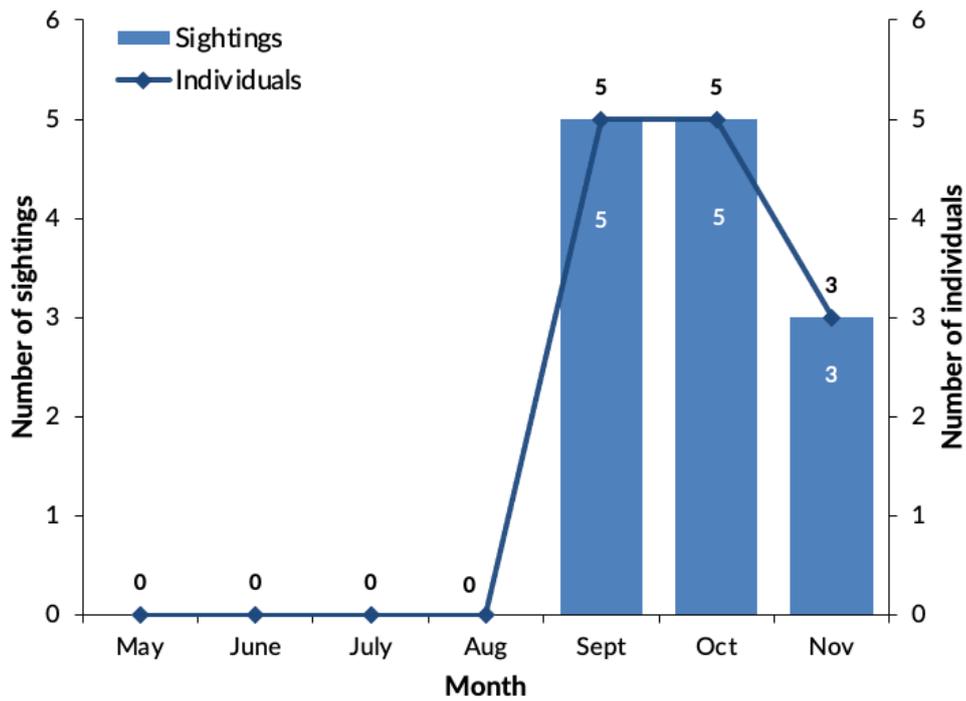
through November were most favourable for these planktivorous creatures. Within Hanifaru Bay, October and November marked the peak in manta ray sightings ( $n=1,109$ ,  $n=1827$  respectively), while August marked the peak of whale shark sightings in the bay ( $n=5$ ) (Fig. 18).

Overall, whale shark sightings in Hanifaru comprised of 77% ( $n=10$ ) of the total sightings in Baa. It should be highlighted there were no recorded sightings during 2020 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 2020 revealed a decline in sightings throughout Baa Atoll of 41% from 2019 ( $n=22$ ), we remain optimistic that 2021 will reveal stability within the population.

