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Manta ray (*Manta alfredi*) tourism in Baa Atoll, Republic of Maldives: human interactions, behavioural impacts and management implications.

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Abstract

Encounters with marine animals provide tourists with a unique and memorable wildlife experience and can make considerable economic contributions to local communities. The large population of mantas within the Maldives, and the predictability of certain aggregations, has allowed the development of a significant manta ray tourism industry. Previous observations of tourism impacts on mantas in the Maldives, however, have highlighted issues of concern, and there is evidence that tourism pressure on the resident manta ray population is increasing. Therefore, the impacts of human encounters on mantas and associated levels of disturbance need to be assessed.

This study examined video footage of human-manta interactions at six feeding aggregations, and six cleaning stations, in Baa Atoll, Republic of Maldives. Video footage captured divers and snorkelers interacting with mantas, with a total of 407 unique human-manta interactions from 138 encounters analysed from feeding aggregations, and 38 unique human-manta interactions from 11 encounters analysed from cleaning stations. Human behaviours in response to manta encounters included passive observation, following, accidental obstruction, diving under or near a manta, and intentional contact. Mantas response behaviours included avoidance and flight behaviours.

The results of this study showed that the majority of participants in manta ray tourism in Baa Atoll behave in a responsible and non-disruptive manner, and the majority of interactions do not result in manta disturbance. Behaviours prone to causing disturbance can be mitigated for by inclusion in a manta Code of Conduct. Although further research is required to aid our understanding of the impacts of repeated disturbance on the longer-term health status and survival of mantas, Manta ray tourism in the Maldives, with appropriate management of human interactions, can represent a long-term and sustainable tourism practice, and a viable alternative to fishing.

Introduction

Gentle giants

Manta rays are filter-feeding elasmobranchs with a circumglobal distribution in tropical and subtropical oceans (Marshall, 2009). Mantas feed almost exclusively on zooplankton, actively seeking and aggregating in areas of high zooplankton abundance (Dewar *et al.*, 2008; Luiz *et al.*, 2009). Whilst in an area for feeding, mantas will also visit nearby cleaning stations (Kitchen-Wheeler, 2010).

In 2009, the genus *Manta* underwent a taxanomic revision in recognition of two distinct species, with *M. alfredi* (Krefft, 1868) added to the genus, which had long consisted of only *M. birostris* (Walbaum, 1792). The reef-associated manta ray (*Manta alfredi*) is commonly found along the continental shelf, around islands, coral and rocky reefs and along coastlines (Marshall *et al.*, 2009), and is the most commonly sighted of the two species within the Maldives (Anderson *et al.*, 2011). Migration of *M. alfredi* within the Maldives is strongly associated with seasonal monsoonal conditions driving changes in zooplankton abundance (Kitchen-Wheeler, 2010; Anderson *et al.*, 2011).

The development of manta ray tourism

Tourism based on wildlife interactions has seen significant increases in popularity across the world (Reynolds and Braithwaite, 2001). Manta rays are often easily approached (MacCarthy *et al.*, 2006; Marshall *et al.*, 2011), which, together with the predictability of certain aggregations, has allowed the development of a tourism sector based around mantas (Anderson *et al.*, 2010). Manta tourism is now widespread, operating in numerous countries including the Maldives, Hawaii, Australia and the Philippines (Anderson *et al.*, 2010). Tourism based on local megafauna has the potential to make considerable contributions to local economies, particularly in relatively poor tropical countries (Homma *et al.*, 1999).

Tourists have been visiting the Maldives with the anticipation of a manta encounter ever since the 1970's (Kitchen-Wheeler, 2008). At the end of 2009, there were 97 exclusive island resorts and 145 registered live-aboard vessels operating throughout the Maldives (Ministry of Tourism, Arts and Culture, 2010), all of which can offer tourists the chance of a manta ray encounter whilst they visit feeding sites or cleaning stations.

The Maldives has the largest recorded population of *Manta alfredi* in the world, with an estimated population of 5000-7000, with over 2000 individuals catalogued by the Maldivian Manta Ray Project (MMRP) to date (Stevens, 2011). It is on this large population of manta rays that the growing manta ray tourism industry in the Maldives depends.

Anderson *et al.* (2010) identified 91 manta dive and snorkel sites in the Maldives, worth an estimated US$8.1 million per year. The success of the Maldivian tourism industry is therefore inherently linked to its marine environment and its sustainable use (Ministry of Tourism and Civil Aviation, 2007). Recognition of the value of mantas to the tourism industry in the Maldives has contributed to their protection, with an export ban on all rays since 1995 and a ban on the export of ray skins since 1996.

Furthermore, five of the 32 marine protected areas in the Maldives exist because of the seasonal presence of manta rays (Anderson *et al.*, 2010), including Hanifaru Bay Marine Protected Area in Baa Atoll, which since 2008, has become one of the best known and must-see tourist destinations for manta encounters (Brooks, 2010; AEC Project, 2011). A management plan exists for Hanifaru Bay, and as such, megafauna visiting the bay should be afforded a high level of protection in relation to tourism pressures (AEC Project, 2011), however, this level of protection does not currently extend to human-manta interactions elsewhere in Baa Atoll.

Threats to manta rays

Away from the Maldives, mantas are targeted by fisheries in several countries, including the Philippines, and Sri Lanka, as well as being caught as by-catch (Marshall *et al.*, 2006; White *et al.*, 2006). Recent demand for branchial filaments for use in traditional Chinese medicine, however, has increased fishing activity worldwide resulting in severely reduced regional manta populations. Because of their slow growth rate, late age at maturity and low fecundity, mantas are highly susceptible to fishing pressure and other anthropogenic impacts (Deakos *et al.*, 2011).

Mantas are currently listed as Near Threatened/ regionally Vulnerable by the IUCN (International Union for Conservation of Nature) Red List of Threatened Species (Marshall *et al*., 2006), however, the IUCN, currently only recognises one species, *M. birostris*, and therefore does not account for the different threats specific to the two distinct species (Marshall *et al.*, 2009).

Previous observations of tourism impacts on mantas in the Maldives have highlighted issues of concern (Nevez and Stevens, 2009; Anderson *et al.*, 2010; Brooks and Stevens, 2011), with a deterioration in behaviour observed when large numbers of people and mantas use the bay simultaneously (Brooks, 2010). Furthermore, the 158% increase in the average number of tourists, and an 82% increase in the number of boats visiting Hanifaru Bay MPA in 2010 compared to 2009 (Brooks and Stevens, 2011), provides evidence that tourism pressure on the resident manta population is increasing.

The Maldivian Government recognises that the continuing growth of tourist activities within Hanifaru Bay MPA threatens the sustainability of this unique site, and therefore requires very careful management, including codes of practice in respect of the animals (AEC Project, 2011). Furthermore, the Atoll Ecosystem Conservation Project identified disturbance to mantas as a direct threat to the Baa Atoll ecosystem and its biodiversity (AEC Project, 2009).

As the popularity of interacting with marine animals in the wild grows, there is increasing concern over the negative impacts which the target species is subjected to (Roe *et al.*, 1997). This is of concern due to the potential short-term and longer term impacts which could affect an individual's behaviour, reproductive success and fitness (Sorice *et al.*, 2003), with possible implications at the population and community levels (Sorice *et al.*, 2006). Individuals subject to disturbance may spend less time in critical behaviours such as feeding, cleaning or resting, and divert their energies to avoidance behaviours, which may ultimately reduce their chances of long-term survival (Sorice *et al.*, 2003), or alternatively, force them to move to less productive feeding grounds (Tapper, 2006).

Constantine (2001) found that bottlenose dolphins (*Tursiops truncatus*) increased avoidance behaviours in response to the presence of swimmers in New Zealand. In whale sharks, avoidance behaviours such as rapidly diving away from the surface, banking, and attempts to leave an area have been observed in response to interactions with swimmers (Quiros, 2007).

Disturbance to animals as a result of human activity is confounded by an animal's sensitivity, tolerance and habituation (Gill *et al.*, 2001), and management guidelines which aim to alleviate behavioural responses of wildlife may not be reasonably precautionary, largely because physiological responses to disturbance may occur at much lower levels of exposure than those required to elicit behavioural reactions (Holmes *et al.*, 2005). For example, tourist-exposed stingrays exhibit haematological changes indicative of physiological costs of wildlife tourism, including evidence of weakening of the immune system, with significant probability of compromised long-term health and survival (Semeniuk *et al.*, 2009).

It is imperative that any disturbance to megafauna due to interactions with people is acceptable in terms of the overall health of individuals and the population (Mau, 2008). One method of regulating human behaviours which have the potential to negatively impact mantas during encounters, is the implementation of a Code of Conduct, which have been implemented for other marine encounters, such as whale shark encounters in Western Australia (Rodger *et al.*, 2010) and for dwarf minke whale interactions in the Great Barrier Reef (Valentine *et al*, 2004).

There currently exists a lack of research on the impacts of tourism on manta behaviour which this study aims to address. This study aims to:

- Assess interaction types and human behaviours when snorkelers and divers encounter mantas (when feeding and cleaning).
- Assess manta behaviours in response to encounters with people. Identification of tourist behaviours which negatively impact behaviour can rationalise the need for strict compliance to a Code of Conduct (Quiros, 2007).
- Assess levels of disturbance to mantas during encounters with people.
- Inform management actions in relation to the growing manta tourism industry in Baa Atoll, providing the first evidence-based recommendations for a Code of Conduct for manta tourism. In addition, this could be applied to other manta tourism hotspots globally.

