

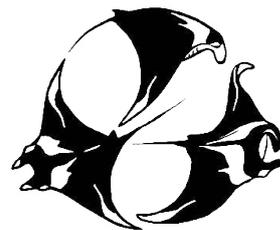


Maldives Manta Conservation Programme

BAA ATOLL | ANNUAL REPORT 2023

*Conservation through
research, education, and collaboration*

- The Manta Trust



MALDIVES MANTA
CONSERVATION
PROGRAMME

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.

MALDIVES MANTA CONSERVATION PROGRAMME



Formed in 2005, the Maldives Manta Conservation Programme (MMCP), formerly the Maldivian Manta Ray Project (MMRP), is the founding project of the Manta Trust, and has been a Maldives registered charity since 2022. It consists of a country-wide network of dive instructors, biologists, communities and tourism operators, with more than a dozen MMCP staff based across a handful of atolls, on both resort islands and local islands.

The MMCP collects data around the country's manta population, its movements, and how the environment and tourism / human interactions affect them. Since its inception, the MMCP has identified over 6,000 different individual reef manta rays, from more than 80,000 photo-ID sightings. This makes the Maldives manta population the largest, and one of the most intensively studied populations in the world. The MMCP has also identified more than 1,000 different individual oceanic manta rays.

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 monitored by the Maldives Manta Conservation Programme (MMCP). Reef manta rays and whale sharks (*Rhincodon typus*) frequent the eastern side of Baa Atoll each year to feed on the abundant zooplankton prey that results from the productive Southwest (SW) Monsoon conditions. Baa Atoll is internationally renowned as 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 2023 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 Baa Atoll during 2023.

The MMCP, with outside contributions, documented 1,807 reef manta ray surveys on 247 days in 2023. The MMCP conducted 1,611 of these surveys over 185 days, with outside parties contributing 196 surveys on an additional 62 survey days. Of the 247 survey days in 2023, 186 fell between the 1st May and 30th November. Key findings of the MMCP in Baa Atoll during 2023 include a total of 5,268 sightings of 672 individual manta rays. Of these individuals, each manta ray was observed on average 7.8 times. The mean daily number of reef manta ray sightings between May and November was 28, with a peak during the month of August ($n=52$). A Residency Index (RI) was calculated to gauge the extent of movement amongst those frequenting the region. The RI for 2023 (3.2%) represented a slight decrease from 2022 (3.4%). The total number of sightings ($n=4,454$) and number of individual manta rays ($n=584$)

recorded in Hanifaru Bay MPA in 2023 was also lower than in 2022 (sightings, $n=5,053$; individuals, $n=596$).

As of 2023, the population demographics of Baa Atoll constitute 2,457 individuals, of which 1,312 (53%) are female, 1,132 (46%) are male, and 13 (0.5%) are of unknown sex. Of these Baa Atoll individuals ($n=2,457$), 49% ($n=1,193$) have also been seen in at least one other atoll in the Maldives. Of the 672 individuals observed in 2023, 352 were female and 315 were male.

A total of 260 new reef manta rays were added to the MMCP database from across the Maldives in 2023, bringing the total number of identified individuals in the Maldives to 5,870. Of the new manta rays identified in 2023, 20% ($n=52$) were documented in Baa Atoll, similar to the previous year (2022, $n=50$). Within Baa Atoll, 41 of these new individuals were juveniles.

The number of pregnancies recorded in Baa Atoll ($n=54$) in 2023 was a decrease from 2022 ($n=66$), which saw the highest number in any year since data collection began. Of the 54 pregnant females observed, 69% ($n=37$) were recorded in the later stages of gestation (3rd - 4th trimester) when first sighted in 2023. A further 26 females were recorded with fresh reproductive wounds but were not recorded as pregnant.

Despite being unable to deliver the planned six-month Moodhu Madharusaa Marine Education Programme at B. Kihadhoo school throughout 2023, the MMCP team delivered and attended education and outreach events, one-day Marine Education Programmes, community engagement, workshops, stakeholder meetings, and festivals.

THE BAA ATOLL REGION

Geographically, the Baa Atoll region 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 km²) 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 km²), 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 km²), 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.

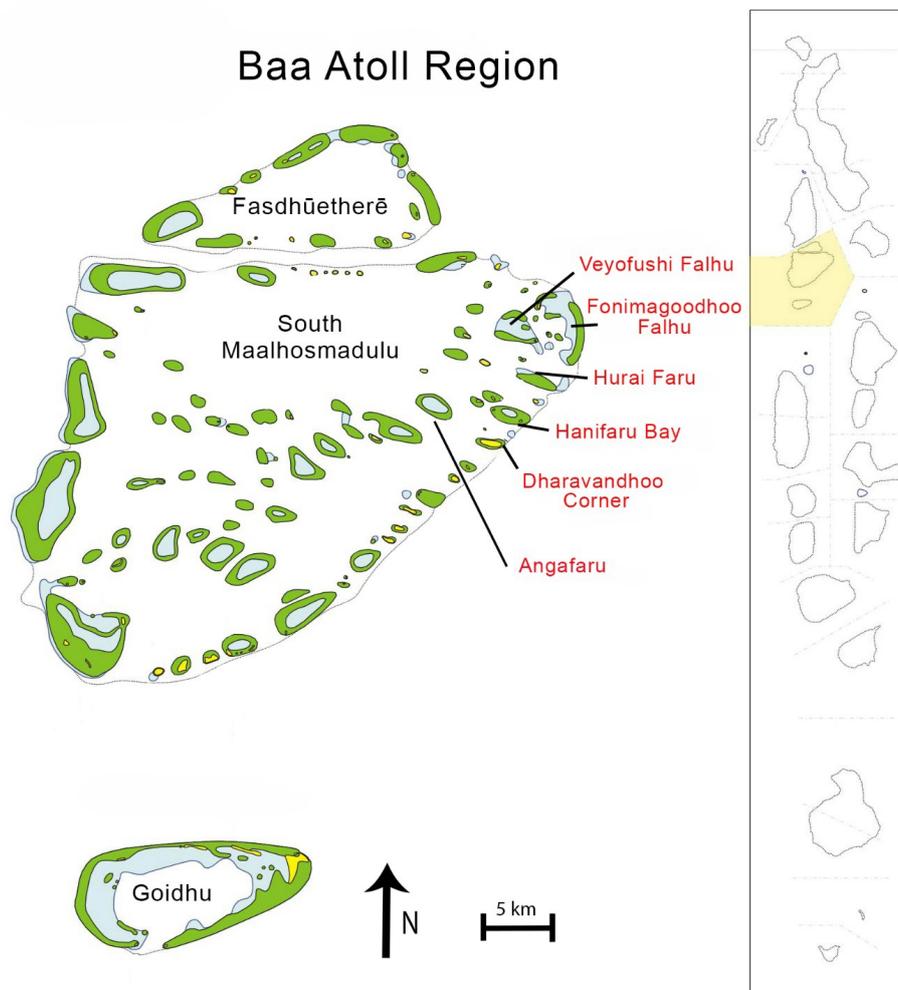


Figure 1: Map of the Baa Atoll region showing the three geographical atolls (in black), six of the key reef manta ray (*Mobula alfredi*) aggregation study sites (in red), and the region in relation to the rest of the Maldives Archipelago (shaded yellow).

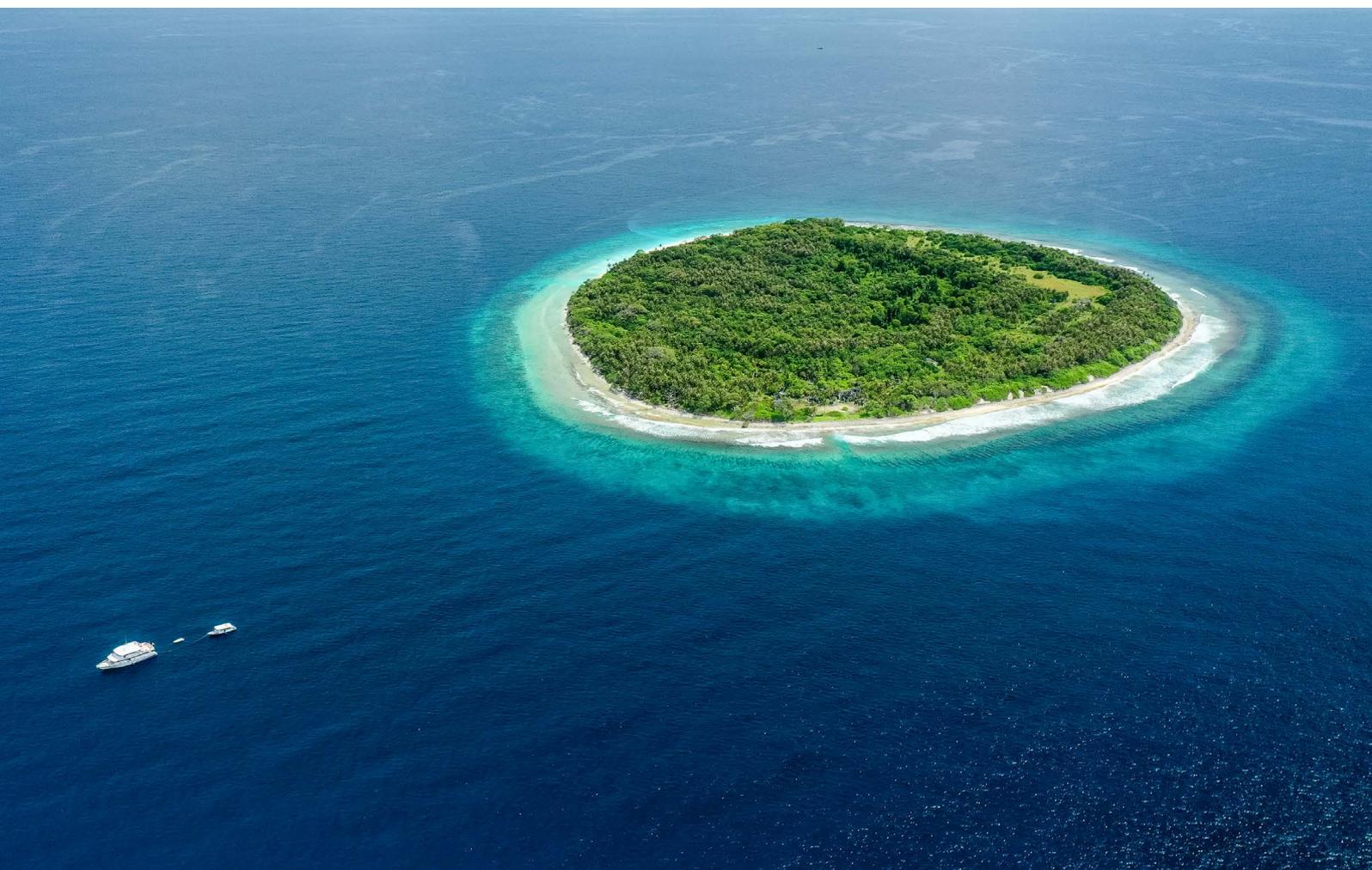
UNDERSTANDING THE MONSOONS

Understanding the effects of the Maldives Southwest (SW) Monsoon is inherently vital to understanding why 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 to October is recognized as *Hulhangu*, while December to 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 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 MMCP's Baa Atoll Project is based at the Four Seasons Resort on the island of Landaa Giraavaru, located in the northeast of Baa Atoll. In 2023, MMCP researchers carried out directed surveys on as many days as the weather conditions allowed between the 6th of May and the 28th of November, in line with the Southwest Monsoon. These intensive surveys were conducted at six key manta aggregation sites, including Hanifaru Bay, and a dozen other sites around the eastern border of Baa Atoll (Fig. 1). The MMCP also collected self reported data from citizen scientists, which include dive guides, marine biologists, and tourists. These external reports made up the bulk of surveys conducted during the months of the Northeast Monsoon (December to April).