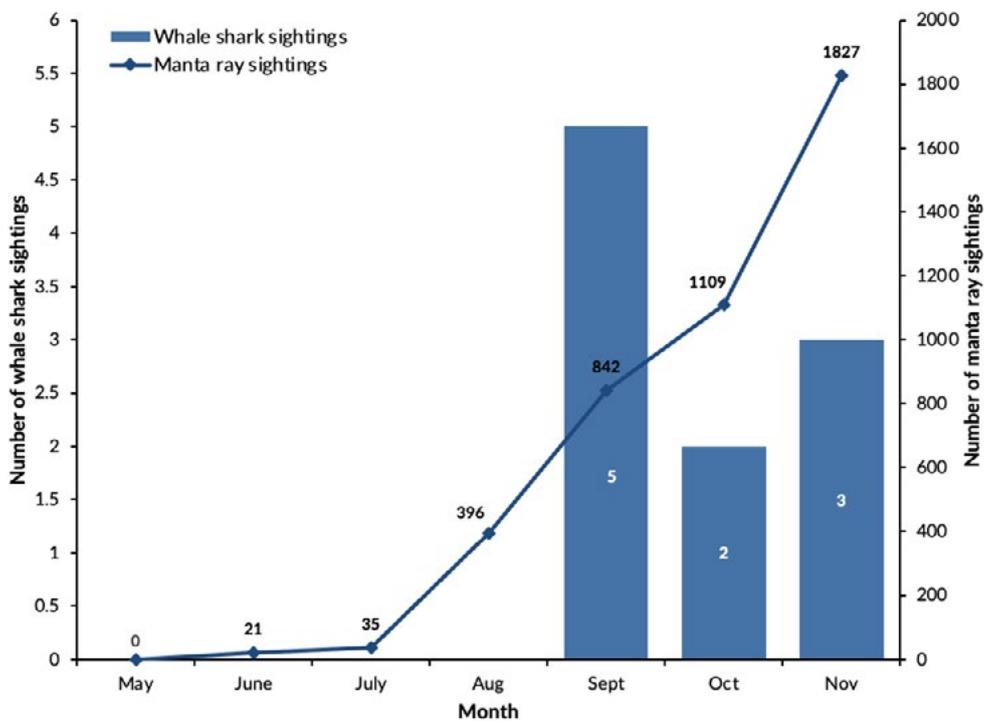


**Figure 16:** Annual sightings of whale sharks (*Rhincodon typus*) in Baa Atoll.





**Figure 17:** Whale shark (*Rhincodon typus*) sightings in Baa Atoll during 2020, and the total number of individuals recorded each month.

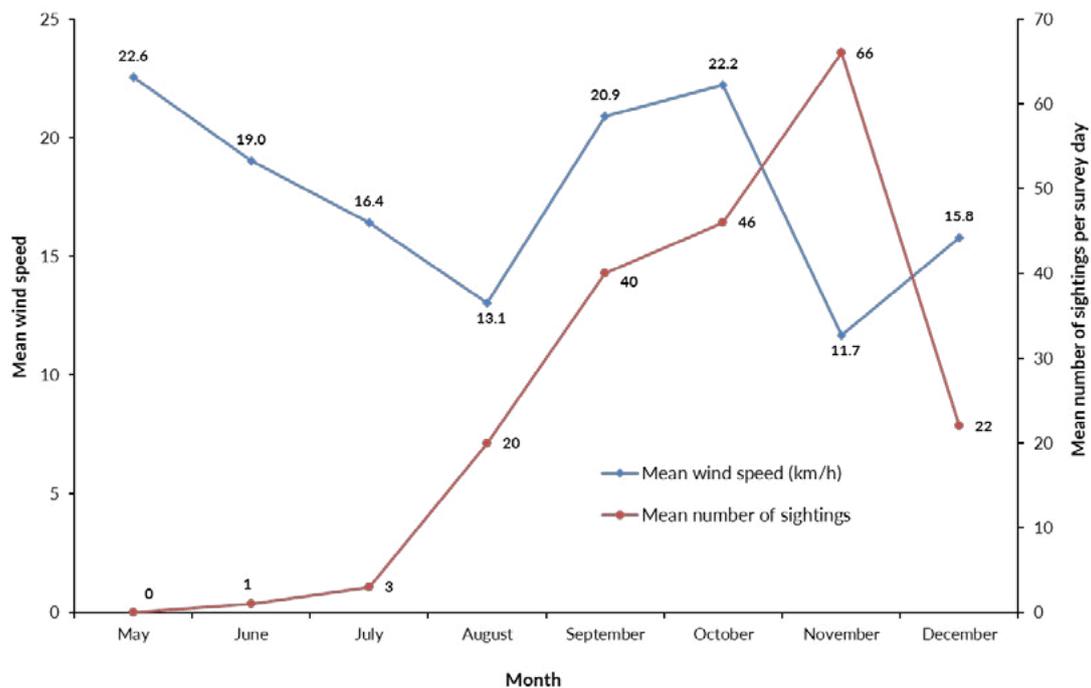


**Figure 18:** Monthly whale shark (*Rhincodon typus*) and reef manta ray (*Mobula alfredi*) sightings recorded at Hanifaru Bay, Baa Atoll in 2020.

