Int. J. Aquat. Biol. (2021) 9(2): 71-78
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.ij-aquaticbiology.com

Original Article

Some ecophysiological information on *Geloina expansa* (Bivalvia: Cyrenidae) population in Santiago River, northern Philippines: prelude to aquaculture technique development

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Abstract: Knowledge on the optimum environmental conditions for a potential aquaculture species is necessary to simulate an artificial setting. The current study investigated the influence of several environmental parameters on the physiology of the mud clam *Geloina expansa* under natural condition. Highest CIs were recorded during the months of May to August, averaging to 179.79 (±6.47 SE) while the rest of the months averaged only 158.53 (±2.68). *Geloina expansa* population monthly GSI in Santiago River ranged from 9.64 to 26.51, low values were observed from November to February (12.00±0.36) and from June to July (12.24±2.59). Chlorophyll *a* concentration and sediment TOM have significant influence in CI variations. DO significantly affected the changes in GSI. These ecophysiological information are vital for the development of aquaculture techniques for *G. expansa* in northern Philippines.

Article history:
Received 19 April 2020
Accepted 13 November 2020
Available online 25 April 2021

Keywords:
Bivalve
Pangasinan
Estuarine
Growth
Reproduction

Introduction

The aquaculture industry is an important fisheries sector in the Philippines, providing cheap but nutritious food for many Filipinos. In 2018, the industry produced a total of 2.30 M metric tons of various commodities (PSA, 2019). However, the Philippine aquaculture industry may now be in a critical state due to climate change (Santos et al., 2011; Macusi et al., 2015). Several high-valued cultivable species in Southeast Asia have shown signs of vulnerability to the changing environmental conditions (Piamsomboon et al., 2016; Guerrero, 2019). One of the proposed measures to mitigate the undesirable effects of climate change in the aquaculture industry is the search for new and better adapted species (D'Abramo and Slater, 2019). Facts on the biology of a potential aquaculture species should be generated to prelude the development of aquaculture techniques. Ideal environmental conditions for optimal physiological responses are vital biological information to establish a sound cultivation technology. Knowledge on the optimum environmental conditions for a potential aquaculture species is necessary to simulate such situation in an artificial setting.

Geloina expansa (Fig. 1) is one of the usual mud clam species found in Santiago River, Dagupan City, northern Philippines. It is a suspension filter-feeder which thrives in muddy bottoms of shallow estuarine waters. Economically, *G. expansa* supports an artisanal fishery in Santiago River as well as in other parts of the Philippines (Argente, 2013). This bivalve also plays a major role in its environment as a bioremediation agent, having the capacity to accumulate various heavy metals and persistent organic pollutants in its natural habitat (Dsikowitzky et al., 2011; Elvira et al., 2016; Ali and Yep, 2016). It has also been reported to be resilient to adverse environmental conditions (Morton, 1976; Argente et al., 2014). These features make this clam species as a potential candidate for aquaculture. Therefore, gaps on the biology of this bivalve should be addressed.

Biological indices such as the condition index (CI) and gonadosomatic index (GSI) were used to characterize various physiological activities of cyrenid clams such as growth and reproduction

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DOI: https://doi.org/10.22034/ijab.v9i2.858

Figure 1. *Geloina expansa* in Santiago River, Pangasinan, northern Philippines.

under given environmental conditions (Gimin et al., 2005; Rahim et al., 2012; Castañeda et al., 2018). These ecophysiological parameters can provide significant information for the development of aquaculture techniques for *G. expansa* in northern Philippines. As of the moment, limited physiological information is known on this bivalve species. Hence, the current study investigated the influence of several environmental parameters on the physiology of *G. expansa* under natural conditions.

Materials and Methods

Clam collection: Mud clams utilized in this study were harvested from Santiago River, Dagupan City (16.018665°N, 120.317598°E). The area is an identified gleaning site for *G. expansa* which supports artisanal fishery. Moreover, the river is a site for various aquaculture activities. It has brackish hydrographic features with muddy substrate, which is an ideal environment for *G. expansa* since this species is a known tropical estuarine inhabitant (Morton, 1976; Argente, 2016). Clams were gathered on a monthly basis (November, 2014 to December, 2015) with the aid of a commissioned bivalve gleaner. No discrimination of sizes was done during the monthly collection.

