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# The Appearance of Whale Sharks (*Rhincodon typus*) Based on Environmental Factors in Kwatisore Waters, Nabire Regency, Central Papua Province

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## ABSTRACT

The appearance of whale sharks (*Rhincodon typus*) is related to the availability of food in a water area, and it has become a tourist attraction which requires integrated management to prevent it from becoming threats to whale sharks. The appearance of whale sharks is regular throughout the year with the highest number of individuals occurring only in Kwatisore waters. This study aims to examine the bio-ecology of whale sharks related to their appearance based on individuals, quantity, time of appearance, and sex. Primary data collection carried out from January 16 to March 26, 2023, using a census method on 4 units of fishing lift-net deployed in Kwatisore waters. The results showed that 21 individual whale sharks appeared with a total of 225 occurrences in January, 245 occurrences in February, and 248 occurrences in March. There was also one new individual that migrated into Kwatisore waters with the ID number 184. Whale shark appearances mostly happened in the morning and the appearance percentage was 100% male with a total length ranging from 3 to 7.5 m. Environmental factors in Kwatisore waters were in normal conditions supporting the appearance of whale sharks.

**Keywords:** Whale sharks, appearance, new individual, environmental factors.

## *ABSTRAK*

Kemunculan hiu paus (*Rhincodon typus*) berhubungan dengan ketersediaan makanan pada suatu perairan dan kemunculan hiu paus menjadi daya tarik wisata sehingga dibutuhkan pengelolaan secara terintegrasi agar tidak menjadi ancaman terhadap hiu paus. Kemunculan hiu paus secara tetap dan berlangsung sepanjang tahun dengan jumlah individu terbanyak hanya terjadi di perairan Kwatisore. Penelitian ini bertujuan untuk mengkaji bioekologi hiu paus, yang berkaitan dengan kemunculan berdasarkan individu, jumlah dan waktu kemunculannya serta jenis kelaminnya. Pengambilan data primer dilakukan pada tanggal 16 Januari sampai dengan 26 Maret 2023, dengan menggunakan metode sensus pada 4 unit alat tangkap bagan yang dilabuhkan di perairan Kwatisore. Hasil penelitian menunjukkan terdapat 21 individu hiu paus yang muncul dengan total keseluruhan kemunculan pada bulan Januari sebanyak 225 kemunculan, bulan Februari sebanyak 245 kemunculan dan bulan Maret sebanyak 248 kemunculan serta adanya satu individu baru yang migrasi masuk ke perairan Kwatisore dengan nomor ID 184. Kemunculan hiu paus lebih banyak terjadi pada pagi hari dan persentase kemunculan 100% berjenis kelamin jantan dengan ukuran panjang total berkisar antara 3 hingga 7,5 m. Faktor lingkungan di perairan Kwatisore berada dalam kondisi normal sehingga menunjang kemunculan hiu paus.

**Kata kunci:** Hiu paus, kemunculan, individu baru, faktor lingkungan.

## 1. Introduction

The appearance of whale sharks in several Indonesian water regions has become an interesting phenomenon. Whale sharks are categorized as a threatened species since they are hunted for various purposes and their slow growth adds to their vulnerability. The appearance of whale sharks becomes an attraction heightened by their non-aggressive and docile nature, making interactions with them safe as well as having values in ecotourism development (Djunaidi et al., 2020;

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Maruanaya, 2022). The distinctive white spot pattern on the whale shark's body is hypothesized as a form of camouflage, aiding in individual recognition and adaptation to ultraviolet light filters. This adaptation is crucial as whale sharks spend a significant amount of time near the ocean's surface and have visual abilities (Colman, 1997). Whale sharks are known for their fast swimming capabilities, widespread distribution, and being the largest species of fish, potentially reaching lengths of 18 – 20 meters. They are believed to migrate widely in the North Pacific Ocean, a process that takes several years (Eckert and Brent, 2001). The distribution of whale sharks spans tropical and subtropical waters with temperatures ranging between 18 – 30°C and between 30° North and 30° South latitude (Colman, 1997; Tania and Beny, 2014; Maruanaya, 2022).

The compatibility of whale shark habitats in the Indian Ocean correlates with variations in spatial sea surface temperatures, showing a strong preference for temperatures between 26.5 – 30°C. This is based on the hypothesis that whale sharks avoid higher temperatures, so that their metabolic rate increases and subsequently raise their food requirements (Sequeira et al., 2011). Indonesian waters are migration areas for whale sharks, extending from the Indian Ocean, South China Sea, Java Sea, Pacific Ocean, Makassar Strait, Sulawesi Sea, Flores Sea, Sawu Sea, Banda Sea to Arafura Sea (Sadeli et al., 2015), including Kwatisore waters (Maruanaya, 2022). Kwatisore waters have a distinct whale shark appearance pattern compared to other regions in Indonesia. Whale shark sightings occur every day throughout the year, with the highest number of individuals (Toha et al., 2018; Maruanaya et.al., 2021; Maruanaya and Yvonne, 2023). They migrate to other waters but return to Kwatisore waters (Djunaidi et al., 2020), and there is also the migration of new individuals into the area (Maruanaya, 2022; Punusingon et al., 2023).

The appearance of whale sharks in Kwatisore waters is linked to the availability of anchovies (*Stolephorus* sp.) as a food source making Kwatisore a feeding ground and primary habitat throughout the year (Tania and Beny, 2014; Enita et al., 2017; Maruanaya, 2022). To maintain the appearance of whale sharks in Kwatisore waters, a study of their appearances over time and environmental factors is essential for rational management by both government and private sectors.

