SPATIAL VARIATION IN POPULATION CHARACTERISTICS OF VENUS CLAM GAFRARIUM TUMIDUM RŌDING, 1798 (BIVALVIA: VENERIDAE) IN AMBON BAY, MALUKU

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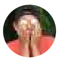
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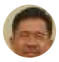
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SPATIAL VARIATION IN POPULATION CHARACTERISTICS OF TUMID VENUS CLAM *GAFRARIUM TUMIDUM* RÖDING, 1798 (BIVALVIA: VENERIDAE) IN AMBON BAY, MALUKU

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ABSTRACT

Ambon Bay consists of two regions, *i.e.*, Inner and Outer Ambon Bay that are separated by Galala-Poka sill. Consequently, these waters have different local environmental conditions that lead to bivalve population differences, including the ribbed or tumid venus clam *Gafrarium tumidum*. In this study, the distribution and spatial variation in population characteristics of different populations of tumid venus clam were quantified based on the analysis of their twelve shell dimensions. Fieldwork and analyses were conducted on April – June 2013. A total of 585 individuals clam was found and divided into ten size-classes of three size categories, *i.e.*, small (< 23.11 mm), medium (23.12–32.05 mm) and large size (> 32.06 mm). Medium size was found as the highest size-class density. Spatial distribution was related to the characteristics of sediment and other potential factors. The result of the discriminant analysis showed that shell-width (SW) was the variable with the highest discriminating power distinguishing between Inner and Outer Ambon Bay populations.

Keywords: tumid venus clam, *Gafrarium tumidum*, shell dimensions, density, spatial variation.

INTRODUCTION

Ambon Bay is located in the middle of Ambon Island where the inner Ambon Bay (IAB) and outer Ambon Bay (OAB) that was separated by the Galala-Poka sill. Various activities, such as fishing, shipping, aquaculture, and other marine-fisheries activities were carried out in this water. Coastal people also take advantage of this bay by collecting economically important biota for daily consumption, for example, clams.

One of the economically important marine organism collected by local people in Ambon Bay is venus *Gafrarium tumidum* (venus clam). This clam is known as tasty and nutritious food and called “bia manis” or “bia pica balanga” in the local language.

Gafrarium tumidum belonging to the family Veneridae, is one of the important species of bivalves of Ambon Bay because it is commonly collected and consumed by coastal people. Generally, this clam lives in intertidal sandy or muddy substrate (Baron and Clavier, 1992b; Poutiers, 1998); it has a thick shell shape with maximum shell size of 4-5 cm (Kurihara, 2003), immersed vertically, but sometimes the posterior of shells appear on the surface of the substrates (Kilburn, 1999). Tumid venus clams are widely distributed in the Indo-Pacific region including India, Sri Lanka, Japan, Philippines, Indonesia, Mauritius and Seychelles, Melanesia, Australia and New Caledonia (Abbot and Dance, 1990; Lamprell and Whitehead, 1992; Poutiers, 1998; Jagadis and Rajagopal, 2007).

Differences in location, geographical structure, and other environmental parameters may result in different shell shape and size spatially (Costa *et al.*, 2008; Caill-Milly *et al.*, 2012). Ambon Bay consists of two regions (inner and outer bay) with known specific environmental characteristics such as water currents, bottom sediment, nutrients and other factors. These characteristics may affect shell dimensions of tumid venus clams found in both locations. A study was recently undertaken to determine the distribution and spatial variation in the population of tumid venus clam *G. tumidum* concerning habitat characteristics in both parts of Ambon Bay.

MATERIALS AND METHODS

Study Site

Tumid venus clams (*G. tumidum)* individuals were collected from April to June 2013 at Inner Ambon Bay (IAB) and Outer Ambon Bay (OAB) (Figure 1). Sampling was conducted in each month using a systematic random sampling method, by plotting a 0.5 m x 0.5 m quadrat in each station. The clams inside these transects were picked up by shoveling substrate manually to a depth of 15-20 cm. Each station consists of 3 line transects and each line transect consists of 5 quadratic transects.

