Manta TRUST

Maldivian Manta Ray Project

RAA ATOLL | ANNUAL REPORT 2021

Conservation through research, education, and collaboration

- The Manta Trust

MALDIVIAN MANTA RAY PROJECT

WHO ARE THE MANTA TRUST?

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

The Manta Trust takes a multidisciplinary approach to conservation. We focus on conducting robust research to inform important marine management decisions. With a network of 29 projects worldwide, we specialise in collaborating with multiple parties to drive conservation as a collective; from NGOs and governments, to businesses and local communities. Finally, we place considerable effort into raising awareness of the threats facing manta rays, and educating people about the solutions needed to conserve these animals and the wider underwater world.

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

MALDIVIAN MANTA RAY PROJECT

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

The MMRP collects data around the country's manta population, its movements, and how the environment and tourism / human interactions affect them. Since its inception, the MMCP has identified over 5,500 different individual reef manta rays, from more than 80,000 photo-ID sightings. This makes the Maldives manta population the largest, and one of the most intensively studied populations in the world. The MMCP has also identified more than 830 different individual oceanic manta rays.

The long-term and nationwide data collected by the MMRP has allowed researchers to record and identify key patterns within this population over time. Not only does this invaluable information improve our understanding of these animals, but it informs their ongoing management and protection both in the Maldives, and around the world.

THE CONSERVATION CHALLENGE

In the last two decades, manta and mobula rays have faced increasing threats from both targeted and bycatch fisheries, due in part to a growing trade in Asia for their gill plates. The gill plates are what these rays use to filter zooplankton from the water. In Traditional Asian Medicine, it is believed these gill plates will filter the human body of a variety of ailments when consumed in tonic. There is no scientific evidence to support this claim.

Unregulated and badly managed tourism is also negatively affecting manta rays, while climate breakdown, reef degradation and pollution is reducing the manta's food supply and suitable habitat.

Manta and mobula rays are particularly vulnerable because of their aggregating behaviour and conservative life-history; they grow slowly, mature late in life, and give birth to few offspring. These traits make it very easy to wipe out entire populations in a relatively short period of time. With protection in place, populations are still slow to recover.

Photo by Marla Tomorug

EXECUTIVE SUMMARY

This report presents data collected by the Manta Trust's Maldivian Manta Ray Project (MMRP) on the reef manta ray (*Mobula alfredi*) population of Raa Atoll in 2021. Data used in this report was collected by MMRP staff, collaborating tour guides, and by citizen scientists submitted to the Manta Trust's through its IDtheManta database.

Since the establishment of the MMRP's first permanent research base in Raa Atoll in 2019, there has been significantly higher survey effort within the region. Details on the ecology, population demographics, and movements of Raa Atoll's reef manta rays throughout 2021 are provided in this report.

Raa Atoll supports a year-round presence of reef manta rays, which follow the seasonal abundance of their zooplanktonic prey across the atoll with the changing South Asian Monsoon. Key findings include 4,458 sightings of 927 individual reef manta rays, recorded at 46 different sites within Raa Atoll between 2007 and 2021. Twenty-six percent (*n*=82) of the individuals sighted in Raa Atoll in 2021 (*n*=312), were new to the Raa Atoll reef manta ray population. Of the 82 new individuals, 39% (*n*=32) were new to the Maldives population, with two individuals being recorded as new-born young of the year.

The demographics of the Raa Atoll regional reef manta ray population (*n*=927) are split almost equally by gender; with 485 (52%) females, 436 (47%) males, and six individuals (1%) for which sex could not be determined. Overall, 59% (*n*=544) of the individuals are mature adults, while 41% are immature: 38% (*n*=350) juveniles and 4% (*n*=33) subadults.

The Maamunagau sub-region in southern Raa Atoll provides suitable habitat for a large sub-population of immature reef manta rays (*n*=293), which exhibit high fidelity to this region during the Northeast Monsoon. Demographically, there is a higher presence of juvenile females (*n*=110) than there are juvenile males (*n*=45) within the Maamunagau population. Dissimilarly, the proportion of adults in the Maamunagau population are higher in males (*n*=89) than in females (*n*=31).

Of the 927 individual reef manta rays recorded in Raa Atoll, 86% (*n*=794) have been re-sighted within the region, or elsewhere in the Maldives, suggesting that the vast majority of the individuals which frequent this region have now been identified. Sixty-seven percent (*n*=622) of the recorded manta ray population has been recorded in other geographical atolls throughout the Maldives. This migratory behaviour suggests a large proportion of the population is, at least some of the time, highly mobile; travelling hundreds of kilometres throughout the archipelago.

Throughout the study period, reproductive activity (including courtship events and visible pregnancies) was recorded in Raa Atoll. In 2021, three courtship events involving six individuals were recorded at cleaning stations on the East of Raa Atoll, although more data is needed to understand courtship activity within the

atoll. Twenty-nine percent (*n*=16) of the adult female manta rays recorded in 2021 (*n*=56), were observed to be visibly pregnant. However, this should not distract from the overall low fecundity of these animals.

Tourism pressures in Raa Atoll are increasing, with the number of tourists swimming with manta rays doubling in 2021, compared to previous years. Extensive studies by the MMRP show that unregulated tourism can have a negative impact on marine megafauna. The Manta Trust and the MMRP continued to disseminate their 'How to Swim with Manta Rays' tourism code of conduct in 2021 to as many involved tourism operators as possible. Operators and tourists will continue to be equipped with the tools and information they need to make their excursions as sustainable as possible.

Efforts to conserve the natural heritage of Raa Atoll and manage the increasing human impacts upon the environment are encouraging. 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 to the Maldives, bringing tens of thousands of divers and snorkellers to the country every year, and generating millions of USD for the economy annually. Being able to pinpoint the reasons for any observed trends in, or threats to, the Maldives manta ray population is crucial for the ongoing management and protection of these animals.

STUDY AREA

Raa Atoll is a large (1,180 km^2) complex atoll, consisting of 95 islands. The atoll is part of the Northern province of the Maldives archipelago. Administratively, Raa Atoll also includes the very small (4 km^2) oceanic platform reefs of Alifushi Atoll, which consists of two islands. However, this report does not include Alifushi Atoll due to the lack of manta sightings from this area. Raa Atoll remains relatively underdeveloped compared to the more central atolls of the Maldives, only opening to tourism in the late 1990s. Although tourism is gradually increasing with the opening of two more resorts in Raa Atoll in 2021 bringing the total to 14 resorts within the atoll, it is the further five forecast to open in 2022/23 that are of more concern.

Most of the data collected in Raa Atoll to date has been collected from the central to southern areas of the atoll. However, future site exploration and data collection in the more northern regions is necessary to gain a better understanding of the entire Raa Atoll reef manta ray population. Due to the seasonal migration patterns of the manta rays, research efforts are focused on the west side of the atolls during the Northeast Monsoon (December to April), and on the east during the Southwest Monsoon (May to November).

Photo by Simon Hilbourne

STUDY PERIOD & SAMPLING METHODOLOGIES

Sampling Methodology

Manta ray sightings data in Raa Atoll was obtained via photo identification (photo-ID) and was collected throughout the atoll both by full-time MMRP researchers and citizen scientists (tourists, local dive guides, snorkel leaders, and marine biologists). Individual manta rays that were sighted in the water were documented by photographing the unique spot patterns on their ventral surface, allowing for the identification of individuals. In the context of this report, a sighting is defined as a confirmed photo-ID of an individual manta ray on a given day at a specific location. Surveys were conducted from the research vessel or in-water, both on SCUBA and via snorkelling, with sightings recorded at 46 different sites during the study period 2007 – 2021. Twelve of these sites were classified as key aggregation sites due to higher (>40) numbers of manta ray sightings. These key sites were then pooled into five sub-regional groups for comparative analysis based on their geographical position within the atoll and the demographics of the manta rays that frequent the sites (Fig. 1) (Table 1).

During each survey performed by the MMRP researchers, individual manta ray sightings were documented via photo-ID. In addition, researchers collected data on location, manta ray numbers and predominant behaviour, environmental variables (including wind speed, current direction, and plankton density), and tourism data (including the number of divers/snorkellers, number of boats, and number of paying guests). Data was collected during all surveys, regardless of whether manta rays were sighted or not. Citizen scientists recorded data only during surveys resulting in a confirmed manta ray sighting. In addition to submitting sighting photos to the MMRP for identification purposes, citizen scientists noted the trip location, manta ray sighting time, and the manta ray's prevalent behaviour.

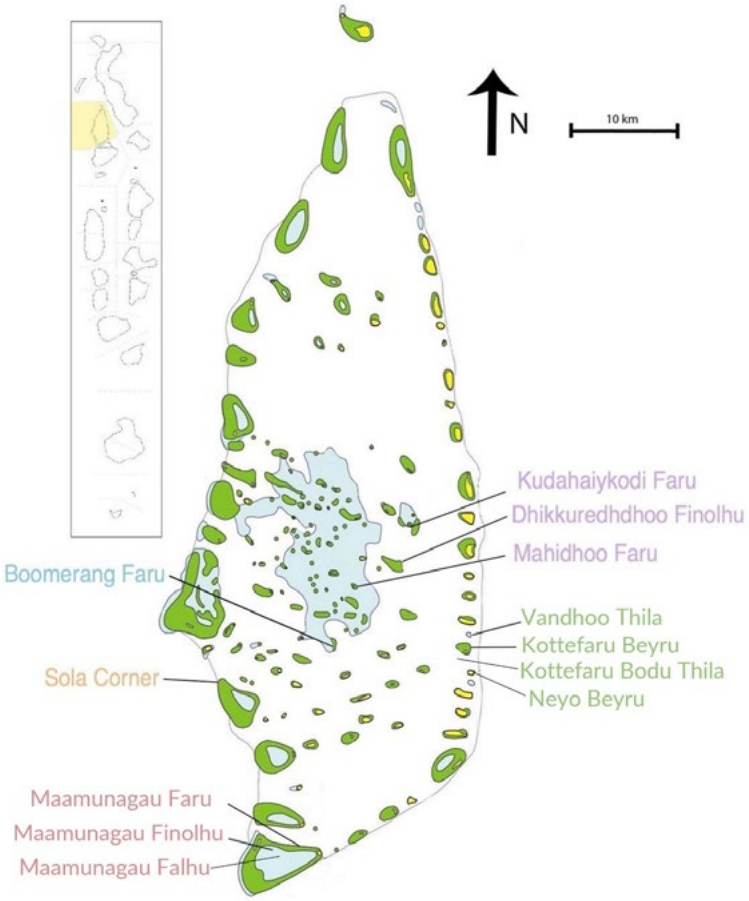

Figure 1: Map of Raa Atoll showing twelve of the key reef manta ray (*Mobula alfredi*) aggregation sites (colour-coded by five sub-regional areas) within the geographical atoll. Also shown in the inset box is Raa Atoll in relation to the rest of the Maldives Archipelago.

Table 1: Twelve key reef manta ray (*Mobula alfredi*) aggregation sites within Raa Atoll pooled into five sub-regional areas for comparative analysis based on their geographical position and population demographics.

	Site Name	Atoll	Location	Habitat	Demographic
1	Kottefaru Beyru	Raa Atoll	East	Outer Reef	Adults
	Kottefaru Bodu Thila	Raa Atoll	East	Channel	
	Neyo Beyru	Raa Atoll	East	Outer Reef	
	Vandhoo Thila	Raa Atoll	East	Channel	
2	Kudahaiykodi Faru	Raa Atoll	Central	Inner Reef	Adults
	Mahidhoo Faru	Raa Atoll	Central	Inner Reef	
	Dhikkuredhdhoo Finolhu	Raa Atoll	Central	Inner Reef	
3	Boomerang Faru	Raa Atoll	Central	Inner Reef	Adults
4	Maamunagau Falhu	Raa Atoll	West	Lagoon	Juveniles
	Maamunagau Faru	Raa Atoll	West	Inner Reef	
	Maamunagau Finolhu	Raa Atoll	West	Lagoon	
5	Sola Corner	Raa Atoll	West	Outer Reef	Adults

Study Period

Prior to 2019, nearly all sightings were reported by citizen scientists as the MMRP researchers conducted only periodic surveys in Raa Atoll during this time. Between 2007 through 2018, only surveys resulting in a confirmed manta photo-ID sighting were recorded, therefore sightings cannot be standardised for effort prior to 2019. The MMRP conducted an initial scoping project based at Maamunagau Island from February to March 2019, before establishing a permanent research base at the InterContinental Maldives Maamunagau Resort in September 2019.

During 2021, surveys to look for manta rays (*n*=693) were carried out on as many days (*n*=163) that conditions and logistical operations allowed. Ninety percent of surveys conducted in 2021 (*n*=622) were performed by the MMRP, carried out either by trained researchers (*n*=513) or Remote Underwater Video systems (*n*=109). In addition to the data collected by the MMRP, 71 surveys were also conducted by external parties.

Although survey efforts varied throughout 2021 (Fig. 2), there was much higher survey effort during the Northeast Monsoonal months of February and March (Fig. 2). This is a result of the MMRP team based in Raa Atoll having access to a dedicated research vessel for these two months, allowing for intensive daily surveys to be conducted. The lower survey effort between May and September 2021 (Fig. 2) is due to the lack of access to a research boat, and most guest-orientated trips being led to Baa Atoll, to visit the world-famous Hanifaru Bay, which is excluded from this report. The slight increase in survey effort during the Southwest Monsoonal months of October and November were mostly a result of Manta Expedition Liveaboard excursions passing through Raa Atoll with a Manta Trust representative onboard, as well as the Manta Trust-led Far North Expedition, which passed through Raa Atoll as part of their route and itinerary.

