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Species density and morphometric variation of species belonging to *Conus* (Gastropoda: Conidae) genera in the coastal waters of Ambon Island, Indonesia

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Abstract. *Tebiary LA, Leiwakabessy F, Rumahlatu D. 2022. Species density and morphometric variation of species belonging to* Conus *(Gastropoda: Conidae) genera in the coastal waters of Ambon Island, Indonesia. Biodiversitas 23: 1664-1676.* Genus *Conus* Linnaeus, 1758 belongs to the class Gastropods, order Neogastropoda, family Conidae, and its presence in marine ecosystem is influenced by multiple environmental factors. Therefore, this study aims to determine the density and morphometric variations of *Conus* species in the coastal waters of Ambon Island, Indonesia. This study was carried out from March-April 2021 using the purposive sampling method. The environmental parameters: temperature, salinity, pH, and DO of seawater were measured in-situ, the *Conus* species were identified at the Central Marine Research Laboratory, the Indonesian Institute of Sciences (LIPI) Ambon, Indonesia while the density data and morphometric variation were determined quantitatively. The results of environmental physico-chemical parameters showed varying values; temperatures ranged from 25.00-29.50ºC, salinity 34.00-35.00‰, pH 6.00-7.53, and dissolved oxygen (DO) 4.00-8.00 mg/L. Meanwhile, 7 *Conus* species was recorded with the density ranging from *C. ebraeus* with 0.16-0.18 ind/m^2, *C. rattus*, *C. sponsalis*, and *C. lividus* ranging from 0.13-0.11 ind/m^2, *C. monachus*, *C. muriculatus*, and *C. coronatus* ranging from 0.10 ind/m^2. The results of morphometric measurements including shell length (SL), width (SW), thickness (ST), spire height (SH), shell aperture length (SAL), and aperture width (SAW) showed varying values, while the regression analysis results showed that there was a varied relationship between environmental physicochemical parameters and morphometric variations in *Conus* species. Furthermore, the physico-chemical parameters such as temperature and DO provided the most effective contribution to all morphometric variables.

Keywords: *Conus*, density, environmental factor, morphometric variation

INTRODUCTION

Ambon is a small island in the Maluku Province, Indonesia with a land area of 359.45 km^2 and an ocean area of 17.55 km^2 with a coastline length of 98 km (Pemkot Ambon 2020). Geologically, it is formed in a complex manner with high tidal wave dynamics (Salamena et al. 2021) and a relatively high diversity of marine life (Limmon et al. 2020) including mangroves, seagrasses, coral reefs, crabs, fishes, and mollusks (Suyadi et al. 2021). Furthermore, several previous studies reported high diversity of fishes (Limmon et al. 2018; Loupatty et al. 2021), phytoplankton (Pello et al. 2014), zooplankton (Mulyadi and Radjab 2015; Latumeten et al. 2021; Huliselan et al. 2021), crustaceans, cirripedia (Pitriana et al. 2020; Irwansyah et al. 2021), echinoderms (Setyastuti et al. 2018), and gastropods (Rumahlatu and Leiwakabessy 2017; Yonow and Jensen 2018; Latupeirissa et al. 2020; Wiraatmaja et al. 2022).

Genus *Conus* Linnaeus, 1758 is found in the tropical and subtropical seas of the world, at depths ranging from the sublittoral to 1,000 m with an estimated number of 500 species (Muttenthaler et al. 2012). Khon (1959) reported that *Conus* species is widespread in Hawaii with up to 25 species. Furthermore, 61 species are found in the Tamil Nadu Beach, India (Franklin et al. 2009), 54 in Colombia (Díaz et al. 2005), 138 in the Indo-Pacific, eastern Pacific and Atlantic Ocean regions (Duda and Kohn 2005), 14 in the Gulf of Aqaba, Northern Red Sea (Zauner 2015), 47 in Lakshadweep-India (Ravinesh et al. 2018), and 30 in Bismarck Archipelago of New Ireland Province, Papua New Guinea (Muttenthaler et al. 2012). *Conus* species are also found in various coastal waters in Indonesia and till now 5 species have been reported (Febiansi et al. 2018). Seven *Conus* species (*C. ariejoostei*, *C. auricomus*, *C. bandanus*, *C. harmoniconus*, *C. judaeus*, *C. nusatella*, and *C. terebra*) were found in Aceh Besar (Nurhasballah et al. 2019). 11 *Conus* species (*C. arenatus*, *C. coronatus*, *C. ebraeus*, *C. imperialis*, *C. lividus*, *C. marmoreus*, *C. quercinus*, *C. rattus*, *C. sponsalis*, *C. varius*, and *C. virgo*) were found in Bali (Sudewi et al. 2019). Latuconsina and Buano (2021) reported 5 *Conus* species from Gorom Island, East Seram, Maluku namely *C. magus*, *C. leopardus*, *C. marmoreus*, *C. miles*, and *C. virgo*. Rumahlatu and Leiwakabessy (2017) reported 4 *Conus* species from Ambon Island namely *C. ebraeus*, *Dauciconus jorioi*, *Tenorioconus mappa*, and *C. leporiconus*. Specifically, *C. ebraeus* was found in the mangrove area of the Suli Beach of Ambon Island (Kho et al. 2020).

Meanwhile, the presence of *Conus* species in coastal waters is influenced by various environmental factors such as the substrate condition at the bottom of the water (Nybakken and Bertness 2005; Imamsyah et al. 2020; Kho et al. 2020). Muddy conditions are optimal habitats for gastropods, while sandy are rarely occupied (Peters et al. 2013; Rahmasari et al. 2015; Susintowati et al. 2019) which may be due to the abundant organic matter content in the muddy substrate (Pancawati et al. 2014). Budi et al. (2013) reported that the abundance of gastropods was found in muddy areas immersed under the substrate. Furthermore, Peters et al. (2013) stated that the increase in sea surface temperature poses a threat to the existence of *Conus* species. Temperature can also affect metabolic processes, and the reproduction and breeding process of gastropods (Bancin et al. 2020; Kho et al. 2020). When the sea temperatures continue to increase, it can elevate the risk of extinction of *Conus* species as well as affect the dissolved oxygen (DO) content in seawater. Furthermore, the low salinity affects the decreased respiration rate as indicated by the number of gastropods hiding in the shell when the salinity is low (Islami 2015), which might have potential impacts on the morphometric and meristic diversity of gastropods.

