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Environmental factors influencing population density of freshwater clam *Batissa violacea* (Bivalvia) (Lamarck, 1818) in Cagayan River, Northern Philippines

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Abstract: Freshwater mollusks are among the most diverse and imperiled groups of animals around the world experiencing severe population decline. This study reports the population characteristics of *Batissa violacea* (Lamarck, 1818) - an indigenous non-marine edible freshwater clam, in relation to the ecological condition in the largest river ecosystem in the Philippines. The *B. violacea* has been rated as a threatened species requiring urgent special attention for its conservation. The sampling stations were established along the downstream area of Cagayan River where the *B. violacea* are found covering three municipalities in the province of Cagayan. The mean density of *B. violacea* in Cagayan River is 1.80/m^2 with a range of 0.12-11.12 clam /m^2. The abundance of *B. violacea* in Cagayan River were found to be determined by the condition of water quality and soil substrate particularly in terms of soil pH ($r=0.560$; $P<0.01$), water pH ($r=0.380$; $P<0.05$) and total suspended solids ($r=0.256$; $P<0.01$). These results could be utilized in the formulation of the general management plan of a sanctuary established in Lallo, Cagayan, as well as the implementation of planned interconnected network of sanctuaries across the Cagayan River, to ensure a successful stock enhancement of *B. violacea* in Cagayan River.

Keywords: *Batissa violacea*; freshwater clam; Cagayan River; population density

Introduction

The *Batissa violacea* is a non-marine edible mollusk indigenous of Cagayan River in the Northern Philippines that occur across the western Pacific including Malaysia, Indonesia, Northwestern Australia, Fiji, and Papua New Guinea (Morton, 1991; Richards, 1994; Ledua *et al.,* 1996; Thangavelu *et al.,* 2011). The clam can be found in sandy or muddy beds of rivers, in fresh and brackish, often running water (Poutiers, 1998) and to almost freshwater areas of mangrove swamp (Carpenter and Niem, 1998).

In the Philippines, the populations of *B. violacea* stocks in the Cagayan River have dwindled due to over-harvesting (Layugan *et al.,* 2013). In response, a sanctuary was established in year 2004 to revive the bivalve resource. However, the technical basis for site selection is incomplete. As such, the established sanctuary covering a 1.5 kilometer length of the Cagayan River might have been established in a non-strategic location. This is because the sanctuary was established in the part of the river with a 20-30 meter water depth and a bottom substrate of mostly cobbles and rocks. This is in contrast to available information that provides that *B. violacea* favor to thrive in shallow water area ranging from 0.67-2.80 meters and a soil substrate of 99-100% sand (Layugan *et al.,* 2013).

Several studies on the influence of environmental parameters on population densities of bivalves have been conducted (Soares-Gomes and Pires-Vanin, 2005; McLeod and Wing, 2008; Tanyaros and Tongnunui, 2011) showing that water quality and bottom material composition have association to abundance, distribution and diversity of non-marine mollusk (Baron and Clavier, 1992; Hoey *et al.,* 2003; Baldigo *et al.,* 2004; U.S Geological Survey, 2007; Tanyaros and Tongnunui, 2011; Satheeshkumar and Khan, 2012). Though, the degree of such relationship varies across geographical regions (Tanyaros and Tongnunui, 2011).

Although few studies were done related to the biology of the clam, no study has so far been conducted to determine the influence of water quality and bottom sediment to the abundance of *B. violacea* in Cagayan River (Layugan *et al.,* 2013). As this is a dominant harvested freshwater bivalve in Cagayan River, knowledge on the environmental parameters affecting its population characteristics is required for its management. For instance, knowledge on the distribution and habitat characteristics of the bivalve

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could facilitate the selection of possible sanctuary areas in the river. In the future, it is likewise necessary to determine the favorable environmental condition of the clam in the wild in order to ensure successful breeding and culture of the bivalve in captivity to replenish natural stocks in Cagayan River.

This study has been conducted in the identified major harvesting areas of *B. violacea* in Cagayan River, Northern Philippines (Layugan *et al.,* 2013). It aims to characterize the water quality and bottom sediment of Cagayan River; and analyze the population density of *B. violacea* across major harvesting areas in Cagayan River.

Materials and Methods

Description of the study area

The Cagayan River, also known as the Rio Grande de Cagayan, is the longest and largest river in the Philippines specifically located in the Cagayan Valley region in northeastern part of Luzon island. It traverses the provinces of NuevaVizcaya, Quirino, Isabela and Cagayan (Fig. 1). With an estimated length of 505 kilometers, the river's headwaters are at the Caraballo Mountains of the Central Luzon at an elevation of approximately 1524 meters and flows north to the Babuyan Channel near the town of Aparri, Cagayan elevation dropping rapidly to 91 meters at the river mouth. Its principal tributaries are the Chico, Siffu, Mallig, Magat and Ilagan Rivers.

