Manta TRUST

Maldivian Manta Ray Project

BAA ATOLL | ANNUAL REPORT 2021

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 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 the Baa Atoll Region has been continuously monitored by the Maldivian Manta Ray Project (MMRP). Reef manta rays and whale sharks (*Rhincodon typus*) frequent the eastern side of the Baa Atoll Region each year to feed on the abundant zooplankton prey that results from the productive Southwest (SW) Monsoon conditions. The Baa Atoll Region is internationally renowned as being one the most reliable places to see and swim with these planktivorous megafauna.

Details on the ecology, population dynamics, and movements of the region's reef manta rays throughout 2021 are provided in this report, with the majority of presented results focused on data collected during the intensive survey period from May through November. Furthermore, this report discusses various tourism and education activities conducted within the Baa Atoll Region during 2021, with many restrictions following the COVID-19 pandemic in 2020 still in place.

The MMRP, with outside contributions, conducted 2,413 reef manta ray surveys on 224 days in 2021. Of these, 206 survey days (92%) fell between the 1st of May and the 30th of November 2021. Key findings of the MMRP in the Baa Atoll Region during 2021 include a total of 7,299 sightings of 647 individual manta rays. Of these individuals, each manta ray was observed on average 11.3 times. The mean daily number of reef manta ray sightings between May and November was 35, with a peak in daily manta ray sightings seen during the month of September (*n*=62). A Residency Index (RI) was calculated to gauge the extent of movement amongst those frequenting the region. The RI for 2021 (5.0%) represented a slight decrease from 2020 (5.3%) and is still one of the highest RIs recorded since the MMRP's inception. The total number of sightings (*n*=6,137) and number of individual manta rays (*n*=603) recorded in Hanifaru Bay MPA in 2021 increased from 2020 records, when 4,659 sightings were recorded of 521 individuals. The number of sightings in Hanifaru Bay more than doubled from 2019 records (*n*=2,874), representing a 114% increase.

As of 2021, the population demographics of the Baa Atoll Region constitutes 53.4% females (*n*=1,213), 46.1% males (*n*=1,047), and 0.5% (*n*=11) unsexed individuals. Of these manta rays (*n*=2,271), 48% (*n*=1,085) have also been seen in at least one other atoll in the Maldives.

A total of 208 new reef manta rays were added to the MMRP database from across the Maldives in 2021, bringing the total number of identified individuals in the Maldives to 5,247. Of the new manta rays identified in 2021, 29% (*n*=61) were documented in the Baa Atoll Region, an increase from the previous year (*n*=27 in 2020). Within the Baa Atoll Region, 57 of these new individuals were juveniles.

The number of pregnancies recorded in the Baa Atoll Region (*n*=64) was more than ten times the number recorded in 2020 (*n*=6). In addition, 24 females were recorded with fresh reproductive wounds but not pregnant. Of the 64 pregnant females observed, 73% (*n*=47) were recorded in the later stages of gestation (3rd–4th trimester).

The Baa Atoll Marine Education Programme, 'Moodhu Madharusaa', was unable to hold classroom or practical activities this year due to restrictions presented by the COVID-19 pandemic. The MMRP took this time to review its outreach programme activities and educational material for future anticipated programme resumption in 2022.

THE BAA ATOLL REGION

Geographically, the Baa Atoll Region is comprised of three geographical atolls: South Maalhosmadulu, Fasdhūetherē, and Goidhu (administratively and collectively, Baa Atoll) (Fig. 1). South Maalhosmadulu Atoll is a very large (943 km^2) 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. Fasdhūetherē Atoll is much smaller (134 km^2), 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^2), 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; Fasdhūetherē lies just 1km to the north of South Maalhosmadulu and the two atolls are separated by a shallow channel (Kudarikilu Kandu). 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).

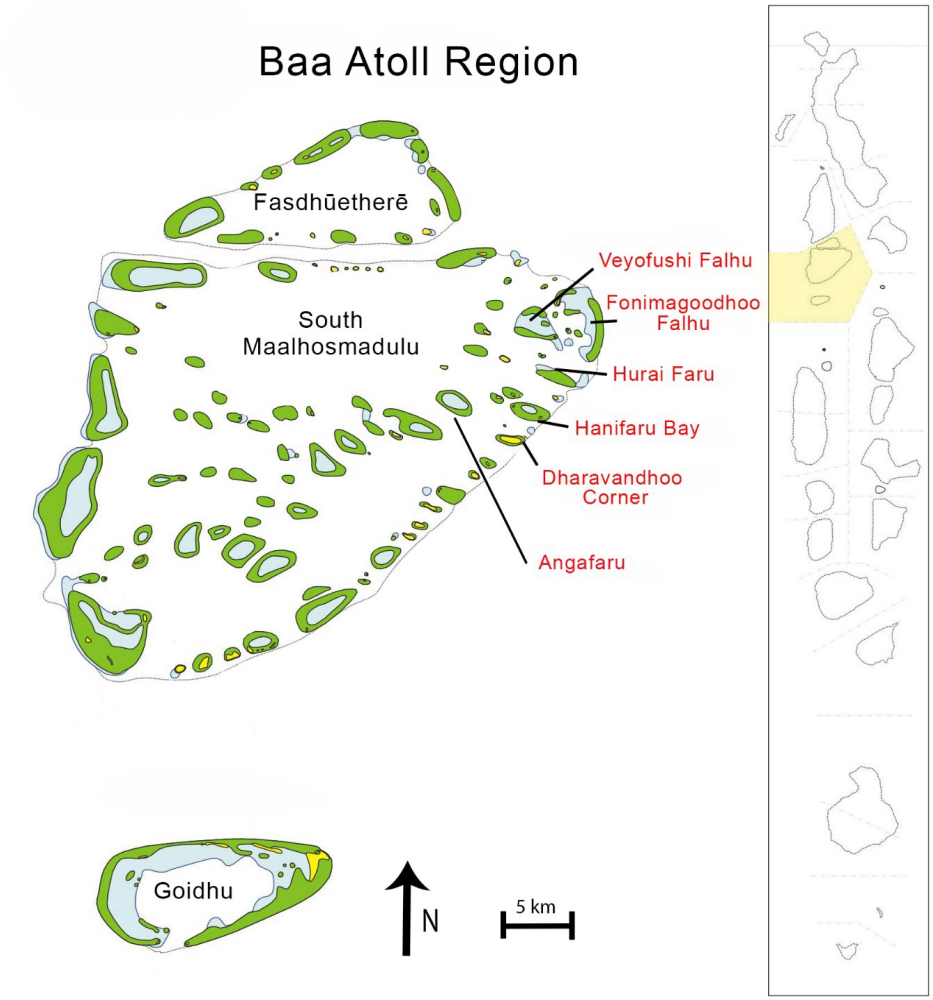


Figure 1: Map of the Baa Atoll Region showing the three geographical atolls (in black), six of the key reef manta ray (*Mobula alfredi*) aggregation study sites (in red), and the region in relation to the rest of the Maldives Archipelago (shaded yellow).

UNDERSTANDING THE MONSOONS

Understanding the effects of the Maldives Southwest (SW) Monsoon is inherently vital to understanding why the Baa Atoll Region 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 typus*, while December – March is known as *Iruvai*. *Hulhangu typus* 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 Hanifaru 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 MMRP's regional personnel are based at the Four Seasons Resort on the island of Landaa Giraavaru, which is in the northeast of Baa Atoll. The MMRP conducted 1,722 surveys to locate manta rays in Eastern Baa Atoll between the 10th of May and the 30th of November 2021. Surveys were conducted on as many days as the weather conditions allowed, on a total of 189 days within a 214-day time-frame (May – November), or 88% of the possible monitoring period. MMRP surveys were carried out by observers (*n*=1,365), remote underwater video systems (*n*=215), remote underwater photo systems (*n*=140), and unmanned aerial vehicles (i.e., drones) (*n*=2). Surveys were conducted at Hanifaru Bay, one of six key manta aggregation sites, and at a dozen other sites around the eastern border of Baa Atoll (Fig. 1). The MMRP conducted an additional 19 observer surveys in January (*n*=1), February (*n*=2), and December (*n*=16).

In addition to the data collected by the MMRP, 672 surveys were also conducted by external parties throughout the year. The photographs submitted by outside contributors accounted for the majority of the sightings data outside the months of May through November. Supplementary to the 195 survey days carried out by the MMRP, external parties conducted surveys on a further 29 days in 2021, bringing the total number of survey days to 224 in 2021.

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, 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. 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 2021, Baa Atoll Biosphere Reserve rangers were on site to maintain the rules and regulations of Hanifaru Bay MPA, and to collect visitor entry fees. Their presence resulted in a decrease of infractions and a well-maintained schedule of alternating tourism days. The regular collection of tourism fees for entry into the Bay has 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 the regional MPAs in conserving the Maldives reef manta ray population by mitigating the harmful ramifications arising from human-manta ray interactions.

REEF MANTA RAY SIGHTING TRENDS

Baa Atoll Region

In 2021, a total of 7,299 reef manta ray sightings were recorded in the Baa Atoll Region. The data shows an increase (33.4%) in reef manta ray sightings compared to the previous year (*n*=5,471 in 2020). The number of sightings documented in the Baa Atoll Region during 2021 is the highest on record, with previous years of high sighting numbers recorded in 2020 (*n*=5,471) and 2018 (*n*=4,816) (Fig. 2).

