



Population structure and relative growth of rock snails *Reishia bitubercularis* (Gastropoda: Muricidae) from Ambon Island, Eastern Indonesia

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Abstract

The present study reports and discusses population structure and morphometric relationships of muricid *Reishia bitubercularis* in two populations from Ambon Island, Maluku. Field sampling was conducted at two locations with typical hard substrate i.e. Ambon Bay and Central Maluku, where each location comprises three different stations. Morphometric relationships were analyzed for shell dimensions i.e., shell length (SL), shell width (SW), shell height (SH) and total weight (TW). A total of 496 individuals of *R. bitubercularis* were collected in both locations. SL ranged from 7.07 to 42.38 mm in Ambon Bay, and 12.45 to 42.69 mm in Central Maluku. The highest number of individuals in Ambon Bay and Central Maluku was in size 26-28 mm and 30-32 mm, respectively. The mean SW/SL ratio ranged from 0.67 mm to 0.73 mm. Sex ratio was significantly different from 1:1, with females outnumbered males in both locations. Morphometric relationships indicated SL grows faster than SW in both locations and faster than SH and TW in Central Maluku. While the growth rate between SL vs SH; and TW vs SL are relatively similar in Ambon Bay. Overall, both Ambon Bay and Central Maluku have a similar variation of abiotic factors which also play an important role in shell morphometrics and relative growth of muricids, especially related to the exposed area in the rocky intertidal zone where sampling was conducted.

Keywords: Muricid, *Reishia bitubercularis*, population structure, morphometrics, relative growth, Ambon Island.

Abstrak

Struktur populasi dan pertumbuhan relatif keong *Reishia bitubercularis* (Gastropoda: Muricidae) dari Pulau Ambon, Indonesia. Studi ini melaporkan dan membahas struktur populasi dan hubungan morfometrik *R. bitubercularis* pada dua populasi dari Pulau Ambon, Maluku. Pengambilan sampel di lapangan dilakukan pada enam stasiun dengan substrat keras khas Teluk Ambon dan Maluku Tengah. Analisis morfometrik dilakukan terhadap dimensi cangkang yaitu panjang cangkang (SL), lebar cangkang (SW), tinggi cangkang (SH), dan berat total (TW). Sebanyak 496 individu keong dikumpulkan dari kedua lokasi. Panjang cangkang berkisar antara 7,07–42,38 mm pada Teluk Ambon, dan 12,45–42,69 mm pada Maluku Tengah. Jumlah individu tertinggi pada Teluk Ambon dan Maluku Tengah masing-masing pada kelas ukuran 26–28 mm dan 30–32 mm. Rata-rata rasio SL/SW berkisar antara 0,67–0,73 mm. Rasio kelamin berbeda signifikan dari perbandingan ideal 1:1, dengan jumlah individu betina lebih banyak daripada jantan di kedua lokasi. Hubungan morfometrik mengindikasikan SL, SH tumbuh lebih cepat

dibandingkan SW di kedua lokasi, dan lebih cepat daripada SH dan TW di Maluku Tengah. Sementara itu, SL vs SH dan TW vs SL memiliki laju pertumbuhan yang relatif sama di lokasi Teluk Ambon. Secara keseluruhan, baik Teluk Ambon maupun Maluku Tengah memiliki variasi faktor abiotik yang mirip, yang memiliki peranan penting dalam mempengaruhi morfometrik cangkang dan pertumbuhan relatif siput muricid, terutama terkait dengan area yang terpapar di zona intertidal berbatu di mana pengambilan sampel dilakukan.

Kata kunci: Keong *Reishia bitubercularis*, struktur populasi, morfometrik, pertumbuhan relatif, Pulau Ambon.

