



Maldivian
Manta Ray Project

2015 Baa Atoll Report

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



Executive Summary

This report presents data collected by the Maldivian Manta Ray Project (MMRP) on Baa Atoll's reef manta ray (*Manta alfredi*) population between May and December 2015.

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 2015 include a record total of 4,852 sightings of 778 individual manta rays, recorded throughout the year (4,785 sightings of 765 individuals if only the Southwest Monsoon period is considered). This equates to a 45% increase in sightings compared to the previous year, and is (by 1,248 sightings) the highest number of encounters ever recorded by the MMRP in Baa Atoll in 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 in recent years and increased access allowed in Hanifaru Bay Marine Protected Area (MPA). However, when standardised and compared to previous years, 2015 sightings were still consistent with those recorded between 2008 and 2010.

Throughout the 6 months of surveying, each of the 778 different individuals were observed on average 6.24 times, a significant increase from 2014 (average 4.54 sightings per manta) and the highest thus far recorded. The proportion of rays seen on more than one occasion also increased, from 72% in 2014, to 79%, a figure which is also in line with pre 2011 data records. It is interesting to note that, as in 2014, sightings showed a clear peak in July with 1,423 encounters (second highest monthly total after August 2010) and a steady drop during the



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

following months. July's exceptional sightings number was coupled with strong monsoonal winds, likely to be the cause of increased productivity and thus food availability for the manta rays, which steadily decreased in the following months. 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) and remain fairly high until December.

Reproductive activity in Baa Atoll decreased in 2015, with only 17 pregnancies recorded during the year, compared to 37 in 2014. When compared to 2014, the prevalence of courtship activity and fresh reproductive wounds also decreased in 2015. The intense reproductive activity recorded in 2014 led to a big jump in the number (n=15) of young of year (YoY – individuals recorded for the first time at birth size ~1.5m DW) recorded in Baa Atoll in 2015. 13 of these YoY individuals were first identified, and subsequently re-sighted on multiple occasions, at Maaneigaa, a protected reef system in the southern region of Baa Atoll. This aggregation site appears to be a key nursery feeding site for juvenile reef manta rays.

Observations for possible correlations between environmental variables (most notably wind speed) and manta ray abundance were continued in 2015 as they appear to have a strong influence on the numbers of manta rays seen in the atoll during the Southwest Monsoon.



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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.

However, this trend was not as closely correlated as in previous years. In 2015 the highest wind speeds were recorded during May and September, while the highest number of manta sightings was recorded in July and August. 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 influencing factors.

Further studies on the social behaviour of manta rays, tourism and the value of divers' knowledge for manta rays' conservation were also undertaken. The Baa Atoll Marine Education Programme was also extended and expanded in 2015.

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 2016 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 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 sun's life giving energy and through photosynthesis kick start the food chain, first with phytoplankton, then with zooplankton which predate 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



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

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.

Study Period and Sampling

Surveys to look for manta rays were carried out in Baa Atoll between the 20th May and the 30th November 2015 on as many days as possible where conditions allowed. Full day survey trips were made on 156 days within this 195 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 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 efforts 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 with the minimum of 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 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 inside Hanifaru MPA, 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 2014, 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 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 2016.



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A reef manta ray hovers above a cleaning station, slowly circling the reef crest as small cleanerfish remove parasites from the manta's body.

Manta Ray Sightings

Baa Atoll

Sightings throughout Baa Atoll in 2015 greatly increased from 2014, reaching a record number of 4,852; an increase of over 1,000 from the highest number ever recorded in previous years (Fig. 1). A monthly breakdown of these sightings, standardised for survey effort, shows a clear peak in July and a steady decrease over the following months (Fig. 2).

Figure 1. Annual sightings of reef manta rays (*Manta alfredi*) in Baa Atoll (2008-2015).

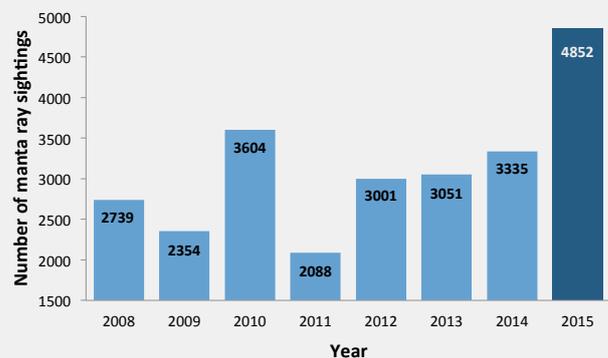
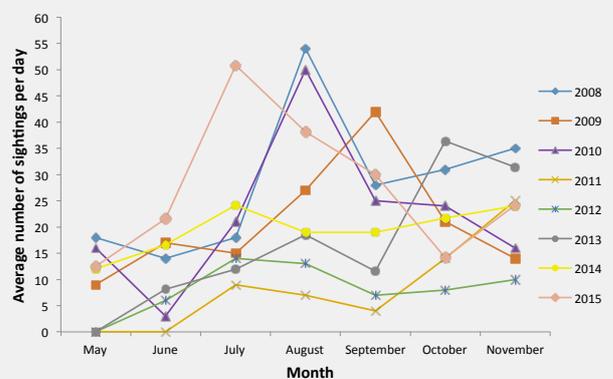
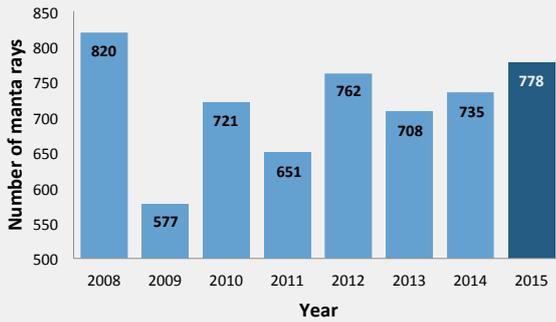