Monthly breakdowns of these sightings in 2021, standardised for survey effort, show a general increase in average daily sightings from May to November (Fig. 3). Manta ray sightings peaked in September (*n*=62, average number of sightings per survey day) and remained above at least 26 average daily sightings from July to November (Fig. 3). On average, 33 manta rays were sighted per survey day in 2021 overall, with an average of 35 manta rays sighted per survey day during the Southwest Monsoon (May to November). Both the overall mean and Southwest Monsoon mean in sightings per survey day are the highest ever recorded in the Baa Atoll Region.

During 2021, a total of 647 different individual reef manta rays were recorded in the region. This accounts for 12.3% of the total recorded Maldives population (*n*=5,247), an increase from 2020 (*n*=562) (Fig. 4). Throughout 2021, each reef manta ray was observed on average 11.3 times, the highest since this research programme began in 2008 (Fig. 4). Similarly, during the intensive survey period in 2021 (May – November), where 7,271 sightings of 640 individuals were recorded, each individual reef manta ray was sighted on average 11.4 times. Monthly, the average number of sightings per manta ray increased from May to September, with a peak of 4.1 sightings per individual, followed by a slight decline in October and November (Fig. 5). The individual with the highest number of sightings in 2021 was MV-MA-2248 (Omnipresence), who was sighted 60 times.

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 2021 (5.0%) was higher than in 2019 (3.8%), and slightly lower than 2020 (5.3%) (Fig. 6). Monthly breakdowns show that the RI was lowest during the month of June (6.4%) but increased substantially throughout the study period, with the highest peak noted in September (13.8%) (Fig. 7). The increasing RI recorded throughout the Southwest Monsoon in the region indicates manta rays are less transient as the season progressed, especially in September when the number of sightings and RI were highest.

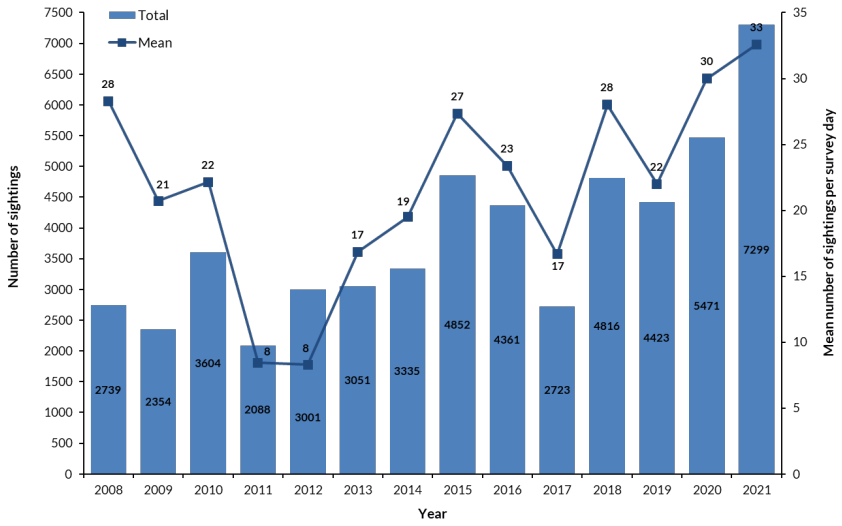


Figure 2: Annual sightings of reef manta rays (*Mobula alfredi*) in Baa Atoll Region from 2008 – 2021, and the mean number of sightings per survey day.

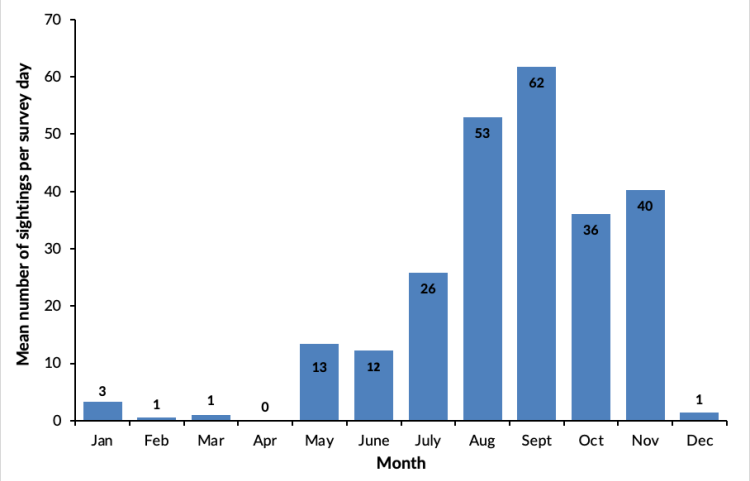


Figure 3: Monthly breakdown of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll Region during 2021.

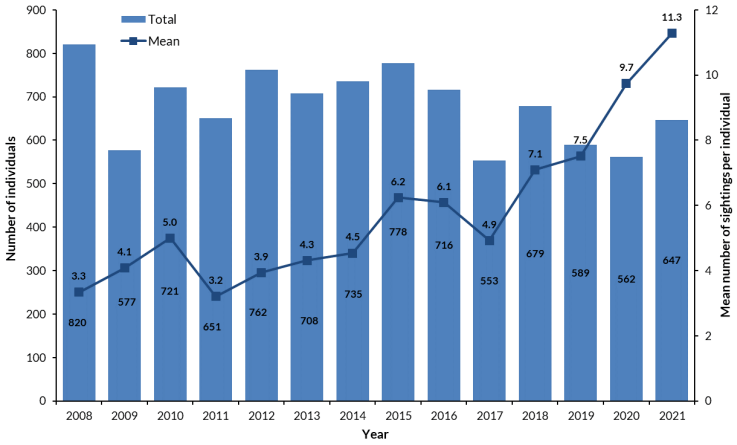


Figure 4: Annual number of individual reef manta rays (*Mobula alfredi*) sighted in the Baa Atoll Region from 2008 – 2021, and the mean number of sightings per individual.

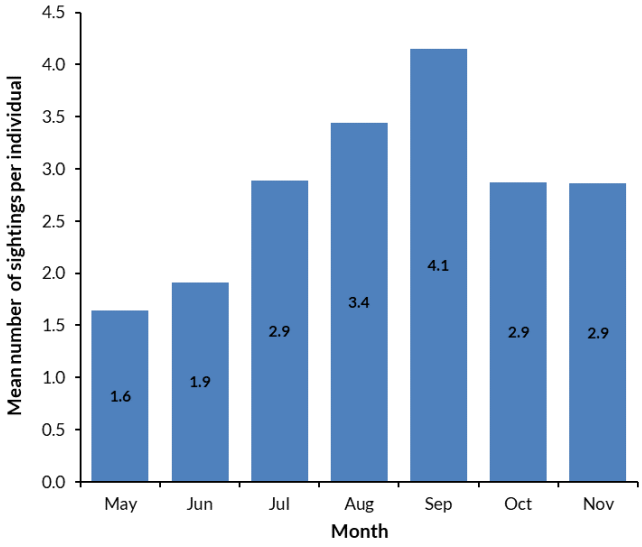


Figure 5: Mean number of sightings per reef manta ray (*Mobula alfredi*) during each month of intensive surveying in 2021.

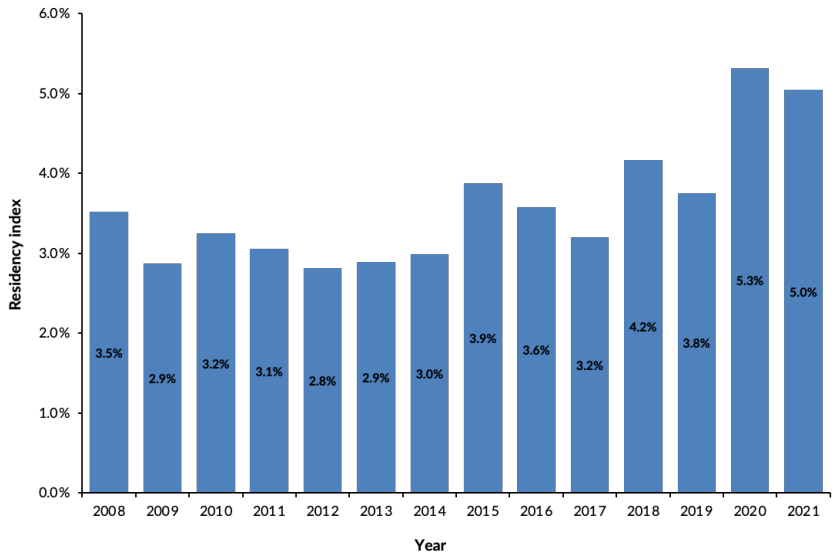


Figure 6: Annual Residency Index (RI) of the reef manta rays (*Mobula alfredi*) in the Baa Atoll Region from 2008 – 2021. RI is calculated as the average of each individuals' residency score (= number of times sighted annually divided by the total number of survey days).

