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Density, Growth Pattern and Condition Index of Western Hemisphere Blue Mussel (*Mytella charruana*) in the Riverine System of Binmaley, Pangasinan, Philippines

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Abstract *– The density, growth pattern and condition index of western hemisphere blue mussel Mytella charruana d'Orbignyi, 1846 (Bivalvia: Mytilidae) were assessed in the mangrove, residential and aquaculture areas including its riverbeds in the riverine system of Binmaley, Pangasinan, Philippines. Data were gathered through descriptive field survey using wooden quadrat. Inferential statistics was employed to analyze the data. There were 9 species of shell mollusks identified in the riverine system of Binmaley, with M. charruana as the most abundant both in surface and riverbed of the sampling areas (61.71% and 75.58%, respectively).The highest mean density of M. charruana in both surface and riverbeds was observed in mangrove area with 1045.6 individuals m^{-2} (36.44%) and 840.8 individuals m^{-2} (36.06%), respectively. The high density and abundance of M. charruana in the sampling areas indicates its resiliency to wide range conditions of the riverine systems. The growth pattern of M. charruana in three sampling areas demonstrate negative allometric ($b<3.0$) which suggest that the species tended to be narrower (flatter) as it increased in length as it grows. Highest mean condition index was observed in aquaculture area (17.35 %) which suggests that the mussels are in a healthy condition and suitable to be sold in the market and for aquaculture. In 2015, Vallejo et al. (2017) cited that the Bureau of Fisheries and Aquatic Resources noted that this species is used for mariculture in Lingayen Gulf. However, no significant differences ($p>0.05$) were observed in all sampling areas in terms of samples condition index. Moreover, the water quality parameters in three sampling areas were favourable to the growth of M. charruana.*

Keywords *– western hemisphere blue mussel, Mytella charruana, density, growth pattern, condition index.*

INTRODUCTION

Binmaley is one of the coastal areas along Lingayen Gulf that is endowed with vast brackishwater rivers or estuaries which are conserved, managed and utilized for capture fisheries and water source for brackishwater aquaculture. The municipality has a total land area of 6,120 hectares (Bravo et al., 2011). Its bodies of water are rich in marine life which serves as the source of livelihood of the local fishermen who operate various types of fishing apparatus, keep fish cages and raise oysters in cultured beds and the others engage themselves in offshore fishing in Lingayen Gulf**.**

Binmaley river is located along the Sinocalan-Dagupan riverine system which covers 23 barangays. Riverine systems of Binmaley are complex aquatic ecosystems governed by physical, chemical and biological factors. Such biological factor is the presence of benthic fauna such as mussel that play an important role in the intrinsic and extrinsic ecology influencing dynamics of this type of aquatic ecosystems.

Western hemisphere blue mussel (*M. charruana*) is a mussel with dark brown to bluish black external shell with semi-circular rings with a wavy dark pattern (Rosario & Salinas, 2016). It could thrive in brackishwater with salinity of 22 ppt. This exotic blue mussel was a native species in tropical Eastern Pacific Guaymas and first appeared in Manila Bay specifically in Cavite Province (South Manila Bay) in early 2014. It was probably introduced in 2013 via transPacific shipping through Panama Canal to Manila. Also, it was found in Tambac Bay in 2014 dominating in wet season

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and alternating with *Perna viridis* in dry summer (Rice et al., 2016).

At present, no data are available on density, growth pattern and condition index of western hemisphere blue mussel in Binmaley River System (Municipal Agriculture Office-Binmaley, 2018). Related to that, recent reports appeared the widespread of western hemisphere blue mussel (*M. charruana*) throughout entire Dagupan-Binmaley-Lingayen Estuary System, Pangasinan from 2014 to 2016 (Rice et al., 2016). It populates some areas of Northern Philippines including the said estuary systems and is increasing abundantly. Hence, this study was being conducted to assess the present status of western hemisphere blue mussel in the riverine system of Binmaley, Pangasinan, Philippines.

