Assessment of *Corbicula moltkiana* Growth by Different Methods on Variation of Substrates in Lake Maninjau, West Sumatera, Indonesia

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**Abstract.** *Corbicula moltkiana* is a mussel species in Lake Maninjau and one of the targeted fisheries resources in the lake. This study aimed to determine the feasibility of a controlled growth experiment of mollusk biota in describing their natural growth. The assessment was carried out in areas with different habitats in shore lake, namely sand and gravel-stone substrates. A consecutive 12 month- sampling was carried out from June 2013 to May 2104 using a Surber sampler at a 1-3 m depth were used to assess the wild population growth. Moreover, the growth of the controlled population was observed by rearing various sizes of mussels in artificial substrate namely three small baskets which installed in the shore area with 1-3 m depth at each station for four months. Monthly sampling was carried out to measure the shell length. The growth of *C. moltkiana* on wild population by VBGF methods show that at the gravel-stone substrate was higher, but the growth a controlled population in artificial substrate seemed in the sand substrate was higher than that in the gravel-stone substrate. The growth of aquatic biota in a controlled system (especially *C. moltkiana*) does not always reflect similar conditions to their wild growth.

1. **Introduction**

*Corbicula moltkiana*, Prime 1878 is a freshwater mussel inhabiting Lake Maninjau, West Sumatra. This species has been distributed from Sumatra to the Malay Peninsula and also found in other lakes in Sumatra i.e. Lake Singkarak, Lake Ditas, and Lake Ranau [1]. *Corbicula moltkiana*, locally known as Pensi, is a unique biological resource in Lake Maninjau and has become a target of fishing activity as the local people livelihood. The fishing of the mussel takes place almost along the shore of the lake, and the production can reach 750 tons per year [2]. The exploitation of *C. moltkiana* by the local community is quite popular and become a tourist icon commodity of Lake Maninjau, even though, it is a relatively small fishery activity compared to capture fisheries of other fish and fish culture in floating net cages [3].

The population of *C. moltkiana* in Lake Maninjau has been reasonably abundant with the density ranging from 148 to 3994 ind.m⁻² and has become the most dominant benthic biota. Substrate type significantly influences the presence of Pensi where they are more abundant in sand substrate compared
to other substrates [4]. According to [4], sand substrate is only found on the north and east shores of the lake, meanwhile, the south and west shores are dominated by the gravel-stone substrate.

An important characteristic of the aquatic biota population is the growth pattern that will characterize the integration of their habitat conditions [5]. The growth and also glycogen levels of mussels can provide an overview of population health and environmental conditions both in the past and present [6]. Sand and gravel-stone are the most dominant C. moltkiana habitat substrates in Lake Maninjau. The different locations and other environmental parameters can affect the shape and size of bivalvia shell spatially [7] [8] and under suitable environmental conditions allowed growth optimally [9]. Moreover, shore conditions can influence the survival and growth of the invertebrate community especially in the juvenile stage [10]. Therefore, further investigation of how these two different habitats support C. moltkiana populations is required.

Studies on the growth dynamics of many commercial molluscs, especially in marine waters, have been carried out [11][12][13]. Unfortunately the growth study of aquatic biota on Indonesian inland waters is rarely done. This is because the study on biotic growth generally requires a long time and maximum effort. On the other hand, the intensive use of a biota really requires basic observations regarding the condition of its population, including its growth rate. The alternatives of method for biota growth assess with methods other than VBGF are urgently needed. Thus, the research is needed to compare the other methods with VBGF model as basic mesure for measuring biotic growth. The purpose of this study was to determine the feasibility of a controlled growth experiment of mollusk biota in describing their natural growth.

