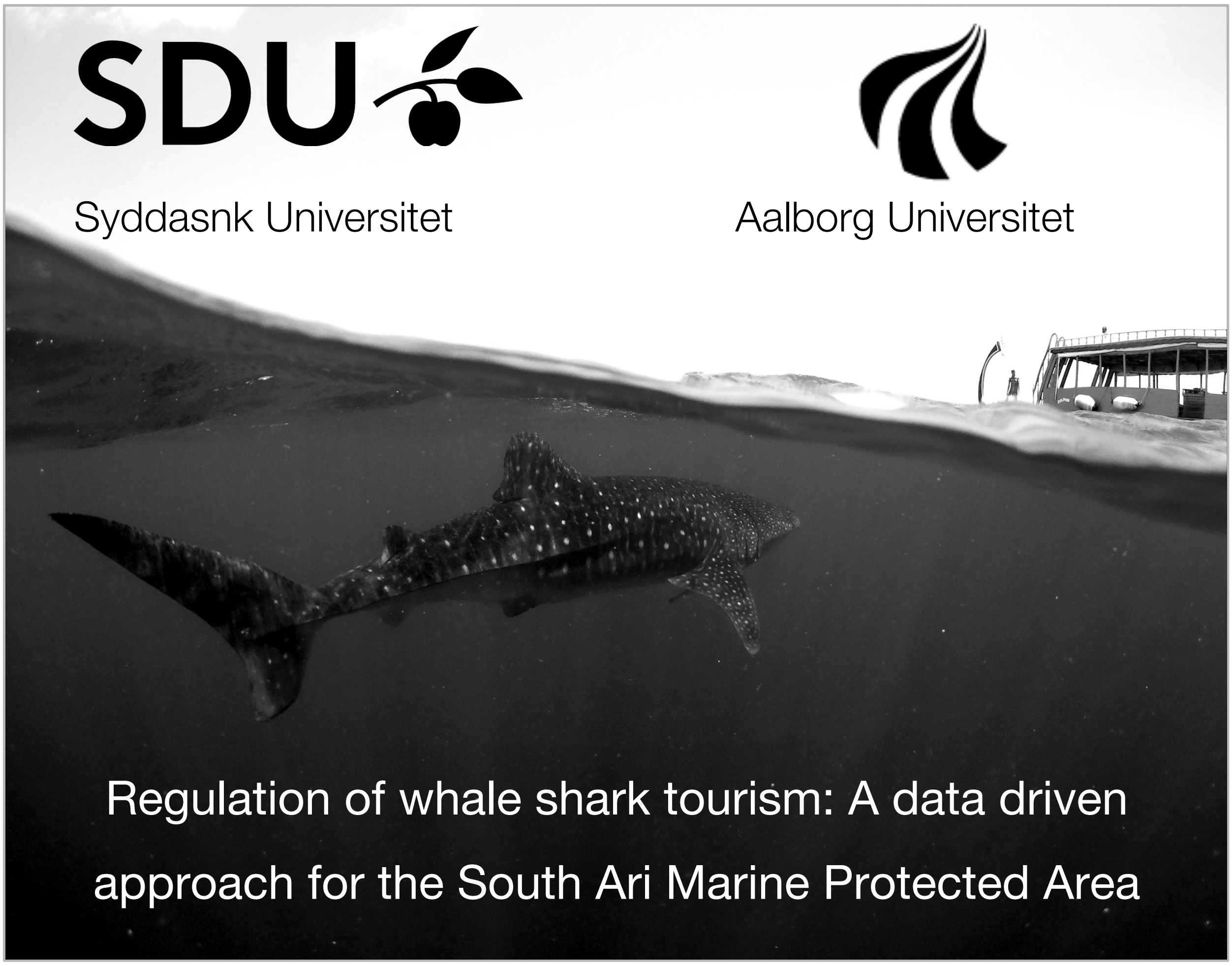

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Regulation of whale shark tourism: A data driven approach for the South Ari Marine Protected Area

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Abstract

The whale shark was first described scientifically in 1828 by Andrew Smith. But even though it is the world's largest fish (Rowat & Brooks, 2012, p. 1019; Bradshaw, et al., 2008, p. 1895) there had been only 320 credible reports of whale shark sightings until 1985 (Stevens, 2007, p. 4). However, since then "a huge increase in recreational diving and boating activity around the world" (Stevens, 2007, p. 5) has led to the discovery of several whale shark aggregation sites with a reliably predictable abundance of whale sharks. At most of these sites, whale shark tourism has become a popular and economically important activity.

The non-consumptive use of the whale shark has fostered the conservation of the species and its habitat on a local scale e.g. the declaration of marine protected area to protect important foraging grounds of the whaleshark. But the intrusion of humans into the habitat of the whale shark can also have adverse effects, especially if the whale shark aggregation represents a common pool resource. Since the knowledge of the ecology and biology of whale sharks is still very incomplete, it is also unclear how tourism affects whale sharks and which factors have a major influence on the extent of the negative impacts.

This knowledge gap is also one of the biggest obstacles to the effective regulation of whale shark tourism, which is reflected in the inconsistent regulations and standards at the different whale shark tourism destinations.

In this thesis, a data-driven approach to the regulation of whale shark tourism is presented using the example of the whale shark tourism in the South Ari Marine Protected Area (SAMPA) in the Maldives. 964 whale shark encounters are evaluated and four random forest models are developed to identify the most important factors influencing the positive course of a whale shark encounter. Based on the results of the models and successful aspects of regulations from other whale shark destinations a regulation proposal for the whale shark tourism in the SAMPA is developed.

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Acknowledgements

First of all, I would like to thank the Maldives Whale Shark Research Programme for giving me access to its database and allowing me to stay on Dhigurah for a three-month internship. Then, I would like thank the director of the programme, Richard Rees, and the operations manager, Jim Hanckock, for their feedback and their suggestions.
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1 Introduction

The whale shark was first described scientifically in 1828 by Andrew Smith. But even though it is the world's largest fish (Rowat & Brooks, 2012, p. 1019) there were only 320 credible reports of whale shark sightings until 1985 (Stevens, 2007, p. 4). However, since then "a huge increase in recreational diving and boating activity around the world" (Stevens, 2007, p. 5) has led to the discovery of several whale shark aggregation sites with a reliably predictable occurrence of whale sharks. At most of these sites, whale shark tourism has become a popular and economically important activity.

Since 2016 whale sharks have been listed as endangered on the IUCN's red list of threatened species due to an estimated decrease of the global whale shark population of more than 50% over the past 75 years (Pierce & Norman, 2016). While the revenues generated by whale shark tourism offer strong incentives for local communities to engage in the protection of the species, the IUCN lists tourism also as a potential threat for the species (Pierce & Norman, 2016).

Although several studies have tried to identify and quantify the impacts of tourism on whale sharks, the findings are often site-specific and inconsistent (Mau, 2008, p. 215). In addition, there is a lack of long-term studies (Mau, 2008, p. 215). Thus, "management must proceed before scientifically valid responses to the harassment question can be brought forth from the research community" (Duffus & Dearden, 1990, p. 220).

I present a data driven approach to improve the management of the whale shark tourism in the South Ari Marine Protected Area (SAMPA), the most famous whale shark aggregation site in the Maldives. The proposed regulations are derived from the analysis of 593 surveys of the SAMPA by the Maldives Whale Shark Research Programme (MWSRP).

To put the proposed regulations into perspective I will first give an overview of the literature on wildlife tourism, the evolutionary stages of a wildlife tourism destination and instruments to regulate wildlife tourism. Chapter three will place the focus on whale shark tourism and its ecological and socio-economic impacts. Furthermore, chapter three includes a review of regulatory approaches at different whale shark aggregation sites. Following a description of the study site and the data, the methodology and the data driven approach are introduced. In the discussion, a management proposal is developed based on the results of the data driven approach and regulations at other whale shark aggregation sites. The last chapter will summarize the results and provides recommendations for future research.

2 Wildlife Tourism

The literature offers several definitions and synonyms for the term wildlife tourism. Duffus and Dearden (1990) define wildlife tourism as non-consumptive wildlife-oriented recreation and describe it "as a human recreational engagement with wildlife wherein the focal organism is not purposefully removed or permanently affected by the engagement" (Duffus & Dearden, 1990, p. 215). This definition reduces wildlife tourism to interactions with wildlife in its natural habitat. It also excludes any activities that are lethal to the focal organism such as hunting or fishing (see figure 1). However, Duffus and Dearden (1990) emphasize that non-consumptive does not mean zero impact (Duffus & Dearden, 1990, p. 215), as the mere presence of a person in the vicinity of the focal organism will have an impact.

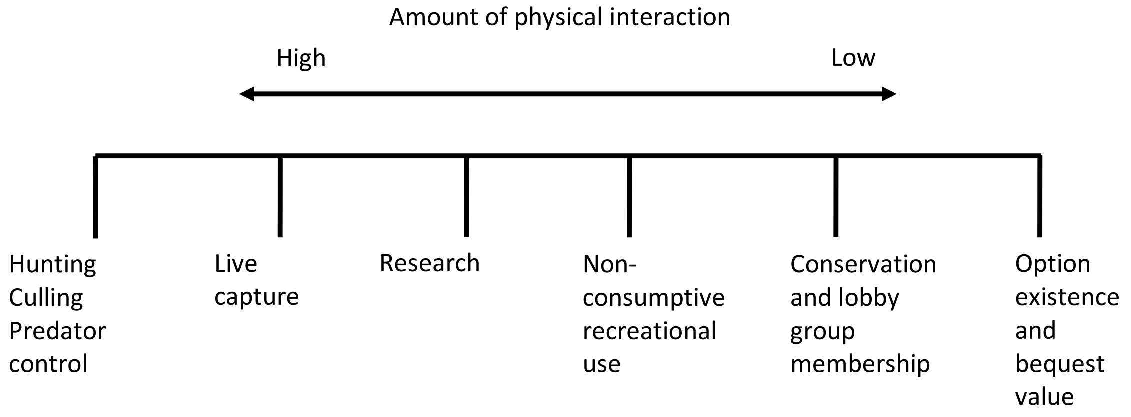


Figure 1: Human activities and their amount of physical interaction (source: Duffus & Dearden, 1990, S. 215)

Wildlife tourism can be opportunistic focusing on the occurrence of a variety of wildlife at a particular site or be concentrated on observing a particular species (Burgin & Hardiman, 2015, p. 210; Wilson & Tisdell, 2001, p. 280). The latter form of wildlife tourism requires a predictable occurrence of the targeted species in a relatively small area (Duffus & Dearden, 1990, p. 220). Natural features of the site often lead to aggregations of the targeted species e.g. an excess supply of prey during a certain time of the year.

The targeted species are normally extraordinarily charismatic species. There are different aspects that make a species a charismatic one and Newsome, Dowling and Moore (2005) distinguish between three categories (Newsome, et al., 2005, pp. 95-96; Gallagher & Hammerschlag, 2011):

1. Similarity to humans

   Similarity is not limited to the physical appearance but also includes similarities in behaviour and social structures of the species (Newsome, et al., 2005, pp. 95-96; Gallagher & Hammerschlag, 2011).

2. Aesthetic properties
   Although the evaluation of aesthetic proprieties depends heavily on the observer, wildlife tourism operations often focus on ‘cute’ and large animals (megafauna) (Gallagher & Hammerschlag, 2011). Furthermore, “colour, shape, movement and visibility” (Newsome, et al., 2005, p. 95) are important aesthetic properties
3. Rarity and conservation status
   If an animal is extremely rare or threatened with extinction, watching it in the wild heightens the exclusivity of the experience (Newsome, et al., 2005, pp. 95-96; Gallagher & Hammerschlag, 2011).

Duffus and Dearden (1990) also mention that the interest in a species depends on the historic relationship and “eating preferences: either humans would eat the animals or vice versa” (Duffus & Dearden, 1990, p. 219). The human-animal relationship is not static and attitudes towards a certain species can change over time, e.g. the success of shark diving can be explained by “a gradual change in attitude […], whereby ‘excitement’ has replaced ‘fear’” (Richards, et al., 2015, p. 200).

Although the exact number of people participating in wildlife tourism is unknown, Catlin et al. (2010) estimated that wildlife tourism already “attracts millions of people worldwide” (Catlin, et al., 2010, p. 351) and the interest is still growing (Reynolds & Braithwaite, 2001; Trave, et al., 2017). Since it is a recreational activity, participants in wildlife tourism seek satisfaction (Duffus & Dearden, 1990, p. 221). Reynolds and Braithwaite (2001) identified six factors that determine the quality of a wildlife encounter and the level of satisfaction:

- Authenticity: Are the setting and the displayed behavior of the focal organism natural?
- Intensity: What is the level of excitement during the encounter?
- Uniqueness: How exclusive is the encounter?
- Duration: How long does the encounter last?
- Species popularity: How charismatic is the focal species?
- Species status: How rare is the focal species?

These factors also determine the willingness to pay for a wildlife encounter and thus indirectly affect the economic value of a wildlife tourism site or a species which is often measured in direct expenditures by participants.

2.1 Marine wildlife tourism

Marine wildlife tourism can be defined as “[a] form of non-consumptive tourism that focuses on the observation of marine species and habitats” (Trave, et al., 2017, p. 212). Marine wildlife tourism started developing in the early 1990s (Ziegler, et al., 2012, p. 692; Burgin &

Hardiman, 2015, p. 210; Valentinea, et al., 2004) and can be distinguished as ‘swim-with’ operations including scuba diving or snorkelling and boat- or shore-based operations. Despite its young history, Higham et al. estimate that revenues from marine wildlife tourism exceed the combined revenues from fisheries and aquacultures (Higham, et al., 2016, p. 74). Therefore, marine wildlife tourism can offer an alternative source of income to the consumptive use of marine resources and thereby foster the conservation of threatened or endangered species (Gallagher, et al., 2015, p. 365; Topelko & Dearden, 2005). Non-opportunistic marine wildlife tourism “primarily encompasses whales, dolphins, porpoises, penguins, sharks, rays and marine turtles” (Schofield, et al., 2015, p. 517). Whale watching is the most developed sector within marine wildlife tourism and in 2008, 13 million participants generated a total worldwide expenditure of 2.1 billion US$ (O’Connor, et al., 2009, p. 3). Swim-with shark operations have also become more popular recently (Richards, et al., 2015, p. 200) and Csineros-Montemayor, et al. (2013) estimated that 590,000 people participated in shark watching in 2013 (Cisneros-Montemayor, et al., 2013, p. 381). Locating and observing marine wildlife can be more difficult than with terrestrial animals, and in shark watching especially operators use provisioning to increase the likelihood of an encounter with the targeted species (Burgin & Hardiman, 2015).

2.2 Evolution of a wildlife tourism destination

The growth in the number of participants in wildlife tourism operations leads to rising visitor numbers at existing wildlife tourism sites and the development of new wildlife tourism destinations (Ballantyne, et al., 2009, p. 658). Duffus and Dearden (1990) invented a conceptual framework to model the evolution and change of a wildlife tourism site. Catlin, Jones and Jones reviewed the framework twenty years after its publication and concluded that the model “remains the most relevant framework for wildlife tourism since it integrates environmental and tourism management issues and links them to temporal, user, and impact considerations” (Catlin, et al., 2011, p. 1539).

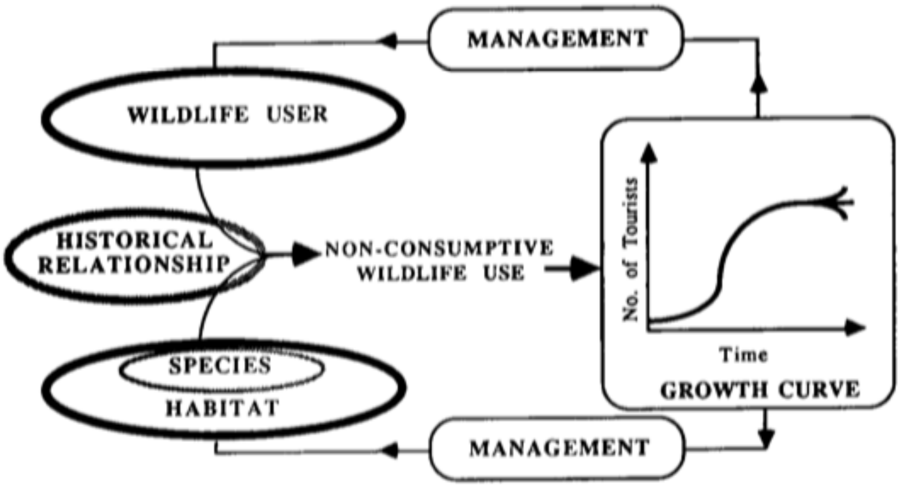


Figure 2: Components of Duffus' & Dearden's wildlife tourism management framework (source: Duffus & Dearden, 1990, p. 218)

The framework incorporates three variables to explain the evolution of a wildlife tourism destination: the wildlife user, the focal species (and its habitat) and their historical relationship (Duffus & Dearden, 1990, p. 217). The historical relationship is the link between the wildlife user and the species/habitat (see figure 2) because it determines the demand to observe a particular species in its natural environment.

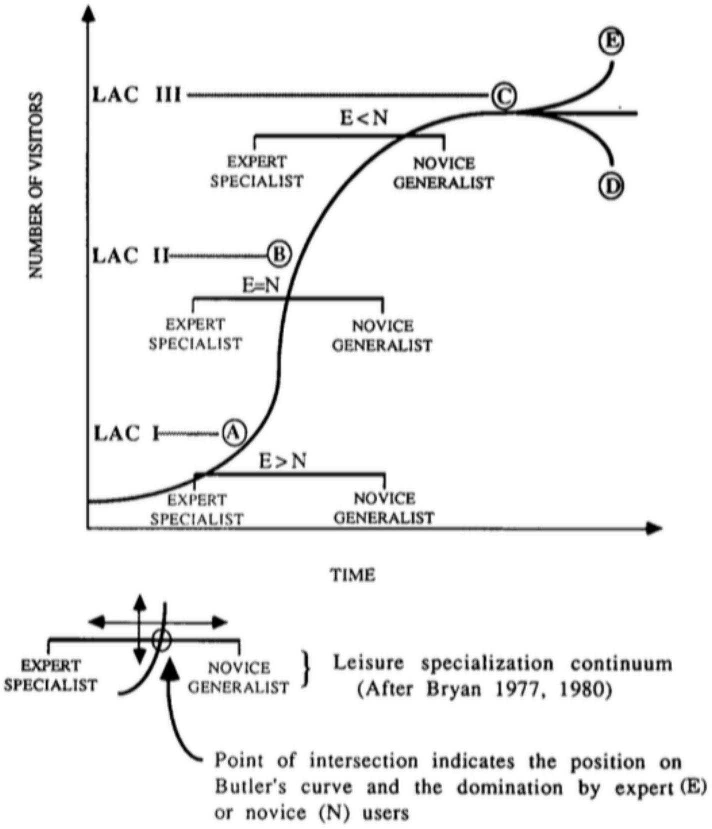


Figure 3: S-shaped growth curve of a wildlife tourism destination (source: Duffus & Dearden, 1990, p. 223)

Duffus' and Dearden's (1990) growth curve of a wildlife tourism destination combines Butler's concept of a tourist area cycle of evolution and Bryan's leisure specialization continuum. Thus, the curve not only projects the development of the number of visitors at a wildlife tourism site, but also the change in the expert level of the visitors (Duffus & Dearden, 1990, pp. 223-224). Duffus and Dearden (1990) divided the development of a wildlife tourism destination into five stages (letters A to D in figure 3). If the limits of acceptable change (LAC) of a wildlife tourism destination in one stage are exceeded then the destination will evolve to the next stage.

The expert level plays an important role in distinguishing between the different stages. In stage A, the site is almost exclusively visited by a relatively small number of expert specialists. Expert specialists have all the required equipment, skills and an extensive knowledge of the focal species. Hence, they do not need extensive supportive infrastructure at the destination. At this stage, the missing infrastructure limits the number of visitors and the impact on the targeted species and its habitat is low. Thus, there is a natural or maximal abundance of the targeted species at the site (Catlin, et al., 2011, p. 1542).

Reports of the site in the media can lead to a growing influx of visitors at the site. Often the newly arriving visitors are not as specialized and thus require more supportive infrastructure. But the growing number of visitors and the improved infrastructure impair the authenticity, uniqueness and intensity of the wildlife experience and cause expert specialists to abandon the site. At this stage, the negative impacts on the focal species caused by the growing number of tourists lead to a reduction of the population/occurrence of the focal species (Catlin, et al., 2011, p. 1542).

At stage C, the site accommodates only the smallest possible population of the focal species to sustain wildlife tourism at the site (Catlin, et al., 2011, p. 1542). The type of visitors at this stage is dominated by novice generalists and the site is at a tipping point (Hammit, et al., 2015, p. 13; Salerno, et al., 2013).

A further growth of the infrastructure and the number of visitors will not leave enough space for the focal species (Hammit, et al., 2015, p. 13). The absence of the focal species in combination with the high density of visitors will erode the experience of the visitors and as a result the wildlife tourism destination will collapse (trajectory D in figure 3,) (Hammit, et al., 2015). But a successful management intervention as shown by trajectory E in figure 3 can prevent the collapse of the site and even sustain further growth.

The development described by Duffus' and Dearden's (1990) growth curve can be irreversible and once the focal species has abandoned the destination it might may never return, even if the original state of the site is restored (Duffus & Dearden, 1990, p. 225).

2.3 Wildlife tourism and conservation

Wildlife tourism and conservation share an ambivalent relationship (Trave, et al., 2017, p. 212). The benefits of wildlife tourism for conservation “include financial and practical contributions by tourists and tourism operators, economic incentives for wildlife conservation (acting through local communities, the tourism industry and governments) and environmental education” (Green & Higginbottom, 2000, p. 183).

Among the most common direct financial contributions to conservation from wildlife tourism are user fees for protected areas. Fees can be paid directly as entrance fees by visitors or in the form of licence fees by operators. The raised revenues can offset the costs for monitoring, regulating and maintaining the protected area (Mau, 2008, pp. 223-224; Green & Higginbottom, 2000, pp. 188-189; Newsome, et al., 2005, p. 49). Other important forms of direct financial contributions are donations or voluntary contributions (Green & Higginbottom, 2000, p. 189).

Operators and wildlife tourists can also directly participate in “management (e.g., weed control, habitat restoration) or monitoring activities or […] research which contributes to conservation” (Green & Higginbottom, 2000, p. 190). Often these activities are coordinated by not-for-profit organizations e.g. the MWSRP.

Non-consumptive wildlife tourism can create substantial revenues (Duffus & Dearden, 1990, p. 214) and the non-consumptive economic value of a living charismatic animal often exceeds its consumptive value (Catlin, et al., 2013). By offering an alternative source of income to the consumptive use of wildlife, non-consumptive wildlife tourism can offer economic incentives for local communities to engage in conservation (Trave, et al., 2017, p. 212; Elbroch, et al., 2017, p. 2988; McNeely, 1988, p. 75).

The integration of an educational component in non-consumptive wildlife tourism can also provoke pro-environmental behaviour and attitudes in the participants and raise awareness for the importance of conservation (Burgin & Hardiman, 2015, p. 210). However, these positive educational effects can only be reached if wildlife tourism is “carefully designed, managed and delivered” (Ballantyne, et al., 2009, p. 658).

Besides these positive effects of wildlife tourism, any form of wildlife tourism that involves the “relatively proximal contact between man and nature can cause changes to the focal species, the local ecosystem or other incidentally encountered species” (Duffus & Dearden, 1990, p. 215).

The intensity of these negative impacts depends on eight factors:

- The type of activity (Knight & Cole, 2012, p. 53; Duffus & Dearden, 1990, p. 215)
  Non-consumptive wildlife tourism can include various forms of interaction with the focal organism and the impacts partly depend on the type of the activity e.g. passive

observing vs. photographing vs. feeding (Knight & Cole, 2012, p. 55; Buckley, 2003, p. 57; Newsome, et al., 2005, p. 70).

- Mode of access (Newsome, et al., 2005, p. 70)
  The mode of access is often directly related to the type of activity e.g. motorized safari vs bushwalks. It also determines the required infrastructure and the level of intrusion into the habitat of the focal organism (Newsome, et al., 2005, pp. 55-65; Hammit, et al., 2015, p. 15).
- Visitor pressure (temporal) (Newsome, et al., 2005, p. 70)
  The impact on the focal organism and its habitat can depend on the total number of visitors, the size of groups and the frequency that groups of or individual recreationists seek proximity to the focal organism (Newsome, et al., 2005, p. 70).
- Visitor pressure (spatial)
  The spatial visitor pressure is high when wildlife tourism concentrates on a small area that plays an important role in the viability of the focal species e.g. waterholes. However, visitor pressure can also increase if recreationists are spread out and the species has no place to escape from visitors (Knight & Cole, 2012, p. 62; Hammit, et al., 2015, p. 15).
- Attitudes of visitors towards wildlife (Newsome, et al., 2005, p. 40)
  The general view of tourists on wildlife can influence their sensitivity towards the impact of his/her actions, e.g. a tourist with a protectionist view might act more prudently than a tourist with a utilitarian view on wildlife (Newsome, et al., 2005, p. 101).
- The type/specialization level of visitors
  As described in the previous section, the intensity of the impacts can be related to the prevailing expertise and knowledge of the users (Duffus & Dearden, 1990, p. 222; Newsome, et al., 2005, p. 70; Buckley, 2003, p. 57; Hammit, et al., 2015, p. 10).
- Environmental sensitivity (Newsome, et al., 2005, p. 70)
  The environmental sensitivity describes how sensitive the habitat of the focal species is to the presence of humans and the offered recreational activity (Newsome, et al., 2005, p. 70; Hammit, et al., 2015, p. 15).
- Sensitivity of the focal species (Newsome, et al., 2005, p. 70)
  Different species and animals tolerate different levels of disturbance (Sorice, et al., 2003, p. 321; Hammit, et al., 2015, p. 57; Knight & Cole, 2012, p. 62; Newsome, et al., 2005, pp. 40,70). Factors that influence the sensitivity of an individual animal or species include age, breeding season, time of year, habitat type and habituation (Newsome, et al., 2005, pp. 65-66).

The negative impacts of wildlife tourism on the focal organism can be categorized as direct and indirect impacts (Knight & Cole, 2012, p. 51; Hammit, et al., 2015, p. 14). Direct impacts can be further distinguished into behavioural and physiological impacts (Newsome, et al., 2005, p. 72). Within the behavioural and physiological impacts there can be differences in the temporal scope e.g. immediate impacts and long-term impacts (Knight & Cole, 2012, p. 52). Long-term impacts are often a direct consequence of the repeated occurrence of immediate impacts (Trave, et al., 2017, p. 213). The impacts can affect only an individual animal or the entire population (Knight & Cole, 2012, p. 53). Furthermore, impacts can be distinguished according to their interdependencies into synergistic and compensatory impacts (Hammit, et al., 2015, p. 15).

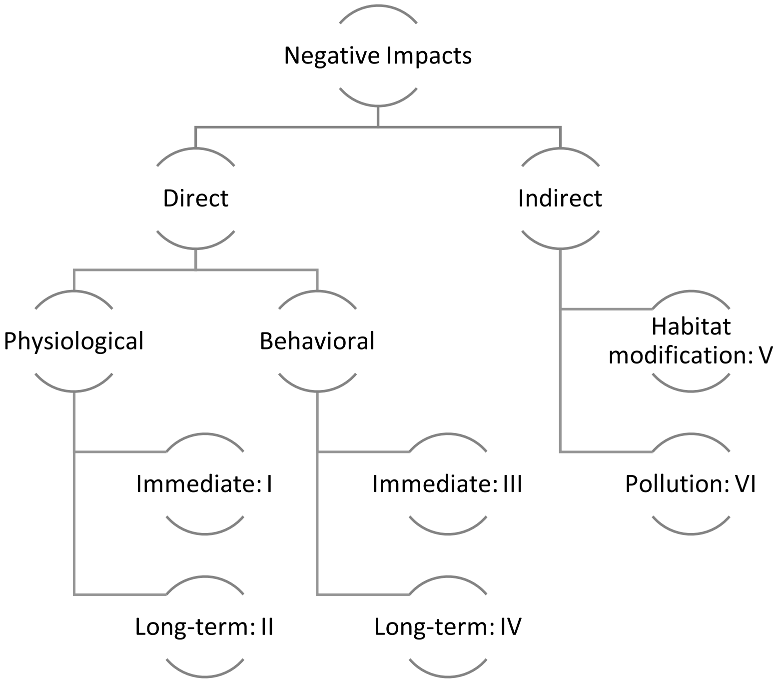


Figure 4: Classification of negative impacts of wildlife tourism (derived from Sorice, et al., 2003, p. 322; Newsome, et al., 2005, p. 72; Knight & Cole, 2012, p. 52)

Using only the directness and time horizon as criteria the negative impacts of wildlife tourism on the focal organism can be classified into six different categories:

I. <u>Direct immediate physiological impacts</u>
   a) injuries and death of the focal organism directly caused by the recreational activity e.g. road kills (Knight & Cole, 2012, p. 52)
   b) stress or an increase in the metabolic rate of the focal organism due to disturbance e.g. flight (Knight & Cole, 2012, p. 52; Schofield, et al., 2015, p. 517)
   c) transfer of diseases by recreationists (Newsome, et al., 2005, p. 216)

II. <u>Direct long-term physiological impacts</u>

    a) deterioration of the overall physiological condition of the animal e.g. due to frequently occurring elevated levels of stress (Trave, et al., 2017, p. 212; Reynolds & Braithwaite, 2001, p. 35)
    b) lower reproduction rate of the population due to the deterioration of the overall physiological condition of the population (Trave, et al., 2017, pp. 212-213; Reynolds & Braithwaite, 2001, p. 35)
    c) elevated risk for predation e.g. tourists' paths leading predators to their prey (Newsome, et al., 2005, pp. 72,216)
    d) negative dietary changes due to provisioning (Reynolds & Braithwaite, 2001, p. 35)
    e) changes in the population structure e.g. changes in the age distribution (Hammit, et al., 2015, p. 21)

III. <u>Direct immediate behavioral impacts</u>
    a) disruption of natural behavior due to disturbance by recreationists (Burgin & Hardiman, 2015, p. 213; Knight & Cole, 2012, p. 52)

IV. <u>Direct long-term behavioral impacts</u>
    a) habituation of the focal organism to the presence and interaction with recreationist e.g. change of feeding patterns (Reynolds & Braithwaite, 2001, p. 35)
    b) emigration of animals due to frequent presence of and disturbance by recreationists (Burgin & Hardiman, 2015, p. 213; Knight & Cole, 2012, p. 53; Reynolds & Braithwaite, 2001, p. 35)
    c) changes in the species composition e.g. due to the emigration of one species another species might take up its place (Hammit, et al., 2015, p. 21; Reynolds & Braithwaite, 2001, p. 35)

V. <u>Habitat modification</u>
    a) reduction of habitat e.g. to extend the infrastructure at a wildlife tourism site (Reynolds & Braithwaite, 2001, p. 35)
    b) changes in the vegetation e.g. by trampling or the introduction of exotic species (Reynolds & Braithwaite, 2001, p. 35; (Hammit, et al., 2015, p. 7
    c) emigration of animals due to habitat modifications (Reynolds & Braithwaite, 2001, p. 35)
    d) changes in the species composition (Hammit, et al., 2015, p. 21; Reynolds & Braithwaite, 2001, p. 35)

VI. <u>Pollution</u>
    a) contamination of the habitat with solid waste or harmful chemicals (Hammit, et al., 2015, p. 89)
    b) emigration of animals due to pollution (Reynolds & Braithwaite, 2001, p. 35)

c) changes in the species composition (Hammit, et al., 2015, p. 21)

One requirement for a full impact assessment is the “[c]omprehensive knowledge on the biology, ecology and behaviour of a particular species or population” (Trave, et al., 2017, p. 216). Without solid baseline data, no conclusions on any changes in the habitat, the abundance of a species or any other indicators can be made. While obvious immediate behavioural or physiological responses might be measurable even with incomplete baseline data, the tracking of long-term impacts is impossible without sufficient baseline data. The lack of baseline data might be one reason why many studies concentrate on the assessment of immediate or short-term impacts of wildlife tourism (Knight & Cole, 2012, p. 52; Trave, et al., 2017, p. 213).

