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Monitoring tourist pressure on whale shark (*Rhincodon typus*) behaviour in South Ari MPA, Maldives

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ABSTRACT OF THESIS

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Title of Thesis **Monitoring tourist pressure on whale shark (*Rhincodon typus*) in South Ari MPA, Maldives.**

Whale sharks, the largest fish and shark, occur throughout all tropical and warm temperate oceans. They have been hunted traditionally for a number of years, and together with the estimation of a declining population is considered by the IUCN as vulnerable.

Nowadays, fishing and finning of whale sharks are almost stopped, however, new challenges appear with the increasing wildlife tourism activities, where people can swim with these gentle giants, originating another potential negative impact on whale sharks.

The South Ari MPA in the Maldives, one of the few places with a year-round population of whale sharks, does not have any formal management plan, only a Code of Conduct issued in 2009 when the MPA was declared. However, the lack of any kind of enforcement in the area causes regulations to be ignored.

By video analyzing each whale shark encounter in South Ari and record tourist and whale shark behaviour underwater, results suggest a low tourist compliance to regulations. Therefore, whale sharks are under a big anthropogenic pressure due to the unmanaged tourism activities.

Moreover, shark behaviour observed suggest that South Ari MPA could be a recovery area for whale sharks after performing deep dives, and disturbing them during the recovery phase would have detrimental effects on the population of whale sharks in the Maldives.

The results obtained and the different management measures recommended, have the potential to improve our understanding of whale shark ecology and the management in South Ari MPA.

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Abbreviations

Change of Direction **(CoD)**

Code of Conduct **(CoC)**

Convention on Migratory Species **(CMS)**

Food and Agriculture Organization of the United Nations **(FAO)**

International Union for Conservation of Nature **(IUCN)**

Marine Protected Area **(MPA)**

Maldives Whale Shark Research Programme **(MWSRP)**

Standard deviation **(S.D)**

South Ari Marine Protected Area **(S.A MPA)**

United Nations Convention on the Law of the Sea **(UNCLOS)**

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I. Introduction

The whale shark (*Rhincodon typus*) is the largest fish and shark in the ocean. The earliest data on whale sharks sightings are from near the Seychelles during Marc-Joseph Marion du Fresne expedition in 1768, and by captain Philip Beaver in 1805 (Rowat & Engelhardt 2007). However, the first detailed scientific description did not come until 1828 when Andrew Smith, a Scottish military surgeon and naturalist, described the species from a whale shark caught near the coast of South Africa (Davies 2014).

Whale sharks inhabit all tropical, subtropical and warm temperate oceans (Tyminski et al. 2015). Although, limited connectivity between the populations exists, according to a global scale genetic study on whale sharks (Vignaud et al. 2014), the population in the Atlantic and the Indo-Pacific population are functionally divided into two different sub-populations.

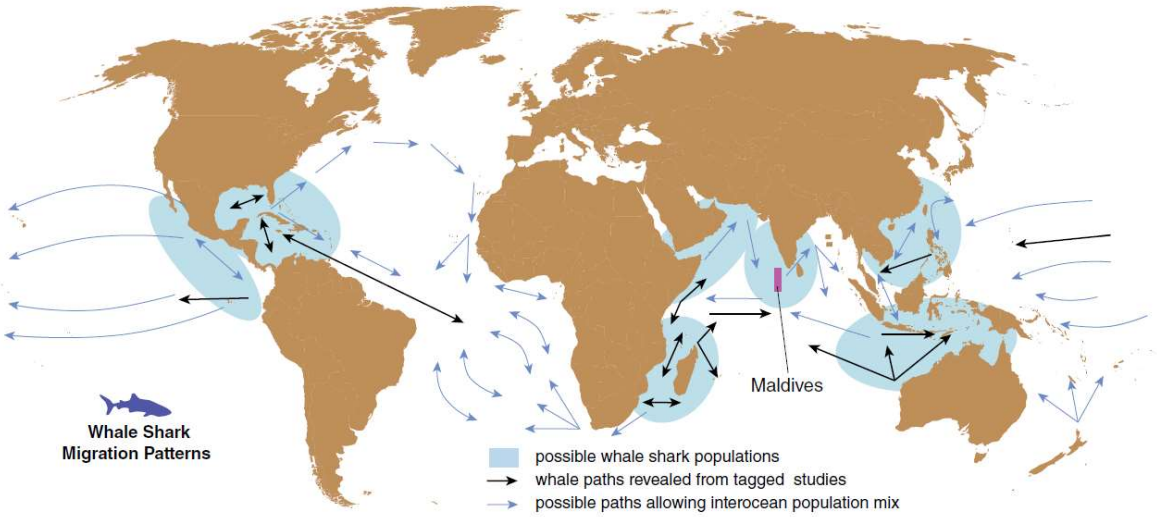


Figure 1: Whale shark populations and migration patterns. Source: Davies (2014).

It is thought that whale sharks can grow more than 15 meters and possibly live up to more than 100 years (Davies 2014) and, like the majority of the sharks, have a slow growth rate, late sexual maturity, and low reproduction rates, making them vulnerable to extensive exploitation.

Despite the general belief, whale sharks do have teeth. Each jaw has from 3000 to 3500 small teeth pointing backwards. Although not very functional, they can retain the small organisms ingested by the animal. For instance, a whale shark of about 9.7 meters long possessed, small teeth of approximately 0.3 centimeters (Gudger 1941). The whale shark is one of the three species of sharks, along with the Basking shark and the Megamouth shark that can feed by filtering water. Their diet

consists, above all, in a variety of micro-organisms filtered through its gills, but it can catch larger preys like squids or small schooling fishes (Davies 2014).

Whale shark are a highly mobile species, and migratory pathways are still unknown; Figure 1 shows some of the migratory routes discovered during tagging studies, and other possible routes (Davies 2014). Sightings occur mostly in coastal feeding areas where the sharks aggregate when the productivity is thriving (Rowat & Brooks 2012), peculiarly, the whale sharks sighted in these areas are usually small and immature male individuals (Davies 2014).

The average size of the sharks in these feeding grounds is about 6 to 7 meters, and large mature sharks are rarely sighted in such places (Catlin & Jones 2010; Hancock et al. 2013; Donati et al. 2016). Despite the number of investigations about whale sharks, there are many questions that remain unanswered, such as, “where are the large mature whale sharks?”, “where or when they feed?” (Davies 2014; Giulia Donati personal communication, June 2016), but with increasing research technology is a matter of time until such questions are solved (Davies 2014).

II. Importance of sharks

Sharks as apex predators play a significant role regulating the oceans and maintaining a healthy and balanced ecosystem, they have a key position in the food chain and their removal can have severe consequences. Besides the implications for the species itself, several studies highlight the negative effect of the elimination of sharks on fisheries and coral reefs (Techera 2012; Hardiman & Burgin 2010). When comparing the whale shark to other large sharks or predators at the top of the food chain that help to remove weak or sick individuals, whale sharks feeding on zooplankton have less impact on the maintenance of the species in the ecosystem, but their role is still important.

Biodiversity has an important role in the functioning of the ecosystems and in the maintenance of the ecosystem services which humans benefit from (Pratchett et al. 2011; Jobstvogt et al. 2014). Moreover, whale sharks are an indicator species for changes in the ecosystem (Marine Megafauna Foundation, 2016). Zooplankton is susceptible to changes in the ocean conditions and responds rapidly to them, large herbivores like the whale shark, which feed directly on zooplankton, are affected by changes in the zooplankton distribution. Furthermore, other small herbivores may not be as easy to track as the whale shark, or they might feed indirectly on zooplankton up in the food chain.

The slow growth rate and low reproduction rates of sharks, make them very susceptible to overfishing. Globally, around 26 and 73 million sharks are caught and subjected to trade each year mainly for the food industry, and half of the catches are estimated to be fished accidentally. The final destination shark's products are usually markets in China, Malaysia, Taiwan, Indonesia and Thailand (Techera 2012).

Currently, unsustainable fishing practices threaten sharks world's population, and according to the Marine Megafauna Foundation (MMF), whale sharks belong to one of the taxa requiring an urgent protection and conservation measures. In recent years, wildlife tourism has added a significant value to whale sharks, in Australia, the value of each living shark is calculated to be approximately 282.000 Australian dollars per shark (MMF). A well –managed ecotourism has the capability to overcome the benefits of killing a whale shark and become a sustainable alternative. This may be the rightmost strategy for the protection of the species, perhaps leading to the closure of fisheries and the creation of new Marine Protected Areas. Whale sharks are in need of protection from human exploitation, and despite their big dimensions, they are not immune to human threats (Davies 2014).

III. Threats: Fishing and Finning

In the past, whale sharks were hunted for their meat and the oil contained in their livers for waterproofing boats in India, Pakistan and the Maldives (Rowat 2007; Jackson et al. 2001). Nowadays, the whale shark fishing industry has stopped on a large scale. However, the major threats include some remaining legal and illegal fisheries, bycatch and vessel strikes (Techera 2012).

In the present, whale sharks are fished legally and illegally for their big fins, meat, and liver. Normally, whale shark fins are less valuable, nonetheless, in Asia, the demand is increasing due to their big size (Rowat 2007). A large-scale fishery which continues to hunt whale sharks is located in China, and according to Li et al. (2012) the fishing effort and the number of sharks caught each year appears to increase. The increasing demand for large shark fins and an emerging market for the consumption of all parts of the whale shark appears to be driving this increase, and making the whale shark a target species for fisheries in China. Whale shark products go mainly to Asia with target destinations including China, Malaysia, Taiwan, Indonesia, and Thailand, with the largest shark fin market placed in Hong Kong (Techera 2012; Li et al. 2012; Clarke et al. 2006).

The Food and Agriculture Organization of the United Nations (FAO) notes that some small harpoon fisheries are still placed in Pakistan, India, China and Senegal, and given the decrease in catch rates in some of the fisheries whale sharks exploitation runs unchecked.

According to Hardiman & Burgin (2010), results from Australia show that when specific species are targeted, the direct impacts could be highly concentrated in the population of such species, resulting in a reduced abundance and breeding success, and a possible cascade effect, which, will indirectly affect other non-targeted species.

In the Maldives, fishermen used to hunt the whale sharks using harpoons in order to harvest the oil in the liver for the boat and meat until 1995, when the government decided to protect the species and close all the fisheries. Later, in June 2009 three Marine Protected Areas were created to ensure the continued presence of whale sharks in the Maldives.

Figure 2: Whale shark fins being dried; Photo source: Paul Hilton (WildLifeRisk).

Bycatch is also a significant problem, it is thought to be one of the causes of the decrease in shark populations worldwide. Although whale sharks are legally protected in some countries, these can be caught accidentally in fishing nets. Typically, during the exploitation of fisheries, not only the targeted species are affected, but also non-targeted species through bycatch (Torres-Irineo et al. 2014).

