Seasonal Constellation of Juvenile Whale Sharks in Gorontalo Bay Coastal Park

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Abstract

The population of whale sharks (Rhincodon typus Smith, 1828), the world's largest endangered extant fish species, has declined in the last three decades. Their appearance in the Botubarani Waters has attracted much attention. This study aimed to determine the whale shark's appearance, their habitat constellation pattern during 2019-2022, and its oceanographic conditions. The Photographic Identification (Photo-ID) method is used to observe and determine whale shark individual's number and pattern of presence. Oceanographic data includes chlorophyll-a concentration using Ocean Color Image data and sea surface temperature (SST) using OSTIA image data processed with Interactive Data Language (IDL) software. The research showed there are 38 individuals with an estimated total length of 2.3-7.3 meters. All whale sharks appearing in Botubarani include juvenile male individuals with a composition of 53% new (N=20) and 47% (N=18) old individuals seen again with a rare seasonal and sporadic presence pattern mainly in the Eastern season (June). The average SST value ranged from 28.36-30.29℃ while chlorophyll-a ranged from 0.174-0.698 mg.m^{-3}. Although the present findings show that the whale shark's appearance in Botubarani waters was not significantly influenced by SST and chlorophyll-a, it might be affected by other oceanography factors such as Sea Surface Height Distribution (SSHD) and depth (bathymetry). As the Botubarani aggregation site is the only whale shark emergence area with easy access throughout the year and is rapidly developing into a new ecotourism industry in Indonesia, the information on whale shark appearance provides useful support for their sustainable protection and conservation in the future.

Keywords: Whale Shark, Photo ID, chlorophyll-a, Sea Surface Temperature, Gorontalo

Introduction

Whale sharks (*Rhincodon typus*) are among the largest filter-feeding fish in the world (Rowat and Brooks, 2012). They often congregate near coastal waters seasonally (Guzman *et al.*, 2022). The habit of whale sharks congregating seasonally in certain locations is known as constellations (Dove and Pierce, 2021). This constellation of behavior has made whale sharks the subject of a highly profitable ecotourism industry worldwide (Rowat and Engelhardt, 2007). In several countries with regular seasonal constellation patterns, whale shark ecotourism areas have developed and attracted many tourists, such as in Oslob, Philippines (Craven, 2012), Isla Holbox, Mexico (Ziegler *et al.*, 2012) and Ningaloo Reef, Australia (Mau, 2008). In Indonesia, several locations have been developed into whale shark tourism destinations such as Kwatisore Waters, Cendrawasih Bay National Park, Papua (Maruanaya

et al., 2022), Bentar Beach Waters, Probolinggo (Kapinangasih *et al.,* 2022), Labuhan Jambu Waters in Saleh Bay, Sumbawa, West Nusa Tenggara and Botubarani Waters, Gorontalo (Djunaidi *et al.*, 2020).

Over the last three decades, whale shark populations have decreased by more than 50% worldwide (Pierce and Norman, 2016; Anna and Saputra, 2017; Guzman *et al.*, 2021; Farid *et al.*, 2021). Biological characteristics of slow growth, late sexual maturation, and low fecundity make whale sharks very vulnerable to extinction (Dove and Pierce, 2021). Therefore, since 2002, the international organization CITES (Convention on International Trade in Endangered Species) has included Whale Sharks in the Appendix II list. In 2016, the IUCN (International Union for Conservation of Nature) organization also updated the protection status of whale sharks from the vulnerable category to endangered due to continuous population decline

(Pierce and Norman, 2016). Then, in 2021, another assessment was carried out on the conservation status of whale sharks, putting them in a largely depleted category based on the IUCN Green List assessment (Pierce *et al.*, 2021). Additionally, Indonesian whale sharks are also fully protected by Decree 18/KEPMEN-KP/2013 of the Maritime Affairs and Fisheries Minister (Sadili *et al.*, 2015).

Coastal waters at Botubarani are part of Tomini Bay's whale shark constellation. Because whale sharks are present almost every day of the year, makes them ideal for regular observations: (Rahman *et al.*, 2017; Handoko *et al.*, 2017). In general, the seasonal constellation of whale sharks is influenced by oceanographic processes such as sea surface temperature, coastal currents, and increased productivity of the surrounding environment, particularly the abundance of phytoplankton (Heyman *et al.*, 2001; Fox *et al.*, 2013). In the Kwatisore waters of Cendrawasih Bay National Park, the seasonal constellation of whale sharks follows a fluctuating trend of increasing chlorophyll-a values and sea surface temperature (Enita *et al.*, 2017; Manuhutu *et al.*, 2021). Similarly, research carried out by Sakuntala *et al.* (2016) on the emergence of whale sharks based on environmental factors in Probolinggo waters demonstrated that surface temperature and chlorophyll-a influence the pattern of whale sharks appearance. According to Rahman *et al.* (2017), in Botubarani Gorontalo the emergence of whale sharks may be influenced by food availability, with copepods and fish larvae being abundant in the area where whale sharks appear.

Observing oceanographic factors is important to determine the relationship between habitat characteristics and the frequency of whale shark presence in constellation habitats (Sequeira *et al.*, 2014). Therefore, this research aims to determine the whale shark constellation pattern of Botubarani waters of Gorontalo Coastal Park and to observe oceanographic factors, specifically the chlorophyll-a and sea surface temperature, using remote sensing. This work used the whale sharks' appearance data series obtained using the Photo-ID technique from 2019 to 2022 to provide an overview of the constellation patterns of whale sharks in Botubarani waters. This information is necessary to protect and conserve this endangered species in the future.

