Manta TRUST

Maldivian Manta Ray Project

BAA ATOLL | ANNUAL REPORT 2017

Conservation through
research, education and collaboration.

- The Manta Trust

MALDIVIAN MANTA RAY PROJECT

www.mantatrust.org

WHO ARE THE MANTA TRUST?

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

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

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

MALDIVIAN MANTA RAY PROJECT

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

The MMRP collects data around the country's manta population, its movements, and how the environment and tourism / human interactions affect them. Since its inception, the MMRP has identified over 4,650 different individual manta rays, from more than 50,000 photo-ID sightings. This makes the Maldivian manta population the largest, and one of the most intensively studied populations in the world.

The long-term and nationwide data collected by the MMRP has allowed researchers to record and identify key patterns within this population over time. Not only does this invaluable information improve our understanding of these animals, but it informs their on-going 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 body of a variety of ailments when consumed in a tonic. There is no scientific evidence to support this claim.

Manta and mobula rays are particularly vulnerable because of their aggregately 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, and slow to recover if protected.

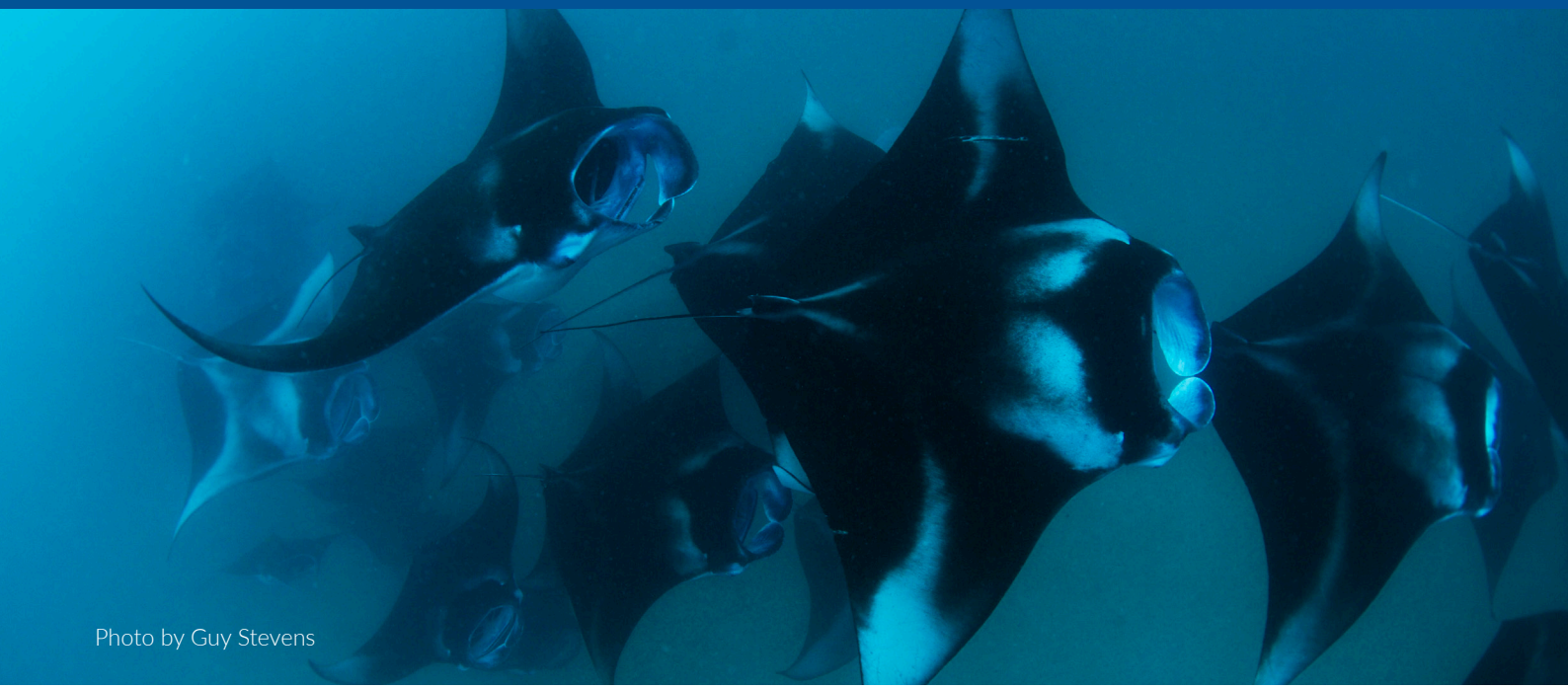

Photo by Guy Stevens

EXECUTIVE SUMMARY

This report primarily presents data collected by the Maldivian Manta Ray Project (MMRP) on Baa Atoll's reef manta ray (*Mobula alfredi*) population throughout 2017. The report also details the MMRP's other research and education activities in the atoll.

Baa Atoll has an international reputation as one of the most reliable places in the world to see reef manta rays and whale sharks (*Rhincodon typus*). These animals frequent the waters of Baa Atoll due to the conditions created by the South Asian Monsoon, which provides an abundant source of food for these planktivorous creatures in the region. In Baa Atoll, these animals have been continuously studied since 2007 by the MMRP.

Key findings of the MMRP in 2017 include; a total of 2,723 sightings of 553 individual manta rays, recorded throughout the year in Baa Atoll. The 2017 data equate to a 38% decrease in sightings compared to the previous year, and is the lowest total number of sightings recorded in Baa Atoll since 2011 (n= 2,088). Furthermore, when standardised for effort, 2017 sightings produced a significant reduction in encounters when compared to the previous two years.

Throughout the seven months of intensive surveying (May – November), each of the 553 different individuals were observed on average 4.9 times; a marked decrease from the recordings in 2016 and 2015, when there were on average 6.1 and 6.2 sightings per manta, respectively. Although the direct mechanisms which control manta sighting frequency in Baa Atoll are not yet clear, fluctuations in the monsoon weather patterns are thought to be the most influential factors, effecting primary productivity levels and thus food availability for the manta rays locally. Observations in previous years support this theory by demonstrating an apparent correlation between environmental variables (most notably wind speed and direction) and manta ray abundance. Increased wind speed appears to kick-start productivity and food availability, thereby influencing manta ray abundance positively in subsequent months. As in preceding years, manta ray sightings in 2017 saw a steady increase from May through to July. However, although May was characterised by high wind speeds at the start of the 2017 Southwest Monsoon, there was a sharp reduction in wind speed between the end of May and July (with an average decrease of 6 km/hr). It is hypothesised that this reduction in wind speed had a knock-on effect, resulting in a decline in primary productivity, and therefore secondary zooplankton food availability for the mantas. This hypothesis provides an explanation for the initial peak and then drop in manta sightings witnessed in the first half of the Southwest Monsoon. Unlike in some previous years, manta sightings were highest much later in the season, with

a marked increase during the month of October, with a total of 645 encounters. October's high manta sightings number was coupled with stronger monsoonal winds, which prevailed during the second half of the season.

In contrast to 2016, sightings of manta activity at the cleaning stations in 2017 in eastern Baa Atoll during the Southwest Monsoon were minimal, with only a few fleeting encounters documented, and a reduction in courtship and mating activity noted. Our investigations suggest that this decrease may be linked to the weakened monsoon winds observed in 2017. However, the number of pregnant mantas recorded in Baa Atoll during 2017 was the largest recorded during a single season, with a total of 55 pregnancies. With a gestation period of 12 months, it should be highlighted that 76% (n=42) of these pregnant females were already in the later stages of gestation (3rd- 4th trimester) when first observed in 2017. Consequently, the large number of recorded pregnancies in 2017 are a result of the high level of reproductive activity documented in 2016, when the manta's food supply was likely to be in greater abundance.

Further research on the social behaviour of manta rays was undertaken in 2017, as well as the continuation of manta ray tourism interaction studies, building on the evidence base of previous study years. In 2017, the Manta Trust launched a new initiative and toolkit on '*how to swim with manta rays*', providing a set of guidelines and a briefing video detailing the best codes of conduct for manta ray tourism. The Maldives was the first country to see these interaction guidelines and briefing videos introduced by marine biologists and tour operators, making it a forerunner in initiatives to ensure more sustainable manta ray tourism.

In 2017, the Baa Atoll Marine Education Programme continued to raise awareness about manta and devil rays, and the importance of the marine environment. In addition, a follow-up Master of Science research project was undertaken to evaluate the effectiveness of this programme.

Efforts to conserve the natural heritage of Baa Atoll and manage the increasing human impacts upon the environment are encouraging, providing much to look forward to in 2018 and beyond. However, it is crucial that active research into manta rays and other marine life continues in order to monitor the effects of both tourism and environmental change. Manta rays are an incredibly important economic resource for the Maldives, bringing tens of thousands of people to the country each year to dive and snorkel with them, generating millions of USD for the economy each year. Being able to pinpoint the reasons for any observed threats to the Maldives manta ray population is crucial for the ongoing management and protection of these animals.

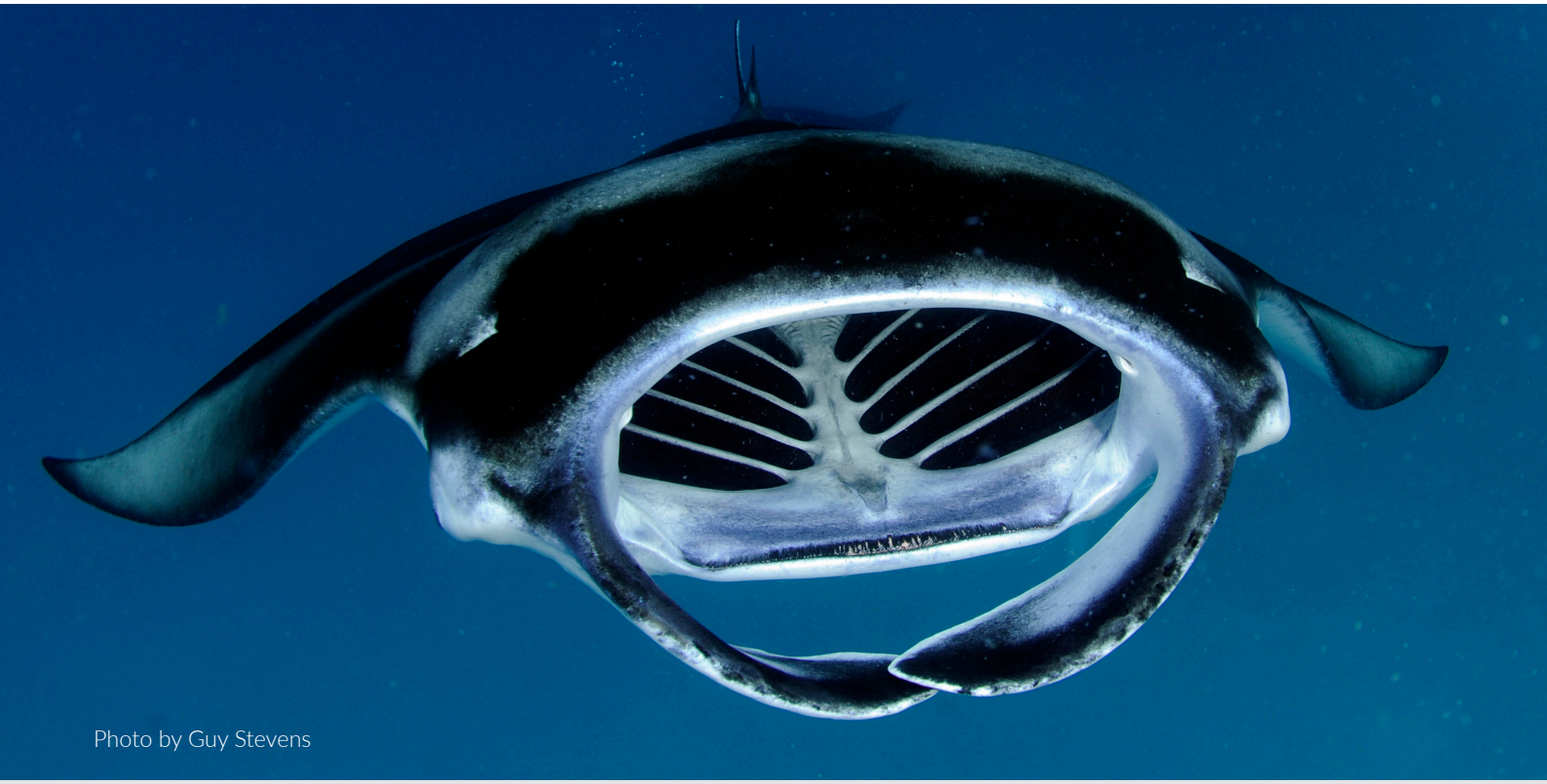

Photo by Guy Stevens

UNDERSTANDING THE MONSOONS

As outlined in previous MMRP reports, understanding the effects of the Maldives Southwest Monsoon is critical to understanding the reasons for the abundance of manta rays and whale sharks that are seen in Baa Atoll during this season.