Cagayan River Basin classified under Type III climate zone characterized by a no pronounced maximum rain period and a short dry period (BRS-DPWH, 2002). It is relatively dry from November to April and wet for the rest of the year (DOST-PAGASA, 2013). The northern part of the basin has an average annual rainfall of 1,000 mm and 3,000 mm in the southern mountains (DOST-PAGASA, 2009). The mean annual temperature and average relative humidity are 23.6-26.0C and 75-85%, respectively (DPWH and JICA, 2001; Principe, 2012).

The river basin is relatively flat plain but is broken by low rising ridges and hummocks in some places (BRS-DPWH, 2002). Approximately 50% of the area is relatively flat with slope that varies from 0-17%. About 33% of the area has slopes between 17-42% while the rest are with slopes greater than 42% based on a slope map derived from the SRTM-DEM. It is also surrounded by three mountain ranges: Sierra Madre, Cordillera Central and Caraballo-Maparang in the east, west and south respectively (DPWH and JICA, 2001; Principe, 2012).

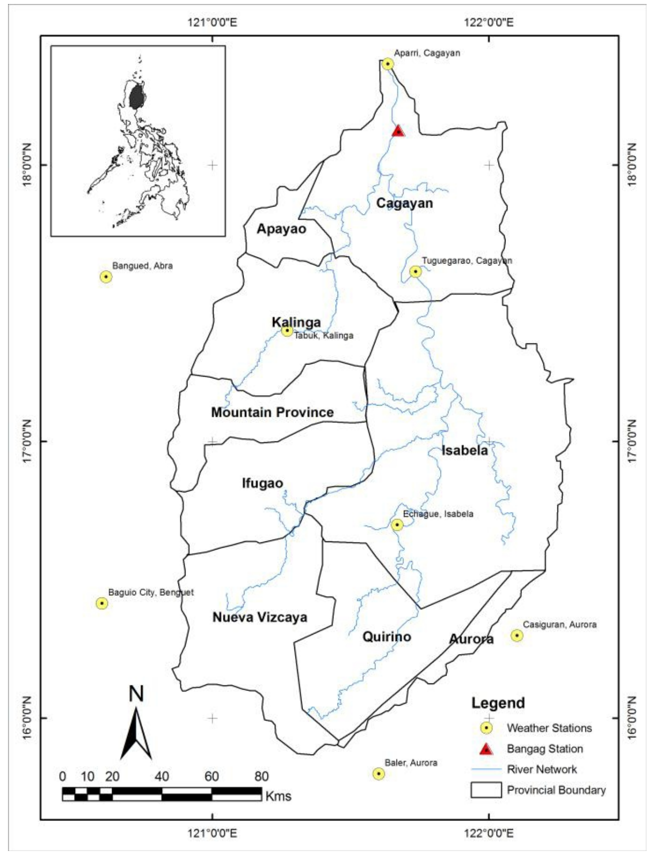

Fig. 1: The Cagayan River Basin, its provinces, the Bangag Station and weather stations (Principe, 2012).

In terms of land-use, about 37% of the area is covered by forest while grassland, agricultural area, and settlement and water area occupies 34%, 27% and 2%, respectively. Of the 741,000 hectares of agricultural area, 94% are crop fields while the rest are fruit trees. The crop fields are further subdivided into 68% paddy field, 22% cornfield and 10% upland crop field (DPWH and JICA 2001; Principe, 2012).

Sampling areas

Six sampling stations were established along the downstream area of Cagayan River where the *B. violacea* are harvested. The mean distance between stations is approximately 3.3 km with a range of 1.8 km to 6.4 km. The stations were assigned along the stretch of the river covered by three municipalities of Cagayan province where the *B. violacea* thrive. Six active fishing sites along the rivers were assigned as stations. Station 1 is located in the upper stream portion in the boundary of the municipality of Gattaran and Lallo; stations 2, 3, 4 and 5 in middle strea portion in Lallo and station 6 in the lower stream portion in the boundary of Lallo and Camalaniugan (Fig. 2). Selections of sampling stations and transect lines considered the typical sandy-substrate habitat of *B.*

violacea and the dredgeable areas of the river.