Condition (CI) and gonadosomatic (GSI) indices: Thirty clams of various sizes were collected every month to estimate the CI of *G. expansa* population in the river. Internal shell capacity (*ISC*) and dry weight of the soft tissues were obtained. The calculation of CI was based on Ilano et al. (2007):

$$CI = \frac{dw}{ISC} \times 1000$$

Where *dw* is the dry weight of the soft tissue and *ISC* is the internal shell capacity derived from the difference between the total weight and shell weight. Another 30 clams of different sizes were used to determine the GSI of *G. expansa* in Santiago River. Individual soft tissue weights were taken using digital weighing balance. The soft tissue of each clam was further dissected to determine gonad weight. The GSI of each individual was computed according to the equation used by Del Norte-Campos (2004):

$$GSI = \frac{stw}{gw} \times 100$$

Where *stw* is the soft tissue weight and *gw* is the gonad weight of the clam.

Environmental parameters: Water temperature, salinity, dissolved oxygen (DO), Chlorophyll *a* (Chl *a*) concentration and total organic matter (TOM) of the sediment were monitored on weekly basis during the period of the study. Observations of all parameters, except for TOM, were done three times (5 am, 12 pm and 6 pm) on the day of monitoring. Monthly water temperatures (°C) were recorded based from the readings of a field thermometer. Monthly salinity (ppt) measurements were done with the use of a field refractometer. Monthly DOs (mg L^{-1}) were monitored using a DO meter. Monthly estimation of Chl *a* was based on the trichromatic method described by Aminot and Rey (2000) and Argente and Estacion (2014). Three replicates of 1 L water samples were collected at different times during the day of monitoring and immediately filtered using Whatman™ GFC (47 mm diameter) filters. Pigment extraction was done by macerating the filters in 90% acetone producing 10 mL extracts. Extracts were mixed thoroughly and centrifuged for 10 minutes at 500 RPM. Extracts were transferred to glass cuvette and absorbance at 750, 664, 647 and 630 nm against a