Methods

Study Area

This study was conducted at manta feeding aggregations and cleaning stations within Baa Atoll, Republic of Maldives (Fig. 1), a recently declared UNESCO Biosphere Reserve in recognition of its globally significant biodiversity (UNESCO, 2011).

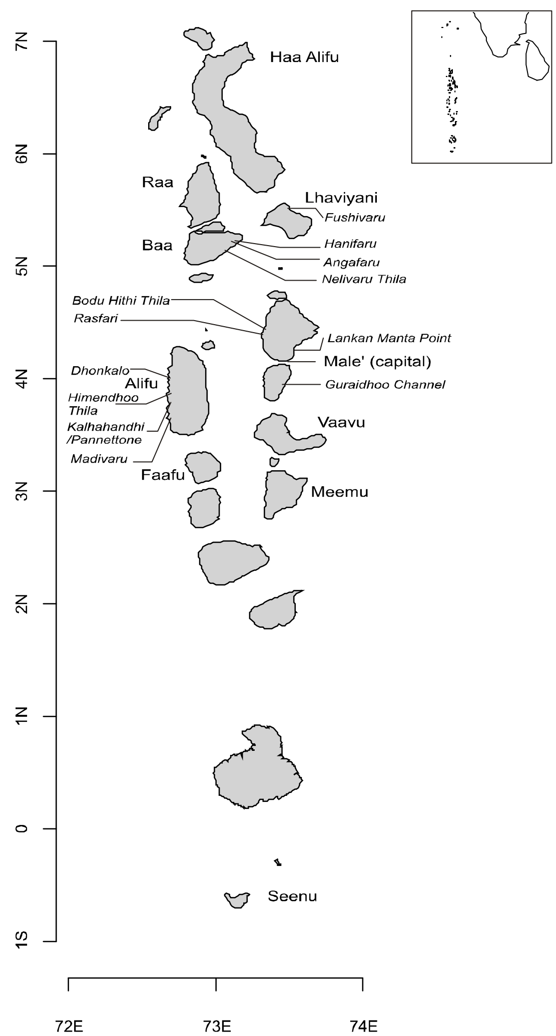

Figure 1. Location of Baa Atoll, Maldives, and locations of popular dive sites.

Source: Anderson *et al.*, 2010.

Data collection was carried out during the south-west monsoon, when west-southwest winds predominate and consequently, nutrient upwelling results in increased phytoplankton on the eastern side of the atoll, coinciding with an increased abundance of mantas (Anderson *et al.*, 2011). Because of the relatively predictable nature of the occurrence of mantas in Baa Atoll during the south-west monsoon, and with seven resorts within Baa Atoll which can utilise the feeding aggregations and cleaning stations for manta excursions, in addition to the large number of live-aboard vessels operating in the area (41 observed between 7th July and 1st September 2011, MMRP unpublished data), this made it an ideal location to observe human-manta interactions.

Data collection and analysis

In order to assess the impact of human interactions on mantas, the author firstly familiarised themself with natural, undisturbed behaviours of mantas. This was achieved through in-water observations, analysis of video footage, and extensive discussions with experienced Maldivian Manta Ray Project (MMRP) researchers. This culminated in the characterisation of typical undisturbed manta behaviours, commonly observed by people (table 1). In addition, typical human behaviours in response to manta encounters (interaction types), and typical manta behavioural responses to interactions with humans were also defined through a similar process (see tables 2 and 3, respectively).

Table 1. Description of typical undisturbed manta behaviours commonly observed by humans at feeding aggregation sites or cleaning stations

Undisturbed behaviour	**Description**
Cleaning	Present at a cleaning station, cleaner fish actively cleaning manta, cephalic fins usually unrolled, but may be rolled up.
Feeding (Co-operative)	Chain, cyclone and stacked feeding behaviours - two or more mantas travelling together in a given direction/orientation with mouth wide open and cephalic fins unfurled.
Feeding (Individual)	Surface, bottom and barrel rolling feeding behaviours - travelling in a given direction/orientation with mouth wide open and cephalic fins unfurled.
Travelling	Swimming through an area with mouth closed and usually accompanied by cephalic fins rolled up.

Table 2. Description of potential human behaviours (interaction type) in response to an encounter with manta rays

Interaction type	Description
Accidental contact	Unintentional contact - may include touching or kicking whilst swimming out of path of manta or contact whilst manta swam around snorkeler or diver.
Accidental obstruction	Unintentionally in the path of approaching manta i.e. manta swimming towards human and human remaining in position.
Chasing	Swimming after manta without consideration of distance to be maintained, and may include swimming after manta at a quickened pace (distance <5m).
Diver bubbles	Bubbles exhaled from regulator of diver in path of manta / make contact with manta.
Diving under or near manta	Snorkelers duck-diving down or divers diving deeper to position themselves nearer to or underneath manta.
Flash photography	Snorkelers or divers using flash photography within range of manta.
Following	Swimming after manta whilst maintaining appropriate distance (>5m) and pace.
Intentional attempt to touch / make contact	Intentionally trying to make contact with manta with hands or feet, without success.
Intentional obstruction	Intentionally swimming into path of approaching manta.
Intentional touching	Intentionally approaching and touching manta with hand.
Over-crowding at cleaning station	10 or more divers per manta present at cleaning station, within 15m of manta.
Over-crowding at feeding aggregation	20 or more snorkelers per feeding manta, within 15m of manta.
Passive observation	Snorkeler or diver remaining in one position to passively observe mantas either at depth or at the surface.
Riding manta	Diver or snorkeler grabbing onto manta with one or both hands and towed along.
Splashing / fin kicking	Splashing with hands or fins at surface

Table 3. Description of observable manta behaviour in response to interaction with humans, including level of disturbance

Behavioural response	Disturbance level	Description
Approach diver / snorkeler	No disturbance	Manta makes no attempt to maintain distance between itself and divers or snorkelers, may come within 1m of diver or snorkeler, and may repeatedly return to diver or snorkelers' location. May also include manta displaying ventral surface towards diver or snorkeler, and swimming underneath or around diver or snorkeler for a closer look.
Avoidance	Minor disturbance with negligible energy consumption	Manta makes a change in direction and swims away from the diver or snorkeler without gaining speed. May include shallow dive.
Dive Avoidance	Minor disturbance with negligible energy consumption	Manta dives steeply to greater depth to avoid snorkelers or divers.
Flight	Major disturbance and energy-consuming	Manta swims away from diver or snorkeler with a quick burst of speed, may include a sudden change in direction.
No response	No disturbance	No alteration in behaviour observed.
Stops cleaning[a]	Minor disturbance with potential impacts on health status	Manta moves away from cleaning station directly following interaction with human(s).
Stops feeding[a]	Major disturbance due to potential for reduced energy intake.	Manta closes mouth, may be accompanied by cephalic fins being rolled up.

[a]Considered in addition to initial behavioural response

Data was collected between the 7th July and the 1st September 2011, on each occasion that the research vessel encountered a group of snorkelers or divers from a resort or live-aboard vessel in the water with an aggregation of feeding mantas. Data was also collected from 'Manta on Call' excursions for guests of The Four Seasons Resort, Landaa Giraavaru, on which the researcher was sometimes present. Data from cleaning stations was collected when divers encountered mantas on planned dive trips from The Four Seasons Resort, Landaa Giraavaru. Snorkelers and divers on manta ray excursions were not made aware of the nature of the research, to avoid influencing behaviours.

Data was collected at six feeding sites on the eastern side of Baa Atoll, predominantly from Hanifaru Bay MPA. There were 18 distinct groups on 'swim-with' excursions observed on 14 separate days (table 4).

Table 4. Baa Atoll feeding aggregation sites used in the study, and dates of data collection

Feeding site	**Dates of data collection**
Hanifaru Bay MPA	12th July 2011, 14th July 2011, 19th July 2011, 30th July 2011, 29th August 2011, 31st August 2011
Bathalaa	15th July 2011, 16th August 2011
Veyofushi thila	29th July 2011
Dhonfan reef	31st July 2011
Hanifaru outside reef	10th August 2011, 11th August 2011
Reethi Beach outside reef	21st August 2011, 22nd August 2011

Data was collected at six cleaning stations on the eastern side of Baa Atoll, with mantas encountered on seven out of 30 dives (table 5).

Table 5. Baa Atoll cleaning stations used in the study and dates of data collection

Cleaning station	Dates of data collection
Dhigu Thila	13th July 2011, 22nd July 2011
Dharavandhoo Thila	23rd July 2011
Dhonfan Reef[a]	25th July 2011
Dhonfan Pinnacle	10th August 2011
Anga Thila	14th August 2011
Hanifaru outside reef	19th August 2011

[a]Not a known cleaning station, but in close proximity to a cleaning station (Dhonfan pinnacle)

Video recordings of snorkelers and divers interacting with mantas were taken by one researcher using a digital camera (Canon G12) placed in underwater housing (Canon WP-DC34). All filming of groups on 'swim-with' excursions at feeding aggregations took place whilst snorkeling, and between the hours of 10:00 and 18:00, with over 20 hours spent in-water with these groups. To capture divers interacting with mantas on cleaning stations on video, over 24 hours was spent SCUBA diving on cleaning stations. Dives were always between 09:00 and 12:00.

