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The Existence of the Halmahera Walking Shark (Hemiscyllium Halmahera), How are Coral Reefs as the Primery Habitat in Maitara Small Island Sea. North Maluku. Indonesia?

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Abstract

The Halmahera walking shark is an endemic marine species distributed in the Halmahera Sea. This species is found in the North Maluku archipelago and the Halmahera mainland. The Halmahera walking shark's dependence on coral reef ecosystems is very clear. Small islands such as Maitara Island are unique because of the availability of natural resources, namely the Halmahera walking shark. The study aimed to observe the condition of coral reefs, the morphometrics of the Halmahera walking shark, and the marine environment on Maitara Island. Analysis included coral cover, coral life forms, morphometrics, relationship analysis, marine environment, and sediment analysis. The results of the study found good coral cover, varied coral life forms with a high percentage of Acropora sp. We found five species distributed in marine areas with varying morphometrics. Regression showed that body weight and length were influenced by coral reefs. The marine environment showed that environmental parameters were normal. We found medium sand that dominated, indicating the preference for sand preferred by the Halmahera walking shark.

Introduction

Indonesia is widely recognized as a maritime nation with exceptionally high marine biodiversity and substantial potential for further scientific investigation. The vast distribution of its islands contributes to unique biogeographical characteristics, including the occurrence of various endemic marine species (Mu'min et al., 2021;Wahab et al., 2022). Indonesia possesses an extensive cluster of small islands in its eastern region. North Maluku Province is characterized by numerous small islands, one of which is Maitara Island. Maitara is a small island located in eastern Indonesia and forms part of the administrative region of North Maluku Province. Maitara Island is a small island situated between Ternate and Tidore Islands. Administratively, it is part of the Tidore Islands City. The island hosts three major coastal ecosystems coral reefs, mangroves, and seagrass beds (Akbar et al., 2017; Ramili et al., 2018; Subur & Sarni, 2018; Titaheluw et al., 2021; 2024). The distribution of these ecosystems occurs both horizontally and vertically across the coastal zone of Maitara Island (Subur & Sarni, 2018; Titaheluw et al., 2023; 2024). These key ecosystems play an essential role in supporting marine biota and other fisheries resources. Maitara Island also possesses significant potential for marine tourism. Umasugi (2023) describes Maitara Island as a small island tourism area with considerable development prospects. The island is known for its scenic natural landscape and is famously depicted on the Indonesian 1,000-rupiah banknote (Rauf et al., 2023). Another remarkable feature of Maitara Island is the presence of the Halmahera Walking Shark, an endemic species found in Halmahera Sea, North Maluku (Akbar et al., 2019; Madduppa et al., 2020; Galitan et al.,2023).

The Halmahera Walking Shark (*Hemiscyllium halmahera*) is one of the endemic species of North Maluku, distinguished by its unique ability to move in a walking-like manner along the seafloor using its pectoral and pelvic fins. This species was first formally described by Allen et al. (2013) from the waters of Halmahera, and since then it has been widely recognized as one of the characteristic species of North Maluku. Beyond its scientific significance, the uniqueness and visual appeal of the Halmahera Walking

Shark also make it an iconic attraction for diving tourism in the marine areas of Halmahera and its surroundings, thereby providing both ecological and economic value for coastal communities. Previous reports of this species in Maitara Island, specifically in several shallow sea locations (Akbar et al., 2019; Madduppa et al., 2020; Akbar et al.,2023c; Akbar et al., 2025).

Coral reefs, as one of the major tropical marine ecosystems, play a crucial role in maintaining ecological balance in the ocean. These ecosystems function as habitats, spawning grounds, feeding areas, and protective structures for a wide variety of marine organisms. The condition of coral reefs in many coastal regions is increasingly threatened by anthropogenic activities and climate change. Global climate change has led to rising sea surface temperatures and widespread coral bleaching, further exacerbating the degradation of coastal ecosystems (McLeod et al.,2009). Although coral reefs cover only about 1% of the global seafloor, they support more than 25% of all known marine species (Wilkinson, 2008). The Halmahera Walking Shark also utilizes coral reef ecosystems as its primary habitat, largely due to the availability of its preferred prey such as mollusks, crustaceans, and small fishes. The complex microhabitat structures within coral reefs provide essential shelter for this species (Allen et al., 2013). Therefore, coral reef ecosystems serve as a critical ecological component supporting the persistence of the Halmahera Walking Shark. The degradation of coral reefs ultimately has direct implications for the survival of the Halmahera Walking Shark, which is highly dependent on this ecosystem for its habitat.

Materials and Mehod

This study was conducted in June 2025 at three coastal sites: the waters of Doe Doe Village (Station I), Akebay Village (Station II), and Pasimayou Village (Station III), located on Maitara Island, North Tidore District, Tidore Islands City, North Maluku Province (Figure 1).

Data Collection

Coral Reef Data Collection

Data on coral cover and *lifeform* (English et al.,) composition were collected using the *Underwater Photo Transect* (UPT) method, employing an underwater camera equipped with a protective housing (Figure 2). Photographs were taken within quadrats measuring 58 × 44 cm placed adjacent to a 50-m transect line (Figure 2). The quadrats were positioned from meter 1 to meter 50 in a zigzag pattern, with a 1-meter interval between each quadrat. Thus, each 50-m transect yielded a total of 50 photographs for subsequent analysis (Giyanto, 2013; Giyanto et al.,2017) (Figure 2).

The transect line was established at representative points within the three predetermined study sites, with one 50-m transect deployed at each location. Field data collection was carried out by a team of four divers, in which one diver deployed the 50-m transect line, one positioned the 58 × 44 cm quadrats, one captured the transect photographs, and another collected sediment samples at three points along the transect: 0 m, 25 m, and 50 m. The transect was laid horizontally, parallel to the shoreline, at a depth of 3 m. Quadrats were then placed from meter 1 to meter 50 in a zigzag pattern at 1-m intervals, followed by

photographic documentation, resulting in a total of 50 images per transect. After completing the coral reef data collection, the divers continued with the search for the Halmahera Walking Shark (*Hemiscyllium halmahera*) at depths of 3-5 m, and subsequently conducted measurements of environmental parameters at each study site.