Introduction

Rock snail *Reishia bitubercularis*, an accepted name of *Thais kienerii* (MolluscaBase Eds., 2021) is one of the members of the family Muricidae (Claremont et al., 2013). Muricidae is the second largest family in the order Neogastropoda, a speciose group of marine-predator gastropods in the Indo-West Pacific region (Vermeij, 1996; Houart, 2017). *Reishia bitubercularis* has an oval to spirally elongated shape (biconical) with a round pointed tip, a thorn-like structure in the shell edge, and thick fasciola. The outer lip consists of four inner teeth that expand to the aperture, columella with one or more anterior folds. Shell color is black or dark purple with white patches between nodules (Wilson, 1994; Houart, 2017). The distribution range of *R. bitubercularis* is in the Indo-West Pacific, from Southeast Asia (the Philippines and Indonesia) to Australia, Polynesia, and New Zealand (Abbot and Dance, 1990; Wilson, 1994; Houart, 2017).

This species and other muricids play an important role in the marine macrobenthic community. Despite their predatory habits, they were used as indicator species for marine environmental studies, such as organotin pollution which led to the imposex phenomenon (Horiguchi et al., 1997; Liu et al., 1997; Rumengan et al., 2008; Ruaza et al., 2013; Islami et al., 2019), and heavy metal contamination (Han et al., 1997; Blackmore and Wang, 2004). They are often found in high densities especially on rocky and hard substrates in the upper intertidal areas. They attach not only on natural substrates, but also on

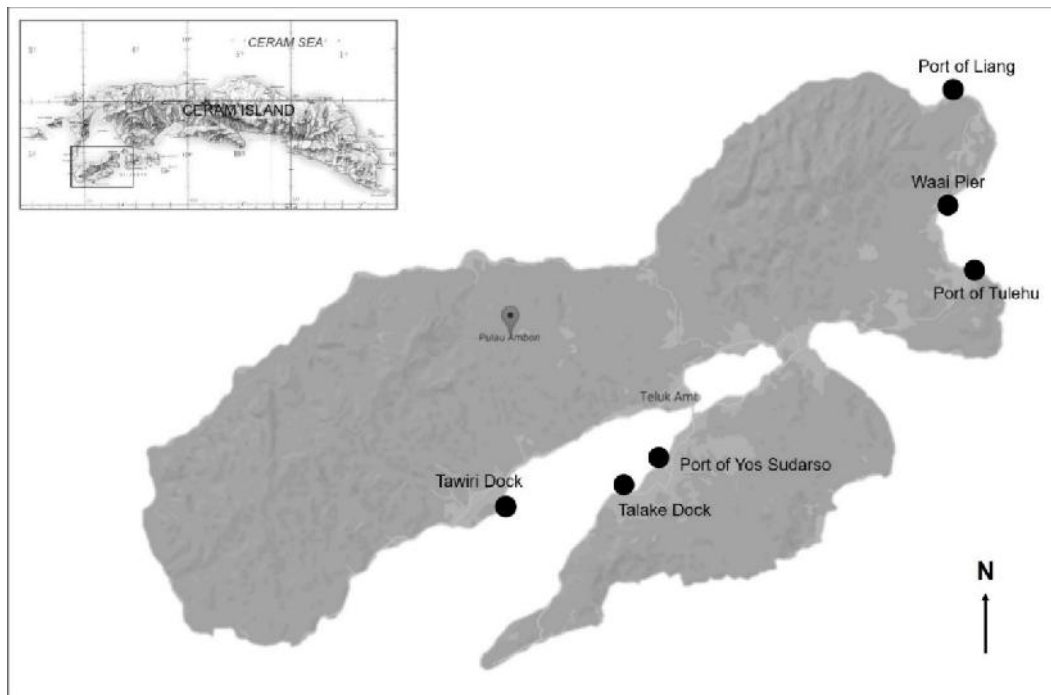
artificial hard substrates such as dock poles, piers, or other concrete submerged structures (Tan and Liu, 2001; Claremont et al., 2013).

Several related studies on the species composition attached to the hard substrates have been carried out in Indonesia but are mostly limited to ecological approaches of unspecific organisms (Yusron, 1990; Hartono *et al.*, 2012; Mudzni, 2014; Ruslan, 2014). Nevertheless, a more specific study on morphological variations and relationships of *R. bitubercularis* has not been conducted in Ambon Island, Maluku. Therefore, this study aimed to determine the population structure and relative growth of *R. bitubercularis* associated with hard substrates in Ambon Island, Maluku. The results would provide an overview of morphological differentiation of *R. bitubercularis* population and information about the intertidal hard substrate communities from Ambon Island, Eastern Indonesia.