Figure 2. Average number of reef manta ray (*Manta alfredi*) sightings per day each month in Baa Atoll (2008-2015).



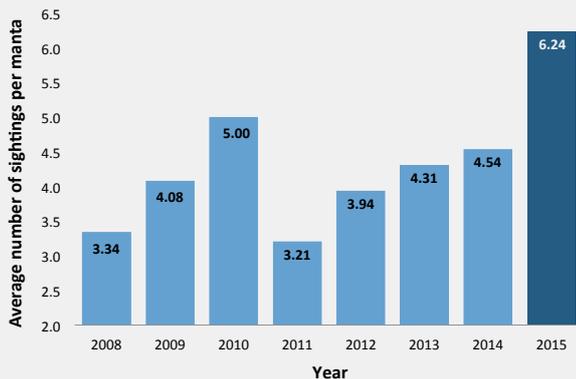
A total of 778 different individual reef manta rays were recorded in Baa Atoll during 2015 (Fig. 3) (765 when accounting only for the southwest monsoon); 20% of the total recorded Maldivian population of 4,000 individuals. In the last eight years the total number of different individual mantas which have been recorded in Baa Atoll is 1,861, or 47% of the total recorded Maldives population.

Figure 3. Annual number of individual reef manta rays (*Manta alfredi*) sighted in Baa Atoll (2008-2015).



Throughout the season each manta was observed on average 6.24 times (Fig. 4), an increase from 2014 (average 4.54 sightings per individual). The proportion of rays seen on more than one occasion also increased from 72% in 2014, to 79%, the highest recorded (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 2015 resulted in being the highest recorded, further suggesting the consistent availability of manta rays' prey in the region compared to previous years (Fig. 6).

Figure 4. Average number of sightings per individual reef manta ray (*Manta alfredi*) in Baa Atoll (2008-2015).



During 2011's survey period there was a marked reduction in the number of individuals sighted on multiple occasions, suggesting a more transient population of mantas during this time, possibly linked to a reduction in the localised abundance of the manta ray's plank-

tonic food source. In 2012, 2013 and 2014 the sighting frequency returned to levels exhibited in the first three study years. The further increase in 2015 might be linked to the increased food availability observed during the season.

Figure 5. Percentage of individual reef manta rays (*Manta alfredi*) sighted on multiple occasions per season in Baa Atoll (2008-2015).

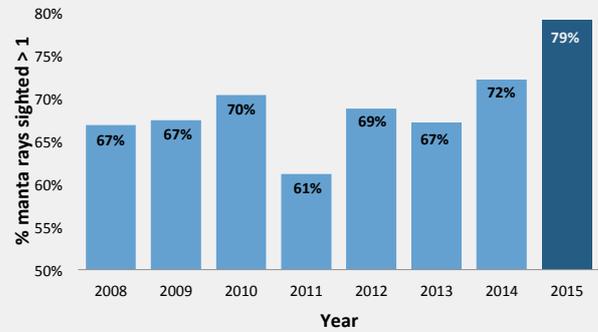
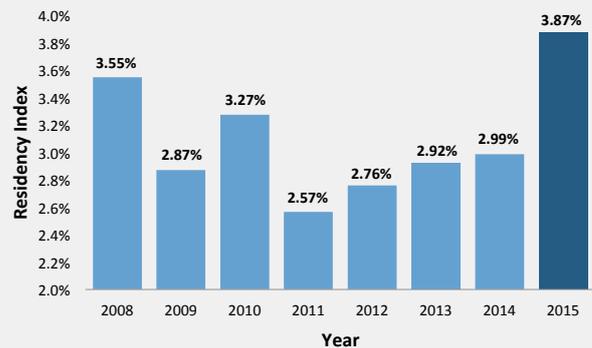


Figure 6. Average Residency Index of reef manta rays (*Manta alfredi*) in Baa Atoll (2008-2015).



