Evidence of residential area of whale sharks in Saleh Bay, West Nusa Tenggara

M F Farid¹*, S Hariyadi², M M Kamal² and H A Susanto²

¹ Graduate Student of the Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University (Bogor Agricultural University), Jl. Agatis, Kampus IPB Dramaga, Bogor 16680, Indonesia
² Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University (Bogor Agricultural University), Jl. Agatis, Kampus IPB Dramaga, Bogor 16680, Indonesia

*Corresponding author: muh.fdlfrd@gmail.com

Abstract. Saleh Bay is one of the locations where whale sharks (Rhincodon typus) occurrence observed in Indonesia and can be found all year round. Whale sharks broadly distributed throughout tropical and sub-tropical waters of the world’s oceans. Immature male is less than 7 m long, while female is less than 10 m, mostly tend to coastal habitat related. Result of research by Conservation International presented at International Whale Shark Conference in Australia in 2019, Whale Sharks in Saleh Bay had home movement patterns. This study aims to prove that Saleh Bay is the residential area of the whale shark. This study was conducted from November 2019 to January 2020. The Photo-ID data obtained were compared with CI’s Saleh Bay Whale Shark ID Catalog data which last update on April 2020. Surface temperature was measured directly in the range of 29-32°C, data for chlorophyll-a were taken from marine.copernicus.eu and bathymetry from cmap.ihms.us then interpolated using QGIS 3.10 software. From this study period, 24 Photo-IDs were obtained from 39 whale sharks, which identified as 23 males, 1 female, and 6 were new individuals from June 2019 to April 2020. The size of the whale sharks recorded in this study ranged from 2,5 to 7 m with 4,86 m in average, and considered as juveniles.

Keywords: ecology; photo-ID; Saleh Bay; whale shark

1. Introduction

Whale shark (Rhincodon typus) (Smith, 1828) is a highly migratory species and is distributed around the globe in tropical and subtropical waters. Although they are highly migratory species, seasonal whale shark aggregations occur in the shallow waters of many countries. Whale sharks are known to congregate in areas with high biological productivity, such as near plankton-rich areas, fish spawning, and areas where water temperature changes [1–5]. Their movement may be affected by oceanographic conditions, such as temperature, current, and chlorophyll-a concentration [2, 4, 6, 7]. Juvenile whale sharks measure less than 7 m [8–12], females less than 9 m [13–15]. Several studies have shown that juvenile whale sharks tend to reside in coastal habitats [12, 16–18] whereas adults tend to be in pelagic habitats [19, 20].

There are several locations where whale sharks occur in Indonesia, Probolinggo (East Java) [11], Botubarani (Gorontalo), Kaimana and Cendrawasih Bay (Papua) [21, 22], and Teluk Saleh (West
Nusa Tenggara). Saleh Bay is located in the northeast area of Sumbawa Regency, which is a semi-closed water area and is directly connected to the Flores Sea [23]. The appearance of whale sharks in Saleh Bay has been known since 1992 according to local fisherman in the village of Labuan Jambu (Teluk Saleh, Sumbawa) based on the results of personal communication [24]. Based on the results of research by Conservation International presented at International Whale Shark Conference in Australia in 2019, whale sharks in Saleh Bay had home movement patterns indicate that the waters are the area to whale sharks gathering throughout the year, so can show that Saleh Bay is a residential area for whale sharks. This study aims to obtain data that can prove that Saleh Bay is a residential area for whale sharks.

2. Materials and methods
This research used quantitative methods, used data in the form of photo-ID data collection during field surveys, recording the number of individuals encountered, size estimates, sex and recording time and location of encounters with whale sharks. The materials and equipment used include basic diving equipment (masks, snorkels, fins), GPS (Global Positioning System), digital cameras, Interactive Individual Identification System (I3S2.0), QGIS 3.10, and R 1.3 software.

2.1. Study area
The research was conducted from November 2019 to January 2020, which is the transitional season from the East to the West season. The appearance of whale sharks in Saleh Bay is usually seen around bagan (floating lift nets, which targets pelagic fish such as flying fish, mackerel, anchovies, skipjack fish) in the morning around 05:00 to 09:00.