Halmahera Walking Shark Sampling

Sampling of the Halmahera Walking Shark was conducted during both daytime and nighttime surveys using basic diving gear and scuba equipment at depths ranging from 3 to 15 meters within coral reef areas. Individuals were captured manually using hand sampling techniques and subsequently brought to the water surface for morphometric measurements. After measurements were completed, all specimens were released back into the water (Akbar et al., 2019).

Morphometric Data Collection

A total of several external body dimensions were recorded, including total length (PT) until precaudal length (EBB), (Figure 3). All measurements were taken using a flexible measuring tape and Vernier calipers to the nearest 0.1 cm. Photographs of each specimen were also taken for documentation and verification purposes. After completing all measurements, each individual was safely returned to the same location where it was captured to minimize handling stress and ensure post-release survival.

The morphometric measurements recorded for each specimen included the following parameters (Akbar et al., 2019):

1. Total Length (PT): the distance from the tip of the snout to the tip of the caudal fin.
2. Standard Length (PS): the distance from the tip of the snout to the base of the caudal fin.
3. Head Height (LK): the maximum vertical height of the head.
4. Head Length (PK): the maximum linear distance from the snout to the posterior end of the head.
5. Pectoral Fin Length (SP): the maximum length of the pectoral fin.
6. Anal Fin Length (SA): the maximum length of the anal fin.
7. Dorsal Fin Length (SD): the maximum length of the dorsal fin.
8. Posterior Caudal Length (EBB): the maximum length of the posterior portion of the caudal fin.

Environmental Parameters and Sediment Collection

Environmental parameter salinity, temperature, DO and pH measurements were conducted in situ using Horiba instruments in accordance with the appropriate *Standard Operating Procedures* (SOP). A Secchi Disk is a simple instrument used to measure water brightness or transparency in marine environments. The disk is lowered into the water until it is no longer visible, and then raised again until it reappears. The average depth at which the disk disappears and reappears is recorded as the transparency value (Boyd, 2004). Depth sea water measurements were taken using a dive computer at each sampling point to

ensure data accuracy and consistency. Sediment samples were collected using a sediment core, consisting of a 3-inch diameter PVC tube with a length of 30 cm, which was inserted into the seabed to a predetermined depth. Once the target depth was reached, the top end of the tube was sealed to retain the sample before it was retrieved. Sampling points were positioned along the transect line at 0 m, 25 m, and 50 m, resulting in three sediment samples per transect for subsequent analysis.

Data Analysis

Photographic data of coral cover were processed and analyzed using the *Coral Point Count with Excel extensions* (CPCe) version 4.1. Each photo frame was analyzed using 30 randomly distributed points, followed by identification of the benthic category at each designated point. According to Giyanto et al. (2014), the use of 30 points per frame is considered representative for estimating the percentage cover of benthic categories and substrate types. Based on the photo analysis performed for each quadrat frame, the percentage cover values for each benthic category were obtained and calculated following the formula described by Giyanto et al. (2014). The classification of coral reef conditions was determined based on the percentage of live coral cover (Tabel 1), Based on ,Ministry of Environment Decree (KEPMENLH) No. 4/2001 categories.

Table 1. Coral reef condition categories based on live coral cover

Condition Criteria	Live Coral Cover (%)
Poor	0–24.9
Fair	25–49.9
Good	50–74.9
Excellent	75–100

Simple Linear Regression Analysis

Simple linear regression analysis was used to examine the relationship between coral cover (%) as the independent variable (X) and the body weight (g) and total length (cm) of the Halmahera Walking Shark as the dependent variables (Y). The general form of the simple linear regression equation applied in this study is:

$$Y = a + bX$$

where *Y* represents the dependent variable, *X* represents the independent variable, *a* is the regression constant, and *b* is the regression coefficient indicating the direction and magnitude of the influence of the independent variable (X) on the dependent variable (Y). The coefficient of determination (R^2) was used to assess the proportion of variation in the dependent variable explained by the independent variable, while the correlation coefficient was used to determine the strength of the relationship between variables.

Sediment Grain Size Analysis

The sediment samples were first weighed in their wet condition, then rinsed with freshwater and air-dried until completely dry. After drying, the samples were weighed again to obtain their dry weight. The next step involved sieve analysis using a sieve shaker for three minutes with nine sieve sizes: 4.75 mm (#4), 2.00 mm (#10), 1.18 mm (#16), 0.850 mm (#20), 0.425 mm (#40), 0.250 mm (#60), 0.150 mm (#100), 0.075 mm (#200), and >0.075 mm (>#200). The resulting fractions were separated according to mesh size, weighed individually, and placed into labeled sample bags. The weight of each fraction was then converted into percentage weight (%) to determine the dominant grain size distribution in each sample. Grain size classification followed the Afnor Scale (Pinot, 1992 in Repi, 1999) (Table 2), which categorizes sediment as follows: boulders (>20 mm), gravel (20–2 mm), coarse sand (2–0.8 mm), medium sand (0.8–0.315 mm), fine sand (0.315–0.125 mm), very fine sand (0.125–0.05 mm), and silt (<0.05 mm). This classification was used to determine the dominant sediment category in each sample.

Table 2. Afnor Scale Classification (Pinot (1992) *in* Repi (1999).

Sediment Type	Size (mm) (α)
Boulders	>20 (<–13)
Gravel	20–2 (–13 to –3)
Coarse Sand	2–0.8 (–3 to –1)
Medium Sand	0.8–0.315 (1–5)
Fine Sand	0.315–0.125 (5–9)
Very Fine Sand	0.125–0.05 (9–13)
Silt	<0.05 (>13)

Result and Discussion

Maitara Island is located between Ternate and Tidore Islands, within the administrative area of Tidore Islands City, North Maluku Province. Geographically, the island is located at coordinates 0°43'41" N and 127°23'45" E. It covers an area of approximately 14 km² and is known for its beautiful coastline, consisting of white sandy beaches and crystal clear waters. The surrounding marine ecosystem is well-preserved, dominated by coral reefs, seagrass beds, and mangrove forests. This area is also a critical habitat for various reef fish species, including the Halmahera Walking Shark (Akbar et al., 2018). In local oral tradition, there is a belief that disturbing or capturing the Halmahera Walking Shark can lead to disaster. Over time, an unwritten prohibition has developed prohibiting hunting and engaging with the species. The Maitara Island community demonstrates a high level of respect for the Halmahera Walking Shark. Some people even believe that anyone who catches a Halmahera Walking Shark will experience a "hunched" body or a bent spine.