Figure 3: Whale shark caught as bycatch; Photo source: Greenpeace.

IV. Legislation and protection

The whale sharks are protected by governmental legislation in some countries (Table 1), although it is unclear if such protection is adequate or efficient given the example of the small-scale fisheries in some countries. Taking into account that, whale sharks occur all throughout tropical, subtropical and warm temperate oceans around the globe and they have a highly migratory behaviour, the best management option would be the proposal of some international standards. For example, establishing only a local protection for whale sharks in Australia would not be the best practice if they move seasonally to China or other countries where they can be fished. However, reaching an international agreement on the protection of whale sharks is unlikely.

4.1 International protection

The whale shark is recognized by several international organizations as a vulnerable animal to human threats due to their high value in the international trade, their highly migratory behaviour and their low abundance (Rowat 2007). Therefore, it is listed in different international conventions or agreements including:

- Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2002), being one of the eight species of shark listed on Appendix II of this convention in order to regulate their trade implementing import and export permits internationally. However, this convention does not control trading inside a given country (Techera 2012). The inclusion of the whale shark in this convention should allow the monitoring and restriction of the trade of whale shark products between countries and help with the conservation of the species (Rowat 2007). This inclusion was proposed by India and Philippines in 2002, two countries with a national policy for the protection of the whale shark and a high number of wildlife tourism activities.

- Bonn Convention for the Conservation of Migratory Species (CMS, 2005). Due to the ability to travel great distances and cross the borders of different countries, whale sharks are included in Appendix II of the list of migratory species prohibiting their harvest (Techera 2012; Rowat 2007).

- United Nations Convention on the Law of the Sea (UNCLOS, 1982), this agreement recognizes that coordinated management and assessment of migratory species included in Annex I would improve the understanding of fishing impacts and in the knowledge of the species (Rowat 2007).

- The Food and Agriculture Organization of the United Nations (FAO, 2000) has the only shark-specific plan to improve the conservation status of sharks. The International Plan of Action for the Conservation and Management of Sharks by the FAO is a voluntary treaty to improve the understanding of the species by doing shark population assessments and national plans of actions for the conservation of sharks (Rowat 2007). The FAO plan for whale shark conservation has the

potential to improve the status of whale sharks. However, the implementation by members states is limited, decreasing the effectiveness of the project (Rowat 2007).

- International Union for the Conservation of Nature (IUCN, 2016). Whale sharks are listed in the Red List of Threatened Species by the IUCN, and their conservation status is classified as "vulnerable". For the species listed as vulnerable, the population size is expected to decrease by 30% in the next ten to hundred years.

4.2 National Protection

Despite the protection of whale sharks in some countries, the success of such protection strategies on a national level is unclear Table 1 shows a number of countries with known presence of whale sharks and the status of national legislation regarding their protection.

Table 1: Protection status of whale sharks at the national level; Adapted from Rowat (2007).

Location	Status	Location	Status
Australia	Protected (1994)	Mexico	Protected (2000)
Bangladesh	Not protected	Mozambique	Not protected
Belize	Habitat protection (2000)	Philippines	Protected (1998)
China	Not protected	Seychelles	Protected (2003)
Djibouti	Protected (2004)	South Africa	Not protected
Honduras	Protected (1999)	Tanzania	Not protected
India	Protected (2001)	Thailand	Protected (2000)
Kenya	Not protected	USA	Protected
Maldives	Protected (1995)		

From the 16 different countries listed in Table 1, eleven have the whale shark as a protected species in their legislation. Species protection is important in countries where whale sharks are still being caught; according to Rowat (2007), in Bangladesh, India, and Mozambique the presence of fisheries targeting whale sharks is confirmed. Moreover, according to IUCN Red list (2016), whale sharks are still being caught as a target species and bycatch in China, Oman, Pakistan, and Tanzania.

The majority of the countries without any kind of protection towards the whale shark are concentrated in the Indian Ocean, and bearing in mind the separation of the two subpopulations and their seasonal migration patterns, the Indo-Pacific population moves through some countries without protection.

For a successful protection of the whale sharks, the different countries in the Indian Ocean that host the same population of sharks must work together for their protection, creating new agreements between governments to prohibit hunting and the import and export of whale shark derived products.

V. Wildlife tourism

Sharks, in general, have been exploited as a valuable resource for fisheries for a long time, and some shark populations have rapidly decreased (Topelko & Dearden 2005). In the last decades, concern about the collapse of shark fisheries and the reduction of shark's world populations is causing the creation of alternative, more sustainable ways to manage sharks related activities. With the closure of fisheries, opportunities are emerging for the wildlife tourism sector.

Ecotourism has the potential to help in the conservation status of sharks and improve public understanding about the species (Techera 2012), therefore, shark tourism can offer multiple benefits to wildlife compared to most of the alternatives (Quiros 2007).However, unregulated tourism activity has the potential to negatively affect shark conservation.

The benefits of shark-related tourism include the closure of fisheries, the creation of Marine Protected Areas (MPA), obtaining a different sustainable way of life for some communities, and raising awareness about sharks when many conceive sharks as fearless predators (Techera 2012). Nowadays, diving with sharks and rays is a popular recreational attraction (Hardiman & Burgin 2010) worth millions of dollars each year to local and regional economies (Brunnschweiler & Baensch 2011). However, despite the benefits, shark tourism remains controversial due to the need of the tour operators to use bait in order to attract the sharks and ensure the presence of the animal to the visitor.

Normally, the impacts of human activity on marine ecosystems are less understood than in their terrestrial counterparts, probably because ecological impacts on marine ecosystems are difficult to quantify and the effects are not so obvious (Hardiman & Burgin 2010; Halpern et al. 2008). Using bait to attract sharks is a common practice in the ecotourism activity (Clua 2010), and it can affect the target species by altering its natural behavior. However, the potential effects on the species and on the balance of the ecosystem are not fully known.

A study carried out in Australia, revealed a potential change in the natural behaviour of sharks trough continuous feeding during ecotourism activities. Whitetip sharks, which normally hunt during night time hours, were seen congregating and searching for food during the day where feeding activities are carried out (Fitzpatrick et al. 2011). Another study in French Polynesia showed a similar outcome with lemon sharks congregating at the feeding site (Clua 2010).

Together these results suggest yet another potential threat to the global population of sharks, feeding. Undeniably, Ecotourism has some benefits such as the profit generated to the local economy, helping low-density species meet in the feeding site for reproduction, and improving people's image towards

shark. However, ecotourism has negative impacts, including an increase in human interactions with sharks and, therefore, the possibility of an attack, negative effects on the ecosystem by altering the feeding patterns of a super predator, and changing the behaviour of sharks, increasing the risk of sharks becoming accustomed to human presence (Clua 2010; Brunnschweiler & Baensch 2011; Hardiman & Burgin 2010).

Most of the studies regarding wildlife tourism have been conducted on dolphins and small whales during swimming interactions with tourists, for studies regarding swimming with larger whales and whale sharks there are a limited amount of data, increasing the uncertainties of these activities (Valentine et al. 2004).

5.1 Whale shark tourism

The calmed behaviour of whale sharks and their seasonal aggregation in coastal feeding areas makes them a suitable target species for wildlife tourism, which is now in practice in several countries worldwide, including the Maldives, Ningaloo, Philippines, Mozambique, Mexico, Seychelles, and Honduras. Ningaloo Marine Park, in Western Australia, was the first place in the world to offer a swim with whale sharks experience to visitors in 1989 (Catlin & Jones 2010; Mau 2008) and is considered as the benchmark for a good practice in whale shark tourism (James Hancock personal communication, July 2016).

The swim with whale sharks operators works in locations where whale sharks can be found reliably. Normally, whale sharks are found seasonally in coastal feeding ground of the countries of occurrence and not all year round. However, the Maldives is known for being one of the few countries with a year round aggregation of whale sharks (Hancock et al. 2013; Castro et al. 2007; Rowat 2007) increasing the opportunity of exploitation of this type of tourism.

In Ningaloo, the estimated tourist expenditure on whale shark tourism in 2004 and 2006 was of 13.3 (Cagua et al. 2014) and 4.5 (Catlin & Jones 2010) million US dollars respectively. In the Maldives (South Ari MPA), the estimated expenditures on whale shark tourism for 2012 and 2013 accounted for 7.6 and 9.4 million US dollars respectively, and the number of tourists involved annually is estimated to be 72.000- 78.000 visitors (Cagua et al. 2014).

In 1995 the government of the Maldives decided to protect and ban the hunting of whale sharks, and in 2009 three Marine Protected Areas were created (Cagua et al. 2014). One of the three MPA created was the South Ari Atoll Marine Protected Area, where whale sharks are seen all year round. In 2009, with the declaration of the MPA, a Code of Conduct (CoC) was issued by the government in order to ensure a sustainable tourism practice. However, since 2009 the Code of Conduct has not been enforced (James Hancock personal communication, July 2016).

The absence of enforcement in the MPA, together with guest pressure on stakeholders, leads tour operators to not follow the Code of Conduct religiously (James Hancock personal communication, July 2016). Without an effective management and enforcement, unregulated tourism can have several negative impacts on the whale shark, and can pose a threat to the long-term sustainability of the population.

Considering the growing number of the "swim with whale sharks" experiences, the possible negative impacts of these activities should be monitored. A review of the literature revealed boat strikes, pollution and changes in the behaviour of the shark as potential impacts of unmanaged wildlife tourism.

Pollution levels might increase with tourism activity, whale sharks normally feed on small organisms which are very susceptible to any changes in the environment, and chemicals discharged from boats can harm not only these organisms but also the whale sharks (Hardiman & Burgin 2010). Although chemical discharges and solid waste of the boats cannot legally be dumped in the water, they still end up in the water or as landfill, incrementing the degradation of the ecosystem (Hardiman & Burgin 2010).

The negative impacts of boats are not only limited to the possible chemical discharges, boat strikes due to the proximity of the boat to the shark are also a major concern (Rowat et al. 2007; Araujo et al. 2016; Hardiman & Burgin 2010; Rowat & Brooks 2012). For instance, Figure 4 shows a photo from the Philippines of Fermin, a whale shark with propeller injuries in the eye from 2012.

Figure 4: Injured whale shark; Photo source: LAMAVE project, Philippines.

The behaviour of the shark can be affected in different ways, with the disturbance of people swimming in the water and boat traffic, sharks can be displaced from feeding grounds where the wildlife tourism is placed, causing a disruption of their feeding behaviour (Rowat & Brooks 2012; Catlin & Jones 2010). Changes in natural behavior of the whale shark can cause deviations in their usual migration patterns, together with changes in their reproduction and social behaviour (Castro et al. 2007; Hardiman & Burgin 2010; Clua 2010).