# 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 2020, May (which marks the start of the Southwest Monsoon) typically demonstrates characteristically high wind speeds. In 2020, maximum wind speeds were recorded in June and October ( $n=22.6$  km/h and  $n=22.2$  km/h respectively). The months of May through October showed little variation other than a dip in wind speed in August at 13.1 km/h, before declining to 11.7 km/h in November 2020. In turn, average manta ray sightings per survey day steadily increased throughout August and November where it reached its final peak ( $n=66$ ) following the stronger monsoonal winds noted later in the season (September – October) (Fig. 19). It is difficult to elude season-long trends between weather and manta sightings in 2020 due to the disruption to MMRP routine monitoring during May – August. However, 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 delay between increased primary productivity and the blooms of zooplankton to occur. The average wind speed observed in 2020 was 17.4 km/h, 3.1 km/h higher than the average in 2019 ( $n=14.3$  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 increase in the average number of sightings per day in 2018 and 2020 in comparison to 2019 that hosted the lowest average wind speed ( $n=14.3$  km/h) since the inception of this long-term monitoring in 2008.

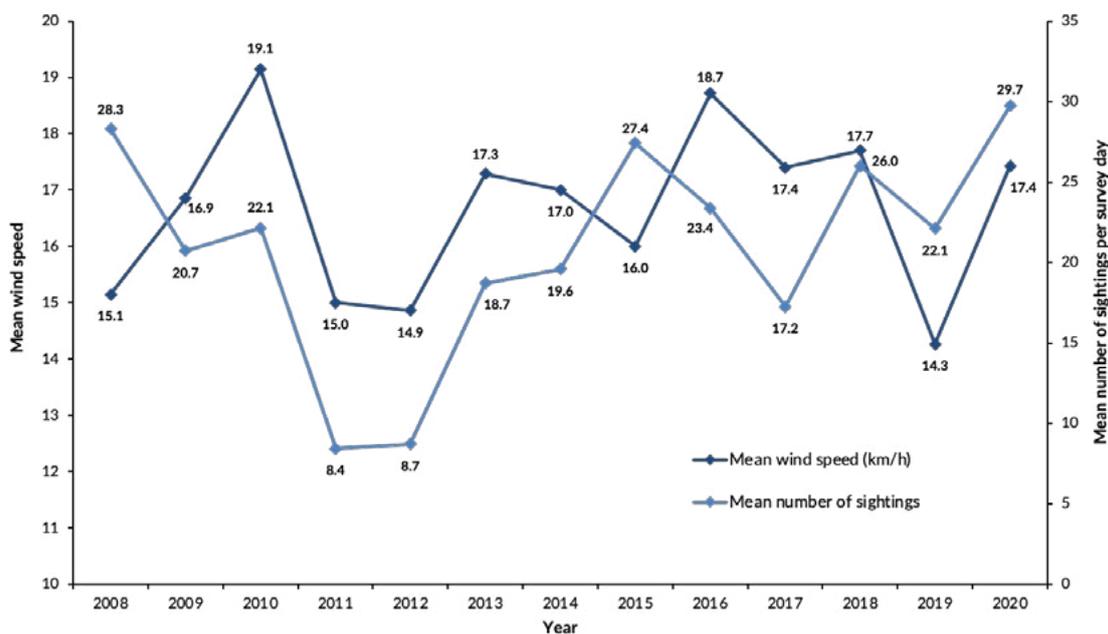


**Figure 19:** Mean monthly wind speed (km/h) and mean number of reef manta rays (*Mobula alfredi*) sightings per survey day in the Baa Atoll Region (2020).