2. Materials and Methods

2.1 Study area and sampling design
Lake Maninjau (0°19′S, 100°11′E), a volcano-tectonic lake with an area of 97.4 km2, is located in West Sumatra Province, Indonesia. The functions of Lake Maninjau are for tourism, source of water for hydropower power plant, fisheries activity, and cage aquaculture, and as a source of raw material for drinking water. The cage aquaculture activity which distributed evenly in a long coast of the lake and the number of the cage in Lake Maninjau in 2013 was 18630 units. Based on total nitrogen and total phosphorus indicate that the water of Lake Maninjau indicates in eutrophic condition [14].

This study was carried out at two stations where Station 1 (Sta. 1) represents the sand substrate areas and Station 2 (Sta.2), represents the gravel-stones substrate areas (Figure 1). Furthermore, the growth of C. moltkiana would be assessed based on two approaches consisting of the growth of the wild population and controlled population in a natural environment.

2.2 Growth of wild population
The study of the wild population of C. moltkiana was conducted from June 2013 to May 2014 in the fourth week of every single month. The samples were collected using a Surber sampler with 0.4 x 0.5 m² area which was operated at a 1 m depth. At each sampling station, there were three transects installed parallel to the coastline, with 50 m distance between the transects. Subsequently, the C. moltkiana was sorted out using a sieve with a mesh size of 1 mm, and the anterior-posterior length of each individual was measured to the lower 0.01 mm with an electronic digital caliper.

Growth parameters were estimated following recognizable cohorts with size-frequency distribution from the successive 12 monthly sample dates. The growth was described by the von Bertalanffy growth function (VBGF) [15] as follows:

\[ L_t = L_\infty \left(1 - e^{-k(t-t_0)}\right) \] (1)

Where \( L_t \) was the shell length (mm) at time \( t \) (year), \( L_\infty \) was the asymptotic or theoretical maximum length (mm), \( k \) was the rate at which \( L_\infty \) was approached (year\(^{-1}\)) and \( t_0 \) was the theoretical age at which \( L_t = 0 \) (year). The infinity length (\( L_{\infty} \)) was estimated based on the biggest sample (\( L_{max} \)) following Taylor (1958) in [16]:

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\[ L_\infty = \frac{L_{\text{max}}}{0.95} \quad (2) \]

Furthermore, the growth coefficient (k) was estimated using ELEFAN I (Electronic frequency analysis) I in FiSAT II package (FAO-ICLARM Stock Assessment) [17]. Theoretical age at zero-length was estimated partially using Pauly’s empiric equation [18] as follows:

\[ \log (-t_0) = -0.392 - 0.275(\log L_\infty) - 1.038(\log k) \quad (3) \]

The life span \( t_{\text{max}} \) of \( C. \text{moltkiana} \) theoretically was estimated by the inverse of the von Bertalanffy growth equation i.e. maximum shell length as 95% of the asymptotic length [19]:

\[ t_{\text{max}} = \frac{[\ln \ln L_{95\%} - \ln \ln (L_{\infty} - L_{95\%})]}{k} \quad (4) \]

Finally, the overall growth performance index [19]

\[ \text{OGP} = \log (K[L_{\infty}]^3) \quad (5) \]

Which represents growth rate at the point of inflexion of the size–growth curve [18] was calculated to compare the growth of \( C. \text{moltkiana} \) between two substrate types.

2.3 Growth of controlled population
The growth of the controlled population in natural conditions was observed by conducting an experiment directly in the lake waters, by rearing a number of \( C. \text{moltkiana} \) in a small basket (40 x 20 x 15 cm³) made of wire mesh (0.5 cm mesh size). Three baskets were installed at the bottom of the shore area at a 1 – 3 m depth in each station.

The \( C. \text{moltkiana} \) was divided into three size groups based on shell length measured from anterior to posterior. The size groups were small (S) (10-12 mm), medium (M) (16-18 mm), and large (L) (20-22 mm). The grouping of test size was based on the maximum shell length of the \( C. \text{moltkiana} \) found on

![Figure 1. Substrate type distribution of the shore area of Lake Maninjau [4] and observation stations.](image)
wild population that reach 25 mm, so that the size of the experiment animal group was divided into three size groups.