Previous research has recorded 54 species of reef fish spread across eight families in the waters around Maitara Island, indicating a relatively high level of biodiversity (Akbar et al., 2018). The coastal sediment is dominated by medium to fine sand, with relatively good stability on the eastern side, although the northern and southern areas show potential for erosion (Najamuddin & Tahir, 2021). Furthermore, the potential for ecotourism development based on local community involvement is being promoted as an effort to preserve the environment while improving the economic well-being of local residents.

This research was conducted at three stations, which constitute marine tourism areas and also include coastal fishing areas on Maitara Island: the waters of Doe Doe Village (station I), the waters of Akebay (station II), and the waters of Pasimayou Village (station III). Station I (in the waters of Doe Doe Village) is a village located in the northern part of Maitara Island. Geographically, Station I is located at coordinates 0°44'27.82" N and 127°19'36.88" E. This village is a prominent marine tourism destination due to its views directly overlooking Tidore Island and Ternate Island. Furthermore, the availability of facilities such as homestays, kiosks, and photo spots adds to the attraction for tourists. However, to the south of this village's waters, there is reclamation. Station II (in the waters of Akebay Village) is also located in the northern part of Maitara Island. Geographically, Station II is located at coordinates 0°46'51.47" N and 127°22'59.61" E, directly facing Ternate Island. This village, famous for its white sandy beaches and mangrove forests, is a popular tourist destination attracting many tourists. Station III (Pasimayou Village waters), different from the previous 2 stations, this village is located in the southern part of Maitara Island which faces Tidore Island. This village also has a mangrove and coral reef area. The geographical location of station III is at coordinates 0°43'32.03" N and 127°22'28.21" E**.**

Percentage coral reef cover

Based on the analysis results at Station I Doe Doe, hard coral (HC) dominated the benthic cover with a percentage of 67.67%, while soft coral accounted for only 0.13%, resulting in a total coral reef cover of 67.80% (Figure 4a). According to the coral cover classification stipulated by the Indonesian Ministry of Environment Decree (KEPMENLH No. 4, 2001), this level of coral cover indicates a good reef condition. Such conditions are highly supportive of the presence and persistence of the Halmahera walking shark, which relies on coral reef ecosystems as its primary habitat.

A good coral reef condition was also observed at Station II (Akebay), where hard coral (HC) remained the dominant component with a coverage of 58.73%, while soft coral accounted for 1.13%, resulting in a total coral reef cover of 59.86% (Figure 4b). This finding shows a significant difference compared to the study by Titaheluw et al. (2020) conducted in Akebay waters, which reported a coral reef cover of only 24%. The discrepancy is likely attributable to differences in coral reef sampling locations. Another possible factor is that the coral reef area surveyed in this study, particularly at sites where the Halmahera walking shark was observed, experiences minimal disturbance from land-based inputs and human activities. Local community-based restrictions on activities within the reef area at Station II have been implemented, as evidenced by the designation of this site as an ecotourism area by the local government since 2023. Frequent marine tourism activities in this area, when properly managed, appear

to be associated with increased coral cover, indicating the effectiveness of conservation efforts in the region.

In contrast, observations at Station III (Pasimayou) revealed a degraded reef condition, with the benthic substrate dominated by dead coral (DC), accounting for 51.53% of total cover (Figure 4c). Hard coral (HC) cover was relatively low at 24.20%, while soft coral (SC) contributed only 2.40%. Although this value is higher than that reported by Titaheluw et al. (2024), who recorded approximately 17% coral cover, the difference is likely attributable to variations in sampling locations, as the present study targeted reef areas associated with the occurrence of the Halmahera walking shark. The high level of coral degradation at this station is primarily linked to anthropogenic disturbances, including destructive fishing practices such as blast fishing, cyanide use, and damage from fishing vessel anchors (Titaheluw et al., 2024; Umanahu et al.,2020; Ariyanti et al., 2022). These conditions are considered unfavorable for the Halmahera walking shark, given its strong reliance on structurally complex and healthy coral reef habitats.

Life form percentage

dominant coral growth forms (life forms) at Station I (Doe Doe) were *Acropora* branching (ACB), accounting for 23.07% of total cover, followed by branching corals (CB) at 22.27%, foliose corals (CF) at 16.87%, and *Acropora* tabulate (ACT) at 2.47%. Other coral forms contributed relatively low proportions, including massive corals (CM) at 0.80%, mushroom corals (CMR) at 0.13%, encrusting corals (CE) at 0.33%, and submassive corals (CS) at 1.73% (Figure 5a). The composition of coral growth forms at Station I indicates that this area plays a significant role as a primary habitat for the Halmahera walking shark. The dominance of branching, tabulate, and foliose coral forms provides high structural complexity, which is crucial for the formation of microhabitats supporting a wide range of reef-associated organisms. Nabillah et al. (2025) reported that the Halmahera walking shark is frequently associated with branching coral growth forms, including both *Acropora* and non-*Acropora* taxa, further supporting the ecological importance of this station.

Meanwhile, coral growth forms (life forms) at Station II (Akebay) showed that *Acropora* branching (ACB) remained the dominant form, accounting for 26.00% of total cover, followed by *Acropora* tabulate (ACT) at 17.87% and submassive corals (CS) at 6.07%. Branching corals (CB) were recorded at only 0.93% (Figure 5b). however, this growth form contributes additional microhabitat crevices that are particularly important for the Halmahera walking shark. Other life forms were present in lower proportions, including encrusting corals (CE) at 4.93%, massive corals (CM) at 2.07%, foliose corals (CF) at 0.80%, and mushroom corals (CMR) at 0.07%.

Coral cover based on life-form composition at Station III (Pasimayou) indicated that branching corals (CB) were the most dominant category, accounting for 20.40% of total cover. This was followed by submassive corals (CS) at 1.80% and foliose corals (CF) at 1.33% (Figure 5c). Other life forms were present at considerably lower proportions, including Acropora branching (ACB) at 0.53%, while massive corals (CM) and mushroom corals (CMR) each contributed only 0.07%. Such a limited representation of

coral growth forms may reduce habitat carrying capacity for other marine organisms, as diverse coral morphologies are essential for providing structural complexity that supports marine biodiversity. As reported by Hendrik and Cappenberg (2017), higher structural complexity and healthier reef conditions are positively associated with increased diversity of reef-associated biota.