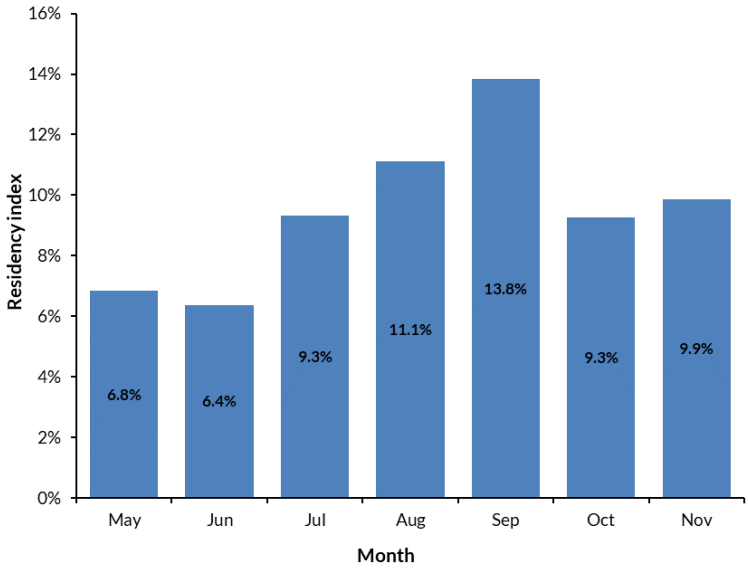
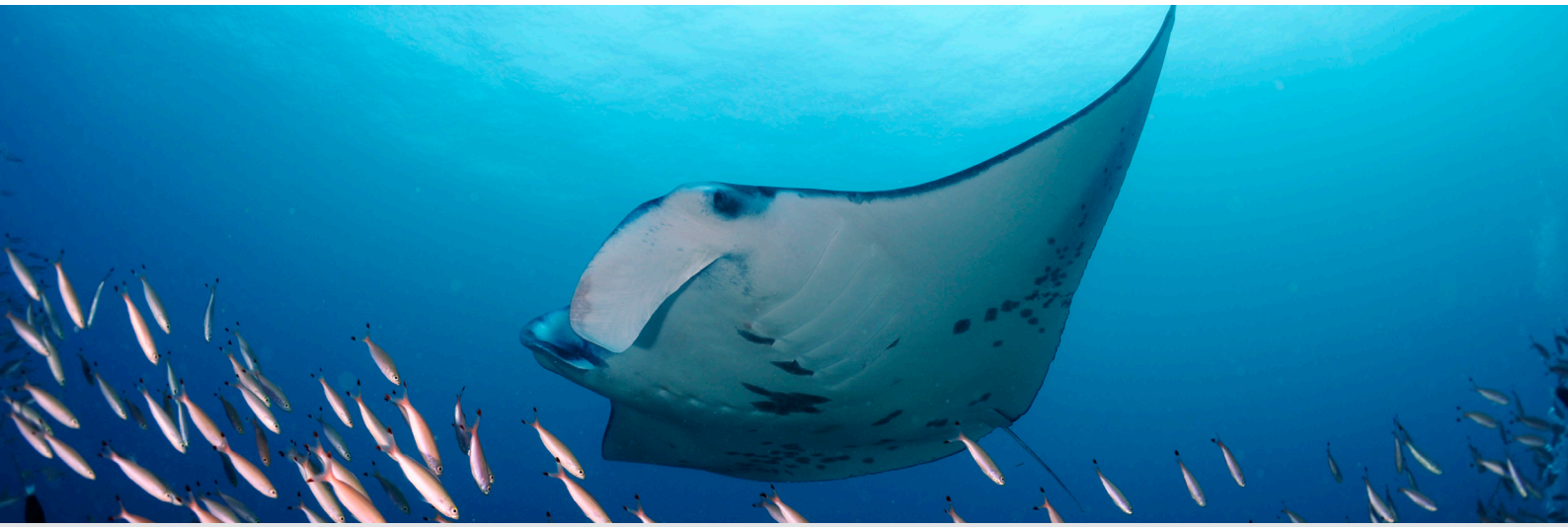


Figure 7: Residency Index of reef manta rays (*Mobula alfredi*) for each month of intensive surveying in the Baa Atoll Region during 2021.



Hanifaru Bay (Marine Protected Area)

In trend with previous observations at the regional level, the total number of sightings (*n*=6,137), and number of individual reef manta rays (*n*=603), recorded in Hanifaru Bay Marine Protected Area (MPA) in 2021 were higher than in 2020 (*n*=4,659 and 521, respectively) (Fig. 8). Monthly breakdowns reveal that the average number of manta ray sightings per survey day at Hanifaru Bay peaked in September (*n*=59) (Fig. 9), while the greatest number of individuals was recorded in August (*n*=443). The 21st August 2021 saw the greatest number of individuals recorded on a single day during the year, with a total of 188 confirmed individual reef manta rays identified from Hanifaru Bay.

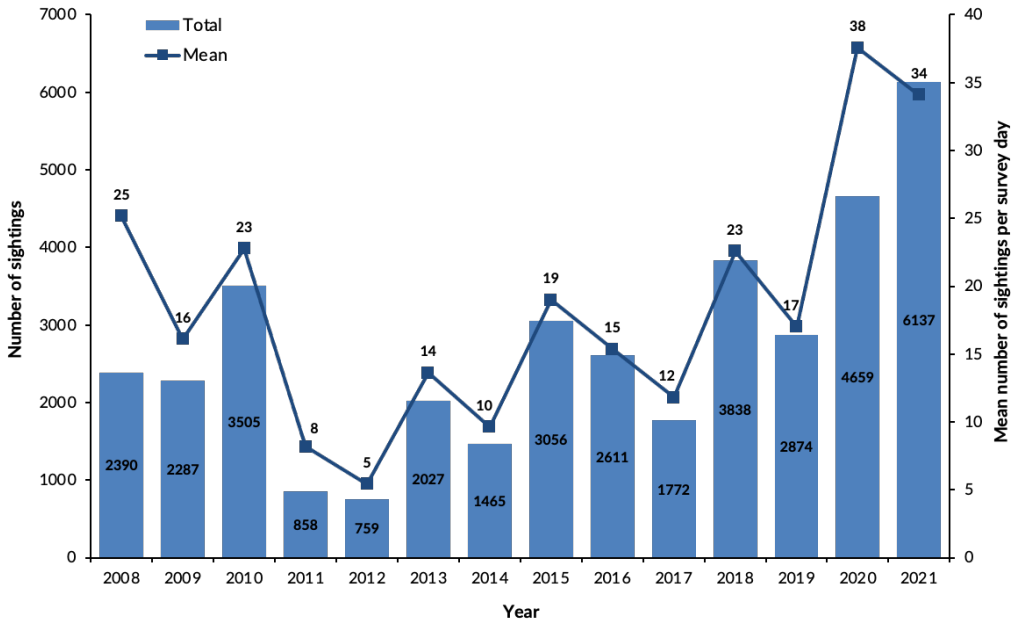


Figure 8: Annual sightings of reef manta rays (*Mobula alfredi*) in Hanifaru Bay MPA from 2008 – 2021, and the mean number of sightings per survey day.

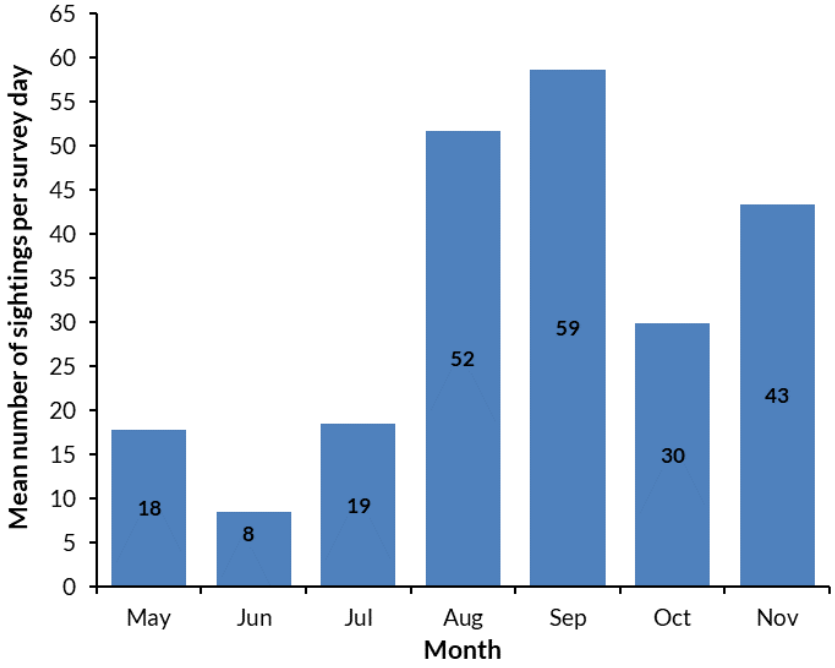


Figure 9: Average number of reef manta ray sightings (*Mobula alfredi*) recorded per survey day inside Hanifaru Bay MPA during each month of intensive surveying in 2021.

Angafaru Area (Marine Protected Area)

The Angafaru MPA includes Angafaru, Angafaru Falhu, Dhonfanu Thila, and Dhigu Thila. In past years (2010 – 2020), the total number of sightings recorded in this area has fluctuated between one and 209, with the highest number of sightings occurring in 2019 (*n*=209) and 2020 (*n*=85) (Fig. 10). In 2021, there were 45 sightings of 41 unique individuals in the Angafaru MPA. When standardising the data by number of days this area was surveyed, 2021 shows a decrease in the average number of sightings per day (*n*=0.4) as opposed to 2019 (*n*=2.3) and 2020 (*n*=1.8). Monthly breakdowns of average sightings per survey day revealed peaks in May (*n*=1.4), August (*n*=0.9), and October (*n*=0.8), while all other months had an average of between zero and 0.2 sightings per survey day (Fig. 11). The highest number of individuals recorded in one day in the Angafaru MPA occurred on 31st May at Dhigu Thila (*n*=11): the site at which the majority of sightings (*n*=41) and individuals (*n*=37) were recorded in the area in 2021. While mass feeding has been recorded in Angafaru Falhu in 2019 and 2020, no such events were observed within the MPA in 2021. However, the past 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.