## 2. Materials and methods

### 2.1. Time and Location of the Research

This research was conducted from January 16 to March 26, 2023, on four fishing lift-net units deployed in Kwatisore waters within the Cenderawasih Bay National Park. The research location map is illustrated on figure 1.

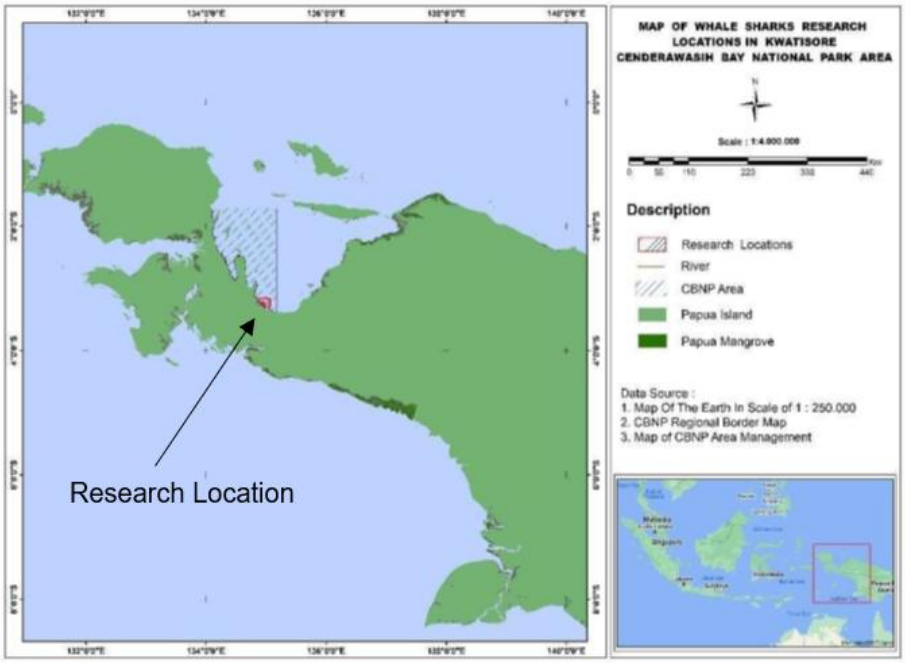


**Figure 1.** Cenderawasih Bay National Park and research location.

### 2.2. Data Collection

Data on whale shark appearances were collected through a census method using four fishing lift-net units over three months. Each boat life net unit collaborated in recording the number of appearing whale sharks and maintaining their presences by giving anchovies. Fishermen on the fishing lift-net informed the researchers through All-band Radio and the researchers conducted photo identification for individual identification (ID). The appearance of whale sharks on each fishing lift-net unit was recorded according to the number of individuals, estimated size, and time of appearance (morning, afternoon, evening).

The appearance of whale sharks follows the position of the fishing lift-net, so that the position of each is determined using GPS. By determining the position of the fishing lift-net, the spatial distribution of whale sharks in the waters of Kwatisore can be identified. For each whale shark that appears, photo identification is conducted using an underwater camera (Canon G-12). The photo ID technique for whale sharks is performed by observing the left side from the last gil or gill number five to the tip of the pectoral fin, and the right side from the last gill or gill number five to the tip of the pectoral fin. Meanwhile, to determine the gender of the whale shark, direct observations are made. The environmental factors measured include surface water temperature, pH, salinity, and brightness. Environmental factor measurements are carried out at four boat life net units as locations of whale shark appearances.

#### 2.2.1. Identification of Individual Whale Sharks

The identification of whale shark individuals based on white spots on each whale shark's body. Following the results of photo ID, each individual is then identified using the software "Interactive Individual Identification System Version 2.0" (I3Sv2) (van Tienhoven et al., 2007) and the photo ID database owned by the Nabire Region I National Park Management Section of Region I Nabire. This is because the National Park Management Section of Region I Nabire has a database of whale sharks in the Cenderawasih Bay National Park. The technique for identifying whale sharks using I3Sv2 involves marking the white spots (enclosed in a red box), and then I3Sv2 reads and identifies each individual (Figure 2).

#### 2.2.2. Population Characteristics of Whale Sharks

The population characteristics of whale sharks are assessed based on size and gender. Determination of the body length of whale sharks is carried out by swimming parallel to the whale shark and comparing its length with the body of the swimmer, allowing for the estimation of the whale shark's size (Tania and Beny, 2014; Himawan et al., 2015; Jentewo et al., 2021; Maruanaya, 2022). The determination of the gender of whale sharks is observed visually, specifically by directly examining the anatomical structure of males (clasper), which are elongated and located near the anal fin, while female whale sharks do not have claspers.

### 2.3. Data Analysis

#### 2.3.1. Whale Shark Appearances

Daily whale shark appearances were recorded through a census technique, documenting the number of individuals at each fishing lift-net unit and conducting photo