The presence of *B. violacea* in the selected stations was validated on field by key informants. Coordinates of each sampling station were taken using a Global Positioning System (GPS) and was likewise photo documented. Six transect line replicates were laid out along a 50m length in each station parallel to the river (Ledua *et al.,* 1996). Within the transect line, measurement of water quality parameters and sampling of soil substrate were done. Collection of *B. violacea* was done on each of the six sampling stations namely: Station 1 = Aguiguican, Gattaran (18°6'10.98" N - 121°39'20.48" E); Station 2 = Sta. Maria, Lallo (18°8'16.84" N - 121°39'50.29" E); Station 3 = San Lorenzo, Lallo (18°9'5.93" N - 121°39'13.38" E); Station 4 = Catayauan, Lallo (18°10'11.89" N - 121°39'5.72" E); Station 5 = Tucalana, Lallo (18°11'16.97" N - 121°39'33.62" E); and Station 6 = Jurisdiction, Camalaniugan (18°14'40.53" N - 121°40'22.87" E) (Fig. 2.). Quantitative sampling (Ledua *et al.,* 1996) was used to estimate population characteristics of *B. violacea* stocks in the river.

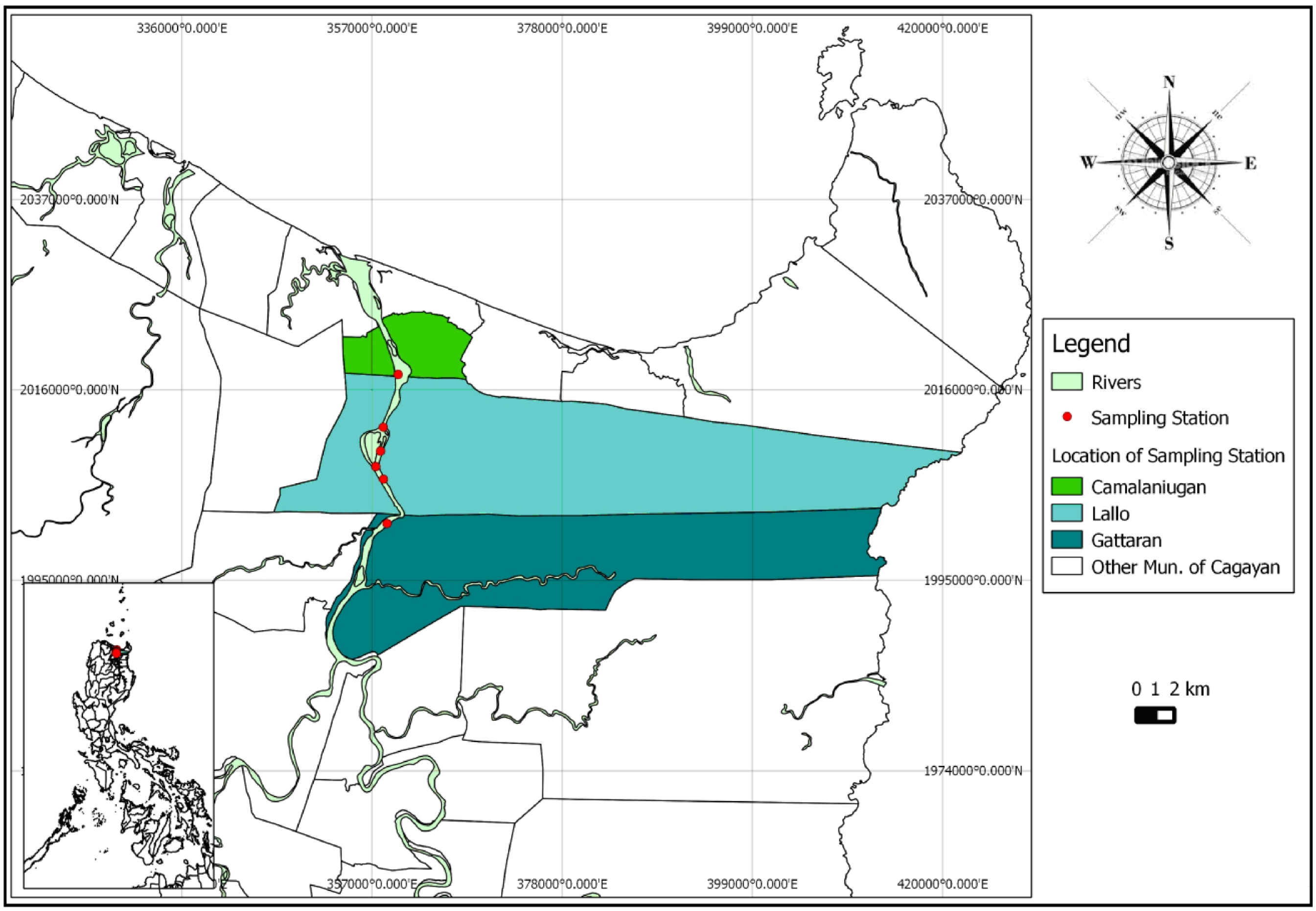

Fig. 2: Sampling site of the study along the Cagayan River Basin.