Footage was considered relevant for analysis when both humans and mantas were present within the video clip, with individual video clips starting at the point at which a manta came into view of the researcher and ending when the manta was no longer visible. The length of time a manta was visible was considered the encounter time. Each video clip was named and saved separately. Video footage of human-manta interactions at feeding aggregations were analysed separately to the video footage of human-manta interactions at cleaning stations.

The length of each individual encounter was documented, and for each human-manta interaction observed in each encounter, the data presented in table 6 was recorded.

Table 6. Data collection variables for analysis of video footage of human-manta interactions at feeding aggregations and cleaning stations

Subject	Data collection variables
Manta	• Number of mantas per interaction. • Individual manta identification numbers or sex, where possible. • Position of manta(s) in the water column at the start of the interaction using the categories: surface (within 1m of the surface), mid-water and bottom. • Typical undisturbed behaviour of manta (observed behaviour as it came into view) (table 1). • Observed change in manta behaviour (response) (table 3). • Whether mantas stopped feeding or cleaning as a result of the interaction. • Whether mantas resumed feeding or cleaning if it had stopped as a result of the interaction.
Human	• Estimated number of snorkelers or divers involved in the interaction (number visible within video clip), including the researcher. • Estimated closest distance the snorkelers or divers came to the manta(s), to the nearest metre. • Type of human behaviour observed (interaction type) (table 2). • Direction from which the interaction came using the categories: directly in front of manta, to the side of manta, behind manta (behind pectoral fins), and directly above or below manta.
General	• Feeding aggregation site / reef name or cleaning station reef name. • Date of data collection. • Location of data collection. • Video clip number. • Number of boats at each site during data collection. • Estimated total number of snorkelers and/or divers in the water. • Estimated number of mantas in the area. • Estimated visibility. • Estimated total duration snorkelers and/or divers were in the water per trip. • Specific details pertaining to observed interactions.

Results

Human-manta interactions at feeding aggregations

Over 20 hours of in-water observations culminated in the extraction of 111 minutes of relevant footage for analysis, illustrating interactions between divers and/or snorkelers and mantas at feeding aggregations. A total of 407 unique human-manta interactions from 138 encounters were analysed. Interactions occurring when mantas were at the surface accounted for 86% of all interactions, and the number of snorkelers and divers per interaction ranged from 1 to 15 (mean = 3.80 ± 2.17 SD).

The most commonly observed undisturbed manta behaviour at feeding aggregations was individual feeding, which was observed in 65% of the interactions (Fig. 2).

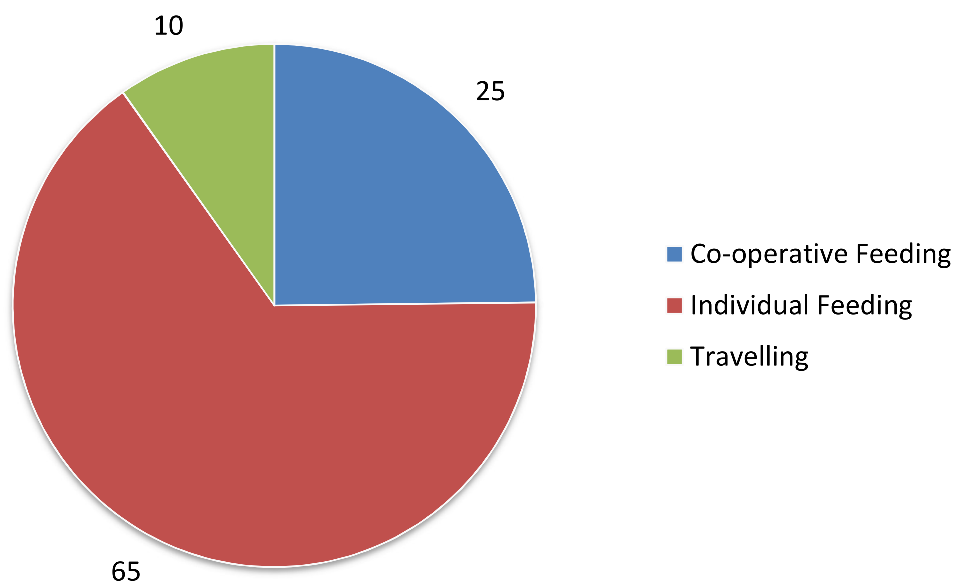

Figure 2. Proportion of observed undisturbed manta behaviours at manta feeding aggregations (%)

Observed human behaviours (interaction type) in response to an encounter with a manta at feeding aggregations are shown in Fig. 3. The most frequently observed human behaviour was passive observation, comprising 50% of all observed interactions. Accidental obstruction was the second most frequent interaction type, observed in 27% of interactions.

Diving under or near a manta was observed in 11% of interactions. The remaining observed behaviours each comprised 4% or less of all observed interactions.

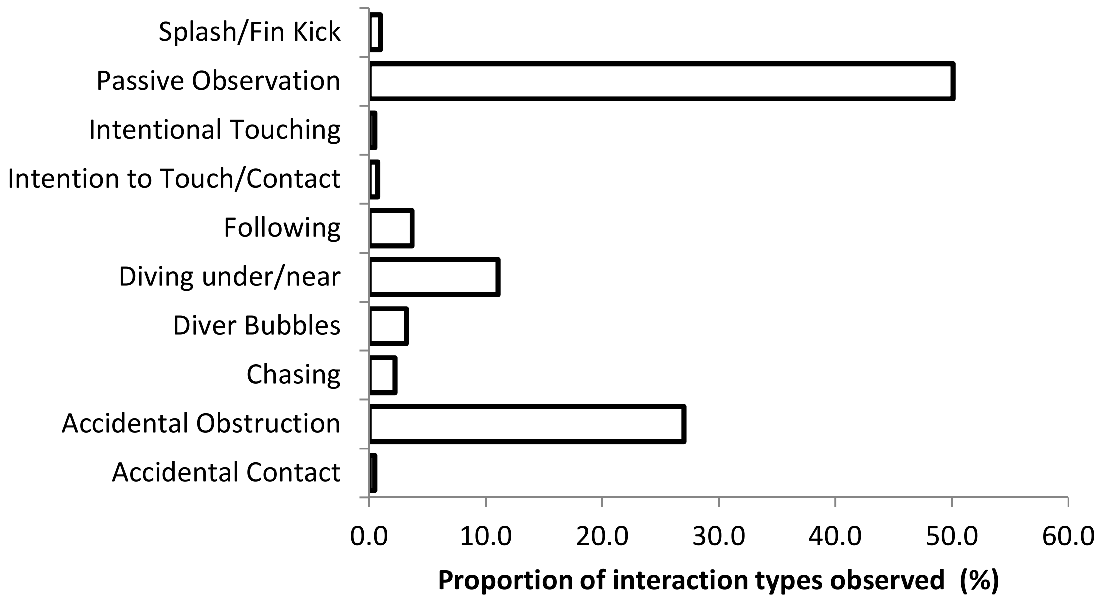

Figure 3. Observed human behaviours (interaction types) in response to an encounter with a manta ray at feeding aggregations (%)

In the majority of human-manta interactions there was no response (62%) (Fig. 4). Avoidance behaviour was the most common disturbance response by mantas to a human interaction, comprising 32% of responses. Flight was only observed in response to 2% of interactions.

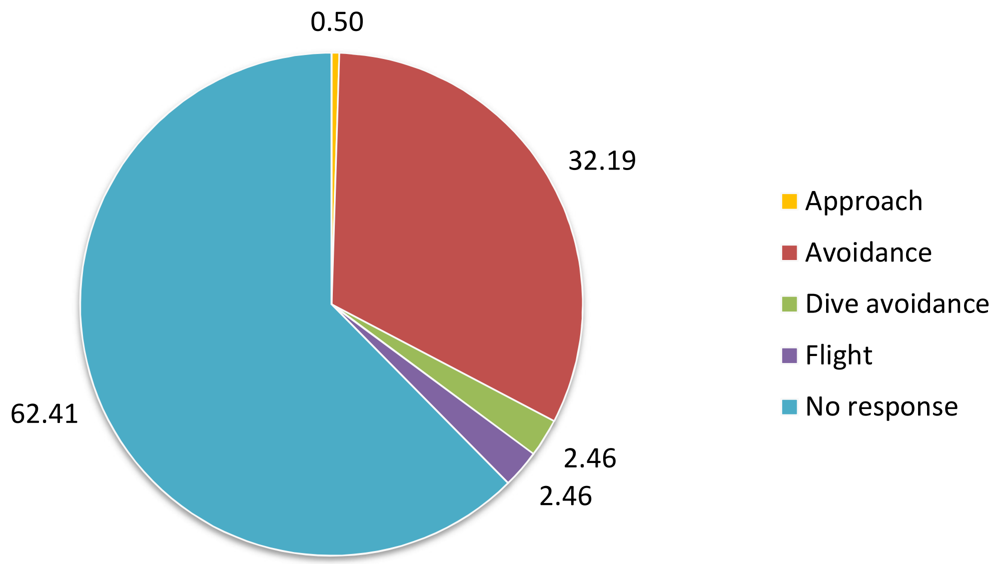

Figure 4. Observed manta behaviours in response to human interactions at feeding aggregations (%)

Mantas were considered not to have been disturbed in 63% of interactions (Fig. 5). The majority of disturbance behaviours were minor (avoidance and dive avoidance), comprising 35% of responses. Only 2% of responses to an interaction were considered major disturbance (flight behaviour).