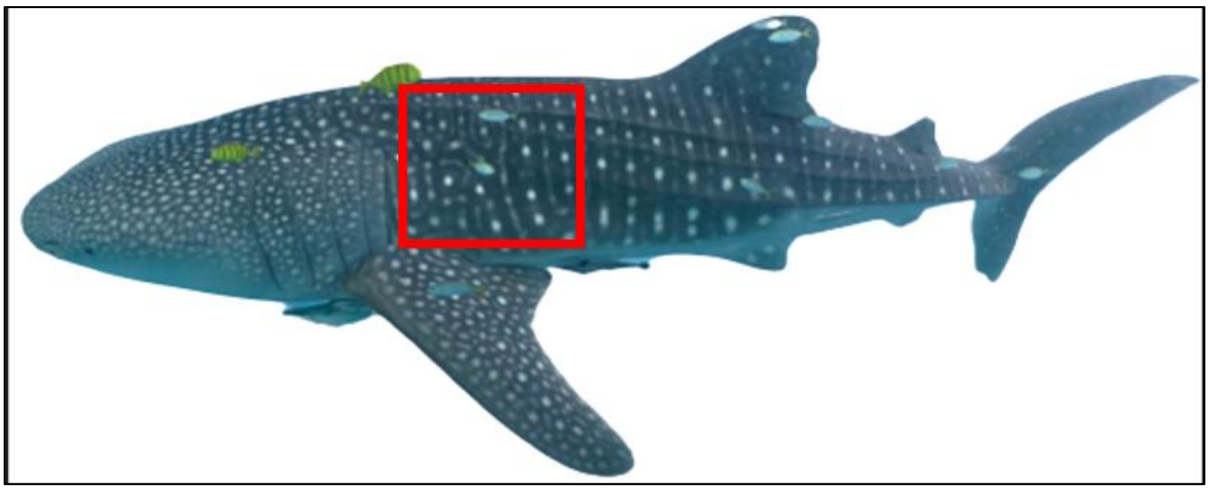

**Figure 2.** Individual whale shark identification technique (Toha et al. 2015; Maruanaya, 2022).

identification for individual identification. Visual observation.

2.3.2. Population Characteristics

Population characteristics of whale sharks were assessed based on the length and sex that appeared on the water surface in the fishing lift-net area. The distribution of identified whale shark lengths was calculated using the formula according to Tania and Beny (2014), Sadili et al. (2015), and Maruanaya (2022):

$$\% \text{ N} = \frac{\text{ni}}{\text{N}} \, x \, 100$$

Where:
%N is the percentage of whale sharks with a length of i meters,
ni is the number of whale sharks with a length of i meters,
N is the total number of identified whale sharks.

To examine the percentage of whale shark sex (male and female) that were identified, the following formula according to Tania dan Beny (2014); Sadili et al. (2015); and Maruanaya (2022) was used:

$$\% \text{ J} = \frac{\text{nj}}{\text{N}} \, x \, 100$$

$$\% \text{ B} = \frac{\text{nb}}{\text{N}} \, x \, 100$$

Where:
%J is the percentage of male whale sharks,
nj is the number of male whale sharks,
%B is the percentage of female whale sharks,
nb is the number of female whale sharks,
N is the total number of identified whale sharks.

2.3.3. Spatial and Temporal Distribution

The movement of whale sharks from one position to another is greatly influenced by the presence of fishing lift-net. The daily movement of whale sharks in different fishing lift-net units indicates local movement (Maruanaya et al., 2022). The coordinates of daily whale shark appearances in fishing lift-net areas were determined using GPS (Global Positioning System), mapping the distribution of whale sharks in Kwatisore waters.

2.3.4. Appearance Time

Whale shark appearance time was observed based on daily appearances in the morning, afternoon, and evening. The presence of whale sharks in the morning, afternoon, and evening during the observation months was tested for its relationship using the chi-square test based on contingency analysis. This involved calculating the observed $\chi^2$ and comparing it with the tabled $\chi^2$ (Sudjana, 1996; Tiro, 1999).

2.3.5. Environmental Factors

Environmental parameters, including surface temperature, salinity, pH, and brightness, were measured in the fishing lift-net area. All parameters were analyzed using multiple linear regression. The independent variables (x) totaled 4, assuming that it influences whale shark appearances (Y) (Adrianto, 2006).

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4$$

Where:
Y: Whale shark appearances;
$x_1$: temperature average value;
$x_2$: salinity average value;
$x_3$: pH average value, and
$x_4$: brightness average value.

## 3. Results and Discussion

### 3.1. Whale Shark Appearances and New Individual Migration Catch Productivity

The consistent appearance of whale sharks over time in Kwatisore waters exhibits unique characteristics. The characteristics of whale shark appearances are confined to a limited area, concentrated in Kwatisore waters only with a significant number of individuals. Kwatisore's characteristics, coupled with the potential anchovy population as a crucial food source, contribute to whale sharks residing in the area throughout the year (Maruanaya et al., 2021). The topographic conditions of Kwatisore's waters that are characterized by coral reefs and seagrasses along the coast significantly influence the availability of sufficient food for whale sharks (Suruan et al., 2018).

Research results from January to March 2023 show that whale shark appearances are concentrated only in the fishing lift-net units deployed in Kwatisore waters with a limited or narrow area (Figure 3). Beyond this area, especially in open waters or distant areas, no whale sharks were observed. This condition indicates that whale shark appearances from day to day are restricted to the vicinity of fishing lift-net units in Kwatisore waters, directly related to the catch of anchovies. Maruanaya's study (2022) found that the overall area of whale shark appearances in Kwatisore waters is only 22,706 ha.