The coastal waters of Ambon Island have a high diversity of gastropods, but they are under serious threat due to increased human activities, such as waste disposal that ends up in the sea, tourism infrastructure development, and environmental changes. This certainly affects the presence of *Conus* in the coastal waters, therefore, a study on species density and morphometric variation is needed as the first step to determine species and genetic information, namely morphologically visible traits. Furthermore, information on morphometric variations can indicate of the state of *Conus* and the coastal environment of Ambon Island. This study aims to determine the species of *Conus*, the density, and morphometric variations in the coastal waters of Ambon Island, Indonesia.

MATERIALS AND METHODS

Study sites

This study was conducted from March-April 2021 in the coastal waters of the Ambon Island, Indonesia: Station 1 - Latuhalat Beach (-3047'38”S, 128005'42”E), Station 2 - Hatiwe Besar Beach (-3067'97”S, 128013'99”E), Station 3 - Suli Beach (-3037'56”S, 128018'30”E) (Figure 1). The data collection stations were determined by purposive sampling based on the habitat of *Conus* species (Gastropoda: Conidae) on coral, rocky, and muddy substrates (Rumahlatu and Leiwakabessy 2017; Kho et al. 2020).

Sampling and laboratory procedures

Data collection in the coastal waters of the Ambon Island was done using Global Positioning System (GPS), to determine the position of transects and plots of samples at the study site. Data collection followed the following procedure; (1) Sampling of *Conus* species was done at the lowe tide line using the plotted transect method. At each station, 5 transects were made vertically from the high tide line towards the sea with an interval of 50 m between each transect. Then, 10 plots were made on each transect with a size of 1 × 1 m^2 at a distance of 10 m apart from one plot to another. Hence, the number of transects at the three stations was 15 with a total of 150 plots in the study area. (2) Measurement of environmental physicochemical parameters such as temperature, salinity, pH, and DO, performed in-situ on 10 plots at each station. (3) *Conus* samples were taken from each plot, placed into a plastic ethylene bag and labeled based on transect, station and substrate types, then placed into an icebox, and brought to the laboratory for identification and morphometric measurements of the *Conus*. Furthermore, sample identification and species descriptions used Dharma (1989), Leiwakabessy (1999), and WoRMS (2020).

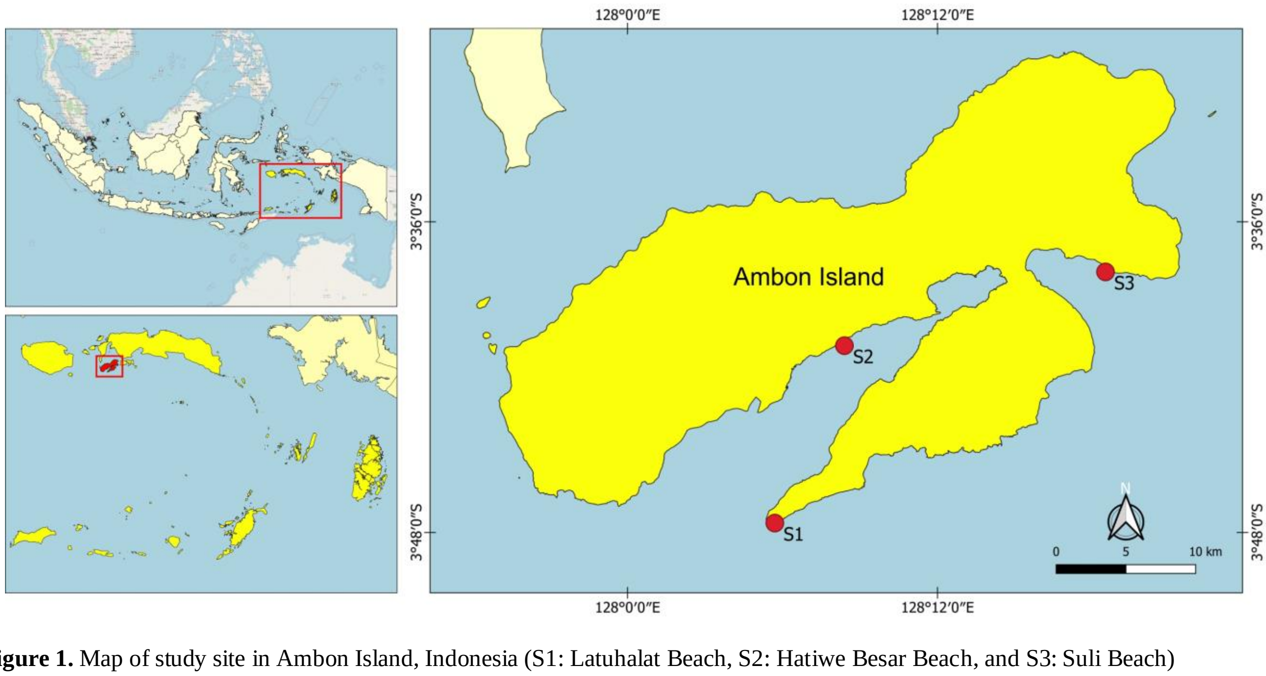

Figure 1. Map of study site in Ambon Island, Indonesia (S1: Latuhalat Beach, S2: Hatiwe Besar Beach, and S3: Suli Beach)