Another controversial issue is the practice of whale shark feeding to attract them to the surface near the tourists. In Oslob (Philippines) whale sharks are fed during the encounters in a provisioning site; the compliance to regulations was evaluated in Schleimer et al. (2015) and high rates of non-compliance by tourist and operators was recorded. For instance, in 89% of the encounters, the feeder makes contact with the whale shark touching their mouth (Figure 5). Whale sharks come close to the boats looking for food and occasionally the feeders push them away to prevent the whale shark from turning the boat.

Figure 5: Whale shark being pushed by a feeder; Photo source: LAVAME project, Philippines.

Such practices can change the natural behaviour of the shark towards humans and boats, and now whale sharks approach boats instead of avoiding them, increasing the chances of boat strikes. Unmanaged tourism might increase the risk of suffering from negative impacts (Pierce et al. 2010), therefore, creating management plans and Codes of Conduct with a proper enforcement can help reduce the effects of the negative impacts and ensure the sustainability of swim with whale sharks tourism.

VI. General objectives

The aim of this study is to improve our understanding of whale sharks and the impacts of whale shark tourism in the Maldives, by evaluating shark behaviors towards the presence of swimmers and the compliance of these swimmers to the existing Code of Conduct.

South Ari Atoll Marine Protected Area is a non-regulated MPA, therefore, subjected to a big anthropogenic pressure. This study has the potential to help improve the conservation status and management of whale sharks in the Maldives by encouraging the implementation of site-specific effective management measures and the enforcement of the MPA, to offer the visitor a high quality experience.

VII. Methods

The methodology followed in order to accomplish our objectives is described in this chapter and summarized in Figure 6.

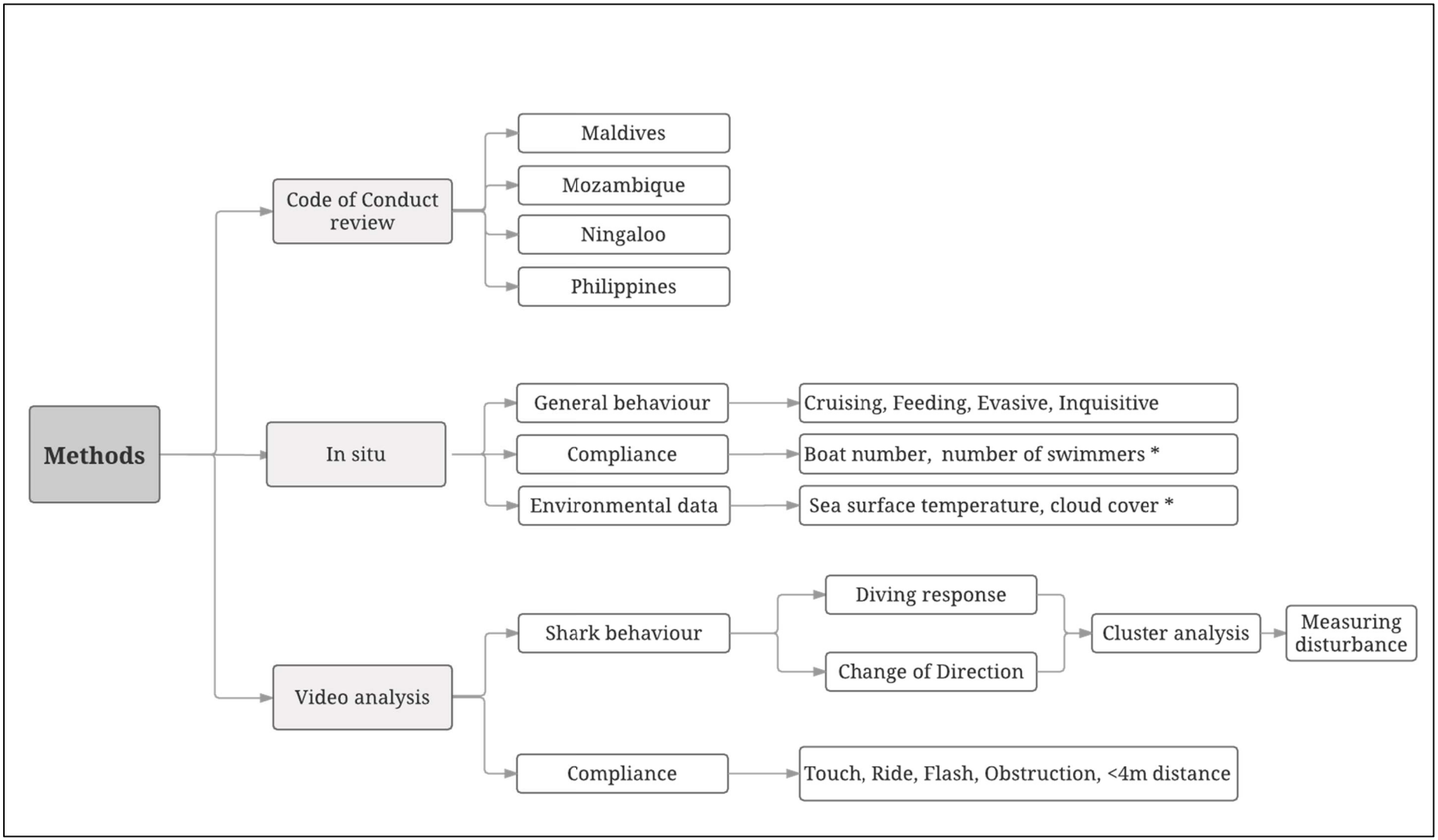
The data concerning the whale shark encounters was recorded in two different ways. First, data was collected in situ during swim with whale sharks activities on South Ari MPA by the Maldives Whale Shark Research Programme (MWSRP). Afterwards, a video analysis was carried out for each video recorded encounter to note the different behaviors of the sharks and the people under the water.

Finally, a literature review of different Code of Conducts around the Indo-Pacific region was carried out in order to compare the current situation in those regions to the Maldives, and compare the results obtained from the whale shark encounters.

7.1 Code of Conduct review

Information of the Code of Conduct in the Philippines, Mozambique, and Ningaloo (Australia) was collected and compared to the Maldives Code of Conduct. Ningaloo reef is considered to be one of the most distinguished places with a high level of development in this industry.

Whale sharks in Australia, the Maldives, and the Philippines are protected by national legislation, although they are protected the level of the protection is different and worth comparing. In Mozambique, the status of the whale shark is still unprotected, and the presence of a fishery targeting whale sharks can be a threat to the population (Rowat 2007).



* See Table 2 for a full list of variables

Figure 6: Methodology followed in the study.

7.2 In situ study at South Ari MPA

The Maldives Whale Shark Research Programme (MWSRP) with the help of several tour operators from South Ari, is trying to gather information on whale shark encounters occurring inside the MPA.

Tour operators from different atolls make speed boat trips of several hours to bring their guests to swim with whale sharks. The lack of managing plans and restrictions means that there are no limits to the total amount of trips carried out in a single day. Moreover, the task of the MWSRP is challenging without any enforcement inside the marine protected area.

Study area

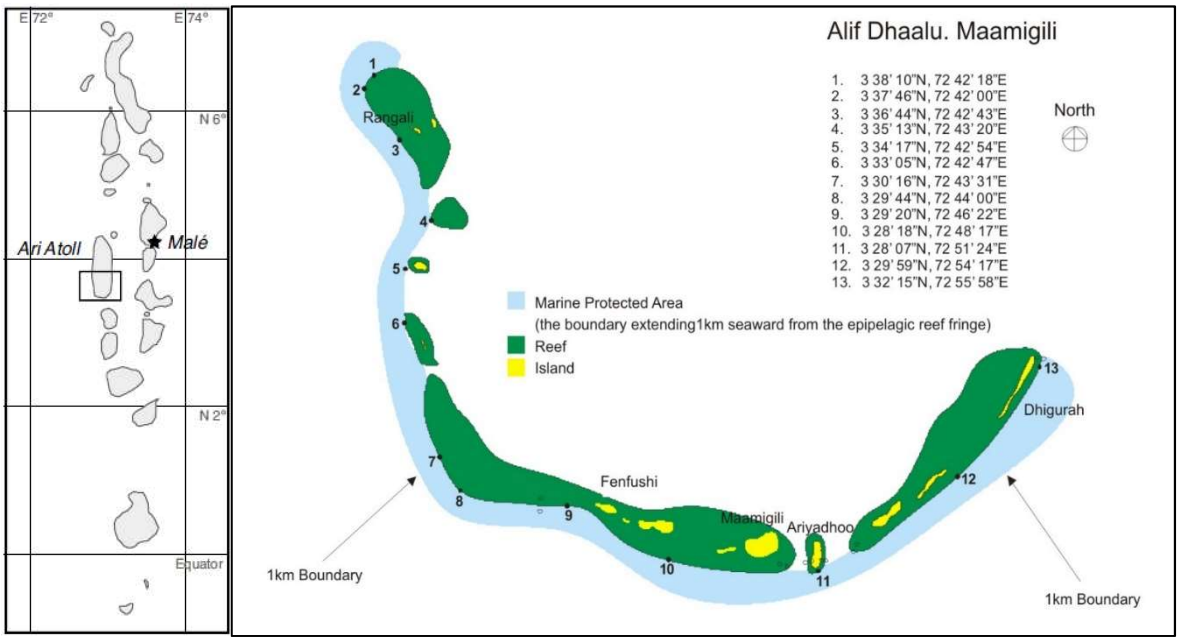
The Republic of the Maldives in the Indian Ocean is formed by 26 different atolls and numerous islands (Naseer & Hatcher 2000). As Darwin properly explained (Grigg 1982), these coral islands have their origin in the deep ocean, where ancient volcanoes rose due to the tectonic activity.

In one of these 26 atolls, the Maldivian government created, in 2009, the largest protected area in the country, the South Ari atoll Marine Protected Area (S.A. MPA), located 105 Km southwest of the capital (Malé) and spanning an area of 42 km^2. This territory is known worldwide for being one of the few to have a year-round aggregation of whale sharks (*Rhincodon typus*) (Morgan J. Riley et al. 2009; Sampa maldives 2011).

The MPA runs from Rangali Island in the North-west until Dhigurah in the eastern part and comprises 4 local islands plus 4 resort islands (Figure 7 & 8). Furthermore, the inner lagoon areas reach depths of 3-16m and the deep ocean areas of 1500m (Sampa maldives, 2011).

Whale sharks are fundamentally pelagic species and they can dive to extreme depths (perhaps more than 3400m) looking for food (Hancock et al. 2013). The population of whale sharks in South Ari might be using the deeper waters near the MPA to feed. When they perform the deep dives to find food, the temperature of the water is significantly lower than in the surface, making the body temperature of the shark drops below the normal temperature (Hancock et al. 2013; M. Thums et al. 2012).