Total of 9 stations, consisting of 5 stations in IAB include Tanjung Tiram (St.1: 03°39’18’’S, 128°11’56’’E); Hunuth (St.2: 03°38’01’’S, 128°12’48’’E); Passo (St.3: 03°38’15’’S, 128°14’35’’E); Lateri (St.4: 03°38’55’’S, 128°13’58’’E); and Halong (St.5: 03°39’36’’S, 128°12’31’’ E); and 4 stations in OAB include: Tantui (St.6 : 03°40’41’’S, 128°11’30’’E); Wailela (St.7 : 03°39’46’’S, 128°10’60’’E); Hative Besar (St.8 : 03°41’06’’S, 128°07’30’’E); and Tawiri (St.9 : 03°42’02’’S, 128°06’19’’E).

Sample Collection and Shell Dimensions Measurement

Twelve shell dimensions following Kong *et al.*, 2007 of all individuals were measured using a digital caliper to the nearest 0.01 mm (Figure 2). Only the left valve was measureed because, generally, tumid venus clams have the same shape for both left and right valves. Before analysis, the valves were cleaned of their soft tissue and each dimension measured precisely. Total body weight (wet weight with shell) was weighed using digital Ohaus Precision Plus® balance.

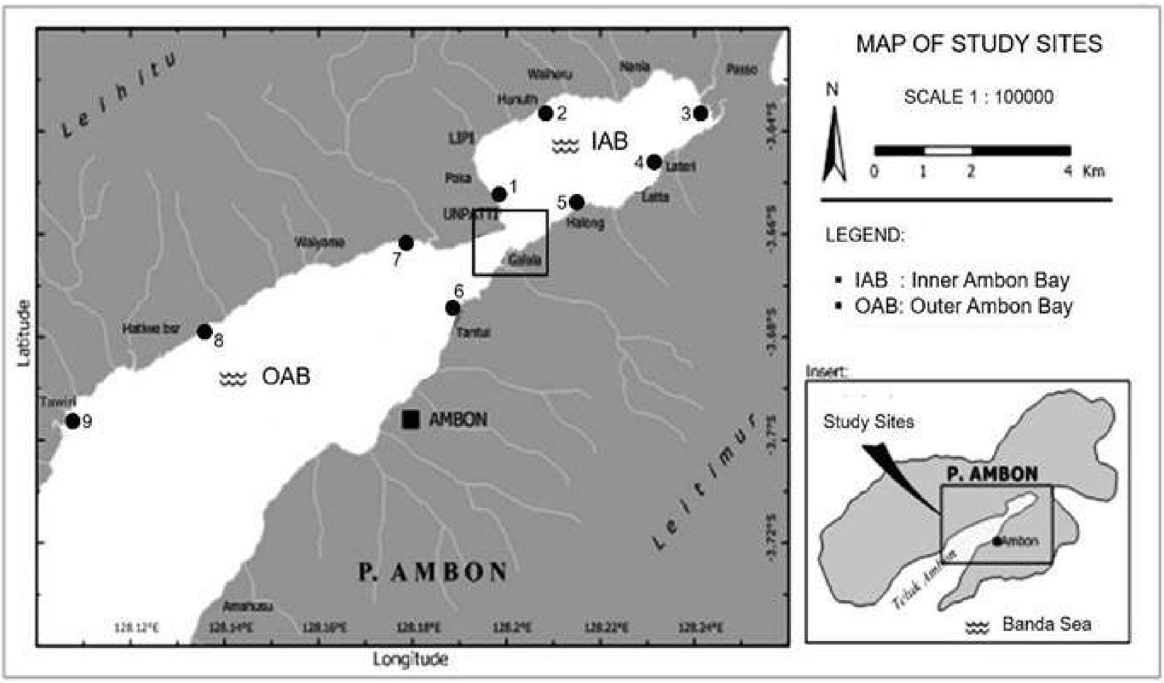

Figure. 1. Study sites (●) in Inner Ambon Bay and Outer Ambon Bay and sill (☐) between Galala and Poka.