Across stations, station 1 is the farthest from the river mouth while station 6 is the nearest from the river mouth. The shape of the river stretch in the stations is from straight to curve and the river banks are either covered with or combined with woods, residential houses, agricultural farms, pasture land and/or idle land. The field guide evaluation of Barbour *et al*., 1999 was used to observe the other physical habitat characteristics of *B. violacea* across stations. The river banks of station 1 to 4 are moderately stable in which 5-30% of banks have erosion areas while station 5 and 6 have unstable banks in which 60-100% of the river bank has erosion scars. Eroded banks indicate a problem of sediment movement and deposition suggesting the scarcity of riparian cover and organic input to streams (Barbour *et al*., 1999).

The Moron's I spatial correlation test (Moran, 1950) of water quality and soil substrate parameters shows that all the parameters have no significant correlation across stations (Z<1.96; Z>-1.96) (Tab. 1). This means that environmental parameters have complied with the assumptions of independence across stations. Hence, parametric test has been applied in this study.

Tab. 1: Physico-chemical characteristics of the water and soil substrate of Cagayan River.

Parameters	Sampling Stations						Class
	1	2	3	4	5	6	C[b]
Depth (m)*	2.30±0.04 (2.25-2.37)	3.33±0.45 (2.73-3.70)	5.57±0.83 (4.45-6.20)	3.05±1.08 (2.13-4.56)	3.22±0.65 (2.36-3.90)	2.09±0.45 (1.75-2.64)	-
Current (m/sec)*	1.71±0.11 (1.57-1.83)	1.75±0.11 (1.64-1.88)	1.84±0.11 (1.73-2.00)	2.45±0.61 (1.93-3.40)	2.33±0.10 (2.19-2.46)	1.89±0.13 (1.68-2.03)	-
T (^{0}C)	30.23±0.44 (29.60-30.70)	30.21±0.46 (29.79-31.03)	29.45±0.52 (28.43-29.83)	29.59±0.38 (29.30-30.33)	29.76±0.48 (29.33-30.60)	29.92±0.42 (29.07-30.20)	25-31
Water pH	8.71±0.35 (8.25-9.27)	8.60±0.19 (8.32-8.81)	8.30±0.23 (7.93-8.54)	8.47±0.21 (8.07-8.66)	8.41±0.21 (8.13-8.60)	8.76±0.41 (8.27-9.40)	6.5-9.0
D.O (mg/l)*	6.09±0.34 (5.60-6.58)	6.10±0.68 (5.27-7.04)	6.56±0.47 (5.79-7.00)	6.59±0.39 (5.87-6.97)	6.90±0.25 (6.51-7.27)	6.72±0.30 (6.27-7.07)	5[a]
TSS (mg/l)*	728.88±184.52 (527.00-946.75)	267.50±5.52 (262.25-277.12)	391.03±19.64 (371.35-418.00)	322.09±5.64 (314.88-331.75)	424.81±48.92 (364.52-476.44)	573.64±80.32 (481.34-665.26)	80
Sand%	94.17±1.47 (92.00-96.00)	92.50±1.87 (90.00-95.00)	96.67±1.21 (95.00-98.00)	97.50±0.84 (96.00-98.00)	97.50±0.84 (96.00-98.00)	94.50±0.84 (93.00-95.00)	-
Silt%*	4.00±2.10 (1.00-6.00)	3.33±1.86 (1.00-5.00)	2.17±1.17 (1.00-4.00)	1.50±0.84 (1.00-3.00)	1.33±0.52 (1.00-2.00)	4.00±0.63 (3.00-5.00)	-
Clay%*	1.83±1.17 (1.00-4.00)	4.17±1.83 (1.00-6.00)	1.17±0.41 (1.00-2.00)	1.00±0.41 (1.00-2.00)	1.17±0.41 (1.00-2.00)	1.50±0.84 (1.00-3.00)	-
OM%	1.15±0.07 (1.06-1.25)	1.44±0.05 (1.38-1.50)	1.60±0.68 (1.10-2.50)	1.14±0.04 (1.08-1.20)	1.14±0.02 (1.11-1.18)	1.16±0.04 (1.13-1.21)	-
Soil pH*	6.69±0.35 (6.40-7.25)	7.36±0.06 (7.30-7.44)	7.56±0.06 (7.50-7.65)	7.67±0.04 (7.60-7.72)	7.69±0.06 (7.60-7.77)	8.35±0.13 (8.10-8.45)	-

- *= Significantly different across stations at 0.05 level of significance
- Values are mean±standard deviation (range)
- a= minimum D.O; b= Class C for Revised Water Classification and Usage of Inland Surface Waters (DENR Administrative Order 2008 – XX); c=These values refer to the geometric mean of the most probable number of coliform organism during a 3-month period and that the limit indicated shall not be exceeded in 20 percent of the samples taken during the same period (DENR ADMINISTRATIVE ORDER No. 34 Series of 1990); and d=Fecal coliform (DENR Administrative Order 2008 – XX)