Moreover, typically at 200 meters depth, the oxygen minimum zone can be found in the Maldives (Hancock et al. 2013), and at these depths, the layer of water contains a low concentration of oxygen. When the shark passes through this layer of water, the oxygen concentration in their blood goes down. In order to re-warm their bodies and re-oxygenate their blood again, sharks might be using the shallower parts of the reef to recover swimming slowly and recover from the dive (Michele Thums et al. 2012). During the recovery in the shallow reef area, they are protected from pelagic predators like tiger sharks or Orcas (rarely sighted in the shallow reef), and in the case of any danger they can dive away instantly (Hancock et al. 2013).



Figures 7 & 8: Map of South Ari Atoll Marine Protected Area. Source: Cagua et al. 2014 (left) and SAMPA Maldives (right).

In situ data collection

The Maldives Whale Shark Research Programme believes that the convergence of environmental factors, deep feeding areas just off the reef, and the safer shallow parts of the reef makes South Ari MPA a suitable place for the whale sharks. This year-round aggregation of whale sharks attracts tens of thousands of tourists, however, no exact data on the number of visitors and the economic extent of this activity exists due to the lack of a management plan for the MPA (Cagua et al. 2014).

The data available has been collected from January 2015 till January 2016 following Haskell et al. (2015) protocol. During each of the encounters data on whale shark general behaviour, compliance with the Code of Conduct (CoC) and environmental was recorded. Table 2 summarizes the different variables collected during the encounter.

Table 2: Variables collected In situ during the encounters.

General behaviour	Compliance	Environmental Variables
Cruising	Boat number at the start	Sea temperature
Feeding	Max boat number	Wind direction and speed
Evasive	Swimmers at the start	Cloud cover
Inquisitive	Max number of swimmers	Sea state
	Distance to closest boat	Visibility
	Divers presence	Current direction and strength

The surveys were generally performed along the reef between Rangali and Dhigurah (inside the MPA area) from a traditional motorized wooden boat called Dhoni. Whale sharks were spotted by a doing visual search of the water, following the encounter with the shark, the boat moved in the same direction and drop the swimmers on the deep side of the reef to start the encounter.

During each encounter, data collected in the field about the whale sharks also included variables referring to the specific shark sighted such as the sex of the shark, determined by the presence (male) or not (female) of claspers (Morgan J. Riley et al. 2009), the total length of the whale shark, which was taken with a measuring tape or by visual estimation following established guidelines, the injury information in every encounter and their severity (major or minor), as well as the total encounter duration and direction of the shark at the start and at the end of the encounter. Simultaneously a video recording of the total duration of the encounter (when possible) and photographs of both sides of the pectoral fin area were taken for identification purposes. Later, using a pattern-recognition software (I^3S, Interactive Individual Identification System) (Morgan J. Riley et al. 2009) the ID of the whale shark was determined.

In reference to the tourist compliance to the Code of Conduct data (Table 2) included: the number of people at the start of the encounter and the maximum number of people recorded in the water, the number of boats at the start of the encounter and the maximum number of boats, and divers presence.

Lastly, the environmental variables (Table 2) were collected independently if there was an encounter with a shark or not. Wind speed was calculated in Km/h and also using the Beaufort wind speed scale, in the case of visibility, it was calculated with the Secchi disk and by visual estimation by the guides.

7.3 Video analysis

From all the information on whale shark encounters available (January 2015 till January 2016), a video analysis was performed in all the encounters with video recording from May till October 2015 to study the whale shark behaviour and the compliance of tourist inside the water.

The analysis was done using the computer software EthoLog to aid the transcription and timing of behavioral observation sessions (Ottoni 2000). With this software, the aim is to describe the general activity of the shark through the frequency of the tail swipes, the vertical and horizontal movements of the shark, among others.

EthoLog software allows you to work with State Events (events with a certain duration) or Instant Events (events with times of occurrence). This software specification is crucial, for instance, for the estimation of the tail swipes of the shark per minute, which can be used as a proxy for the swimming speed. The frequency of the tail swipes is calculated from the total number of tail swipes (Instant Event or IE) out of the total amount of in-sight time (State Event or SE) when the shark is visible.

At the end of the session, the occurrence of the Instant Events and the duration of the State Events of all the variables are shown in the output files, additionally the complete event sequence and the exact time of occurrence is shown. Additionally, an ethogram (an inventory of all the different behaviors shown in each encounter) of the responses of the shark in the presence of swimmers was created.

During the video analysis shark behaviour and the tourist compliance of the Code of Conduct was evaluated, and the different variables recorded are shown in Table 3. The different shark behavioral responses to the presence of swimmers were divided into two different categories, dive responses and changes of directions (CoD).

Table 3: Variables noted during the video analysis.

Shark behaviour	Shark behaviour explanation	Compliance
Gradual dive	Dive angle <20º	Touch
Steep dive	Dive angle >20º	Ride
Parabola dive	Up and down in regular intervals	Obstruction
Ascendance	Up swim	Flash
Banking	Rolling its back toward swimmers	Less 4m distance
CoD circular	CoD of at least 180º	
CoD gradual	CoD of <90º	
CoD abrupt	CoD of >90º	

Cluster analysis and measuring disturbance

Determine if a whale shark has been disturbed or not by tourist presence in the water is not straightforward, a big issue is the absence of information about the natural behaviour of sharks, i.e. without people in the water and without any kind of disturbance, because you always have the presence of at least the person who is recording shark behaviour. So determining what is "disturbance" and what constitute an "avoidance behaviour" is subjective; in the literature different methods are used (Quiros 2007; Riley et al. 2009; Haskell et al. 2015; Pierce et al. 2010) to determine if the sharks is showing an avoidance behaviour due to the disturbance, and sometimes they can contradict each other. Is not well-known what reactions constitutes an avoidance behaviour and which reactions not; the methodology adopted here to distinguish between a disturbed and non-disturbed whale shark is based on Quiros (2007) that uses composite scores to quantify the behaviour of the shark.

In Quiros (2007) the different behavioral responses lie along a gradient, this gradient goes from a whale shark showing neutral responses to a whale shark showing multiple avoidance responses. The considered neutral behaviors in that study were swimming in circles, feeding and paraboling, while the considered avoidance behaviors were banking, steep dives and abrupt changes in direction. Finally, the gradual dives and gradual changes in direction lie in between the neutral and the avoidance behaviors.

In order to test the prior considerations, a cluster analysis was done using the ethogram of the different behaviors (Appendix I) created during the video analysis session, in order to group together similar sets of data. Using the matrix obtained from the ethogram, the clustering will show the behaviors that are seen more often together during all the encounters analyzed. Furthermore, the presence of injuries and feeding behavior was also introduced in the cluster analysis.

VIII. Results & general discussion

The following chapter contains the different results obtained for the Code of Conduct review, the in situ data collected, and the video analysis with a general discussion in each section.

8.1 Code of Conduct review

The review of four different Codes of Conduct from the Maldives (South Ari), Mozambique (Tofo beach), Philippines (Donsol) and Australia (Ningaloo) is presented in the following section.

The Maldives

The South Ari Marine Protected Area in the Maldives has a Code of Conduct (Appendix 2) issued by the government in 2009 and is based following the guidelines established in Ningaloo, Australia.

Concerning the vessel approach to the whale shark, only one vessel is allowed to be with the whale shark at a time and not closer than 10 meters, while the remaining vessels should remain at least 250 meters away from the shark. The speed of the boat should be reduced to 2 knots within the firsts 50 meters from the shark, and to 10 knots within 1 kilometer from the shark.

When tourist approach to the whale shark they must not go closer than 4 meters from the tail, and 3 meters from the head and body. Flash photography is forbidden together with the use of scuba scooters. Moreover, diver's presence is allowed during the encounter and the same rules apply to them.

Mozambique

Mozambique is one of the countries without a legal protection of whale sharks, therefore, in Praia do Tofo no Code of Conduct is in place at the moment. However, a voluntary CoC created by the Marine Megafauna Foundation and verbally agreed between the tour operators is in place (Alexandra Childs (MWSRP) personal communication, July 2016).

As in the Maldives, just one vessel at a time is allowed with a whale shark, however, a maximum encounter time is set in 30 minutes. One boat can approach until 30 meters from the shark and the remaining boats have to remain at least 300 meters from it. The maximum speed allowed inside the first 150 meters is 5 knots.

Inside the water, the restrictions are the same applied as in the Maldives but the maximum number of swimmers during the encounter is 10, and flash photography can be used with precaution and never from underneath the shark.

Philippines

Traditionally whale sharks were hunted in the Philippines, until 1998, when the government protected whale sharks and banned the hunting of these animals. However, since then no guidelines for good practices or regulations were never established for whale shark tourism at a national level. Inside the Philippines whale sharks can be sighted in different locations and the guidelines followed are similar.

In the encounter, the maximum interaction time is set in 30 minutes, and the same limit of one boat per shark is established. The speed limit is not regulated, however, the minimum distance for motorized boats should be of 20 meters.

Inside the water distances from the shark remain the same as in the Maldives and Mozambique, and the maximum number of people per shark is 10. In the Philippines, unlike in the Maldives, scuba diving with the shark is not allowed.

Australia

Ningaloo Marine Park was the first location to offer a swim with whale shark experience and nowadays is considered one of the hotspots for this kind of tourism (Mau 2008). The Department of the Environment and Conservation is the responsible for the protection of whale sharks in Ningaloo, and also of developing a sustainable tourism.

In Ningaloo, aerial surveys of the water are done in order to locate the shark and communicate its position to the tour operators. When the encounter starts, only one vessel can be in contact with the shark at one time for 90 minutes and within a minimum distance of 30 meters, all other vessels must remain more than 400 meters away. Finally, the speed is limited to 8 knots in the firsts 250 meters.

Inside the water, distances remain the same as in the other CoC reviewed and the number of tourists is limited to 10 plus a tour guide. In Ningaloo scuba diving with whale sharks is strictly prohibited, together with flash photography and the use of extension poles for cameras.

Moreover, whale sharks are sighted with aerial surveys and during the encounter in Ningaloo Marine Park, a second small boat with guards is present to ensure compliance with the rules. Australia has one of the most advanced managements in the swim with whale sharks tourism, with full compliance concerning the number of boats and their speed or distance, and 97.2 % of compliance (in 2005) inside the water (Catlin & Jones 2010).

8.2 In situ study

Encounters data summary

Between January 2015 and January 2016, a total of 684 whale shark interactions occurred, over the course of 721 trips. The human-shark interactions are distributed over 230 days, with an average of 2.97 interactions per trip (Standard Deviation, S.D. = 2.37), a maximum of 18 encounters in a single trip and a minimum of 1 encounter. Information on the duration of the encounter was collected on 631 encounters (53 without data) and total duration ranged from a maximum of 119 minutes and a minimum of 1 minute, being the mean duration 13.74 minutes (S.D. =14.61).