Materials And Methods

The research location is in Botubarani village, on the north coast of Tomini Bay, Kabilabone District, Bone Bolango Regency (Figure 1). The topographic characteristics of Botubarani Beach are steep drop-offs. The location for recording the appearance of whale sharks is in an interaction zone of 0.82 hectares, approximately 20 meters from the beach.

Whale shark observations were conducted daily, corresponding with the times whale sharks appeared in the Botubarani interaction zone. The location where the whale shark appears in Botubarani is also within the limited-use zone of the Gorontalo Bay Coastal Park Conservation Area (Ministerial Decree Number 127 of 2023) and the Wallacea bio ecoregion of Gorontalo (Adisubroto and Pardede, 2021).

The constellation pattern of whale sharks was determined using photo-ID and whale shark data were analyzed using I3S (Interactive Individual Identification System) software developed by Pierce (2007). The position for taking Photo-ID on the whale shark's body is on the left and right sides near the pectoral fins. The horizontal composition of the photo includes a white spot pattern between the 5th gill and the tip of the inner pectoral fin. Vertically, photos were taken from the base of the pectoral fin to the end of the whale shark's dorsal line. The collected field identification photo files were standardized in naming and size using Photoscape software for cropping and color-editing before being identified with I3S software. The results of I3S data processing confirmed the presence of each individual during the research period to determine the constellation pattern of the Botubarani whale shark.

The sea surface temperature (SST) and chlorophyll-a data in this study were obtained through satellite imagery. The source of SST data was from Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) downloaded from https://ghrsst-pp.metoffice.gov.uk/ostia-website/index.html, and chlorophyll-a data were obtained from The Ocean Color Climate Change (OC CCI) satellite image downloaded from https://oceancolor.gsfc.nasa.gov/. The data cover a period of four years from January 1st, 2019 to December 31st, 2022. Chlorophyll-a and SST image data were processed using Interactive Data Language (IDL) software version 8.5 according to Purwanti *et al.* (2017).

Individual whale shark presence data per day were tabulated into monthly and annual presence data to see the pattern of the presence of the whale shark population in Botubarani. Individual attendance pattern data were used to create graphs of total annual and monthly attendance and profiles of each individual's attendance pattern based on the results of ID photo analysis using the Interactive Individual Identification System (I3S). The description of the whale shark constellation pattern follows Thomson *et al.* (2017), wherein the presence of whale sharks at the observation location was grouped into 3 categories per observation period (Table 1). The relationship between SST and whale shark appearance and chlorophyll-a and whale shark appearance was analyzed using Pearson correlation with SPSS

Table 1. Categories of whale shark presence patterns based on Thomson *et al.* (2017)

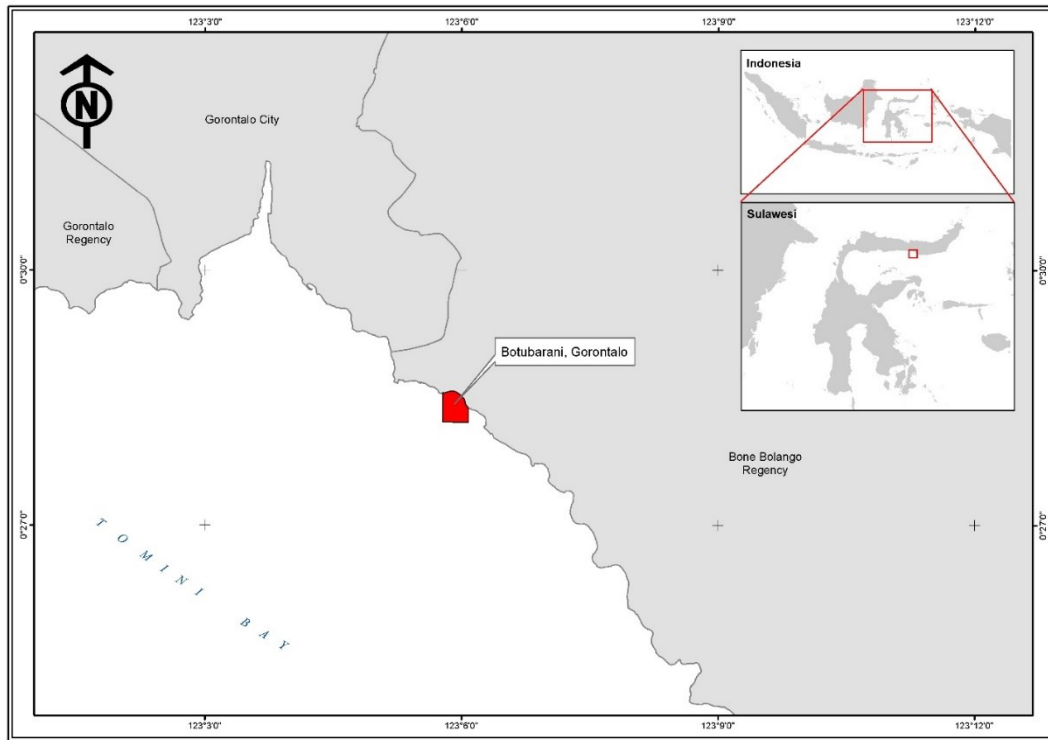| Category	Number of days	Presence Patterns
Single-sighting	1	Sporadic
Infrequent	30	Seasonal
Frequent	60	Stay

Figure 1. Research Location Map

Results and Discussion

The identification results using I3S (Interactive Individual Identification System) software carried out by the Marine and Coastal Resource Management Agency yielded 33 ID Photos of whale sharks documented in Botubarani waters from 2016-2018. However, during the research period (2019-2020), a total of 38 documented ID photos of whale sharks were obtained (Table 2) with a composition of 53% (N=20) including new individuals that appeared at the research location, while the remaining 47% (N =18) including old individuals who had been recorded in previous years (2016-2018).