In order to adjust the wild population condition, each basket was reared with various sizes of *C. moltkiana* consisting of the sizes of S, M, and L as 50, 25, and 13 individuals, respectively. Furthermore, the measurement was conducted once a month for four months. The shell length of all individuals was measured using an electric digital caliper with an accuracy of 0.01 mm.

3. Results and Discussion

3.1 Growth of wild population

The size-frequency distributions were analyzed for recognizable cohorts. During the 12 months of sampling, we observed 3 and 4 distinct cohorts from two stations of Station 2 and Station 1 respectively (Figure 2). The smallest cohort ranged between 2.22 and 4.54 mm and the biggest cohort length between 24.77 and 25.00 mm.

![Figure 2. Estimated cohorts and VBGF curve of *C. moltkiana* at Station 1 and 2](image)

Moreover, the estimated VBGF parameters are presented in Table 1. The *OGP* index was included in order to compare *C. moltkiana* population growth between Station 1 and 2. The index is habitat-specific and suitable inter- and intraspecific comparison even for various clam species. *OGP* is proportional to the maximum rate of body mass increase during a lifetime, i.e. mass increase at the inflexion point of the VBGF [19].

The growth of *C. moltkiana* is relatively higher than another sea clam that has been observed in Indonesian waters, namely razor clams (*Solen regularis*) on the East Java coast. With the theoretical maximum length (*L∞*) 8.0 cm (80 mm) the annual growth rate (*k*) of *S. regularis* reached 0.7 year⁻¹ [20].

The *L∞* of *C. moltkiana* at the two stations was almost similar. However, the growth constant (*k*) and the *OGP index* varied, indicating that the growth rate in Station 2 tended to be higher than that in Station 1.
This shows that the gravel-stone habitat (Sta.2) appeared more suitable to support the growth of *C. moltkiana* compared to sandy habitat. This condition is almost similar to the clam species of *Mya arenaria* in the White Sea that showed the highest growth rate in habitats with the lowest silt and clay content [5]. The growth differences of the same clam population could occur, as reported in *Glycymeris nummoria* Linnaeus (1758) from eastern Adriatic [21].

### Table 1. The estimated von Bertalanffy Growth Function parameters of *C. moltkiana*

| Station | $L_\infty$ (mm) | $k$ (y$^{-1}$) | $t_0$ | $t_{\text{max}}$ (y) | OGP |
|---------|----------------|---------------|-------|---------------------|-----|
| 1       | 26.32          | 0.81          | -0.21 | 3.64                | 1.46|
| 2       | 26.07          | 1.20          | -0.14 | 2.45                | 1.65|

However, the growth parameters of mollusc (Bivalvia) were unequal even within one species. These parameters could be varied, as in and *Mesodesma macroides*, *Mya arenaria*, *Ruditapes philippinarum*, *Tagelus plebeius* species mainly related to location (latitude; country) and time differences (Table 2).

### Table 2. The growth performance of several bivalvia species

| Species             | $L_\infty$ (mm) | $k$ (y$^{-1}$) | Life span (y) | References |
|---------------------|----------------|---------------|---------------|------------|
| *C. moltkiana*      | 26.1 - 26.3     | 0.81 - 1.20   | 2.4 - 3.6     | This study |
| *M. matroides*      | 74.7 - 85.0     | 0.47 - 0.48   | 6             | [19] [22] |
| *M. arenaria*       | 82.0            | 0.06          | 20            | [5]        |
| *R. philippinarum*  | 46.6 - 51.0     | 0.17 - 0.34   | 6             | [23] [24] |
| *T. plebeius*       | 74.1 - 67.0     | 0.52 - 1.73   | 1.6 - 2.6     | [25] [26] |

Based on these growth parameters, the $k$ value of *C. moltkiana* was considerably high with a short life span (3.6 years), indicating the relatively fast turnover or renewed rate of the *C. moltkiana* population. These conditions allow the potential production of *C. moltkiana* in Lake Maninjau to be reasonably high, marked by an intensive fishing activity [2]. In addition, there were four and three identified cohorts at Station 1 and Station, respectively (Fig. 2). The existence of several different cohorts in the *C. moltkiana* population, as stated by [25], can also be related to the short life span of the Bivalvia species.

