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Habitat Characteristics and Distribution of Ternate Island's Endemic Halmahera Shark (Hemiscyllium halmahera)

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ABSTRACT

The Halmahera walking shark (Hemiscyllium halmahera) is a newly discovered endemic species found only in Halmahera's marine waters. Ternate Island's waters are known to provide habitat for the Halmahera walking shark species; the coastal water ecology is primarily made up of seagrass beds and reefs, which help to sustain the species' population. However, knowledge on ecological characteristics and distribution of walking sharks remains scarce. The study aimed to determine the habitat characteristics and distribution of this rare species on Ternate Island's coastal waters. This study was carried out from March to July 2024, with four stations located in the waters of Ternate Island. The data obtained included the number of walking shark sightings, water quality, seagrass bed characteristics, and coral reef conditions. The number of shark appearances varied significantly. The number of appearances was highest at Muhajirin Station and lowest at Kayu Merah Station. Seagrass beds at all four observation stations were categorized as damaged or poor, and coral reefs had begun to erode.

Keywords: coral reef, habitat condition, Hemiscyllium halmahera, seagrass bed

INTRODUCTION

The Halmahera walking shark, also known as the Halmahera epaulette shark (*Hemiscyllium halmahera*), is a new species of endemic walking shark found in the maritime ecosystems of Halmahera. Dr. M. Erdman found this species in 2008 while diving at night in the waters of South Halmahera, Bacan Island, and Ternate Island. This kind of shark is a popular tourist attraction on Ternate Island and elsewhere (Allen *et al*. 2013). Walking sharks of the genus Hemiscyllium (family Hemiscyllidae) are nine species of small sharks that live in shallow waters throughout the Indo-Pacific area. Four of them are only found in Indonesian waters, namely the first Raja Ampat walking shark (*H. freycineti*), found in the waters of Raja Ampat (West Papua); the Cendrawasih Bay walking shark (*H. galei*), found in the waters of Cendrawasih Bay, Nabire (Papua) to Manokwari (West Papua); the Kaimana Triton Bay walking shark (*H. henryi*), found in the waters of Kaimana (West Papua); and the Halmahera walking shark (*H. halmahera*), which is found in the waters of Halmahera (North Maluku) (Dudgeon *et al*. 2020)

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Allen and Dudgeon (2010) confirmed that endemic species are vulnerable to environmental change, habitat degradation, and overfishing. According to a preliminary study by Jutan *et al*. (2017) in Kao Bay, North Halmahera, the probable drop in fish populations is attributable to habitat deterioration induced by anthropogenic activities and mining activities, both of which result in the entry of mercury waste. Because of its high selling price, this fish is trafficked live as an ornamental fish for aquariums (Bennett *et al*. 2015). Fishing operations influence the dynamics of fish populations, as evidenced by size and reproduction structures (Satria and Kurnia 2017). Sharks are especially vulnerable because they have slow growth and limited fecundity, with only 20 embryos per parent per year, resulting in few progenies. This fish moves rather slowly, making it easier to catch (Jutan *et al.* 2016; Saraswati 2016).

According to the IUCN Red List, the Halmahera walking shark is considered near threatened in 2020 (https://www.iucnredlist.org/). Because of their low swimming mobility, these species have a very limited distribution and cannot migrate through the deep sea, despite their close vicinity. The Government of the Republic of Indonesia has established protection for this species by the Minister of Maritime Affairs and Fisheries Decree No. 30 of 2023 on the Full Protection of Walking Sharks (*Hemiscyllium* spp.) in Indonesian seas. The Halmahera walking shark is known to inhabit the waters of Ternate Island. Ternate Island's coastal water ecology is primarily constituted of seagrass meadows and relatively healthy coral reefs (Rahmawati and Rasyidin 2012). These conditions are favorable to the species' survival. There is currently minimal information on the characteristics of habitat and distribution of walking sharks. Priatna and Natsir (2007) stated that the presence of a species in a habitat is influenced by its state. A disturbance to a habitat has an impact on the survival of the species as well as the overall community. Nybakken (1992) suggested that the number of species in a community is used as a measure of a population.

Walking sharks are currently a popular tourist attraction for divers along the Ternate Coast and its vicinity. If not adequately handled, diving tourism operations can raise the risk of disturbances to wandering sharks. Based on the facts presented above and in the interest of long-term management. This study looked at the ecological characteristics and distribution of indigenous walking shark species in Ternate Island's coastal waters.