Water and soil substrate sampling and analysis

Physico-chemical factors of the river were determined in situ and in laboratory. Three replicates per physico-chemical factor were measured in each of the laid out 50 meter transect line prior to the sampling of *B. violacea*. Physical factors such as water depth (m) was measured using an improvised calibrated meter gauge, improvised floater to measure water velocity (cm./sec) and thermometer for temperature (^{0}C). For total suspended solid (TSS), a composite sample of 1000 ml volume of water was taken from 20 cm below the water surface in each station (Bartram and Balance, 1996; Tanyaros and Tongnunui, 2011). This was placed in a labeled 1000 ml plastic bottle and was kept on iced styrofoam box prior to submission to laboratory for analysis by the Department of Science and Technology (DOST) Region 02. Total suspended solid was analyzed using the Gravimetric SMEWW. The chemical factors of the riverine water such as pH were measured using a pH meter (milkwaukee handheld), temperature and Dissolve Oxygen (D.O) (mg/li) using water quality checker (YSI model 55 handheld).

Six replicates of composite soil samples approximately 1 kg each (Beasley and Kneale, 2003) were taken from each sampling station to a depth of 0-10cm of the substratum (Charkhabi *et al.,* 2008) using a core sampler. A composite sample was prepared by mixing three subsamples in a polyethylene bag (Moore *et al.,* 2011). All samples were air-dried, homogenized and brought to the laboratory for analysis of organic matter content, percentage of sand, silt and clay and hydrogen ion concentration (pH).

Batissa violacea sampling and analytical method

B. violacea samples were collected using a dredging material locally known as *"tako"* (Fig. 3) in each 50 m transect line at each station. The *tako* is made up of a triangular metal frame covered with ¼ inch metal screen at the base with a width of 2 m and a long wooden handle. The *tako* was dropped down in an upright position in the water to sink in at the bottom substrate and then towed by a boat. The dredging and towing process is facilitated by moderate water current and regulated by a bamboo wing (3.5 m × 1.5 m) that is placed in both sides at the bow end of the boat. The collection of *B. violacea* in the 50 meter-long transect line would take 10 to 20 minutes. The *tako* was towed by a boat starting from the upstream portion to downstream similar to the flow of water current to facilitate dredging.

Fig. 3: Fishing gear for *B. violacea* locally known as *"tako"* in Cagayan.

All live *B. violacea* stocks collected were placed in a moist sack. The density of the population defined as the number of organisms in a particular area at a given time (Pacardo *et al.,* 2000; Thakur *et al.,* 2012) was then calculated. From the six transect lines in each sampling station, the number of *B. violacea* collected per transect line was counted. To compute for population density (m^2) per transect line, the number of *B. violacea* collected was divided to the product of distance dredged and width area of the dredging material (Pacardo *et al.,* 2000).

Data analysis

Statistical analyses were performed using SPSS (statistical Version 16.0). One way analysis of variance (ANOVA) was used to compare water quality parameters, bottom sediment characteristics and population density of *B. violacea* across stations. The Post Hoc Test using Tukey HSD was used to further determine significant difference of these parameters across stations. A step-wise multiple linear regression was also performed to determine the linear relationship of water and soil substrate parameters to the population density of *B. violacea* in Cagayan River. The predictor variables such as water quality parameters (depth, velocity, temperature, D.O, TSS and pH) and soil substrate characteristics (O.M, %sand, %silt, %clay and pH) were log-transformed in order to comply with the statistical assumptions.

Results and Discussion

Physico-chemical characteristics of the water and soil substrate of Cagayan River

Table 1 shows that physico-chemical characteristics of the water and soil substrate of Cagayan River. Across all sampling stations, zero salinity was observed in the surface water and a water transparency of 5 cm was observed in all stations. The *B. violacea* tends to inhabit at a water depth range of 1.75-6.20m. As confirmed by the Post Hoc Test analysis, water depth significantly varied (p<0.05) across stations with station 6 (2.09m; 1.75-2.64m) as the shallowest while the deepest is in station 3 (5.57m; 4.45-6.20m).

Population density of *B. violacea*

One way analysis of variance showed that these is a significant difference of the population density of *B. violacea* across stations (p<0.05). The clams were found to be mostly abundant in station 6 and least abundant in station 1 (Tab. 2). The station 4 has the second highest population density of *B. violacea*, followed by station 5, station 2, station 3 and the least in station 1. Post Hoc Test revealed that station 6 has the highest population density (p<0.05) among all sampling stations.

Tab. 2: Descriptive statistics of frequency and population density of *B. violacea* in the six stations in the Cagayan River.