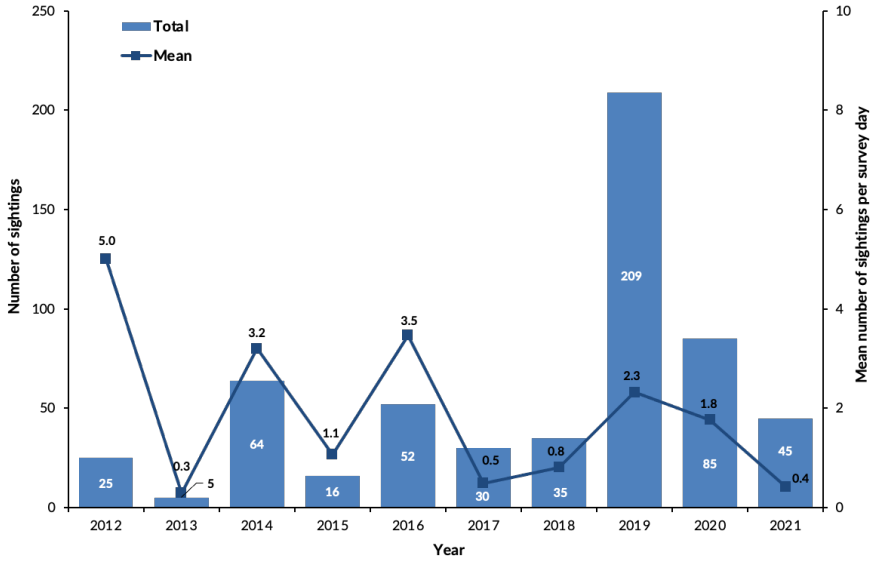


Figure 10: Annual sightings of reef manta rays (*Mobula alfredi*) in the Angafaru MPA from 2012 – 2021, and the mean number of sightings per survey day.

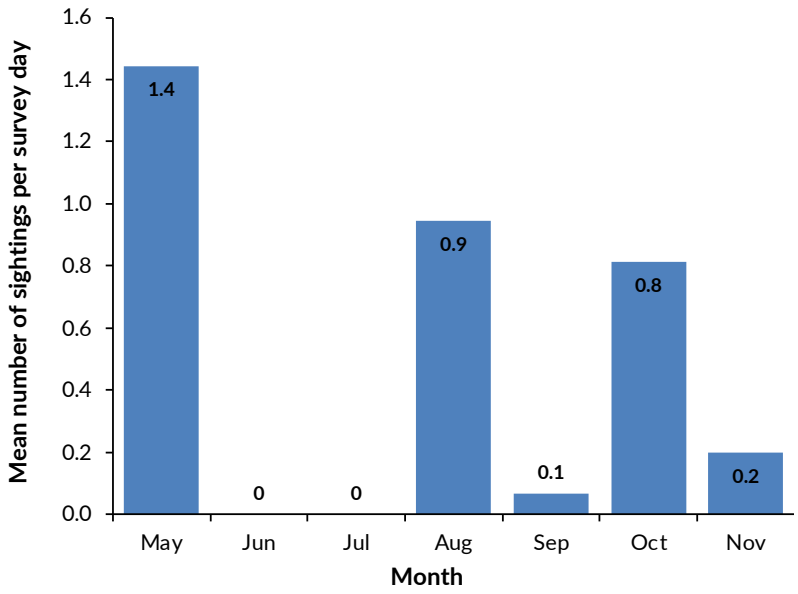


Figure 11: Average number of reef manta ray (*Mobula alfredi*) sightings recorded per survey day in the Angafaru MPA during each month of intensive surveying in 2021.

Population Demographics

The total number of individual reef manta rays recorded in the Baa Atoll Region since data collection began in 1992 is 2,271, almost half (43%) of the Maldives reef manta ray population recorded to date (*n*=5,247). As of 2021, population demographics of the region constitute 53% females (*n*=1,213), 46% males (*n*=1,047) and 0.5% individuals for which the sex could not be determined (*n*=11). The subpopulation comprises 1,395 adults, 83 subadults, 790 juveniles, and three of unknown maturity status.

Of the manta rays recorded in Baa Atoll (*n*=2,271), 48% (*n*=1,085) 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 2021, a total of 425 adult, 25 subadult, and 197 juvenile reef manta rays were sighted. This included 329 females, 315 males, and three individuals for which sex could not be determined. Of these, there were 174 adult females, 155 juvenile females, 251 adult males, 64 juvenile males (including subadults), and three juveniles of unknown sex. Maturation was defined by the presence of dorsal or ventral mating scars, visible pregnancies, or an estimated disc width of >320 cm in females, and by the enlargement and calcification of claspers in males. All other individuals were classified as juveniles, or subadults in the case of males when their claspers reach but do not extend past the posterior edge of the pelvic fins and are not fully calcified.

In every month of the main sampling period (May - November), adult females accounted for the largest proportion of reef manta ray sightings (43% overall, *n*=3,096), followed by adult males (29% overall, *n*=2,121) (Fig. 13). For juvenile manta rays, accounting for 27% (*n*=1,995) of sightings during these months, there was a more pronounced skew towards females (23% overall, *n*=1,665), while juvenile (including subadult) males accounted for just 5% (*n*=330). These figures highlight the importance of the region for sexually mature and reproductive females, which is likely to be driven by the high abundance of zooplankton trapped at Hanifaru Bay and other feeding sites during the Southwest Monsoon. Indeed, of the 3,096 sightings of adult females recorded between May and November, 92% (*n*=2,837) were recorded engaging in feeding behaviour at sites throughout the region, with Hanifaru Bay accounting for the majority of these (*n*=2,649).

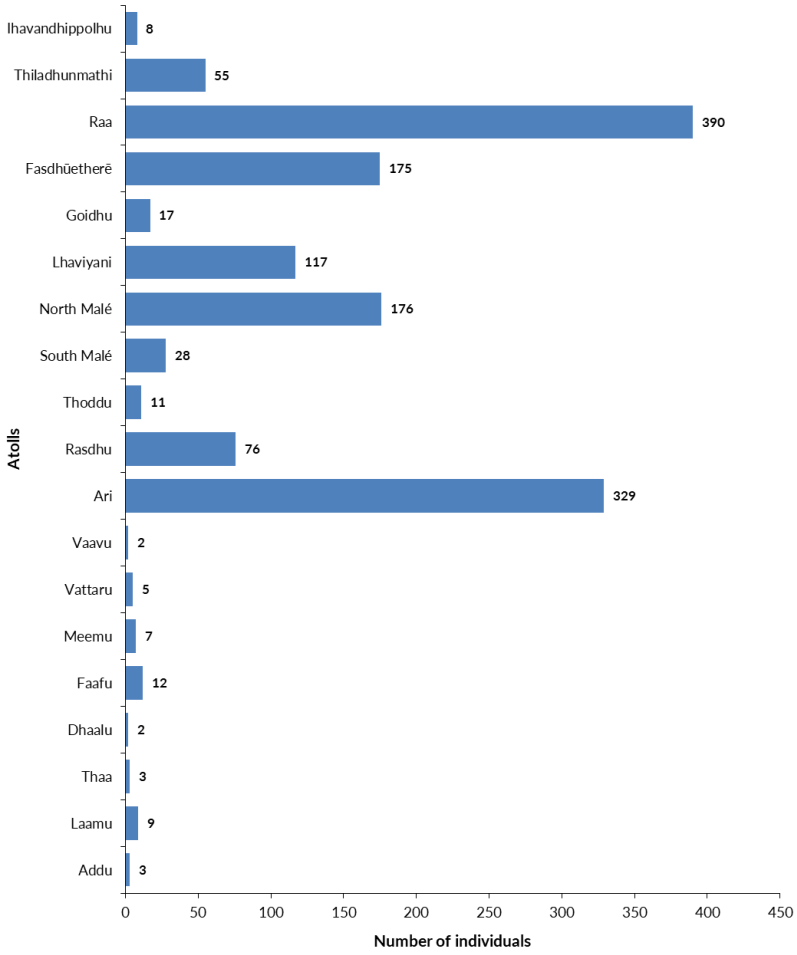


Figure 12: Number of reef manta ray (*Mobula alfredi*) individuals (*n*=1,085) from among the Baa Atoll subpopulation (*n*=2,271) which have been recorded in other atolls throughout the Maldives Archipelago. **Many of these cross-atoll individuals have been observed in more than two atolls.*