METHODS

Time and Location of the Study

This study was carried out from March to July 2024, marking the end of the western season and the start of the eastern season. Ternate Island's waters were sampled at four points: Station 1 (Fitu), Station 2 (Kayu Merah), Station 3 (Muhajirin), and Station 4 (Salero) (Figure 1). The observation location was chosen based on the findings of surveys and interviews with local populations and diving industry actors, as well as previous research. Walking sharks are nocturnal species, therefore their existence was observed at night, whereas habitat surveys were conducted during the day.

Sampling Procedure

Observations of habitat conditions were conducted during the day. The proportion of seagrass closure was calculated using the square transect approach (Hutomo and Nontji 2014). The percentage of seagrass cover area was measured using a 50 × 50 cm² square transect method. The transect was placed at the base of the seagrass and pulled along 50 m horizontally perpendicular with 25 m between transects and 5 m for each quadrant. Coral reef habitats were sampled for coral reef health evaluation using the underwater photo transect (UPT) method (Giyanto 2012a; Stuart 2012b). The UPT approach makes use of both digital camera and computer software technologies. Data collection in the field was limited to underwater photos taken using underwater digital cameras or standard digital cameras equipped with waterproof shields (housing). The photographs from the session were then processed using computer tools to produce quantitative data. Photo analysis was done using Coral Point Count with Excel® Extension (CPCe) software and coral cover criteria (Kohler and Gill 2006; Scott 2013; Giyanto *et al*. 2017a).

Aquatic conditions were monitored by measuring the physical-chemical parameters of the water, i.e. temperature, salinity, DO, pH, and depth. The environmental parameters of the waters were measured using Horiba water quality. Halmahera walking sharks have been sighted at depths ranging from 1 to 5 m utilizing basic diving equipment and scuba diving. The observation took place at night, beginning around 8 p.m. and continuing until it was completed. The observation approach involved swimming freely with simple diving equipment as far as 150 m parallel to the water column's coastline, which was surrounded by seagrass beds and coral reefs, the primary ecosystems in Ternate Island's waters. The shark's appearance was documented at the time of observation using the Garmin GPSMap 78s, and the sex was determined visually by the presence of its claspers. This method of visual identification was a simple and noninvasive way to detect the sex of a

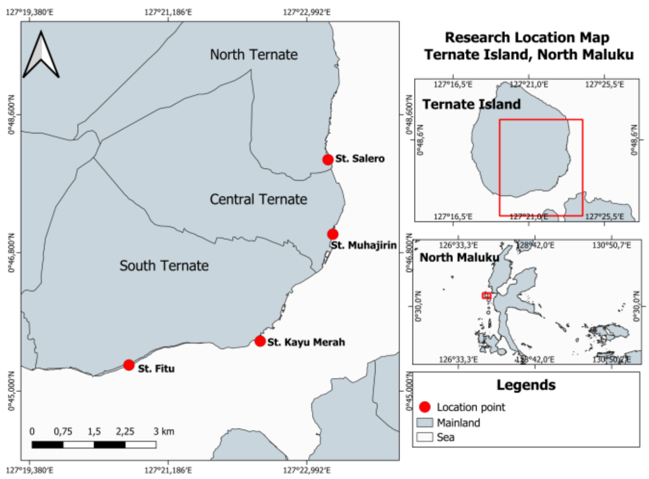

Figure 1 Research location on habitat and distribution of the endemic shark (*Hemiscyllium halmahera*) of North Maluku on Ternate Island (Geospatial Information Agency 2024).

wandering shark without catching or disturbing the animal too much.

Data Analysis

The percentage of seagrass closure (C) was calculated using the formula according to English *et al*. (1997).

$$C = \frac{M_i \times F_i}{f}$$

where:
C = closing percentage
M_i = middle value of the i closing class
F_i = frequency of occurrence of the i–closing class
f = total number of class closure frequencies

The proportion of seagrass closure was classed to determine the health of the seagrass. The determination was based on Table 1. Coral reef closure referred to the area covered by coral reefs. Aldyza *et al*. (2015) used criteria developed by Gomez and Yap (1988) to assess coral reef conditions based on percentage of cover (Table 2).

The abundance analysis was conducted using the coral fish abundance calculation (Odum 1996).

$$x = \frac{x_i}{A}$$

where:
x = abundance of walking sharks (ind/ha)
x_i = number of walking sharks in the observation quadrant i
A = observation quadrant area (50 × 50 m^2)

The association or link between aquatic habitat parameters and fish abundance was investigated using the PCA (Principal Component Analysis) method. The PCA was used to determine the link between fish abundance and aquatic environmental characteristics in a body of water: temperature, salinity, dissolved oxygen (DO), seagrass conditions, and coral cover. The association between parameters was examined using a *t*-test on the matrix correlation with a significance level of $p < 0.0$. The data provided in the PCA analysis was in the form of graphs created using information from a data matrix organized in rows and columns. The rows indicated the research station, while the columns depicted the aquatic environment's features. XLSTAT2023 software was used to conduct PCA analyses.