Whale shark appearances heavily depend on the presence of fishing lift-net deployed in Kwatisore waters. The correlation between the reduction in the number of fishing lift-net units

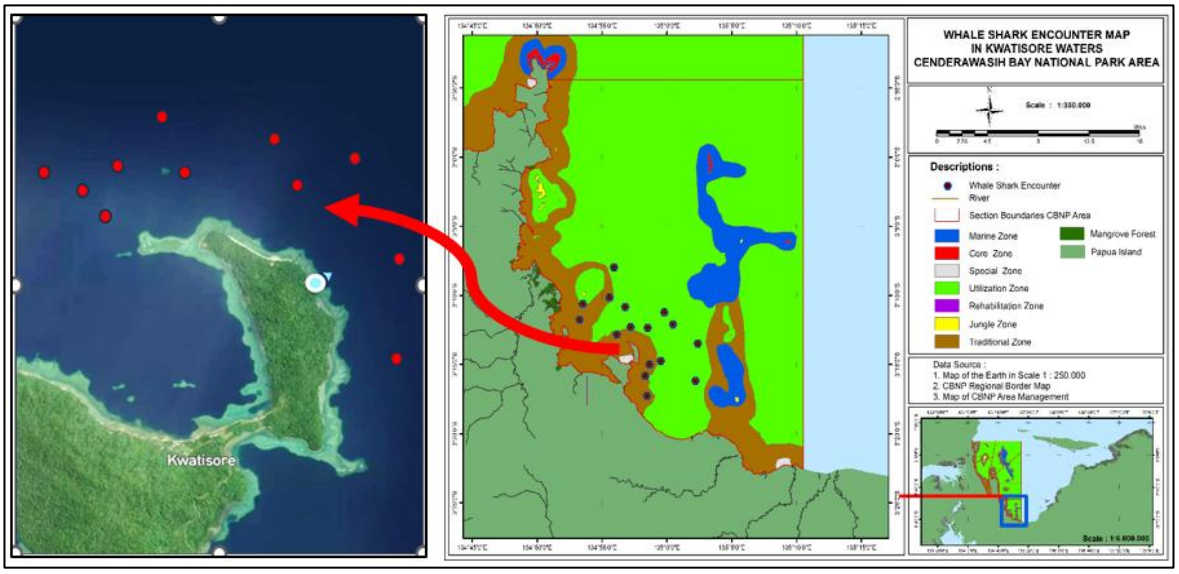


**Figure 3.** Whale shark (*Rhincodon typus*) appearances (red and black dots) in Kwatisore waters.

and the decrease in whale shark appearances is evident. The reduction in fishing lift-net units results in a decrease in anchovy catches, illustrating the dependence of whale shark appearances on the catch of anchovies by fishing lift-net units. Furthermore, whale shark appearances in Kwatisore waters, based on bathymetric conditions, are at depths ranging from 29 m to 83 m, indicating that whale sharks in Kwatisore waters inhabit the continental shelf area above 200 m (Maruanaya et al., 2021).

Whale shark appearances daily in Kwatisore waters are always focused and follow the deployment of fishing lift-net. The position and location of fishing lift-net units significantly determine whale shark appearances. Whale sharks have memories of certain feeding places. Eventually, they will return to those places for feeding (McKinney et al., 2017). The total number of individuals and whale shark appearances based on the research period in January, February, and March 2023 are presented in figure 4. Details of total individuals by ID number and total sightings in January, February and March can be seen in Table 5.

The total appearance of individual whale sharks during the research period from January to March 2023 tends to be the same. This suggests that these whale sharks are present and resident in Kwatisore waters for three months. The highest appearance of whale sharks occurred in March which correlates with the increased catch of anchovies by fishing lift-net, influencing the frequency of whale shark appearances. According to Enita et al. (2017), the appearance of whale sharks in Kwatisore waters is related to anchovies, a primary food source. The abundance of anchovy catches is attributed to the similar food preferences of both species. Maruanaya (2022) further states that the prolonged residence of whale sharks in Kwatisore waters is closely tied to the availability of anchovies as food. Stewart (2012) suggests that the concentration of pelagic fish attracts whale shark groups to specific areas, while Suprapti (2015) notes that whale sharks prefer to dive deep and surface when searching for food.

Maruanaya (2022) emphasizes that the fluctuation in whale shark appearances in Kwatisore waters depends on two main aspects: 1) the catch of anchovies by each fishing lift-net, and 2) the provision of anchovies by fishermen as food. The more anchovies are caught and provided as food, the faster and longer whale sharks appear in the fishing lift-net area. Suruan et al. (2018) state that whale sharks in Kwatisore waters spend 64% of their time foraging, 21% playing, and 15% traversing, with most of their time spent at depths of 7 to 10 meters.

Kwatisore waters are a specific region serving as both the residence and feeding ground for whale sharks and as a migration area for incoming whale sharks. The migration area is characterized by the appearance of identified individuals and new individuals. According to Maruanaya (2022), the migration of new whale shark individuals to Kwatisore waters is not yet understood, but it is predicted to be related to food availability and water conditions. The migration of whale sharks into

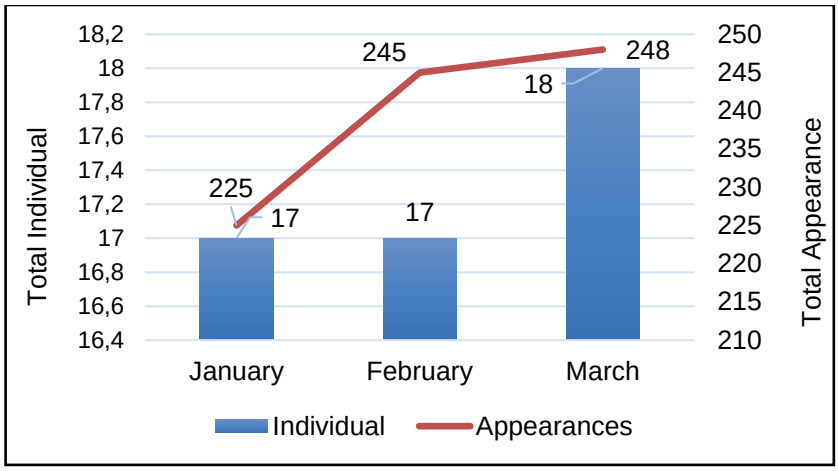


**Figure 4.** Number of individuals and total occurrence of whale sharks (*Rhincodon typus*) in Kwatisore waters during January, February, March 2023

**Figure 5.** A new individual with ID number 184 and its white spot pattern, which appeared in January 2023 in Kwatisore waters

Kwatisore waters aims to make it a feeding ground, as studies show that whale sharks entering Kwatisore waters are categorized as juvenile whale sharks (Maruanaya, 2022). The appearance of juvenile whale sharks and the highest number of individuals indicate that Kwatisore waters are not only an essential area for daily feeding but also a migration area for whale sharks. Ranintyari et al. (2018) state that the appearance of whale sharks in Kwatisore waters shows more than one individual and represents aggregation behavior. Although whale sharks are generally solitary, they are found in groups or aggregates in some locations (Toha et al., 2018).