OBJECTIVES OF THE STUDY

This study aimed to determine the density, growth pattern and condition index of western hemisphere blue mussel (*M. charruana*) in the riverine systems of Binmaley, Pangasinan, Philippines.

Specifically, the study sought to answer the following questions:

1. What are the species compositions of shell mollusks in the three sampling areas (mangrove area, residential area, and aquaculture area)? ;
2. What is the density of western hemisphere blue mussel (*M. charruana*) and other shell mollusks thriving in the surface and riverbed of the three sampling areas?;
3. What is the growth pattern of *M. charruana* using length and weight relationship? ;
4. What is the condition index of *M. charruana* thrive in the riverine system?; and
5. What are the physico-chemical characteristics of the river waters in terms of: water depth, temperature, salinity, dissolved oxygen, pH and chlorophyll-*a* concentration?

MATERIALS AND METHODS

The study employed a descriptive field survey research. A total of 15 sampling points per samplings areas (mangrove area, residential area, and aquaculture area) were established in the Binmaley riverine system (Fig. 1). Each sampling stations were characterized with an assemblage of fish/cage structures, mangroves and houses adjacent to the river. *M. charruana* were collected from the walls and prop roots of the aquaculture, residential and mangrove areas using a wooden quadrat, respectively. Local divers were commissioned in gathering *M. charruana* into the riverbed of the sampling areas. The area was determined to estimate the density of *M. charruana* within the sampling areas. Subsequently, body weight and the total length of each sample were measured using digital caliper and digital weighing scale at the PSU-Binmaley Campus Fisheries Science Laboratory. Length-weight relationship was established through the use of linear regression analysis. For the condition index, thirty specimens per sampling points in each sampling areas were shocked using knife and soft tissues were removed from its shell and weighed individually using a digital weighing scale. Dried in an oven at 70˚C for 24 hours and weighed. Determining the condition index of *M. charruana* was based on the formula cited by Lucas and Beninger (1985). Chlorophyll *a* concentration analyzed through the use of spectrophotometer. Water parameters such as water depth, temperature, salinity, water pH and dissolved oxygen were monitored once in every sampling point using a tag rope with sinker, YSI DO meter Model 55, refractometer, thermometer and digital pH meter, respectively. Data on relative density was subjected to

Figure 1.Location of the sampling areas in the riverine system of Binmaley, Pangasinan, Philippines.

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two-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) to test for significant differences among the sampling areas and shell mollusks species means at 0.05 levels.

Results and Discussion

Species Composition

The result showed that there were 9 species of shell mollusks being identified, namely: *Mytella charruana*, *Modiolus philippinarium*, *Perna viridis*, *Crassostrea malabonensis*, *Crassostrea iredalie*, *Littorina littoralis*, *Isognomon ephippium*, *Polymesoda erosa* and *Telescopium telescopium* (see Table 1).

Among the species of shell mollusks identified, *M. charruana* or western hemisphere blue mussel is the new emerging species in the riverine system of Binmaley. According to Rice et al. (2016), these mussels were originated from the Brazilian and Columbian coast of South America transversing the Panama Canal reaching coastal waters of Philippines (the first country in Southeast Asia to report the presence of western hemisphere blue mussel) by way of tropical Eastern Pacific.

Table 1. Species of shell mollusks present in surface and riverbed of the three sampling areas in the riverine system of Binmaley, Pangasinan, Philippines.