Various distinct cohorts reflect differences in juvenile settlement [5]. A settlement is the transition process from the planktonic larval phase in the water column to the benthic phase at the bottom. The settlement processes of juvenile, particularly post-settlement processes, are the main factors of the recruitment success, although temporal variability and size of the mussel also influence the settlement pattern [27][28][29]. Hence, in this study, based on the presence of the cohort, it appears that the sand substrate is more encouraging for larva recruitment. A previous study of *Ruditapes philippinarum* showed that the grain size of the substrate has no effect, but without substrate, the settlement of larvae is very low [30].

### 3.2 Controlled growth experiment

The survival rate (SR) of the tested *C. moltkiana* ranged from 59 to 61%. On size L was the highest SR (61%; average), and from S to L size was 21.6%, cumulatively (Table 3). During this experiment, the
maximum shell length of *C. moltkiana* reached 25.00 mm and the minimum was 2.22 mm, both of them were found at Station 1.

**Table 3. Survival rate (SR) of tested *C. moltkiana***

| Location | Size | ∑Initial individu als | ∑Final individu als | Survival Rate (%) | Average of Survival Rate from two stations (%) |
|----------|------|------------------------|---------------------|-------------------|---------------------------------------------|
| Sta. 1   | S    | 150                    | 88                  | 58.7              | S = 59.3                                    |
|          | M    | 75                     | 45                  | 60.0              | M = 59.3                                   |
|          | L    | 39                     | 22                  | 56.4              | L = 61.5                                   |
| Sta. 2   | S    | 150                    | 90                  | 60.0              | Survival cumulative from S to L size:       |
|          | M    | 75                     | 44                  | 58.7              |                                             |
|          | L    | 39                     | 26                  | 66.7              | 59.3% × 59.5% × 61.5% = 21.62%.             |

Furthermore, the survival rate (SR) of the controlled population showed that there was still the potential of *C. moltkiana* mortality as >80% (SR<21.2%) from the larvae to the adult stage. Based on the studies of 20-30 papers, [31] suggested that the mortality of marine invertebrates was high, more than 90%, mainly found in the juvenile phase. The phenomenon at older *C. moltkiana* where the lower growth rate was found, it seems to be general in mollusc species, as on *M. mactroides* and *Glycymeris longior* growth. The first two-year growth (from 7-8 years life span) of *M. mactroides* in the Argentina coast was very fast and decreased during the following years [22]. A similar pattern found on *G. longior* species in the Argentina sea showing a rapid growth rate in early life and would decrease in subsequent years [32], and also on the clam *Ensis arculatus* which demonstrate a swift growth in the first three years and after the third year. The growth gradually declines between the fourth and sixth year [33].

The growth rate represented by shell length increment of *C. moltkiana* varied at each group of S, M, or L. However, the length increment decreased in line with the size group increased that parallel to age (Figure 3).

![Figure 3](a)

**Figure 3. Length increment of different sizes group of *C. moltkiana* at (a) Station 1 and (b) Station 2**

The length increment of *C. moltkiana* showed that the growth tended to be slower at the end of the experiment period. During the approximate 90 days of the observation period, the length increment of
**C. moltkiana** in Sta.1 for S size was 3.56 mm and 1.53 mm for L size, while in Sta.2, the length increment for L size was 0.60 and 3.00 mm for S size (Figure 4).