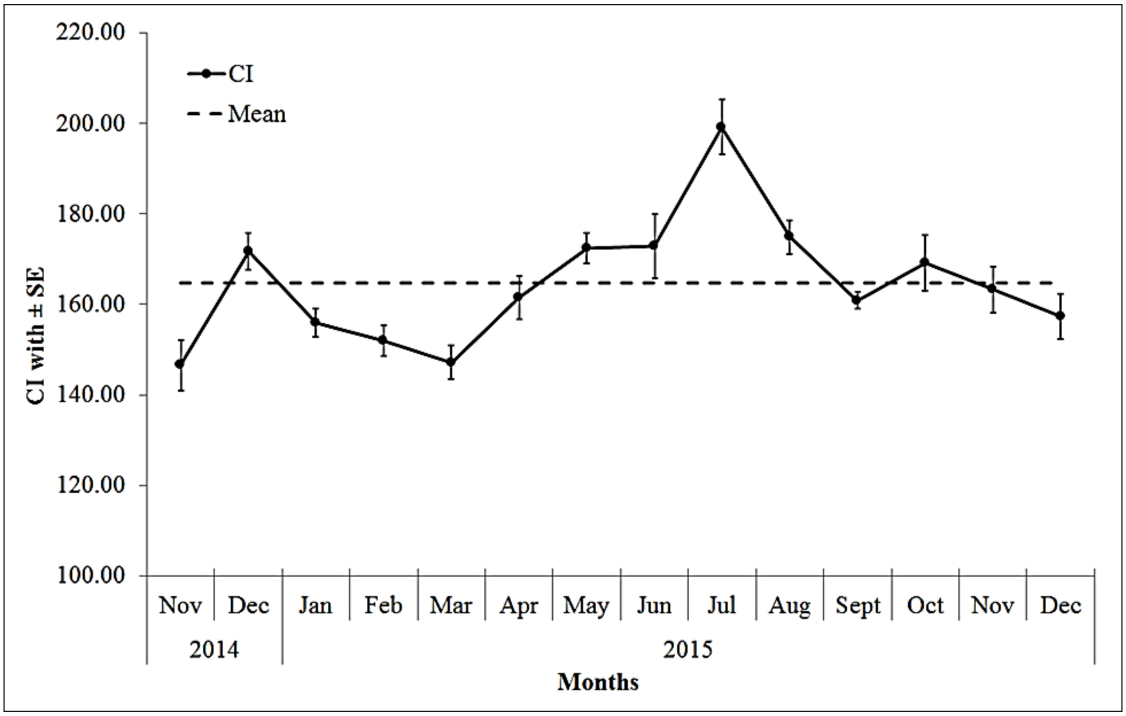

Figure 2. Monthly mean CI of *Geloina expansa* population in Santiago River.

90% acetone blank were measured with the use of a spectrophotometer. Chl *a* concentration (mg m^{-3}) was calculated according to the equation of Jeffrey and Humphrey (1975) as cited by Aminot and Rey (2000):

$$Chl\ a = ([11.85 \times \{E_{664} - E_{750}\}] - [1.54 \times \{E_{647} - E_{750}\}] - [0.08 \times \{E_{630} - E_{750}\}]) \times \frac{V_e}{L} \times V_f$$

Where L is the cuvette light-path in cm; V_e is the extraction volume in mL; and V_f is the filtered volume in liters. Three weekly (12 in one month) replicates of sediment samples from the clam bed were used to measure the TOM using the loss-on-ignition technique (Argente et al., 2013). Two-gram samples from each replicate were placed in pre-weighed crucibles, burned inside a muffle furnace at 650°C for 5 hrs, cooled down, weighed and recorded, accordingly. TOM (% loss) was determined by the equation:

$$TOM = \frac{S_i - S_f}{S_i} \times 100$$

Where S_i is the initial weight of the sediment before ashing and S_f is the final weight of the sediment after ashing.

Environmental influence to CI and GSI: Standard multiple regression analyses were done to determine which among these environmental parameters had the most influence on the monthly variations of CI and GSI in *G. expansa* population in Santiago River. The significance level was set at $P \leq 0.05$.

Results

Condition (CI) and gonadosomatic (GSI) indices: The observed monthly CI values (Fig. 2) for *G. expansa* in Santiago River varied from 146.51 to 199.12 with an average of 164.61 (±3.53 SE). Highest CIs were recorded during the months of May to August, averaging to 179.79 (±6.47) while the rest of the months averaged only 158.53 (±2.68). *Geloina expansa* population monthly GSI (Fig. 3) in Santiago River ranged from 9.64 to 26.51, averaging to 16.04 (±1.54). It appeared that the trend of monthly GSI have two pulses with different strengths and duration. High GSI values were recorded during March to May (17.04±2.15 average) and August to October (25.64± 0.52). Consequently, reduced GSI values were observed from the months of November to February (12.00±0.36) and June to July (12.24±2.59).

Environmental parameters: Generally, water temperature increased from November 2014 to succeeding months with mean value (30.57°C±0.28)

Table 1. Standard multiple regression analysis of *Geloina expansa* condition index (CI) with the environmental parameters in Santiago River.

Parameter	Standard Estimate (*β*)	Standard Error	Parameter Estimate (B)	Standard Error	P-level
Intercept			39.07	45.79	0.418
Water Temp.	0.33	0.16	2.97	1.42	0.070
Salinity	-0.24	0.11	-0.42	0.20	0.063
DO	0.21	0.12	1.77	0.99	0.113
Chl *a*	0.46	0.19	0.69	0.28	0.039
TOM	0.40	0.16	3.01	1.19	0.035