In order to compare this results, encounter data from different studies in the Indian and Pacific Ocean region was gathered (Table 4). Some locations as Ningaloo (Australia) have a legislation that only allows the vessel to stay for a maximum of 90 minutes during the interaction, thereby, the encounter durations are not as high as in the Maldives. Moreover, the average encounter time in the Maldives is higher than in the other locations showed in the table, and this may be due to different reasons, discussed in the next chapter, such as the recovery state of the whale shark or a certain degree of habituation of some sharks to tourists. On the other hand, in the Philippines the average encounter duration is lower than the other locations; Quiros (2007) explains that Donsol (Philippines) waters are feeding grounds for whale shark, and sharks are more likely to show avoidance behaviors when feeding, additionally, the maximum encounter time permitted in the Philippines is 30 minutes.

As mentioned before, whale sharks in the Maldives might come up to the surface to recover and re-warm their bodies swimming slowly, and sometimes, unresponsive. Therefore, the recovery state of the shark might not be enough to perform more dives, when disturbed, to end the interaction.

Finally, the results of the table are consistent throughout the different regions. However, an unusually high concentration of whale sharks occurred in the Philippines (Quiros 2007) which can explain the higher average interactions per trip.

Table 4: Summary of the encounter data compared to other relevant studies.

	Present study	Quiros (2007)	Haskell et al. (2015)	Pierce et al. (2010)
Location	Maldives	Philippines	Mozambique	Mozambique
Total interactions	684	620	689	411
Mean interactions per trip	2,97	8,15	2,73	3,00
Max. interactions per trip	18	No data	14	14
Average encounter time	13 min 45 s	3 min	9 min 46 s	8 min 48 s
Max. encounter time	119 min	No data	No data	49 min

Whale shark aggregation in South Ari

From the encounters where it was possible to record the sex of the whale shark, 62 different individuals were identified, 50 of them were males (80.65 %) and 12 (19.35%) were females. In terms of the overall encounters, in 536 interactions the shark was identified as a male, and on 24 occasions the shark was female; in the remaining encounters (124), shark's sex was not possible to determine.

Maximum shark length recorded was 11 meters, whilst the minimum was 2 meters, and the Average length of the sharks found in South Ari was 5.68 meters (S.D. =1.38). The Average size of the females was 4.98 (S.D. =1.63), while the average size of the males was 5.66 (S.D. = 1.23). Throughout the year, resightings of the sharks varied between 63 times and just 1.

Results match with the expectations and suggest that the whale shark aggregation in South Ari MPA is formed by young and immature sharks with a strong male bias in the population. Similar results appear in Riley et al. (2009), a study carried out also in South Ari MPA, where during the course of three years (2006 to 2008) 204 encounters were analyzed and 64 immature sharks identified. For 59 unique individuals the sex was determined, 56 being males (94.92%) and only 3 females (5.08%); for the remaining 5 sharks the sex was unknown. In the same study, the average size of the sharks was 5.98 meters, while maximum length recorded was 10.5 meters and the minimum 2.5 meters. Not just in South Ari, but also in other locations a strong male bias in the populations and a short average size of the sharks can be seen (Table 5).

Table 5: South Ari whale shark aggregation structure.

	Present study	Riley et al. (2009)	Haskell et al. (2015)
Location	Maldives	Maldives	Mozambique
Total sharks	62	59	128
% Males	80,65%	94,92%	74,20%
% Females	19,35%	5,08%	25,80%
Average Size	5,68 m	5,98 m	6 m
Max. Size recorded	11 m	10,5 m	No data

Since 2006, the MWSRP has been collecting data on whale sharks in South Ari, and according to their data, between 2006 and 2013 the average size of the sharks sighted in S.A. MPA is 5.92. There is also a strong male sex bias in the population, with just 8% females (Hancock et al. 2013).

The IUCN (2016) recognizes that the available data on the populations are typically dominated by juvenile male sharks which are the visible fraction of the population, moreover, the wildbook for whale sharks, an online web page where people can upload pictures from encounters and help identify whale sharks, have a dataset of up to 7563 individuals (3701 with sex identification) of which 2610 (70.52%) are males and 1091 (29.48%) females. In the literature there is a large number of studies showing this trend of young male-dominated populations: Philippines (Araujo et al. 2016), the Maldives (Morgan J. Riley et al. 2009; Hancock et al. 2013; Donati et al. 2016), Mozambique (Haskell et al. 2015), Djibouti (Rowat et al. 2007), Australia (Catlin & Jones 2010).

Usually, young and immature sharks, from four to seven meters, are the ones most commonly found and no answer is given to the question "where are the mature adult whale sharks". Big mature whale sharks have fewer predators and spend their time in open water (Hancock et al. 2013), certainly, they are not found in the coastal areas where the tourism thrives. The answer is unclear, and it is just one of the many questions that remain unanswered about the life of the whale shark.

General behaviour of the whale shark

During the encounters the general behaviour of the shark was recorded, the different behaviors noted were Feeding, Cruising, Evasive, and Inquisitive and, from the 684 total encounters, in 634 general behaviour was recognized, in 102 encounters the shark was feeding (16.09%), in 489 encounters the shark showed a cruising behaviour (77.13%), the shark was evasive in 142 encounters (22.4%), and the rare inquisitive behaviour was seen in 38 different encounters (5.99%). In 122 of the 634 interactions, more than one different behaviour was noted, thus, showing the complex behaviour of the shark in front of people.

Table 6: Results on general whale shark behaviour.

	Present study	Quiros (2007)	Haskell et al.(2015)	Pierce et al. (2010)
Location	Maldives	Philippines	Mozambique	Mozambique
% Feeding	16,09%	36%	19,50%	19,40%
% Cruising	77,13%	No data	No data	No data

Whale sharks can perform deep dives to feed, but they can also feed on the surface. In South Ari MPA very few sharks encountered showed a feeding behaviour. In Hancock et al. (2013) suggest that South Ari is not used as feeding grounds for these sharks, instead, in Baa atoll (north of South Ari atoll) sharks displayed feeding behaviour and is the primary behaviour encountered there. In the

Philippines during 2005, sharks showed feeding behaviour on 36% of the encounters, higher than in the rest of the locations, since Donsol waters are feeding grounds for the whale sharks (Quiros 2007).

With 77.13% the most common behaviour of the whale sharks in South Ari is cruising, once again, it might be related to the recovery state of the shark or a high degree of disturbance among other things. Therefore, the response of the shark in each encounter could be related to the recovery state of the shark; hence, a whale shark showing different avoidance behaviors and leaving the reef might indicate a nearly or fully completed recovery, while a cruising behaviour without diving response could suggest a partial recovery of the shark. Moreover, slow moving sharks and sharks drifting in the current have been sighted in South Ari, indicating a poor recovery state (Author personal communication, 2016).

Compliance with the code of conduct: Ship data

The Code of Conduct in South Ari MPA limits the numbers of boats to only one per shark and keeping a minimum distance of 10 meters from the shark. The remaining vessels need to stay further than 250 meters from the shark at all times. To evaluate the compliance with the Code of Conducts, data on the total number of ships in each encounter was recorded on 601 interactions, and the distance of the closest boat to the shark was noted in 542 interactions. The results (Table 7) show that in a high percentage of the encounters the Code of Conduct was not followed by tour operators. In Mozambique, despite not having an official Code of Conduct the percentage of boat crowding incidents is very low.

Table 7: Results on vessels compliance.

	Present study	Pierce et al. (2010)
Location	Maldives	Mozambique
Boat crowding incidents	382 (63,56 %)	20 (4,87 %)
Average boats per encounter	4,22	No data
Total encounters	601	411
Boats less 10m from shark	382 (70,48 %)	No data
Total Encounters	542	

Compliance with the code of conduct: Tourist data

In terms of tourism, South Ari receive between 72000 and 78000 tourist a year (Cagua et al. 2014), accounting only for the tourism related to whale sharks. With the high number of tourist in a single year, limits on the number of swimmers in one interaction have to be set. Many Codes of Conducts are based on guidelines established in the Ningaloo Marine Reserve (James Hancock personal communication, June 2016), arguably, the benchmark for good practice on whale shark tourism, where the regulations establish a limit of 10 people in the water at the same time.

Table 8 shows the number of tourists in the water during the interactions in South Ari (Maldives), Donsol (Philippines), and Praia do Tofo (Mozambique). The average people inside the water in each encounter is 25.53 persons for the Maldives, more than two times the amount of people allowed at a time. In the case of Mozambique and Philippines, the average number of swimmers are near the permitted limit, the maximum number of divers in a single encounter was 18 and 16 respectively. Additionally, in 61.50% of the encounters in the Maldives, the number of people in the water exceeded the limit of 10 swimmers set in Ningaloo.

Table 8: Results on tourist's compliance.

	Present study	Quiros (2007)	Pierce et al. (2010)
Location	Maldives	Philippines	Mozambique
Average people in the encounters	25,53	5	10,8
Max number of people in the water	165	16	18

Even with twice the amount of people allowed in average, there is no relation between the amount of people in the water and the encounter time. Pierce et al. (2010) suggest, with similar findings, that the number of people and the encounter time are not related. The reason of the lack of relation could be linked to the recovery state of the shark, instead of, a lack of disturbance by the swimmers.

Moreover, measuring the tail swipes of the shark can give some insight about the speed; the average tail swipes per minute recorded dugong the video analysis of the encounters was 13.97 TS/min. Looking at the average of tail swipes and at the same time the number of people in the water, there is a relationship between them; with fewer people in the water, the tail swiping decreases while having more people in the water makes the tail swipes increase. Whale sharks move faster with more people in the water, indicating, once more that the recovery state of the whale shark can be related.

Disturbed sharks with a poor recovery state, stay on the surface and try to avoid the swimmers by increasing their speed.

8.3 Video Analysis results

Summary

A video analysis was done to the encounters occurring between May 2015 and October 2016, 140 encounters occurred during 260 trips. Such analysis was carried out only in 116 videos, due to the short durations of some encounters that did not allow to record. In the videos, the tourist behaviour in the water and the whale shark behaviour was recorded.

Tourist compliance

Having too many people in the water and boat crowding are incidents where the tour operators are accountable for, on the other hand, the tourist are responsible for their behaviour in the water. In south Ari, the most frequent incident are tourist swimming too close to the whale shark with 173 incidents in 59 different encounters. Tourist not respecting the 4 meters distance from the shark is the most common incident with tourists in the water (Quiros 2007; Haskell et al. 2015).

During the video analysis when the shark was obstructed it was more likely to show a Change of Direction (CoD) to avoid the swimmer, and with 65 obstructions occurring in 116 encounters is the second most usual incident in South Ari. Rides and touches, although with limited presence in South Ari, are significant predictors of a whale shark's violent shudder or a fast swimming. Finally, people using flash was not a widespread practice, however, in the presence of divers with big underwater cameras flashes were more common.

Table 9: Results on video analysis tourist compliance.