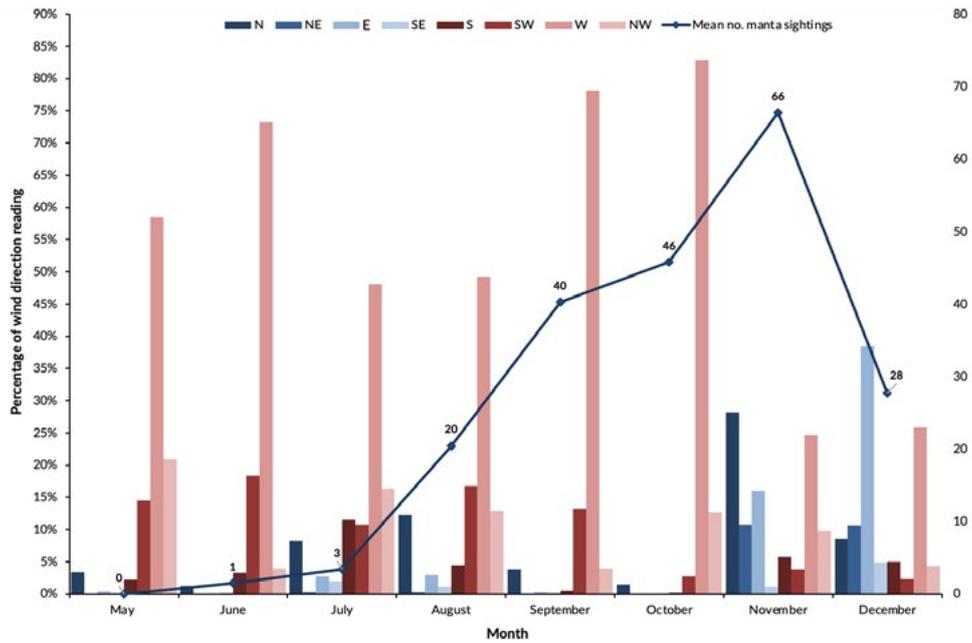
At the beginning of 2019, a local Vantage Vue weather station was deployed at the Four Seasons Resort on Landaa Giraavaru to log fine scale changes in weather conditions for the region. Wind directions recorded from the Vantage Vue station reveal variability throughout May to December (Fig. 21). Directions were classified into eight 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 western direction dominated from May to October contributing to 48% – 83% of wind direction readings during this time (Fig. 21). The beginning of the season (May and June) and end of the season (September and October) were marked with distinctly high westerly readings with a decrease during the middle of the season (July and August). However, with a greater contribution of winds from the west (83%) in October, average sightings increased once again subsequently reaching a final peak in November ( $n=66$ ) (Fig. 21). Wind direction in November and December varied substantially representing the transitional period of the change in seasons to the Northeast Monsoon. 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 mechanisms, such as the Indian Ocean Dipole (IOD), Madden-Julian Oscillation (MJO) and El-Niño Southern Oscillation (ENSO), are likely to be connected to these fluctuations as all have been known to strongly influence currents throughout the atoll and exert control over productivity. All 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. 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 20:** Mean annual wind speed (km/h) and the mean number of reef manta ray (*Mobula alfredi*) sightings per survey day in the Baa Atoll Region.