Methodology

Study sites

Field surveys were conducted at six stations in Ambon Island, Maluku (Figure 1). Three stations were in Ambon Bay, i.e. Port of Yos Sudarso (YS), Talake Dock (TK), and Tawiri Dock (TR). While three remaining stations were in Central Maluku, outside Ambon Bay, i.e. Port of Tulehu (TH), Waai Pier (WA), and Port of Liang (LG).



Gambar 1. Peta lokasi penelitian di Pulau Ambon, Maluku

Figure 1. The geographic location of study sites in Ambon Island, Maluku

Data collection

Individuals of *R. bitubercularis* were randomly collected from the intertidal area at low tide. All visible muricids were collected from open areas of the shore and under overhangs and behind pilings. Approximately 10-150 specimens were collected from each location to balance obtaining reliable data (Spence et al., 1990; Castro et al., 2004) and to avoid oversampling of potentially stressed populations. The samples obtained were transported to the laboratory in plastic bags and frozen until analyses. In the laboratory the samples were counted and identified following Poppe. The identification process and sample analyses were carried out in the Reference Collection, Center for Deep-Sea Research, BRIN, Ambon. In addition, physical-chemical profile and bottom substrate were also analyzed to determine hydrographic conditions and habitat characteristics in the study sites.

Data analysis

Shell dimensions including length, width, and height were measured to the nearest 0.01 mm using a digital caliper to evaluate the minimum, maximum, mean of shell length and size class. The snail was weighed to the nearest 0.01 g using a digital scale. The sizes of individuals from each station were distributed to each size class formed (sixteen classes). Variations of the mean of shell

dimension ratio (SW/SL and SH/SL) in each study site were analyzed using one-way ANOVA, after confirming data normality using the Kolmogorov-Smirnov test. The sex ratio was calculated and then tested against the balanced proportion of male and female individuals (1M:1F) using Chi-square analysis (Steel & Torrie, 1993).

Log-transformation of allometric equation $Y=aX^b$ was used to evaluate the relationships between shell dimensions, shell length and width, height, weight, and shell width and height independently. Y is the response variable, and X is the predictor, a is the intercept, and b is the regression slope of the morphometric relationships. In relationships between the same variables, i.e. SL, SW, and SH, an isometry is defined as $b = 1$, negative allometry $b < 1$; and positive allometry $b > 1$. Meanwhile, in relationships between TW vs. SL, isometry occurs when $b = 3$, negative allometry $b < 3$; positive allometry $b > 3$ (Huxley and Teissier 1936; Elhasni et al., 2018a). Subsequently, a *t*-test ($H_0: b = 1$ or 3; $H_A: b \neq 1$ or 3) was applied to confirm whether the slopes (*b*) of the regression lines were in the allometric ranges. Level of significance $P < 0.05$ was used in all statistical analyses. Most statistical analyses were performed manually using Microsoft Excel of Microsoft 365 and SPSS version 24.

Results

Population structure

A total of 496 individuals of *Reishia bitubercularis* were collected from six study sites in two locations, specifically 305 individuals in Ambon Bay and 191 individuals in Central Maluku. In Ambon Bay, shell length ranged between 7.07 mm and 42.38 mm. The highest number of individuals was found in TK (N=156), and the lowest was in TR (N=29). The mean sizes

were 24.61 ± 7.80 ; 28.36 ± 5.34 ; and 29.59 ± 7.01 mm in TK, YS, and TR, respectively. In Central Maluku, the size varied from 12.45 to 42.69 mm SL, which was slightly bigger than that in Ambon Bay. The highest and the lowest number of individuals were found in WA (N=120) and LG (N=16), respectively. The mean size of SL in TH, WA, and LG varied as large as 25.61 ± 8.20 , 27.60 ± 5.81 , and 34.38 ± 5.21 mm, respectively (Table 1).

