Manta TRUST

Maldivian Manta Ray Project

2016 Baa Atoll Report

A report for the Ministries of Environment and Fisheries, Maldives; EPA and MRC

Maldivian Manta Ray Project

Executive Summary

This report presents data collected by the Maldivian Manta Ray Project (MMRP) on Baa Atoll's reef manta ray (*Manta alfredi*) population primarily between May and December 2016.

Baa Atoll has an international reputation as one of the most reliable places in the world to see 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, a non-profit, independent conservation and research focused organisation; and the founding project of the UK charity, The Manta Trust.

Key findings of the MMRP in 2016 include a total of 4,361 sightings of 716 individual manta rays, recorded throughout the year (4,304 sightings of 705 individuals if only the Southwest Monsoon period is considered). This equates to a 10% decrease in sightings compared to the previous year but still a notable increase in sightings pre-2015 records (31%, 43%, 45%, 100% increase in sightings reported from 2014, 2013, 2012 and 2011 respectively) and is (by 757 sightings) the second highest number of encounters recorded by the MMRP in Baa Atoll during a single season. These numbers reflect pre-2011 monsoon conditions and are likely related to environmental factors; such as monsoonal strength and wind speed. It is also worth noting however that the increased number of sightings has also been influenced by a greater level of effort in research by both the MMRP and supporting resorts in recent years as well as increased access allowed in Hanifaru Bay Marine Protected Area (MPA). However, when standardised for effort and compared to previous years, 2016 sightings were still consistent with those recorded between 2007 and 2010, prior to the decreased sightings period of 2011 - 2014.

Throughout the six months of surveying, each of the 705 different individuals were observed on average 6.09 times, a slight decrease from that recorded in 2015 (average 6.24 sightings per manta) but still higher

A reef manta rays feeds in the shallow lagoon water's of Baa Atoll, Maldives

than that noted for 2014 and all preceding years. The proportion of rays seen on more than one occasion match 2015 records at 79%, a figure which is also in line with pre-2011 data records. Together, these findings reinforce the hypothesis that environmental factors linked to the monsoon strength regulate the prevalence of reef manta ray sightings in Baa Atoll annually.

It is interesting to note that, unlike in previous years, sightings peaked much later in the season with a marked increase during the month of September, with 1,109 encounters (reflecting a similar trend to that observed in 2009), and a sudden decrease during the following months. September's exceptional sightings number was preceded by stronger monsoonal winds in June, July and August (measuring an average of 23 km/h, 21 km/h, and 21 km/h respectively), that were likely the cause of increased productivity and thus food availability for the manta rays. The August sightings peaks observed in pre-2011 years no longer appear to be the norm, as hypothesized in the past, and may have been linked to particularly intense monsoonal activities during the previous months in those years. Overall, sightings of reef manta rays in Baa Atoll peak at the heart of the Southwest Monsoon (July-September).

It is worth noting that during the 2016 Southwest Monsoon a large number of reef manta ray encounters were recorded at the cleaning station of Hanifaru Beyru located on the outer edge of the atoll (frequently over 30 individuals recorded within a few surveying hours). The location of this site, coupled with in-water observations, suggest that feeding may have

Spectacular mass feeding events like this occur about a dozen times a year inside Hanifaru Bay in the Maldives, where as many as 250 individual mantas feed together inside this small natural cul-de-sac of reef.

occurred at greater depths outside Hanifaru in the channel between Aidhoo & Hanifaru Beyru and between Dharavandhoo & Hanifaru Islands. A similar reasoning was used to explain the high number of manta ray encounters recorded by the MMRP team from Dharavandhoo Corner cleaning station in 2014, when sightings reports mirrored these findings now recorded from Hanifaru Beyru in 2016. Furthermore, surface feeding near this cleaning station was observed on multiple occasions during the season, providing additional support for this theory. Recent findings from other Manta Trust project locations globally also suggest that reef manta rays may spend long hours feeding in large aggregations at depths ranging between 100-200 meters where the deep scattering layer often occurs. Oceanographic studies coupled with tagging would allow testing for these hypotheses in the Maldives.

Reproductive activity in Baa Atoll during 2016 was comparable to that observed in 2015, with only 16 pregnancies recorded during the year, and 17 noted in 2015. It should be highlighted that this is a discernible decrease compared to some previous years, with as many as 37 pregnancies reported in 2014 for example. However, when taking into consideration the level of courtship activity and incidence of fresh reproductive wounds, this was much more prevalent in 2016 than in 2015 and predating seasons – 43 individuals were recorded with fresh reproductive wounds in 2016 compared to 11 in 2015 and one individual in 2014.

Observations for possible correlations between environmental variables (most notably wind speed) and manta ray abundance were continued in 2016 as they appear to have a strong influence on the numbers of manta rays seen in the atoll during the Southwest Monsoon. In 2016 the highest wind speeds were recorded between June-August, while the highest number of manta sightings was recorded during (July), and directly after this windy period (September-October). Although the direct mechanisms which control reef manta ray sightings frequency in Baa Atoll are not clear, large scale fluctuations in the regional climate and weather patterns are still thought to be the ultimate factors, influencing productivity levels and thus food availability for the manta rays.

Further research on the social behaviour of manta rays was undertaken in 2016 and a follow-up study focussed on evaluating best practises for sustainably interacting with mantas. Advancing this, the results support a set of guidelines detailing the code of conduct for human and manta ray tourism interactions. The Baa Atoll Marine Education Programme was also extended and expanded in 2016.

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 2017 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 annually. Being able to pinpoint the reasons for any observed trends in, or threats to, the Maldivian manta ray population is crucial for the ongoing management and protection of these animals.

Understanding the Southwest Monsoon

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, stronger winds and rougher seas.

During the Southwest Monsoon the strong winds in turn create oceanic currents which flow from the southwest towards the northeast. The Maldivian islands and atolls, rising some 2,000 meters 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 suns life giving energy and through photosynthesis kick start the food chain, first with phytoplankton, then with zooplankton which predates upon the phytoplankton. Zooplankton is the prey of manta rays (and whale sharks) and as strong lunar currents flow into the shallows of the atolls through the channels, the concentrated zooplankton is so abundant that the Maldivian waters support 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 mantas 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 and these are the sites at which we are more likely to observe planktivorous megafauna in the greatest concentrations.

A feeding manta ray is unperturbed by the torrential rain that pummels the sea surface as monsoon winds whip up waves above.

Study Period and Sampling

Surveys to look for manta rays were carried out in Baa Atoll between the 21st May and the 30th November 2016 on as many days as possible where conditions allowed. Full day survey trips were made on 170 days within this 194 day survey period. As per previous years, management measures (see section below) meant that access to the main study site of Hanifaru MPA was more restricted than in the years prior to 2011. Therefore, both Hanifaru Bay and other sites around the eastern border of Baa Atoll were surveyed, as per the protocol implemented during 2011. To account for changes in sampling effort at key sites, data from all years was standardised where possible to give comparable results.

On each research trip location, wind speed, wind direction and other environmental weather variables were noted alongside manta ray numbers and prevalent behaviours. In-water, individual mantas were documented by photographing the unique spot patterns on their undersides (ventral surface). The whole team were experienced free divers, using this advanced snorkelling technique to allow them to take photo-ID shots ensuring minimum disturbance to the animals. For the purposes of this report a sighting is defined as a confirmed photo identification of an individual manta ray on a given day.

Management Changes and Initiatives

Management initiatives at Hanifaru 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 inside Hanifaru Bay, a fishing ban inside the 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 path. Snorkel guides escorting tourists into Hanifaru 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 2015, this season has been characterised by the constant presence and patrol of EPA Rangers on site which resulted in a decrease of infractions such as SCUBA diving inside the bay, disrespectfulness of scheduled alternation day and illegal fishing inside the bay and throughout the buffer zone. Few illegal activities were observed and rangers have 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 2017.