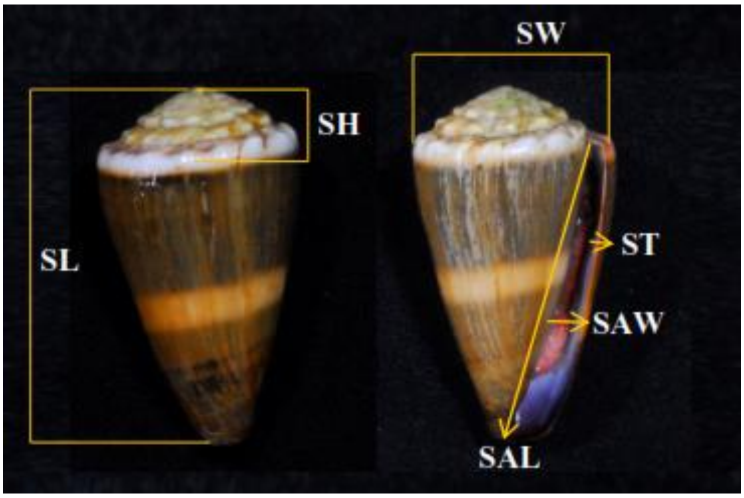

Figure 2. Morphometric measurements of *Conus* (Gastropods: Conidae)

The morphometric measurements were carried out at the Central Marine Research Laboratory, the Indonesian Institute of Sciences (LIPI) Ambon. Shell morphometric variations were measured such as shell length (SL), width (SW), thickness (ST), spire height (SH), aperture length (SAL), and aperture width (SAW). The measurement of morphometric variation of *Conus* species is described as follows: (1) SL were measured from the apex to the umbilicus of the *Conus*. (2) SW was measured from the outer body to the lip. (3) ST was measured from the lip of the shell. (4) SH was measured from the tip of the apex to the lowest circle namely spiral line. (5) SAL were measured from the posterior to the siphonal/anterior canal. (6) SAW was measured from the outer shell body to the lip (Figure 2).

Data analysis

Data on environmental parameters, species density, and morphometric measurements of *Conus* (Gastropods: Conidae) for shell length (SL), width (SW), thickness (ST), spire height (SH), shell aperture length (SAL), and aperture width (SAW) were analyzed using descriptive statistics. Conus species density data were obtained from calculations using the formula from Odum (1993), as follows.

$$\text{Absolute density (ind/m}^2) = \frac{\text{The number of individuals of each species}}{\text{The number of individuals of all species}}$$

$$\text{Relative density (\%)} = \frac{\text{The number of individuals of each species}}{\text{The number of individuals of all species}} \; x\ 100$$

Multiple linear regression inferential statistics were used to analyze the relationship between environmental physicochemical parameters and morphometric variations of *Conus* in the coastal of Ambon Island. Furthermore, it was continued with the calculation of the effective contribution from each independent variable of environmental physicochemical parameters to the dependent variable of morphometric variation with the formula as follows.

Relative contribution analysis (RC%)

$$\text{Predictor } X_1 : RC\% = \frac{a_1 \sum X_1 y}{a_1 \sum X_1 y + a_2 \sum X_2 y + a_3 \sum X_3} X100\%$$

$$\text{Predictor } X_2 : RC\% = \frac{a_2 \sum X_2 y}{a_1 \sum X_1 y + a_2 \sum X_2 y + a_3 \sum X_3} X100\%$$

$$\text{Predictor } X_3 : RC\% = \frac{a_3 \sum X_3 y}{a_1 \sum X_1 y + a_2 \sum X_2 y + a_3 \sum X_3} X100\%$$

Analysis of the effective contribution (EC) of each predictor

$EC\%X_n = RC\%X_n \text{ x } R^2$ (Hadi 2004)

$$R^2 = \frac{SSregresi}{SStotal}$$ (Hasan 2002)

Where: EC: Effective contribution, X_n: n^{th} independent variable, RC: Relative contribution, R^2: Coefficient of determination, SS Regression: Sum of squares of regression, SS Total: Sum of total squares

RESULTS AND DISCUSSION

Environmental physicochemical parameters

The results of environmental parameters (Table 1) shows that the seawater temperature of the Ambon island ranged from 25.00-29.50^{o}C, with the highest on Latuhalat Beach (29.50^{o}C) and the lowest on Hatiwe Besar and Suli beaches (25.00^{o}C). The salinity ranged from 34.00-35.00‰, with the highest found on the Suli and Latuhalat beaches (35.00‰), while the lowest was on the Hatiwe Besar beach (34.00‰). Furthermore, the pH ranged from 6.00-7.53, with the highest to the lowest pH respectively, Latuhalat Beach (7.53), Suli Beach (7.50), and Hatiwe Besar Beach (6.00). DO concentration ranged from 4.00-8.00 mg/L, with the highest to the lowest level found in

Latuhalat Beach (8.00 mg/L), Hatiwe Besar Beach (6.00 mg/L), and Suli Beach (4.00 mg/L). Several previous studies reported that environmental physicochemical conditions play an important role in the growth and survival of gastropod populations (Susiana 2011; Bharda et al. 2020). The environment parameters in the study site were influenced by the seasonal changes, upwelling, and the flow of water currents (Pennington and Chaves 2000). Furthermore, the decrease in temperature and salinity affects the high DO-binding capacity thereby influencing the diversity of intertidal gastropod species (Vandarwala et al. 2020). Moulin et al. (2011) and Paganini et al. (2014) explained that human activities tend to reduce the pH value of seawater as well as the physiological performance of various types of organisms. Anthropogenic activities also reduce the level of DO required by gastropods to breathe, perform metabolism, as well as the process of oxidation and reduction of organic and inorganic materials (Salmin 2005; Aininnur et al. 2015). The present results indicated that the environmental physicochemical parameters are still appropriate to sustain *Conus*-type gastropods.