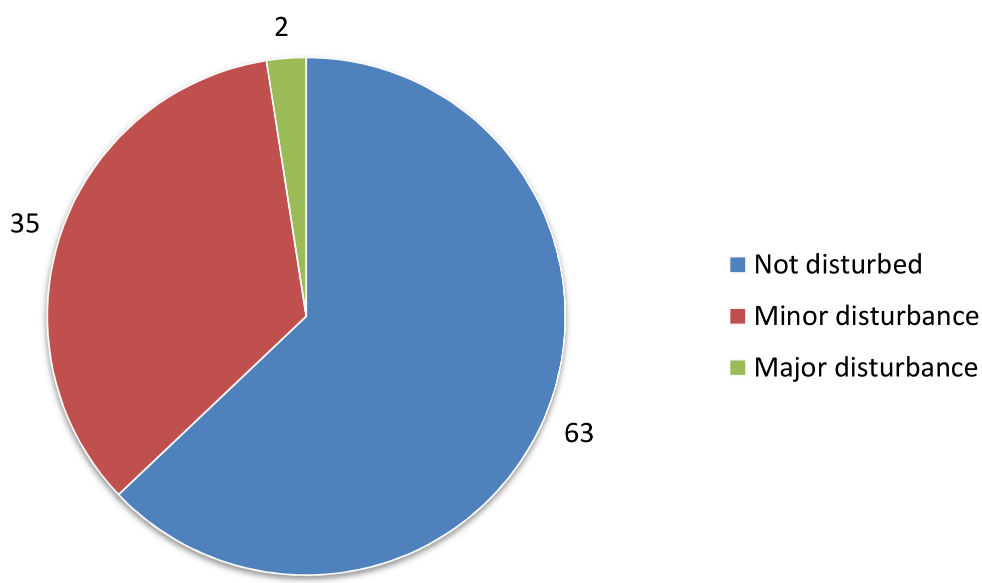

Figure 5. Behavioural responses at feeding aggregations categorised according to level of disturbance (%)

The most common cause of avoidance and dive avoidance behaviours was accidental obstruction, accounting for 100 of 131 and 8 of 10 interactions, respectively (table 7). Avoidance behaviours in response to chasing (including dive avoidance) were observed in 2 of 9 interactions. Chasing came from behind a manta on 5 of 9 occurrences.

Diver bubbles resulted in avoidance behaviour in 6 of 7 interactions coming from in front of the manta. Avoidance behaviours (including dive avoidance) were observed in response to diving under or near a manta in 16 of 45 interactions, and flight was observed in 5 of 45 interactions. Diving under or near a manta accounted for half of all observed flight responses (5 of 10).

An intentional attempt to touch a manta elicited a flight response in 1 of 3 of this type of interaction. Intentional touching of a manta always resulted in flight behaviour. Passive observation elicited no response in 204 of 206 interactions. Splashing and fin kicking at the surface resulted in avoidance behaviour in all occurrences.

Table 7. Matrix of manta responses against interaction types and directions of approach at feeding aggregations (total counts).

Interaction type Direction of approach	**Response**				
	Non-disturbance		**Minor disturbance**		**Major disturbance**	
	No response	**Approach**	**Avoidance**	**Dive avoidance**	**Flight**	***Grand total***
Accidental contact						
Above/below	1					*1*
Behind					1	*1*
Accidental obstruction						
Front			100	8	1	*109*
Side			1			*1*
Chasing						
Behind	5					*5*
Front			1	1		*2*
Side	2					*2*
Diver bubbles						
Front	1		6			*7*
Side	6					*6*
Diving under/near						
Above/below	12					*12*
Behind	6				2	*8*
Front			8	1	1	*10*
Side	6		7		2	*15*
Following						
Behind	10		1			*11*
Side	1		3			*4*

Table 7 cont. Matrix of manta responses against interaction types and directions of approach at feeding aggregations (total counts).

Interaction type Direction of approach	**Response**					
	Non-disturbance		**Minor disturbance**		**Major disturbance**	
	No response	**Approach**	**Avoidance**	**Dive avoidance**	**Flight**	***Grand total***
Intention to touch/contact						
Behind	1					*1*
Side	1				1	*2*
Intentional touching						
Behind					1	*1*
Side					1	*1*
Passive observation						
Above/below	16	1				*17*
Behind	19					*19*
Front	5					*5*
Side	162	1				*163*
Splash/fin kick						
Above/below			2			*2*
Front			2			*2*
Grand total	***254***	***2***	***131***	***10***	***10***	***407***

The estimated closest distance for human-manta interactions at feeding aggregations ranged from 0 to 15 metres, with a mean distance of 3.63 m per interaction (± 2.44m). Divers and snorkelers were able to get closest to mantas whilst feeding when the approach was from the front, with a mean distance of 2.48 m (±1.99m) (table 8).

Table 8. Summary of estimated closest distances between snorkelers and/or divers and mantas rays at feeding aggregations, dependent on direction of approach

Direction of human approach towards manta	Estimated mean closest distance per interaction (metres) (± SD)
Above or below manta	3.97 (± 2.65)
Behind manta (behind pectoral fins)	4.43 (± 2.35)
In front of manta	2.48 (± 1.99)
From the side	4.18 (± 2.44)

Flight responses were observed only when divers or snorkelers came within 0 to 3 metres of a manta (table 9). Avoidance behaviours were observed when divers or snorkelers were between 0 and 10 metres away from a manta.

Over half of all interactions (229 of 407) occurred when snorkelers or divers were within 3 metres of a manta, with the majority of all observed interactions (350 of 407) occurring within 5 metres of a manta. In addition, most interactions (199 of 254) resulting in no observable changes in manta behaviour occurred when snorkelers or divers were at a distance greater than 3m from a manta.

Accidental obstruction was more frequent the closer divers or snorkelers were to a manta, with the vast majority of interactions (97 of 110) occurring within 3 metres of a manta. Passive observation was observed at a distance of between 1 and 15 metres of a manta, with just over half (117 of 204) occurring at a distance greater than 3m from a manta (table 9).

Table 9. Matrix of interaction type against estimated closest distance snorkeler or diver came to manta during interaction and elicited manta behavioural response at feeding aggregations (total counts)

Estimated Distance (m) Response	**Interaction type**										
	Accidental Contact	**Accidental Obstruction**	**Chasing**	**Diver Bubbles**	**Diving under/near**	**Following**	**Intention to make contact**	**Intentional Touching**	**Passive Observation**	**Splash/Fin Kick**	***Total count***
0 metres											
Avoidance			1								*1*
Flight	1							2			*3*
No response	1						1				*2*
1 metre											
Approach									1		*1*
Avoidance		42			3					2	*47*
Dive avoid		3									*3*
Flight		1					1				*2*
No response			1				1		21		*23*
2 metres											
Avoidance		31			1						*32*
Dive avoid		2									*2*
Flight					2						*2*
No response			4		1				25		*30*
3 metres											
Avoidance		16		1	4	3					*24*
Dive avoid		2			1						*3*
Flight					3						*3*
No response			2	2	6	1			40		*51*

Table 9 cont. Matrix of interaction type against elicited behavioural response of manta and estimated closest distance snorkeler or diver came to manta during interaction at feeding aggregations (total counts) cont.

Estimated Distance (m) Response	**Interaction type**										
	Accidental Contact	**Accidental Obstruction**	**Chasing**	**Diver Bubbles**	**Diving under/near**	**Following**	**Intention to make contact**	**Intentional Touching**	**Passive Observation**	**Splash/Fin Kick**	***Total count***
4 metres											
Approach									1		*1*
Avoidance		5		1	3					2	*11*
Dive avoid		1	1								*2*
No response					7				32		*39*
5 metres											
Avoidance		3			3	1					*7*
No response				4	5	5			47		*61*
6 metres											
Avoidance		**2**			1						*3*
No response						1			9		*10*
7 metres											
Avoidance		1									*1*
No response					1	1			4		*6*
8 metres											
Avoidance		1		1							*2*
No response					4	1			10		*15*
10 metres											
Avoidance				3							*3*
No response				1		2			12		*15*
15 metres											
No response									2		*2*
Total count	***2***	***110***	***9***	***13***	***45***	***15***	***3***	***2***	***204***	***4***	***407***

From 407 unique interactions, 17 (4%) resulted in mantas ceasing feeding behaviour (table 10). Of those 17, mantas were observed to resume feeding on 11 (65%) of them. Accidental obstruction accounted for 9 of the 17 interrupted feeding interactions. Diver bubbles, diving under or near a manta, following, intentional touching and splashing and fin kicking at the surface were also observed to have an impact on feeding behaviour. All 10 instances of flight behaviour observed during the study at feeding aggregations resulted in the cessation of feeding.

