

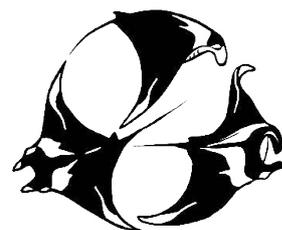


Maldives Manta Conservation Programme

BAA ATOLL | ANNUAL REPORT 2022

*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); the founding project of the Manta Trust. 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 globally to see and swim with these planktivorous megafauna.

Details on the ecology, population dynamics, and movements of Baa Atoll's reef manta rays throughout 2022 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 2022.

The MMCP, with outside contributions, documented 1,824 reef manta ray surveys on 255 days in 2022. The MMCP conducted 1,572 of these surveys over 185 days, with outside parties contributing 252 surveys on an additional 70 survey days. Of the 255 survey days in 2022, 189 fell between the 1st May and the 30th of November. Key findings of the MMCP in Baa Atoll during 2022 include a total of 5,847 sightings of 667 individual reef manta rays. Of these individuals, each manta ray was observed on average 8.8 times. The mean daily number of reef manta ray sightings between May and November was 31, with a peak in daily manta ray sightings seen during the month of August ($n=46$). A Residency Index (RI) was calculated to gauge the extent of movement amongst those frequenting the region. The RI for 2022 (3.4%) represented a decrease from 2021 (5.0%). The total number of sightings ($n=5,053$)

and number of individual manta rays ($n=596$) recorded in Hanifaru Bay MPA in 2022 is also lower than in 2021 (sightings, $n=6,137$; individuals, $n=603$).

As of 2022, the population demographics of Baa Atoll constitute 2,368 individuals, of which 1,262 (53%) are female, 1,094 (46%) are male, and 12 (0.5%) are of unknown sex. Of these Baa Atoll individuals ($n=2,368$), 48% ($n=1,142$) have also been seen in at least one other atoll in the Maldives. Of the 667 individuals observed in 2022, 347 were female and 317 were male.

A total of 372 new reef manta rays were added to the MMCP database from across the Maldives in 2022, bringing the total number of identified individuals in the Maldives to 5,619. Of the new manta rays identified in 2022, 14% ($n=51$) were documented in Baa Atoll, representing a decrease from the previous year (2021, $n=61$). Within Baa Atoll, 44 (86%) of these new individuals were juveniles.

The number of pregnancies recorded in Baa Atoll in 2022 ($n=66$) was an increase from the previous year (2021, $n=64$), and the highest in any year since data collection began. Of the 66 pregnant females observed, 82% ($n=54$) were recorded in the later stages of gestation (3rd to 4th trimester) when first sighted. A further 26 females were recorded with fresh reproductive wounds but were not recorded as pregnant.

Following an interruption to the programme in 2020 and 2021 due to COVID-19, the Baa Atoll Marine Education Programme, 'Moodhu Madharusaa', was able to resume educational activities in 2022 at B. Kamadhoo School. A total of 20 students completed the course of five learning and practical modules highlighting the ecology of marine ecosystems in the Maldives.

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 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.

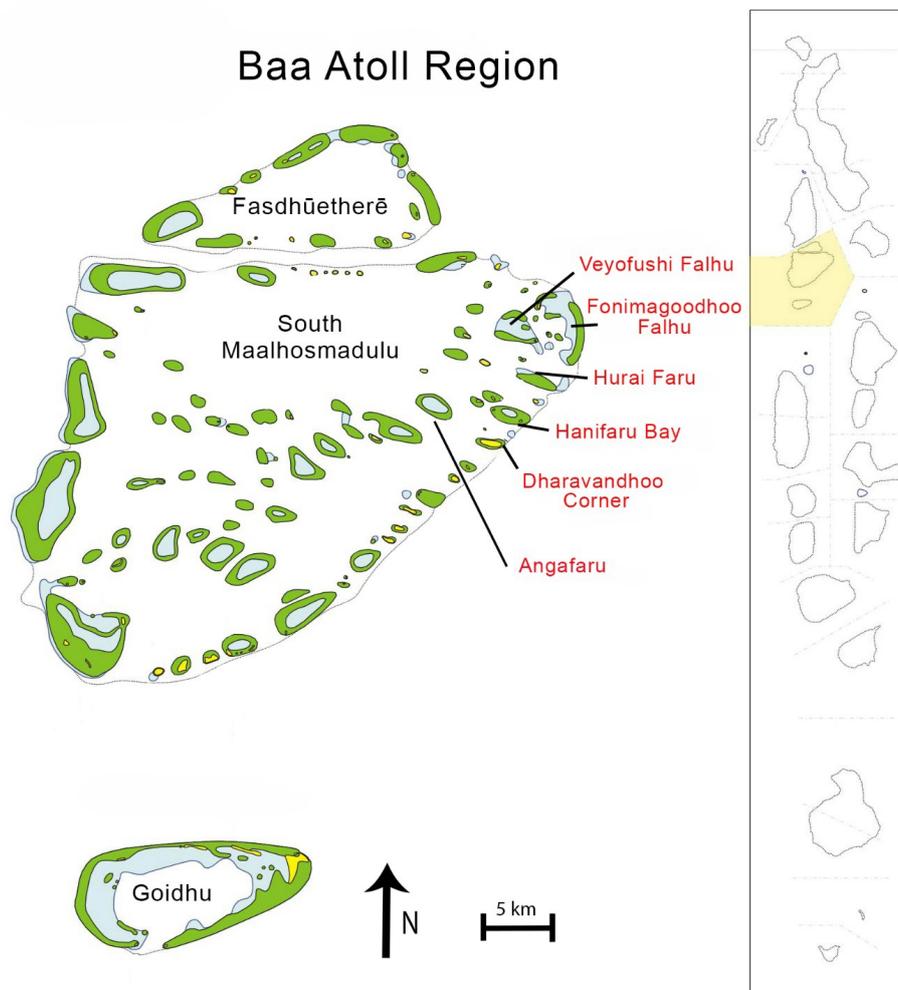


Figure 1: Map of the Baa Atoll region showing the three geographical atolls (in black), six of the key reef manta ray (*Mobula alfredi*) aggregation study sites (in red), and the region in relation to the rest of the Maldives Archipelago (shaded yellow).

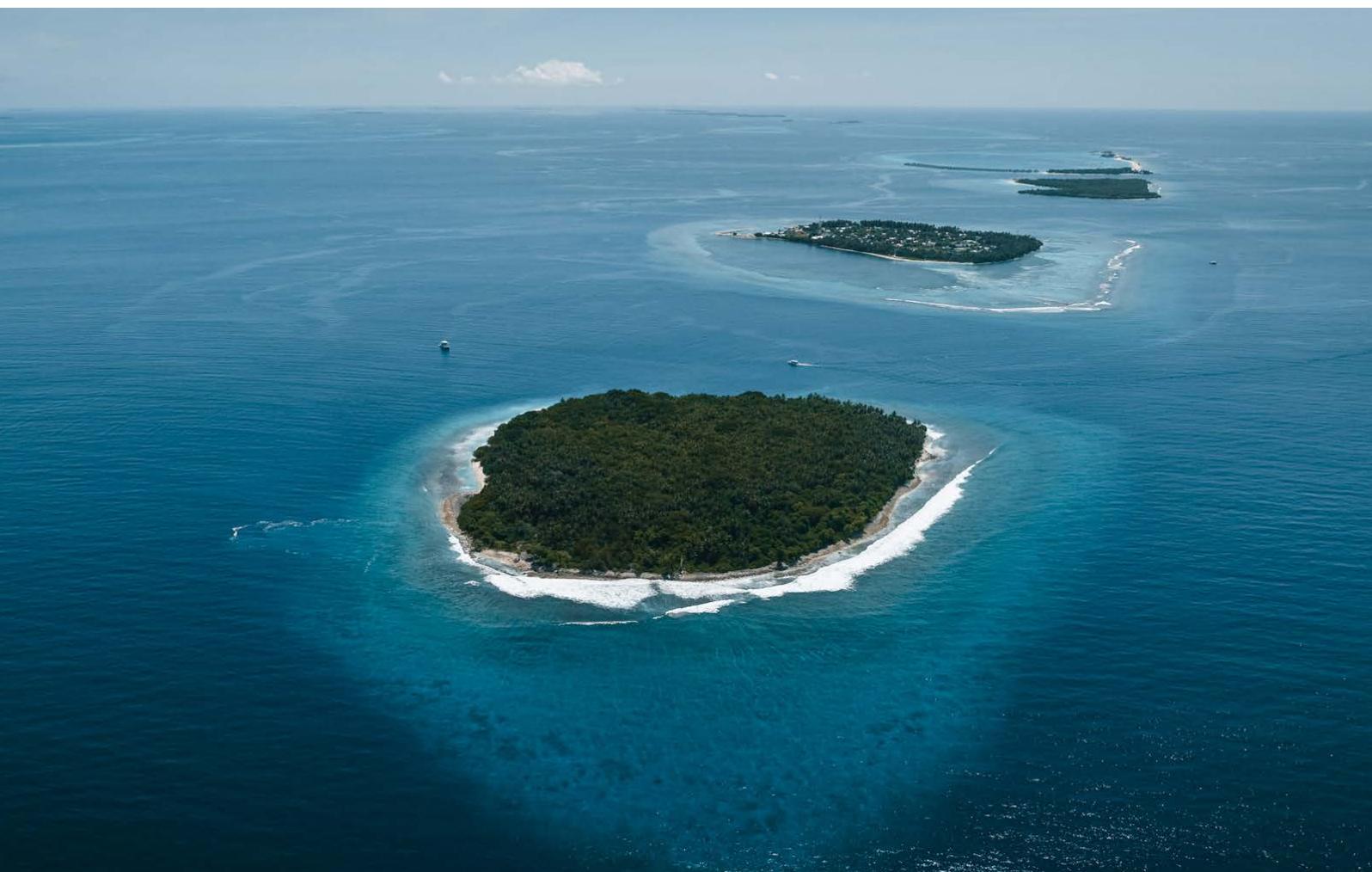
UNDERSTANDING THE MONSOONS

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 2022, MMCP researchers carried out directed surveys on as many days as the weather conditions allowed between 15th of May and the 24th of November, in line with the Southwest Monsoon. These intensive surveys were conducted at Hanifaru Bay, one of six key manta aggregation sites, and 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 1,824 manta ray surveys were undertaken in Baa Atoll during 2022 across 255 survey days, or 70% of the total possible days within the year. The MMCP alone conducted 1,572 surveys on 185 days. MMCP surveys were carried out by observers ($n=1,307$), remote underwater video systems ($n=163$), remote underwater photo systems ($n=94$), and unmanned aerial vehicles (i.e., drones) ($n=8$). External parties contributed an additional 252 surveys across 174 survey days; 70 of these survey days were days when MMCP did not conduct any surveys. During the months of the Southwest Monsoon (May – November), surveys were conducted on 189 days, representing 89% of the total possible survey period of 214 days. Within this period, MMCP researchers conducted 1,537 surveys over 174 days, while external parties contributed an additional 184 surveys across 115 days.