Identification of *Conus* species

In the present study, 7 *Conus* species (Gastropoda: Conidae) were recorded from Ambon Island (Figure 3); *C. lividus* (34 individuals), *C. monachus* (30 individuals), *C. rattus* (33 individuals), *C. muriculatus* (30 individuals), *C. spongeiali*s (34 individuals), *C. ebraeus* (51 individuals), and *C. coronatus* (48 individuals). Previously, the existence of *Conus* species in Indonesia has also been reported by several researchers. Febiansi et al. (2018) found *C. coronatus*, *C. ebraeus*, *C. capitaneus*, *C. betulinus*, *C. fergusoni* at Krakal Beach, Gunungkidul, Yogyakarta. Rumahlatu and Leiwakabessy (2017) in a study on the coastal waters of the Ambon Island found four species of *Conus* namely *C. ebraeus*, *D. jorioi*, *T. mappa*, and *C. leporiconus*. Specifically, *C. ebraeus* was found in the mangrove area of the Suli Beach of Ambon Island (Kho et al. 2020). In addition, *C. ebraeus* and *C. muriculatus* were found in the coastal waters of Marsegu Island, West Seram Regency, Maluku, Indonesia (Bula et al. 2017). Several previous studies have reported the presence of *Conus* in other parts of the world such Kohn (1990) found that *Conus* lives in tropical and subtropical coastal waters worldwide with more than 630 species, while Olivera et al. (2013) showed that there are 500-700 species scattered throughout the world's waters. This is confirmed by data from the International Union for Conservation of Nature (IUCN) which shows that 632 species of *Conus* are endemic to the East Atlantic and Cape Verde (IUCN 2013; Tenorio 2012). Furthermore, in tropical and subtropical seas such as the South China Sea, Australia, and the Pacific Ocean, nearly 700 species have been found (Peters et al. 2016). In Indonesia, more than 20 species have also been observed living in association with coral reefs, and a maximum number of 27 species (Kohn and Nybakken 1975; Kohn 1990). A recent study reported that more than 900 species of *Conus* spread across the intertidal zone to the deep sea (Tenorio et al. 2020; WoRMS 2020).

Density of *Conus* species

The density of *Conus* species (Table 2) showed significant differences between the stations. *C. ebraeus* was found on the Latuhalat and Suli beaches with the highest density values of 0.18 ind/m^2 and 0.16 ind/m^2. Zauner and Zuschin (2016) reported that habitats with various coral reefs and algae are very good for the growth of *C. flavidus* because they provide stable environment and enough prey to feed. In the present study also it was noticed that the stations (Latuhalat and Suli areas) with high coral reefs, and macroalgal density provided favorable conditions for growth of *Conus* species. Mardatila et al. (2016), Romdhani et al. (2016), and Sandewi et al. (2019) stated that environmental factors, availability of food sources, and the level of tolerance of gastropods could affect their density in waters. Based on the calculation results, *C. monachus, C. muriculatus,* and *C. coronatus* was found to have the lowest density (0.10 ind/m^2) in Hatiwe Besar and Suli Beach. This results were similar to Kohn (1959) and Budi et al. (2013), who also reported that the density of *Conus* in sandy areas is usually lower. However, in the Suli area, there was a decrease in the species density due to differences in the number of the algae layer and the sandy areas. Ira et al. (2015) and Sandewi et al. (2019) reported that rocky substrates provide optimal shelter for gastropods to escape currents by attaching themselves to rock basins.

Table 1. Results of physicochemical parameters

	Station	Environmental physicochemical parameters			
		Temperature (°C)	Salinity (‰)	pH	DO (mg/L)
1	Latuhalat Beach	29.50 ± 0.00	35.00 ± 0.00	7.53 ± 0.00	8.00 ± 0.00
2	Hatiwe Besar Beach	25.00 ± 0.00	34.00 ± 0.00	6.00 ± 0.00	6.00 ± 0.00
3	Suli Beach	25.00 ± 0.00	35.00 ± 0.00	7.50 ± 0.00	4.00 ± 000

Figure 3. Various *Conus* species recorded from the coastal waters of Ambon Island, Indonesia

Table 2. The density of *Conus* species from the coastal waters of Ambon Island, Indonesia

	Station	Species	Number of individuals	Absolute density (ind/m²)	Relative density (%)
1	Latulalat Beach	*Conus sponsalis* Hwass, 1792	34	0.12	0.40
		Conus ebraeus Linnaeus, 1758	51	0.18	0.60
2	Hatiwe Besar Beach	*Conus lividus* Hwasss, 1792	34	0.13	0.26
		Conus monachus Linnaeus, 1758	30	0.10	0.23
		Conus rattus Hwass, 1792	33	0.11	0.25
		Conus muriculatus Sowebry, 1833	31	0.10	0.23
3	Suli Beach	*Conus coronatus* Gmelin, 1791	32	0.10	0.40
		Conus ebraeus Linnaeus, 1758	48	0.16	0.60

Table 3. The morphometric measurements results of *Conus* (Gastropod: Conidae)

Morphometric (mm)		Station							
		Hatiwe Besar				Latuhalat		Suli	
		C. lividus	*C. monachus*	*C. rattus*	*C. muriculatus*	*C. sponsalis*	*C. ebraeus*	*C. coronatus*	*C. ebraeus*
SL	Mean±SD	21.54±1.90	22.18±2.99	21.45±1.55	24.64±11.44	20.52±2.34	21.02±1.99	20.26±2.54	20.15±3.02
	Range	18.74-27.34	19.42-31.44	19.42-25.27	17.82-72.66	16.37-25.34	17.82-25.49	11.49-25.34	15.35-25.49
	n	28	29	55	29	30	30	30	30
SW	Mean±SD	13.01±1.91	12.74±1.87	12.56±1.68	14.77±5.94	12.70±1.78	13.34±1.61	12.45±1.84	12.61±2.08
	Range	6.91-16.5	6.91-16.5	6.91-15.18	10.34-39.54	10.34-16.55	10.9-16.67	7.48-16.5	9.26-16.67
	n	28	28	30	29	30	30	30	30
ST	Mean±SD	0.81±0.21	0.73±0.29	12.56±1.67	0.81±0.27	0.90±0.22	0.80±0.22	0.71±0.24	1.14±2.27
	Range	0.33-1.14	0.32-1.15	6.91-15.18	0.32-1.54	0.44-1.20	0.32-1.15	0.32-1.09	0.35-13.13
	n	28	29	30	29	30	30	30	30
SH	Mean±SD	4.42±1.00	4.32±1.10	4.60±1.11	5.18±1.80	4.89±0.92	4.71±17.41	4.96±0.99	4.61±1.17
	Range	2.97-6.88	2.97-6.98	2.97-6.44	3.31-11.89	2.83-6.88	2.34-7.27	2.68-6.88	2.81-7.28
	n	28	29	30	29	30	30	30	30
SAL	Mean±SD	16.91±2.61	17.82±2.90	16.95±1.80	19.10±10.45	16.54±2.43	16.03±2.48	16.00±2.51	16.31±2.68
	Range	9.44-20.89	14.56-25.64	14.56-20.89	9.44-62.12	12.45-20.78	9.44-20.56	9.72-20.78	11.87-20.56
	n	29	29	30	29	30	30	30	30
SAW	Mean±SD	2.19±0.33	2.21±0.46	2.15±0.40	2.68±1.04	2.88±3.56	2.05±0.43	1.94±0.38	1.91±0.47
	Range	1.33-2.95	1.33-2.32	1.33-2.87	1.87-6.63	1.19-17.6	1.12-3.00	0.88-2.87	1.11-2.87
	n	28	29	24	30	30	30	30	30