Manta Ray Sightings

Baa Atoll

Sightings throughout Baa Atoll in 2016 decreased slightly from 2015 figures, totalling at 4,361; but still ahead of all pre-2015 season records by over 700 sightings (Fig. 1). Monthly breakdown of these sightings, standardised for survey effort, shows a clear peak in September and a marked decrease over the following months (Fig. 2).

A total of 716 different individual reef manta rays were recorded in Baa Atoll during 2016 (Fig. 3) (705 when accounting only for the southwest monsoon); 17% of the total recorded Maldivian population of 4,261 individuals. In the last eight years the total number of different individual mantas which have been recorded in Baa Atoll is 1,940, or 46% of the total recorded Maldives population.

Figure 1: Total annual sightings of reef manta rays (*Manta alfredi*) in Baa Atoll (2008-2016).

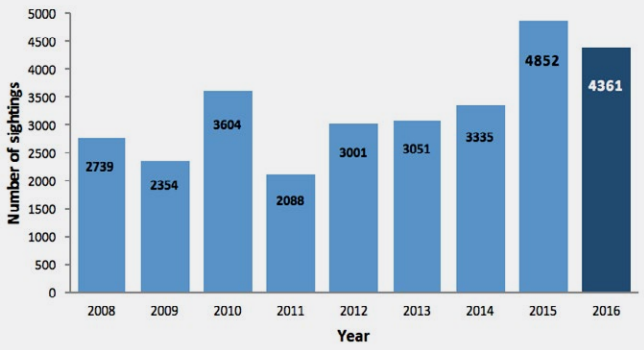


Figure 2: Mean number of reef manta ray (*Manta alfredi*) sightings per day each month in Baa Atoll (2008-2016).

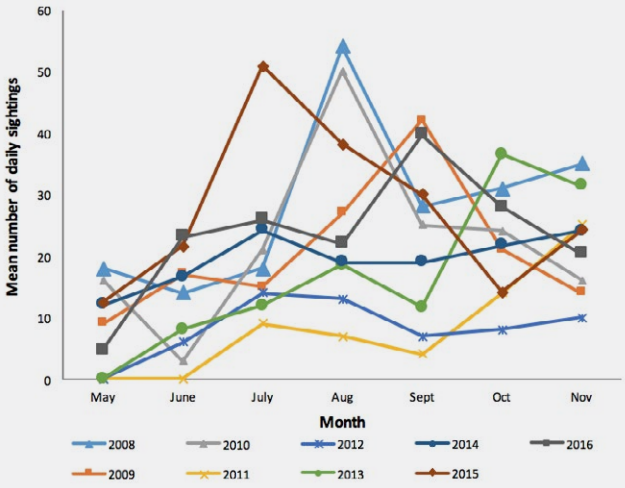
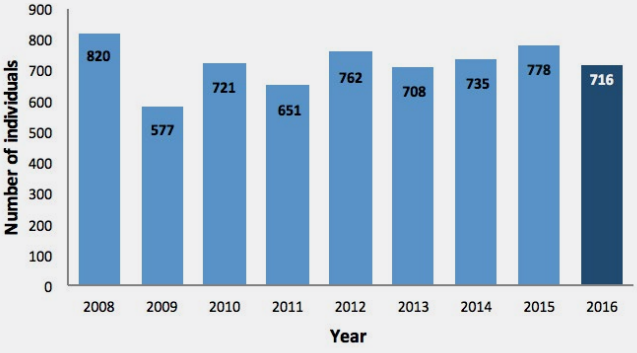


Figure 3: Total annual number of individual reef manta rays (*Manta alfredi*) sighted in Baa Atoll (2008-2016).



Throughout the season each manta was observed on average 6.09 times (Fig. 4), a slight decrease from 2015 (average 6.24 sightings per individual), but an increase from pre-2015 records (average of 5.00 sightings per individual or less). The proportion of rays seen on more than one occasion in 2016 was comparable to 2015

records and notably greater than that recorded prior to 2015 (Fig. 5). To account for survey effort an average 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 of 2016 was only slightly lower than that noted in 2015, but still much higher than the preceding survey years, suggesting an abundance of planktonic food for the manta rays locally throughout the Southwest Monsoon (Fig. 6).

Figure 4: Mean number of sightings per individual reef manta ray (*Manta alfredi*) in Baa Atoll (2008-2016).

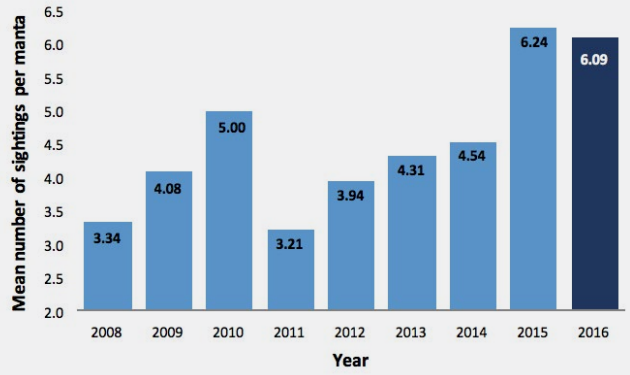


Figure 5: Percentage of individual reef manta rays (*Manta alfredi*) sighted on multiple occasions per season in Baa Atoll (2008-2016).

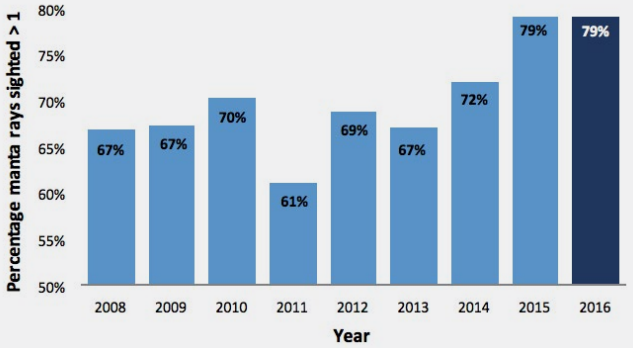
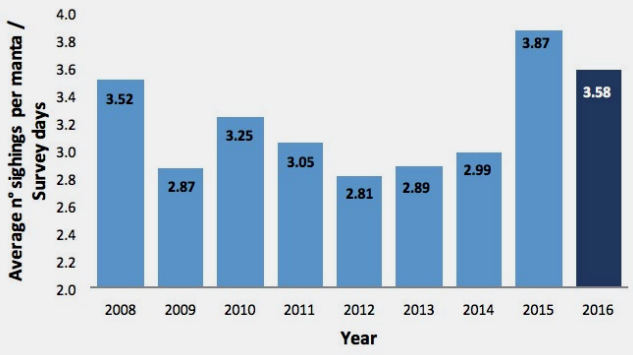


Figure 6: Average Residency Index (RI) of reef manta rays (*Manta alfredi*) in Baa Atoll (2008-2016). RI is calculated as the average of each individuals' residency score (number of days sighted over the total number of surveyed days).



Hanifaru Bay (MPA)

Sightings of mantas rays at Hanifaru Bay MPA in 2016 saw a slight decrease compared to 2015 records which could also be linked to food availability and more activity on the cleaning station located outside the primary feeding grounds (Fig. 7). The standardised graph for survey effort reveals that the number of manta rays sighted per day in 2016 is still relatively high, peaking at 56 in September (Fig. 8). This again suggests that consistent food availability (mainly during the second half of the season) is a key factor in influencing number of manta ray sightings in Hanifaru Bay. It should be highlighted that on the 27th of September 2016, a total of 243 different individuals were recorded in Hanifaru Bay. This has set a new record for the total number of mantas encountered in a single day. The next highest reported sightings count was recorded over eight years ago on the 25th of August 2008 with a total of 240 mantas confirmed.