SHELL MOLLUSKS IDENTIFIED	MANGROVE		RESIDENTIAL		AQUACULTURE	
	SURFACE	RIVERBED	SURFACE	RIVERBED	SURFACE	RIVERBED
Mytella charruana	+	+	+	+	+	+
Modiolus philippinarium	+	+	+	+	+	+
Perna viridis	+	+	+	+	+	+
Crassostrea malabonensis	+	+	+	+	+	+
Crassostrea iredalie	+	+	+	+	+	+
Littorina littoralis	+	+	+	-	-	+
Isognomon ephippium	+	-	-	-	+	-
Polymesoda erosa	-	+	-	+	-	+
Telescopium Telescopium	-	-	-	+	-	-

Legend: (+) = indicates that species of shell mollusks were present in the area
(-) = indicates that species of shell mollusks were absent in the area

It was found in Tambac Bay, Pangasinan in July 2014 dominating in the wet season and alternating with *P. viridis* in dry summer but beginning in early 2014 it was observed in the region of Bacoor Bay, Cavite in Manila Bay. The accidental introduction of this species displays competition to the native mussels (*P. viridis*) and oysters (*Crassostrea*) which populated any colonizable substrate where population based on this study is significantly highest to all identified shell mollusks species because it has a potential to reproduce rapidly. Moreover, in the study of Rosario and Salinas (2016), this species is resilient in different ranges of temperature and salinity becoming a potential invasive species.

Density of Western Hemisphere Blue Mussel

The density of western hemisphere blue mussel (*M.* charruana) collected on the surface area of the three sampling areas in the riverine system of Binmaley, Pangasinan is presented in Fig. 2. The data obtained shows that the Mangrove Area got the highest mean density of western hemisphere blue mussel with 1045.6 individuals m^{-2} that comprised a relative density of 36.44%. This was followed by Residential Area with 960.8 individuals m^{-2} (33.48% relative density) and Aquaculture Area with 863.2 individuals m^{-2} (30.08% relative density). However, Analysis of Variance revealed that mean density of western hemisphere blue mussel in the surface area in each sampling areas failed to show significant differences (P>0.05).

Likewise, in the riverbeds of each sampling areas in the riverine system of Binmaley, Pangasinan, Mangrove Area also obtained the highest mean density of western hemisphere blue mussel with 840.8 individuals m^{-2} (Fig. 2) that comprised a relative density of 36.06%. This was

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followed by Aquaculture Area with 803.2 individuals m^{-2} (34.45% relative density) and Residential Area with 687.7 individuals m^{-2} (29.49% relative density). However, Analysis of Variance revealed that mean density of western hemisphere blue mussel in the riverbeds of each sampling areas failed to show significant differences (P>0.05).