The monsoons, which dictate the weather in the Maldives, are characterised by their winds, which blow consistently and reverse their direction seasonally. The Maldives Southwest Monsoon, or *Hulhangu*, runs from May-October, while the Northeast Monsoon, or *Iruvai*, runs from December-March each year, with the months of November and April acting as transitional periods of change in between. The Southwest Monsoon typically brings with it much more rain and cloud cover, with reduced visibility and rougher seas.

During the Southwest Monsoon, strong winds create oceanic currents which flow from the southwest towards the northeast. The Maldives' islands and 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 within reach of the sun's life-giving energy, and through photosynthesis, kick-start the food chain, which supports the world's largest known population of reef manta rays.

During a typical Southwest Monsoon, the wind blows consistently and steadily from the southwest, causing the greatest concentrations of the manta's planktonic food on the monsoonal down-current edges of the atolls. Stronger monsoonal winds generate stronger currents, more upwelling and more primary productivity, which in turn generate more of the zooplankton food, therefore attracting higher numbers of these animals into shallow waters. When tidal exchanges bring water from the outside of the atoll in through the channels along the atoll's eastern edges, they become, temporarily, dense plankton funnels. These are the sites at which we are more likely to observe planktivorous megafauna in the greatest concentrations.

STUDY PERIOD & SAMPLING METHODOLOGY

Surveys to look for manta rays were carried out in eastern Baa Atoll between the 15th May and the 26th November 2017 on as many days as possible where conditions allowed (Fig. 1). Full day survey trips were made on 150 days within this 198-day survey period. As per previous years, management measures (see section below) meant that access to the main study site of Hanifaru Bay MPA was more restricted than in the years prior to 2011. Therefore, Hanifaru and a dozen other sites around the eastern border of Baa Atoll were surveyed, as per the protocol implemented during 2011. To ensure comparable results, data was standardised where possible to account for changes in sampling effort spatially and temporally.

On each research trip; location, wind speed, wind direction and other environmental and weather variables were noted alongside manta ray numbers and their prevalent behaviours (feeding, cleaning, cruising, etc.). In-water, individual mantas were documented by photographing the unique spot patterns on their undersides (ventral surface). The whole team were experienced freedivers, allowing them to obtain photo-ID shots whilst ensuring minimum disturbance to the animals. For the purposes of this report, a *sighting* is defined as a confirmed photo-ID of an individual manta ray on a given day.

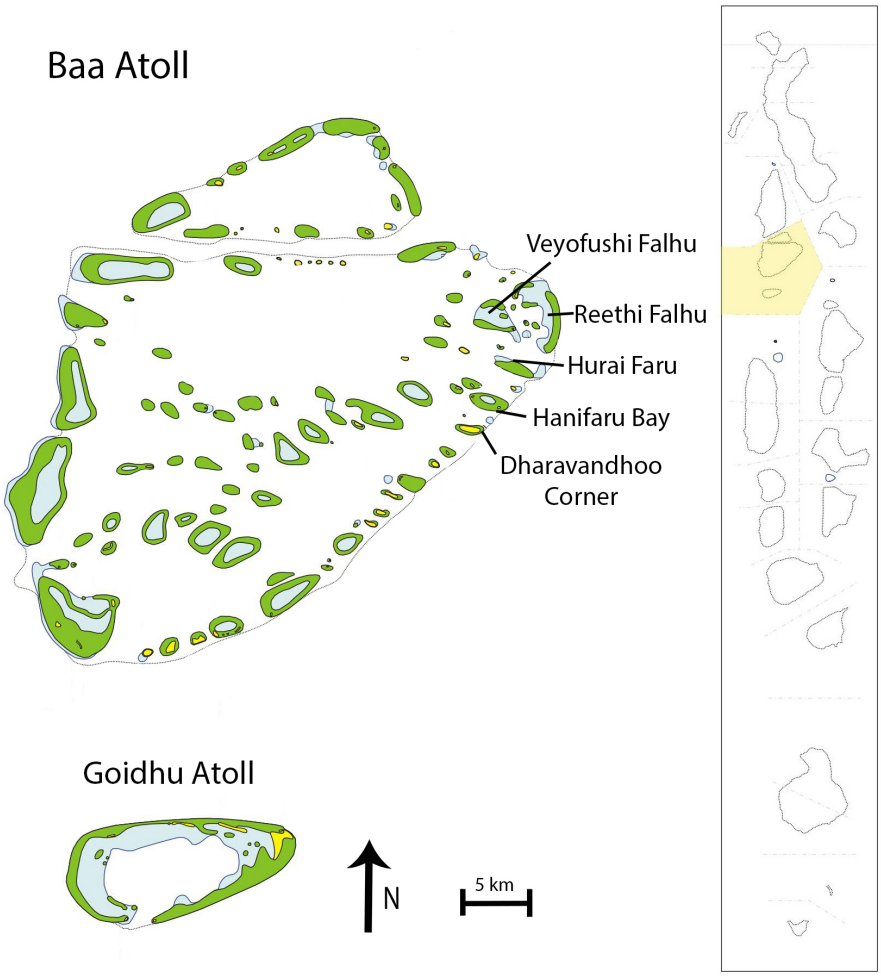

Figure 1: Map of Baa Atoll showing five of the key manta aggregation sites within the atoll, and Baa Atoll (shaded orange) in relation to the rest of the Maldives Archipelago.

MANAGEMENT CHANGES & INITIATIVES

Management initiatives at Hanifaru Bay MPA are continuing to be implemented as per the 2012 government management plan. The main regulations include tourist and boat limits, a ban on SCUBA diving and fishing inside Hanifaru Bay MPA, a schedule for the alternation of entrance days between liveaboard and resort boats, boats' entrance speed limit, and the use of a specific entrance/exit path. Snorkel guides escorting tourists into Hanifaru Bay MPA were also required to sit an exam qualifying them to guide tourists inside the bay. Minimum levels of in-water/dive qualifications and first aid certifications were also required for these guides.

As in 2016, this season has been characterised by the constant presence and patrol of Environmental Protection Agency (EPA) rangers on site, which resulted in a decrease of infractions such as; SCUBA diving inside the bay, disrespect of scheduled alternation day, and fishing inside the bay and throughout the buffer zone. Few illegal activities were observed and the rangers intervened promptly when necessary. Entry tokens have been regularly collected resulting in a minimum estimated revenue of US$ 30,000 for the Biosphere Reserve's Baa Atoll Conservation Fund. We strongly hope that such exemplary conduct will be replicated in 2018.

REEF MANTA RAY SIGHTINGS

BAA ATOLL

The total (n=2,723) and mean daily (n=17) number of reef manta ray sightings throughout Baa Atoll in 2017 decreased substantially from 2016 figures; the lowest number recorded since 2011 (Fig. 2). Monthly breakdown of these sightings, standardised for survey effort, shows a subtle spike in July, and a clear peak in Sept-Oct, followed by a marked decrease in sightings over subsequent months (Fig. 3). A total of 553 different individual reef manta rays were recorded in Baa Atoll during 2017, 12% of the total recorded Maldivian population of 4,445 individuals (Fig. 4). This is the lowest annual number of individuals recorded since the MMRP started collecting consistent data in Baa Atoll a decade earlier.

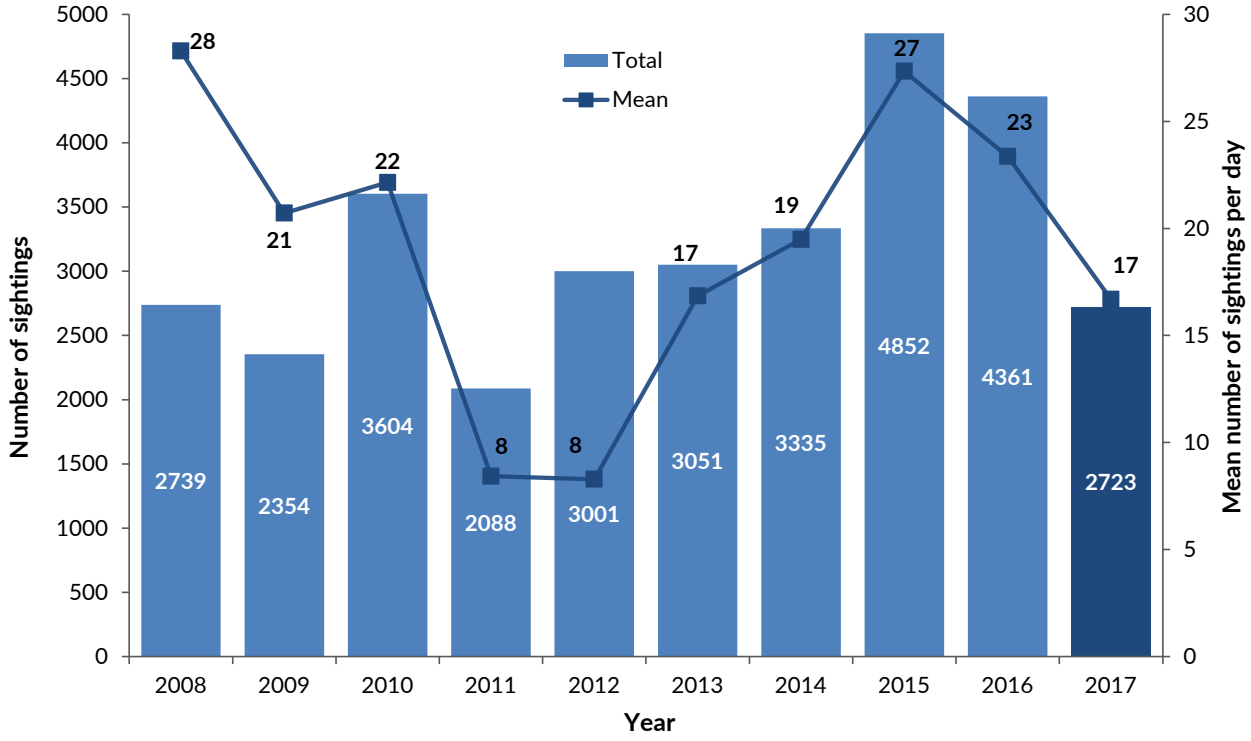

Figure 2: Total annual sightings of reef manta rays (*Mobula alfredi*) in Baa Atoll and the mean number of sightings per survey day (2008-2017).

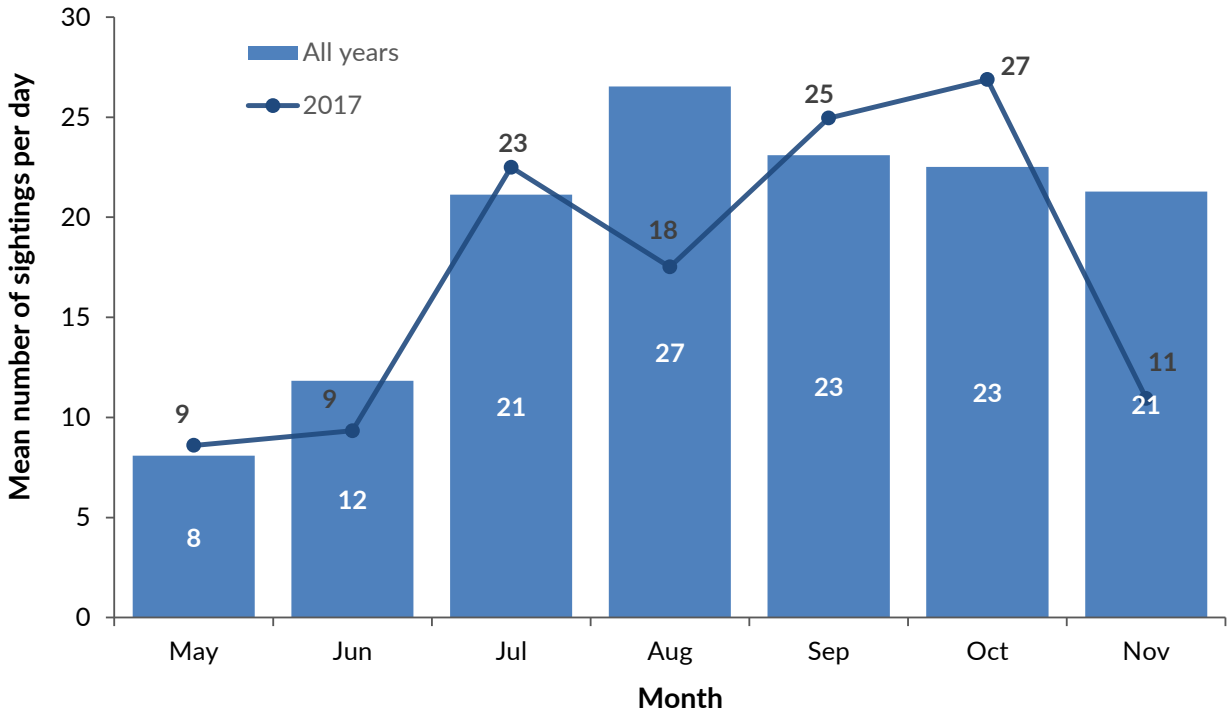

Figure 3: Mean daily number of reef manta rays (*Mobula alfredi*) observed between May and November in Baa Atoll each year (2008-2017).