The results of recording the number of whale shark individuals appearing each month in Botubarani waters for 4 years (2019-2022) are presented in Figure 2. The graph shows variations in the increase in the number of different individuals between months each year. An upward trend in the number of individuals begins from January to June and begins to decline from July to December. This pattern occurs almost the same every year, except in 2020, when the highest increase in the number of individuals occurred in March. The highest peak appearance occurred in 2021 (18 individuals), namely in May and June. In the peak emergence period in 2021, whale sharks can be found every day for 2 consecutive months, and it has been recorded those 12 sharks were found per day (data collection date 16 June 2021).

A total of 38 whale shark individuals were identified over 4 years with an average attendance of 5.6 individuals.month^{-1} (range=1-18). The results of the estimated body length measurements of 38 individual whale sharks identified from January 2019 to December 2022 ranged from 2.5 – 7.3 meters, with an average size ranging between 4.47 and 4.73 meters. These findings indicated that all individual whale sharks identified in Botubarani waters are

included in the Juvenile category, and the gender observations showed that all Whale Sharks appearing in Botubarani waters are male (Figure 3.), shown by their unclassified claspers.

Based on the presence frequency categories per year in Table 3, whale sharks in Botubarani are dominated by individuals with seasonal visit patterns with a frequency of presence in the rare category (7-17 individuals). Meanwhile, 1-3 individuals have a single visit pattern or only appear once a year. 2-7 individuals are often seen and tend to stay around. The average annual individual attendance ranges from 18.16 to 82.91 days per year, with the highest peak attendance occurring in 2021 (995 days, n=25). The annual constellation pattern further suggests that the Botubarani whale shark is dominated by old individuals that have been recorded in previous years, with an average return of sightings ranging between 54-84% each year.

Table 2. Total photo ID data collection for Botubarani whale sharks from 2016 to 2022

Year	Month	Day Appearance	Code ID	Total ID
2016*	April, May, September, October and November	65	GT 001-GT 017	17
2017*	April and May	25	GT 018-GT 020	3
2018*	May, June, July, August	123	GT 021-GT 033	13
2019	January-December	365	GT 034-GT 037	4
2020	January-December	366	GT 038-GT 043	6
2021	January-December	365	GT 044-GT 047	4
2022	January-December	365	GT 048-GT 0453	6
	Total			53

Note: * Secondary data from Marine and Coastal Resource Management Agency, Makassar, Year 2016-2018.

Table 3. Frequency of sporadic, seasonal, and persistent presence patterns of Botubarani whale sharks during the study period

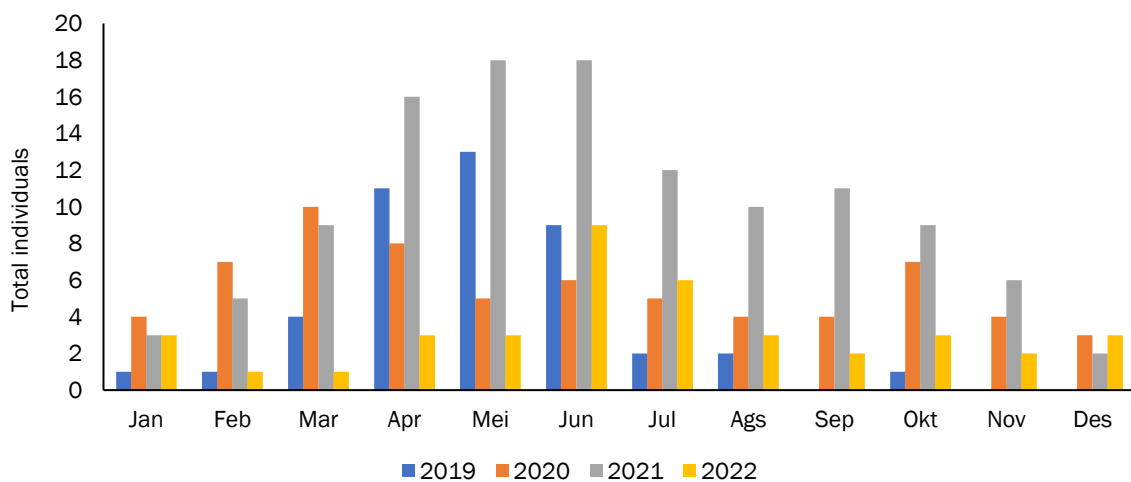| Category (day)	Presence Patterns	2019	2020	2021	2022
Single-sighting (1)	Sporadic	2	3	1	0
Infrequent (30)	Seasonal	12	17	17	7
frequent (60)	Stay	2	3	7	5
Number of individuals		16	23	25	12
New Individual		4	6	4	6
Old individual		12	17	21	6
% Ind Looks Back		75%	74%	84%	50%
Total Attendance.Year^{-1} (days)		218	383	995	401

