

The Yasawa Islands Annual Report 2022



MANTA PROJECT
FIJI



WHO ARE THE MANTA TRUST?



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

The Manta Trust takes a multidisciplinary approach to conservation. We focus on conducting robust research to inform important marine management decisions. With a network of over 28 projects worldwide, we specialise in collaborating with multiple parties to drive conservation as a collective; from NGOs and governments, to businesses and local communities.

Finally, we place considerable effort into raising awareness of the threats facing mantas, and educating people about the solutions needed to conserve these animals and the wider underwater world.

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

MANTA PROJECT FIJI



Formed in 2012, Manta Project Fiji (MPF) consists of a network throughout Fiji of dive instructors, marine biologists, communities and tourism operators.

Working in conjunction with Government agencies, NGO's and resorts across Fiji, Manta Project Fiji is attempting to estimate the size of Fiji's manta population and the movement of these animals within and around the archipelago, in order to gather baseline data on the current state of the country's resident population.

Research data is being used to inform relevant stakeholders and policy makers so that effective conservation management strategies can be implemented that will safeguard against mobulid bycatch.

Ultimately the project hopes to assist the Fijian people in making informed and effective management decisions that protect their manta and devil ray populations, and help to promote responsible tourism as a sustainable revenue stream that benefits both man and manta.

BAREFOOT MANTA ISLAND RESORT



Since formation Barefoot Manta Island Resort has been an integral partner of Manta Project Fiji. As our initial partner in country Barefoot Manta Island Resort has contributed significantly to the research efforts within the Yasawa Islands, leading the way towards sustainable manta ray encounters at the Manta Channel.

The main reef manta aggregation site is just off the island, where strong currents funnel zooplankton into the shallow channel between Drawaqa and the largest island in the Yasawas, Naviti. Barefoot Manta staff and MPF researchers collect daily data on the manta rays sighted, building an invaluable data set which will allow effective management strategies to be developed.

We are extremely grateful to The Barefoot Collection for their support, without which we would not be able to conduct our work in Fiji.



EXECUTIVE SUMMARY

This report presents the data collected by the Manta Project Fiji (MPF) research team and Barefoot Manta staff on the Yasawa Island's manta ray (*Mobula alfredi* and *Mobula birostris*) populations from 2013-2022. MPF has been collecting data on manta rays at the Manta Channel in the Yasawa Islands consistently since the end of 2012, with the exception of 2017 due to logistical constraints. MPF are incredibly grateful and proud to have the support of Barefoot Manta Island Resort as one of our key Regional partners.

The Manta Channel in the Yasawa Islands supports manta ray sightings from April through to October each year. This site is characterised by strong currents funnelling dense zooplankton through the channel, where manta rays gather to forage on the high tide, however courting and cleaning behaviour are also observed in the channel, albeit much less frequently.

In 2022, surveys were conducted on a total of 201 days by MPF researchers and Barefoot staff members. This figure is lower than the previous three years, due to sightings dramatically decreasing towards the end of the season. Manta rays were present on 70 % (n = 140) of survey days in 2022, this was the highest percentage since 2016, but lower than 2013, 2014 and 2016. Key findings in 2022 include a total of 588 sightings of 52 individual manta rays. Overall sightings remained high, consistent with 2020 (n = 637) & 2021 (n = 504), considerably higher than pre-COVID years (2013-2019, mean = 303).

Of the 52 individuals recorded, each manta ray was observed on average 11.3 times, the highest since records began. The mean number of manta ray sightings per survey was 2 in 2022, with peak sightings occurring in July (n = 209). As with previous years a Residency Index (RI) was calculated to gauge the extent of movement amongst those frequenting the Manta Channel. The RI for 2022 (5.6 %) was at its highest since 2018 (n = 5.7 %) and considerably higher than the previous three years (mean = 4). Interestingly only 15 manta rays make up 87 % of all sightings at the site since 2013. In 2022 the mean RI index for the 15 most sighted mantas was 17 %, the highest on record.

As of 2022, the population demographics of the Yasawa Island population constitutes of 49 % (n = 68) female, 51 % (n = 71) male. Overall, 41% (n = 58) comprise adults, 26 % (n = 36) juveniles and 29 % (n = 40) are considered sub-adult. Of the population known to the Yasawa Islands only 9 manta rays have been seen in another geographical region in Fiji. Sighting demographics over the years has shifted, adult manta ray sightings have decreased from 80 % to 60 % and juvenile manta ray sightings have increased from 20 % to 40 %, this could be due to a natural period of population fecundity.

In 2022, 14 individuals were identified as new to the Fiji database and 12 new to the Yasawa Islands having been recorded at another site in Fiji. Over the years recruitment has been consistent to the site with on average 38 % of individuals making up new additions to the database. In 2022 there were 2 pregnancies recorded, less than one of the lowest years on record, 12 courtship sightings were recorded.

Manta sightings are typically only recorded from April - October when the SE/E trade winds start across the region. This period is characterised by cooler air and water temperatures and an increase in zooplankton. The majority of manta sightings are recorded on an E wind with water temps equal to and below 28.

Tourism in the region is incredibly important to the local economy, especially surrounding the Manta Channel, with two operators containing the word 'Manta' in their name. Up until COVID-19 (2013-2019) the average number of snorkellers in the water on a single day was 42, during 2020 and 2021 that reduced to only 3. In 2022 that number remained low with 18 snorkellers on average. This could be a factor in why manta sightings remained high during 2022.

Overall indications point to the Yasawa Island population of manta rays being in a healthy state. However, manta sightings through COVID-19 eluded to tourism pressures impacting manta visitations, despite sightings in 2022 remaining high we should remain cautious and strive for more sustainable management protocols to be put in place in order to limit anthropogenic disturbances.



STUDY LOCATION



1. THE FIJI ISLANDS

The Fiji Islands are a group of 500+ volcanic and coralline islands found between 12 ° and 21 ° South and between 175 ° West and 177 ° East (Evenhuis, 2005). Despite consisting of over 500+ islands and islets, the two largest islands of Viti Levu and Vanua Levu make up over 87 % of the total land area (Smith, 1979). Fiji boasts a diverse reef system including fringing reefs, barrier reefs, platform reefs, atolls and near-atolls forming an estimated 10,000 km² of coral reef habitat (Zann, 1992) (Figure 1).

Manta Project Fiji (MPF) currently collects detailed data on manta rays from two regions in the country, the Yasawa Island Chain to the West and the Kadavu Island Group to the South (Figure 1). Sporadic data and contributions from citizen science have come from three further regions in the country, the Lomaiviti Group, the Lau Group and from the Taveuni area (Figure 1). This is by no means an exhaustive map of areas that manta rays are found, but the current remit of data collection by MPF. This report will focus on the Yasawa Island chain and the manta ray population found there.

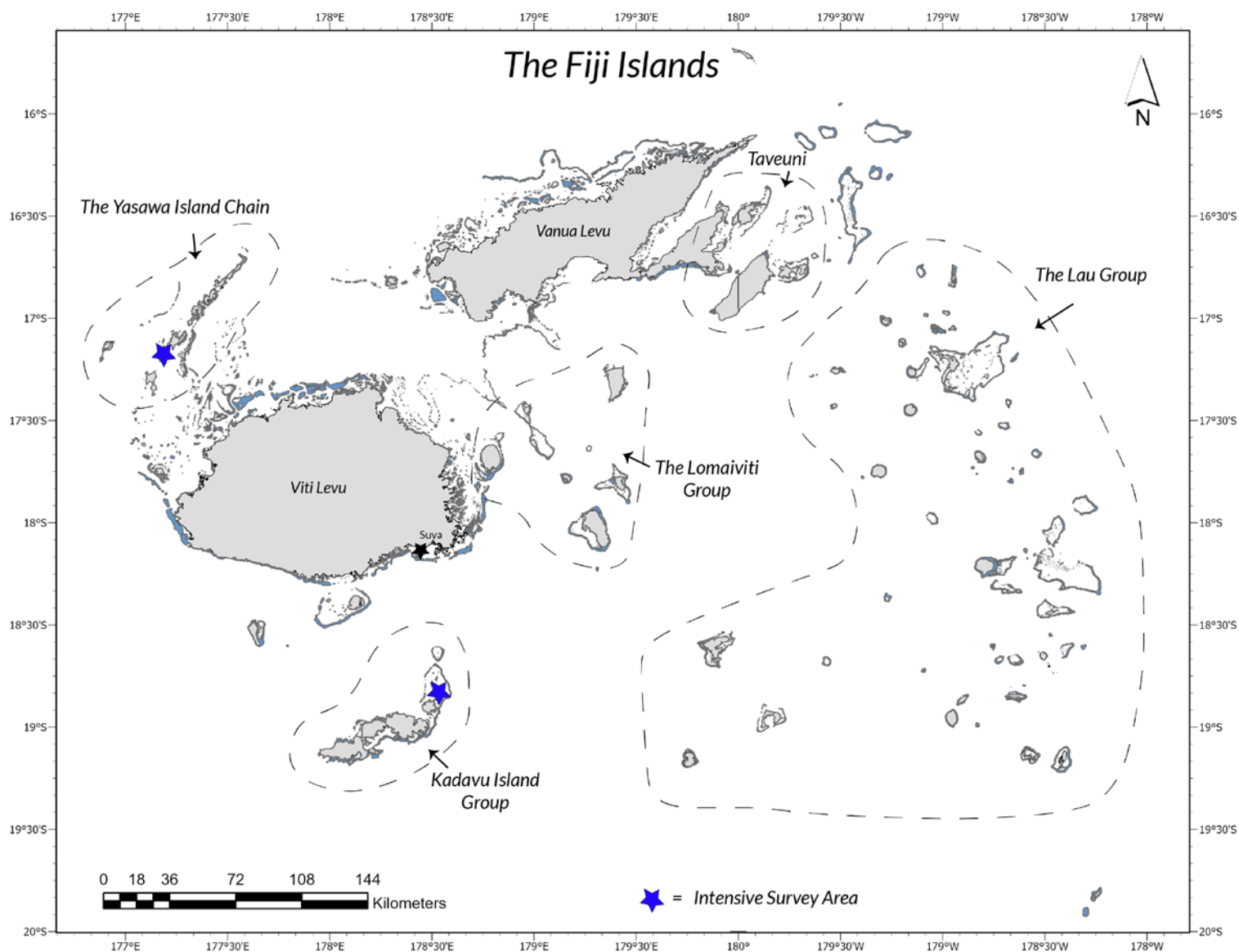


Figure 1 - Map of The Fiji Islands displaying the main island groups, Suva capital city (black star) and Intensive Survey Areas (blue stars) where data has been collected during the data collection period





1.1. THE YASAWA ISLANDS

The Yasawa Islands are located on the north-western side of the Fiji Islands, approximately 40 km from Viti Levu and consist of 11 main volcanic islands running 90 km to the north-east (Ward et al., 2007). As one of Fiji's busiest tourist attractions, the Yasawa Island chain attracts almost 90,000 visitors every year and was increasing year on year between 2012 - 2019 (International Visitor Survey, Fiji 2019). During 2020 and 2021 the COVID-19 pandemic heavily affected tourism throughout the country, with an 81% and 98% reduction in visitors to the country during 2020 and 2021 respectively (Fiji bureau statistics).

The Manta Channel is located towards the Southern end of the island chain between Drawaqa Island and the largest island in the chain, Naviti Island (Figure 2). This small channel is approximately 250 m long, 300 m wide (100 m wide in middle of the channel where mantas forage and clean) and approximately 7 m deep at high tide in the deepest section and 1 m in the shallowest section. The Manta Channel is dominated by hard coral and is subject to high currents during the daily tidal fluctuations, it is on the falling tide when the current runs from east to west that mantas forage in the current within the channel and in the deeper zones east of the channel where dense zooplankton can be found (Figure 2).

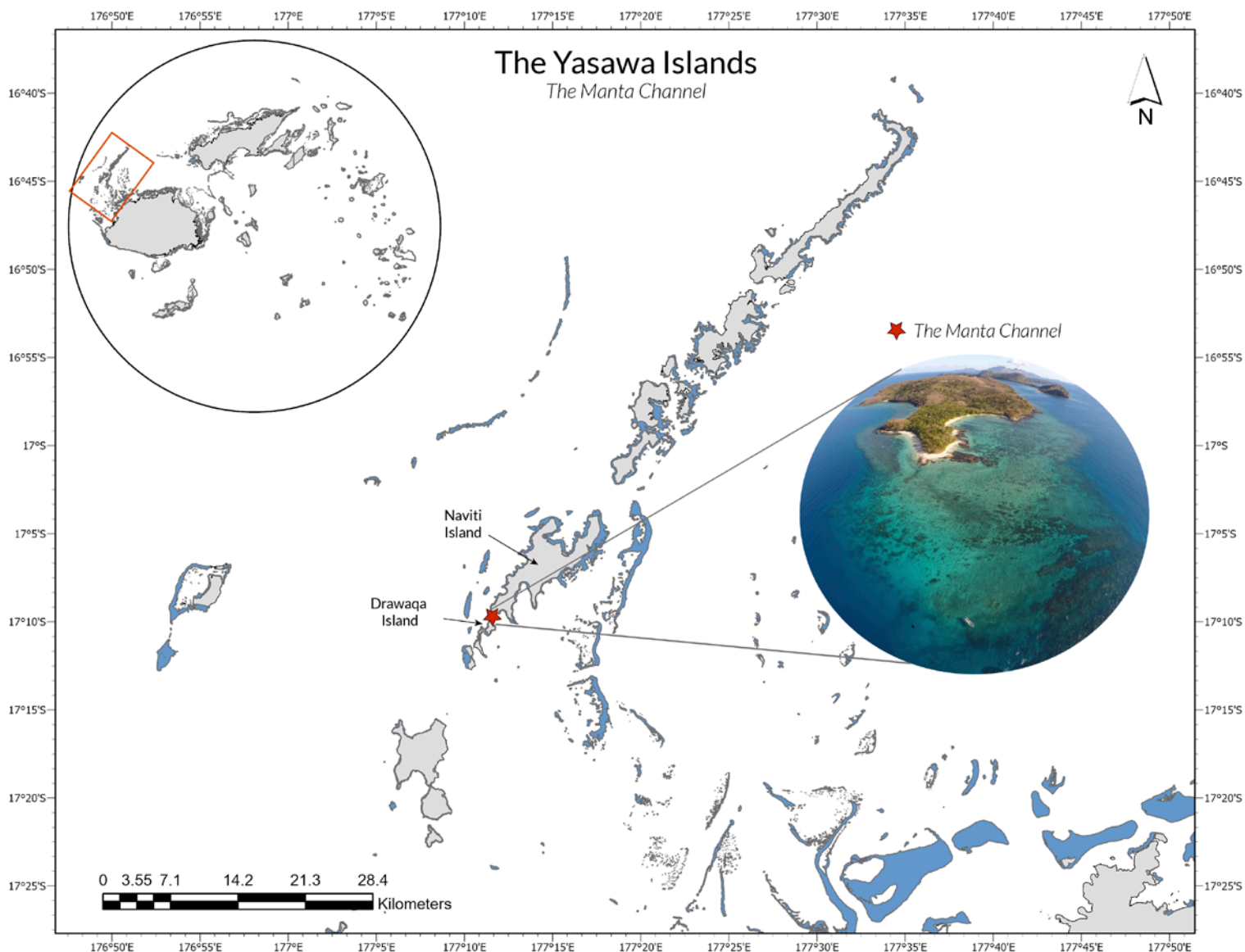


Figure 2 - Map showing the location of the Manta Channel (red star) study site between Drawaqa and Naviti Island in the Yasawa Island group in the Fiji Islands



2. SAMPLING METHODOLOGY

Manta surveys are conducted by MPF researchers and partner resorts using survey guidelines and methodologies laid out by the Manta Trust. From 2012 detailed photographic identification data of Reef Manta Rays (*Mobula alfredi*) and Oceanic Manta Rays (*Mobula birostris*) were collected at the Manta Channel, Yasawa Islands. MPF records sightings of manta rays through photographs of the unique ventral spot patterns of different individuals during manta surveys. For this report, a sighting is defined as a confirmed photographic identification of an individual manta ray on a given day at a specific location.

Majority of the data were collected while snorkelling due to the shallow depths of survey locations with some data collected on drone. For this report, a survey is defined by time spent at a single location each day. If multiple snorkels or dives took place with a short surface interval (approx. 60 mins) at a single site, it was considered a single survey. If an extended surface interval (i.e., morning and afternoon dives) occurred between these are counted as two separate surveys. Survey days refers to the number of days when surveys were conducted.