Morphometrics of the Halmahera Walking Shark

The total number of Halmahera Walking Sharks found at the three research sites was 5 individuals, consisting of 3 females and 2 males. The number found at the three stations showed an increase, but not significant, compared to the study by Akbar et al. (2019), where 3 individuals were found. This is due to the Halmahera Walking Shark's very low fecundity, with only two eggs laid per year (Jutan et al., 2017). The overall weight of the samples ranged from 201 to 790 grams (Table 3). According to Akbar et al. (2019), weight variations between fish samples were due to differences in body length and circumference. Males and females were found at two research sites: Station I Doe Doe and Station II Akebay, while only one female was found at Station III Pasimayou (Table 3). The highest standard length of the Halmahera Walking Shark was found at Station I Doe Doe, followed by Station II Akebay, and the lowest at Station III Pasimayou. The highest head length and body circumference were also found at Station I Doe Doe, followed by Station II Akebay, and the lowest at Station III Pasimayou (Table 3).

Tabel 3. Morphometric measurements Halmahera Walking Shark

Morphometrics	**Station I**		**Station II**		**Station I**
(cm)	**Specimen 1**	**Specimen 2**	**Specimen 3**	**Specimen 4**	**Specimen 5**
Total Length (PT)	45	71	57	55	41
Standard Length (PS)	33	58	48	47	31
Head Length (PK)	7	12	10	8	7
Body girth (cm)	13	18	17	15	11
Head Height (LK)	3	4.5	5	5	3.5
Pectoral Fin Length (SP)	4	7	5	6	3.4
Dorsal Fin Length (SD)	4	7.1	5	6	3
Anal Fin Length (SA)	5	5.5	7	6	3.6
Posterior Caudal Length (EBB)	3	14.3	4	4	3
Body weight (g)	263	790	401	450	201
Sex	Female	Male	Female	Male	Female

The head height of the Helmahera Walking Shark was higher at Station II Akebay than at the other stations, followed by Station I Doe Doe, and the lowest at Station III Pasimayou. The highest pectoral and dorsal fin lengths were found at Station I Doe Doe, the second highest at Station II Akebay, and the lowest at Station III Pasimayou. The highest anal fin length was found at Station II Akebay, followed by Station I Doe Doe, and the lowest at Station III Pasimayou. The lower tail length of the Halmahera Walking Shark at Station I Doe Doe was also higher than at other stations. The second highest value was found at Station II Akebay, and the lower tail length at Station III Pasimayou was lower compared to other stations.

Overall, the total length of the Halmahera Walking Shark found at all locations ranged from 41 to 71 cm, indicating that the samples found were considered adults (Table 3). According to Akbar et al. (2019), a total length of >40 cm may indicate that the Halmahera Walking Shark has reached adulthood, while a total length of <40 cm indicates that the individual is still in the juvenile or juvenile stage. This condition was also explained by Akbar et al. (2019) in their study, which found that the Halmahera Walking Shark found on Maitara Island was considered adult. Differences in standard length were found at each location, but the standard length of the Halmahera Walking Shark at station I Doe Doe was the highest, this has similarities with the research results which show good coral reef cover conditions at station I Doe Doe compared to other stations with a total percentage of coral reef cover at station I Doe Doe of 67.80%.

Relationship analysis

Simple linear regression analysis was used to test the effect of coral cover on the weight (grams) and total length (cm) of the Halmahera Walking Shark. The results of the regression analysis can be seen in (Figure 6), as a basis for interpreting the influence between the independent and dependent variables. The results of simple linear regression analysis between the body weight of the Halmahera walking shark (Y) and coral cover (X) produced the equation $Y = 7.6729X - 11.649$ (Figure 6a). The regression coefficient (7.6729) indicates that a 1% increase in coral cover is associated with an increase of approximately 7.67 g in body weight. The coefficient of determination ($R^2 = 0.327$) suggests that coral cover explains 32.7% of the variation in body weight, while the remaining 67.3% is influenced by other factors.

The correlation coefficient (r = 0.572) indicates a positive relationship of moderate strength between the two variables. Meanwhile, the regression analysis between total length of the Halmahera walking shark (Y) and coral cover (X) yielded the equation $Y = 0.4202X + 30.107$ (Figure 6b). The regression coefficient (0.4202) indicates that each 1% increase in coral cover corresponds to an increase of approximately 0.42 cm in total length. The coefficient of determination ($R^2 = 0.377$) shows that coral cover accounts for 37.7% of the variation in total length. The correlation coefficient (r = 0.614) indicates a positive relationship with relatively strong strength between the two variables.

Overall, the results demonstrate that coral cover exerts a positive influence on the growth of the Halmahera walking shark, both in terms of body weight and total length. Nevertheless, other factors

such as food availability, hydrodynamic conditions, and water quality are also likely to contribute to the observed variation in growth of this species.

Sediment grains

Based on the results of sediment grain analysis conducted using the sieving method, different distributions of sediment fractions were obtained at each research station (Figure 7). These results indicate variations in dominant grain size at each location, which were then classified according to the Afnor Scale (Pinot, 1992 *in* Repi, 1999). Analysis results at station I (Doe Doe Village) showed that the dominant fraction was 0.425 mm (medium sand) across all transects (0 m, 25 m, and 50 m) (Figure 7). At station II (Akebay Village), the dominant mesh size was 1.18 mm (coarse sand) at the 0 m and 25 m transects and 0.425 mm (medium sand) at the 50 m transect (Figure 7). Meanwhile, station III (Pasimayou Village) showed a dominance of 0.425 mm (medium sand) at the 0 m and 25 m transects, and 1.18 mm (coarse sand) at the 50 m transect (Figure 7).

Overall, the analysis results indicated a predominance of medium sand (0.425 mm) (Figure 7). This analysis also confirms Najamuddin & Tahir (2021) that the dominant sediment grain category composing the Maitara Island coast is medium sand. This condition is generally stable for coral reefs because coarse particle sizes (> 2 mm) typically settle to the bottom and can erode coral during high wave energy (Jones et al., 2016; Prasetyo et al.,2018). Meanwhile, fine particle sizes (< 0.063 mm) tend to remain suspended and persist in the water column for longer periods which then reduces light penetration (Torres-Pérez et al., 2021).