To ensure comparable results, data was standardised where possible to account for changes in sampling effort spatially

and temporally. All surveys undertaken by the 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 2022, 163 RUV surveys were conducted over 99 survey days.

This is the third year that the MMCP has used a remote underwater photo (RUP) system to capture photo-IDs of reef manta rays that visit selected 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. In 2022, the MMCP used RUPs to conduct 94 surveys over a period of 94 days.



REEF MANTA RAY SIGHTING TRENDS

Baa Atoll Region

In 2022, a total of 5,487 sightings of reef manta rays were recorded in Baa Atoll (Fig. 2). This represents a 24% decrease in reef manta ray sightings compared to the previous year ($n=7,299$ in 2021); however, the number of sightings in 2022 is the second highest on record. On average, 23 manta rays were sighted per survey day in 2022 overall, with an average of 33 sighted per survey day during the months of the Southwest Monsoon (May to November). Monthly breakdowns show fluctuations in manta ray sightings per survey day, with peaks in June ($n=42$), August ($n=46$), and October ($n=37$) (Fig. 3).

A total of 667 different individual reef manta rays were recorded in Baa Atoll in 2022, which comprises 11.9% of the total recorded Maldives population ($n=5,598$) and represents a slight increase from 2021 ($n=647$) (Fig. 4). Throughout 2022, 82% of individuals ($n=546$) were observed more than once, and each manta ray was observed

8.8 times on average (Fig. 4). The number of sightings per individual was highest in August, with an average of 3.3 sightings per individual (Fig. 5). The most sighted individual in 2022 was MV-MA-3583 (Villoch), an adult female who was recorded 49 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 2022 (3.4%) was slightly lower than in 2021 [5.0% (Fig. 6)], potentially indicating a more transient population in 2022 compared to previous year. The RI fluctuated inconsistently throughout the Southwest Monsoon period but was highest in the month of August at 11.5% (Fig. 7).

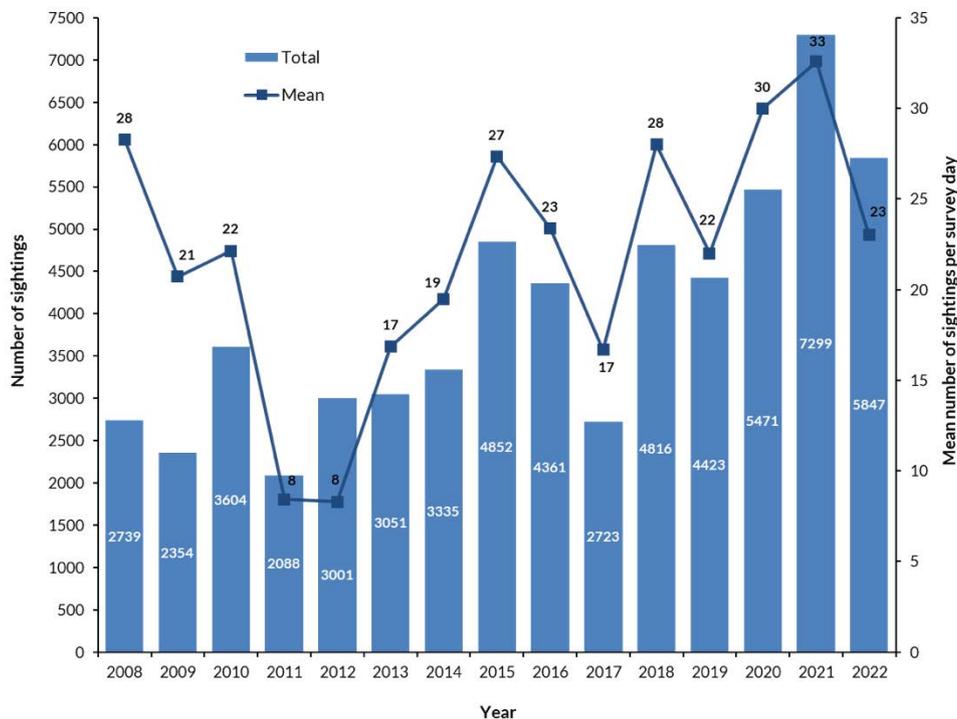


Figure 2: Annual sightings of reef manta rays (*Mobula alfredi*) in Baa Atoll Region from 2008 to 2022, and the mean number of sightings per survey day.

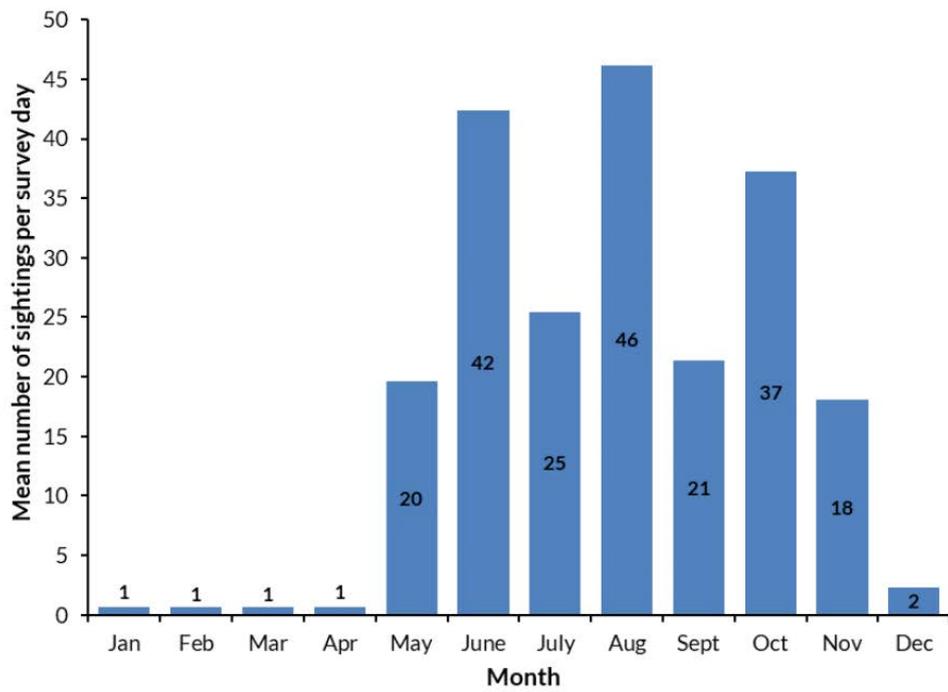


Figure 3: Monthly breakdown of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll Region during 2022.

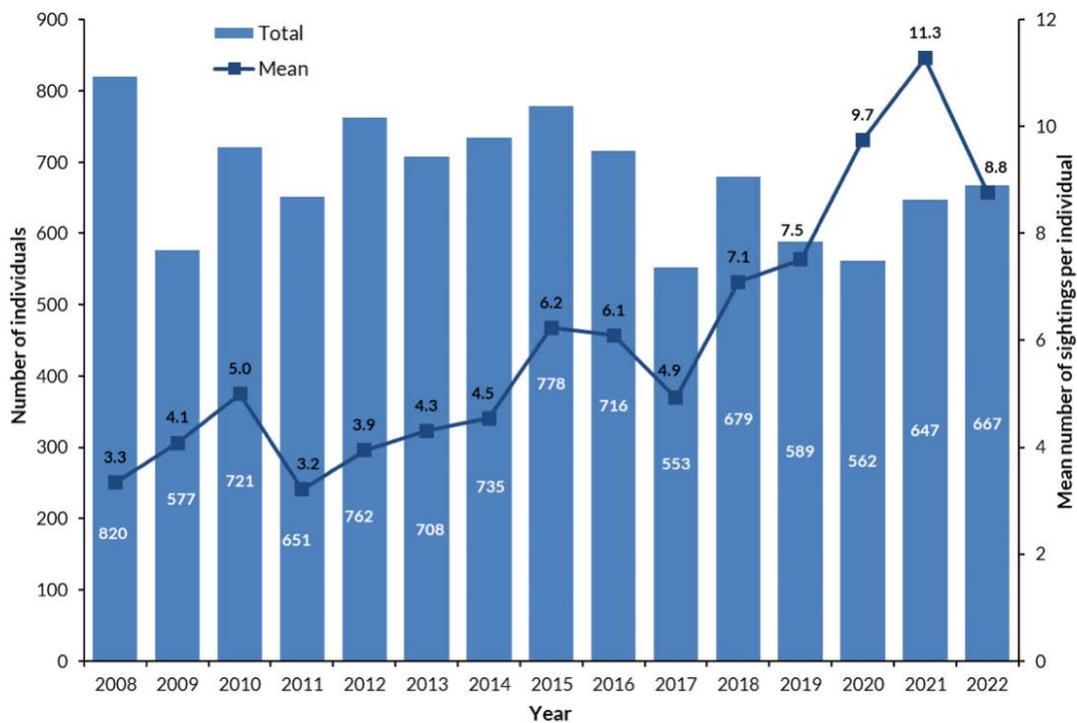


Figure 4: Annual number of individual reef manta rays (*Mobula alfredi*) sighted in the Baa Atoll Region from 2008 to 2022, and the mean number of sightings per individual.