RESULTS AND DISCUSSION

Morphological and Morphometric Description

Morphological investigations of Halmahera walking sharks revealed several dark brown patches of varying sizes and shapes (Figure 2). These brown patches

Table 1 Criteria for seagrass health conditions (Minister of State for the Environment of the Republic of Indonesia 2004b)

	Seagrass conditions	Closing (%)
Good	Rich/healthy	≥ 60.0
	Bad	30.0–59.9
Damaged	Poor	≤ 29.9

Table 2 Criteria for coral reef conditions

Percentage of cover (%)	Condition criteria
Low	Poor
Medium	Fair
High	Good

Source: (Gomez and Yap 1988 in Aldyza *et al*. 2015).

Figure 2 Sharks are walking in Halmahera. (Personal documentation, Nabillah 2024).

were distributed all throughout the fish's body. This section of the shark's body is typically marked with light brown patches (Akbar *et al*. 2019). The markings on the body of this wandering shark measure 0.5−1.2 cm in diameter. The shark's abdomen and upper body extended to the tail, where big spots appear, while minor spot patterns could be found in the front mouth, fins, and tail. Jutan *et al*. (2018) discovered this species in the waters of Kao Bay, North Halmahera, with a distinctive light brown color and a nicely organized pattern of dots. from tail to head.

The Halmahera walking shark is a particularly uncommon species of shark with pectoral and anal fins that allow it to move or walk on the seafloor. The shark's mouth is subterminal in shape and placed at the bottom of the head near the tip of the nose (Figure 3). The shape of this shark's mouth reflects its distinctive feeding style. The mouth is small and placed near the base of the head, allowing it to effectively search for food on the substrate. This shark's pointed teeth, which are not overly huge, indicate that it is an omnivore.

These sharks' reproductive organs, both male and female, are positioned in the ventral region of the body, near the anal fin (Figure 4). The morphological distinctions between the two sexes are extremely noticeable. In male, the genital organs are in the shape of an oval, elongated structure that resembles a torpedo and measures around 1−2 cm in length; this structure is known as a clasp. Meanwhile, female reproductive organs are identified by the existence of a tiny hole in the lower abdomen. These two reproductive systems are adjacent to the anal fin, making it simple to determine the sex without requiring significant manipulation of the wandering shark.

Male and female Halmahera walking sharks could be found throughout the area. The western season's 16 individuals were divided into 12 males and 4 females, or 4:1 (Table 3). For the eastern season, there were 12 individuals, with 9 males and 3 females, or a 3:1 ratio. The sharks possess unique characteristics such as walking with pectoral fins, being less likely to be seen in groups, having minimal migration, and being geographically isolated, all of which indicate endemism. Endemic species have a high risk of exploitation due to public ignorance, commercial value, habitat specialization, biodiversity, and global heritage (De Silva *et al*. 2007).

Figure 3 Morphology of the shark mouth walking in Halmahera (Personal documentation, Nabillah 2024).

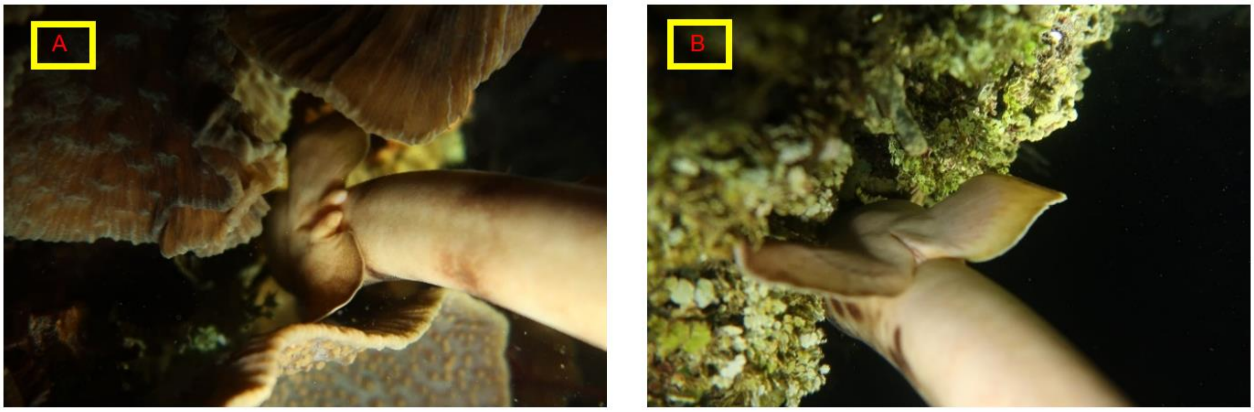

Figure 4 Sexual classification of walking sharks observed at the study site. (A) Male specimen and (B) female specimen (Personal documentation, Nabillah 2024).