Photo by Jasmine Corbett

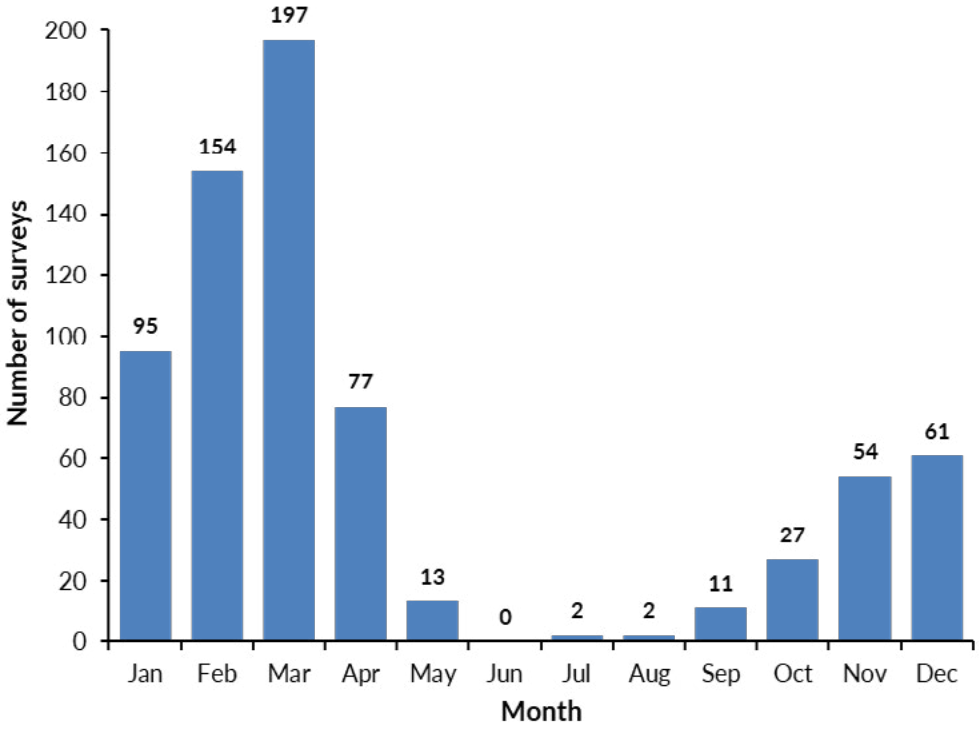

Figure 2: Number of surveys (*n*=693) undertaken in Raa Atoll (2021).

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Raa Atoll Sighting Records

A total of 4,458 sightings were recorded at 46 different sites throughout Raa Atoll between 2007 – 2021. Seventy-five percent (*n*=3,324) of all sightings were recorded between 2019 – 2021 due to increased survey efforts (Fig. 3).

In 2021, a total of 1,366 reef manta ray sightings were recorded in Raa Atoll, the highest number of recorded sightings in the atoll to date. The data shows a substantial increase (124.3%) in reef manta ray sightings compared to the previous year (*n*=609) in 2020, and a minor increase (1.25%) compared to 2019 (*n*=1,349). This is because the national pandemic lockdown in 2020 prevented any research efforts from taking place between April to November, and hence a full year of data collection on the Raa Atoll reef manta ray population was unable to be obtained.

A monthly breakdown of manta ray sightings across 2021 shows that sixty-eight percent of the sightings (*n*=924) were recorded from January to April (Fig. 4), with MMRP researchers performing regular surveys at this time. A second peak in sightings was recorded from October to December 2021 (*n*=403), a similar trend as seen in 2019 but not in 2020. When standardised for survey effort, the mean number of individuals sighted per survey peaked during the Northeast Monsoon month of February (*n*=2.6), with a second peak recorded in October (*n*=4.4) during the Southwest Monsoon (Fig. 4).

When looking at the three months of comparable data collection efforts for Raa Atoll across the past three years (January, February, and March), interestingly 2019 and 2021 seem to follow a similar trend of a lower number of sightings in January, and a higher number of sightings in March (Fig. 5). In contrast, 2020 shows a higher number of sightings in January and lower number in March (Fig. 5). This likely reflects the sighting activity recorded in the previous years' month of December, and therefore the timing of the monsoon seasonal change. For example, with an all-time low of manta sightings recorded during December 2020 (*n*=7), a slow start to manta sightings in 2021 was also seen (*n*=67). Comparatively, with much higher sighting numbers recorded in December 2019 (*n*=93); sightings were also high during the month of January 2020 (*n*=173). Without certain knowledge of the survey effort in December 2018, the same conclusion cannot be drawn for January 2019. However, with more years of data collection, more in-depth comparisons between the years can be made.

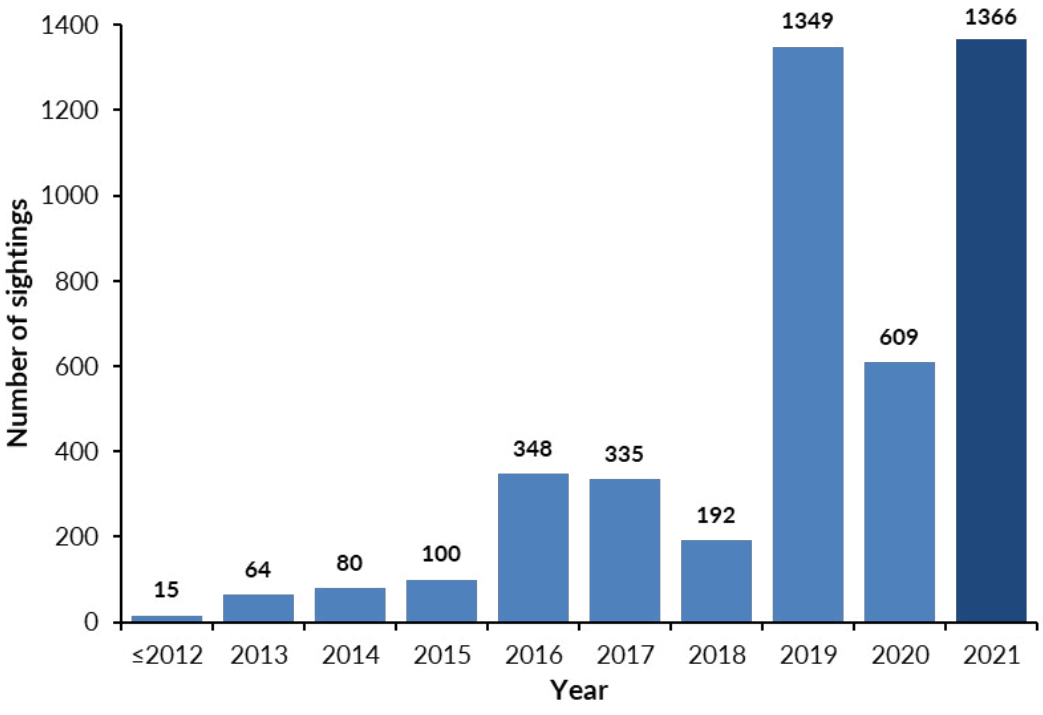

Figure 3: Annual sightings of reef manta rays (*Mobula alfredi*) in Raa Atoll.

During 2021, 90% (*n*=1,228) of sightings were recorded by MMRP researchers, whilst the remaining records were submitted by citizen scientists. Prior to 2019, the MMRP relied almost solely upon manta ray encounter reports from citizen scientists based at resorts, guest houses, and liveaboards within Raa Atoll. Citizen science remains an important tool for collecting reef manta ray sightings data. However, more consistent, year-round monitoring by MMRP researchers in the future will allow for a better understanding of trends in manta ray sightings in the region.

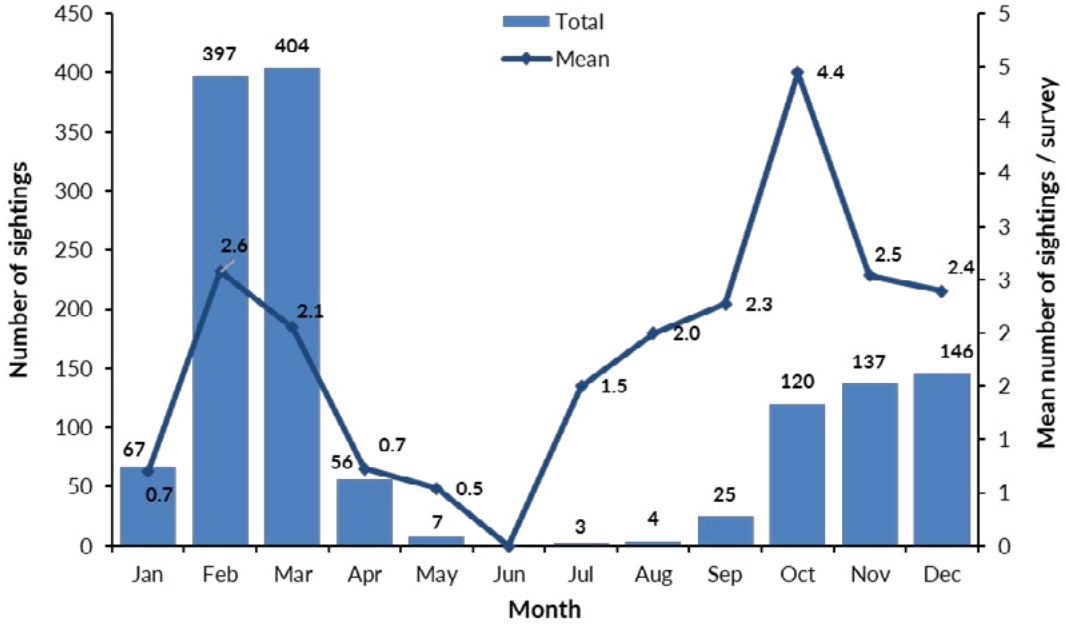

Figure 4: Monthly sightings of reef manta rays (*Mobula alfredi*) in Raa Atoll, and the mean number of sightings per survey (2021).

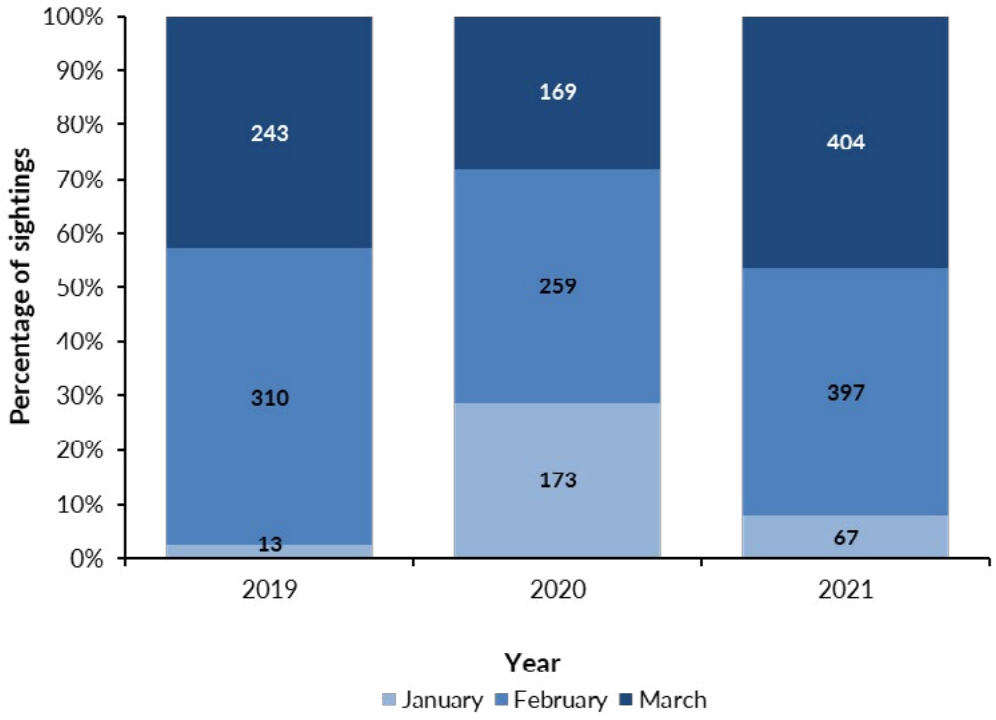

Figure 5: Distribution of reef manta ray (*Mobula alfredi*) sightings by month in Raa Atoll, during the Northeast Monsoon. Actual numbers within bars.

Raa Atoll Population Demographics

The current recorded population of reef manta rays in Raa Atoll is 927 individuals, 18% of the total recorded Maldives population (*n*=5,251).

The population demographics in Raa Atoll are split almost evenly by gender, with 485 (52%) females, 436 (47%) males, and six individuals (1%) for which gender could not be determined (Fig. 6). Overall, 59% (*n*=544) of the Raa Atoll population are mature adults, while 41% are immature: with 38% (*n*=350) juveniles and 4% (*n*=33) subadults (Fig. 6). When looking at the maturity of the population by gender, Raa Atoll has a higher number of juvenile females (*n*=274), compared to juvenile males (*n*=71), whereas there are more adult males (*n*=336), than adult females (*n*=208) (Fig. 6).

A total of 312 individual reef manta rays (5.9% of the Maldives population) were recorded in Raa Atoll in 2021, which is a substantial increase compared to the number of individuals sighted in 2020 (*n*=178), but a decrease compared to 2019 (*n*=485) (Fig. 7). This reflects the differences in survey effort compared to 2020 and 2019. During 2021, twenty-six percent (*n*=82) of the individuals sighted were new to the Raa Atoll reef manta ray population.

A slight increase in new individuals sighted compared to the 21% in 2020 (*n*=37), but a major decrease compared to the 51% of new individuals identified in 2019 (*n*=245) (Fig. 7). This downward trend in newly sighted individuals is expected. As years pass and more data is collected, sightings of new manta rays become less frequent.

In 2021, of the 82 new individuals recorded, 39% (*n*=32), had never been recorded elsewhere in the Maldives, while 61% (*n*=50) had previously been recorded in other atolls. Comparatively, in 2020, of the 37 new individuals recorded, 46% (*n*=17) had never been recorded elsewhere in the Maldives, while 54% (*n*=20) had previously been recorded in other atolls.

To date, 86% (*n*=794) of Raa Atoll's reef manta ray population (*n*=927) has been re-sighted in either Raa Atoll or elsewhere in the Maldives, suggesting most of the reef manta ray population which frequent Raa Atoll has now been recorded. Of the 82 new individuals recorded in 2021, two individuals were estimated to be young of the year, based on their small disc widths, measuring approximately 150 centimetres.