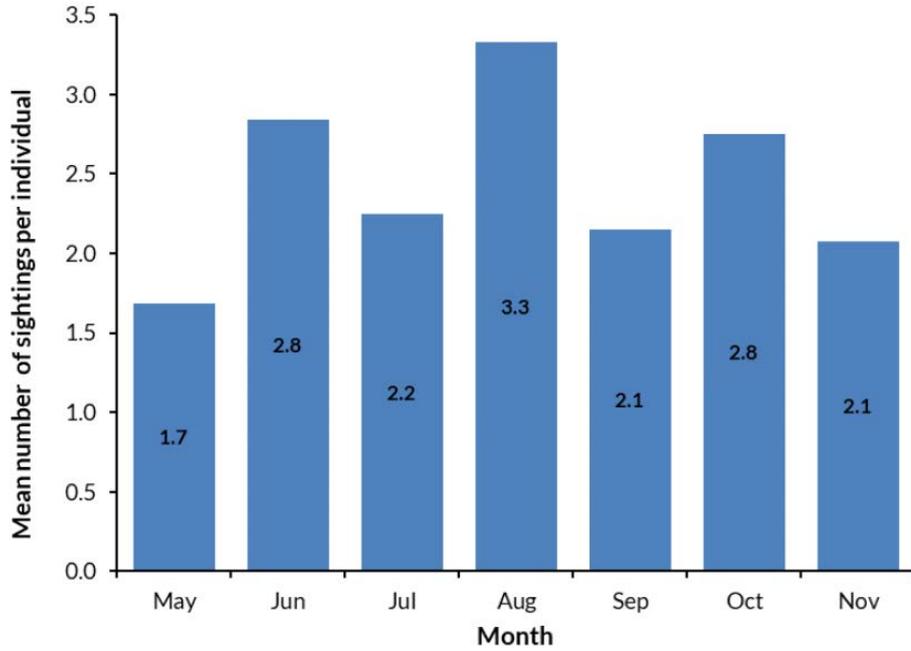


Figure 5: Mean number of sightings per reef manta ray (*Mobula alfredi*) during each month of intensive surveying in 2022.

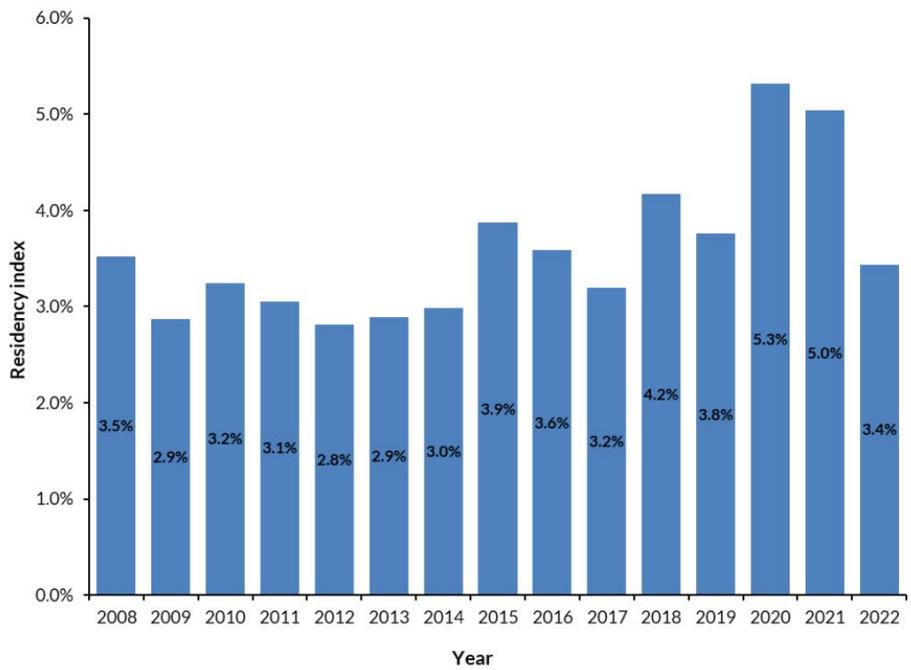


Figure 6: Annual Residency Index (RI) of the reef manta rays (*Mobula alfredi*) in Baa Atoll from 2008 to 2022.

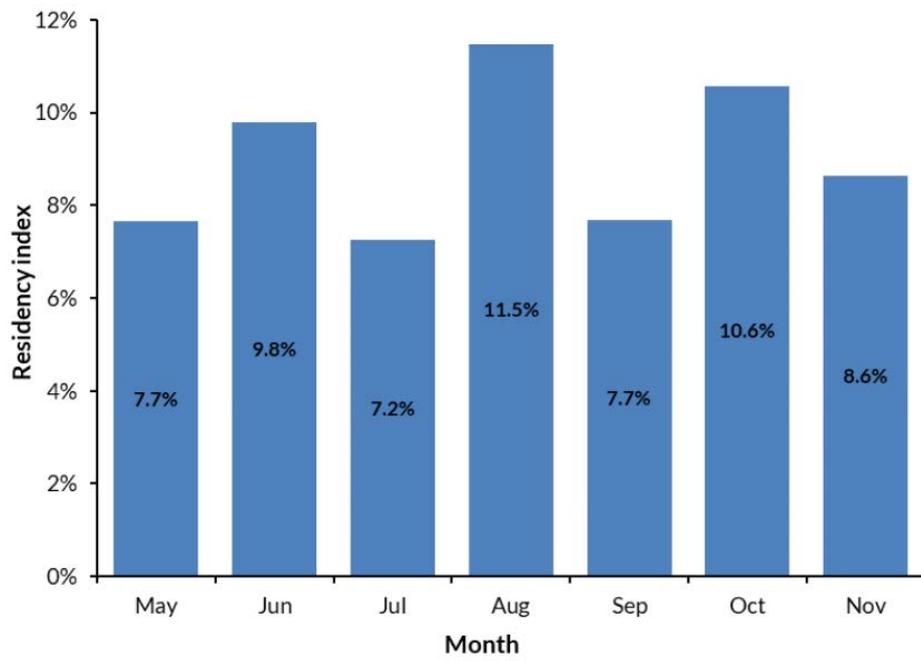


Figure 7: Residency Index of reef manta rays (*Mobula alfredi*) for each month of intensive surveying in Baa Atoll during 2022.



Hanifaru Bay (Marine Protected Area)

In 2022, 5,053 sightings of 596 reef manta rays were recorded in Hanifaru Bay MPA alone (Fig. 8), accounting for 86% of sightings recorded in Baa Atoll overall ($n=5,847$). This figure reiterates the site's importance as critical habitat for the species and further warrants its status as a marine protected area. All but seven of these sightings occurred between May and November, during the Southwest Monsoon. During this period, 32 reef manta rays were sighted per survey day on average, with a peak occurring in August ($n=51$) (Fig. 9). Each manta ray was sighted 8.5

times on average, and three individuals tied for the highest number of recorded sightings ($n=46$) during the season: MV-MA-3325 (Gapafra), MV-MA-3583 (Villoch), and MV-MA-4110 (Wilfreda). The 25th of August saw the greatest number of individuals recorded on a single day during the year, with a total of 212 confirmed reef manta rays identified from Hanifaru Bay. August was also the month during which the highest number of overall sightings ($n=1,275$) and individuals ($n=393$) were recorded in Hanifaru Bay.

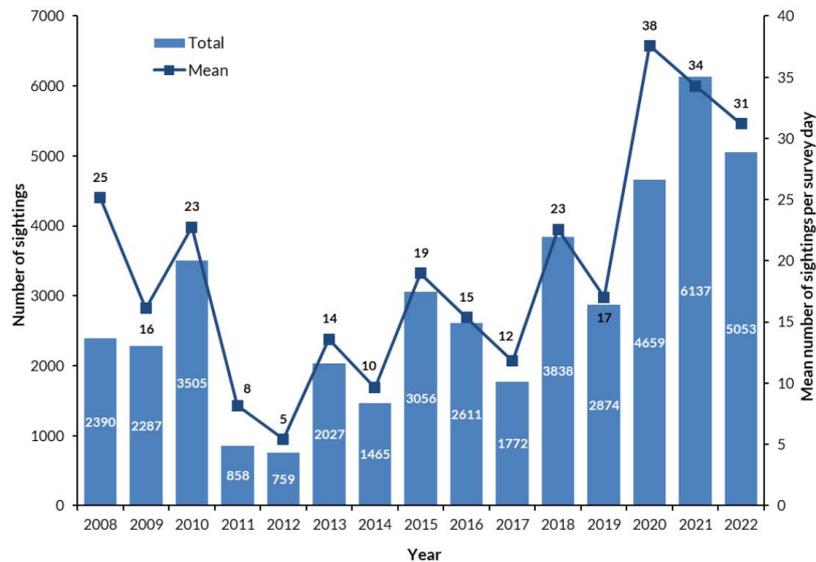


Figure 8: Annual sightings of reef manta rays (*Mobula alfredi*) in Hanifaru Bay from 2008 to 2022, and the mean number of sightings per survey day.

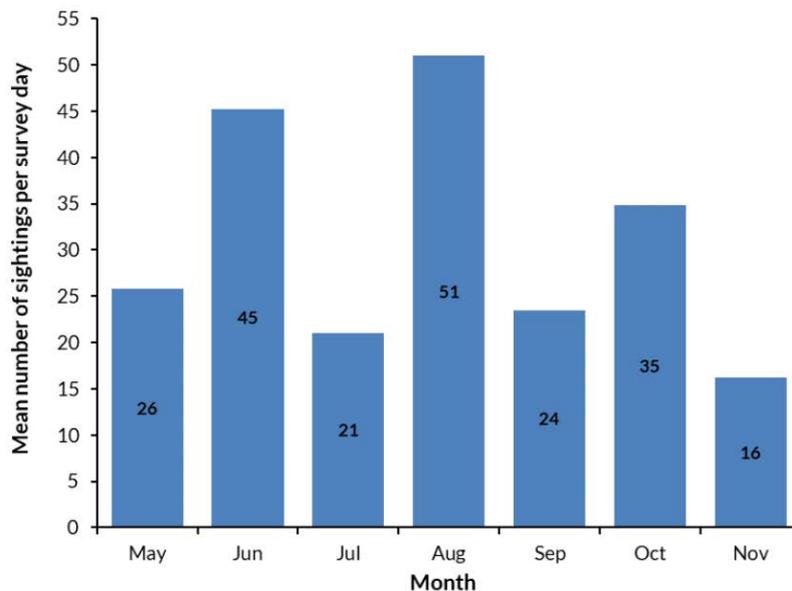


Figure 9: Average number of reef manta ray sightings (*Mobula alfredi*) recorded per survey day inside Hanifaru Bay during each month of intensive surveying in 2022.