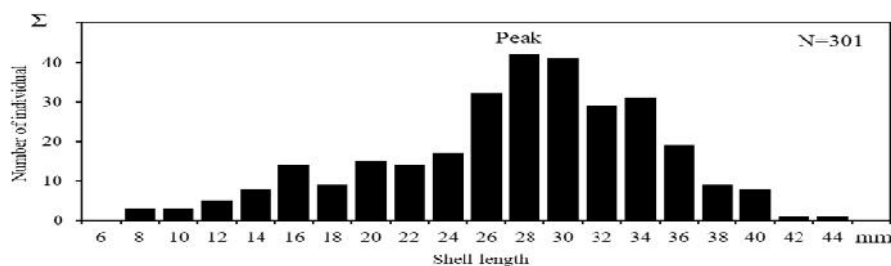
Tabel 1. Nilai minimum (Min), maksimum (Max), and rerata (Mean) panjang cangkang (SL) pada enam stasiun penelitian di Pulau Ambon (N: jumlah individu).

Table 1. Minimum (Min), maximum (Max), and average values (Mean) of shell length (SL) within the six study sites in Ambon Island (N: number of individuals).

Sites	N	Min SL (mm)	Max SL (mm)	Mean \pm SD
<i>Ambon Bay</i>				
▪ YS	116	12.20	39.67	28.36 ± 5.34
▪ TK	156	7.07	42.38	24.61 ± 7.80
▪ TR	29	15.46	41.15	29.59 ± 7.01
<i>Central Maluku</i>				
▪ TH	55	13.24	42.69	25.61 ± 8.20
▪ WA	120	12.45	40.18	27.60 ± 5.81
▪ LG	16	24.12	42.65	34.38 ± 5.21

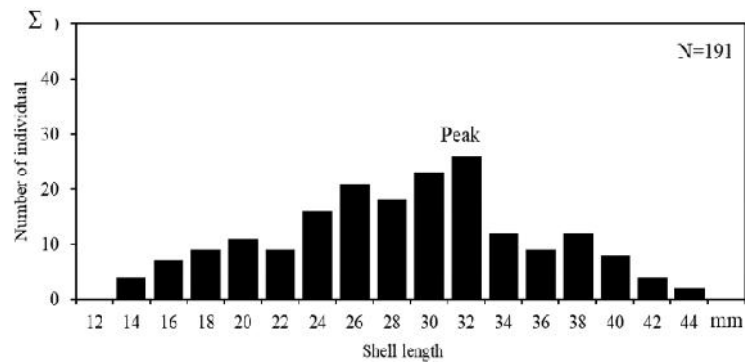
Moreover, the shell length-frequency distribution of *R. bitubercularis* was also analyzed in both Ambon Bay and Central Maluku locations (Figures 2 and 3). Based on the Kolmogorov-Smirnov test, the distribution in both locations was normal ($P > 0.05$). In Ambon Bay, the highest number of individuals was found in the size class

26-28 mm (42 individuals) and the lowest number (1 individual) was found in the size class 40-42 mm and 42-44 mm (Figure 2). Meanwhile, the highest number of individuals in Central Maluku was found in the size class 30-32 mm (26 individuals), and the lowest number was found in the size class 42-44 mm (2 individuals) (Figure 3).



Gambar 2. Sebaran frekuensi panjang cangkang *R. bitubercularis* di Teluk Ambon.

Figure 2. Shell length-frequency distribution of *R. bitubercularis* in Ambon Bay.



Gambar 3. Sebaran frekuensi panjang cangkang *R. bitubercularis* di Maluku Tengah.
Figure 3. Shell length-frequency distribution of *R. bitubercularis* in Central Maluku.

The mean SW/SL dimension ratio of *R. bitubercularis* ranged between 0.67 mm and 0.73 mm. In Ambon Bay, the highest SW/SL ratio was found in TK (1.12 mm) which was also the highest for all study sites, and the lowest ratio was found in YS (0.57 mm). In Central Maluku, the highest ratio was found in WA (0.84 mm) and the lowest ratio was found in TH (0.58 mm). Meanwhile, the mean SH/SL dimension ratio

ranged between 0.54 mm and 0.60 mm. In Ambon Bay, the highest SH/SL ratio was found in TK (1.19 mm) and the lowest ratio was found in YS and TR (0.48 mm). In Central Maluku, the highest and the lowest ratios were found in WA (0.70 mm) and LG (0.48 mm), respectively (Table 2). Furthermore, no significant variations occurred between mean values of SW/SL and SH/SL from all study sites within two locations ($P>0.05$).