Another challenge for researchers is the establishment of cause-and-effect relationships, because the behaviour and physiological state of an animal is simultaneously influenced by both natural and anthropogenic factors (Hammit, et al., 2015, p. 14). Furthermore, the relationship between the trigger activity and the intensity of the impact are often non-linear and impacts can be amplified or compensated by other impacts (Hammit, et al., 2015, p. 15).

If the occurring negative impacts of wildlife tourism are not sufficiently mitigated, they might outweigh the positive impacts on conservation (Trave, et al., 2017, p. 212) described above.

2.4 Regulation of a wildlife tourism site

In 1968, Garret Hardin’s article “The Tragedy of the Commons” was published in the Journal “Science”. In his article, Hardin (1968) describes how the economic incentives of the users of a common pool resource can cause a complete and irreversible depletion of the resource. Common pool resources are characterized by two distinguishing properties:

a) The consumption is not excludable, because there are no property rights assigned to the resource and there is free access (Pirotta & Lusseau, 2015, p. 729).
b) The consumption is rivalrous, hence the amount of the resource used by one user won’t be available for another user (Hackett, 2015, pp. 49-50; Pirotta & Lusseau, 2015, p. 729). The rivalrous character of a common pool resource also implies that the resource is exhaustible.

A common pool resource is not automatically doomed to be overexploited. A small number of co-operating users can lead to a sustainable use of the resource. However, if the number of users exceeds the carrying capacity of the common pool resource and all users try to maximize their utility, the resource will get fully depleted.

The reason that users consume the resource faster than it recovers, lies in the economic incentives. While every user gets the full benefit of every additional unit of the common pool resource he/she is consuming, the negative effects or the social costs are distributed among all users of the resource. Hence every user pays only a relative small fraction of the social costs of their consumed units, while receiving the full benefit. If every user wants to maximise his/her utility, he/she has an incentive to use as much of the resource as possible even though this means the long-term collapse of the entire resource base (Hardin, 1968, p. 1245).

In his article, Hardin also presents an example for a common pool resource:

“*The National Parks present another instance of the working out of the commons. At present, they are open to all, without limit. The parks themselves are limited in extent – there is only one Yosemite Valley - whereas population seems to grow without limit. The values that visitors seek in the parks are steadily eroded. Plainly, we must soon cease to treat the parks as commons or they will be of no value to anyone*” (Hardin, 1968, p. 1245).

The example Hardin gives in his article is surprisingly similar to the evolution of a wildlife tourism site described by Duffus and Dearden (1990).

Therefore, the incentive structure described above in Hardin’s “The Tragedy of the Commons” can help to understand the underlying reasons for some of the occurring negative impacts in wildlife tourism. Wildlife tourism sites are often open to the public. Hence, their use is not excludable (Moore & Rodger, 2010, p. 832) and the first criterion of a common pool resource is met. The second criterion of a common pool resource requires the consumption to be subtractive. But how can a non-consumptive activity be subtractive, when nothing is consumed? Pirotta and Lusseau (2015) argue that “[t]our operators, who aim at maximizing their present benefit, make such resource subtractable by exploiting it to a level at which detrimental effects are instigated, compromising the viability of the wildlife population and hence their future payoffs” (Pirotta & Lusseau, 2015, p. 729). Following this line of argumentation, the second criterion of a common pool resource is also met.

In case of non-consumptive wildlife tourism, the maximum level of exploitation of a wildlife tourism destination is limited by the social and environmental carrying capacity of the destination (Salerno, et al., 2013). The social carrying capacity refers to threshold levels for the visitor satisfaction and for the quality of the experience (Salerno, et al., 2013, p. 118; Lawson, et al., 2003, p. 305). If the social carrying capacity is exceeded the wildlife site will collapse due to diminishing visitor numbers (see section 2.2).

The environmental carrying capacity refers to the negative impacts described in section 2.3. Exceeding the environmental carrying capacity will displace the focal species and thus the site will lose its main attraction. The environmental and social carrying are strongly interrelated (Hammit, et al., 2015, p. 13) e.g. satisfaction and the quality of the experiences depend on the abundance of the focal species.

The successful management of a wildlife tourism site requires a multidisciplinary approach as “[i]t depends on the biological sciences to understand the nature of the support system that presents the opportunity for contact between the users and the focal species, and the techniques of the social scientist to understand the interrelated concepts of satisfaction that produce the recreational benefits” (Duffus & Dearden, 1990, p. 217).

To prevent a wildlife tourism site from collapsing and to mitigate the negative impacts decision makers can choose from variety of instruments. In 2005, the United Nations Environmental Programme and the World Tourism Organization published “A Guide for Policy Makers” including a list of thirteen instruments for sustainable tourism (United Nations Environment Programme, World Tourism Organization, 2005). In their report, the United Nations Environmental Programme and the World Tourism Organization distinguish between five categories of instruments: measurement instruments, command-and-control instruments, economic instruments, voluntary instruments and supporting instruments. In the following the most relevant instruments in respect to the management of a wildlife tourism destination are introduced:

<u>Sustainability indicators and monitoring</u> (United Nations Environment Programme, World Tourism Organization, 2005, pp. 72-75)

Sustainability indicators need to be defined and measured in the earliest stages of the regulation process to assess the status quo of a wildlife tourism destination and to serve as baseline data to monitor the success or shortcomings of regulations. The indicators can also be used to establish tangible targets for regulations and Lawson et al. note that “[m]anagement objectives are made operational through a set of empirically based indicators” (Lawson, et al., 2003, p. 305). Long-term regulation schemes especially require a careful selection of indicators as altering the indicators later could lead to inconsistency in the monitoring. The United Nations Environmental Programme and the World Tourism Organization defined five criteria for the selection of indicators:

- “Relevance of the indicator to the selected issue.
- Feasibility of obtaining and analysing the information required.
- Credibility of the information and reliability for users of the data.
- Clarity and ease of understanding amongst users.
- Comparability over time and across regions.” (United Nations Environment Programme, World Tourism Organization, 2005, p. 73)

<u>Identifying the limits of a tourism destination</u> (United Nations Environment Programme, World Tourism Organization, 2005, pp. 75-77)

The extent of tourism at a destination can be limited by ecological, socio-cultural, psychological, infrastructural and management constraints. These constraints are all important to determine the carrying capacity of a tourism site. Further the authors suggest the establishment of ranges rather than precise values and to use these ranges as a starting point for a debate with the stakeholders (United Nations Environment Programme, World Tourism Organization, 2005, p. 76).

Direct command-and-control instruments (United Nations Environment Programme, World Tourism Organization, 2005, pp. 78-89)

With command-and-control instruments regulators define a clear set of limitations and/or standards to ensure that the carrying capacity of a wildlife tourism site is not exceeded. There are different leverages for command-and-control instruments and in the case of tourism the most relevant are the regulation of the:

- "Access to certain areas.
- Frequency and length of tourism use.
- Qualifications of operators.
- Safety standards of equipment and facilities (applying, for example, to activity based tourism).
- Certain seriously damaging activities that should be controlled." (United Nations Environment Programme, World Tourism Organization, 2005, p. 81)

Indirect economic instruments: taxes and charges (United Nations Environment Programme, World Tourism Organization, 2005, pp. 89-93)

Economic instruments try to internalize any social costs from externalities and thus change the economic incentive structures for consumers. If properly designed, economic instruments use the market to reach an economically efficient level of consumption of the common pool resource. In case of wildlife tourism, the most common instrument are entrance fees or charges for the use of a site. Following the "polluter-pays" principle the revenues can be used to offset the costs of a regulation scheme and compensate for any negative impacts. A transparent communication of the reason and the purpose of the charges is important to prevent pushbacks from operators and users (United Nations Environment Programme, World Tourism Organization, 2005, pp. 89-93).

Voluntary instruments: guidelines and codes of conduct (United Nations Environment Programme, World Tourism Organization, 2005, pp. 95-99)

Guidelines or codes of conduct can serve as a framework for a wildlife tourism destination to establish standards on a voluntary basis that minimize the negative impacts of wildlife tourism. While guidelines typically include comprehensive information on how to conduct wildlife tourism, a code of conduct is normally only a set of favoured and avoidable/forbidden behaviours.

"It may be more appropriate to use codes and guidelines rather than regulations where:

- Regulations are difficult to disseminate and compliance cannot be controlled.
- The consequences of certain actions may be less serious.
- It is important or helpful to communicate positive actions to pursue, as well as negative actions to control.
- There are stakeholder groups with whom guidelines and codes can be developed and who promote compliance." (United Nations Environment Programme, World Tourism Organization, 2005, p. 96)

Voluntary instruments: voluntary certification (United Nations Environment Programme, World Tourism Organization, 2005, pp. 102-106)

Voluntary standards are another way of setting standards for wildlife tourism. There are numerous certification schemes in the tourism industry and most of them try to achieve some environmental standard. One key precondition for a successful certification scheme is the existence of a totally independent and widely recognized agency to lead the auditing and assessment process and control compliance (United Nations Environment Programme, World Tourism Organization, 2005, p. 102). Passing the auditing and assessment process gives the operator the right to display a label or logo to signalize their compliance to the standard. To avoid misuse of the certificate, the standard should be clearly formulated.

Selecting the right instrument requires the definition and weighting of criteria to solve trade-offs between "the values of conservation, animal welfare, visitor satisfaction, and profitability" (Reynolds & Braithwaite, 2001, p. 31). Newsome et al. (2005) list seven criteria that influence the choice of the right instrument:

1. Economic efficiency (Newsome, et al., 2005, p. 170)

Economic efficiency "[o]ccurs when a market allocates the quantity of resource, good, or service that maximizes total surplus. In theory, this is the equilibrium quantity in a well-functioning competitive market" (Hackett, 2015, p. 71). In the case of wildlife tourism, it is important to consider also intertemporal effects as overexploitation in the present may reduce the abundance of the targeted species in the future and thus potential future revenues (Pirotta & Lusseau, 2015, p. 730). The allocation of the resource should be optimal over time, so that the present value of the surplus totalled over all periods is maximised.

2. Administrative feasibility and cost (Newsome, et al., 2005, p. 170)

The instrument should be easy to implement by the affected parties and the costs for implementing and enforcing the instruments low. (Newsome, et al., 2005, p. 170)

3. Political Acceptability (Newsome, et al., 2005, p. 170)

The instrument and the reason for its application should be accepted by all stakeholders (Newsome, et al., 2005, p. 170). Further, policies should be consistent across different levels e.g. international, national and local (Trave, et al., 2017, p. 216).

4. Equity (Newsome, et al., 2005, p. 170)

All parties should be treated equally by the instrument. (Newsome, et al., 2005, p. 170)

5. Flexibility (Newsome, et al., 2005, p. 170)

The instrument should be capable of being adapted to changing circumstances e.g. changes in the technology (Newsome, et al., 2005, p. 170).

6. Biodiversity robustness (Newsome, et al., 2005, p. 170)

The instrument should ensure that the ecological carrying capacity is not exceeded despite any social or economic factors (Newsome, et al., 2005, p. 170).

7. Precaution (Newsome, et al., 2005, p. 170)

If there is a lack in the knowledge of cause-and-effect relationships, the instrument needs to take a precautionary approach to prevent any irreversible change (Newsome, et al., 2005, p. 170).

The management process itself can be divided into five elements (Trave, et al., 2017), as shown below in figure 5.

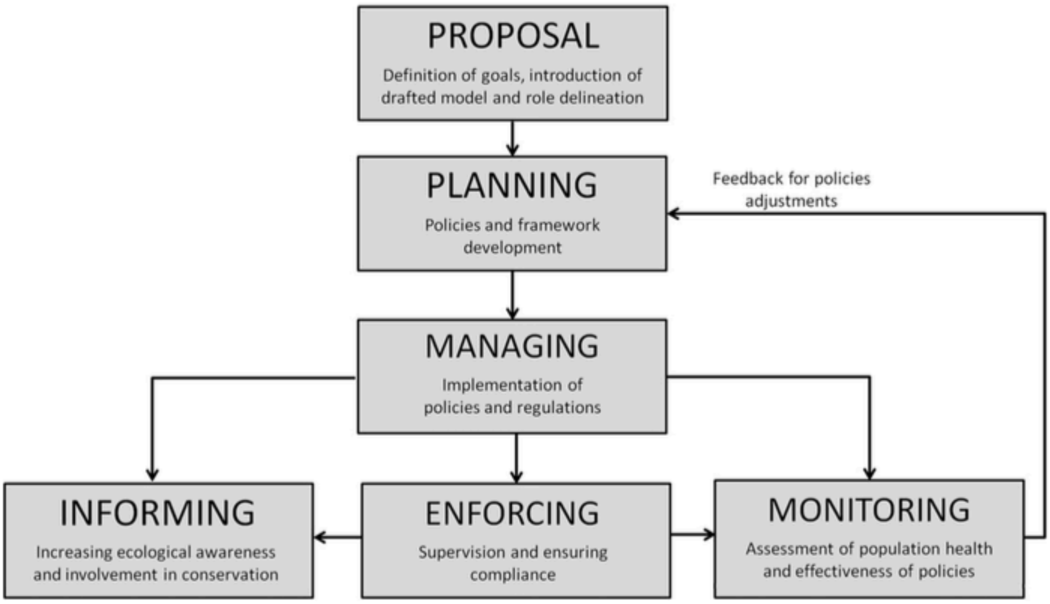


Figure 5: Elements of the management process (source: Trave, et al., 2017, p. 219)

The first element, the initial proposal, should include clearly formulated objectives and define roles for all stakeholders (Trave, et al., 2017, p. 217). With the planning phase, the management process enters an adaptive feedback loop, which plays a decisive role in the successful regulation of a wildlife tourism destination (Trave, et al., 2017). The planning requires knowledge of the ecological processes of the focal species for the development of policies. The management can be separated into three steps: the implementation and enforcement of the policies, the education and informing of the public to raise awareness and acceptance and the monitoring of long-term impacts on the focal species and its habitat. The information of the negative impacts is essential for the feedback loop to ensure that the policies achieve the set objectives.

3 Whale shark tourism

Whale shark tourism commenced in 1989 at the Ningaloo Reef in north-west Australia (Mau, 2008; Catlin & Jones, 2010). Today whale shark tours are offered at 18 aggregation sites around the globe (Dobsen, 2008, p. 54).

The whale shark is a migratory species that, even though it can withstand short exposures to water of ten degrees Celsius and below, prefers tropical and warm temperate seas (Rowat & Brooks, 2012, p. 1027). The species can mainly be found in coastal and oceanic waters between the tropics of Cancer and the tropics of Capricorn, although there are rare reports of whale shark sightings further north and south (Rowat & Brooks, 2012, p. 1027). As shown in figure 6, the whale shark population is distributed over a large spatial area.

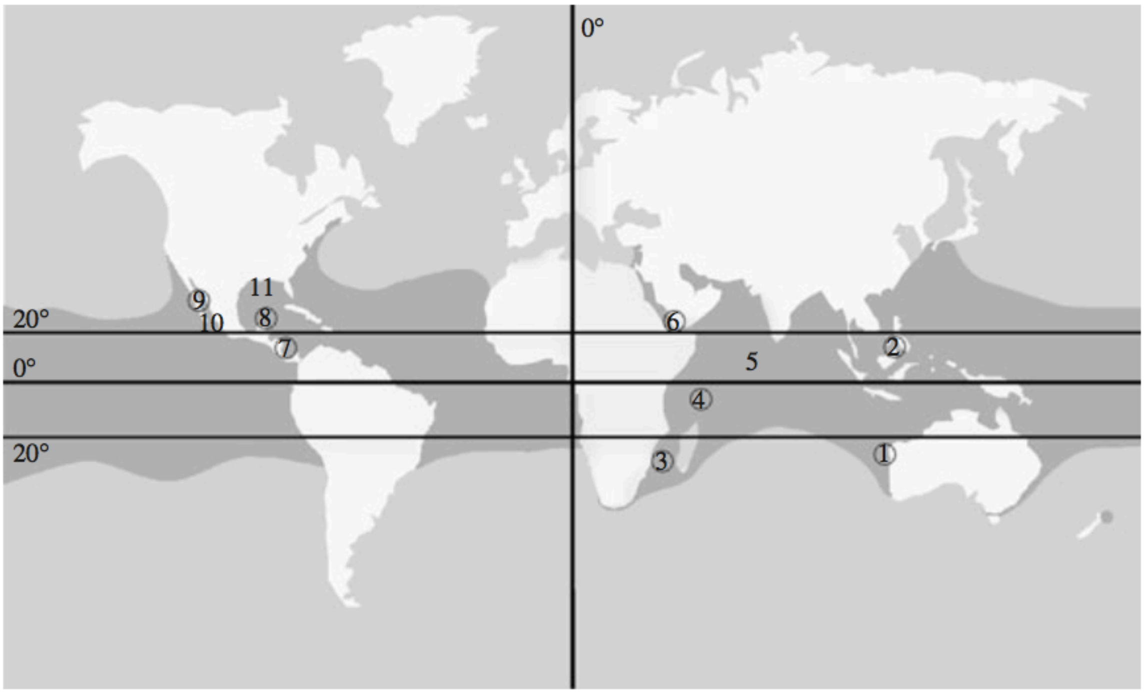


Figure 6: Geographical distribution of whale sharks and known aggregation sites: 1. Ningaloo; 2. Philippines; 3. Mozambique, 4. Seychelles; 5. Maldives; 6. Djibouti; 7. Belize; 8. Holbox; 9. North Gulf of California; 10. South Gulf of California; 11 North Gulf of Mexico (source(Rowat & Brooks, 2012, p. 1028)

One precondition for the successful development of a whale shark tourism destination is a reliable and predictable aggregation of whale sharks. Many of the aggregations are only seasonal and correlate with an excessive supply of food e.g. coral spawning events at the Ningaloo reef (Anderson, et al., 2014, p. 110) or snapper spawning events at Gladden Spit in Belize (Graham & Roberts, 2007, p. 71).

Whale sharks unite several characteristics of a charismatic species. The whale shark is the world's largest fish and can grow up to 18 metres in length (Compagno, 1984, p. 211). As large animals attract more wildlife tourists (Newsome, et al., 2005, p. 97), the enormous size of the whale shark is one reason for its popularity (Sanzogni, et al., 2015, p. 2).

Besides their size, the whale shark is characterized by a wide and flat head with an immense mouth and relative small eyes on the sides. The body of the whale shark has "three conspicuous longitudinal ridges (carina) along its dorsal flanks, a large first dorsal fin and semi-lunate caudal fin" (Rowat & Brooks, 2012, p. 1020). Furthermore, every whale shark carries a unique pattern of light spots and stripes (Compagno, 1984, p. 210).

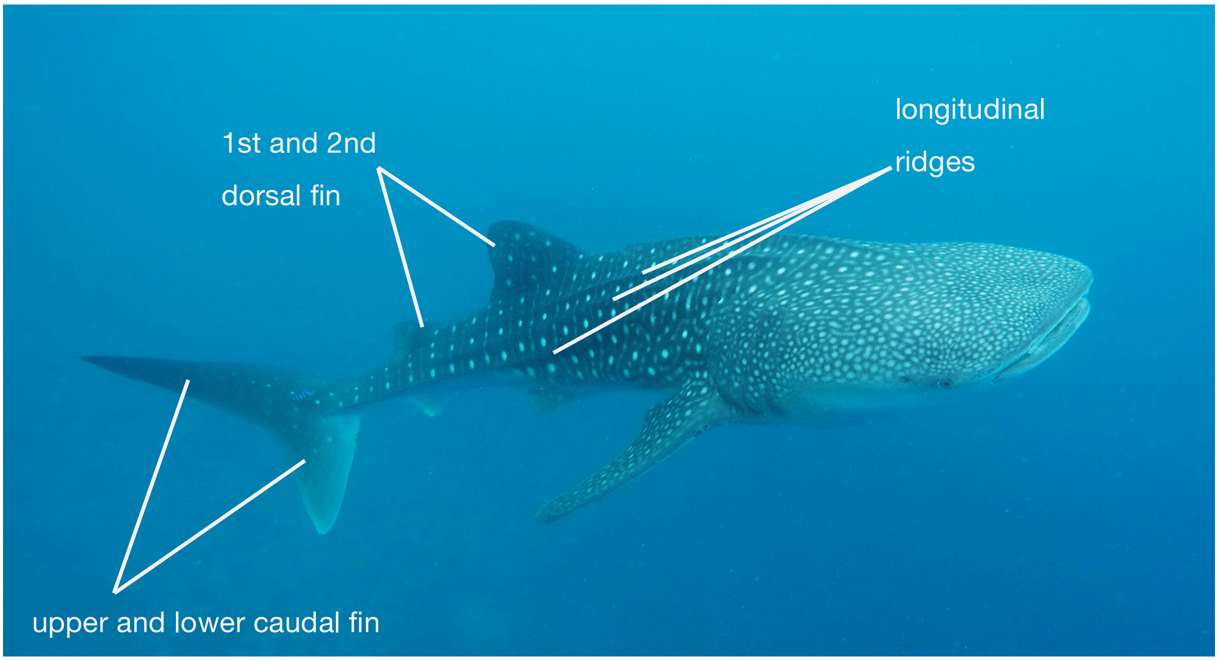


Figure 7: A whale shark swimming in the South Ari Marine Protected Area (source: author)

Whale sharks are filter feeders, feeding on planktonic and small nektonic organisms. Hence, despite their size they are harmless to humans (Compagno, 1984, p. 211; Sanzogni, et al., 2015, p. 2). Whale sharks are slow swimmers "and adult whale sharks typically cruise at speeds of 0.05 – 1.0+ m/s" (Martin, 2007, p. 11). Because of their slow movements and their docile nature, whale sharks are also known as the "gentle giants" (Burgin & Hardiman, 2015, p. 211). Although the data on diving patterns is very sparse, some tagged whale sharks in the Ningaloo Marine Reef Park in Australia stayed more than 50% of the daytime close to the surface not deeper than ten metres (Rowat & Brooks, 2012, p. 1035).

The amount of time whale sharks spend close to the surface (Rowat, et al., 2009, p. 1), their swimming behaviour, their docile nature and the warm to tropical water temperatures at the aggregation sites are ideal conditions for a 'swim-with' form of marine wildlife tourism (Sanzogni, et al., 2015). The operations at the different aggregation sites differ slightly due to natural, regulatory and infrastructural differences. Most of the whale shark tour operators offer snorkelling with whale sharks because it is often easier to interact with the whale shark without scuba equipment (Colman, 1997, p. 20) and because scuba diving has been banned at several whale shark aggregation sites e.g. at the Ningaloo Reef in Australia scuba diving was banned, because the exhaust bubbles may disturb the whale shark (Colman, 1997, p.20; Norman, 1999, p. 78).

The popularity of whale shark tourism can also be attributed to the rarity and conservation status of the species. After being listed as vulnerable for 16 years in the IUCN red list of endangered species, the conservation status of the whale shark was raised to endangered in 2016. The raised conservation status was mainly due to an estimated 63% decline of the Indo-Pacific whale shark population over the past 75 years. As 75% of the global whale shark population is believed to occur in the Indo-Pacific region, the global population is estimated to have declined by more than 50% over the past 75 years (Pierce & Norman, 2016). Like many other shark species, the whale shark is characterized "by slow growth, high longevity, late age of sexual maturity and low fecundity" (Richards, et al., 2015, p. 200). Hence, the population will need a long time to recover.

The main current threats for whale sharks are fisheries directly targeting whale sharks, bycatch in nets and boat collisions. Whale sharks are caught for several reasons:

- Whale shark meat is also known as tofu shark and at peak prices the meat of a 2t whale shark was worth up to 14,000 USD (Pierce & Norman, 2016).
- Whale sharks carry an oil filled lever and in some countries the oil was used to water proof boats (Rowat & Brooks, 2012, p. 1040).
- Whale shark fins are a status symbol in some Asian countries and restaurants serving shark fin soup put them on display for advertisement (Pierce & Norman, 2016).

The direct fisheries of whale sharks in several countries have been closed recently due to declining catch numbers per unit effort, declines in catch sizes or the increased value of living whale sharks for the tourism sector. Currently the only place with a large-scale whale shark fishing industry is Southern China (Pierce & Norman, 2016). Whale sharks are listed on appendix II in the convention on international trade in endangered species of wild fauna and flora.

Whale sharks regularly end up as bycatch in tuna purse seine nets. Some tuna fishermen use whale sharks as indicator species because tuna often aggregate around whale sharks. The bycatch often remains unreported and even if the whale shark is later released it might be fatally injured in the process (Pierce & Norman, 2016).

As a highly mobile epipelagic species, whale sharks are at high risk of colliding with boats. Especially the collision with large and fast-moving ships is likely to be fatal for the whale shark and to remain unnoticed by the ship's crew (Pierce & Norman, 2016).

3.1 Negative impacts of marine wildlife tourism on whale sharks

The "confluence of species vulnerability and increased tourism volume could be an indicator of an ecological and economic problem for whale shark tourism" (Ziegler, et al., 2012, p. 692). The IUCN lists tourism "in some circumstances (for example from interference, crowding or provisioning)" (Pierce & Norman, 2016) as an indirect threat for the whale shark. A review of studies and articles on the negative ecological impacts of whale shark tourism showed that most of the authors were very careful in drawing conclusions because their studies were often influenced by logistical constraints and thus many articles conclude that more research is required to confirm their findings (Speed, et al., 2008, p. 1498; Araujo, et al., 2017, p. 992; Haskell, et al., 2015, p. 497; Anderson, et al., 2014, p. 118).
The following will give an overview on findings regarding the negative impacts of whale shark tourism referring to the defined categories in chapter 2.2.

I. <u>Direct immediate physiological impacts</u>
   a) <u>injuries and death of the focal organism directly caused by the recreational activity</u>

The same characteristics that make the whale shark easily accessible for a 'swim-with' form of marine wildlife tourism, make the species extremely vulnerable for collisions with boats or getting struck by propellers (Speed, et al., 2008, p. 1489; Mau, 2008, pp. 218-219; Department of Parks and Wildlife, 2013, p. 2). Whale shark tourism can further increase the likelihood of collisions or propeller strikes as whale shark tourism operators will concentrate at spots with the highest potential abundance of whale sharks. Furthermore, whale shark tourism operators will actively seek the proximity of whale sharks to make sure their customers can enter the water as close to the whale shark as possible (Mau, 2008, pp. 218-219; Haskell, et al., 2015, p. 496; Anderson, et al., 2014, p. 117; Rohner, et al., 2013, p. 154).

Figure 8: Collision of a whale shark with a vessel in the South Ari Marine Protected Area (source: author)

A study by Speed et al. (2008) on “Scarring patterns and relative mortality rates of Indian Ocean whale sharks” showed that “[m]any whale sharks bore the evidence of collisions with boats and this phenomenon was probably responsible for the majority of lacerations, amputations and blunt trauma injuries” (Speed, et al., 2008, p. 1496). Arujo, et al. found that 56% of the whale sharks at Panaon Island in the Philippines had scars from anthropogenic caused injuries (Araujo, et al., 2017, p. 990) and Ramírez-Macías, et al. found that 25% of the whale sharks observed over a four-year period off the Yucatan Peninsula bore signs of collisions with boats (Ramírez-Macías, et al., 2012, p. 1408).

Compared to the collision with large commercial ocean-going ships there is a high chance for whale sharks to survive collisions or a propeller strike by a recreational vessel, because whale shark tourism is normally conducted on smaller vessels. However, it is difficult to assign injuries directly to tourism vessels due to the migratory nature of the whale shark and the presence of various types of vessels at the aggregation site e.g. fishing boats, military boats, commercial vessels etc. (Ramírez-Macías, et al., 2012; Rowat, et al., 2007).

Figure 9: 'Fresh' parallel lacerations from a propeller close to the whale shark's caudal fin (source: author)

b) <u>stress or an increase in the metabolic rate of the focal organism due to disturbance</u>

To judge whether the focal organism shows signs of stress, requires knowledge of the behaviour the animal would display if undisturbed. The studies that investigated the behaviour of whale sharks were all done by visual observation with the researcher snorkeling or scuba diving next to the whale shark. Therefore, there is a lack of baseline data as there are no records on the behavior the whale shark would display in absence of any humans and it is difficult to determine reliable cause-effect-relationships (Haskell, et al., 2015, p. 494; Quiros, 2007, p. 103; Catlin & Jones, 2010, p. 389). But even though baseline data is missing, there seems to be some consensus among researchers on signs of stress displayed by whale sharks. In "a pioneering behavioral study in Ningaloo Reef, Western Australia from observations on commercial whale shark tours" (Quiros, 2007, p. 103), Brad Norman established a set of whale shark behaviours that many later studies refer to as 'avoidance behaviour'. These behaviours include ''banking, diving, fast swimming, changes in direction, violent shudder" (Ziegler, et al., 2016, p. 618) and eye-rolling (Quiros, 2007, p. 103; Haskell, et al., 2015, p. 493). Mau (2008) suggest that beside these widely agreed on obvious avoidance behaviours there "are of course more subtle stress responses that are very difficult to detect" (Mau, 2008, p. 217).

Different studies at different aggregation sites found different possible anthropogenic factors that provoke avoidance behaviour:

- boat proximity or the distance at which swimmers enter the water (Catlin & Jones, 2010, p. 389; Mau, 2008, p. 217; Pierce, et al., 2010; Norman, 1999, p. 77),
- arrival of a second boat/group of snorkelers (Pierce, et al., 2010),
- path obstruction of the whale shark (Quiros, 2007; Catlin & Jones, 2010, p. 389),
- proximity of swimmers to the whale shark (Quiros, 2007; Catlin & Jones, 2010, p. 389; Mau, 2008, p. 217),
- snorkelers touching the whale shark (Quiros, 2007; Catlin & Jones, 2010, p. 389; Norman, 1999, p. 78),
- the use of flash photography (Quiros, 2007; Catlin & Jones, 2010, p. 389; Norman, 1999, p. 78),
- snorkelers diving towards the whale shark (Quiros, 2007; Catlin & Jones, 2010, p. 389; Norman, 1999, p. 78),
- splash entry of snorkelers (Araujo, et al., 2017, p. 993)
- the use of scuba diving equipment (Catlin & Jones, 2010, p. 389; Norman, 1999, p. 78).