**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 (2020).

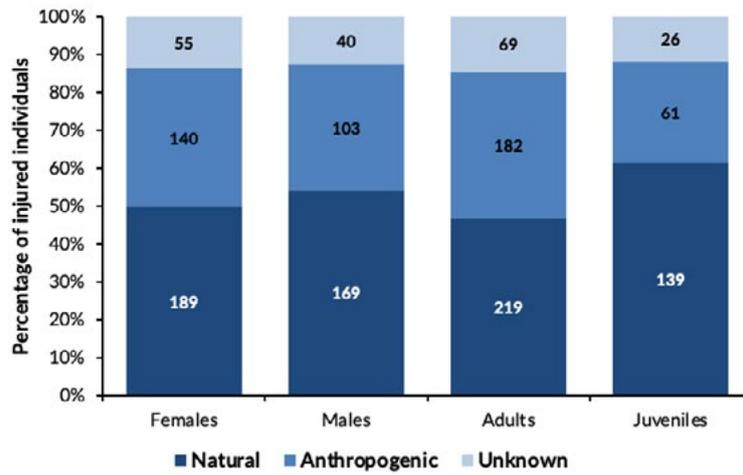
## SUB-LETHAL INJURIES

Of the 2,122 individual reef manta rays recorded in Baa Atoll, 30% ( $n=638$ ) were recorded with sub-lethal injuries. Of those injured manta rays, 89% ( $n=569$ ) have only one injury, 10% ( $n=66$ ) have two recorded injuries, and three individuals (1%) have three injuries, for a total of 710 recorded injuries. Fifty-six percent ( $n=358$ ) of rays had at least one injury (with known origin) resulting from a natural source, while the remaining 38% ( $n=243$ ) had at least one injury resulting from an anthropogenic source and 6% had an injury of unknown origin. Demographically, instances of injuries are roughly the same between females and males, but higher in adults than juveniles. Sixty-six percent ( $n=139$ ) of injuries recorded to juveniles are naturally caused while only 53% of injuries in adults are naturally caused (Fig. 22). In adults, 44% of injuries were from anthropogenic causes while in juveniles, this figure was 29%. Overall, 26% and 32% of the Baa juvenile and adult reef manta ray population had an injury, respectively. 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.

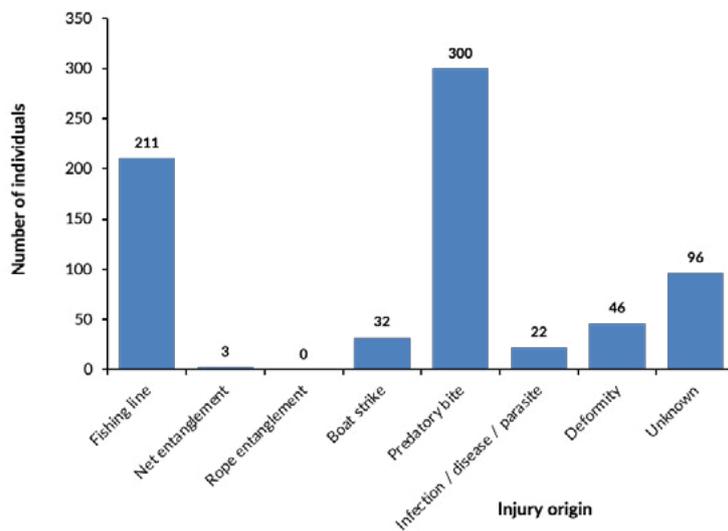
Across all individuals sighted within Baa Atoll, the most

common cause of injuries (for both adults and juveniles) was from predatory bites ( $n=300$ ), followed closely by fishing line ( $n=210$ ). Deformities ( $n=46$ ), boat strikes ( $n=32$ ), infections, disease, parasites ( $n=22$ ), net and rope entanglement ( $n=3$ ) were less frequent (Fig. 23). Of all the manta injuries recorded across four different demographics (male, female, adult and juvenile), 65 - 70% 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 2020 across the Maldives ( $n=70$ ) follow a similar trend to that of the whole Baa Atoll Region population in terms of injury origin. Of all injuries ( $n=85$ ), 51% could be identified to a specific cause ( $n=43$ ). Most injuries were attributed to fishing line ( $n=20$ ) and predatory bites ( $n=18$ ), followed by infection, disease and parasites ( $n=3$ ), boat strikes ( $n=1$ ) and deformity ( $n=1$ ) (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.