Figure 7: Total yearly sightings of reef manta rays (*Manta alfredi*) at Hanifaru Marine Protected Area (2008-2016).

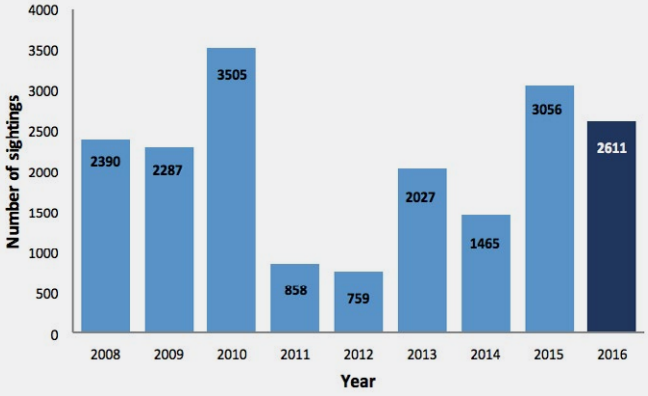
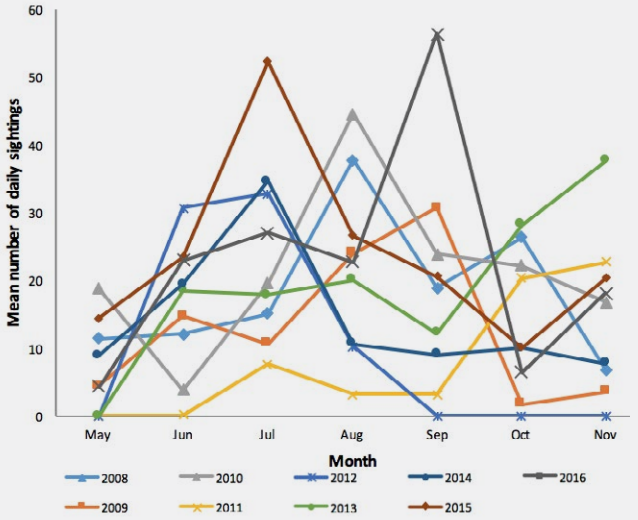


Figure 8: Mean daily number of reef manta rays (*Manta alfredi*) observed between May and December each year (2008-2016).



New Manta Rays

Fifty-eight new individual manta rays were identified during the survey period in Baa Atoll in 2016 (55 during the Southwest Monsoon). The proportion of newly sighted individuals recorded between 2007 and 2016, both in Baa Atoll and more specifically in Hanifaru Bay, keeps following a downward trend, as more years pass and more data is collected, new mantas become less frequent (Fig. 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 became limited. After the fifth year of regular surveying of those new sites the percentage of newly identified individuals has now dropped to 8%, suggesting that most of the Baa Atoll manta ray population has been recorded and identified.

Figure 9: Proportion of the total yearly sightings of reef manta rays (*Manta alfredi*) in Baa Atoll which were newly sighted individuals (2008-2016).

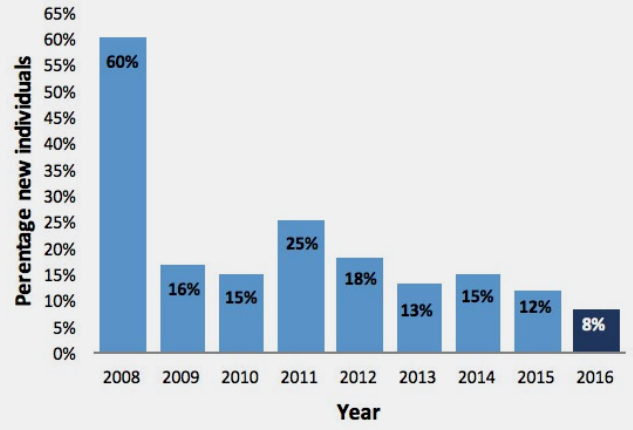
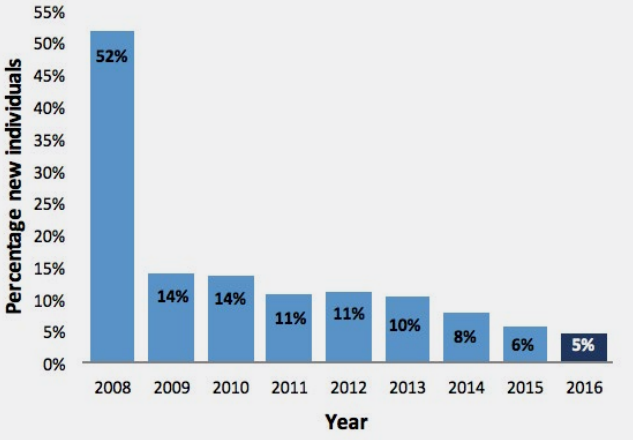


Figure 10: Proportion of the total yearly sightings of reef manta rays (*Manta alfredi*) in Hanifaru Bay which were newly sighted individuals (2008-2016).



Reproductive Fecundity

For the third consecutive year we have recorded pregnancies among the Maldivian manta ray population. A total of 33 different females have been observed pregnant throughout the year, 16 of which were in Baa Atoll. The proportion of pregnancies recorded among Hanifaru Bay's core population of mature female reef manta rays in 2016 is consistent with that recorded in previous years and indicates an overall very slow reproductive rate with, on average, only 10-15% of the mature females reproducing each year (Fig. 11). 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 manta rays' key 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 CoC has been implemented by various operators in the country and we aim to keep disseminating it, hopefully with the support of the Maldivian Government. Advancements in this regard have also provided scope for channelling the directive into creating a CoC snorkelling and SCUBA diving 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. This is still in the production phase and is expected to be released during the 2017 'manta season' in Baa Atoll.

Courtship & Mating Behaviour

Throughout their range globally, reproductive activity in manta rays is often seasonally variable. In the Maldives courtship behaviour and mating are much more frequently observed during the months of October and November, and again in March and April, when the country's two monsoons (seasons) 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. The males know this, so during the mating season these cleaning stations become the focal point for courtship behaviour

Figure 11: Percentage of Hanifaru Bay's core adult female reef manta ray (*Manta alfredi*) population (n°50) sighted annually, and the percentage of those females which were recorded pregnant in the same year.

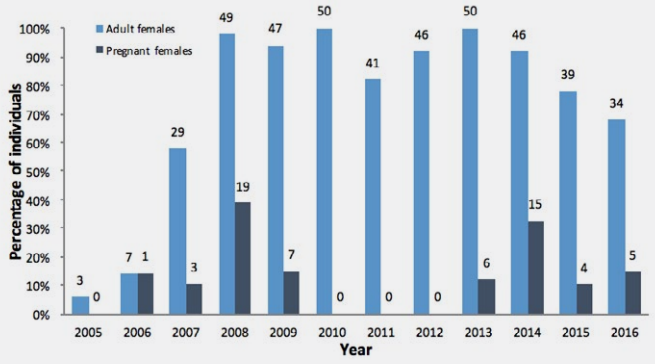
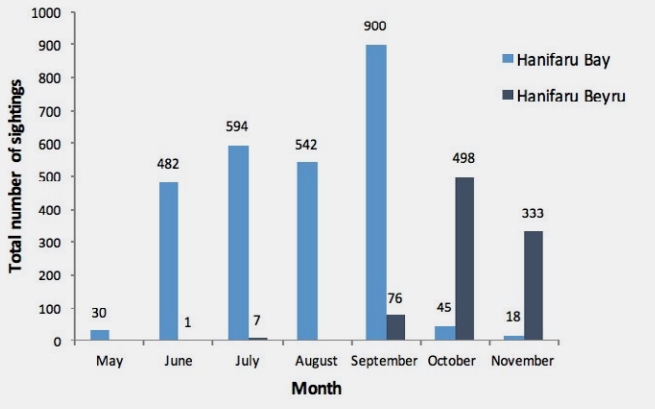


Figure 12: Shift in reef manta ray (*Manta alfredi*) site occupancy within Hanifaru MPA (May-November 2016).



and manta activity, with groups of males hanging around the site waiting for the females to turn up.

