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Stock assessment of *Spondylus varius* (Sowerby, 1827) in lianga bay, surigao del sur, Eastern Mindanao, Philippines

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Abstract

The study was conducted to determine the status of the current stocks of the *S. varius* in Lianga Bay, Surigao del Sur from July 2016 to August 2019. Some variables in population dynamics, such as asymptotic length ($L\infty$), growth coefficient (K), mortality rate (Z, F and M) and the exploitation rate of *S. varius* were estimated from length frequencies analyses by means of FAO-ICLARM Stock Assessment Tools (FISAT). Results showed that the growth performance index (φ) was 3.79, asymptotic length ($L\infty$) was 202.65mm and growth coefficient (K) was predicted to be $0.15yr^{-1.}$ Total mortality (Z) for *S. varius* was $1.04yr^{-1}$ with fishing mortality (F) and natural mortality (M) of $0.74yr^{-1}$ and $1.90yr^{-1}$, respectively. The increased of fishing mortality over natural mortality, decreased of size of the catch, inflated current exploitation rates (E) of 0.7 which was higher than the optimum level of exploitation (E= 0.50). The $E_{max,}$ and E_{10} were 1.29, and 1.55 respectively which interpreted as overexploited. It is therefore to recommend for immediate action in ecological, economical and legal aspects in the fishery of *S. varius* in Lianga Bay Surigao del Sur, Philippines.

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Introduction

The worldwide status of bivalves catches have increased consistently since 1950, peaking in 1984 at approximately 2.2 MT have subsequently fallen in 2010 for almost 1.7 MT which has been associated with a worldwide trend of over harvesting invertebrate stocks (Anderson *et al.,* 2011). Many invertebrates species has a deficiency of information on its stocks due to its unregulated fishery of which official landings were never controlled or recorded. Also, marine invertebrates are fished under open access conditions, it may lead to the over-exploitation of the stock. There must be indicators of healthy fishery and healthy fishing industry while still preserving vital recreational activities. To address this problem, study on its stock assessment is needed. A stock assessment give decision makers with much of the information necessary to make thoughtful choices and decisions (Cooper, undated). It also aids to make projections about how the stock will respond to current and future management options. As the result, it will help to the manager to decide from the data and information from the stock assessment and determine which best options are best overall.

The Lianga Bay has an abundant supply of seashells. One of them is the spiny oyster particularly the giant spiny oyster, which has a high demands on the local markets, restaurants and resorts. Economically, it become a good source of income of fishers living nearby the coastal areas of Surigao del Sur. Nevertheless, the unregulated, uncontrolled and constant harvest of the young and adult spiny oyster is now being threatened. Anecdotal observation that the landings of this resource are poorly documented. Besides, not only the diversity of *Spondylus* in area will be affected but the diversity of hard corals species where these species naturally dwell.

With the daily harvesting of the spiny oyster in the bay, it is not possible that the resource will be depleted and over exploited. This study will determine the current stocks of the *S. varius* whether the population are on the status of under, over or fully exploited. The data that can be generated on this study can be used in crafting policies to manage the resources and can be useful as a reference for ecological, biological and cultivation studies. This study aim to determine the growth, mortality and the current status of exploitation rate of giant spiny oyster *S. varius* in Lianga Bay, Surigao del Sur, Philippines.

Materials and Methods

Study Sites

Assessment of the natural stocks of *S. varius* was specifically situated in the Southern area of the bay considering that this is the top collection sites of *S. varius.*

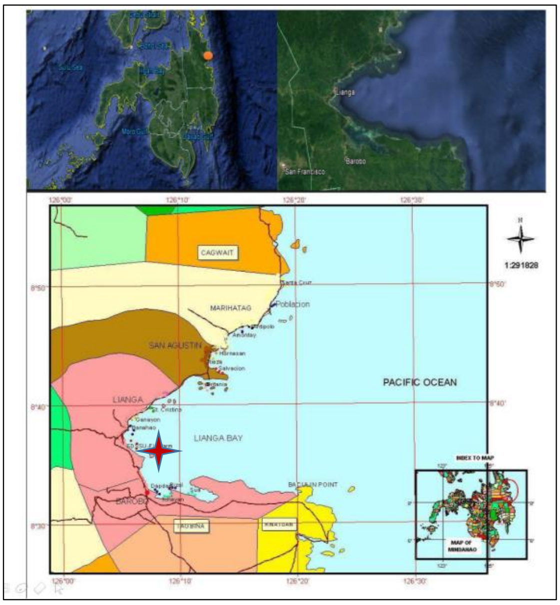

Fig. 1. Map showing the Lianga Bay, Surigao del Sur, Eastern Mindanao Philippines *(redasterisk represent the Southern part of the bay).*