Hanifaru Bay (MPA)

Sightings of mantas rays at Hanifaru Bay MPA saw a dramatic increase compared to the past two years (Fig. 7) and this result is not due to the increased access allowed to the MPA. The standardised graph for survey effort, in fact, reveals that the number of manta rays sighted per day in 2015 is extremely high with a record of 52 in July (Fig. 8). Again, consistent food availability (mainly during the first half of the season) is probably the reason for such an increased number of manta rays' sightings in Hanifaru Bay.

Figure 7. Annual sightings of reef manta rays (*Manta alfredi*) at Hanifaru Marine Protected Area (2008-2015).

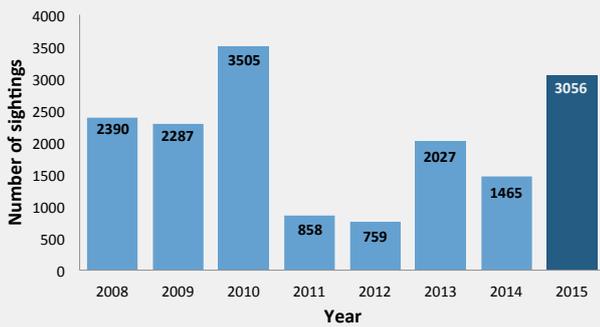


Figure 9. Proportion of the total yearly sightings of reef manta rays (*Manta alfredi*) in Baa Atoll which were newly sighted individuals (2008-2015).

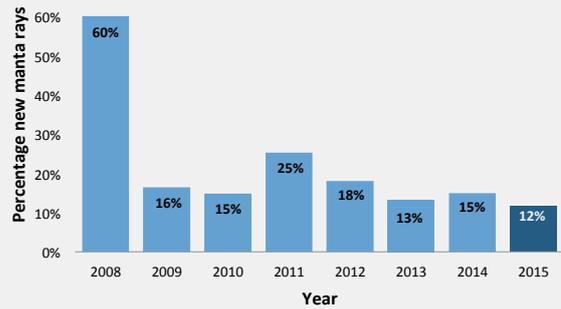


Figure 8. Average daily number of reef manta rays (*Manta alfredi*) observed between May and December each year (2008-2015).

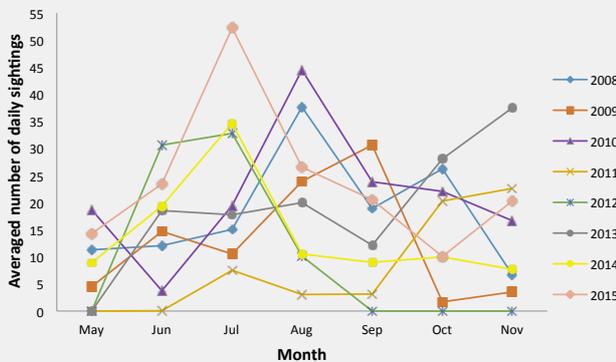
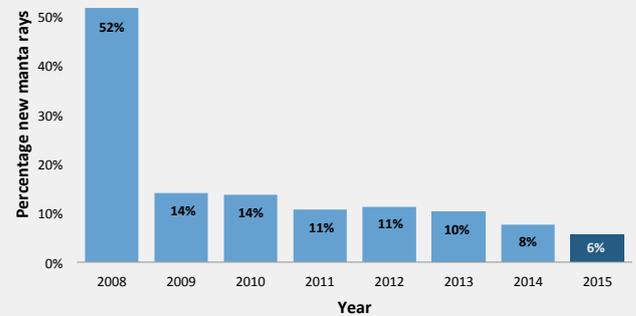


Figure 10. Proportion of the total yearly sightings of reef manta rays (*Manta alfredi*) in Hanifaru Bay which were newly sighted individuals (2008-2015).



New Manta Rays

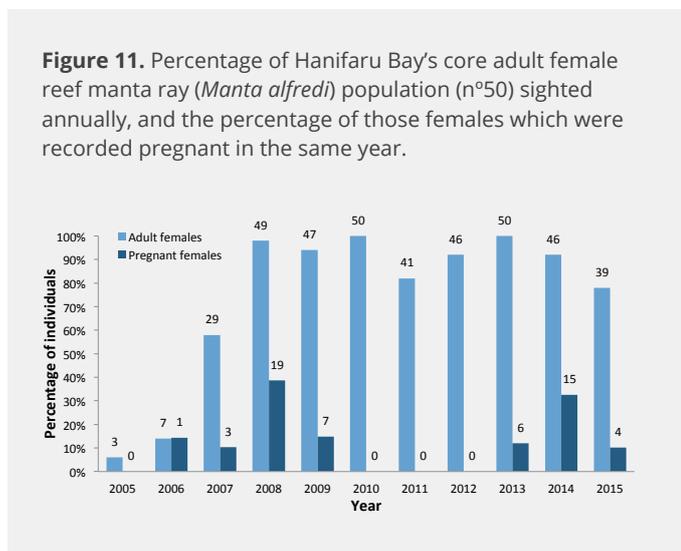
91 new individual manta rays were identified during the survey period in Baa Atoll in 2015 (83 during the South-west Monsoon). The proportion of newly sighted individuals recorded between 2007 and 2015, both in Baa Atoll and more specifically in Hanifaru Bay, keeps following a downward trend, as more 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 12%, suggesting that most of the Baa atoll mantas' population has been recorded and identified.