According to the 2016 sightings reports for Baa Atoll, during the month of October there was a noticeable shift in manta behaviour from reported feeding activity, documented within Hanifaru Bay, to cleaning and courtship interactions, observed along the outer north corner of Hanifaru, at a cleaning site known as Hanifaru Beyru (Fig 12). It is also worth noting that similar reports of increased courtship activity along cleaning stations in the latter half of the season were documented throughout the Maldives at sites which are monitored on a regular basis by the Maldivian Manta Ray Project. For example, at Lankan Beyru in North Malé Atoll, Neyo Beyru in Raa Atoll and Hithadhoo Corner in Laamu Atoll. Based on these findings and acknowledging the importance of mating activity for ensuring the long term survival of the Maldivian manta ray population, it is crucial that particular care be taken to minimise disturbance to manta ray during these months.

Courtship behaviour, as well as other signs of mating activity, was noticeably higher in 2016 than in the previous two years and may indicate another increase in pregnancies in the 2017.

Whale Shark Sightings

Whale sharks (*Rhincodon typus*) reflect similar lifestyle characteristics to manta rays. Both species are large, migratory, filter-feeding elasmobranchs. Additionally, the two species share common niche habitats and are often sighted in similar locations. In contrast to the lack of official sightings reported last year (2015), five sightings of whale sharks (WS178, WS187, WS206, WS222, and WS268) were reported in Baa Atoll during 2016, the highest recorded number of sightings since 2012, although still significantly less than in earlier study years (Fig. 13). All five of the whale sharks sighted in Baa Atoll in 2016 have been previously recorded in other atolls of the Maldives (four individuals in South Ari Atoll and one in Thaa Atoll). Two of the individuals (WS178 and WS187) have been previously seen in Baa Atoll (in 2011 and 2014 respectively) and sighted in South Ari between, and since, their Baa sightings. For the other three individuals, this was the first record in Baa Atoll.

The location of whale shark sightings has historically been concentrated in Hanifaru Bay. Although more sightings were made in 2016 than the previous three years, all the sightings were outside of Hanifaru Bay (Fig. 14).

The slight increase in whale shark sightings in the 2016 season is a positive finding in light of the overall declining trend in sightings in recent years. Whale sharks are listed as an 'Endangered' species on the IUCN Red List and therefore any positive increase in sightings is valuable. Hanifaru has previously been regarded as a very good site to see whale sharks alongside manta rays but in recent years it has lost that side of the appeal somewhat. It is hoped that in the 2017 season we will see a continued increase in whale shark visitations to Hanifaru Bay and Baa Atoll in general.

Figure 13: Total annual sightings of whale sharks (*Rhincodon typus*) in Baa Atoll (2008-2016).

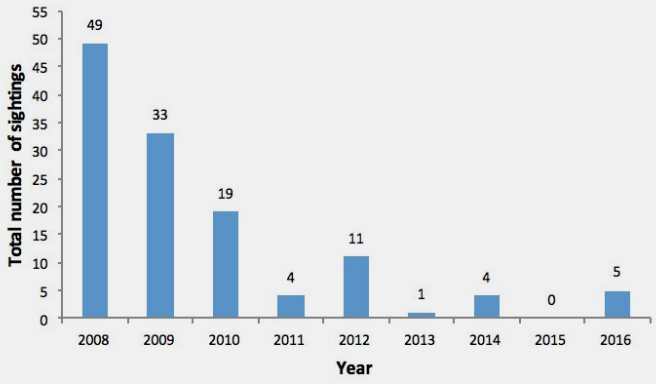
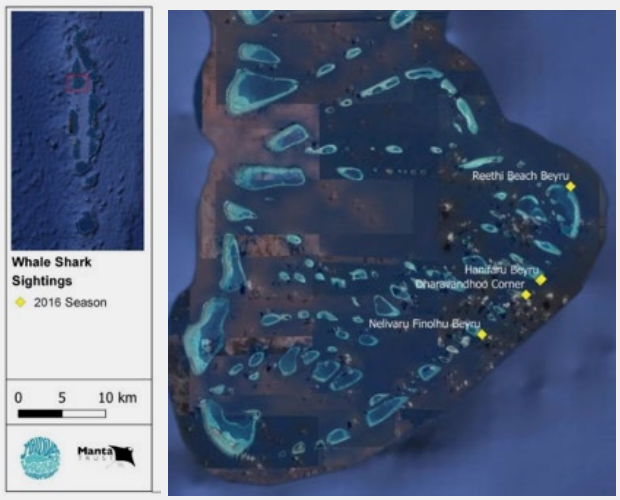


Figure 14: Location of reported whale sharks (*Rhincodon typus*) sightings in Baa Atoll during 2016.



Intra-annual Sighting Variation

Sightings frequencies for both reef manta rays and whale sharks peak in the months of June through November, with 25% and 39% of the total yearly manta and whale shark sightings respectively occurring in the month of August alone (Figs. 15 & 16). These findings suggest a higher presence of manta rays during the second half of the Southwest Monsoon compared to the first half, asymmetrically distributed around August's peak (Fig. 15). When accounting for the differential survey effort the trend becomes more evident (Fig. 17).

Figure 15: Monthly sightings of reef manta rays (*Manta alfredi*) in Baa Atoll (2008-2016).

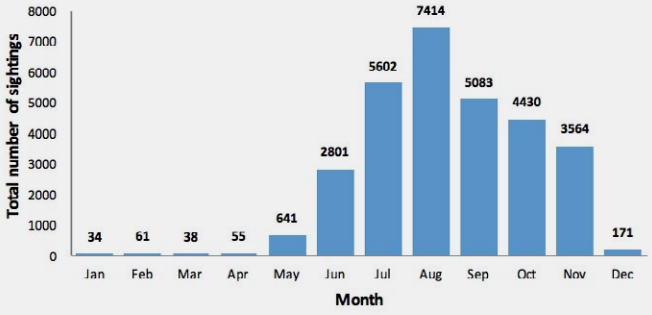


Figure 16: Monthly sightings of whale sharks (*Rhincodon typus*) in Baa Atoll (2008-2016).

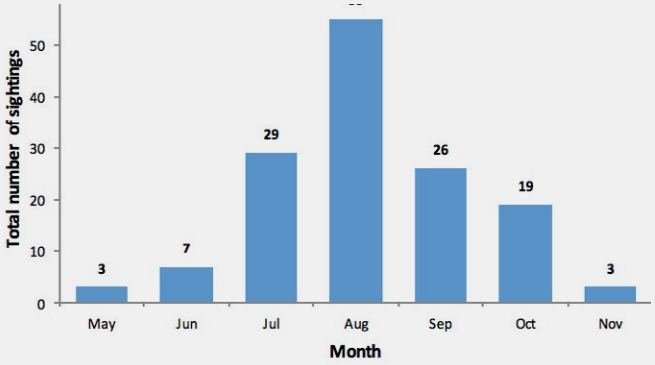
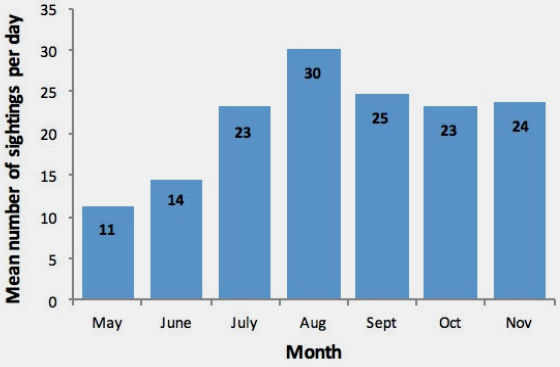


Figure 17: Mean monthly sightings of reef manta Ray (*Manta alfredi*) per survey day in Baa Atoll (2008-2016).