Figure 2. Number of whale shark individuals per month in Botubarani Waters during 2019-2022
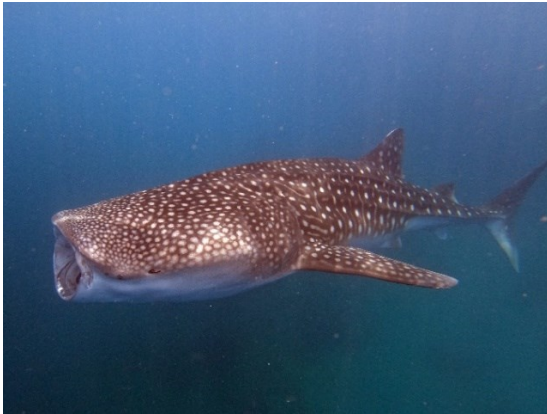
Figure 3. Male Juvenile whale shark in Botubarani Waters, Gorontalo

In general, the Botubarani whale shark constellation pattern tends to show the same trend of appearance every year. The emergence begins at the end of the western season (February) and slowly increases into the first transition season (March-May). The highest peak attendance occurred during the eastern season in June, except in 2020 when it occurred in March and October. Entering the beginning of the second transition season, the whale sharks that appear in Botubarani begin to decline until they enter the western season. The occurrence data also shows that during the study period (Figure 4), the trend in the presence of Botubarani whale sharks began from March to June with the highest peak season presence in June. The highest peak attendance occurred in 2021, namely 18 individuals appearing alternately for 159 days.

Chlorophyll-a concentrations at Botubarani waters during the study period ranged from 0.174-0.698 mg.m^{-3}. The results of Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) image data processing from January 2019–December 2022 showed that the average value of chlorophyll-a concentration varied every year. In 2019, chlorophyll-a concentrations ranged from 0.184-0.364 mg.m^{-3}. In the following year (2020) the chlorophyll-a value increased, although not significantly, with a concentration between 0.174-0.382 mg.m^{-3}. The highest chlorophyll-a concentration occurred in 2021 (0.182-0.698 mg.m^{-3}) and decreased in 2022 (0.183-0.535 mg.m^{-3}). Based on the average value of chlorophyll-a concentration per month during the 4 years research period, the highest chlorophyll-a concentration value occurred in September 2021 (Figure 5B) with an average value of 0.698 mg.m^{-3} which is included in the initial period of transition season II. Meanwhile, the lowest average value of chlorophyll-a was obtained in April 2021 with a value of 0.17 mg.m^{-3} which was included in the mid-season period of transition I.

The chlorophyll-a concentration value in the surrounding Botubarani waters has different monthly variability. A graph of the variability of chlorophyll-a values per month during the research period in Botubarani waters and its surroundings is presented in Figure 6. The data processing results show that the trend of chlorophyll-a concentration values each month shows the same pattern yearly; entering the western season (December to January), chlorophyll-a conditions increased until February. However, it declined until the middle of the first transition season (April). The chlorophyll concentration value in April during the study period consistently decreased (0.174-0.191 mg.m^{-3}) every year compared to the chlorophyll-a concentration in other months. The concentration of chlorophyll-a increases at the beginning of the east monsoon and continues until the end of the 2nd rainy season (September-November).

During the research period, the highest chlorophyll-a concentration occurred in September 2021 and indicated a sharp increase compared to other months. The upwelling phenomenon that occurs often in Tomini Bay may have caused this phenomenon. According to Burhanuddin *et al*. (2004), in the waters of Tomini Bay, indications of upwelling areas often occur around Tomini Bay, the Togean Islands, and south of Gorontalo. This is also following the results of an upwelling study in Tomini Bay conducted by Amri *et al*. (2005), where the upwelling phenomenon occurs in the east season (July-August), which is marked by a sharp increase in chlorophyll-a concentrations between 0.8 -1.25 mg.m^{-3}. According to Amri *et al*., (2005), this upwelling phenomenon occurs due to the movement of the northern lower water mass at a depth of 150 m which forces the Maluku Sea water mass at the mouth of Tomini Bay (the location where the Botubarani whale shark appears) to collide with the

shelf area, thus triggering an increase in the water mass from the inside to the surface.

The results of Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) image data processing during the period January 2019–December 2022 showed that the average sea surface temperature in Botubarani and the surrounding waters ranged from 28.36-30.29°C. The highest average sea surface temperature value was obtained in November 2021 with a value of 30.29°C, included in the transition season period 2 to the west monsoon. The lowest average sea surface temperature value was obtained in August with a value of 28.36°C which is included in the period from the end of the east season to the transition season II.

The monthly SST data processing results during the research period also show that the distribution of sea surface temperature values in Botubarani waters and surrounding waters have different variability values each month. Inter-month sea surface temperature variability values during the study period are presented in Figure 7. The trend in SST variability values shows an increase in sea surface temperature during the transition season I (March, April, May) to the beginning of the East

season (June). The decrease in SST occurs in the middle of the East season (July and August) and begins to increase during the second transition season (September, October, and November).