Tabel 2. Rasio dimensi cangkang *R. bitubercularis* pada tiap lokasi penelitian di Pulau Ambon. (SW: Lebar Cangkang; SL: Panjang Cangkang; SH: Tinggi Cangkang; Min: Minimum; Max: Maksimum; SD: Standar Deviasi).

Table 2. Shell dimension ratio of *R. bitubercularis* at each study site in Ambon Island (SW: Shell Width; SL: Shell Length; SH: Shell Height; Min: Minimum; Max: Maximum; SD: Standard Deviation).

Sites	SW/SL (mm)		Mean \pm SD	SH/SL (mm)		Mean \pm SD
	Min	Max		Min	Max	
<i>Ambon Bay</i>						
▪ YS	0.57	0.89	0.67 \pm 0.05	0.48	0.79	0.60 \pm 0.04
▪ TK	0.59	1.12	0.71 \pm 0.06	0.49	1.19	0.60 \pm 0.06
▪ TR	0.62	0.84	0.72 \pm 0.05	0.48	0.63	0.54 \pm 0.04
<i>Central Maluku</i>						
▪ TH	0.58	0.78	0.67 \pm 0.05	0.51	0.65	0.56 \pm 0.04
▪ WA	0.59	0.84	0.73 \pm 0.05	0.49	0.70	0.60 \pm 0.04
▪ LG	0.66	0.77	0.72 \pm 0.02	0.48	0.64	0.59 \pm 0.04

Sex ratio

In this study, the sex ratio of *R. bitubercularis* was significantly different from the ideal proportion (M:F = 1:1, X^2 -test, $p<0.05$) in

both locations. In Ambon Bay, the highest ratio of M:F was found in TK (1:5.8), while in Central Maluku was found in TH (1:3.0). Females outnumbered males in all study sites (Table 3).

Tabel 3. Rasio kelamin dan hasil analisis Chi-square *R. bitubercularis* di Teluk Ambon dan Maluku Tengah.
 Table 3. Sex ratio and Chi-square analysis results of *R. bitubercularis* in Ambon Bay and Central Maluku.

Location	Male	Female	Total	M:F	Expected Male and Female	X ² value	Probability
<i>Ambon Bay</i>							
▪ YS	5	12	17	1:2.4	8.5	2.88	<0.05
▪ TK	23	133	156	1:5.8	78	77.56	<0.05
▪ TR	5	15	20	1:3.0	10	5.00	<0.05
<i>Central Maluku</i>							
▪ TH	4	12	16	1:3.0	8	4.00	<0.05
▪ WA	15	20	35	1:1.3	17.5	0.71	<0.05
▪ LG	5	11	16	1:2.2	8	2.25	<0.05

Relative growth

Table 4 represents total individual numbers, morphometric relationships, and type of growth of *R. bitubercularis*. The relationships established for both locations were significant ($p < 0.05$) and showed high degree of correlation (Ambon Bay, $r^2 = 0.92$ to 0.98 ; Central Maluku, $r^2 = 0.94$ to 0.96). The allometry coefficients of shell dimension relationships (b) ranged from 0.96 to 1.03 and the b value for shell length and total length relationship was 2.99 in Ambon Bay. Meanwhile, in Central Maluku, b values ranged from 0.96 to

1.07 for shell dimension relationships and shell length and total length relationship was 3.20 . In Ambon Bay, morphometric relationships for SL vs SW and SW vs SH displayed positive allometry ($b = 1.03$ and 0.96); and for SL vs SH ($b = 1.01$), but for TW vs SL ($b = 2.99$) were isometry. In the Central Maluku population, all morphometric relationships for SL vs SW, SL vs SH, SW vs SH, and TW vs SL displayed positive allometry with b values were 1.07 ; 1.05 ; 0.96 ; and 3.20 , respectively.

Tabel 4. Hubungan morfometrik tiap dimensi cangkang dan berat total *R. bitubercularis*.