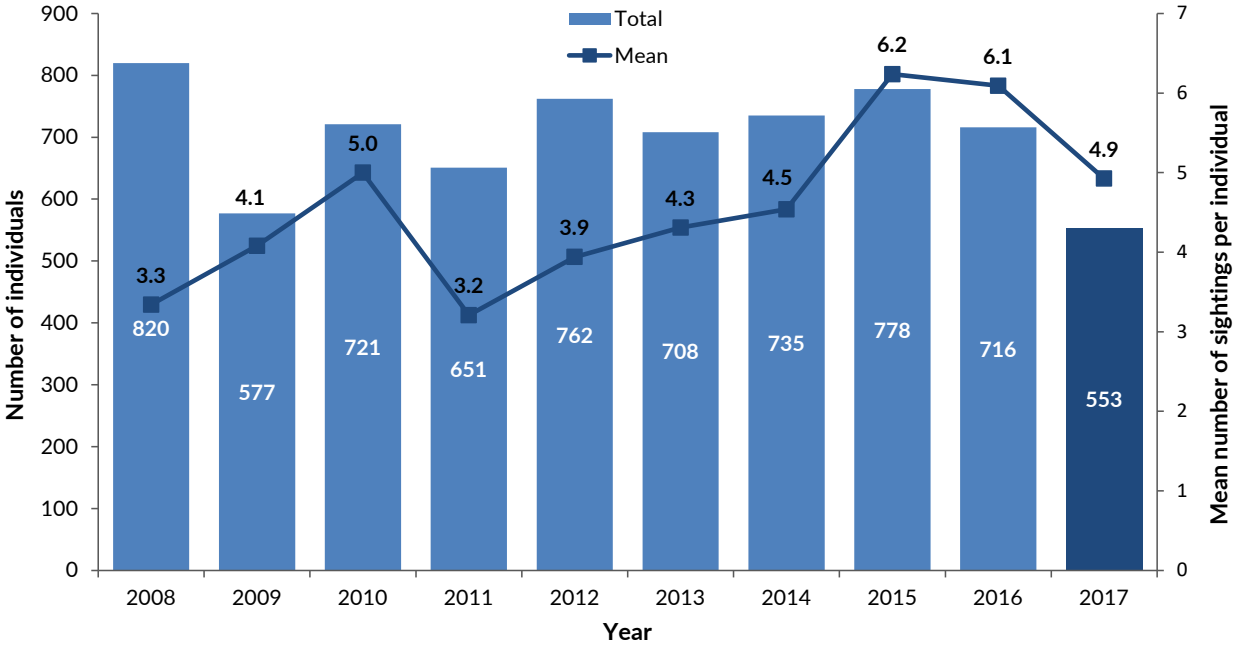

Figure 4: Total annual number of individual reef manta rays (*Mobula alfredi*) sighted in Baa Atoll and the mean number of sightings per individual (2008-2017).

Population demographics of Baa Atoll constitute 54% females (n=1,060) and 46% males (n=909), plus seven individuals for which the sex remains unknown. During the last decade, the total number of individual mantas recorded in Baa Atoll is 1,976, almost half (45%) of the entire recorded Maldives population. Forty four percent (n=867) of these Baa Atoll mantas have also been recorded in 19 of the other atolls throughout the Maldives; from the very northern atoll of Ihavandhippolhu, down to the southernmost atoll of Addu (Fig. 5). This demonstrates the importance of eastern Baa Atoll as a core aggregation area for the Maldives reef manta ray population during the Southwest Monsoon.

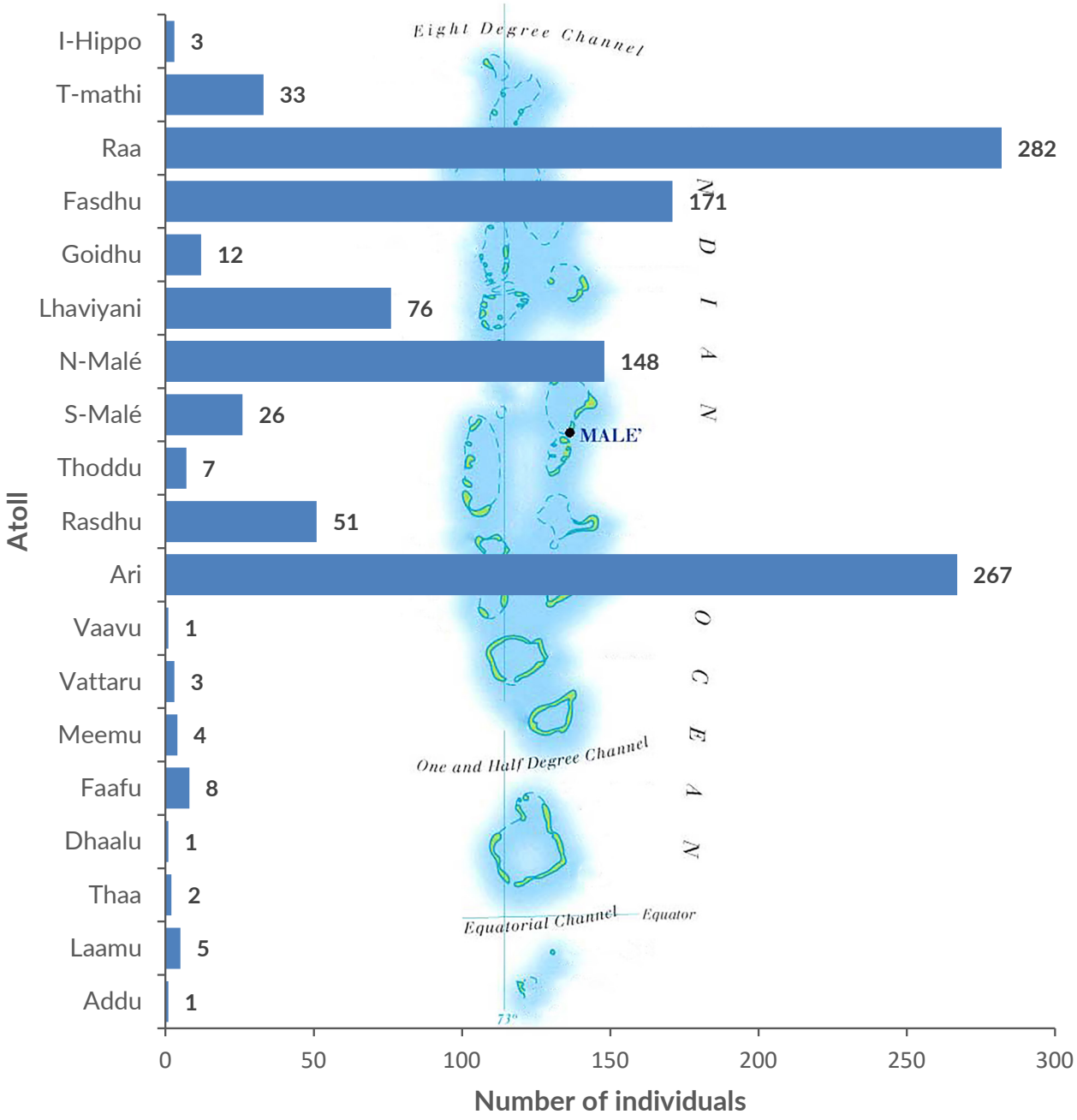

Figure 5: Number of reef manta ray (*Mobula alfredi*) individuals (n=867) from among the Baa Atoll population (n=1,976) which have been recorded in other atolls throughout the Maldives Archipelago. Note: many of these cross-atoll individuals have been observed in more than two atolls.

Throughout the season, each manta was observed on average 4.9 times (Fig. 4), a marked decrease from that recorded in 2016 and 2015 (average 6.1 and 6.2 sightings per manta, respectively), reflecting a more transient population. To account for survey effort, a Residency Index (RI) was calculated for each year based on the ratio between the number of days each individual was sighted and the total number of surveyed days (e.g. an RI of 3% means that, on average, each individual was sighted on 3% of the total surveyed days). The RI for 2017 (3.2%) was slightly lower than that noted in 2016 (3.6%) and 2015 (3.9%), reinforcing the hypothesis of a more transient population of mantas during this time in Baa Atoll, possibly linked to a reduction in the localised abundance of the manta ray's planktonic food source (Fig. 6).

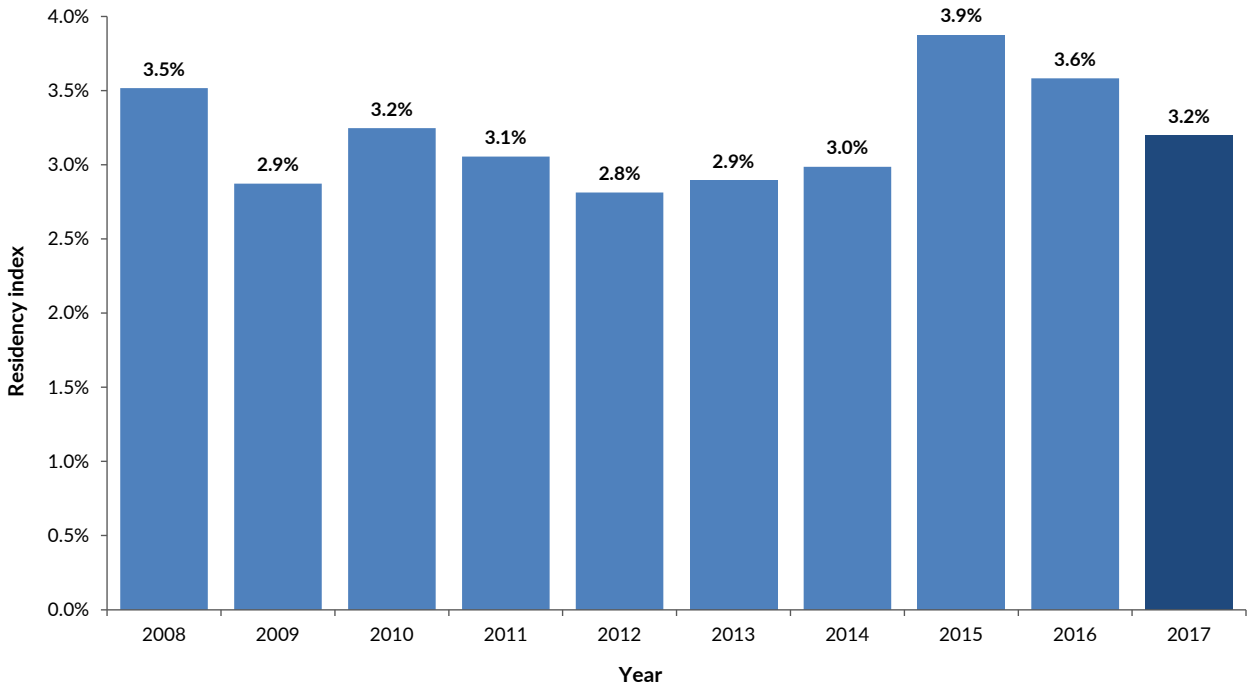

Figure 6: Annual Residency Index (RI) of the reef manta rays (*Mobula alfredi*) in Baa Atoll (2008-2017). RI is calculated as the average of each individuals' residency score (= number of times sighted annually divided by the total number of survey days).

HANIFARU BAY (MARINE PROTECTED AREA)

As observed at the atoll level, sightings of manta rays in Hanifaru Bay MPA in 2017 were much lower than 2016 and 2015 records (Fig. 7). The standardised graph for survey effort reveals that the average number of manta rays sighted per survey day at Hanifaru in 2017 was still relatively high earlier in the season, peaking at 27 during the month of July (Fig. 8). This again suggests that the strong monsoonal currents influenced by characteristically high wind speeds during the month of May, kick-started the food chain and resulted in increased food availability - a key factor influencing the number of manta ray sightings in Hanifaru Bay. It should be highlighted that the 23rd July 2017 saw the greatest number of individuals recorded on a single day throughout the year, with a total of 110 confirmed reef manta rays in Hanifaru Bay alone.