Based on the average value of sea surface temperature (28.36-30.29°C) obtained during the research period, the condition of Botubarani waters and the surrounding waters are warm waters (Tita *et al*., 2020). Tropical waters with SST values above 28 0C are categorized as warm waters (Vinayachandran and Shetye, 1991) which geographically are ideal locations for the main distribution of whale sharks globally (McKinney *et al*. (2012). According to Toha *et al*. (2018), The SST range for whale sharks in Kwatisore waters ranges from 29.5–31.8°C with an optimum range of 30.3–31.3 °C. SST variability at the research location also shows increased sea surface temperature during transition season I. A decrease in SST occurs in the middle of the East monsoon and begins to increase during the transition season II. Observations of Tita *et al*. (2020) at the same location suggest that this pattern is not much different from the research results. The SST in Tomini Bay increased during transition seasons I and II while decreasing in the West and East seasons, a similar pattern observed by Tita *et al*. (2020).
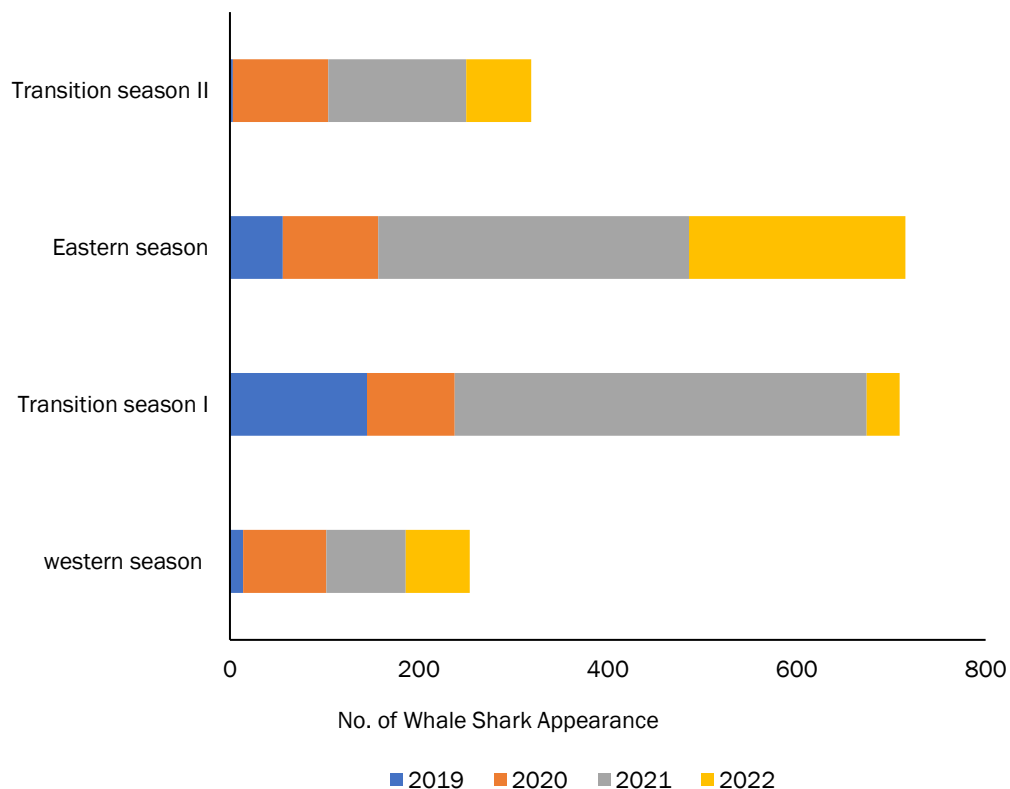

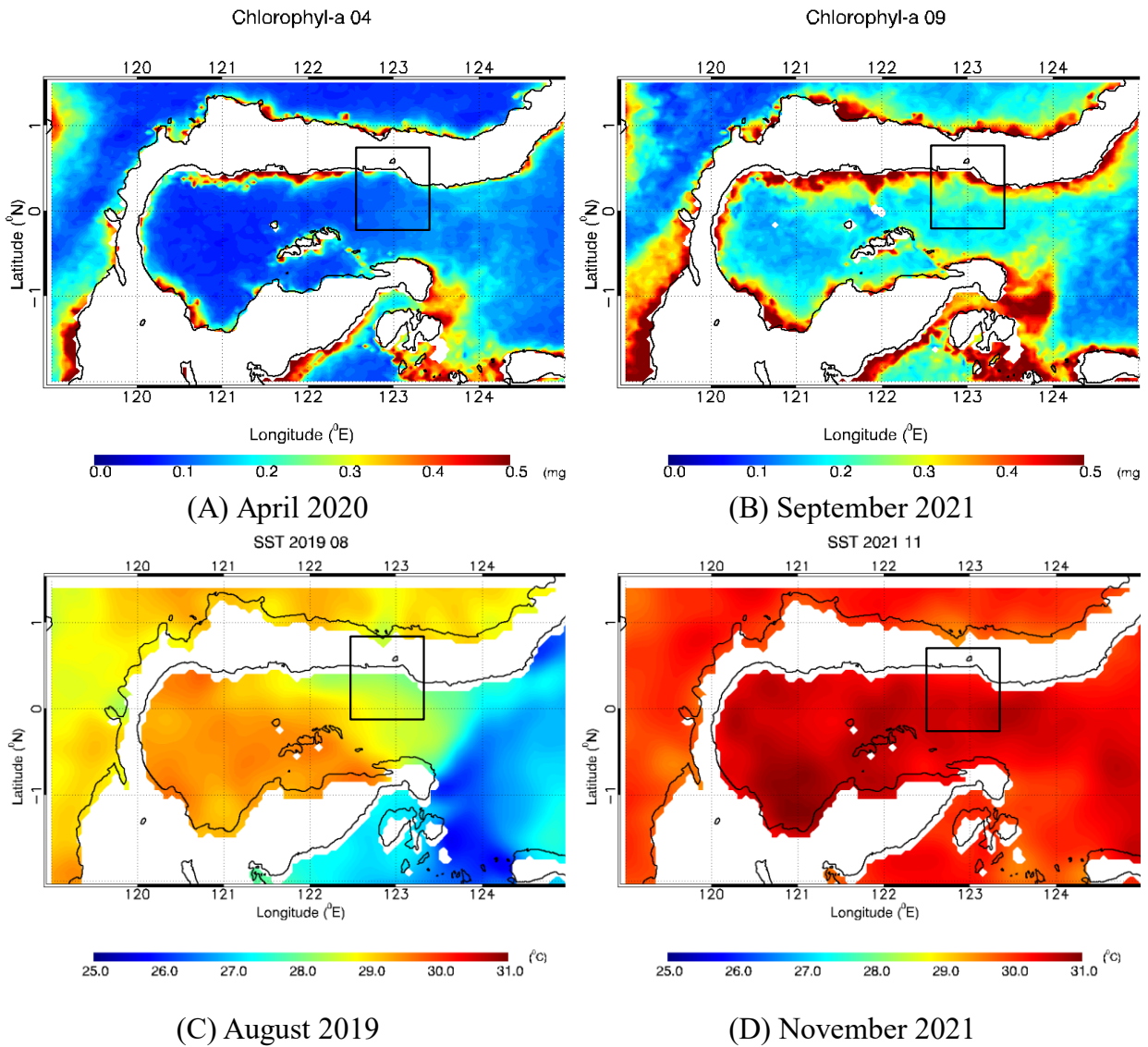**Figure 4.** Seasonal constellations of Gorontalo whale shark juveniles