Table 4. Morphometric relationships of shell dimensions (mm) and total weight (g) of *R. bitubercularis*.

Relationship	N	b±SE	a	r	t-val	Type of growth
<i>Ambon Bay</i>						
•SL vs SW	301	1.03±0.01	0.64	0.98	3.00*	+ allometry
•SL vs SH		1.01±0.02	0.57	0.97	0.50 ^{ns}	isometry
•SW vs SH		0.96±0.02	0.97	0.96	2.00*	+ allometry
•TW vs SL		2.99±0.03	0.0002	0.98	0.33 ^{ns}	isometry
<i>Central Maluku</i>						
•SL vs SW	191	1.07±0.02	0.57	0.97	3.50*	+ allometry
•SL vs SH		1.05±0.02	0.50	0.97	2.50*	+ allometry
•SW vs SH		0.96±0.02	0.93	0.98	2.00*	+ allometry
•TW vs SL		3.20±0.05	0.0001	0.98	4.00*	+ allometry

Environmental parameters

In general, characteristics of the aquatic environment at each study site in Ambon Island showed various conditions. Some environmental

parameters investigated in this study included temperature, salinity, pH, dissolved oxygen (DO), the concentration of phosphate, nitrate, turbidity, water current, and type of substrates (Table 5).

Tabel 5. Parameter lingkungan tiap lokasi penelitian di Pulau Ambon.
Table 5. Environmental parameters of each study site in Ambon Island.

Parameters	Ambon Bay			Central Maluku		
	YS	TK	TR	TH	WA	LG
1 Temperature (°C)	27.00	27.00	27.50	29.25	28.50	27.50
2 Salinity (‰)	31.00	29.83	30.50	24.00	27.00	30.50
3 pH	7.83	7.24	7.30	7.70	8.02	8.03
4 Dissolved Oxygen/ DO (mg.l ⁻¹)	5.69	6.17	6.20	5.61	6.27	6.26
5 Phosphate/ PO4 (mg.l ⁻¹)	0.02	0.05	0.02	0.08	0.03	0.02
6 Nitrate/ NO3 (mg.l ⁻¹)	0.06	0.05	0.03	0.11	0.01	0.05
7 Turbidity (FTU)	0.40	0.43	0.30	0.51	0.63	0.73
8 Current (cm.s ⁻¹)	9.75	8.34	21.22	3.12	3.91	5.32
9 Percentage of substrate (%)						
▪ Gravel	26.20	22.45	38.37	28.40	18.19	34.93
▪ Sand	59.57	54.55	42.90	50.36	60.61	50.29
▪ Clay	14.23	23.00	18.73	21.24	21.20	14.78
▪ Type of substrate	Gravelly sand	Clayey sand	Gravelly sand	Gravelly sand	Clayey sand	Gravelly sand

Results showed the highest record of seawater temperature was in TH (29.25 °C), and the lowest record was in YS and TK (27 °C). The highest record of salinity was in YS (31 ‰), while the lowest record was in TH (24 ‰). Seawater-pH showed varied values, reaching more than 7.24 for all study sites. Meanwhile, the highest value of dissolved oxygen was found in WA (6.27 mg.l⁻¹) and the lowest was in TH (5.61 mg.l⁻¹). The highest phosphate concentration was found in TH (0.08 mg.l⁻¹), while the lowest concentration (0.02 mg.l⁻¹) was in YS, TR, and LG. The highest concentration for nitrate was found in TH (0.11 mg.l⁻¹), while the lowest concentration was in WA (0.01 mg.l⁻¹). Turbidity ranged from 0.30 FTU to 0.73 FTU with the highest and the lowest values were in LG and TR, respectively. While the highest water currents (21.22 cm.s⁻¹) was found in TR and the lowest value (3.12 cm.s⁻¹) was in TH. In terms of substrate types, four study sites had gravelly sand substrates (YS, TR, TH, and LG) and the two remaining sites had clayey sand (TK and WA).