A total of 1,807 manta ray surveys were undertaken in Baa Atoll during 2023 across 247 survey days, or 68% of the total possible days within the year. The MMCP alone conducted 1,611 surveys on 185 days. MMCP surveys were carried out by observers ($n=1,380$), remote underwater video systems ($n=214$), and remote underwater photo systems ($n=17$). External parties contributed an additional 196 surveys across 138 survey days; 62 of these survey days were days when MMCP did not conduct any surveys. During the months of the Southwest Monsoon (May to November), surveys were conducted on 186 days, representing 87% of the total possible survey period of 214 days. Within this period, the MMCP conducted 1,399 surveys over 176 days, while external parties contributed an additional 130 surveys across 83 days.

To ensure comparable results, data were standardised where possible to account for changes in sampling effort spatially and temporally. All surveys undertaken by the MMCP team were recorded, whether manta rays were sighted or not.

The results presented in this report also include sightings submitted to the MMCP 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 MMCP; location, tourism information, and multiple environmental variables were collected, along with manta ray abundance and behaviours (e.g., 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 uniquely identifiable manta ray observed at a particular site on a particular day.

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 GoPros 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 Baa Atoll, the MMCP's long-term aim is to increase survey effort at these sites. In 2023, 214 RUV surveys were conducted over 121 survey days.

This is the fourth year that the MMCP has used a remote underwater photo (RUP) system to capture photo-IDs of reef manta rays that gather at cleaning stations. This camera system 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 5 to 7 day deployment periods. Technical difficulties limited the team's use of RUPs in 2023, with 17 surveys conducted over a period of 17 days.



REEF MANTA RAY SIGHTING TRENDS

Baa Atoll Region

In 2023, a total of 5,268 sightings of reef manta rays were recorded in Baa Atoll (Fig 2). This represents a 10% decrease in reef manta ray sightings compared with 2022 ($n=5,847$), which had the second highest number of sightings on record. On average, 21 manta rays were sighted per survey day in 2023 overall, with an average of 28 sighted per survey day during the months of the Southwest Monsoon (May to November). Monthly breakdowns reveal that daily sightings increased rapidly in the first half of the season, peaking in July ($n=48$) and August ($n=52$), before declining in the latter months of the Southwest Monsoon (Fig. 3).

A total of 672 different individual reef manta rays were recorded in Baa Atoll in 2023, which comprises 11.4% of the total recorded Maldives population ($n=5,870$) and represents a very slight increase from 2022 ($n=665$) (Fig. 4). Throughout 2023, 83% of individuals ($n=556$) were observed more than once, and each manta ray was observed 7.8 times on average (Fig. 4). The number of sightings per

individual was highest in August, with an average of 3.5 sightings per individual (Fig. 5). The most sighted individual was MV-MA-5259 (Lulu Laurent), a juvenile female who was recorded 44 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 2023 (3.2%) was marginally lower than in 2022 (3.4%) (Fig. 6), potentially indicating a more transient population in 2023 compared to the previous year. Monthly breakdowns show that the RI was lowest at the start (May, 5.2%) and end (November, 5.1%) of the Southwest Monsoon, while manta rays were less transient in months that fell in the middle of the season, with RI reaching its highest peak in August (12.1%) (Fig. 7).



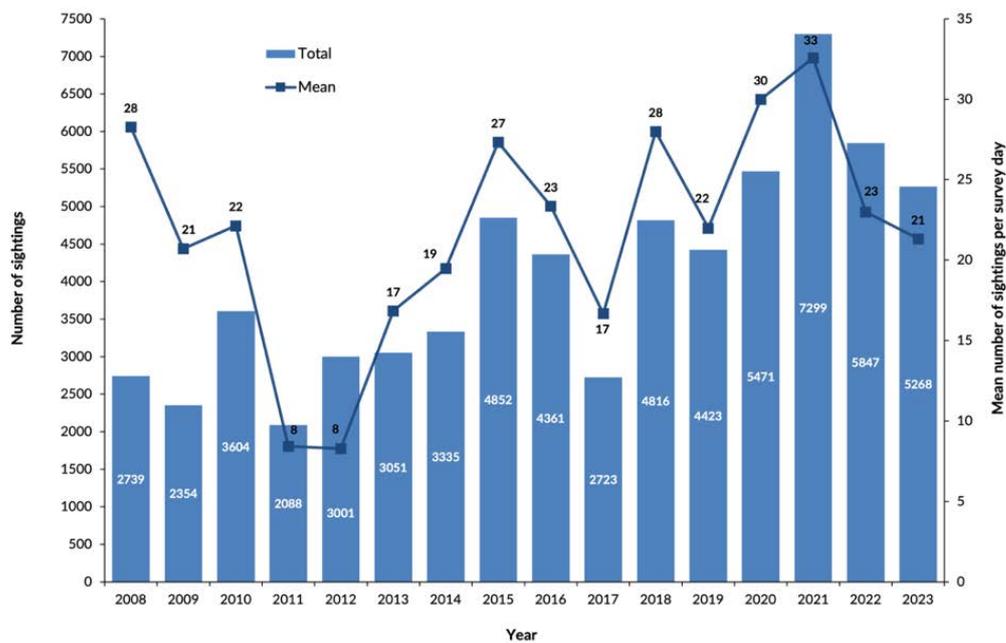


Figure 2: Annual sightings of reef manta rays (*Mobula alfredi*) in Baa Atoll Region from 2008 to 2023, and the mean number of sightings per survey day.

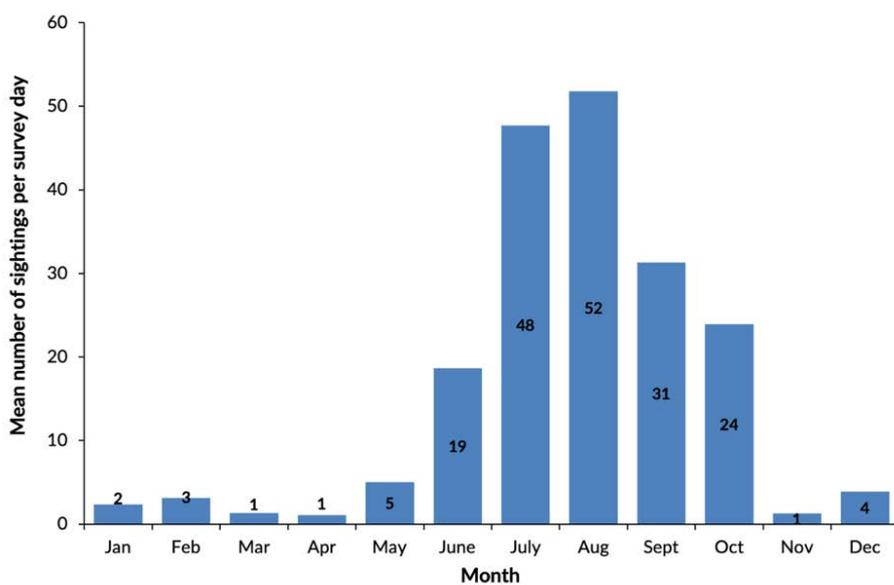


Figure 3: Monthly breakdown of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll Region during 2023.

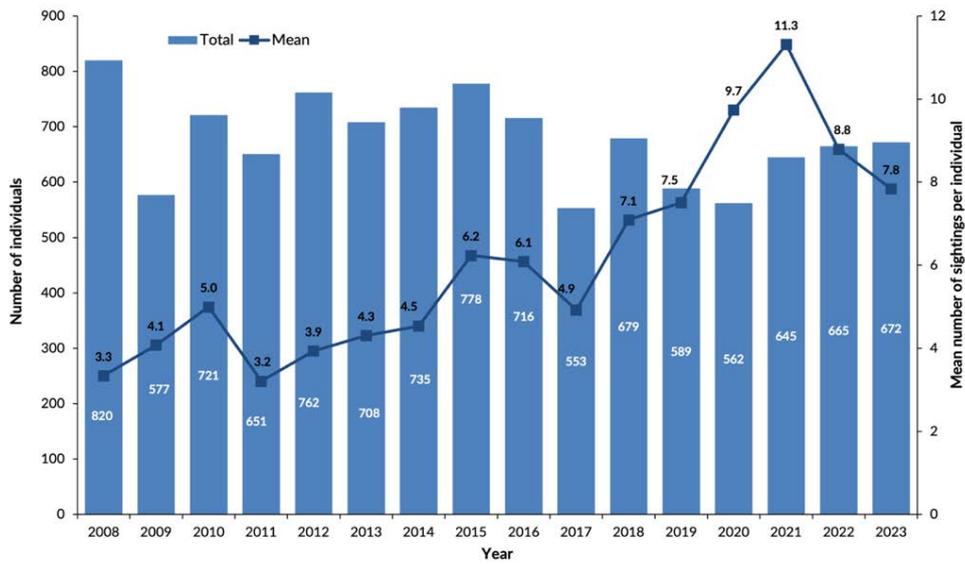


Figure 4: Annual number of individual reef manta rays (*Mobula alfredi*) sighted in the Baa Atoll Region from 2008 to 2023, and the mean number of sightings per individual.

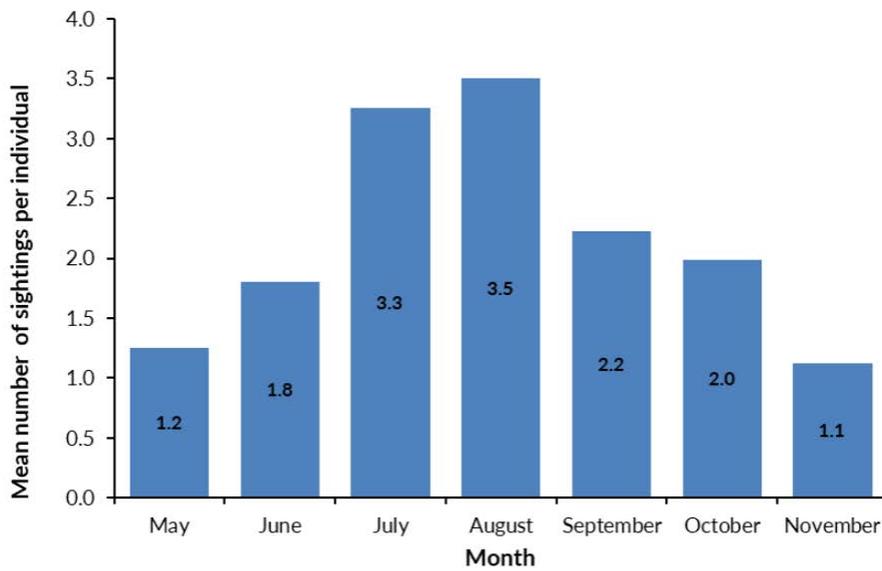


Figure 5: Mean number of sightings per reef manta ray (*Mobula alfredi*) during each month of intensive surveying in 2023.