Station	Frequency (ind. clam)	Population Density (ind./m^2)
1	7.50±3.62 (3-13)	0.30±0.15 (0.12-0.52)
2	25.50±19.02 (6-57)	1.02±0.76 (0.24-2.28)
3	13.17±7.28 (6-23)	0.53±0.29 (0.24-0.92)
4	41.50±24.30 (12-67)	1.67±0.97 (0.48-2.68)
5	29.33±28.16 (7-83)	1.17±1.13 (0.28-3.32)
6	152.67±93.25 (54-278)	6.11±3.73 (2.16-11.12)

- Values are mean±standard deviation (range)
- Station 1 = Aguiguican, Gattaran; Station; 2 = Sta. Maria, Lallo; Station; 3 = San Lorenzo, Lallo; Station; 4 = Catayauan, Lallo; Station; 5 = Tucalana, Lallo; Station 6=Jurisdiction, Camalaniugan.

The mean density of the clam in Cagayan River is 1.8/ m^2 within the range of 0.12-11.12 clam/m^2 (Fig. 4) which is comparable to previous studies. The bivalves tends to occupy areas with a high percentage of sand substrate and less percentage of silt and clay, and with a depth ranging from 1.70 m (shallow) to 6.25 m (deep) part of Cagayan river. The findings of this

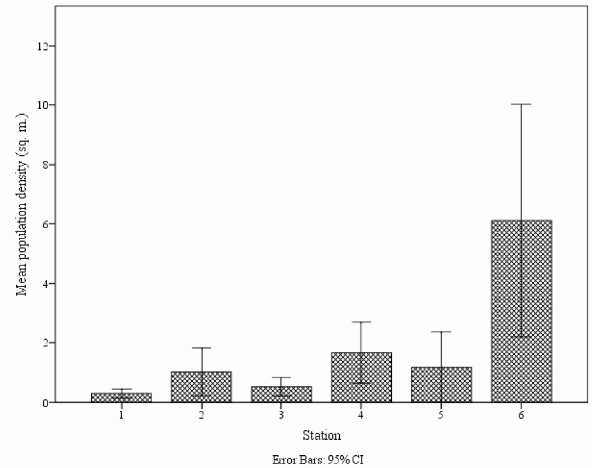

Fig. 4: Mean population density of *B. violacea* in the six stations in the Cagayan River.
Station 1 = Aguiguican, Gattaran; Station 2 = Sta. Maria, Lallo; Station; 3 = San Lorenzo, Lallo; Station; 4 = Catayauan, Lallo; Station; 5 = Tucalana, Lallo; Station; 6 = Jurisdiction, Camalaniugan.

study is similar to the observation of Ledua *et al.* (1996) in the Ba River in Fiji wherein the clams were only abundant on areas where the substrate was made up of a mixture of fine sand, fine gravel and firm bluish black mud. The sandy or muddy beds of flowing rivers affect the distribution and abundance of *B. violacea* (Ledua *et al.,* 1996) because one of their biological activities is to burrow to a permeable depth in river beds to endure drought periods (Carpenter and Niem, 1998). Also, the type of soil substrate preferred by *B. violacea* also afford other set of environmental conditions (e.g. water velocity, depth and organic content of the sediment) that may affect the population density *B. violacea* in Cagayan River.

Influence of environmental parameters to population density of *B. violacea*

The influence of physico-chemical factors of the water and sediments to population densities of bivalves vary among geographical areas (Tanyaros and Tongnunui, 2011). Environmental parameters such as soil and water pH were found to be significantly correlated to the population density of *B. violacea* in Cagayan River. The coefficient of correlation (r) indicated that there is a moderate positive correlation between the population density of *B. violacea* and soil pH (r = 0.560; P<0.01); water depth and O.M (r = 0.478; P<0.01); water current and sand (r = 0.602; P<0.01); temperature and silt (r = 0.437; P<0.01); D.O and soil pH (r = 0.459; P<0.01), sand (r = 0.453; P<0.01); *B. violacea* population density and water pH (r = 0.380; P<0.05); TSS and silt (r = 0.369; P<0.05); and water pH and temperature (r = 0.406; P<0.05). On the other hand, a moderate negative correlation exists between water depth and TSS (r = -0.430; P<0.01); water current and silt (r = -0.550; P<0.01); temperature and sand (r = -0.539; P<0.01); sand and silt (r=-0.739; P<0.01), clay (r = -0.673; P<0.01); water depth and temperature (r = -0.334; P<0.05); water current and temperature (r = -0.406; P<0.05); water pH and sand (r = -0.348; P<0.05); temperature and D.O (r = -0.402; P<0.05), D.O and clay (r = -0.390; P<0.05) with physico-chemical parameters of water and sediment characteristics in Cagayan River (Tab. 3).