2.2. Data collection
2.2.1. Photo-ID. The whale shark spotted pattern is unique to each individual and is an effective marker for catchment recapitulation studies [25, 8]. When a whale shark appeared, a researcher entered the water and took pictures of the left and right pectoral fins which focused on the spots on the top and bottom of the fifth-gill slit to the tip of the pectoral fin to identify the individual. Sex was confirmed by the presence (male) or the absence of (female) claspers in the pelvic area [8]. Size is estimated by comparing objects of known length, such as swimmers or boats. Photos that have been taken are then identified by the Interactive Individual Identification System (I3S2.0). The distribution of whale sharks was analyzed using QGIS (Geographic Information System) through a process of digitization and overlay. This software is used to form an image of the distribution of whale sharks based on the area of the observation area. Conservation International has been monitoring whale sharks in Saleh Bay since 2017, mostly around bagan. The data obtained was then adjusted to data from CI’s Saleh Bay Whale Sharks ID Catalog last updated April 2020 (unpublished data).

2.2.2. Population structure. The presence of whale sharks in Saleh Bay was recorded through direct observation surveys (SURV) by free dive observers. Occurrence data includes: date, time, location, number of individuals, sex and estimated size. The collected data are tabulated and then displayed in tables and histograms.

2.2.3. Oceanographic conditions. Sea surface temperature (SST) (°C) is measured directly in the field on each trip. Chlorophyll-a (CHL-a) (mg/L) data in this study used monthly from Global Ocean Biogeochemistry data were obtained from website marine.copernicus.eu and were collected from 01 November 2019 to 31 January 2020, bathymetric data was from website cmap.ihms.us then the two parameters were interpolated using QGIS 3.10 software.
3. Result

3.1. Photo ID and Population structure
Total 11 trips during the research period, there were 8 trips (1st, 2nd, 3rd, 4th, 7th, 8th, 10th and 11th trips) with the appearance of a whale shark, 3 trips without appearing (5th, 6th and 9th) and 2 trips (2nd and 11th) with appearances without photo-ID (table 2). There are 6 trips (1st, 3rd, 4th, 7th, 8th and 10th) whale shark with photo-ID. On 1st trip, a whale shark was found with 8 individuals, 7 males and 1 female, 3rd trip with 3 male individuals, 4th trip with 2 male individuals, 7th trip with 3 males individuals, 8th trip with 1 male individual and trip 10 with 7 males individual (figure 1 (A)). Based on photo-ID data there are 23 males and 1 female ranging in size from 2.5 to 7m with an average size value of 4.86 m ± 1.17 which is juvenile and no encounter with an adult whale shark (figure 1 (B)).

![Figure 1](image_url)

**Figure 1.** (A) Recorded sightings of whale sharks during the period November 2019 to January 2020, (B) Size Frequency distribution of whale sharks during the period November 2019 to January 2020 observed in Saleh Bay.

This study with the observation period November 2019 to January 2020 found 7 new individuals, 5 individuals who have entered CI’s Calatog, namely SB-RT-0078, SB-RT-0085, SB-RT-0087, SB-RT-0089 and SB-RT-0092; 2 individuals who have not entered into CI’s Catalog, namely SB-RT-F-0001 and SB-RT-F-0002 (table 1). The repeated appearance of individual whale sharks during this study period, SB-RT-0085 appeared on 1st trip and 3rd trip, SB-RT-0019 and SB-RT-0050 appeared on 1st trip and returned on 10th trip.

3.2. Oceanographic conditions
Several oceanographic conditions, sea surface temperature, bathymetry and chlorophyll-a concentrations were presented to help understand the appearance of whale sharks in Saleh Bay. The surface temperature (SST) on each trip ranges from 29-32°C with an average value of 31.09°C ± 0.943. Based on the two-sample t-test (p value 0.2334), there was no significant difference between the mean sea surface temperature with the appearance and without the appearance of whale sharks (table 2).
Table 1. Whale sharks occurrences in Saleh Bay during the period November 2019 to January 2020.