The absolute density of *Conus* species such as *C. rattus*, *C. sponsalis*, and *C. lividus* (Table 2) varied from 0.11-0.13 ind/m^2. Variations in species density between habitats are influenced by different physical and chemical environmental conditions (Raghunathan et al. 2003; Zauner and Zuschin 2016; Dave and Chudasama 2018). Fadli et al. (2012) stated that strong currents affect the density of gastropods in a habitat. Previous studies also concluded that the highest gastropod density is found in an environment with clean water conditions and a temperature ranging from 28-30ºC (Bae and Park 2020; Bhuyain et al. 2020). In contrast, low temperature affects the osmotic pressure which causes intracellular damage to gastropods concerning digestion, respiration, and excretion (Matsukura et al. 2009; Zhang et al. 2016), while the low DO value causes gastropods to experience hypoxia due to the lack of oxygen (Weisberg et al. 2008; Ekau et al. 2010).

Morphometric variations of *Conus* species

The *Conus* morphometric measurement results at the three stations showed variations in shell length (SL), width (SW), thickness (ST), spire height (SH), shell aperture length (SAL), and width (SAW) (Table 3).

Shell length-SL

The results at the three stations showed varying shell length for each species. The range measurement from the highest and the lowest was *C. muriculatus* (24.64 ± 11.64 mm), *C. monachus* (22.18 ± 2.99 mm), *C. lividus* (21.54 ± 1.90 mm), *C. rattus* (21.45 ± 1.55 mm), *C. ebraeus* (21.02 ± 1.99 mm), *C. sponsalis* (20.52 ± 2.34 mm), *C. coronatus* (20.26 ± 2.54 mm), and *C. ebraeus* (20.15 ± 3.02 mm). The high and low dimensions of shell length are influenced by the condition of the substrate in the waters (Nybakken 1992). Furthermore, the rocky substrate in the coastal waters of the three stations is the habitat of the Conidae family. In addition, Peters et al. (2013) found that water conditions with high levels of pollution can also affect the reduction of shell size in several *Conus* species such as *C. echinophilus*, *C. hybridus*, *C. mercator*, and *C. unifasciatus*. Environmental factors such as the movement of water currents are known to reduce the body size of *Conus* in sandy habitats due to the absence of protected areas (Zauner and Zuschin 2016). Moreover, the size and shape of *Conus* body in the intertidal zone are affected by temperature, tides, and waves (Levinton 2001).

Shell width-SW

The results at the three stations showed varying shell widths for each species. The range measurement from the highest and the lowest was *C. muriculatus* (14.77 ± 5.94 mm), *C. ebraeus* (13.34 ± 1.61 mm), *C. lividus* (13.01 ± 1.91 mm), *C. monachus* (12.74 ± 1.87 mm), *C. sponsalis* (12.70 ± 1.78 mm), *C. ebraeus* (12.61 ± 2.08 mm), *C. rattus* (12.56 ± 1.68 mm), and *C. coronatus* (12.45 ± 1.84 mm). The high and low dimensions of the shell width are influenced by the substrate conditions of waters (Nybakken 1992). Furthermore, the rocky substrate type at the three stations strongly supports the presence of gastropod organisms in the Conidae family in terms of growth.

Changes in shell width are associated with increased tolerance levels toward high and low temperatures, as well as environmental stress (Márquez et al. 2015). Matos et al. (2020) stated that the pattern of changes in shell width can be influenced by different substrates. Other factors at play include temperature (Chapperon et al. 2013; Seuront et al. 2018), food availability (Apolinário et al. 1999), and density (De Magalhães 1998). Moreover, previous studies found that disturbing shade causes the gastropod body size to decrease (Bulleri and Chapman 2010; Pardal-Souza et al. 2017), while gender differences also contribute as the female has a larger shell width than the male (Márquez et al. 2015).

Shell thickness-ST

The results at the three stations showed varying shell thickness for each species. The range measurement from the highest and the lowest was *C. rattus* (12.56 ± 1.67 mm), *C. ebraeus* (1.14 ± 22.7 mm), *C. sponsalis* (0.90 ± 0.22 mm), *C. muriculatus* (0.81 ± 0.27 mm), *C. lividus* (0.81 ± 0.21 mm), *C. ebraeus* (0.80 ± 0.22 mm), *C. monachus* (0.73 ± 0.29 mm), and *C. coronatus* (0.71 ± 0.24 mm). The dimensions of the shell width are influenced by the substrate conditions of waters (Nybakken 1992). Furthermore, the rocky substrate type at the three stations strongly supports the presence of gastropod organisms in the Conidae family in terms of growth. Changes in shell thickness dimensions in *Conus* species in the subtidal zone are caused by adaptation due to the presence of predators (Obaza and Ruehl 2013; Márquez et al. 2015). Moreover, the formation of shell thickness is related to the response of gastropods to environmental factors. The main factor influencing the formation of thick-walled shells is temperature fluctuations such as the water temperature gradient from cold to warm can be a trigger mechanism for thickening of the shell. In contrast, current and wave factors are known to have no significant effect on increasing shell thickness (Bondarev 2013). Other influencing factors are the availability of food and carbonate ($CaCO_3$) (Watson et al. 2012). However, there is no direct relationship between salinity, calcium carbonate content, and shell thickness (Bondarev 2013).