To measure the extent of correlation of environmental factors to the population density of *B. violacea*, a multiple linear regression was performed. The predictor variables such as water quality parameters (depth, velocity, temperature, D.O, TSS and pH) and soil substrate characteristics (O.M, %sand, %silt, %clay and pH) were used in a stepwise multiple regression analysis to predict the population density of *B. violacea* in Cagayan river. The prediction model comprised three out of the 11 predictor variables and was reached in three steps wherein eight variables were removed. The model was statistically significant F (3, 32) = 17.090, p <0.001 and accounted for approximately 62% of the variance of population density of *B. violacea* (R^2 = 0.616, Adjusted R^2 = 0.580). The population density of *B. violacea* was primarily predicted by both log pH in the soil substrate and water and the level of log TSS (Tab. 4).

The log soil pH received the strongest weight in the model followed by the log water pH while the log TSS received the lowest weights. The variance of correlations between predictor variables as shown in the squared semi-partial correlations was relatively low in log soil pH (44%), log water pH (17%) and log TSS (8%). The values of the coefficients suggest that soil pH was a relatively strong indicator of the population density of *B. violacea* whereas water pH and TSS was a moderate indicator of population density of *B. violacea.*

The log soil pH was positively correlated (r = 0.560; P<0.01) with the population density of *B. violacea* (N = 1,618; 9.64 clam/m^2) in the Cagayan River and was the strongest predictor (*BETA* = 0.676 and *SC* = 0.713) among environmental parameters studied. This is because pH concentration influences the bottom sediment to absorb and lose calcium concentrations which are involved in muscular contractions, cellular cohesion, nervous functions by

Tab. 3: Correlation of *B. violacea* population density with environmental parameters.

Variables	*B. v.* pop. den.	Water Depth	Water Current	Water PH	Temp.	D.O	TSS	Soil pH	O.M	Sand	Silt	Clay
***B. v.* pop. den.**	1											
Water Depth	-0.311	1										
Water Current	0.059	0.002	1									
Water pH	0.380*	-0.322	-0.297	1								
Temp.	0.087	-0.334*	-0.406*	0.406*	1							
D.O	0.118	0.032	0.247	-0.119	-0.402*	1						
TSS	0.256	-0.430**	-0.256	0.187	0.172	-0.043	1					
Soil pH	0.560**	-0.045	0.318	-0.146	-0.290	0.459**	-0.181	1				
O.M	-0.190	0.478**	-0.225	-0.079	-0.044	0.011	-0.325	-0.009	1			
Sand	-0.137	0.210	0.602**	-0.348*	-0.539**	0.453**	-0.037	0.242	-0.065	1		
Silt	0.268	-0.229	-0.550**	0.191	0.437**	-0.233	0.369*	-0.036	-0.085	-0.739**	1	
Clay	-0.025	-0.040	-0.318	0.292	0.326	-0.390*	-0.306	-0.239	0.178	-0.673**	0.055	1

* = Correlation is significant at the 0.05 level (2-tailed)
** = Correlation is significant at the 0.01 level (2-tailed)
= Correlation is significant at the 0.05 level (2-tailed)
B. v. pop. den. = *Batissa violacen* population density; Temp = Temperature; D.O = Dissolved Oxygen; TSS= Total Suspended Solid; OM = Organic Matter

bivalves and the maintenance of acid-base balances (Chetail and Krampitz, 1982; Tanyaros and Tongnunui, 2011). A soil pH lower than pH 6.8-6.9 will cause lose of calcium to the external environment which exceeds the calcium gains by sediments (Vindograv *et al.,* 1993; Tanyaros and Tongnunui, 2011). As a result, the calcium necessary for normal metabolic functions by the bivalves is lost and will result to mortality of the organism (Tanyaros and Tongnunui, 2011). This could be the reason of the observed highest population density of *B. violacea* in station 6 (6.11±3.73; 2.16-11.12 clam/m^2) that displayed the highest concentration of soil pH (8.35±0.13; pH 8.10-8.45) that supported the metabolic processes of the clam thus making the clam thrive in the area.

Tab. 4: Stepwise Regression Results.

Model	B	*SE-B*	Beta	Pearson *R*	SR^2	St. Coef.
(Constant)	-125.021	20.046				
Log Soil pH**	56.309	9.350	0.676	0.560	0.436	0.713
Log Water pH*	69.264	18.381	0.423	0.380	0.171	0.484
Log TSS**	4.925	1.861	0.299	0.256	0.084	0.326

- St. Coef. = Structure Coefficient
-The dependent variable was *B. violacea* population density. R^2 = 0.616 Adjusted R^2 = 0.580, *p<0.05, **p<0.01.