Table 10. Impact of human-manta interactions on feeding behaviour at feeding aggregations

		Were mantas observed resuming feeding behaviour?		
Interaction type Response	**No. of mantas stopped feeding**	**Yes**	**No**	**Unknown**
Accidental Obstruction				
Avoidance	2	2		
Dive avoid	6	4		2
Flight	1	1		
Diver bubbles				
Avoidance	1			1
Diving under / near manta				
Dive avoid	1			1
Flight	2	1		1
Following				
Avoidance	1	1		
Intentional touching				
Flight	2	2		
Splash/fin kick				
Avoidance	1		1	
TOTAL COUNT	***17***	***11***	***1***	***5***

Human-manta interactions at cleaning stations

Over 24 hours of SCUBA diving on cleaning stations culminated in the extraction of 20 minutes of relevant footage for analysis. A total of 38 unique human-manta interactions from 11 encounters were analysed. All observed interactions occurred when mantas were in mid-water. The number of divers per interaction ranged from 2 to 7 (mean = 3.45 ± 1.68).

Cleaning behaviour accounted for 92% of undisturbed manta behaviour at cleaning stations, travelling behaviour accounted for the remaining 8%.

All human behaviours observed at cleaning stations are shown in Figure 6. The most frequently observed human behaviour was passive observation, comprising 61% of interactions. Diver bubbles and diving under or near a manta were observed in 16% and 13% of interactions, respectively.

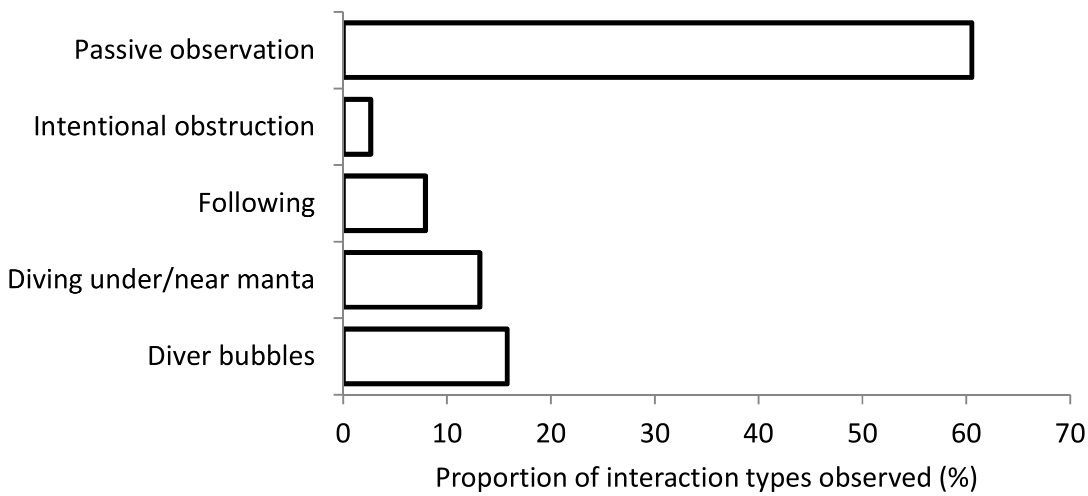

Figure 6. Observed human behaviours (interaction types) in response to an encounter with a manta ray at a cleaning station

In 81.6% of human-manta interactions at cleaning stations there was no observable change in manta behaviour (Fig. 7). Minor disturbance was caused in 10.5% of interactions in the form of avoidance, and flight (a major disturbance) was observed in 7.9% of interactions.

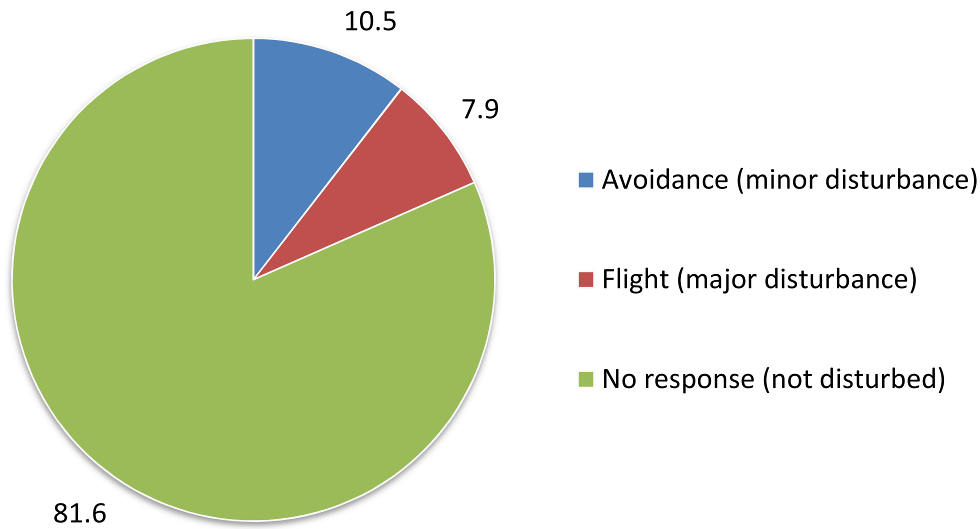

Figure 7. Observed manta behaviours (and level of disturbance) in response to human interactions at cleaning stations (%)

Diving under or near a manta was the most common cause of flight behaviour (Table 11). On one occasion, flight was also observed in response to diver bubbles directly below the manta, which made contact with its ventral surface. Intentional obstruction was observed on one occasion, where the diver approached from the front and which resulted in avoidance behaviour. Following also elicited avoidance behaviour.

Passive observation interactions caused no observable changes in behaviour in all interactions, with 65% of passive observation interactions (15 of 23) occurring when the diver was to the side of a manta.

Table 11. Matrix of manta responses against interaction types and directions of approach at cleaning stations (total counts).

Interaction type Direction of approach	Response			
	No response (Non-disturbance)	**Avoidance (Minor disturbance)**	**Flight (Major disturbance)**	***Grand total***
Diver bubbles				
Above/below			1	*1*
Front	3			*3*
Side	1	1		*2*
Diving under/near				
Above/below			1	*1*
Front	1	1		*2*
Side	1		1	*2*
Following				
Behind	2			*2*
Side		1		*1*
Intentional obstruction				
Front		1		*1*
Passive observation				
Above/below	3			*3*
Behind	1			*1*
Front	4			*4*
Side	15			*15*
Grand total	***31***	***4***	***3***	***38***

The estimated closest distance for human-manta interactions at cleaning stations ranged from 2 to 12 metres, with a mean distance of 4.84 m per interaction (± 2.56m). Divers were closest to mantas whilst at a cleaning station when the approach was from behind, with a mean distance of 3.67 m (± 1.15m) (table 12).

Table 12. Summary of estimated closest distances between divers and mantas at cleaning stations, dependent on direction of approach

Direction of human approach towards manta	**Estimated mean closest distance per interaction (metres) (± SD)**
Above or below manta	5.20 (± 3.11)
Behind manta (behind pectoral fins)	3.67 (± 1.15)
In front of manta	3.70 (± 2.36)
From the side	5.50 (± 2.63)

Twenty-nine of 38 interactions (76%) at cleaning stations occurred within 5 metres of a manta (table 13). Flight responses were observed when divers were within 6 metres of a manta, and avoidance behaviours were observed when divers were within 7 metres of a manta.

Table 13. Matrix of interaction type against estimated closest diver distance to manta and elicited behavioural response at cleaning stations (total counts)

Estimated Distance (m) Response	**Interaction type**					
	Diver Bubbles	**Diving under/near**	**Following**	**Intentional obstruction**	**Passive Observation**	***Total count***
2 metres						
Flight	1					1
No response	1				2	3
3 metres						
Avoidance		1				1
Flight		1				1
No response	1	2	2		4	9
4 metres						
Avoidance				1		1
No response	1				4	5
5 metres						
Avoidance			1			1
No response	1				6	7
6 metres						
Flight		1				1
No response					1	1
7 metres						
Avoidance	1					1
8 metres						
No response					1	1
10 metres						
No response					4	4
12 metres						
No response					1	1
Total count	***6***	***5***	***3***	***1***	***23***	***38***

Passive observation occurred when divers were within an estimated distance of between 2 and 12 metres of a manta. Diving under or near a manta and following behaviour occurred within 3 metres of a manta on 4 out of 5 occasions and 2 out of 3 occasions, respectively.

From 38 interactions, 5 (13%) resulted in mantas ceasing cleaning behaviour (table 14). Of those 5 occasions, the mantas were observed to resume cleaning on 2 occasions (40%), and on 2 occasions the mantas left the cleaning station and were not observed returning. Diving under or near a manta accounted for 3 out of 5 interactions (60%) which resulted in the cessation of cleaning behaviour, in addition, diver bubbles and intentional obstruction also impacted cleaning behaviour.