Table 3 The size and sexual classification of the Halmahera walking shark found at four observation locations during the eastern and western seasons

Station	Number of objects	Gender	Length (cm)
Western season			
Fitu	3	Male	65
		Male	74
		Female	78
Kayu Merah	2	Male	65
		Male	67
Muhajirin	6	Male	76
		Male	43
		Male	57
		Male	49
		Male	57
		Female	73
Salero	5	Male	68
		Male	64
		Male	64
		Female	71
		Female	74
Eastern Season			
Fitu	3	Male	28
		Male	23
		Female	54
Kayu Merah	0		
Muhajirin	7	Male	23
		Male	24
		Male	28
		Male	32
		Male	46
		Female	75
		Female	65
Salero	2	Male	68
		Male	64

Composition of The Number and Size

The quantity, sex, and total number of Halmahera walking sharks varied by observation point. The overall length varied between 43 and 78 cm in the western season and 23−75 cm in the eastern season (Table 3). Male walking sharks were discovered to be 23 to 76 cm long. Female wandering sharks found ranged in length from 54 to 78 cm. Allen *et al*. (2013) reported total lengths ranging from 65.6 to 68.1 cm for specimens from Ternate and Bacan Islands. Allen *et al*. (2016) discovered lesser total lengths in the waters of Veda, Central Halmahera, ranging from 40 to 45 cm. These findings are consistent with Allen *et al*. (2016)'s observation that members of the Hemiscyllidae family are generally tiny, measuring less than 85 cm and rarely reaching 70 cm. Despite the size variance, Akbar *et al*. (2019) reported that the morphological traits of the Halmahera walking shark are highly consistent among populations. This suggests the possibility that these populations are of the same lineage, albeit spread over different places.

The Halmahera walking shark has an oviparous reproductive strategy, however little is known about its reproductive parameters, such as egg size and fecundity. However, according to data from other Hemiscyllium species, spawning often happens when the female individual reaches a minimum size of 57 cm. The species is thought to lay two egg capsules in a single egg-laying cycle, with reproductive patterns that can last all year, as shown in the genus Hemiscyllium (Allen *et al*., 2016; Dudgeon *et al*., 2020). These reproductive traits are consistent with the K-selected method found in the Elasmobranchii group, albeit with lower fertility than other shark species. Species with the K-selected strategy exhibit sluggish maturation, fewer and larger young ages, longer lifespans, more maternal care, and more intense competition for resources.

Habitat Characteristics

In general, the observation station at Fitu station, which is near to the fishermen's hamlet, is in poor shape, with waste piled high on the beach. Meanwhile, Kayu Merah station is a reclamation site with mud deposits at the bottom of the lake. In addition, there is an electric generator cooling system at the place. Muhajirin Station is a crowded crossing point. This is also a tourist destination in the heart of Ternate City. Finally, Salero station, which is in a heavily populated area with plenty of waste on the beach, has a reclamation area. Table 4 shows statistics on water

Table 4 Parameters of water quality in the waters of Ternate Island

Station	Temperature (°C)	pH	DO (mg/L)	TDS (g/L)	Salinity (ppt)	Depth
Western season						
Fitu	30.86	5.67	20.10	30.20	32.81	2.67
Kayu Merah	29.40	3.16	0.01	30.20	30.33	4.00
Muhajirin	30.00	5.32	19.50	30.10	32.27	3.17
Salero	30.08	8.01	19.20	30.20	33.04	4.40
Eastern season						
Fitu	30.33	7.15	19.37	30.30	33.30	2.67
Kayu Merah	29.30	6.30	18.50	29.50	33.22	4.00
Muhajirin	29.75	7.19	20.50	30.20	32.90	2.29
Salero	30.29	7.18	19.55	30.50	33.40	3.50

quality parameters. Measurements at each site and in different seasons giving results that were close to a nonsignificant variation in values. Overall, the aquatic environment at the four station locations remains in excellent shape for the survival of the species that inhabit it.

Sharks from the genus *Hemiscyllium* spp. typically hide throughout the day to avoid the effects of rising water temperatures. According to Gervais *et al*. (2018), the optimal water temperature for sharks walking at night is approximately 28.54 °C. Temperature at Fitu, Kayu Merah Muhajirin, and Salero stations remain within the ideal range for these sharks' survival (about 29−30 °C at night). Walking sharks' nocturnal behavior has several advantages, including reduced predation risk and exposure to high temperatures. However, a sudden increase in temperature can affect the physiology of the species. Pistevos *et al*. (2016) also stated that higher water temperatures can make sharks more active, but this has a negative impact on their growth.