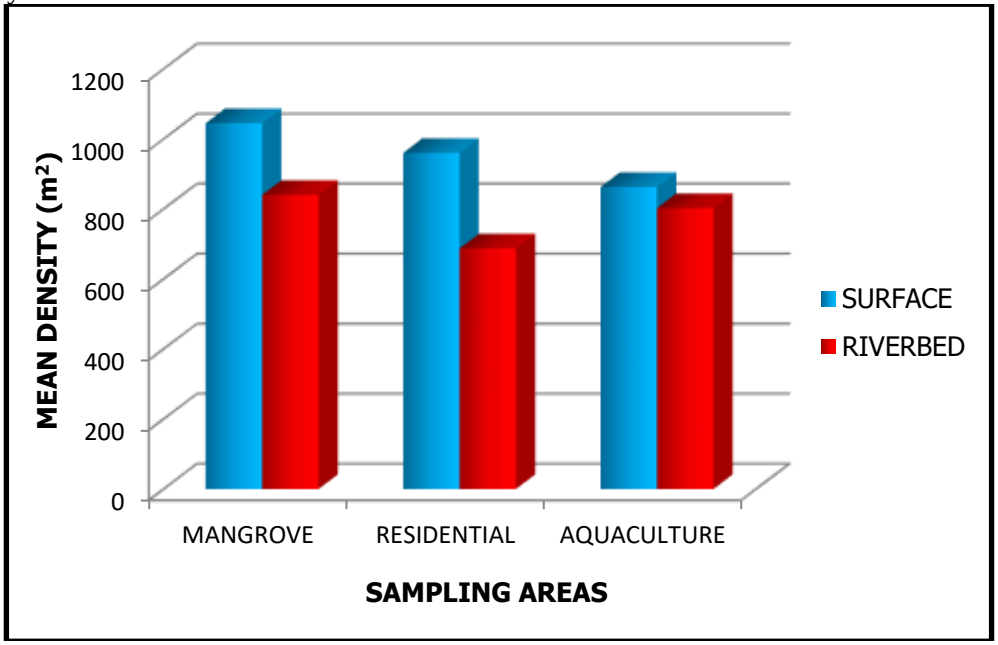

Figure 2. Mean density of western hemisphere blue mussel collected in the surface and riverbed of the three sampling areas in the riverine system of Binmaley, Pangasinan, Philippines.

The highest percentage of *M. charruana* in the mangrove area may indicates that the environment of this area were favourable to the increase of its population. According to Sibaja (1988), *M. charruana* mostly lives in muddy areas of bays and estuaries forming dense aggregations or covering mangroves roots and other hard substrates.

Meanwhile, significant differences in the mean density of western hemisphere blue mussel thriving in the surface and riverbed of the three sampling areas were tested at 5% level of significance using ANOVA. Result revealed that western hemisphere blue attached in the surface of the three sampling areas had a higher mean density of 2869.6 individuals m^{-2} as compared to the western hemisphere blue mussel thriving in the riverbed of the three sampling areas having a mean density of 2331.7 individuals m^{-2}. However, Analysis of Variance showed that the density of western hemisphere blue mussel attached in surface of the three sampling areas is not significantly different to those western hemisphere blue mussels thriving in riverbeds of the three sampling areas. This indicates that western hemisphere blue mussels are evenly distributed in the surface and riverbeds of the three sampling areas in the riverine system of Binmaley, Pangasinan, Philippines.

Relative Density of Western Hemisphere Blue Mussel and Other Shell Mollusks

As observed, the number of shell mollusks collected on the surface area of the three sampling areas in the riverine system of Binmaley, *M. charruana* got the highest relative density of 61.71% (see Table 2) that comprised of 2869.60 individuals m^{-2}. This was followed by *M. philippinarium* with 36.71% relative density (1683.20 individuals m^{-2}) *C. iredalie* with 1.22% relative density (56.80 individuals m^{-2}), *C. malabonensis* with 0.51% relative density (23.73 individuals m^{-2}), *P. viridis* with 0.31% relative density (14.40 individuals m^{-2}), *L. littoralis* with 0.04% relative density (1.87 individuals m^{-2}) and *I. ephippium* with 0.02% relative density (0.80 individuals m^{-2}). Analysis of variance ($p<0.05$) revealed that there are significant differences among the mean densities of *M. charruana* and the other shell mollusks collected in the surface of the three sampling areas. Thus, comparison of mean densities of *M. charruana* with the other shell mollusks

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using DMRT confirms that *M. charruana* is significantly highest among the other shell mollusks collected in the surface of the three sampling areas.

Table 2: Summary of the density of western hemisphere blue mussel (*Mytella charruana*) and other shell mollusks collected in the surface and riverbed of the three sampling areas in the Riverine System of Binmaley, Pangasinan.