	Present study	Quiros (2007)	Catlin & Jones (2010)	Catlin & Jones (2010)
Location	Maldives	Philippines	Ningaloo (1995)	Ningaloo (2005)
% Touch	7,69%	20%	7,30%	2,80%
% Ride	0,85%	No data	No data	No data
% Obstruction	22,22%	34%	No data	No data
% Flash	5,98%	No data	No data	No data
% Tourists <4m distance	50,43%	No data*	No data	No data

*Distance from the shark was recorded in Quiros (2007), showing an average of 1,84 meters.

In some locations, as in Ningaloo, divers are not allowed to swim with sharks, depending on the code of conduct of the particular area; in South Ari, divers are allowed to be in the water with whale sharks and in 18 encounters of 140, diver presence was noted.

Whale shark behaviour

The most frequent diving behaviour observed was a gradual dive, occurring in 75.21% of the encounters and with a maximum of 5 occurring in one encounter. Steep diving and Paraboling have the same occurrence, and a maximum of 2 and 6 respectively. The gradual change of direction was observed in 41.88% of the encounters, being the most frequent CoD behavior, while abrupt CoD had a frequency of 25.64 and circular CoD a frequency of 12.64%.

Table 10: Results on video analysis whale shark behaviour.

	Present study	Quiros (2007)	
Location	Maldives	Philippines	Score
Encounters with gradual dive	75,21%	37%	2
Encounters with Steep dive	28,21%	12%	3
Encounters with Parabola dive	28,21%	8%	1
Encounters with Banking	16,24%	11%	3
Encounters with gradual CoD	41,88%	No data	2
Encounters with abrupt CoD	25,64%	11%	3
Encounters with circular CoD	12,82%	16%	1

In Quiros (2007) the different behaviors of the shark are classified along a gradient that ranges from not responsive to exhibiting multiple behaviors. In Table 10 following Quiros (2007) protocol, different scores are given to diving and CoD responses ranging from 0 to 3, a higher score suggests a higher degree if avoidance, and a score of 0 if the shark does not show any kind of behaviour.

Briefly, steep diving, banking and abrupt changes in directions are classified as avoidance behaviors, while gradual CoD, parabola, and gradual dives lie towards the neutral behaviour. Furthermore, swimming in circles is considered a natural behaviour of the shark along with feeding.

Cluster analysis

With the different scores given to the shark's responses, a cluster analysis was used to determine which of the behaviour were linked together to test the suitability of the scores and if it can be applied in South Ari. Behaviors not grouped together are less likely to find them in the same interaction.

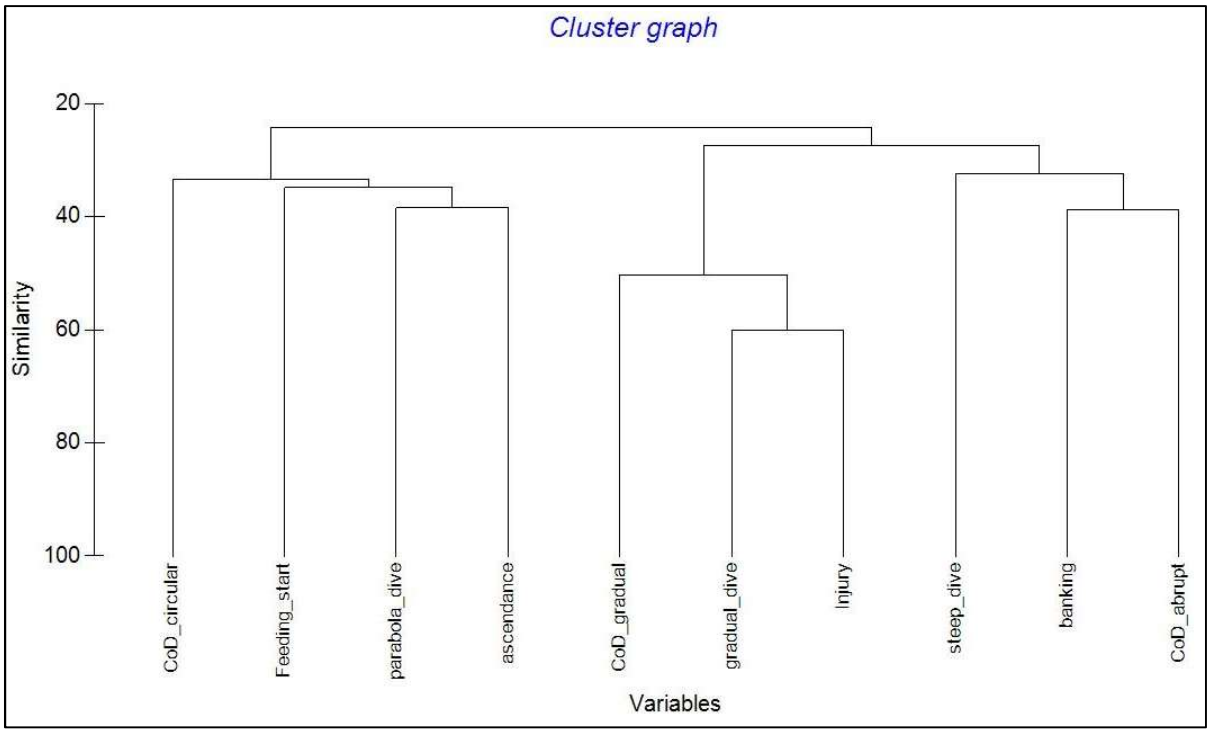


Figure 9: Graphic results of the cluster analysis.

In Figure 9 we can see the results of the cluster analysis, and the different behavioral responses of the whale shark grouped together. On the right side of the figure, the behavioral responses together are Steep Dive, Banking, and Abrupt CoD; three responses classified as avoidance behaviour. The four linked together on the right side of the graph are CoD circular and Parabola dive, the behaviors associated with a more neutral behavior. Finally, in the middle of the graph CoD gradual and gradual dive are grouped together.

Furthermore, the figure shows three more variables, feeding at the start of the encounter and ascendance behaviour, which as natural behaviors of a shark are paired with the neutral behaviors; and injured sharks grouped with gradual diving and gradual CoD, suggesting that injured sharks are less likely to show avoidance behaviour with higher score, therefore, the encounter time was not affected. In South Ari, 27 sharks had major injuries and 53 sharks had minor injuries, while in 60 different sharks no injury was recorded.

Although injured whale sharks can be injured because they do not show much avoidance behaviour to escape from the boats, and are naturally slower than other individuals. In Quiros (2007) the results also suggested that injured whale sharks are less likely to exhibit avoidance behaviour, and sharks feeding at the start of the encounter are more likely to show avoidance during the encounter.

In summary, it shows the considered avoidance behaviors (with a higher score) together, and on the other hand, the behaviors with a lower score grouped together as well, suggesting a relationship between them and potentially showing the suitability of the scores proposed.

Measuring disturbance

The scores given to each behaviour are for determining if the whale shark has been disturbed or not during the encounter, following Quiros (2007) when the shark shows a response behaviour a score is given to such behaviour according to Table 10. As in Quiros (2007), the whale sharks with a score higher than 2 in the same encounter are considered as disturbed.

Table 11: Encounter data results depending on the type of the encounter.

	Present study	Present study	Present study
Location	Maldives	Maldives	Maldives
Type of encounter	"Non-avoidance" behaviour	"Avoidance" behaviour	All video-analyzed encounters
Average encounter duration	7 min 38s	12 min 52 s	11 min 47 s
Average number of boats	2,96	3,03	3,01
Average number of people	15,26	20,27	19,27
Average tail swipes per minute	6,8	15,68	13,97
Average depth of the shark	11,38	7,84	8,64

From the 116 encounters video-analyzed, in 24 of them, the shark was considered as not disturbed. Table 11 shows also the average encounter durations of those 24 encounters, the average number of boats, people and the tails swipes per minute. The mean encounter durations when the shark was classified as "not showing avoidance behaviour" is significantly lower than the average of all encounters, the same happens with the average number of tail swipes and people. Interestingly, sharks showing disturbed behaviour also show a lower depth average.

Here, once more, the recovery state of the shark can be related to the results obtained. Whale sharks with scarce recovery from deep dives might decide to stay longer near the surface to keep recovering

instead of diving away, showing different kinds of avoidance behaviors and increasing speed (tail swipes) in order to avoid the human disturbance. On the other hand, whale sharks with a good recovery state can stay on the surface or dive away when they get disturbed, which will decrease the tail swipes and the encounter duration.

Furthermore, when sharks dive away, they stop tail swiping while descending. The average tail swipes per minute during the encounters where whale sharks performed steep dives is 15.28, suggesting that the sharks were swimming rapidly before performing the dive, perhaps increasing the speed and carrying out different avoidance behaviour were not sufficient to avoid the disturbance and finish the encounter, and the sharks. Finally, shark ID and length were not related to the presence or absence of avoidance behaviour, different sharks showed in some encounters avoidance behaviors and in some other not.

An avoidance behaviour can be the response of the shark to a given disturbance; even if the shark did not show any conduct classified as avoidance behaviour, it does not mean that the shark did not experience any disturbance. Maybe, the sharks that did not show avoidance behaviour also were under a disturbance at some point of the encounter, but the recovery state allowed that shark to perform a gradual dive to avoid the swimmers and finish the encounter.

Environmental variables

Environmental variables were recorded in order to evaluate their relationship with the shark behaviour.

It is thought that recovering whale sharks swim in the same direction of the current to be more efficient, the direction of the shark was recorded at the start and at the end of the interactions, and in 40 out of 119 encounters the direction at the start was the same as the current direction at that time, on the other hand, 29 encounters ended with the current and the shark heading in the same direction. Moreover, in 66.12% of the encounters the shark was heading in the same direction at the start and at the end of the encounter.

The temperature of all the encounters was between 29 and 30 Celsius degrees, expect two encounters with 32 degrees, with data on 138 encounters no relation with sea surface temperature (SST) can be established. In Pierce et al. (2010) they found that an increase in the SST was a significant predictor of a decrease in avoidance response by the shark.

In terms of cloud cover and sea state, data on 138 encounters was recorded and in 122 and 105 encounters, respectively, occurred when the conditions ranged between good and medium. The lack of whale shark sightings during bad weather can be related to the lack of searching trips during rough conditions; also, no weather data was recorded during the days without any trips and accurate conclusions cannot be made.

IX. Discussion

9.1 Code of Conduct review

The impact of the swim with wildlife tourism vary with the different species, populations and locations, therefore, management measures should be site-specific (Valentine et al. 2004). The different countries analyzed in the Code of Conduct review have different populations of whale sharks, and also the areas where they are sighted are used by the whale sharks for different purposes.