3. STUDY PERIOD

3.1. 2012–2019

At the end of 2012 MPF was founded and a small number of sightings and identifications were collected from the Manta Channel. Intensive survey effort began at the beginning of the 2013 manta season (Apr 2013).

During 2013-2019 data collection was focused in the Manta Channel. The data was collected by MPF researchers and resort staff from Barefoot Manta Resort working in collaboration with the project. Unfortunately, due to logistical constraints no data is available for 2017.

3.2. 2020 & 2021

The 2020 & 2021 survey period represented a unique opportunity for the project, being able to consistently collect data with dramatically reduced tourism pressures at the Manta Channel due to COVID-19. This was only possible due to the incredible support of our in-country project partner Barefoot Manta Resort.

The Fiji Islands closed international borders in March 2020 due to the outbreak of COVID-19, the country was able to contain the outbreak, but international borders remained closed for the duration of the year. COVID-19 re-emerged in early 2021 causing international borders to remain shut until the end of the year. The only tourists present at manta aggregation sites during the 2020 & 2021 manta season were a reduced number of yachts that were allowed into the country through Fiji's Blue Lane Initiative. Fiji's borders reopened on the 1st December 2021.

3.3. 2022

In 2022, all surveys conducted by MPF, and partner resort Barefoot Manta Resort in the Manta Channel were recorded regardless of if mantas were recorded or not. Surveys were conducted on as many days (n=201) as conditions allowed (Figure 3). Data was therefore collected only on dedicated manta research snorkels, with few ID contributions from other sources.

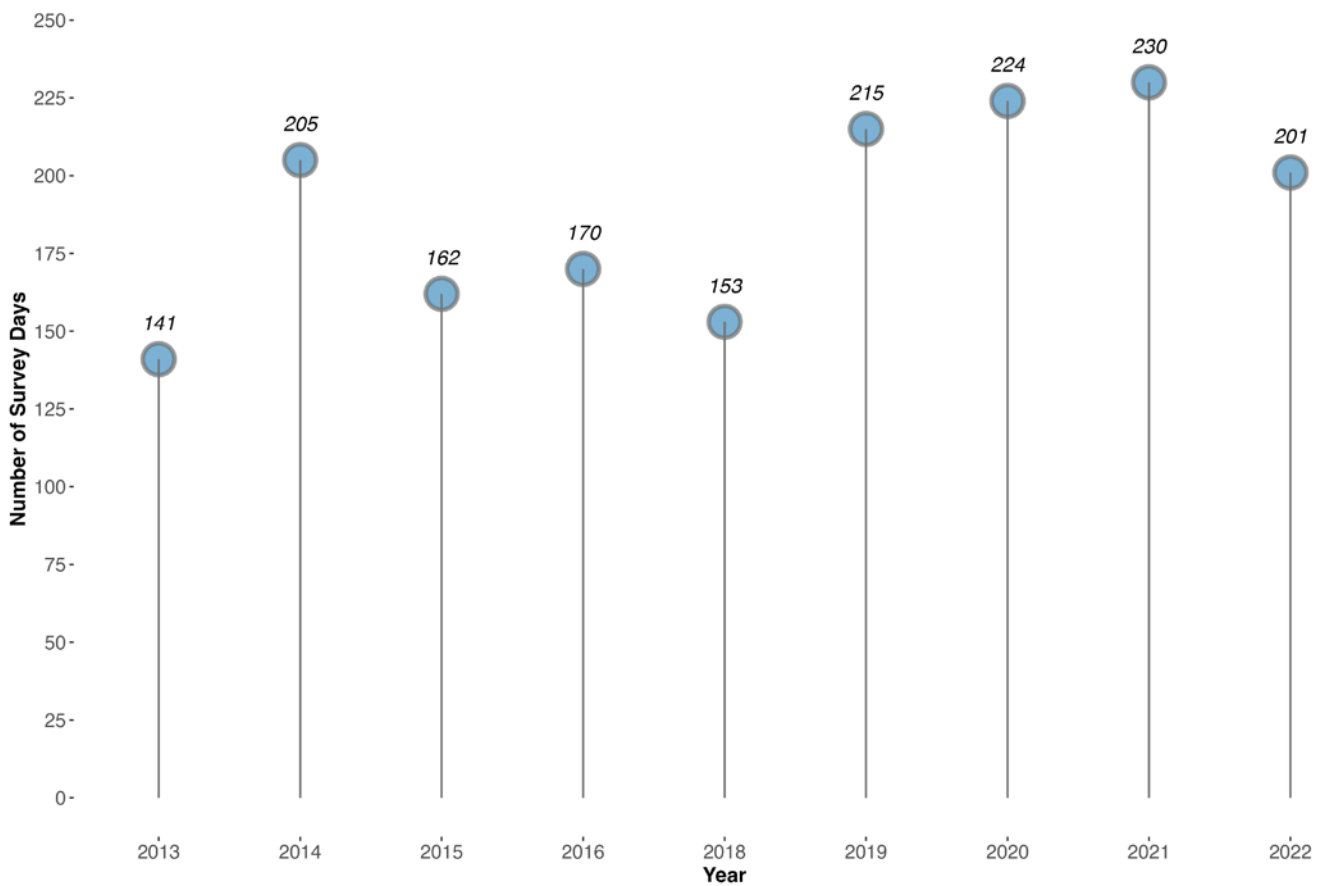


Figure 3 - Dot plot showing the number of survey days undertaken each year at the Manta Channel, Yasawa Islands, Fiji

Survey days ranged from 141 days to 230 days between 2013 and 2022 at the Manta Channel, with the most survey days being recorded in 2021 (n = 230). During the 2022 manta ray season survey effort was lower than the previous three years (2019-2021) and 2014, with 201 days surveyed (Figure 3). This is likely due to sightings dramatically decreasing towards the end of the season, meaning less surveys were conducted as the season ended.

Mantas were present on 140 days (70 %) in 2022, as a percentage this is the highest since 2016, but lower than 2013, 2014 and 2016. Between 2018-2021 the percentage of survey days with mantas ranged from 54 %-63 %, this could be caused by the increase in survey effort between 2019-2021 or may indicate that mantas were visiting the site less frequently than previous years. Despite recording a smaller percentage of survey days with manta rays present, the number of days with mantas present (n = 140,) was consistent with both 2020 (n = 139) and 2021 (n = 141) (Figure 4).

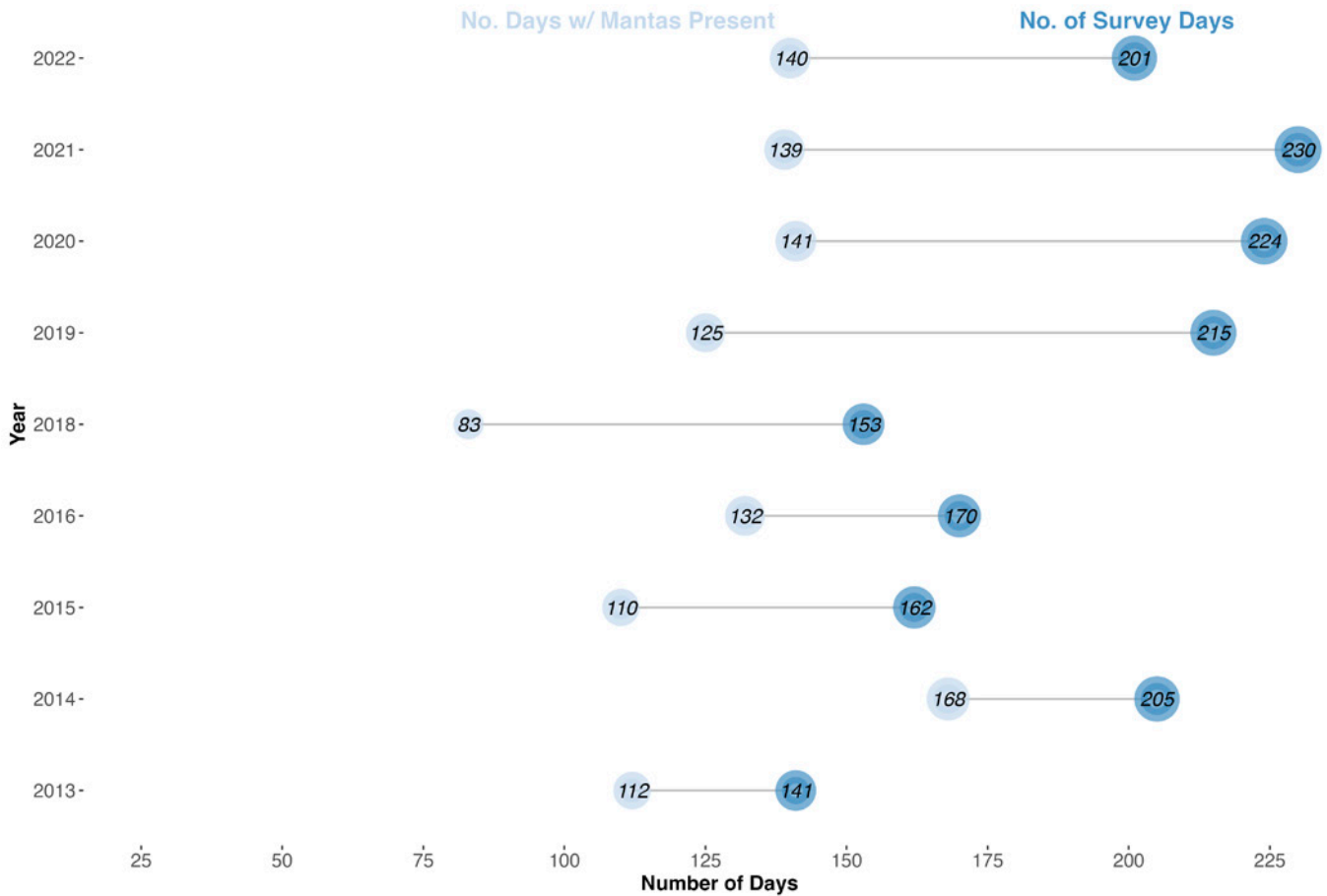


Figure 4 - Dot plot showing annual number of survey days vs the number of survey days with mantas present at the Manta Channel, Yasawa Islands (Fiji).

4. OCEANIC & REEF MANTA RAY SIGHTING TRENDS

To date MPF have identified both reef manta rays (*M. alfredi*) and oceanic manta rays (*M. birostris*) at the Manta Channel.

4.1. OCEANIC MANTA RAY SIGHTING TRENDS

Oceanic manta ray sightings are incredibly rare, with only three sightings being recorded in 2020 at the Manta Channel, this marks the first occasion since records began at this site that the species has been recorded. One confirmed identification was recorded, and the manta was re-sighted the next day.



Image: Mathjis Carmen

4.1. REEF MANTA RAY SIGHTING TRENDS

Since the beginning of 2013 a total of 3548 sightings of reef manta rays have been recorded at the Manta Channel by MPF researchers, project partners and citizen scientists. Between 2013 and 2016 sightings and mean number of sightings per survey remained stable, ranging from 304 - 392 sightings per year and from 1.7 - 2.2 mean sightings per survey. (Figure 5). Sighting data is unavailable for 2017.

The 2018 manta season displayed a dramatic decrease in both sightings and mean number of sightings per survey with 166 and 1.1 respectively (Figure 5). Interestingly, the low sighting numbers could have been caused by a lower number of survey days conducted throughout 2018 (n = 153, Figure 3). Reef manta sightings then increased in 2019 (n = 295) despite the mean number of sightings per survey remaining low (n = 1.1), due to an increase in survey days (n = 215, Figure 3).

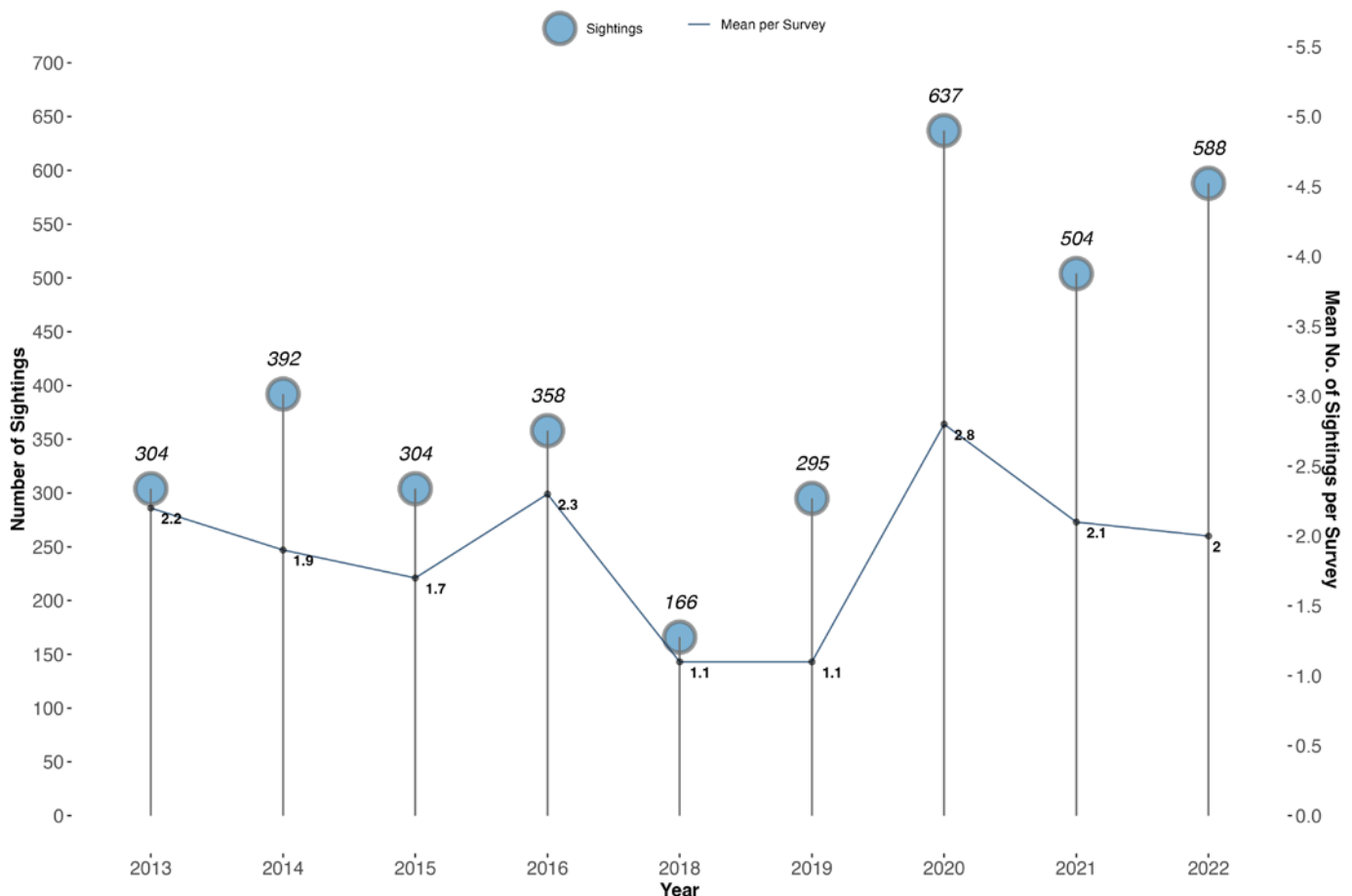


Figure 5 - Dot plot showing annual number of sightings vs the mean number of sightings per survey at the Manta Channel in the Yasawa Islands (Fiji).

Between 2020 & 2022 the highest number of sightings were recorded since records began, with 2020 displaying the single highest year of sightings (n = 637) and mean number of sightings per survey (n = 2.8) on record (Figure 5). Sightings then decreased in 2021 (n = 504) before increasing again in 2022 (n = 588) with the mean number of sightings per survey remaining similar to 2013 - 2016 (Figure 5).

The dramatic increase in sightings during 2020 (62% increase when compared to the previous best year in 2014) coincided with the COVID-19 pandemic and reduction of tourism pressure, however such a significant increase is likely due to a combination of favourable environmental conditions with the lack of tourism pressures. Interestingly tourism returned in 2022 where sightings increased when compared to 2021, this is discussed in further details in the Tourism section.