Species	TOTAL NUMBER OF SHELL MOLLUSKS PER SAMPLING AREA						MEAN DENSITY (M2)	RELATIVE DENSITY (%)
	MANGROVE		RESIDENTIAL		AQUACULTURE			
SURFACE	TOTAL	MEAN	TOTAL	MEAN	TOTAL	MEAN		
Mytella charruana	3921	261.40	3603	240.20	3237	215.80	956.53[a]	**61.71**
Modiolus philippinarium	1545	103.00	1914	127.60	2853	190.20	561.07[b]	**36.19**
Perna viridis	14	0.93	29	1.93	11	0.73	4.80[c]	**0.31**
Crassostrea malabonensis	29	1.93	36	2.40	24	1.60	7.91[c]	**0.51**
Crassostrea iredalie	69	4.60	4	0.27	140	9.33	18.93[c]	**1.22**
Littorina littoralis	4	0.27	3	0.20	0	0.00	0.62[c]	**0.04**
Isognomon ephippium	2	0.13	0	0.00	1	0.07	0.27[c]	**0.02**
TOTAL	5584	372.27	5589	372.60	6266	417.73	**1550.13**	
								100.00
RIVERBED	TOTAL	MEAN	TOTAL	MEAN	TOTAL	MEAN		
Mytella charruana	3153	210.20	2579	171.93	3012	200.80	777.24[a]	**75.58**
Modiolus philippinarium	1595	106.33	326	21.73	744	49.60	236.89[b]	**23.04**
Perna viridis	19	1.27	16	1.07	19	1.27	4.80[c]	**0.47**
Crassostrea malabonensis	10	0.67	23	1.53	22	1.47	4.89[c]	**0.48**
Crassostrea iredalie	25	1.67	1	0.07	9	0.60	3.11[c]	**0.30**
Polymesoda erosa	3	0.20	5	0.33	5	0.33	1.16[c]	**0.11**
Littorina littoralis	1	0.07	0	0.00	1	0.07	0.18[c]	**0.02**
Telescopium telescopium	0	0.00	1	0.07	0	0.00	0.09[c]	**0.01**
TOTAL	4806	320.40	2951	196.73	3812	254.13	**1028.36**	
								100.00

** Treatment means with same superscript are not significantly different*

On the other hand, *M. charruana* also dominated the number of shell mollusks collected from the river bed of the sampling areas gaining a relative density of 75.58% (see Table 2) that comprised of 2331.73 individuals m^{-2}. This was followed by *M. philippinarium* with 23.04% relative density (710.67 individuals m^{-2}), *C. malabonensis* with 0.48% relative density (14.67 individuals m^{-2}), *P. viridis* with 0.47% relative density (14.40 individuals m^{-2}), *C. iredalie* with 0.30% relative density (9.33 individuals m^{-2}), *P. erosa* with 0.11% relative density (3.47 individuals m^{-2}), *L. littoralis* with 0.02% relative density (0.53 individuals m^{-2}) and *T. telescopium* with 0.01% relative density (0.27 individuals m^{-2}). Analysis of variance ($p<0.05$) revealed that there are significant differences among the mean densities of *M. charruana* and the other shell mollusks collected in the riverbed of the three sampling areas. Thus, comparison of mean densities of *M. charruana* with the other shell mollusks using DMRT confirms that *M. charruana* is significantly highest among the other shell mollusks collected in riverbed of the three sampling areas.

The highest percentage of dominance of *M. charruana* in both surface and riverbed of the three sampling areas indicates that this species has the high adaptive capability which enables it to thrive in a variety of habitat. As cited by Gillis et al. (2009), *M. charruana* have great dispersal ability and traits which make this species appear to readily colonize a variety of habitats noting this mussel was becoming a significant invasive species in several regions of the world.

Growth Pattern of Western Hemisphere Blue Mussel

Results revealed that the growth of *M. charruana* collected in the surface area of Mangrove, Residential and Aquaculture Areas demonstrated negative

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allometric growth with "b" values of 2.726, 2.394 and 2.622, respectively (Figure 3).