For instance, the population of whale sharks in the Maldives is believed to be a separate population from the rest of the Indo-Pacific ones (Morgan J. Riley et al. 2009; Rowat 2007), and evidence of behavioral thermoregulation in South Ari might suggest that whale sharks are using the MPA area for recovery reasons (M. Thums et al. 2012). Furthermore, Donsol is believed to be a place with rich nutrient waters where whale sharks go and feed seasonally during November and June (Quiros 2007; Araujo et al. 2016), while in the other locations feeding is not the primary behaviour observed. These results show the heterogeneity of the different population analyzed.

Codes of conducts for whale sharks are created in order to have a minimum impact towards the shark, and a high quality and safe experience. The Codes of Conducts are normally based on the regulations and guidelines followed in Ningaloo. However, the differences between the four locations are clear and, therefore, the Code of Conduct must adapt to the conditions of the specific location.

9.2 Whale sharks reaction to tourist disturbance

The Maldives is one of the few places to have a whale shark aggregation throughout the year (Rowat 2007), a fact that increases the importance of this location for tour operators looking for maximum benefit. Therefore, whale shark tours can be performed all the year round, having a peak of incoming tourists from September to March.

Encounter duration is higher in the Maldives compared to Mozambique or the Philippines, and results suggest that the number of people in the water does not affect the encounter duration. However, the number of people seems to increase the average tail swipes during the encounter.

There are different explanations for long and crowded encounters. The first possibility is that whale sharks in South Ari have a certain degree of habituation to the presence of swimmers. Some studies suggest that some individuals of the population can become accustomed to the presence of tourists in the water, while some reluctant individuals might leave the area when disturbed (Mau 2008; Pierce et al. 2010; Scarpaci et al. 2003).

Another explanation could be the constant obstruction of the path of the shark, making them show multiple avoidance behaviors and become disoriented by people in the water and boats. When sharks are cruising along the reef and get surrounded by people they will dive away, after showing some

changes in direction, to avoid people. However, the presence of divers underneath the shark might provoke an ascendance behaviour to the surface, finding once again the swimmers and exhibiting more avoidance behaviors. In some of the encounters, dive guides obstructed the path of the shark several times to make them come up again in order for the shark to be visible to their guests, same practice was seen with boats and some tour operators (Giulia Donati personal communication, August 2016).

One of the hypotheses is related to the thermoregulation behaviour shown by sharks (M. Thums et al. 2012). The whale sharks could be recovering from the deep dives they perform in order to look for food where they find cold and low oxygenated water. During their recovery, sharks swim slowly to the surface, therefore, disturbing a shark during its recovery phase, means that diving away might be more costly than increasing the speed in order to avoid the swimmers. Therefore, disturbed sharks with a low recovery state will stay longer increasing their speed, while sharks with a good recovery state can dive away instantly without showing a wide range of avoidance behaviors. This hypothesis would explain the results obtained in the cluster analysis, where the average encounter time was higher when sharks displayed more disturbance behaviour and lower when they did not show avoidance behaviour.

Finally, another explanation could be the presence of feeding behavior. If whale sharks are showing feeding behaviour, it can be less costly to be disturbed by the people around than to avoid them. As in the study carried out in Mozambique by Haskell et al. (2015), whale sharks were less likely to show avoidance behaviors when they were feeding; in the Maldives, the average encounter time when the whale shark was feeding increased to 25 minutes and 32 seconds. On the contrary, whale sharks in the Philippines showed increasing avoidance when feeding (Quiros 2007). Once again, these country specific reactions highlight the need of a site-specific management.

In addition, the results showed that the size and ID of the shark did not influence the encounter duration. Furthermore, the average encounter time for injured (major or minor injuries) and non-injured sharks was not affected. Additionally, the cluster analysis showed that injured sharks tend to show gradual avoidance behaviors instead of abrupt avoidance behaviors, however, this could be explained by the lower reaction times and reduced agility of some sharks as a consequence of the injuries (Haskell et al. 2015).

9.3 Description of the whale shark aggregation in South Ari MPA

The population is formed by young individuals, predominantly males, similar to other aggregations worldwide (Davies 2014; Rowat 2007; Vignaud et al. 2014). It is thought that whale sharks sighted in South Ari MPA are just a visible part of a bigger population in the Maldives (Donati et al. 2016). Moreover, it is believed that the immature whale sharks stay in the protected shallow reef area until

they reach sexual maturity (Hancock et al. 2013; Morgan J. Riley et al. 2009). According to Mau (2008), whale sharks reach sexual maturity when they are between 8 and 9 meters.

Although whale sharks can feed on the surface, instead of performing deep dives, feeding is not a usual behaviour displayed by the sharks sighted in South Ari. Therefore, according to the previous hypothesis, the whale sharks might be using the MPA to recover from the deep dives, and disturbing them in the recovery phase whilst preventing a full recovery, can have serious detrimental effects on their health and the survival of the species.

A study in Mozambique demonstrates that encounter durations can be useful to evaluate whale shark behaviour (Haskell et al. 2015). However, as shown in this study, disturbed whale sharks in South Ari might extend the encounter duration due to their recovery state. Considering the potential importance of the South Ari MPA as a recovery site for the whale sharks, management measures should be focused on the reduction of the disturbance.

9.4 Tourist compliance with the Code of Conduct

The average number of swimmers in South Ari during each encounter is considerably higher than in Philippines or Mozambique. However, it seems that more than the quantity of the people in the water is their behaviour and the distance between them and the shark that is influencing the avoidance behaviour of the shark. Table 12 represents the compliance with the Code of Conduct in Donsol and the Maldives, contrasting these results, South Ari has a low average of compliance in most of the aspects. Nonetheless, the percentage of compliance regarding touching and flash photography are acceptable.

In this study, the distance of the swimmers in relation with the shark was not recorded, however, Pierce et al. (2010) results suggest that avoidance behaviour is associated with the distance of the swimmers. The minimum distance for the swimmers in the CoC adopted in the Maldives is derived from the distances recommended in Ningaloo. Therefore, consider increasing the minimum distance, in order to adapt it to South Ari, should reduce the level of disturbance and, consequently, the avoidance behaviors of sharks.

Normally, underwater visibility in the Maldives is good, a fact that makes feasible the increase of the minimum distance from the whale shark. Increasing the distance lead tourists to have less sensation of crowding during the encounter (Pierce et al. 2010) and a wider field of vision allowing more people in the water. In addition, touching incidents are usually accidental and incrementing people to shark distances will decrease the accidental touches, together with the avoidance responses by the shark.

Table 12: Percentage of compliance with the Code of Conduct.

	Present study	Quiros (2007)	
Location	Maldives	Philippines	who is accountable
Minimum distance kept swimmers	49,57%	44%	Swimmers
Maximum number of swimmers	38,50%*	82%	Swimmers
No touching	92,31%	82%	Swimmers
No obstruction	77,78%	82%	Swimmers
No flash	94,02%	99%	Swimmers
One boat per shark	36,44%	89%	Operators
Minimum distance kept by boats	29,52%	No data	Operators

* In the Maldives the maximum number of people is not given in the CoC, in order to compare the value used as a maximum was 10 as in the other CoC.

According to Catlin & Jones (2010) surveys done in Ningaloo (Australia), one of the most important conditions for the tourist, to enjoy the experience with the whale sharks, is the reduction of the sensation of crowding during the encounter. In South Ari, the encounters with a high number of people inside the water are usual; the maximum number of people in one single encounter is 165, and the top ten encounters in terms of people had over 100 persons swimming at the same time.

Furthermore, the risk level in these activities is increased by encounters of long durations (119 minutes was the highest duration in South Ari) together with the ability of whale sharks to swim at high speeds. Occasionally, tour operators require liability release forms for their legal protection (Catlin & Jones 2010). Therefore, limiting the number of people in the water can minimize crowding incidents, and setting a time limit for the encounters, as occurs in Ningaloo, can also increase the safety of the participants as well as allowing the tourists to enjoy the experience.

In summary, with the estimation of Cagua et al. (2014) of 72000 to 78000 people coming to South Ari to be involved in whale shark tourism, and additionally, the government expectation to attract more tourism to the country to increase these numbers in the future. Limiting the number of people per encounter, the maximum time allowed and, the minimum people to shark distance can be an effective management measure to increase the quality of the experience in South Ari.

Applying this management measures may seem to restrict the potential of the whale shark tourism in South Ari, but increasing tourist satisfaction leads to increasing the quality of the experience and, ultimately, the attraction of more tourists. Without effective management measures, a possible increase in the incoming tourism may compromise such experience as well as having negative impacts on wildlife.

X. Conclusions and recommendations

Achieving a balance between a good tourist experience and a reduction in the impacts to whale sharks is not straightforward, and sometimes the interests of both can be opposed. Two different ways of managing the impact of whale shark tourism industry are through the regulation of the activity of the different tour operators and the behavior of tourists. However, some restrictions can affect tourist satisfaction (Catlin & Jones 2010).

Regulations exist in South Ari MPA, nevertheless, the results of this study show little compliance with the Code of Conduct, meaning a failure in the management of the MPA. Codes of Conducts are an effective management tool but the lack of enforcement in South Ari reduces its effectiveness.

To minimize the impacts on whale sharks, a full compliance of the code is needed; and in order to accomplish a 100% compliance, tour operators and tourists need to do their part, with the enforcement in the area being essential. Experiences from other countries have shown that unmanaged tourism can have detrimental effects on the population (Scarpaci et al. 2003; Hardiman & Burgin 2010; Rowat & Brooks 2012).

The basic mitigation measures to prevent detrimental effects of this type of ecotourism in Sout Ari are easy to apply. The proposed measures for South Ari MPA are:

The basic and most urgent measure is to enforce the MPA in order to reduce the high percentage of non-compliance among tourist and tour operators. The enforcement can be accompanied by penalties for non-compliance. In South Ari, just one ride incident occurred during the time of the study (Figure 10) and the touching incidents where normally unintentional. Establishing penalties for intentional misconduct, as in the ride incident, might be a way to discourage tourist from disturbing the shark. However, in order to apply these measures, the visitors should be aware of the regulations and the penalties applied. For that reason, tour operators that work in the area need to help with the management of the MPA and notify the tourist before the start of the encounter.

The best way to implement this measure is to provide tour operators with forms to be filled by each guest before the encounter, recognizing that they have been notified of the regulations and penalties. If the forms are not given to the tourist, the tour operator would have full responsibility for their guest's behaviors and would assume their penalties. Moreover, in South Ari, there are no limitations regarding the number of tourist in the water, and increasing the minimum distance from the shark could reduce the accidental touches by the tourists, and allow more people in the water.