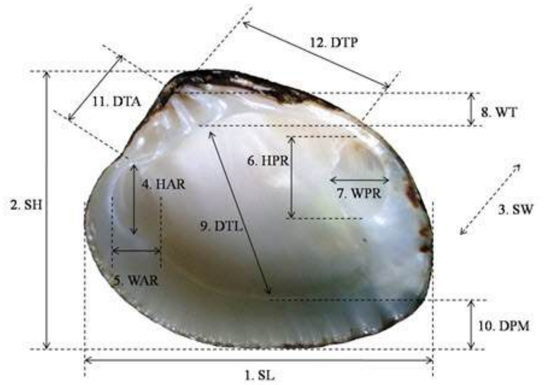

Figure. 2. Shell dimensions of venus clam *Gafrarium tumidum*. Total shell length (SL), maximum shell height (SH), total width of two valves (SW), height of anterior adductor muscle scar (HAR), width of anterior adductor muscle scar (WAR), height of posterior adductor muscle scar (HPR), width of posterior adductor muscle scar (WPR), width of cardinal tooth (WT), distance between cardinal tooth and pallial line (DTL), distance between pallial line and ventral shell margin (DPM), distance between cardinal tooth and anterior end of escutcheon (DTA), distance between cardinal tooth and posterior end of escutcheon (DTP).

Data Analysis

Size classes were determined based on the Sturge rule (Walpole, 1992). These size classes were grouped into three categories, *i.e.,* small (< 23 cm), medium (23 cm – 32 cm) and large size (> 32 cm) based on their estimated age. Small was estimated to be one year old, medium was two years old, and large was above three years old (Jagadis and Rajagopal, 2007). Size-class density was defined as the total number of individuals per unit area for each size class category. It was calculated by a formula adopted from Brower *et al.* (1990). Spatial distribution of *G. tumidum* in each station was analyzed using a multivariate Correspondent Analysis (CA) (Legendre and Legendre, 1998; Bengen 2000). Discriminant Analysis (DA) was used to evaluate spatial variation in population characteristics based on location differences and the twelve shell dimensions measured (Bengen, 2000). The purpose of this analysis includes describing, classifying and comparing groups of individuals, in this case, both IAB and OAB groups, characterized by different shell dimensions, as quantitative variables.

RESULTS

Frequency and Size-class Density

A total of 585 individuals found in nine study sites was divided into ten size-classes and grouped into three main categories (Figure 3). The highest frequency of individual size was found in the large size (207 individuals of 4 size-classes) and the lowest was found in the small size (172 individuals of 4 size-classes).

The highest value of size-class density was found in medium size individual at Station 3 (9.2 individuals/m^{-2}). In general, the total density of the medium size category (47.5 individuals/m^{-2}) was higher than large size (29.5 individuals/m^{-2}) and small size (7.2 individuals/m^{-2}).

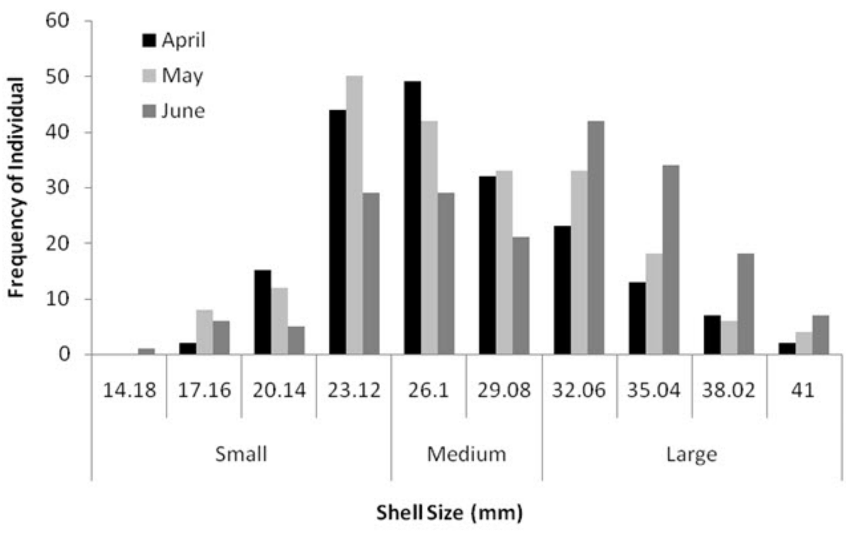

Figure. 3. The frequency of individual on each size-class categories.

Table 1. Size-class density (individuals/m²) of *G. tumidum* for each station at Inner and Outer Ambon Bay.