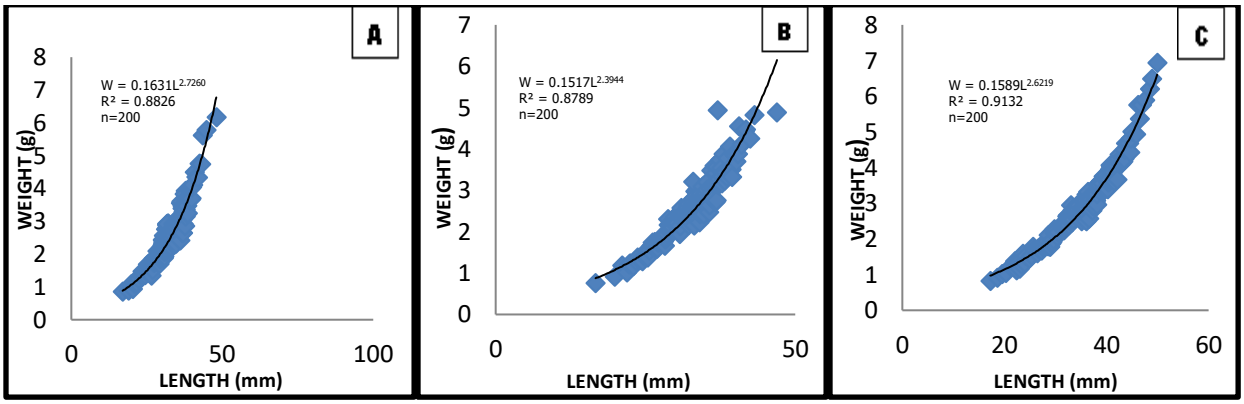

Figure 3. Growth pattern of western hemisphere blue mussel (*M. charruana*) collected in the surface of the (a.)mangrove, (b.) residential and (c.) residential areas.

Likewise, the growth of *M. charruana* collected in the riverbed of Mangrove, Residential and Aquaculture Areas demonstrated negative allometric growth with "b" values of 2.431, 2.573 and 2.628, respectively.

According to Pauly (1984), when the parameter "b" is equal to 3.0, the organisms tend to show an isometric growth pattern and when the values are greater or lesser than the isometry situation, it is said to be that the sampled species is growing in a positive (b>3.0) or negative (b<3.0) way.

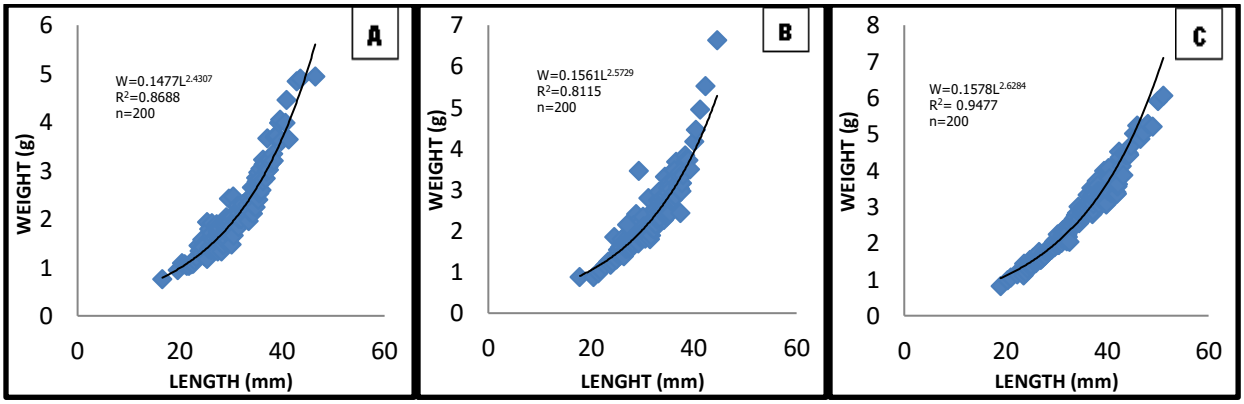

Figure 4. Growth pattern of western hemisphere blue mussel (*M. charruana*) collected in the riverbed of the (a.)mangrove, (b.) residential and (c.) residential areas.