Sighting trends at the Manta Channel have remained relatively consistent over the years with >99% of sightings being recorded from April-October every year and a typical peak in sightings being recorded between June - September. 2022 followed a similar pattern to 2013-2019 with peak sightings occurring during June through to September, during 2022, peak sightings were recorded in July (n=209), the highest sighting month on record(Figure 6).

Interestingly sightings have exceeded 100 sightings in a single month ten times, eight of which have been recorded between 2020 and 2022 (Figure 6).

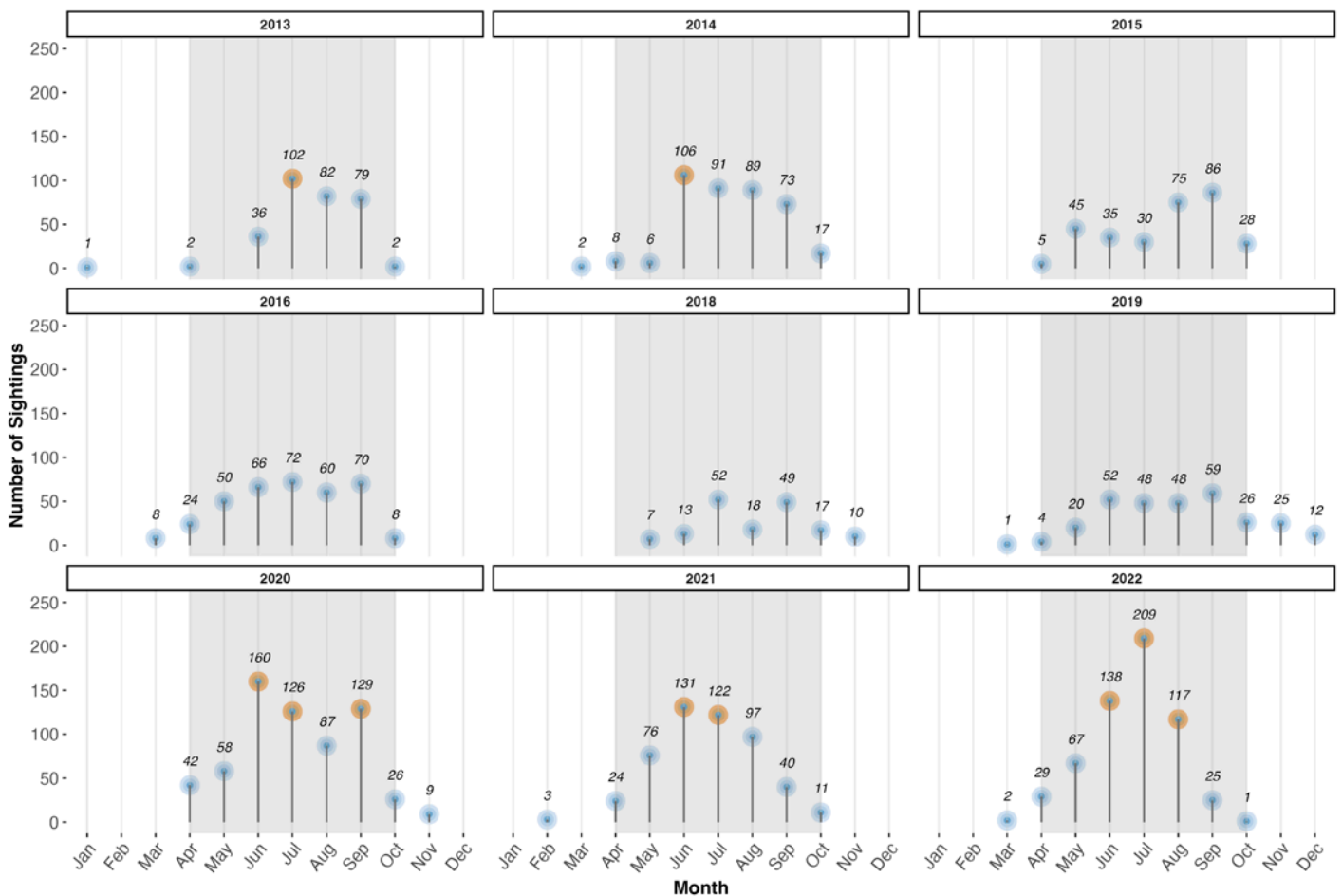


Figure 6 - Dot plot displaying the number of sightings per month for each year of data collection at the Manta Channel in the Yasawa Islands (Fiji). Months with >100 sightings are highlighted in orange.

Consistent with the increase in sightings during 2020-2022, we also recorded an increase in the number of different individual manta rays that visited the Manta Channel (Figure 7). This number remained relatively stable from 2013 through to 2016 with between 30 and 41 different manta rays visiting the site, however during the 2018 season this dropped to only 19 individuals (Figure 7). During 2019 this figure increased again to comparable levels to previous years with 39 individuals, however during 2020-2022 we recorded between 50 and 69 different individuals visiting the Manta Channel (Figure 7).

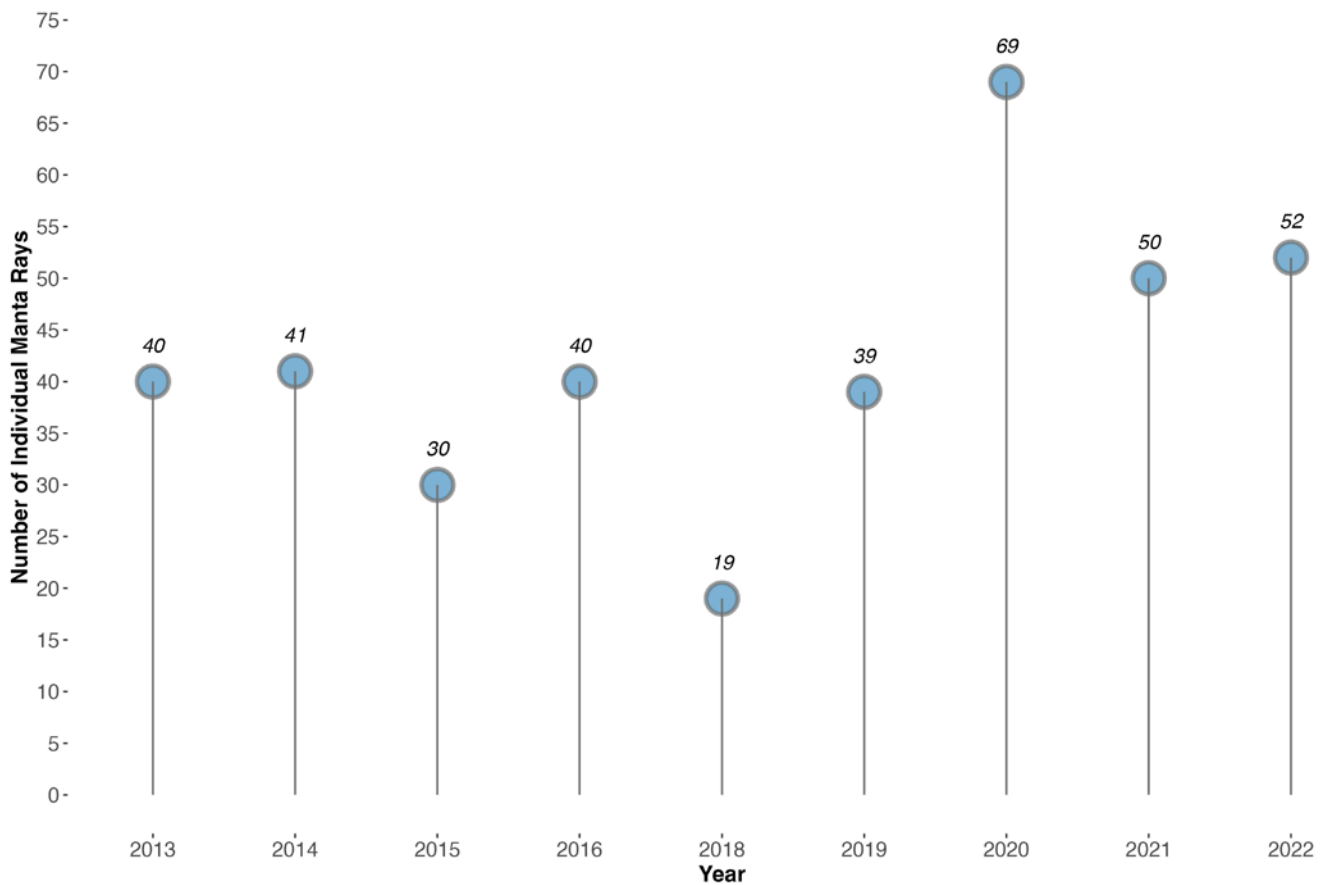


Figure 7 - Dot plot showing the number of different individual manta rays recorded annually at the Manta Channel in the Yasawa Islands (Fiji).



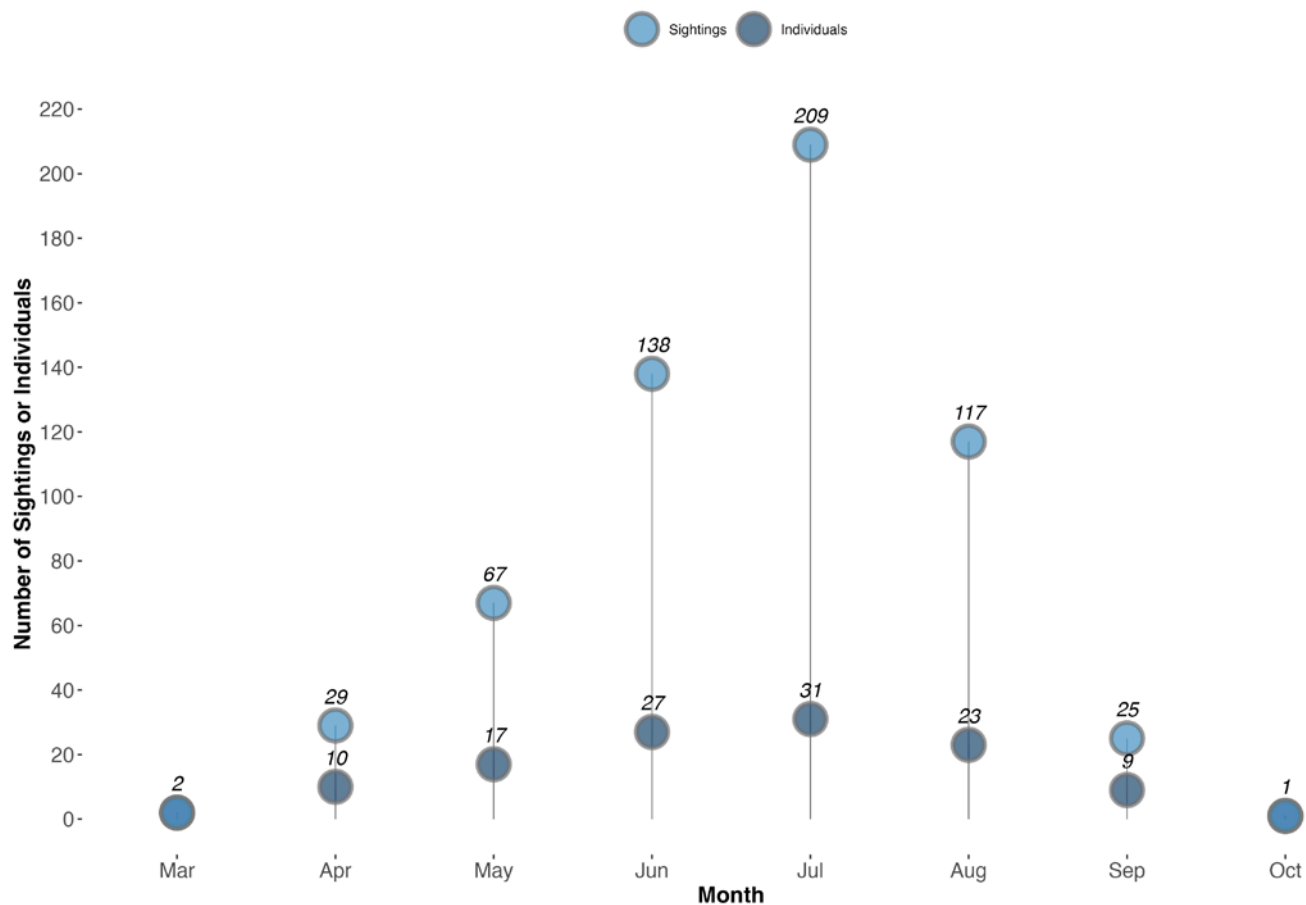


Figure 8 - Dot plot showing the number of sightings vs the number of different individuals each month in 2022 at the Manta Channel in the Yasawa Islands (Fiji).

The highest number of confirmed sightings (n = 209) and different individuals (n = 31) during 2022 was recorded in July (Figure 8). This pattern is typical of most years with a peak in both sightings and individuals being recorded from June-August, with local environmental conditions dictating which month observes a peak in manta activity.

Manta Rays in the Channel

The annual records on the survey days when manta rays were recorded in the channel

YEAR	MAX # OF MANTAS ON SINGLE DAY	# OF DAYS WITH >8 MANTAS	MEAN # OF MANTAS WHEN MANTAS PRESENT	DISTRIBUTION IN THE # OF MANTA RAYS RECORDED EACH DAY WHEN MANTAS PRESENT
2013	13	5	3	
2014	14	6	4	
2015	12	5	3	
2016	11	1	3	
2018	7	0	2	
2019	7	0	2	
2020	15	15	5	
2021	12	10	4	
2022	13	13	4	

Table 1 - Table showing survey data on days when manta rays were recorded in the Manta Channel, Yasawa Islands, Fiji

During the 2022 season the highest number of individuals on one survey was 13 different mantas. This is comparable to 2013-2016 and 2020 and 2021 where the highest number was between 11-15 different mantas recorded on one survey (Table 1). During 2018 and 2019 however this number was only 7 individuals. 2020-2022 display a large difference in the number of days where >8 different mantas were sighted on a single survey compared to previous years with 15 days, 10 days and 13 days respectively compared to the previous high of 6 days in 2014 (Table 1).

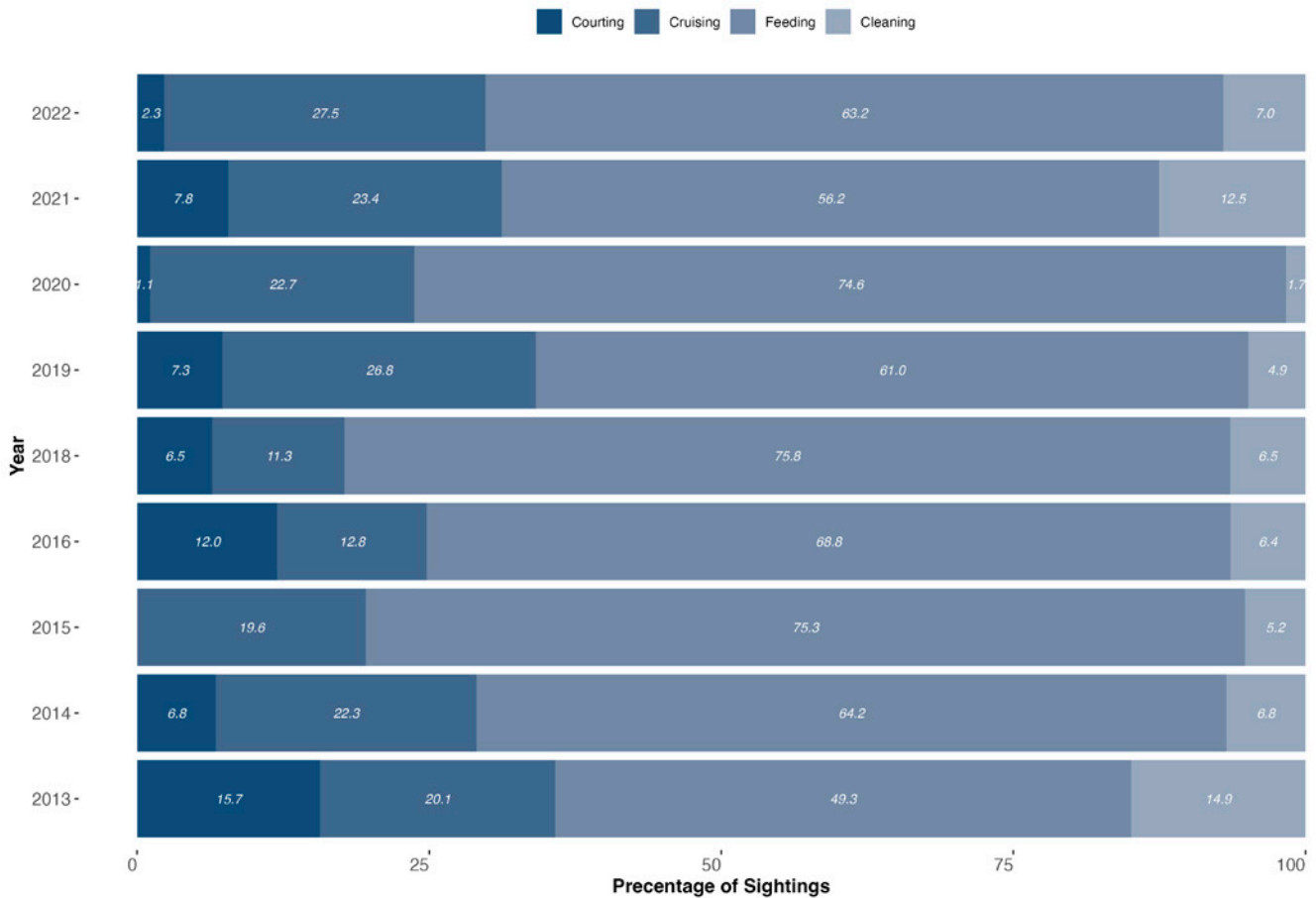


Figure 9 - Predominant behaviour recorded during each reef manta ray sighting at the Manta Channel in the Yasawa Islands (Fiji).