Water Quality

Water quality parameters were measured at each research station during the day to determine environmental conditions that could affect coral growth and the presence of the Halmahera Walking Shark. Observed parameters included temperature, salinity, clarity, pH, dissolved oxygen (DO), and depth (Table 4).

Table 4. Results of water quality parameter measurements

Station	Temperature (°C)	Salinity (‰)	Water transparency (%)	pH	Dissolved oxygen (mg L^{-1})	Depth (m)
1	27.5	28	100	7.5	11.8	3
2	31	30	100	7.28	9.4	3
3	31	30	100	7.58	9.4	3

The temperature at station I was 27.5℃, at station II 31℃, and at station III 31℃. Therefore, the temperature ranges found are within the normal range for coral growth. Nybakken (1992) stated that coral reefs can tolerate a minimum temperature of 20℃ and an optimum temperature range of 36℃-40℃. Salinity at the three research stations ranged from 28-30 ppt. This salinity is considered

good but not optimal for coral growth. According to Zurba (2019), coral can grow and develop well at a salinity range of around 34-36 ppt. According to Minister of Environment Decree No. 51 of 2004, coral reefs thrive at a salinity of 33-35 ppt. The pH range recorded at the three research sites was 7.5 at station I, 7.28 at station II, and 7.58 at station III. This range is considered ideal for supporting coral reef growth. According to Minister of Environment Decree No. 51 of 2004, the optimal pH range for coral growth is between 7 and 8.5. Dissolved oxygen values at the three stations ranged from 9.4 to 11.8 mg/L, which falls within the acceptable range according to Minister of Environment Regulation No. 51 of 2004 concerning Seawater Quality Standards. A DO level of ≥5 mg/L is stated to support the biota living in the waters.

Results of clarity measurements using a Secchi disk showed that all three study locations had 100% clarity, as the black and white pattern on the instrument was clearly visible down to the bottom. This value indicates favorable conditions for photosynthesizing zooxanthellae, which live symbiotically with coral, leading to optimal coral growth. This condition generally occurs at depths of less than 5 meters (Salim et al., 2017; Patty & Akbar.,2018; Galitan et al.,2023). Data collection at the three stations was conducted at a depth of 3 meters, which also affects the intensity of sunlight penetrating the waters, which is crucial for the photosynthesis process of algae that live in symbiosis with coral reefs. This depth is generally favorable for coral reefs due to the availability of more favorable light (Wijaya et al., (2016).

The results of water quality parameter measurements at the three stations remained within the stable range for the coral reef ecosystem of Maitara Island, which significantly impacts the survival of the Halmahera Walking Shark. Akbar et al., (2019), explain that aquatic environmental factors influence the availability of food sources and the formation of fish morphology patterns, as well as the formation of strong morphological connectivity. Research by Nabillah et al., (2025), also found the Halmahera Walking Shark in stable water quality conditions for its environment.

Conclusion

The habitat characteristics of the Halmahera walking shark around Maitara Island indicate that Stations I and II represent suitable and well-functioning habitats, characterized by high live coral cover (59–68%), dominance of branching coral forms (*Acropora* and non-*Acropora*), and medium sand substrates (0.425 mm). Coral reef condition was positively associated with the morphometric traits of the Halmahera walking shark, with larger individuals consistently recorded in areas with healthier coral cover. Regression analyses further confirmed a positive relationship between coral cover and both body weight and total length, underscoring the critical role of intact coral reef ecosystems in supporting the growth and persistence of this endemic and conservation-priority species. Water quality parameters were within optimal ranges, supporting coral reef integrity and the availability of structurally complex microhabitats essential for this species. In contrast, Station III exhibited degraded conditions, with a high proportion of dead coral, rendering it less suitable as habitat. These findings highlight the importance of maintaining

coral reef health through effective local management and conservation strategies to ensure the long-term sustainability of Halmahera walking shark populations.

Declarations

Author Contribution

Nebuchadnezzar Akbar and Yunan Gilang Restu was the activity conceptor, Halmahera Walking Shark data collection, data analysis, writing, and discussing the article.Furqan N, Sudibyo Yudoatmojo, Siti Fadilah Sofyan, and Restu Fajar Hai assisted with research equipment and sampling of the Halmahera Walking Shark, coral and environmental data collection.Firdaut Ismail, Dondy Arafat, and Beginer Subhan assisted with article writing and coral data analysis.Irmalita Tahir, Rustam Paembonan, Ikbal Marus, Zulhan A Harahap, and Najamuddin provided reviews, references, graphic displays, and location map creation.Riyadi Subur, Dietriech G Bengen, I Wayan Nurjaya, and Nyoman MN Natih provided an overview of the results, in-depth discussion, and final proofreading before submission.

