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Population Structure, Site Fidelity, and Residency Patterns of Whale Sharks (*Rhincodon typus*) in Botubarani Waters, Gorontalo Province, Indonesia

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ABSTRACT

Whale shark (*Rhincodon typus*) is the largest fish species in the world and is classified as endangered. This study is crucial for the conservation of this species and developing effective conservation strategies. The research was conducted in the Botubarani waters, Gorontalo Province. Individual whale shark identification was performed using Photo ID, including the identification of sex and wound location. Photo IDs were processed using the Interactive Individual Identification System (I3S) software and includes information related to the ID, body length, and the time the individual was previously identified. Monitoring of the location, number, timing of whale shark presences and water parameters, was carried out through direct field observations. The results showed that 5 whale shark individuals were identified, all of which were male, with lengths ranging from 4.5 to 4.8 meters, and 1 individual had visible wounds. From 78 days of monitoring, Whale sharks were observed for 70 days and not observed for 8 days. The frequency of whale shark appearances ranged from 1 to 4 individuals per day. Whale sharks in Botubarani waters exhibited site fidelity and a mixed migration pattern. The intensity of their presence is quite high. This intensity is supported by ecological conditions that are optimal for the life of whale sharks, particularly those of juvenile age. The measured water parameters significantly influence their presence.

1. Introduction

The whale shark (*Rhincodon typus*) is the largest shark species (Alam *et al.* 2014) among the 509 shark species in the world (Weigmann 2016), highly migratory (Sleeman *et al.* 2010), and often spends its time in the water column near the surface (Sequeira *et al.* 2012). This shark has a broad geographical habitat range in tropical waters with warm temperatures (Wilson *et al.* 2006). In various waters, resident whale sharks are typically dominated by juvenile males (Fox *et al.* 2013). This fish can be found in some waters in Indonesia, such as in the Thousand Islands, Padang, Sabang, Ujung Kulon, Probolinggo, East Kalimantan, Sunda Kecil Islands, Central Sulawesi, Gorontalo, Maluku, and Cenderawasih Bay in Papua (Mustika *et al.* 2020; Azizurrohman *et al.* 2021). Globally, Whale sharks are distributed and seasonally inhabit coastal waters areas in tropical and subtropical regions (Hacohen-Domené *et al.* 2015), specifically between latitudes 30°N-35°S or around 124 countries worldwide, excluding the Mediterranean Sea (Morales-Ramirez & Wang 2020).

Whale sharks have been listed on the IUCN (International Union for Conservation of Nature) Red List as vulnerable since 2000. In 2002, the whale shark was included in Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), which means that international trade in whale sharks must comply with regulations that ensure their use does not threaten their survival in the wild.

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The species has been fully protected throughout the waters of Indonesia since 2013. This is based on The Ministry of Marine Affairs and Fisheries of the Republic of Indonesia No. 18 of 2013, which grants complete protection status, meaning that all forms of exploitation of whale sharks, including using their body parts, are legally prohibited. However, the economic potential of whale sharks can still be developed through ecotourism activities.

Protection efforts involve establishing protected areas and enforcing strict regulations on whale shark capture and resources. Additionally, raising public awareness about the crucial role of whale sharks in marine ecosystems is key to achieving adequate protection. Protecting whale sharks ensures the species' survival and maintains the balance and sustainability of the entire marine ecosystem. Education and increased public awareness about the whale shark's critical role contribute to building community support for conservation efforts. Moreover, ongoing scientific research and monitoring of whale shark populations help design more effective protection strategies.

The population, residency, and ecology study of whale sharks is an important research topic in efforts to conserve this species. The whale shark is the largest fish species in the world and is endangered, making a deep understanding of its population, behavior, and habitat crucial. Additionally, the trend of whale sharks being used as a tourism attraction, such as in Botubarani and Gorontalo, could become an issue for their sustainability. This knowledge is essential for developing effective conservation strategies and supporting the sustainable management of whale shark tourism.

2. Materials and Methods

The research location is Botubarani, Kabila Bone District, Bone Bolango Regency, Gorontalo Province (Figure 1). The study was carried out over approximately 3 months, from February 18 to May 5, 2024. The research location is presented in Figure 1. Monitoring was divided into four periods based on the observation months: February (from the 18th to the 29th, 12 days), March (from the 1st to the 31st, 31 days), April (from the 1st to the 30th, 30 days), and May (from the 1st to the 5th, 5 days).