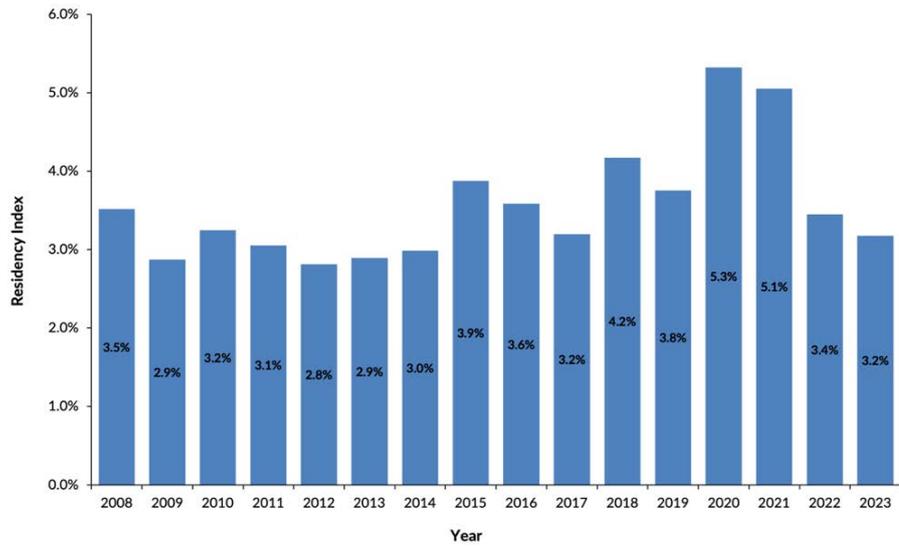


Figure 6: Annual Residency Index (RI) of the reef manta rays (*Mobula alfredi*) in Baa Atoll from 2008 to 2023. RI is calculated as the average of each individuals' residency score (= number of times sighted annually divided by the total number of survey days).

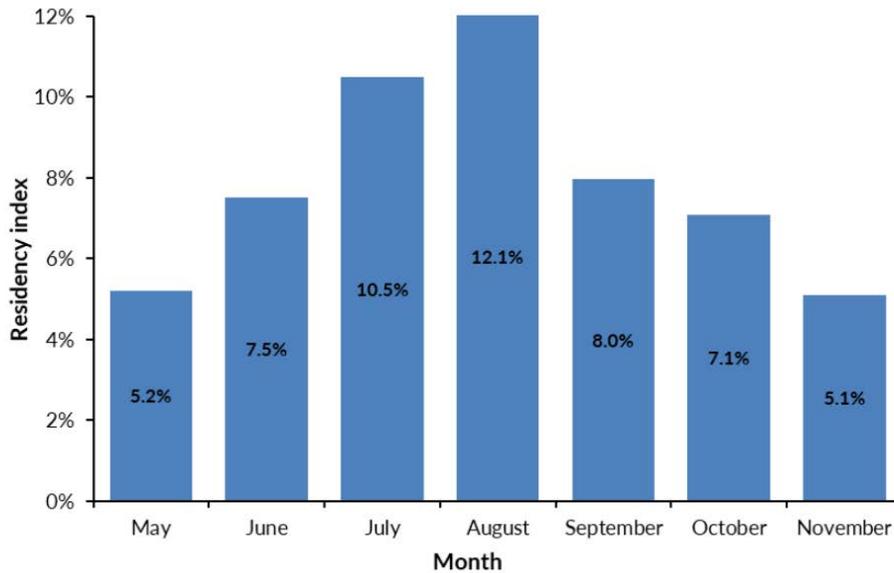


Figure 7: Residency Index of reef manta rays (*Mobula alfredi*) for each month of intensive surveying in Baa Atoll during 2023.

Hanifaru Bay (Marine Protected Area)

In 2023, 4,454 sightings of 584 reef manta rays were recorded in Hanifaru Bay MPA alone (Fig. 8), accounting for 85% of sightings recorded in Baa Atoll overall ($n=5,268$). This figure reiterates the site's importance as critical habitat for the species and further warrants its status as a marine protected area. All of these sightings occurred between May and November, during the Southwest Monsoon; during this period, 31 reef manta rays were sighted per survey day on average, with a peak occurring in August ($n=59$) (Fig. 9). Each manta ray was sighted 7.6 times on average, and the

individual with the highest number of recorded sightings was MV-MA-5259 (Lulu Laurent) ($n=43$). The 12th of August saw the greatest number of individuals recorded on a single day during the year, with a total of 234 confirmed reef manta rays identified from Hanifaru Bay. August was also the month with the highest number of overall sightings ($n=1,404$), while September was the month in which the highest number of individuals ($n=418$) was recorded in Hanifaru Bay.

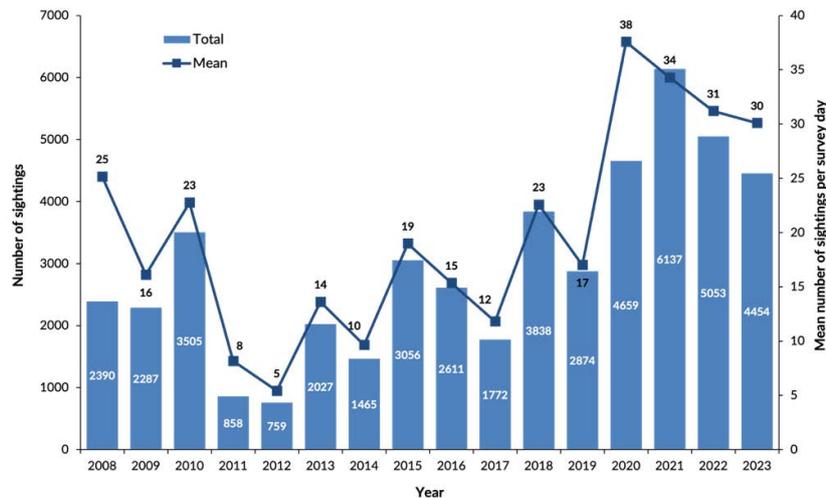


Figure 8: Annual sightings of reef manta rays (*Mobula alfredi*) in Hanifaru Bay from 2008 to 2023, and the mean number of sightings per survey day.

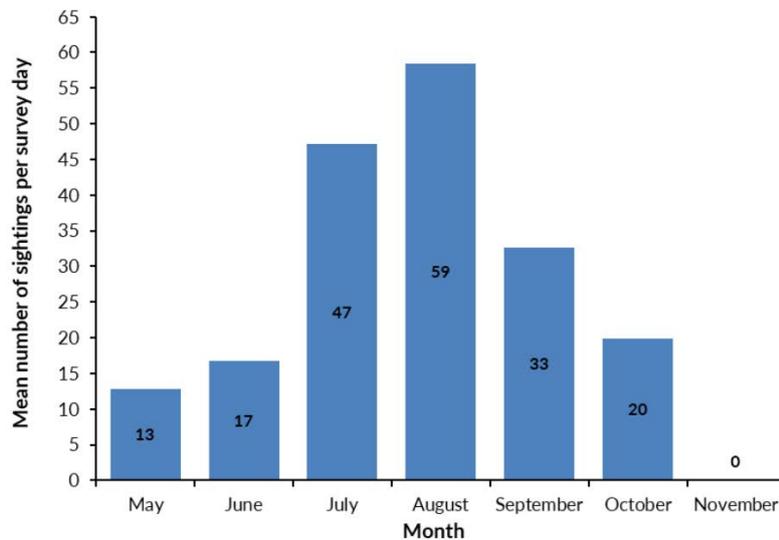


Figure 9: Average number of reef manta ray sightings (*Mobula alfredi*) recorded per survey day inside Hanifaru Bay during each month of intensive surveying in 2023.

Angafaru Area (Marine Protected Area)

The Angafaru MPA includes Angafaru, Angafaru Falhu, Dhonfanu Thila, and Dhigu Thila. In past years (2010 to 2021), 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 2023, 39 sightings of 38 individuals were recorded in the Angafaru MPA, all of which occurred between May and November. Standardising the data by

the number of days this area was surveyed ($n=68$) revealed that sightings per survey day increased slightly in 2023 ($n=0.6$) compared to the previous year ($n=0.3$) (Fig. 10). Monthly breakdowns reveal the highest average number of sightings per survey day occurred in June ($n=1.6$) (Fig. 11). The highest number of individuals recorded in a single day in the Angafaru MPA occurred on 26th June, when nine individuals were sighted at Dhigu Thila.

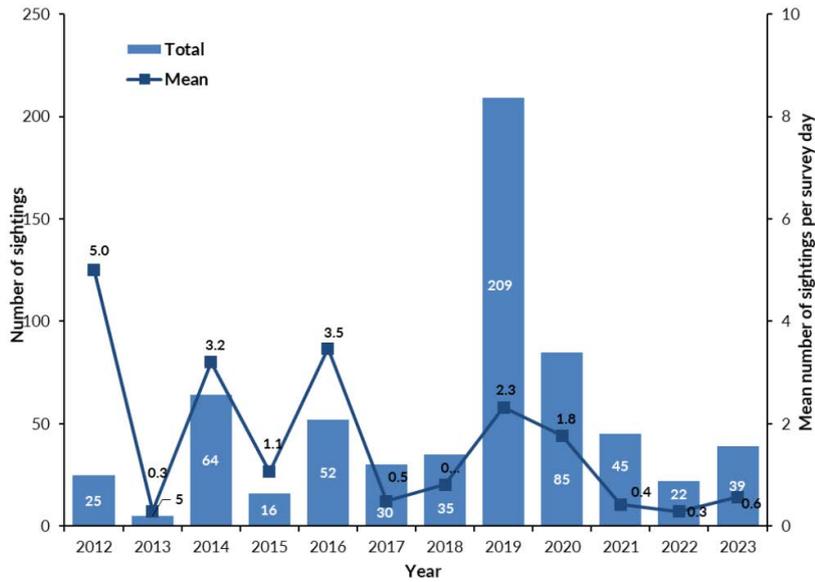


Figure 10: Annual sightings of reef manta rays (*Mobula alfredi*) in the Angafaru MPA from 2012 to 2023, and the mean number of sightings per survey day.

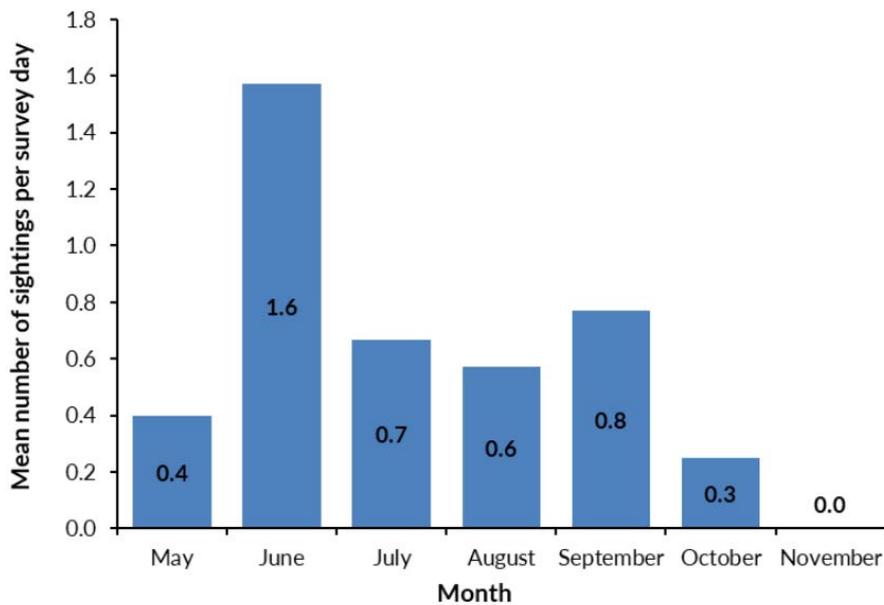


Figure 11: Average number of reef manta ray (*Mobula alfredi*) sightings recorded per survey day in the Angafaru MPA during each month of intensive surveying in 2023.