The concentration of dissolved oxygen (DO) correlates closely with the pH of the water. A drop in DO levels may suggest an increase in CO_2 concentration and a decrease in the pH of the water (Briffa *et al*. 2012). The four research stations revealed that the pH remained appropriate for aquatic life. According to the Decree of the Minister of Environment of the Republic of Indonesia (2004a), the pH is also within the ideal range for walking shark habitats. Walking sharks are typically found on flat reef settings. Biota and corals in these locations require a pH range of 7.80 to 8.70 (Wijgerde *et al*. 2014). However, Heinrich *et al*. (2016) found that pH had little effect on the survival of *Hemiscyllium* spp. sharks, likely because the sharks have evolved to pH changes. Heinrich *et al*. (2016) discovered that even when the pH went from 8.01 to 7.70, wandering sharks' feeding and protection remained unaffected. Nonetheless, the pH of the water still influences the shark's ability to track prey. Gardiner *et al*. (2014) were concerned that this ability may deteriorate in the presence of severe pH fluctuations.

Total dissolved solids (TDS) in water are derived from a variety of pollutants, including easily dissolved domestic, industrial, and agricultural wastes. The measured TDS concentration at the four observation stations was relatively high, although it remains below safe limits for marine life, according to earlier study. Referring to Voutchkov (2010), marine benthic species can tolerate TDS concentrations of up to 40 g/L, which is assumed to apply to reef-dwelling sharks. Although TDS concentrations were below acceptable limits, changes in them could drastically alter water conditions, particularly salinity and the presence of hazardous ions. Moore *et al*.'s (2015) study highlighted the harmful effects of toxic ions on shark body tissues, particularly the liver organs and reproductive abilities. Drastic fluctuation in TDS concentrations can be fatal to aquatic creatures, affecting their existence and health.

Walking sharks are commonly found in seagrass ecosystems dominated by *Thalassia* spp. and *Enhalus* spp. The status of seagrass beds at the four observation sites, as measured by the percentage of seagrass closure on Ternate Island's shore, was very low, indicating that they are damaged and poor. The proportion of seagrass cover at both observation locations is less than 29.9%.

Walking sharks were also found in areas dominated by branching corals (Acropora and non-Acropora). Figure 5 shows data on the percentage of lifeform closures. Based on the coral cover presentation data (Figure 6), the coral reefs in the four observation sites were in poor condition, as defined by Gomez and Yap (1988) in Aldyza *et al*. (2015), with a percentage of live coral cover less than 25%. Salero Station had the largest proportion of coral cover, while Muhajirin Station the lowest. The low coral cover percentage at all stations suggests that coral reef ecosystems are being degraded because of human activity.

Distribution

During the western and eastern seasons, Halmahera walking sharks were discovered at all four study stations: Fitu, Kayu Merah, Muhajirin, and Salero. In the western season, the total number of individuals detected was 0.064 ind/m², spread in four stations: Fitu (1.20 ind/100m²), Kayu Merah (0.80 ind/100m²), Muhajirin (2.40 ind/100m²), and Salero (2.00 ind/100m²), as illustrated in Figure 7. In the eastern

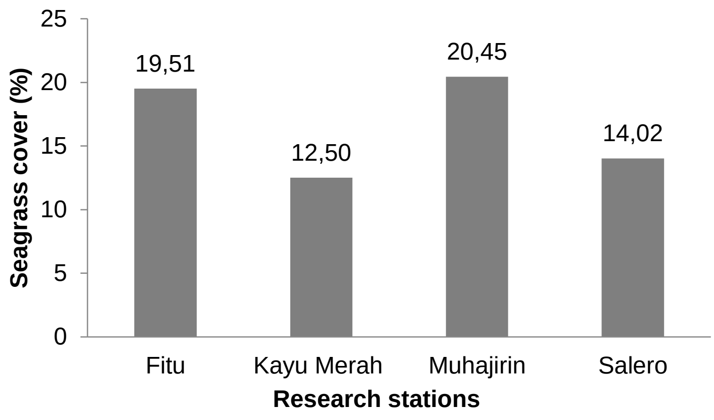

Figure 5 Percentage of sea cover in the waters of Ternate Island.