Figure 5. The distribution of chlorophyll-a and SST with the lowest chlorophyll concentration values in April 2020 (A) the highest in September 2021 (B) and the lowest SST in August 2019 (C), and the highest in November 2021 (D).
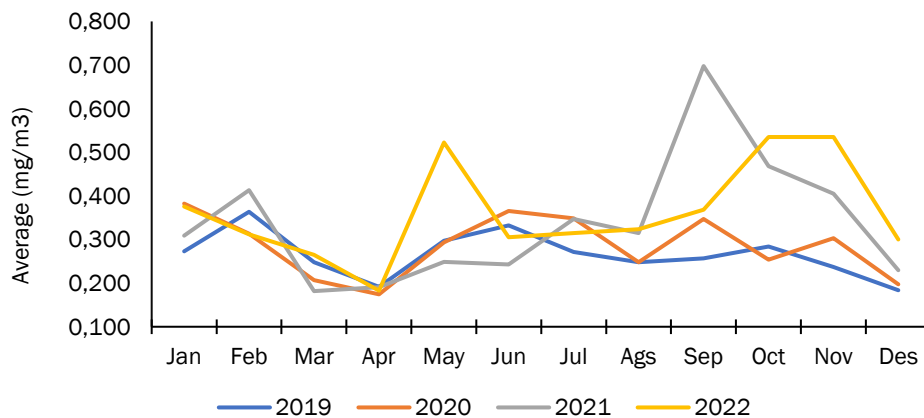

Figure 6. Average monthly chlorophyll-a concentration values during 2019-2022
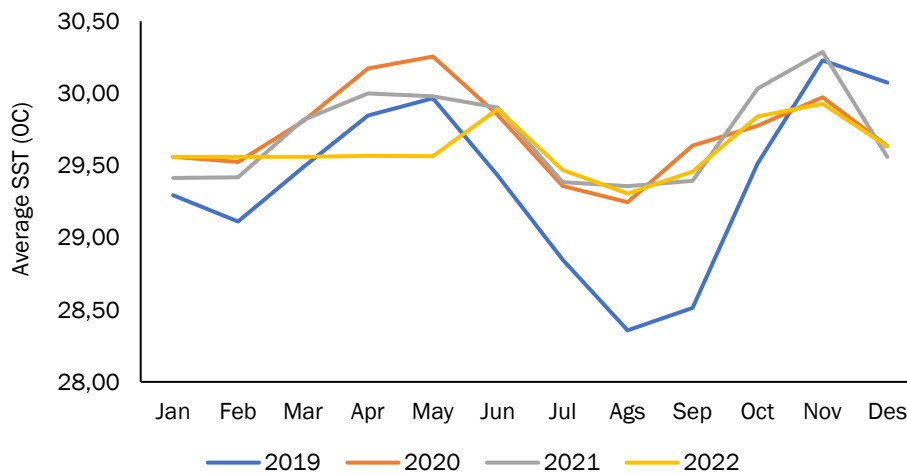
Figure 7. Average monthly SST values during 2019-2022

A total of 58 Botubarani whale sharks have been identified using photo ID techniques over the past 8 years. When compared with the number of individuals in other places, such as research by McKinney *et al.* (2017) in the Gulf of Mexico (n=1,361), or the results of research by Tania *et al.* (2016) in Cenderawasih Bay, Papua (n=131), the population of Gorontalo whale sharks is relatively small, so it still requires individual-based data collection in the long term. Photographic identification (photo-ID) techniques are the appropriate method for studying long-term population structure in Botubarani. This method is also the most widely used globally to evaluate population structure, residency patterns, population size, residence patterns, habitat use, movement patterns, philopatry assessment, and other population dynamics (Andrzejaczek *et al.,* 2016; Araujo *et al.*, 2022).