During the January 2023 research, one new individual migrated to Kwatisore waters and was named Olfie Punusingon, with the ID number 184 (Punusingon, 2023). In 2020, two new individuals migrated, named Yan Maruanaya (ID 182) and Bram Maruanaya (ID 183) (Maruanaya, 2022). The migration of new individuals adds to the collection of individuals in Kwatisore waters. The new individual with ID number 184 is shown in Figure 5.

### 3.2. Number of Whale Shark Appearances

Throughout the research, the total appearance of whale sharks based on ID numbers (individual numbers) was 21 individuals, each with varying appearance times. The frequency of appearance for each whale shark from January to March 2023 indicates that each whale shark has a different appearance frequency, but several individuals remain present for the entire three-month

**Table 1.** Whale shark (*Rhincodon typus*) appearances frequency in Kwatisore waters

| No. | ID Number | Month | | | Total |
|---|---|---|---|---|---|
| | | January | February | March | |
| 1 | 56 | 9 | 12 | 27 | 48 |
| 2 | 69 | 4 | 10 | 9 | 23 |
| 3 | 72 | 11 | 3 | 8 | 22 |
| 4 | 89 | 19 | 22 | 10 | 51 |
| 5 | 104 | 20 | 24 | 6 | 50 |
| 6 | 106 | 8 | 5 | 14 | 27 |
| 7 | 112 | - | 17 | - | 17 |
| 8 | 114 | 25 | 22 | 15 | 62 |
| 9 | 125 | - | - | 6 | 6 |
| 10 | 129 | 10 | 8 | 26 | 44 |
| 11 | 138 | 18 | 21 | 29 | 68 |
| 12 | 150 | 10 | 18 | 21 | 49 |
| 13 | 151 | 15 | 7 | 17 | 39 |
| 14 | 154 | - | 31 | 20 | 51 |
| 15 | 159 | 6 | - | 9 | 15 |
| 16 | 163 | 13 | 9 | 7 | 29 |
| 17 | 172 | 28 | 12 | 21 | 61 |
| 18 | 176 | 25 | 10 | 1 | 36 |
| 19 | 180 | 3 | 14 | - | 17 |
| 20 | 183 | - | - | 2 | 2 |
| 21 | 184 | 1 | - | - | 1 |
| Total | | 225 | 245 | 248 | 718 |

period. The frequency of whale shark appearances is shown in Table 1.

The features appearances of 14 individuals observed with ID numbers 56, 69, 72, 89, 104, 106, 114, 129, 138, 150, 151, 163, 172, and 176, it is observed that these individuals consistently appeared during January, February, and March 2023. In contrast, some individuals appeared only in specific months: ID 112 in February, ID 125 in March, ID 154 in February and March, ID 159 in January and March, ID 180 in January and February, ID 183 in March, and ID 184 in January. Specifically, individuals with ID 138, 114, and 172 appear to be residents in Kwatisore waters throughout the research period. Maruanaya and Sumaryono (2023), in a study from April to August 2022, found that ID 47, ID 69, ID 125, and ID 156 were individuals that appeared every day during the research period. The identification results of the 21 whale shark individuals based on the IS3V2.0 program are shown in Figure 8.

### 3.3. Spatial and Temporal Distribution

The daily movements of whale sharks during the research period exhibit spatial and temporal distribution patterns. Spatial distribution involves whale sharks residing exclusively in Kwatisore waters, while temporal distribution relates to the timing of whale shark appearances. The study result indicates that the spatial and temporal distribution patterns of whale sharks are concentrated in boat life net areas deployed in the Kwatisore waters. The movement of fishing lift-net from one location or coordinate to another influences the daily migration pattern of whale sharks. This illustrates that the spatial and temporal distribution of whale sharks heavily depends on the position and location of fishing lift-net deployed in Kwatisore waters (Maruanaya, 2022).

Spatial and temporal distribution patterns of whale sharks show specificity in limited areas. Their appearances tail the deployment of fishing lift-net in Kwatisore waters, and do not appear in fishing lift-net outside Kwatisore waters.

### 3.4. Characteristics of Whale Sharks Based on Length

The appearances of whale sharks in Kwatisore waters during January, February, and March 2023 reveal size variations. The purpose of migration can be determined based on varied length. The 21 identified whale shark individuals have a total length ranging from 3 m to 7.5 m. Based on their length, these whale sharks are categorized as young or adolescent.