Table 14. Impact of human-manta interactions on cleaning behaviour at cleaning stations

		Were mantas observed resuming cleaning behaviour?		
Interaction type Response	**No. of mantas stopped cleaning**	**Yes**	**No**	**Unknown**
Diver bubbles				
Flight	1		1	
Diving under / near manta				
Avoidance	1			1
Flight	2	2		
Intentional obstruction				
Avoidance	1		1	
TOTAL COUNT	***5***	***2***	***2***	***1***

In addition, data on feeding aggregation and cleaning station use was also collected, and although not specifically analysed for the purposes of this study, data are presented in appendix 1 for information.

Discussion

Diving and snorkeling encounters with marine animals have the potential to alter their behaviour, and a major challenge for marine managers is to ensure adequate protection of the target species whilst providing a fulfilling encounter (Sorice *et al.*, 2003), a necessity for maintenance of a sustainable tourism sector. The results of this study have shown that the majority of human encounters with mantas do not result in disturbance, with the majority of participants in manta tourism in Baa Atoll behaving in a responsible and non-disruptive manner.

Feeding aggregations

Accidental obstruction was the interaction most likely to elicit avoidance behaviour at feeding aggregations, particularly when people were within 3 metres proximity. Accidental obstruction was also the most common cause of interrupted feeding behaviour, however, feeding resumed in the majority of cases, therefore, interruptions appear largely to be temporary. Accidental obstruction is often difficult to avoid, as mantas repeatedly swim through patches of zooplankton, changing direction as they do so to maximise consumption, often resulting in people being caught in their direction of feeding. Mantas were often observed avoiding people with just millimetres to spare, minimising deviation from the intended feeding path and therefore minimising energy expenditure, but possibly demonstrating a tolerance to human proximity.

Alternatively, feeding mantas may be less readily disturbed as they try to maximise feeding opportunities. The majority of feeding behaviours observed in this study involved individual feeding, however, should feeding intensity be increased with a concomitant increase in co-operative feeding behaviour (Stevens, G., pers. comm,), this may also reduce likelihood of disturbance, with observations from Brooks (2010) that reactions of mantas to disturbance whilst feeding may depend on the intensity of feeding, which in turn may relate to zooplankton abundance, relationships which require further investigation. Blane and Jaakson (1994), for example, found that feeding beluga whales (*Delphinatperus leucas*) were less prone to disturbance from vessels, compared with belugas involved in other behaviours.

At feeding aggregations, major disturbance was most commonly observed in response to people duck-diving under or near a manta, and only when they were within 3 metres of a manta. A major disturbance was also caused by people making contact with, or attempting to make contact with, a manta and all instances of flight responses resulted in the cessation of feeding. Therefore, recommending that tourists maintain a minimum distance of 3m or more between themself and mantas would greatly reduce levels of major disturbance.

Brooks and Stevens (2011) recommended that diving during encounters with mantas at Hanifaru Bay is not necessary and should be banned. The present study supports this recommendation given the predominance of interactions occurring at the surface, and should be extended to all feeding aggregations within Baa Atoll. Given that diver bubbles can cause major and minor disturbances, removal of this type of interaction at feeding aggregations would reduce the potential level of disturbance. Furthermore, banning diving would afford mantas the ability to avoid snorkelers via dive avoidance, rather than limiting their movement by the presence of divers at greater depth (Brooks and Stevens, 2011).

Cleaning stations

Disturbances were more likely when divers were within 5 metres of a manta, and were comprised of similar amounts of minor and major disturbance, albeit low in frequency. Diving under or near a manta and diver bubbles making contact with the ventral surface of a manta were causes of major disturbance and the cessation of cleaning behaviour, all occurring within 6m of a manta, all of which can be controlled for by implementing a minimum distance for observations and advising divers during pre-dive briefings to avoid these intrusive behaviours.

A fundamental component of environmental management concerns the education of users (Marion and Rogers, 1994). Medio *et al*. (1997) demonstrated the important role of frequent and effective environmental briefings in influencing appropriate diver behaviour in an environmental setting, and in limiting negative impacts. Tourists can only be expected to adhere to codes of conduct or avoid certain in-water behaviours if they are informed prior to encountering the marine environment.

Whilst a Guest Fact Sheet (see appendix 2) was available to participants of The Four Seasons 'Manta on Call' for 'swim-with' excursions, this was not consistently distributed during excursions and briefings were not routinely given, however, the necessity for dive safety briefings prior to any dive facilitated the communication regarding diver conduct during dives at cleaning stations, although the type of information and level of detail varied considerably (pers. obs.). Furthermore, because footage was collected from encounters involving numerous resort and live-aboard tour operators, specific details pertaining to briefings were not available to assess, however, this would prove an insightful study for the future.

The proportion of cleaning behaviour which was interrupted as a result of a human-manta encounter at cleaning stations was greater than the proportion of feeding behaviour which was interrupted at feeding aggregations, suggesting that mantas are more readily disturbed whilst they are cleaning than when they are feeding. Furthermore, following interruption, cleaning behaviour was less likely to resume than feeding behaviour. A possible explanation is that, unlike feeding, cleaning behaviour is not dependent on such limited resource availability, and mantas can choose to return to a cleaning station at any time.

Because mantas were observed at cleaning stations largely in solitude, whereas feeding aggregations were observed with up to 40 individuals within an area (see appendix 1), perceived threat of human presence by a manta may be associated with density of mantas, which may also play a role in the level of disturbance. Where there are greater numbers of mantas in close proximity there may be ‘safety in numbers’, and thus the likelihood of disturbance is reduced.

Reduced numbers of manta sightings this year compared with previous years resulted in the collection of less data than anticipated. Whilst it provides some useful insights, due to the small sample size, cleaning data should be treated with some caution. Estimated total manta sightings this year (to 1st September) was 307, for previous years manta sightings were estimated at 2015 (2008), 1277 (2009), 1682 (2010), with August the peak season for manta encounters (G. Stevens, unpublished data). The reason for this reduction in sightings is unclear, however, it has been suggested that a late monsoon and associated oceanographic conditions may have delayed the manta migration.

An alternative hypothesis is that extensive use of Hanifaru Bay in previous years has resulted in mantas migrating elsewhere, as may have been observed at popular manta dive sites elsewhere in the Maldives (Anderson *et al.,* 2010), however, this appears unlikely as the author and other MMRP researchers observed generally low zooplankton abundance in Baa Atoll. However, given the uncertainties, limiting disturbance through management of behaviours is essential if manta tourism is to persist in the region, with longitudinal studies of site fidelity a necessity in light of increased tourism and associated impacts.

The number of people at feeding aggregations at any one time has been observed to correlate positively with the number of mantas present, with deterioration in observer behaviours linked to greater densities of megafauna (Brooks, 2010), therefore, the reduced number of manta sightings for the period of the study may well explain the relatively high levels of non-disturbance interactions during this study. Further research on the impacts of group size on manta disturbance should be considered, which could inform managers regarding acceptable group sizes for manta ‘swim-with’ excursions, with group size an important consideration in relation to customer satisfaction (Inglis *et al.*, 1999).

Conclusions and recommendations

Levels of disturbance at manta feeding aggregations and cleaning stations in Baa Atoll are low, however, the precautionary principle should be applied to limit possible longer-term impacts of repeated minor disturbance, and management actions should be implemented to facilitate this, particularly until the biological significance of human interactions are established (Sorice *et al.*, 2003; Lusseau and Higham, 2004). By implementing a Code of Conduct relating to manta tourism, and by ensuring its proper enforcement, including minimum distances and behaviours to avoid, levels of disturbance can be further reduced. Recommendations are summarised in table 15:

Table 15. Recommendations for manta ray tourism, for inclusion in management strategies and Code of Conduct

Application	Recommendations
Feeding aggregations	○ Maintain minimum distance of 3 metres between participant and manta at all times. ○ Do not: touch, chase, follow or intentionally create an obstruction in front of manta. ○ Avoid: splashing at surface in close proximity to manta and approaching from behind. ○ Ban diving
Cleaning stations	○ Maintain a minimum distance of 5m ○ Do not: dive under or near manta or intentionally create an obstruction in front of manta
General	○ Implement an education programme as part of manta excursions and make briefings mandatory prior to all snorkel and dive tours.

There has to be an economic basis to conserving mantas, and manta tourism presents a real incentive to conserve the species and a viable alternative to fishing in other parts of the world where exploitation is decimating populations. Heyman *et al*. (2010) concluded that diver tourism at fish spawning aggregations (FSAs) in the Caribbean represents an economically viable and less exploitative alternative to commercial fishing, supporting findings by Sala *et al.* (2001), who estimated that diver tourism in Belize on grouper FSAs could produce 20 times the income from fishing them.

This study provides the first formal description of manta behaviour in a tourism context and the first quantitative review of human-manta interactions, providing evidence-based recommendations for a manta Code of Conduct for application within the Maldives and elsewhere. Manta tourism, with appropriate management of human interactions, can be a long-term and sustainable practice, and a viable alternative to fishing.

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References

Atoll Ecosystem Conservation (AEC) Project (2009) *Baa atoll conservation programme: 5 year strategy / 2009-2013*. Malé: AEC Project, Ministry of Housing, Transport and Environment.

Atoll Ecosystem Conservation (AEC) Project (2011) *Management plan for Hanifaru marine protected area, Baa atoll, Maldives. Version: April 2011.* Malé: AEC Project, Ministry of Housing, Transport and Environment.