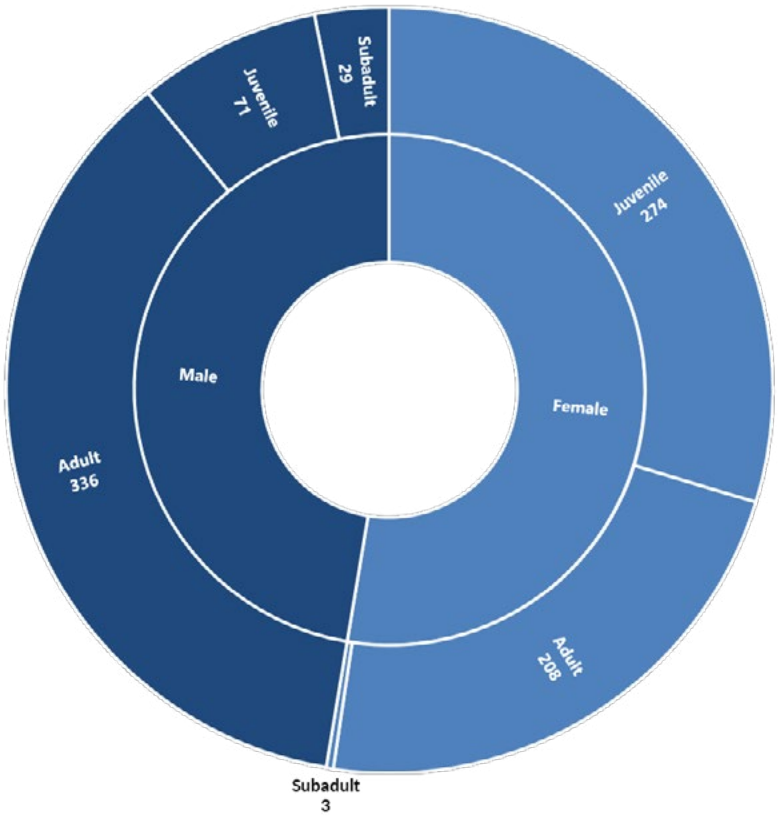

Figure 6: Demographics of the reef manta ray (*Mobula alfredi*) population (*n*=927) recorded in Raa Atoll (2007 – 2021).

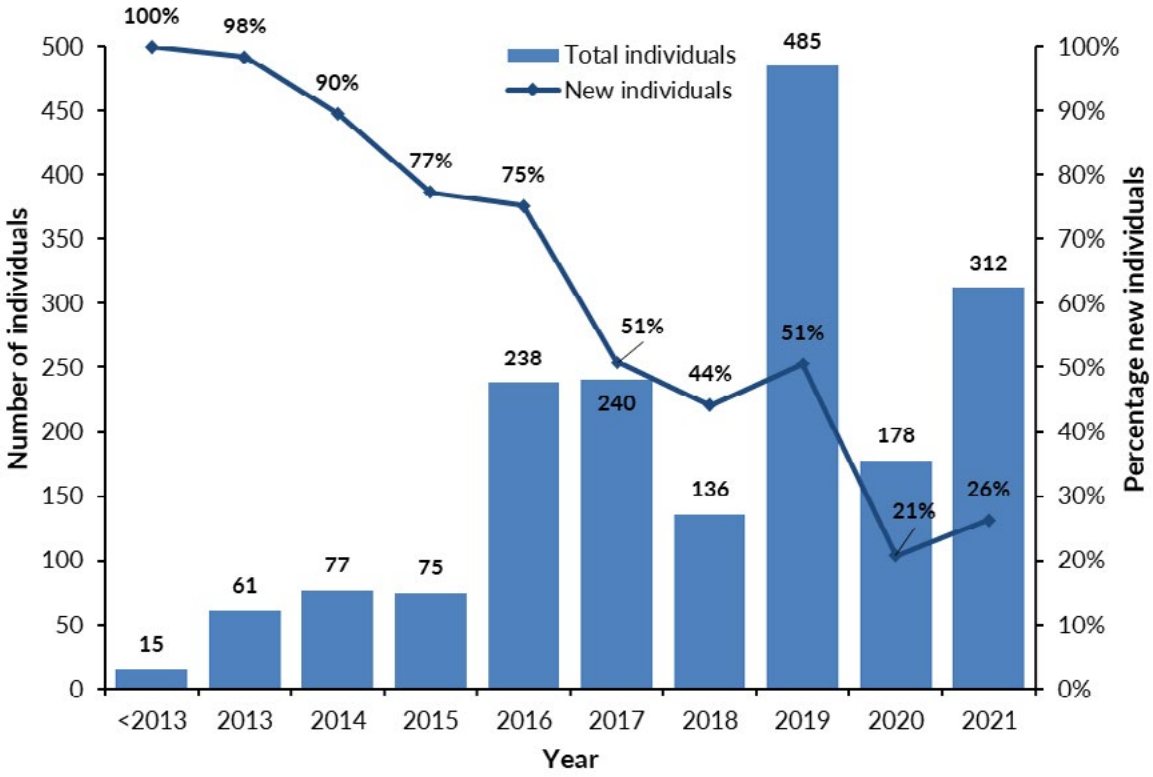

Figure 7: Number of individual reef manta rays (*Mobula alfredi*) sighted annually in Raa Atoll and the percentage of those individuals that were newly recorded.

Intra-Atoll Migrations

Reef manta rays in the Maldives migrate seasonally, moving between the eastern and western sides of the atoll with the changing South Asian Monsoon. Overall, sightings in Raa Atoll show the same seasonal movement patterns as the country's other larger atolls, with reef manta rays visiting the western aggregation sites during the Northeast Monsoon (December to April), before returning to the eastern aggregation sites during the Southwest Monsoon (May to November). Ninety-five percent (*n*=4,228) of all sightings from 2007 - 2021 were recorded at the twelve key reef manta aggregation sites in Raa Atoll (Fig. 1). Variations in site use can be better understood by pooling sightings from these locations into five groups based on their geographical position within the atoll and population demographics (Table 1).

Overall, in 2021, intra-annual sightings of reef manta rays mostly conform to the expected migration patterns in the region. This is evident as the sightings peak first during the months of January to April (Northeast Monsoon) at Maamunagau (Group Four) and Sola Corner (Group Five) situated on the west of the atoll (Fig. 8). From May onwards, sightings at these sites decrease, with a noticeable lull in manta ray sightings across all sites until August when sightings gradually increase at the eastern sites (Group One) during the Southwest Monsoon, with a peak in sightings at this aggregation area during the months of October and November (Fig. 8). The lack of manta sightings from June to August is a likely result of lower survey effort in the region rather than a reflection of the manta ray activity, with Manta Trust staff absence (annual leave), no access to a research boat, and the majority of guest orientated trips being led to Baa Atoll, Hanifaru Bay, leaving the Raa Atoll sites mostly unmonitored, and only four external IDtheManta survey contributions from citizen scientists at this time.

The unmentioned aggregation areas Kudahaiykodi Faru (Group Two) and Boomerang Faru (Group Three) are both centrally located in the atoll and had no reef manta ray recorded activity in 2021, except three individuals identified in November, during a Manta Trust led research expedition. Compared to previous years of data collection (2007-2020) we would expect reef manta ray activity at Group Two to conform to similar trends of Group One, with activity increasing during the Southwestern Monsoon months of August to November. This data highlights the importance of the Manta Trust having year-round access to monitoring of all these aggregation areas, the hopes for the next year are to have consistent access to a research boat facility and increase awareness within the

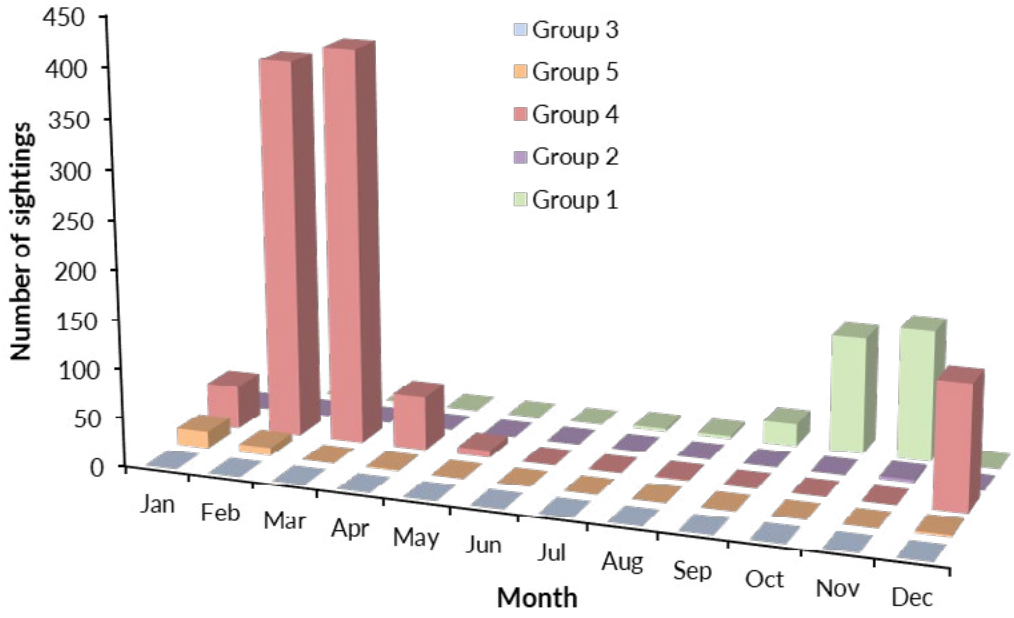

Figure 8: Intra-annual variations in sightings of reef manta rays (*Mobula alfredi*) at twelve key aggregation sites (pooled into five sub-regional areas) in Raa Atoll (2021).

Atoll community to encourage IDtheManta submissions.

There is a significant amount of inter-annual variation in reef manta ray sightings between, and within, these regional groups (Fig. 9), this is mostly due to the varying survey effort across years and the seasons during which effort was focussed.

A closer analysis of reef manta ray activity within Maamunagau (Group Four) reveals the importance of this location, which supports the highest number of reef manta ray sightings compared to any of the other aggregation groups in Raa Atoll (*n*=2,112). This is likely a result of the higher levels of survey effort in this region by MMRP researchers. Ninety-nine percent (*n*=2,092) of sightings from these sites were collected during 2019 (*n*=558), 2020 (*n*=510), and 2021 (*n*=1,024). During the 2019 and 2020 survey years, sightings peaked during the month of February (Fig. 10). However, in 2021 sightings peaked in March and remained high in April (Fig. 10). December saw the highest number of sightings in 2021 (*n*=128) compared to 2019 (*n*=83) and 2020 (*n*=5); although it should be noted that survey effort was highest in December 2021 (*n*=51) compared to 2019 (*n*=36), and 2020 (*n*=35). The early presence of manta rays at the start of the Northeast Monsoon during both December 2019 and December 2021 is likely due to the timing of the change in season in the Maamunagau region during the month of December, as witnessed by a low number of manta ray sightings in December 2020 followed by a longer period of activity through to April 2021 (Fig. 10), suggesting a delayed change between seasons (Southwest to Northeast) from 2020 to 2021.

The second-highest number of reef manta ray sightings in 2021 (*n*=283) occurred at the eastern sites (Group One) (Fig. 9). To better understand the movement of manta rays from East to West as the seasons change within the atoll, we can use aggregation sites Group One (East) and Group Four (West) to describe some initial trends. However, without data from Group One in 2020, we can only preliminarily compare data from 2019 and 2021 (Fig. 11). Interestingly 2021 shows a very quick seasonal change, with manta rays sightings peaking in the East (Group One) in November (*n*= 134) and similarly peaking again in December (*n*=128) on the West (Group Four) (Fig. 11). In comparison when we look at the 2019 data (Fig. 11), we see that sightings peaked at the Eastern sites (Group One) in October (*n*=198), before dropping in November (*n*=36), and then increasing in December (*n*=83) at the Western sites (Group Four). This lull in sightings observed during the last quarter of 2019 is typically expected as seasons change and is a pattern described in historical MMRP reports in various atolls. The quick seasonal change and resultant migration of manta ray activity from the East to the West of the atoll in the last quarter of 2021, is suggestive of an instantaneous seasonal change that year. This is the first time that this trend has been recorded in Raa Atoll. More consistent monitoring by MMRP researchers in the future will hopefully help to elucidate any trends in manta ray sightings at these key aggregation areas and intra-atoll migrations between seasons.

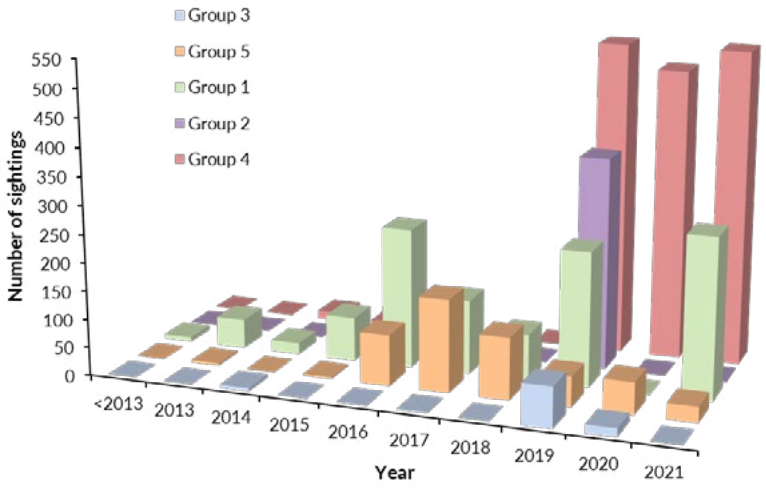

Figure 9: Inter-annual variations in sightings of reef manta rays (*Mobula alfredi*) at twelve key aggregation sites (pooled into five sub-regional areas) in Raa Atoll.

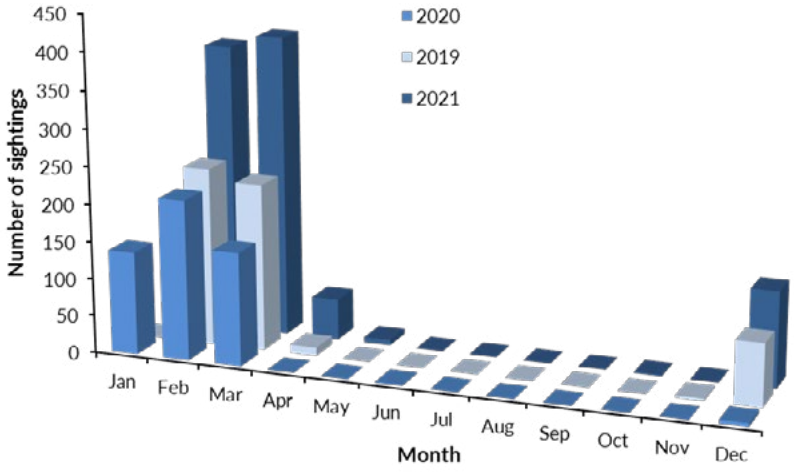

Figure 10: Intra-annual variations in sightings of reef manta rays (*Mobula alfredi*) at key aggregation sites Maamunagau Falhu, Maamunagau Finolhu and Maamunagau Faru (Group 4) (2019 – 2021).