Feeding behaviour has been the most prominent behaviour observed between 2013 - 2022 at the Manta Channel, ranging from 49 % of sightings to 76 %, with cruising being the second most prominent behaviour observed every year (Figure 9). Sixty-three percent of all sightings during the 2022 manta season were associated with feeding behaviour and increase of 7 % when compared to 2021 (n=56.2 %) (Figure 9).

Courting behaviour in 2022 only made up 2.3 % of sightings, in previous years this behaviour has ranged from 15.7 % in 2013 to 0 % in 2015 (Figure 9). Cleaning behaviour decreased from 15 % of observed sightings in 2013 to only 1.7 % of observed sightings in 2020, before increasing again in 2021 to 12.5 % then decreasing to 7 % in 2022 (Figure 9).





5. POPULATION DEMOGRAPHICS

As of 31st December 2022, the total number of different reef manta rays which have been recorded at the Manta Channel since the project was first created is 135 individuals (10 individuals were recorded before 2012), with the total number of reef manta rays recorded at the site standing at 140 individuals (5 mantas were first recorded first elsewhere).

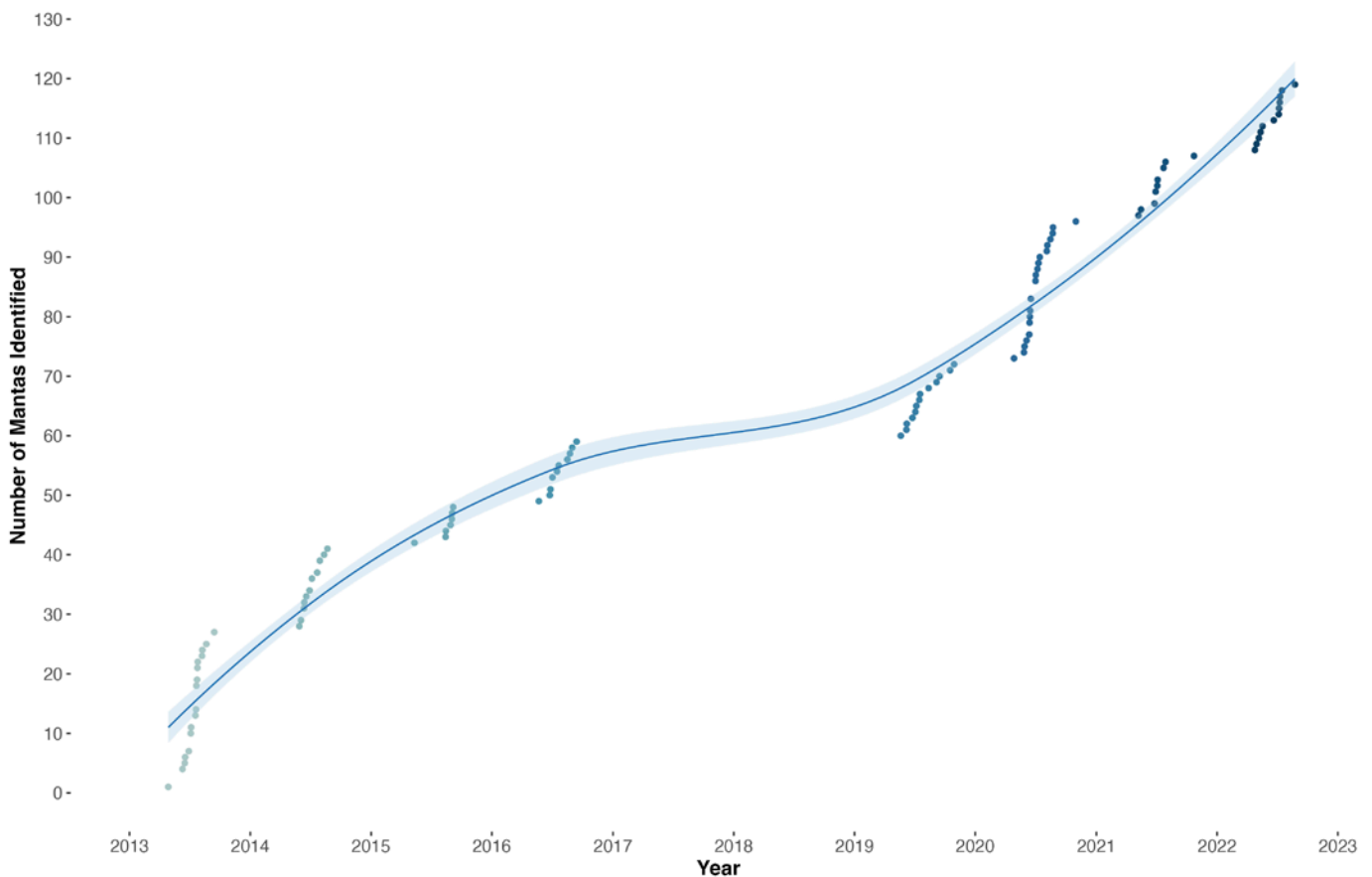


Figure 10 - Discovery curve of the Yasawa Island population

When looking at the discovery curve (Figure 10) we can see that every year a consistent number of new manta rays are recorded, except for 2017-2019 when no new manta rays were recorded. With the curve still on an upward trajectory it could indicate that this population of manta rays is both healthy and larger in size than what we have recorded and that the manta rays which make up the majority of sightings show high site fidelity to the Manta Channel.

5.1. SEX DEMOGRAPHICS

Since 2012, 140 individual reef manta rays (71 males, 68 females and 1 individual of unknown gender) have been identified at the Manta Channel comprising of 31 % of the whole Fiji reef manta ray population. The split of almost 50/50 between males and females is typical of a site predominantly used for foraging as the channel is (Figure 11).

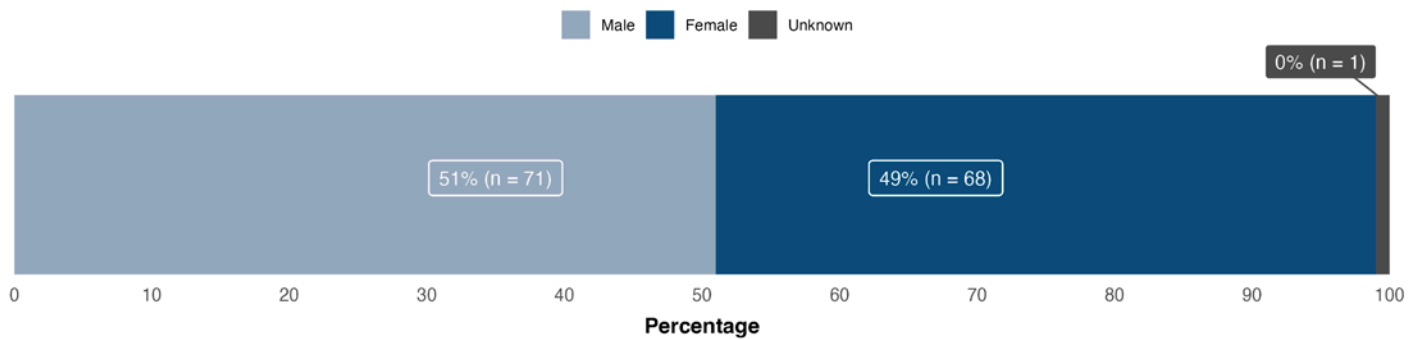


Figure 11 - Sex demographics of the Yasawa Island population

5.2. MATURATION DEMOGRAPHICS

Maturation status in manta rays can be determined by the presence of mating scars or visible pregnancies in females, or by the enlargement and calcification of claspers in males. If visual features are not apparent, then the size and historical sighting records of individuals can be considered to help estimate maturation status. If an individual was estimated or measured to be at, or larger than, 320cm disc width in females, or 270cm disc width for males, they were considered adults.

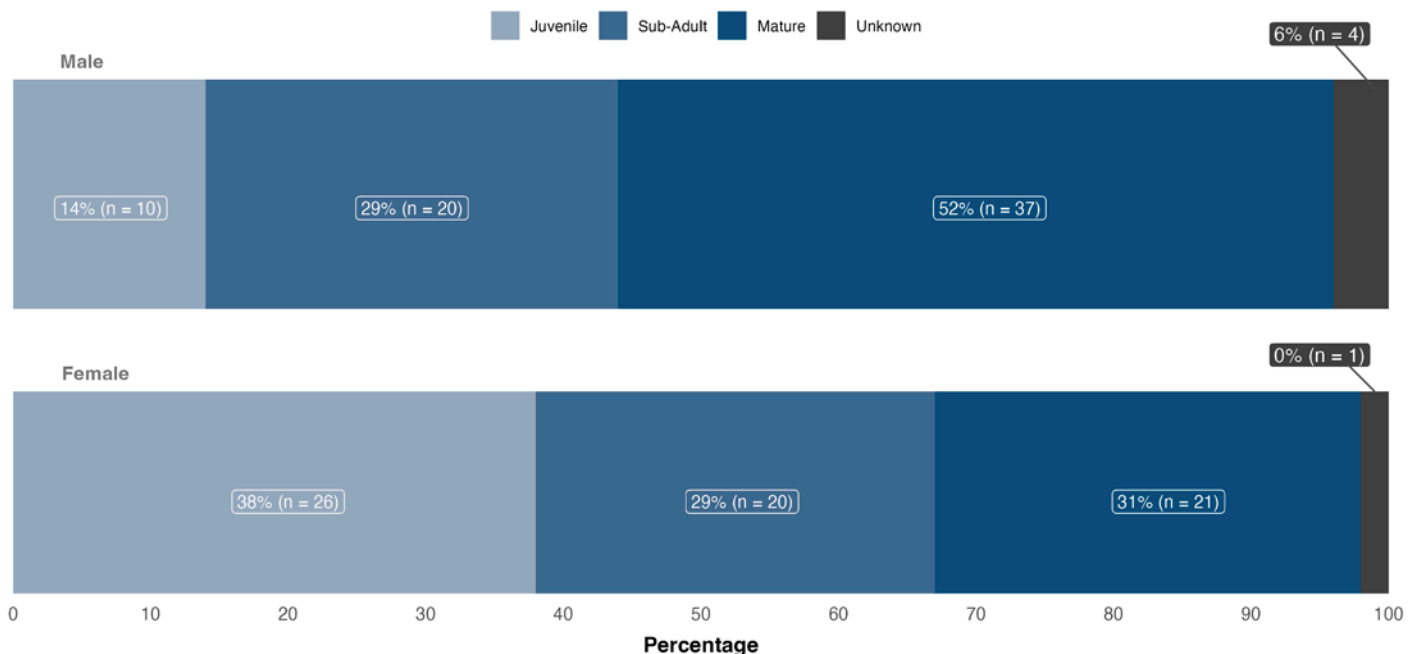


Figure 12 - Lifestage demographics of the Yasawa Island population

The Yasawa Island population when split by sex into different life stages can be seen in Figure 12. 52 % (n = 37) of males are mature compared to only 31 % (n = 21) of females being mature, both male and females are comprised of 29% sub-adults (n = 20). Juvenile males only make up 14 % (n = 10) of the male population, however, juvenile females make up 38 % (n = 26) of all females (Figure 12).

5.3. COLOR MORPH DEMOGRAPHICS

The reef manta ray population in The Fiji Islands includes individuals of both chevron colour morph and the less common melanistic (black) colour morph. Melanism, a recessive genetic trait, leading to an over-production of the skin pigment melanin, causing individuals expressing the gene to be completely black in colouration apart from a ventral area of white between the gills which varies in shape and size amongst individuals.

Amongst the global reef manta ray population this condition is rare, the Maldives for example, which is home to the largest reef manta ray population in the world (n = >5000 individuals) does not have any melanistic individuals currently in the database, however in certain areas of the Pacific Ocean melanism is much more common.

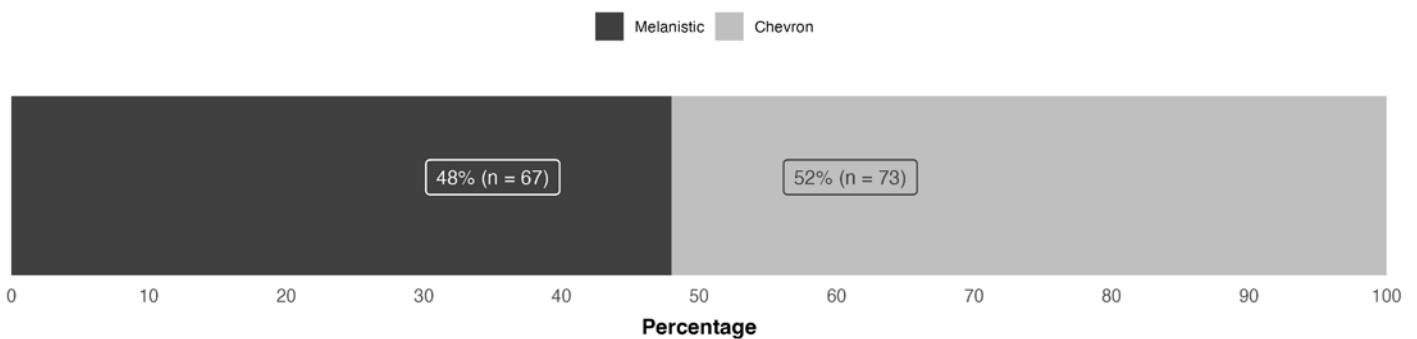


Figure 13 -Color Morph demographics of the Yasawa Island population

The Yasawa Island population currently displays the highest proportion of melanistic manta rays within the country, 48 % of individuals (n = 67) are melanistic morphs and 52 % of individuals (n = 73) are chevron morphs (Figure 13). This could tentatively indicate a limited genetic connection to the populations in other parts of the country which have a lower melanistic proportion.



5.4. NEW INDIVIDUALS

During the 2022 manta season 52 individuals were photographed, 37 % of the current population (n = 140), slightly less than the 39 % (pop = 128 end of 2021) photographed in 2021. Twelve new individuals were recorded over the 2022 season, making up 23% of the total number of manta rays recorded (Figure 14). Eight of the newly identified individuals were identified as juveniles, two sub-adults and two were mature individuals.

With the exception of 2013 & 2018 the percentage of new individuals recorded every year has ranged between 22 % and 35 % with juveniles typically making up >50 % of the newly identified individuals (Figure 14). This consistent rate of recruitment to the site is a very promising insight into the health and size of the Yasawa Island reef manta ray population, the consistent recruitment of juveniles indicates a stable and healthy, reproductive population.