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 2022, 22 sightings of 19 individuals were recorded in the Angafaru MPA, all but one of which occurred between May and November. Standardising the data by the number of days this area was surveyed ($n=76$)

revealed 2022 to have the lowest number of sightings per survey day on average ($n=0.3$) since 2013 (Fig. 10). The highest number of individuals recorded in a single day in the Angafaru MPA occurred on 20th May, when eight individuals were sighted at Dhigu Thila. Monthly breakdowns of average sightings per survey day ranged between zero and one, with the highest number of sightings per survey day occurring in May ($n=1.0$) (Fig. 11).

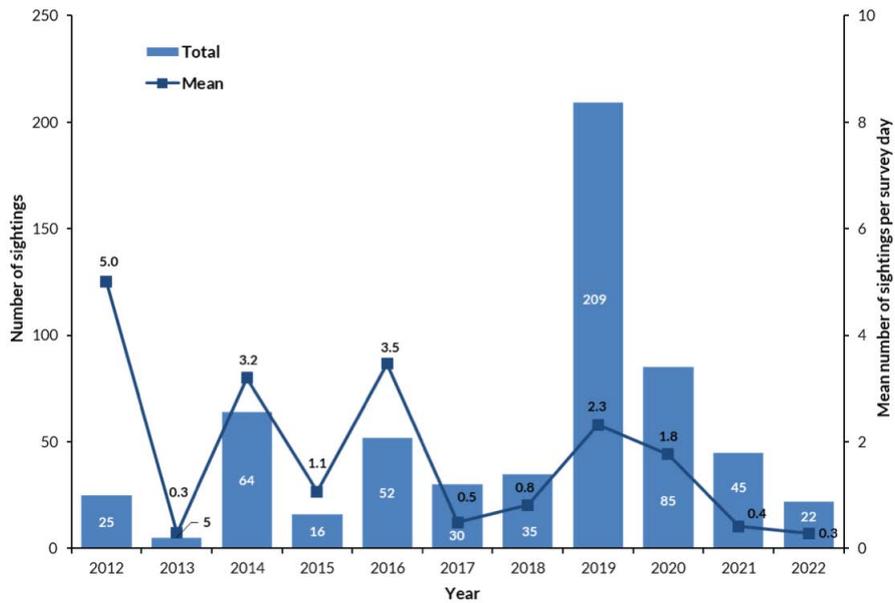


Figure 10: Annual sightings of reef manta rays (*Mobula alfredi*) in the Angafaru MPA from 2012 to 2022, and the mean number of sightings per survey day.

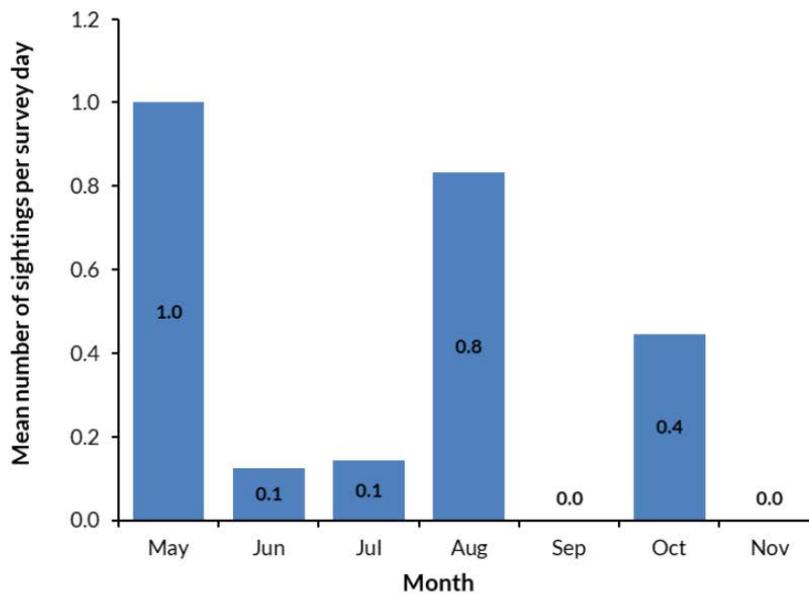


Figure 11: Average number of reef manta ray (*Mobula alfredi*) sightings recorded per survey day in the Angafaru MPA during each month of intensive surveying in 2022.

Weather & Climactic Variation

The MMCP continued to investigate the possible correlation of environmental variables (such as wind speed and direction) and the frequency of reef manta ray sightings (see 'additional research' section later in the report). In the years preceding 2022, May (which marks the start of the Southwest Monsoon) typically demonstrates characteristically high wind speeds. In 2022, average wind speeds in March and April were 13.9 km/h and 13.4 km/hr, respectively, before increasing to an annual peak of 25.8 km/h in May. In subsequent months of the Southwest Monsoon, the lowest wind speeds were recorded in June (17.1 km/h) and November (15.4 km/h), while July to October maintained average wind speeds varying between 20.3 and 22.0 km/h (Fig. 12). Data from previous years indicate cyclical trends where average manta ray sightings tend to increase one or two months following an increase in average wind speeds. A similar trend was observed in 2022, which experienced an increase in manta ray sightings in June (following high wind speeds recorded in May), with 42 recorded per survey day on average (Fig. 12). However, there was also a great deal of variation in manta ray sightings over the months that followed, despite monthly average wind speeds remaining relatively constant (within 1.75 km/h) between July and October. Data pertaining to the wind speed, direction, and fine scale changes in the weather conditions in the region throughout 2022 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 2022 was 18.4 km/h, lower than in 2021, which had an average wind speed of 19.8 km/h. The overall number of reef manta ray sightings per survey day also dropped from an all-time high of 33 in 2021, to 23 in 2022. However, increased 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). Furthermore, 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 Hulhule Island, North Malé Atoll) reveal variability throughout May to December (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, westerly winds dominated from May to November, contributing to 42% to 90% of wind direction readings each month during this time (Fig. 14). Winds from the southwest were the second most common overall, and were most prevalent in May, accounting for 45% of daily wind direction readings that month. There was no clear pattern of correlation between changing wind directions and monthly manta ray sightings during the Southwest Monsoon, however; the highest number of reef manta ray sightings were recorded in August (average per survey day, $n=46$), when 48% ($n=15$) of daily wind direction readings were recorded as westerly, while June, which saw the second highest number of manta sightings (average per survey day, $n=42$), experienced westerly winds on 90% of days ($n=27$).

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), Madden-Julian Oscillation (MJO) and El-Niño Southern Oscillation (ENSO) are also 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 changing trends, but also on a wider scale, they will affect the tourism and fishing sectors, which heavily rely upon the ocean's productivity, and therefore the strength of the monsoons.

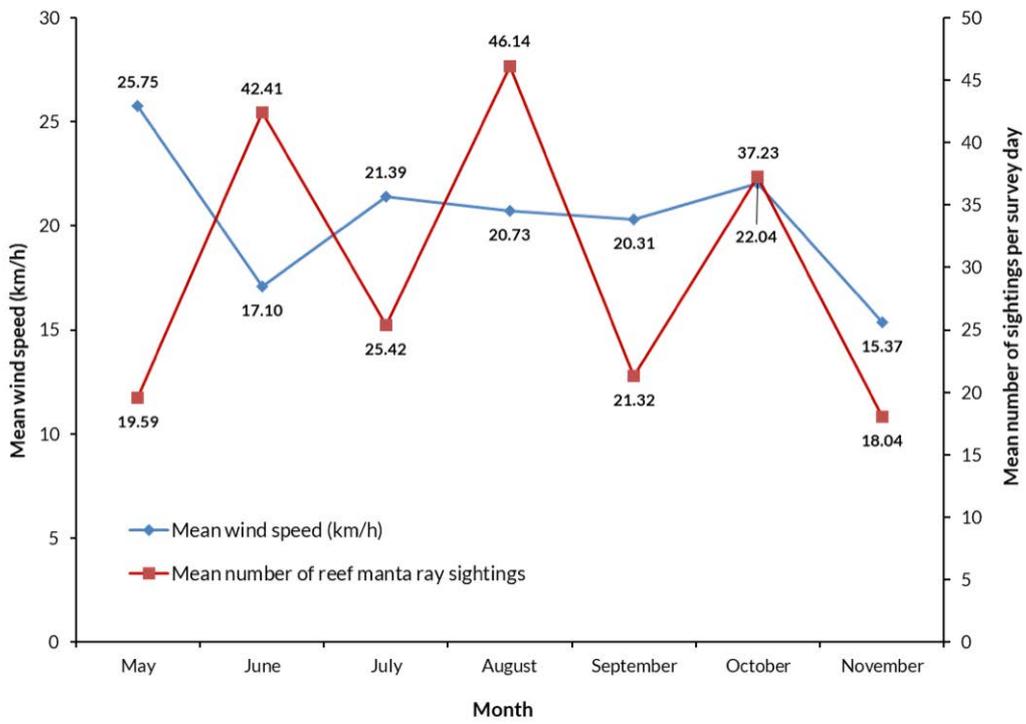


Figure 12: Mean monthly wind speed (km/h) and mean number of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll (2022).

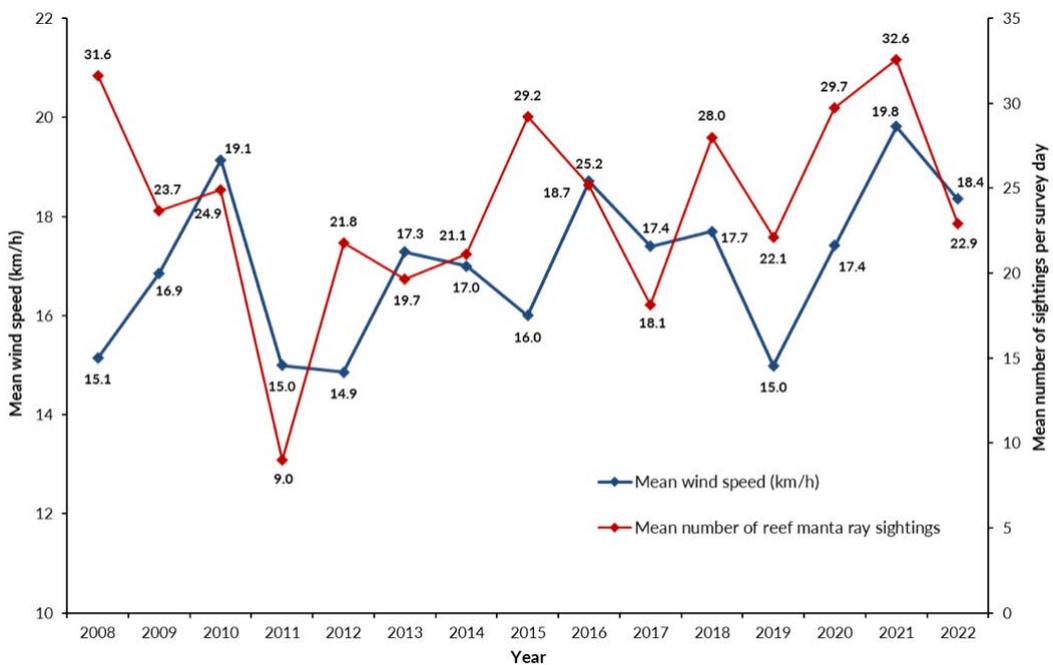


Figure 13: Mean annual wind speed (km/h) and the mean number of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll.