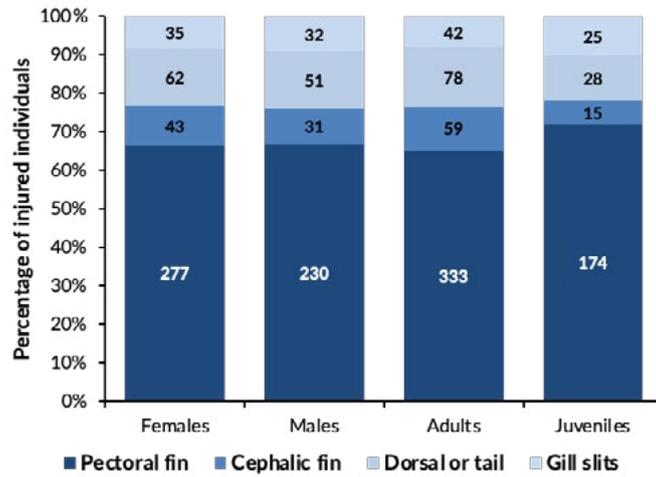


**Figure 22:** Demographic variations in the number of sub-lethally injured ( $n=638$ ) reef manta rays (*Mobula alfredi*) within the Baa Atoll Regional subpopulation ( $n=2,122$ ), and likely injury origin (natural, anthropogenic or unknown). Actual number of injuries on bars.

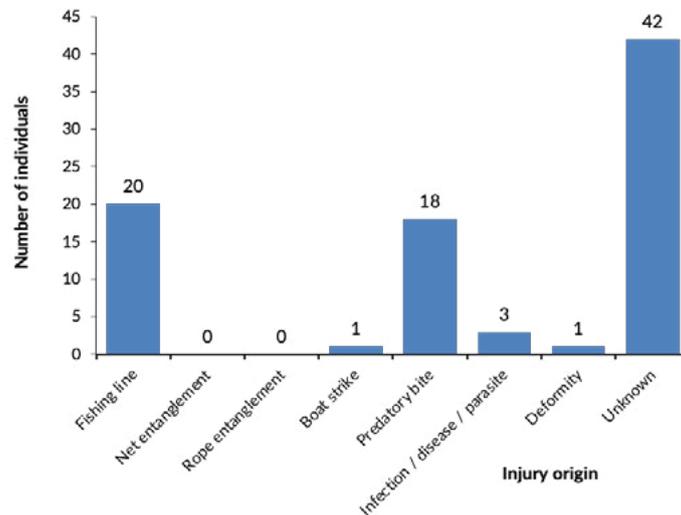


**Figure 23:** Variations in the likely origin of sub-lethal injuries ( $n=710$ ) within the injured reef manta ray (*Mobula alfredi*) subpopulation of the Baa Atoll Region ( $n=638$ ).





**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 ( $n=638$ ). Actual number of injury locations on bars. Note that one injury can affect multiple parts of the body.

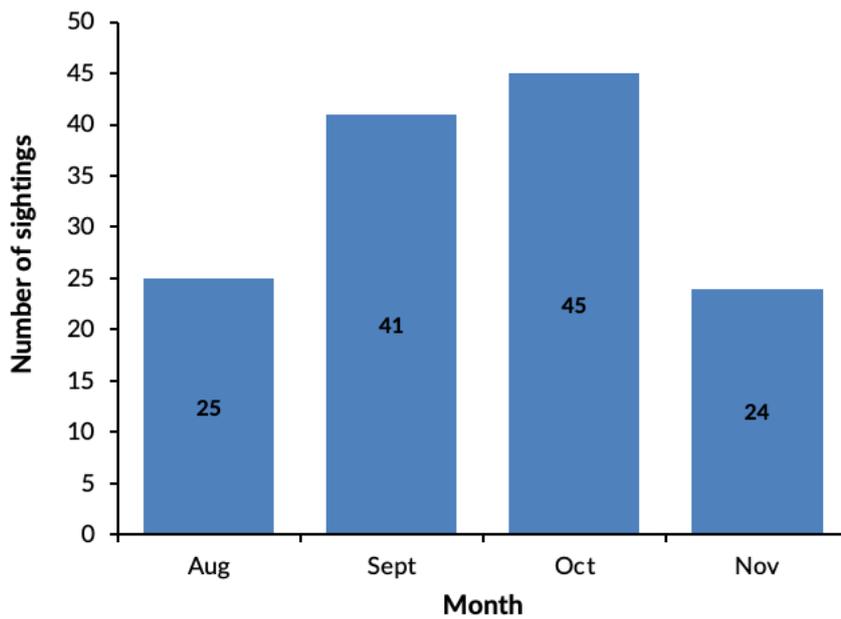


**Figure 25:** Variations in the likely origin of sub-lethal injuries ( $n=85$ ) within the reef manta rays (*Mobula alfredi*) recorded injured in the Baa Atoll Region in 2020.