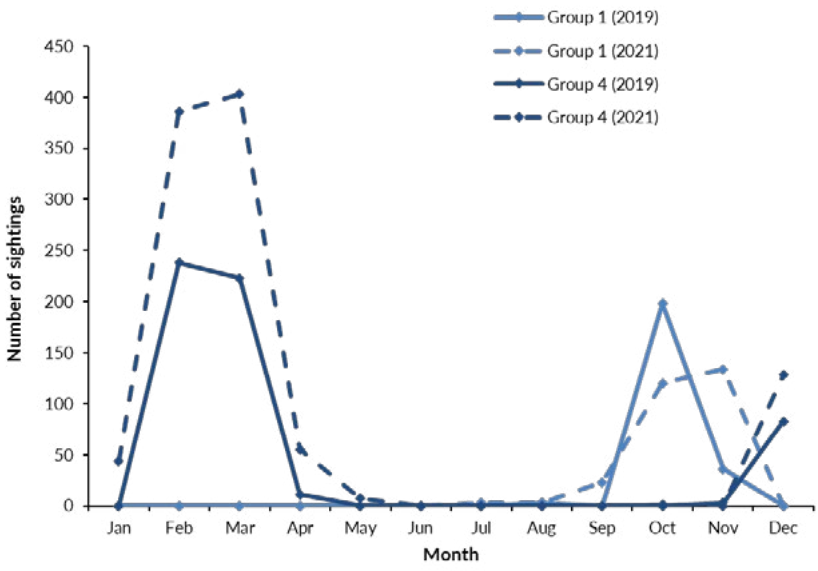

Figure 11: Inter-annual variations in sightings of reef manta rays (*Mobula alfredi*) at the two main aggregation sites (Group 1 & 4) in Raa Atoll, across comparable survey years (2019 & 2021).

Maamunagau Sighting Records

The Maamunagau sub-region of Raa Atoll is comprised of six survey sites; Maamunagau Falhu, Maamunagau Faru, Maamunagau Beyru, Maamunagau Finolhu, Maamunagau Bodu Hiri, and Maamunagau Giri (hereinafter referred to as Maamunagau) (Fig. 12). The high number of sightings and re-sightings of juvenile reef manta rays in Maamunagau, combined with the prevalence of many new-born pups recorded each year, continues to indicate that Maamunagau may serve as nursery habitat for these young individuals. To better understand the population of reef manta rays in this sub-region, survey efforts continued at these sites in 2021 (*n*=488), allowing further analysis to be performed.

In 2021, a total of 1,026 reef manta ray sightings were recorded at five of the Maamunagau sites: Maamunagau Falhu (*n*=786), Maamunagau Finolhu (*n*=225), Maamunagau Faru (*n*=13), Maamunagau Beyru (*n*=1), and Maamunagau Bodu Hiri (*n*=1). The data shows a huge increase (96.5%) in sightings compared to the previous years (*n*=568 in 2019 and *n*=522 in 2020). A monthly breakdown of reef manta ray sightings across 2021, when standardised for survey effort, shows that the mean number of individuals sighted per survey peaked during the month of February (*n*=386), was similar between March (*n*=403) and December (*n*=129), but significantly lower in January (*n*=45) (Fig. 13). It should be noted that the peak witnessed in August (*n*=1) is a complete outlier, with only one juvenile manta ray seen during one citizen science survey, on one day. To understand whether juvenile manta rays are remaining in Maamunagau during months outside of the normal season (Northeast Monsoon), more survey efforts would be required across the Southwest Monsoon months (June through November).

The survey site, Maamunagau Falhu, accounted for seventy-seven percent (*n*=786) of the reef manta ray sightings (*n*=1,026) in the Maamunagau sub-region in 2021, a slight decrease compared to the eighty-six percent (*n*=449) of sightings (*n*=522) in 2020. This is due to the increased monitoring efforts through the use of Remote Underwater Videos (RUV's) which were deployed at Maamunagau Finolhu and accounted for 22% (*n*=225) of all Maamunagau sightings in 2021. Maamunagau Falhu is predominately utilised by feeding manta rays (Fig. 14). In contrast, at Maamunagau Finolhu, the primary behaviour observed is cleaning (Fig. 14). Manta rays tend to frequent cleaning stations that are near their plankton-rich feeding areas.

Remote underwater video (RUV) surveys are commonly used in research to monitor specific areas and their use by different marine life whilst humans are absent. Twenty percent (*n*=100) of the surveys conducted within Maamunagau in 2021 (*n*=488) were collected using RUVs. A total of 166 sightings of 58 individuals were recorded over the 100 RUV surveys, which makes up 16% of the total Maamunagau sub-regional sightings (*n*=1,026). Of the 58 individuals recorded, ninety-five percent (*n*=55) were also recorded during human observations somewhere within Maamunagau throughout 2021. The three remaining individuals (MV-MA-4277, MV-MA-4830 & MV-MA-4920) would have not been recorded in the Maamunagau region without the deployment of the RUV systems, proving the value of this method when monitoring

Photo by Jasmine Corbett

Figure 12: Map of Maamunagau in Raa Atoll, showing the six reef manta ray (*Mobula alfredi*) survey sites within the sub-region.

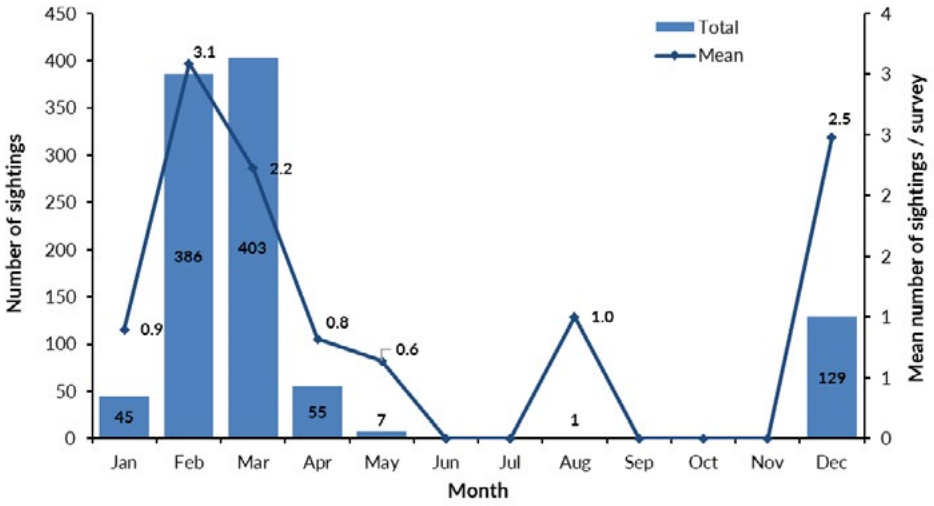

Figure 13: Monthly sightings of reef manta rays (*Mobula alfredi*) at Maamunagau in Raa Atoll, and the mean number of sightings per survey (2021).

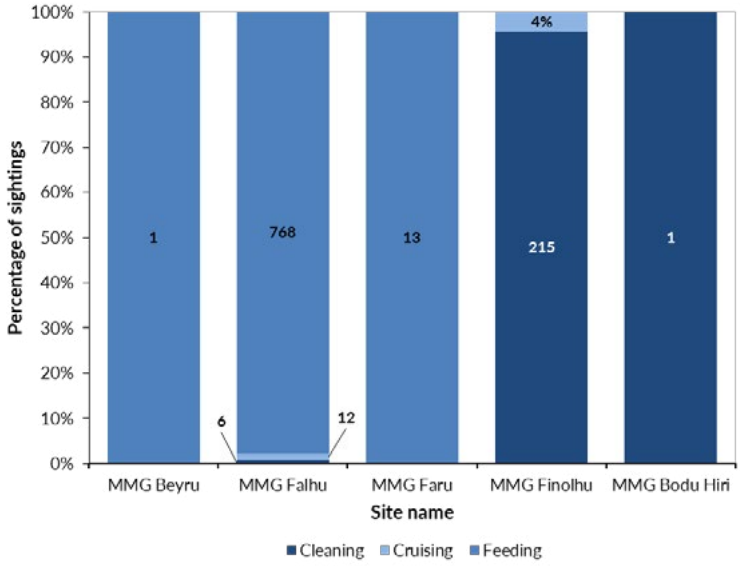

Figure 14: Reef manta ray (*Mobula alfredi*) sightings at the five survey sites within the Maamunagau (MMG) subregion of Raa Atoll. Distribution categorised by primary behaviour recorded at each survey site. Actual numbers within bars (2021).

Maamunagau Population Demographics

To date, the Maamunagau population consists of 293 individuals, accounting for 32% of the overall Raa Atoll population (*n*=927). Throughout 2021, sixty-one percent (*n*=178) of the population was recorded in Maamunagau. Of these individuals sighted in 2021, 48% (*n*=85) had been recorded in either/both the 2019 and 2020 survey years and 52% (*n*=93) were new to the sub-region, with 15 individuals being new to the MMRP database overall.

The population demographics of Maamunagau are split almost equally between sexes, with 49% (*n*=144) females, 50% (*n*=147) males, and two individuals for which sex could not be determined (Fig. 15). The sub-regional population has a higher percentage (58%) of immature individuals than the wider Raa Atoll population (41%), with 53% (*n*=155) juveniles and 5% (*n*=16) subadults (Fig. 15). Maturation was defined by the presence of mating scars and visible pregnancies in females, and by the enlargement and calcification of claspers in males. Furthermore, if an individual is estimated to be at, or larger than, the known size at maturation for this species in the Maldives (320 - 330 cm disc width for females, 270 - 280 cm disc width for males), adult status was also assigned.

Further analysis of the available data shows that there was a higher presence of juvenile females (*n*=110) than juvenile males (*n*=45) within the Maamunagau population (Fig. 15). Whereas the proportion of adult males (*n*=89) was higher than that of females (*n*=31) (Fig. 15). Similarly, individuals sighted in 2021 (*n*=178) show a similar ratio of juvenile female and male manta rays and there is a definite bias towards adult males compared to females across all three survey years (Fig. 16). It is possible that this higher presence of adult males frequenting the Maamunagau region can be explained by males maturing at an earlier age than females, therefore individuals of the same age likely have the same habitat use, but females would still be recorded as immature, while the males would be classified as sexually mature. It has also been noted that males may have a higher affiliation to lagoonal feeding grounds than females, as observed in other areas of the Maldives.

Overall, 57% (*n*=102) of the individuals recorded in 2021 were sighted more than once, with an average of 5.76 sightings per individual. When split by demographic, juvenile manta rays exhibit higher site fidelity to Maamunagau than adults. On average, each juvenile was recorded 7.41 times,

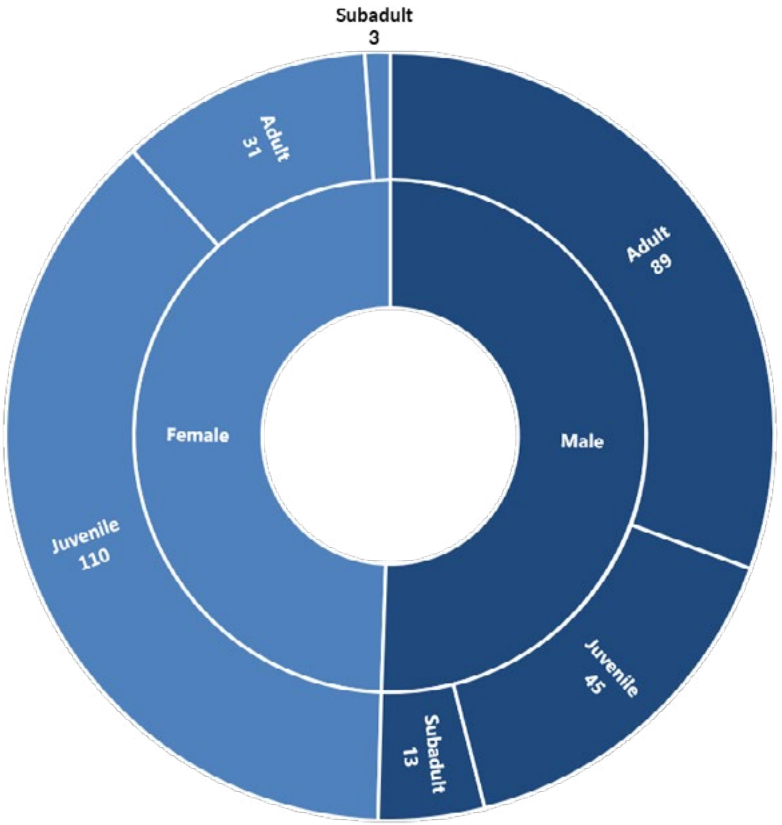

Figure 15: Maturity status of the reef manta ray (*Mobula alfredi*) population (*n*=293) at Maamunagau in Raa Atoll categorised by gender (2019 – 2021).

compared to 3.45 times for each adult. Furthermore, the maximum number of sightings for any individual recorded within Maamunagau in 2021 was higher in juveniles (*n*=47) than in adults (*n*=18). To account for the survey effort, a residency index (RI) was calculated to determine how often each individual reef manta ray was seen throughout each survey year. The RI is based on the ratio between the number of days each individual was sighted, and the total number of surveyed days. For example, an RI of 3% means that, on average, each individual was sighted on 3% of the total surveyed days. The RI for juvenile reef manta rays in 2021 (7.56%) was higher than the RI for adults (3.52%).