Anderson, R.C., Adam, M.S., Kitchen-Wheeler, A.M. and Stevens, G. (2010) *Extent and economic value of manta ray watching in Maldives*. Tourism in Marine Environments 7(1): 15-27.

Anderson, R.C., Adam, M.S. and Goes, J.I. (2011) *From monsoons to mantas: seasonal distribution of Manta alfredi in the Maldives*. Fisheries Oceanography 20(2): 104-113.

Blane, J.M. and Jaakson, R. (1994) *The impact of ecotourism boats on the St. Lawrence beluga whales.* Environmental Conservation 213: 267-269.

Brooks, K. (2010) *Investigating tourism at Hanifaru Bay marine protected area, Maldives*. M.Sc. Thesis, University of York, UK.

Brooks, K. and Stevens, G. (2011) *Developing tourism at Hanifaru Bay Marine Protected Area (MPA): a short report for the Ministry of Environment, Maldives; EPA and AEC Project.*

Constantine, R. (2001) *Increased avoidance of swimmers by wild bottlenose dolphins (Tursiops truncatus) due to long-term exposure to swim-with-dolphin tourism*. Marine Mammal Science 17(4): 689-702.

Deakos, M.H., Baker, J. D. and Bejder, L. (2011) *Characteristics of a manta ray Manta alfredi population off Maui, Hawaii, and implications for management*. Marine Ecology Progress Series 429: 245-260.

Dewar, H., Mous, P., Domeier, M., Muljadim, A., Pet, J. and Whitty, J. (2008) *Movements and site fidelity of the giant manta ray, Manta birostris, in the Komodo Marine Park, Indonesia*. Marine Biology 155(2): 121-133.

Gill, J.A., Norris, K. and Sutherland, W.J. (2001) *Why behavioural responses may not reflect the population consequences of human disturbance*. Biological Conservation 97(2): 265-268.

Hennerman, R.M. (2001) *Sharks and rays: elasmobranchs guide of the world.* Frankfurt, Germany: IKAN.

Heyman, W.D., Graham, R.T., Kjerfve, B. and Johannes, R.E. (2001) *Whale sharks Rhincodon typus aggregate to feed on fish spawn in Belize*. Marine Ecology Progress Series (215): 275-282.

Heyman, W.D., Carr, L.M. and Lobel, P.S. (2010) *Diver ecotourism and disturbance to reef fish spawning aggregations: It is better to be disturbed than to be dead*. Marine Ecology Progress Series 419: 201-210.

Holmes, N., Giese, M. and Kriwoken, L.K. (2005) *Testing the minimum approach distance guidelines for incubating Royal penguins, Eudyptes schlegeli*. Biological Conservation 126(3): 339-350.

Homma, K., Maruyama, T., Itoh, T., Ishihara, H. and Uchida, S. (1999) Biology of the manta ray, *Manta birostris* Walbaum, in the Indo-Pacific. In: Séret, B. and Sire, J.Y. (eds) *Proceedings of the 5th Indo-Pacific fish conference*. Paris: Societe Francaise Ichtyologie. p. 209-216.

Inglis, G.J., Johnson, V.I. and Ponte, F. (1999) *Crowding norms in marine settings: A case study of snorkeling on the Great Barrier Reef*. Environmental Management 24(3): 369-381.

Kitchen-Wheeler, A. (2008) *Manta rays: research in the Maldives.* Shark Focus(31): 4.

Kitchen-Wheeler, A. (2010) *Visual identification of individual manta ray (Manta alfredi) in the Maldives Islands, Western Indian Ocean*. Marine Biology Research 6(4): 351-363.

Luiz, O. J., Balboni, A. P., Kodja, G., Andrade, M. and Marum, H. (2009) *Seasonal occurrences of Manta birostris (Chondrichthyes: Mobulidae) in southeastern Brazil*. Ichthyological Research 56(1): 96-99.

Lusseau, D. and Higham, J.E.S.(2004) *Managing the impacts of dolphin-based tourism through the definition of critical habitats: the case of bottlenose dolphins (Tursiops spp.) in Doubtful Sound, New Zealand*. Tourism Management 25(6): 657-667.

MacCarthy, M., O'Neill, M. and Williams, P. (2006) *Customer satisfaction and scuba-diving: Some insights from the deep*. The Service Industries Journal 26(5): 537-555.

Marion, J.L. and Rogers, C.S. (1994) *The applicability of terrestrial visitor impact management strategies to the protection of coral reefs.* Ocean and Coastal Management 22: 153-163.

Marshall, A., Ishihara, H., Dudley, S.F.J., Clark, T.B., Jorgensen, S., Smith, W.D. and Bizzarro, J.J. (2006) *Manta birostris*. In: IUCN 2011. *IUCN Red List of Threatened Species. Version 2011.1.* Available at: http://www.iucnredlist.org/apps/redlist/details/39417/0 [Accessed: 14th September 2011].

Marshall, A.D. (2009) *Biology and population ecology of Manta birostris in southern Mozambique.* PhD Thesis, University of Queensland, Australia.

Marshall, A. D., Compagno, L.J.V. and Bennett, M. B. (2009) *Redescription of the genus manta with resurrection of manta alfredi (krefft, 1868) (chondrichthyes; myliobatoidei; mobulidae)*. Zootaxa(2301): 1-28.

Marshall, A.D., Dudgeon, C.L. and Bennett, M.B. (2011) *Size and structure of a photographically identified population of manta rays Manta alfredi in southern Mozambique*. Marine Biology 158(5): 1111-1124.

Mau, R. (2008) *Managing for conservation and recreation: the Ningaloo whale shark experience.* Journal of Ecotourism 7 (2-3): 213-225.

Medio, D., Ormond, R.F.G. and Pearson, M. (1997) *Effect of briefings on rates of damage to corals by SCUBA divers.* Biological Conservation 79: 91-95.

Ministry of Tourism, Arts and Culture (2010) *Tourism Yearbook 2010.* Malé: Ministry of Tourism, Arts and Culture. pp 69.

Ministry of Tourism and Civil Aviation (2007) *Maldives third tourism master plan 2007-2011.* Malé: Ministry of Tourism and Civil Aviation. pp 92.

Neves, L. and Stevens, G. (2009). *Investigating anthropogenic impacts on the manta rays and whale sharks of Hanifaru Bay, Maldives: a short report for the Ministry of Environment, Maldives; EPA and AEC project.*

Quiros, A.L. (2007) *Tourist compliance to a Code of Conduct and the resulting effects on whale shark (Rhincodon typus) behavior in Donsol, Philippines*. Fisheries Research 84(1): 102-108.

Reynolds, P.C. and Braithwaite, D. (2001) *Towards a conceptual framework for wildlife tourism*. Tourism Management 22(1): 31-42.

Rodger, K., Smith, A., Davis, C., Newsome, D. and Patterson, P. (2010) *A framework to guide the sustainability of wildlife tourism operations: examples of marine wildlife tourism in Western Australia.* Queensland, Australia: CRC for Sustainable Tourism Pty Ltd.

Roe, D., Leader-William, N. and Dalal-Clayton, B. (1997) *Take only photographs, leave only footprints: the environmental impacts of wildlife tourism.* Wildlife and Development Series, No. 10. London: International Institute for Environment and Development.

Sala, E., Ballesteros, E. and Starr, R.M. (2001) *Rapid decline of Nassau grouper spawning aggregations in Belize: fishery management and conservation needs*. Fisheries 26(10): 23-30.

Semeniuk, C.A.D., Bourgeon, S., Smith, S.L. and Rothley, K.D. (2009) *Hematological differences between stingrays at tourist and non-visited sites suggest physiological costs of wildlife tourism*. Biological Conservation 142(8): 1818-1829.

Sorice, M.G., Shafer, C.S. and Scott, D. (2003) *Managing endangered species within the use/preservation paradox: Understanding and defining harassment of the West Indian manatee (Trichechus manatus)*. Coastal Management 31(4): 319-338.

Sorice, M.G., Shafer, C.S. and Ditton, R.B. (2006) *Managing endangered species within the use-preservation paradox: the Florida manatee (Trichechus manatus latirostris) as a tourism attraction*. Environmental Management 37(1): 69-83.

Stevens, G. (2011) *For the love of mantas.* Asian Geographic(1): 52-55.

Stevens, G. Personal communication (July - September 2011). Founding Director, Maldivian Manta Ray Project, Maldives.

Tapper, R. (2006) *Wildlife watching and tourism: a study on the benefits and risks of a fast growing tourism activity and its impacts on species.* Bonn, Germany: UNEP/CMS Secretariat. pp 68. Available at: http://www.cms.int/publications/pdf/CMS_WildlifeWatching.pdf [Accessed: 18th August 2011].

UNESCO (2011) *18 new Biosphere Reserves added to UNESCO's Man and the Biosphere (MAB) Programme*. Available at: http://www.unesco.org/new/en/media-services/single-view/news/18_new_biosphere_reserves_added_to_unescos_man_and_the_biosphere_mab_programme/ [Accessed: 16th September 2011].

Valentine, P.S., Birtles, A., Curnock, M., Arnold, P. and Dunstan, A. (2004) *Getting closer to whales - passenger expectations and experiences, and the management of swim with dwarf minke whale interactions in the Great Barrier Reef*. Tourism Management 25(6): 647-655.