The presence of whale sharks in the Botubarani whale shark interaction zone is dominated by new individuals with an average of 5 new individuals appearing yearly. The rest are old individuals with seasonal site fidelity patterns in Botubarani waters. Various research results using the same method also show this return pattern, for example, the research results on Ningaloo Reef, Australia, where 35% of individuals were again observed at that location (Holmberg et al., 2009). In the Philippines, 53% of the whale shark population in Donsol returns to the same location in at least 2 seasons (McCoy *et al.,* 2018), although in a separate place, namely on Panon Island, Philippines, Araujo *et al.* (2016) noted that only 32% of individuals returned. Increasing the presence of new individuals and the return of old individuals with different presence times every year confirms the importance of this area as an important habitat in the cycle and development of this endangered species.

The absence of female individuals and adult whale sharks in Botubarani is also important to highlight. This condition shows that Botubarani waters are an important habitat for developing male juvenile whale sharks (Valsecchi *et al.*, 2021) or as a secondary nursery area (Allen *et al.*, 2021) for male juveniles in Tomini Bay. The results of research on the emergence of whale shark habitats so far show that the habitats of adult and female whale sharks generally tend to be in offshore waters (Dove and Pierce, 2021) and are mostly epipelagic, meaning they spend most of their time at depths between (0-200 meters) such as tagged adult whales in Mexican waters (Ramírez-Macías *et al.,* 2017). Meanwhile, juvenile whale sharks tend to be found congregating in shallow waters near the coast (Dove and Pierce, 2021). In Indonesia, the whale shark is also found in Cenderawasih Bay, Papua (Manuhutu *et al*., 2021), Talisayan waters, Kalimantan (Himawan *et al*., 2017), and Probolinggo waters (Syah *et al*., 2018; Kapinangasih *et al.,* 2022). Large adult whale sharks are rarely found on the coasts because of their diving abilities and adaptations that allow them to obtain more prey in deep waters (Dove and Pierce, 2021).

The Botubarani whale shark constellation pattern is dominated by whale sharks, and they visit every year with a seasonal pattern. These results are in line with the pattern of whale shark presence in Oslob which shows variations in seasonal and sporadic visitation patterns. There were 208 whale sharks monitored for three years, of which only nine regularly appeared for a long period, while the others appeared seasonally, sporadically, or only once (Thomson *et al.,* 2017). In Botubarani, of the 38 individuals that appeared during the study period, only 3 consistently returned every year and tended to stay in the whale shark tourism interaction zone. Whale shark ID GT 32 is the one that appears most

often in the Botubarani whale shark interaction zone. This return may be caused by injury to his eye, which alters how the eye moves and affects their behavior (Yasir *et al.,* 2024, in press) and influences the number of whale sharks appearing. Whale sharks display different patterns of presence in aggregation areas globally. The appearance of whale sharks is dynamic because of their natural nature as a highly migratory species so their presence patterns are different each season (Parra Venegas *et al*., 2011).

The peak appearance of whale sharks in Botubarani occurs during the first transition season, especially in June. This result is different from the season for whale sharks appearing at Bentar Beach, Probolinggo, where whale sharks are often found in December – March (Syah *et al.,* 2018). However, in other locations, the research results by Rowat (2007)

show the same results, where whale sharks gather in South Africa, Mozambique, and Kenya, especially in summer and last until autumn (April-June). Whale sharks migrate during their peak emergence season, influencing the peak emergence season. Whale shark migration patterns are generally driven by foraging and reproductive opportunities (Rohner *et al.,* 2015). By instinct, whale sharks move from one place to another to look for food and continue their life cycle (Kapinangasih *et al.,* 2022). This is related to the natural nature of whale sharks as a species with a high migration rate (highly migratory) over distances of thousands of kilometers (Rowat and Gore, 2007) to areas with high productivity, such as research results on whale sharks in the Gulf of Mexico (Motta *et al.,* 2010) and in the Philippines (McCoy *et al.,* 2018).
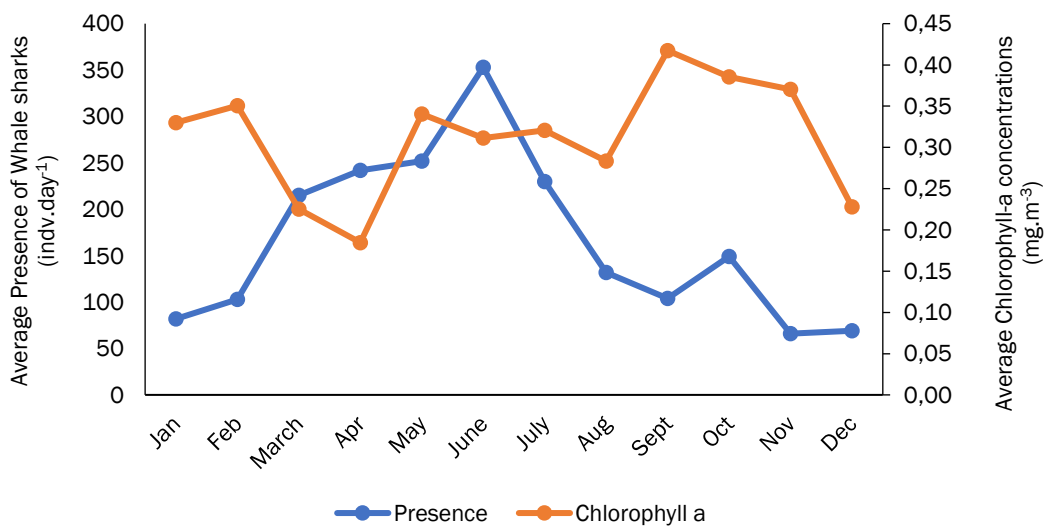