The guidelines for collecting data on whale shark monitoring in this research adhere to the "General

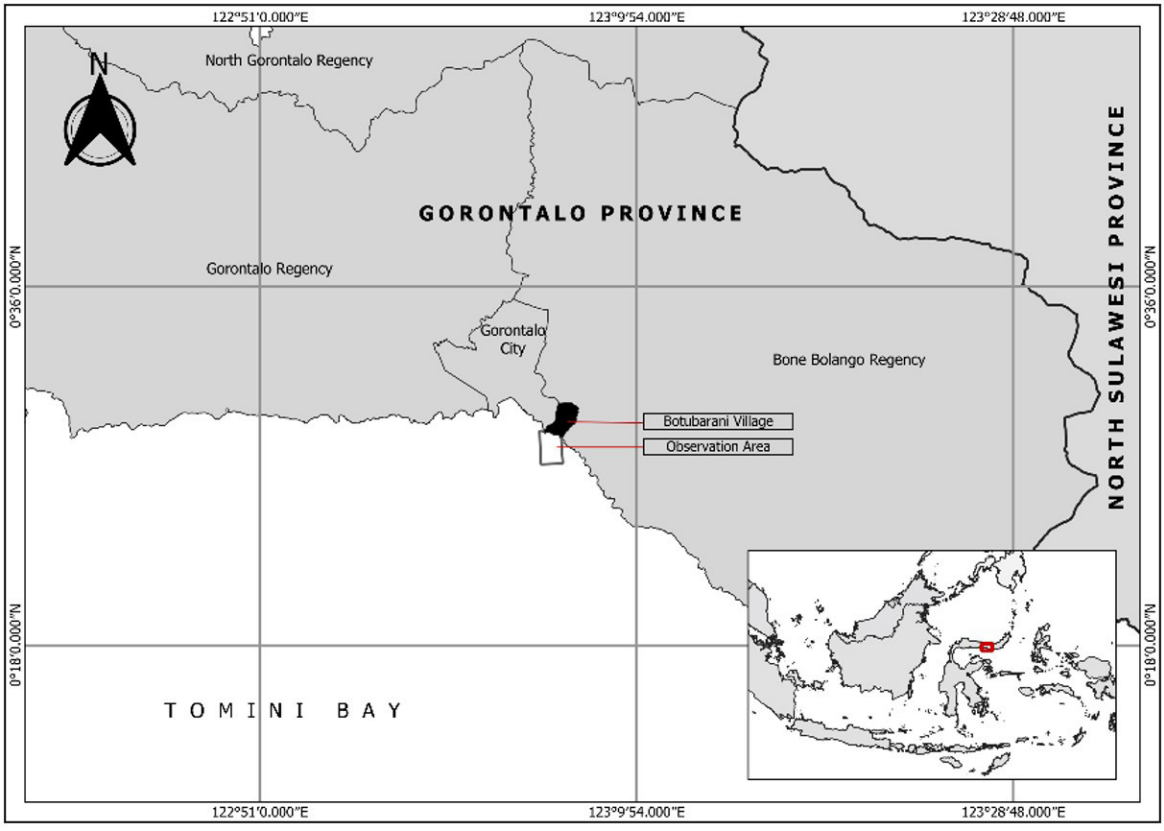


Figure 1. The research map's location

Guidelines for Whale Shark in Indonesia" published by the Ministry of Marine Affairs and Fisheries in 2015. The data collected includes primary data (Photo ID, sex, injured location, appearance location, number of appearances, time of appearance, and water quality) and secondary data from a whale shark's appearance.

Individual whale shark identification is done using a Photo ID. The spot patterns and lines on the whale shark's body are used to identify individual sharks. Photo IDs are taken of each shark that surfaces by following the direction of the whale shark's swim while adhering to the guidelines and technical. Photos for Photo ID should be taken from the left and right side of the fifth or last gill slit to the tip of the pectoral fin of the whale shark. Photo ID data is processed using the Interactive Individual Identification System (I3S) software to match with the whale shark database previously collected by enumerators from the Makassar Marine and Coastal Resource Management Agency. The information obtained and used from the matching results includes the name/number ID, size, and the year the individual was previously identified.

The sex of whale sharks is determined based on the claspers. The morphology of claspers is an effective and non-invasive method for assessing the sex of whale sharks. Sex is distinguished by diving and directly observing the underside of the pelvic fins, where claspers can be seen as two projections, commonly referred to as the pelvic fin rays or claspers, on both median sides of the fin. If claspers are found, the whale shark is male. If claspers are not found, the whale shark is female. For analyzing scarring locations and patterns on the whale shark's body, the process involves directly diving around the shark to observe any wounds. Injuries in specific areas are recorded and photographed.

The location, number, and time of whale shark presence were monitored through direct observation during the research period. Observations were conducted systematically based on time divisions, specifically by the hour (from morning to afternoon), with coordination between researchers, fishermen, awareness groups, and the community involved in whale shark tourism management. In the morning, whale shark tracking was carried out using two methods: from above the water (by boat) and from the air (using a drone). In the afternoon, whale shark monitoring was conducted using drones, supported by coordination and reports from the monitoring group and boat guides, while tourism activities were ongoing. Identification photo capture and individual count were carried out through diving or snorkeling following the tracking and monitoring process. It is important to note that observations (particularly identification photo capture) could be conducted at any time or specific intervals, depending on the most recent presenting information or the identification of an increase in the number of whale sharks. Each whale shark observed or surfaced for the first time is counted, its coordinates are marked using a Global Positioning System (GPS) device, and the number of appearances and time of the presencing is recorded.