Reproductive Fecundity

For the third consecutive year we have recorded pregnancies among the Maldivian manta ray population. A total of 47 different females have been observed pregnant throughout the year, 17 of which in Baa Atoll. Data on the percentage of pregnant mature females indicate 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 has released a 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 possibly with the support of the Maldivian Government.

The intense reproductive activity recorded in 2014 led to a big jump in the number (n=15) of young of year (YoY – individuals recorded for the first time at birth size ~1.5m DW) recorded in Baa Atoll in 2015. Thirteen of these YoY individuals were first identified, and subsequently re-sighted on multiple occasions, at Maaneigaa, a protected reef system in the southern region of Baa Atoll. This aggregation site appears to be a key nursery feeding site for juvenile reef manta rays.

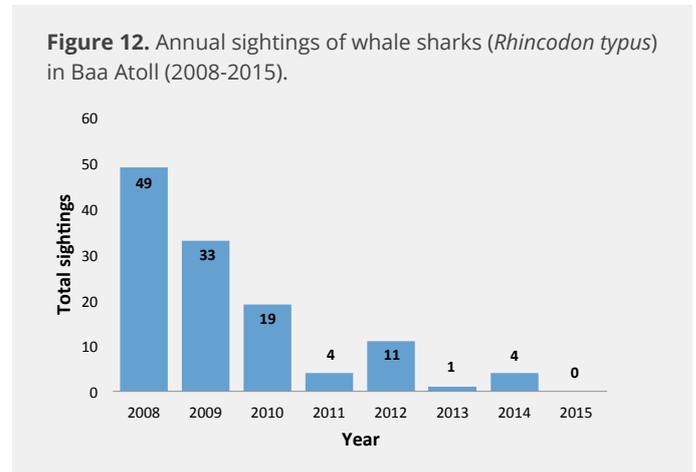
Courtship behaviour as well as signs of mating activity slightly decreased from 2014 following the decrease of pregnancies and might indicate a further decrease in reproductive activity in the upcoming year.



Whale Shark Sightings

Surveys for manta rays as described above also looked for whale sharks as the two species often aggregate at the same locations to feed. For the first time since the MMRP started surveying the region no official sighting of a whale shark has been recorded during the season in Baa Atoll (although a few unofficial sightings were reported by local guides and fishermen) (Fig. 12). The lack of whale sharks in the region is somewhat puzzling when compared to the increase in manta rays' activity. The observed trend may be the result of multiple factors. On one side the lack in localised, consistent and predictable availability of planktonic food experienced in previous years may have modified the seasonal migratory movements of whale sharks in the Maldives. While on the other side, some of the commonly sighted whale

sharks of Baa Atoll may have left the Maldives or died. To support the above statements the Maldives Whale Shark Research Programme (MWSRP) have recorded the occurrence of some of Baa Atoll's regular whale sharks in other regions such as Ari and Thaa Atolls (e.g. WS010, WS014 & WS187), while other sharks have not been observed since their last encounter in Baa Atoll (WS005, WS008, WS012, WS015, WS017, WS089).



Intra-annual Sighting Variation

Sightings frequencies for both reef manta rays and whale sharks peak in the months of June through November, with 27% and 40% of the total yearly manta and whale shark sightings respectively occurring in the month of August alone (Figs. 13 & 14). 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. 13). When accounting for the differential survey effort the trend becomes more evident (Fig. 15).

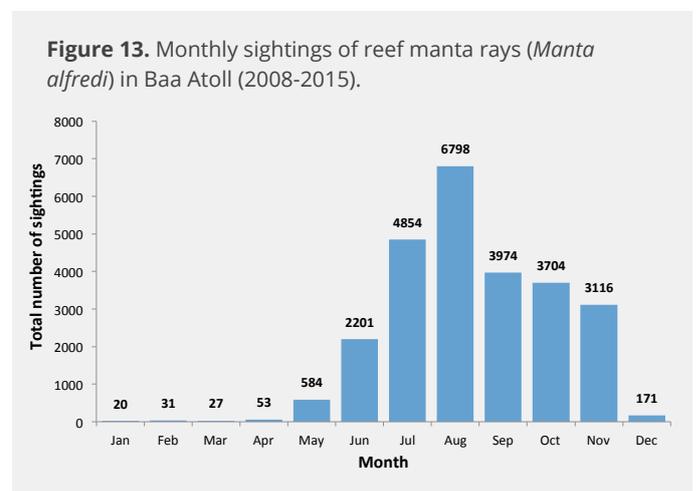


Figure 14. Monthly sightings of whale sharks (*Rhincodon typus*) in Baa Atoll (2008-2015).