Figure 8. The relation between the monthly average of whale shark appearance and chlorophyll-a concentration during 2019-2022
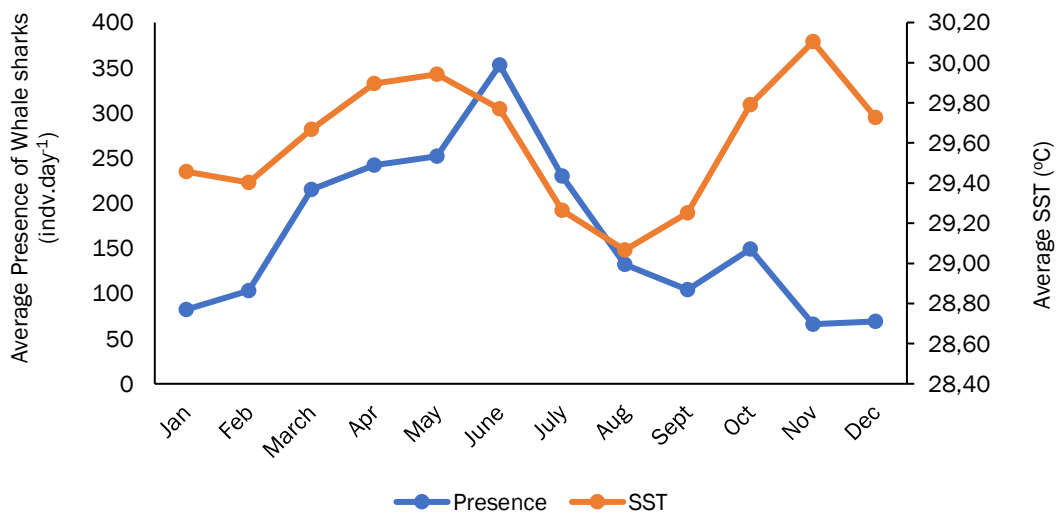

Figure 9. The relation between the monthly average of whale shark appearance and SST during 2019-2022

Globally, the distribution and abundance of whale sharks are influenced by oceanographic processes such as sea surface temperature and increased productivity of the surrounding environment, especially the abundance of phytoplankton (Heyman *et al*., 2001; Fox *et al*., 2013; Sakuntala *et al*., 2016). In remote sensing, chlorophyll–variables are observed as a proxy for phytoplankton models because phytoplankton abundance is often linked to chlorophyll–to explain the emergence and movement of marine animals, including planktivorous Elasmobranchii such as whale sharks (Rohner *et al*., 2013). Observations of chlorophyll-a concentrations in Botubarani waters and the surrounding sea are slightly different from the results of previous research conducted by Amri *et al.,* (2005) in 2003-2004 in Tomini Bay, where the chlorophyll-a content values ranged between 0.32-1.25 mg.m^{-3}. Compared with the results of research at other whale shark emergence locations such as in Probolinggo (Sakuntala et al., 2016) and Panama, Eastern Pacific Ocean (Guzman *et al.,* 2022), the chlorophyll-a concentration value in Botubarani is not much different from research results in these two locations. The result of Pearson analysis showed that there is a negative, very low correlation between the yearly average of whale shark appearance and yearly average chlorophyll-a concentration (r=0,029) (Figure 8), while there is a positive, low correlation between yearly average whale shark appearance and yearly average SST (r=0,279) (Figure 9). These findings are contrary to the study of Manuhutu *et al.* (2021) which used the Generalized Additive Model (GAM) analysis of the presence of whale sharks in the waters of Cenderawasih Bay National Park, Papua, Indonesia, the oceanographic parameters that have the most influence are Sea Surface Temperature (SST) and Chlorophyll-*a* and indicated that there are several other oceanographic factors influenced the whale shark's appearance in Botubarani waters, such as Sea Surface Height Distribution (SSHD) and depth (Bathymetry). Since the oceanographic conditions in Indonesia are diverse and complex, further study is important to draw a firm conclusion.

The Gorontalo whale shark aggregation site is the only whale shark emergence area on Sulawesi Island with easy access throughout the year. Only a few locations where whale sharks appear with a very close range, access, and distance from the beach (only 20 m), such as in the Botubarani whale shark interaction zone. This ease of access and accommodation has rapidly developed Botubarani into a new ecotourism industry in Indonesia. However, it is important to remember that unregulated ecotourism could threaten the long-term sustainability of whale sharks (Allen *et al.,* 2021; Harvey-Carroll *et al.,* 2021). Therefore, it is critical to understand the population characteristics and seasonal constellation patterns of whale sharks and the importance of their occurrence habitats. There is a need for special attention to be given to the whale sharks living in Botubarani, both through better management of tourism attractions and through action plans to protect and preserve them.

Conclusion

The population of whale sharks that appear in Botubarani waters are male juvenile whale sharks. Botubarani Gorontalo whale shark constellations are dominated by whale sharks with a seasonal infrequent presence pattern, with the highest peak presence occurring in the east season, especially in June. The pattern of whale shark presence in the Botubarani Gorontalo fishery tends to follow the fluctuating trend of Sea Surface Temperature variables. Meanwhile, the chlorophyll-a variable has no significant effect on the presence of whale sharks in Gorontalo.

Acknowledgment

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