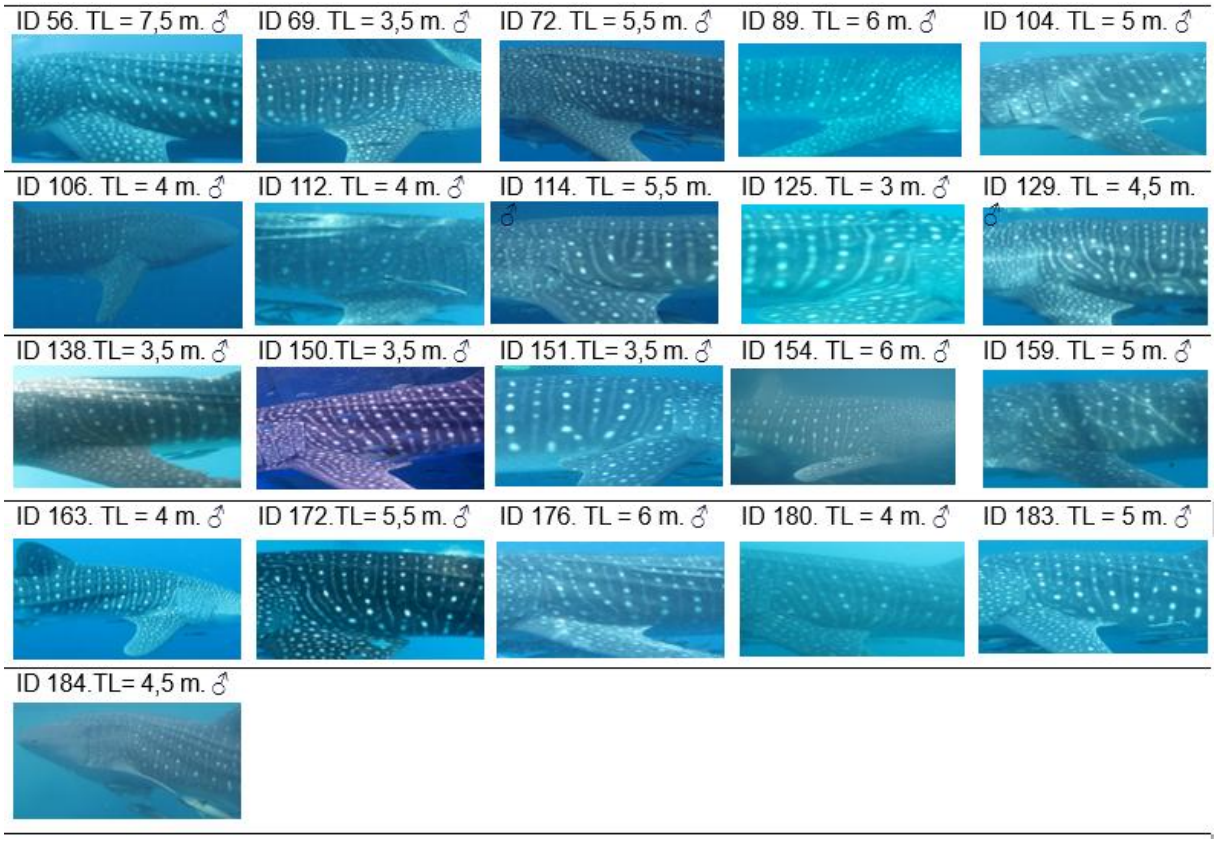


**Figure 6.** Result of Identification of 21 whale shark (*Rhincodon typus*) individuals in Kwatisore waters

**Table 2.** Body length distribution of whale sharks (*Rhincodon typus*) in Kwatisore waters

| Length (m) | ID Number | Number of Individual | Percentage (%) |
|---|---|---|---|
| 3 | 125 | 1 | 4.76 |
| 3.5 | 69, 138, 150, 151 | 4 | 19.05 |
| 4 | 106, 112, 163, 180 | 4 | 19.05 |
| 4.5 | 129, 184 | 2 | 9.52 |
| 5 | 89, 104, 159, 183 | 4 | 19.05 |
| 5.5 | 72, 114, 172 | 3 | 14.29 |
| 6 | 154, 176 | 2 | 9.52 |
| 7.5 | 56 | 1 | 4.76 |
| Total | | 21 | 100.00 |

According to Maruanaya (2022), knowing the length of whale sharks can serve as an indicator of their purpose for being in Kwatisore waters. The size range of 3 m to 7.5 m suggests that the whale sharks entering Kwatisore waters are juveniles, as they are not categorized as mature enough for mating. Maruanaya (2022) notes that Kwatisore waters serve as a growth area and a place for feeding but not for reproduction, as no very small or juvenile whale sharks have been found. The distribution of the total body length of whale sharks during the research period is shown in Table 2.

### 3.5. Number of Whale Shark Appearances Based on Time

The temporal appearance of whale sharks in boat life net areas is heavily influenced by the catch of anchovies, the duration anchovies are kept in containers, and the provision of anchovies by the fishermen. Whale shark appearances in fishing lift-net areas occur in the morning, afternoon, and evening, with higher frequencies in the morning compared to the afternoon and evening. The total number of whale shark appearances based on time is

**Table 3.** The total of whale shark (*Rhincodon typus*) appearances based on time in Kwatisore waters

| Month | Time of appearances | | | Total |
|---|---|---|---|---|
| | Morning | Afternoon | Evening | |
| January | 135 | 36 | 54 | 225 |
| February | 146 | 34 | 65 | 245 |
| March | 145 | 40 | 63 | 248 |
| Total | 426 | 110 | 182 | 718 |