Whale sharks “possess the largest known inner ear in the animal kingdom” (Rowat & Brooks, 2012, p. 1026) and hence are potentially extremely sensitive to low frequency noise. Martin (2007) observed whale sharks responding with diving to the noise of inboard engine boats as these types of engines produce a noise with a lower frequency than outboard engines (Martin, 2007, p. 11).

II. Direct long-term physiological impacts

a) deterioration of the overall physiological condition of the animal

Whale sharks have incredible healing abilities and Speed et al. (2008) found that whale sharks carrying scars from past boat collisions or propeller strikes did not show a higher mortality rate (Speed, et al., 2008). Thus, nonfatal collisions with boats or propeller strikes seem to affect the physiological condition of the animal only in the short-term. However, the injuries “may still demonstrate reductions in maturation time or reproductive output” (Speed, et al., 2008, p. 1498). The study by Speed et al. is the only study that used empirical data to investigate how short-term impacts translate into cumulative long-term impacts. Quiros (2007) mentions that repeatedly disturbing a feeding whale shark might have a deteriorating effect on the overall physiological condition the whale shark and increase the mortality.

b) lower reproduction rate of the population due to the deterioration of the overall physiological condition of the population

The understanding of the reproductive ecology of the whale shark is very poor (Pierce & Norman, 2016). Thus, it is difficult to infer how the deterioration of the overall physiological condition of the population might affect the reproduction rate. However, injuries from vessel collisions or propeller strikes “may still demonstrate reductions in maturation time or reproductive output” (Speed, et al., 2008, p. 1498).

d) negative dietary changes due to provisioning

Cebu in the Philippines is the only whale aggregation where the animals are attracted through provisioning but the effect on the diet is unknown (Araujo, et al., 2014, p. 15).

e) changes in the population structure

The determination of the exact whale shark population size and structure at an aggregation is impossible (Graham & Roberts, 2007, p. 71; Rowat, et al., 2009, p. 1) mainly because whale sharks are a highly mobile species. Hence, also the reasons for a change in the whale shark population structure at an aggregation site might be located somewhere else e.g. Bradshaw et al. (2008) conclude that a reduction in the mean size of whale sharks at the Ningaloo Reef might have been caused by overharvest of whale sharks in Indonesia and South-East Asia (Bradshaw, et al., 2008). Models are used to estimate population size, structure and trends. However, the design of the models often differs and thus results are not comparable (Rowat, et al., 2009, p. 6; Holmberg, et al., 2008, p. 223). The lack of knowledge on the ecology and biology of the whale shark makes it very difficult to identify the potential drivers for the changes in the population structure or the influence of marine wildlife tourism on the whale shark population structure (Mau, 2008, pp. 217-218).

III. Direct immediate behavioral impacts

a) disruption of natural behavior due to disturbance from recreationists

As described under point I b), some studies indicate that the presence of swimmers or boats can lead to changes in the behaviour of the whale shark. However, there are no studies on the natural undisturbed behaviour of whale sharks and thus it is difficult to identify disruption of natural behaviour due to disturbance from recreationists.

IV. Direct long-term behavioural impacts

a) habituation of the focal organism to the presence and interaction with recreationist

Every whale shark carries a unique spot pattern that can be used as a finger print to identify each one. Photo-identification and conventional tagging of sharks at aggregation sites revealed that whale sharks often repeatedly visit a site and thus are repeatedly in contact with boats and swimmers (Pierce, et al., 2010, p. 787). Quiros (2007) found indicators for habituation of whale sharks in Donsol in the Philippines to the presence and interaction with swimmers as whale sharks sighted for the first time were more likely to show an avoidance reaction. Sanzogni et al. came to a similar conclusion for whale sharks at Ningaloo Reef in Australia where whale sharks visiting the site for the first time are less often encountered in one season than returning whale sharks (Sanzogni, et al., 2015, pp. 10-11).

However, these findings were not confirmed by Haskell, et al (2015) who found “that the number of previous encounters with swimmers did not affect the likelihood that a whale shark would display avoidance behaviour (Haskell, et al., 2015, pp. 495-496). Araujo, et al. (2017) suggest that the response to swimmers or boats is not dependent on the degree of habituation but rather on the personality of the whale shark, “defined as behavioural differences between individuals that are stable over time” (Araujo, et al., 2017, p. 992). Whale shark tour operators at Ningaloo Reef made a similar discovery as they identified several whale sharks that are exceptionally tolerant to the presence of humans and hence are very popular among them (Mau, 2008, p. 217). In any case, Mau (2008) highlights the danger of whale sharks losing fear of boats and humans, because this makes them an easy target if they migrate to countries where they are not protected and fishing takes place (Mau, 2008, p. 217).

b) emigration of animals due to frequent presence of and disturbance by recreationists

The number of whale shark tour operators and visitors at most of the aggregation sites has increased in the past. As a result, the pressure from marine wildlife tourism on whale sharks has risen at these sites and at some aggregation sites whale shark sightings have decreased (Anderson, et al., 2014, p. 114; Ziegler, et al., 2016, p. 617). But it is difficult to definitively link the reduced abundance of whale sharks at an aggregation site to an increase in tourism activity (Mau, 2008, pp. 217-218). As described under point II e) the measurement of any anthropogenic caused changes in the whale shark population requires knowledge of natural factors influencing the abundance of whale sharks and in the case of whale sharks, these factors are very poorly understood (Theberge & Dearden, 2006, p. 340). Furthermore, the migratory nature and wide geographical distribution of whale sharks make it difficult to find the geographical source for any changes in the population (see point II e)) (Bradshaw, et al., 2008). Araujo, et al. (2014) found no evidence that whale sharks carrying signs of boat collisions or propeller strikes abandon the whale shark tourism destination (Araujo, et al., 2014, p. 13).

V. Habitat modification

d) changes in the species composition

Graham and Roberts (2007) found that whale shark tourism can impact the reproductive activity of snappers at Gladden Spit in Belize. As the spawning snappers are the reason for the whale sharks to aggregate at Gladden Spit, a disturbance of the snappers might also affect the whale shark aggregation (Graham & Roberts, 2007, p. 79).

VI. Pollution

a) contamination of the habitat with solid waste or harmful chemicals

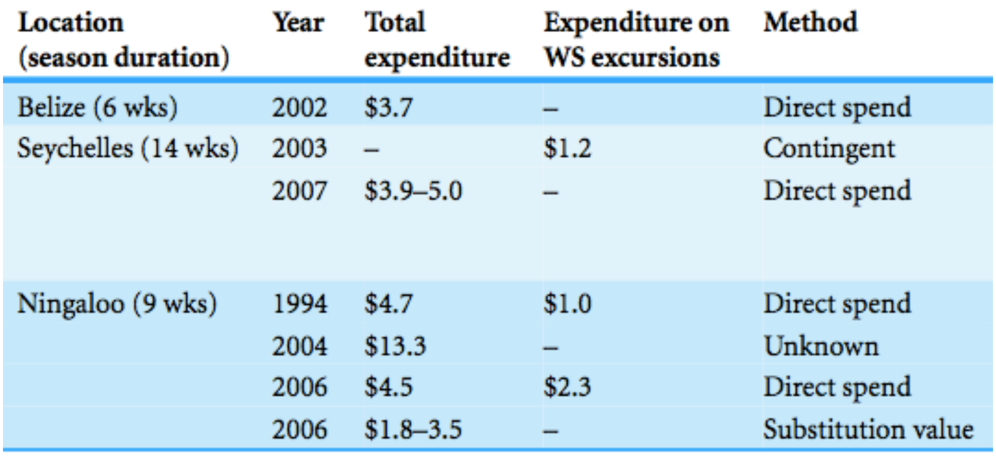
Boat engines discharge up to 20% of their fuel through their exhaust (Hammit, et al., 2015, p. 89). Thus, whale sharks feeding in the proximity of boats might also intake petrol, diesel and oil residues from recreational vessels.

As the extent of the impacts listed above is often unclear and impacts might be irreversible, several authors suggest a precautionary approach for the formulation of mitigation policies (Rowat, 2007, p. 100; Theberge & Dearden, 2006, p. 341; Ziegler, et al., 2012, p. 699; Graham & Roberts, 2007, pp. 78-79; Araujo, et al., 2017, p. 986)

3.2 Socio-economic impact of whale shark tourism

Most of the aggregation sites report rapid growths rates in the number of visitors and the number of tours offered (Ziegler, et al., 2016). Whale shark tourism can offer a new alternative source of income and employment for the local communities and thus often has a positive economic impact on the local economies (Ziegler, et al., 2016), e.g. in 2005, whale shark tourism offered a possibility for 11% of the local fishermen in Donsol in the Philippines to earn a supplementary income during whale shark season (Pine, 2007, p. 22).

Several studies have tried to estimate the economic value of whale shark tourism. However, as the applied methodologies vary from study to study the results are often not comparable (see figure 10).



Location (season duration)	Year	Total expenditure	Expenditure on WS excursions	Method
Belize (6 wks)	2002	$3.7	–	Direct spend
Seychelles (14 wks)	2003	–	$1.2	Contingent
	2007	$3.9–5.0	–	Direct spend
Ningaloo (9 wks)	1994	$4.7	$1.0	Direct spend
	2004	$13.3	–	Unknown
	2006	$4.5	$2.3	Direct spend
	2006	$1.8–3.5	–	Substitution value

Figure 10: The economic value of whale shark watching industries in Belize, the Seychelles and Australia (Ningaloo) (source: Cagua, et al., 2014, p. 2)

A lot of the whale shark aggregation sites are located in developing countries with poorly developed and financed local authorities. The arrival of tourists often hits local communities and authorities unprepared, with potentially negative consequences for the whale sharks, tourists and the image of the place. (Pine, 2007, p. 15). For example, the first season after whale sharks had been discovered in Donsol was described as chaotic, because “[t]he influx of tourists in 1998 overwhelmed the tourism council, especially since its members were trained in neither the hospitality industry nor conservation management" (Pine, 2007, p. 13).

As a destination and the generated income from whale shark tourism grows, the economic success of the local communities gets tied more and more closely to the viability of the whale shark population reinforcing incentives to engage in the protection of the species and its habitat (Araujo, et al., 2017, p. 987) to prevent the destination from deterioration as described in section 2.2.

3.3 Regulation of whale shark aggregation sites

In their papers, Rodríguez-Dowdell (2007) and Moore & Rodger (2010) conclude that whale shark tourism in the Bahia De Los Angeles in Mexico and the Ningaloo Reef in Australia can be classified as a common pool resource and resembles a problem as described in Hardin's article "The Tragedy of the Commons" (Hardin, 1968). As described in section 2.4., to prevent overexploitation of the resource, the extraction rate of the common pool resource must not overshoot the carrying capacity of the resource.

The carrying capacity of a wildlife tourism site can be differentiated into the social and ecological carrying capacity. In the case of whale shark tourism, the ecological carrying capacity refers to the negative impacts of tourism on whale sharks described in section 3.1 (Mau, 2008, p. 215), while the social carrying capacity refers to the quality of the experience for participants (Ziegler, et al., 2016, p. 617; Catlin & Jones, 2010).

The instruments used by regulators to manage whale shark tourism can be mainly categorized as command-and-control instruments. As explained in section 2.4 the choice and how an instrument is applied are influenced by several factors. In the case of whale shark tourism, the different conditions at the different aggregations sites led to the development of different standards and limits. In Isla De Holbox in Mexico, for example, the visibility is often only three metres and thus the minimum distance between swimmers and the whale shark is lower than at the Ningaloo Reef in Australia where the visibility is generally better.

Besides these differences, there are some reoccurring aspects that are shared by the regulations at several aggregation sites:

- <u>Licencing of tour operators</u>

  Many aggregation sites make whale shark tourism exclusive by granting access only to licenced tour operators. By limiting the number of licences or permits, managers can directly control the number of operators. Furthermore, managers can define minimum standards for the tour operators in the permit/licence conditions. These typically include:

    - technical standards for the deployed vessel e.g. minimum/maximum length of the deployed vessels, radio or propeller guards
    - a limitation of the number of passengers per vessel
    - a minimum guides-per-guest ratio
    - training standards and certification of guides and boat captains.
- Limiting the number of vessels and visitors in the whale shark observation area
  Another possibility for regulators to avoid free access is to limit the maximum number of boats and visitors in the whale shark observation area at one time. Some sites have defined time slots and set limitations on the number of boats and/or visitors per time slot.
- Limiting the number of vessels/operators in contact with the whale shark
  Most of the aggregation sites put a limit on the number of boats and people interacting with one whale shark at a time.
- Limiting the encounter duration per whale shark and operator
  To use the time a whale shark spends close to the surface more efficiently, the encounter duration per operator is limited, so that several operators and more visitors can interact successively with the same whale shark. The limitation of the encounter duration is often used in combination with a limitation of the number of boats and people in contact with the whale shark (see above).
- Introduction of a code of conduct for swimmers/scuba divers and operators/boat captains
  Most of the aggregation sites introduced a code of conduct for swimmers and boat captains in form of "short lists of 'do's' and 'don'ts'" (United Nations Environment Programme, World Tourism Organization, 2005, p. 96). The code of conduct can be voluntary or be integrated in the licence, permit or certification conditions. Codes of conduct for boat captains typically include speed limits, rules on how to approach a whale shark and minimum distances to the whale shark and other vessels.
  While 'Do's' listed in the codes of conduct for swimmers typically include minimum distances to keep from the whale shark, 'Don'ts' ban the:
    - physical contact with the whale shark
    - the use of flash photography
    - the use of motorized swimming aids
    - obstruction of the natural path of the whale shark.
- Surveillance and enforcement of the existing regulations
  A visitor survey of whale shark tour participants at the Ningaloo Reef in Australia showed that finding and interacting are the most important determinants for the success of a

whale shark tour (Catlin & Jones, 2010). Hence, especially at times of lower abundance of whale sharks “competition and pressure among tour operators to deliver a guaranteed interaction with whale sharks” (Ziegler, et al., 2012, p. 627) can lead to violations of the regulations (Ziegler, et al., 2012, p. 627). The effective enforcement of the regulations is a key to the successful management of a whale shark tourism site.

Appendix 2 will give an overview of key components of whale shark tourism regulations in Australia, the Philippines, Belize and the Maldives. For most of the aggregation sites the regulation process is poorly documented, making it difficult to retrace how standards were set or to track adaptive changes in the management.

Among the whale shark aggregation sites, the Ningaloo Reef in north-west Australia was the first site to regulate whale shark tourism. The regulations at the Ningaloo Reef became the benchmark for international whale shark tourism and influenced the design of regulations at many other aggregation sites (Rowat & Brooks, 2012). Furthermore, the regulation process is well documented by the regulating institutions and several research papers. Hence, the regulations at the Ningaloo Reef are presented in more detail in section 3.3.1. Hanifaru Bay, a well-known aggregation site for manta rays and whale sharks is an example of successful wildlife tourism management in the Maldives and is presented as a second case study in section 3.3.2.

3.3.1 Case study 1: Ningaloo Reef, Australia

With a length of more than 300 kilometres, the Ningaloo Reef is Australia’s largest fringing coral reef. In 1987, the Ningaloo Reef became a marine protected area (Davis, et al., 1997, p. 260) and since 2011, the Ningaloo Coast is listed as a UNESCO World Heritage.

Among the reasons for the listing was the annual aggregation of whale sharks between March and July. The whale sharks visit the Ningaloo reef to feed on coral spawn (Anderson, et al., 2014, p. 110) and it is estimated that three to five hundred whale sharks migrate annually to the Ningaloo Reef (Bradshaw, et al., 2008, p. 1894).

The Ningaloo Reef was the first place to exploit the seasonally aggregating whale sharks for non-consumptive wildlife tourism and the first operators offered tours to swim with whale sharks in 1989 (Catlin & Jones, 2010, p. 386). Since 1993, whale shark tourism at the Ningaloo Reef has been regulated and the regulations have served as a model for the development of management plans at several other aggregations sites around the world. Since its beginnings, whale shark tourism has constantly grown from 1,000 visitors in 1993 to more than 27,000 visitors in 2016 (Department of Biodiversity, Conservation and Attractions, 2013).

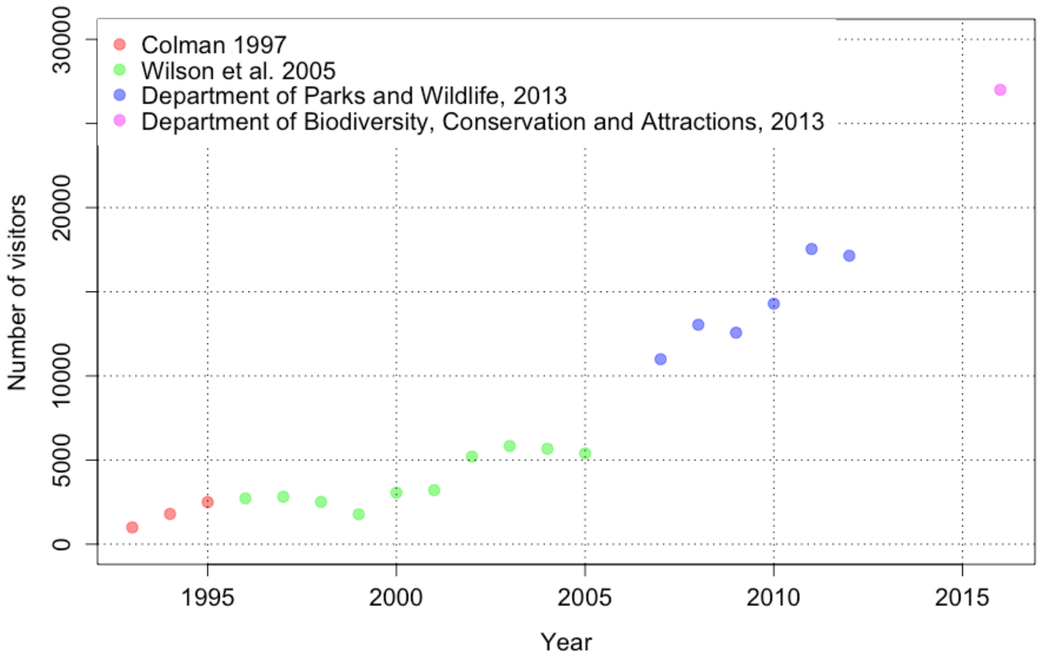


Figure 11: Number of whale shark tour participants in the Ningaloo Marine Reef Park (source: see top left corner in the figure)

There are two points of departure for whale shark tours: Exmouth in the north and Coral Bay further south. The tours depart typically at eight o'clock in the morning and, depending on how long it takes to find a whale shark, return between two and four o'clock in the afternoon (Anderson, et al., 2014, p. 110). As the search area is very large, the operators use spotter planes to locate the whale sharks.

The whale shark aggregation site lies entirely within the waters of the Ningaloo Marine Park which is managed by the Department of Parks and Wildlife (Department of Parks and Wildlife, 2017), an institution of the state of Western Australia. The entire park is divided into different zones to allow for different recreational uses e.g. sanctuary zones and recreation zones. Whale shark tourism operators use about 25% of the marine protected area (Mau, 2008, p. 217) and whale shark interactions concentrate mainly on the areas closest to the reef passages/points of departure (Anderson, et al., 2014, pp. 111,117).

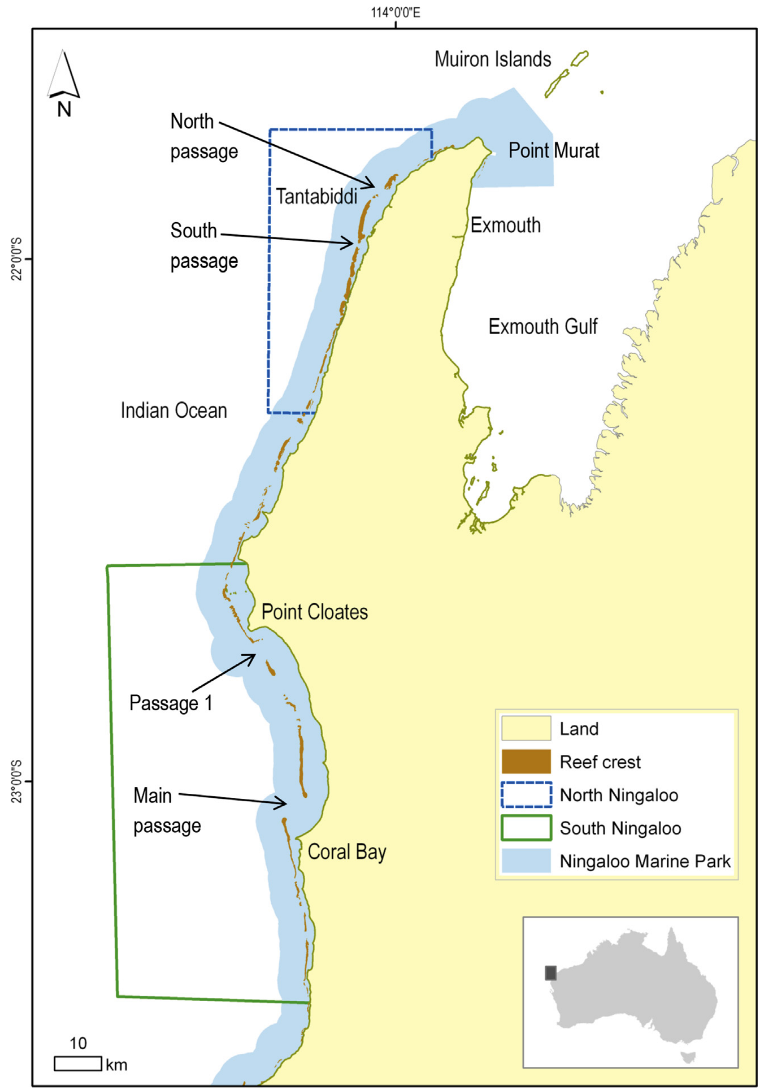


Figure 12: Map of the Ningaloo Marine Park (source: Anderson, et al., 2014, p. 111)

The whale shark tourism management in the Ningaloo Marine Park is, like the marine park itself, under state control and managed by the Department of Parks and Wildlife (Department of Parks and Wildlife, 2017). The Department of Parks and Wildlife uses command-and-control instruments for the management and there have been several adaptive changes to the regulations since 1993.

The regulations are based on a licencing system that limits the number of commercial whale shark tour operators. Commercial tour operators are required to hold two licences: a commercial operator licence and an animal interaction licence. The commercial operator licence includes general requirements for the operator to conduct commercial whale shark tours, while the animal interaction licence specifies how to behave during a whale shark interaction. The number of commercial licences is limited to fifteen and the licences are distributed "via a competitive expression of interest (EOI) process" (Department of Parks and Wildlife, 2013, p. 17). The commercial licences are valid for up to ten years, while the animal interaction licences are valid for five years.

There is a code of conduct for swimmers and vessels which must be followed by all licensees (Department of Parks and Wildlife, 2013, p. 18). The codes of conduct have been copied by several other whale shark aggregation sites.

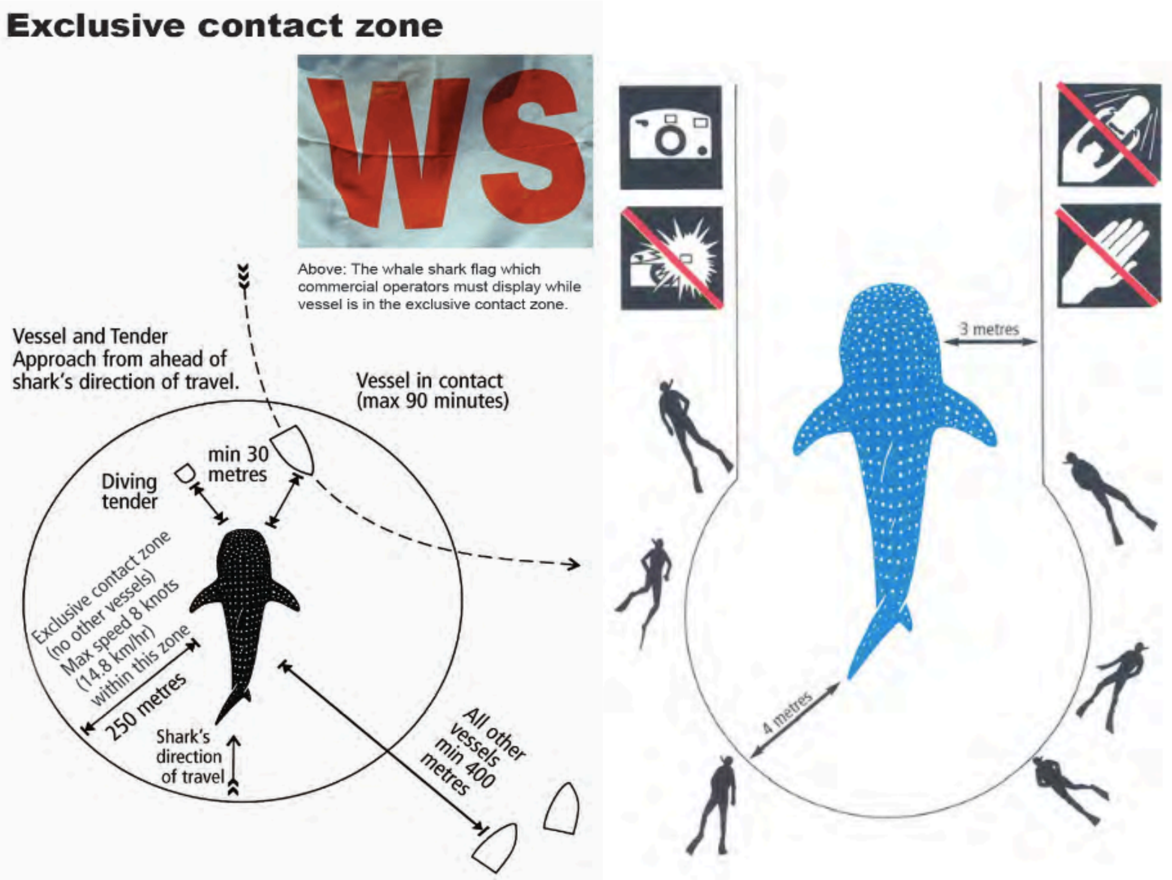


Figure 13: Code of conduct for vessels (left) and swimmers (right) (source: Department of Parks and Wildlife, 2013, pp. 19-20)

As shown in figure 13, within 250 metres of a whale shark the exclusive contact zone in which only one operator is allowed at a time starts. The vessel in the contact zone has the right to stay in contact with the whale shark for up to 90 minutes and must display the whale shark interaction flag during the entire encounter. The whale shark interaction flag shows all other operators in the vicinity that the vessel is in contact with a whale shark and that they need to keep a distance of at least 400 metres from the whale shark. The swimmers of the vessel in contact with the whale shark are allowed to spend no more than 60 minutes in the water with the whale shark. The total number of passengers per vessel is limited to 23 of which a maximum of 20 passengers "are whale shark interaction swimmers" (Department of Parks and Wildlife, 2013, p. 19). The number of swimmers in the water with the whale shark is limited to 10 at a time, excluding one guide and one videographer.

Before terminating the whale shark interaction, the operator in contact with the whale shark can invite a second operator into the exclusive contact zone to ‘pass’ the whale shark on to the invited operator. This practice is called ‘handballing’ and in the transition phase, a second vessel is allowed in the exclusive contact zone (Department of Parks and Wildlife, 2013, pp. 19,73).

The Department of Parks and Wildlife conducts “boat ramp inspections, industry vessel placements, covert operations, aerial surveillance and boat patrols” (Department of Parks and Wildlife, 2013, p. 20) to monitor compliance of operators with the licence conditions. Furthermore, all operators need to carry “an electronic GPS log book system” (Department of Parks and Wildlife, 2013, p. 21) on their vessel. The system was introduced in 2009 and allows the department of parks and wildlife to remotely monitor compliance of the operators e.g. speed limits within the exclusive contact zone.

Figure 14: The electronic GPS based log book system (EMS) (source: Department of Parks and Wildlife, 2013, p. 22).

But the system was also developed to improve the data on whale shark sightings and interactions collected by the tour operators. Since 1995, the operators have been required to collect data during their whale shark interactions. The collected data is one important information stream for the Department of Parks and Wildlife to assess the impact of tourism on whale sharks and improve the management of the whale shark tourism in the Ningaloo Marine Park

The costs for monitoring and other management costs are partly paid by visitor fees. Operators are obligated to pay a licence charge for every whale shark tour participant of 25 AU$ per adult and 12.50 AU$ per child (6 to 16 years) to the Department of Parks and Wildlife.

All staff working on tour operator vessel must visit the “Interacting with Whale Sharks course” (Department of Parks and Wildlife, 2013, p. 37) offered by the department of parks and wildlife. The training was introduced to compensate for the large turnover of staff from season to season (Mau, 2008, p. 220; Bradshaw, et al., 2008).

Due to an incomplete understanding of the negative impacts of tourism on whale sharks, the Department of Parks and Wildlife pursues a precautionary management approach for the regulation of whale shark tourism in the Ningaloo Marine Park (Department of Parks and Wildlife, 2013, p. viii). The development of two aspects of the regulations in the Ningaloo Marine Park shows how "the management equation is often weighted toward opinion" (Duffus & Dearden, 1990, p. 221) when there is an incomplete understanding of the ecology and biology of the focal organism:

a) The number of commercial operator licences

The licencing system for whale shark tour operators in the Ningaloo Marine Park was introduced in 1993 (Department of Parks and Wildlife, 2013, p. viii). In the first year, all fourteen applicants were granted a licence to offer whale shark tours in the Ningaloo Marine Park and the only requirement or licence condition was "the capability to run commercial charters" (Davis, et al., 1997, p. 268). The low requirements at the time show the inexperience of the authorities dealing with a newly developing form of tourism and that whale shark tourism at the Ningaloo Reef was only a small niche market. In the first whale shark season with the licencing system in place, 1000 people participated in swim-with whale shark tours in the Ningaloo Marine Park (Davis, et al., 1997, p. 262). From 1993 to 1994 the number of people participating in whale shark tours increased by almost 80%, while the interest in the licenses and thus the number of tour operators remained stable. In 1995, demand for the licences started to grow and the state of Western Australia limited the number of issued licences to fifteen. Since then the maximum number of licences has not been raised. But the limit of 15 licences seems to have rather a historic reason (originally fourteen applicants for the licences) than it does reflect the ecological or social carrying capacity of the whale shark aggregation in the Ningaloo Marine Park. This is also confirmed by the ever-growing number of tourists, which has increased more than ten-fold since 1995, despite an unchanged number of operators.

b) The distance between swimmers and the whale sharks

In 1995, a minimum distance of one metre between the whale shark and swimmers was set in the licence conditions. In the same year, Davis et al (1997) conducted a visitor survey at the Ningaloo Reef and found that proximity to the whale shark was one important influencing factor on the level of satisfaction and one major motivation for visitors to participate in a whale shark tour. But even though proximity had a strong influence on the quality of the experience for the visitors, Davis et al. (1997) came to the conclusion that a minimum distance of one metre was not very practical for two reasons. First, while the licence conditions prohibit touching the whale shark, a minimum distance of only one metre leaves a high chance of unintentional physical contact with the whale shark. Second, the distance of only one metre leads to a higher level of perceived crowding as swimmers concentrate within a small area around the shark. The authors also pointed out the discrepancy between the one metre minimum distance between whale sharks and swimmers and the 30 metres minimum distance required by the code of conduct for ‘swim-with’ humpback whale interactions (Davis, et al., 1997). Davis et al. (1997) recommended increasing the minimum distance between the whale shark and swimmers from one to three metres. The state of Western Australia followed the recommendation and since 1996 swimmers need to keep at least three metres distance from the head and body of the whale shark and four metres from the tail. In a follow-up study on visitor satisfaction of whale shark tour participants in 1996, Davis (1998) found that the increase in the distance between swimmers and the whale shark led to lower levels of perceived crowding and fewer instances of people touching the whale shark (Davis, 1998) without compromising the level of satisfaction. The two studies by Davis et al. in 1995 and Davis in 1996 show how scientific input can help to improve regulations and how difficult it is for regulators to define standards without any valid information.