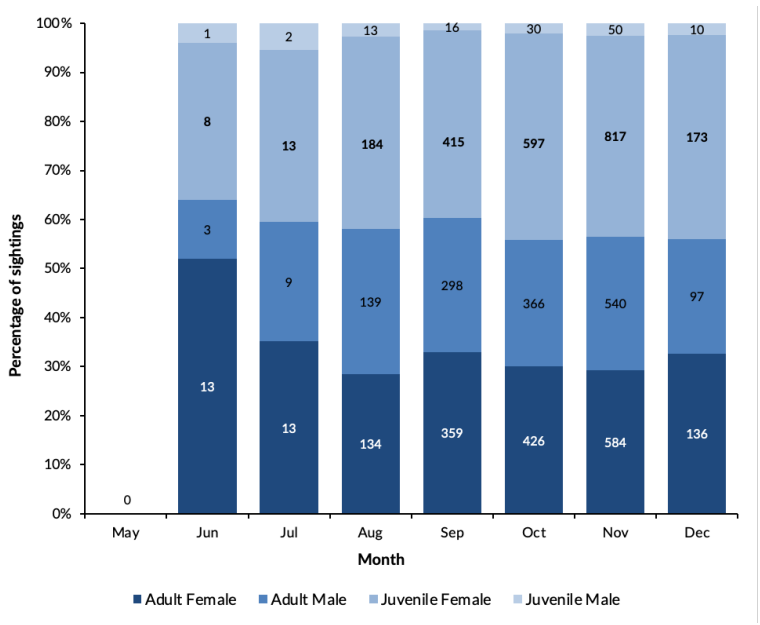


Figure 13: Reef manta ray (*Mobula alfredi*) sightings distribution categorised by maturity status during each month of intensive surveying effort in the Baa Atoll Region in 2021. *Actual numbers within bars.*

POPULATION RECRUITMENT

A total of 208 new individual reef manta rays were documented across the Maldives during 2021, a population recruitment of approximately 4.1% from the previous year (2020, *n*=5,039). As of 2021, the Maldives reef manta ray population was comprised of 5,247 individuals. Of the 208 new individuals added to the MMRP database in 2021, 29% (*n*=61) were documented in Baa Atoll, representing an increase from the previous year (2020, *n*=27) (Fig. 14). Of the 61 new manta rays sighted in Baa in 2021, 6.6% were adult manta rays (*n*=4), 8.2% were subadult males (*n*=5), and 85.3% were juveniles (*n*=52). Of these individuals, 54 were first identified in Baa Atoll with the other seven first identified in other atolls but later sighted in Baa Atoll. For example, one newly identified adult male was first observed in Kottefaru Bodu Thila, Raa Atoll, in October before being sighted in Hanifaru Bay less than one month later. Further, five juveniles and one subadult were newly identified in the putative nursery ground of Maamunagau Falhu in Raa Atoll during the Northeast Monsoon and were subsequently sighted in Hanifaru Bay during the Southwest Monsoon. Of the individuals first identified in Baa Atoll, 54% (*n*=29) were first recorded in Hanifaru Bay, 11% (*n*=6) in Fonimagoodhoo Falhu, and 11% (*n*=6) in Maaneigaa Falhu. The latter two sites are shallow lagoon areas, which are thought to be a preferred habitat for juvenile manta rays due to their sheltered nature, offering reliable foraging opportunities and protection from predators.

While there was a slight increase in the number of newly identified manta ray individuals during 2021, there is a general downward trend of the proportion of newly sighted individuals throughout study years (Fig. 14). As more data is collected over the years by the MMRP in the Baa Atoll Region, the number of new individuals (especially adults) becomes less frequent, suggesting that most of the regions reef manta ray subpopulation has been recorded and identified. The increase in newly identified individuals in 2021, the majority of which were juveniles, is a positive indication of reproductive success.

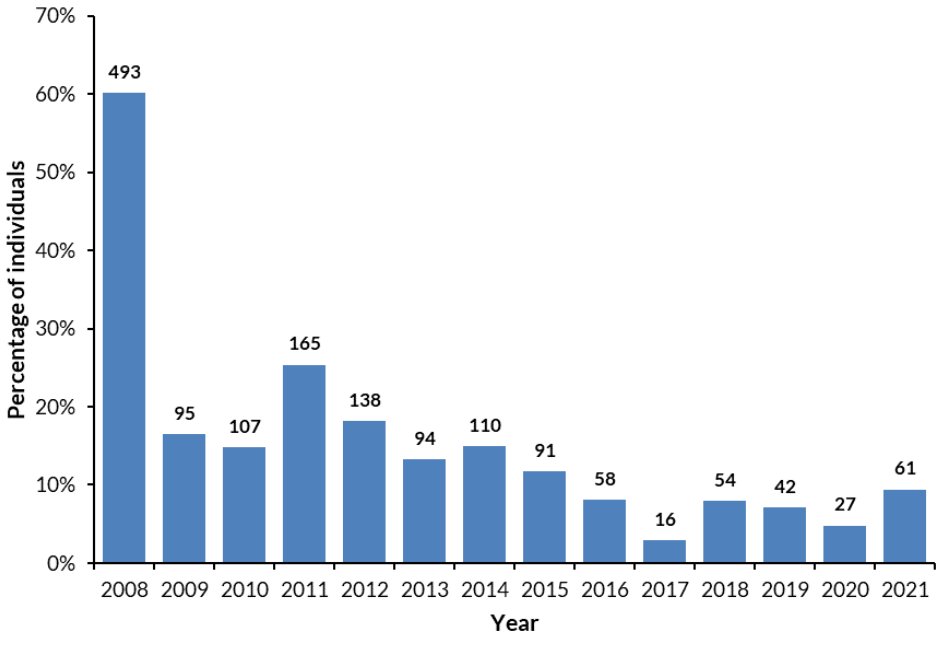


Figure 14: Proportion of the total reef manta rays (*Mobula alfredi*) sighted annually in the Baa Atoll Region, from 2008 – 2021, which were newly sighted individuals. *Actual number of new individuals above bars.*

REPRODUCTIVE ACTIVITY

This report marks the ninth year in a row that the MMRP has recorded pregnancies among the Maldives reef manta ray population. A total of 64 individuals were recorded as pregnant in the Baa Atoll Region in 2021; this was a more than ten-fold increase from the previous year (*n*=6 in 2020), and the second highest in any year since data collection began (Fig. 15). 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 64 pregnant females observed in the region during 2021, 73% (*n*=47) were in the later stages of gestation (3rd or 4th trimester) when first sighted. A further 24 females were recorded with fresh reproductive wounds but were not recorded as pregnant. Courtship behaviour was observed during 14 surveys during the Southwest Monsoon (June: *n*=1; July: *n*=3; October: *n*=7; November: *n*=3).

While 2021 experienced a relatively high number of recorded pregnancies, it remains important to continue and increase the protection of the species and its habitats in a changing environment. Overall, manta rays display slow reproductive rates, with, on average, only 13% of the mature females sighted in the Baa Atoll Region annually being recorded as pregnant. 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.

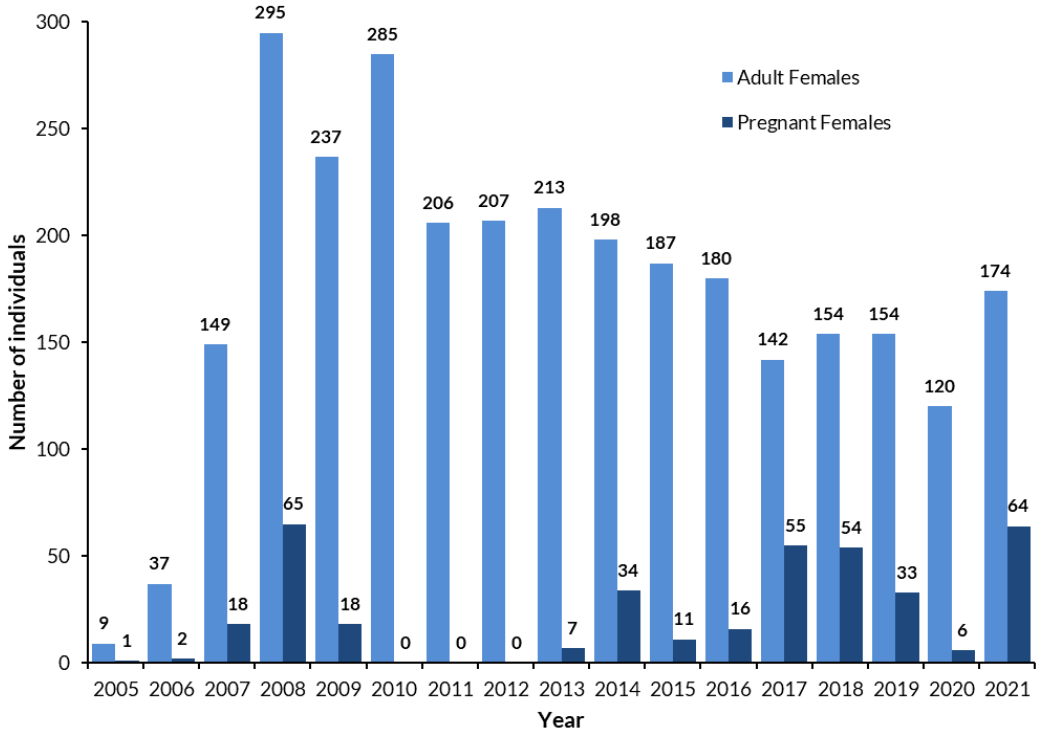


Figure 15: Number of adult female reef manta ray (*Mobula alfredi*) individuals sighted annually in the Baa Atoll Region from 2005 – 2021, and the number of those females which were recorded as being pregnant in the same year. *Actual numbers above bars.*

WHALE SHARK SIGHTING TRENDS

In the Baa Atoll Region, whale sharks often inhabit the same feeding grounds as reef manta rays and are regularly sighted together along shallow reefs throughout the Maldives. In 2021, the MMRP team recorded 37 whale shark sightings of 21 different individuals in the Baa Atoll Region between May and November (Fig. 16). Of these 21 individuals, 19% (*n*=4) were new to the Maldives Whale Shark Research Programme's database. Sightings of whale sharks in 2021 increased by 185% compared to the previous year (2020, *n*=13), and had the highest number of sightings in the region since 2008, when 49 sightings were recorded. Overall, whale shark sightings in Hanifaru Bay in 2021 accounted for 32% (*n*=12) of the total sightings.