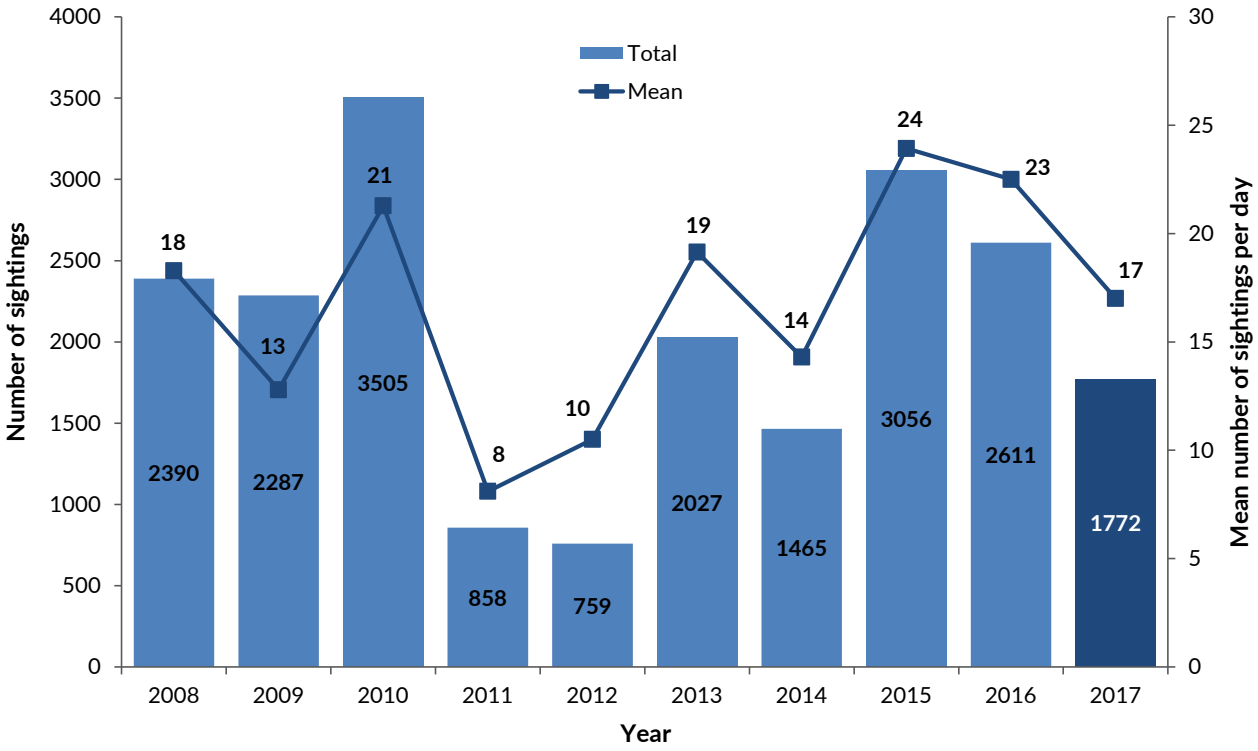

Figure 7: Total annual sightings of reef manta rays (*Mobula alfredi*) in Hanifaru Bay and the mean number of sightings per survey day (2008-2017).

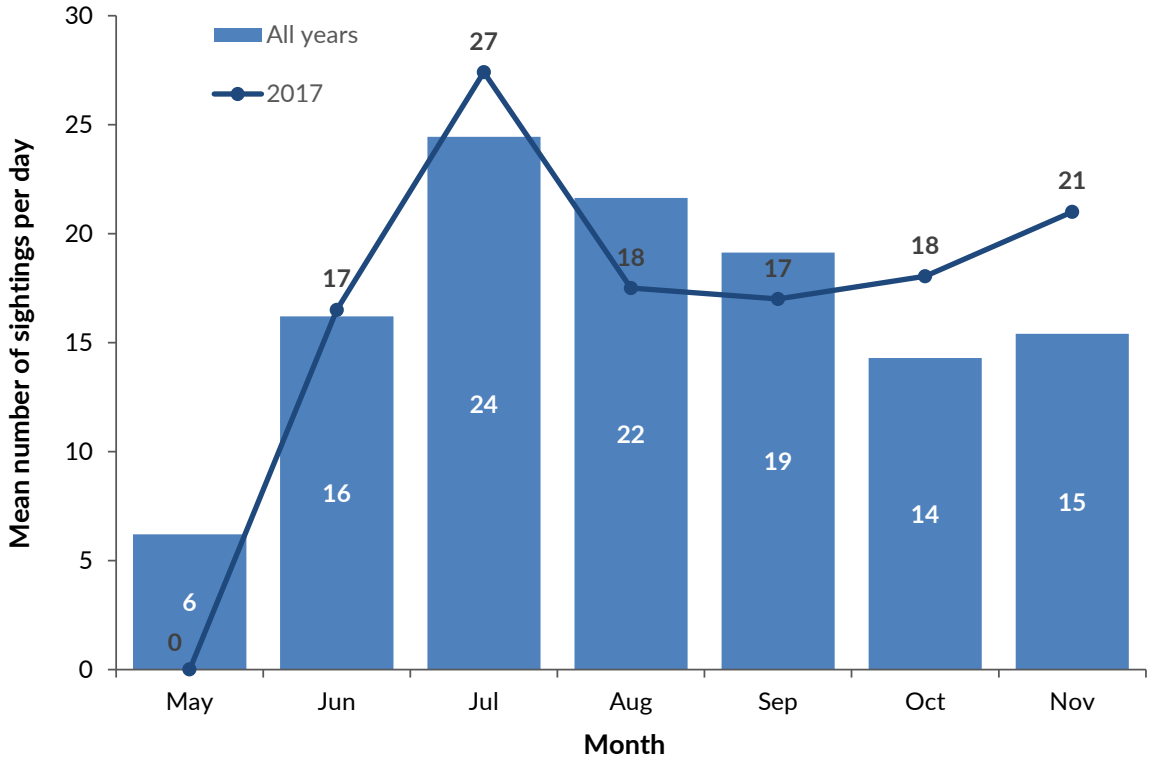

Figure 8: Mean daily number of reef manta rays (*Mobula alfredi*) observed between May and November in Hanifaru Bay each year (2008-2017).

NEW MANTA RAYS

A total of 16 new individual reef manta rays were identified during the survey period in Baa Atoll in 2017. This is a large decline from 2016 records, which saw a total of 58 new individuals added to the database. The proportion of newly sighted individuals recorded between 2008 and 2017, both in Baa Atoll and in Hanifaru Bay, keeps following a downward trend, as more years pass and more data is collected, new mantas become less frequent (Figs. 9-10). The slight increase in the proportion of newly sighted individuals in Baa Atoll observed in 2011 and 2012 was due to the addition of several new survey sites established in the region when daily access to Hanifaru Bay became limited. After the fifth year of regular surveying of those new sites, the percentage of newly identified individuals has now dropped to 3%, suggesting that most of the Baa Atoll manta population has been recorded and identified.

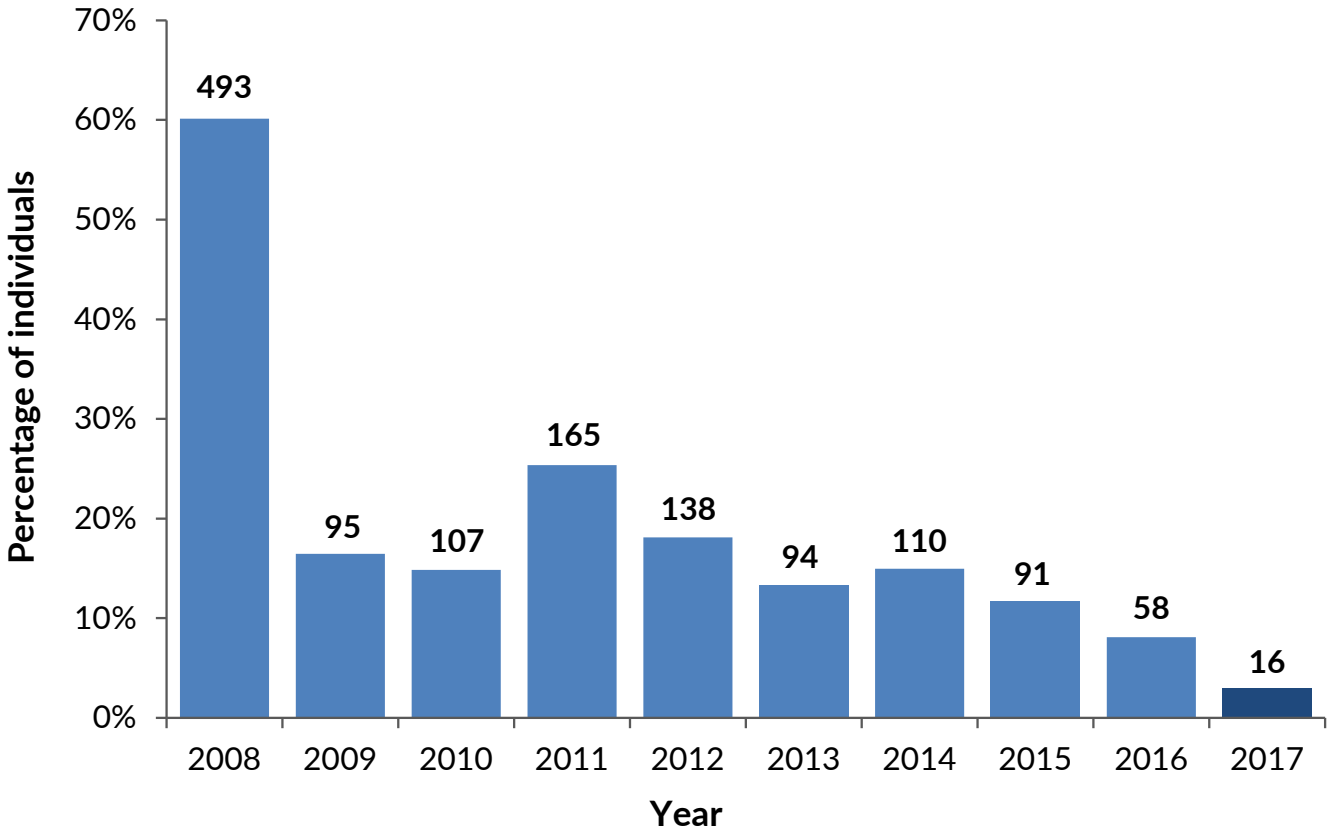

Figure 9: Proportion of the total reef manta rays (*Mobula alfredi*) sighted annually in Baa Atoll which were newly sighted individuals (2008-2017). Actual numbers above bars.

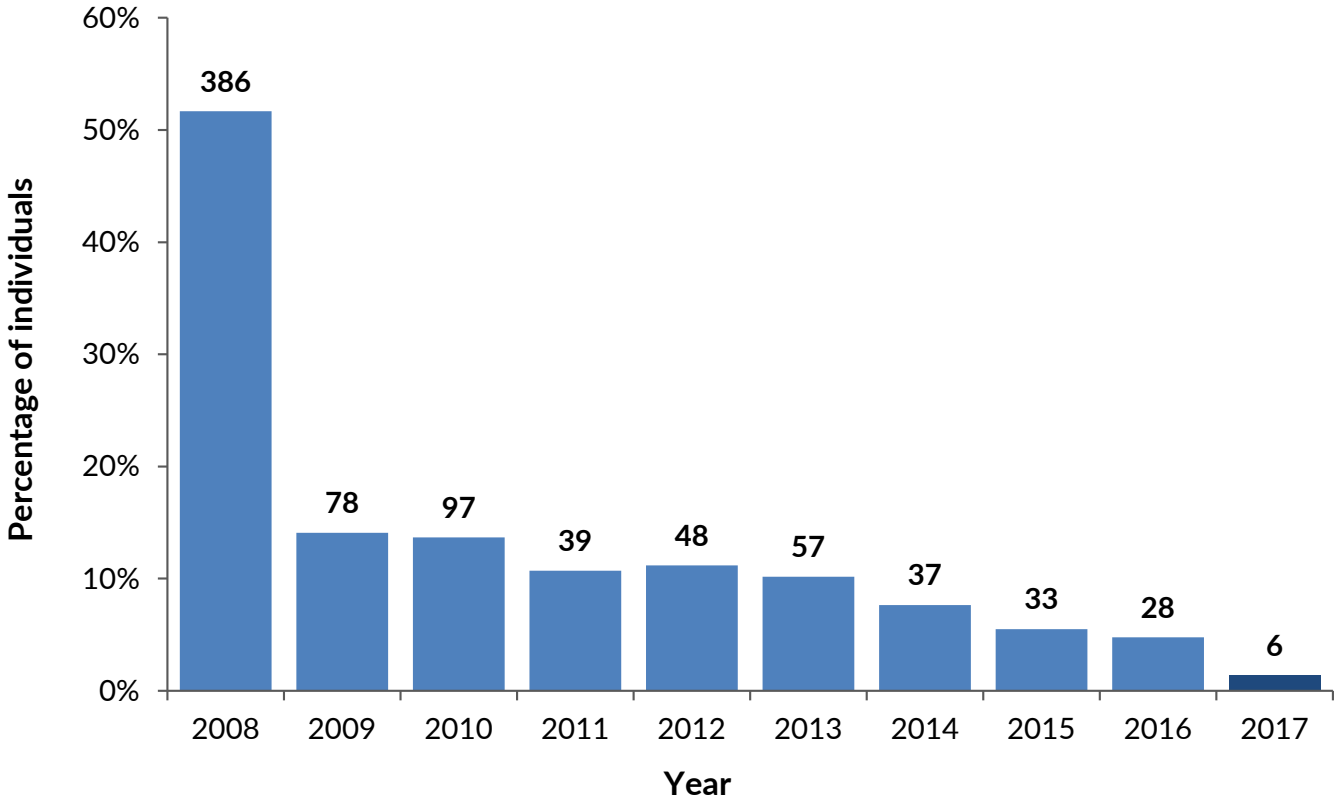

Figure 10: Proportion of the total reef manta rays (*Mobula alfredi*) sighted annually in Hanifaru Bay which were newly sighted individuals (2008-2017). Actual numbers above bars.