White, W.T., Giles, J., Dharmadi, and Potter, I.C. (2006) *Data on the bycatch fishery and reproductive biology of mobulid rays (Myliobatiformes) in Indonesia*. Fisheries Research 83(1-3): 65-73.

Appendix 1. Feeding aggregation and cleaning station utilisation

The number of boats observed at feeding aggregation sites ranged from 1 to 11, with a mean of 2.72 (±2.26 SD) boats per site (table A1). When data from the 10/08/2011 at Hanifaru outside reef is removed due to the presence of a whale shark (a rare sighting which attracted an exceptional level of boats, with little focus on the mantas), the mean is reduced to 2.22 (±1.06 SD) boats per site.

The maximum number of people (including guides and researchers) in the water with an aggregation of mantas, ranged from 5 to 182 people, with a mean of 26.56 (±39.04 SD), however, when data from the 10/08/2011 is excluded, the maximum number of people in the water with an aggregation of mantas ranged from 5 to 52 people, with a mean of 17.56 (±10.45 SD). The estimated number of mantas present at feeding aggregation sites with groups of people on 'swim-with' excursions ranged from 2 to 40, with a mean of 18.44 (±12.13 SD).

Table A1. Details of Baa Atoll feeding aggregation site use by groups on 'swim-with' excursions included in the study (standard deviation in parenthesis).

Date	Feeding site	Max no. of boats at site	Max no. of people in water	Estimated no. of mantas present	Estimated time spent with mantas (mins)
12/07/2011	Hanifaru	2	10	25	45
14/07/2011	Hanifaru	2	9	10	60
14/07/2011	Hanifaru	2	20	10	60
15/07/2011	Bathalaa	2	9	15	60
19/07/2011	Hanifaru	3	16	40	60
29/07/2011	Veyofushi thila	2	11	15	45
30/07/2011	Hanifaru	2	20	5	60
30/07/2011	Hanifaru	2	26	15	75
31/07/2011	Dhonfan reef	1	5	3	75
10/08/2011	Hanifaru outside reef	11	182	20	85
11/08/2011	Hanifaru outside reef	6	52	22	80
16/08/2011	Bathalaa	3	24	15	60
21/08/2011	Reethi Beach outside reef	2	13	30	30
21/08/2011	Reethi Beach outside reef	2	15	20	30
22/08/2011	Reethi Beach outside reef	1	10	2	45
29/08/2011	Hanifaru	2	14	40	45
29/08/2011	Hanifaru	2	24	40	45
31/08/2011	Hanifaru	2	18	5	25
Mean ± SD		**2.72 (±2.26)**	**26.56 (±39.04)**	**18.44 (± 12.13)**	**54.72 (±16.87)**
(Mean ± SD*)		***2.22 (±1.06)***	***17.56 (± 10.45)***	***17.89 (±12.48)***	***55.00 (±18.21)***

*Excludes data from 10/08/2011 when a whale shark was also present, resulting in skewed data

The estimated time groups spent in the water with the mantas ranged from 25 to 85 minutes, with a mean of 54.72 minutes (± 16.87 SD). When data from the 10/08/2011 is excluded, time spent in the water with the mantas ranged from 25 to 80 minutes, with a mean of 55.00 minutes (± 18.21 SD). Estimated visibility in-water ranged from 10 to 20 metres, with a mean of 17.14m (±2.47 SD).

Cleaning station use

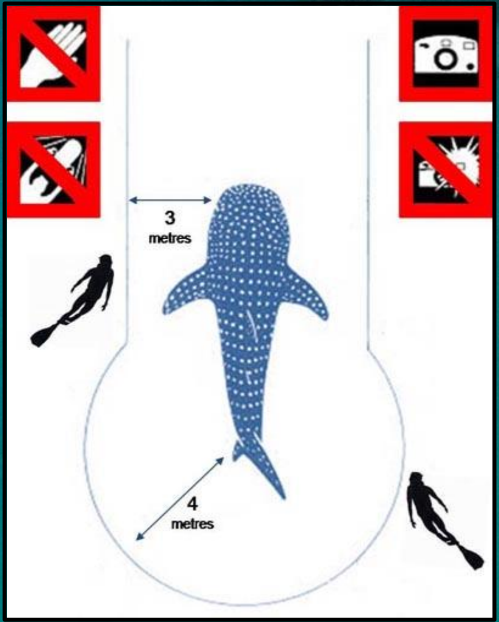
A maximum of two boats were observed at a cleaning station at any one time during data collection. The number of people in a dive group observing mantas at a cleaning station at any one time ranged from 2 to 7 (mean = 3.45 ± 1.68 SD), and the maximum number of mantas present at a cleaning station at any one time was 2 (mean = 1.29 ± 0.45 SD). SCUBA dives on cleaning stations lasted between 38 and 67 minutes (mean = 50.00 ± 10.73 SD), with in-water visibility ranging from an estimated 15 to 20 metres (mean = 15.71 ±1.75 SD).

Appendix 2. Maldivian Manta Ray Project Guest Fact Sheet for use during Four Seasons Landaa Giraavaru 'Manta on Call' excursions

Manta Rays & Whale Sharks...How to get the most from your experience!

Follow the **CODE OF CONDUCT...**

Snorkelling or diving with manta rays and whale sharks is one of the most spectacular underwater experiences possible. To make sure that encounters with these magnificent creatures are conducted in a safe and environmentally conscious way **Maldivian Law requires** that the following guidelines are adhered to:



DO NOT restrict the normal movements of the animals...

The best encounters are the ones where we see the animals acting as they naturally would,. Swimming in front of the animals or restricting their movements might cause them to swim away or dive, ending your encounter and disturbing the feeding animals. Where ever possible maintain a distance of 3m between yourself and the animals. Should an animal swim towards you remain motionless until it moves away.

DO NOT attempt to touch, ride or chase the mantas or whale sharks....

Manta rays are naturally quite curious, but they don't enjoy being chased! For the best possible manta experience stay calm in the water, don't splash and let the mantas come closer to you....

Research and conservation... how can you help?

We still know relatively little about these species, but new discoveries are being made all the time by researchers around the world. Here in the Maldives the Maldivian Manta Ray Project has been researching mantas since 2005 using the unique patterns described overleaf to identify individuals of both species. This has allowed us to unravel some of the mysteries of population sizes, migration routes and find out more about the life history strategies of these animals.

If you have a camera with you on your whale shark or manta ray interaction then your photos might be very useful to researchers. Please contact us and send your images to:
maldivianmantarayproject@hotmail.com
www.mantatrust.org / idthemanta@mantatrust.org

Find out more... join the Maldivian Manta Ray Project team on Monday nights from 6pm for an educational talk and workshop. Learn more about manta rays, our research and help us to ID some of the mantas we have seen recently. For more information ask at recreation.

Manta TRUST

MALDIVIAN MANTA RAY PROJECT

Did you know?

Here in Baa Atoll during the South West Monsoon season (May-November) our waters become rich with plankton attracting some of the world's most exciting marine species…

Dinner Time!

Both manta rays and whale sharks are filter feeders feeding on the tiny zooplankton found in Baa Atoll at this time of year. By swimming through areas of plankton rich-water mantas filter out the plankton using their gills to get a tasty treat!

Ocean GIANTS…

The whale shark is the world's BIGGEST fish, the largest one ever reported was a MASSIVE 18m in length and weighed 34 tonnes! It's thought they could live for over 100 years.

Brains as well as beauty…

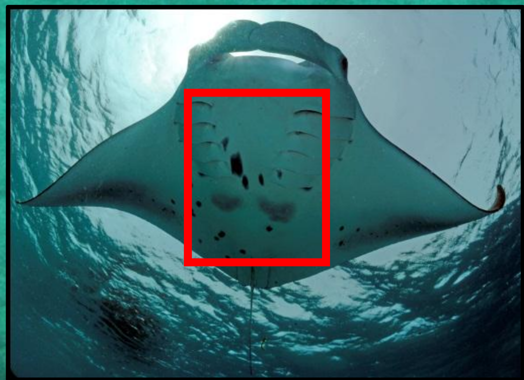
Manta rays have the biggest brain to body ratio of all the marine fishes… that makes them pretty smart!

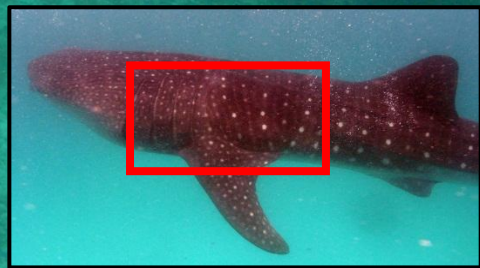
2 kinds of manta…

It was long thought that all manta rays were the same species however, recently scientists established that there are in fact 2 species of manta ray! The giant oceanic manta spends its life roaming the oceans making long migrations and can grow to have a wing span of over 7m. The reef manta is a smaller species with a wing span of up 5.5m, this species has a smaller range and is often resident to certain reefs and atolls. It's the reef manta that we see most commonly in the Maldives.

Seeing Spots…

Both manta rays and whale sharks have unique spot patterns, manta rays on their ventral (belly) area and whale sharks on their flanks. These spot patterns do not change over time and can be used year after year by researchers to study these animals.





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