Monthly breakdowns reveal that the greatest number of sightings in 2021 were recorded during the months of September (*n*=13) and October (*n*=17) (Fig. 17). Interestingly, the MMRP recorded the highest number of manta ray sightings in September (*n*=1,855), followed by August (*n*=1,640) and November (*n*=1,166), suggesting that the prevailing conditions from September through November were most favourable for these planktivorous species. Indeed, within Hanifaru Bay, September marked the peak in both manta ray (*n*=1,700) and whale shark (*n*=9) sightings (Fig. 18).

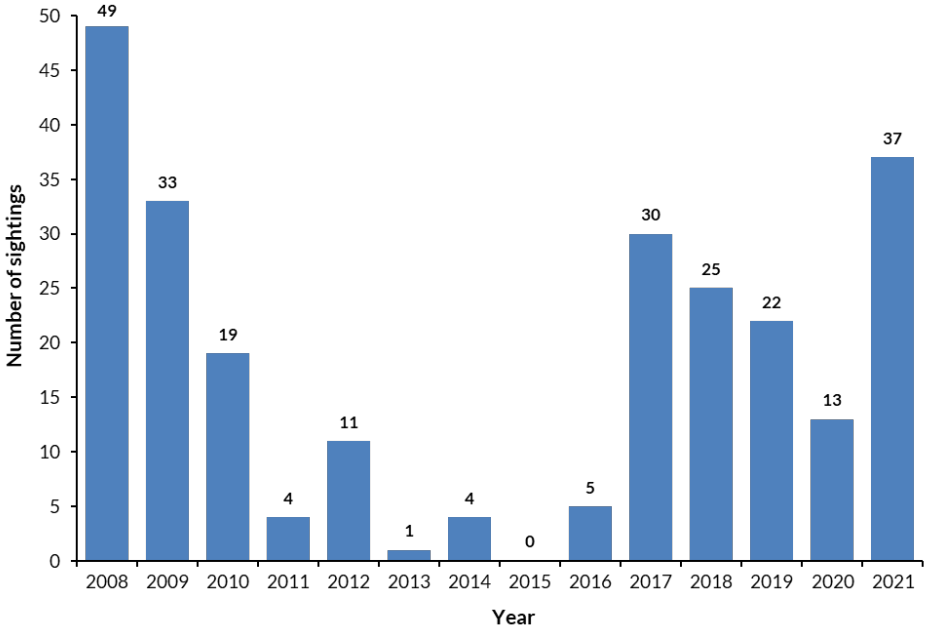


Figure 16: Annual sightings of whale sharks (*Rhincodon typus*) in Baa Atoll.

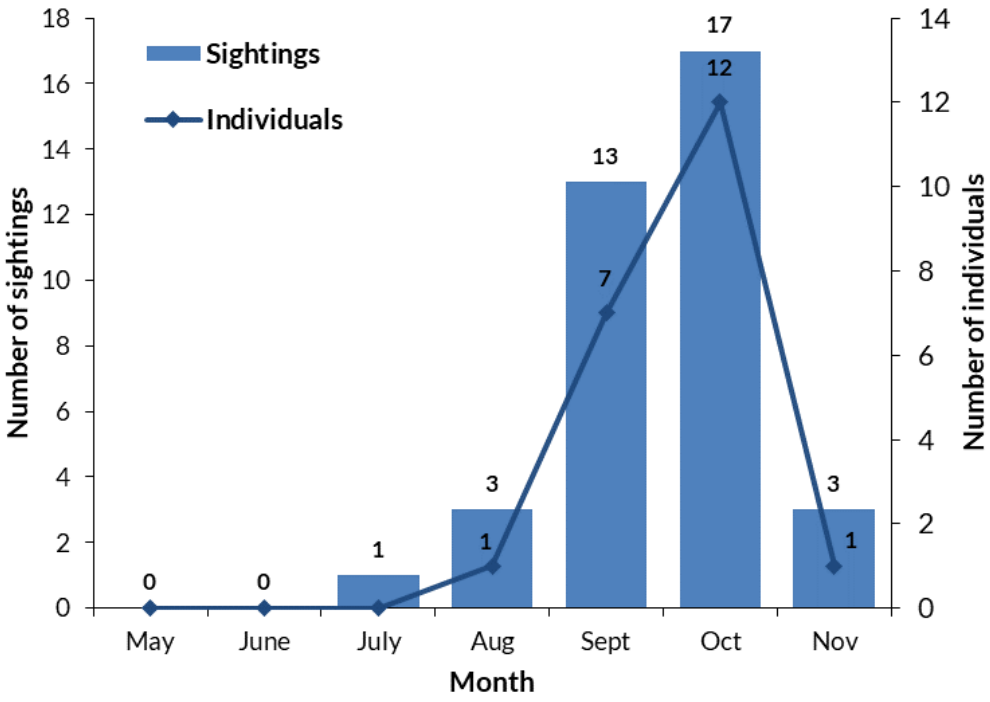


Figure 17: Whale shark (*Rhincodon typus*) sightings in the Baa Atoll Region during 2021 (*n*=37), and the total number of individuals (*n*=21) recorded each month.

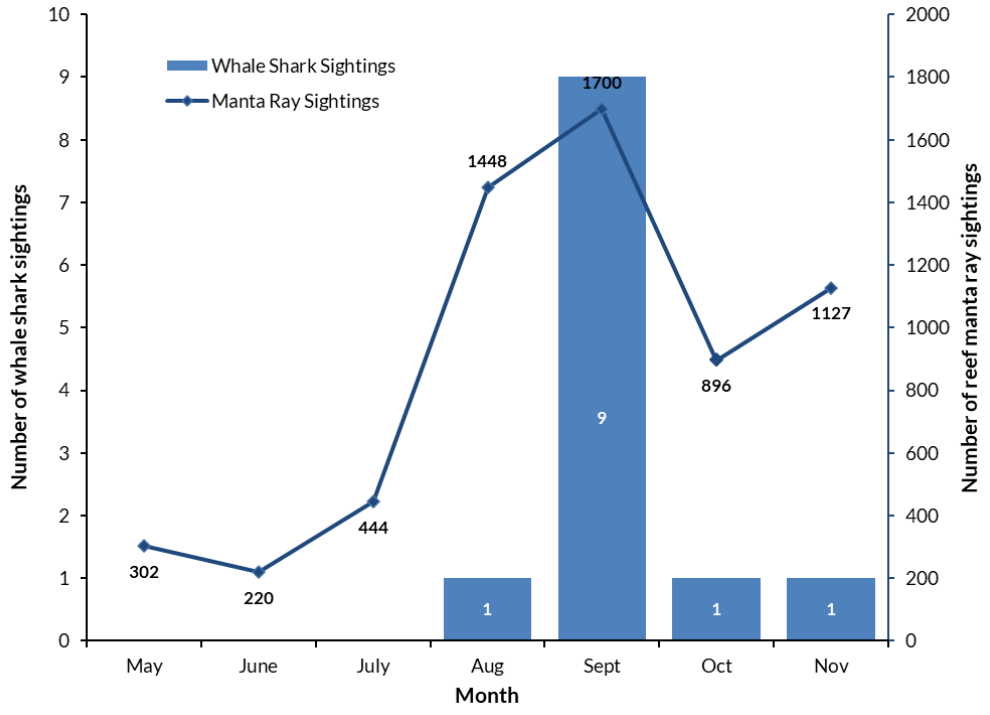


Figure 18: Monthly whale shark (*Rhincodon typus*) and reef manta ray (*Mobula alfredi*) sightings recorded at Hanifaru Bay, Baa Atoll in 2021.

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 2021, May (which marks the start of the Southwest Monsoon) typically demonstrates characteristically high wind speeds. In 2021, average wind speeds in March and April were 14.22 km/h and 13.95 km/h, respectively, before increasing to 22.82 km/h in May at the start of the Southwest Monsoon. 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. Similar trends were observed in 2021, where manta ray sightings then began to increase from May to June before peaking in September. Wind speeds reached their maximum towards the end of the Southwest Monsoon in October and November (*n*=23.19 km/h and *n*=26.61 km/h, respectively) while the lowest minimum wind speeds were recorded in July and September (19.59 km/h and 19.08 km/h, respectively). Compared to the lowest recorded average wind speed from 2020 (13.06 km/h in August), this "low" wind speed recorded in September 2021 (19.09 km/h) is more than 6 km/h higher. Data pertaining to the wind speed, direction, and fine scale changes in the weather conditions in the region throughout 2021 were provided to the MMRP by the Maldives Meteorological Service.