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Figures

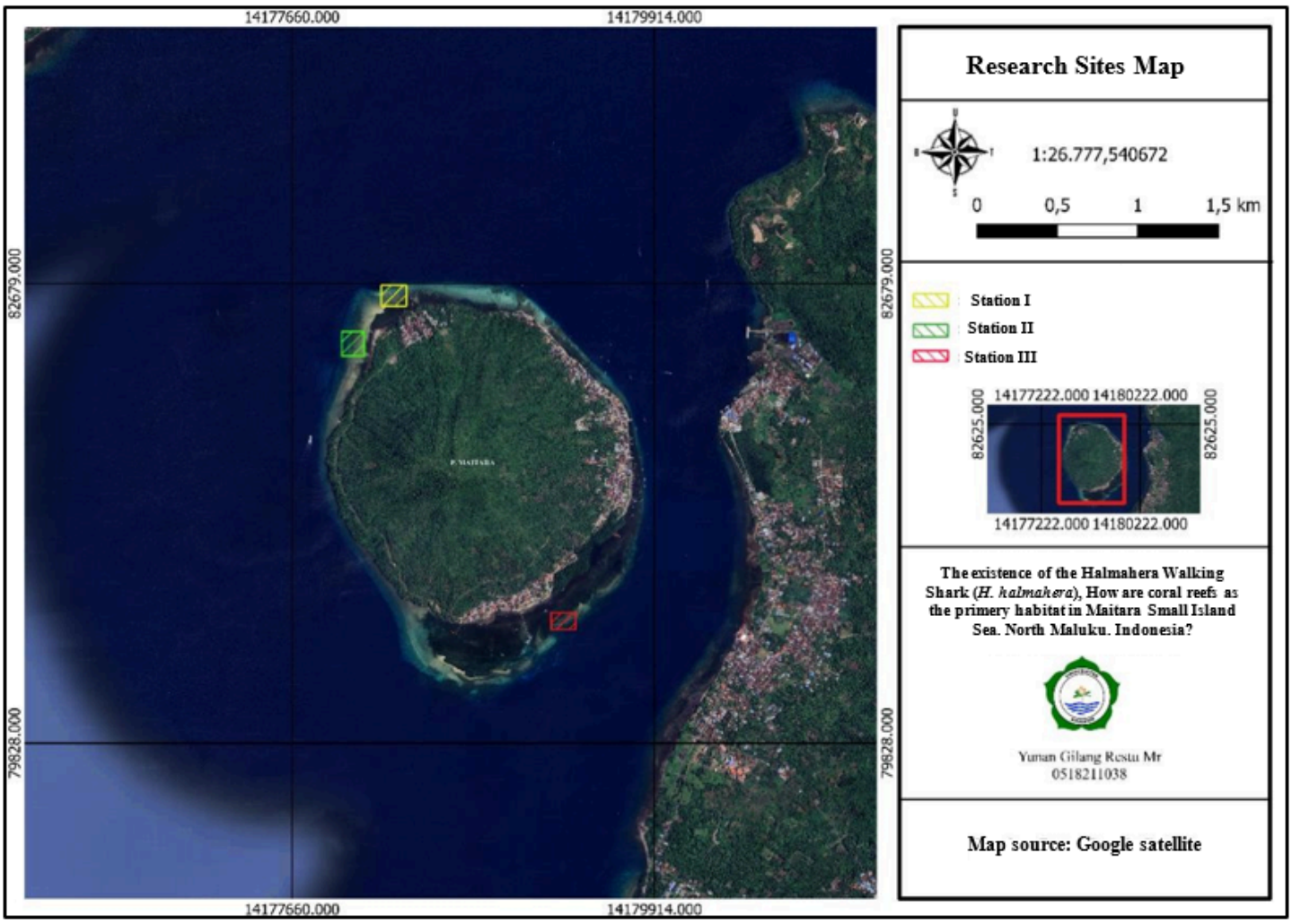


Figure 1

Research site map coral reef and Halmahera Walking Shark sampling in Maitara Island Sea. North Maluku. Indonesia

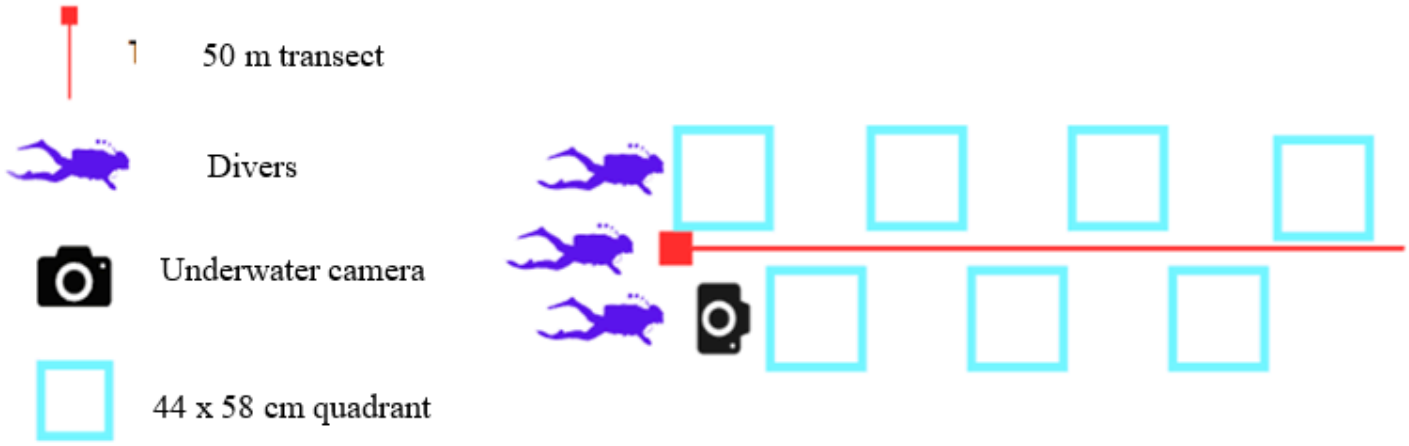


Figure 2

illustration of coral reef data collection

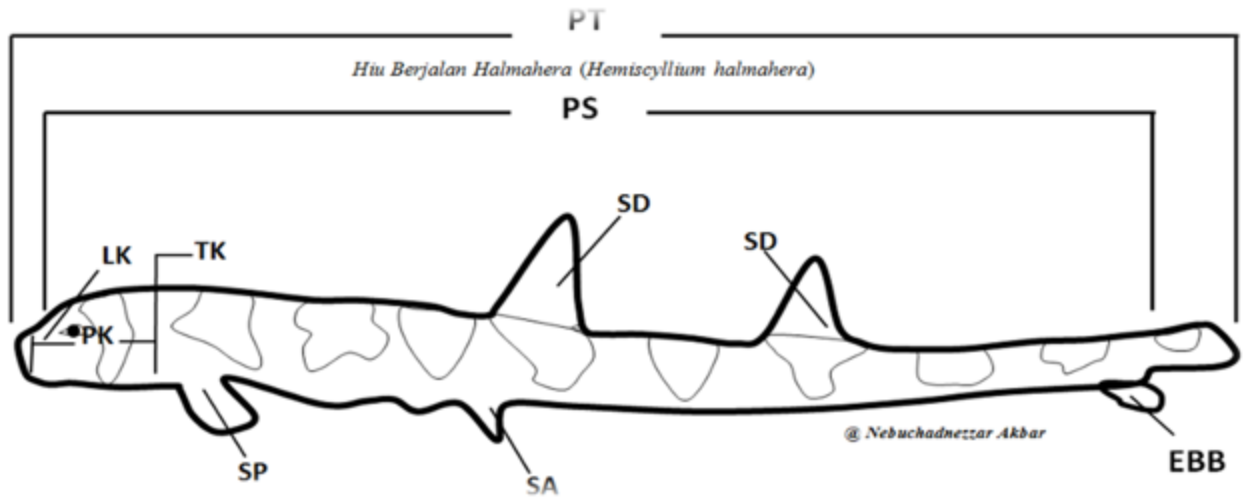


Figure 3

Morphometric measurements of the Halmahera Walking Shark (*Hemiscyllium halmahera*) (source: Akbar et al., 2019).