COURTSHIP & MATING BEHAVIOUR

Throughout their range, manta courtship and mating activity often occurs at particular times of the year. In the Maldives reproductive activity is much more frequently observed during the months of October and November, and again in March and April, when the country's two monsoons transition from one to the other. Throughout the day manta rays spend a significant amount of their time visiting cleaning stations, with female mantas often spending several hours each day cruising around a favoured cleaning site. During the mating season these sites become a focal point for manta courtship behaviour, with mature males aggregating at these sites in search of sexually receptive females.

In contrast to 2016, when a high incidence of reproductive activity was recorded at cleaning stations during the second half of the Southwest Monsoon, sighting records of manta activity at well-known cleaning stations in Baa Atoll during 2017 were minimal (Fig. 11). Similar reports of reduced activity at cleaning stations in the latter half of the season in 2017 were also documented throughout the Maldives at sites which are monitored on a regular basis by the MMRP.

Reproductive synchronicity is a strategy employed by many elasmobranch species. It is thought that mantas synchronise their mating to coincide with favourable years when food is abundant, providing females with the necessary energy reserves to sustain the development of the pup to birth. Plankton concentrations in 2016 correlated with high levels of reproductive activity that year. The weakened monsoon winds observed in 2017 are most likely responsible for a lack of primary production, and therefore a lack of food for manta rays, resulting in the observed reduction in courtship and reproductive behaviours during the second half of 2017.

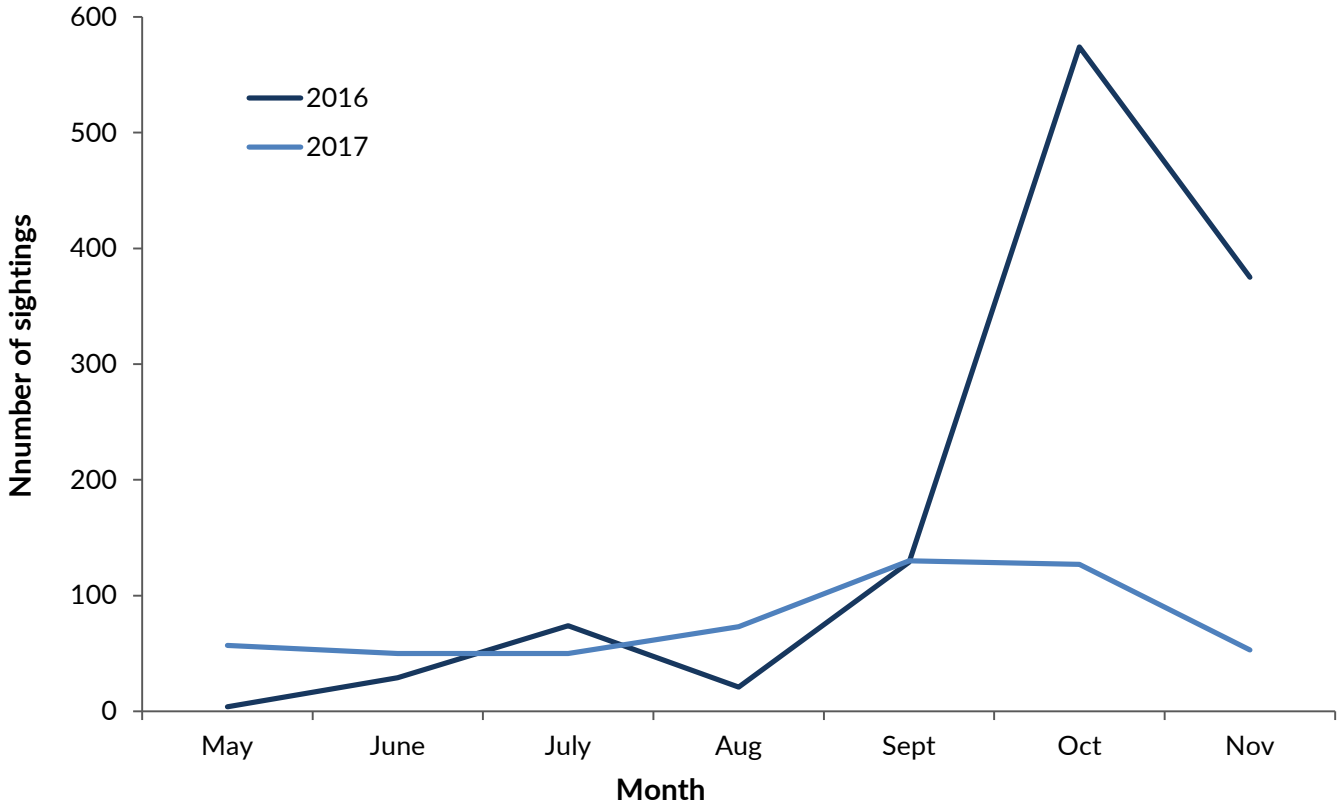

Figure 11: Number of reef manta ray (*Mobula alfredi*) sightings each month during the Southwest Monsoon (May-Nov) at cleaning stations in Baa Atoll (2016-2017).

REPRODUCTIVE FECUNDITY

For the fourth consecutive year the MMRP have recorded pregnancies among the Maldives manta ray population. A total of 100 different females were observed pregnant throughout the Maldives in 2017. The number of pregnancies recorded in Baa Atoll alone, during 2017, was the greatest number ever recorded during a single season, with a total of 55 pregnancies and a further 28 females recorded with fresh reproductive wounds. Furthermore, the proportion of pregnancies recorded among Hanifaru Bay's core population of mature female reef manta rays in 2017 is considerably greater than that recorded in previous years. In 2017, 60% of Hanifaru Bay's core adult female population were sighted, and 53% of these individuals were visibly pregnant (Fig. 12).

With a gestation period of one year, manta pregnancies become easily visible at about six months into the pregnancy. Of the 55 females observed to be pregnant in Baa Atoll in 2017, 76% (n=42) were already in the later stages of gestation (3rd- 4th trimester) when first observed in 2017. It is therefore hypothesised here that the large number of recorded pregnancies in 2017 are a result of the high level of reproductive activity documented in 2016, when the manta's food supply was likely to be in greater abundance. Similar reports of a higher occurrence of pregnancies amongst the manta ray population in 2017 were documented throughout the Maldives at sites which are also monitored on a regular basis by the MMRP.

The high incidence of pregnancies reported in 2017 should not however detract from the overall very slow reproductive rate for this species, which, on average, sees only 17% of the mature females reproducing annually. With such low fecundity it becomes vital for the survival of these animals to minimise anthropogenic and natural impacts. Effective measures include the establishment of functional MPAs and the adherence to sustainable tourism activities at key manta ray mating, cleaning and feeding sites.

The Manta Trust released a guide for the Best Practice Code of Conduct (CoC) in 2014, aimed at minimising tourism activities' impact on the natural behaviour of manta rays in the Maldives. The Manta Trust's CoC has now been implemented by various operators in the country, and in 2017 the Trust launched a new '*How to Swim with Manta Rays*' toolkit; including an updated 10-Step Guide for snorkelling and SCUBA diving interactions. The toolkit includes a briefing video which aims to deliver a pertinent message on sustainable tourism - how to get the most out of your experience with the manta rays while ensuring that interactions do not disturb or negatively impact the animals (www.swimwithmantas.org). In 2017, The Maldives became the first country to see these interaction guidelines and briefing video being introduced by marine biologists and tour operators, making it a forerunner in initiating protocols for protecting manta rays.

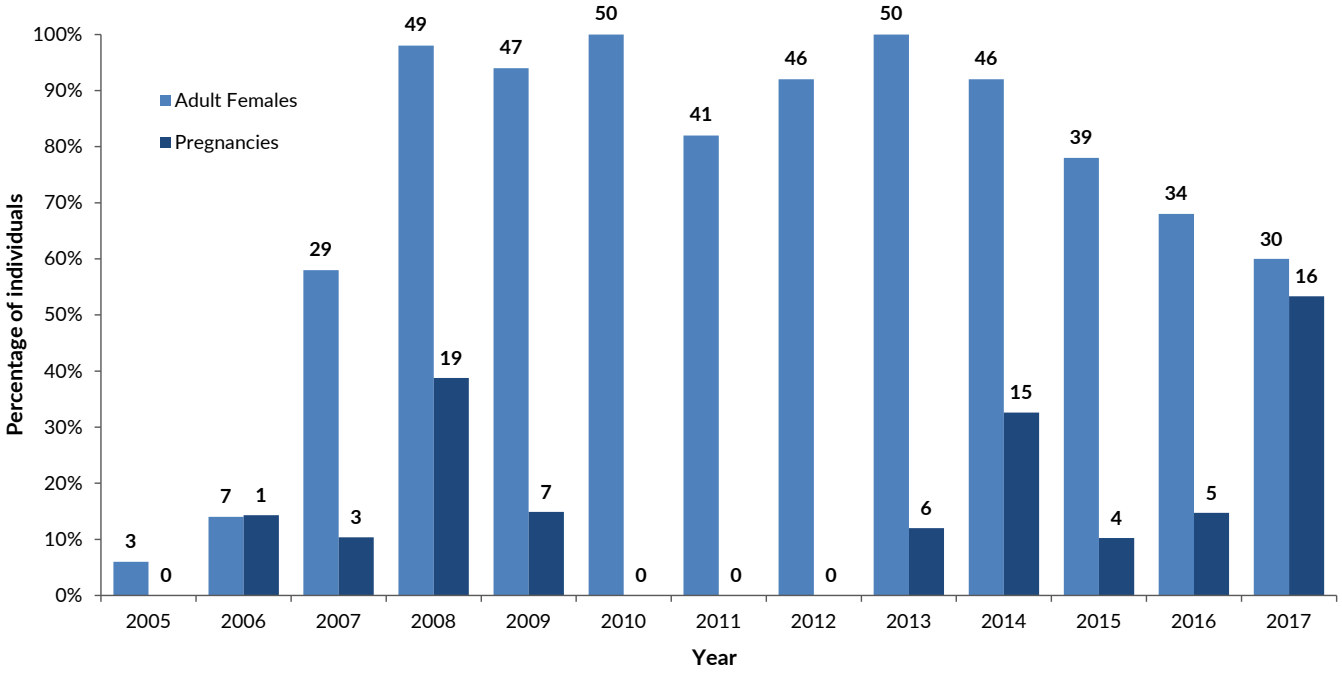

Figure 12: Percentage of Hanifaru Bay's core adult female reef manta ray (*Mobula alfredi*) population (n=50) sighted annually, and the percentage of those females which were recorded pregnant in the same year. Actual numbers above bars.

Photo by Guy Stevens

WHALE SHARK SIGHTINGS

Whale sharks reflect similar lifestyle characteristics to manta rays. Both species are large, migratory, filter-feeding, elasmobranchs. Additionally, the two species share common habitat and are often sighted together along shallow reefs in the Maldives. Since 2008, the total number of whale sharks recorded in Baa Atoll had followed a downward trend. However, 2017 saw the return of these charismatic megafauna - with a total of 30 encounters of at least 19 different individuals in Baa Atoll. This marks the highest number of reported sightings in Baa Atoll since 2009 (Fig. 13). Eleven individuals were new sharks to the Maldives Whale Shark Research Programme's database, and of the remaining eight, five had been sighted in Baa Atoll previously (WS-014, WS-178, WS-187, WS-206, and WS-222), while three whale sharks, although previously known to the MWSRP, were recorded in Baa Atoll for the first time in 2017.

In addition to the increase in whale shark sightings atoll wide, there was also an increase in the number of sightings inside Hanifaru Bay. There were five separate whale shark encounters inside Hanifaru Bay of four different individuals. Of these, three sharks (WS-014, WS-178, and WS-222) had previously been recorded inside the bay. As with previous years, the highest concentration of sightings were around the Hanifaru Beyru and Dharavandhoo Corner areas, although whale sharks were observed along much of the east side of Baa in 2017. Hanifaru Bay has traditionally been known as an important aggregation site for whale sharks, and it is hoped that 2018 will see a continued increase in visitations to this location.

INTRA-ANNUAL SIGHTING VARIATIONS

Sighting frequencies for both reef manta rays and whale sharks peak in the months of July through October, with 24% and 35% of the total yearly manta and whale shark sightings respectively occurring in the month of August alone (Fig. 14). These findings suggest a higher presence of manta rays during the second half of the Southwest Monsoon compared to the first, asymmetrically distributed around August's peak. When accounting for the differential survey effort the trend becomes more evident (Fig. 3). In 2017, whale shark sightings matched the trend in manta sightings, with July and October representing peaks in total whale shark and manta ray encounter reports.