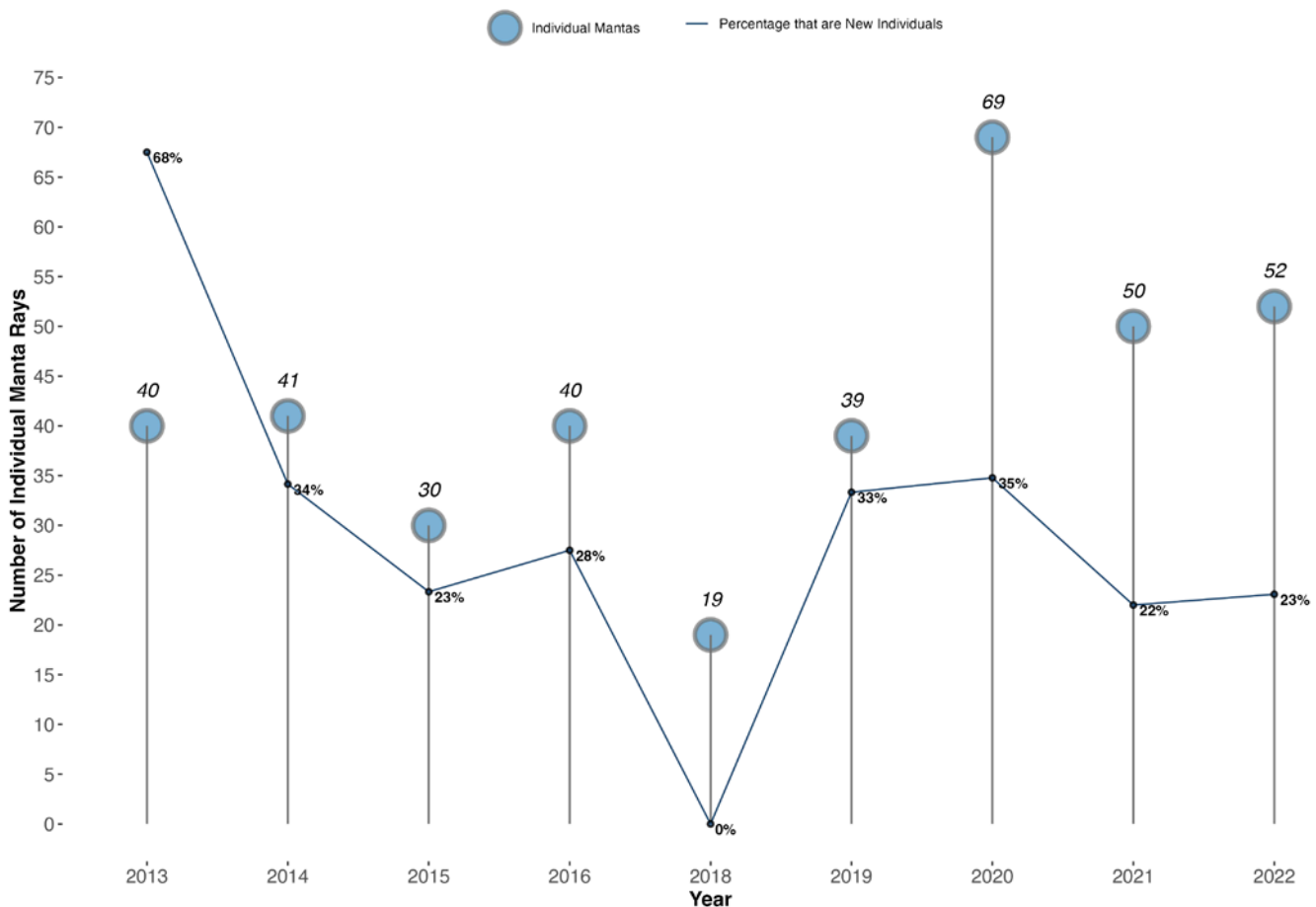


Figure 14 -Dot plot showing the number of individual manta rays annually and the percentage of these that are new individuals



5.5. SIGHTING DEMOGRAPHICS

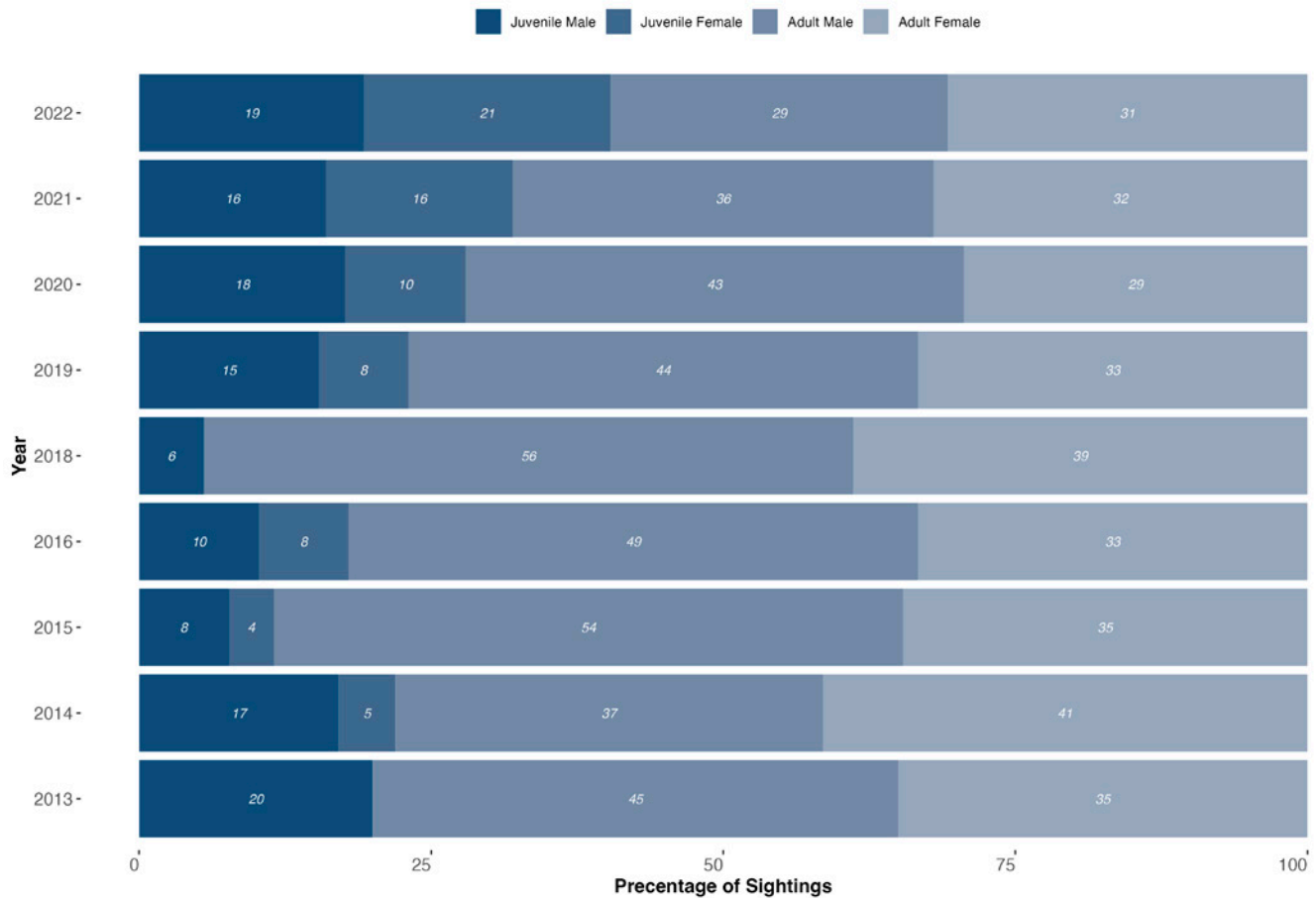


Figure 15 - Annual sighting demographics at the Manta Channel, Yasawa Islands, Fiji

During 2022 adult manta rays made up 60 % of the sightings (31 % adult females and 29 % adult males) and juvenile 40 % of the sightings (21 % juvenile females and 19 % juvenile males)(Figure 15).

With sightings broken down by maturation status it can be seen that adult manta rays make up the larger percentage of sightings between 2013-2022, however despite this there has been a roughly 20 % decrease in adult manta ray sightings between 2013-2022, with the increase in juvenile sightings being specifically, juvenile female manta rays (Figure 15). This could be due to a natural period of population fecundity leading to more juveniles utilising the site, however this also could be a direct result of less adults using the site meaning juveniles have an enhanced foraging opportunity in the absence of adult manta rays.



6. RESIDENCY & MIGRATION

The population of reef manta rays in the Yasawa Islands is small ($n=140$) and most likely resident (resight rate of 76 %, the resight rate is the percentage of manta rays sighted >1 in the island chain) to the island chain as very few of the individuals have been sighted elsewhere in Fiji. However, more investigation is needed to understand where the majority of the population move to during the rest of the year.

It is possible that several smaller sub-populations make up this population, with overlap happening in certain habitats, or individuals exhibiting varying degrees of spatial habitat use. After having recorded 140 different individuals since 2012, only 15 of these individuals make up over 85 % of all recorded sightings at the Manta Channel.

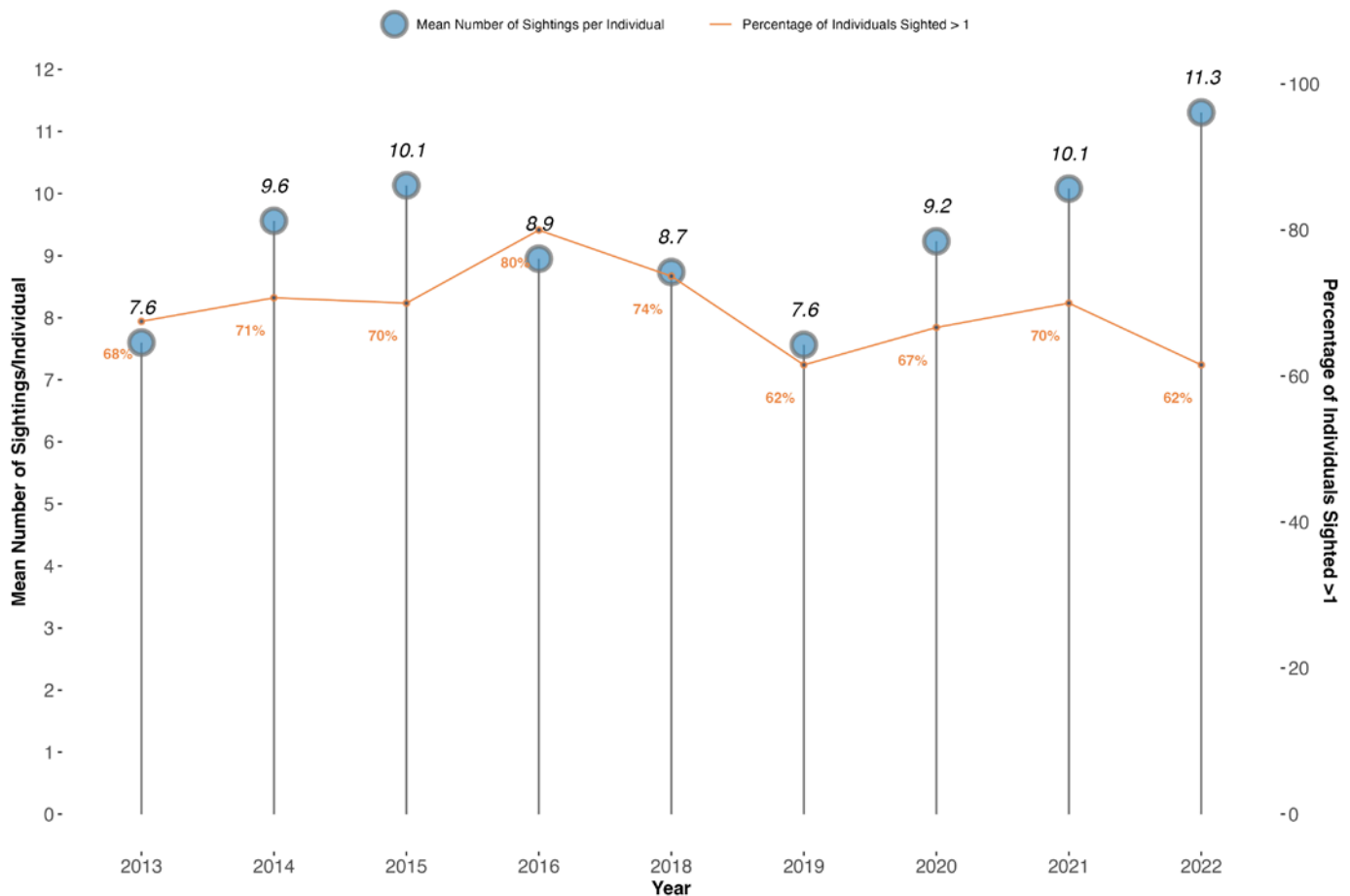


Figure 16 - Dot plot with the mean number of sightings per individual against the percentage of individuals sighted >1 at the Manta Channel, Yasawa Islands, Fiji

Individuals were sighted an average of 11 (n=11.3) times during the 2022 season, an increase from the previous three years (2019, n=7.6; 2020, n=9.2; & 2021, n=10.1 respectively) and the highest figure since records began (Figure 16). The percentage of individuals sighted more than once however decreased to the joint lowest percentage recorded with 2019 (n = 62 %), an 8 % decrease from 2021 (Figure 16).

This is because despite 52 different manta rays being recorded during 2022, 15 of those individuals made up >85 % of sightings and only 2 of those manta rays made up >25 % of all sightings. Suggesting a larger percentage of the population than normal were spending more time away from the Manta Channel during 2022.

To investigate the residency and account for survey effort over the years a Residency Index (RI) has been calculated for each year and month. This index is based on the ratio between the number of days each individual was sighted and the total number of surveyed days (e.g., a RI of 5 % means that on average each individual was sighted on 5 % of the total days surveyed).

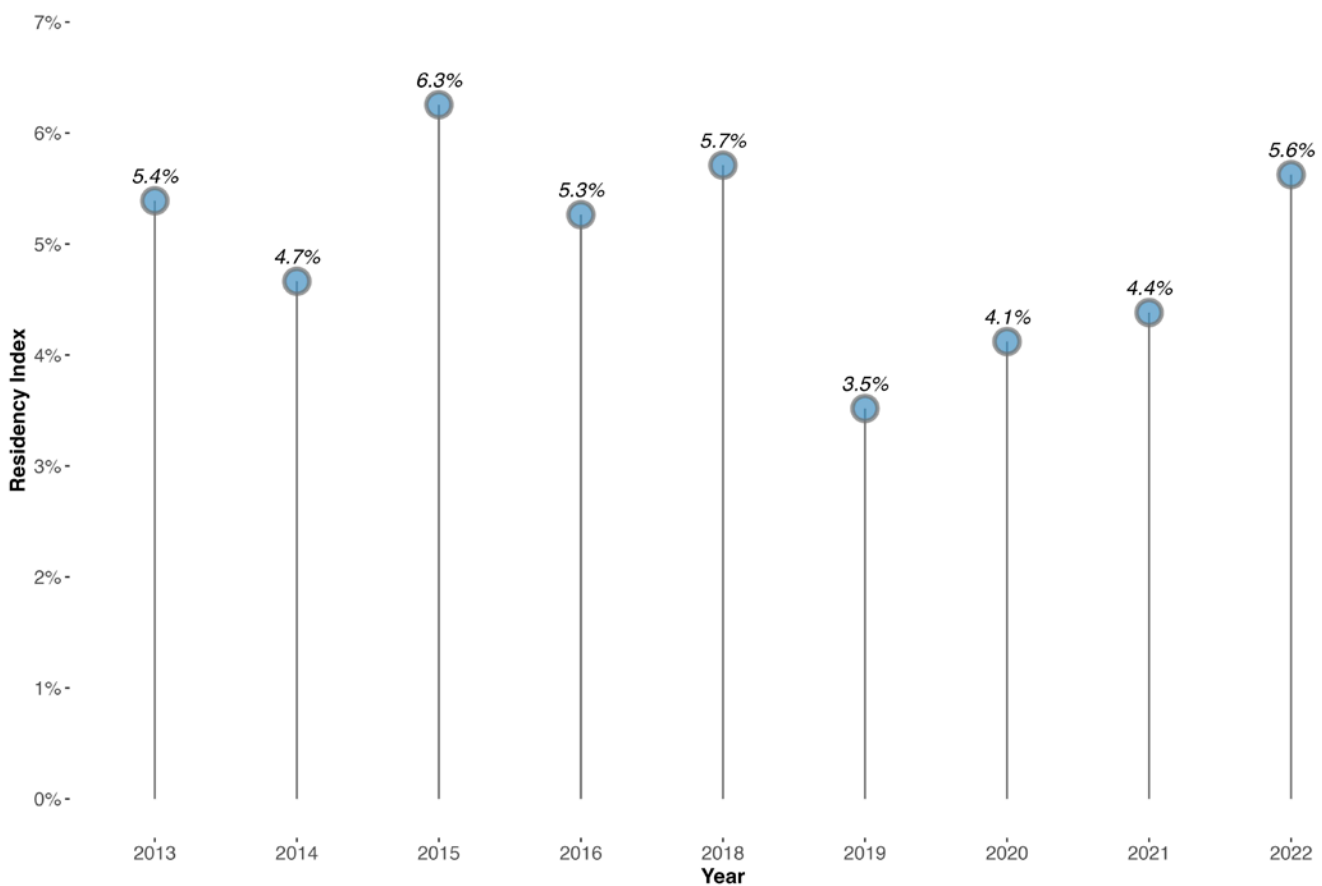


Figure 17 - Annual Residency Index (RI) of the reef manta rays sighted annually at the Manta Channel. RI was calculated as the average of each individual's residency score (equal to the number of times sighted annually divided by the number of surveyed days in the atoll).