Size-class Category (mm)	Station								
	1	2	3	4	5	6	7	8	9
Small (< 23.11)	0.5	0.2	0.1	0.3	0.3	0.2	0.6	1.0	4.0
Medium (23.12 - 32.05)	4.9	5.7	**9.2**	5.0	2.2	2.8	6.1	5.0	6.6
Large (> 32.06)	7.2	1.2	4.0	6.9	4.8	2.8	1.7	0.6	0.3
Total	12.7	7.1	13.3	12.1	7.4	5.7	8.3	6.5	10.9

Spatial Distribution of *G. tumidum*

Assessing the spatial distribution of *G. tumidum* based on size class density was performed by Correspondent Analysis (CA). Results showed that information focused on two main axes F1 and F2 with a total of 85.4 % level of explanation, each axis explained 63.8% and 21.6% of the total variance (Figure 4a). It also showed the formation of several groups with a strong correlation between the station and size class density at the intersection of the axes F1 and F2. The first group (consists of St-1, St-4, St-5 and St-6, respectively) was characterized by a large size category. The second group (St-2, St-3 and St-7) respectively was characterized by the medium-size category, the last group (consists of St-8 and St-9) was dominated by small size category. Spatial distribution of *G. tumidum* based on size-class density for each station was illustrated in Figure 4b.

Variation in Population Characteristics of *G. tumidum*

Discriminant Analysis to evaluate spatial variation in the *G. tumidum* population characterized by twelve shell-dimensions. However, two dimensions were excluded in the discriminant model, *i.e.,* width of posterior adductor muscle scar (WPR) and the distance between the cardinal tooth and pallial line (DTL). Further, out of the ten shell-dimensions calculated in the model, only seven shell-dimensions were significant (*p-level* < α = 0.05), namely DPM, HPR, DTA, WT, SW, SH and WAR, respectively (Table 2).

On the other hand, the standardized coefficients and structure matrix of discriminant functions varied among shell-dimensions, revealing shell width (SW= 1.114;-0.323) being the most significant value and characterized as a primary distinguishing dimension between IAB and OAB population (Table 3).

An equation based on the standardized coefficients of each variable formed the discriminant function:

$$D = 6.32 - 0.34DPM - 0.35HPR + 0.64DTA - 0.29WT + 1.11SW - 0.66SH + 0.37WAR$$

D = discriminant score

The discriminant analysis also showed quite satisfactory separation of the two groups IAB and OAB (73.2% of the samples were correctly reclassified with the computed discrimination function).

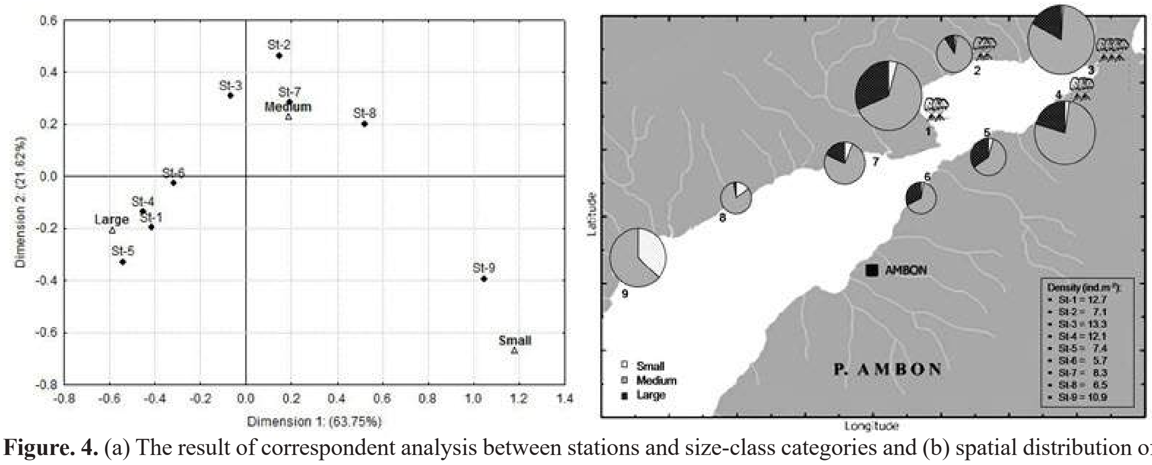

Figure. 4. (a) The result of correspondent analysis between stations and size-class categories and (b) spatial distribution of tumid venus clam *G. tumidum* in each station.