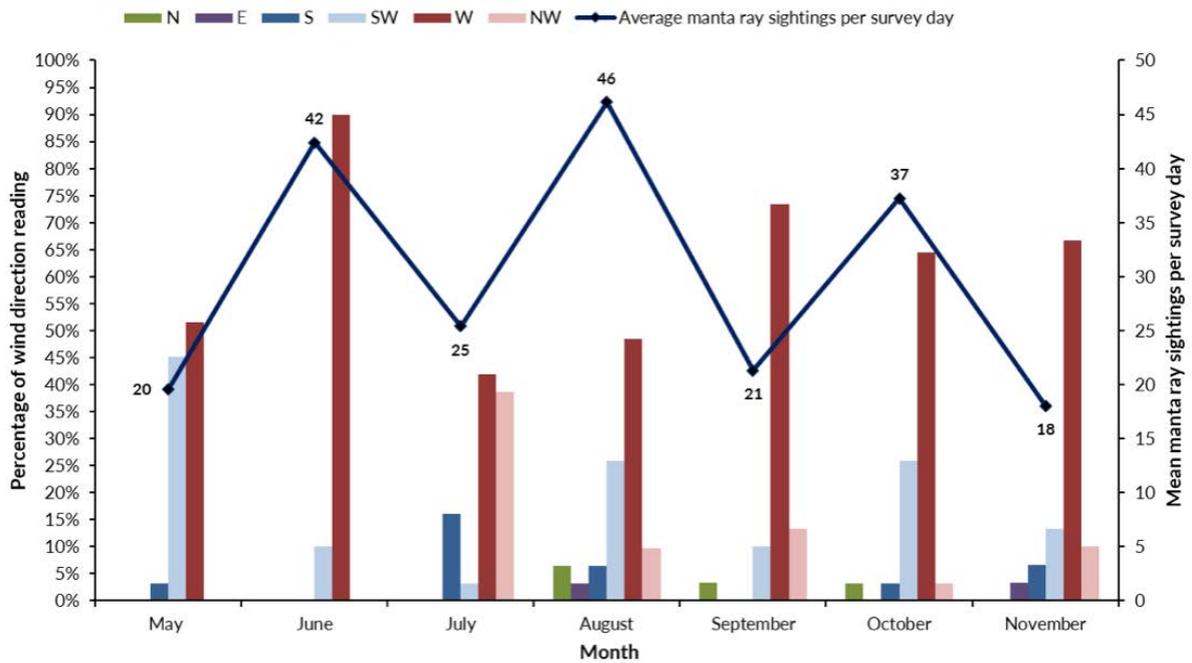


Figure 14: Monthly breakdown of the percentage of wind direction readings from the Maldives Meteorological Society’s weather station, and the average number of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll (2022).



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 2022, the MMCP team recorded a total of 39 whale shark sightings in Baa Atoll, a 5% increase from the previous year (2021, $n=37$). This total makes 2022 the highest year for whale shark sightings since 2008, when 49 sightings were recorded (Fig. 15). Of these, researchers collected ID photographs for 74% of sightings ($n=29$), confirming the presence of 19 different individuals in Baa Atoll, including three which were new to the Maldives Whale Shark Research Programme's database. Overall, Hanifaru Bay accounted for 72% ($n=28$) of the total whale shark sightings in Baa Atoll in 2022.

All recorded whale shark sightings occurred during the Southwest Monsoon (May to November), and monthly breakdowns revealed sighting peaks in June ($n=10$) and August ($n=10$) (Fig. 16). August saw the highest number of identified individuals ($n=6$). Interestingly, the MMCP also recorded the highest number of manta ray sightings in August ($n=1,338$), followed by June ($n=1,230$), suggesting that the prevailing conditions during these months were most favourable for these planktivorous species. Indeed, within Hanifaru Bay, peaks in whale shark sightings followed the same general trend as peaks in reef manta ray sightings (Fig. 17), with August marking the peak in both manta ray ($n=1,275$) and whale shark ($n=10$) sightings.

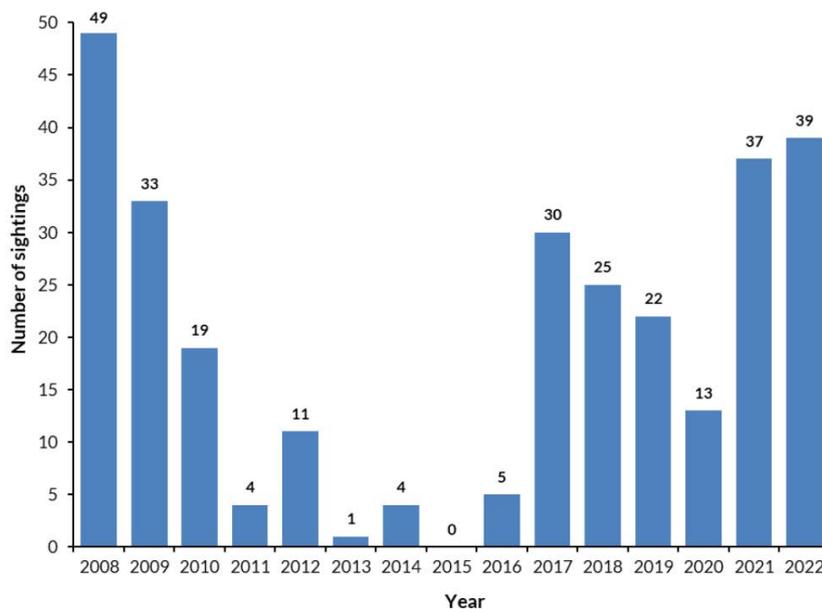


Figure 15: Annual sightings of whale sharks (*Rhincodon typus*) in Baa Atoll from 2008 to 2022.



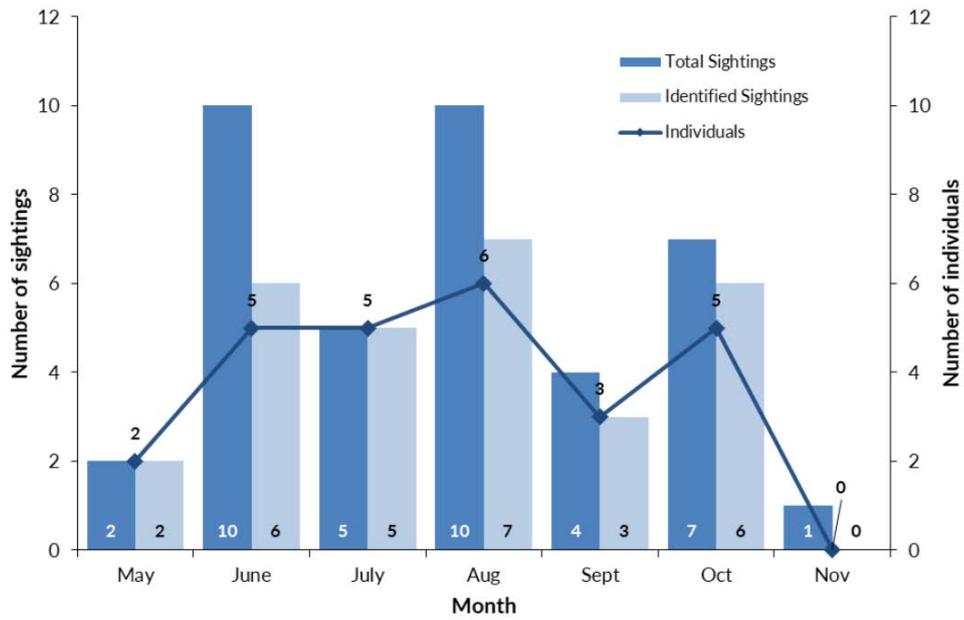


Figure 16: Whale shark (*Rhincodon typus*) sightings (total and identified) recorded by the MMCP in Baa Atoll during 2022, and the total number of individuals recorded during each month of intensive surveying.

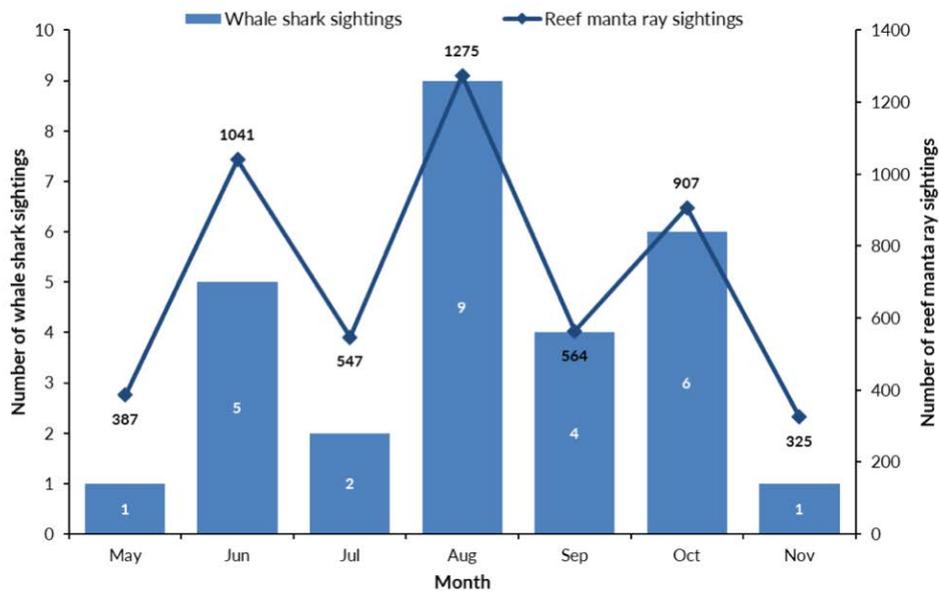


Figure 17: Monthly whale shark (*Rhincodon typus*) and reef manta ray (*Mobula alfredi*) sightings recorded at Hanifaru Bay, Baa Atoll in 2022.