The two examples demonstrate how regulations evolve when decision makers lack the necessary knowledge to make well-informed decision and how important scientific input is to support decision makers.

3.3.2 Case study 2: Hanifaru Bay, Maldives

Hanifaru Bay is a small bay in Baa-Atoll in the Maldives that has the size of a football field. During the southwest monsoon currents push plankton-rich water into the bay and the high density of prey attracts masses of manta rays and also whale sharks.

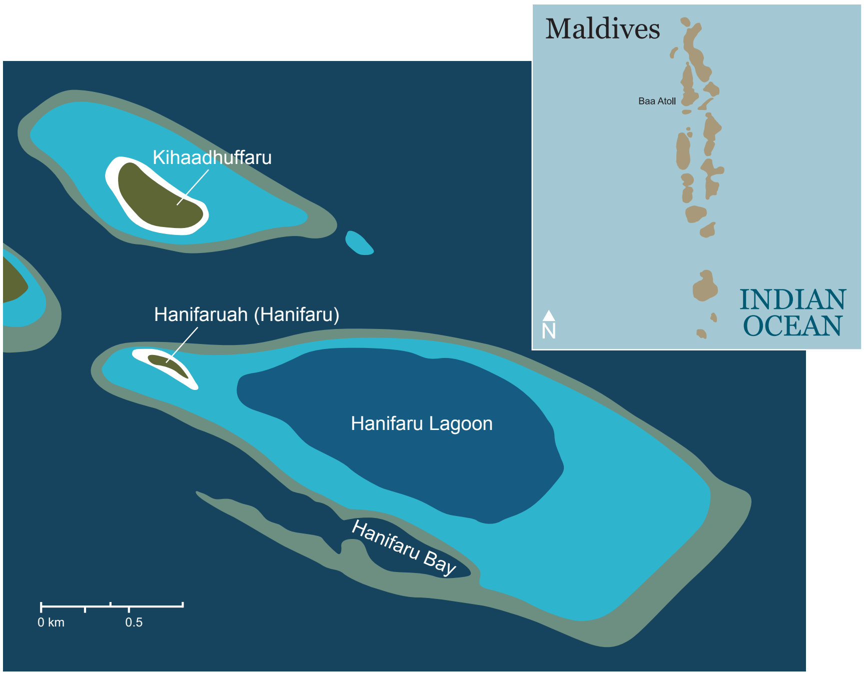


Figure 15: Map of Hanifaru Bay (source: Manta Trust; Project AWARE; WWF, 2016, p. 2)

On the 8th of June 2009, the federal government of the Maldives declared Hanifaru Bay a marine protected area and two years later Hanifaru Bay became a UNESCO World Bisophere reserve. Three years after becoming a marine protected area and after two years of planning, a management plan for the MPA was implemented. Although there have been some adaptive changes to the management plan since then, the main components have not change and have proved successful.

The access to the bay is limited to 5 vessels and 80 visitors at a time. The management plan distinguishes between two groups of operators: resorts and live-aboard-safaris/guesthouses. There is a fixed schedule that allocates the access to the MPA on a given day to one of the groups of operators, see figure 16 below.

(May 2018 – November 2018)

United Nations Educational, Scientific and Cultural Organization · Baa Atoll Biosphere Reserve since 2011 Man and the Biosphere Programme

August	September	October	November
01 Live Aboard/ Guest House	01 Resort	01 Resort	01 Live Aboard/ Guest House
02 Resort	02 Live Aboard/ Guest House	02 Live Aboard/ Guest House	02 Resort
03 Live Aboard / Guest House	03 Resort	03 Resort	03 Live Aboard / Guest House
04 Resort	04 Live Aboard/ Guest House	04 Live Aboard/ Guest House	04 Resort
05 Live Aboard / Guest House	05 Resort	05 Resort	05 Live Aboard / Guest House
06 Resort	06 Live Aboard/ Guest House	06 Live Aboard/ Guest House	06 Resort
07 Live Aboard / Guest House	07 Resort	07 Resort	07 Live Aboard / Guest House
08 Resort	08 Live Aboard/ Guest House	08 Live Aboard/ Guest House	08 Resort

Figure 16: Extract from allocation schedule for the different operator groups (source: Baa Atoll UNESCO Biosphere Reserve Office, 2018)

All visitor groups must be led by a certified guide and guides must pass an exam organised by the Maldivian Environmental Protection Agency. There is a visitor fee of twenty dollars per visitor to offset any costs of the regulation. These costs arise mainly from the almost daily ranger patrols of the MPA during 'manta season'. The visitor fees are paid to the Baa Atoll Conservation Fund which is controlled by representatives of all stakeholder groups.

4 Study site: South Ari Marine Protected Area (SAMPA)

4.1 Geography, topography, weather and climate

The Maldives are an island nation in the Indian ocean and the smallest country in Asia. The country consists of 1190 islands and the archipelago is divided into 26 atolls.

The South Ari Marine Protected Area (SAMPA) is the largest marine protected area in the Maldives and was established in 2009. The protected area stretches along the southern fringe of the South Ari Atoll. It is about 41 kilometres long and it encloses an area of approximately 41 square kilometres.

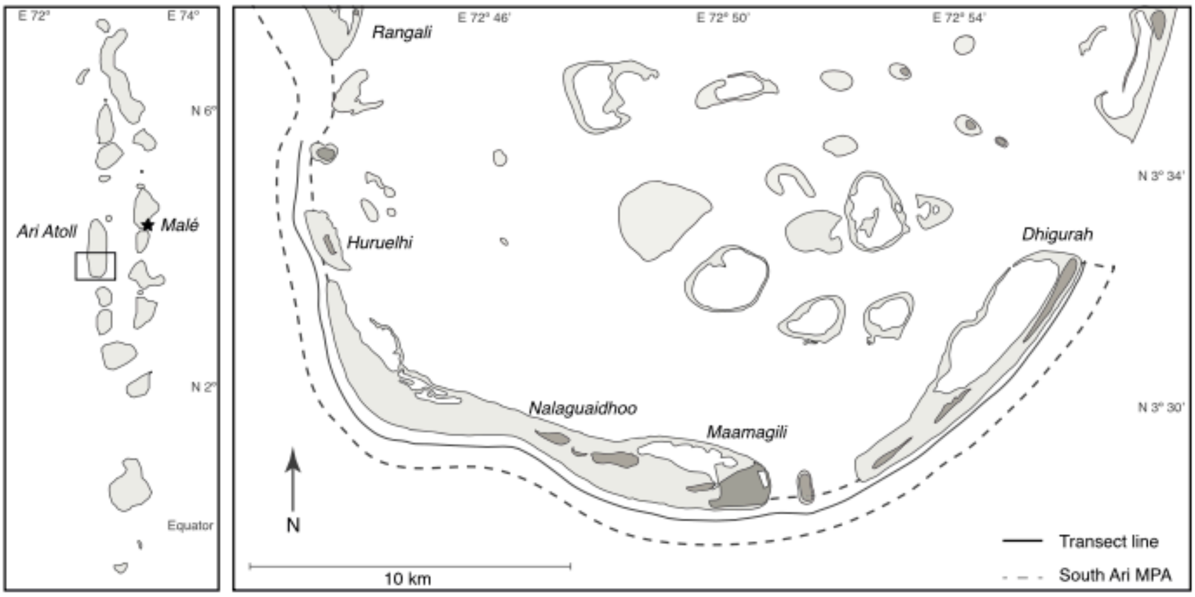


Figure 17: Map of the South Ari Marine Protected Area (source: Cagua, Collins, Hancock, & Rees, 2014, S. 4)

Because of the bended/ c-shaped outline, the SAMPA is affected by wind very differently. The wind follows seasonal changes and there are two distinct seasons in the Maldives: dry season/northeast monsoon from January to March and wet season/southwest monsoon from mid-May to November. During wet season, there are mainly westerly winds and higher chances for rainfall. Dry season, the high season for tourism, is characterized by northerly and easterly winds and more sunshine hours (Maldives Meterological Service, 2018).

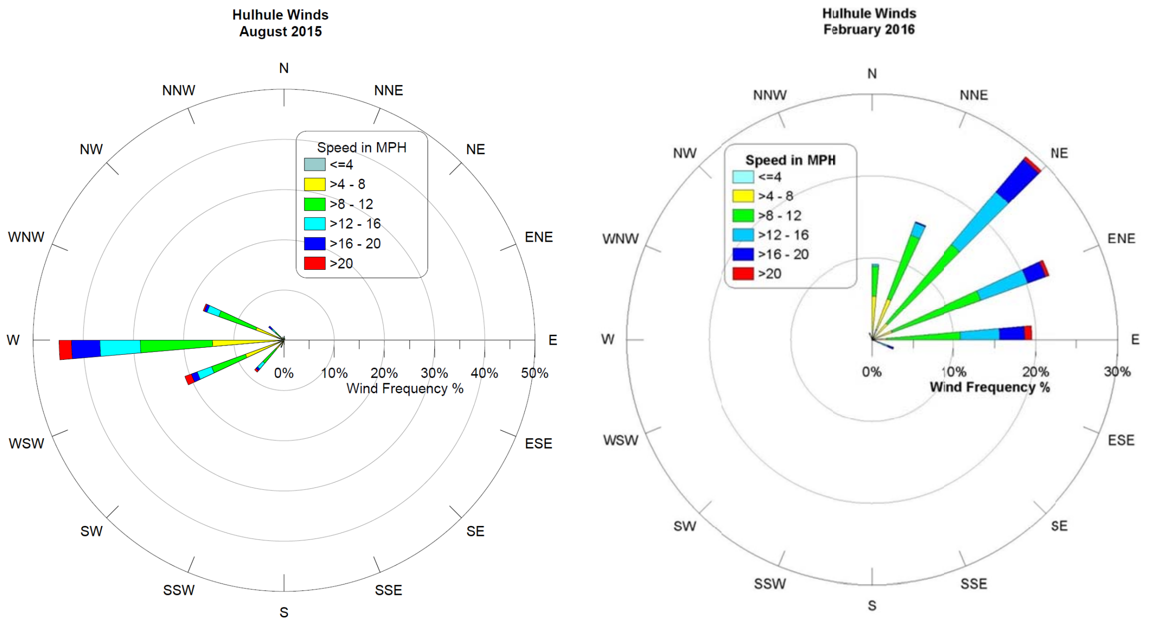


Figure 18: Distribution of wind strength and direction for August 2015 and February 2016 (source: Maldives Meterological Service, 2018)

During the southwest monsoon, the eastward facing side of the SAMPA is often sheltered from the westerly winds, while sea conditions on the westward facing side of the MPA are often rough - the opposite is the case during the northeast monsoon. Thus, there can be seasonal and weather-dependent changes in the spatial distribution of vessels and tourists in the SAMPA (author, personal observation).

The reef crest forms one natural border of the SAMPA. The water close to the reef crest area is only a few centimetres deep and at low tide parts of the algal ridge can even fall dry. From the reef crest the protected area reaches out one kilometre to the ocean-facing side and thus the entire buttress and fore reef zone are protected. The width of the buttress zone varies between 50 and 350 metres and it is significantly narrower on the south-easterly facing side of the marine protected area. The deep fore reef drops down to several hundred metres.

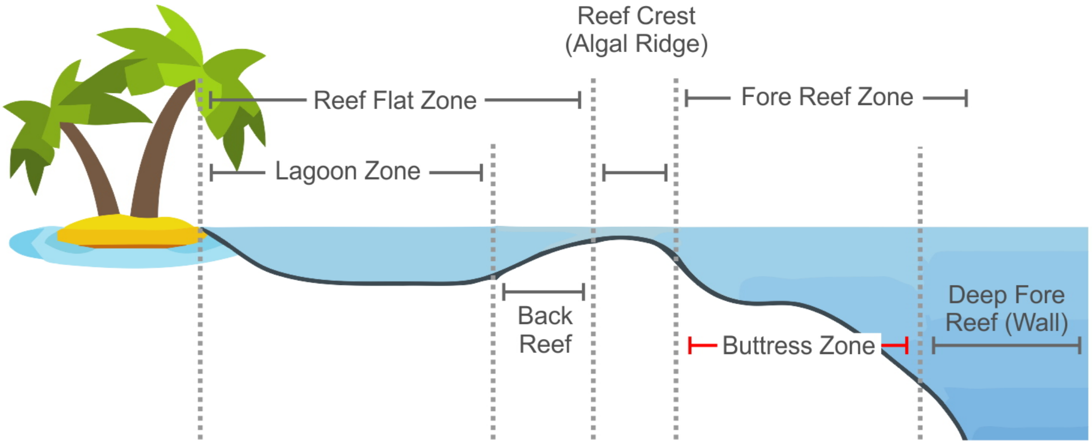


Figure 19: Typical reef topography in the Maldives and the SAMPA (source: Environmental Protection Agency, 2011)

Twelve islands directly border the SAMPA. These include four local islands, four resort islands and four uninhabited islands. There are six tidal channels within the SAMPA that connect the inside of the Atoll with the open ocean.

4.2 Whale shark population in the Maldives and in the SAMPA

With the help of photo-identification, the MWSRP has identified 354 whale sharks in the Maldives (Rees & Hancock, 2018). Since 2006, the organization has logged more than 6000 whale shark encounters in the Maldives with the help of citizen science contributors (Rees & Hancock, 2018). Among the different atolls in the Maldives, most of the whale shark encounters are reported from the North/South Ari Atoll. 81% of all whale shark encounters in the Maldives in 2017 occurred in the North/South Ari Atoll (Rees & Hancock, 2018).

In his review on whale shark occurrences in the Indian Ocean, Rowat (2007) notes that the South Ari Atoll might be the only whale shark aggregation site with a year around “resident population” (Rowat, 2007, p. 99).

The number of whale shark encounters during the MWSRP’s surveys of the SAMPA has been stable over the past five years (see figure 20). However, as these numbers do not consider variations in the search effort, this allows no inference on whale shark population trends or trends in whale shark abundance.

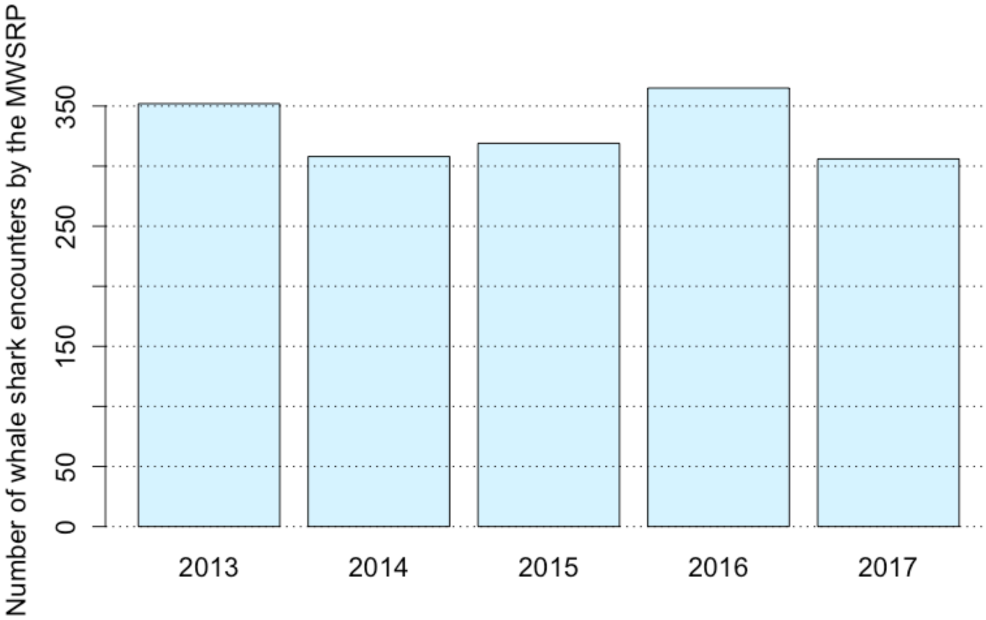


Figure 20: The number whale shark sightings by the MWSRP (source: Rees & Hancock, 2018)

The whale sharks visiting the SAMPA show high site fidelity and are often seen repeatedly. The whale shark with the ID-number WS071, for example, has been identified in 238 encounters over a ten-year-period (Rees & Hancock, 2018, p. 4). The aggregation in the SAMPA is (as in many other aggregation sites (Rowat & Brooks, 2012, p. 1032)) dominated by immature males. The gender of 241 whale sharks has been identified and 85.5% of these whale sharks are males (Rees & Hancock, 2018, p. 9). The average size of the encountered whale sharks in the SAMPA was 5.7 metres with a ranges of 2.5 metres and 8 metres (Rees & Hancock, 2018, p. 8).

More than 50% of the whale sharks in the SAMPA bear signs of anthropogenic injuries (Hindle, 2017). This rate is twice as high as the rate observed off the Yucatan Peninsula in Mexico (Ramírez-Macías, et al., 2012, p. 1408) and comparable to the rate at Panaon Island in the Philippines (Araujo, et al., 2017, p. 990).

4.3 Development of whale shark tourism in the SAMPA

In 2016, the Maldives were visited by 1,286,135 tourists (Ministry of Tourism, 2017). Tourism is the nation's most important economic sector contributing 22.7% to the country's gross domestic product in 2016 (Ministry of Tourism Arts & Culture, 2013). A visitor survey conducted by the Maldivian Ministry of Tourism in February 2017 showed that 11% of the respondents visited the Maldives for snorkelling or scuba diving and that for 16% of the respondents the underwater beauty was the motivation for their travel (Ministry of Tourism, 2017).

High season in the Maldives is during dry season/northeast monsoon from January to April.

The Maldivian Ministry of Tourism distinguishes between four accommodation categories:

1. Resorts: A resort takes up a whole island and is the most popular form of lodging in the Maldives. In 2016, there were 126 resort islands in operation with a total capacity of 27,031 beds.
2. Hotels: Hotels are located on inhabited islands and provide full board service for their guests. In 2016, there were 16 Hotels with 1713 beds.
3. Guest Houses: In 2009, the Maldivian government opened local islands for tourism and this led to the development of a new tourism sector in the Maldives. Guest houses are located on inhabited local islands and normally offer only lodging. The number of guest houses increased five-fold between 2012 and 2016 and in 2016, there were 393 guest houses with a total capacity of 6,044 beds.
4. Safari Vessels: Safari boats are small cruise ships that host mainly divers. Safari vessels typically pick up their guests at the international airport close to the capitol Malé and then cruise through the Maldives visiting different dive sites. In 2016, there were 144 safari vessels with a bed capacity of 2694 beds.

Tourism in the South Ari Atoll began in 1978 with the opening of the first resort island (Ministry of Tourism, 2002). Since then, the bed capacity in the South Ari Atoll has constantly grown from 36 beds in 1978 to 4379 beds in 2016. Recently, especially guest houses were responsible for the increase in the total bed capacity in the South Ari Atoll. 33 guest houses and 17 resorts were located in the South Ari Atoll in 2016 (Ministry of Tourism, 2017).

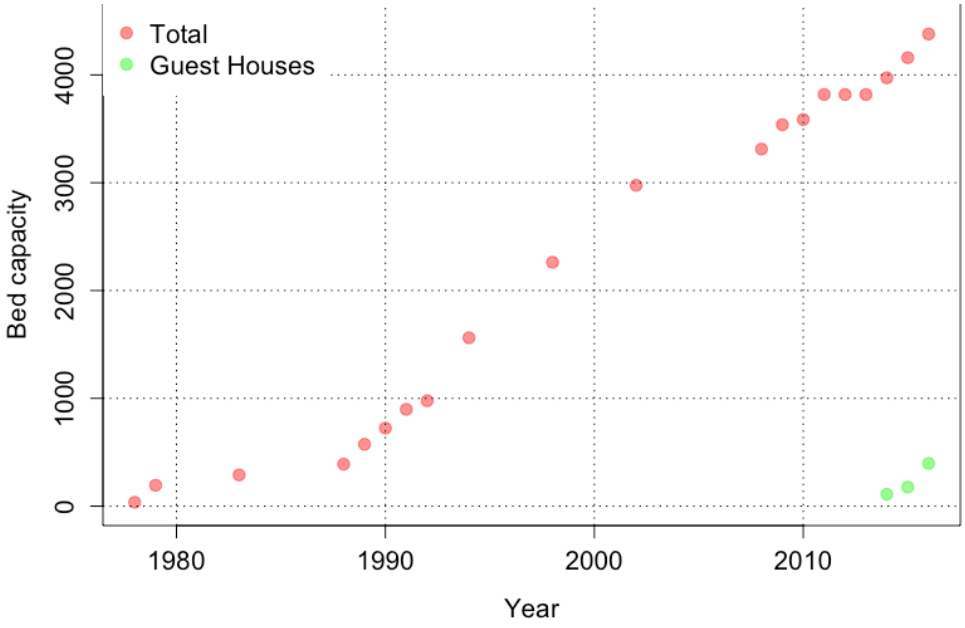
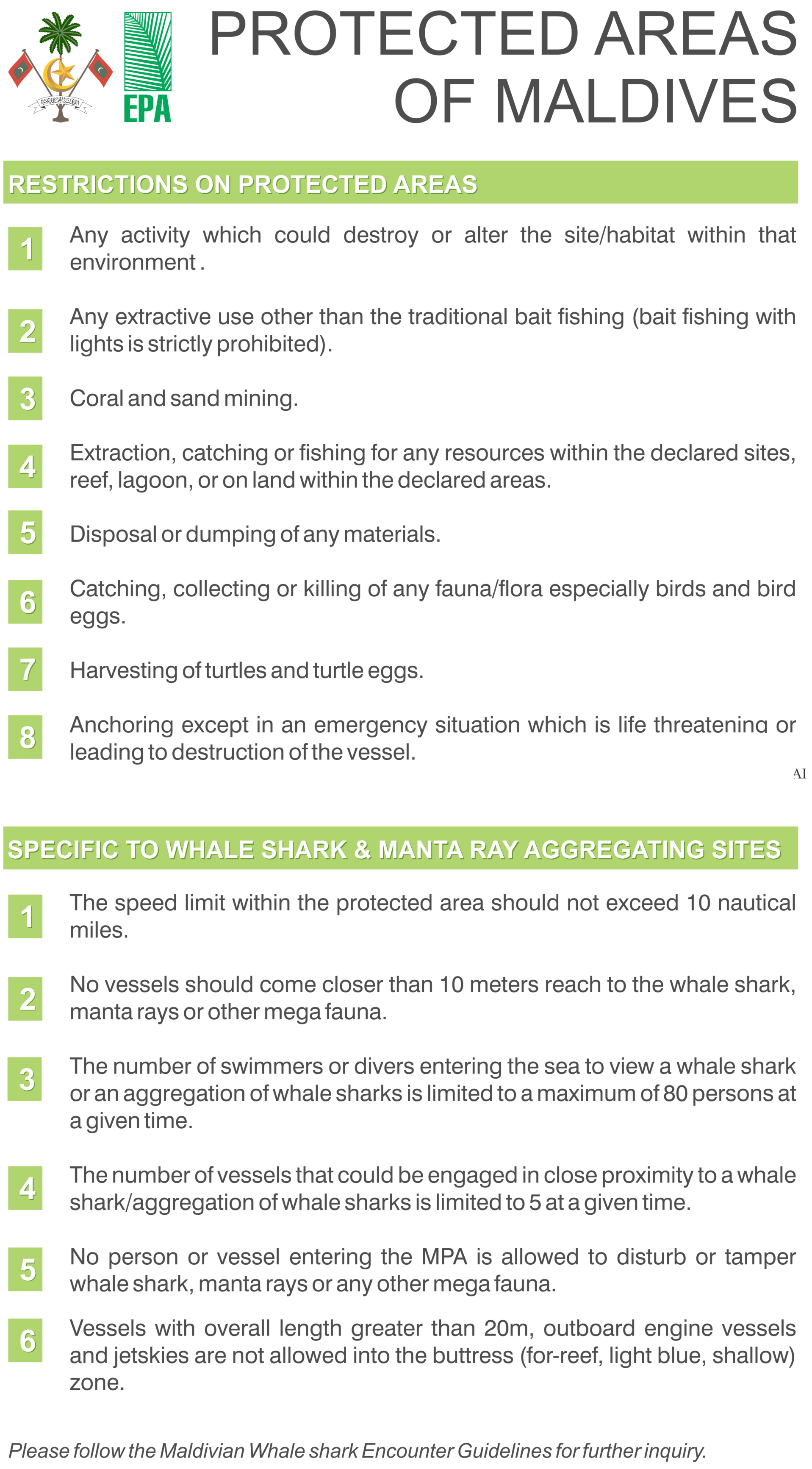


Figure 21: Bed capacity in the South Ari Atoll has increased from 36 in 1978 to 4379 in 2016 (source: Ministry of Tourism, 2017)

It is unclear when the first swim-with whale shark tours were offered in the SAMPA but the development of tourism in neighbourhood to the whale shark aggregation at the southern tip of the South Ari Atoll suggests that the first whale shark tours were offered in the 1990's. Anderson and Ahmed proposed in their review of the shark fisheries in the Maldives in 1993 to ban whale shark fisheries partly due to "the low monetary value of the existing fishery, the serious impact that the fishery may nevertheless be having on Whale Shark stocks, and the possible benefits of Whale Shark to the tuna fishery and to the tourist industry" (Anderson & Ahmed, 1993, p. 45). The government of the Maldives followed this recommendation and since 1995 whale sharks have been protected by in the Maldives.
Cagua, Collins, Hancock and Rees (2013) calculated that the whale sharks in the SAMPA attracted 78,000 visitors in 2013 and that direct expenditures on whale shark tours totalled 9.4 million US$. A visitor survey conducted by the Maldivian Ministry of Tourism showed that "[o]ne out of every four visitors to the Maldives during the peak season of 2017 visited the whale shark point in Ari Atoll" (Ministry of Tourism, 2017, p. 52). High Season (January to April) 2016 saw 447,659 visitors, which would mean that more than 100,000 visitors visited the SAMPA in just these four month. Hence, the demand to swim with sharks in the Maldives and the popularity of the whale shark aggregation in the SAMPA seem to have grown significantly since 2013.

4.4 Current regulation

There are currently eight restrictions that apply to all protected areas, including marine protected areas, in the Maldives. Additionally, the Maldivian environmental protection agency has introduced six specific restrictions for whale shark and manta ray aggregation sites (see figure 22).



PROTECTED AREAS OF MALDIVES

RESTRICTIONS ON PROTECTED AREAS

1. Any activity which could destroy or alter the site/habitat within that environment .
2. Any extractive use other than the traditional bait fishing (bait fishing with lights is strictly prohibited).
3. Coral and sand mining.
4. Extraction, catching or fishing for any resources within the declared sites, reef, lagoon, or on land within the declared areas.
5. Disposal or dumping of any materials.
6. Catching, collecting or killing of any fauna/flora especially birds and bird eggs.
7. Harvesting of turtles and turtle eggs.
8. Anchoring except in an emergency situation which is life threatening or leading to destruction of the vessel.

AI

SPECIFIC TO WHALE SHARK & MANTA RAY AGGREGATING SITES

1. The speed limit within the protected area should not exceed 10 nautical miles.
2. No vessels should come closer than 10 meters reach to the whale shark, manta rays or other mega fauna.
3. The number of swimmers or divers entering the sea to view a whale shark or an aggregation of whale sharks is limited to a maximum of 80 persons at a given time.
4. The number of vessels that could be engaged in close proximity to a whale shark/aggregation of whale sharks is limited to 5 at a given time.
5. No person or vessel entering the MPA is allowed to disturb or tamper whale shark, manta rays or any other mega fauna.
6. Vessels with overall length greater than 20m, outboard engine vessels and jetskies are not allowed into the buttress (for-reef, light blue, shallow) zone.

Please follow the Maldivian Whale shark Encounter Guidelines for further inquiry.

Figure 22: Current regulations applying to the SAMPA (source: Environmental Protection Agency, 2011)

Regulation	**Ningaloo Reef, Australia** (Department of Parks and Wildlife, 2013)	**Donsol, Philippines** (Pine, 2007) (Quiros, 2007)	**Gladden Spit, Belize** (Wildtracks, Belize; SEA Belize; Belize Fisheries Department, 2010; Graham & Roberts, 2007)	**Isla Holbox, Mexico** (Ziegler, et al., 2016; Suárez, et al., 2007)	**Bahía De Los Angeles, Mexico** (Cárdenas-Torres, et al., 2007; Rodríguez-Dowdell, et al., 2007)	**South Ari Marine Protected Area** (Environmental Protection Agency, 2011)
Speed Limit	8 knots within 250 metres of the whale shark	N/A	< 2 knots in vicinity of the whale shark	3 knots in the observation area	8 mph in the observation area	10 knots in the marine protected area and 2 knots within 50 metres of the whale shark
Minimum distance between vessels and the whale shark	30 metres	N/A	50 feet from the whale shark and 200 feet from other vessels	10 metres from the whale shark and 100 metres from other vessels	5 metres	10 metres
Limiting the number of boats in contact with one whale shark:	1	1	N/A	1	1	5
Limiting the number of people in contact with one whale shark:	10 tourist plus 1 guide and 1 videographer.	6	N/A	2 swimmers and 1 guide per whale shark	4 in total 2 swimmers on each side of the whale shark	80
Minimum distance of swimmers from the whale shark	4 metres distance from the tail and 3 metres distance from the head and body.	4 metres distance from the tail and 3 metres distance from the head and body.	15 feet	Swimmers must keep at least 2 metres distance from the whale shark	2 metres distance from the tail and 1 metre distance from the head and body.	4 metres distance from the tail and 3metres distance from the head and body.

Table 1: Overview of whale shark tourism regulations in Australia, the Philippines, Belize Mexico and the Maldives (source: see table top row)

Table 1 shows that the limitations for the number of swimmers and vessels in contact with one whale shark exceed the limits set at other aggregation sites substantially, e.g. five times the amount of boats and twenty times the amount of people as compared to the regulations in Bahìa De Los Angeles in Mexico.

The code of conduct for swimmers and operators/boat captains was adopted from the Ningaloo Reef with only a few changes (see figure13) e.g. minimum distance for vessels was decreased from 30 to ten metres, speed limits were changed and the use of scuba diving equipment is allowed in the SAMPA.