Weather and Climatic Variation

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 2016. The average wind speed observed in 2016 was 19.0 Km/h, slightly higher than the previous year

Huge paddle-like cephalic (head) fins are held in front of the manta ray's lower jaw, helping to funnel plankton-rich water into a mouth, while rudderfish above pluck their plankton prey from the water one at a time.

(16.0 Km/h). Wind speed peaked in June, measuring an average of 23 Km/h. Wind speed decreased slightly (21 Km/h) but remained constant between July and August, with a further drop in speed noted during the month of September (17.0 Km/h). This was followed by an increase in wind speed and return to 21 Km/h during the month of October ahead of a sharp decrease in average speed recorded for November (10.0 Km/h). Manta sightings pattern for 2016 follows a similar trend to that observed in previous years (bar the apparent anomaly recorded in 2015). Here it is noted that 2016 saw a higher overall average wind speed and a correspondingly greater number of manta ray sightings than that observed between 2008-2014 (Fig. 18). While there appears to be a link between yearly average wind speed and average manta sightings per day ($R^2 = 0.1418$) (Fig.19), these results are not statistically significant 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 (Fig. 20). The strong monsoonal winds generally experienced in June-August are likely to kick start the plankton production through upwelling and are possibly the reason for July and September'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.

Figure 18: Mean yearly wind speed (Km/h) and mean number of reef manta rays (*Manta alfredi*) sightings per day (2008-2016).

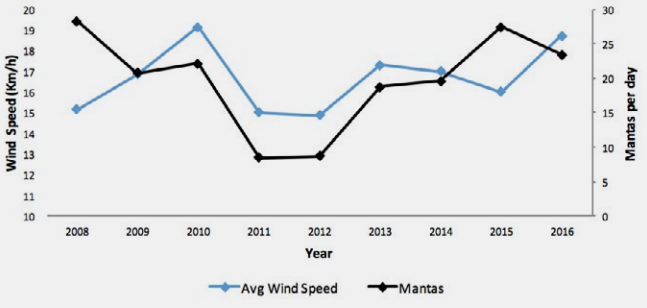


Figure 19: Average yearly wind speed (Km/h) and average number of reef manta ray (*Manta alfredi*) sightings.

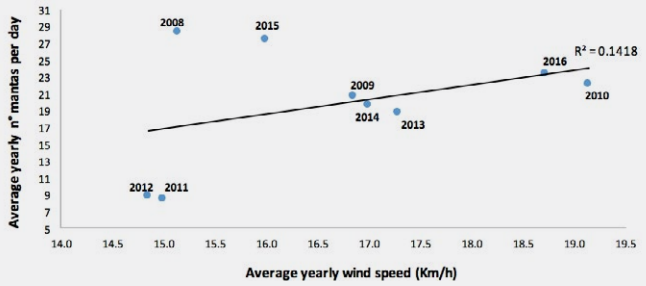
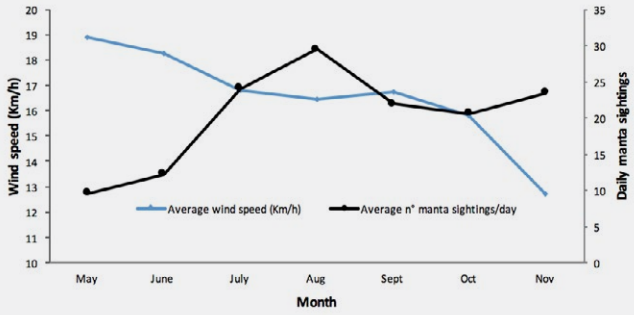


Figure 20: Average yearly wind speed against yearly average number of reef manta ray (*Manta alfredi*) sightings per day (2008-2016).



The fluctuation of food availability, monsoonal strength, manta rays' sightings and fecundity might be part of a natural cycle of variable weather patterns which occur within the Maldives over time, or more worryingly, they may be connected to 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 show what might be causing such changes, and therefore what measures need to be taken to manage them. Regardless of cause, and leaving aside the ecological ramifications, these observations should be considered very 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 rest of the tourism and fishing industries which heavily rely upon the ocean's productivity, and therefore the strength of the monsoons.

It is very likely that this lack of food, brought about by the weakened Maldives monsoon, is responsible to some extent for the reduced number of pregnancies observed

Five pairs of gill slits, each encircled by feathery gill plates, separate the planktonic food from the water as it flows out through the gills, directing the prey back into the manta's throat.

in the Maldivian manta ray population in recent years. Elasmobranch reproduction varies widely between species and reproduction within the genus *Manta* is very poorly understood, with much of what we know coming from just a few studies globally. Sharks and rays within the subclass Elasmobranchii have a wide range of reproductive techniques with some species able to store sperm or to repress or stagger pregnancies. It is likely these strategies have been developed in order to provide offspring with the best chances of survival. It has been suggested that manta rays are using similar strategies to ensure that their offspring are born during years which have a greater abundance of food to increase their chances of survival.

Tourism

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 that came into effect starting January 2012, has had a significant impact on the number of safari boats observed, despite the good manta ray sightings inside the MPA in the past two years (Fig. 21). 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 practical itinerary,

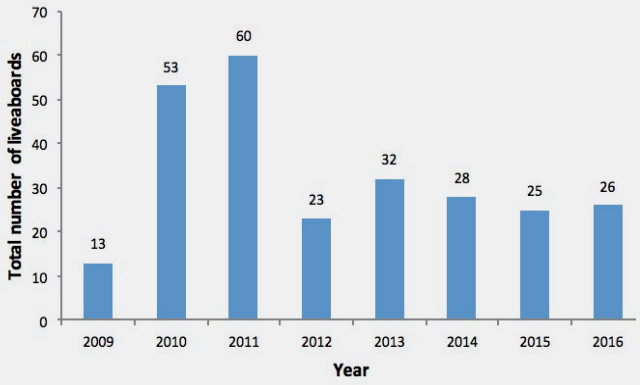
Baa Atoll Marine Education Programme: School kids celebrate with the Manta Trust team after an afternoon snorkelling with manta rays in Hanifaru Bay.

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. The resorts have continued to visit the MPA as in previous years.

It should be highlighted that the cleaning station known as Hanifaru Beyru, located on the North East Corner of Hanifaru Bay MPA, delivered a wealth of manta activity this past season and became a popular destination for liveaboard groups and resorts to stop off at for their manta viewing. The reputation of this site as a reliable manta viewing station was however only realised towards the end of the season and therefore was most likely not included in many of the Safari itineraries during 2016. It is however predicted that this relatively 'new' manta hotspot may encourage an increase in liveaboards visits to Baa Atoll this upcoming season, making it paramount for improved monitoring of diver and snorkeler related activities at this site and ensuring sustainable tourism is practiced so as to avoid any negative implications towards the manta population visiting these grounds.