![Figure 4. Average of length increment of *C. moltkiana* at the two stations](image)

**The measurement of *C. moltkiana* size at the two experimental sites shows that the length increment at Sta. 1 was higher than that of Sta. 2 (Figure 5).**

![Figure 5. Length increment patterns of *C. moltkiana* from two experimental sites](image)

**Based on the growth patterns of *C. moltkiana* at two experimental sites, it can be expected that Sta. 1 is more appropriate to support the growth of *C. moltkiana* than Sta. 2. Hence, the sand substrate might be a more suitable habitat for *C. moltkiana* than the gravel-stones substrate. Although, both substrate conditions play an important role in determining different growth patterns of the mussel. This result is similar to that obtained by [25] who found that fine sediment with high organic matter could encourage mussel growth due to the high environmental stability and availability of food for suspension-feeding biota.**

The growth of *C. moltkiana* at Station 1 and Station 2 show a different rate between wild and controlled population where the growth rate of the wild population was found higher in Station 2 with a gravel-stone substrate. Vice versa, the controlled experiment showed that *C. moltkiana* grew better in Station 1 with sand substrate. It might be due to the limitation conditions at the controlled experiment where the wild population *C. moltkiana* is relatively buried in the substrate freely. Meanwhile, in the controlled experiment, their burying activity has been restricted, even though they hide in the substrate.

The growth of a mussel is a complicated process. For instance, *Glycymeris* sp. growth is affected by various environmental factors [34]. However, according to [19], *D. hanleyanus* growth is presumably determined by water temperature and food availability. Meanwhile, based on the study of [35], *G.*
vanhengstumi growth at NE Atlantic is influenced by the primary production of the surface water, which is controlled by the trophic state of the photic zone. Therefore, the growth of *C. moltkiana* in the controlled experiment may also be supported by the primary production of the surface water because they stay outside the substrate more frequently. However, as a filter-feeding species, particularly phytoplankton, the grazing rate is strongly influenced by the hydrodynamic process. The flow or movement of water, even only a thin layer of water around the substrate, will be a significant supplier of food sources of a mussel [36]. Station 1 is located on the middle edge of the lake, while Station 2 is on the southern side of the lake (Figure 1). The existence of a cape on the east and west part of Lake Maninjau will further limit the movement of water mass in the southern part of the lake. Therefore, it assumed that the flow of a water mass that supplying plankton would be relatively lower at Station 2. It is an expected factor that allows the growth of *C. moltkiana* in a controlled experiment at Station 1 to be higher than that at Station 2.

4. Conclusion
There was the difference in growth result of *C. moltkiana* which measured by two methods, for natural and the controlled population respectively. The growth of *C. moltkiana* on wild population by VBGF methods show that at the gravel-stone substrate was higher, but on controlled population in artificial substrate seemed in the sand substrate was higher. From those study shows that the growth of aquatic biota in a controlled system (especially *C. moltkiana*) does not always reflect similar conditions to their wild growth.

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References
[1] Djajasasmita M. 1977. Bulletin Zoologisch Museum Universiteit van Amsterdam, 6 (1), 1 – 9. https://eurekamag.com/research/004/717/004717444.php
[2] Lukman L, I S, I M and S. H 2018 Adv. Soc. Sci. Res. J. 5 72–82
[3] Anonymous. 2015. Laporan produksi perikanan Kabupaten Agam, Provinsi Sumatera Barat tahun 2014 (Fisheries Production Report in Agam District-West Sumatera in 2014). Marine and Fisheries Board of Agam District-West Sumatera Province (unpublished)
[4] Lukman, I. Setyobudiandi, Muchsin I and Hariyadi S 2015 Limnol 22 12–21
[5] Gerasimova A V., Martynov F M, Filippova N A and Maximovich N V. 2016 Helgol. Mar. Res. 70 1–14
[6] Hornbach D J, Stutzman H N, Hove M C, Kozarek J L, MacGregor K R, Newton T J and Ries P R 2021 Hydrobiologia 848 3045–63
[7] Caill-Milly N, Bru N, Mahé K, Bortie C and D’Amico F 2012 J. Mar. Biol. 2012 1–11
[8] Kandratavicius N and Braziero A 2014 J. Aquat. Sci. 9 31–8
[9] Islami M M, Bengen D G and Dody S 2018 Gafrarium tumidum Röding, 1798 (Bivalvia: Veneridae) in Ambon Bay, Maluku Mar. Res. Indones. 43 63–70
[10] McDevitt-Irwin J M, Iacarella J C and Baum J K 2016 Mar. Ecol. Prog. Ser. 557 133–43
[11] Ferreira J G, Corner R A, Moore H, Service M, Bricker S B and Rheault R 2018 J. Shellfish Res. 37 709–26
[12] Mugabe E D, Amoda C A and Griffiths C L 2019 African J. Mar. Sci. 41 385–93
[13] Saraiva S, Fernandes L, van der Meer J, Neves R and Kooijman S A L M 2017 Ecol. Modell. 359 34–48
[14] Lukman, Stryobudiani I, Muchsin I and Hariyadi S 2015 Int. J. Sci. Basic Appl. Res. 23
120–37