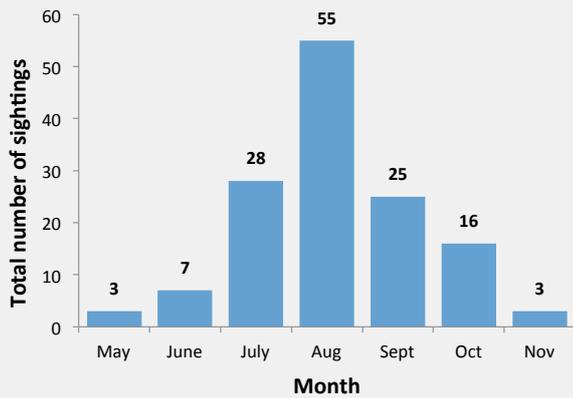
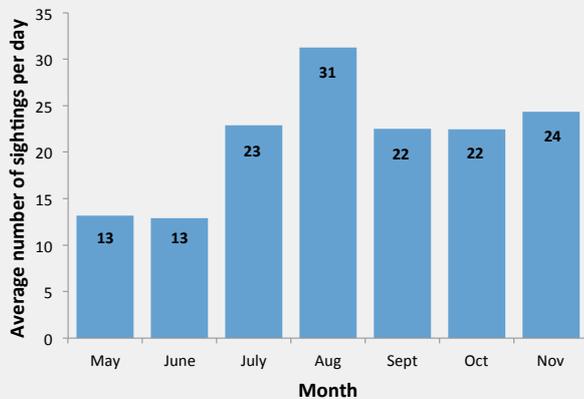


Figure 15. Average monthly sightings per survey day of reef manta Ray (*Manta alfredi*) in Baa Atoll (2008-2015)



Weather and Climatic Variation

As a continuation of the investigation instigated 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 mega fauna abundance in 2014. The average wind speed observed in 2015 was 16.0 Km/h, slightly lower than the previous year. Wind speed peaked in May (20 Km/h) and again in September (19.0 Km/h) and dropped significantly in October and November. Manta sightings pattern for 2015 is somewhat in contradiction to previous years. Although the overall average wind speed was lower than 2014, manta rays' sightings greatly increased (Fig. 16). While there appears to be a link between yearly average wind speed and average manta sightings per day ($R^2=0.1087$) (Fig.17), 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. 18). The strong monsoonal winds generally experienced in May and June are likely to kick start the plankton production through upwelling and are possibly the reason for August'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 16. Average yearly wind speed (Km/h) and average number of reef manta rays (*Manta alfredi*) sightings per day (2008-2015).

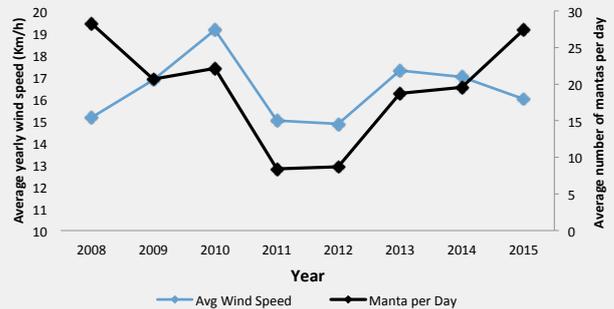


Figure 17. Average yearly wind speed (Km/h) and average number of reef manta ray (*Manta alfredi*) sightings per day (2008-2015).

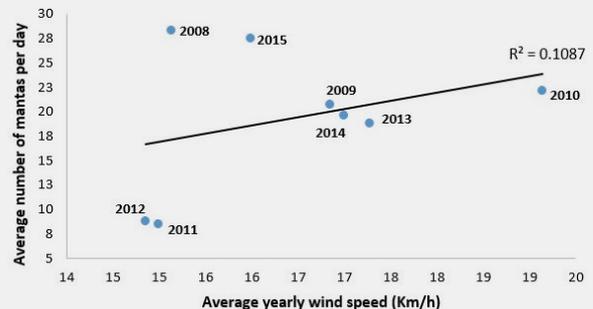
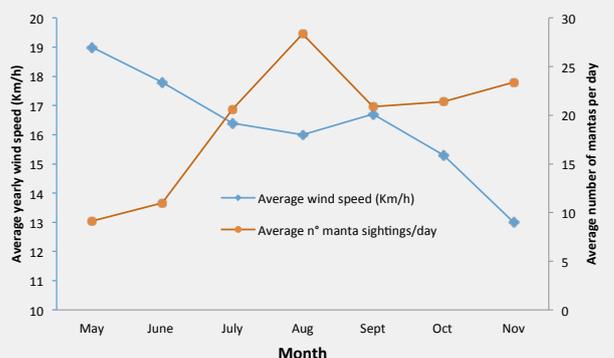


Figure 18. Average yearly wind speed against yearly average number of reef manta ray (*Manta alfredi*) sightings per day (2008-2015).