The counting of whale shark individual presence is based on the results of individual identification photo captures (Photo ID) conducted daily throughout the research period, along with the recording of the time of presence (hour and date). These Photo IDs are then matched with the whale shark identification database. From this matching process, the number of individual whale sharks present each day (distinct individuals observed on a given day) is determined, allowing the frequency or presence of whale sharks to vary according to specific time categories (such as day or month) and the number of days each whale shark individual is present. Meanwhile, the time series data of whale shark presence dates were obtained from the Botubarani Whale Shark Awareness Group. The Botubarani Whale Shark Awareness Group and enumerators from the Makassar Marine and Coastal Resource Management Agency have recorded these presenting dates from 2016 to 2023.

Water quality measurements were conducted during the observation period of whale sharks at the research location, based on the presence of the whale sharks. The measured parameters affecting the life and presence of whale sharks include temperature, water clarity, salinity, pH, and dissolved oxygen (DO). Temperature, pH, and salinity measurements were conducted at the surface water level. The calibration of the measuring instruments was carried out prior to each sampling session to ensure the accuracy of the measurements. Calibration was performed using known reference standards, and the instruments were calibrated according to the manufacturer's guidelines to address any potential drift or variation, thereby ensuring the reliability of the measurements taken at the water's surface. Subsequently, tests were performed to assess the relationship between water parameters and whale shark presence. The analysis was conducted using correlation level and was evaluated with Pearson's bivariate correlation test. The testing was carried out using Statistical Product and Service Solutions (SPSS) software.

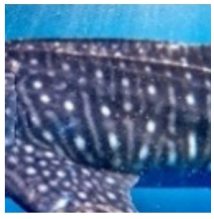
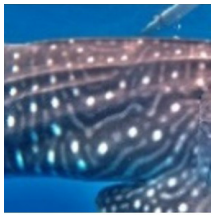
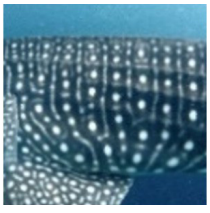
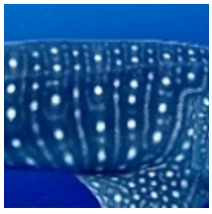
3. Results

Based on the research (Table 1), there are five different individual whale sharks present in the waters of Botubarani during the observation period. These whale sharks have been previously identified in earlier years. One individual has been identified since 2022 (GT 053), and four individuals have been identified since 2023 (GT 054, GT 057, GT 058, and GT 059). All identified individuals are male.

The results of individual identification through Photo ID, which were then matched with the whale shark ID database, revealed a range of sizes for the whale sharks. The lengths of the whale sharks found varied from 4.5 to 5.8 meters. The condition of the identified whale sharks was that one individual had injuries, and the others were without injuries. The injured individual had wounds on its fins and body, which appeared as pale scratches.

Observations of whale sharks in the Botubarani waters also identified specific appearing points (Figure 2). Each appearing coordinate indicates a single individual and can represent more than one whale

Table 1. Identities of identified individual whale sharks

Photo ID		ID name	Year identified	Sex	Size (meters)	Wound position
Left	Right					
		GT 058	2023	Male	5.0	Fin and body
		GT 054	2023	Male	5.8	-
		GT 053	2022	Male	4.5	-
		GT 059	2023	Male	5.5	-
		GT 057	2023	Male	5.5	-