| No | Trip 1 (26 Nov 2019) | Trip 3 (04 Dec 2019) | Trip 4 (07 Dec 2019) | Trip 7 (25 Dec 2019) | Trip 8 (30 Dec 2019) | Trip 10 (07 Dec 2019) | Σ |
|----|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|---|
|    | (118.0119–8,53322)   | (117.9069–8,56065)   | (117.803–8,52253)    | (117,7989–8,52428)   | (117,7977–8,52605)   | (117,803–8,52253)    |   |
|    | Male Male 6.5 m     | Male Male 5.5 m      | Male Male 5.5 m      | Male Male 5.6 m      | Male Male 5.6 m      | Male Male 5.8 m      |   |
| 1  | SB-RT-0050          | SB-RT-0071           | SB-RT-0092           | SB-RT-0051           | SB-RT-0042           | SB-RT-0007           |   |
|    | 4 m SB-RT-0037      | 5 m SB-RT-0078       | 4.8 m SB-RT-0002     | 4 m SB-RT-0004       | 2.5 m SB-RT-0056     | 5.8 m SB-RT-0007     |   |
| 2  | SB-RT-0070          | SB-RT-0085           | SB-RT-0085           | SB-RT-0056           | SB-RT-0004           | SB-RT-0007           |   |
|    | 6.6 m               | 5 m                  | 4.8 m                | 2.5 m                | 4 m                  | 5.8 m                |   |
| 3  | SB-RT-0019          | SB-RT-0078           | SB-RT-0085           | SB-RT-0056           | SB-RT-0004           | SB-RT-0007           |   |
|    | 3.5 m               | 4 m                  | 4.8 m                | 2.5 m                | 4 m                  | 5.8 m                |   |
| 4  | SB-RT-0020          | SB-RT-0085           | SB-RT-0085           | SB-RT-0056           | SB-RT-0004           | SB-RT-0007           |   |
|    | 4.7 m               | 5 m                  | 4.8 m                | 2.5 m                | 4 m                  | 5.8 m                |   |
| 5  | SB-RT-0024          | SB-RT-0085           | SB-RT-0085           | SB-RT-0056           | SB-RT-0004           | SB-RT-0007           |   |
|    | 4.3 m               | 5 m                  | 4.8 m                | 2.5 m                | 4 m                  | 5.8 m                |   |
| 6  | SB-RT-0085          | SB-RT-0085           | SB-RT-0085           | SB-RT-0056           | SB-RT-0004           | SB-RT-0007           |   |
|    | 5 m                 | 5 m                  | 4.8 m                | 2.5 m                | 4 m                  | 5.8 m                |   |
| 7  | SB-RT-0001          | SB-RT-0085           | SB-RT-0085           | SB-RT-0056           | SB-RT-0004           | SB-RT-0007           |   |
|    | 4.5 m               | 5 m                  | 4.8 m                | 2.5 m                | 4 m                  | 5.8 m                |   |

SB-RT (Saleh Bay-(Rhincodon typus), Conservation International’s naming code identifies location and species
SB-RT-F personal photo-ID data
a new individual

Table 2. Whale shark trip coordinates with depth (m) and sea surface temperature (ºC).

| Trip   | Longitude | Latitude | Depth (m) | SST (ºC) | Occurrence | No occurrence |
|--------|-----------|----------|-----------|----------|------------|---------------|
| 1 (26 Nov 2019) | 118.0119  | -8.53322 | 70.6      | 31       | v          |               |
| 2 (28 Nov 2019) | 118.0076  | -8.53456 | 81.5      | 29       | v          |               |
| 3 (04 Dec 2019) | 117.9069  | -8.56065 | 46.8      | 30       | v          |               |
| 4 (07 Dec 2019) | 117.803   | -8.52253 | 58.8      | 31       | v          |               |
| 5 (20 Dec 2019) | 118.0152  | -8.53768 | 58        | 32       | v          |               |
| 6 (21 Dec 2019) | 118.0005  | -8.576   | 50.2      | 31       | v          |               |
| 7 (25 Dec 2019) | 117.7989  | -8.52428 | 51.3      | 32       | v          |               |
| 8 (30 Dec 2019) | 117.7977  | -8.52605 | 50.2      | 31       | v          |               |
| 9 (16 Jan 2020) | 118.0164  | -8.53486 | 57        | 32       | v          |               |
| 10 (21 Jan 2020)| 117.803   | -8.52253 | 48.9      | 31       | v          |               |
| 11 (31 Jan 2020)| 117.7648  | -8.51135 | 36        | 32       | v          |               |