The RI for the Manta Channel in 2022 was 5.6 %, one of the highest on record (Figure 17). In 2022 (n = 5.6 %) there was an increase in RI from the previous three years (2019, n = 3.5 %; 2020, n = 4.1 %; & 2021, n = 4.4 % respectively) and was the third highest RI on record behind 2015 (n = 6.3 %) and 2018 (n = 5.7 %) (Figure 17). This increase is an encouraging sign, however the fact that such a small number of manta rays make up such a large percentage of the sightings indicate how fragile this site could be to disturbance as if any of those 15 manta rays are absent it can have a large impact on sightings and tourism.

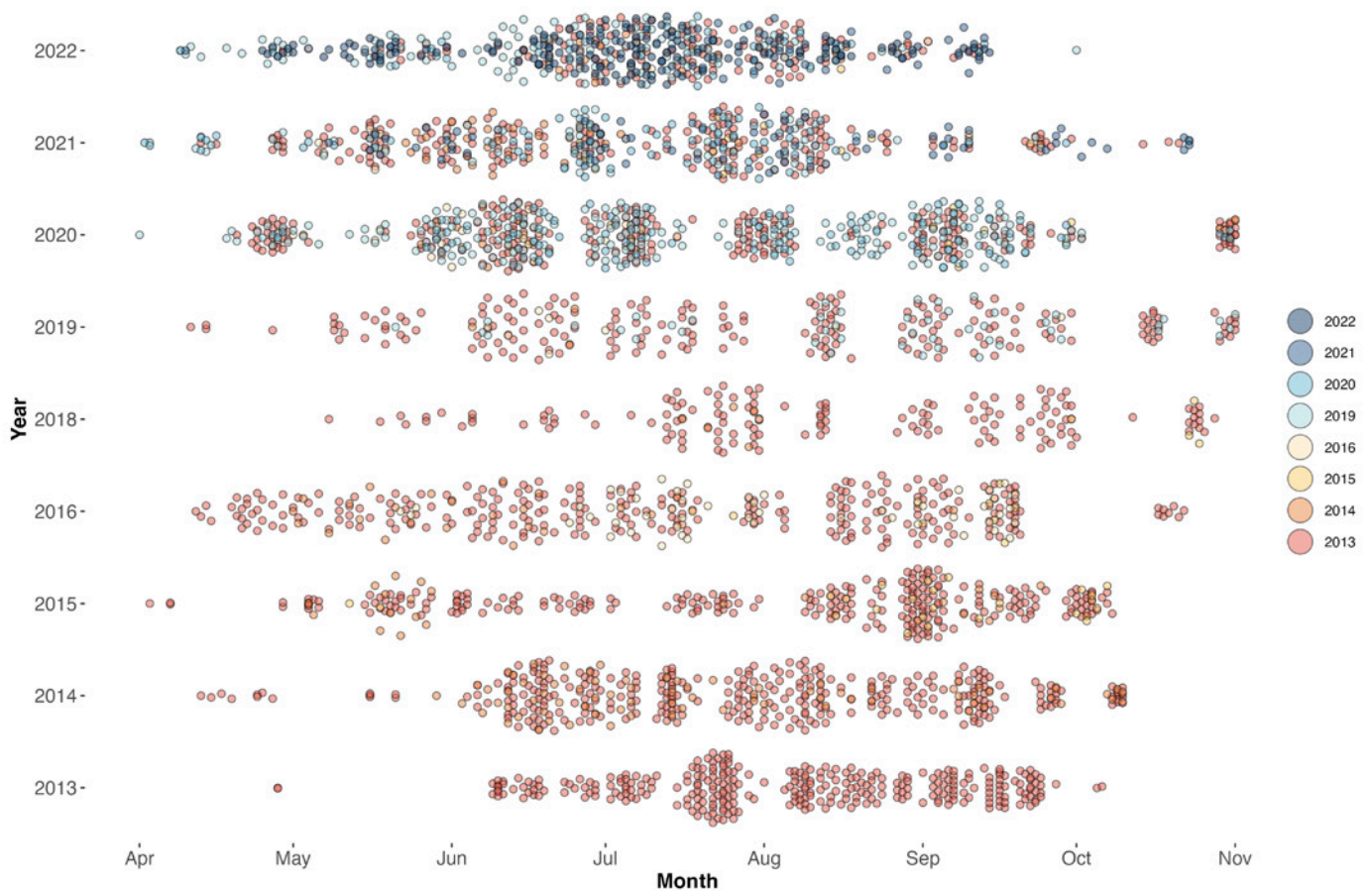


Figure 18 - Dot plot showing manta sightings each year. Each dot represents one individual manta sighting, colored by the first year the manta was identified at the Manta Channel, Yasawa Islands, Fiji

Of the top 15 most resident manta rays in 2013, 2014, 2015 and 2016, only 5 of those individuals were in the top 15 for 2022, the other ten are all recent recruits to the population. This can be clearly seen in Figure 18 where sightings throughout 2022 are dominated by recently identified manta rays.

This shift could have happened for a couple of reasons; older, mature manta rays that were first sighted in earlier years use the site less due to reasons such as changing long-term ecological needs or external chronic pressures from anthropogenic sources, leading to further foraging opportunities for juvenile manta rays.

Another reason could be a natural period of population fecundity leading to more juveniles being present in the area, in turn using the site more. However, this doesn't explain the decrease in site use by older individuals, it is possible that a mix of both reasons is a cause for the recorded change.



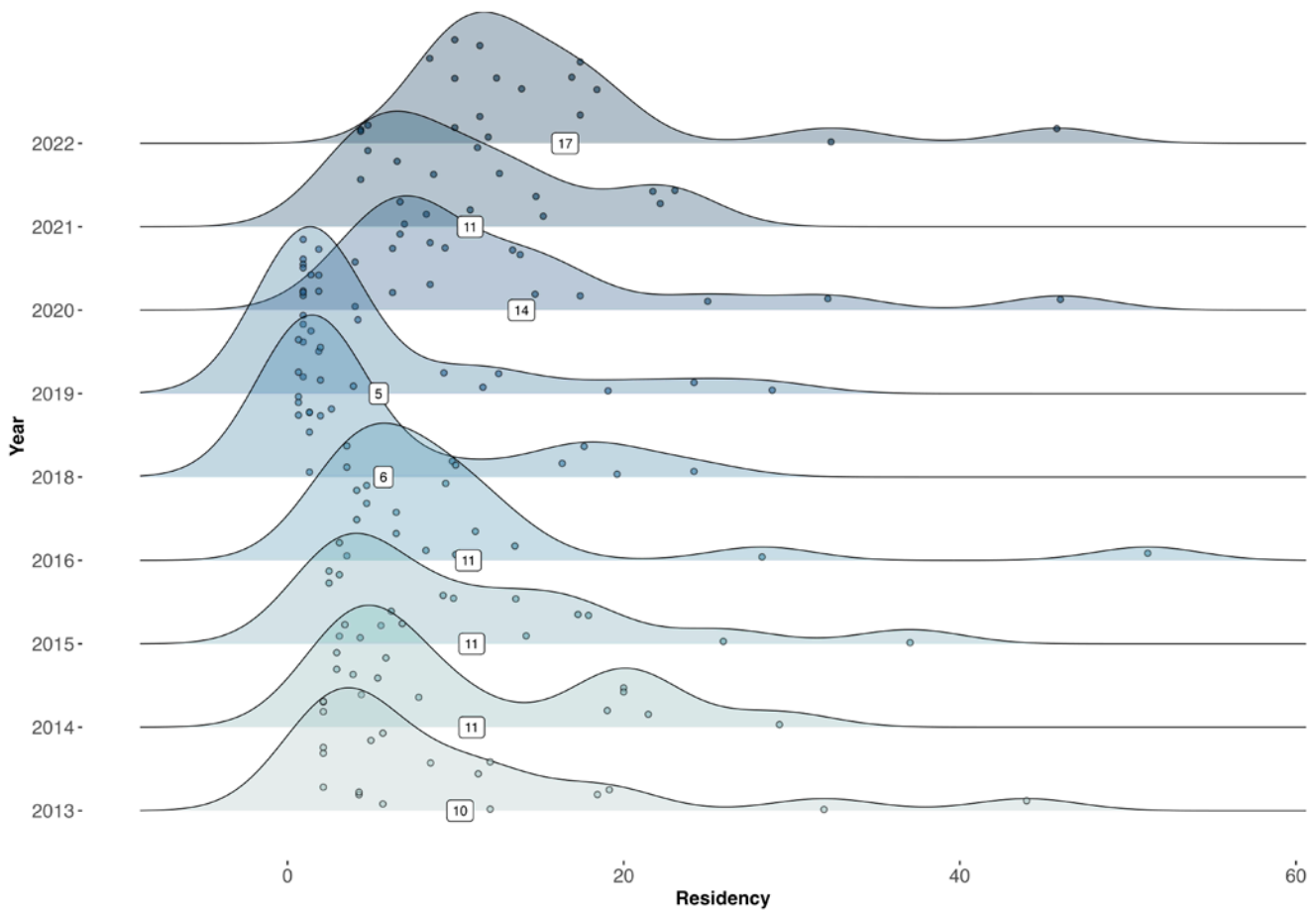


Figure 19 - Density plot showing the RI distributions of the top 15 resident manta rays annually at the Manta Channel, Yasawa Islands, Fiji. The mean RI is highlighted in white and labelled for each year.

We can infer the resilience of the site by investigating the distribution of the residency index's throughout the population which make up the majority of sightings, in this case the top 15 sighted manta rays every year. The theory being that if sightings are more evenly distributed between the top 15 individuals then the site could be more resilient to disturbance compared to if just one or two manta rays made up the bulk of sightings. In 2022 the top 15 manta rays displayed the highest distribution and highest mean residence on record with 17 %, 3 % higher than 2020 and 6 % higher than 2014, 2015, 2016 and 2021 (Figure 19).

Despite this result it is clear from 9 years of data that only a limited number of manta rays make up the majority of sightings at this site, if these select few manta rays are disturbed from external pressures such as tourism, sightings could drastically decrease.

Nine manta rays (6.4 % of the total population) have been sighted in other regions around the country (Figure 20, Table 2). Four of these manta rays have been recorded making return legs of the same migration. It is likely that more individuals make long-distance migrations to other regions but as of right now our data collection is limited to only a few sites in Fiji.



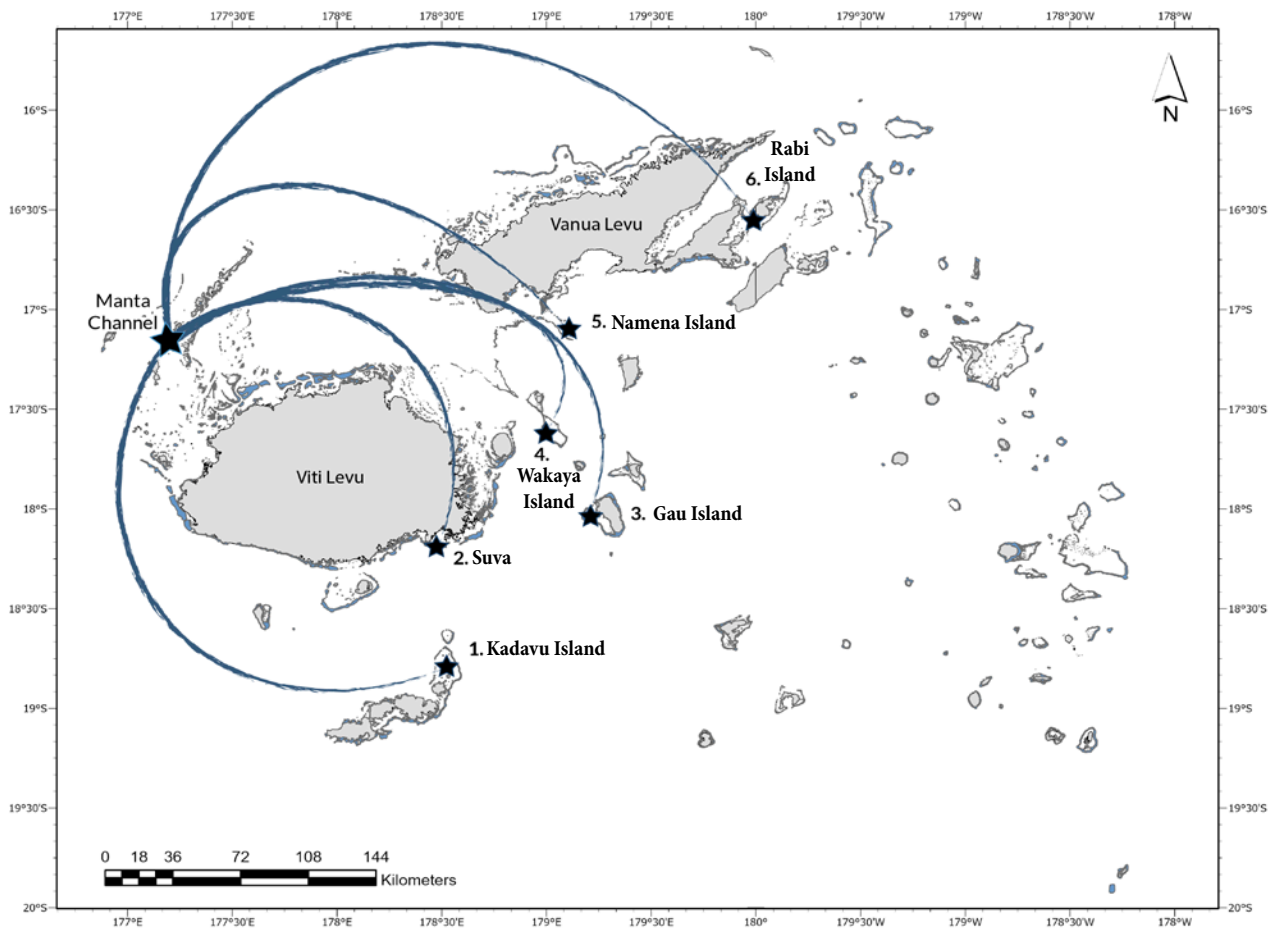


Figure 20 - Map showing the migration routes that have been recorded from or to the Manta Channel, Yasawa Islands, Fiji

Route # on map	Approx Distance (km)	Origin Location	Origin Date	Destination Location	Destination Date	Manta ID	Sex	Maturity
1	>260	Kadavu Island	04/12/2012	Manta Channel	23/08/2015	M31	F	Sub-Adult
1	>260	Manta Channel	23/08/2015	Kadavu Island	07/08/2019	M31	F	Sub-Adult
1	>260	Kadavu Island	07/08/2019	Manta Channel	15/06/2020	M31	F	Sub-Adult
1	>260	Manta Channel	06/07/2020	Kadavu Island	03/08/2020	M31	F	Mature
1	>260	Manta Channel	07/07/2022	Kadavu Island	11/09/2022	M430	F	Juvenile
2	>260	Manta Channel	17/08/2015	Suva	10/08/2020	M99	M	Mature
3	>270	Gau Island	10/09/2010	Manta Channel	05/07/2013	M45	M	Mature
4	>230	Wakaya Island	07/05/2019	Manta Channel	29/05/2020	M243	F	Sub-Adult
4	>230	Manta Channel	05/09/2021	Wakaya Island	19/04/2022	M243	F	Sub-Adult
4	>230	Wakaya Island	19/04/2022	Manta Channel	20/05/2022	M243	F	Sub-Adult
4	>230	Wakaya Island	06/05/2019	Manta Channel	06/09/2021	M240	F	Sub-Adult
4	>230	Manta Channel	06/09/2021	Wakaya Island	06/10/2022	M240	F	Sub-Adult
4	>230	Wakaya Island	02/06/2020	Manta Channel	30/08/2022	M127	F	Sub-Adult
5	200	Manta Channel	10/07/2016	Namena Island	26/02/2019	M71	F	Mature
5	200	Namena Island	26/02/2019	Manta Channel	03/05/2020	M71	F	Mature
6	>300	Manta Channel	30/07/2014	Rabi Island	27/11/2020	M305	F	Mature

Table 2 - Table to show the migration data of mantas sighted at the Manta Channel, Yasawa Islands, Fiji

7. PREGNANCIES & COURTSHIP

Courtship has only been recorded in July, August and September at the Manta Channel, indicating that these months are considered to be the courting season for mantas in the Yasawa Islands. Courtship sightings peaked in 2013, 2016 and 2021 (2013, n = 32; 2016, n = 39; & 2021, n = 22 respectively). In 2022, 12 courtship sightings were recorded (Figure 21).