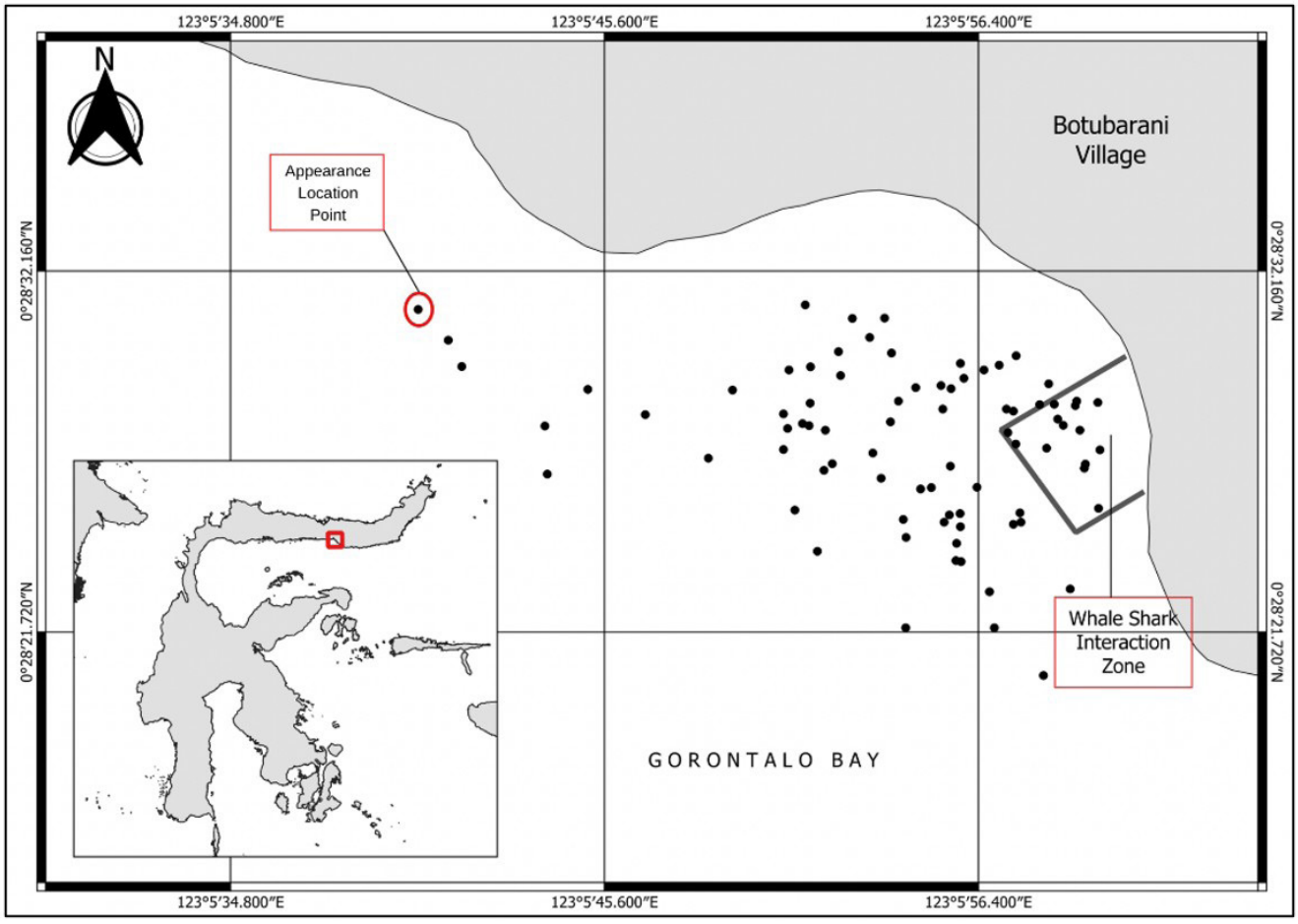


Figure 2. Collection of the first detected appearance locations of whale sharks on each day of their presence in the waters of Botubarani, Gorontalo Province, during the monitoring period

shark. Whale shark appearances are more frequently found around the whale shark interaction zones.

The daily presence status of whale sharks is based on monitoring their presence each day in the observation area during the observation period. Whale sharks are recorded daily, and their presence and absence are compiled. Out of the 78 days of monitoring, whale sharks were recorded as being present for 70 days and not 8 days (Figure 3).

From Figure 4, the number of daily appearances of whale sharks compiled during the observation period in that month, when compared with the results of Photo ID matching with the whale shark database, shows that each month, the number of appearances is consistently higher and significantly exceeds the number of identified individuals. Connected to Figure 3, in February, there were 23 appearances, representing the repeated presence of 3 whale shark individuals over 12 days. Similarly, in March, 35 appearances were recorded across 26 days, with 4 individuals identified, each appearing multiple times throughout the month. Furthermore, in April, the number of appearances increased to 71, corresponding to 5 individuals observed over 27 days. Whereas, in May, 7 appearances were recorded, all from 3 individuals, who appeared repeatedly over the course of 5 days.

After matching with the database, the daily appearance frequency of whale sharks was found to vary as follows: in February and March, the daily frequency ranged from 1 to 3 individuals per day. In April, it ranged from 1 to 4 individuals, and in May, it ranged from 1 to 2 individuals per day (Figure 5). This frequency refers to the number of whale shark individuals detected on each day of their presence, ranging from the lowest to the highest number observed.

The observation results of the initial daily presence time (first detection) of whale sharks on 69 days in the waters of Botubarani indicate that whale sharks were more frequently present in the morning, with some occurrences recorded in the afternoon (Figure 6).

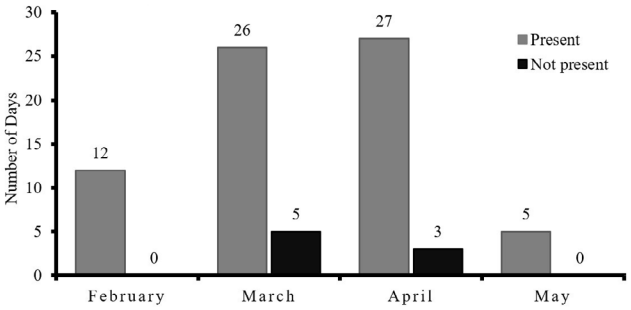


Figure 3. The daily presence status of whale sharks at the observation site during the monitoring period is classified based on monthly divisions. The number above the bar shows the number of observed days

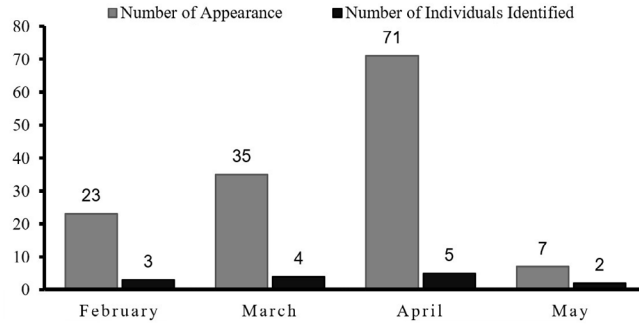


Figure 4. Comparison between the total daily appearances of whale sharks compiled per month and the number of individuals identified each month during the monitoring period