n = 14; r^2 = 0.93; P<0.00024

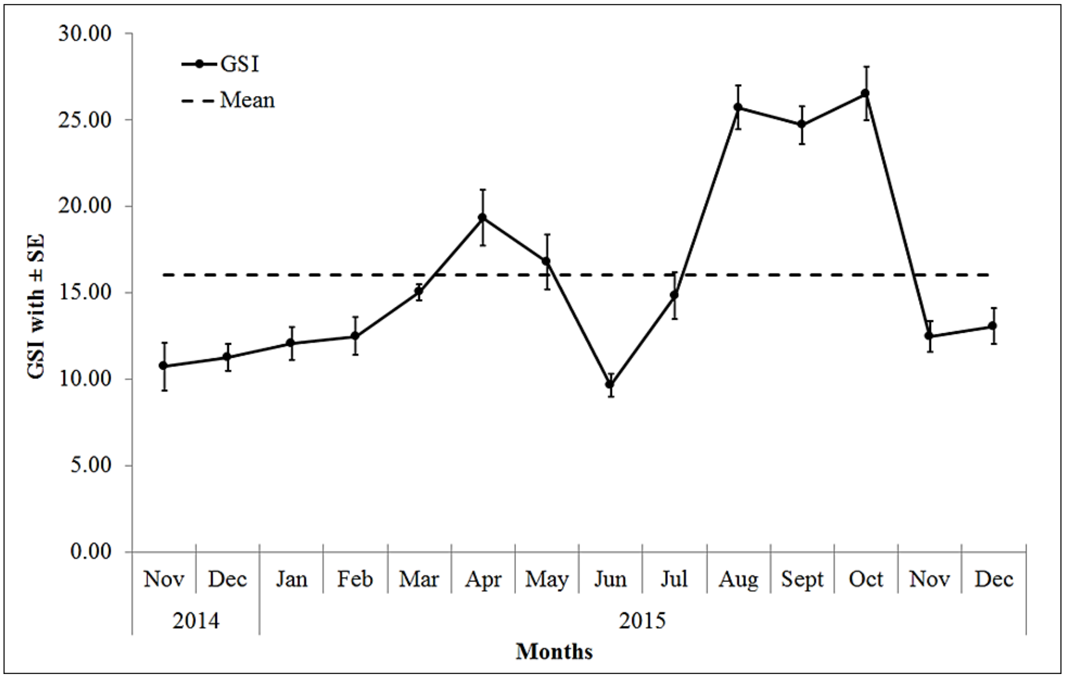

Figure 3. Monthly mean GSI of *Geloina expansa* population in Santiago River.

peaking in July (32.57°C), then decreased rapidly from August to December (28.23°C±0.29) (Fig. 4A). Mean monthly water temperature was 29.73°C (±0.41). Salinity in the clam bed oscillated from 5.50 to 23.50 ppt (14.32 ppt±2.08) (Fig. 4B). Maximum salinity was detected from January to June (22.34 ppt ±0.27) while minimum salinity values were monitored during July to December (8.31 ppt ±1.41).

Gradual increase in DO (4.38 to 8.62 mg L^{-1}) was observed from November 2014 to May 2015 then values fluctuated thereafter (Fig. 4C). The monthly mean DO in the clam bed was 6.72 mg L^{-1} (±0.44).

The water Chl *a* concentration (17.54±2.43 mg m^{-3}) in the *G. expansa* clam bed exhibited high variability throughout the duration of the study (Fig. 4D). Elevated Chl *a* concentration was recorded from May to August (29.00±1.94 mg m^{-3}) while only a mean of 12.96 mg m^{-3} (±1.80) were observed for other months. The monthly monitoring of sediment TOM in the clam bed recorded an average of 6.44% (±0.49) with highest record in August (8.34%) and least in May (2.01%) (Fig. 4E).

Environmental influence to CI and GSI: All environmental parameters monitored in the clam bed contributed to the monthly variations of *G. expansa* CI (r^2=0.93) in Santiago River (Table 1). Among the parameters observed, only Chl *a* concentration and sediment TOM have significant influence in CI variations. Between the measured parameters, Chl *a* concentration has better association with CI. All parameters, except for salinity, have positive correlation with CI.