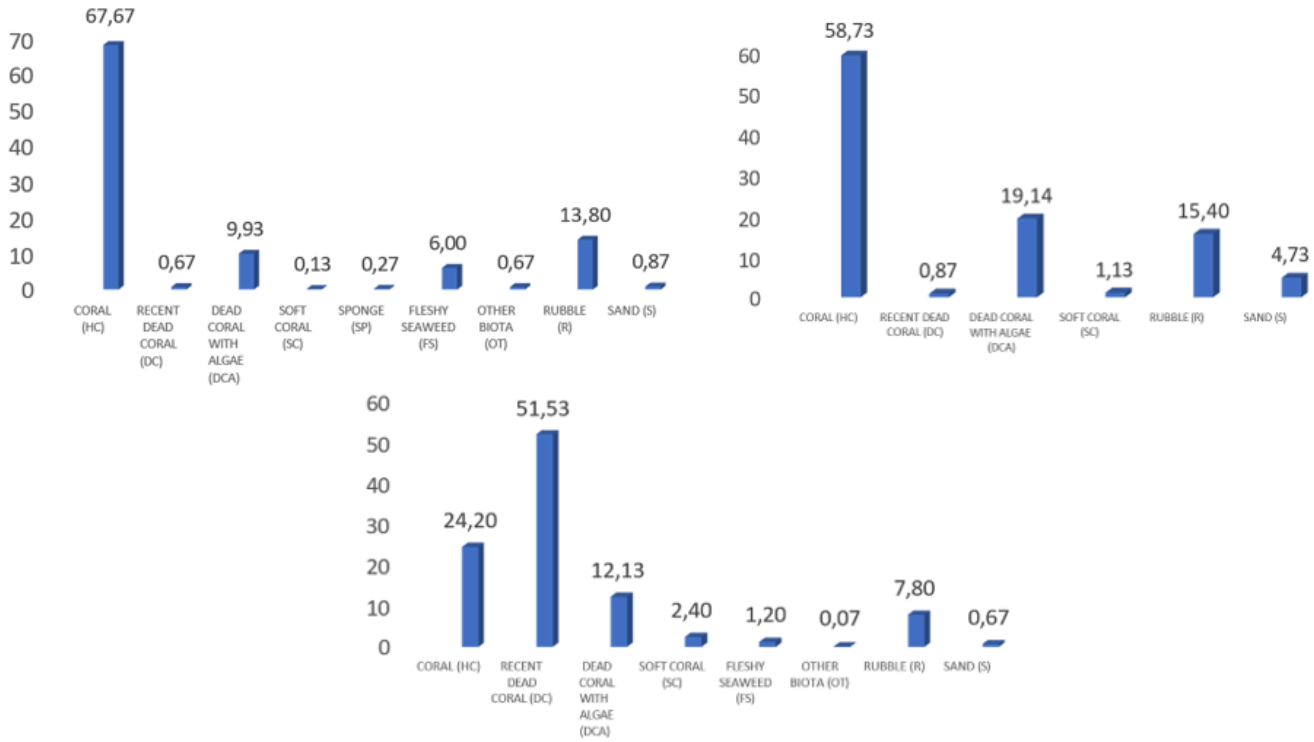


Figure 4

Coral reef cover. a). Station I, b). Station II and c). Station III

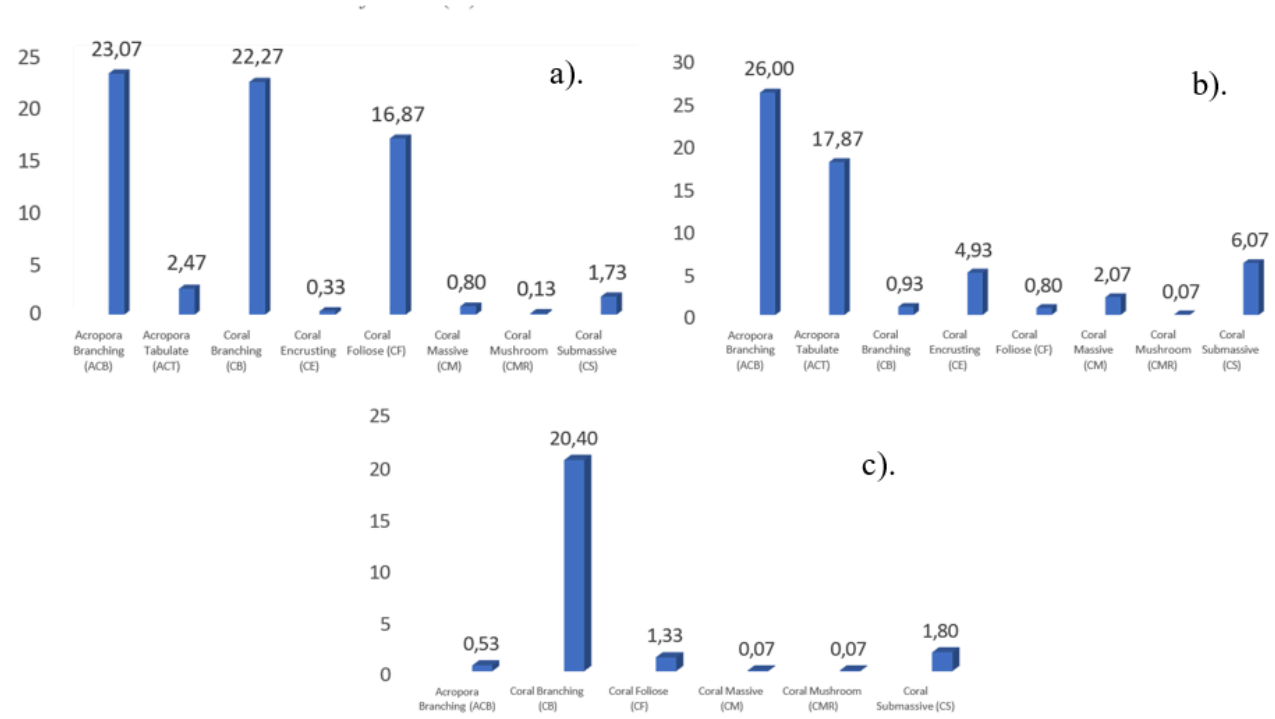


Figure 5

Life form. a). Station I, b). Station II and c). Station III