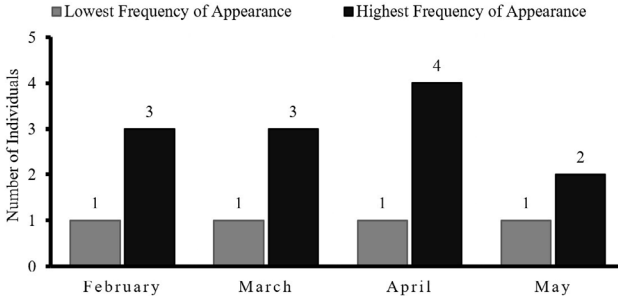


Figure 5. The frequency of whale shark individuals appearing per day is based on monthly divisions. The number above the bar shows the number of individuals observed

Figure 7 shows that the whale sharks with IDs GT 053 and GT 058 are the two individuals most frequently present in the Botubarani waters during the study period, as they were detected each month. GT 053 was present for 43 days, and GT 058 for 65 days, out of a total of 70 days of whale shark presence in the Botubarani waters. Additionally, a whale shark identified as GT 054 was detected in February, March, and April, with a total of 17 days of presence. Other identified whale shark individuals include GT 057 (detected in April and May) and GT 059 (detected in March and April), with 2 and 9 days of presence, respectively.

Daily fluctuations in whale shark presence cannot be concluded due to the varied patterns of their appearances (Table 2). Whale sharks have been consistently detected every month from 2020 to 2023. The data also reveals that the months with the highest daily intensity of whale shark presence are from May to August. The calendar also indicates that the beginning and end of the year have seen a significantly high presence in recent years.

Marine water quality is an important factor influencing the presence of whale sharks in a particular area, especially in the Botubarani waters, making it necessary to understand this aspect. The following are the results of water quality measurements (Figure 8) and their analysis concerning whale shark presence using a bivariate Pearson correlation test (Table 3).

The surface temperature in the waters of Botubarani ranges from 29 to 32°C, with water clarity ranging from 9 meters to 23 meters. Salinity measurements in the waters range from 24 to 32‰. The pH value in these waters ranges from 7.4 to 7.8, and the dissolved oxygen (DO) levels range from 6.04 to 7.16 mg/L.

The analysis results on the relationship between marine water quality parameters and the presence of whale sharks in the waters of Botubarani, using Pearson correlation, show a value of 0.473 for temperature, 0.771 for water clarity, and 0.649 for salinity. Additionally, the correlation indicates that pH has a value of 0.786 and DO (dissolved oxygen) has a value of 0.797. The correlation values ranging from 0.400 to 0.599 are categorized as having a moderate relationship, those from 0.600 to 0.799 as having a significant relationship, and those from 0.800 to 1.000 as having a very significant relationship.

4. Discussion

4.1. Identification of Individual Whale Sharks

Efforts to recognize different individuals are crucial for whale shark conservation. By identifying individuals, it is possible to estimate the number of whale sharks in a specific area and determine their population. Whale sharks are known as the largest fish in the world (Weber *et al.* 2020), adorned with patterns of white spots and stripes (Rodrigues *et al.* 2012). The pattern of white spots located behind the gills on either side of the whale shark is used to identify and distinguish between individuals (Brooks *et al.* 2010). These unique round spot patterns

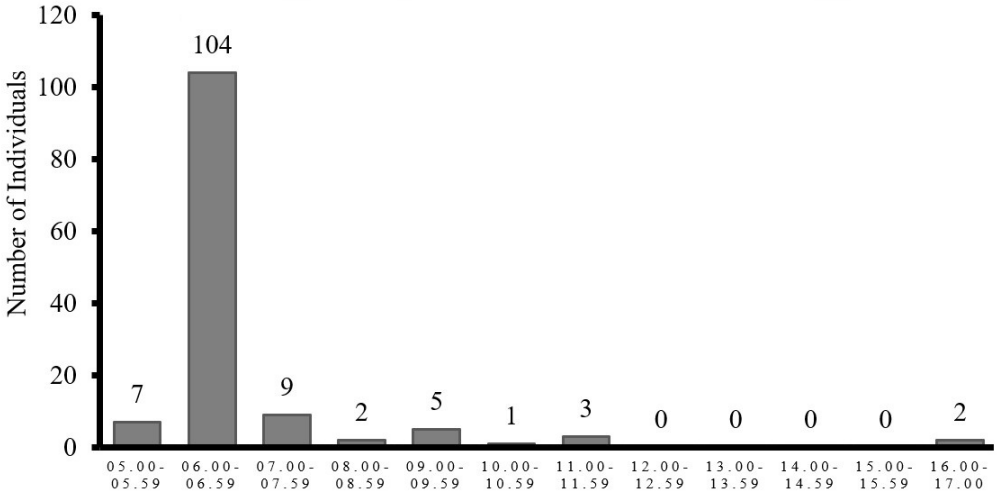


Figure 6. Presence time of whale shark individuals based on the time range when they were first detected each day during the monitoring period