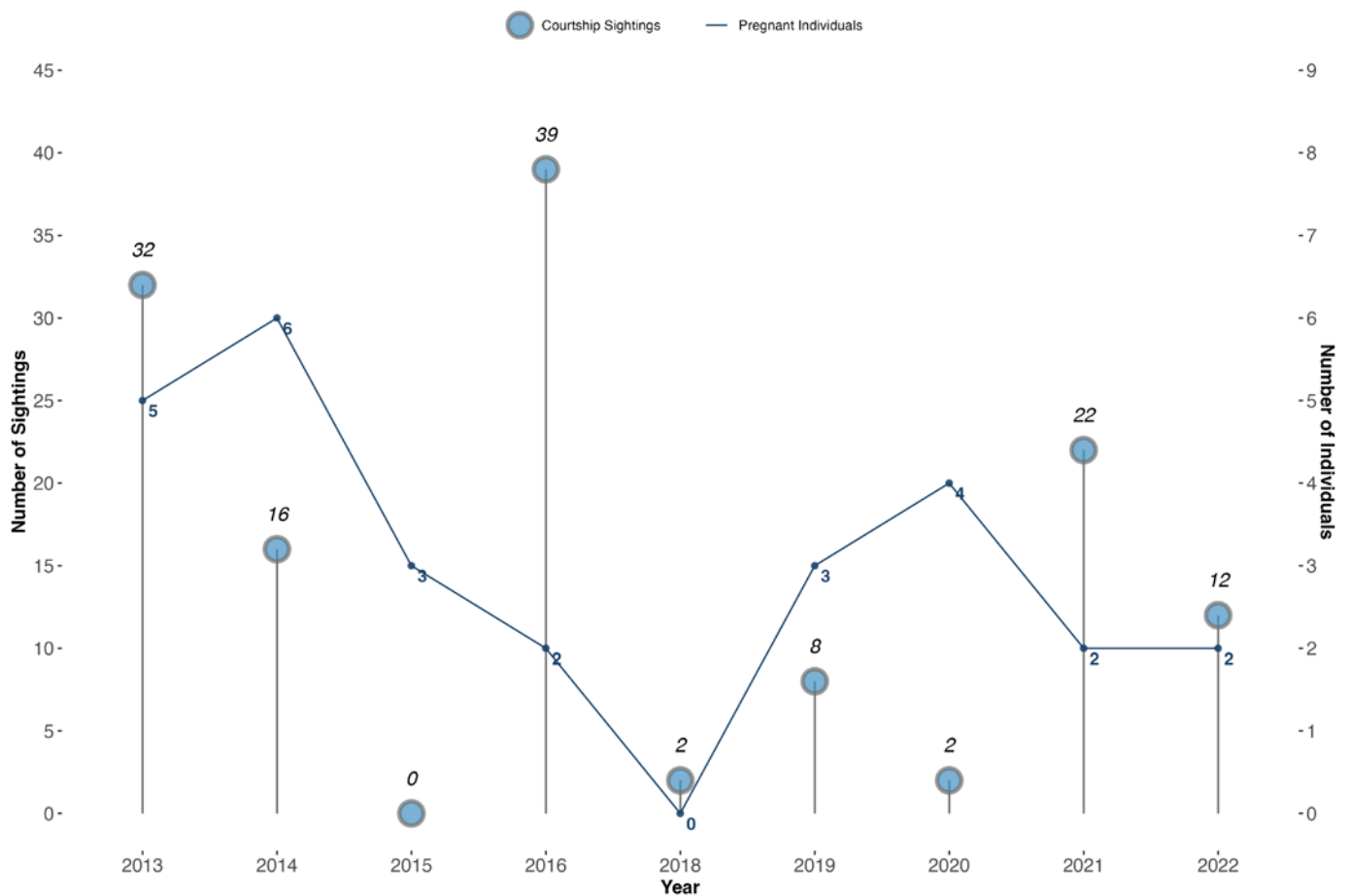


Figure 21 - Dot Plot with the number of annual courtship sightings against the number of pregnant individuals recorded at the Manta Channel, Yasawa Islands, Fiji

The gestation period of manta rays is a little over one year, with pregnancies becoming visible to researchers between 4-6 months. In the Yasawa Islands we estimate pupping season to be roughly September and October based on gestation periods. 15 different females have been recorded pregnant at the Manta Channel since 2012, with one female (FJ-MA-0018) having been recorded pregnant 5 times. Pregnancies were recorded to be the highest in 2013 and 2014 with 5 and 6 pregnancies respectively (Figure 21). Of the 2 recorded pregnancies in 2022, one was the first recorded pregnancy for that particular female (FJ-MA-0016), a female who had been sighted at the Manta Channel every year since 2012 when she was a juvenile.

Of the 21 mature females that have been recorded at the site, 71 % have been recorded pregnant at least once and 35 % more than once. Of the 27 recorded pregnancies at this site 37 % are from just two females, with both being recorded pregnant multiple years in a row.

Recent findings (Froman et al., 2023) evoke particular scrutiny to establishing a mantas maturity status by using the traditional methods: visual features, size and historical sighting records. There may be far more mature females in the Yasawa manta population than what is currently quantified because we employed traditional techniques to determine the maturity status of the Yasawa mantas.



8. SUB-LETHAL INJURIES

Of the 140 individuals identified at the Manta Channel, 23 % (n = 32) have been recorded with at least one sub-lethal injury, with a total of 58 injuries now documented in the Yasawa Islands. Of the 58 injuries, 59 % (n = 34) were of natural origin, 33 % (n = 19) were of anthropogenic origin, and 8 % (n = 5) were of unknown origin (Figure 22).

Of the 58 injuries, both males and females have had 29 injuries recorded each, with predator bites taking up a larger percentage of the injuries in males compared to females with 72 % to 41 % respectively. Males also show more boat strike injuries, however females also display injuries from fishing gear which the male mantas do not (Figure 23). The larger number of boat strikes and shark bites seen in males could likely be due to the fact that males are typically more migratory and nomadic than females in their behaviour, leading to more time spent at the surface and travelling in deeper waters.

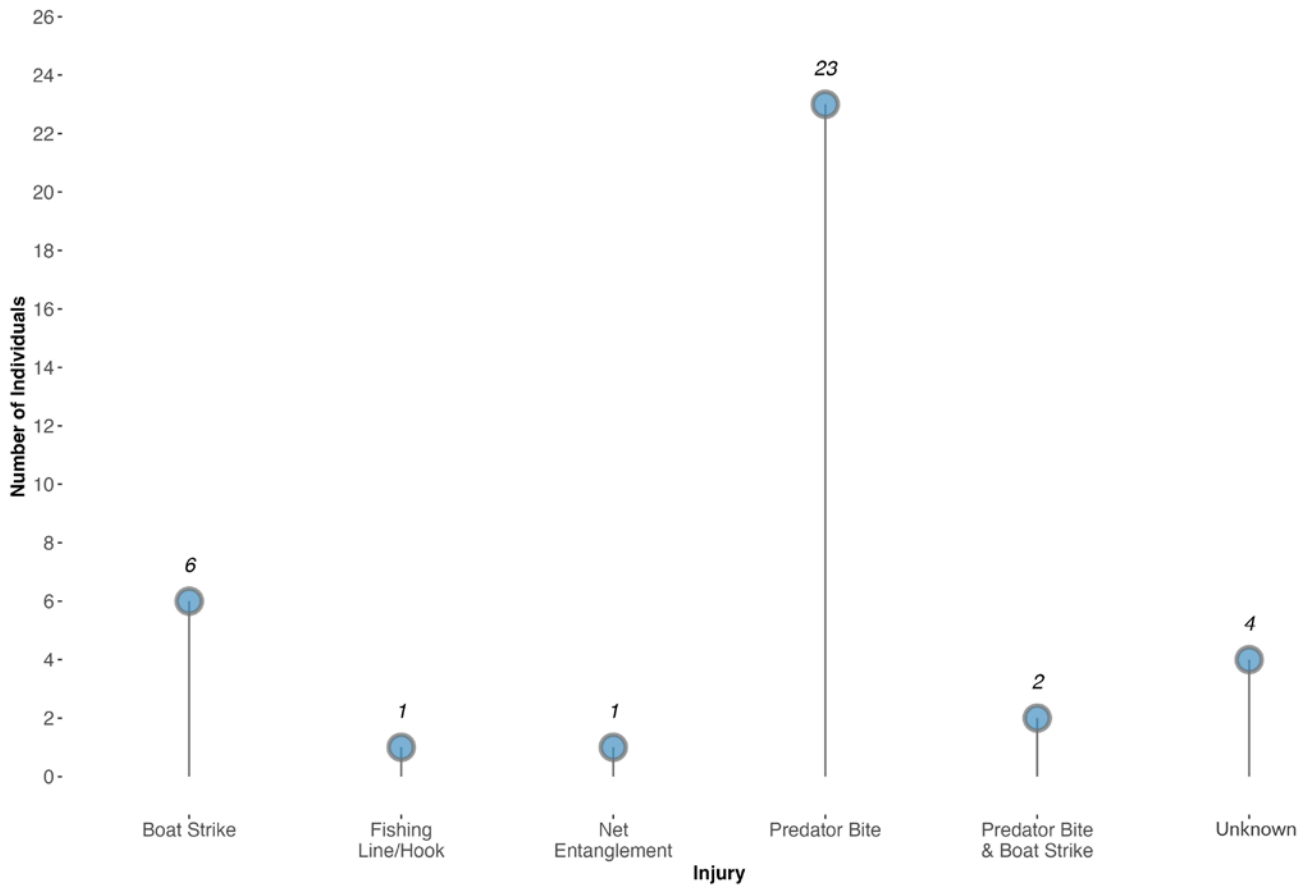


Figure 22 - Dot plot showing the causes of the different injuries recorded on individuals at the Manta Channel, Yasawa Islands, Fiji

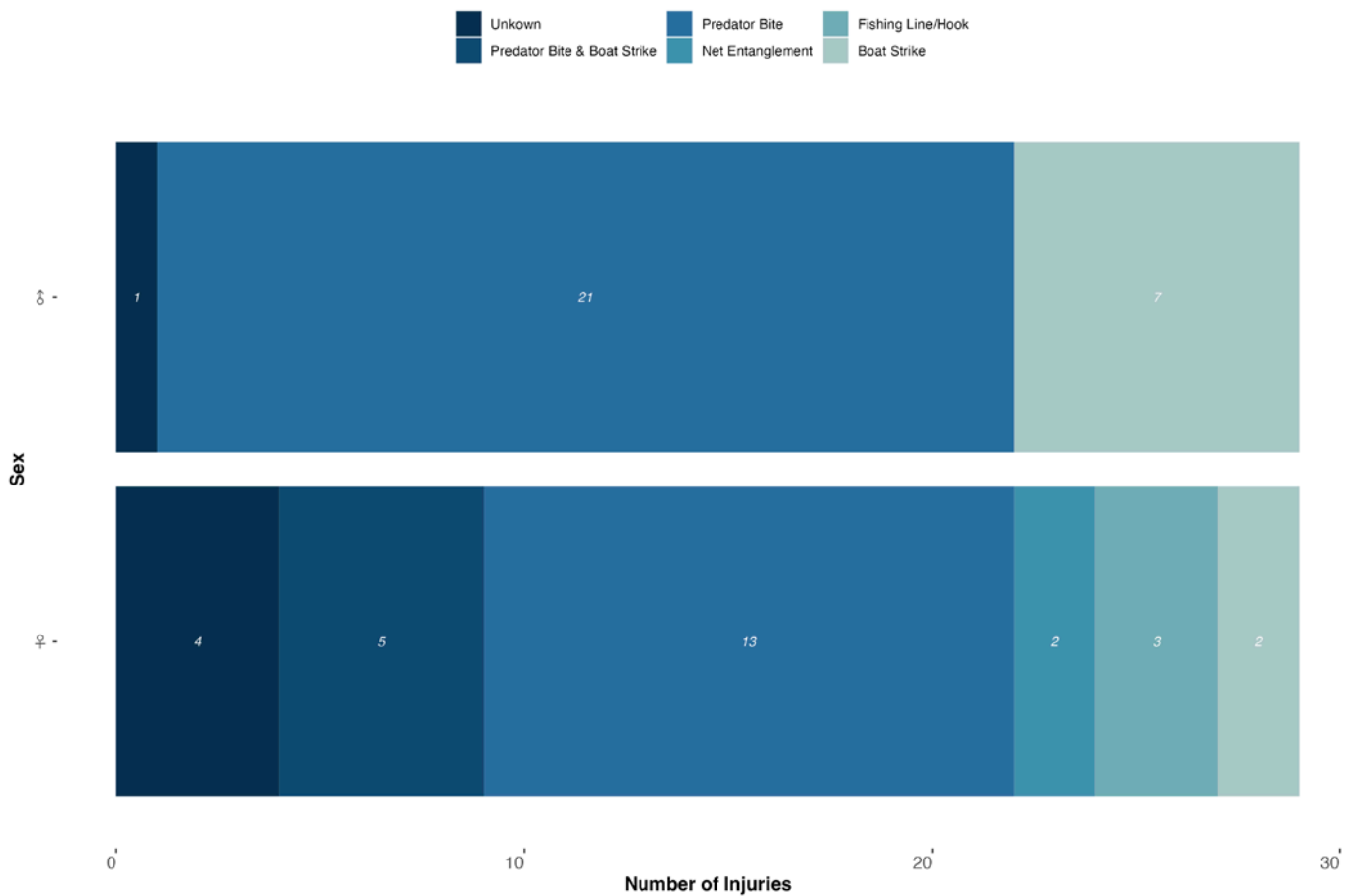


Figure 23 - Plot to show the origin of the different injuries recorded on both male and female manta rays at the Manta Channel, Yasawa Islands, Fiji



9. ENVIRONMENTAL VARIABLES

Manta ray sightings at the Manta Channel are seasonal, increasing during the cooler months from April through to October and dying off in the warmer summer months from November-March (Figure 16). Manta rays are not sighted at all during peak summer months (December - February) at the Manta Channel.

The Manta Channel is primarily a foraging site for the manta rays that visit (Figure 9), which means that environmental conditions directly affecting zooplankton abundance directly affect the number of manta rays that utilise the habitat. Understanding the environmental conditions that lead to high plankton diversity will allow us to better understand the drivers behind manta ray movements in the region.

It is well documented in other locations that increases in chlorophyll-*a* concentration and primary productivity coincides with peak manta season (Dewar et al., 2008; Anderson et al., 2011). In the Maldives, for example, it has been documented that predominant wind direction and chlorophyll-*a* concentration heavily affects monthly manta ray sightings at down current sites (Harris, 2020). We believe similar dynamics are at play at the Manta Channel due to the increase in sightings through the SE trade wind season.

The vast majority of manta sightings are recorded at the channel when the wind is blowing from an easterly direction, including SE and NE (Figure 24). These winds are characteristic for the time of year when manta ray sightings peak at the Manta Channel. The cooler water temperature also likely aids plankton density as it appears higher densities are associated with water cooler than 28 degrees celsius (Figure 25).

It is likely that due to the geographical position of the channel, nutrient rich water is blown with the winds into the channel and surrounding waters, creating favourable environments for plankton density. This plankton is then funnelled through the narrow channel, creating a perfect foraging opportunity for manta rays.