Weather & Climactic Variation

The MMCP continued to investigate the possible relationship between environmental variables (such as wind speed and direction) and the frequency of reef manta ray sightings. In the years preceding 2023, May (which marks the start of the Southwest Monsoon) typically demonstrates characteristically high wind speeds. In 2023, the average wind speed rose from 9.33 km/h in April to 16.27 km/h in May with the arrival of the Southwest Monsoon. Average wind speed increased to an annual peak of 20.11 km/h in June and remained between 14.1 and 16.9 km/h in subsequent months before declining to an annual low of 8.45 km/h in November (Fig. 12). Data from previous years indicate cyclical trends where average manta ray sightings tended to increase one or two months following an increase in average wind speeds. A similar trend was observed in 2023, which experienced an increase in manta ray sightings in July and August (following high wind speeds recorded in May and June), with 48 and 52 sightings recorded per survey day on average in July and August, respectively (Fig. 12). Data pertaining to the wind speed, direction, and fine scale changes in the weather conditions in the region throughout 2023 were provided to the MMCP by the Maldives Meteorological Service.

It has been previously hypothesised by the MMCP that higher overall wind speed results in more favourable conditions for zooplankton, contributing to the concentration of localised prey patches and attracting manta rays to the region. Across all years, generally, when the annual wind speed increases, so do the average number of manta ray sightings (Fig. 13). The average wind speed recorded in 2023 was 14.6 km/h, lower than in 2022 which had an average wind speed of 18.4 km/h. The overall number of reef manta ray sightings per survey day also saw a slight decrease from 23 in 2022, to 21 in 2023. However, elevated wind speed is by no means the sole contributing factor in predicting manta ray sightings. For example, the number of sightings per survey day in 2020 ($n=30$) was considerably higher than in 2022 ($n=23$); yet the average wind speed in 2020 (17.4 km/h) was lower than the average from 2022 (18.4 km/h). Further, while average wind speeds in 2008 and 2011 were similarly low (15.1 km/h and 15.0 km/h, respectively), there was a drastic difference in the mean sightings per survey day ($n=32$ in 2008, and $n=9$ in 2011).

Wind directions recorded from the Maldives Meteorological Society's met station (situated at Dharavandhoo Island, Baa Atoll) reveal variability throughout May to November (Fig. 14). Directions were classified into eight main directions combining multidirectional winds into their main category (i.e., NNW winds were classified as N). As expected during the Southwest Monsoon of 2023, westerly and south-westerly winds dominated from May to November, contributing to 29% and 36% of daily average wind direction readings during this time, respectively (Fig. 14). Winds prevailing from the southwest accounted for 61% and 60% of readings in May and June, respectively, preceding higher numbers of manta ray sightings recorded in July and August. In four of the five months that followed, winds prevailing from the west accounted for between 48% and 67% of readings (with September being the exception at 17% westerly winds). These months saw a steady decline in manta ray sightings per survey day.

The fluctuation of monsoonal strength, food availability, manta ray sightings and reproductive activity are likely part of a natural cycle which occurs within the Maldives over time. Larger climatic mechanisms, such as the Indian Ocean Dipole (IOD), the Madden-Julian Oscillation (MJO) and the 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 can have an impact on the tourism industry, which relies heavily on advertising nearly guaranteed sightings of manta rays at certain times of year at specific sites. 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.



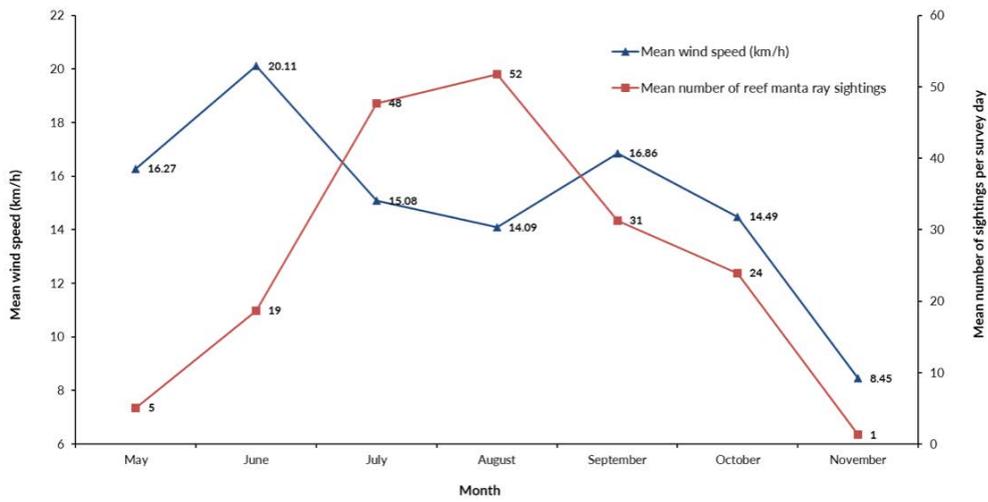


Figure 12: Mean monthly wind speed (km/h) and mean number of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll (2023).

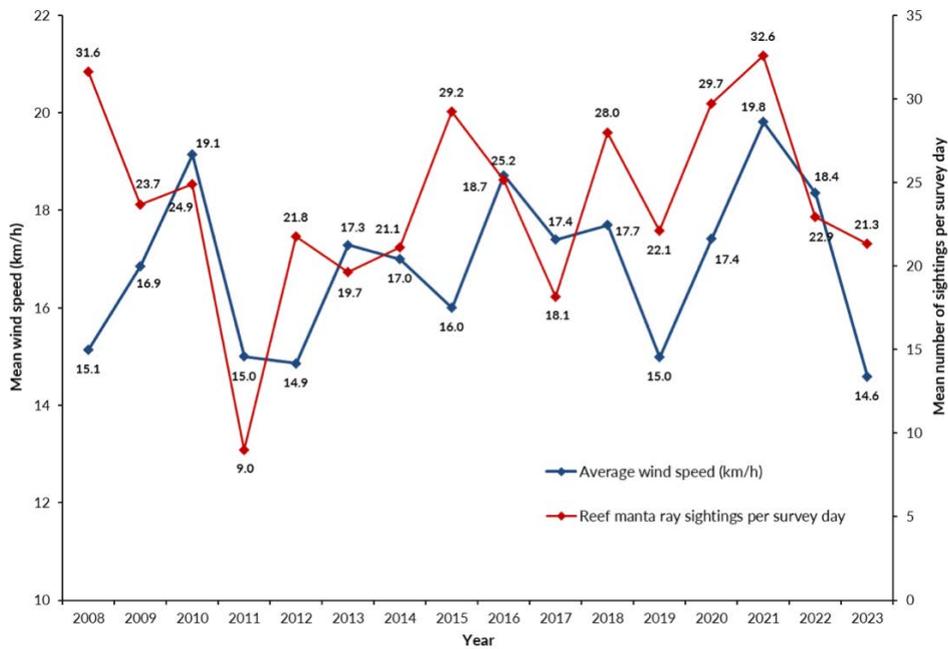


Figure 13: Mean annual wind speed (km/h) and the mean number of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll from 2008 to 2023.

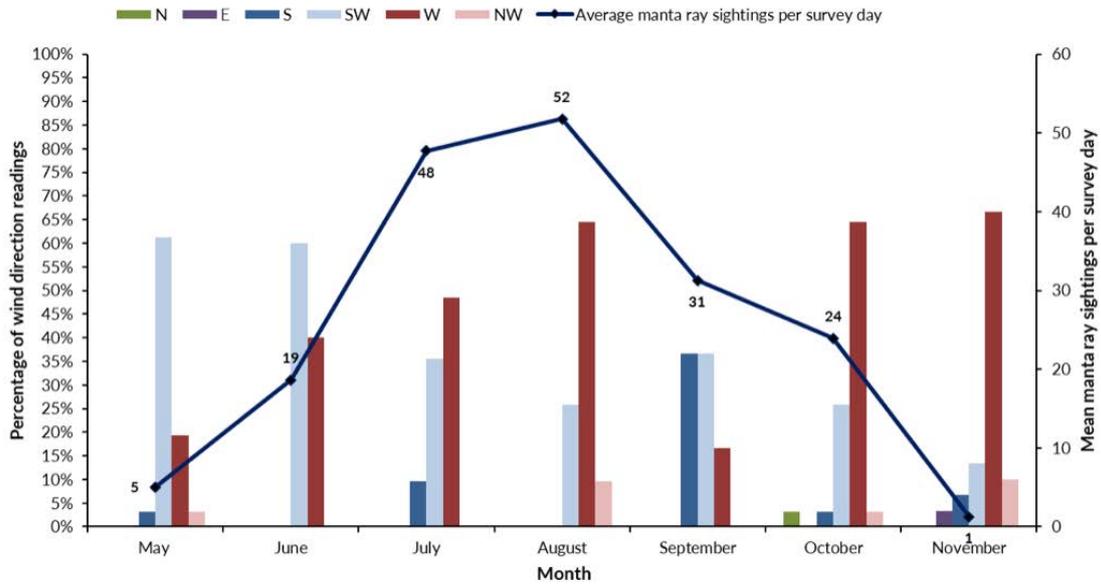


Figure 14: Monthly breakdown of the percentage of wind direction readings from the Maldives Meteorological Society’s weather station, and the average number of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll (2023).



WHALE SHARK SIGHTINGS

Whale sharks often inhabit the same feeding grounds as reef manta rays, and these species are regularly sighted together along shallow reefs throughout the Maldives. In 2023, the MMCP team recorded a total of 25 whale shark sightings in Baa Atoll, a 36% decrease from the previous year (2022, $n=39$) (Fig. 15). Of these, researchers collected ID photographs for 76% of sightings ($n=19$), confirming the presence of 14 different individuals in Baa Atoll. Overall, whale shark sightings in Hanifaru Bay accounted for 40% ($n=10$) of the total recorded in Baa Atoll in 2023.

All recorded sightings occurred during the Southwest

Monsoon (May – November), and monthly breakdowns revealed peaks of total whale shark sightings in August ($n=10$) and September ($n=10$) (Fig. 16). September saw the highest number of identified sightings ($n=9$) and individuals ($n=8$). Interestingly, the MMCP recorded the highest number of manta ray sightings in August ($n=1,502$), suggesting that the prevailing conditions during this month were most favourable for these planktivorous species. Indeed, within Hanifaru Bay, whale shark sightings followed a similar general trend as reef manta ray sightings (Fig. 17), with August marking the peak in both manta ray ($n=1,502$) and whale shark ($n=10$) sightings.

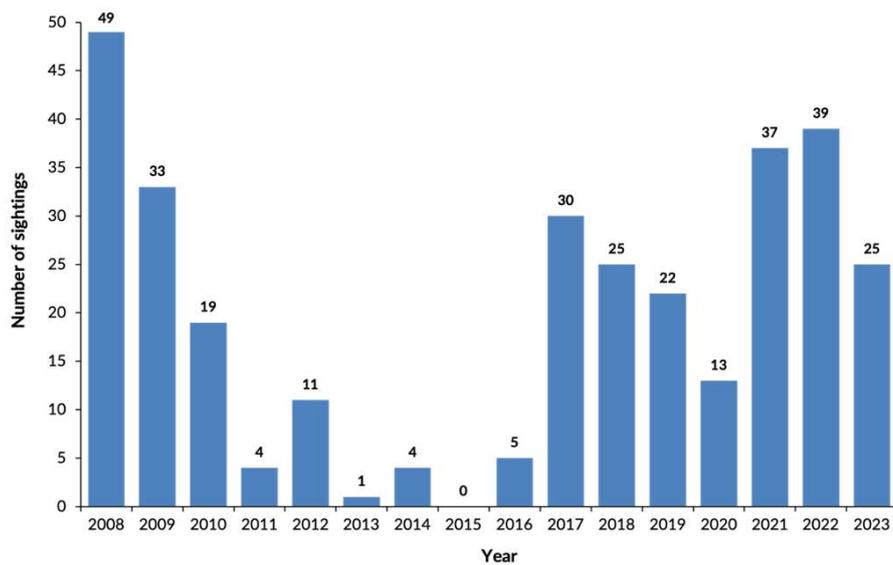


Figure 15: Annual sightings of whale sharks (*Rhincodon typus*) in Baa Atoll from 2008 to 2023.