Table 2. Summary of Discriminant Analysis result for shell-dimensions of *G. tumidum* .

N = 585; Constant = 6.32 Variable	Wilks' Lambda	F-value	p-level
DPM*	0.736	7.889	0.005
HPR*	0.737	8.570	0.004
DTA*	0.759	26.448	0.000
WT*	0.732	5.226	0.023
SW*	0.783	45.518	0.000
SH*	0.733	6.108	0.014
WAR*	0.738	9.893	0.002
SL	0.730	3.639	0.057
DTP	0.730	3.313	0.069
HAR	0.730	3.233	0.073

*) Significantly influenced variables in the discriminant function

Table 3. Standardized coefficient and structure matrix of Discriminant Analysis result for shell-dimensions of *G. tumidum.*

N = 585; Constant=6.32 Variable	Standardized Coefficients	Structure Matrix
DPM	-0.337	-0.658
HPR	-0.345	-0.636
DTA	0.644	-0.165
WT	-0.291	-0.506
SW	**1.114**	**-0.323**
SH	-0.657	-0.631
WAR	0.371	-0.337
SL	-0.509	-0.637
DTP	-0.287	-0.433
HAR	-0.241	-0.576

DISCUSSION

The population of *G. tumdium* in Ambon Bay was dominated by large size or adult stage, especially in St.1, St.4 and St.5 (IAB). This result has a similar trend in other studies. Nurdin (2009) reported that the distribution of shell-length of *G. tumidum* ranged between 5.5-58.9 mm in Kabung Bay, West Sumatra. The size distribution was concentrated in three groups, small size (5.5-13.5 mm), medium (13.5-19.5 mm) and large (>19.5 mm). Larger size clams (35-45 mm) were found by Malau (2002) in Pari Island. Jagadis and Rajagopal (2007) also found various size class of *G. tumidum* in Chinnapalam, Pamban, Southeast Coast of India. The various size class suggested that the entire growth phase of *G. tumidum* either juvenile phase, youth and adults can be found throughout the year.

Total number and size-class density varied in each station, with higher figures mostly found in IAB than that in OAB. The presence of bivalves was correlated to the substrates. Based on the sediment analysis result, IAB has finer bottom substrate composition than OAB. Several studies showed that the number of species and density was related to the type of substrates. Baron and Clavier (1992b) found higher densities of individuals of *G. tumidum* in soft sediment. Batomalaque *et al.* (2010) found mollusks were distributed according to the substrate type. Only a few species were found on loose or unstable substrate while those substrates that are compact have more species. Another study (Lastra *et al.*, 2006) showed that the number of species and density of individuals increased with decreasing mean grain size of substrate.

Spatial distribution of the clams showed that large size or older individuals mostly occurred in IAB. Besides having finer sediment, IAB is also located in the inner area restricted by Galala-Poka sill (Figure 1). It protects IAB from high wave energy especially from the Banda Sea and affects the suitability of substrate as a habitat, by influencing the burrowing behavior and life habits of clams. Mangrove and seagrass in this area also provide food supply and shelter for soft bottom communities. Nagelkerken *et al.* (2008) stated that the soft bottom substrate in the mangrove vegetation provides shelter and food for macrofauna. Furthermore, the spatial distribution of some species of macrofauna was correlated with substrate grain size (McLachlan *et al.*, 1995; Dugan *et al.*, 2000). Sediment heterogeneity was a reflection of the low tidal energy observed in the inlet. This condition influenced the differential distribution of clams by size or age, primarily in the intertidal zone (Figure 5). Smaller individuals commonly occured highest on the shore and larger individuals closed to the level of low water of spring tide.

The morphological differences of *G. tumidum* populations between IAB and OAB reflected on