Spire height-SH

The results at the three stations showed varying spire height for each species. The range measurement from the highest and the lowest was *C. muriculatus* (5.18 ± 1.80 mm), *C. coronatus* (4.96 ± 0.99 mm), *C. sponsalis* (4.89 ± 0.92 mm), *C. ebraeus* (4.71 ± 17.41 mm), *C. ebraeus* (4.61 ± 1.17 mm), *C. rattus* (4.60 ± 1.11 mm), *C. lividus* (4.42 ± 1.00 mm), and *C. monachus* (4.32 ± 1.10 mm). The dimension size of the spire height is influenced by the condition of the substrate in the waters (Nybakken 1992). Furthermore, the rocky substrate at the three stations strongly supports the presence of gastropod organisms in the Conidae family in terms of growth. Olabarria and Thurston (2004) stated that the shape of the shell and the height of the spire are influenced by the depth of the water. The deeper the water, the slimmer the shell shape, and the higher the spire compared to shallow water. These changes are associated with various factors such as habitat type, physicochemical disturbances, hydrodynamics, competition, and predators (Vermeij 1978). The availability of calcium carbonate in the environment also affects the increase in spire height of gastropod shells (Olabarria and Thurston 2004). This is also supported by Chiu et al. (2002) which stated that calcium is an important environmental factor for shell spiral growth. Shorter spiral sections can cause growth constraints due to the low calcium and acidic environment. The height of the spire is also related to the gastropod's ability to carry and balance the shell (Okajima and Chiba 2013).

Shell aperture length-SAL

The results at the three stations showed varying shell aperture length for each species. The range measurement from the highest and the lowest was *C. muriculatus* (19.10 ± 10.45 mm), *C. monachus* (17.82 ± 2.90 mm), *C. rattus* (16.95 ± 1.80 mm), *C. lividus* (16.91 ± 2.61 mm), *C. sponsalis* (16.54 ± 2.43 mm), *C. ebraeus* (16.31 ± 2.68 mm), *C. ebraeus* (16.03 ± 2.48 mm), and *C. coronatus* (16.00 ± 2.51 mm). The dimensions size of the aperture length is influenced by the condition of the substrate in the waters (Nybakken 1992) and the rocky substrate type at the three stations strongly supports the presence of gastropod organisms from the Conidae family in terms of growth. Linsley (1977) suggested the law of "tangential apertures" stating that the size of the shell aperture length (SAL) is related to the gastropod body circumference, the higher the shell growth, the larger the aperture length thereby affecting the shell balance (Okajima and Chiba 2013). The large shell aperture length makes it easier for gastropods to attach tightly to the substrate (Noshita et al. 2012). This is in line with Verhaegen et al. (2019) which stated that large shell aperture length is associated with water flow, with strong currents making the aperture length larger. The shell aperture of gastropods offshore is usually wider than those on the coast in the presence of shade (Crothers 1985).

Shell aperture width-SAW

The results at the three stations showed varying shell aperture width for each species. The range measurement from the highest and the lowest was *C. sponsalis* (2.88 ± 3.56 mm), *C. muriculatus* (2.68 ± 1.04 mm), *C. monachus* (2.21 ± 0.46 mm), *C. monachus* (2.21 ± 0.46 mm), *C. lividus* (2.19 ± 0.33 mm), *C. rattus* (2.15 ± 0.40 mm), *C. ebraeus* (2.05 ± 0.43 mm), *C. coronatus* (1.94 ± 0.38 mm), and *C. ebraeus* (1.91 ± 0.47 mm). The dimensions size of the aperture length is influenced by the condition of the substrate in the waters (Nybakken 1992) and the type of substrate in the three rocky stations strongly supports the existence of gastropod organisms from the family Conidae in terms of growth. According to Haumahu et al. (2014), the substrate type can cause variations in the morphological development of various gastropods. Moreover, gastropod habitats that are frequently exposed to waves have wider shell apertures, while relatively quiet habitats show smaller shell apertures (Carvajal-Rodríguez et al. 2005). The wider the gastropod shell aperture, the higher the ability to withstand strong waves and the stronger the foot attachment to the aquatic substrate (Márquez et al. 2015).

Morphometric variations of *Conus* species with relation to environmental parameters in Ambon Island

The relationship between environmental parameters (temperature, salinity, pH, and DO) and morphometric variations (SL, SW, ST, SH, SAL, and SAW) of 7 *Conus* species *C. rattus*, *C. lividus*, *C. monachus*, *C. muriculatus*, *C. ebraeus*, *C. spongeialis*, and *C. coronatus* recorded from Ambon Island were found to vary significantly (Table 4).

Table 4. The relationship between environmental parameters (temperature, salinity, pH, and DO of seawater) and morphometric characteristics of *Conus* species recorded from Ambon Island, Indonesia