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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 cavernous mouth.

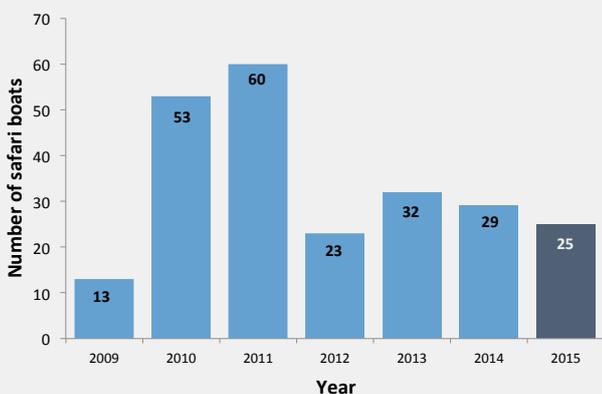
The fluctuation of food availability, monsoonal strength, manta rays' sightings and fecundity might be part of a natural cycle of variable weather patterns which occur within the Maldives over time, or more worryingly, they may be connected to larger climatic phenomenon such as the Indian Ocean Dipole (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 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 can be 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, having 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. 19). 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, 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 in the past few years. The resorts have continued to visit the MPA as in previous years.

Figure 19 . Number of different safari boats observed in Baa Atoll (June-November 2009-2015).



Baa Atoll Marine Education Programme

Building on the experience and network of contacts with the local communities developed over the past year, the MMRP proudly launched the first Marine Education Programme for local students. On the 17th October 2015 the Manta Trust and Kamadhoo School signed an official



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.

Memorandum of Understanding stating the reciprocal intention to initiate a yearlong Marine Education Programme for 8th and 9th grade students. With logistical support from the Four Seasons Resort at Landaa Giraavaru, the programme takes a holistic approach to marine biology themes and conservation issues with the aim to raise awareness and educate the young Maldivian generation, fostering a passion for the marine environment. The ultimate aim of the project is to inspire young students to pursue a career in marine biology and conservation. The programme is the result of a common effort between all resident marine biologists of Baa Atoll and has been designed to cover marine biology themes relevant to Baa Atoll Biosphere Reserve. So far we have conducted four teaching experiences under the topic of 'manta rays & whale sharks' and 'coral reefs'. The experiences consisted of two classroom-based lesson and two field trips; one to Hanifaru Bay MPA where the students were able to see and swim with manta rays, and the second to a coral reef where students had the opportunity to snorkel on a pristine reef and observe the importance of a healthy reef ecosystem. The education programme as a whole follows this arrangement structure, consisting of theory classes, which are conducted in classroom, and class fieldtrips, which will engage the students through 'hands-on' learning.

Led by our Education and Outreach Co-ordinator, Ibrahim Lirar, this initiative is the first of its kind in the Maldives and we seek to expand the programme to other local islands in Baa Atoll and the Maldives in the coming



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

years, as well as provide further job opportunities to Maldivian biologists and conservationists.

Educational activities have also been organised in North Malé and Laamu Atolls. Students of Bodu Huraa have participated in an environmental summer camp which allowed them to learn and experience more about manta rays, turtle and reef research and conservation. The camp was organised by the Manta Trust representative in collaboration with Seamarc at Four Seasons Kuda Huraa. Furthermore, as in previous years, MMRP members have actively participated to numerous environmental initiatives organised by local NGOs, such as Katti Hivvaru Festival, One Nation Coral Revival and the Whale Shark Festival in Ari Atoll.

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 2016.

Social Behaviour of Manta Rays

Leaders and Followers: individual differences in the social foraging strategies of reef manta rays (*Manta alfredi*)