Although a constant presence by EPA rangers was noted inside Hanifaru Bay, regular patrols in this buffer zone of the MPA were lacking, leading to a number of infractions being committed here during 2016. Reluctance to adhere to any codes of conduct regarding manta ray tourism particularly at a cleaning station was most certainly cause for concern. Furthermore, the disregard by each tour operator for respective groups' time in the water or lack of consideration for type of tourism activities practiced on-site (SCUBA vs snorkelling) led to much in-water frustration by guides and viewing parties. Actions of misconduct by divers, snorkelers and boats (sometimes resulting in dangerous incidents in which serious injuries to tourists and guides were narrowly avoided) at the cleaning station were noted on several occasions. In light of the incidents witnessed during 2016 and in preparation for the 2017 season, it is advised that the cleaning station on this North East corner of Hanifaru MPA be clearly demarcated in order to prevent boat traffic from interfering with manta activity and to avert any serious risks imposed on divers/snorkelers in the region. In addition to this, there is an urgent appeal for effective monitoring by EPA rangers in this area to curb any infringements on-site. In accordance with law no. 4/93 (Maldivian Environment Protection and Preservation Act), this cleaning station falls within the jurisdiction of the Hanifaru Bay buffer zone and as such should still be afforded a similar level of protection and regulation as that implemented inside the core zone.

Figure 21: Total number of different safari boats (liveaboards) observed in Baa Atoll (June-November 2009-2016).



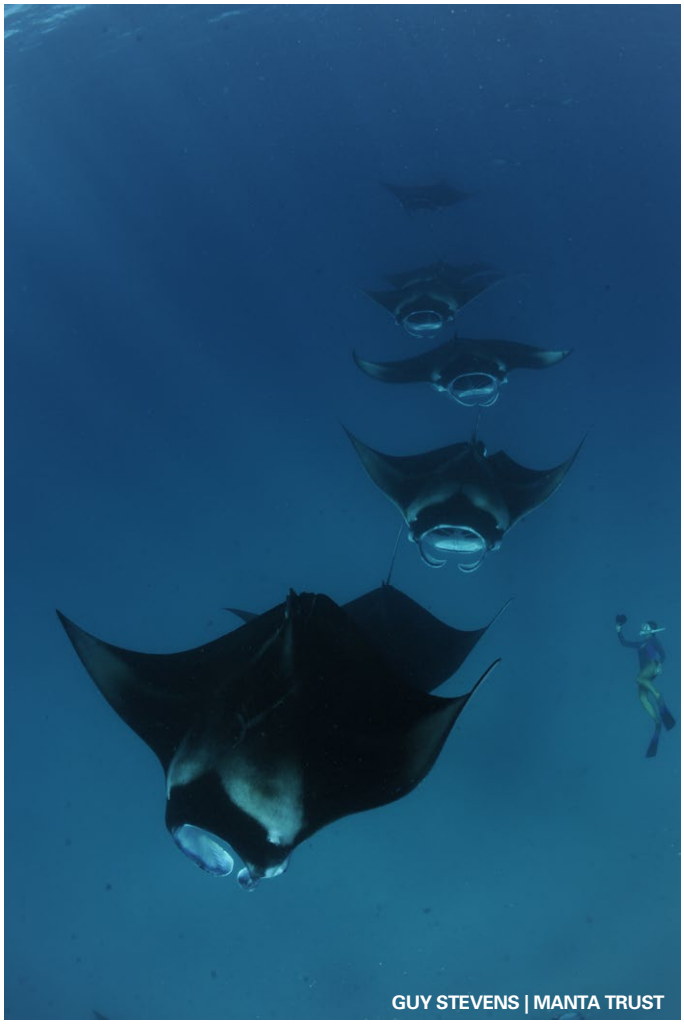
Baa Atoll Marine Education Programme

On the 17th October 2015 the Manta Trust and Kamadhoo School signed an official Memorandum of Understanding stating the reciprocal intention to initiate a yearlong Marine Education Programme for 8th and 9th grade students. Following the aims and objectives proposed through this initiative, the MMRP are proud to announce the successful completion of Manta Trust's very first marine education programme

in 2016 for school students in the Maldives. The programme adhered to a holistic approach to marine biology themes and conservation issues with the aim of raising awareness and educating the young Maldivian generation, inspiring a passion for the marine environment. The programme incorporated a range of topics relating to marine biology and conservation management and was designed with pertinence to the Baa Atoll Biosphere Reserve. The course consisted of theoretical components with classroom-based lessons and practical modules whereby students were provided with the opportunity to practice and apply the skills administered in the classroom to real-life contexts in the field- whether it be to visit Hanifaru Bay MPA and swim with manta rays, learn about waste management programmes on local islands, or realise the importance of healthy reef ecosystems following informative field trips to coral reefs and distinguishing healthy reefs from degraded ones.

Led by our Education and Outreach Co-ordinator, Ibrahim Lirar, and with the logistical support from the Four Seasons Resort at Landaa Giraavaru, this project saw a successful execution during 2016 with the top three students being presented with prizes complimentary of Manta Trust and Four Seasons Maldives at the end of year awards ceremony at Kamadhoo School. The programme proved to be an effective platform to inspire and encourage students to improve their overall academic and life skills along with marine environment knowledge. In addition, the course was able to support and supplement the school's Marine Science subject and was well received by students and the local community. Kamadhoo School have already expressed their interest in hosting the Manta Trust Marine Biology course again in 2017 for new school students and have encouraged increased involvement following the positive appraisal it received from students, staff and parents in 2016. The aim for 2017 is to expand the programme into Kendhoo and to explore the opportunities of delivering a few informative sessions on Kihaadhoo and Dharavandhoo Islands.

Educational activities have also taken place in North Malé and Laamu Atolls where the MMRP project representatives have directed a series of classroom, and in-field training sessions based on the components



A group of chain feeding reef manta rays line up behind each other in Hanifaru Bay.

drawn from the Manta Trusts' core marine biology curriculum. Furthermore, as in previous years, MMRP members have actively participated in numerous environmental initiatives and events throughout the Maldives in 2016.

We anticipate 2017 will be an exciting year for the Baa Atoll Marine Education Programme. The programme is developing and establishing itself as a nationally recognised extra-curricular activity. It has now been granted its own logo and title and work has begun on developing a course textbook to provide detailed insight into the different modules addressed in class (Fig. 22). The aim is to have this ready for launching at the end of 2017. 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 Maldivian waters. We look forward to working in

collaboration with Maldivian governmental bodies and other environmental organisations in order to further improve and expand this educational programme in 2017.

Figure 22: Manta Trust Marine Education Programme Logo: Hanhaara Veshi - 'Passion for one's environment'

Manta Ray Social Behaviour

A study of the social behaviour of an unfished population of Reef Manta Rays (*Manta alfredi*) in the Maldives: a project summary- PhD Research by Annie Murray – University of York, UK

After three years of data collection in Baa Atoll, Annie in the final year of her PhD and aims to complete and publish the following chapters based on the Maldivian population of reef manta rays in 2018.

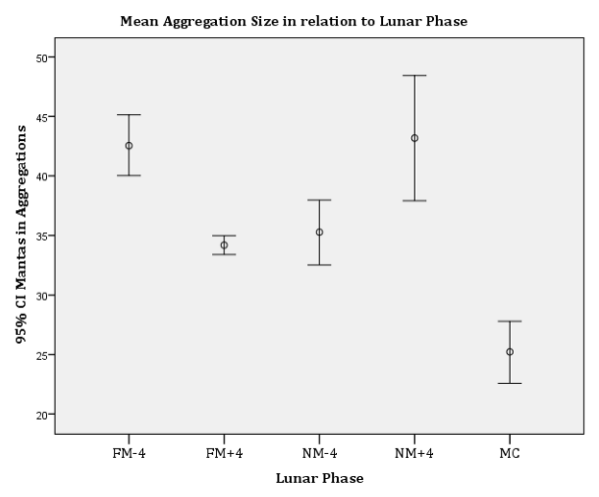
Chapter One: Determine whether *Manta alfredi* show social network structure within or between years and sites; Do *Manta alfredi* show social network and does this vary between age, sex and size?