It has been previously hypothesized by the MMRP that higher overall wind speed results in more favourable conditions for zooplankton and attract manta rays to the region. The average wind speed observed in 2021 was 19.82 km/h, which was 2.4 km/h higher than 2020 and 5.5 km/h higher than in 2019, when the average wind speed was 17.4 km/h and 14.3 km/h, respectively (Fig. 20). Across all years, generally, when the annual wind speed increases, so do the average number of manta ray sightings

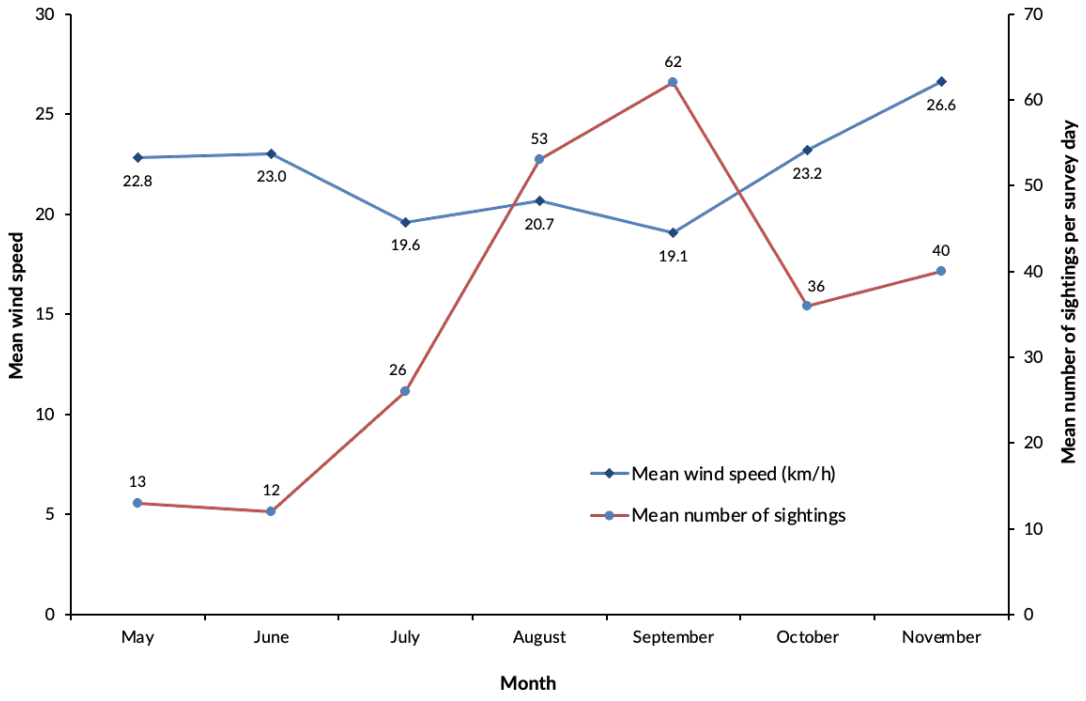


Figure 19: Mean monthly wind speed (km/h) and mean number of reef manta rays (*Mobula alfredi*) sightings per survey day in the Baa Atoll Region (2021).

(Fig. 20). This hypothesis may explain the increase in the average number of sightings per day in 2020 and 2021 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. The overall trend shows that years with increased wind speeds generally produce higher sighting rates for manta rays (Fig. 20).

Wind directions recorded from the Maldives Meteorological Society's met station (situated at Hulhule Island, North Malé Atoll) reveal variability throughout May to November (Fig. 21). Directions were classified into eight main directions combining multidirectional winds into their main category (i.e., WSW winds were classified as W). As expected during the Southwest Monsoon, winds coming in from the general west direction dominated from May to November contributing to 42% – 80% of wind direction readings during this time (Fig. 21). The beginning of the season (June) and end of the season (November) were marked with distinctly high westerly readings with a decrease during the middle of the season (September). The highest numbers of manta ray sightings occurred in September, when the contribution of winds from the west was at one of its lowest points in the season at 57%.

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. Disrupted trends in manta sightings. 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.

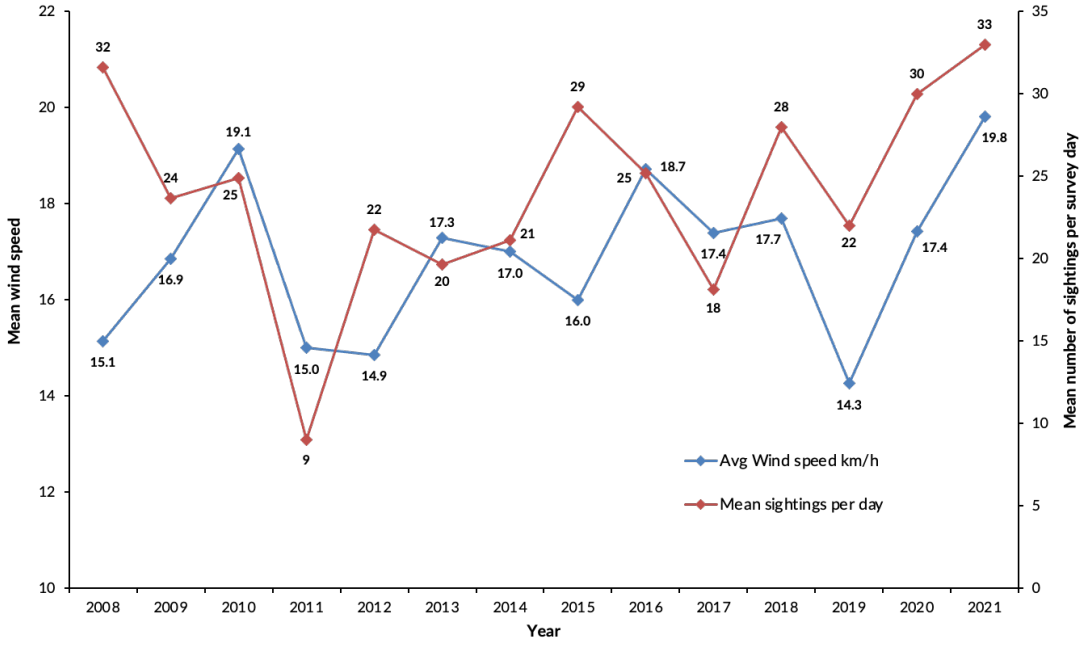


Figure 20: Mean annual wind speed (km/h) and the mean number of reef manta ray (*Mobula alfredi*) sightings per survey day in the Baa Atoll Region, from 2008 – 2021.

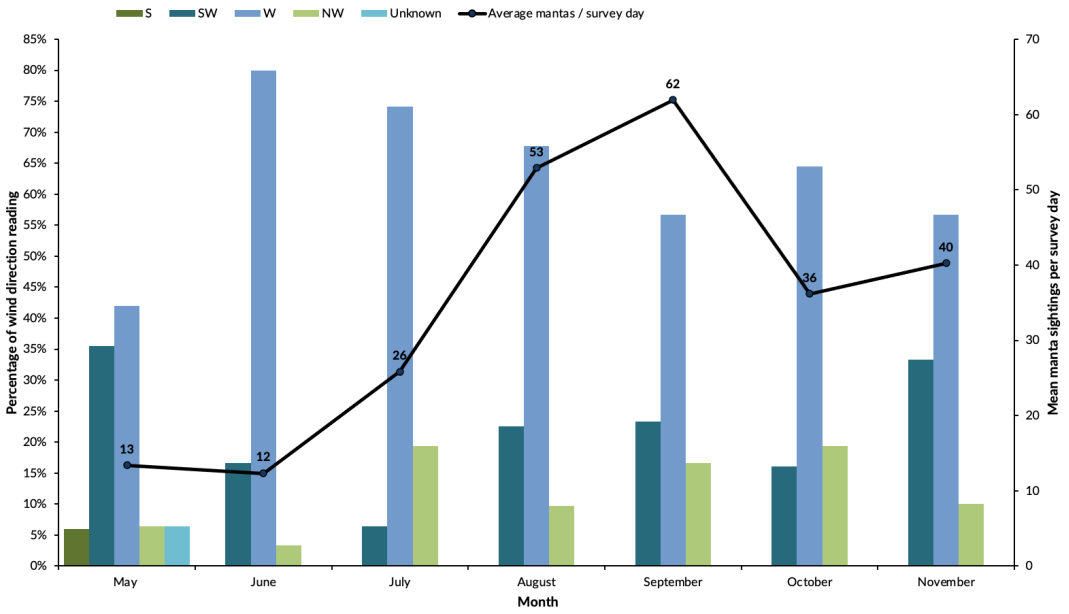


Figure 21: Monthly breakdown of the percentage of Baa Atoll wind direction readings from Vantage Vue weather station situated at Landaa Giraavaru, and the average number of reef manta ray (*Mobula alfredi*) sightings per survey day (2020).

SUB-LETHAL INJURIES

Of the population of reef manta rays recorded in the Baa Atoll Region across all study years (*n*=2,271), 831 injury events have been recorded from 707 individuals, with the highest cause of injury attributed to predatory bites (individuals, *n*=332), followed by fishing line entanglement (*n*=237) (Fig 22). Manta rays that have been recorded with new injuries in 2021 follow a similar trend to that of the whole Baa Atoll population in terms of injury origin. Of all injury events (*n*=64), 78% could be identified to a specific cause (*n*=50). Most injuries were attributed to fishing line (*n*=21) and predatory bites (*n*=16), followed by deformity (*n*=7), boat strikes (*n*=4), and infection, disease and parasites (*n*=2) (Fig. 23). Over 56% of these injury events recorded in 2021 affected the pectoral region of the animal (*n*=36) (Fig. 24), which in severe cases could impair a manta ray's swimming efficiency or ability to evade predators.