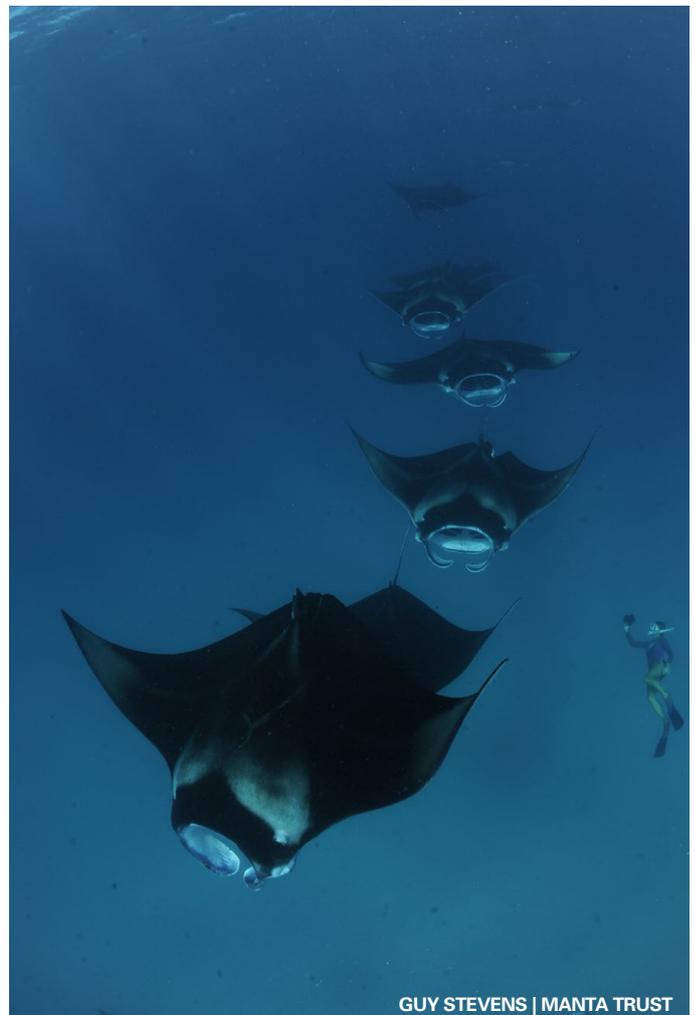
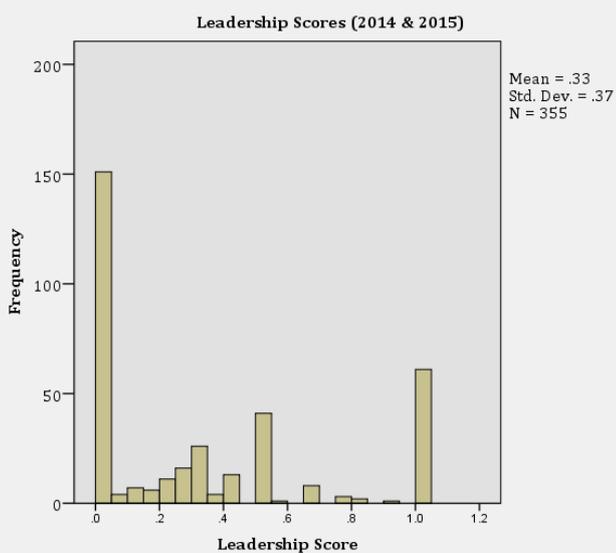
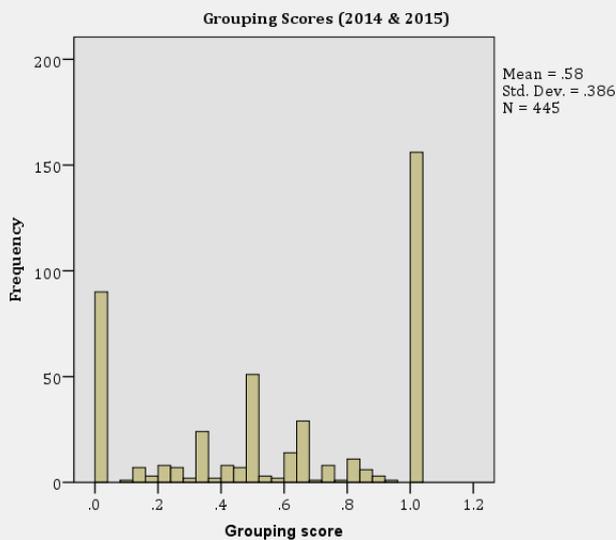
(PhD project – Annie Murray, University of York)

For her second field season Annie's main focus was on data collection to examine the roles played by individuals during social aggregations. Within animal groups, individuals will exhibit different types of behaviour, some acting as leaders in group decision making and some as followers. Thus, 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 follower. Most groups experience changes in leadership either intermittently or as part of a regular 'taking in turns' to lead. Individuals appear to change roles, leader or follower, in response to external factors such as environmental conditions (temperature, food availability), as well as internal factors including state dependent variables (body condition, hunger levels, reproductive status), demographic traits (age and sex) and group composition or dynamics. This study examines the emergence of leadership behaviour recorded within groups of wild reef manta rays (*M. alfredi*) and the traits influencing an animal's tendency to lead or follow during group interactions.

Analysis & Data Exploration

With two years of data resulting in 2133 individual feeding observations, Annie used a simple equation to examine the propensity of animals of individuals to adopt both grouping and leadership behaviour. Of those individuals which had a grouping score higher than zero (individuals which had been recorded in a group at least once) Annie then calculated a 'leadership score' to examine the propensity for these individuals to be a leader or a follower. Whilst 40 – 50% of individuals were only ever seen foraging alone, the majority of the remaining individuals showed a mixed or flexible foraging strategy - sometimes feeding alone and sometimes feeding in a group (Fig. 20a). Leadership analysis also shows a division between animals with a lower leadership score (less preference to lead) and higher scores (more likely to act as leader). The majority of mantas recorded a leadership score of 0 in both 2014 and 2015 meaning that they were never leaders, however combined data from 2014 and 2015 show a small group of animals with a score of 1 demonstrating a subgroup with leadership habits (Fig. 20b).