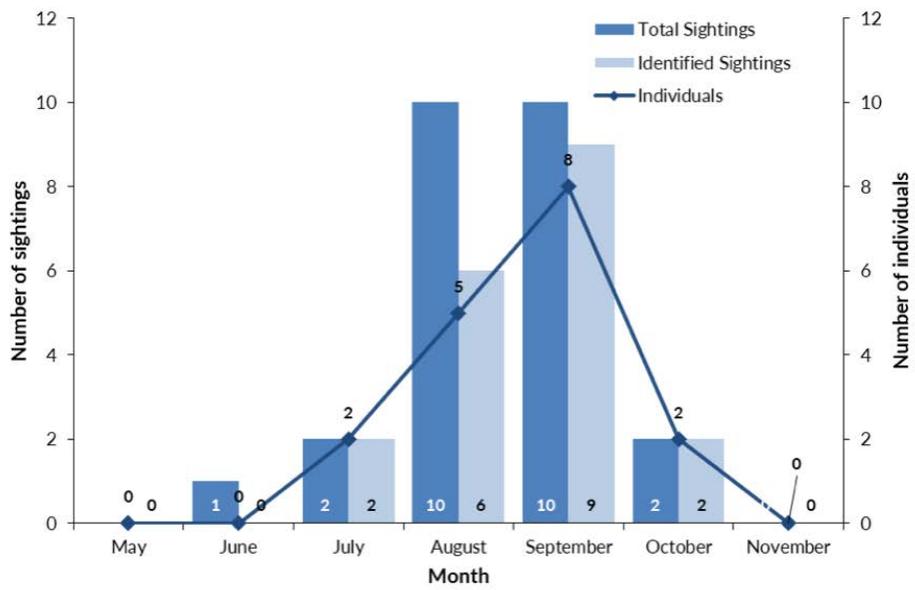


Figure 16: Whale shark (*Rhincodon typus*) sightings (total and identified) recorded by the MMCP in Baa Atoll during 2023, and the total number of individuals recorded during each month of intensive surveying.

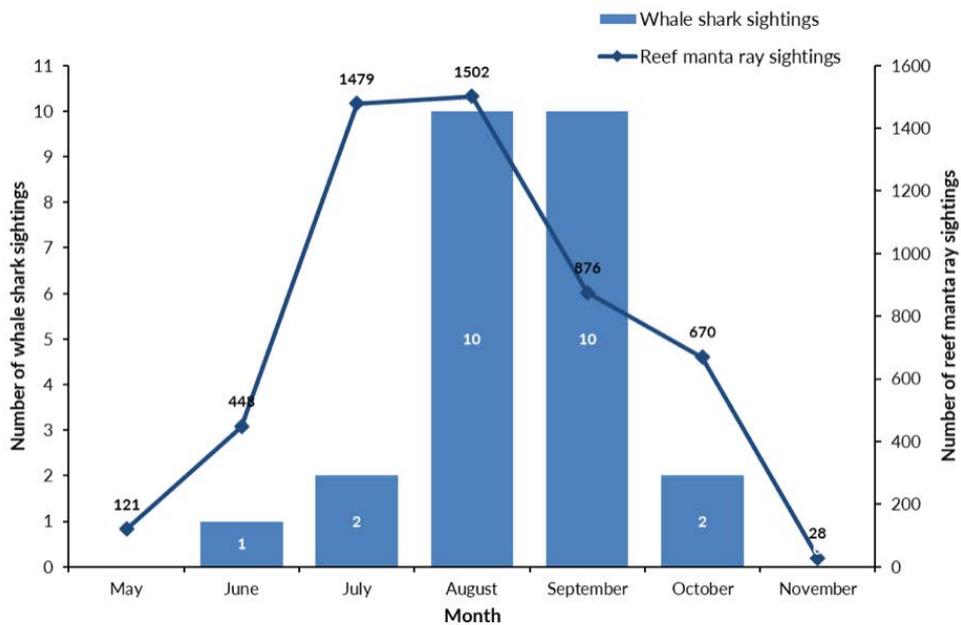


Figure 17: Monthly whale shark (*Rhincodon typus*) and reef manta ray (*Mobula alfredi*) sightings recorded at Hanifaru Bay, Baa Atoll in 2023.

POPULATION SIZE & DEMOGRAPHICS

The total number of individual reef manta rays recorded in Baa Atoll since data collection began in 1992 is 2,457, almost half (42%) of the Maldives reef manta ray population recorded to date ($n=5,870$). As of 2023, population demographics of Baa Atoll constitute 53% females ($n=1,312$), 46% males ($n=1,132$) and 0.5% individuals for which the sex could not be determined ($n=13$). The population comprises 1,514 adults, 937 juveniles, and six individuals of unknown maturity status. Of the manta rays recorded in Baa Atoll ($n=2,457$), 49% ($n=1,193$) have also been seen in at least one other atoll in the Maldives: from the northernmost atoll of Ihavandhippolhu, down to the southernmost atoll of Addu (Fig. 18). This highlights the importance of Baa Atoll as a core aggregation site for the Maldives manta ray population during the Southwest Monsoon.

Throughout 2023, a total of 447 adult and 222 juvenile reef manta rays were sighted, as well as three individuals for which maturity status could not be determined. This included 352 females, 315 males, and five individuals for which sex could not be determined. Maturation was defined by the presence of dorsal or ventral mating scars/wounds, visible pregnancies, or an estimated disc width of > 320 cm in females, and by the enlargement and calcification of claspers in males.

In the main sampling period (May to November), adult females accounted for the largest proportion of reef manta ray sightings in every month except November (50% overall, $n=2,570$), followed by adult males (25% overall, $n=1,305$) (Fig. 19). For juvenile manta rays, accounting for 24%

($n=1,246$) of sightings during these months, there was an even more pronounced skew towards females (19% overall, $n=966$), while juvenile males accounted for just 5% ($n=279$). The only month which did not follow this general pattern was November, likely owing to the uncharacteristically low number of sightings recorded ($n=28$). These figures highlight the importance of Baa Atoll 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.

A total of 260 new individual reef manta rays were documented across the Maldives during 2023, a population increase of approximately 5% from the previous year (2022, $n=5,610$), bringing the total Maldives population to 5,870. Of these new individuals added to the MMCP database in 2023, 20% ($n=52$) were documented in Baa Atoll, similar to the previous year (2022, $n=50$) (Fig. 20). Of the 52 new manta rays sighted in Baa in 2023, 15% were adult manta rays ($n=8$), 79% were juveniles ($n=41$), and 6% were of unknown maturity status ($n=3$). Of these individuals, 47 were first identified in Baa Atoll, while the other five were first identified in other atolls but later sighted in Baa Atoll. While the number of newly identified manta ray individuals remained at a similar number during 2023, there is a general downward trend in the proportion of newly sighted individuals throughout study years (Fig. 20). As more data is collected over the years by the MMCP, 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.



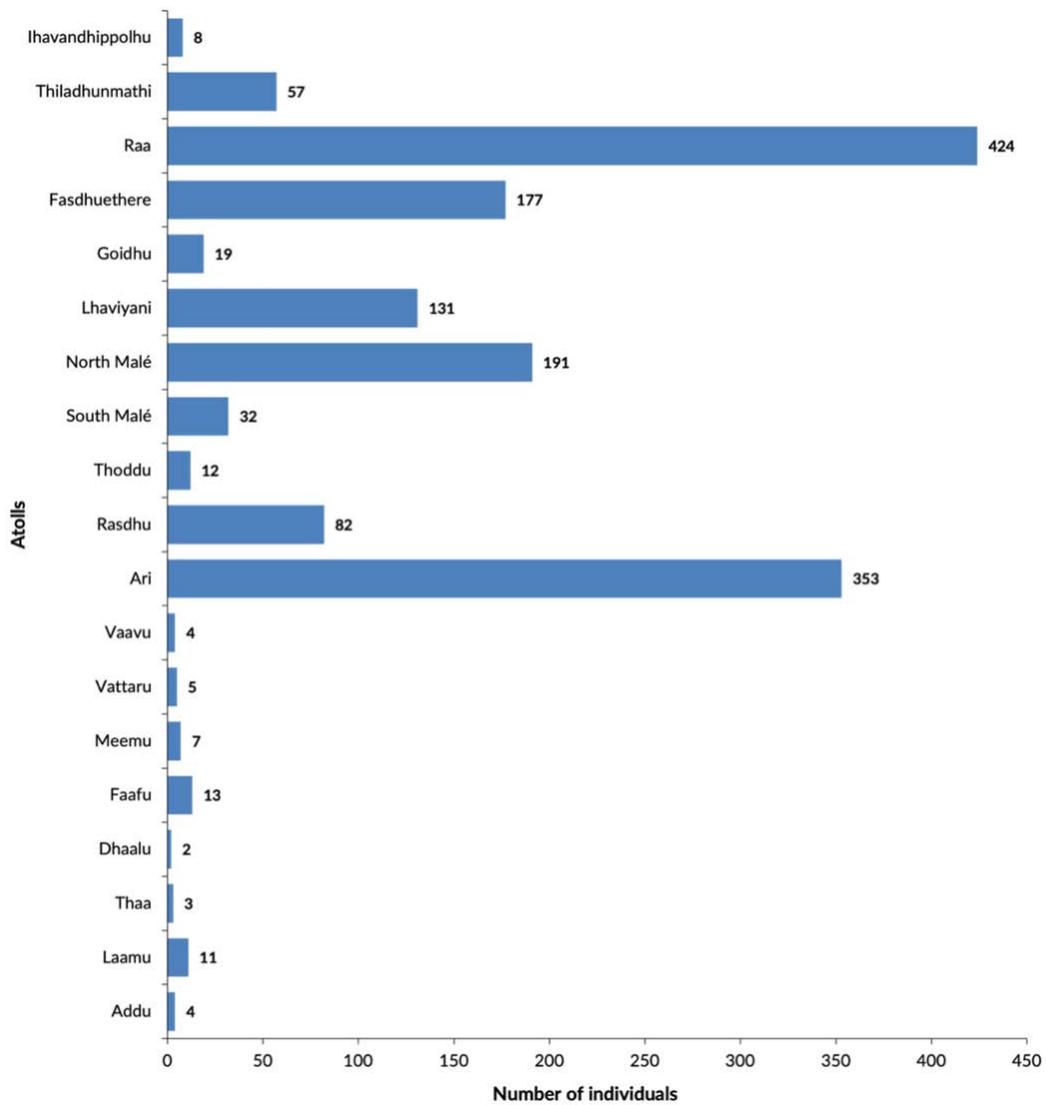
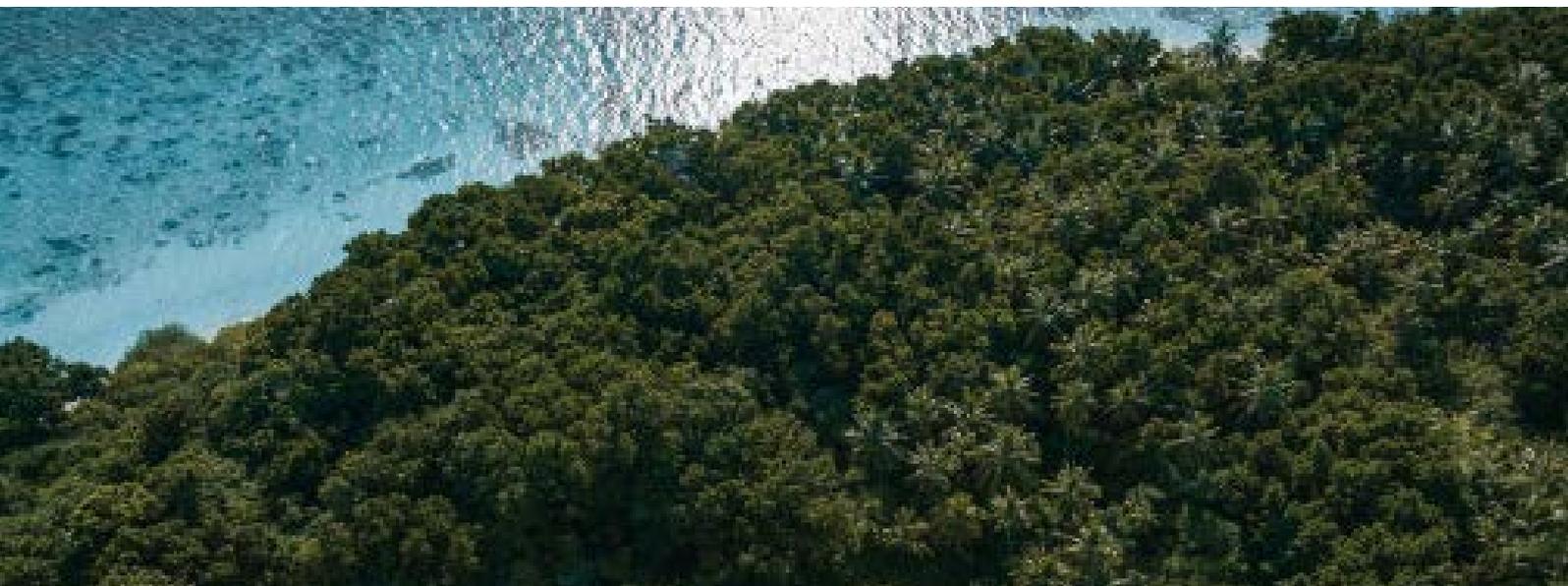