To better understand the affiliation of male manta rays to Maamunagau, we use the residency index (RI) to determine how often each demographic was seen across all three survey years (2019 – 2021). Overall, males exhibit higher site fidelity with a higher RI in juvenile males (5.71%) compared to juvenile females (4.31%), as well as a higher RI in adult males (2.57%) compared to adult females (1.4%). There is also a notably higher number of sightings per individual for juvenile males (*n*=11.07), and adult males (*n*=4.99), compared to their counterpart females (*n*=8.8 and 2.71, respectively). This highlights that the Maamunagau sub-region is of particular importance for male manta rays throughout their entire lifespan. Future year-round monitoring of Maamunagau will help to better understand this trend as we begin to observe juveniles maturing into adulthood.

Of the individual reef manta rays sighted in Maamunagau in 2021, two were estimated to be new-born young of the year, and another two were estimated to be new-born from 2020 but only first recorded in 2021. The large number of sightings and re-sighting rates of juvenile reef manta rays in Maamunagau, and the repeated prevalence of new-born pups in the last three years indicate that Maamunagau may serve as a nursery habitat for these young individuals. Juvenile reef manta rays are likely utilising Maamunagau due to the large, sheltered lagoon, which offers these smaller individuals greater protection from predation and ample foraging opportunities.

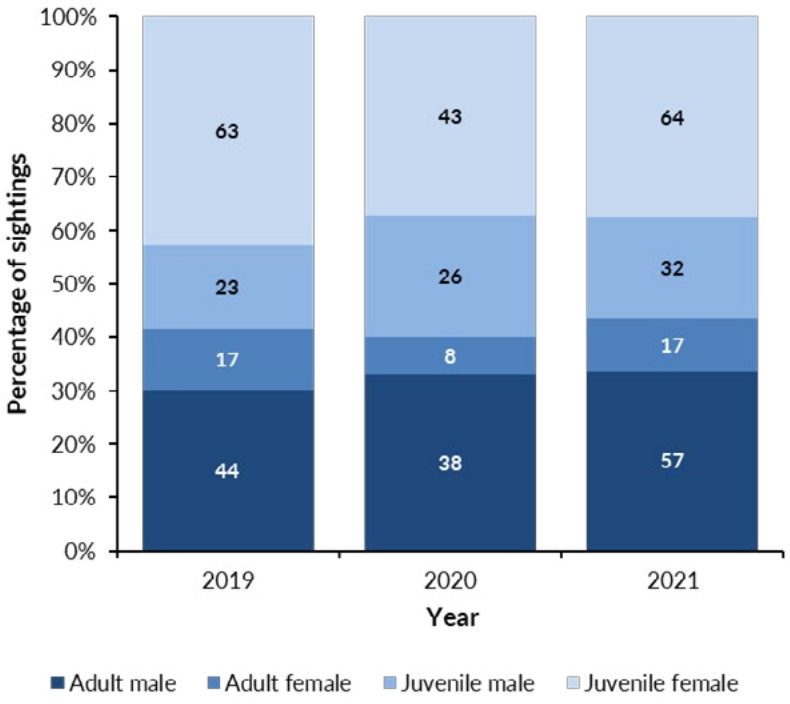

Figure 16: Reef manta ray (*Mobula alfredi*) sightings distribution categorised by maturation status during the first three years of intensive surveying effort in Maamunagau in Raa Atoll. Actual numbers within bars (2019 – 2021).

Photo by Jasmine Corbett

Atoll Residency

To date, 61% (*n*=566) of the Raa Atoll population (*n*=927) have been recorded on more than one occasion within the atoll. One hundred and two of those individuals have been sighted more than 10 times throughout the study period (2007 – 2021), and 36 of those individuals more than 20 times.

Throughout 2021, each individual manta ray was observed on average 4.4 times within Raa Atoll (Fig. 17), a slight increase compared to 2020 (*n*=3.4). The percentage of reef manta rays seen more than once in Raa Atoll in 2021 was also higher than in 2020, but lower than that in 2019, with a 54% re-sighting rate (Fig. 17). To account for survey effort, a Residency Index (RI) was calculated for 2021, based on the ratio between the number of sightings per individual manta ray and the total number of surveyed days. The RI for 2021 (3.2%) was lower than that noted in 2020 (3.98%), but higher than that noted in 2019 (2.12%). The lower residency of manta rays in Raa Atoll during 2021 is likely a result of the increased year-round monitoring efforts within the atoll, compared to 2020 when research was limited due to COVID-19, and efforts that did take place, primarily focused on surveying sub-regional aggregation area Maamunagau which has already been highlighted as a site with higher fidelity. Without sophisticated tracking methodologies, such as telemetry, it is difficult to create a detailed picture of how individual reef manta rays utilise their habitat within Raa Atoll, however, more years of consistent and increased survey effort across the entire atoll will help to determine and clearer understanding of the reef manta ray population residency in Raa Atoll.

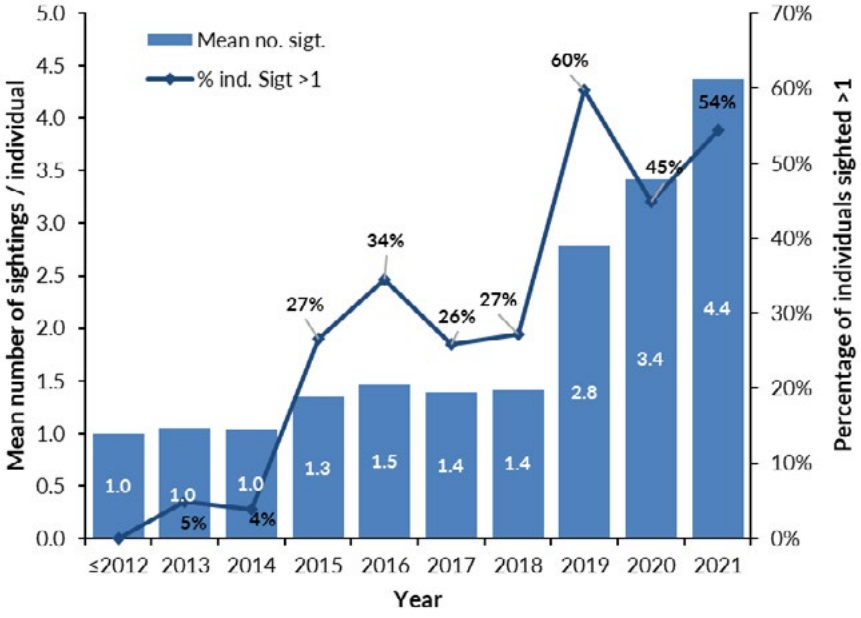

Figure 17: Mean number of sightings per individual reef manta ray (*Mobula alfredi*) in Raa Atoll, and the percentage of individuals sighted on multiple occasions during the same year.

Inter-Atoll Migrations

Due to its north-central location, and proximity to other atolls, 67% (*n*=622) of the recorded reef manta ray population of Raa Atoll have been recorded in 15 other geographical atolls throughout the Maldives, suggesting high inter-atoll mobility within the Maldives population (Fig. 18). Forty-three percent (*n*=357) of the Raa Atoll population have been recorded in two atolls (Fig. 19). The most common inter-atoll movement occurs between those atolls closest geographically to the study region, with the highest number of re-sightings recorded in neighbouring Baa Atoll (*n*=533), followed by Ari Atoll (*n*=106) (Fig. 18). This is likely due to the relatively small distances (10s km) between the atolls in the central and northern regions of the Maldives, along with the shallow maximum ocean depths (<300m) between these atolls, limiting barriers to migration. Indeed, several individuals have also been recorded traveling between other atolls, particularly Baa and Raa Atolls, multiple times within a single season. However, these results are also likely influenced by greater levels of MMRP survey effort in these atolls.

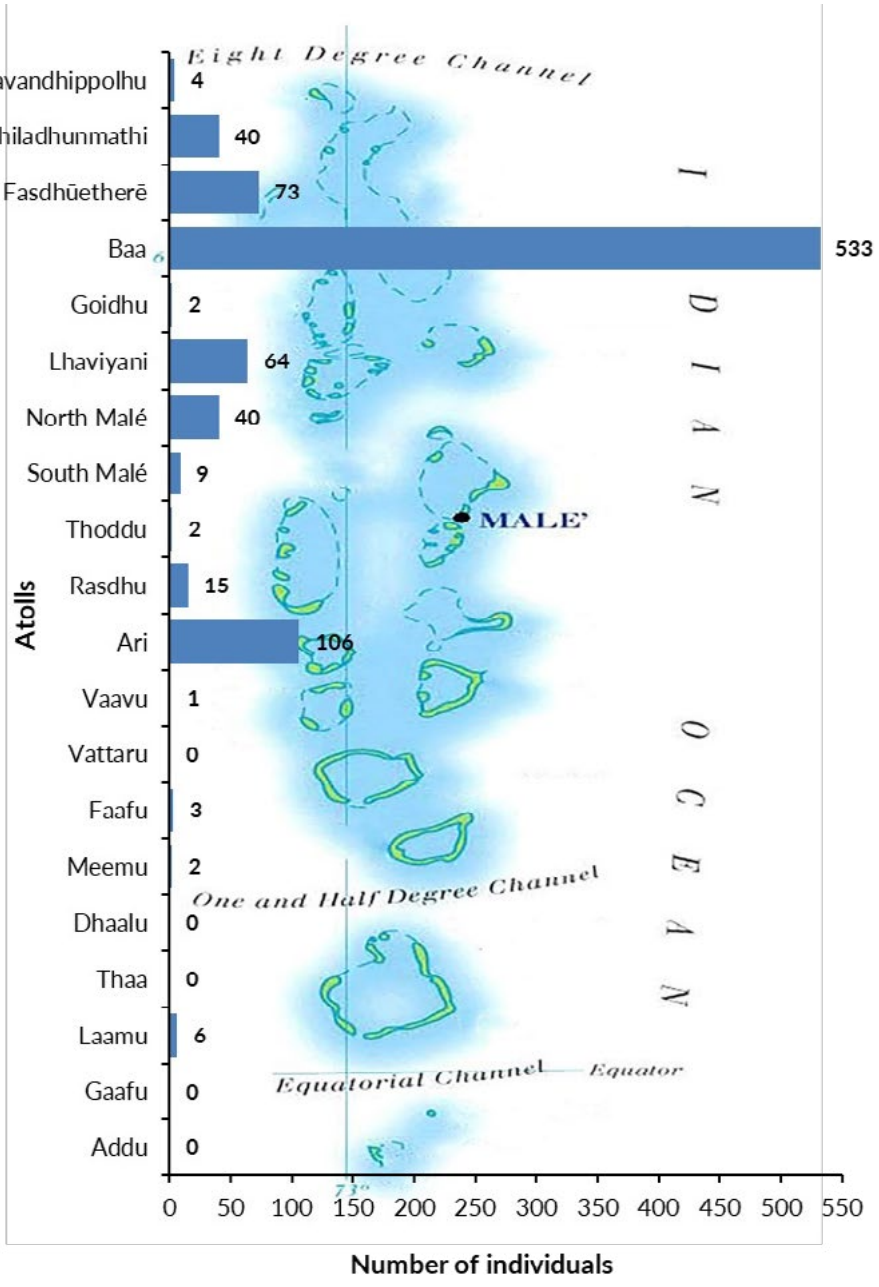

Figure 18: Number of reef manta rays (*Mobula alfredi*) (*n*=622) from within the Raa Atoll population (*n*=927) which have been recorded in other geographical atolls throughout the Maldives Archipelago. Note — some individuals have been sighted in more than one atoll.

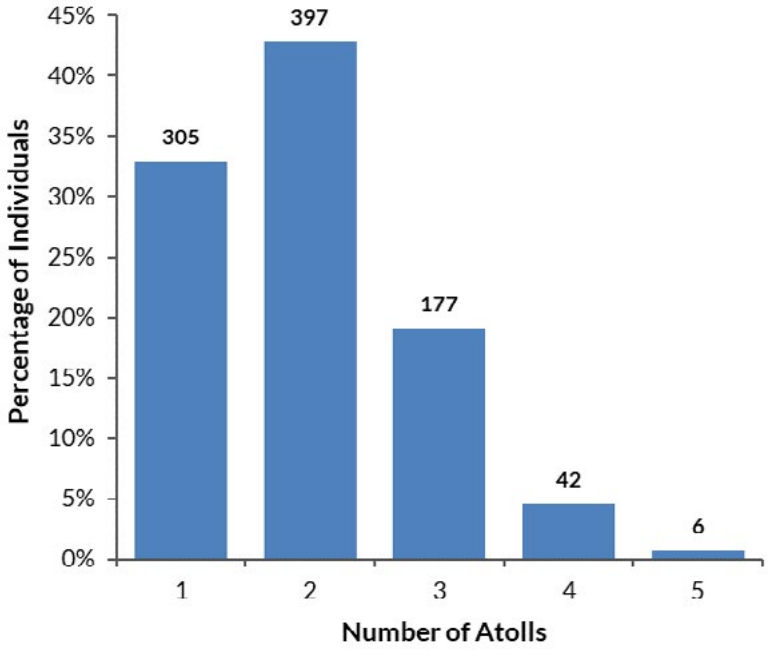

Figure 19: Percentage of Raa Atoll's reef manta ray (*Mobula alfredi*) population (*n*=927) sighted in one or more atolls. Actual numbers above bars.

Courtship & Reproduction

Throughout their range globally, reef manta ray reproductive activity often peaks at specific times of the year. 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 transition from one to the other. Throughout the day, adult manta rays spend a significant amount of their time cleaning, with female manta rays often spending several hours each day cruising around a favoured cleaning site. Therefore, cleaning stations often become the focal point for courtship and mating activity, with mature males aggregating at these sites in search of sexually receptive females.

To date, only eleven courtship events have been documented in Raa Atoll, involving 34 individuals. In 2021, three courtship events, involving six individuals were recorded at cleaning stations on the East of Raa Atoll (Aggregation Group 1) (Fig. 1). One courtship event occurred in October and two in November, fitting with the predicted trend that courtship activity peaks, with the transitional period between monsoons.

Throughout the Maldives, the MMRP has observed a cyclical fluctuation in reproductive fecundity, with higher numbers of courtship events reflecting higher numbers of pregnant females in the following year. Without consistent data collection from Raa Atoll in 2020, it is not possible to draw definitive conclusions about the findings in 2021. However, the high number of pregnant females recorded within the atoll in 2021 (*n*=16), may suggest that 2020 was a year of high courtship activity. Due to the global pandemic and lack of researchers in the atoll at that time, no courtship events were recorded (Fig. 20). Further research by trained observers which can recognize and accurately document courtship activity will help to better understand seasonal courtship trends in Raa Atoll.