a No photo-ID
Based on coordinates each trip, the appearance of the whale sharks in Saleh Bay is at a depth (T1-T11: 70.6 m; 81.5 m; 46.8 m; 58.8 m; 58 m; 50.2 m; 51.3 m; 50.2 m; 57 m; 48.9 m; 36 m) (table 2). The appearance of whale sharks in Saleh Bay is at a depth of less than 100 m. On the map (figure 4), high chl-a concentrations are in coastal areas, the appearance of whale sharks is at low chl-a concentrations in the monthly average range of 0.2153 mg/L. At the beginning of the transitional season the emergence is in the eastern part of the bay (T1, T2, T5, T6 and T9), when entering the west season the emergence is in the western part of the bay (T4, T7, T8, T10 and T11).
4. Discussion

Whale sharks are currently listed as an Endangered species by the International Union for Conservation of Nature (IUCN) and are included in Appendix II of the Convention on International Trade in Endangered Species (CITES). This list is based on their vulnerability to aquatic conditions and slow recovery [26]. In Indonesia this fish species has been fully protected in accordance with the Minister of Marine Affairs and Fisheries Decree No. 18 of 2013, so all types of use are not allowed. Knowledge of whale sharks is needed to maintain their sustainability. Saleh Bay [23], Arabian Gulf [27] and Gulf of California [28] are semi-enclosed seas. The appearance of whale sharks on the surface in Saleh Bay commonly occurred around the bagan area [24]. Whale sharks appear around the bagan for their feeding behavior [29]. Research by Hsu et al. [6] stated that there are many categories of zooplankton and small fish and squid which are also the prey of whale sharks. Some of the catches from bagan are used as food for whale sharks, namely anchovy (Teluk Cendrawasih) [21], and small shrimp (masin, local language) krill (Teluk Saleh) [24].

Several studies show clear differences in movement patterns between adult and juvenile whale sharks, adult whale sharks have a wide-ranging and tend in the open ocean [18, 19, 30–32], whereas juveniles tend to be near shorelines or have coastal habitats [8, 33–36]. Photo-Id taken during this research period shows a recurring appearance, SB-RT-0085 first appearance on 1st trip (26 November 2019) back on 3rd trip (04 December 2019), SB-RT-0019 and SB-RT-0050 appearance first on 1st trip (26 November 2019) then reappeared on 10th trip (21 January 2020), based on photo-Id data of repeated occurrences at the same location showing that juvenile whale sharks have high site fidelity [18], which is most likely related with food [26, 35, 37], juvenile whale sharks have main purpose in life actually feed as much as they can to grow to mature size. In our big ocean whale shark use different parts of the ocean for their life stages, majority of whale sharks in Galapagos and St. Helena dominated by adult female dan several whale sharks indicated pregnant [32, 38].

Whale sharks that appeared around the bagan in the morning were observed feeding with observation times ranging from 05.00 to 09.00, then after that they were no longer seen in the bagan area, allegedly they dived to the depths following their food. The loss behavior of whale sharks during the day can be attributed to their feeding behavior in copepods that migrate vertically, descending into the water column during the day and rising at night [39]. This statement is in line with Brunnschweiler et al. [40] and Rohner et al. [41] which state that the whale shark’s tendency to dive into deeper waters is thought to follow the movement of food. Juvenile whale sharks during the day tend to be in deeper areas and spend most of their time at depths less than 100 m [17]. Research Rowat and Gore [42] found that whale sharks residing in Seychelles waters spend 96% of their time at depths less than 100 m. Berumen et al. [43] report that whale sharks in the Red Sea often reside in waters less than 50 m deep. Based on the point where the whale sharks appear in Saleh Bay, it is at a depth of less than 100 m.