Figure 18: Number of reef manta ray (*Mobula alfredi*) individuals ($n=1,193$) from among the Baa Atoll population ($n=2,457$) which have been recorded in other atolls throughout the Maldives Archipelago.
 * Many of these cross atoll individuals have been observed in more than two atolls.



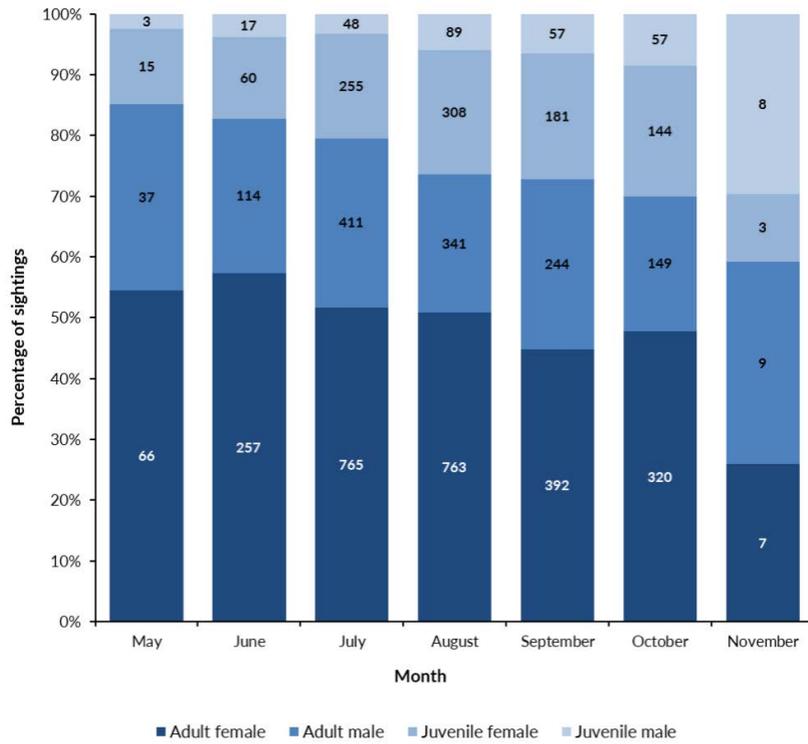


Figure 19: Reef manta ray (*Mobula alfredi*) sightings distribution categorised by maturity status during each month of intensive surveying effort in Baa Atoll in 2023. Actual numbers within bars.

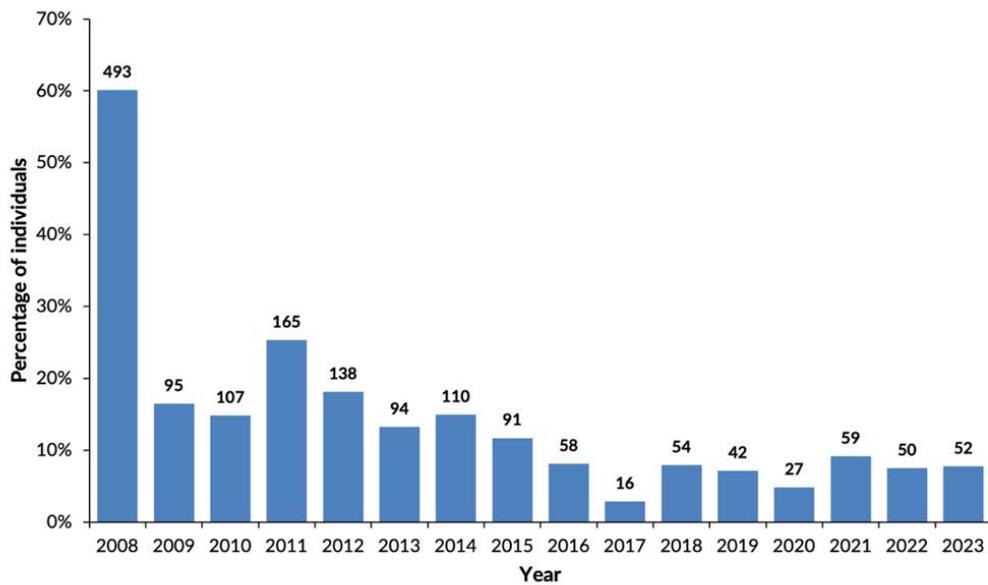


Figure 20: Proportion of the total reef manta rays (*Mobula alfredi*) sighted annually in Baa Atoll which were newly sighted individuals. Actual number of new individuals above bars.

REPRODUCTIVE ACTIVITY

This report marks the eleventh year in a row that the MMCP has recorded pregnancies among the Maldives reef manta ray population. A total of 54 individuals were recorded as pregnant in Baa Atoll in 2023, 27% of all adult females sighted in the atoll that year ($n=200$). The number of pregnancies recorded in 2023 was a decrease from the previous year (2022, $n=66$), which was the highest in any year since data collection began (Fig. 21). 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 54 pregnant females observed in Baa Atoll during 2023, 69% ($n=37$) were in the later stages of gestation (3rd or 4th trimester) when first sighted. A further 26 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: $n=3$; July: $n=3$; August: $n=2$; September:

$n=5$; October: $n=1$), which occurred at Hanifaru Bay ($n=8$), Dhonfanu Faru ($n=3$), Dhigu Thila ($n=2$), and Hurai Faru ($n=1$).

While 2023 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 15% of the mature females sighted in Baa Atoll 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, nursery, and feeding sites.

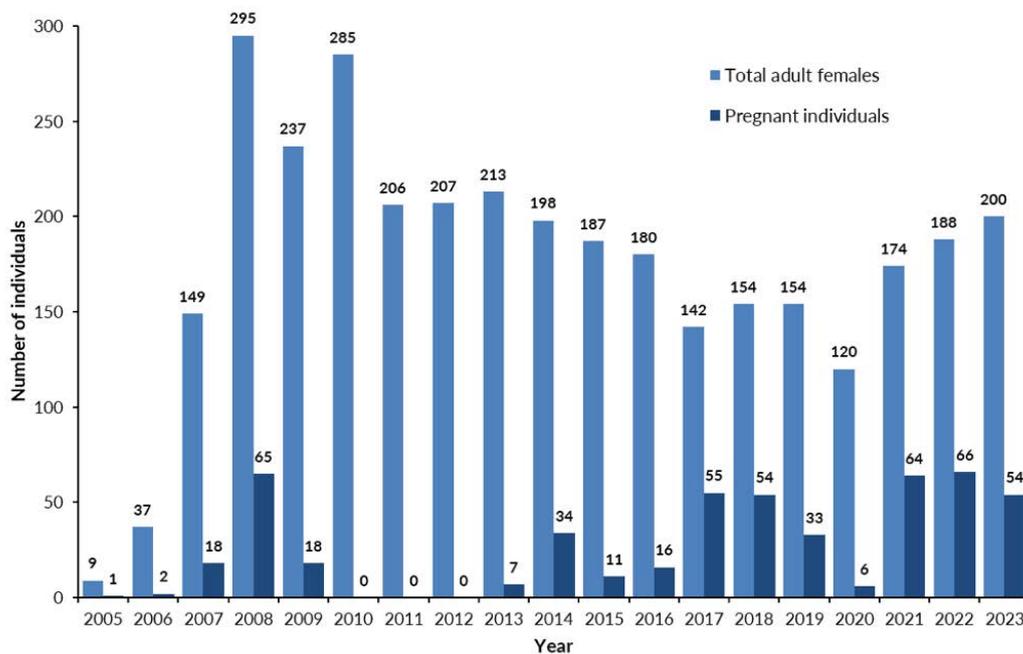


Figure 21: Number of adult female reef manta ray (*Mobula alfredi*) individuals sighted annually in Baa Atoll from 2005 to 2023, and the number of those females which were recorded as being pregnant in the same year. Actual numbers above bars.

SUB-LETHAL INJURIES

A total of 34 new sub lethal injury events were recorded for reef manta rays in Baa Atoll in 2023 (Fig. 22), affecting 32 different individuals. Of these injuries, 41% (n=14) originated anthropogenically, 47% (n=16) originated naturally, and 12% (n=4) were caused by an undetermined source. Anthropogenic injury types included fishing line entanglement (n=10), boat strike (n=2), rope entanglement (n=1), and net entanglement (n=1), while natural injury events were attributed to predatory bites (n=12) and deformity (n=4). Over 50% of the injuries recorded in 2023 affected the pectoral region of the animal (n=18) (Fig. 23), 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 sub-lethal injuries for the health and fitness of these animals are unclear. Of the anthropogenic threats, entanglement in fishing line (n=10) was the most common injury type affecting the Baa Atoll manta ray population, highlighting an area where management should be improved to protect the species in this region. Of additional concern is the continued occurrence of boat strike injuries, which have been recorded for nine individuals in Baa Atoll since 2020. This 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.

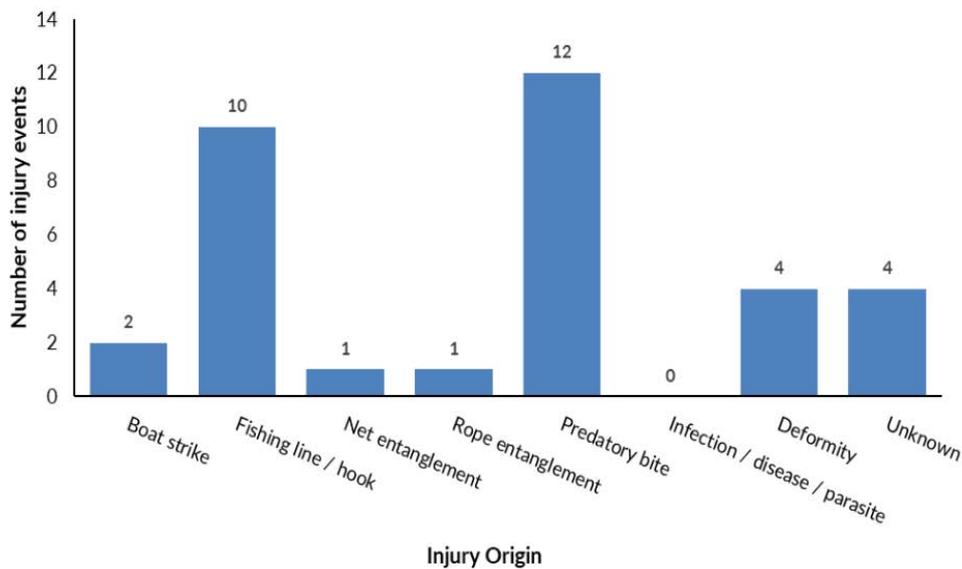


Figure 22: Variations in the likely origin of sublethal injury events (n=34) among the reef manta rays (*Mobula alfredi*) recorded injured in Baa Atoll in 2023.