Discussion

Shell dimensions of *R. bitubercularis* represent a broad size range in both populations (Ambon Bay: 7.07–42.38 mm SL; Central Maluku: 12.45–42.69 mm SL). This result fairly reflects the sizes of muricids commonly found throughout the species geographical distribution, especially in Southeast Asia. Several studies have reported the shell size of some members of the genus *Thais* (the previous name of *Reishia*). The

shell size of *Thais jubilaea* ranged from 25 mm to 38 mm, from Singapore (Tan and Sigurdsson, 1990), *T. pinangensis* (15–21 mm) from Pulau Pinang, Malaysia; *T. rufotincta* (12.3–31.9 mm) from Singapore; *T. blanfordi* (15.8–30.7 mm) from the western half of the Indian Ocean; *T. tissoti* (10.1–27 mm) from the west coast of India and Sri Lanka, and the east coast of Africa (Tan and Sigurdsson, 1996a); *T. malayensis* (13–41 mm) from the Malayan archipelago and *T. javanica* (18.1–33.1 mm) from the east coast of India through the Malayan archipelago and northwards to China and Taiwan (Tan and Sigurdsson, 1996b); *T. clavigera* and *T. luteostoma* (up to 34 mm and 35 mm, respectively) from Hong Kong; and *T. keluo* and *T. rufotincta* (up to 29 mm and 44 mm, respectively) from Taiwan (Tan and Liu, 2001). Another study found the shell size of *T. aculeata* ranged from 11.6 mm to 38.4 mm in Ambon Island (Islami et al., 2019).

The shell length-frequency distribution of *R. bitubercularis* for Ambon Bay and Central Maluku were normal and showed a similar mound-shaped or unimodal pattern (Figure 2 and 3). It could be inferred that the populations are distributed in an even manner, implying a numerical predominance of medium size class (Derbali et al., 2012). Both Ambon Bay and Central Maluku showed only one peak in the size classes 26–28 mm and 30–32 mm, but SL-frequency distribution in Central Maluku was slightly flatter than that in Ambon Bay, due to the broad size range of individuals but in a few numbers of collected specimens. Similar patterns

of shell length-frequencies were also found in other molluscs such as *Strombus gigas* from Jaragua, Dominica (Posada et al., 1999); *Bolinus brandaris* from northern Tunisia (Abidli et al., 2012); *Cerastoderma glaucum* from the Gabes coasts (Derbali et al., 2012); *Plicopurpura pansa* from Guerrero, México (Flores-Garza et al., 2012); *Margarya melanioides* from Kunming, China (Song et al., 2013); *Conus* spp. from Northern Red Sea (Zauner and Zuschin, 2016); and *Rhinoclavis vertagus* from Saparua Island, Maluku (Islami and Indrabudi, 2020).

Moreover, both SW and SH of *R. bitubercularis* were shorter in size than SL, and the mean of shell dimension ratios (SW/SL and SH/SL) showed similar values (above 0.5) in both Ambon Bay and Central Maluku populations. These results are to be expected because the shell shape of *R. bitubercularis* is spirally elongated, or spindle-shaped. The similar shell shape was also found in other muricids species such as *T. malayensis*, *T. javanica*, *T. keluo*, *T. luteostoma*, *T. lacera*, *T. blanfordi* and *T. aculeata* (Tan and Sigurdsson, 1996b; Tan and Liu, 2001; Kumar et al., 2017; Islami et al., 2018).

The sex ratio in both Ambon Bay and Central Maluku populations showed that females predominated males in all study sites. Similar patterns were found in other Neogastropoda species such as *Hexaplex trunculus* from the Ria Formosa, Portugal (Vasconcelos et al., 2008) and Bizerte lagoon, northern Tunisia (Gharsallah et al. 2010) the Gulf of Gabès, southern Tunisia (Elhasni et al., 2018b); *T. aculeata* from Ambon Island, Indonesia (Islami et al., 2019); and *Babylonia areolata* from Gulf of Thailand (Sriwong and Poonsud, 2019). This unbalanced proportion in which females predominates is frequently found in gonochoristic gastropods (Fretter & Graham 1964). Differential growth rates between sexes, with females dedicating higher energy expenditure to growth than to reproduction, are likely to explain the increasing sex proportion of females with larger size classes (Derbali et al., 2012).