POPULATION SIZE & DEMOGRAPHICS

The total number of individual reef manta rays recorded in Baa Atoll since data collection began in 1992 is 2,368, almost half (42%) of the Maldives reef manta ray population recorded to date ($n=5,619$). As of 2022, population demographics of Baa Atoll constitute 53% females ($n=1,262$), 46% males ($n=1,094$) and <1% individuals for which the sex could not be determined ($n=12$). The population comprises 1,440 (61%) adults, 924 (39%) juveniles, and four (<1%) individuals of unknown maturity status. Of the manta rays recorded in Baa Atoll ($n=2,368$), 48% ($n=1,142$) 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. 18). This highlights the importance of Baa Atoll as a core aggregation site for the Maldives manta ray population during the Southwest Monsoon.

Throughout 2022, a total of 423 adult and 243 juvenile reef manta rays were sighted, as well as one individual for which maturity status could not be determined. This included 347 females, 317 males, and three individuals for which sex could not be determined. Maturation was defined by the presence of dorsal or ventral mating scars or wounds, 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 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 (51% overall, $n=2,955$), followed by adult males (23% overall, $n=1,318$) (Fig. 19). For juvenile manta rays, accounting for 26% ($n=1,511$) of sightings during these months, there was a

more pronounced skew towards females (20% overall, $n=1,183$), while juvenile males accounted for just 5% ($n=316$). These figures highlight the importance of Baa Atoll for sexually mature and reproducing 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 2,955 sightings of adult females recorded between May and November, 90% ($n=2,663$) were recorded engaging in feeding behaviour at sites throughout Baa Atoll, with Hanifaru Bay accounting for the majority of these ($n=2,501$).

A total of 372 new individual reef manta rays were documented across the Maldives during 2022, a population increase of approximately 7% from the previous year (2021, $n=5,247$), bringing the total Maldives population to 5,619. Of these new individuals added to the MMCP database in 2022, 14% ($n=51$) were documented in Baa Atoll, representing a decrease from the previous year (2021, $n=61$) (Fig. 20).

Of the 51 new manta rays sighted in Baa in 2022, 11.8% were adults ($n=6$), and 86.3% were juveniles ($n=44$). Of these individuals, 49 were first identified in Baa Atoll, while the other two were first identified in other atolls but later sighted in Baa Atoll.

The decrease in newly identified manta ray individuals during 2022 follows the general downward trend of the proportion of newly sighted individuals throughout previous years (Fig. 20). As more data is collected over the years by 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.



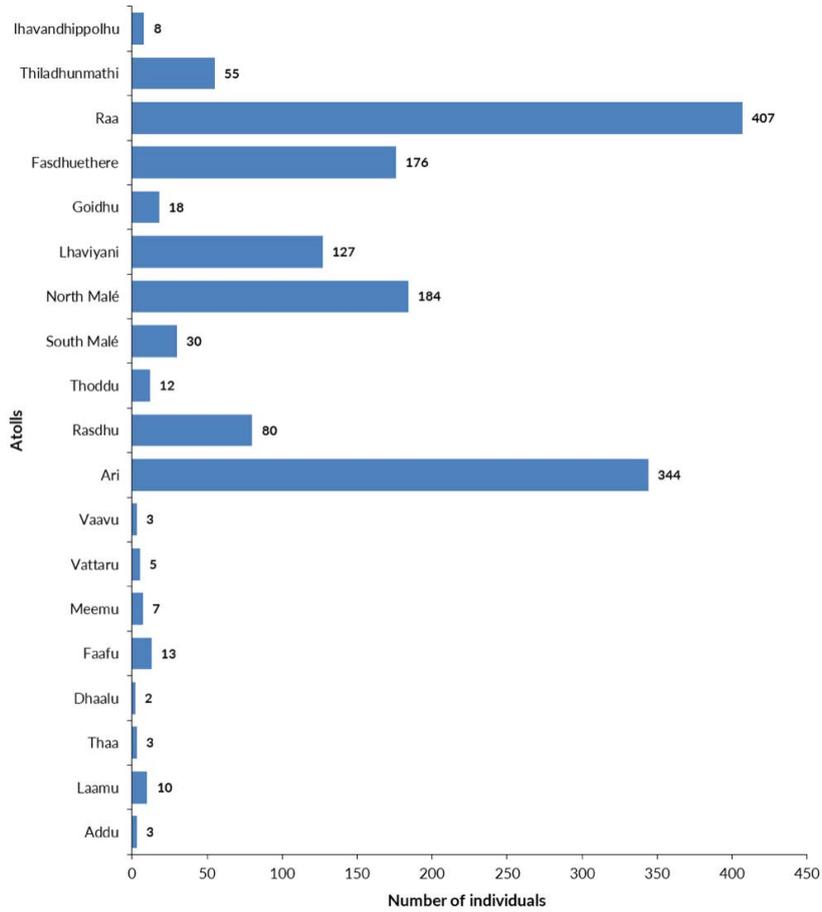


Figure 18: Number of reef manta ray (*Mobula alfredi*) individuals (n=1,142) from among the Baa Atoll population (n=2,368) which have been recorded in other atolls throughout the Maldives Archipelago.
 * Many of these cross atoll individuals have been observed in more than two atolls.

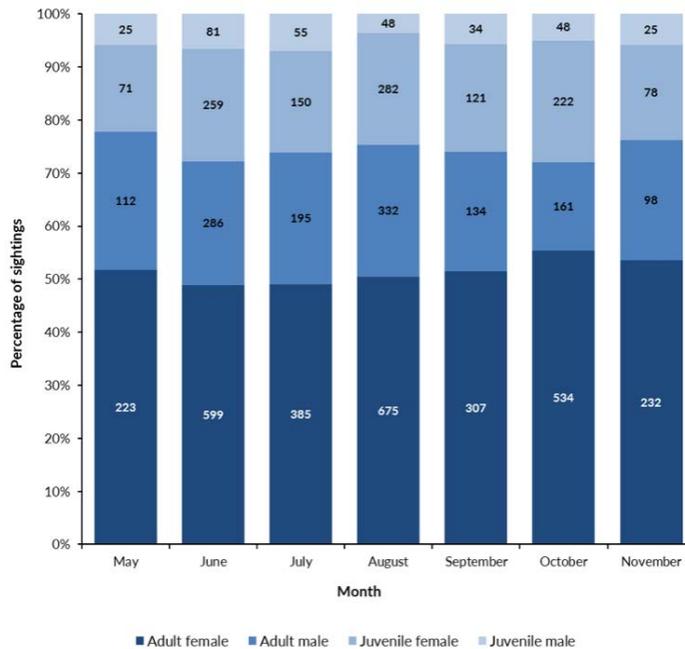


Figure 19: Reef manta ray (*Mobula alfredi*) sightings distribution categorised by maturity status during each month of intensive surveying effort in Baa Atoll in 2022.
 Actual numbers within bars.

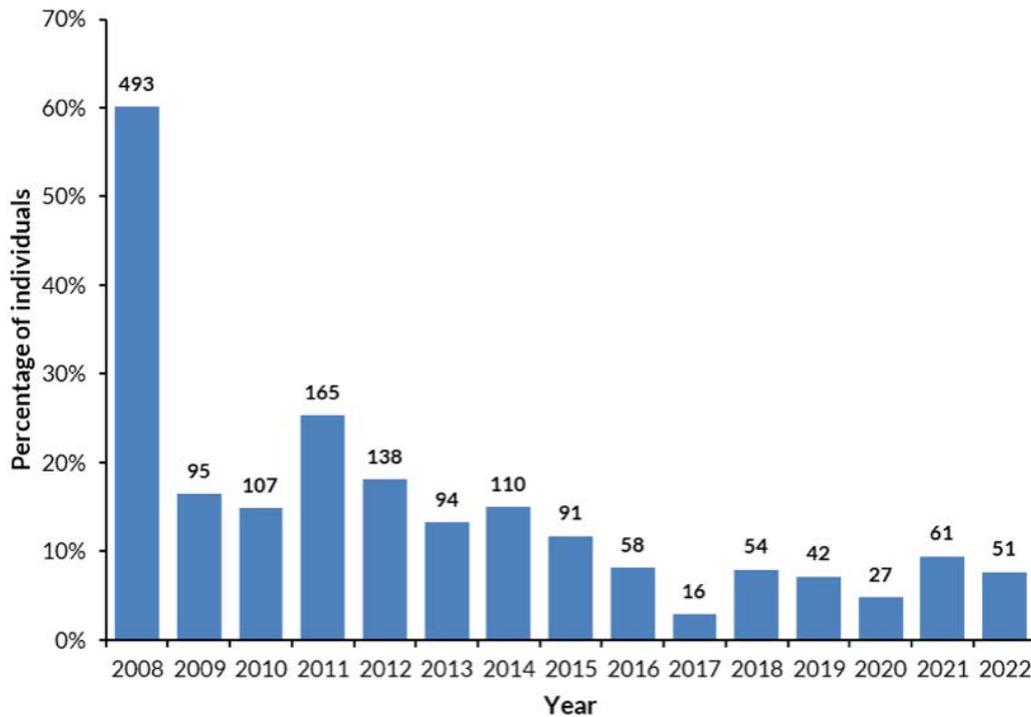


Figure 20: Proportion of the total reef manta rays (*Mobula alfredi*) sighted annually in Baa Atoll which were newly sighted individuals.
Actual number of new individuals above bars.

REPRODUCTIVE ACTIVITY

This report marks the tenth year in a row that the MMCP has recorded pregnancies among the Maldives reef manta ray population. A total of 66 individuals were recorded as pregnant in Baa Atoll in 2022, 35% of all adult females sighted in the atoll that year ($n=188$). The number of pregnancies recorded in 2022 was a slight increase from the previous year (2021, $n=64$), and 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 66 pregnant females observed in Baa Atoll during 2022, 82% ($n=54$) 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 11 surveys during the Southwest

Monsoon (May: $n=1$; June: $n=1$; July: $n=2$; September: $n=3$; October: $n=2$; November: $n=2$), all of which occurred at Hanifaru Bay.