Based on the result of the study, it was observed that the western hemisphere blue mussel (*M. charruana)* samples collected in both surface and riverbeds of the three sampling areas in the riverine system of Binmaley, Pangasinan exhibited negative allometric growth pattern. It suggests that the rate of increase in length is not proportional to the rate of increase in weight. According to Babaei et al. (2010) as cited by Aban et al. (2017) on their study on length-weight relationships of the Asian Green Mussel, *P. viridis* (Linnaeus 1758) (*Bivalvia: Mytilidae*) population in Bolinao Bay, Pangasinan, Northen Philippines, bivalve shell growth and shape are influenced by biotic (endogenous/ physiological) and abiotic (exogenous/environmental) factors such as the quality and quantity of food source, water quality, water depth, currents, water turbulence, type of sediments, type of bottom and wave exposure. Negative allometric growth pattern showed by the western hemisphere blue mussel favored the factors affecting its biological condition.

Confirmation of the "b" values obtained whether it is significantly different to 3.0 was made using the t-test modified by (Pauly, 1980). The result showed that the

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values of the parameter "b" in all cases were significantly different to the isometric value. This result conferred with the statement of Gayanilo and Pauly (1997) that the growth of the organisms proceeds in a different dimension differing from the cube of the length. It was also noted that the slopes of the morphometric characteristics were lesser than 3.0. This means that western hemisphere blue mussels collected in both surface and riverbed of the three sampling areas are growing in a negative allometric way and suggested that the length increases faster than the weight.

Condition Index of Western Hemisphere Blue Mussel

The condition index of *M. charruana* in the three sampling areas was presented in Figure 5. Results showed that the *M. charruana* collected in the Aquaculture Area have the highest mean condition index with 17.35%, followed by Mangrove and Residential Areas with a mean condition index of 17.33% and 16.65%, respectively. However, Analysis of Variance revealed that the mean condition index of *M. charruana* collected in the three sampling areas in the riverine system of Binmaley, Pangasinan, Philippines failed to show significant differences (P>0.05).

The highest mean condition index of western hemisphere blue mussel (*M. charruana*) collected in Aquaculture Area may be due to the higher chlorophyll-*a* concentration on the area. In the study conducted by YIldiz et al. (2006) on the condition indices of Mediterranean Mussels (*Mytilus galloprovincialis* L. 1891) growing on suspended ropes in Dardanelles revealed that there is statistical relation between condition indices and chlorophyll-*a* ($p<0.05$), thereby, chlorophyll-*a* is a determining factor for condition indices in this area. However, a study made by Karayucel and Karayucel (1997) on influence of environmental factors on condition index and biochemical composition in *Mytilus edulis* L. in cultivated-raft system, in two Scottish Sea Lochs, they found out that condition indices changes in mussels were affected by temperature and salinity in the Loch Etive. Also, seasonal changes affects the condition of mussels resulted from the complex interactions of a variety of factors including food, temperature, salinity, metabolic activities of the mussels and particularly the growth and reproductive process [14]. Based on the result of the study, condition index of western hemisphere blue mussel (*M. charruana*) collected in the three sampling areas of riverine system of Binmaley, Pangasinan is in a healthy condition and suitable to be sold in the market and for aquaculture wherein this result is also similar to the results of Yildiz et al. (2006).