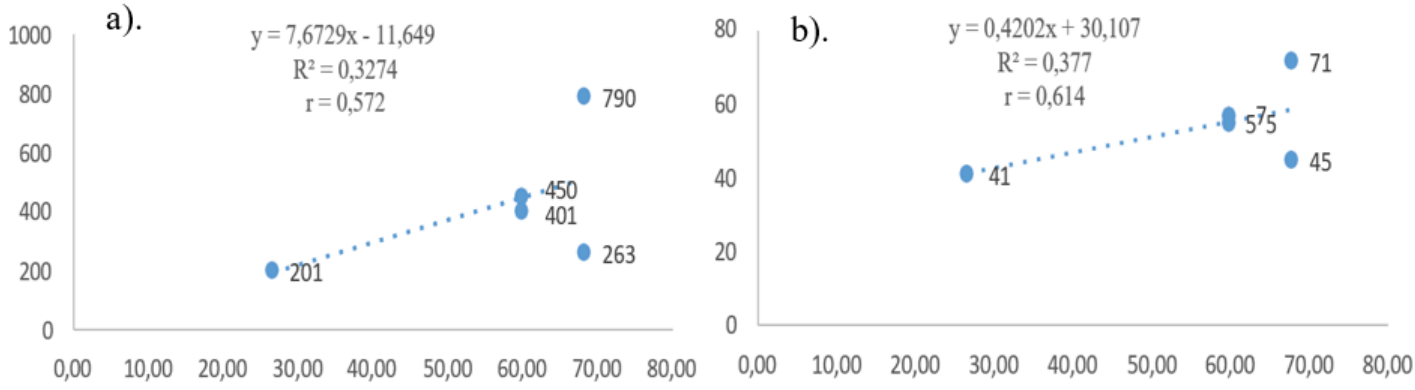


Figure 6

Relationship analysis. a). Weight and coral reefs and b). Total length and coral reefs

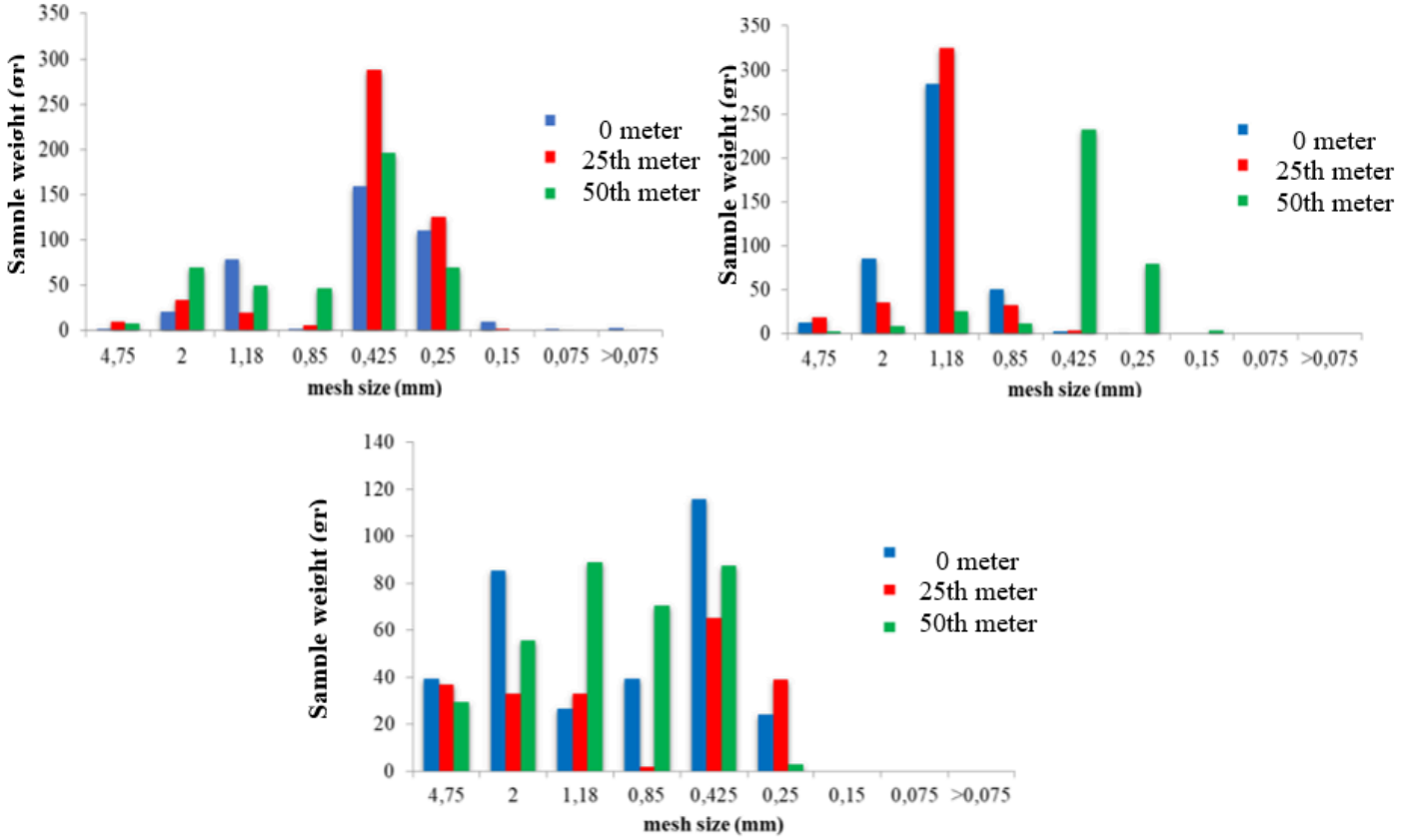


Figure 7

Sediment grain size weight