**Table 4.** Whale shark (*Rhincodon typus*) occurrence by ID number during morning, afternoon and evening in Kwatisore waters

| No. | Number ID | January | | | February | | | March | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Morning | Afternoon | Evening | Morning | Afternoon | Evening | Morning | Afternoon | Evening | |
| 1. | 56 | 8 | - | 1 | 9 | 1 | 2 | 16 | 4 | 7 | 48 |
| 2. | 69 | 3 | 1 | - | 7 | 1 | 2 | 6 | 1 | 2 | 23 |
| 3. | 72 | 6 | 2 | 3 | 3 | - | - | 4 | 2 | 2 | 22 |
| 4. | 89 | 11 | 3 | 5 | 9 | 3 | 10 | 5 | 3 | 2 | 51 |
| 5. | 104 | 18 | 2 | - | 14 | 6 | 4 | 6 | - | - | 50 |
| 6. | 106 | - | - | 8 | 1 | 4 | - | - | 4 | 10 | 27 |
| 7. | 112 | - | - | - | 15 | - | 2 | - | - | - | 17 |
| 8. | 114 | 9 | 6 | 10 | 12 | - | 10 | 9 | 6 | - | 62 |
| 9. | 125 | - | - | - | - | - | - | - | - | 6 | 6 |
| 10. | 129 | 4 | 2 | 4 | 7 | - | 1 | 18 | 4 | 4 | 44 |
| 11. | 138 | 16 | 2 | - | 13 | 5 | 3 | 23 | 2 | 4 | 68 |
| 12. | 150 | 8 | 1 | 1 | 9 | 4 | 5 | 9 | 5 | 7 | 49 |
| 13. | 151 | 15 | 0 | - | 7 | - | - | 5 | 4 | 8 | 39 |
| 14. | 154 | - | - | - | 18 | - | 13 | 11 | 2 | 7 | 51 |
| 15. | 159 | 6 | - | - | - | - | - | 7 | 1 | 1 | 15 |
| 16. | 163 | 7 | 3 | 3 | 3 | 2 | 4 | 7 | - | - | 29 |
| 17. | 172 | 11 | 5 | 12 | 6 | 5 | 1 | 16 | 2 | 3 | 61 |
| 18. | 176 | 9 | 9 | 7 | 5 | 1 | 4 | 1 | - | - | 36 |
| 19. | 180 | 3 | - | - | 8 | 2 | 4 | - | - | - | 17 |
| 20. | 183 | - | - | - | - | - | - | 2 | - | - | 2 |
| 21. | 184 | 1 | - | - | - | - | - | - | - | - | 1 |
| Total | | 135 | 36 | 54 | 146 | 34 | 65 | 145 | 40 | 63 | 718 |
| Total (Month) | | | 225 | | | 245 | | | 248 | | 718 |

shown in Table 3 and whale shark occurrence by ID number during morning, afternoon and evening is shown in Table 4.

Whale shark appearances are most frequent in the morning between 06:00 and 10:00 WIT compared to the afternoon and evening. This morning's prevalence is related to the last hauling of each fishing lift-net at 5:30 WIT, where a large number of live anchovies are caught, causing high-density swimming and attracting whale sharks with movements and the scent of anchovies. On the other hand, the morning hours are associated with the feeding time of whale sharks to meet their daily food requirements. The higher appearance of whale sharks in Kwatisore waters, both in terms of individuals and frequency, between 06:00 and 10:00 WIT is related to the anchovy catch by fishing lift-net throughout the night (Tania et al., 2013; Suruan et al., 2016; Maruanaya et al., 2021).

Chi-Square analysis results show that the $\chi^2$ value of 0.85 is smaller than the $\chi^2$ table value of 13.3 at a 99% confidence level. This indicates that there is no significant relationship between the appearance of whale sharks at the water surface in the morning, afternoon, and evening. This suggests that the appearance of whale sharks is not restricted by time and can occur at any time, including morning, afternoon, and evening, depending on the feeding needs of whale sharks.

### 3.6. Number of Whale Shark Appearances Based on Sex

The appearance of whale sharks in a certain area is dominated by the male sex, while female whale sharks are difficult to spot on the water surface. During the research period, all 21

identified individuals were male whale sharks in Kwatisore waters. This indicates that during the research period, whale sharks in Kwatisore waters were 100% male and 0% female. This condition suggests that the whale sharks appearing and residing from January to March 2023 in Kwatisore waters are male whale sharks.

Himawan et al. (2015) found that whale sharks in the waters of Cenderawasih Baytend to be dominated by males. Hoffmayer, et al. (2021) state that immature or adolescent male whale sharks use shallower waters, while adult whale sharks are found in open habitats. Graham and Callum (2007) state that whale sharks are highly mobile and tend to move, with most being immature males. Most whale shark aggregations with a total length of 6 to 8 meters consist of immature males aiming to find food (Rowat and Brooks, 2012).

### 3.7. Anchovy Catch Results

Kwatisore waters are a habitat for anchovies (Stolephorus sp.), so the activity of catching anchovies by fishing lift-net is directed towards Kwatisore waters. Prihadi et al. (2017) suggest that one factor contributing to the low intensity of whale shark surface appearances is the insufficient food supply of whale sharks, namely anchovies in Kwatisore waters.

The research results show that the catch of anchovies by four fishing lift-net units varied between each month from January to March 2023. The results of anchovy catches by the four fishing lift-net units, including the total number of individuals and appearance frequency, are shown in Table 5. Occurrence frequency indicates the total occurrence of whale sharks in the fishing lift-net area during the study period. The frequency of whale shark occurrence in January, February and March is an accumulation of the number of occurrences that occurred in the morning, afternoon and evening (details in Table 1 and Table 4).