Overall, 22% (*n*=208) of the recorded Raa Atoll population are mature adult females, of which 35% (*n*=73) have been recorded to be visibly pregnant at some point during the study period (2007 – 2021). In 2021, twenty-nine percent of the adult females (*n*=56) were recorded pregnant (*n*=16) (Fig. 21). These results are similar to the findings in earlier years when survey consistency was much lower (2014 – 2018) (Fig. 21). The 2019 survey year remains a contrast to other years, most likely due to the high survey effort during both monsoon seasons within the atoll. The MMRP hopes that survey years 2022 and onwards will allow for consistent year-round monitoring of all Raa aggregation sites to better understand the reproductive traits of this population.

Of the adult females recorded pregnant in 2021 (*n*=16), two individuals had never had any recorded pregnancies before, and the remaining 14 individuals had been

previously recorded as pregnant either in Raa or another atoll. Interestingly, 29% (*n*=4) had been recorded pregnant five years prior (2016), while 14% (*n*=2) were pregnant four years prior (2017), and 36% (*n*=5) were pregnant just 2 years prior (2019). This high frequency of individuals being pregnant in both 2019 and 2021 (*n*=5) suggests that conditions may have been suitable for the reproduction of reef manta rays at this time. However, it should not distract from the overall very slow reproductive rate for this species. With such a low fecundity it becomes vital for the survival of these animals to minimise anthropogenic and natural impacts. Effective measurements include establishing functional marine protected areas (MPAs) and adhering to sustainable tourism activities at key manta ray aggregation sites.

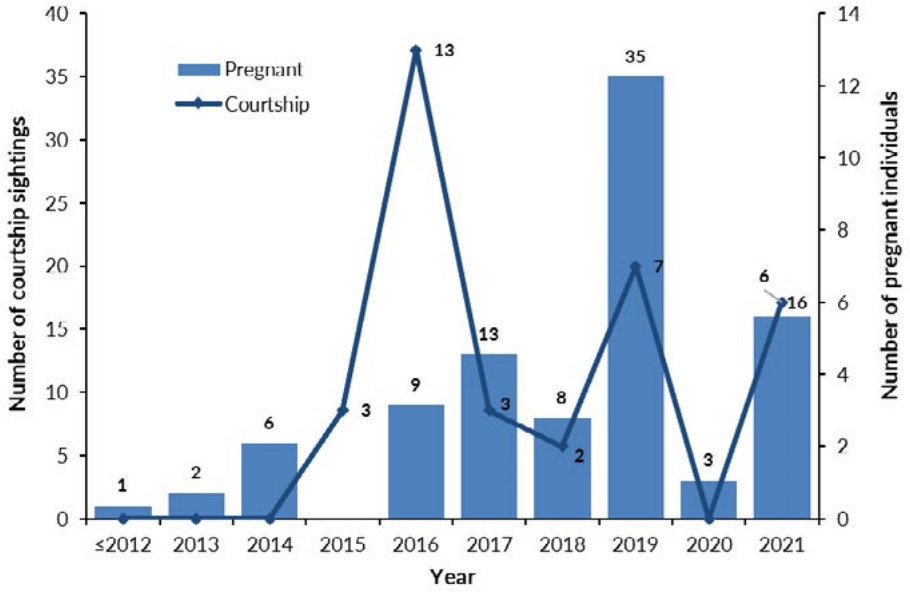

Figure 20: Number of reef manta ray (*Mobula alfredi*) sightings where courtship was the predominant behaviour observed annually in Raa Atoll, and the total number of pregnant females recorded in that same year.

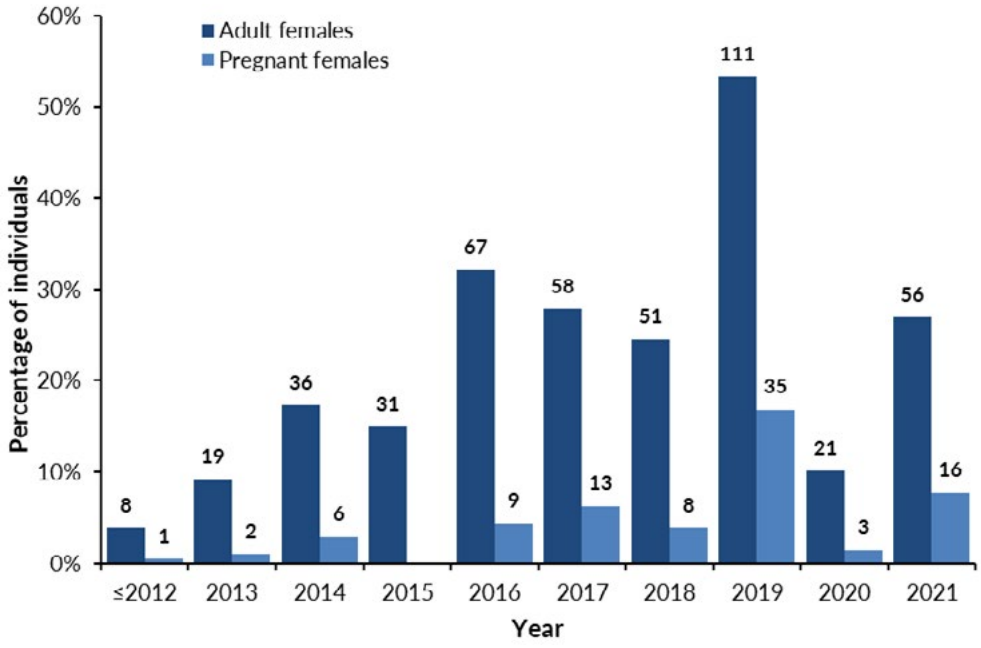

Figure 21: Percentage of Raa Atoll's adult female reef manta ray (*Mobula alfredi*) population (*n*=208) sighted annually, and the percentage of those females that were recorded pregnant in the same year. Actual numbers above bars.

Sub-lethal Injuries

Of the 312 individual reef manta rays recorded in Raa Atoll in 2021, 13% (*n*=39) were recorded with at least one new sub-lethal injury, bringing the overall injured population of reef manta rays to 35% (*n*=323) of the entire Raa Atoll population (*n*=927). Of the injured individuals, 85% (*n*=274) have only one injury, 14% (*n*=45) have two recorded injuries, and four individuals (1%) have three injuries. Overall, 45 new injuries were recorded in 2021, 27% (*n*=12) of which resulted from natural origins (e.g., predatory bites, diseases, deformities, etc.), whilst 24% (*n*=11) resulted from anthropogenic origins (e.g., fishing line entanglement, boat strikes, etc.). The remaining 22 sub-lethal injuries originated from an unknown source (Fig. 22).

Demographically, instances of newly recorded injuries in 2021 were slightly higher in males than in females, with 53% (*n*=24) of all injuries reported on males, and the remaining 47% (*n*=21) on females (Fig. 22). Injuries were relatively even between adults (*n*=23) and juveniles (*n*=22), which is of high concern, especially since Raa Atoll is an important area for the younger generation of this species.

Across all individuals sighted within Raa Atoll, the most common cause of newly recorded injuries (for both adults and juveniles) was from predatory bites (*n*=10) followed by fishing line entanglement (*n*=8) (Fig. 23). Additional anthropogenic injuries included those caused by boat strike (*n*=2), and of these, one was inflicted on a juvenile manta ray. This juvenile was estimated to be a Maamunagau Young of Year in 2019, making this individual only three years old.

Of all manta ray injuries recorded in the Raa Atoll population, the most common body area inflicted by injury (60%) is the manta ray's pectoral fins (Fig. 24); this is a similar finding to previous MMRP atoll annual reports. This is most likely because manta rays cannot see well directly behind them, making them vulnerable to attacks from predators (mainly large sharks) within the anterior pectoral fin region. This region of the body is also where the entangled fishing line often causes the most damage. The proportion of individuals with injured pectoral fins remains consistent between sexes and maturity statuses of the Raa Atoll population (Fig. 24).

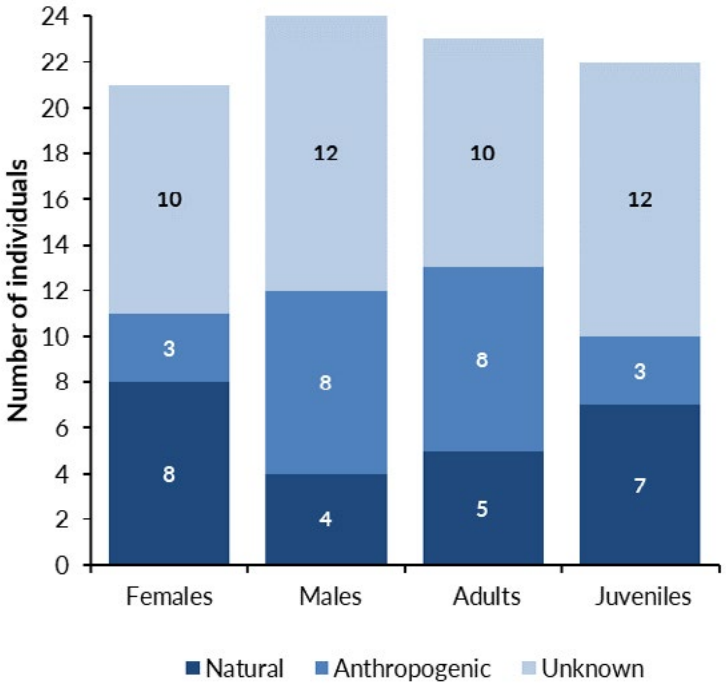

Figure 22: Demographic variations in the number of new sub-lethal injuries (*n*=45) recorded on reef manta rays (*Mobula alfredi*) within the Raa Atoll population (*n*=927) in 2021, and the likely injury origin (natural or anthropogenic).

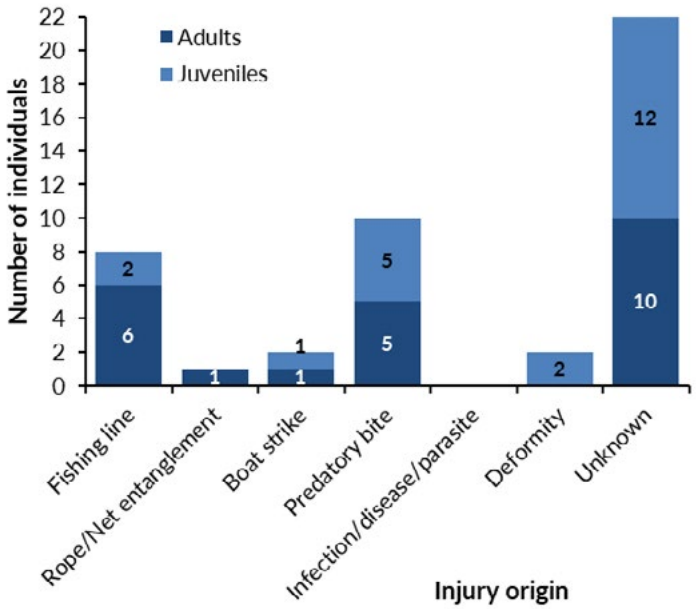

Figure 23: Demographic variations in the likely origin of new sub-lethal injuries (*n*=45) recorded on reef manta rays (*Mobula alfredi*) in 2021.

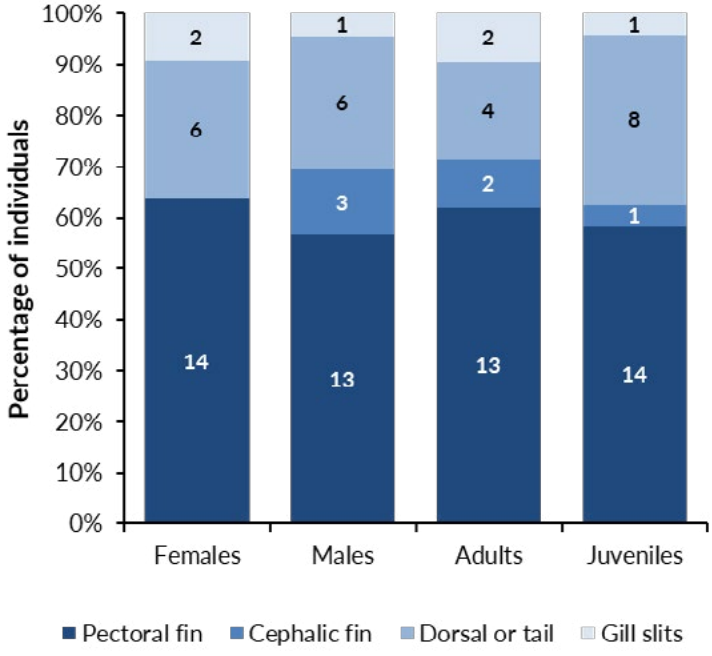

Figure 24: Demographic variations in the location of new sub-lethal injuries (*n*=45) recorded on reef manta rays (*Mobula alfredi*) in 2021. Actual numbers within bars.

ENVIRONMENTAL VARIABLES

Environmental conditions, particularly wind and current strength, have a strong influence on the seasonal abundance of phytoplankton, and therefore zooplankton availability, which in turn is likely to influence manta ray abundance. Weather data for 2021 and previous years were sourced from the Maldives meteorological department and have been analysed together with sightings records to determine whether any correlation exists between manta ray sightings and wind speed. Overall, average wind speeds were higher than in previous years, clocking an average of 19.8km/h in 2021, compared to 17.8km/h in 2020, and 15.0km/h in 2019. With these slightly higher wind speeds in 2021 came a slight increase in the average number of manta ray sightings per survey day in 2021 (*n*=6.3), compared to 2020 (*n*=5.6) and 2019 (*n*=6.2).