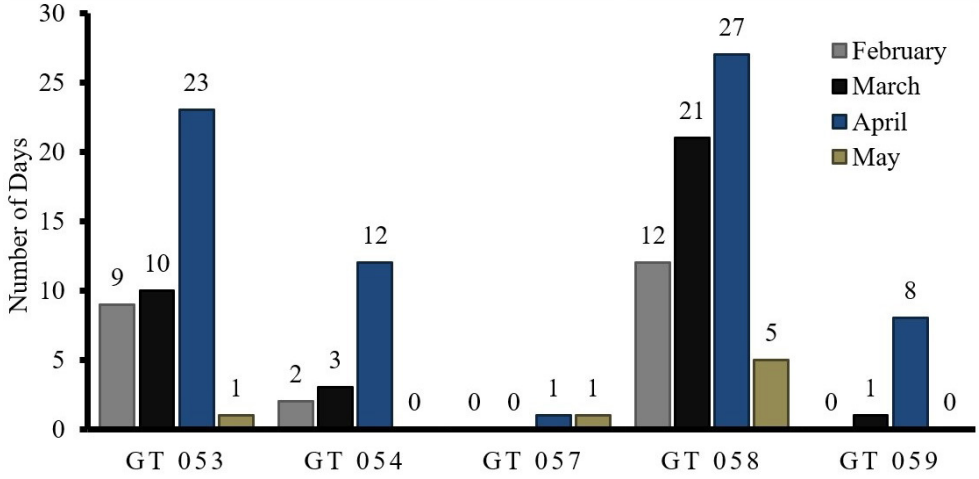


Figure 7. Intensity of whale shark presence days per identified individual each month during the monitoring period

Table 2. Calendar of whale shark presence for the years 2016-2023 in Botubarani Waters, Gorontalo Province

Year	Month (Number of days)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2016	0	0	15	25	30	30	31	16	0	0	17	0
2017	2	14	8	0	28	21	2	0	0	0	0	3
2018	0	0	1	0	29	30	31	31	24	6	18	7
2019	7	7	17	27	28	21	16	12	0	6	5	5
2020	18	18	28	13	16	21	20	16	18	12	7	11
2021	16	28	31	30	31	30	30	31	28	29	14	5
2022	22	1	5	5	17	30	28	9	17	18	30	31
2023	31	28	31	30	31	31	31	29	27	21	23	29

are similar to human fingerprints, remain unchanged, and allow each whale shark to be individually identified (Mckinney *et al.* 2017).

The research (Table 1) suggests that male whale sharks are more dominant in the Botubarani waters, while females did not appear during the study period. This finding is consistent with previous research conducted in Botubarani waters (Handoko *et al.* 2017; Rahman *et al.* 2017; Rosalina *et al.* 2021; Rombe *et al.* 2022;). A male bias is often observed in monitored whale shark

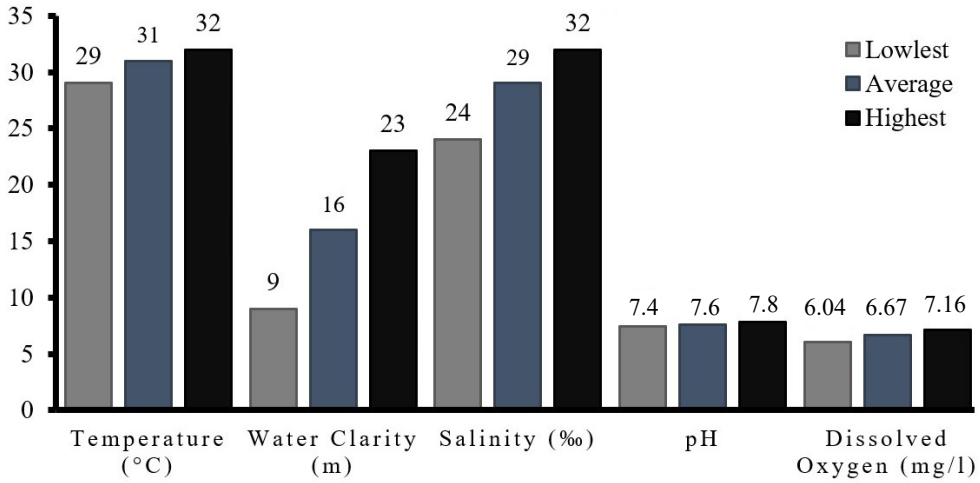


Figure 8. Range of water parameter measurements in the observation area, which is the location of whale shark presence in the waters of Botubarani

Table 3. Analysis of the correlation between marine water parameter measurements and whale shark presence

		Temperature	Water clarity	Salinity	pH	Dissolved oxygen
Number of presence	Pearson correlation	0.473**	0.771**	0.649**	0.786**	0.797**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000
	N	77	77	77	77	77

aggregation sites. The percentage of male whale sharks in Mozambique (76%) is similar to that in the northeastern part of South Africa (73%) and the Gulf of California coast (75%) but lower compared to Tanzania (88%), the Maldives (95%), Djibouti (83%), Ningaloo Reef (85%), or Seychelles (82%) (Rohner *et al.* 2015). This indicates that male whale sharks may have more extensive territorial ranges than females. This is one reason males of whale sharks frequently appear in Botubarani waters.