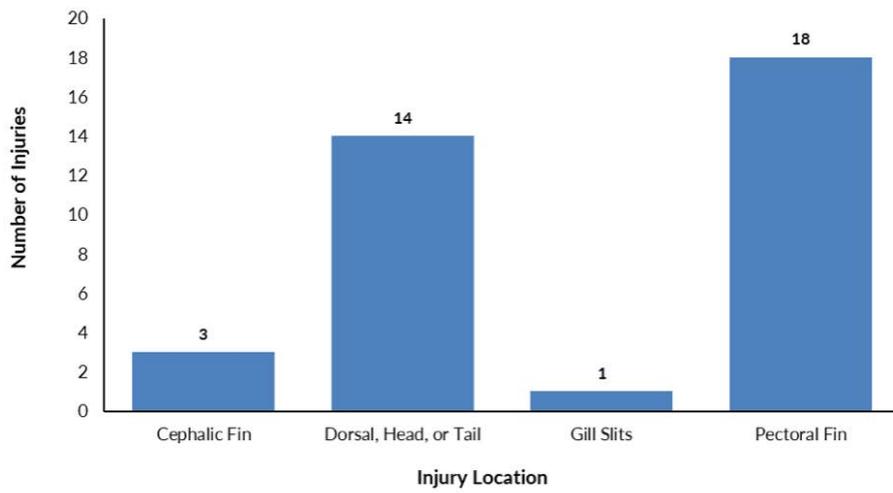
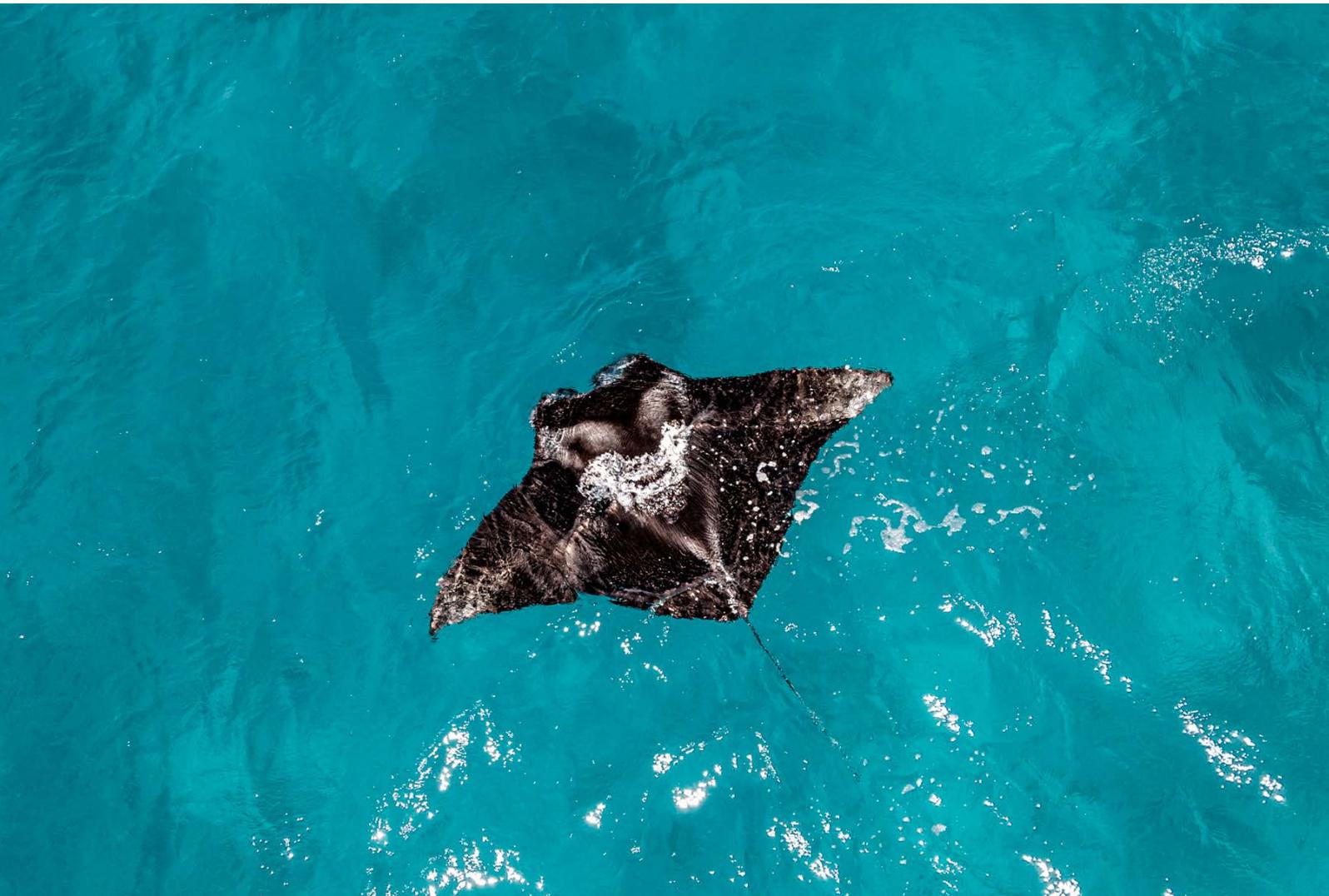


Figure 23: Variations in the locations (by body part) of sublethal injuries ($n=36$) among the reef manta rays (*Mobula alfredi*) recorded injured in Baa Atoll in 2023. Actual number of injuries on bars. Note that injury events can affect multiple parts of the body.



ADDITIONAL RESEARCH

Oceanography - Oceanic Drivers of Reef Manta Ray Behaviour Within Baa Atoll

Since August 2022, the MMCP has been collaborating with the University of Plymouth, the Maldives Environmental Protection Agency, the Garfield Weston Foundation, and the Bertarelli Foundation to conduct a long term oceanography study, with co-operation and support from the Baa Atoll Biosphere Reserve Office and Four Seasons Resort at Landaa Giraavaru. The project aims to determine the drivers for spatiotemporal changes in the availability and density of zooplankton throughout Baa Atoll, and the corresponding response in the resident reef manta ray population.

In February and August 2023, the MMCP team assisted Dr. Phil Hosegood from the University of Plymouth (UK) to retrieve, maintain, and redeploy oceanographic moorings within Hanifaru Bay MPA and the surrounding waters of Baa Atoll to monitor the evolution of currents, water properties, and zooplankton abundance.

Working with Dr. Hosegood and other visiting research assistants from the University of Plymouth since August 2022, the MMCP team have deployed numerous oceanographic sensors (Nortek Signature 1000 Acoustic-Doppler-Current-Profilers, ADCP) in and around Hanifaru Bay MPA. Two of the ADCPs will remain deployed for six months from August 2023 to February 2024. Deep moorings were deployed in Dharavandhoo Channel at

38 to 39 m (Signature 500 and Thermistor String), and in the channel close to Landaa Giraavaru at a depth of 50 m (Aquadopp and Thermistor String), to be retrieved and redeployed in February 2024. In August 2022 and February 2023, bathymetry data of Hanifaru Bay and the surrounding shallow reef was collected using a multibeam echosounder and aerial drones; to be used in numerical modelling and analysis. In addition, a 3D printed model of the bathymetry of Hanifaru Bay was created for educational purposes.

This important work will vastly improve our understanding of how Hanifaru Bay functions, and, in turn, how key drivers influence the aggregative behaviour of manta rays, and indeed other megafauna, within this critical habitat. Observations from this study are already providing a significant insight into the dynamic regime over Baa Atoll, which could provide the oceanographic knowledge for further assessments throughout the region. The success of these observations and modelling approach, combined with observations of manta ray behaviours by the MMCP over the past 20 years, are changing our understanding of how tropical ecosystems function. Future plans include continuing the current work for a third year during 2024 and 2025 to observe the impacts of the Indian Ocean Dipole during later 2023 and El Niño during 2024.



Manta Ray Foraging & Zooplankton (PhD)

The predictability and consistency of manta ray visitation in Hanifaru Bay, coupled with the convenience of access to this site for surveys and equipment deployment, makes it an ideal location to test hypotheses on feeding dynamics and environmental drivers of these aggregations. Due to the ephemeral nature of these feeding events, studying the feeding ecology of highly mobile planktivores can be challenging. However, understanding the environmental and oceanographic drivers of the zooplankton dynamics that lead to such feeding aggregations and behaviour remains a key question for understanding their movement ecology.

The MMCP is supporting PhD candidate, Hannah Moloney, University of Sunshine Coast, CSIRO, whose study aims to investigate the feeding environment of reef manta rays in Hanifaru Bay. This research aims to assess the relative importance of different feeding environments, the nutritional quality of the food and associated foraging behaviours, and to explore the oceanographic drivers that are influencing these seasonal aggregations.

In combination with physical environmental and oceanographic data, this study used plankton tows (hand towed) to sample over the tidal cycle, lunar phases, and temporally during the Southwest Monsoon (*Hulhangu*) in Hanifaru Bay MPA and core zone within the Baa Atoll Biosphere Reserve.

In September 2023, MMCP researchers collected 28 zooplankton samples across three sites, with Hanifaru Bay as the primary study site (Hanifaru Bay $n=13$, Hanifaru Faru $n=2$, Fonimagoodhoo Falhu $n=10$, Olhu Kolhu $n=3$) over 12 unique sampling days. Eight different manta ray feeding strategies have been described, and all have been observed in Hanifaru Bay. Researchers collected samples that targeted feeding strategies ($n=22$), with control samples in place ($n=6$) from six of the eight known strategies. These include two coordinated strategies (e.g., chain and cyclone) where two or more manta rays feed together. In 2023, 13 zooplankton samples were collected from Hanifaru Bay across four feeding strategies.

Research activities also included continued deployments of bed-mounted, upwards-facing Nortek Signature 1000 ADCPs at 15m depth in Hanifaru Bay between 2022 to 2023 to investigate predator-prey interactions between manta rays and zooplankton. To validate the acoustic backscatter measurements collected by the ADCPs, a total of 59 zooplankton samples were collected (feeding = 22, non-feeding = 22, absent = 15) over a period of 24 days between 2022 and 2023. Zooplankton densities ranged from 0 to 4 using a visual density index. To assess prey dynamics, zooplankton community composition, size spectra, and biovolume will be investigated using the ZooScan (and sorted using EcoTaxa). These data will be compared to the ADCP acoustic backscatter measurements.