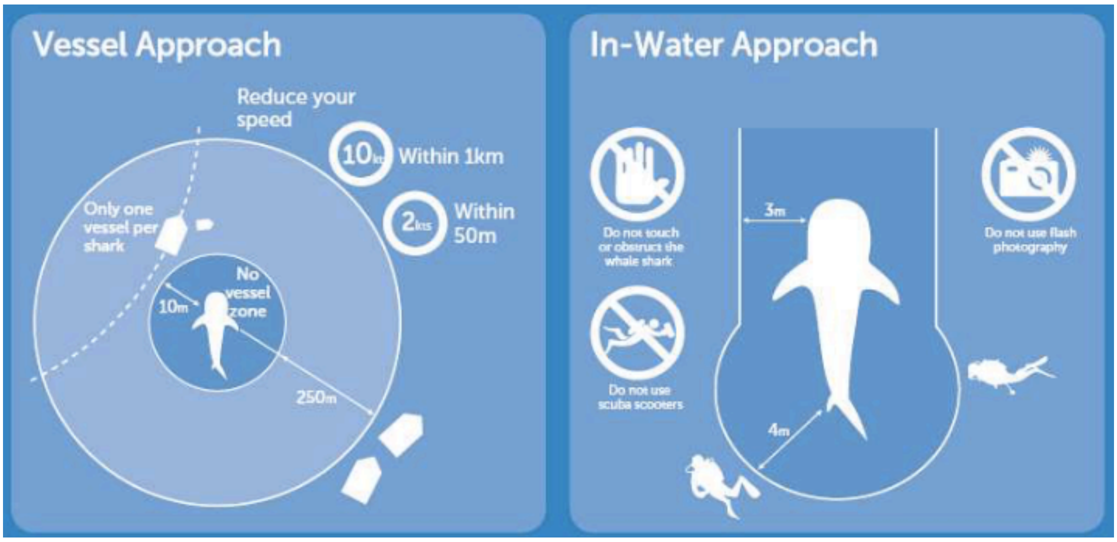


Figure 23: Code of conduct for vessels and swimmers in the SAMPA (source: Leston, 2016, p. 42)

The current regulations do not require commercial operators to hold a licence, permit or certification to offer ‘swim-with’ whale shark tours in the SAMPA. Furthermore, there is no cap on the number of vessels and tourists in the SAMPA at one time. Thus, there is free access to the resource and the whale shark aggregation can be classified as a common pool resource.

The compliance of operators and swimmers with the existing regulations is not monitored and hence in up to 75.58% of the whale shark encounters at least one of the rules applying to whale shark tourism in the SAMPA was broken. This high non-compliance rate not only reflects the lack of enforcement but also the lack of acceptance of the current regulations by swimmers and operators. In the following chapter, 964 whale shark encounters in the SAMPA are analysed to quantify the discrepancy between the existing regulations and the current practice.

4.5 Data summary and current practice

The data used to build the models was collected between 02.02.2015 and 19.12.2017. In total 593 surveys of the SAMPA by the MWSRP are analysed. The average net time searching per survey was 261 minutes ranging from only three up to 523 minutes. The net time searching is the time that the research team spends on the roof of the research vessel surveying the SAMPA and is mainly influenced by organizational constraints, weather and sea conditions (e.g. rough seas conditions can shorten a survey).

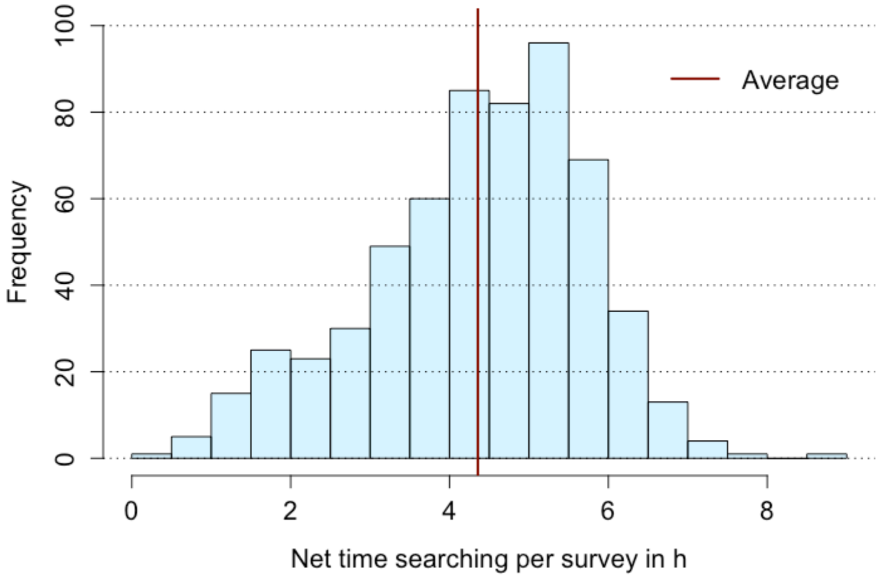


Figure 24: Histogram of the net time searching the red vertical line shows the average

Due to variations in the duration of the surveys, the net time searching is used as an approximate value for the search effort instead of the number of surveys. The annual net time searching increased from 822 hours in 2015 to 928 hours in 2017.

The monthly distribution of the net time searching shows that in the months of December, June and January the search effort was below the monthly average - mainly due to organizational constraints of the programme. August, September and October were the months with the highest search effort.

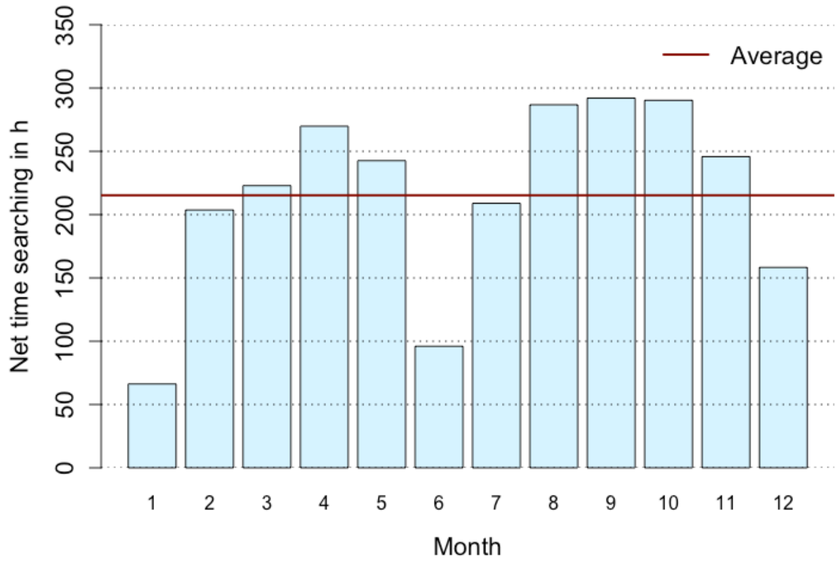


Figure 25: Monthly distribution of the net time searching

The MWSRP conducts surveys on five days a week and the programme stays on the island on most of the Fridays and Saturdays (see Figure 26).

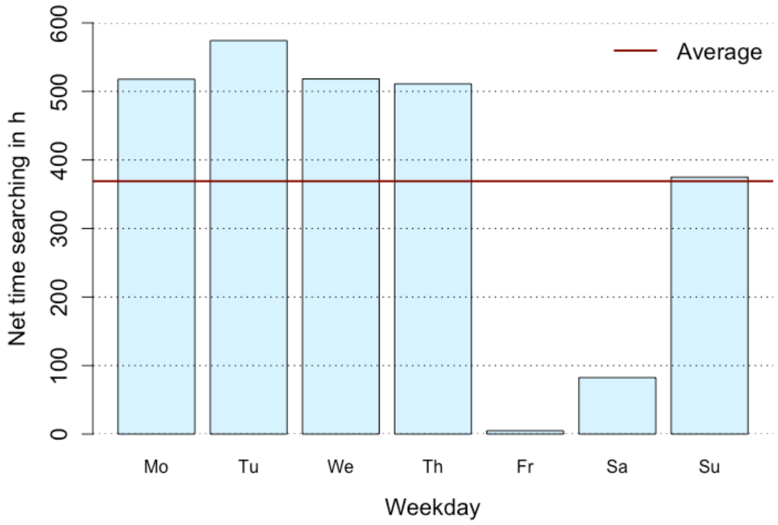


Figure 26: Distribution of the net time searching across the different weekdays

Whale sharks were encountered in 61.72% of the surveys. The number of whale shark encounters varied between zero and 3.33 encounters per hour net time searching (see figure 27). On average, there were 0.36 whale shark encounters per hour net time searching.

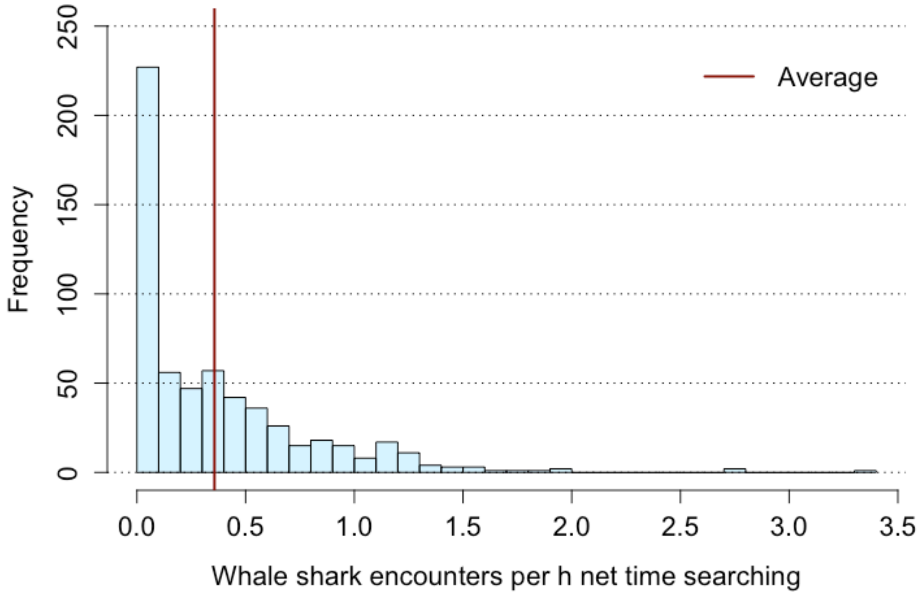


Figure 27: Histogram of whale shark encounters per hour net time searching

The whale shark encounters lasted between one and 76 minutes. The median encounter duration was 7 min. These numbers refer only to whale shark encounters that were started by the researchers and ended with the whale shark swimming or diving out of sight. Encounters that were joined or ended by the researchers were not considered.

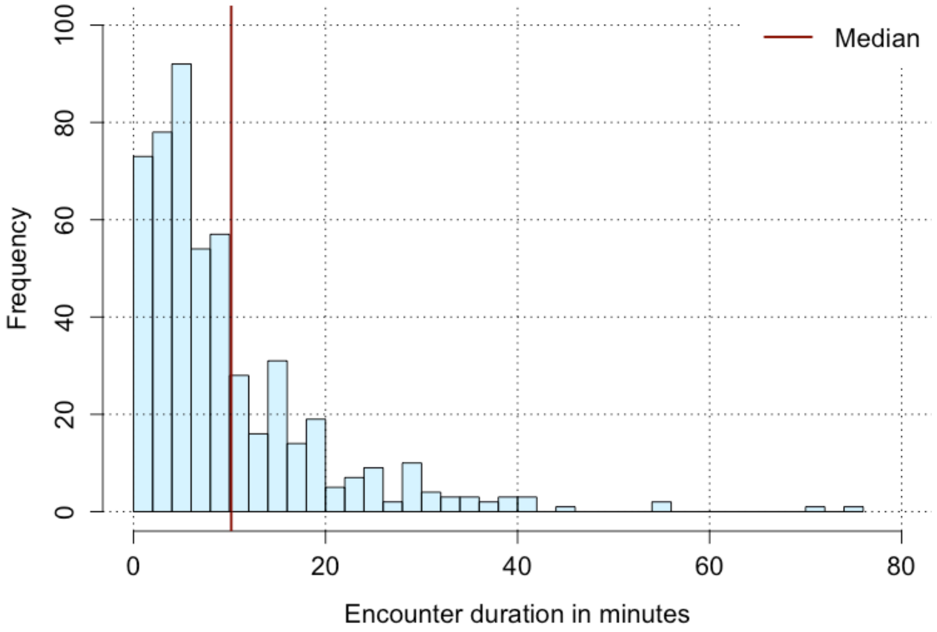


Figure 28: Histogram of the encounter duration

In contrast to many other whale shark aggregation sites, whale sharks are spotted all year-round in the SAMPA. However, the monthly distribution of the average number of whale shark encounters per hour net time searching shows strong variations between the different months (see figure 28). Except for the month of February and September, the average number of whale shark encounters per hour net time searching follows the course of a parable with the minimum turning point in June

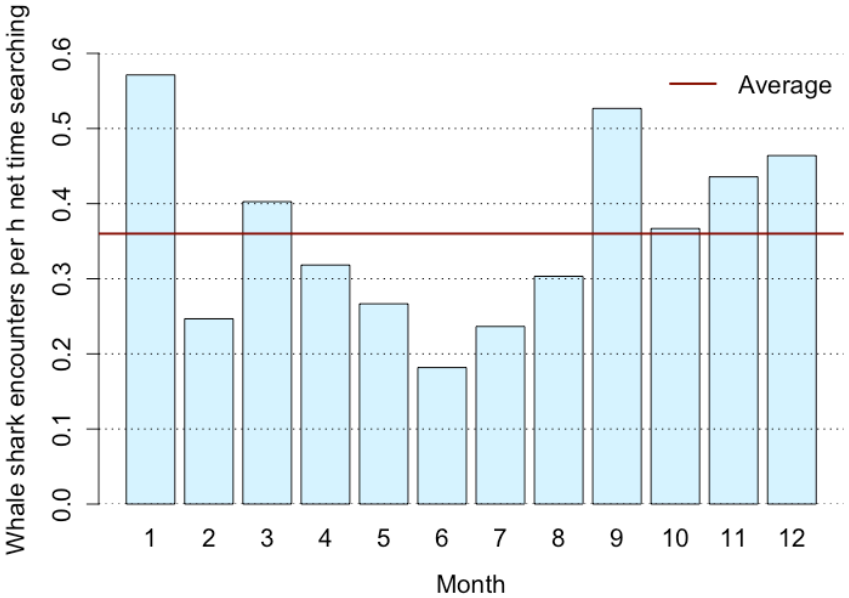


Figure 29: Monthly distribution of the whale shark encounters per h net time searching

Most of the whale sharks were spotted around midday (see figure 30). During midday, the sun is at its zenith and hence it is easier to spot the silhouette of a whale shark from a boat (see figure 31).

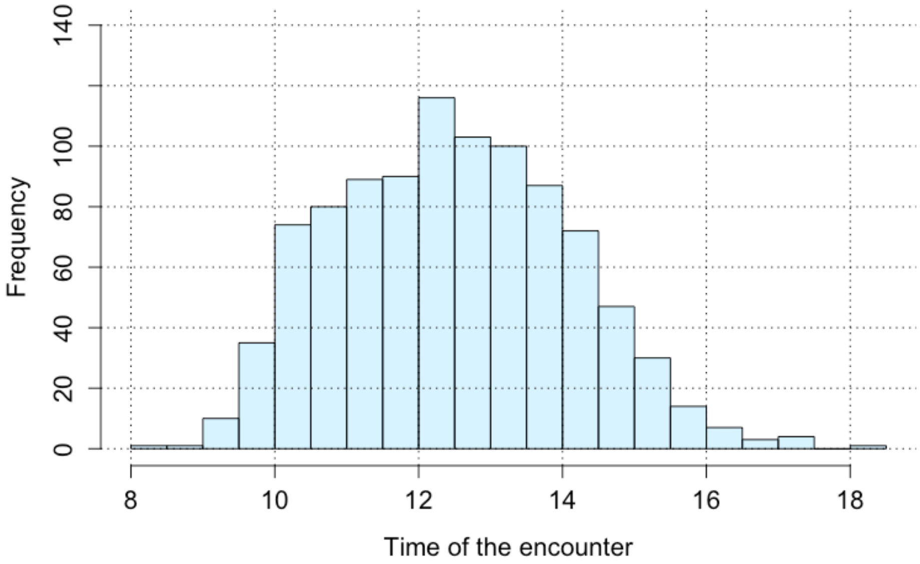


Figure 30: Histogram showing the time of the encounter

Besides the position of the sun, the sea state, the underwater visibility, cloud cover and glare are factors influencing the likelihood of a whale shark being spotted (Rowat, et al., 2009, p. 2). The better the conditions for spotting, the more likely it is to find a whale shark deeper in the water column.

Figure 31: The silhouette of a whale shark photographed from the roof of the research vessel (source: author)

About two thirds of the whale sharks were sighted in the fore reef zone (encounters left of the dark red vertical line) and 19.48% of the whale shark encounters were started in the very shallow buttress zone of the reef (encounters left of the pink line).

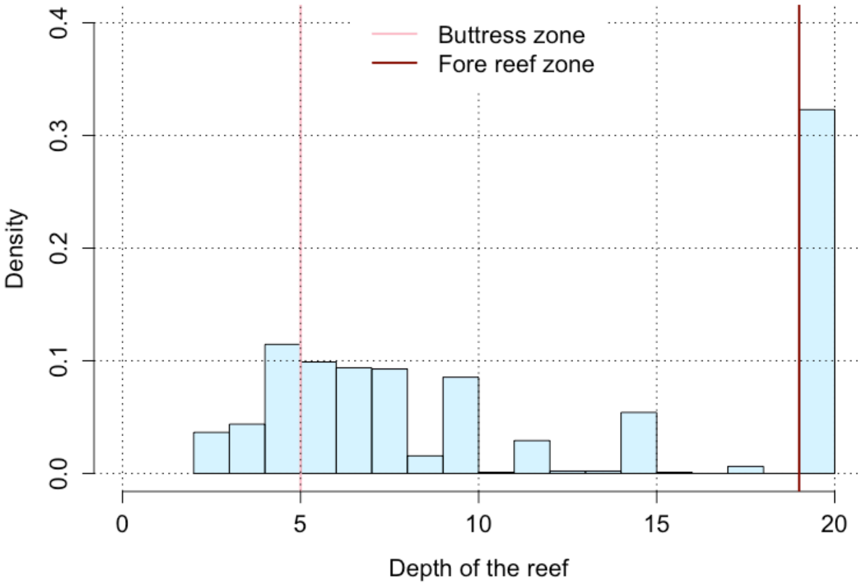


Figure 32: Distribution of the recorded reef depth; the pink vertical line shows the border of the buttress zone and the red vertical line shows the border of the fore reef zone

The water depth also influences the minimum recorded depth of the whale shark which ranged from zero to 25 metres.

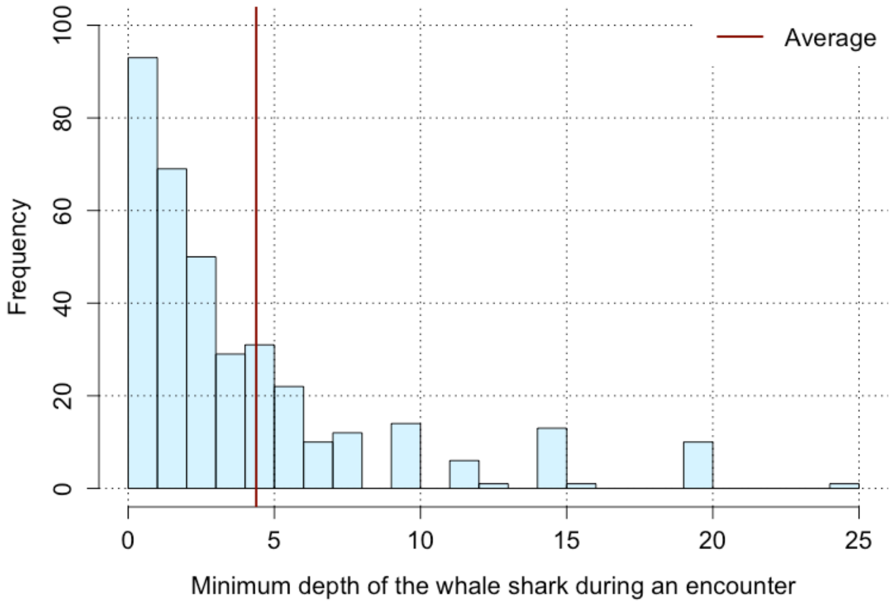


Figure 33: Distribution of the minimum recorded depth at which the whale shark was seen at an encounter

In 93 or 25.69% of the whale shark encounters in which the minimum shark depth was recorded, the whale shark was swimming at a water depth of just one metre or shallower. Therefore, there is a high risk for whale sharks to collide with vessels (see figure 8) or be struck by a propeller in the SAMPA.

The MWSRP logs all vessels inside the SAMPA and their number of passengers on their surveys.

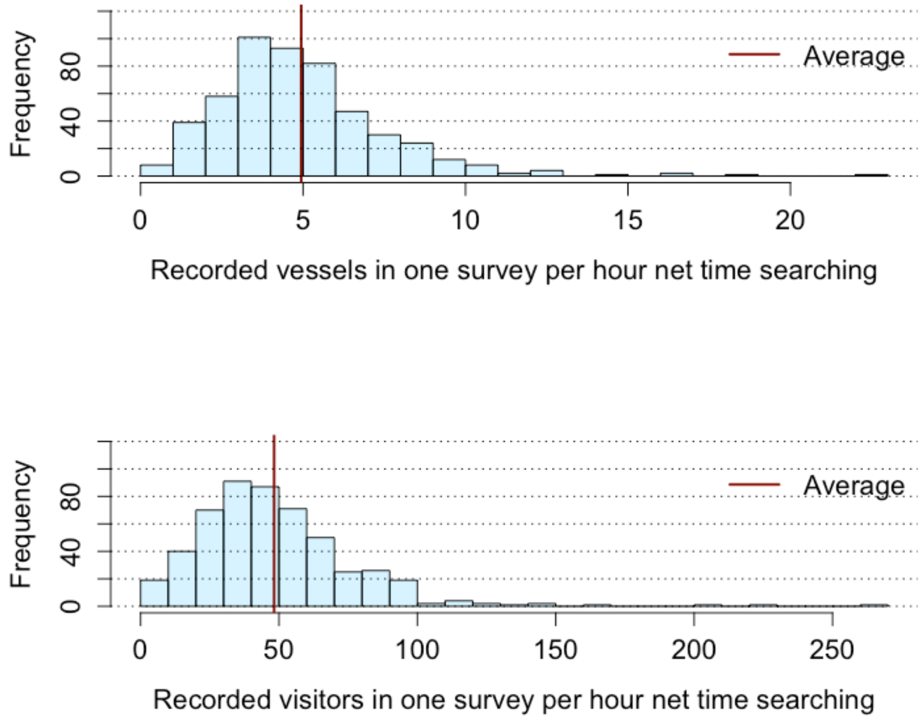


Figure 34: Histograms showing the total number of people and the total number of boats counted per hour net time searching

The maximum number of boats and the maximum number of people counted in one hour net time searching were 22 and 268 respectively (see figure 34). On average, there were 4.94 boats and 48.25 visitors recorded per hour net time searching. These numbers are likely to underestimate the total number of people and boats, as the surveys lasted on average only 262 minutes and rarely covered the entire SAMPA. Therefore, chances are high that vessels visiting the SAMPA were not recorded by the MWSRP. Furthermore, counting the exact number of passengers can be challenging as people can be hidden, moving or scuba diving at the time the number of people on a vessel is counted.
There is a strong correlation between the number of boats and the number of people (Pearson's correlation coefficient: 0.9241 with the 95% confidence interval ranging from 0.9104 to 0.9358). Plotting the number of people over the number boats shows a linear relationship between the two variables (see figure 35).

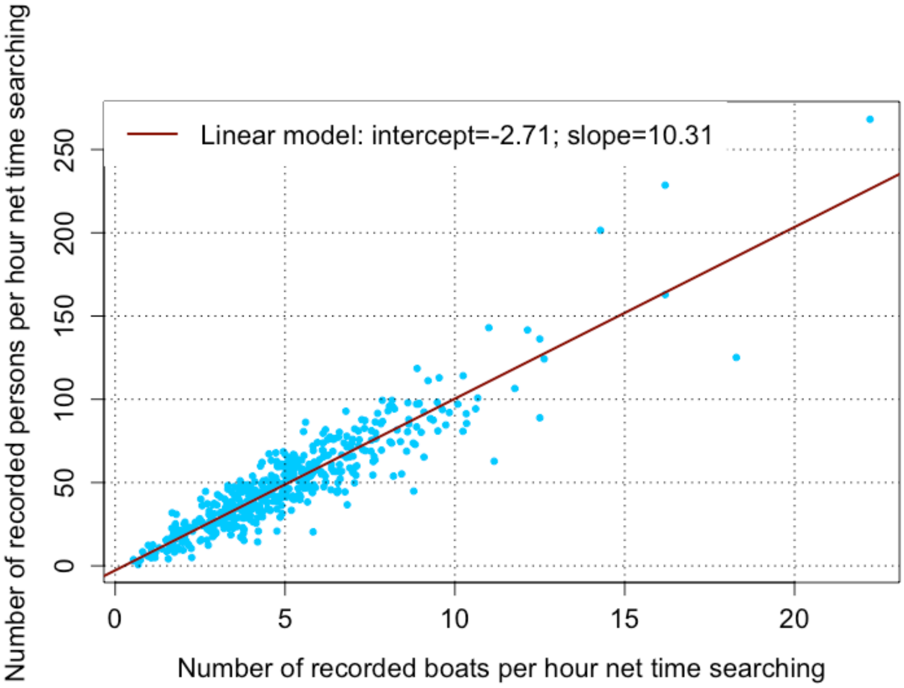


Figure 35: Number of recorded boats and people per hour net time searching with a linear model

The number of boats recorded in one hour net time searching increased from 4.47 in 2015 to 5.25 in 2017 and the number of visitors recorded in one hour net time searching increased from 41.4 in 2015 to 50.8 in 2017, peaking in 2016 at 53.4.

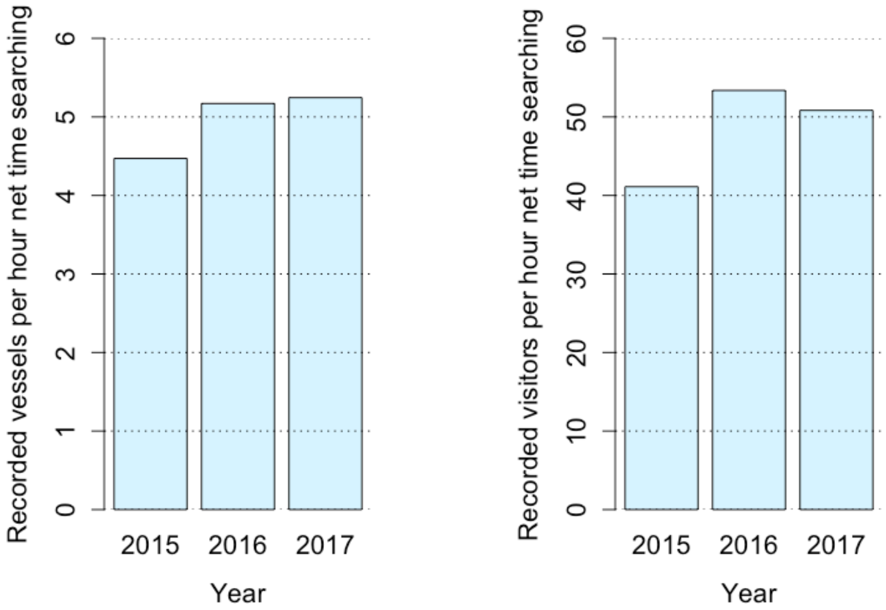


Figure 36: Annual development of the recorded number of boats and people per hour net time searching

Looking at the monthly average recorded number of passengers per hour net time searching shows that for the months between March and November, the number of passengers follows the seasonal trends of the visitor numbers of the entire Maldives (Ministry of Tourism, 2017). However, the seasonal variations in the recorded number of passengers per hour net time searching are more distinct than the seasonal changes on the national level. There are up to twice as many passengers recorded per hour net time searching in peak season (January, February and March) compared to the number of visitors in low season (Mai, June and July).

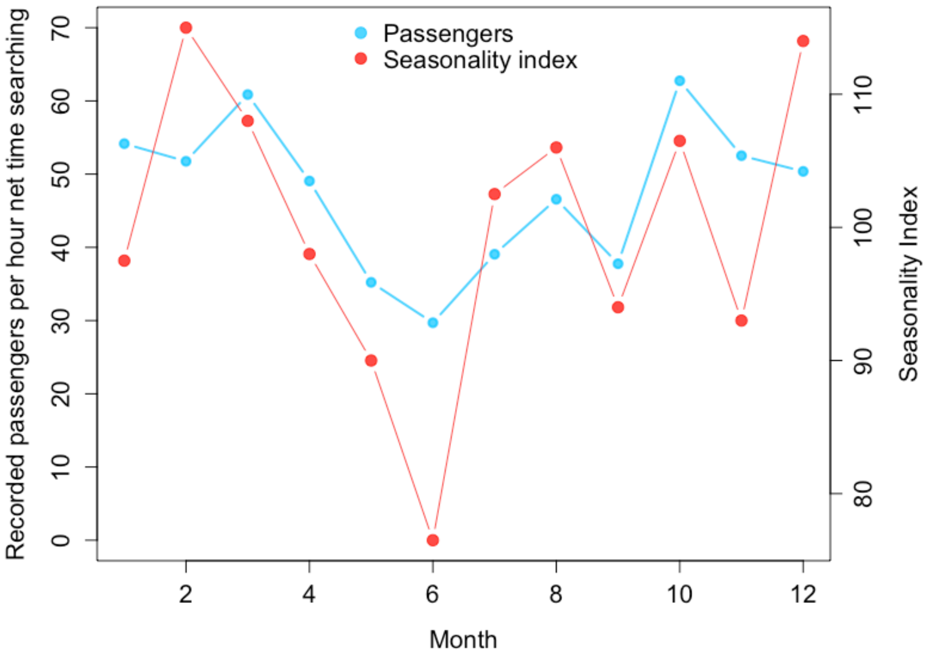


Figure 37: Average number of visitors per hour net time searching and average seasonality index for the years 2015 and 2016 (source: Ministry of Tourism, 2017)

The distribution of vessels over the different weekdays shows that there are more boats in the middle of the week than on the weekends. The peak in the number of vessels on Wednesdays is caused by the safari boats. While the resorts and guesthouses visit the area on a daily basis, safari boats visit the SAMPA only on a weekly basis. Typically, passengers board the safari boats in Malé on the weekend and then cruise through the Maldives following different routes. The SAMPA is a famous destination for safari boats and most of the safari vessels arrive on Tuesday, Wednesday and Thursday in the South Ari Atoll. Thus, the safari boats add to the normal crowd on these days.