Growth

Around 2780 individuals of *S. varius* was collected and measured from July 2016- August 2019 (38 months). About 6-10 gleaners were commissioned to measured the length and weight of the bivalve weekly, considering that many *Spondylus* gleaners prefer to collect weekly.

The Length Frequent Distribution was analyzed from the catch monitoring of the gleaners using the FAO-ICLARM Stock Assessment Tools (FISAT II) software (Gayanilo and Pauly 1997). In order to identify the modes (cohorts) in the monthly length frequency distribution, the Bhattacharya's method was applied (Bhattacharya 1967).

The relationship on the total length (L) and weight (W) was computed using the formula of $W= aL^b$ (Quinn and Deriso 1989), where a is the intercept and b is the slope. The parameter a and b were estimated by least squares linear regression on log- log transformed data: $\log_{10} a + b \log_{10} L$ (Scherrer, 1984). The asymptotic length (L_∞) and growth coefficient (K) of the von Bertalanffy Growth Function (VBGF) were estimated by Electric Length Frequency Analysis (ELEFAN 1). The estimates growth parameters based on the VBGF by von Bertalanffy (1934):

$$L_t= L_\infty[1-e^{-k(t-to)}]$$

where:

L_t = predicted length at age t

L_∞ = asymptotic length or the mean length of the spiny oyster of a given stock would reach if they were to grow indefinitely

K = growth constant rate at which L_∞ is approached

T_o = age of the spiny oyster at zero length

The estimated L_∞ and K was to calculate the growth performance index (ϕ) on the equation of Pauly and Munro (1984). The growth index phi prime (ϕ) defined as:

$$\phi' = 2 \log_{10} L_\infty + \log_{10} K$$

Mortality

A linearized length- converted catch curve was made to estimate total mortality (Z) using the equation below if the growth factors of the VBGF was done.

$$\ln (N_t/\Delta_t)= a + bt$$

where:

N = number of bivalve in length class i

Δt = time needed for bivalve to grow in length class to i

t = is age (or relative age, calculated with to = 0) related to median value of i^{th} class

b= slope as the value of Z

Natural mortality rate (M) was estimated on the equation (Beverton, 1992)

$$M= K \times [(3\, L_\infty / L_{opt})- 3$$

where:

L_{opt} = optimum shell length of the population

To acquire an estimate of L_{op}, the animal weight in each length classes (class size= 20mm) were summed up and the length class with maximum weight was determined as was described by Froese and Palomares (2000); Cob *et al.* (2009). The Pauly's empirical equation (Pauly, 1980) was not applied considering it was applicable only to fish species not in shelled mollusks. The Z and M were further used to estimate death of caught oyster (F) with relationship:

$$F = Z- M$$

where:

Z = total mortality and M is natural mortality

The exploitation rate E was computed as E= F/Z. Catch curve analysis was extended to an estimation of probabilities of capture by backward projection of the number in each length class, with subsequent estimation using logistic transformation of L_{25}, L_{50} and L_{75} of the spiny oyster was vulnerable to gleaning.

Yield Per Recruit

Beverton and Holt's Yield Per Recruit analysis was done to determine the effects of different levels of exploitation levels for the fishery as well as the current status of the fishery, whether fully exploited, overexploited and underexploited was determined using the analytical tool.

Result and discussions

Growth

The length-weight relationship of *S. varius* in Lianga Bay. It can be summarized on the regression equation of $0.1223\, L^{6.0339}$. The value r = 0.607 means that the length and weight of *S. varius* has a high correlation or it is dependable relationship. This suggest that as the shell length increases, the weight also increases or *vice versa*. Further analysis using the Pearson's correlation showed that the shell length and shell weight was significantly correlated to each other ($p < 0.05$).