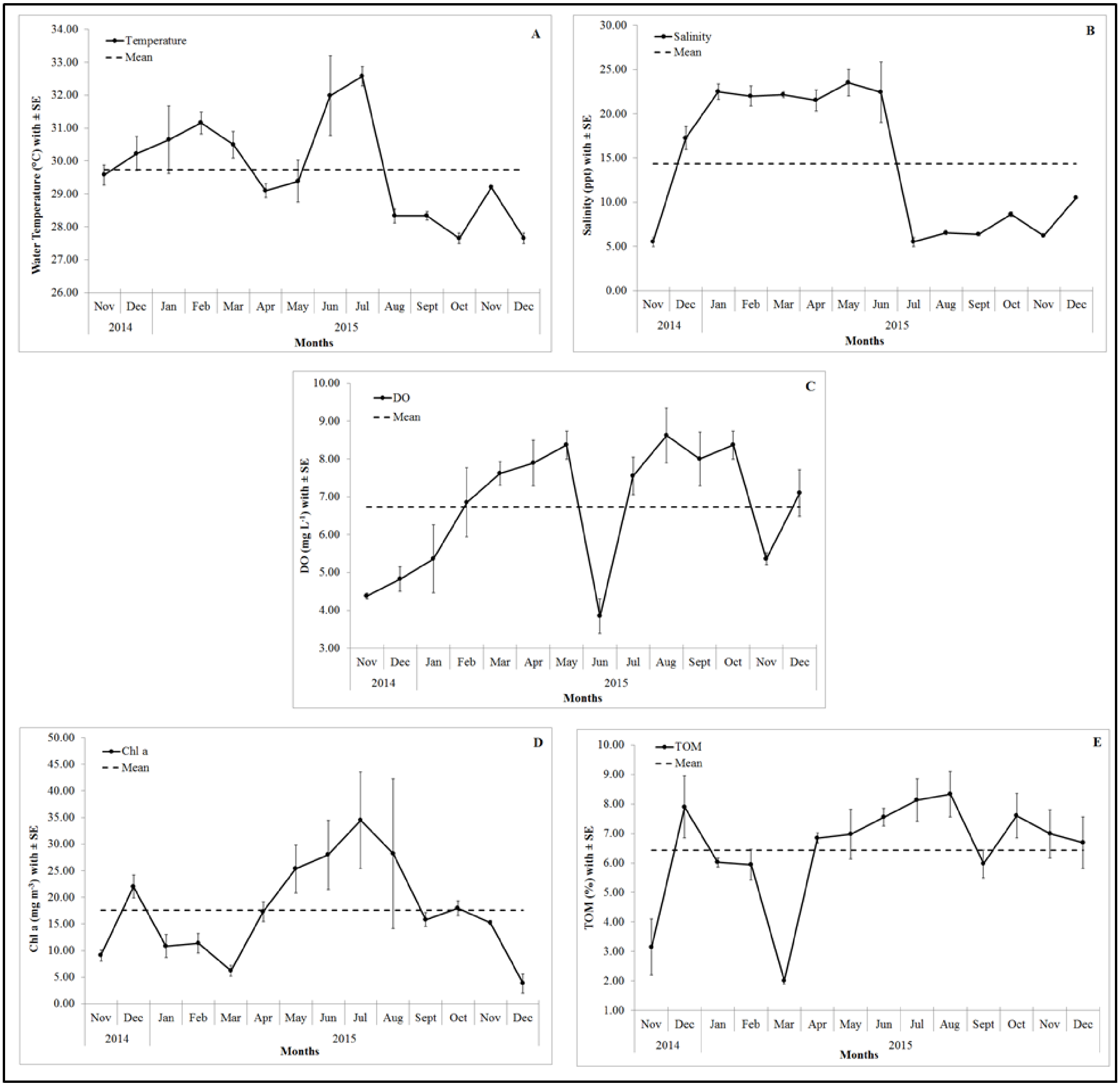

Figure 4. Mean monthly variations in environmental parameters in *Geloina expansa* clam beds in Santiago River, including (A) water temperature, (B) salinity, (C) DO, (D) Chl a concentration and (E) sediment TOM.

The results of the multiple regression analysis for GSI and environmental parameters (Table 2) showed that all environmental parameters contributed in the monthly variations of GSI (r^2=0.83). However, only DO significantly affected the changes in the *G. expansa* population's GSI. Variations in DO were directly associated with the changes GSI.

Discussions

The ranges of the monitored environmental parameters in the *G. expansa* clam bed in Santiago River suggest the threshold of the clam. The mean values of environmental characters may indicate the ideal conditions for *G. expansa*. Such information should be validated under laboratory conditions. In

Table 2. Standard multiple regression analysis of *Geloina expansa* gonadosomatic index (GSI) with the environmental parameters in Santiago River.