While 2022 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 14% 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.

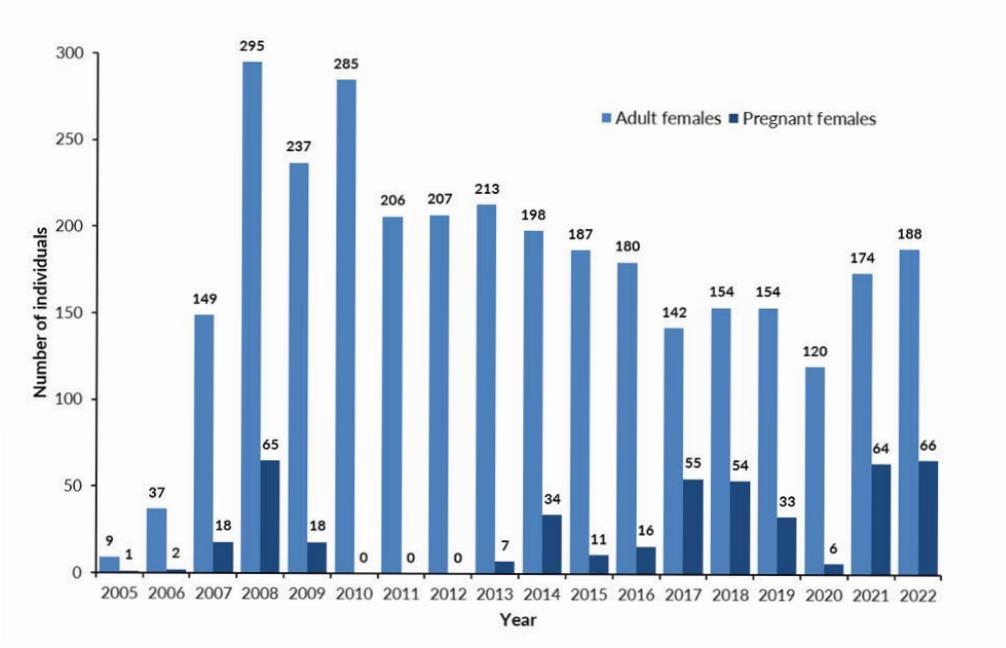


Figure 21: Number of adult female reef manta ray (*Mobula alfredi*) individuals sighted annually in Baa Atoll from 2005 to 2022, and the number of those females which were recorded as being pregnant in the same year. *Actual numbers above bars.*



SUB-LETHAL INJURIES

A total of 57 new injury events were recorded among reef manta rays in Baa Atoll in 2022 (Fig. 22), affecting 54 different individuals. Of these injuries, 42% ($n=24$) originated anthropogenically, 47% ($n=27$) originated naturally, and 11% ($n=6$) were caused by an undetermined source. Anthropogenic injury types included fishing line entanglement ($n=20$), boat strike ($n=2$), and net entanglement ($n=2$), while natural injuries were attributed to predatory bites ($n=20$), deformity ($n=6$), and infection, disease, and parasites ($n=1$). Over 77% of these injury events recorded in 2022 affected the pectoral region of the animal ($n=44$) (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 sublethal injuries for the health and fitness of these animals are unclear. Of the anthropogenic threats, entanglement in fishing line ($n=20$) 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 seven 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.

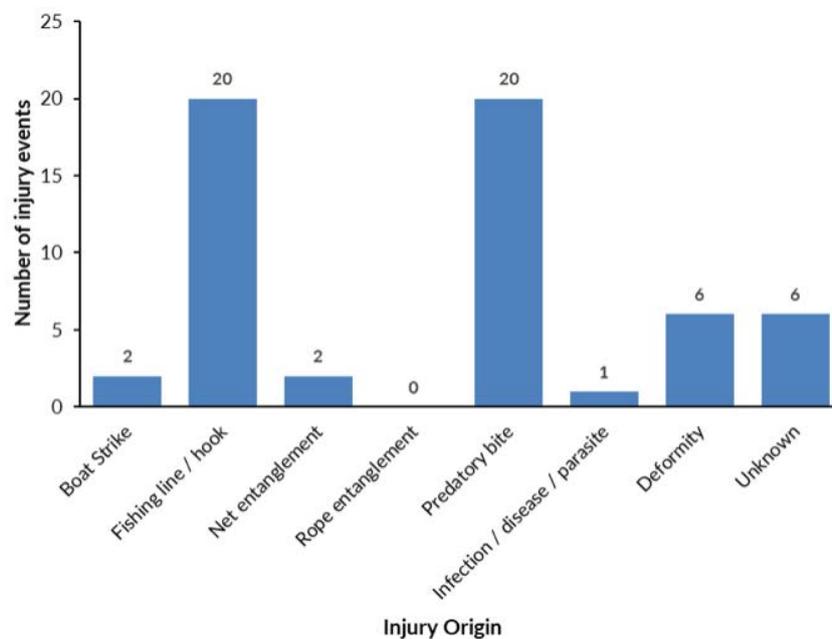


Figure 22: Variations in the likely origin of sublethal injury events ($n=57$) among the reef manta rays (*Mobula alfredi*) recorded injured in Baa Atoll in 2022.

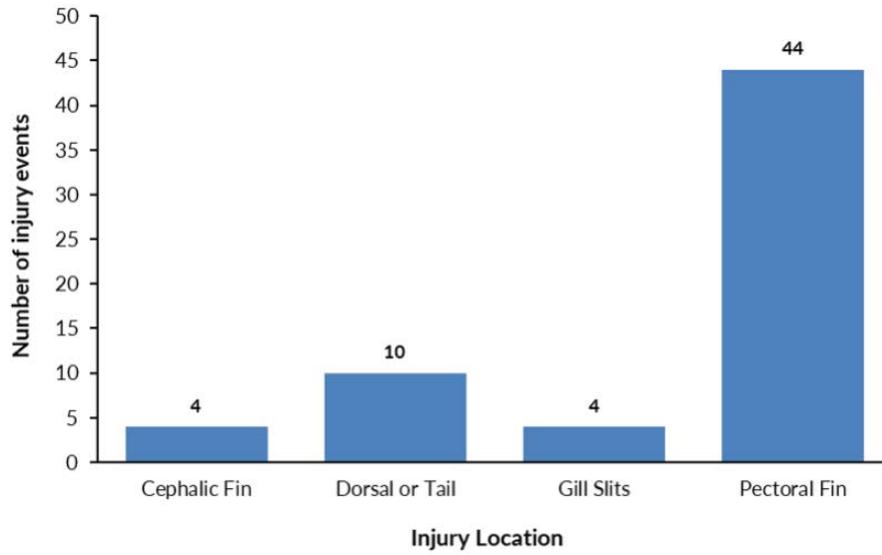


Figure 23: Variations in the locations (by body part) of sublethal injury events (n=57) within the reef manta rays (*Mobula alfredi*) recorded injured in Baa Atoll in 2022. Actual number of injuries on bars. Note that injury events can affect multiple parts of the body.



ADDITIONAL RESEARCH - EYES ON THE REEF

During 2022, master's student Henry Gould, from the University of Exeter, conducted a study investigating the [impact of environmental factors on the reef manta rays of Baa Atoll](#), using data collected between 2019 and 2021 via remote underwater photo (RUP) surveys.

The use of remote time-lapse cameras, running for up to thirteen hours per day, enabled monitoring of reef manta ray visitation at selected cleaning stations in northeastern Baa Atoll. Manta ray sighting abundance was then assessed against the following environmental factors: seasonality (month and year), water temperature, moon phase, time of day, wind speed, and wind direction. Wind speed and direction were both found to play an influential role in manta ray abundance, with westerly winds showing an increased visitation rate. New and full moon lunar phases were shown to have the greatest influence on manta ray abundance. Conversely, evening was found to be less favourable for manta ray visitation to cleaning stations, with visitation declining as the day progressed. Overall, 146 individual reef manta rays were identified at these cleaning stations over

the three-year study period, with 30.2% of these returning more than once, demonstrating a degree of site fidelity.

Future analyses should include factors which were beyond the scope of this study, such as current direction and strength, cloud cover, or sea state. These additional environmental factors may well contribute as drivers of reef manta ray abundance. Nevertheless, this study has shown environmental factors do impact manta ray visitation to these Baa Atoll cleaning stations, which is an important insight into the behaviour of this species.

The use of time-lapse underwater recording systems deployed by the MMCP research team has shown to be a useful aid in monitoring manta rays in the absence of humans. The ability to monitor a site continuously for months over the course of three years has revealed important information about reef manta ray behaviour. This, and future studies, can be used to enhance conservation management initiatives in the Maldives, and further afield.





TOURISM ACTIVITIES

With the onset of a global pandemic in 2020, the tourism industry in the Maldives was greatly impacted. The borders of the Maldives closed to international tourists on 27th March 2020 and reopened again on 14th July 2020. International arrivals to the Maldives decreased from 1,702,887 arrivals in 2019 to 55,494 arrivals in 2020 (Ministry of Tourism). International visitors increased in 2021 to 1,321,937, which mirrors pre-pandemic levels. The tourism continued to recover from the impacts of the pandemic in 2022, with a recorded 1,675,294 international tourists entering the Maldives.

Manta rays are very sensitive to disturbance, and if left without proper management 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 2022, 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 crews 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 and throughout the country. It is crucial the tourist community understand the importance of safe boating and in water best practices.