On the other hand, the lowest population density observed in station 1 (1.80 clam/m^2) could be due to the lesser capability of the soil substrate to retain calcium to support the survival of the clam in the area, as influenced by low soil pH concentration of 6.69 which is less than pH 6.8-6.9. Low pH may also impair ion exchange (Hunter, 1990) and affect glutamate catabolism in the mitochondria of the bivalve mantle (Moyes *et al.,* 1985; Tanyaros and Tongnunui, 2011). Hence, pH concentration beyond optimum level in the river beds would indirectly affect population density of *B. violacea.* This result is in agreement with the study of Tanyaros and Tongnunui (2011) wherein they concluded that low pH in the sediment during the rainy season was the cause for the low abundance of *Meretrix casta* in the estuary of Palian River, Trang Province, Southern Thailand.

The water pH determines the solubility and biological availability of nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.) and determines whether aquatic organisms can use it (US-EPA, 2013). This study showed that log water pH is the second moderately strong (r = 0.380; P<0.05; *BETA* = 0.423; *SC* = 0.484) environmental factor affecting population density of *B. violacea* in Cagayan river. Although the log water pH was not significantly different (p>0.05) across stations, it can be observed that station six has the highest alkaline pH value (8.76±0.41; pH 8.27-9.40) which favoured the highest density (6.11±3.73; 2.16-11.12 clam/m^2) of the bivalve. Previous studies (Makela and Oikari, 1992; Silva and Barros, 2001) show that an acid pH is unfavorable to the occurrence of molluscs which prefer slightly alkaline environments (Silva and Barros, 2001). This was also noted in the study of Silva and Barros (2001) that found out that freshwater molluscs *Physella cubensis*, *Melanoides tuberculata*, *Biomphalaria straminea* and *Pisidium species* appear highest in number in the Riacho Fundo Creek Basin, Brazil with pH value of 6.7-7.2. The acidity and alkalinity of aquatic ecosystems is important for bivalve shellfish, which construct their calcareous shells through pH-sensitive calcification processes (Gazeau *et al.,* 2007). High metabolic acid load caused by respiratory or acid stress may totally inhibit shell formation (Pynnonen, 1995).

The total suspended solid (TSS) is the dry weight material removed from a measured volume of water sample by filtration (Bartram and Balance, 1996). In this current study, log TSS is the least (r = 0.256; P<0.01; *BETA* = 0.299; *SC* = 0.326) among the predictors of population density of *B. violacea* in the Cagayan River. Results suggest that beyond optimum TSS level, population density of the bivalve decreases with an increased TSS level. It was observed that station six, having the highest clam population density (6.11±3.73; 2.16-11.12 clam/m^2), has a TSS mean level of 573.64 mg/L. This TSS level is within the range of 0 to 600 mg/L suspended solids wherein green-lipped mussel *Perna viridis* revealed no significant changes (p>0.05) in oxygen consumption and dry gonosomatic index (Shin *et al.,* 2002) showing that *P. viridis* could tolerate a high level of suspended solids in the laboratory. However, the TSS mean level of 728.88 mg/l observed in station one in this current study which is far beyond 600 mg/L as shown in the study of Shin *et al.,* (2002) could have resulted to the observed least population density (1.80/m^2) of the *B. violacea*. Previous studies explained that the increase of suspended sediment concentrations decrease clearance rates (Bricelj and Malouf, 1984), oxygen consumption (Grant and Thorpe, 1991; Alexander *et al.,* 1994; Tanyaros and Tongnunui, 2011), growth of organisms (Macdonald *et al.,* 1998; Tanyaros and Tongnunui, 2011) and increases gill damage (Shin *et al.,* 2002; Cheung and Shin, 2005).

Conclusion and Recommendation

The high density of *B. violacea* population in Cagayan River was predicted by the combination of three environmental factors such as soil pH, water pH and total suspended solids (TSS). The soil pH ranges from pH 8.10-8.45; water pH ranges from pH 8.27-9.40; and TSS from 481.34-665.26 mg/l. This suggests that the conditions of the three environmental factors (soil pH, water pH and TSS) are most favorable for *B. violacea* to thrive and grow in the river. It is therefore important to consider the significant role of these three environmental factors for future fishery development on breeding and production of the clam in captivity to replenish natural stocks in the river and when venturing to aquaculture production of *B. violacea* particularly in Cagayan River. For instance, in rearing and growing *B. violacea* in ponds, tanks and cages, the soil and water to be used should be on the range values of pH and TSS in this study. This is necessary in order to achieve a good result from *B. violacea* aquaculture.

On the other hand, the areas with recorded high frequency of *B. violacea* with favorable conditions of environmental parameters such as water quality and soil substrate could be considered as candidate areas where sanctuary could be established. For instance, the sanctuary can be established in station 5 and 6 with water current ranging from 1.50-2.50 m/sec. These ranges of favorable water current influences the distribution of food and the availability of oxygen for the clams. Hence, it is a critical environmental factor in the propagation and development of *B. violacea* in Cagayan River.

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