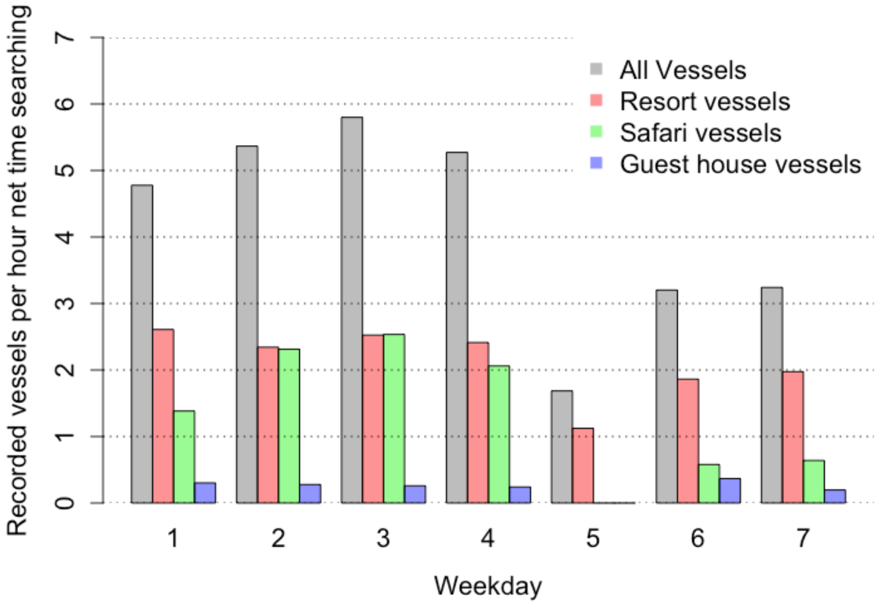


Figure 38: Distribution of vessels by type for the different weekdays

There was an average maximum number of 3.95 vessels interacting with one whale shark at same time. The histogram below shows that the most frequent value is only one vessel (only the research vessel) per whale shark (33.51%).

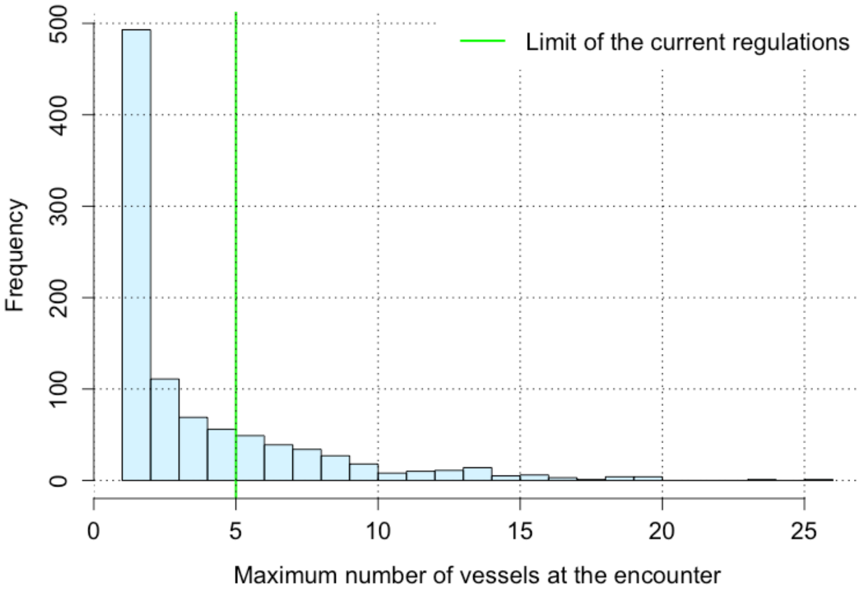


Figure 39: Distribution of the maximum number of vessels per encounter; the vertical green line shows the current limit for the number of vessels in contact with one whale shark

The vertical green line in figure 39 shows the current limit for the number of vessels in contact with one whale shark. In all encounters to the right of that line the current regulations were broken. The non-compliance rate with the rule was 24.38% and the maximum number of vessels recorded at one encounter was 26.

Figure 40: A whale shark encounter with nine vessels interacting with the same whale shark in the centre of the picture (source: author)

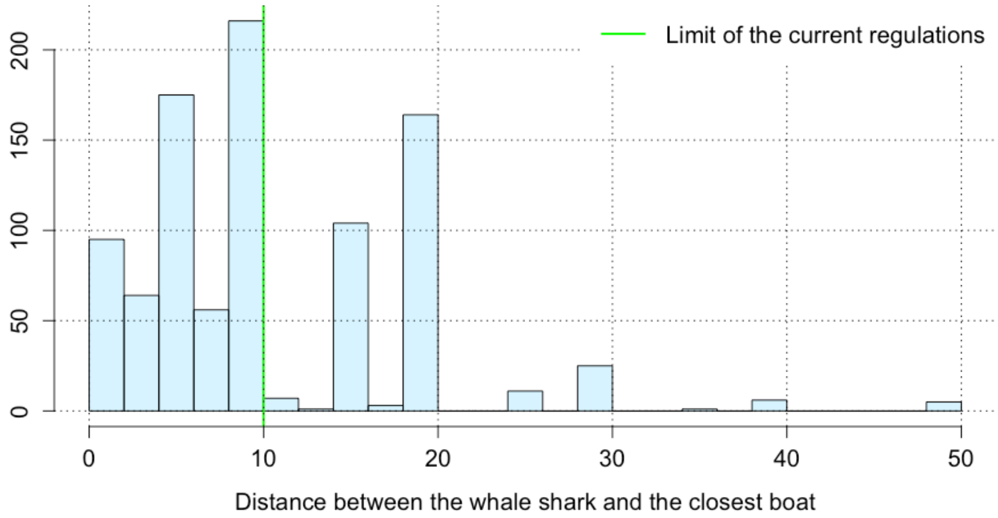


Figure 41: Distribution of the distance between the whale shark and the closest vessel; the vertical green line shows the current limit for the minimum distance between vessels and a whale shark

The current regulations for whale shark tourism in the SAMPA require a minimum distance of ten metres between the whale shark and any vessel. The non-compliance rate with the rule was 64.95%, hence in the majority of the encounters vessels came too close to the whale shark. The high number of vessels in the immediate vicinity of the whale shark can have several negative effects:

- There is an added risk for boat collision.
- There is an added risk for swimmers or submerged scuba divers to get run over by boats.
- Since whale sharks are often seen close to the water surface, there is an added risk of collision with a vessel or getting struck by a propeller.
- The number of boats and their proximity are two critical factors influencing the level of perceived crowding and the quality of the experience (Ziegler, et al., 2016, p. 617).

The speed limit inside the SAMPA is currently 10 knots. 7.55% of the recorded vessels were clearly exceeding this speed limit. 65.14% of these vessels were speed boats operated by resorts or guest houses (figure 42). Speed boats can carry up to 25 passengers and are typically powered by one or two outboard engines. For resorts from further away, speed boats are the only option to offer convenient day-trips for their guests to the SAMPA; speed boats all the way from Kaafu Atoll (100 kilometres north west of the SAMPA) were registered.

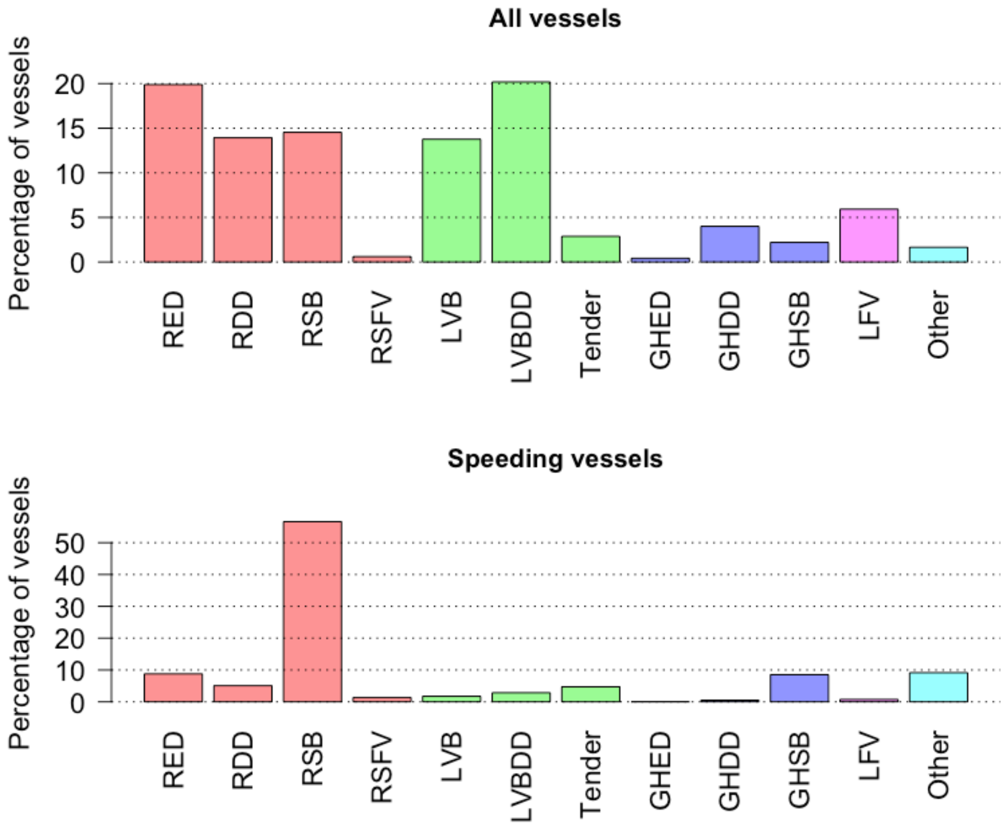


Figure 42: Composition of vessels recorded inside the SAMPA : RED = Resort Excursion Dhoni, RDD = Resort Dive Dhoni, RSB = Resort Speed Boat, RSFV = Resort Fishing Vessel, LVB = Safari Live-Aboard Vessel with cabins and kitchen etc., LVBDD = Boat travelling with a LVB that takes the divers to the different dive sites, carries the compressor and diving equipment, Tender = small dinghy belonging to a LVB, GHED = Guest House Excursion Dhoni, GHDD = Guest House Diving Dhoni, GHSB = Guest House Speed Boat, LFV = Local Fishing Vessel

The median maximum number of people interacting with the same whale shark was 16. In 35 instances the existing limit of 80 people interacting with the same whale shark was exceeded (see figure 43). Besides the number of boats, the number of people is another important factor influencing the level of perceived crowding.

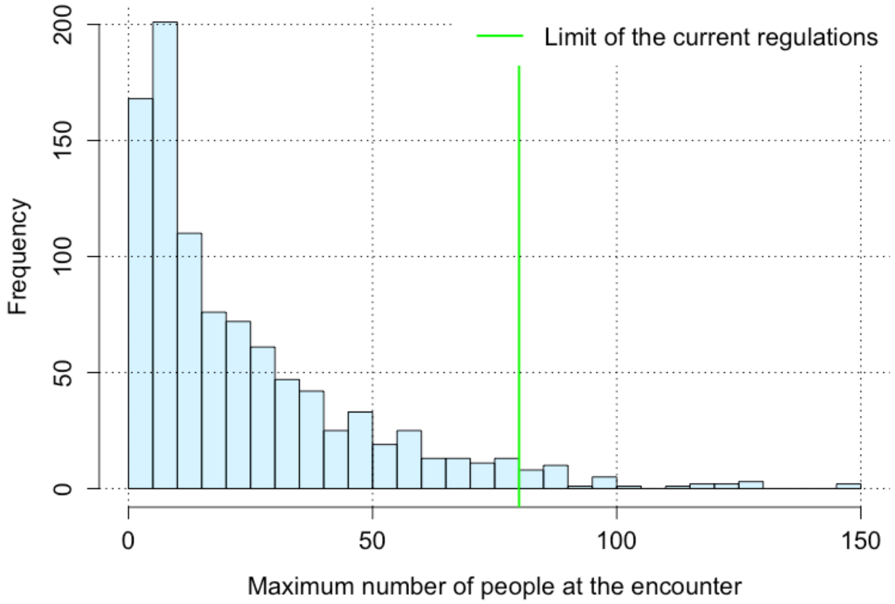


Figure 43: Distribution of the maximum number of people at an encounter; the vertical green line shows the current limit for the number of people in contact with one whale shark

The compliance rate with the in-water guidelines was 60.14% in encounters with at least more than one other boat than the research vessel present.

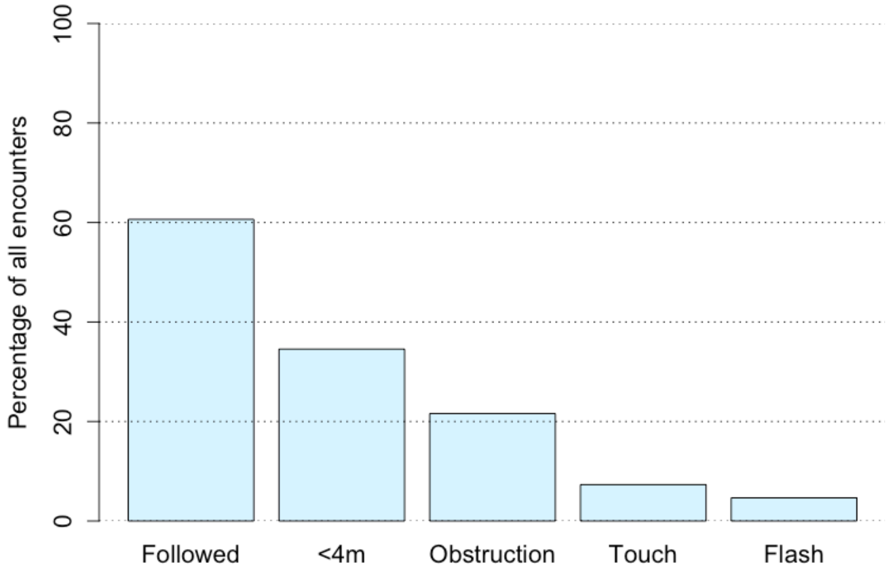


Figure 44: Compliance to the in-water code of conduct

In most of the instances in which the code of conduct was broken, people got too close to the whale shark (35.53%). In 21.66% of the encounters, the path of the whale shark was obstructed by people swimming or diving in front of the animal (see figure 45). Physical contact and the use of flash photography were observed in 7.11% and 4.51% of the encounters.

Figure 45: Obstruction of the natural path of a whale shark by a diver taking a photo (source: author)

The wide-spread misconduct of operators and swimmers might intensify the occurring negative impacts of tourism on whale sharks described in section 3.1 e.g. vessels exceeding the speed limit having a higher chance of accidently running over a shark than slow moving vessels obeying the speed limit (Burgin & Hardiman, 2015, p. 214). But not only are the whale sharks impacted by violations of the existing regulations, the quality of the experience for the participants is also adversely affected by the misconduct of operators and swimmers e.g. the level of perceived crowding is influenced by the number of vessels and swimmers. If no changes to the current form and extent of tourism in the SAMPA are made, this may result in an overshoot of the social and ecological carrying capacity of the whale aggregation (see section 2.2 and 2.4).

5 Modelling

The aim of the modelling is to find patterns in the data described above that stimulate compliance with the code of conduct and the undisturbed behaviour of the whale shark. The patterns can be used to identify the potentially most effective leverages to improve the regulations of the SAMPA and ensure that the social and ecological carrying capacity of the whale shark aggregation is not exceeded. The chapter will start with an introduction of decision trees and random forests, the instruments that were used for the pattern recognition. Following an explanation on how the instrument was applied to the data in section 5.2, the last section of the chapter will give an overview of the results.

5.1 Decision Trees

Decision trees are a nonparametric tool (Barros, et al., 2015, p. 8) used to solve regression and classification problems. One key to the method's success is its simple and thus easily comprehensible structure, which "closely resemble[s] human reasoning" (Kotsiantis, 2013, p. 261).

Decision trees classify data or predict a variable of a given data set by successively splitting the data into different branches. Starting at the root, the algorithm will search for the feature/variable that will yield the maximum information gain for determining the response variable's class. If the most informative variable is found, the observations are divided into two branches. This procedure is repeated until either a pre-defined termination criterion is reached or no more splits are possible. With every split, the purity in the subordinate branches increases. The maximum purity in a branch is reached when it contains only observations of one class of the response variable. As this allows no further splits, this branch or node will form a leaf or terminal node (Barros, et al., 2015, p. 13).

Decision trees can be used for classification and regression problems. Regression trees use the same algorithm as classification trees, with the only difference being that the different classes for the values of the response variable are subsequently defined and introduced because the leafs/terminal nodes are formed by continuous values (Barros, et al., 2015, p. 8).

The stepwise procedure makes the results easy to visualize and allows full comprehension of how the model classifies the observations in the sample into the different classes of the response variable (see figure 46). Additionally, the subsequent partitioning of the data makes it possible to treat every variable independently at each split. Hence, decision trees can contain variables of various types (e.g. binary, numeric, factor) and do not require any scaling (Wehrens, 2011, p. 126).

Figure 46 shows the visualized decision tree model to predict the status of the code of conduct. The tree has four terminal nodes or leafs and uses three different splitting criteria to classify the observations in the sample – two numeric (maximum number of persons and minimum depth of the whale shark) and one binary (divers present or absent).

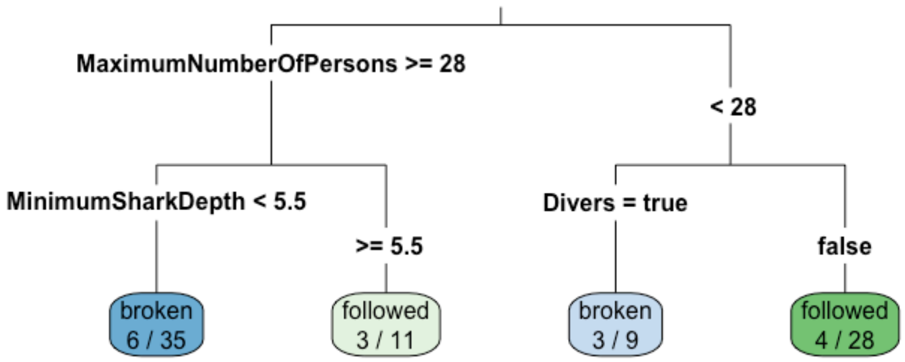


Figure 46: Decision tree to predict the status of the code of conduct.

Another strength of decision trees lies in the variable selection. The algorithm only chooses informative variables that lead to a gain in the accuracy of the predictions of the response variable's class. Thus, noisy variables or variables which are not related to the response variable do not appear as a node in the tree structure (Wehrens, 2011, p. 126).
The biggest disadvantage of decision trees is the risk of overfitting the data to the training sample (Wehrens, 2011, p. 135; Ziegler & König, 2014, p. 55). Decision tree models are very sensitive to changes in the sample as every change in the sample can change the entire structure of the tree and hence the interpretation of the results (Kotsiantis, 2013, p. 277). Overfitting can be avoided by setting a termination criterion, so that not all possible splits are made. Another possibility is to prune the tree afterwards and thus simplify it (Barros, et al., 2015, p. 10).

5.1.1 Random Forests

Random forests are another way to make decision trees less sensitive to changes in the sample and improve the model's predictions of unseen data (observations not used to build the model). The algorithm was invented by Breiman in 2001 (Genuer, et al., 2010, p. 2225) and is an extension of the decision tree algorithm. Random forests use an ensemble of trees to classify the observations according to the classes of the response variable. To prevent the trees from being overly sensitive to small changes in the sample, the construction of the trees depends partly on two random elements (Kotsiantis, 2013, p. 278):

1. The algorithm does not use the entire sample to build each tree, instead using a randomly chosen bootstrap-sample. The use of multiple, randomly permuted samples lessens the effect of changes in the entire training sample on the results of the model (Kotsiantis, 2013, p. 278).
2. The algorithm tries only a randomly chosen fraction of all variables to divide the training sample at each split (Kotsiantis, 2013, p. 278).

Because of the two random elements, all trees of the ensemble differ.

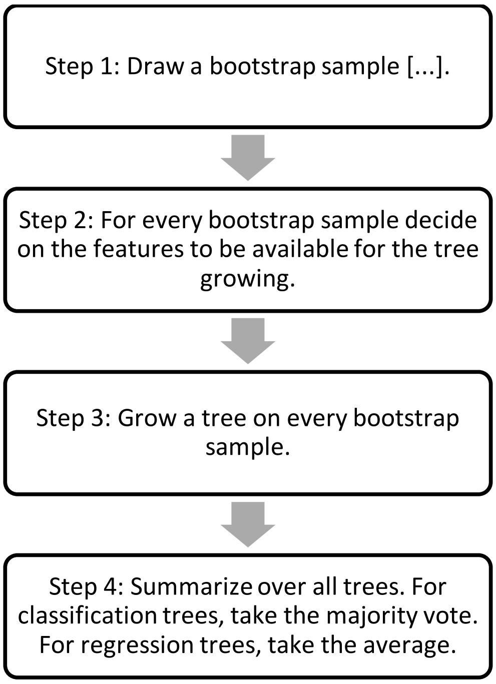


Figure 47: Overview of the four steps to build a random forest model (source: Ziegler & König, 2014, p. 56)

But building an ensemble of trees and using the average values as the result means that the results can't be visualized in a tree like structure as shown in figure 46. The loss of the simple and intuitively comprehensible structure is the biggest disadvantage of random forest compared to decision trees (Ziegler & König, 2014, p. 56).

Using not all observation to build the tree but only the bootstrap-sample allows validation of each tree with unseen data. The misclassification rate of the observations that were not used to construct each tree is called out-of-bag-error (Breiman, 2001, p. 11; Cutler, et al., 2007, p. 2784).

The out-of-bag-error plays an important role in estimating the variable importance. To determine the importance of a variable, the values of that variable are randomly permuted. The model is then run again with the changed sample. The calculated mean decrease in accuracy of the predictions (the average difference in the out-of-bag error divided by the standard error) is used as an approximation for the variable importance - higher values indicating a stronger influence of that variable on the quality of the predictions of the model (Wehrens, 2011, p. 199; Hapfelmeier & Ulm, 2013; Genuer, et al., 2010).

The R package 'randomForest', which is built on Breiman's random forests algorithm, is used for the modelling.

The interpretation of the results follows “an heuristic strategy which does not depend on specific model hypotheses but based on data-driven thresholds to take decisions” (Genuer, et al., 2010, p. 2225), proposed by Genuer, Poggi and Tuleau-Malot (2010).

5.2 Sampling and approach

The Maldives Whale Shark Research Programme has been conducting research on whale sharks in the Maldives since 2006. The information collected for every whale shark encounter has been extended constantly and thus there is some inconsistency in the number of recorded variables e.g. the status of the code of conduct has been systematically recorded since 2015.

To ensure consistency in the information, the sample was reduced to observations made between 02.02.2015 and 19.12.2017. One reason for choosing the random forest as an instrument was the abundance of different variables in sample, e.g. numerical to factor and binary. The variables can be distinguished into three groups:

1. Environmental variables that capture weather and sea conditions.
2. Whale shark related variables capturing distinguishing features of the whale shark and the behaviour and movements during the encounter.
3. Anthropogenic variables that capture the number of operators, swimmers and divers at an encounter and their behaviour.

Of the 964 whale shark encounters only 16.80% contained complete information for all variables. There are various reasons for missing values in the data e.g. weather and sea conditions can make it impossible to measure the visibility. I chose not to replace any missing values with computed values, because:

- For some variables, values were missing in more than 50% of the observations e.g. in 602 or 62.45% of the observations, information for the variable minimum depth of the whale shark is missing.
- The distributions of the numerical variables do not follow a normal distribution.
- Computing binary variables might have a strong biasing effect on the structure of the decision trees.

A three-step approach was applied to identify which variables are related to the response variable. The mean decrease in accuracy was chosen as the criterion for the selection of variables. In a first step, a random forest model was applied using all variables. Depending on the response variable, there can be slight differences in the number of variables. Only observations with complete information and no missing values were used to build the model. As described in section 5.1.1, random forest is a collection of randomly constructed decision trees and 2000 trees were grown to model the response variables. The number of variables tried at each node to split the data is equal to twice the square root of the total number of variables ($m_{try} = 2 \times \sqrt{n_{var}}$).

After the initial run of the model, all variables with a negative value for the mean decrease in accuracy are removed. By removing variables often, previously important variables contributing positively to the quality of the model's prediction (positive value for the mean decrease in accuracy), become noisy (negative value for the mean decrease in accuracy). Therefore, reducing the number of variables is an iterative process and is repeated until all remaining variables have a positive mean decrease in accuracy.

In a final step, the model is tested with unseen data - the test validation set has half the size of the training set.

5.3 Results

5.3.1 Model 1: Status of the code of conduct

The compliance rate of operators and tourists can be used as a proxy for the pressure of tourism on the aggregating whale sharks (Quiros, 2007, p. 103; Ziegler, et al., 2012). Therefore, identifying and facilitating conditions that stimulate compliance with the code of conduct can help to ease the pressure of tourism.

For the model, only observations with at least two vessels (the research vessel plus one additional vessel) were used. Initially the model included 30 variables and the training data consisted of 118 observations with an almost even distribution between the classes 'code of conduct broken' (62 observations) and 'code of conduct followed' (56 observations). Figure 47 shows that 14 of the 30 variables had a negative influence on the accuracy of the model in the initial run of the model. The out-of-box error rate of the initial model was 29.66%.

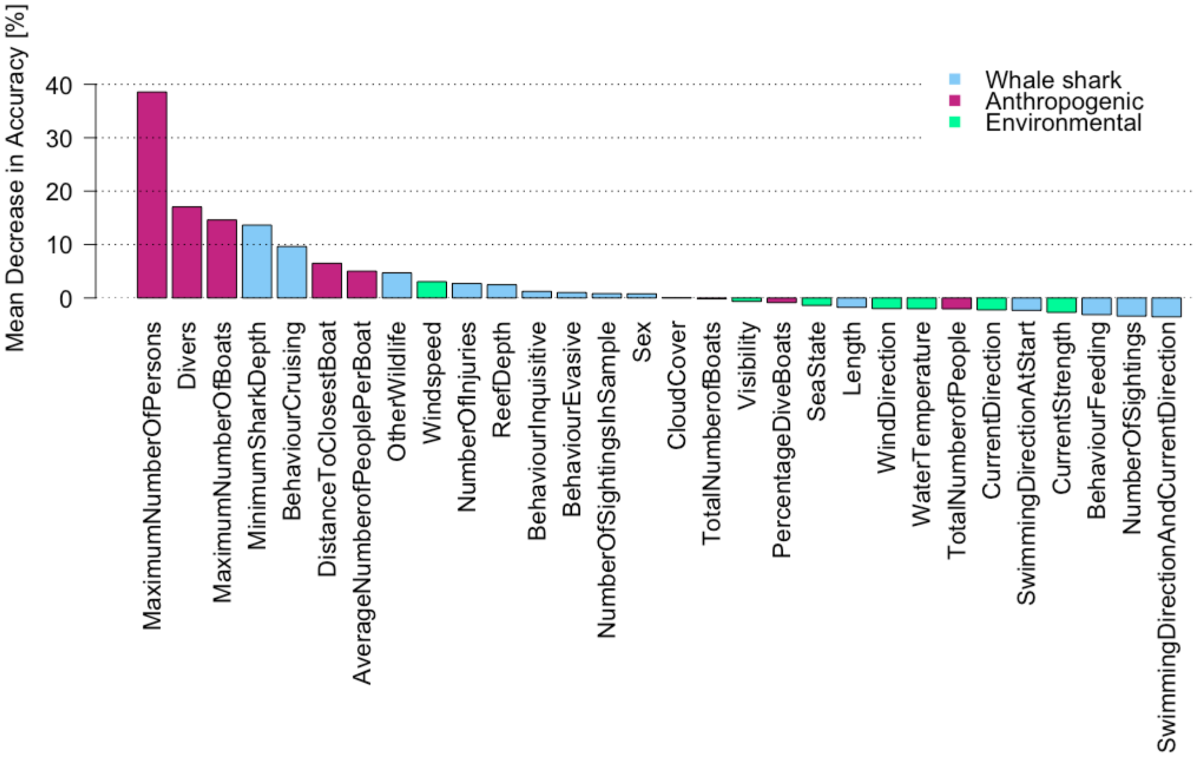


Figure 48: Variable importance for all variables

In an iterative process (see chapter 5.2) all noisy variables with a negative influence on the accuracy of the predictions were removed. The final model included only 14 variables and the accuracy of the predictions for the training set improved to 74.58%. The test validation set contained 59 observations and predictions of the model for the test validation set had an accuracy of 79.66%.

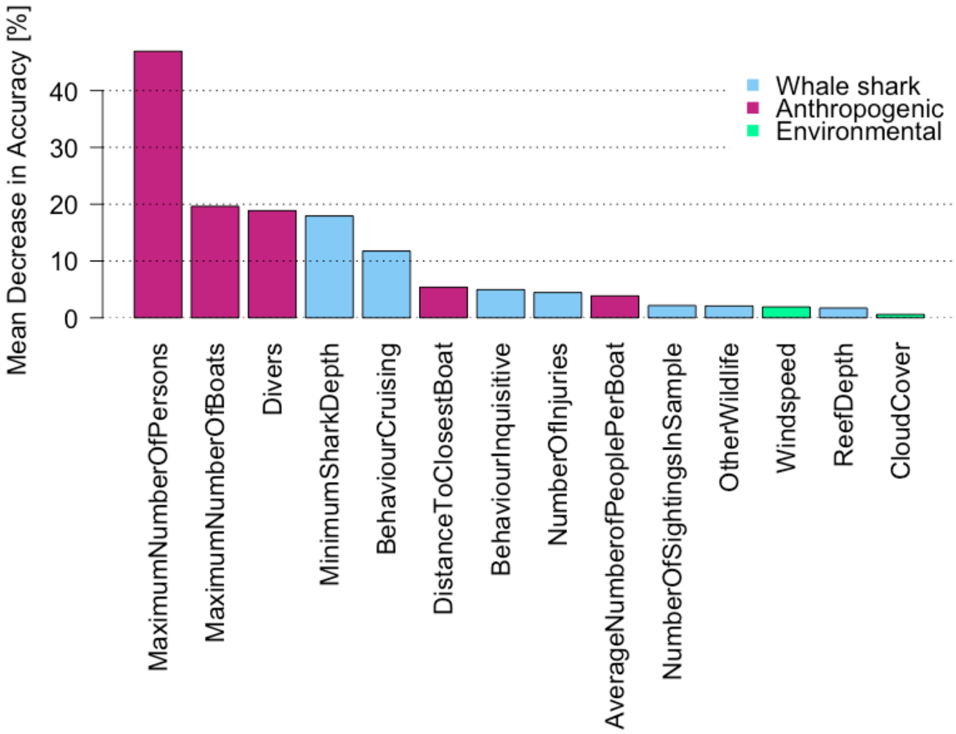


Figure 49: Variable importance for the final model.

The most important variable for the accuracy of the predictions and hence the strongest predictor for the status of the code of conduct is the variable 'maximum number of persons' in contact with the whale shark. The 'maximum number of boats' in contact with the whale shark, which is strongly correlated with the 'maximum number of persons', is the second most important predictor for the status of the code of conduct.

The boxplots in figure 50 clearly show that there tend to be more people and boats in encounters in which the code of conduct is broken. This observation is confirmed by the results of a two-sided Mann-Whitney test that indicate a significant difference in the maximum number of persons and boats in contact with the whale shark for the two classes 'code of conduct broken' and 'code of conduct followed'.