Whale shark appearances in the Botubarani waters are dominated by sizes classified as juvenile whale sharks. Coastal aggregations are typically dominated by immature male whale sharks, around 5-7 meters long (Rowat *et al.* 2007). Adult individuals and juveniles of whale sharks use different habitats. Adult male and female whale sharks are rarely seen in coastal areas and are likely found primarily in the open ocean (Rohner *et al.* 2015). The small size and the absence of female whale sharks in the waters of Botubarani suggest that the area may be more important as a feeding ground rather than a breeding site.

Monitoring these injuries is also crucial for assessing the suitability of whale shark aggregation habitats. Tracking the location and condition of wounds on whale sharks helps facilitate the process of determining their causes. The types of threats leading to injuries in whale sharks vary, such as predator attacks and boats observed in Ningaloo Reef, Australia (Speed *et al.* 2008), or human activities like fishing gear and tourism, which occur in Cenderawasih Bay (Jentewo *et al.* 2021).

4.2. Whale Sharks Appearing Location

These aggregation sites (Figure 2) are related to the ocean's bathymetry. Typically, these locations are shallower and slopes (Petatán-Ramírez *et al.* 2020). This aligns with the conditions observed and the locations of whale shark appearances in the Botubarani waters. Additionally, these appearings locations are associated with food sources, both natural (Allen *et al.* 2021) and due to human interactions, such as feeding by fishermen or communities (Rowat & Brooks 2012; Farid *et al.* 2021).

4.3. Quantity of Whale Shark Presence

Their behavior and changes influence the daily detection of whale sharks (Figure 3) in environmental conditions. Whale sharks migrate to other locations and often return to the areas after some time. Therefore, they undertake long-distance migrations for productive feeding grounds (Thomson *et al.* 2017). Acoustic telemetry has shown that, although whale sharks may stay in a specific region year-round, they use different habitats during different seasons, swimming deeper and further from the coast in response to prey distribution and their exploratory behavior (Cagua *et al.* 2015). This explains

why, some days, whale sharks are not detected in the Botubarani waters.

The number of appearances and individual whale sharks present (Figure 4) is influenced by their seasonal aggregation in specific tropical and coastal regions, as well as their potential for large-scale migrations across borders in search of productive plankton groups as their food sources and the possibility that broadscale shifts in the regional biological and physical dynamics driven by climate change (Afonso *et al.* 2014). Additionally, the age category of the whale sharks affects their appearance. For example, if the observed whale sharks are juveniles, the tendency is that only those individuals will appear because juveniles tend to remain in a particular area to feed (Rowat & Brooks 2012; Acuña-Marrero *et al.* 2014). This results in the number of whale sharks appearing in the Botubarani waters not directly correlating (often being higher) with the number of identified whale sharks IDs. This indicates that several individuals are repeatedly present or always appear on the observation days. In other words, there is a high likelihood of the same whale shark individual appearing each day. This is also related to the frequency or number of individuals present on each day. If the number of individuals present is relatively high, but only those same individuals consistently appear, it will result in a high number of appearances, while the number of identified individuals (individual diversity) will be lower.

In addition to environmental factors, the frequency of individual whale sharks' appearance (Figure 5) is influenced by their aggregation behavior. Whale sharks in the Botubarani waters were observed to be primarily solitary during the study period, but they were also occasionally found in groups. Whale sharks are generally solitary creatures that gather in certain areas, particularly along many coasts (Green *et al.* 2023). While foraging, whale sharks prefer to feed alone in coastal waters. However, during migration, they tend to travel with other individuals. Although whale sharks are usually solitary, they tend to group in aggregation sites when food availability is high (Hoffmayer *et al.* 2021).

Whale sharks are most commonly observed in the morning to early day (Figure 6). This pattern is generally related to whale sharks spending more time in shallow waters or near the surface from morning to afternoon (dawn ascent). The preference for spending time in shallower waters is likely due to the presence of surface-dwelling prey. On the other hand, the tendency of whale sharks to dive into deeper waters, usually during the night (dusk ascent), is believed to be related to the food source or to detecting the condition of the water (Ramírez-Macías *et al.* 2017).

Figure 7 shows that whale sharks in the Botubarani waters tend to stay. This is evident from the consistent presence of several whale sharks each month. While some exhibit migratory or non-resident behavior, they still appear in the Botubarani waters. This is supported by the whale shark ID data (Table 1), where individuals have been recorded in Botubarani since 2022 and 2023, indicating that they have not migrated to other waters or oceans for approximately one to two years. It can be described that whale sharks may migrate to nearby waters and then return to Botubarani.Whale sharks found in the Botubarani waters do not continuously stay there, they typically return to Botubarani specifically. This suggests that some whale sharks exhibit site fidelity, as shown by several individuals with high numbers of appearance days. This relates to the size (age) composition observed, leading some whale sharks to stay in Botubarani.