Regarding the relative growth of *R. bitubercularis*, most of the morphometric relationships displayed positive allometry, except for SW vs SH and TW vs SL (in Ambon Bay population) that showed isometry growth. Positive allometries in the relationships SL vs SW and SW vs SH (in both populations); SL vs SH and TW vs SL (in Central Maluku population), represent that throughout the ontogeny, shell length grows faster than shell width, shell height and total weight.

Meanwhile, isometry in the relationship SL vs SH and TW vs SL (in Ambon Bay population) revealed that growth rates between shell length versus shell height; and shell length versus total weight are relatively similar. Allometric growth patterns for the relationship TW vs SL have also been described for other muricids in several studies. For instance, *T. coronata*, *T. haemastoma*, and *T. lacera* exhibited a negative allometric growth in Bakana, Nigeria (Itolima et al., 2019). The banded murex *H. trunculus* also showed negative allometry, while the purple dye murex *Bolinus brandaris* displayed positive allometry. Both species are from intertidal area of Ria Formosa lagoon, eastern Portugal (Vasconcelos et al., 2016; 2017). Meanwhile, Elhasni et al. (2018a) reported that relative growth of *H. trunculus* was different significantly between populations, negative allometric growth was found in intertidal and positive allometric growth was in the offshore population. Another study found *T. aculeata* displaying a positive allometric growth from Ambon Bay, Indonesia (Islami et al., 2018).

Besides biotic factors, adaptation to environmental dynamics probably plays an essential role in morphometric differentiation. Although Ambon Bay is semi-enclosed water, all study sites in Ambon Bay are located in the outer bay where its dynamic is influenced by water mass from Banda Sea, similar to the sampling sites in Central Maluku. In the present study, the sampling sites are in the intertidal zone with temperatures in Ambon Bay generally lower than that in Central Maluku. Conversely, most study sites in Ambon Bay showed a higher salinity than that in Central Maluku. Both variables may be the most crucial factors influencing the population structure and abundance. These variables are also closely related to the degrees of exposure to wave action, especially in the rocky intertidal zone. Other factors affecting the muricids population include bottom substratum and organic matter content. The density of seashells tends to be higher at the depth of organic matter layer <1m and sand bottom substratum are considered and depends on the habitat preference of the species (Derbali et al., 2012). Elhasni et al. (2018) reported the differences of relative growth and morphometrics of *H. trunculus* between offshore and intertidal populations.

Exposed areas in the study sites also tend to have sparse populations, particularly between tide lines, whereas few organisms that live on wave-swept rocky shores are usually firmly cemented or

anchored to the substratum. Morphometric differentiation associated with tidal, or wave exposure has been documented for several gastropods such as *Littorina saxatilis* (Johannesson *et al.*, 1993; Rolán-Alvarez *et al.*, 1996), *Nucella lapillus* (Kirby 2000; Rolán *et al.*, 2003), and *H. trunculus* (Marzouk *et al.*, 2016). Besides environmental dynamic variables, other factors may influence the existence of marine fauna in the intertidal zone such as food availability, desiccation, tidal range, predator-prey interaction, and anthropogenic stressors (Chapman, 2000; Avaca *et al.*, 2013).

Conclusion

Reishia bitubercularis represented a broad size range of shell dimensions, with its SL-frequency distribution was normal, exhibiting a similar mound-shaped pattern and predominance of medium size in both Ambon Bay and Central Maluku. The shell shape of *R. bitubercularis* is spirally elongated, or spindle-shaped, with an unbalanced sex ratio which females predominated males in all study sites. Most of the morphometric relationships displayed positive allometry, except for SW vs SH and TW vs SL (in Ambon Bay population) showed isometry growth. Temperature, salinity and other abiotic factors also play a key role in shell morphometrics and relative growth, especially related to the exposed area in the rocky intertidal where the study was conducted. Further studies focusing on morphological differentiation associated with other factors such as food availability, desiccation, predator presence, and human impact in the intertidal zone would be essential for quantification, analyses, and a better understanding of variation in biological forms.

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Author Contribution

MMI and FN conceived the work. MMI, FN, and DJT conducted the fieldwork and

performed the laboratory work. MMI analyzed the data and wrote the manuscript with relevant contributions from all authors.

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