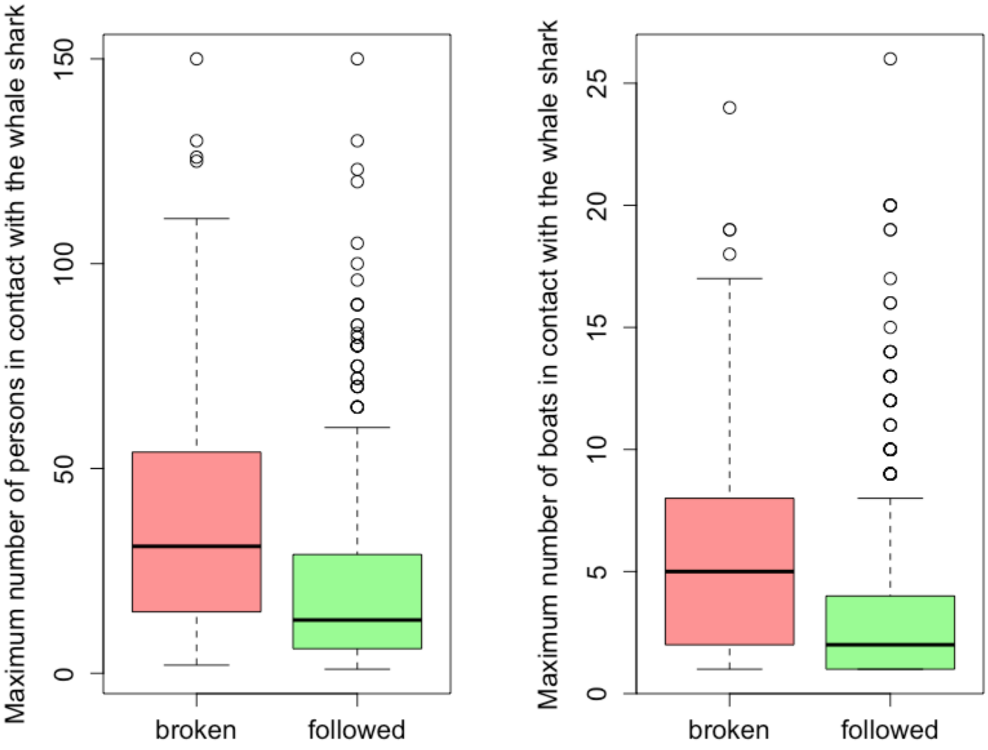


Figure 50: Boxplots of the maximum number of persons and boats in contact with the shark for the two classes 'code of conduct broken' and 'code of conduct followed'

A two-sided Mann-Whitney test also confirms a significant variation in the minimum depth of the whale shark between the two classes 'code of conduct followed' and 'code of conduct broken'.

Variable	**average for the class 'code of conduct followed'**	**average for the class 'code of conduct broken'**	**median for the class 'code of conduct followed'**	**median for the class 'code of conduct broken'**	**p-value Mann-Whitney-test**
Maximum number of people in contact with the shark	20.57	33.16	12	26	$1.94*10^{-6}$
Maximum number of boats in contact with the shark	3.32	5.17	2	4	$5.41*10^{-6}$
Minimum depth of the whale shark	6.02	3.07	4	2	$1.32*10^{-3}$

Table 2: Mann-Whtiney test results for the two classes ‘code of conduct followed’ and ‘code of conduct broken’

The density histogram of the minimum depth of the whale shark for the two classes shows that if the whale shark swims at five metres or shallower, the non-compliance rate (red) is higher than the compliance rate (green).

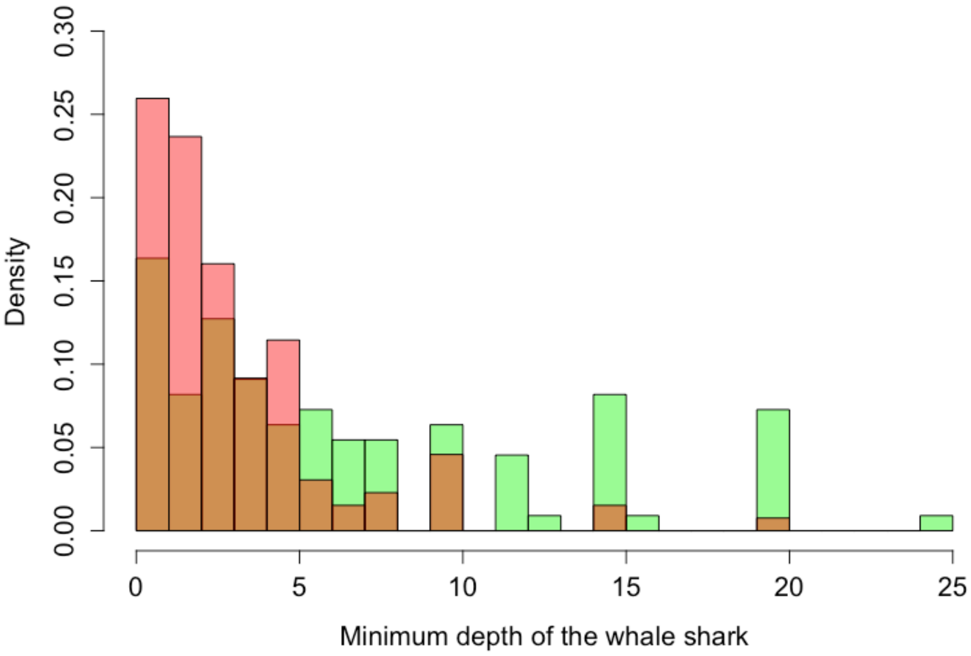


Figure 51: Density histogram showing the minimum depth of the whale shark for the two classes ‘code of conduct followed’ (green) and ‘code of conduct broken’ (red)

The difference in mean of the maximum number of boats and persons in contact with the whale shark for the two classes ‘code of conduct broken’ and ‘code of conduct followed’ intensifies for encounters in which the whale shark was swimming at five metres or shallower.

Variable	**average for the class ‘code of conduct followed’**	**average for the class ‘code of conduct broken’**	**median for the class ‘code of conduct followed’**	**median for the class ‘code of conduct broken’**	**p-value Mann-Whitney-test**
Maximum number of people in contact with the shark	15.59	31.55	10	24	0.011
Maximum number of boats in contact with the shark	2.79	5.23	2	3	$1.78*10^{-4}$

Table 3: Mann-Whitney test results for the two classes ‘code of conduct followed’ and ‘code of conduct broken’ if the whale shark swims at 5m or shallower

The third most important variable to predict the status of the code of conduct is the binary variable divers (present or absent). Divers were present in 11.61% of the encounters in the sample and in 66.96% of these encounters the code of conduct was broken. Thus, the non-compliance rate in encounters with divers being present is almost twice as high as the non-compliance rate in encounters without divers (33.06%).

5.3.2 Model 2: Display of evasive behaviour

The MWSRP defined four categories of whale shark behavior. Whale sharks can display more than one behavior in one encounter and in almost 80% of the encounters in the sample the whale shark was cruising (swimming slowly in one direction). Unlike many other whale shark aggregation sites where feeding is the dominating type of behaviour, feeding was observed in only 15.77% of the encounters. In less than 10% of the encounters the whale shark was actively approaching swimmers or boats, showing inquisitive behaviour. The opposite of inquisitive behavior is evasive behavior. Behavior of a whale shark is categorized as evasive, when the whale shark actively avoids interaction with swimmers or boats. Whale sharks can express evasive behaviour very differently and the most obvious sign of evasive behavior is banking - the whale shark rolls on its back to expose the dorsal fin area (where the skin is extra thick) to the potential threat, e.g. a scuba diver or swimmer that comes too close (Haskell, et al., 2015, p. 493). Other forms of evasive behaviour are steep dives, abrupt changes of direction or an increase in the swimming speed. Evasive behaviour was recorded in 43.88% of the encounters and is the second most common behaviour after cruising.

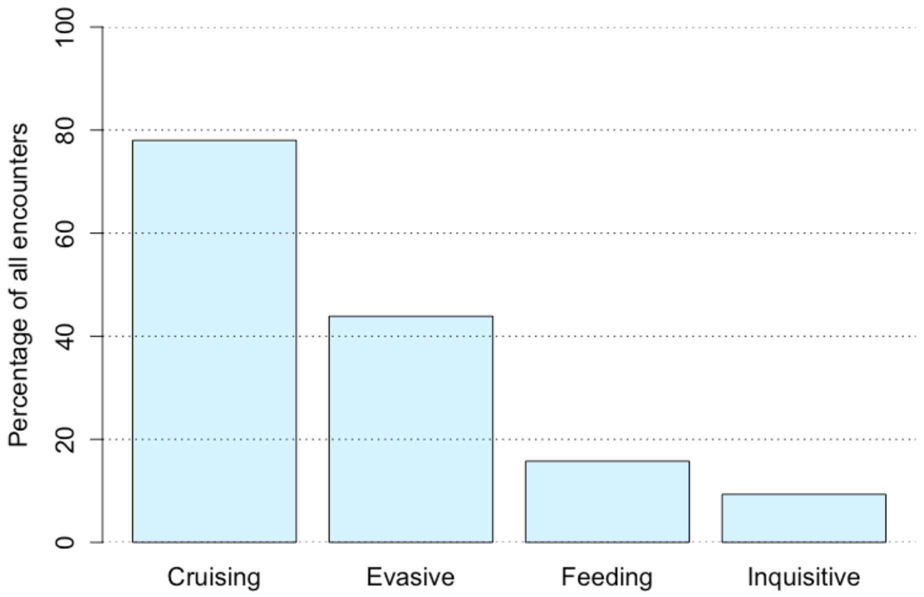


Figure 52: The four behavior categories and their frequency in percent of all encounters

34 variables were used in the initial random forest model to predict whether the whale shark would display evasive behaviour or not. Twelve of these 34 variables were negatively influencing the quality of the predictions of the model and were subsequently removed. Removing the noisy variables improved the accuracy of the model for the training set from 73.73% to 77.97%. The error rate of the model's predictions for the test validation set is twice as high as for the training set (44.07% compared to 22.03%).

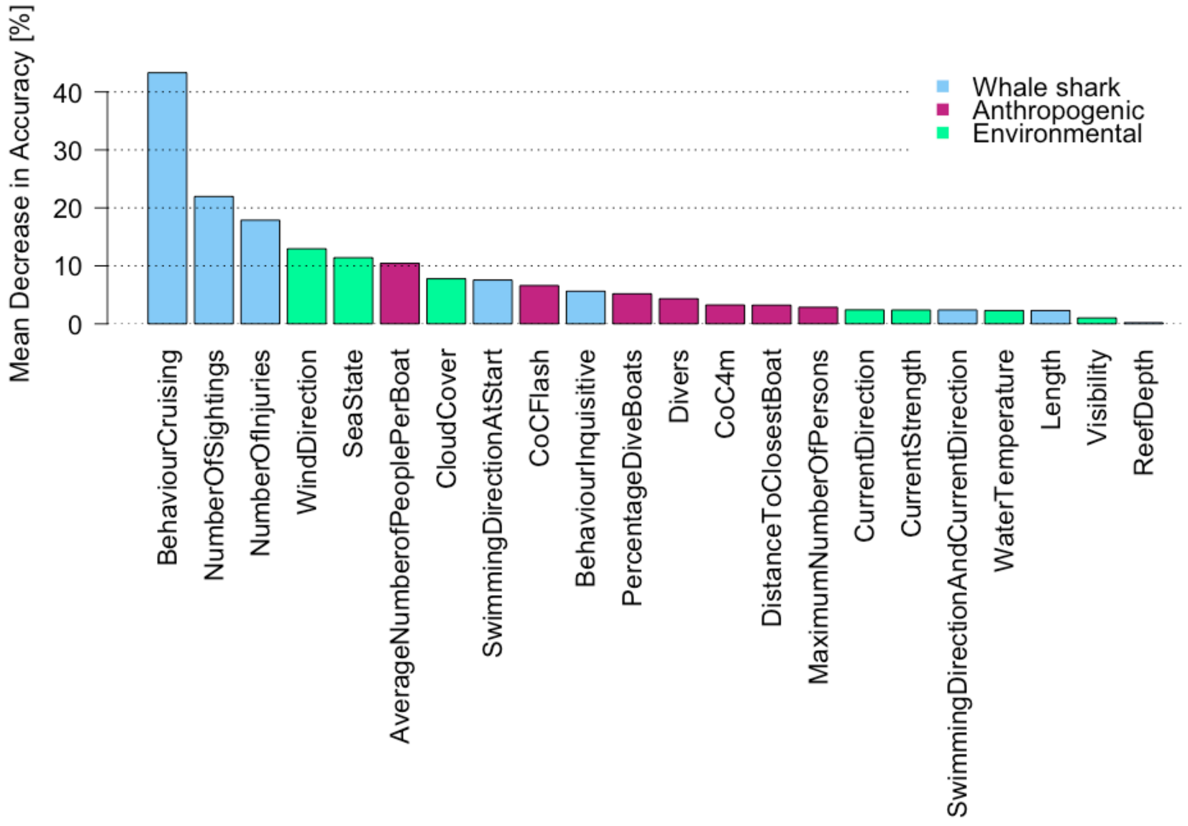


Figure 53: Variables and their importance in the final model

The most important predictor of the model is the binary variable behaviour cruising. As described above, a whale shark can display multiple behaviours in one encounter. In 79.71% of the encounters in which the whale shark was not cruising, it showed evasive behaviour (compared to 33.78% of the encounters when the whale shark was cruising). Thus, the observations in the branch ‘not cruising’ show a high purity as they correspond to a very high percentage of observations from the class ‘evasive behaviour’.

The p-value of a two-sided Mann-Whitney test does not indicate that there is a significant difference in the number of sightings and the number of injuries between the populations of the two classes ‘evasive behaviour’ and ‘no evasive behaviour’.

5.3.3 Model 3: Reaction of the whale shark

To draw a more differentiated picture of the reaction of a whale shark in an encounter, Quiros’ approach to quantify avoidance behaviour was adopted (Quiros, 2007). Quiros rated the movements of whale sharks to measure the intensity of the whale shark’s reaction in an encounter. This approach was adopted to the categories used in the surveys of the MWSRP (see table 4).

Diving	**Swimming**	**Change of Direction (CoD)**
No Diving → Score = 0	Slow → Score = 0	No CoD → Score =0
Gradual → Score = 1		Gradual → Score = 1
Parabola → Score = 2	Fast → Score = 2	Circular → Score = 2
Steep → Score = 3	Banking → Score =3	Abrupt → Score = 3

Table 4: Rating for the different categorizations used by the MWSRP in their surveys

The composite score was calculated by adding the individual scores for the diving, swimming, and change of direction. Depending on the composite score, the reaction of the whale shark was classified into one of three categories:

- Small: composite score < 3
- Medium: 2 < composite score < 6 AND no single parameter > 2
- Strong: composite score > 5 OR one single parameter = 3.

32 variables were used to predict the reaction of the whale shark in an encounter. Twelve variables were subsequently removed as they had a negative influence on the mean accuracy of the predictions of the model.

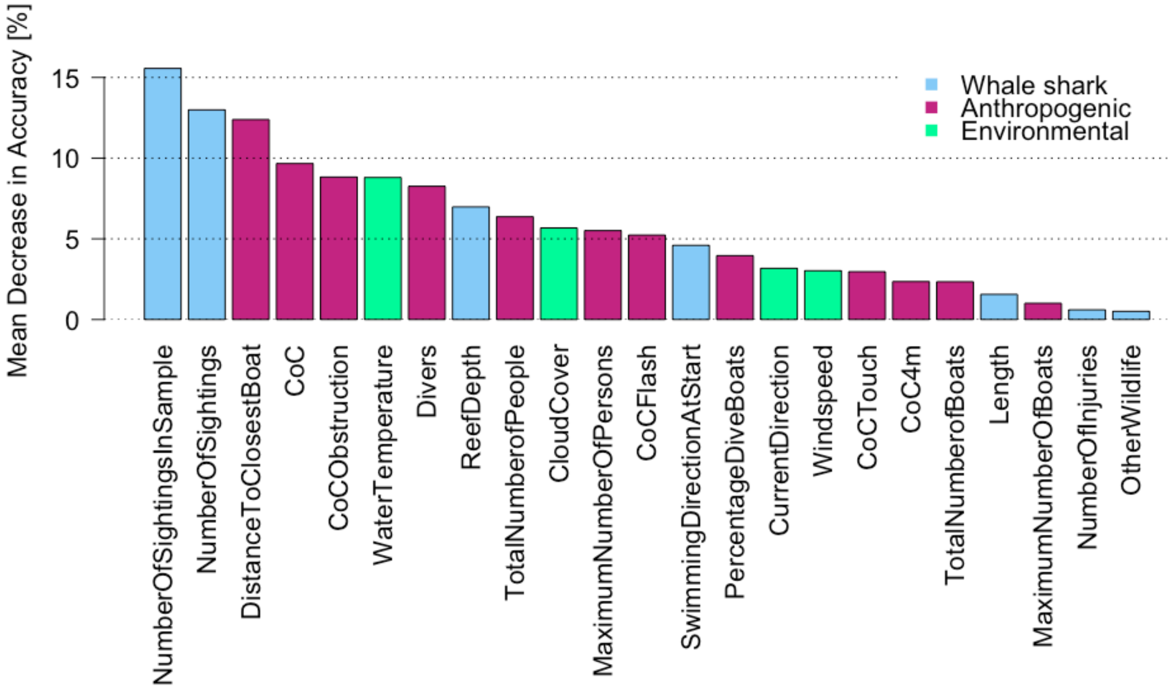


Figure 54: Variable importance of the model to predict the reaction of the whale shark

The error rate of the model's predictions for the training set was 50.88% and for the test validation set 64.91%.

The two most important variables were the number of sightings of the whale shark in the sample and the total number of sightings of the whale shark. A Mann-Whitney test revealed that the number of sightings in the sample and the total number of sightings of the whale shark show a significant difference between encounters with a small reaction of the whale shark (fewer sightings) and encounters with a medium or strong reaction of the whale shark (more sightings).

The third most important predictor for the reaction of the whale shark is the distance to the closest boat. A two-sided Mann-Whitney test did not show any significant differences in the distance to the closest boat between the observations of the three classes of the response variable.

All five variables to describe the status of the code of conduct are among the important predictors and the binary variable 'code of conduct broken/followed' is the fourth most important predictor for the reaction of the whale shark. Figure 55 shows that the fraction of encounters in which the code of conduct was broken is higher in encounters in which the whale shark showed a strong reaction compared to encounters in which the reaction of the whale shark was classified as medium or small.

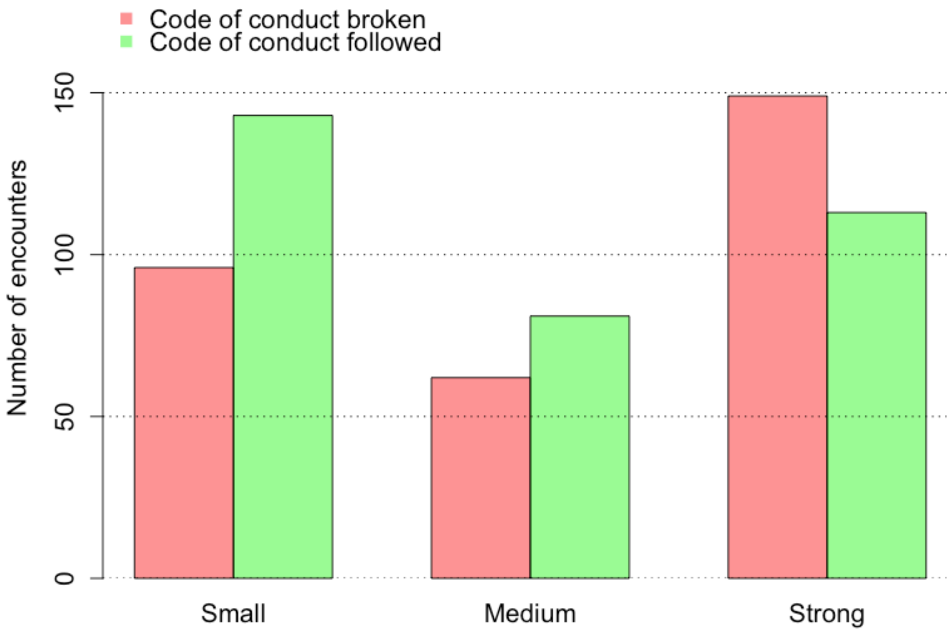


Figure 55: Bar plot showing the number of encounters over the composite score: red bars for code of conduct broken and green bars for code of conduct followed

5.3.4 Model 4: Encounter duration

In a study on whale shark tourism in Mozambique, Pierce et al. found that the encounter duration was significantly shorter when the whale shark displayed avoidance behaviour (Pierce, et al., 2010, p. 785). Based on these findings, Haskell et al. used the encounter duration in a later study “as a proxy for avoidance” (Haskell, et al., 2015, p. 494). For the encounter duration, only encounters that were started by the researchers and ended with the whale shark leaving the encounter were used to build the model. These constraints reduced the size of the sample from 964 to 521 observations. Of these 521 observations, 88 had complete information for all 32 variables.

The number of variables was subsequently reduced to 12 and the reduction of the number of variables led to an increase of the explained variance of the regression model from only 1.27% to 22.14%. The most important variables for the accuracy of the model are the maximum number of people, the minimum depth of the whale shark and the number of injuries. A correlation test showed no systematic influence of the three variables on the encounter duration.

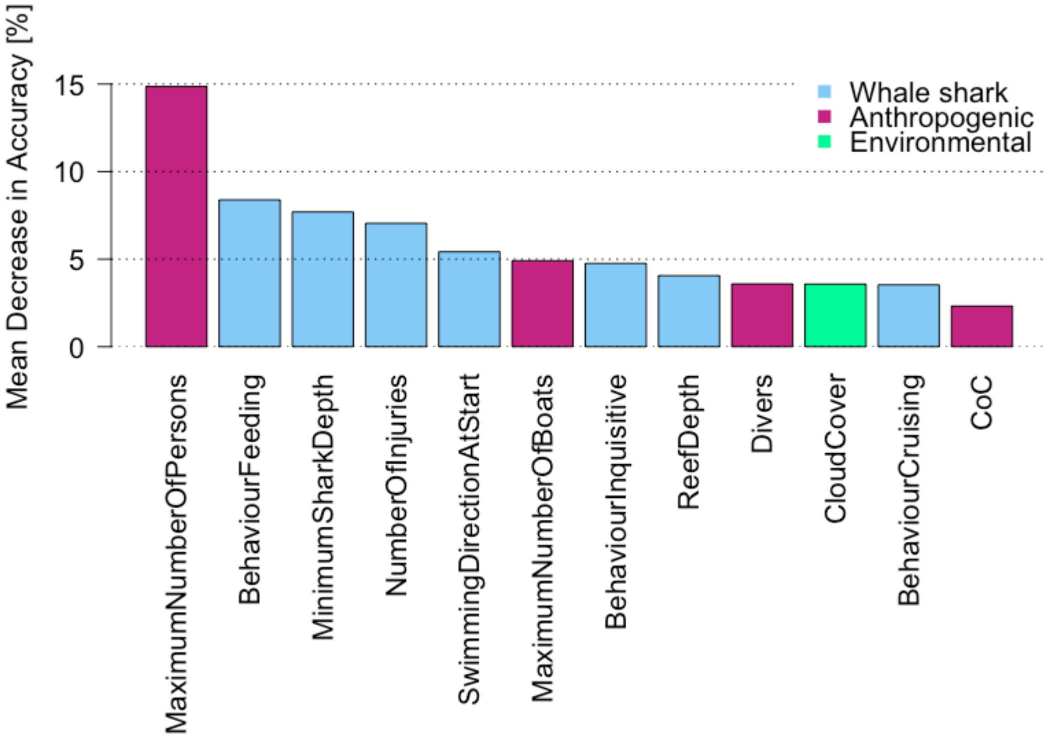


Figure 56: Variable importance of the variable for the prediction of the encounter duration

Table 5 shows that the average and median encounter duration shows distinct variations for the different behaviours and that encounters in which the whale shark was feeding had the longest median and average encounter duration.

Behaviour	Feeding	Inquisitive	Cruising	Evasive
Average encounter duration (min:sec)	15:43	14:41	11:07	7:26
Median encounter duration (min)	11	11	8	5

Table 5: Average and median encounter duration for the behaviours feeding, inquisitive, cruising and evasive

6 Discussion

6.1 Evaluation of the models

Of the four models, the first has delivered the best results - even for the cross-validation set, the predictions of model 1 had an accuracy of 79.66%. The accuracy of the predictions of the second model for the training set (77.97%) is greater than that of the first model (74.58%), but drops sharply for the test set (55.93%).

The out-of-bag-error of model 3 is 49.12% and the increase in the misclassification rate compared to model 1 and 2 may be due to an increase in complexity, as the response variable is not a binary but a factor variable with three different levels.

The regression random forest model to predict the encounter duration relies on the smallest training sample (n=88) and can only explain 22.14% of the variance in the duration of the encounters in the training set.

Model	**Model 1: Status of the code of conduct**	**Model 2: Evasive behaviour**	**Model 3: Intensity of the reaction of the whale shark**	**Model 4: Encounter duration**
Initial number of variables	30	34	32	32
Reduced number of variables	14	22	23	12
Accuracy of the model for predictions of the training set	74.58% $(n_{train}=118)$	77.97% $(n_{train}=118)$	50.88% (ntrain=114)	Explained variance: 22.14% (n=88)
Accuracy of the model for predictions of the test set	79.66% $(n_{test}=59)$	55.93% $(n_{test}=59)$	35.09% $(n_{test}=57)$	

Table 6: Summary of key performance measures of the 4 models.

The mean decrease in accuracy proved to be a very useful criterion for the selection of variables as removing variables with a negative value for the mean decrease in accuracy improved the accuracy of the predictions. For model 1, for example, the accuracy of the predictions for the training set improved from 70.34% to 74.58% by removing 16 variables. Except for model 2, at least half of the eight environmental variables (water temperature, wind direction, wind speed, cloud cover, sea state, current direction, current strength and visibility) were subsequently removed in the optimization process of the models. The importance ranking of the remaining variables in the final models also shows that the environmental variables play a more subordinate role in the predictions of the response variables – again model two is an exception with the wind direction being the fourth most important variable among the 22 remaining variables.

The whale shark ID is not incorporated as a variable in the model because then the models could only be used for data which includes the same individuals as the training sample. The number of sightings, the number of sightings in the sample, the length, the sex and the number of injuries are characteristics to distinguish the individual animals from each other. Of these characteristics, the number of sightings shows the greatest variation and is therefore best suited to distinguish the whale sharks from each other (number of sightings: 226 different values, ranging from 1 to 238; number of sightings in the sample: 29 different values, ranging from 1 to 62; length: 64 different values, ranging from 2 to 8.5; gender: two levels).

Two of the three most important variables for predicting the response variable in model 2 and 3 are variables that describe distinguishing features of the whale shark. Thus, the response variables in model 2 and 3 seem to depend more on the individual whale shark than on environmental or anthropogenic factors.

The importance of the variable ‘number of sightings’ may indicate that whale sharks visiting the SAMPA more often become habituated to the presence of swimmers and boats e.g. in encounters in which the whale shark shows a small reaction, the median value for the number of sightings is 77 compared to a median value of 39 for encounters in which a strong reaction of the whale shark was recorded. However, further research is required to confirm whether individual whale sharks get accustomed to the presence of swimmers and vessels in the SAMPA or if they have certain individual stress threshold levels (see point IV a) in section 3.1).

The differences between the individual whale sharks are also a possible explanation for the drop in the performance of the models when used with unseen data. A comparison of the whale shark ID numbers of the training and test validation sets of model 2 and model 3 shows that

a) the training set includes individual whale sharks that were not encountered in the test validation set (21.19% of the individuals in the training set of model 2 do not reappear in the test validation set of model 2; 29.66% of the individuals in the training set of model 3 do not reappear in the test validation set of model 3)
b) the test validation set includes individual whale sharks on which the model was not trained on (27% of the individuals in the test validation set of model 2 were not part of the training set of model 2; 12.28% of the individuals in the test validation set of model 3 were not part of the training set of model 3).

Thus, the results of the models could be improved if the test and the training set contained only the same individuals.

Another reason for the poorer performance of model 2 and 3 could be the high number of variables used for the prediction of the response variable. While the number of variables of model 1 was reduced by more than 50%, model 2 still employs 65% and model 3 employs 68% of the variables originally used.

The importance ranking of the variables for model 2 shows that the anthropogenic variables play only a subordinate role for the prediction of the response variable ‘evasive behaviour’. One possible explanation could be the lack of knowledge on natural behavioural traits of whale sharks, which makes it difficult to certainly identify evasive behaviour e.g. the instant dive of a whale shark upon the arrival of a small number of tourist does not need to be an expression of evasive behaviour but simply a coincidence. Mistaking natural behaviour for evasive behaviour might be one reason that the model shows only a minor influence of the anthropogenic variables on the response variable. Unbiased baseline data of natural behaviour patterns of whale sharks in the SAMPA could help to better distinguish between natural and evasive behaviour.

Model 4 shows that the behaviour of the whale shark has a strong influence on how long an encounter lasts. Although the maximum number of persons is the most important variable to predict the encounter duration, a correlation test did not show a systematic relationship between the two variables. A possible reason might the schizophrenic relationship between the two variables, because:

a) the encounter duration might positively influence the maximum number of people, because long encounters give more vessels and people the opportunity to join an ongoing encounter (even from far away it is easy to spot if a vessel and its passengers are interacting with a whale shark, see figure 40).
b) the maximum number of people might negatively influence the encounter duration because more swimmers could mean more stress (e.g. higher chances of a breach of the code of conduct) and more stress could cause the whale shark to dive or swim away earlier.

Therefore, the results of the model do not allow the direction of the cause-and-effect relationship between the maximum number of persons and the encounter duration to be identified.

A more systematic record-keeping of the encounter duration (reducing the percentage of encounters predominately left by the researchers) could help to better understand the relationship between the encounter duration and the maximum number of swimmers in contact with the whale shark.

In general, more observations and an expansion of the training sample could improve the performance of the models and the robustness of the results.

6.2 Implications for the whale shark tourism management in the SAMPA

The values for the mean decrease in accuracy of model 3 show that all five binary variables used to describe the status of the code of conduct are among the 23 predictors (see figure 53). Figure 54 also shows that the non-compliance rate of swimmers is higher in encounters in which the whale shark shows a strong reaction compared to encounters in which the whale shark shows a small or moderate reaction. Thus, the existing in-water guidelines seem to be an effective way of lessening the level of disturbance caused by swimmers and vessels.

The predictions for the status of the code of conduct are mainly dependant on the maximum number of swimmers and vessels in contact with the whale shark. As shown in section 5.3.1, whale shark encounters in which the code of conduct is followed are less crowded than whale shark encounters in which the code of conduct is broken. Hence, a tightening of the existing limit values for the number of persons and boats in contact with the whale shark could help to increase the compliance rate with the code of conduct. Taking the compliance rate with the existing code of conduct as the criterion to set the maximum number of people and boats in contact with the whale shark would suggest a limit of 15 swimmers and two boats in contact with one whale shark. These are the rounded down average values for the maximum number of people and boats in encounters in which the code of conduct was followed and the whale shark swam at or shallower than five metres. Using encounters in which the whale shark swam at or shallower than five metres as a benchmark pays attention to the fact, that the non-compliance rate is significantly lower in encounters in which the whale shark is swimming close to the surface e.g. figure 56 shows an encounter in which the whale shark swims very close to the surface and the code of conduct is broken (swimmers are too close to the whale shark and obstruct the path of the whale shark).