[15] Anon 2013 A Quantitative theory of organic growth (Inquiries on growth laws II) Author (s): Ludwig Von Bertalanffy Published by: Wayne State University Press 10 181–213

[16] Nwosu F and Woli M 2009 West African J. Appl. Ecol. 9 1–14 FAO/ICLARM stock assessment tools (FISAT). User’s Guide FAO Comput. Inf. Ser. 8

[18] Pauly D. 1979. Theory and management of tropical multispecies stocks: a review with emphasis on the Southeast Asian demersal fisheries ICLARM Study Review, 1, 35

[19] Herrmann M, Alfaya J E F, Lepore M L, Penchaszadeh P E and Arntz W E 2011 Population structure, growth and production of the yellow clam Mesodesma mactroides (Bivalvia: Mesodesmatidae) from a high-energy, temperate beach in northern Argentina Helgol. Mar. Res. 65 285–97

[20] Trisyani N, Herawati E Y, Widodo M S and Setyohadi D 2016 Biodiversitas 17 808–13

[22] Fiori S M and Morsán E M 2004 ICES J. Mar. Sci. 61 1253–9

[23] Choi Y-M, Yoon S-C, Lee S-I, Kim J-B, Yang J-H, Yoon B-S and Park J-H 2011 T J. Malacol. 27 107–14

[24] Yoon H-S, An Y-K, Kim S-T and Choi S-D 2011 Korean J. Malacol. 27 1–7

[25] da Silva C F, Corte G N, Yokoyama L Q, Abrahão J R and Amaral A C Z A 2015 Helgol. Mar. Res. 69 1–12

[26] Abrahão J R, Cardoso R S, Yokoyama L Q and Amaral C Z A 2010 Zoologia 27 54–64

[27] Fuente-Santos I and Labarta U 2015 Reg. Stud. Mar. Sci. 2 1–10

[28] South P M 2016 J. Exp. Mar. Bio. Ecol. 482 64–74

[29] Azpeitia K, Rodríguez-Ezpeleta N and Mendiola D 2019 Reg. Stud. Mar. Sci. 27 100523

[30] Tezuka N, Kanematsu M, Asami K, Sakiyama K, Hamaguchi M and Usuki H 2013 Effect of salinity and substrate grain size on larval settlement of the asari clam (Manila clam, Ruditapes philippinarum) J. Exp. Mar. Bio. Ecol. 439 108–12

[31] Gosselin L A and Qian P Y 1997 Mar. Ecol. Prog. Ser. 146 265–82

[32] Gimenez L H, Doldan M del S, Zaidman P C and Morsan E M 2020 Helgol. Mar. Res. 74

[33] Hernández-Otero A, Gaspar M B, Macho G and Vázquez E 2014 J. Sea Res. 85 59–72

[34] Peharda M, Black B A, Purroy A and Mihanović H 2016 Mar. Environ. Res. 119 79–87

[35] Németh A and Kern Z 2018 Earth Sci. 6 1–13

[36] Lassen J, Kortegård M, Riisgård H U, Friedrichs M, Graf G and Larsen P S 2006 Mar. Ecol. Prog. Ser. 314 77–88