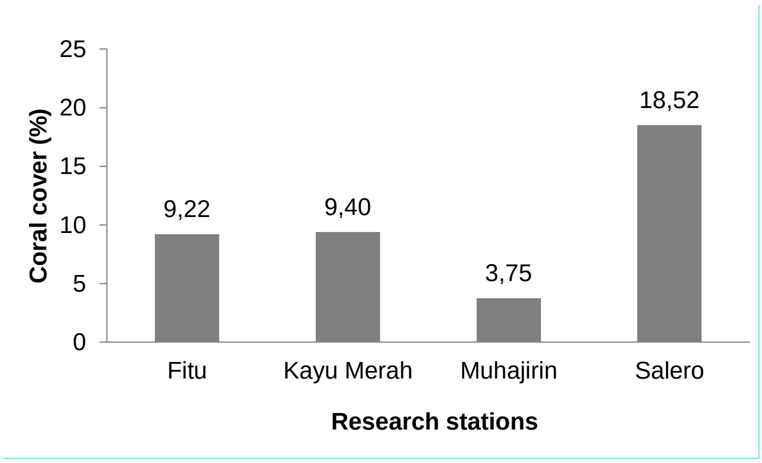

Figure 6 Percentage of coral cover in the waters of Ternate Island

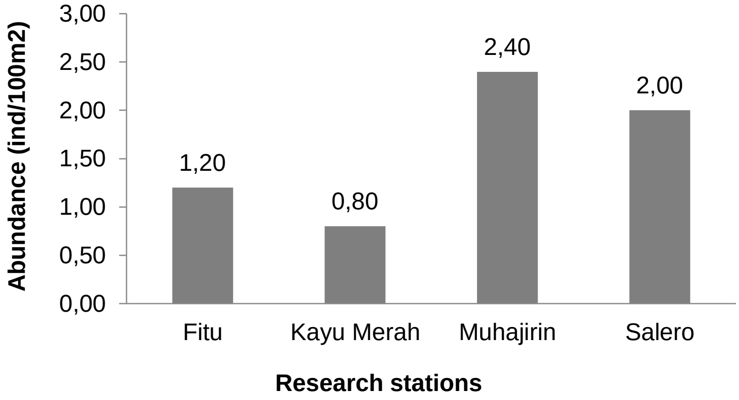

Figure 7 Western season fish abundance

season, the total number of people detected was 0.048 ind/m² spread in four stations: Fitu (0.012 ind/m²), Kayu Merah (0 ind/m²), Muhajirin (0.028 ind/m²), and Salero (0.008 ind/m²) (Figure 8). There were very few sharks walking at Kayu Merah Station during both seasons (Figures 9 and 10) . This is thought to be related to the destruction of shark habitat, particularly due to coastal reclamation activities. According to our observation, Muhajirin and Salero Stations had the highest average number of shark appearances. This is suspected because the waters at both sites are still categorized as good, with enough food available for wandering sharks.

Walking sharks that appear near the study location are thought to consume a variety of foods, including

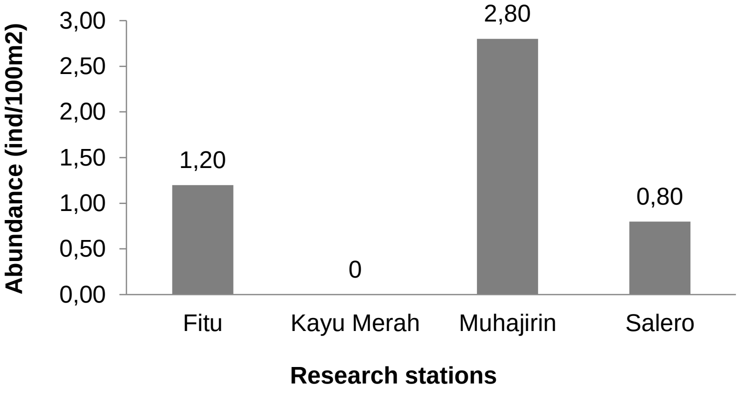

Figure 8 Abundance of fish of the eastern season

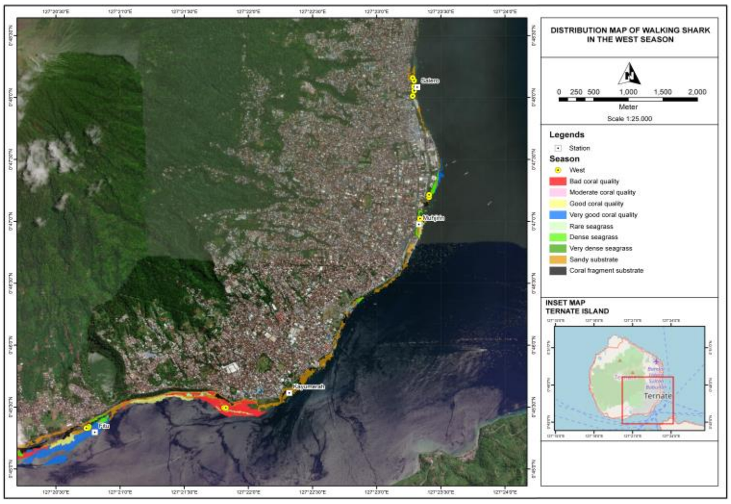

Figure 9 Shark distribution pattern runs during the western season.