Figure 57: Crowding at a whale shark encounter with a breach of a code of conduct by swimmers (source: author)

But limiting the number of swimmers to 15 and the number of boats to two could not only increase the compliance rate with the code of conduct - it could also improve the experience for the swimmers because crowding adversely affects three of the six factors that determine the quality of a wildlife encounter: authenticity, intensity and uniqueness (Reynolds & Braithwaite, 2001).

In 48.86% of the encounters in the sample, the maximum number of boats was above two and in 50.31% of the encounters the maximum number of swimmers was above 15. Thus, roughly half of the whale shark encounters would be affected by the proposed limits. The exclusion of at least some of the vessels/operators in half of the whale shark encounters in the SAMPA would probably cause great resistance among the operators.

One way of alleviating the resistance of providers and achieving a high level of acceptance for tightening the rules could be to introduce an upper limit for the length of the encounters. This would give the operators the chance to interact successively with one whale shark rather than having all operators interact with one animal at the same time.

At the Ningaloo Reef, “handballing” or passing on the shark from one operator on to the next operator has been integrated in the regulations and is a well-established practice among the operators. However, there are fewer operators at the Ningaloo Reef (15 in total) and these operators are also well networked.

In the SAMPA, up to 52 different vessels were logged on a single day and up to 26 vessels were observed interacting with the same whale shark. Thus, the surrounding conditions in the SAMPA differ greatly to those at the Ningaloo Reef. With up to 24 vessels waiting in line to interact with one whale shark, conflicts between operators and violations of the rules will be almost inevitable. Therefore, simply tightening the number of vessels and people in contact with the whale shark and limiting the encounter duration per operator would probably not resolve the problem in a practical way.

The surrounding conditions in the SAMPA are better comparable to those in Gladden Spit in Belize. In Gladden Spit the number of tour operators grew from one to 22 operators between 1997 and 2004 and problems were very similar to those in the SAMPA e.g. crowding and misconduct (Quiros, 2005). As a solution, the authorities in Belize defined different time slots and allow only a small fraction of the operators in the whale shark observation area per time slot. The allocation of the time slots is organized by a lottery system (Wildtracks, Belize; SEA Belize; Belize Fisheries Department, 2010; Quiros, 2005). A similar approach to mitigate crowding has also been made in Hanifaru Bay (see chapter 3.3.2).

A practical solution for the whale shark tourism in the SAMPA would require a combination of the regulations in Gladden Spit and at the Ningaloo Reef. This is because the limitation of the total number of operators in the SAMPA at one time (as practiced in Gladden Spit) would be a necessary precondition to tighten the maximum number of vessels and swimmers per whale shark and to limit the length of the encounter per operator (as practiced at the Ningaloo Reef).

The maximum number of boats allowed in the SAMPA at one time would mainly depend on the average number of individual whale sharks in the SAMPA. A larger number of whale sharks would also allow a larger number of operators. On average, 2.1 different whale sharks were discovered on successful surveys (surveys in which whale sharks were observed). Hence, with a limit of two boats per whale shark the maximum number of boats in the SAMPA at one time should not exceed four.

The length of the introduced time slots should give the operators enough time to find and interact with at least one whale shark. Averaging the net time searching per whale shark over all surveys (successful and unsuccessful surveys) gives a value of 155 minutes of searching per whale shark encounter. Thus, using two-and-a-half-hour or three-hour time slots would allow operators on average enough time on average to find and interact with one whale shark. A possible schedule could have the first time slot from 8 am to 11 am, the second time slot from 11 am and 2 pm and a third time slot from 2pm to 5pm. As most whale sharks are seen around midday (see figure 30), a lottery system could make sure that all operators have the same chance to get the time slot from 11 am to 2 pm with the potentially highest chance to interact with a whale shark. Furthermore, allocating different weekdays to different groups of operators as practiced in Hanifaru Bay could ensure that all groups operators get a fair share of the time in the SAMPA, e.g. reserving Tuesdays and Wednesdays for safari boats.

At the Ningaloo Reef, the encounter duration for swimmers of one tour operator is limited to 60 minutes and in Isla Holbox in Mexico the encounter duration is limited to 30 minutes. The encounter duration exceeded 60 minutes in only three encounters or 0.39% of the encounters in the sample and 30 minutes in only 6.18% of the whale shark encounters. Hence, limiting the encounter duration per operator to 60 or 30 minutes would have almost no effect. Isla Holbox and Ningaloo Reef are both important foraging grounds for whale sharks and they are mainly seen feeding there. On the contrary, whale sharks were only feeding in 15.77% of the encounters in the SAMPA (figure 51). Thus, the shorter encounter durations in the SAMPA might be linked to the difference in the prevailing behaviour of the whale sharks compared to the aggregations in Mexico and Australia (table 5). A more suitable limitation for the encounter duration in the SAMPA would be 15 minutes. Although this might seem very short compared to other aggregation sites, the encounter duration only exceeded 15 minutes in 23.17% of the encounters in the sample. Hence, the limit would not shorten the encounter duration in the vast majority of the whale shark encounters, while ensuring a better and more efficient utilisation of longer encounters exceeding 15 minutes. Model 1 also showed that the presence of divers is an important variable for the prediction of the status of the code of conduct. One explanation for the lower compliance rate could be that it is easier for divers to break the code of conduct as they are not "stuck" at the water surface. The Maldivian law limits the maximum depth for recreational scuba divers to 30 metres. So while it is impossible for most of the snorkelers to get too close, touch or obstruct a whale shark at a depth of 20 metres, scuba divers can still breach the code of conduct (see figure 45). Another reason for the lower compliance rate in whale shark encounters in which divers were present might be that scuba divers often carry professional underwater camera equipment. Hence, in 21.21% of the encounters in which divers were present and the code of conduct was broken it involved the use of flash photography (compared to 8.33% when there were only snorkelers in the water). The higher proportion of divers with professional underwater camera equipment indicates that divers have a higher degree of recreational specialization than snorkelers. In contrast to Duffus' and Dearden's model, the greater negative ecological impact seems to be caused by the more specialized visitors.

Furthermore, scuba diving with whale sharks has been banned at several whale shark aggregation sites (including Hanifaru Bay in the Maldives), mainly due to concerns that the bubbles and noise from the regulator disturb the whale sharks. The recreational scuba diving industry is an important sector within the Maldivian economy and on average 37.30% of the recorded vessels in the sample were carrying scuba divers. Therefore, a complete ban of scuba diving in the SAMPA would probably cause a huge pushback from the scuba diving industry. An alternative to a complete ban of scuba diving could be a special training and certification for dive masters and instructors to lead groups of scuba divers in the SAMPA and a fixed ratio between guides and clients e.g. in Gladden Spit the regulations stipulate a maximum of eight scuba divers per certified guide.

A compulsory training course and the certification of guides and boat captains could also help to ensure the successful implementation of the practice of passing on a whale shark from one operator to the next and ensure all staff are aware of the rules.

Leverage/regulation	**Current limit**	**Proposed limit**	**Aim**
Maximum number of boats in contact with the whale shark	5	2	Increase compliance with the in-water-guidelines.

Maximum number of people in contact with the whale shark	80	15	Increase compliance with the in-water-guidelines.
Maximum encounter duration per operator (minutes)	None	15	More efficient use of long encounters, increase acceptance by tour operators.
Maximum number of operator/vessels in the SAMPA at one time	None	4	Create a regulative framework that allows the implementation of the three rules above.
Maximum duration of excursions in the SAMPA per operator	None	2:30h/3h	Giving each operator enough time to find and interact with one whale shark, while at the same using the SAMPA efficiently.
Compulsory training and certification of guides and operators	No	Yes	Increase compliance with the code of conduct, especially by scuba divers, to ensure guides and operators have a sufficient understanding of the more complex regulations

Table 7: Summary of the proposed limits for a management plan of the whale shark tourism in the SAMPA

The data driven approach to the formulation of a regulation scheme for whale shark tourism in the SAMPA delivered the potentially most effective leverages for regulators. The regulations derived from the results of the models are particularly desirable when applying “biodiversity robustness” and “precaution” as criteria. If another criterion is applied, the proposed results could also be interpreted differently, e.g. from the standpoint of political acceptance, the number of boats in contact with the whale shark would probably be raised to the maximum ecologically justifiable level. Therefore, the results rather represent a single building block to formulate an effective management plan for the SAMPA.

Conclusion

The whale shark aggregation in the SAMPA can be categorized as a common pool resource and the high non-compliance rate of swimmers and operators with the existing regulations indicates that whale shark tourism in the SAMPA has exceeded the carrying capacity of the destination. Hence, there is an urge to reduce the impacts of tourism on the aggregating whale sharks to ensure the long-term viability of the destination.

But general conclusions on how whale shark tourism affects the animals are difficult to make, since the results of the models suggest that the impacts depend strongly on the individual animal. However, it seems that the status of the code of conduct has an influence on the amplitude of the whale shark's reaction in an encounter. Therefore, the code of conduct seems to be an effective means to reduce the negative impact of tourism on the whale sharks.

The random forest model predicting the status of code of conduct shows that the number of people and the number of boats interacting with the whale shark are the two main determinants for the response variable. This relationship allows direct implications for the improvement of the management of the whale shark tourism in the SAMPA to be derived. Based on the analysis of the status of the code of conduct in 964 whale shark encounters, a limitation of the number of swimmers to 15 and the number of boats to two is proposed. But looking at the current level of usage of the SAMPA by operators and comparing it with other aggregation sites showed that the proposed regulations could not be successfully implemented without changing the surrounding conditions in the SAMPA. Thus, a limitation of the total number of vessels in the SAMPA is proposed. Another focus of the proposed intervention is the stricter regulation of divers, as the model has also shown a strong link between the status of the code of conduct and the presence of divers.

The variable importance ranking of the random forest models allows to easy identification of the variables with largest impact on the response variable and thus the potentially most effective leverages for regulations. The ability of decision trees and random forests to process any type of variable does allow a truly holistic assessment and the extension or refining of the models by increasing the number of variables.

The simplicity of the methodology would make it also easy to apply the method at other aggregation sites and to gain a better understanding of site or population specific impacts and global or general impacts and thus reduce the ecological uncertainty that decision makers are faced with.

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Appendix 1: List of all variables included in the models

- In total: 4465 observations/whale shark encounters (21.04.2006-19.12.2017), 4275 whale shark encounters with identified whale sharks, 190 whale shark encounters where identification was not possible, 346 identified sharks,
- For the model: 964 observations/whale shark encounters (02.02.2015 – 19.12.2017)

Whale shark variables

- Length [metres]
    - Type: quantitative, continuous
    - Three methods:
        - Visual estimation
        - Tape measurement
        - Measurement with laser photogrammetry
    - Max: 8.5
    - Min: 2
    - Mean: 5.63
    - NAs: 28
- Injuries
    - Type: quantitative, continuous
    - Max: 8
    - Min: 0
    - Mean: 1.53
    - NAs: 0
    - 54.91% (190 out of 346) of the whale sharks in the data base are/were injured
- Sex
    - Type: qualitative, discrete
    - Male: 849; Female: 27; Undefined/NAs: 88
- Other wildlife
    - Type: binary
    - Present: 302
    - Absent: 662
- Total number of sightings (number of sightings of an individual whale shark in the data base)
    - Type: quantitative, continuous
    - Max: 238
    - Min: 1
    - Mean: 71.45

    - NAs: 0
- Relative number of sightings (number of sightings of an individual whale shark in the sample)
    - Type: quantitative, continuous
    - Max: 62
    - Min: 1
    - Mean: 31.78
    - NAs: 0
- Swimming direction at the start
    - Type: qualitative, discrete
    - N [0°] =34, NE [45°] =148, E [90°] =218, SE [135°] =89, S [180°] =45, SW [225°] =144, W [270°] =216, NW [315°] =57
    - NAs: 13
- Minimum recorded depth of the whale shark during an encounter [metres]
    - Type: quantitative, continuous
    - Max: 25
    - Min: 0
    - Mean: 4.52
    - NAs: 602
- Depth of the reef [metres]
    - Type: quantitative, discrete (because only recorded until 20 metres)
    - Max: 20+
    - Min: 2
    - Mean: 11.65
    - NAs: 4
- Behaviour (A whale shark can show multiple behaviours during one encounter.)
    - Type: qualitative, discrete (four binary variables with values true/false)
    - Cruising 746 (77.39%)
    - Feeding 152 (15.77%)
    - Inquisitive 90 (9.34%)
    - Evasive 415 (43.05%)
- Swimming
    - Type: qualitative, discrete
    - Slow: 470
    - Fast: 106
    - Banking: 88

- Diving
    - Type: qualitative, discrete
    - Gradual: 377
    - Parabola: 174
    - Steep: 105
    - NAs: 320
- Change of Direction
    - Type: qualitative, discrete
    - Gradual: 226
    - Circular: 89
    - Abrupt: 174
    - NAs: 320
- Composite score (reaction of the whale shark)
    - Type: qualitative, discrete
    - Small: 239
    - Medium: 143
    - Strong: 262
    - NAs: 320
- Encounter duration [minutes]
    - Type: quantitative, continuous
    - Max: 76
    - Min: 1
    - Mean: 10,26
    - NAs: 4

<u>Environmental variables</u>

- Sea surface temperature
    - Type: quantitative, continuous
    - Max: 32
    - Min: 27
    - Mean: 29.53
    - NAs: 93
- Wind direction
    - Type: qualitative, discrete
    - N [0°] =48, NE [45°] =147, E [90°] =43, SE [135°] =32, S [180°] =40, SW [225°] =175, W [270°] =246, NW [315°] =211

    - NAs: 22
- Wind speed
    - Type: quantitative, discrete
    - Max: 11
    - Min: 1
    - Mean: 2.60
- Cloud cover
    - Type: qualitative, discrete
    - Clear: 315
    - Partial: 500
    - Total: 149
    - NAs: 2
- Sea state
    - Type: qualitative, discrete
    - Calm: 479
    - Slight: 327
    - Moderate: 133
    - Rough: 22
    - NAs: 3
- Current direction
    - Type: qualitative, discrete
    - N [0°] =31, NE [45°] =128, E [90°] =257, SE [135°] =73, S [180°] =16, SW [225°] =73, W [270°] =164, NW [315°] =28
    - NAs: 194
- Current strength
    - Type: quantitative, discrete (1 to 5)
    - 1: 265
    - 2: 313
    - 3: 163
    - 4: 37
    - 5: 1
    - NAs: 185
- Swimming direction in relation to the current direction
    - Type: qualitative, discrete
    - With the current: 306
    - Cross to the current: 39

  - Against the current: 418
  - NAs: 201
- Visibility
  - Type: qualitative, discrete
  - Good: 361
  - Medium: 489
  - Poor: 103
  - NAs: 11

Anthropogenic variables

- Number of persons at start
  - Type: quantitative, continuous
  - Max: 92
  - Min: 1
  - Mean: 8.97
- Maximum number of persons
  - Type: quantitative, continuous
  - Max: 150
  - Min: 1
  - Mean: 24.84
- Occurrence of divers
  - Type: binary
  - Divers present: 121
  - Divers absent: 843
- Status code of conduct
  - Type: binary (followed, <4m, obstruction, touch, flash)
  - Followed: 637
  - <4m: 292
  - Obstruction: 143
  - Touch: 48
  - Flash: 33
- Number of boats at start
  - Type: quantitative, continuous
  - Max: 19
  - Min: 1
  - Mean: 2.2

- Maximum number of boats
    - Type: quantitative, continuous
    - Max: 26
    - Min: 1
    - Mean: 3.95
    - NAs:31
- Distance to closest boat
    - Type: quantitative, continuous
    - Max: 99
    - Min: 1
    - Mean: 11.2
    - NAs: 31
- Average number of people per boat
    - Type: quantitative, continuous
    - Max: 17.20
    - Min: 4.67
    - Mean: 9.79
    - NAs: 71
- Total number of boats
    - Type: quantitative, continuous
    - Max: 52
    - Min: 1
    - Mean: 23.02
    - NAs: 71
- Total number of People
    - Type: quantitative, continuous
    - Max: 544
    - Min: 7
    - Mean: 226.8
    - NAs: 71

Appendix 2: Key components of whale shark tourism regulations in Australia, the Philippines, Belize, Mexico and the Maldives

Regulation	**Ningaloo Reef, Australia** (Department of Parks and Wildlife, 2013)	**Donsol, Philippines** (Pine, 2007) (Quiros, 2007)	**Gladden Spit, Belize** (Wildtracks, Belize; SEA Belize; Belize Fisheries Department, 2010; Graham & Roberts, 2007)	**Isla Holbox, Mexico** (Ziegler, et al., 2016; Suárez, et al., 2007)	**Bahía De Los Angeles, Mexico** (Cárdenas-Torres, et al., 2007; Rodríguez-Dowdell, et al., 2007)	**Hanifaru Bay** (Manta Trust; Project AWARE; WWF, 2016; Environmental Protection Agency, 2011)
Season	March to July	November to June	March to July	May to October	May to December	May to December
Licensing of tour operators	Operators must hold a commercial operator licence and an animal interaction licence valid for five to ten years; a maximum number of 15 licenses is issued valid	All operators must be registered at the Butanding Interaction Center, the central registration point for all whale shark tours in Donsol	Guides and captains must be certified	Commercial operators must hold a permit to offer tours; maximum number of issued permits increased from 42 in 2003 to 160 in 2015 (Ziegler, et al., 2016, p. 620)	Commercial operators must hold a permit to offer tours	N/A
Defining mandatory training standards for the operators' staff	Yes, guides have to attend the "Interacting with Whale Sharks course" offered by the Department of Parks and Wildlife and skippers must be certified by the	Guides registered as Butanding Interaction Officers must go through training.	Yes, guides must have be licensed and successfully complete a whale shark course; captains must attend whale shark course	All guides must visit a course and pass an exam	Guides must hold a license	All guides must visit a course and pass an exam issued by the Environmental Protection Agency

	Department of Transportation.					
Defining vessel standards	Vessel standards for commercial tour operators are set and enforced by the Department of Transportation.	Vessels must have a propeller guard	Vessels must be at least 23 feet long and are not allowed to exceed 48 feet, must carry oxygen, safety sausages, radio and lights	Boats are not allowed to exceed 12 m in length, propeller guards	N/A	Vessels longer than 20 meters, vessels with outboard engines and jetskis are not allowed in the buttress zone
Restricting the maximum number of passengers per vessel	A total of 23 passengers (a maximum of 20 participating in in-water interaction with the whale shark) plus crew	Boats are allowed to take a maximum of seven passengers plus a spotter, captain and Butanding Interaction Officer	Every vessel can carry up to 12 clients.	For vessels up to 24 feet in length, the maximum number of paying passengers is 5; vessels exceeding 24 feet can carry one additional passenger per additional foot length, but not more than 10 passengers per vessel	N/A	N/A
Limiting the number of boats in the viewing area	N/A	A maximum number of 25 vessels is allowed in the viewing area.	Yes, 1.5-hours-time slots are allocated via a lottery system to licensed operators to conduct whale shark tours in the marked whale shark zone during whale shark season. A maximum of six	N/A	No, free access	A maximum of five vessels and 80 people is allowed inside the bay at one time.

			operator vessels is allowed in the whale shark area per time slot.			
Defining minimum guides to passenger ratios (can be included in the licensing conditions)	There is no clearly defined guides to passengers ratio, however by limiting the maximum number participants of the in-water interaction with the shark, the ratio is at least one guide per ten passengers.	There is no clearly defined guides to passengers ratio, however by limiting the maximum number participants of the in-water interaction with the shark, the ratio is at least one guide per six passengers.	A maximum of 8 divers or scuba divers per certified guide		N/A	N/A
Establishing a code of conduct for tour operators	Yes, included in the licensing conditions	Yes	Yes	Yes	Yes, included in the permit conditions	Yes
Limiting the number of boats in contact with one whale shark:	There is only one boat allowed to be in contact with the shark at one time.	There is only one boat allowed to be in contact with the shark at one time.	N/A	There is only one boat allowed to be in contact with the shark at one time.	There is only one boat allowed to be in contact with the shark at one time. When passing on the whale shark from one operator to the next, there must be minimum lapse time of 15 minutes	Up to five boats are allowed to be in contact with the shark at one time

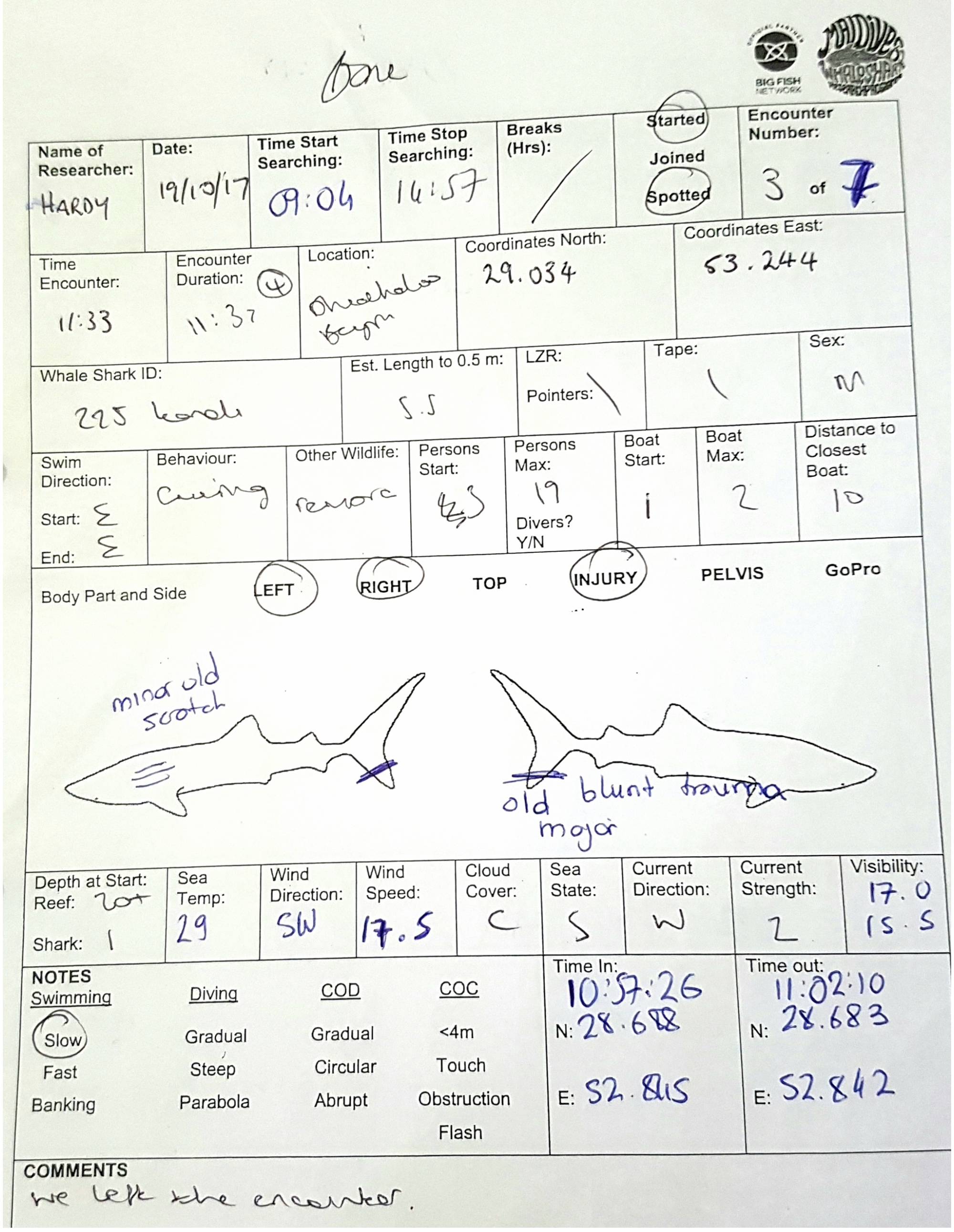
Limiting the encounter time:	A vessel is not allowed to be in contact with the shark for more than 90 minutes and swimmers are not allowed to interact with the shark for more than 60 minutes.	Whale shark tours must last not longer than 3hours.	N/A	A vessel is not allowed to be in contact with the shark for more than 30 minutes		N/A
Limiting the vessel speed in the whale shark viewing area or in proximity to a whale shark	Within 250 metres of the whale shark, the vessel speed must not exceed 8 knots.	N/A	In vicinity to the whale sharks vessels should proceed at idle speed (not exceeding 2 knots)	A maximum of 3 knots in the observation area	There is a speed limit of 8 mph in the observation area	There is speed limit of ten nautical miles per hour in marine protected area.
Defining a minimum distance between vessels and a whale shark:	Vessels must stay at least 30 metres away from the shark	N/A	Vessels should keep a minimum distance of 50 feet from the whale shark and 200 feet from other vessels	A minimum distance of 10 metres between vessels and the whale shark and 100metres between vessels	Within 5metres of the whale shark, captains must stop their engine	Vessels need to keep a distance of at least ten metres to the whale shark.
Banning obstruction of the path of the whale shark by operator vessels	N/A	N/A	N/A	N/A	Captains must respect the natural path of the whale shark	N/A
Establishing a code of conduct for snorkelers/divers	Yes, included in the licensing conditions	Yes	Yes	Yes	Yes, included in the permit conditions	Yes

Limiting the number of people in contact with one whale shark:	The number of swimmers with the shark at one time is limited to ten tourist plus a guide and videographer.	A maximum number of 6 swimmers per whale shark is allowed	N/A	A maximum of two swimmers and a guide per whale shark	The number of swimmers with the shark at one time is limited to four, two swimmers on each side of the whale shark	The number of swimmers in contact with the shark is limited to 80.
Defining a minimum distance between swimmers and a whale shark	Swimmers need to keep at least 4metres distance from the tail and 3metres distance from the head and body.	Swimmers need to keep at least 4metres distance from the tail and 3metres distance from the head and body.	15 feet	Swimmers must keep at least 2metres distance from the whale shark	Swimmers must keep at least 2metres distance from the tail and 1metres distance from the head and body.	Swimmers need to keep at least 4metres distance from the tail and 3metres distance from the head and body.
Banning obstruction of the path of the whale shark by swimmers	Swimmers must respect the natural path of the whale shark and must stay on the sides or behind the whale shark.	Swimmers must respect the natural path of the whale shark and must stay on the sides or behind the whale shark.	N/A	N/A	Swimmers must respect the natural path of the whale shark and must stay on the sides or behind the whale shark.	Swimmers must respect the natural path of the whale shark and must stay on the sides or behind the whale shark.
Banning physical contact with the whale shark	It is forbidden to touch the whale shark.	It is forbidden to touch the whale shark.	It is forbidden to touch the whale shark.	Not explicitly stated but a minimum distance of two meters must be kept at all times	It is forbidden to touch and to ride the whale shark	It is forbidden to touch the whale shark.
Banning the use of scuba diving gear	It is forbidden to use scuba diving equipment.	It is forbidden to use scuba diving equipment.	Scuba diving is allowed	It is forbidden to use scuba diving equipment.	N/A	It is forbidden to use scuba diving equipment inside Hanifaru Bay.
Banning the use of flash photography	It is forbidden to use flash photography	It is forbidden to use flash photography	It is forbidden to use flash photography	N/A	It is forbidden to use flash photography	It is forbidden to use flash photography

Banning the use of motorized swimming aids	It is forbidden to use motorized swimming aids	It is forbidden to use motorized swimming aids	N/A	N/A	It is forbidden to use motorized swimming aids	It is forbidden to use motorized swimming aids
Collection of scientific data	Operators must report the location of the whale shark, swimming direction, length, sex and information on the number of swimmers	N/A	N/A	Operators must log encounters and record length, sex and location of the encountered whale sharks and provide information on the participating tourists	N/A	N/A
Surveillance of compliance/ enforcement	The Department of Parks and Wildlife conducts "boat ramp inspections, industry vessel placements, covert operations, aerial surveillance and boat patrols." (Department of Parks and Wildlife, 2013, p. 20)	N/A	1 head ranger, 2 rangers	Surveys and inspections by the National Commission of Natural Protected Areas, the Federal Government Protection of the Environment, Secretariat of the Environment and Natural Resources	N/A	There are almost daily ranger patrols of the bay during the season
Fees	Every operator pays a deposit of 1250 AU$ for the license and for later charges a license charge of 25 AU$ per adult per day and 12.50 AU$ per child per day (6 to 16 years)	All whale shark tour participants need to register and pay at the Butanding Interaction Centre and 2 US$ for Filipino nationals and 7$ for foreigners of the	A boat license fee of 100 US$ must be paid to the fisheries department and there is an entrance fee of 15 US$ for every visitor of the whale shark zone	N/A	N/A	Operators need to buy tokens (20US$ per visitor), that grant access to the site

	which is conducted from the deposit	total price is charged as registration fee				
Other				Sunscreen used must be biodegradable; the use of noisy devices that could disturb the whale shark is forbidden	Swimmers are ought to avoid a splash entry and the use of jet skis is forbidden	There are designated days for the tours offered by resorts and tours offered by live-aboard-safaris and guesthouses

Appendix 3: Whale shark encounter sheet by the Maldives Whale Shark Research Programme



Done

Name of Researcher: HARDY

Date: 19/10/17

Time Start Searching: 09:04

Time Stop Searching: 14:57

Breaks (Hrs): /

[✓ **Started**] **Joined** [✓ **Spotted**]

Encounter Number: 3 **of** 7

Time Encounter: 11:33

Encounter Duration: ④ 11:37

Location: [illegible]

Coordinates North: 29.034

Coordinates East: 53.244

Whale Shark ID: 225 [illegible]

Est. Length to 0.5 m: 5.5

LZR: Pointers: \

Tape: \

Sex: M

Swim Direction: Start: E End: E

Behaviour: Cruising

Other Wildlife: remora

Persons Start: 43

Persons Max: 19 Divers? Y/N

Boat Start: 1

Boat Max: 2

Distance to Closest Boat: 10

Body Part and Side [✓ **LEFT**] [✓ **RIGHT**] **TOP** [✓ **INJURY**] **PELVIS** **GoPro**

minor old scratch

old blunt trauma major

Depth at Start: Reef: 20+ Shark: 1

Sea Temp: 29

Wind Direction: SW

Wind Speed: 17.5

Cloud Cover: C

Sea State: S

Current Direction: W

Current Strength: 2

Visibility: 17.0 15.5

NOTES

<u>Swimming</u>	<u>Diving</u>	<u>COD</u>	<u>COC</u>
[✓ Slow]	Gradual	Gradual	<4m
Fast	Steep	Circular	Touch
Banking	Parabola	Abrupt	Obstruction
			Flash

Time In: 10:57:26
N: 28.688
E: 52.815

Time out: 11:02:10
N: 28.683
E: 52.842

COMMENTS
we left the encounter.

Source: author/Maldives Whale Shark Research Programme