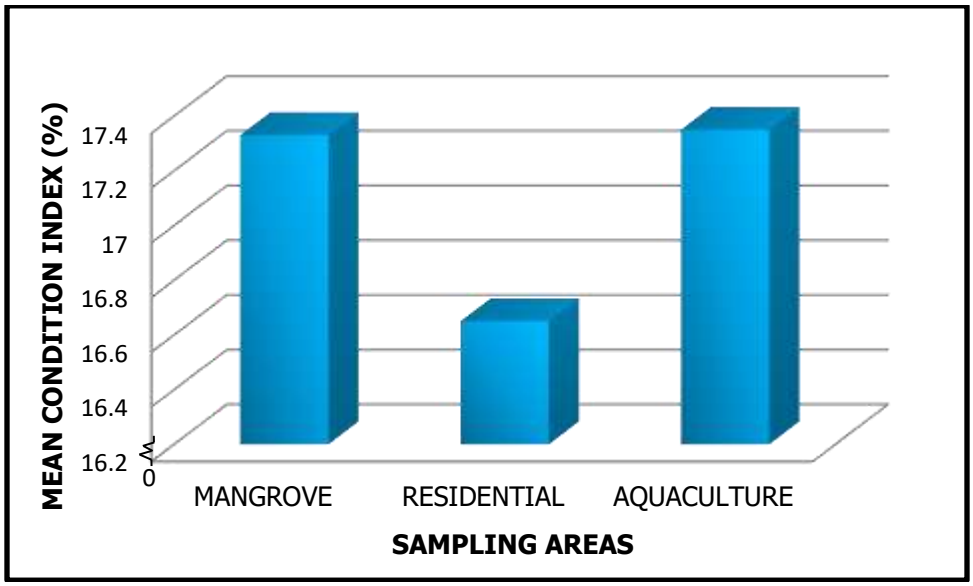

Figure 5. Mean condition index of western hemisphere blue mussel in the three sampling areas in riverine system of Binmaley, Pangasinan, Philippines.

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Physico-chemical Characteristics of River Water

Water quality parameters of the riverine system of Binmaley, Pangasinan are within the range requirements for the growth and survival of *M. charruana* (see Table 3). The water depth was within 0.2-3.76m on which according Karayucel (1996), the growth of mussel was better at 2m than 6m depth. While the temperature of the sampling areas were ranging from 25-30 °C wherein as per Brodsky et al. (2011) as cited by Vallejo et al. (2017), *M. charruana* is capable of tolerating a wide range of temperature from 6–36 °C. Salinity ranges from 14-29 ppt wherein *M. charruana* is a mesohaline and polyhaline species that is found from marine environments with salinities higher than 25 to estuarine environments with salinities as low as 5 (Rice et al., 2017). Dissolved oxygen was 5.44-7.91 mg/L indicating that three sampling areas can sustain the needs of *M. charruana*. Moreover, the pH is in 6.8-8.2 on which Thorp and Covich (1991) stated that the bivalves were mostly found in water with neutral pH throughout a broad range of 5.6-8.3. The chlorophyll- *a* concentration are in 1.24-10.00 mg/m^3 and it tells that the higher mean density of mussels in sampling stations is because of the higher chlorophyll-*a* concentration on the sampling areas.

Table 3. Level/concentrations of water parameters in the three samplings areas in riverine system of Binmaley, Pangasinan, Philippines.

Sampling Stations	Water Depth (m)	Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/L)	pH	Chlorophyll-*a* Concentration (mg/m^3)
MANGROVES	0.6	27.7	23.47	6.75	7.3	3.39
RESIDENTIAL	0.55	27.73	22.87	6.77	7.45	3.28
AQUACULTURE	1.52	27.95	23.07	7.06	7.4	3.33

CONCLUSION AND RECOMMENDATION

We conclude that there were 9 shell mollusks species identified in the river system of Binmaley, namely: *M. charruana*, *M. philippinarium*, *C. iredalie*, *C. malabonensis*, *P. viridis*, *L. littoralis*, *I. ephippium*, *P. erosa* and *T. telescopium*. Among the shell mollusks collected, western hemisphere blue mussel (*M. charruana*) is the most abundant in terms of density both in surface and riverbed but most abundant in the mangrove area. *M. charruana* collected on both surface and riverbed of the three sampling areas in the riverine system of Binmaley, Pangasinan exhibited negative allometric growth pattern which means that the length grows faster than the weight. In terms of condition index, *M. charruana* collected in aquaculture area has the highest mean condition index while residential area has the lowest mean condition index but the values are in healthy condition and suitable to be sold in the market and for aquaculture. The river water quality parameters in all sampling areas were favourable to the growth of western hemisphere blue mussel (*M. charruana*), hence, it increasing abundantly in the riverine system of Binmaley, Pangasinan, Philippines.

The detailed study on the condition index of *M. charruana* using different method is recommended. Further assessment of this species must be conducted on some areas of the Pangasinan taking into account the number of sampling frequency and replications.

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