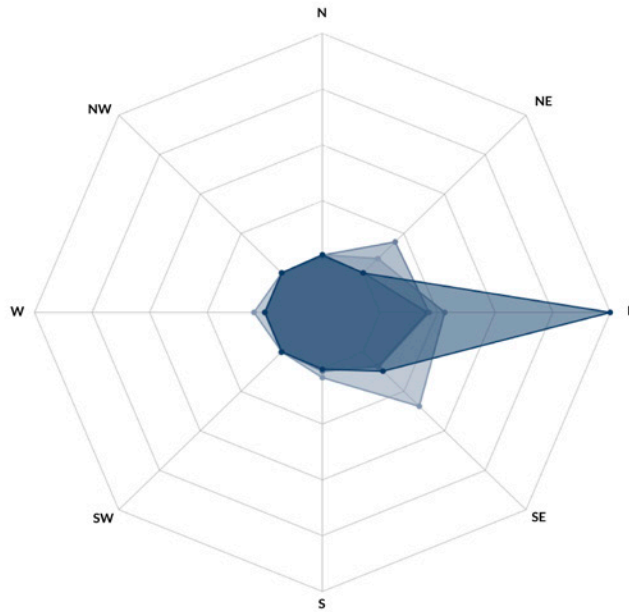


Figure 24 - Radar plot to show how the wind affects manta sightings from 2013-2022 at the Manta Channel, Yasawa Islands, Fiji

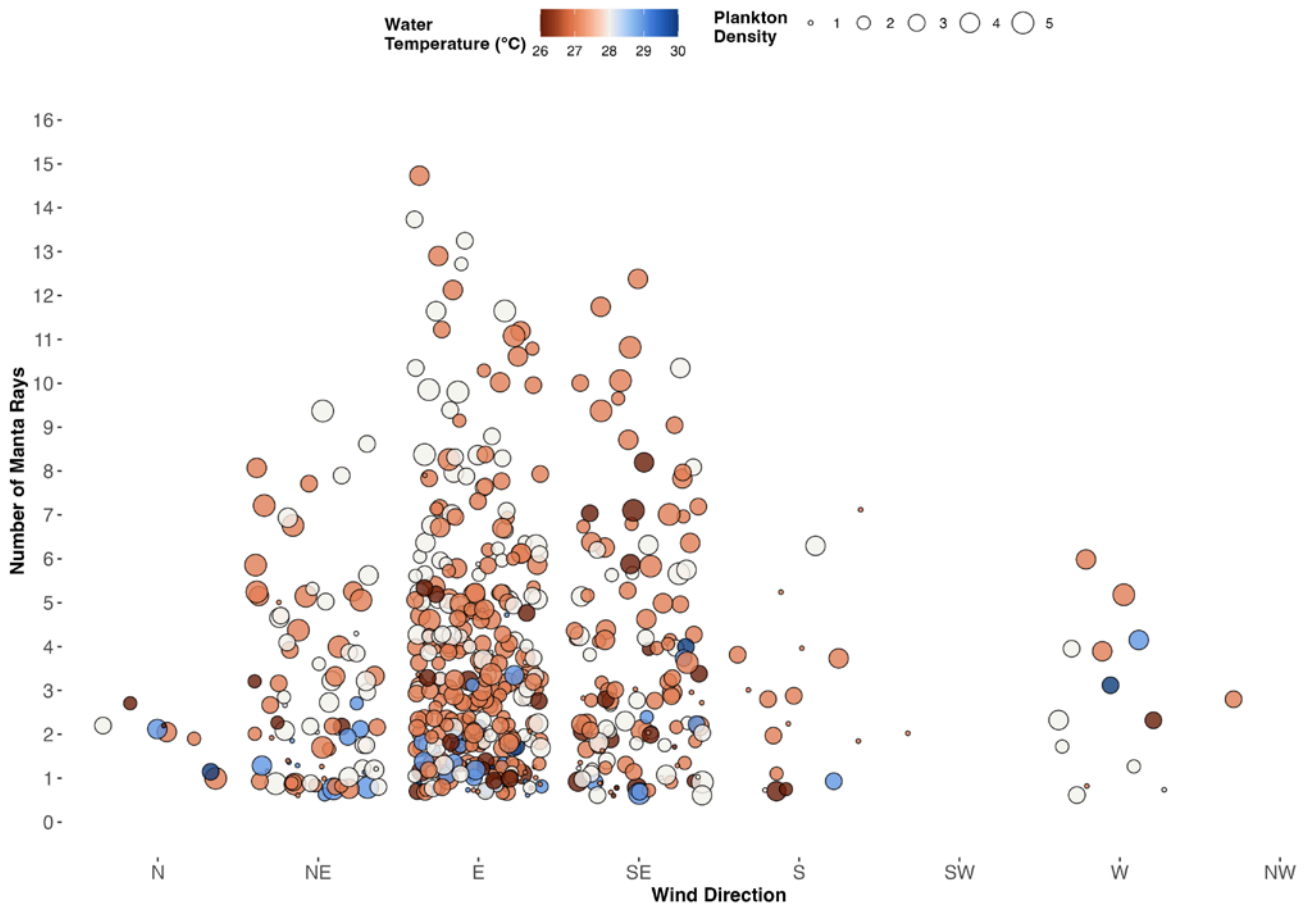


Figure 25 - Bubble plot showing manta sightings related to SST and plankton density recorded (0-5) at the Manta Channel, Yasawa Islands, Fiji



10. TOURISM

Tourism accounts for approximately 38 % of Fiji's GDP (IFC Business Survey, 2020), with manta ray tourism estimated to account for roughly \$1,587,973 USD in 2013 (O'Malley, 2013), this figure, before COVID-19 (2019) was likely much higher. Nature-based tourism can provide a mechanism to support local conservation initiatives through financial support, non-financial contributions, socio-economic incentives, and education (Ingram et.al 2014). This mechanism has been proven to be successful within Fiji, diving with sharks in Pacific Harbour has helped spur conservation plans benefiting both the local communities, businesses, and wildlife (Brunnschweller JM. 2010).

Using data collected between 2013 - 2019 and 2022 (excluding 2017) by MPF researchers and by using a conservative payment price for swimming with manta rays at the Manta Channel taken from Murphy et al. 'Examination of tourists' willingness to pay under different conservation scenarios; Evidence from reef manta ray snorkelling in Fiji' of \$22.5 USD and by using the average number of snorkellers present per day with mantas, the number of days mantas are present per season, we can reach (with the assumption tourists are not charged when no manta rays are present) conservative figures for income to the region from manta ray snorkelling can be attained.

The Manta Channel has traditionally seen very high tourism activity, with on average 5139 snorkellers and 681 boats visiting the channel between April - October each year of 2013 - 2019 (Table 3). The 2020 and 2021 manta seasons were unique due to the Yasawa Island chain being closed for land-based tourism because of COVID-19, the only tourists to visit the channel was a vastly reduced number of yachts. This meant data could be collected with dramatically reduced tourism pressure in the Manta Channel, we documented an 87 % reduction in visitors to the Manta Channel and an 81 % reduction in boat traffic at the site compared to the average (Table 3).

YEAR	MAX # OF		AVERAGE # OF		ESTIMATED INCOME(FJD)	# OF MANTA SIGHTINGS
	TOTAL # OF SNORKELLERS	SNORKELLERS ON A SINGLE DAY	SNORKELLERS ON A SINGLE DAY	TOTAL # OF BOATS		
2013	4995	130	43	594	FJ\$226,038.00	304
2014	5686	119	45	744	FJ\$354,830.00	392
2015	6844	149	48	910	FJ\$247,820.00	304
2016	6246	112	42	710	FJ\$262,069.00	358
2018	3046	90	36	390	FJ\$132,452.00	166
2019	5124	95	36	769	FJ\$208,765.00	295
2020	667	19	4	126	NA	637
2021	718	30	3	84	NA	504
2022	4584	138	18	584	FJ\$126,000.00	588

Table 3 - Table to show tourism data from 2013-2022 at the Manta Channel, Yasawa Islands, Fiji

Fiji reopened its borders to tourism in December 2021, meaning the full 2022 manta season went underway with local businesses operating once more. The maximum number of snorkellers at any one time in 2022 was 138 individuals, slightly higher when compared to the previous maximum average of 116 snorkellers between 2013 - 2019. The average number of snorkellers when mantas were present however was only 18 snorkellers, a much lower number than the average of 41 snorkellers when compared to 2013-2019 (Table 3) but considerably higher than the previous two years.

Between 2013-2019, except for 2018 (data unavailable for 2017), the number of snorkellers visiting the channel from April - October ranged from the lowest of 3046 snorkellers in 2018 to the highest of 6844 snorkellers in 2015, with total manta sightings during these years ranging from the lowest of 295 sightings to the highest of 392 in 2014. Both 2020 & 2021 during COVID-19 produced incredibly high sighting numbers, with 637 and 504 respectively, this trend then continued into 2022 despite over 4500 snorkellers visiting the channel with 588 sightings, the second highest sighting year on record (Table 3).

This, however maybe due to favourable environmental conditions and the fact that the average number of snorkellers in the water when manta rays were present being significantly lower than pre-COVID years (Figure 26).

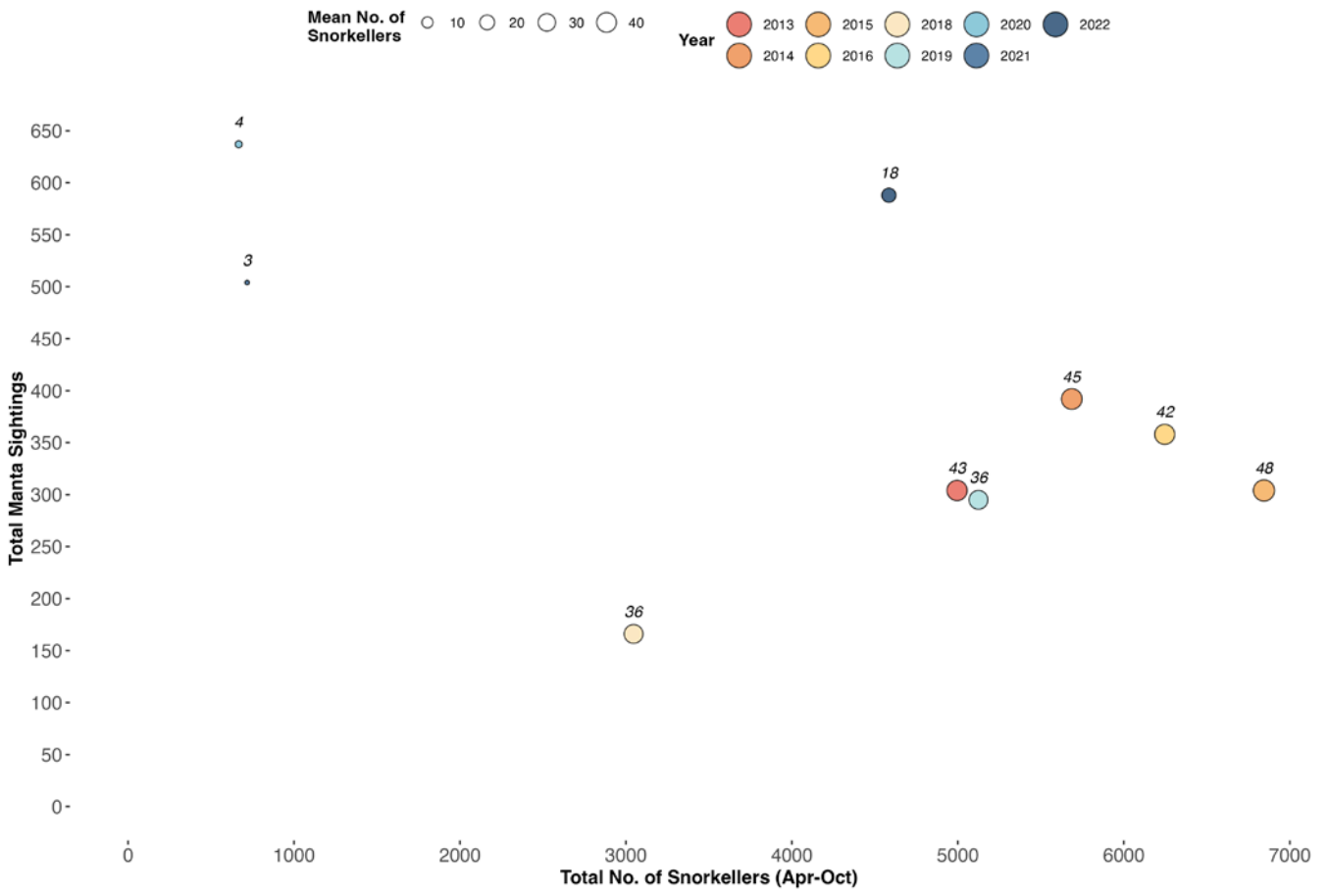


Figure 26 - Bubble plot showing annual manta sightings against total number of snorkellers for that year, sized (labelled) by the mean number of snorkellers present when manta rays were sighted, at the Manta Channel, Yasawa Islands, Fiji





11. CONCLUSION

In 2022, MPF researchers recorded consistent sighting trends with the previous two years (2020 & 2021), however, recorded a large increase when compared to pre-COVID trends (2013-2019). These changes could be due to long-term shifts in manta demographics that use the site due to a period of population fecundity, however it is essential that long-term monitoring continue to document these changes in order to provide a robust scientific analysis of the abundance and seasonality of the Yasawa Island manta ray population into the future.

Fiji is one of the very few nations globally where manta rays exhibit melanism. Currently the melanism proportion amongst the Yasawa Island population is the highest within Fiji and one of the highest globally, with 48 % of manta rays being melanistic.

The Yasawa Island population of manta rays appears to be in a healthy state, indicated by the consistent arrival of new recruits, both juveniles and adults, to the population every year. This also indicates that the population is likely considerably larger than what is currently recorded.

The percentage of sightings made up of adult manta rays has decreased from 2013 to 2022, with juveniles, especially juvenile females making up a larger percentage of sightings, notably in the last three years. This could indicate a recent period of population fecundity or that due to adult manta rays using the site less that there are increased foraging opportunities for juvenile manta rays in the channel.

The manta ray population within the Yasawa Island chain are most likely highly resident to these islands throughout the year, with few individuals known to visit other regions in Fiji. The Manta Channel continues to be a key aggregation site for the wider population, however for a group of <15 manta rays it appears to be a critical foraging site during the cooler winter months (Apr-Oct). With a large percentage of sightings made up by so few individuals this site is fragile to disturbance and it is of particular importance that a management framework be developed amongst relevant stakeholders so that anthropogenic disturbances can be managed sustainably.

Little is known about other critical habitats the manta rays rely upon within the wider Yasawa Island chain. Further exploratory research and trips should be conducted to gain a better understanding of this populations spatial ecology. This in turn would give a better understanding of how critical the Manta Channel is for foraging during the winter months.

The Manta Channel is incredibly important for local tourism in the area with up to 13 different operators visiting the channel each year to swim with manta rays and two operators using 'Manta' in the operation name. During COVID-19 it appeared that manta sightings had likely increased dramatically due to the reduction in tourism pressures at the site, however 2022 remained a very high sighting year with the resumption of tourism. It is possible that the average number of snorkellers in a single day being lower in 2022 was a reason for the high sightings. Sighting evidence does possibly indicate that certain individual manta rays are better able to cope with heavy tourism pressure while foraging.

We should still be mindful that tourism likely plays an impactful role on manta sightings at this site and strive to make a management framework so that anthropogenic disturbances can be managed sustainably.

We remain incredibly grateful to Barefoot Manta and the local communities for supporting our research, education and other outreach activities since 2013. Through collaboration with local communities, local operators and governmental bodies, it is our hope that the Manta Channel and other significant areas of manta ray habitat within the Yasawa Island chain can be protected to safeguard this species, and to conserve the wider biodiversity and marine resources in the island chain.







MANTA PROJECT FIJI

MPF is dedicated to assist local communities, stakeholders and government to gather further information on the manta populations within Fiji. We would welcome the opportunity to continue work with the communities and government and to expand into more regions to assist in the long-term management and conservation of these species in Fijian waters.

MPF and the Manta Trust are happy to share with the Fijian government any data collected as part of this study



Manta Project Fiji is extremely grateful for the ongoing partnership between Barefoot Manta Island Resort and the Manta Trust. Without their support, this important work would not have been possible. Manta Project Fiji are looking forward to carrying this successful relationship into the future.

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