Morphometric	Species	R	R^2	df		SS		MS		F	p
				Reg.	Res.	Reg.	Res.	Reg.	Res.		
SL	*C. rattus*	.166	.028	2	27	1.918	67.579	.959	2.503	.383	.685
	*C. lividus**	.263	.069	2	27	7.143	96.063	3.572	3.558	1.004	.380
	*C. monachus**	.584	.341	2	27	86.611	167.037	43.306	6.187	7.000	.004
	*C. muriculatus**	.400	.160	2	27	589.193	3098.697	294.596	114.767	2.567	.095
	*C. ebraeus**	.595	.355	2	27	40.771	74.235	20.386	2.749	7.414	.003
	*C. sponsalis**	.481	.231	2	27	36.948	122.843	18.474	4.550	4.060	.029
	C. coronatus	.188	.035	2	27	6.643	181.300	3.322	6.715	.495	.615
SW	*C. rattus**	.313	.098	2	27	8.012	73.734	4.006	2.731	1.467	.248
	*C. lividus**	.357	.127	2	27	26.596	182.316	13.298	6.752	1.969	.159
	C. monachus	.239	.057	2	27	16.065	264.313	8.033	9.789	.821	.451
	C. muriculatus	.367	.135	2	27	134.374	862.074	67.187	31.929	2.104	.141
	C. ebraeus	.509	.259	2	27	19.606	56.077	9.803	2.077	4.720	.017
	*C. sponsalis**	.264	.070	2	27	6.425	85.796	3.213	3.178	1.011	.377
	*C. coronatus**	.251	.063	2	27	6.196	92.381	3.098	3.422	.906	.416
ST	*C. rattus**	.217	.047	2	27	.103	2.084	.051	.077	.664	.523
	*C. lividus**	.284	.081	2	27	.203	2.321	.102	.086	1.183	.322
	*C. monachus**	.263	.069	2	27	.171	2.307	.086	.085	1.001	.381
	*C. muriculatus**	.226	.051	2	27	.109	2.026	.054	.075	.724	.494
	*C. ebraeus**	.202	.041	2	27	.058	1.350	.029	.050	.576	.569
	*C. sponsalis**	.447	.200	2	27	.301	1.207	.151	.045	3.368	.049
	*C. coronatus**	.537	.288	2	27	.490	1.209	.245	.045	5.466	.010
SH	*C. rattus**	.337	.114	2	27	4.065	31.702	2.032	1.174	1.731	.196
	*C. lividus**	.335	.112	2	27	3.272	25.835	1.636	.957	1.710	.200
	*C. monachus**	.255	.065	2	27	2.256	32.561	1.128	1.206	.935	.405
	*C. muriculatus**	.310	.096	2	27	8.764	82.334	4.382	3.049	1.437	.255
	*C. ebraeus**	.163	.027	2	27	1.539	56.337	.769	2.087	.369	.695
	*C. sponsalis**	.252	.064	2	27	1.579	23.219	.790	.860	.918	.411
	C. coronatus	.048	.002	2	27	.066	28.933	.033	1.072	.031	.970
SAL	*C. rattus*	.082	.007	2	27	.631	94.032	.315	3.483	.091	.914
	*C. lividus**	.540	.292	2	27	60.676	147.281	30.338	5.455	5.562	.009
	*C. monachus**	.632	.399	2	27	96.800	145.640	48.400	5.394	8.973	.001
	*C. muriculatus**	.344	.118	2	27	368.880	2745.496	184.440	101.685	1.814	.182
	*C. ebraeus**	.334	.112	2	27	20.083	159.667	10.042	5.914	1.698	.202
	*C. sponsalis**	.394	.155	2	27	26.657	144.904	13.328	5.367	2.483	.102
	*C. coronatus**	.291	.085	2	27	15.546	167.759	7.773	6.213	1.251	.302
SAW	*C. rattus*	.150	.022	2	27	.090	3.910	.045	.145	.310	.736
	*C. lividus**	.290	.084	2	27	.282	3.072	.141	.114	1.238	.306
	C. monachus	.189	.036	2	27	.387	10.413	.194	.386	.502	.611
	*C. muriculatus**	.490	.240	2	27	6.600	20.906	3.300	.774	4.262	.025
	*C. ebraeus**	.230	.053	2	27	.286	5.134	.143	.190	.753	.481
	*C. sponsalis**	.417	.174	2	27	1.406	6.685	.703	.248	2.838	.076
	C. coronatus	.030	.001	2	27	.004	4.377	.002	.162	.012	.988

Note: SS: Sum of Squares, MS: Mean Square, Reg: Regression, Res: Residual

Table 5. The analysis results of the effective contribution on each environmental physicochemical parameter variable (temperature, salinity, pH, and DO Seawater) to the morphometric variables (SL, SW, ST, SH, SAL, and SAW) *Conus* (Gastropods: Conidae)

Morphometric	Species	Effective contribution of environmental physicochemical parameter variables				Total (%)
		Temperature (%)	Salinity (%)	pH (%)	DO (%)	
SL	*C. rattus*	2.22	0.00	0.00	0.54	2.76
	C. lividus	3.51	0.00	0.00	3.41	6.92
	C. monachus	33.87	0.00	0.00	0.24	34.11
	C. muriculatus	15.95	0.00	0.00	0.01	15.98
	C. ebraeus	33.92	0.00	0.00	1.53	35.46
	C. sponsalis	21.24	0.00	0.00	1.88	23.12
	C. coronatus	3.57	0.00	0.00	-0.03	3.53
SW	*C. rattus*	6.89	0.00	0.00	2.92	9.82
	C. lividus	12.45	0.00	0.00	0.27	12.72
	C. monachus	5.69	0.00	0.00	0.04	5.73
	C. muriculatus	13.47	0.00	0.00	0.03	13.49
	C. ebraeus	24.74	0.00	0.00	1.12	25.86
	C. sponsalis	5.53	0.00	0.00	1.43	6.96
	C. coronatus	6.32	0.00	0.00	-0.04	6.29
ST	*C. rattus*	0.73	0.00	0.00	3.96	4.67
	C. lividus	8.12	0.00	0.00	-0.07	8.05
	C. monachus	5.51	0.00	0.00	1.38	6.89
	C. muriculatus	0.10	0.00	0.00	4.99	5.09
	C. ebraeus	1.32	0.00	0.00	2.76	4.09
	C. sponsalis	19.98	0.00	0.00	-0.02	19.96
	C. coronatus	28.50	0.00	0.00	0.31	28.81
SH	*C. rattus*	4.44	0.00	0.00	6.92	11.36
	C. lividus	9.39	0.00	0.00	1.82	11.22
	C. monachus	6.42	0.00	0.00	0.05	6.48
	C. muriculatus	9.48	0.00	0.00	0.15	9.63
	C. ebraeus	2.67	0.00	0.00	-0.017	2.66
	C. sponsalis	6.42	0.00	0.00	-0.05	6.37
	C. coronatus	-0.002	0.00	0.00	0.23	0.23
SAL	*C. rattus*	-0.003	0.00	0.00	0.67	0.67
	C. lividus	12.22	0.00	0.00	16.96	29.20
	C. monachus	40.13	0.00	0.00	-0.22	39.90
	C. muriculatus	10.97	0.00	0.00	0.89	11.86
	C. ebraeus	11.28	0.00	0.00	-0.09	11.20
	C. sponsalis	13.72	0.00	0.00	1.82	15.53
	C. coronatus	8.44	0.00	0.00	0.05	8.50
SAW	*C. rattus*	1.021	0.00	0.00	1.22	2.20
	C. lividus	6.43	0.00	0.00	1.96	8.40
	C. monachus	3.61	0.00	0.00	-0.03	3.58
	C. muriculatus	22.92	0.00	0.00	1.08	24.00
	C. ebraeus	5.27	0.00	0.00	0.01	5.28
	C. sponsalis	16.81	0.00	0.00	0.56	17.37
	C. coronatus	0.07	0.00	0.00	0.02	0.09