Individual subjects are part of a network of inter-individual associations which vary in strength, type and dynamics. The structure of social networks in nature have far-reaching implications for the ecology and evolution of individuals, populations and species. For example, a social network supports an array of behaviours that will be influenced by its structure including: finding and choosing a sexual partner, developing and maintaining cooperative relationships and engaging in foraging and anti-predator behaviour. Conducting an analysis on a wide variety of data allows an insight into the impact of the behaviour of an individual on a population level and vice versa.

Key factors for consideration and approach:

- **Lunar cycle** and its influence on period of peak feeding activity: Anecdotal research collected in Baa Atoll has shown that aggregations commonly swell in size during the lead up to New and Full moon as the tidal range reaches monthly maxima (Fig.23).
- **Sex:** Mature females are significantly larger than males which appears to alter their behaviour, often displaying a higher degree of dominance than males and taking more of a leadership role in group feeding events.
- **Age:** With age comes experience, learned knowledge and often more dominant behaviour which juveniles and sub-adults lack.
- What impact does **site** and **annual time frame** have on observed structures? Using over a decade's worth of historical sightings data, the study aims to examine whether social 'groups' are consistent between years and sites.

Figure 23: Mean number of mantas in aggregations in relation to lunar phase Mean Group Size in relation to Lunar Phase (FM-4, FM+, NM-4, NM+4, MC).



Chapter Two: Leaders and Followers: individual differences in the social foraging strategies of *Manta alfredi*.

Coordinated actions within groups can be expedited by the emergence of a leader who initiates and/or directs group movement, with other members of the group adopting the role of followers. Leaders (or decision makers) are those individuals that, even when animals

A hunting blue-fin jack chases a shoal of neon fusiliers which envelop Muthafushi Thila within the Baa Atoll UNESCO Biosphere Reserve as they try to escape the predator.

decide collectively, are more influential with respect to the decision outcome whereas the others will simply accept their decision. Using grouping and leadership scores during feeding events, this study aims to determine whether there is any predilection amongst individuals to feed as part of a group or solo and whether they act as a leader or follower? The way traits linked with dominance (age and sex) or environmental factors influence resource competition (size of foraging aggregations and food availability) and whether any variation in social phenotype affects an individual's grouping and leadership behaviour under the influence of environmental variables was also studied.

Preliminary results show that across the first two years of analysis, sex, plankton density and aggregation sizes provided insight into the grouping and leadership behaviour of Baa mantas (Fig. 24-25). It was found that although there was no effect of sex or age on animals' propensity to feed in groups and no correlation noted between age and leadership roles, **there was a higher tendency** for females to assume leadership during 2015. Initial findings reveal that the propensity to feed in a group or to act as a leader was subjective to year of assessment and by using further statistical analysis, this work aims to decipher the primary factors contributing to this difference between years, e.g. plankton density, aggregation size etc.

Figure 24: A comparison of the median dyadic indexes (DAI) of sex with the leadership score from data collected in 2015 (GLM leadership score, sex, interaction F = 4.41, df = 1, 147, p = .037)

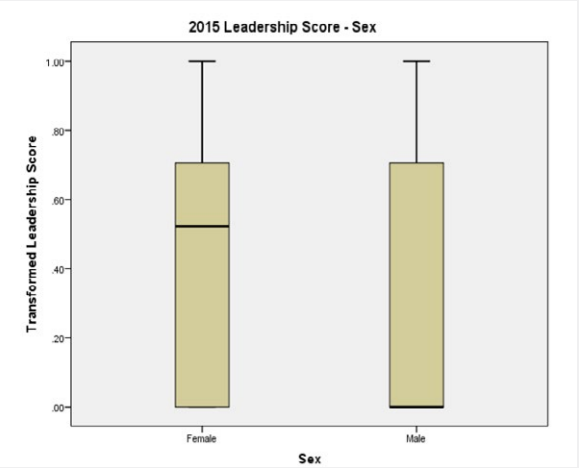
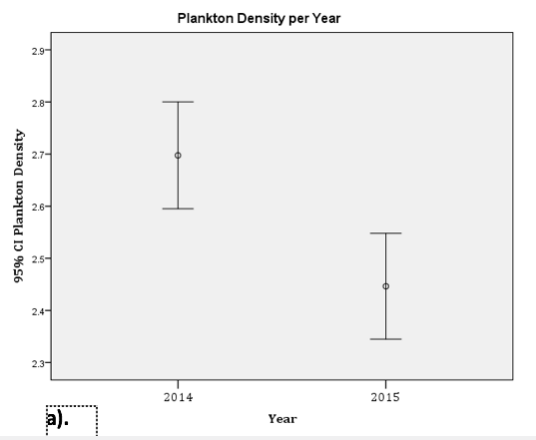
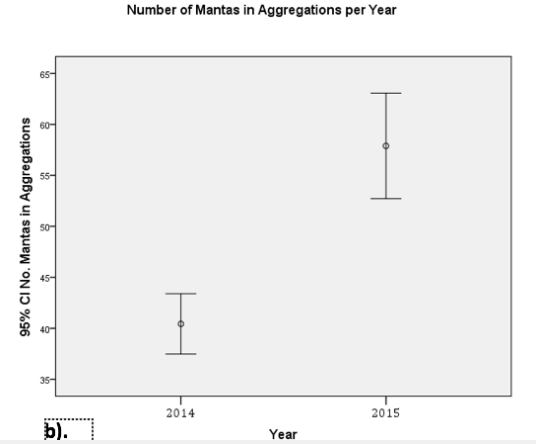


Figure 25a & b: Plankton density per year (Mean Rank 2014 = 242.30, Mean Rank 2015 = 199.44, U = 19209.500, N= 438, p = .000); Number of Mantas in Aggregations per year (Mean Rank 2014 =203.96, Mean Rank 2015 = 240.32, U =20662.000, N= 445, p = .003)





Chapter Three: Determine long term site fidelity of a resident population of *Manta alfredi* in Baa Atoll, Maldives

Using over 10 years (2005-2015) of ID data collected by the Maldivian Manta Ray Project from various study sites in Baa Atoll, plankton density, aggregation size and individual group composition and behaviour, this study intends to examine patterns in behaviour and manta presence. The presence/absence of individual mantas gives insight to site fidelity in different areas, paying particular attention to less visited, smaller aggregation sites such as Veyofushi which is recognised as a juvenile aggregation site. Are there similarities in notable characteristics (gender, maturity) shared by individuals who show higher fidelity over time and whether the pattern of site fidelity by individuals remains constant over the 10 year period? Are social groupings maintained across sites/atolls? This study also aims to assess whether there are any patterns in the distance of inter-atoll sightings; Do mature mantas travel further? Do all members of a "group" travel or do some individuals show more site fidelity than others?

The final chapter for Annie's PhD will be a collaborative project 'Developing a Code of Conduct for Manta Ray Tourism Interactions – The Science Behind interactions'. This study has been five years in the making and provided the basis for this years' MSc student, Ella Garrud's research project.