Parameter	Standard Estimate (*β*)	Standard Error	Parameter Estimate (B)	Standard Error	P-level
Intercept			62.01	29.64	0.070
Water Temp.	-0.53	0.24	-2.00	0.92	0.061
Salinity	-0.07	0.17	-0.05	0.13	0.682
DO	0.53	0.18	1.88	0.64	0.019
Chl *a*	0.45	0.28	0.29	0.18	0.150
TOM	-0.17	0.24	-0.55	0.77	0.495

$n = 14$; $r^2 = 0.83$; $P<0.00652$

this study, CI was used to characterize the quality of the soft tissue of *G. expansa* population at given environmental conditions. The current study showed relatively high CI values during wet season and moderate values for the rest of the year which indicated the good health status of the clams. Similar trends were reported with other *Geloina* species and cultured bivalves (Mohite et al., 2009; McFarland et al., 2016; Ransangan et al., 2019). An ideal bivalve species for aquaculture should have high quality meat as indicated by their condition in their natural habitat (Yildiz et al., 2011; Filguiera et al., 2013). Moreover, there have been reports that high CI in bivalve populations were related with the abundance of available food in their natural environment (Galvao et al., 2015; Pantea et al., 2018) which may be the case of Santiago River.

The results of this study revealed that the increase in Chl *a* concentration and TOM were associated with the increase in CI values of *G. expansa* population in Santiago River. The significant influence of Chl *a* concentration in water and TOM in sediments on CI variations postulates the importance of the plankton and detritus in the diet of *G. expansa*. Similar observations were reported by Bachok et al. (2003) on the corbiculid mud clam, *Geloina coaxans*, a synonym of *G. expansa* (Poutiers, 1998). Likewise, Clemente and Ingole (2011) suggested that the availability of phytoplankton and microalgae influenced the recruitment of *Polymesoda erosa* (also synonym of *G. expansa*) in a mangrove forest.

The GSI of *G. expansa* in Santiago River was utilized to describe the reproductive activities of the clams, revealing the gonadal development and spawning season. Reports on *P. erosa* (*G. expansa*) and other bivalves have claimed that increasing GSI values indicated gonadal development while reduced values implied spawning events (Clemente and Ingole, 2009; Cabacaba et al., 2018; Asaduzzaman et al., 2019). It appeared in this study that there were two peaks of annual reproductive events for *G. expansa* population in Santiago River. Similar observations were reported on *P. erosa* (*G. expansa*) from various regions which exhibited two pulses of annual recruitment pattern and spawning period (Gimin et al., 2005; Dolorosa and Dangan-Galon, 2014). Population spawning of *G. expansa* as depicted by reduced GSI values was observed during the northeast monsoon months and on the onset months of the rainy season (southwest monsoon). Similar trends in GSI observations were reported in other Philippine bivalves (Del Norte-Campos, 2004; Morillo-Manalo et al., 2016). In the Philippines, northeast monsoon or "Amihan" is characterized by cool and dry weather while the southwest monsoon or "Habagat" is typified by rainy weather condition (Oliveros et al., 2019).

The monsoon regimes may have influenced the environmental conditions within the river which affected the variations in the monthly GSI values of *G. expansa* population. Although all the environmental parameters measured in this study contributed in the fluctuation of GSI values, only the DO observations significantly influence the changes in GSI. It appeared that the decrease in DO concentration in the water triggered the spawning activities of the clam. This information is vital in the development of hatchery techniques for *G. expansa* as well as in the management of the clam beds.

This study provided environmental and biological information that may be used to prelude the development of culture techniques for *G. expansa* in northern Philippines. The environment influenced the reproductive and feeding activities of the mud clam. The observed environmental parameters in the clam beds may be utilized to determine the ideal conditions for *G. expansa* in an artificial setting. The soft tissue of the mud clam appeared to be of good quality which is preferred in aquaculture. The plankton and detritus assumed to be important in the diet of *G. expansa*. It appeared the decrease in DO concentrations in the water may trigger the spawning of *G. expansa*. These results should be validated under laboratory conditions.

Acknowledgement

Gratitude is expressed to PSU President, D.R. Buted and the PSU Board of Regents for granting financial support on this study. This is an aquatic science contribution of PSU-CHANOS.

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