CONSERVATION MANAGEMENT

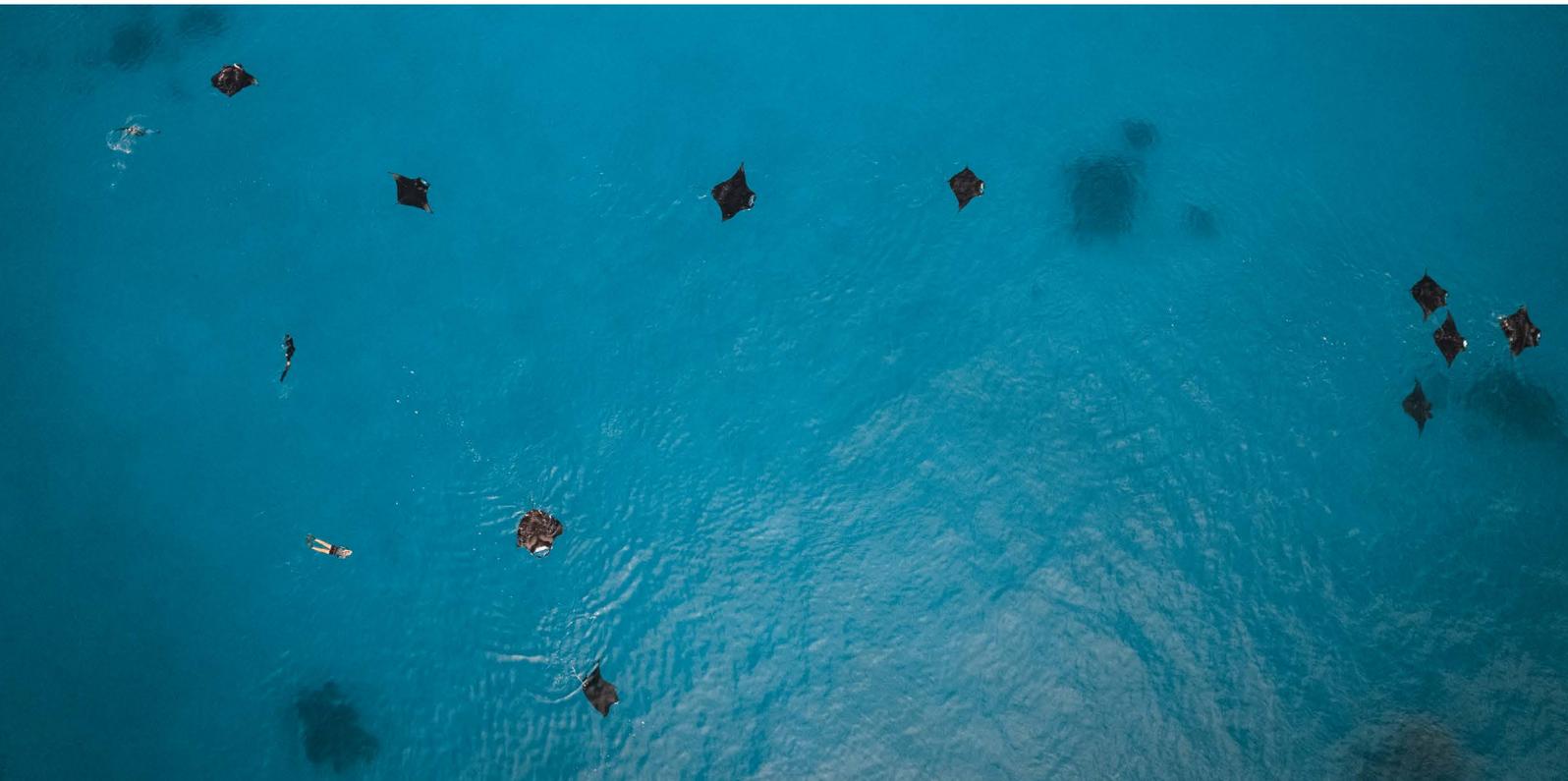
Baa Atoll has been globally recognised as one of ~700 UNESCO World Biosphere Reserves around the globe, in part because of its ecological importance as an aggregation site for manta rays and whale sharks. As such, this region is an extremely important research location for these species globally. The 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 2022, Baa Atoll Biosphere Reserve rangers were again on site to maintain the rules and regulations of Hanifaru 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.



BAA ATOLL MARINE EDUCATION PROGRAMME

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

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

The MMCP, in partnership with the Ministry of Education, spend up to 6-months delivering the programme which is tailored for secondary school students. Through five core modules, students are educated about marine biology and conservation: marine ecology, coral reefs, marine megafauna, seagrass and mangroves, and ecosystem conservation.

The programme promotes experiential learning, whereby students learn through a broad range of activities and experiences. Moodhu Madharusaa prioritises snorkelling and nature exploration field trips, supported by theory classes and practical activities (Fig. 24). From designing and delivering presentations for their younger peers, to creating awareness-raising videos and conservation-inspired artwork, homework is designed to encourage intergenerational learning.

Moodhu Madharusaa has been expanding in reach since its inception in Baa Atoll in 2015. Over 180 students from five schools across two atolls have now completed the programme (Fig. 25). Having successfully completed the programme in 2019 with sixty students from Baa Atoll Education Centre (BAEC), Eydhafushi, the MMCP started delivery of the programme for Baa Kamadhoo School in January 2020. However, with the COVID-19 pandemic came travel restrictions which made it impossible to continue the programme, which was paused until 2022 when MMCP facilitators were able to restart the sessions.

During September – November 2022, twenty students from B. Kamadhoo School completed Moodhu Madharusaa. The three top-scoring students were awarded a special prize and were invited to take part in a 'Discover Scuba Dive' at Four Seasons Landaa Giraavaru (FSLG) in early 2023. Highlights included a student-organised mini "Manta Festival" to celebrate World Manta Day with games, quizzes, and crafts to showcase what they had

learnt during their classes; and taking part in a 'Penpal Project', partnered with a corresponding school in the United Kingdom (UK), whereby they wrote letters about the marine ecosystems in the Maldives, and in return received letters about the marine life in the UK.

Pre- and post-programme surveys were conducted to assess the programme's effectiveness. Results show the students' marine environmental knowledge increased by 5% after completing the Moodhu Madharusaa programme. Students exhibited improved marine environmental attitudes, pro-environmental behaviours, and swimming and snorkelling confidence. The success of the Kamadhoo programme was largely due to the invaluable support and collaboration from the MMCP's partners, particularly the Baa Atoll UNESCO Biosphere Reserve (BR) and Four Seasons Resort at Landaa Giraavaru, and the high level of enthusiasm from students, parents, and teachers from Kamadhoo School.

In addition to the Moodhu Madharusaa Marine Education Programme, the MMCP conducted manta ray ecology presentations for B. Dhonfanu, B. Eydhafushi, and B. Thulhaadhoo Schools - including a field trip to Hanifaru Bay in collaboration with the BR team for Thulhaadhoo students - as well as hosting visits from Fuvahmulah School students and children from Amaan Veshi, Eydhafushi. In collaboration with Reefscapers PVT LTD, the MMCP travelled to N. Velidhoo to conduct a Marine Education and Awareness Day for school children, which included theory classes, practical workshops, and a snorkelling session. In October, the MMCP attended the Vaavoshi Turtle Festival in B. Goidhoo, hosted by Olive Ridley Project, with an estimated 170 visitors throughout the day. The stall enabled children and parents to experience the MMCP's virtual-reality (VR) headsets and take part in quizzes, games, and challenges.

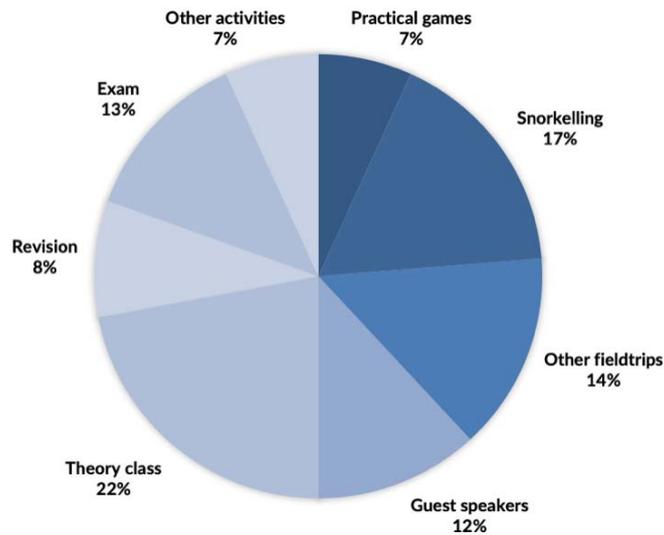


Figure 24: Percentage of time devoted to each activity which comprised the Moodhu Madharusaa Marine Education Programme in 2022.

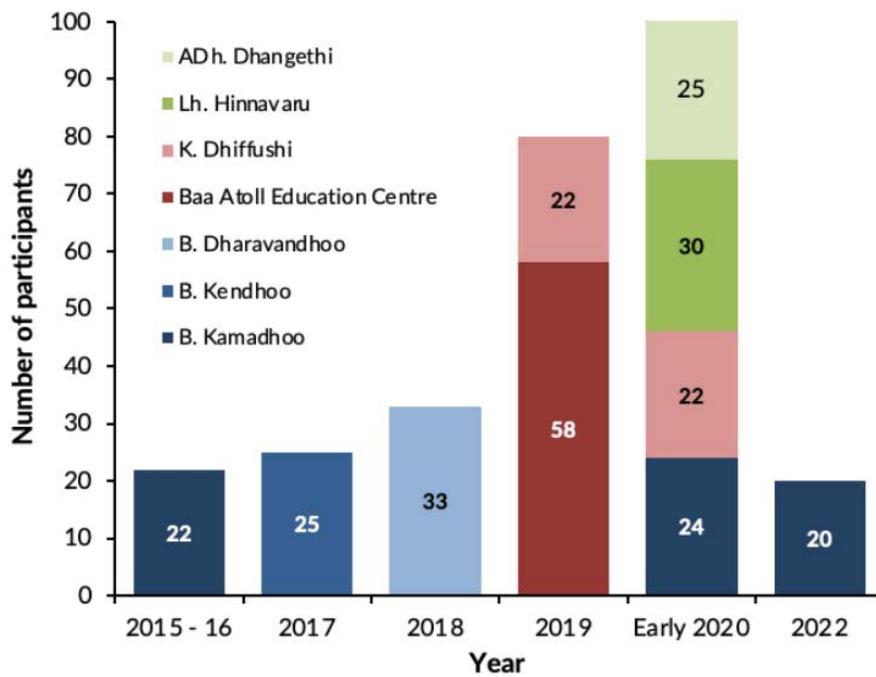


Figure 25: Number of students participating in the Moodhu Madharusaa Marine Education Programme annually on different local islands in the Maldives.

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 2022.



**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.



**MALDIVES MANTA
CONSERVATION
PROGRAMME**

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