Abundance, Site Use & Behaviour of Reef Manta Rays in Baa Atoll (MSc)

In 2023, master's student Jessica Willis, University of Exeter, conducted a study investigating the abundance, site use, and behaviour of reef manta rays in Baa Atoll. The study used a subset of photo-ID sightings records collected by the MMCP from 2007 to 2020 in Baa Atoll during the Southwest Monsoon season to identify annual, monthly, and daily trends in reef manta ray abundance, important sites, and the primary behaviour exhibited in these areas. A subset of this data spanning 2019 to 2020 containing environmental variables was used to investigate the abundance of feeding, cleaning, and cruising reef manta rays. Generalised linear modelling found manta

ray abundance to be highest during the month of August and in the morning, and seven sites had >500 sightings throughout the survey period. Feeding behaviour increased significantly with increased zooplankton density and outgoing current; cleaning behaviour increased at low-mid zooplankton densities; and manta ray abundance decreased as sea surface temperature increased. These findings highlight key areas of habitat which should be considered for enhanced protection and contribute to the understanding of trends in manta ray abundance during the Southwest Monsoon in Baa Atoll, Maldives.





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 to 1,321,937 in 2021, and 1,675,303 in 2022, which mirrors pre-pandemic levels. The tourism continued to recover from the impacts of the pandemic in 2023.

Manta rays are very 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 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 2023, the MMCP 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.

CONSERVATION MANAGEMENT

Baa Atoll has been globally 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 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.

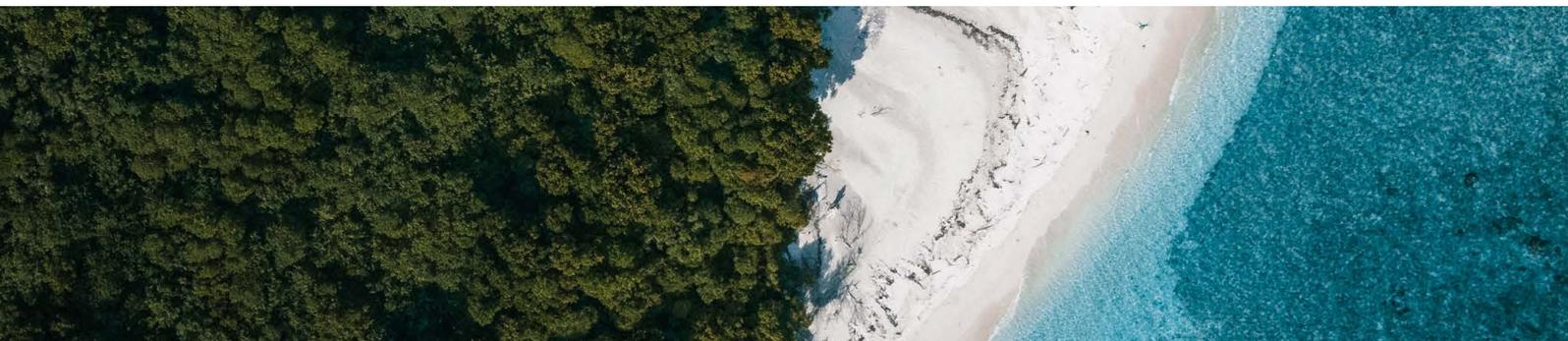
Research within Baa Atoll's UNESCO World Biosphere Reserve must remain a top priority for all involved. Biosphere reserves help us to better understand population dynamics, conservation and management strategies, conflict prevention, and human impacts on certain species. The consistent quality of the long-term data collected within Baa Atoll 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.

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 2023, Baa Atoll Biosphere Reserve rangers were again on site to maintain the rules and regulations of Hanifaru Bay MPA. This act has resulted in a decrease of infractions and a well-maintained schedule of alternating tourism days. Such regulations and management initiatives are vital to ensure the efficacy of Hanifaru MPA in conserving the Maldives manta ray population, by minimizing the harmful ramifications arising from human-manta ray interactions.

In January 2023, the MMCP attended the Hanifaru Bay Stakeholder workshop, hosted by the Biosphere Reserve Office, the Ministry of Environment, Climate Change and Technology, and the UK led Ocean Country Partnership Programme, in B. Eydhafushi. This workshop involved a discussion amongst stakeholders to assist with drafting a Research and Management Action Plan (RMP) for Hanifaru Bay MPA. The MMCP Baa Atoll team will continue to work with scientists from the UK-based Joint Nature Conservation Committee (JNCC) and the Centre for Environment, Fisheries, and Aquaculture (CEFAS) to advise and review drafts of the Hanifaru Bay MPA RMP, and associated documents, during 2023 and 2024.

Other conservation management events attended in 2023 included the first annual symposium of the Maldives Ocean Alliance, held at Soneva Fushi, Baa Atoll. This is a collaboration of civil society organisations, marine biologists, and scientists dedicated to understanding, protecting, and conserving marine life in the Maldives. Additionally, the MMCP attended the Sustainable Tourism Forum (4th edition) organised by the International Maldives Travel Market (IMTM) held in Malé. The goal of this forum was to focus on meaningful action and collaboration towards a more sustainable and responsible future for the tourism industry. Members from the Ministry of Tourism, NGOs, dive centres, resorts, and other tour operators attended this event.



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.

Since its inception in Baa Atoll in 2015, Moodhu Madharusaa has been expanding. In early 2023, the three top-scoring students from the 2022 B. Kamadhoo MEP were awarded a 'DiscoverScubaDive' course at Four Seasons Resort Maldives at Landaa Giraavaru (FSLG). Due to delays in obtaining the necessary permit from the Ministry of Education, the inauguration of the planned Moodhu Madharusaa programme for B. Kihaadhoo School had to be postponed to 2024. During 2023, the MMCP team delivered and attended a variety of education and outreach events, community engagement, workshops, and festivals (Fig. 24).

The MMCP collaborated with Reefscapers PVT LTD, Baa Atoll Council, and the Baa Atoll Biosphere Reserve Office to deliver a three-day Marine Biology Internship for school students from across Baa Atoll, hosted by FSLG. A total of 12 students (one from each school in Baa Atoll) and their teachers were hosted at the resort, taking part in a variety of theory classes delivered by experts in each field. These covered marine megafauna, coral reef ecology, and plankton biology. Practical activities included building a coral frame and a snorkelling excursion, including social team building activities in the evenings. The Baa Atoll Marine Biology Internship (Stage 1) will be repeated in 2024 for a new batch of students and expanded to offer a second stage 'advanced' internship for six students from the initial programme.

The MMCP conducted four Moodhu Vaguthu (one-day) programmes during 2023. Manta ray ecology presentations and snorkelling sessions were delivered for school students from B. Kihaadhoo and B. Dhonfanu, as well as a presentation for students from Immadudin School, Malé. Furthermore, in collaboration with Reefscapers PVT LTD, the MMCP team travelled to R. Kinolhas to deliver a

one day Moodhu Vaguthu education session to students from R. Kinolhas school. Activities included introductory presentations about manta ray biology and behaviour and tropical coral reef ecology, before learning how to build a coral frame to be planted on their house reef. In celebration of World Manta Day in September 2023, students of B. Kihaadhoo School were offered the chance to take part in an art competition for which they submitted drawings centred around this year's World Manta Day theme, "Tourism". Winners were selected based on the quality of the drawing and the relevance to theme. The first-place winner was given the opportunity to name a manta ray from the MMCP's database.

Throughout the year, the MMCP team attended events, festivals, workshops, and forums held around the country. In March, the team attended the Maldives Marine Expo, held in Hulhumalé, during which a total of 599 visitors (150 children and 449 adults) attended the MMCP stall. In April, the MMCP team visited Addu Atoll for the Coral Festival organised by the Maldives Coral Institute and held at MNU Campus in Hithadhoo. During this three-day festival, a total of 299 visitors attended the MMCP stall where they were informed about the research and education work conducted by researchers in Maldives. In October, the team travelled to N. Kudafari for the Little Big Festival where the team joined exhibitors from other Maldives-based NGOs to celebrate the Maldivian culture and share conservation efforts and achievements. During this event, the MMCP team had the opportunity to engage with an estimated total of 187 people from the community. In November, the team hosted a stall at the two-day Turtle Festival held in Lh. Naifaru with a total of 125 visitors attending the stall.

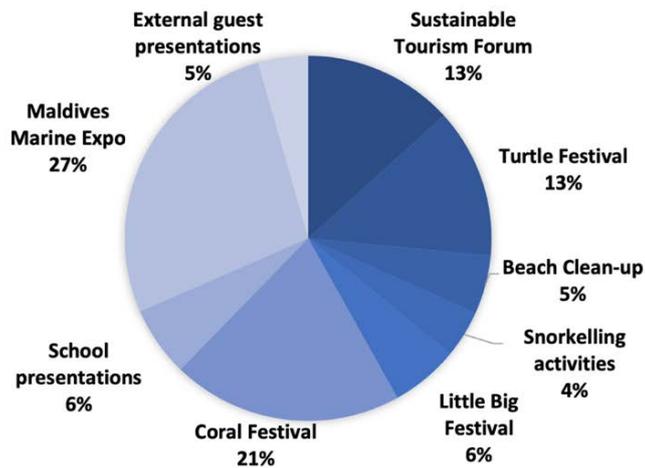


Figure 24: Percentage of time devoted by the Maldives Manta Conservation Programme to outreach sessions, festivals, and community engagement in 2023.



MANTA STORY APP.

In collaboration with the Manta Trust’s partner Four Seasons Resort at Landaa Giraavaru and Loopcraft (Malé), the MMCP were proud to release the world’s first manta ray-focused mobile application to the Apple App Store and Google Play Store. “Manta Story” is a documentary style educational interactive app with virtual and augmented reality features for users to experience the life, biology, and behaviour of reef manta rays in the Maldives. As well as modules focused on feeding, cleaning, courtship, and pupping, the app emphasises why we must protect manta rays, and how we can do so. The content of the app is narrated by David Oakes, Actor and Conservation Ambassador, UK. Updates to the app in 2024 will include a section on the global threats to manta ray populations.

This report was made possible thanks to



MALDIVES GOVERNMENT AUTHORITIES

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

The Manta Trust would also like to extend a warm thank you to all the other resorts, guest houses, liveaboards, dive centres and watersports teams as well as the marine biologists and citizen scientists who have supported our research and submitted sightings.

We thank the Maldives Government for granting us permission to undertake this research and we thank the Baa Atoll Biosphere Reserve Office for their continued support with field work activities and community outreach initiatives. Special thanks to Manta Trust's resort partner Four Seasons Resort Maldives at Landaa Giraavaru. We thank all Manta Trust staff, students, and volunteers in the Maldives as well as the marine biologists, water sports and dive teams in Baa Atoll who contributed huge amounts of photo-ID data used in this report. Finally, we would like to thank all the members of the public who submitted images to the Manta Trust during 2023.



MALDIVES MANTA
CONSERVATION
PROGRAMME

MALDIVES MANTA CONSERVATION PROGRAMME (MMCP)

The Maldives is home to the largest photo-identified population of reef manta rays in the world and the MMCP is privileged to oversee one of the longest running research programs on this species in the world. Numerous advancements on the understanding of the ecology, reproductive biology, and behaviour of reef manta rays have been made based on research conducted or facilitated by the MMCP. We welcome continued collaboration with the Maldivian government for the long-term conservation and management of this incredibly charismatic marine species.

The MMCP 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.org.

The opportunities that the Manta Trust's MMCP 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 MMCP and the Manta Trust by:

Tiffany Bond - MSc (Hons)
Assistant Project Manager - Baa Atoll

Tam Sawers - MSc (Hons)
MMCP Project Leader

Elsbeth Strike - MSc (Hons)
Project Manager - Baa Atoll

Dr. Guy Stevens - (PhD)
Chief Executive & Co-Founder

This document was created by:

Sarah Bennett
Media & Communications Intern

For further information, please email:

baa@mantatrust.org

info@mantatrust.org

The information and ideas within this report are the intellectual property of The Manta Trust. Any scientific data distributed to our collaborators and partners belongs to The Manta Trust and are not to be shared with a third party without prior permission from The Manta Trust. All images, unless otherwise stated, are credited to the Manta Trust.