## REMOTE UNDERWATER VIDEO SURVEYS

Remote underwater video surveys are commonly used in research to monitor specific areas and their use by different marine life whilst humans are absent. In 2020, of the total 1,092 surveys conducted between August and November, 834 were carried out by MMRP researchers (78%), 156 were submitted by outside contributors (13%), and 102 were done using RUVs (9%). A total of 135 sightings were recorded over the 102 RUV surveys, which makes up 2% of the total sightings between August and November ( $n=4,969$ ). Six individuals were sighted only on the RUV surveys and not by human observation, one of which was newly identified in 2020 (MV-MA-5042). The highest

number of monthly sightings recorded by RUVs was 45 (in October), and the lowest was 24 (in November) (Fig. 26). The average sightings per RUV were lower than the average MMRP surveys. Although courtship behaviour was not recorded by RUVs in 2020, out of the 14 individuals recorded engaging in courtship behaviour in 2019, six were documented 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 2021.



**Figure 26:** Monthly breakdown showing the number of reef manta ray (*Mobula alfredi*) sightings using Remote Underwater Video systems in the Baa Atoll Region in 2020.

## TOURISM ACTIVITIES

With the onset of a global pandemic in 2020, the tourism industry in Maldives was greatly impacted. The borders of the Maldives closed to international tourists on 27th March and reopened again on 14th July 2020. International arrivals to the Maldives decreased from 1,702,887 arrivals in 2019 to 55,494 arrivals in 2020 (Ministry of Tourism).

Although the MMRP survey effort was also impacted by the pandemic, tourist numbers were still monitored during each survey. Unsurprisingly, the total number of paying guests at surveyed sites decreased substantially from 2019 to 2020 ( $n=10,325$  and  $n=1,204$  respectively) due to border closures and associated impacts of the pandemic.

Manta rays are sensitive to disturbance, and if left without proper measures, tourism has the potential to do more harm than good. This Best Practice Code of Conduct for manta ray tourism has been formed based on years of research. These guidelines explain how divers and snorkelers should interact in-water to enhance their experience and ensure their presence has the least impact on individual manta rays.

Throughout 2020, the MMRP strove to improve the sustainability of manta ray tourism activities in Baa Atoll by encouraging tour operators to voluntarily sign up as a “How to Swim with Mantas” operator. In doing so, these operators were provided with resources to support and assist dive guides, snorkel guides and boat teams to lead sustainable manta ray watching tours.

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.

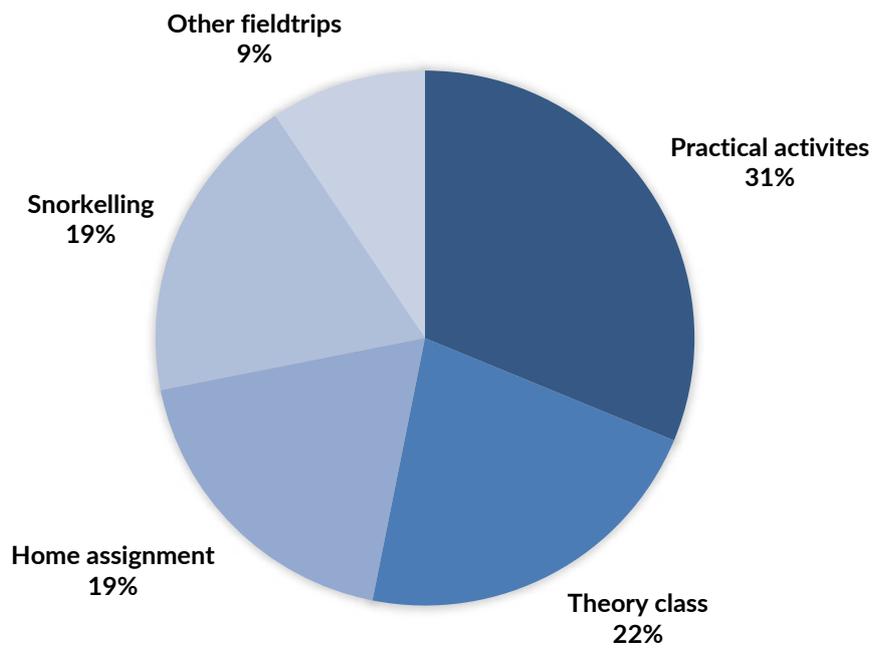
Moodhu Madharusaa has been expanding in reach since its inception in Baa Atoll in 2015. Over 160 students from five schools across two atolls have now completed the programme, and another 78 students across three atolls started the programme pre-pandemic (Fig. 28).