A closer analysis of wind speed and manta ray activity in 2021 shows that reef manta ray sightings followed expected trends and coincided with peaks and dips in wind speed. In 2021 the highest number of sightings recorded per survey day occurred during February (*n*=14.7) and March (*n*=14.4) following the first peak in wind speed recorded in February (*n*=19km/h) (Fig. 25); while a notable drop in sightings during the month of April corresponded to the decrease in wind speed recorded in March (*n*= 14km/h). The gradual increase of manta ray sightings reported throughout the latter part of the year and peaking in October (*n*=9.2) and November (*n*=9.1) are as expected as wind speeds were recorded to progressively increase from September onwards. Interestingly the dramatic drop in wind speeds between November (*n*= 27km/h) and December (*n*=19km/h) did not seem to influence manta ray sightings too drastically (*n*=7.0) and it is hypothesised that if wind speed continues to decrease during the month of January 2022, manta sightings will reflect a correspondingly lower count. While these observations of wind speed are interesting, it is also important to consider whether the direction of the wind is also a factor that potentially influences manta ray activity.

During each of the surveys conducted in 2021, the wind direction was recorded using the online weather forecast platform Windguru (www.windguru.cz/173263). Wind directions recorded between January and March reveal variability throughout these Northeast Monsoon months (Fig. 26). Wind directions were classified into eight main directions, combining multidirectional winds into their main category. As expected during the Northeast Monsoon, winds coming in from the general northeast direction dominated from January to March contributing to 36% – 94% of wind direction readings during this time (Fig. 26). Interestingly, the month of January saw huge fluctuations in wind direction with readings from all eight

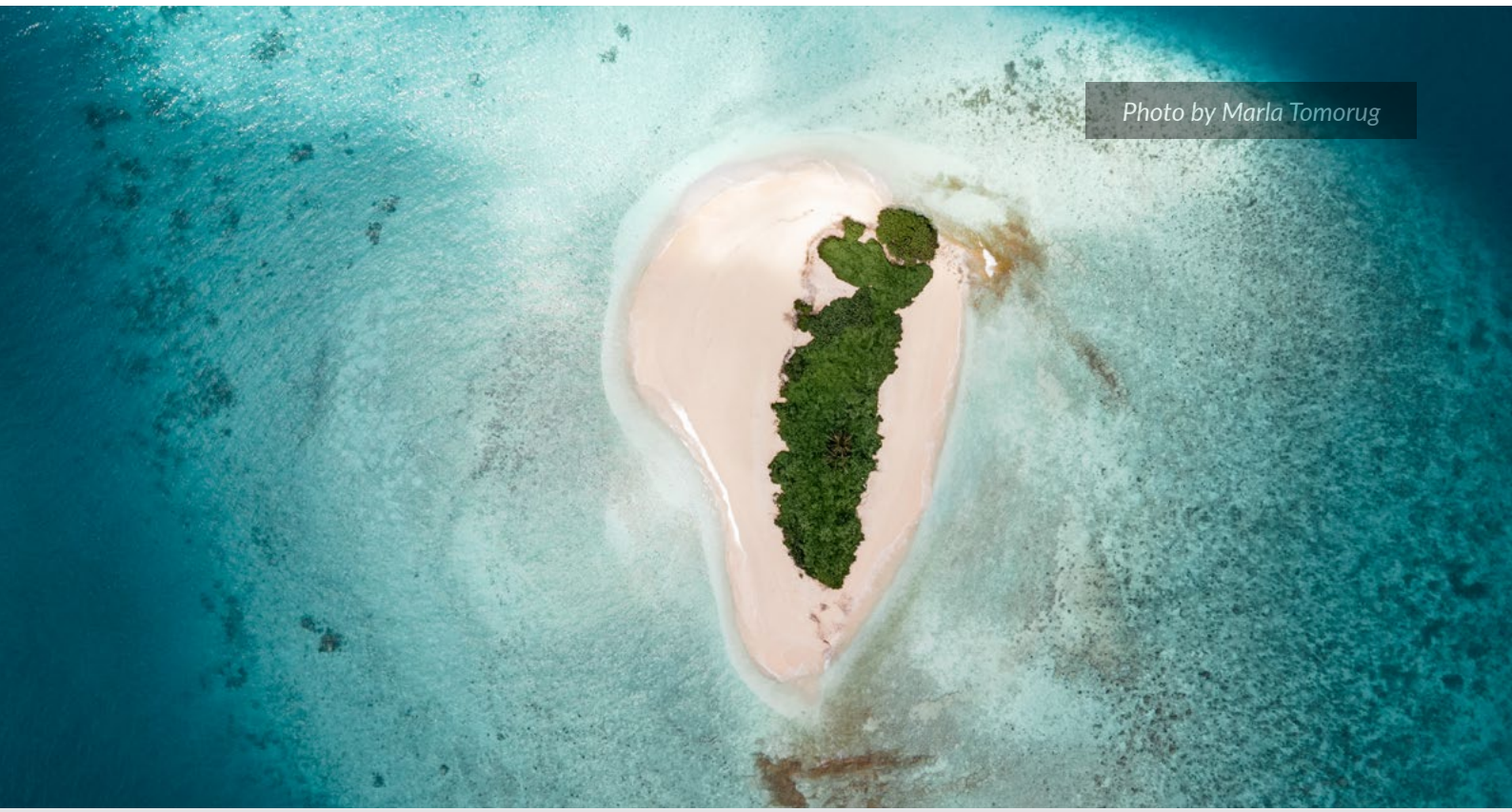

Photo by Marla Tomorug

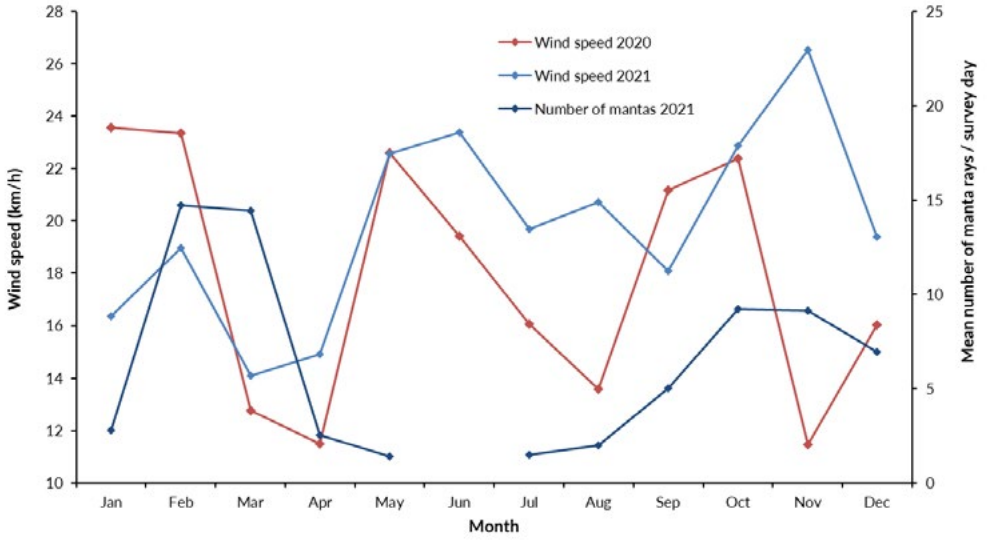

Figure 25: Mean monthly wind speed (km/h) and mean number of reef manta ray (*Mobula alfredi*) sightings per survey day by in Raa Atoll (2020 – 2021).

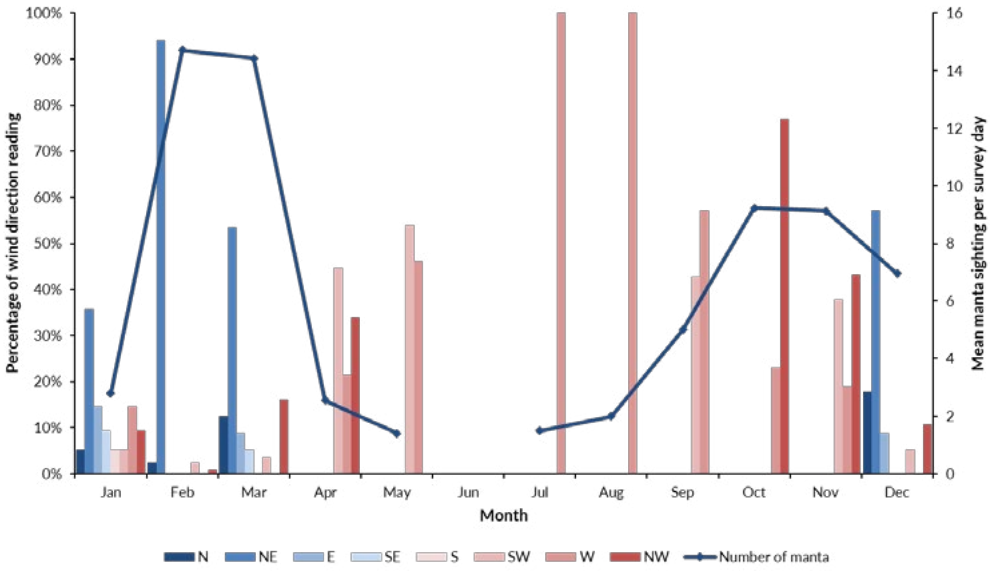

Figure 26: Monthly breakdown of the percentage of Raa Atoll wind direction readings from the online weather forecast platform Windguru, and the average number of reef manta ray (*Mobula alfredi*) sightings per survey day (2021).

categories. Winds from the west and north-westerly directions prevailed throughout the month of January and while a distinctly higher north-easterly reading appeared to dominate the month, it only accounted for 36% of surveys. This suggests that 2021 witnessed a delayed seasonal change from the Southwest Monsoon 2020 to the Northeast Monsoon 2021, which would explain the low number of manta ray sightings per survey day at the start of the year (n=2.8). Throughout February and March, winds from the northeast dominated, and manta ray sightings peaked (Fig. 26). Overall, there were much lower easterly readings across these months compared to 2020. Winds from the southwest and northwest returned during the month of March, with westerly winds dominating the directional forces from April onwards (Fig. 26). December showed an almost instantaneous switch between Monsoons reflected by the notable spike in north-easterly wind directions. This could also explain the reason for the manta ray sightings numbers remaining relatively high (n=7.0 manta rays seen per survey day) despite the dramatic drop in wind speeds noted in December since accounts of sightings were now being reported along the west side of the atoll - driven by monsoon changes (Figs. 8, 11, 25, and 26).

As a force acting in combination with increased wind speed, wind directions dominating from the northeast do seem to influence the favourable conditions which result in an increase in manta ray sightings on the southwest corner of Raa Atoll, where survey efforts were highest (Aggregation Group Four) (Map. 1) (Fig. 8 and Fig. 27), while wind directions dominating from the west and northwest seem to influence the aggregations of manta rays on the east side (Group One) (Fig. 8 and Fig. 27). With continued year-round survey efforts in Raa Atoll, comparisons between all aggregation groups will be able to be assessed.

Tidal currents bring plankton-rich water in to, and out of, the atoll lagoons via channels along the outer rim of the atoll daily. Therefore, it is expected that tidal currents also influence the manta rays' movement, behaviour, and habitat use. To further determine any correlations between current direction and manta ray behaviour, survey data from 2021 included the variables' current direction, current speed, and primary observed behaviour. Of the 693 surveys recorded in 2021, manta rays were present on 57% (*n*=395) of these occasions. In 44% of these surveys when manta rays were present (*n*=173), the current was outgoing, during which time the predominant behaviours observed were feeding (*n*=95) and cleaning (*n*=56) (Fig. 28). Similar overall trends were recorded when assessing the sub-regional aggregation site Maamunagau. In total, manta rays were present in 60% (*n*=295) of the surveys recorded in Maamunagau in 2021. In 45% of these surveys when manta rays were present (*n*=133), the current was outgoing, during which time the predominant behaviours observed were feeding (*n*=90) and cleaning (*n*=25).

Overall, the most common behaviours displayed by the reef manta ray population in Raa Atoll were almost evenly split between feeding and cleaning, constituting 43% (*n*=169) and 42% (*n*=166) of all surveys when manta rays were recorded present in 2021 (*n*=395).

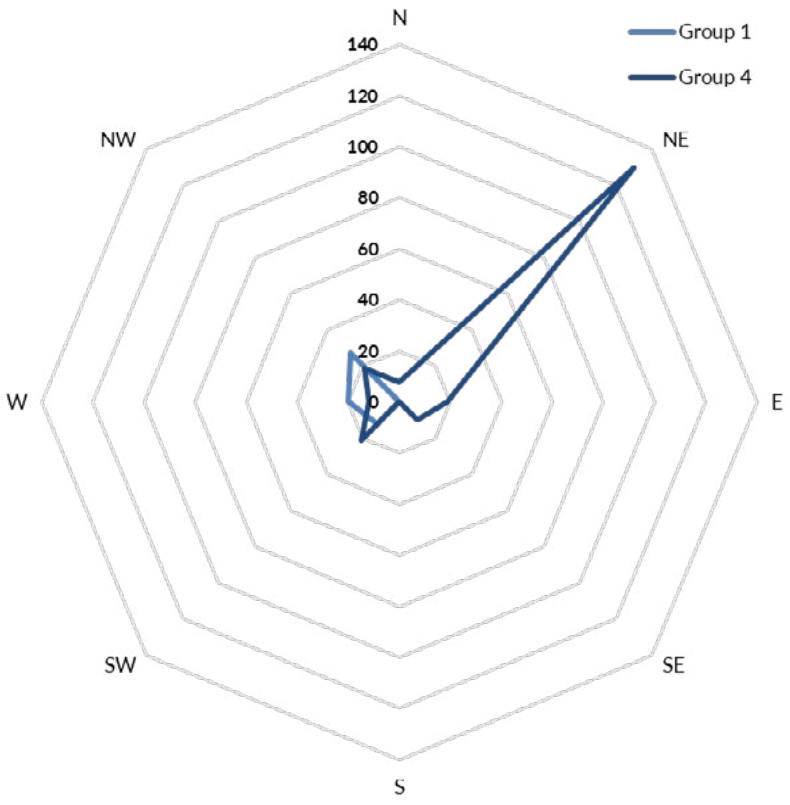

Figure 27: Number of reef manta ray (*Mobula alfredi*) sightings in relation to prevailing wind direction at two key aggregation sites (Groups 1 and 4) in 2021; obtained from surveys where wind direction was recorded, and manta rays were seen (*n*=278).