Whale sharks prefer areas with water temperatures between 23°C and 32°C [6]. The surface temperature range of 27.3°C and 29.58°C in the Arabian Gulf is the temperature at which whale sharks surface to feed [44]. Table 2 shows that the temperature of the whale sharks when they emerge and feed around the bagan area ranges from 29-32°C with an average value of 31.09°C. In figure 3 the chlorophyll-a concentration on the coast is higher than offshore. The high distribution of chlorophyll-a concentrations on the coast is caused by the supply of large amounts of nutrients through runoff from land [45]. The diet of the whale shark in Mexico is ~ 85% copepods. In Australia, the whale shark's diet consists of krill (Pseudeuphausia latifrons), copepods and schools of small fish [5]. In Tanzania, it comprises more than 50 percent of the sergestid shrimp species (Lucifer hanseni) [46]. Copepods are the main constituents of various types of zooplankton on the coast and high seas and the presence of copepods is closely related to the availability of primary producers (phytoplankton) [47]. Research [21] shows the relationship between the appearance of whale sharks and the concentration of chlorophyll-a in water, it can be said that the association between the appearance of whale sharks and chlorophyll-a concentrations indicates the occurrence of food chain processes that are thought to contain krill and copepods, which are then followed by pelagic fish which become the target of the
bagan. The existence of the small fish and krill around bagan area becomes a sign for whale sharks to feed, where the presence of small fish and krill indicates the high concentration of zooplankton in waters which is food for krill, small fish, and whale sharks.

There is a relationship between chlorophyll-a concentration, the appearance of whale sharks and the presence of bagan. From the perspective of strategy feeding behavior of whale sharks, allegedly they will get much more higher energy to find their food such as plankton or krill, so they also appear in bagan area for easy food that is able to save their energy. The existence of the bagan at the beginning of the transition season is in the eastern part of the bay, then when the western season comes with high rainfall and strong winds bagan moves to the western part of the bay with the aim of looking for protected areas (results of interviews with local fishermen). Several islands can be used as protected areas, so during the western season, most of bagan are located in the western part of the bay.

5. Conclusion

Based on observations during the study period (November 2019–January 2020), the whale sharks in Saleh Bay were dominated by male sharks with a size range of 2.5–7 m which are still categorized as juvenile. Whale sharks surfaced early in the morning around the bagan for feeding behavior. Representation of the young whale shark population in Saleh Bay shows that the area is an important habitat for young whale sharks and proves that Saleh Bay is a residential area for whale sharks, although further research is needed with a longer research span.

Acknowledgments

The authors would like to thank Conservation International for supported this study, and to all the people of Labuan Jambu Village, Sumbawa who helped in the field.

References

[1] Compagno L J V 1984 FAO species catalogue. FAO, Rome de la Parra Venegas R, Hueter R, González Cano J, Tyminski J and others 2011 An unprecedented aggregation of whale sharks, Rhincodon typus, in Mexican coastal waters of the Caribbean Sea. PLoS ONE 6:e18994
[2] Taylor J G and Pearce A F 1999 Ningaloo reef currents: implications for coral spawn dispersal, zooplankton and whale shark abundance. J R Soc West Aust. (82) 57–65
[3] Heyman W D, Graham R T, Kjerfve B and Johannes R E 2001 Whale sharks Rhincodon typus aggregate to feed on fish spawn in Belize Mar Ecol Prog Ser. (215) 275–282
[4] Hoffmayer E R, Franks J S and Shelley J P 2005 Recent observations of the whale shark (Rhincodon typus) in north central Gulf of Mexico Gulf Caribb Res (17) 117–120
[5] Taylor J G 2007 Ram filter-feeding and nocturnal feeding of whale sharks (Rhincodon typus) at Ningaloo Reef, Western Australia Fish Res. (84) 65–70
[6] Hsu H H, Joung S J, Liao Y Y and Liu K M 2007 Satellite tracking of juvenile whale sharks, Rhincodon typus, in the northwestern Pacific Fish Res (84) 25–31
[7] Kumari B and Raman M 2010 Whale shark habitat assessments in the northeastern Arabian Sea using satellite remote sensing Int J Remote Sens (31) 379–389
[8] Meekan M G, Bradshaw C J A, Taylor J G, Richards A and McLean C 2006 Population size and structure of whale sharks Rhincodon typus at Ningaloo Reef, Western Australia Mar. Ecol. Prog. Ser. (319) 275–285
[9] Norman B M and Stevens J D 2007 Size and maturity status of the whale shark (Rhincodon typus) at Ningaloo Reef in Western Australia Fish Res (84) 81–86
[10] Rowat D, Brooks K, March A, McCarten C and others 2011 Long-term membership of whale sharks (Rhincodon typus) in coastal aggregations in Seychelles and Djibouti Mar Freshw Res. (62) 621–627
Rhincodon typus