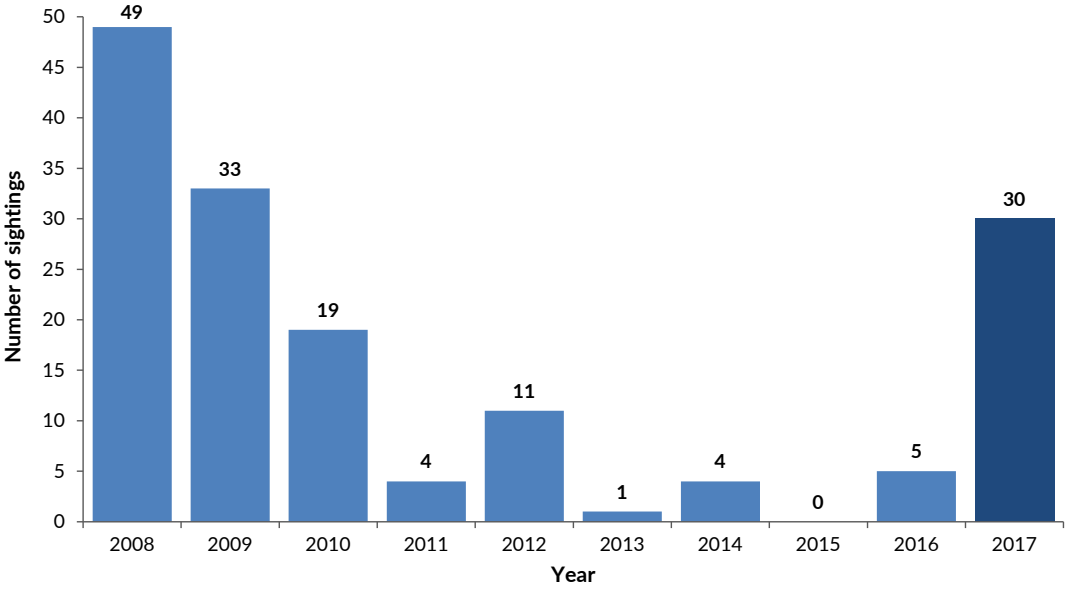

Figure 13: Total annual sightings of whale sharks (*Rhincodon typus*) in Baa Atoll (2008-2017).

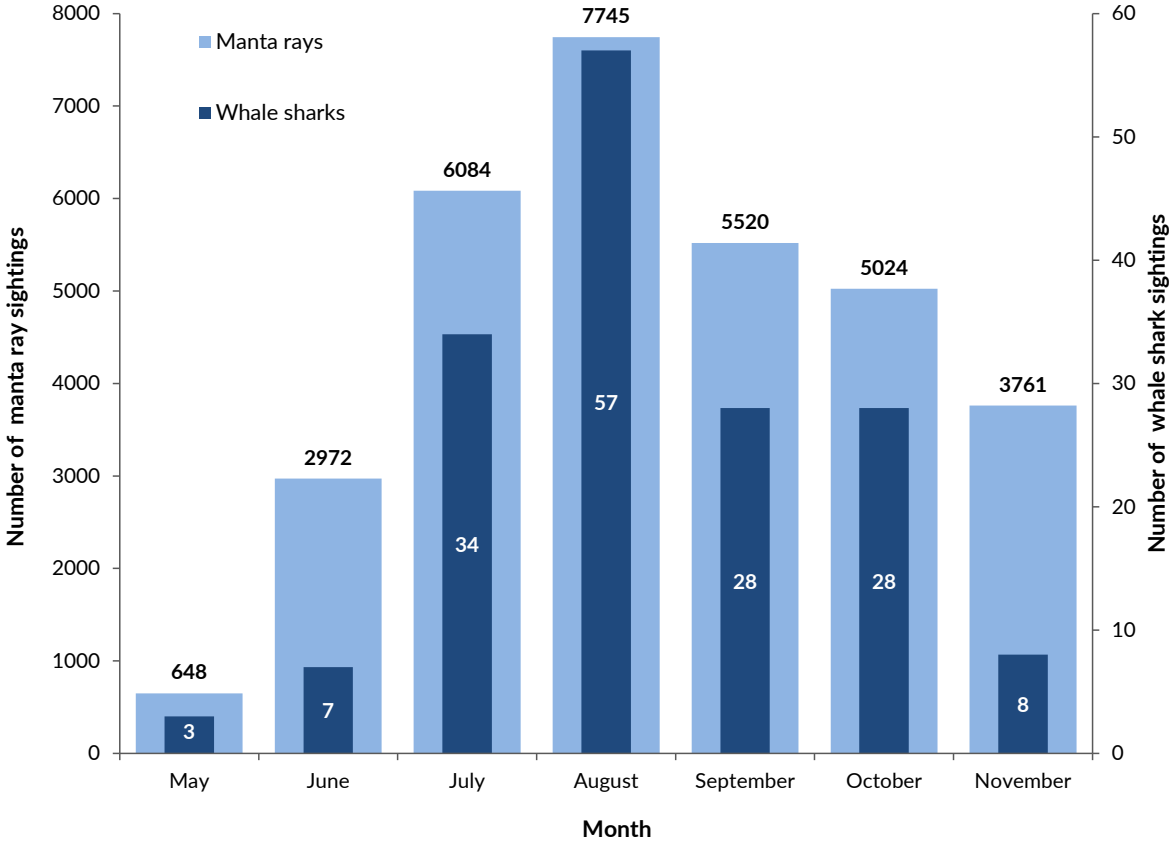

Figure 14: Total monthly sightings of reef manta rays (*Mobula alfredi*) and whale sharks (*Rhincodon typus*) in Baa Atoll (2008-2017).

As a continuation of the investigation initiated in 2011 to look into the possible links between manta ray sightings and the strength of the Southwest Monsoon, the MMRP continued to look at the correlations between weather patterns and megafauna abundance in 2017. The average wind speed observed in 2017 was 17 km/h, lower than 2016 (19 km/h). As in preceding years, the start of the Southwest Monsoon in 2017 was characterised by typically high wind speeds in May (21 km/h) (Fig. 15). Following this initial spike, there was a reduction recorded in wind speed between the end of May and July (with an average decrease of 6 km/h). It is hypothesised that this reduction in wind speed had a knock-on effect on manta sightings, resulting in a slump in primary productivity, and therefore food availability for the rays. If correct, this hypothesis would provide an explanation for the shallow peak and immediate drop in manta sightings witnessed in the first half of the 2017 Southwest Monsoon (Fig. 3).

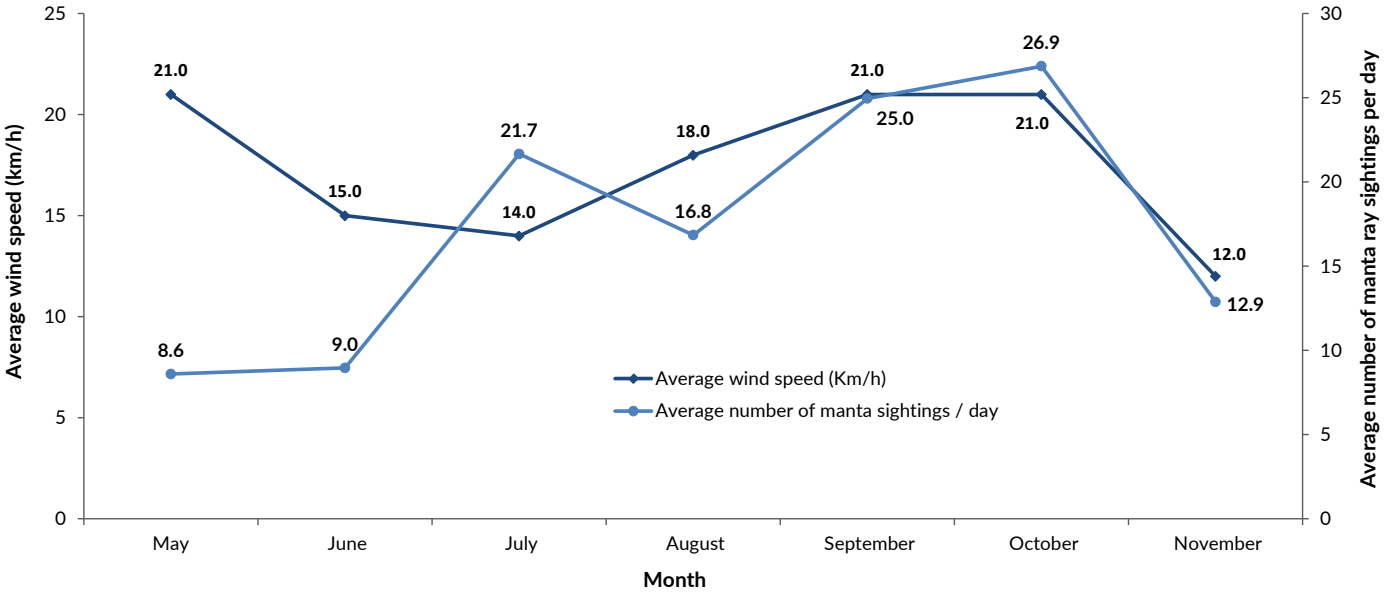

Figure 15: Mean monthly wind speed (km/h) and mean number of reef manta rays (*Mobula alfredi*) sightings per survey day in Baa Atoll (2008-2017).

Unlike in most previous years, seasonal manta sightings in 2017 were highest much later in the Southwest Monsoon, with a marked increase during the month of October (n=645 manta sightings), with a sudden decrease in wind speed and manta sightings during November at the end of the season (Fig. 15). October's high sightings number coincides with stronger monsoonal winds in September and October (Fig. 15). Across all years, sightings of reef manta rays in Baa Atoll typically peak at the heart of the Southwest Monsoon (July-October) (Fig. 14), and overall 2017 saw a similar average wind speed and a correspondingly comparable number of daily manta ray sightings as that observed on average in 2009, 2013 and 2014 (Figs. 16-17).

While there appears to be a link between yearly average wind speed and average manta sightings per day (R^2=0.1235) (Fig. 17), these results have not been statistically tested and more in-depth investigation into the climatic effects on manta rays' population dynamics is necessary. The overall seasonal trend is that of a gradually decreasing wind speed between the beginning and the end of the Southwest Monsoon. The strong monsoonal winds generally experienced at the

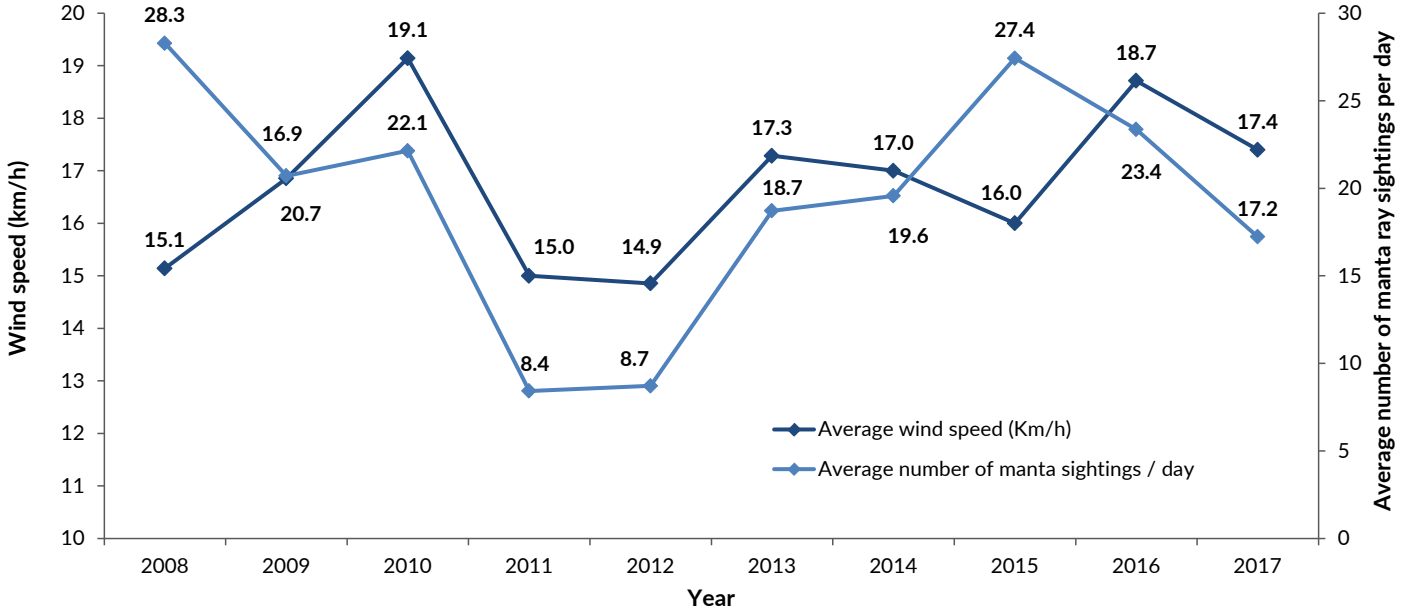

Figure 16: Mean annual wind speed (km/h) and mean number of reef manta rays (*Mobula alfredi*) sightings per survey day in Baa Atoll (2008-2017).