The environmental physicochemical parameters (temperature, salinity, pH, and DO of seawater) had a significant relationship with morphometric variations (SL, SW, ST, SH, SAL, and SAW) of *Conus* species (*) (Table 4). Previous studies also concluded that the gastropods vary morphologically in relation to their environment (Carvajal-Rodriguez et al. 2005; Conde-Padín et al. 2008). Furthermore, Vandarwala et al. (2020) found that similar gastropod species on rocky and sandy substrates can have different morphological forms. This is influenced by abiotic factors including temperature, salinity, DO and pH, as well as the biotic (predator). Bhuyain et al. (2020) in a study concluded that salinity was the main environmental factor influencing gastropod structure. Low pH values can affect the acidity of the water which reduces shell thickness and increases metabolism (hypermetabolism), hence, this condition is fatal to gastropods (Bibby et al. 2007).

In addition, the environmental physicochemical factors including temperature, salinity, pH, and DO of seawater (Table 4) had an insignificant relationship with the shell length for species *C. rattus* F=0.383 and p=0.685 and *C. coronatus* F=0.495 and p=0.615, as well as in the spire height for species *C. ebraeus* F=0.369 and p=0.695 and *C. coronatus* F=0.031 and p=0.970. The insignificant relationship was also shown in the shell aperture length for *C. rattus* species F value=0.091 and p=0.914, as well as in the shell aperture width for *C. rattus s*pecies F=0.310 and p=0.736, *C. monachus* F=0.502 and p=0.611, and *C. coronatus* F=0.012 and p=0.988. Shepard and Minton (2019) reported that the variations in the shell morphometric size of gastropod species *Elimia proxima* had no significant relationship with environmental physicochemical factors. Furthermore, Tattersfield (1981) suggested that changes in shell size are caused by several factors such as gastropod population density, available food sources, genetic differences, and the environmental factors that had a very minimal effect on it.

The effective contribution analysis results (Table 5) showed that the environmental variables had effective contributions to the morphometric variables including SL, SW, ST, SH, SAL, and SAW of *Conus* species.

The analysis results (Table 5) showed that the salinity and pH had the most effective contribution to the shell length of *C. ebraeus* at 33.92% while the DO had the most effective contribution to *C. lividus* at 3.41%, compared to other *Conus* species. Furthermore, the seawater temperature variable had the largest effective contribution to the shell width of *C. ebraeus* at 24.74% and the DO variable had the largest effective contribution to *C. rattus* at 2.92%. The seawater temperature variable gave the most effective contribution to the shell thickness of *C. coronatus* at 28.50%, while the DO had the most effective contribution to *C. muriculatus* at 4.99%. The seawater temperature also gave the largest effective contribution to the spire height of *C. muriculatus* at 9.48% and the DO had the largest effective contribution to *C. rattus* at 6.92%. Moreover, the seawater temperature had the largest effective contribution to the shell aperture length of *C. monachu*s at 40.13% and the DO variable gave the largest effective contribution to *C. lividus* at 16.96%. The seawater temperature also showed the largest effective contribution to the shell aperture width of *C. muriculatus* at 22.92% and the DO variable had the most effective contribution to C. *lividus* at 1.96%.

The results showed that the temperature and DO produce effectively contributed to the morphometric variation (SL, SW, ST, SH, SAL, and SAW) on *Conus* species. According to Matos et al. (2020), shell size is affected by air temperature and rainfall. A previous study also stated that gastropod growth is completely dependent on various physicochemical stresses, where seawater temperature influences the distribution of organisms due to tides (Rivest 1983). This is observed in gastropods with large shell sizes having an extensive water storage capacity in their bodies which prevents them from losing water at low tide and increasing the ability to defend themselves against predators.

Furthermore, the results show that the salinity and pH of seawater do not contribute effectively to morphometric variations. There was no effective contribution from salinity and pH for the positive growth of morphometric variables. Previous studies also concluded that a decrease in pH and salinity caused the changes in shell weight, length, and gastropod features, therefore, ocean acidification occurred which led to reduced calcium availability (Marshall et al. 2008). Moreover, acidification in coastal waters is caused by an increase in CO2 in the atmosphere which leads to the erosion of the shell surface on Neripteron violaceum (Marshall et al. 2018), thereby affecting the size of the gastropod shell.

In conclusion, there are 7 *Conus* species have found with different density levels, from high to low; *C. ebraeus* (0.18 and 0.16 ind/m^2), *C. lividus* (0.13 ind/m^2), *C. sponsalis* (0.12 ind/m^2), *C. rattus* (0.11 ind/m^2), *C monachus* (0.10 ind/m^2), *C. muriculatus* (0.10 ind/m^2), and *C. coronatus* (0.10 ind/m^2). Moreover, the environmental physicochemical parameters (temperature, salinity, pH, and DO of seawater) had a significant relationship with morphometric variations (SL, SW, ST, SH, SAL, and SAW) of *Conus* species (*) (Table 4). In addition, the salinity and pH variable had the most effective contribution. In contrast, salinity and pH of do not contribute effectively to morphometric variables.

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