- juveniles: tracking the habitat use of whale sharks off the Nusa Tenggara Barat. in Probolinggo waters, Madura Strait, Indonesia. *Science Proceedings The 4th International Whale Shark Conference*

- 2018 Satellite tracking of juvenile whale sharks in the Sulu and Bohol Seas, Philippines *PeerJ* 5:231

- 1996 The whale shark, *Rhincodon typus*, is a livebearer: 300 embryos found in one ‘megamamma’ supreme. *Environmental Biology of Fishes* 46(3): 219–223

- 2012a Patterns in composition, abundance and scarring of whale sharks *Rhincodon typus* near Holbox Island, Mexico. *J Fish Biol* (80) 1401–1416

- 2016 Population structure, abundance and movement of whale sharks in the Arabian Gulf and the Gulf of Oman. *PLoS One* 11: e0158593

- 2005 Habitat conditions and potential food items during the appearance of whale sharks (*Rhincodon typus*) in Probolinggo waters, Madura Strait, Indonesia. *Proceedings North American Marine Science Association* 28:67–74

- 2017 Review of the science of whale sharks: *A large animal in a small world*. *Marine Mammal Science* 33(2):327–369

- 2016 The whale shark, *Rhincodon typus*, is a livebearer: 300 embryos found in one ‘megamamma’ supreme. *Environmental Biology of Fishes* 46(3):219–223

- 2012a Patterns in composition, abundance and scarring of whale sharks *Rhincodon typus* near Holbox Island, Mexico. *J Fish Biol* (80) 1401–1416

- 2016 Population structure, abundance and movement of whale sharks in the Arabian Gulf and the Gulf of Oman. *PLoS One* 11: e0158593

- 2016 Adult female whale sharks make long-distance movements past Darwin Island (Galapagos, Ecuador) in the eastern tropical Pacific. *Marine Biology*. (163) 213–24

- 2018 Longest recorded trans-Pacific migration of a whale shark (*Rhincodon typus*). *Marine Biodiversity Records*. 11:8

- 2018 Oceanographic Factors in Fishing Ground Location of Anchovy at Teluk Cenderawasih National Park, West Papua : Are These Factors Have an Effect of Whale Sharks Appearance Frequencies?. *IOP Conf. Series: Earth and Environmental Science*. (9116) 012017

- 2018 Effects of oceanographic factors on spatial distribution of Whale Shark in Cendrawasih Bay National Park, West Papua. *IOP Conf. Series: Earth and Environmental Science* (149) 102050

- 2006 Kondisi oseanografi di Perairan Teluk Saleh Nusa Tenggara Barat. *Prosiding seminar nasional IV*, Jatiluhur 29-30 Agustus 2006 217 – 229

- 2019 Potential tourism development for whale shark (*Rhincodon typus*) watching in eastern Indonesia. *IOP Conf. Series: Earth and Environmental Science* (253) 012043

- 2005 An astronomical pattern-matching algorithm for computer-aided identification of whale sharks *Rhincodon typus*. *Journal of Applied Ecology* 42(6) 999–1011

- 2007 Whale shark (*Rhincodon typus*) biology and ecology: a review of the primary literature. *Fisheries Research* (84):4–9
[27] Naser H A 2014 Book. Biodiversity - The Dynamic Balance of the Planet. Chapter: Marine Ecosystem Diversity in the Arabian Gulf: Threats and Conservation. Publisher: InTech

[28] Wilkinson T, Wiken E, Bezaury-Creel J, Hourigan T, Agardy T, Herrmann H, Janishevski L, Madden C, Morgan L and Padilla M 2009 Marine ecoregions of North America. Canada: Commission for Environmental Cooperation, Montreal

[29] Himawan M R, Tania C, Noor B A, Wijonarno A, Subhan B and Madduppa H 2015 Sex and size range composition of whale shark (Rhincodon typus) and their sighting behaviour in relation with fishermen lift-net within Cenderawasih Bay National Park, Indonesia. Aquaculture, Aquarium, Conservation & Legislation-International. Journal of the Biofuel Society. 8(2)