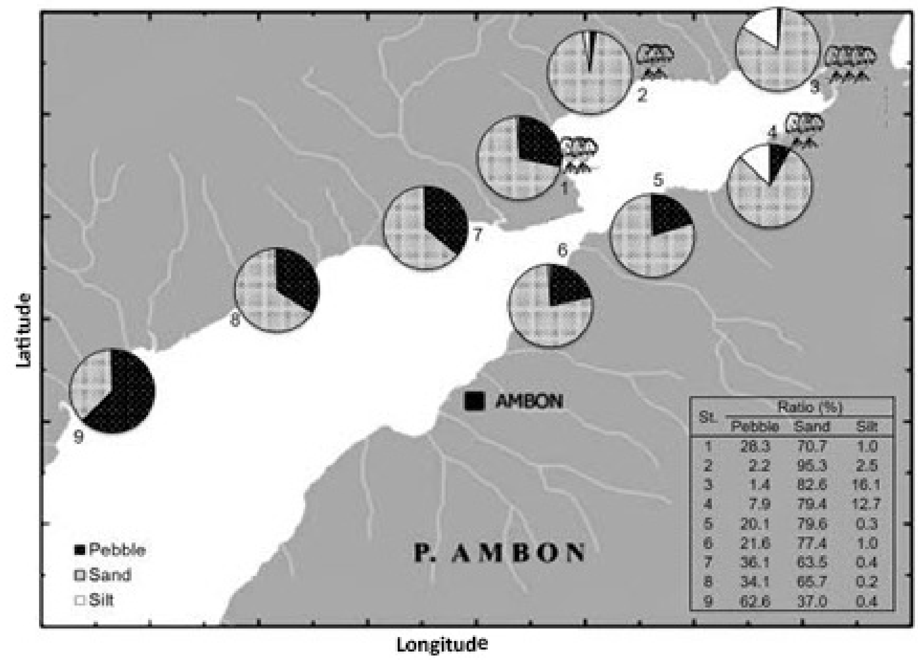

Figure. 5. The result of the particle size analysis of sediment in each station.

their shell shape, especially shell-width (SW) a dimension with the highest discriminating power for both IAB and OAB populations. Many studies stated that shell width is one of the major shell dimensions besides shell length and shell height that affects shell mass and total weight (Vakily 1988; Gimin *et al.* 2004; Huo *et al.* 2010). Kurihara (2003) stated that clam *G. tumidum* have a thick and globose shell with prominent growth lines.

From a practical point of view, generally, *G. tumidum* clams in IAB were thicker than those in OAB. This characteristic could be explained as an adaptation to different soft bottom substrates. As mentioned before, IAB is a sheltered inlet with finer sediment, low tidal energy and water current. As a result, these environmental conditions allowed the clams to grow up optimally. Kandratavicius and Brazeiro (2014) observed the effects of wave exposure on the morphological variation in *Mytilus edulis.* Their result showed that protected areas had larger shell size individuals than those in exposed areas. Savazzi and Salgeback (2004) performed a comparative analysis in *Cardium* and *Budmania*, and found that sharp ribs of shell width offer strength to the clams and providing a larger shell area in contact with the substrate.

Thinner shell shape of *G. tumidum* in OAB was likely caused not only by the environmental factors like substrate, turbulence and currents but also as a strategy to counter stressor or predator, for instance, crab and fish. Hard bottom sediment with no mangrove vegetation in OAB may not support the growth of clams. Shell shape was not wider under the pressure of the surrounding sediment. Differences in shell size and morphology due to environmental factors and geographic differences were also observed in *Ruditapes philippinarum*, *R. decussatus,* and bivalves (Costa *et al.*, 2008; Kanazawa and Sato 2008; Caill-Milly *et al.*, 2012).

Thinner or flatter clams, however, have benefits in their rapid mobility and burrowing ability. Bivalves possibly possess a thin shell or body to avoid the stresses of quick mobility. For example, *Ruditapes variegatus* burrows into the sediment on a cobbled shore rapidly during both high and low tides (Kurihara, 2003). McLachlan (1990) stated that substrate particle size, sediment permeability and water condition influenced the burrowing activity of bivalves. Generally, smaller individuals move faster than larger ones and consequently, older clams were more susceptible to a predator, including exploitation by human activity.

CONCLUSION

This study revealed the spatial variation of tumid venus clam *G. tumidum* population in IAB and OAB, and described their morphological differences based on shell dimensions. The population density was dominated by medium size individuals. Shell width was a variable with the highest discriminating power and characterized as a primary distinguishing dimension between IAB and OAB population. Different circumstances, *for example,* bottom substrates and vegetation between IAB and OAB possibly causing population differences.

In recent years, human activities have changed Ambon Bay and affected the clam population and another biota. Further studies on macrofauna assemblages are required to assess the anthropogenic impact on these areas.

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