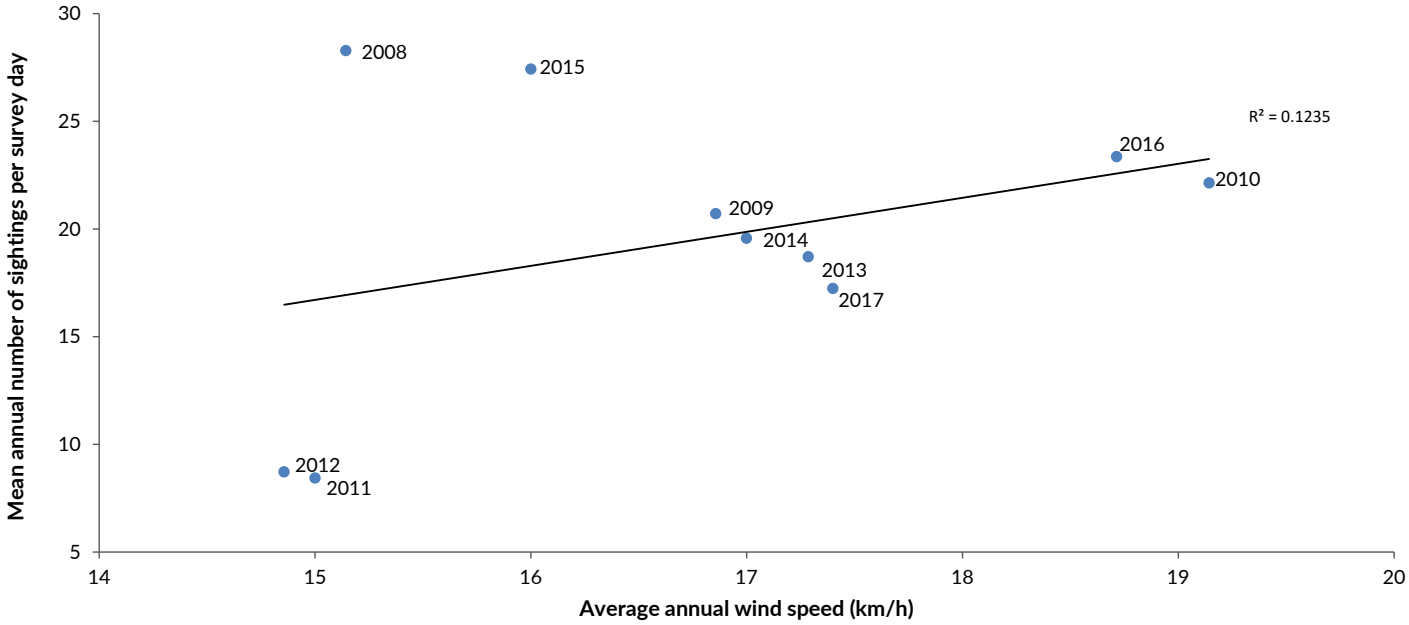

Figure 17: Mean annual wind speed (km/h) and mean number of reef manta ray (*Mobula alfredi*) sightings per survey day in Baa Atoll (2008-2017).

beginning of the season, and the second incline mid-season, are likely to kick start the plankton production through upwelling, possibly explaining July's, and Sept/October's, peak in manta ray sightings. Without the wind, and therefore the strong monsoonal currents required to sustain primary productivity, food availability for these planktivorous species is reduced.

The fluctuation of monsoonal strength, food availability, manta ray sightings, and fecundity are likely to be part of a natural cycle of variable weather patterns which occur within the Maldives over time. These fluctuations are also likely to be connected to, and amplified by, larger climatic phenomenon, such as the Indian Ocean Dipole (IOD) and the El-Niño Southern Oscillation (ENSO); both of which 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. Regardless of cause, and leaving aside the ecological ramifications, these observations should be considered seriously because of the negative economic consequences they can have. Not only will these trends affect manta ray tourism directly, 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 and consistency of the monsoons.

TOURISM ACTIVITIES

Continuing the mandate put in place in 2011, liveaboard vessels and resorts had access to Hanifaru Bay MPA only every other day on an alternating schedule. The ban on SCUBA diving in Hanifaru, which came into effect starting January 2012, has had a significant impact on the number of safari dive boats observed, despite the good manta ray sightings inside the MPA in the past five years (Fig. 18). Many liveaboard vessels cater strictly to SCUBA divers and have a diving intensive schedule. As a result, these boats will not take the time to travel to Hanifaru MPA if they cannot dive, while those vessels that clearly market the benefits of snorkelling with manta rays at this site have continued to run successful trips. For many liveaboard operators however, the lack of diving, coupled with the alternate day restrictions (which make it very hard for liveaboard to schedule a

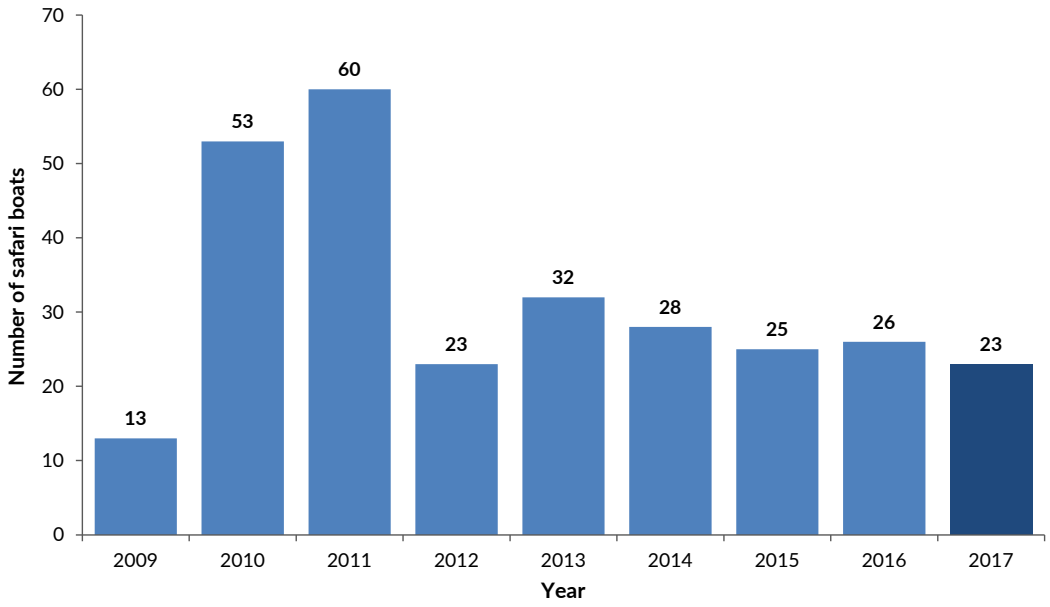

Figure 18: Total number of different safari boats (liveaboards) observed in Baa Atoll (June-November 2009-2017).

practical itinerary), and the increased cost of fuel, have all contributed to a significant reduction in the number of liveaboard vessels which are prepared to travel up to Baa Atoll since 2011. Overall however, the number of visiting vessels has remained consistent for the last six years, while the number of resort, guest house and local Maldivian visitations have all significantly increased.

In 2016, Hanifaru Beyru cleaning station, located on the North East Corner of Hanifaru MPA, attracted a large amount of manta activity, which in turn attracted a large number of liveaboards to the area towards the end of the monsoon. In 2017, manta sightings at the two well-known cleaning blocks, Hanifaru Beyru and Dharavandhoo Corner, were negligible. This, coupled with the reduction in manta ray sightings at snorkelling hotspots in 2017, resulted in many liveaboards altering their schedules to accommodate this lack of activity, moving instead to neighbouring atolls. The resorts have however continued to visit the MPA as in previous years, and in 2017 tourist activity at this world-famous destination was also boosted through newly opened guest houses and local dive centres.

As has been highlighted throughout this report, 2017 saw a considerable decline in total manta ray sightings in comparison to some previous years. Not only were sightings fewer, but also less predictable in terms of timing and location. Consequentially, when mantas were encountered, disorder was noted on several occasions with actions of misconduct by divers, snorkellers, and boats (sometimes resulting in dangerous incidents in which serious injuries to tourists and guides were narrowly avoided). A number of infractions by newcomers and boat handlers unaccustomed to the area and unfamiliar with the rules and regulations governing the zonation of this protected area were noted. It was however apparent that, when present, the EPA rangers did attend to these matters and provided guidance to those unaware of the MPA protocols. In light of the incidents witnessed during 2017, and in preparation for the 2018 season, it is advised that more control be asserted over the MPA usage by tour guides and tour operators. It is also suggested that more EPA rangers be stationed on site at Hanifaru Bay to attend to both in-water activities (by enforcing appropriate manta-human interaction guidelines), and to patrol boat traffic, boat handling, and mooring at the site.


Photo by Guy Stevens

In an effort to educate and facilitate more manageable and sustainable tourism in Baa Atoll in 2018, the MMRP team have also organised a series of informative workshops. These workshops will aim to provide details on the mantas of the Maldives, the history of the MMRP, the research we conduct and why, the best codes of conduct for human-manta interactions, and the rules and regulations currently in place to protect these charismatic creatures and their natural resources. The workshops are also intended to act as the ideal platform for open discussion between resident marine biologists, resorts and dive centres staff, as well as EPA rangers. It is hoped these discussions will focus on how to better manage the current designated protected areas in the future, ensuring 2018 is a successful year in terms of protecting the megafauna and regulating sustainable tourism in the area.

It is of paramount importance that there be improved monitoring of diver and snorkeller related activities at all manta sites (and other protected areas) in Baa, and that efforts are continued to ensure sustainable tourism is practiced to avoid negative impacts on the manta ray population visiting these seasonal foraging and breeding grounds.

Photo by Simon Hilbourne

BAA ATOLL MARINE EDUCATION PROGRAMME

The Maldives relies heavily on a healthy, resilient and biodiverse marine environment. However, to date the Maldives' marine environment is poorly protected and increasingly vulnerable to anthropogenic and climate-change associated threats. Environmental education is an essential tool in effective marine environmental protection. Incorporating environmental education at schools is a key way to develop environmentally aware individuals that can mitigate environmental issues and assist sustainable development. The MMRP started a local education programme in Baa Atoll in 2015, with the aim of increasing marine education and awareness of conservation strategies in the Maldives. Following the aims and objectives proposed through this initiative, in 2016 the MMRP successfully executed the Manta Trust's very first complete marine education programme for school students in the Maldives. The programme adhered to a holistic approach to marine biology themes and conservation issues, inspiring a passion for the marine environment among the young Maldivian population.

Having initiated and successfully completed the programme at Kamadhoo School in 2016, the Baa Atoll Marine Education Programme (BAMEP) expanded to include Baa Kendhoo School in 2017, and achieved great support and success. BAMEP 2017 was a 50-hour course designed to teach secondary school children about the local and global marine environment, threats to the marine environment, and conservation efforts; it focused on providing field experience to deepen theory learning. The marine biology course has motivated participants to build a closer connection with their surrounding marine environment and has proven to help students improve their swimming and snorkelling abilities. Six core modules were conducted from June to November 2017 for the 28 participating 13-16-year-old students from Baa Kendhoo School. The modules included: tropical marine ecosystems, coral reef ecosystems, turtles and reef fish, biosphere reserve, waste, and climate change. Each module comprised a class-room session, a field trip, and a homework assignment to reinforce theory learning and encourage innovative environmental thinking.

In 2017, the course also had the added benefit of receiving the expert educational advice from a University of York Marine Environmental Management Master of Science (MSc) student who conducted her internship with the MMRP and assisted with the implementation of the education programme at Baa Kendhoo School. This MSc student conducted a research study assessing the effectiveness of the programme, with the aim of evaluating if the participating school students' awareness or knowledge about the importance of, and threats to, the sea in the Maldives increased as a result of the programme. This will help the MMRP to assess whether it would be useful to expand the programme

to schools nationwide in following years as part of its community outreach initiative (see below: MSc thesis: The Effectiveness of a Marine Environmental Education Programme in the Maldives).

Educational activities also took place in North Malé, Lhaviyani, and Laamu Atolls where the MMRP project representatives have directed a series of classroom, and in-field training sessions based on the components drawn from the Manta Trusts' core marine biology curriculum. Furthermore, as in previous years, MMRP members have actively participated at numerous environmental initiatives, and organised events in 2017. At each festival, the MMRP team hosted a Manta Trust stall where information about manta rays and the importance of conserving and protecting these iconic marine animals was shared by engaging children with insightful games and presentations.

We anticipate 2018 will be another exciting year for the Baa Atoll Marine Education Programme, which is establishing itself as a nationally recognised extra-curricular activity. In 2018, work will continue to focus on developing a course textbook to provide detailed insight into the different modules addressed in class. The aim is to have this ready for launching at the start of the new school term in 2019 (hopefully in collaboration with other NGOs and the Maldives' government). We believe the involvement and appreciation of young Maldivians for the marine environment is crucial for long-term conservation and sustainable management of the unique marine resources found in the Maldives. We look forward to working in collaboration with the Maldives' governmental bodies and other environmental organisations in order to further improve and expand this educational programme.

The Effectiveness of a **Marine Environmental Education Programme** in the Maldives

Florence Barraud - Marine Environmental Management (MSc), University of York, UK

Pre-programme and post-programme surveys were completed by each participating student from Kendhoo School in Baa Atoll, and used to assess students' marine environmental engagement, knowledge and awareness, and the effectiveness of the programme.