Although manta rays have shown resilience to a range of sublethal injuries, the continued increase in boat traffic, tourism, and fishing activities in the region will likely lead to more frequent injuries, particularly in sheltered lagoonal areas where manta ray habitat and human activities overlap. Despite being protected nationally in the Maldives and having never been targeted by a commercial fishery in the region, incidental bycatch and marine traffic still present a considerable threat. The long-term implications of sublethal injuries for the health and fitness of these animals are unclear. Of the anthropogenic threats, entanglement in fishing line (*n*=21) was the most common injury type affecting the Baa Atoll Regions reef manta ray subpopulation, highlighting an area where management should be improved to protect the species in this region. Of great concern is the increase in the number of boat strikes that occurred this year (*n*=4) as opposed to last year (*n*=1). This increase serves as a reminder that slow speed zones should be respected and followed by all vessel operators to avoid these potentially lethal events from occurring.

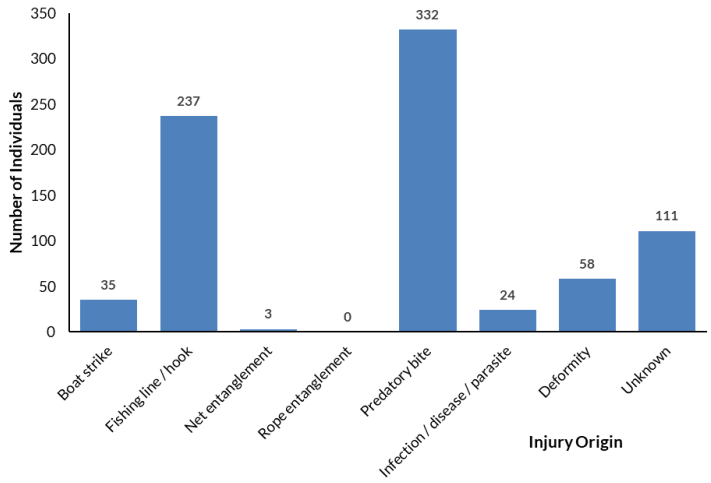


Figure 22: Variations in the likely origin of sublethal injuries (*n*=831) within the injured reef manta ray (*Mobula alfredi*) population of the Baa Atoll Region from 1992 – 2021 (*n*=707).

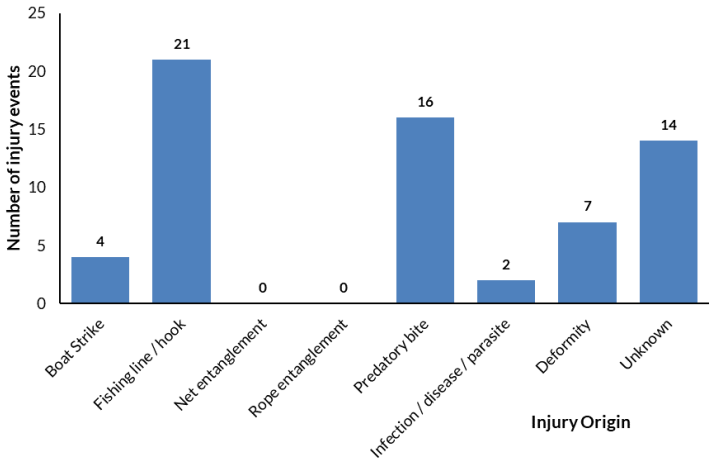


Figure 23: Variations in the likely origin of sub-lethal injuries (*n*=710) within the injured reef manta ray (*Mobula alfredi*) subpopulation of the Baa Atoll Region (*n*=638).

Figure 24: Variations in the locations (by body part) of sublethal injury events (*n*=64) within the reef manta rays (*Mobula alfredi*) that were recorded injured in the Baa Atoll Region in 2021. Actual number of injuries on bars. *Note that injury events can affect multiple parts of the body.*

REMOTE UNDERWATER VIDEO SURVEYS

Remote underwater video (RUV) surveys are commonly used in research to monitor specific areas and their use by different marine life whilst humans are absent. These GoPro RUVs are placed in underwater housings and anchored to the reef with a dive weight, where they continuously record a cleaning station for up to three hours. Having identified several cleaning stations within the Baa Atoll Region, the MMRP's long-term aim is to increase survey effort at these sites. This, in turn, will enable the development of a robust long-term dataset to answer key questions about cleaning station functionality, associated manta ray behaviours, and social interactions. In 2021, 215 RUV surveys were conducted over a period of 114 days and captured 129 sightings of 83 individual reef manta rays (Fig 25).

2021 was also the second year that the MMRP has used a remote underwater photo (RUP) system to capture photo-IDs of reef manta rays (photo-ID data captured by RUPs was not included in the 2020 report) that gather at cleaning stations. This camera system also uses a GoPro that is programmed to take a photo every minute from sunrise (6:00) to sunset (18:00) and is equipped with battery packs that allow for up to 5 – 7-day deployment periods. In 2021, the MMRP used RUPs to conduct 140 surveys over a period of 137 days, which captured 104 sightings of 37 different individuals (Fig 25).

Collectively, RUVs and RUPs recorded 233 sightings of 97 individuals. Only one of these individuals was only seen through these techniques and not recorded by human observers. Nonetheless, these remote monitoring systems are important as they will help the MMRP team to understand the drivers behind manta ray visitations to cleaning stations, capture sightings of manta rays with less bold temperaments which may shy away from human observers and provide a more standardised way of collecting data across multiple temporal scales.

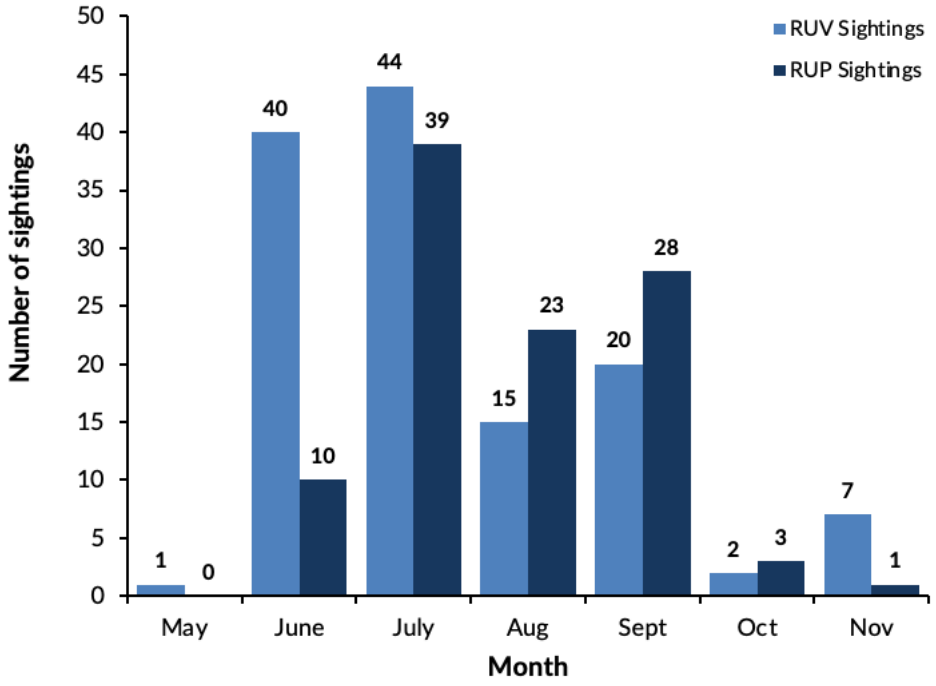


Figure 25: Monthly breakdown showing the number of reef manta ray (*Mobula alfredi*) sightings using Remote Underwater Video (RUV) and Photo (RUP) systems in the Baa Atoll Region in 2021.

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 the 27th of March and reopened again on the 14th of July 2020. International arrivals to the Maldives decreased from 1,702,887 arrivals in 2019 to 55,494 arrivals in 2020 (Ministry of Tourism). International visitors increased in 2021 to 1,321,937, which mirrors pre-pandemic levels. The estimated total number of paying guests at surveyed sites increased substantially from 2020 to 2021 (*n*=1,204 and *n*=13,853, respectively) due to the Maldivian border opening and international lockdowns ending.

Manta rays are sensitive to disturbance, and if left without proper measures, tourism has the potential to do more harm than good. A Best Practice Code of Conduct for manta ray tourism has been formed based on years of research. These guidelines explain how divers and snorkellers should interact with these animals in-water to enhance their experience and ensure their presence has the least impact on individual manta rays. Throughout 2021, the MMRP strove to improve the sustainability of manta ray tourism activities in the Baa Atoll Region 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 the education of marine users, it is crucial for 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 key manta ray sites and other protected areas throughout the region. 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 feeding and cleaning aggregation sites in the Baa Atoll Region. 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.

Unfortunately, the effects of COVID-19 restrictions were still felt throughout 2021, with movement between islands being heavily restricted. Although the MMRP team were unable to resume education initiatives on the local islands in the Baa Atoll Region, time was spent developing learning resources and planning for future programmes. During 2022, Moodhu Madharusaa theory classes and practical sessions with B. Kamadhoo School will be completed.

CONSERVATION & MANAGEMENT

Baa Atoll has been recognised as one of 700 UNESCO World Biosphere Reserves around the globe, in-part because of its ecological importance as an aggregation site for manta rays and whale sharks. As such, this region is an extremely important research location for these species globally. The designation of Hanifaru Bay 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 consistent quality of the long-term data collected within the region allows us to gain a deeper knowledge of manta rays worldwide. Continued access to monitor these animals and how this critical habitat functions to support them 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 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 government data collected as a part of this study. For further information or please email: baa@mantatrust.org or mmcpteam@mantatrust.

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:

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