Figure 20 . Distribution of a) grouping and b) leadership scores from 2014 and 2015. A score of 0 indicates consistent solo feeding and a score of 1 consistent group feeding or an individual who always assumes the leader position and a score of 0 one that is always a follower.



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

Using the grouping and leadership scores, Annie examined the effect of external variables on the pattern of behaviour, for example sex, maturity, size and plankton density. Results from 2015 show that sex had a significant effect on the propensity to lead, indicating a difference between the years resulting in females being significantly more likely to be leaders in 2015 than males. To examine this result in 2015, Annie conducted further analysis on the size of individuals in association with sex for that year's data. Results showed that females had a significantly larger body size than males

in 2015 indicating that body size is a significant variable in leadership amongst reef manta rays, particularly in times of low food availability. This significance of body size in animal ranking is similar to studies of other fish species; Myrberg & Gruber (1974) recorded this same pattern in foraging activity in Bonnethead sharks, where the larger males held the higher rank and less submissive behaviour.

Divers' Knowledge

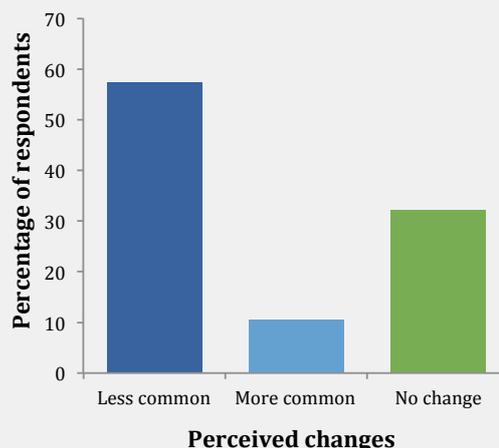
Study on the Value of Divers' Knowledge for Manta Rays' Conservation in the Maldives – MSc Research by Nicola Bassett – University of York, UK

With limited quantitative data of manta populations in the Maldives available prior to 2005, this study utilised diver knowledge to gather historical observations through interviews with experienced divers to assess

diver knowledge to gather historical observations through interviews with experienced divers to assess how manta ray distribution and abundance may have changed over time.

61 interviews with working divers in the Maldives were conducted during July and August 2015, with each interviewee having on average 18 years' experience working in the country. The divers were questioned on historical and current manta ray sightings and their responses suggested that 'hotspots' of manta activity had not changed radically over recent years (Table 1-2). However, at regularly visited sites the majority of divers (57%) perceived a decrease in manta ray numbers (Fig. 21), and particularly since 2010. The divers highlighted specific sites where declines may be more acute, most notably at Dhonkalo Thila (North Ari Atoll) and Lankan Beyru (North Malé Atoll), where it was suggested anthropogenic factors could be responsible. It was also suggested that there are many 'new' manta aggregation sites in the Maldives, however this is most likely due to an expanding tourism industry and exploration for novel areas.

Figure 21 . Perceived changes in manta ray sightings over the last year (2015) as reported by 61 interviewed divers.



Conducting this research afforded the opportunity to evaluate diver knowledge and perception of marine conservation in the Maldives. The majority of respondents (89%) thought the work scientists and marine conservationists do is important and 70% were currently involved in at least one conservation programme, ranging from PADI's Project Aware programme to taking identification photos for Manta Trust or the MWSRP. However, over half (56%) of respondents were not satisfied with the level of communication between scientists/conservationists and the tourism industry, and expressed the need for more interaction between the two groups. Respondents seemed very knowledgeable about appropriate behaviour when diving or snorkelling with manta rays, and it was suggested there was a high level of compliance, either with guidelines issued by their operator, or with the Best Practice Code of Conduct issued by Manta Trust.

These results contribute to continuing research into the Maldivian population of reef manta rays; in particular, how distribution and abundance may have changed over time and also give further insight into societal awareness and attitudes towards marine conservation in the Maldives, which may have implications for future marine management programmes.

Conservation and Management

The declaration, at the end of June 2011, that Baa Atoll was to become a UNESCO World Biosphere Reserve

Table 1. The five most commonly visited sites prior to 2005 as reported by the 61 interviewed divers.

Site	No. of respondents who mentioned visiting each site
Lankan Beyru	26
Dhonkalo Thila	17
Rangali Madivaru	17
Sunlight Faru	11
Hanifaru Bay	10

Table 2. The five most commonly visited sites during the last five years (2010-2015) as reported by 61 interviewed divers.

Site	No. of respondents who mentioned visiting each site
Lankan Beyru	18
Dhonkalo Thila	14
Rangali Madivaru	13
Moofushi Kandu	12
Hanifaru Bay	10



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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.

remains an important milestone for the Maldivian manta rays, with great implications for their ongoing protection, especially given the designation of Hanifaru Bay MPA as a core zone of the reserve. Management of these newly protected areas is crucial and we look forward to a more constant 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.

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:

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

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