Students' marine environmental engagement, awareness and knowledge increased after the programme. Tests revealed a significant increase in knowledge from pre- to post-programme. Mean participant knowledge increased for 83% of environmental topics pre- to post-programme, with the greatest increases in topics including overfishing and ocean acidification, which were covered in depth in the programme (Fig. 19). The programme was highly effective, achieving a mean score of 21 out of 25 for effectiveness, and increased participant's in-water confidence, pro-environmental behaviour, and recreational and academic interest in the sea (Fig. 20). Considerable gender disparity was identified, with females scoring lower than males in all categories. Females marine engagement scores (representing how much time they spent and wanted to spend in the sea) were consistently significantly lower than males (Fig. 21). Religious principles or cultural norms could have impacted females' lower marine engagement scores. Further research is necessary to examine categorical relationships and address gender disparities in marine participation.

The results show that increased marine environmental education incorporating in-water fieldtrips could increase marine participation and awareness, and improve environmental management in the Maldives. The research identified that, due to strong gender disparity, the programme should be expanded in the future to bring female participants into the marine environment. Overall, this study concluded that the education programme would be an effective tool to conduct in more schools in the Maldives.

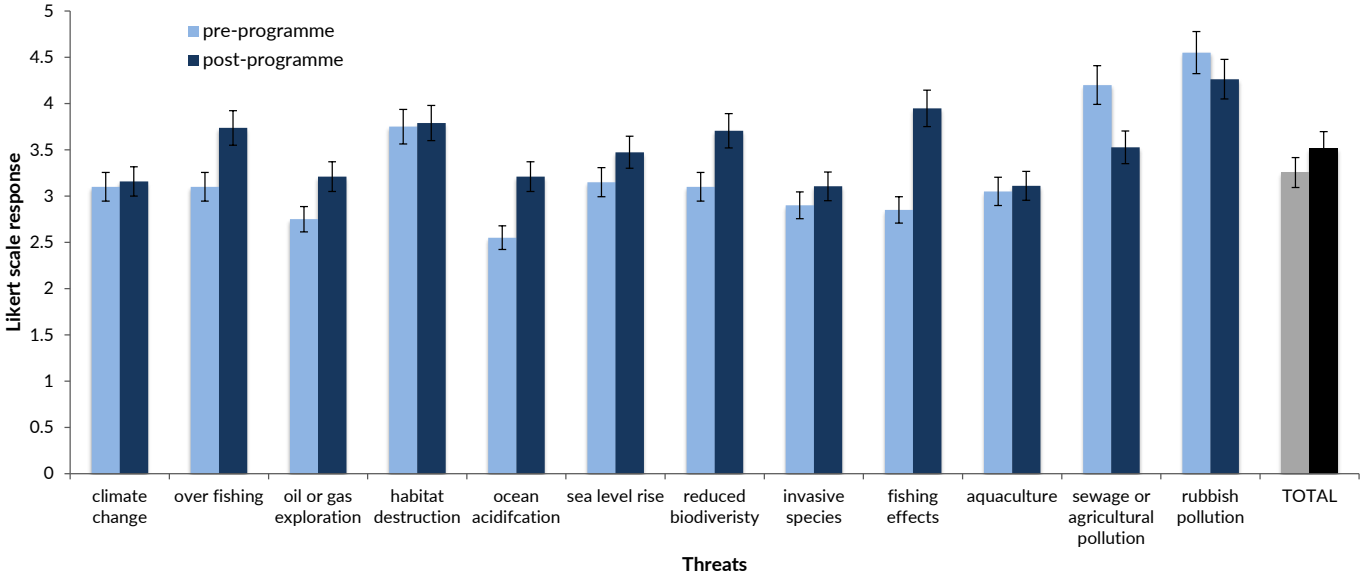

Figure 19: Mean pre- and post-programme self-perceived knowledge for each of the threats listed on the x-axis. Bars show the standard error (95% confidence intervals).

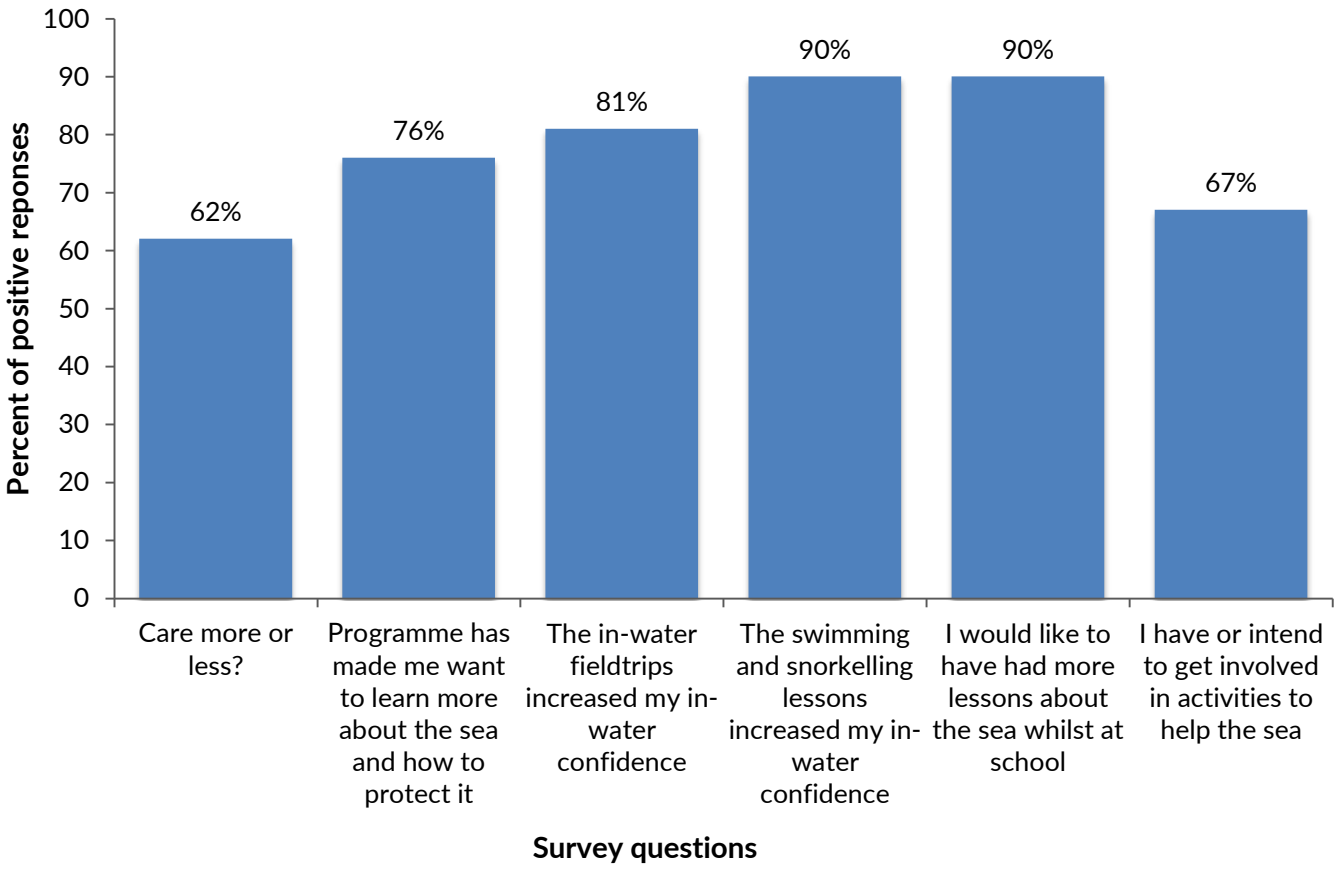

Figure 20: Proportion of students who selected 'quite a lot' or 'very much so' in response to the questions that are displayed as statements below. The percentage of students who selected these responses out of the total number of students (n=21) is shown at the end of each bar.

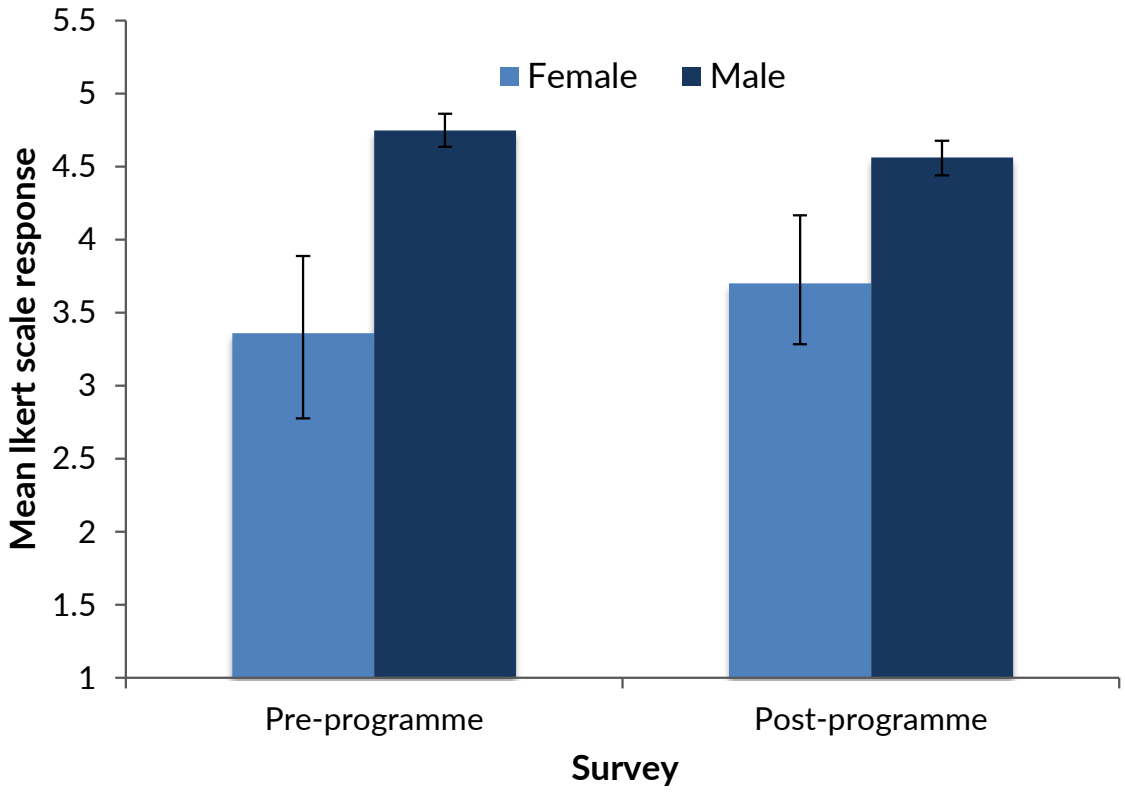

Figure 21: Mean male and female scores in the category 'engagement.' A significant difference exists between male and female engagement both pre ($p<0.001$, $a=0.01$, $W=0$) and post-programme ($p<0.008$, $a=0.001$, $W=13.5$). Error bars represent bootstrapped 95% confidence intervals.

CONSERVATION & MANAGEMENT

The declaration, at the end of June 2011, that Baa Atoll was to become a UNESCO World Biosphere Reserve, remains an important milestone for the Maldives' manta rays, with great implications for their ongoing protection, especially given the designation of Hanifaru Bay MPA as a core zone of the Reserve. However, effective management of these newly protected areas is crucial, and we look forward to further commitment in the near future by the Maldives' Environmental Protection Agency and the Baa Atoll Biosphere Reserve Office to manage this site and the tourism that takes place within.

A World Biosphere Reserve strives to better understand the human impact upon the reserve, and help safeguard natural ecosystems for the future. Long-term, consistent data collection is crucial to grasp the influence and impact of tourism and development on this population of animals, and to gain a broader understanding of manta rays worldwide. Continued access to manta ray sightings is integral to our ongoing research activities. Any interrupted and inconsistent data collection is much harder to accurately analyse or extrapolate trends from, resulting in more inconclusive results. Therefore, the ongoing research of manta rays in Baa Atoll and throughout the Maldives must remain a priority if Baa Atoll's UNESCO World Biosphere Reserve is to be successful.

This report was produced by:

MALDIVIAN MANTA RAY PROJECT (MMRP)

The MMRP is highly regarded within the scientific community. It is the largest and one of the longest running manta ray research programmes in the world. We would welcome the opportunity to continue to work with the Maldives government for the long-term management and conservation of these species in Maldivian waters. The opportunity we have to learn about manta rays in the Maldives is unique, and our findings have important implications for manta ray conservation on a global scale.

The MMRP and the Manta Trust are happy to share with the Maldives government data collected as part of this study.

ACKNOWLEDGEMENTS

The MMRP and the Manta Trust are extremely grateful to all our partners who enable our team to carry out our fieldwork throughout the year. We are also extremely thankful to all those members of the public, dive staff, marine biologists and other manta enthusiasts who submit images of manta rays from around the country to be added to our national database. Without this continued support, our work would not be possible.

This report was compiled on behalf of the MMRP and the Manta Trust by:

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