Manta Ray Tourism in the Maldives

Does tourist behaviour affect reef manta ray feeding behaviour? An analysis of human and *Manta alfredi* interactions in Baa Atoll, the Maldives – MSc Research by Ella Garrud – University of York, UK

The number of tourists travelling to the Maldives specifically to swim with charismatic marine megafauna has increased over recent years. Manta ray tourism in the Maldives is estimated to be worth US$8.1 million annually in direct revenue alone. This type of tourism clearly has significant benefits to the Maldivian economy but there is anecdotal evidence that large numbers of tourists at popular dive and snorkel sites is having a negative impact on reef manta rays' natural behaviour.

This study investigated human and manta ray tourism interactions by collecting video footage (n = 431) over a two-month period in Baa Atoll, Maldives at five feeding aggregation sites, to identify and quantify how human in-water snorkelling conduct affected the manta rays' feeding behaviour.

Human behaviour was separated into 4 categories, increasing in severity, from passively observing the manta, to the most potentially intrusive behaviour of chasing the manta (Fig. 26). The manta rays' response was then also separated into 4 categories, again increasing in severity, the least severe of which was the manta ray showing no visible response to the human presence (Fig. 27). The most severe response recorded was a 'flight' reaction – when a manta puts on a sudden burst of speed to exit the interaction with the tourist

(Fig. 27). Direction of approach and distance between human and manta was also recorded for each human/manta interaction (Fig. 28 & 29)

Figure 26: Number of times each human behaviour was observed.

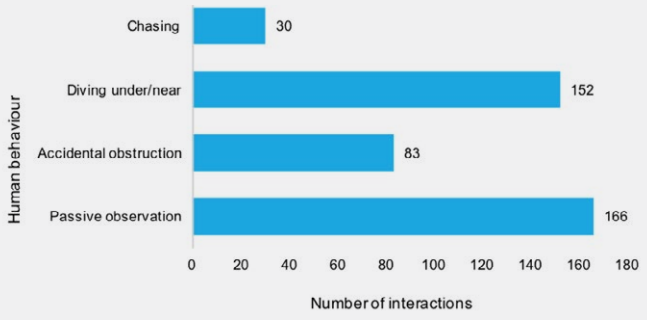


Figure 27: Number of times each manta response was observed.

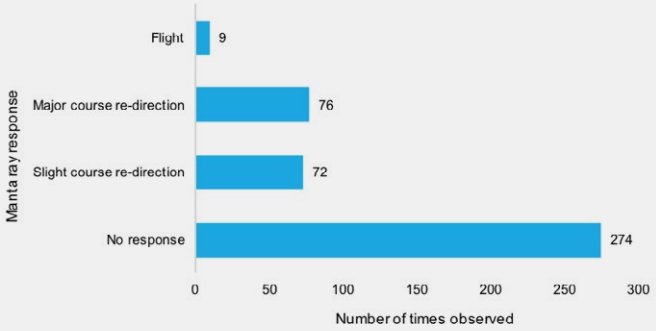
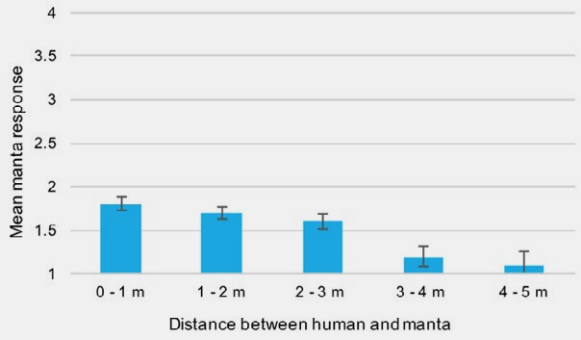
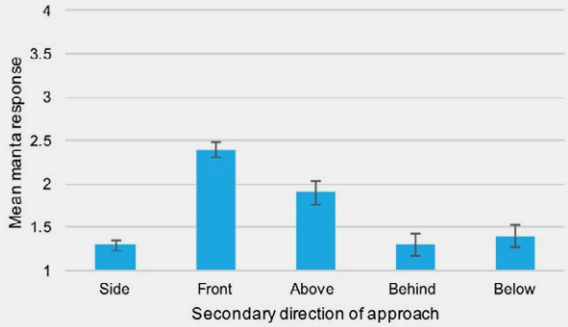


Figure 28: Mean manta response vs. distance between human and manta (n = 431). Error bars represent standard error (SE), the 95% confidence interval



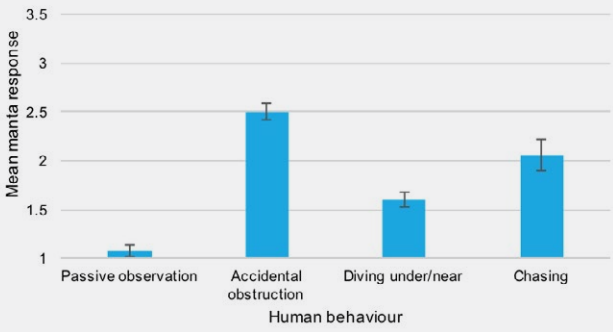
Accidentally obstructing the path of the manta significantly increased the likelihood of the manta displaying avoidance behaviour as did approaching the manta from the front (Fig. 30). Tourists positioned between 0 and 3 m of the manta significantly increased the probability of avoidance behaviour from the manta (Fig. 28). Diving under/near mantas from the front strongly increased the probability of avoidance behaviour from the manta (Fig. 30). However, passively observing the manta – which was characterised as the tourist floating horizontally in the water, with their arms close to their body and not kicking - was found to significantly decrease the likelihood of causing a strong reaction from the manta (Fig. 30). Mantas recorded at sites where juveniles are regularly observed also reacted more strongly to human behaviour.

Figure 29: Mean manta response vs. secondary direction of human approach when diving under/near manta (n = 152). Error bars represent standard error (SE), the 95% confidence interval.



These findings reveal key recommendations: (1) tourists should observe mantas passively, (2) a minimum of 3 m distance should be maintained between human and manta, (3) approach from the side of the focal manta ray, (4) inexperienced snorkelers should not dive underneath or near manta rays, (5) tourists should not dive in front of mantas, (6) at sites where juveniles are regularly sighted, be more cautious when approaching manta rays. All results and recommendations support the Manta Trust Code of Conduct for Tourism Interactions.

Figure 30: Mean manta response vs. human behaviour (n = 431). Error bars represent standard error (SE), the 95% confidence interval.



Conservation and 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 Maldivian manta rays, with great implications for their ongoing protection, especially given the designation of Hanifaru MPA as a core zone of the Reserve. Management of these newly protected renewed commitment in the near future by the Maldivian government's Environmental Protection Agency (EPA) and the Baa Atoll Biosphere Reserve Office to manage this site and the tourism that takes place within it.

A World Biosphere Reserve strives to better understand the human impact and help safeguard natural ecosystems for the future. Long term, consistent data collection is crucial to grasp the influence and impact of tourism on this very unique population of animals and gain a broader understanding of manta rays worldwide. Without access to consistent and reliable manta ray sightings and the constant monitoring of tourism, little weight can be placed on any data collected. Interrupted and inconsistent data collection is much harder to accurately analyse or extrapolate trends from, resulting in more inconclusive results. Although previously gathered data is useful as a baseline, continuous and 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.

Maldivian Manta Ray Project (MMRP)

The MMRP is highly regarded within the scientific community. It is one of the longest running manta ray research programmes in the world. We would welcome the opportunity to continue to work with the Maldivian 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 has many implications on a global scale for manta ray conservation.

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

Tam Sawers - BSc (Hons), MSc (Hons)
Project Leader - Maldivian Manta Ray Project.

Dr. Guy Stevens
Chief Executive / Founder - The Manta Trust.

The MMRP and the Manta Trust are happy to share any data collected as a part of this study.

For further information please email:

guy@mantatrust.org or tam@mantatrust.org