During January–March 2020, twenty-four students from Kamadhoo School participated in Moodhu Madharusaa. Although the planned programme duration was reduced

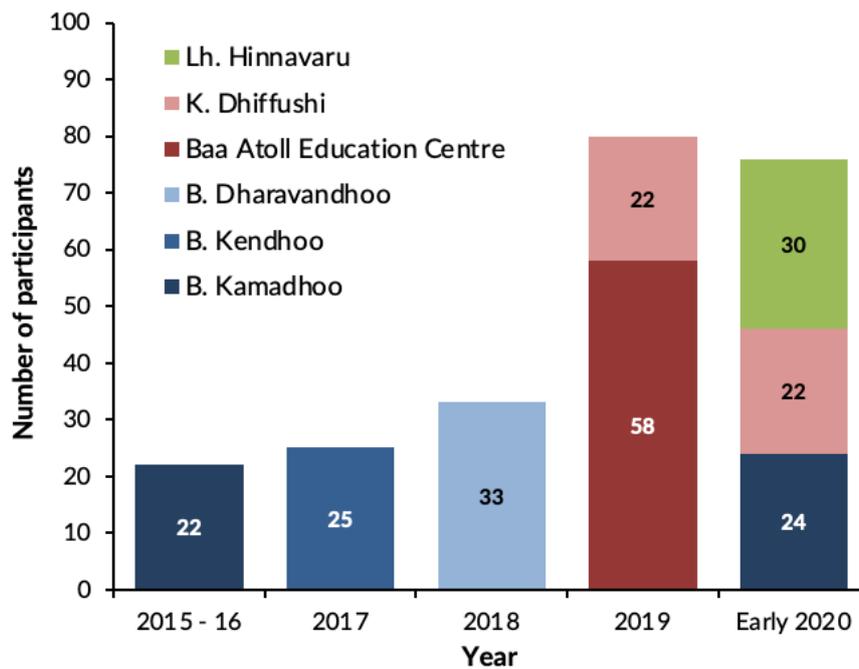
due to the pandemic, students still managed to complete over 30 hours of taught classes and fieldtrips. Highlights include swimming and snorkelling lessons, a trip to Four Seasons Landaa Giraavaru where they visited the Marine Discovery Centre, and the shark research conference where the students presented research methods for debate with their peers. MMRP hopes to continue teaching the outstanding modules of Moodhu Madharusaa at Kamadhoo School when possible, in the future.

Due the programming remaining incomplete in 2020 due to the pandemic, research into the success of this programme was unable to be completed. However, benefits of this programme have been clearly displayed in past years. In 2019, pre- and post-programme surveys showed 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. Moodhu Madharusaa programmes continue to be a great success due to a high level of collaboration between partners and enthusiasm from school communities, local councils and NGOs, and resort partners.





**Figure 27:** Percentage of time devoted to each activity which comprised the Moodhu Madharusaa Marine Education Programme in 2020.



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

# CONSERVATION & MANAGEMENT

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The Baa Atoll Region 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 reef 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*



## **MALDIVES GOVERNMENT AUTHORITIES**

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

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*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 government data collected as a part of this study. For further information or please email: [baa@mantatrust.org](mailto:baa@mantatrust.org) or [mmcpteam@mantatrust.org](mailto:mmcpteam@mantatrust.org).***

*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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