[30] Ramírez-Macías D, Vázquez-Haikin A, Va’zquez-Juárez R 2012b Whale shark Rhincodon typus populations along the west coast of the Gulf of California and implications for management. Endangered Species Research. (18) 115–128

[31] Hueter R E, Tyninski J P and de la Parra R 2013 Horizontal movements, migration patterns, and population structure of whale sharks in the Gulf of Mexico and northwestern Caribbean sea. PLoS One 8

[32] Acuña-Marrero D, Jiménez J, Smith F, Doherty P F, Hearn A, Green J R and others 2014 Whale Shark (Rhincodon typus) Seasonal Presence, Residence Time and Habitat Use at Darwin Island, Galapagos Marine Reserve. PLoS One 9

[33] Nelson J D 2004 Distribution and foraging ecology by whale sharks (Rhincodon typus) within Bahia de Los Angeles, Baja California Norte, Mexico. MSc Thesis, University of San Diego, 118 pp

[34] Riley M J, Hale M S, Harman A, Rees R G 2010 Analysis of whale shark Rhincodon typus aggregations near South Ari Atoll, Maldives Archipelago. Aquatic Biology (8) 145–150

[35] Rowat D and Brooks K S 2012 A review of the biology, fisheries and conservation of the whale shark Rhincodon typus. Journal of Fish Biology (80) 1019–1056

[36] Rohner C A, Richardson A J, Prebble C E M, Marshall A D, Bennett M B, Weeks S J, Cliff G, Wintner S P and Pierce S J 2015b Laser photogrammetry improves size and demographic estimates for whale sharks. PeerJ 3:e886

[37] Martin R A 2007 A review of behavioural ecology of whale sharks (Rhincodon typus). Fisheries Research. (84) 10–16

[38] Clingham E, Brown J, Henry L, Beard A, Dove AD. Evidence that St. Helena island is an important multi-use habitat for whale sharks, Rhincodon typus, with the first description of putative mating in this species. PeerJ Preprints : 4:e1885v1

[39] Lo W T, Shih C T and Hwang J S 2004 Diel vertical migration of the planktonic copepods at an upwelling station north of Taiwan, western North Pacific. J. Plankton Res. (26) 89–97

[40] Brunnschweiler J M, Baensch H, Pierce S J and Sims D W 2009 Deep diving behaviour of a whale shark during long distance movement in the western Indian Ocean. Journal of Fish Biology. (74) 706–714

[41] Rohner C, Couturier L, Richardson A, Pierce S, Prebble C, Gibbons M J and others 2013 Diet of whale sharks Rhincodon typus inferred from stomach content and signature fatty acid analyses. Marine Ecology Progress Series (493) 1–17

[42] Rowat D and Gore M 2007 Regional scale horizontal and local scale vertical movements of whale sharks in the Indian Ocean off Seychelles. Fisheries Research (84) 32–40

[43] Berumen M L, Braun C D, Cochran J E M, Skomal G B and Thorrold S R 2014 Movement patterns of juvenile whale sharks tagged at an aggregation site in the Red Sea. PLoS One 9

[44] Robinson D P, Jaidah M Y, Jabado R W, Lee-Brooks K, Nour El-Din N M and others 2013 Whale Sharks, Rhincodon typus, Aggregate around Offshore Platforms in Qatari Waters of the Arabian Gulf to Feed on Fish Spawn. PLoS One 8(3) e58255

[45] Shaari F and Mustapha M A 2017 Factors influencing the distribution of chl-a along coastal waters of East Peninsular Malaysia. Sains Malaysiana. 46(8): 1191–1200
[46] Rohner C A, Armstrong A J, Pierce S J, Prebble C E M, Cagua E F, Cochran J E M, Berumen M L and Richardson A J 2015a Whale sharks target dense patches of sergestid shrimp off Tanzania. *Journal of Plankton Research* (37) 352–362

[47] Folt C L and Burns C W 1999 Biological drivers of zooplankton patchiness. *Trends Ecol. Evol.* (14) 300–305