The catch of anchovies by fishing lift-net correlates with the abundance of whale shark appearances, both in terms of the number of individuals and the frequency of appearances. The presence and abundance of anchovies in Kwatisore waters are closely related to water quality. The high biomass of anchovies in Kwatisore waters is due to the abundance of phytoplankton as primary producers, followed by zooplankton abundance. The abundance of phytoplankton and zooplankton serves as food for anchovies is the trigger for their abundance (Dinisia et al., 2015). Prihadi et al. (2017) state that a decrease in the number of fishing lift-net and anchovy catch results in fewer whale shark appearances. According to Suruan et al. (2020), fishing lift-net influence the appearance of whale sharks in Kwatisore waters, where fishing lift-net are used as a play and feeding area for whale sharks. Maruanaya (2022) emphasizes the correlation between anchovies as prey and whale sharks as predators, with correlations including: 1) faster whale shark appearances; 2) longer dwell time in boat life net areas; and 3) determining the number of individuals to appear.

### 3.8. Environmental Factors

The movement of whale sharks is significantly influenced by the depth of a region and environmental factors. Syah et al. (2018) state that the high probability of whale shark appearances is due to their familiarity with specific ranges of each environmental parameter. The water mass in Kwatisore waters is entirely influenced by the Pacific Ocean water mass and being a gulf, making it have characteristics of aquatic ecosystems that experience fluctuations in physicochemical parameters throughout the year (Maruanaya, 2022).

Sea surface temperature (SST) distribution is crucial in determining the presence and abundance of aquatic organisms. According to Toha et al. (2018), SST variability in water affects the life of organisms, including their metabolism, activity, and reproduction.

The result of sea temperature measurements around the fishing lift-net area, and the location of whale shark appearances, show that SST ranges from 29°C to 33°C. The values remain relatively stable across the

**Table 5.** The total catch of anchovy by the fishing lift-net in January to March 2023 and the number of whale shark (*Rhincodon typus*) appearances in Kwatisore waters

| Month | Fishing Lift-Net (unit) | Catch result (kg) | Total Individual | Appearances Frequency |
|---|---|---|---|---|
| January | 4 | 1.200 | 17 | 225 |
| February | 4 | 2.600 | 17 | 245 |
| March | 4 | 3.950 | 18 | 248 |

research months from January to March 2023. This indicates that SST in Kwatisore waters remains nearly constant during the three months. Prihadi et al. (2017) found SST ranging from 30°C to 32°C at 11 stations in Kwatisore waters, suitable for whale shark appearances. Additionally, Enita, et al. (2017) reported that the highest frequency of whale shark appearances occurred at SST ranging from 30.5°C to 31.3°C in Kwatisore waters, with the peak appearance increasing at SST above 30.5°C. Ardania et al. (2018) noted that the preferred water temperature for whale sharks in the Cenderawasih Bay waters is within the range of 28°C to 32°C.

Generally, whale sharks inhabit areas with sea surface temperatures between 28°C and 32°C. According to Colman (1997), whale sharks have a pelagic habitat, and some individuals live at depths of 240 meters or more at water temperatures of 10 degrees Celsius or colder. Eckert and Brent (2001) state that whale sharks spend most of their time in areas with surface temperatures between 20°C and 32°C. Colder water does not impede their movement, as some individuals spend time below the surface at temperatures of 10 degrees Celsius or colder.

pH plays a crucial role in the environmental ecosystem of aquatic environments, where aquatic organisms are highly sensitive to changes in pH. pH changes adversely affect marine life, both directly and indirectly, by reducing primary water productivity or altering the toxicity of substances in the water. pH measurements show values ranging from 7.4 to 7.9, with pH conditions being relatively stable across months. Toha et al. (2019) found pH values in Kwatisore waters ranging from 7.95 to 8.07.

Kwatisore waters is an open ocean and is located in the southern part of Cenderawasih Bay. Salinity conditions in Kwatisore waters are significantly influenced by the water mass from the Pacific Ocean. Salinity measurements show values ranging from 31 to 34‰, with little fluctuation between months and similar salinity conditions from January to March 2023. Prihadi et al. (2017) reported salinity ranging from 28‰ to 30‰ at 11 stations in Kwatisore waters. Toha et al. (2018) found salinity in Kwatisore waters ranging from 33‰ to 34‰, with salinity conditions determining the majority of the life community in the waters, including the habitat of whale sharks.

Water clarity is a measurement of water transparency, where high clarity indicates the ability of sunlight to penetrate deep into the water. It is ecologically an important factor in the lives of various aquatic organisms. Water clarity values in Kwatisore waters during the study range from 21 to 33 m, with the highest clarity occurring in March (33 m) and the lowest in January (21 m). Prihadi et al. (2017) found clarity ranging from 11.23 to 18.05 m at 11 stations in Kwatisore waters. Toha et al. (2018) found marine clarity levels in Kwatisore waters ranging from 7 to 12 m. The high water clarity values in Kwatisore are due to measurements taken during sunny days with calm water conditions, minimizing the influence of wave-induced visibility reduction.

Environmental factors influence the appearance of whale sharks, and each factor has their own value, including sea surface temperature, salinity, pH, and water clarity has different degrees of impact. Regression analysis results indicate that an increase in sea surface temperature is followed by an increase in the number of whale shark appearances and an increase in salinity is followed by a decrease in the number of whale shark appearances. pH does not significantly affect the number of whale shark appearances, and an increase in water clarity is followed by a decrease in whale shark appearances

## 4. Conclusion

The appearance of whale sharks in Kwatisore waters in January, February, and March 2023 was concentrated in four fishing lift-net units. The number of whale shark appearances totals 21 individuals, all of which are male, with a total frequency of 718 appearances, and the migration of one new individual with ID 184, named Olfie Punusingon. The size of whale sharks ranges from 3 to 7.5 m. Whale shark appearances and daily movements were concentrated around boat life net areas, with more appearances occurring in the morning. Environmental factors have varying effects on whale shark appearances.

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