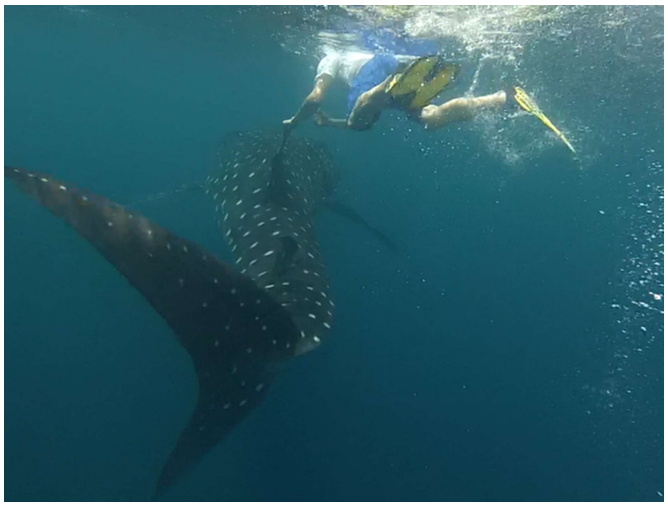


Figure 10: Ride incident in South Ari MPA (May 13, 2015). Photo source: Felipe Lei from MWSRP video.

An average of 25.53 people in the water per encounter was recorded, more than two times the maximum number of swimmers recommended in most of the Code of Conducts of 10 swimmers. The maximum number of swimmers recorded in one encounter was 165 people at a time, therefore restricting the number of people is of major importance due to the crowded encounters in South Ari. Furthermore, with the suggested increase in the minimum distance from the shark, there is a possibility to allow a higher number of people in the water than the recommended without compromising the protection of the whale sharks.

Another measure to reduce negative effects is limiting boat speed in order to reduce vessel strikes and man-made injuries. During the video analysis, 140 different sharks were recognized and 80 individuals (57.14 %) recorded had minor or major injuries. In South Ari speed limits are applicable during the encounters, however, this measure needs to be applied the entire MPA since whale sharks are spotted doing a visual search of water. Depending on visibility, weather conditions or the location of the shark can be challenging, therefore, increasing the possibilities of accidental strikes.

Finally, whale shark tourism in South Ari has two periods, a peak between October and April (high season), and a low season during May to September (Cagua et al. 2014). During the high season, a higher number of visitors arrive and the enforcement of the MPA should be a priority. At the same time, a higher number of people coming to South Ari should be accompanied by more research in order to evaluate the evolution of the industry, assess the potential negative effects, and monitor shark behaviour in order to improve the Code of Conduct if necessary. Moreover, during the high season for tourist presence, the consideration of having a small boat during the encounters, as in Ningaloo, to control the compliance with regulations can help reduce the high non-compliance rate in South Ari.

The results of this study are far from uncovering the full spectra of negative impacts of tourism on whale sharks. However, negative impacts might not be immediate or obvious, and can be expressed as long term detrimental effects on the population. The need for more research on whale sharks is not just relevant in South Ari, Rowat (2007) states, there is a lack of information about the occurrence, biology, and ecology of the species. The previous recommendations are based on what is known about the whale shark. However, given the gaps in the knowledge of the different aspects of the whale shark, the results obtained in this study suggest that applying the precautionary principle can help reduce disturbance to the whale sharks, negative impacts on the ecosystems, and allow the development of a sustainable tourism activity.

Additionally, the results obtained in this study regarding tourist compliance and whale shark behaviour showed some similarities and differences between the different countries analyzed. Therefore, a continuous monitoring of the whale sharks in South Ari can help adapting the tourism industry to new challenges and develop a site-specific management.

A desirable management plan for South Ari MPA would include, the enforcement of the Code of Conduct and regulations, as well as the monitoring of the impacts of ecotourism on the whale sharks. If the current Code of Conduct is not effective in the task of minimizing the impact, the management plan should be adapted applying the precautionary principle. Moreover, in the case of the Maldives, where the tour operators come from different atolls, the different local governments from the atolls should be involved in the management and ensure that their tour operators meet the standards. An estimate of the economic extent of this activity in 2013 and 2014 was done by Cagua et al. (2014), however, the application of the different measures might be difficult to the lack of funds, and a complete evaluation need to be done.

Unmanaged wildlife tourism can have negative effects on whale sharks, but the application of basic management measures and enforcement can lead to a more sustainable tourism, whilst negative impacts to wildlife are reduced.

XI. Recommendations for future work

Additional research must be carried out in order to confirm or refute the different hypotheses presented in this work. With the Number of encounters video analyzed in this study final conclusions cannot be made, hence, in order to obtain more data and compare their results, a continued monitoring of whale shark behaviour should be done; information during different years should be analyzed too in order to assess the evolution of the population of whale sharks in the Maldives. But these are the first steps to improve our understanding of the whale shark population in South Ari, and the importance of the area as potential recovery site.

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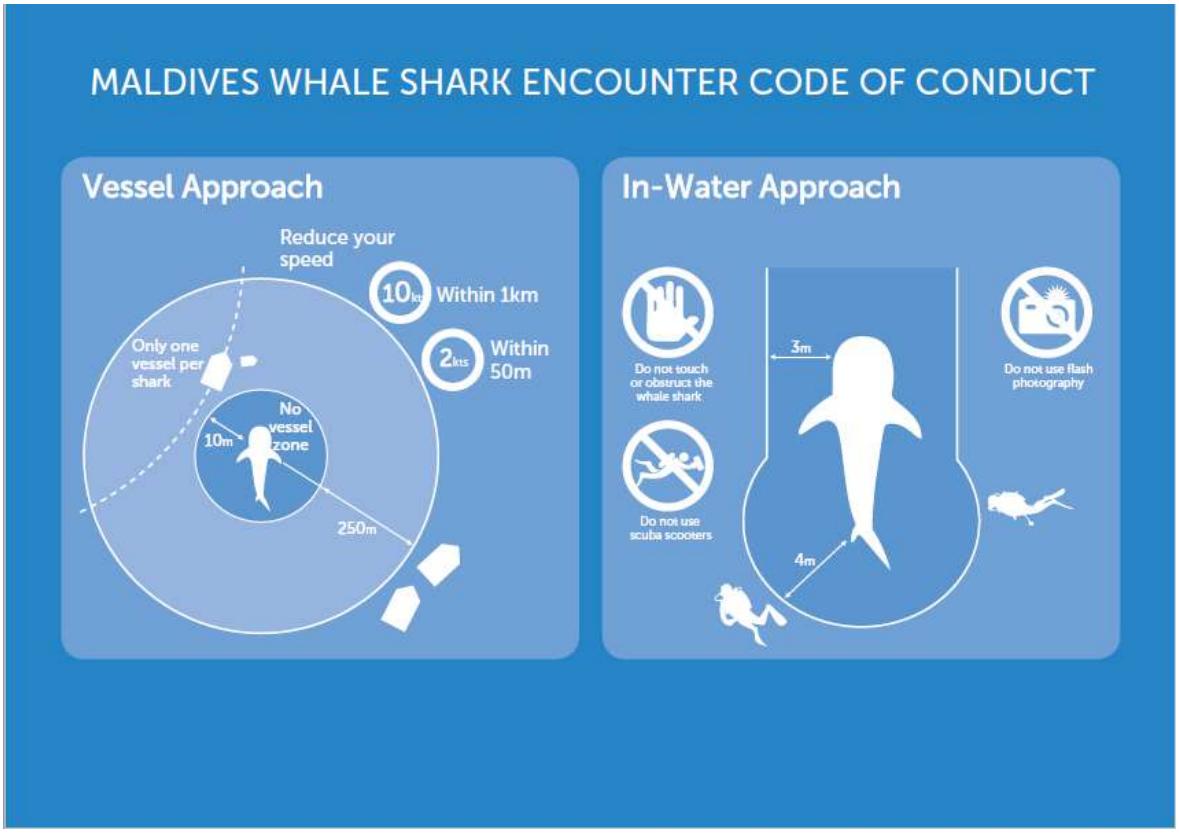
Appendices

Appendix 1. Example of the matrix obtained during video analysis with the different whale shark responses recorded.

gradual_dive	steep_dive	parabola_dive	ascendance	banking	CoD_circular	CoD_gradual	CoD_abrupt	Feeding
2	0	1	1	0	0	4	0	
1	1	0	0	0	0	0	0	
1	0	0	0	0	0	0	0	
1	0	0	0	0	0	1	0	Yes
2	*0*	1	1	2	1	12	7	Yes
4	0	1	3	0	0	3	1	
1	0	0	0	0	0	0	0	
-	-	-	-	-	-	-	-	
3	0	1	2	2	0	0	0	Yes
2	0	1	1	0	0	0	0	
2	0	1	2	0	0	2	1	
1	0	0	0	0	0	0	0	
5	0	1	4	0	0	9	0	Yes
4	0	1	3	0	4	11	0	Yes
3	0	1	2	0	0	2	0	Yes
1	0	0	1	0	0	10	0	Yes
1	0	0	0	0	1	0	0	Yes
1	0	0	2	0	1	0	0	
2	0	1	1	0	0	0	0	
1	0	1	1	0	1	0	0	
0	1	0	1	0	1	0	1	
1	1	0	1	0	0	0	0	
0	1	0	0	0	0	1	0	
1	0	0	0	0	0	0	0	

Appendix 2. Maldives whale shark code of conduct.



Appendix 3. Encounter sheet to record In situ data during whale shark encounters.

Name of Researcher:	**Date:**	**Time Start Searching:**	**Time Stop Searching:**	**Breaks (Hrs):**	**Encounter Number:** _____of_____

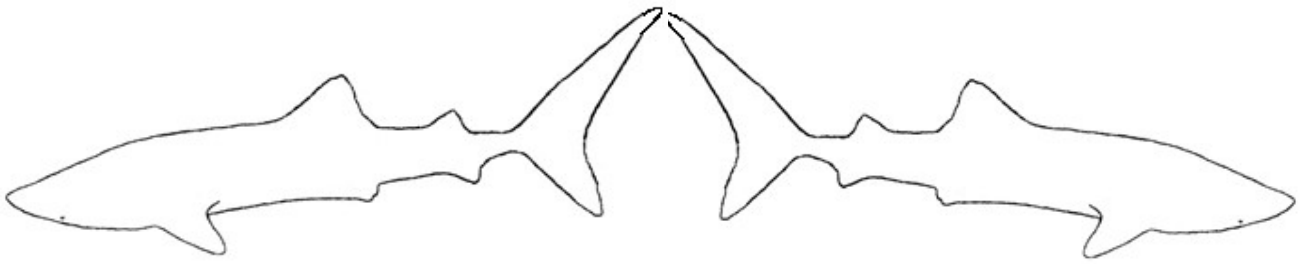
Time Encounter:	Encounter Duration:	Location:	Coordinates North:	Coordinates East:

Whale Shark ID if Known:	Est Length To 0.5m:	Sex:

Swim Direction:	Behaviour:	Other Wildlife:	Persons start:	Persons Max:	Boats Start:	Boats Max:	Distance to closest boat:

Distinguishing feature:	Injury Type:	Severity

Body Part and Side



Reef depth:	Sea Temp:	Wind Direction:	Wind Speed:	Cloud Cover:	Sea State:	Current Direction:	Current Strength:	Visibility:

Notes