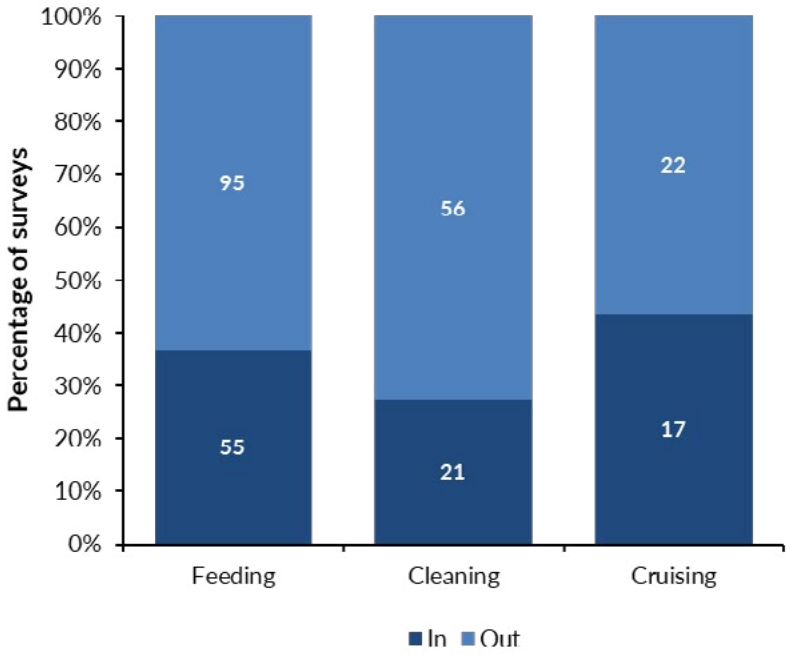

Figure 28: Changes in the behavioural activities of reef manta rays (*Mobula alfredi*) in relation to current direction (In, Out) through the channels in Raa Atoll during surveys (2021) where manta rays were observed (*n*=395).

WHALE SHARK & OCEANIC MANTA RAY SIGHTINGS

The reef manta ray's close relative, the oceanic manta ray (Mobula birostris), can grow to over six metres in disc width and spends more time away from reefs in the open ocean. Virtually all manta ray sightings in Raa Atoll are of reef manta rays, with no recorded sightings of an oceanic manta ray in 2021. To date, there is only two recorded sightings of oceanic manta rays in Raa Atoll. The first recorded sighting was in 2017 during the Northeast Monsoon at Sola Corner, an outer reef feeding and cleaning site commonly frequented by reef manta rays. The second sighting was recorded in November 2021 and observed during the Southwest Monsoon at Vandhoo Beyru, an outer reef on the eastern edge of Raa Atoll.

The whale shark (Rhincodon typus) is another species of large, filter-feeding elasmobranch with similar life history characteristics and overlapping habitat use as reef manta rays in the Maldives. The Maldives Whale Shark Research Programme (MWSRP) monitors the Maldives whale shark population, using photos and videos of a whale shark's unique spot pattern to identify individuals. Whale shark sightings are uncommon in Raa Atoll; however, in 2021 the first confirmed photo-ID sighting was recorded. Whaleshark WS222 'Nooali' was recorded in Raa Atoll, Maarikilu Faru, on the 27th of February 2021, with a recorded sighting just 10 days prior, on the 17th of February 2021 in South Ari Marine Protected Area (SAMPA) on the southwest corner.

MANTA RAY TOURISM

Many tourists visiting the Maldives participate in snorkel and dive excursions during their stay, hoping to see marine megafauna, including manta rays. Tourism in Raa Atoll is increasing, with a total of 14 resorts in operation, two of which opened in 2021. Tourist-related pressures in Raa Atoll have also hugely increased in the two years since the MMRP established a permanent research base. Although the pressures remain lower than at many other manta aggregation sites throughout the Maldives, this rapid increase in manta tourism in the atoll is a cause for concern.

Survey data collected by the MMRP in 2021 showed that, on average, 1.9 boats were present per survey (including the MMRP research boat) (Fig. 29), and an average of 8.0 snorkellers and divers per survey (Fig. 30). The number of tourists swimming with manta rays in Raa Atoll has doubled compared to the numbers recorded in both 2019 (*n*=4.1) and 2020 (*n*=3.9). In general, there are more snorkellers (*n*=4,587) than divers (*n*=940) recorded in Raa Atoll in 2021 (Fig. 31), this is a 481.3% increase in the number of snorkellers recorded compared to 2020 (*n*=953).

Eighty-two percent (*n*=3,740) of the snorkellers recorded in 2021 were utilising the Maamunagau sub-regional sites. These findings also mark a tremendous increase in tourism pressure compared to that recorded in 2019 (*n*=288) and 2020 (*n*=510). In recent years, the Maamunagau subregion has become recognised as one of the top destinations for reliable manta sightings during the Northeast monsoon. The resultant increase in tourist pressure in an area that has proven to be of such high importance to juvenile reef manta rays gives precedence to the urgent need to protect the area and enforce an effective management monitoring plan for the area. Operators that do bring guests to the Maamunagau area mostly do so for snorkelling with manta rays, bringing guests by various modes of transport from speedboats with outboard engines to dhonis, and jet skis. In nineteen percent (*n*=56) of the surveys conducted in Maamunagau where manta rays were present (*n*=301), the code of conduct was not followed by either tourists/ guides swimming with the manta rays or by the captain of vessels that bought the tourists to the area. All ten of the best practice code of conduct were reported as ignored during these surveys with the most prevalent being snorkellers chasing manta rays, and boats approaching too close to the manta rays feeding at the surface.

Manta rays and their habitats are important to the Maldives' economy, evident in the increasing numbers of tourists frequenting manta ray aggregation sites throughout the country. Guests based in local guesthouses, resorts, and on liveaboard dive vessels throughout the country help

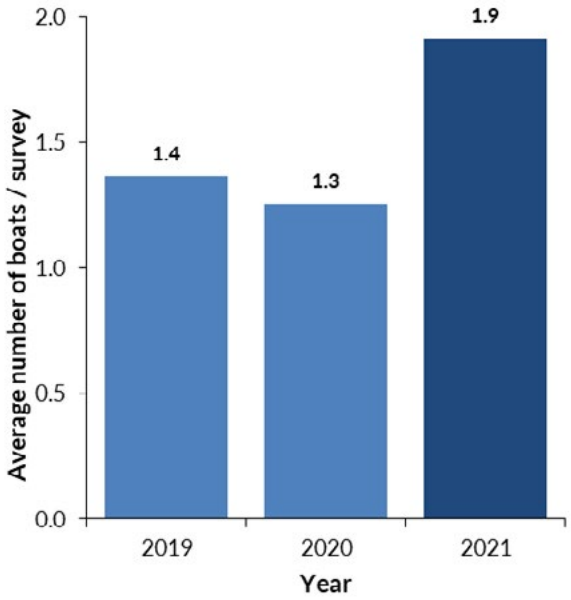

Figure 29: Mean number of marine vessels recorded per survey (*n*=1,240) in Raa Atoll.

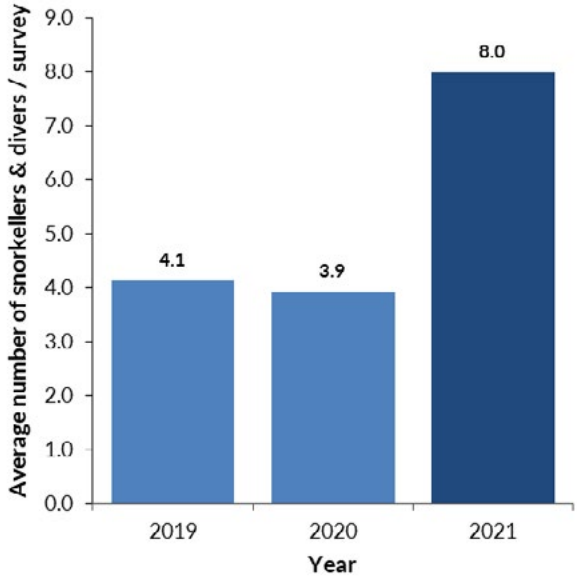

Figure 30: Mean number of snorkellers and divers per survey (*n*=1,240) in Raa Atoll.

to generate tens of millions of USD for the local economy via manta ray dive and snorkel excursions annually, providing further incentive to protect these ecologically vulnerable species. In response to the growing interest in manta tourism, and the negative impacts that result from unregulated wildlife tourism, the Manta Trust published its first Best Practice Code of Conduct (CoC) in 2014, with an updated CoC released in late 2017. The Best Practice CoC is aimed at minimising tourism activities' impact on the natural behaviour of manta rays. The 2017 update included the launch and distribution of a 10-step guide for "How to Swim with Manta Rays", complemented by snorkelling and SCUBA diving briefing video. However, it is clear that operators and their subsequent guests are not all following these guidelines, so it is hoped that further dissemination of these materials with the help of the government to enforce such guidelines will help to deliver this 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.

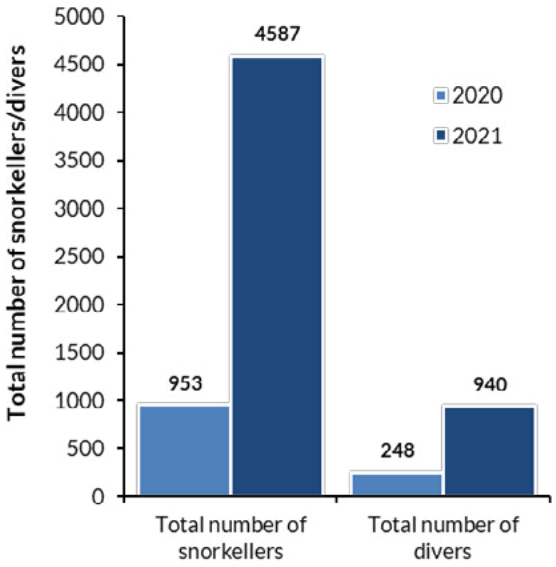

Figure 31: Total number of snorkellers and divers recorded in Raa Atoll (2020 – 2021).

MANAGEMENT CHANGES & INITIATIVES

The Maldives' government has not designated any new MPAs within Raa Atoll since 1999. To date, only one MPA exists in Raa Atoll. Situated in the southwestern corner of the atoll, Villingilee Thila (also known as Fenfushi Giri) was designated protection in 1999. No manta ray sightings have been recorded within this MPA. However, the size of the protected area is extremely small (2.7 km2), and manta rays have been recorded feeding just north of the MPA at Fenfushi Faru. In addition, 1.5km south of the MPA sits the Maamunagau sub-region, recognised as one of the key manta aggregation sites in Raa Atoll, with particular importance for juvenile reef manta rays that utilise Maamunagau as a nursery feeding ground. It is of utmost importance that the growing tourism in this area is managed before negative impacts on the individuals through unsustainable tourism in the area begin to become a problem. Although the designation of this existing MPA is important, it is currently only protected on paper. If manta rays are to continue to flourish in the Maldives, it is urgently required for the MPA to be significantly expanded to encompass the entire Maamunagau sub-region, and for effective management plans to be created, implemented, and enforced. Such an MPA would help mitigate the negative impacts of increasing tourism numbers in Raa Atoll, particularly the pressures on the juvenile reef manta ray population within Maamunagau. In the meantime, the MMRP will continue to disseminate the Manta Trust's Best Practice Code of Conduct (CoC) to various operators in Raa Atoll, hopefully with the support of the Maldivian government, to minimise the impact of tourism activities on the natural behaviour of manta rays.

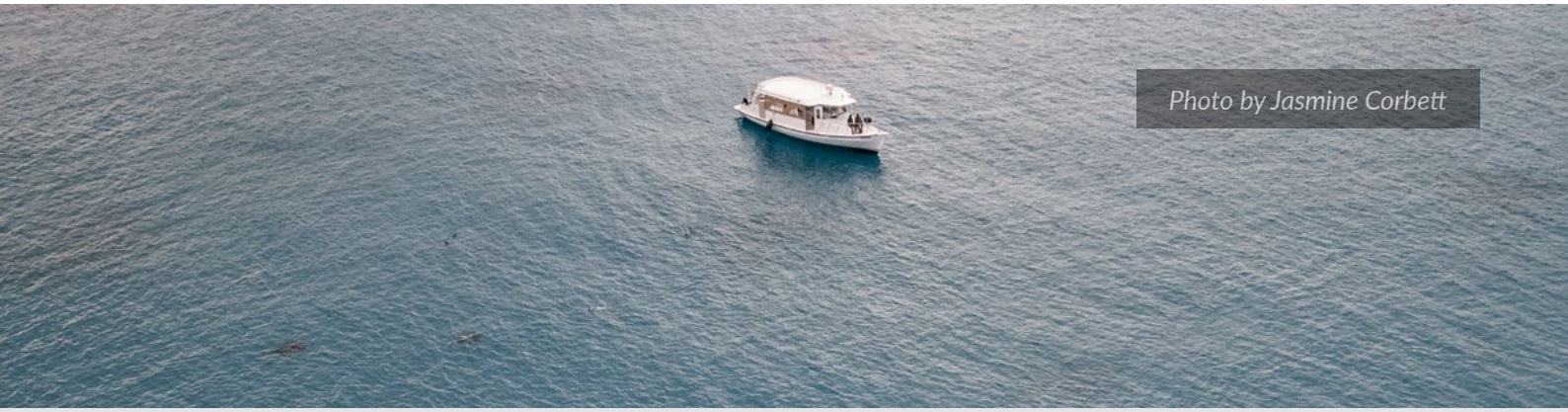

Photo by Jasmine Corbett

This report was made possible thanks to

INTERCONTINENTAL HOTELS & RESORTS

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As our primary supporter in Raa Atoll, the InterContinental Maldives Maamunagau Resort has been incredibly supportive of the Manta Trust and MMRP. We hope this partnership continues to prosper for years to come.

EPA

MARINE RESEARCH CENTRE

MALDIVES GOVERNMENT AUTHORITIES

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

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

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

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

Jessica Haines - BSc (Hons)
Project Manager - Raa Atoll

Tam Sawers - MSc (Hons)
MMRP Project Leader

Dr. Guy Stevens
Chief Executive & Co-Founder

This document was created by:

Jasmine Corbett - BA (Hons)
Media & Communications Manager

For further information, please email:

raa@mantatrust.org **info@mantatrust.org**