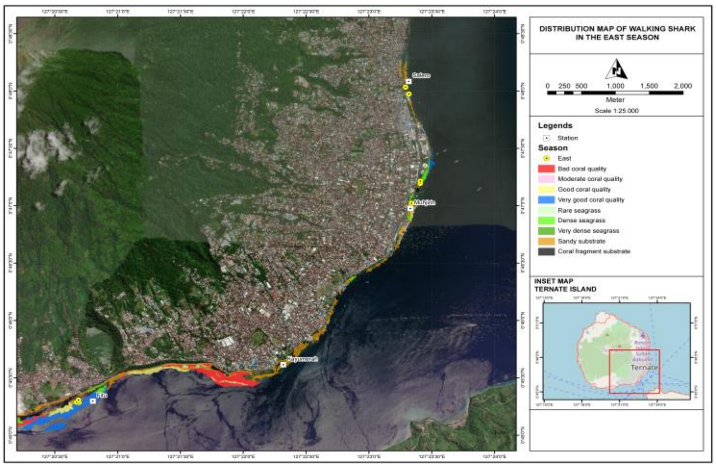

Figure 10 Shark distribution pattern runs during the eastern season.

tiny fish, crustaceans like crabs and shrimp, and mollusks (Allen *et al*. 2013). The shark forages at night in three main ecosystems (coral reefs, seagrass, and mangroves), and during the day it rests (dwells) in coastal ecosystems (mangroves and corals) (Allen *et al.* 2016). They rely heavily on habitats with seagrass and coral reef conditions, as well as optimal water quality. These conditions not only enable the survival of this shark species, but also the existence of numerous other organisms that serve as food sources in their native ecosystems.

Walking sharks were typically seen at depths ranging from 1 to 5 m around 19.00 Eastern Indonesian Time, with a limited frequency of individual presence due to the species' solitary nature. Although the movement pattern is sinusoidal (rotating in the surrounding area) (Raoult *et al.* 2018), the arrival of the walking shark is impossible to forecast due to its constant migration (nomadic). The Halmahera walking shark has a low population density. Mumi'n *et al*. (2021) discovered that the average density was 9 ind/ha, with a range of 5.33−17.33 ind/ha in Weda Bay, Central Halmahera. The abundance of other walking sharks, *H. freycineti*, was discovered to be 5.29 ind/ha (Widiarto *et al*. 2020). The number of individuals found in each location was different, most likely due to seasonal influences (eastern monsoon, western monsoon, and seasonal switches), spawning, mating (gonad maturation), food availability, tides (vertical and horizontal migration), and different habitat characteristics.

This species is commonly collected in coral reef areas (its primary habitat), although it can also be found in seagrass and mangroves. Halmahera walking sharks forage at night in three major ecosystems (coral reefs, seagrass, and mangroves), and during the day, they rest (dwell) in coastal ecosystems (mangroves and corals) (Allen *et al*., 2016). Mumin *et al*. (2021) said that the shark has a random distribution pattern and that distances between individuals are unpredictable. This species' migration varies from one individual to the next, however 1−2 individuals can be found in coastal habitats.

Walking sharks are a type of shark that may thrive in a variety of settings (Chin *et al.* 2012). They may have been able to migrate between the four observation sites, according to distance and bathymetric trends study. The four observation stations remain connected via shallow waters with depths ranging from 0 to 45 m and distances of 2 to 3 km between stations. According to Allen and Erdmann (2008), wandering sharks can be seen at depths ranging from less than 4 m to 30 m. Nonetheless, Allen *et al*. (2013) reported that they have difficulties navigating between significantly different depths. Heupel (2007) reported that the farthest walking shark migration observed on Heron Island was 329 m over a 725-day period. However, in general, these sharks only swim 30 to 40 m in coral reef areas, with no evidence of migration from neighboring islands. Raoult *et al.* (2018) discovered that walking sharks on Heron Island may travel up to 222 m in 10 min, however their movements are restricted to their own natural setting. Based on these data, it is estimated that walking sharks can only migrate locally. This raises the possibility that sharks can move between observation stations on Ternate Island's southern shore, but smaller-scale movements are more likely to occur than interregional migrations.