Juvenile whale sharks in Botubarani imply that some whales tend to be site-fixed in the area. It is known that whale sharks in Botubarani waters exhibit a mixed migration pattern. Whale sharks in the Botubarani waters exhibit behavior where some remain in the area for several years or months, while others may leave for a few months before returning. With their large bodies, whale sharks have evolved to enhance their feeding efficiency. They gather seasonally or temporarily in areas with high natural prey concentrations despite their generally solitary (Legaspi *et al.* 2020).

4.4. Period of Whale Shark Presence

Whale shark presence fluctuations (Table 2) are caused by several factors, such as habitat conditions like oceanography, food source/plankton (Hueter *et al.* 2013), and behavior, sometimes involving moving or exploring different areas related to biological and environmental dynamics. Ocean currents are related to the seasonal presence of whale sharks in the Botubarani waters. Botubarani, located in the Sulawesi region, is influenced by water masses from the Pacific Ocean. The Sulawesi Sea is a gateway for water masses from the Pacific Ocean into the Sulawesi waters and other adjacent waters. Additionally, its position in the Indo-Pacific Tropical region means the coastal and marine areas exhibit high biodiversity (Lasut *et al.* 2021). This significantly affects the presence of whale sharks in these waters.

4.5. Relationship Between Water Quality and the Presence of Whale Sharks

The Botubarani waters, where whale sharks appear, have a temperature range from 29 to 32°C, averaging 31°C. The correlation test shown in Table 3 indicates a positive correlation, meaning that each increase in temperature triggers the appearance of whale sharks. Many whale sharks support the finding observed in sea surface temperatures above 29°C (Ihsan *et al.* 2018). Whale sharks appear at the surface to feed at temperatures as high as 33.8°C (Robinson *et al.* 2013). Other studies on whale shark tolerance to temperature also show that whale sharks can survive up to 35°C (Robinson *et al.* 2017). Mainly, solitary whale sharks, or those not in groups, found in the Indian Ocean, are 90% observed in sea surface temperatures ranging from 26.5 to 30ºC (Robinson *et al.* 2013). These temperature conditions demonstrate that whale sharks thrive in tropical marine environments like Botubarani waters. However, the correlation value based on this test falls into the moderate (Middle) category. This correlation values might happen because whale sharks can also survive and tolerate temperatures up to 10ºC while diving in deepwater (Ihsan *et al.* 2018). Water temperature affects whale sharks' horizontal and vertical distribution due to its relationship with thermoregulation, metabolism, body temperature, and foraging behavior (Meekan *et al.* 2015; Nakamura *et al.* 2020).

Water clarity measurements in Botubarani waters range from 9 to 23 meters. Based on the correlation test results, water clarity has a strong influence and relationship with the presence of whale sharks in Botubarani waters. This indicates that the water clarity in Botubarani waters is categorized as suitable for whale shark aggregation. Water clarity is closely related to how far sunlight can penetrate the water, which is necessary for photosynthesis. Water clarity can be affected by inorganic suspended and dissolved materials (such as silt and fine sand) and organic materials like plankton and other microorganisms (Murdani *et al.* 2018). This is suspected to be due to the influence of weather conditions, measurement time, turbidity, and suspended solids (Patty *et al.* 2020).

Salinity values in the Botubarani waters range from 24 to 32‰, which is still within the natural salinity range that whale sharks can tolerate. The lower minimal salinity limit is due to the proximity to land, causing the mixing of freshwater with seawater (Patty *et al.* 2020). The correlation test shows that salinity has a moderate relationship and a partial effect on the presence of whale sharks. This is because whale sharks have an excellent tolerance to varying salinity conditions. Salinity can influence aspects of marine life, such as migration and distribution. This aligns with the migratory behavior of whale sharks. Previous research has shown that whale sharks appear at salinity values ranging from 33 to 34‰ (Murdani *et al.* 2018). Even Robinson *et al.* 2013, who studied whale sharks in the Al Shaheen waters, found that the sharks appeared in high salinity conditions, ranging from 39.1 to 39.5‰. This indicates that whale sharks have a high tolerance for changes in salinity.

The pH parameter of a water body is an important chemical parameter for monitoring water stability. Seawater has a significant buffering capacity to prevent pH fluctuations. Even a slight deviation from the natural pH can indicate a disruption in the buffering system. This can directly and indirectly affect marine life (Rombe *et al.* 2021). This is supported by correlation test results, which show that pH has a partial effect and a strong relationship with the appearance of whale sharks in Botubarani waters. The study also indicates that the pH values range from 7.4 to 7.8. pH is closely related to plankton, a food source for whale sharks. The pH value influences the dominance or biomass of plankton, so whale sharks are likely to appear in waters abundant with plankton (Rombe *et al.* 2022).

The dissolved oxygen levels, based on observations, fall into the normal or good category and are typical for marine waters. The correlation test results show that dissolved oxygen has a partial effect and a strong relationship with the presence of whale sharks. This is because dissolved oxygen (DO) is a crucial parameter for marine environments, especially for whale sharks. Dissolved oxygen is related to respiration and metabolism for whale sharks.

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this manuscript are original and have not been previously published. All data, analyses, and conclusions are derived solely from the work presented in this manuscript.

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