The Relationship Between the Abundance and Aquatic Habitats

The association between the number of walking sharks and the aquatic environment's habitat in the waters of Ternate was investigated using Principal Component Analysis (PCA). The PCA analysis offers essential information on the two primary axes (F1 and F2), as well as the contribution values for each. The strong association between environmental variables and stations can be described by the F1 and F2 axes (Poedjirahajoe *et al.* 2017).

The PCA analysis of both components, shark abundance and aquatic habitat, revealed that the information describing the relationship of aquatic parameters to the abundance of walking sharks at each observation station was formed by two main axes, F1 by 54.50% and F2 by 32.68%, out of a total variety of 87.72% (Figure 11). In the western season, Salero Station in the positive F1 axis position has the dominant characteristic parameters, namely coral cover, pH, salinity, and DO, which all contribute significantly to the abundance of walking sharks, as do Fitu and Muhajirin Stations, which have contributions related to seagrass cover and water temperature. The Kayu Merah Station is located on the negative F1 axis, and its environmental parameters show no dominant characteristics.

In the eastern season, the percentage of F1 was 64.28%, with F2 accounting for 30.03% of the overall variety (94.31%) (Figure 12). In the eastern season, Salero Station has dominating coral cover and salinity characteristics, but Fitu and Muhajirin Stations have dominant characterizing parameters, such as temperature, pH, DO, and seagrass cover, which all contribute significantly to abundance.

The link between aquatic environmental characteristics and the abundance and distribution of walking sharks at observation locations is highly correlated. The two primary axes form two groupings of physical-chemical factors associated with the research station. Mattjik and Sumertaya (2011) defined the level of correlation based on biplot graphs as the angle formed or flanked by two vectors or variables. If the angle formed is a taper angle (90°), the correlation decreases and becomes negative. If the angle between the two variables is 90°, then there is no correlation between them. The major component analysis results demonstrate a link between walking shark abundance and aquatic habitat factors at each observation station.

CONCLUSION

In general, the habitat of walking sharks on Ternate Island's coast provides relatively appropriate circumstances for roaming sharks to thrive. Although water quality parameters are still effectively maintained, there are signs of deterioration in seagrass habitats and coral reefs that have suffered harm. Walking sharks were observed seldom, particularly at Kayu Merah Station. This low prevalence is assumed to be related to shark habitats (coral reefs and seagrass beds), which are becoming disturbed due to increased anthropogenic activities in these areas.

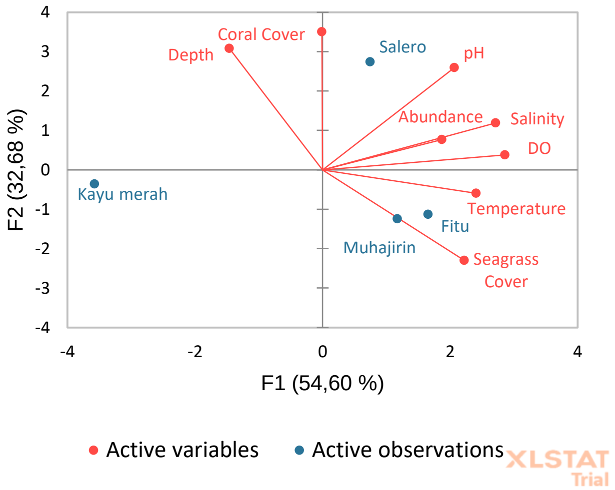

Figure 11 The relationship between shark abundance and aquatic habitats in the western season.

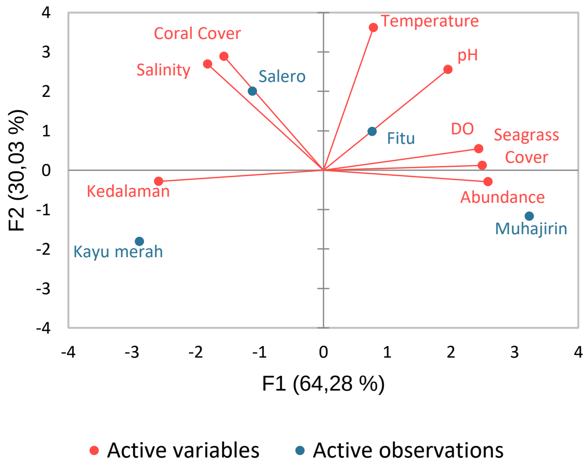

Figure 12 The relationship between shark abundance and aquatic habitats in the eastern season.

A specialized handler is required, with a focus on places with declining seagrass cover and coral reefs. Interventions such as transplantation initiatives and rehabilitation programs for seagrass ecosystems and coral reefs are urgently required, particularly in places that have suffered environmental degradation. This effort is necessary to protect the habitat of walking sharks near Ternate Island's coast.

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