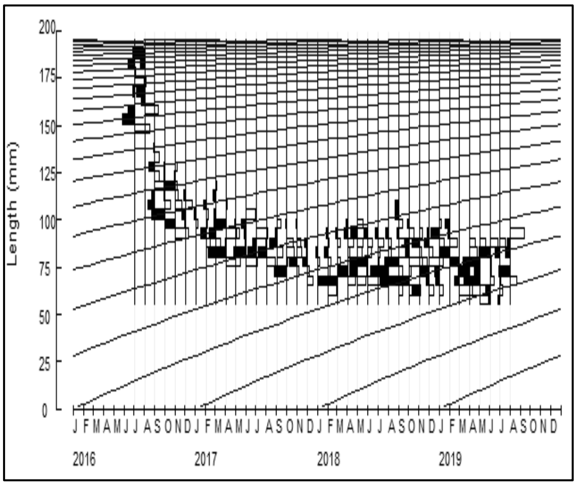

Fig. 2. Length Frequency Plots and von Bertalanffy Restructured Growth Curve for *S. varius* in Lianga Bay, Surigao del Sur.

Figure 2 shows the length frequency plots and von Bertalanffy restructured growth curve for *S. varius* using ELEFAN 1. During the 38 months study period 2780 individuals of *S. varius* were measured at the Lianga Bay. The smallest recorded individual (apSL 56mm) was found during in May to August 2019, and the largest specimen (apSL 192mm) was found during August 2016. The computed L_∞, is 202.65mm while the K value is 0.15yr^{-1}.

Mortality

The length converted catch curve (Fig. 3) calculated the lifespan (Tmax) of *S. varius* was 20 years, with the total mortality (Z) of 1.04yr^{-1} while the natural mortality (M) was 0.30yr^{-1} and fishing mortality (F) about 0.75yr^{-1}. Relative age of population fully gleaned by collectors ranged from 3-9 years at an exploitation rate of 0.71yr^{-1}. Probability of capture analysis shows that the shell lengths of 69.63mm; 75. 73mm and 81mm are the lengths at which 25 %, 50% and 75% are vulnerable to gleaning.

Exploitation Status

The current exploitation rates (E = F/Z) was 0.7 which was higher than the optimum level of exploitation (E= 0.50). In addition the E_{max}, E_{50} and E_{10} were 1.29, 2.18 and 1.55 respectively, which indicates that the stocks of *S. varius* in Lianga Bay is already overexploited.

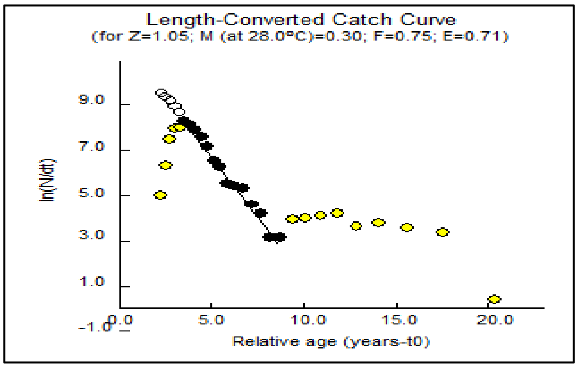

Fig. 3. Length Converted Catch Curve of *S. varius* in Lianga Bay, Surigao del Sur (black circles represent points used in calculating through least squares linear regressions; yellow circles: points either not fully recruited or nearing L∞)

Table 1. Summary of stock indicators of *S. varius* for 38 months (July 2016- August 2019).

Indicators	Values
Data set (no. of months)	38
Asymptotic length (L_∞, mm)	202.65
Growth constant (K, yr^{-1})	0.15
Growth Performance index ( )	3.79
Total Mortality (Z, yr^{-1})	1.04
Fishing Mortality (F, yr^{-1})	0.74
Natural Mortality (M)	0.3
Exploitation Rate (F/Z)	0.7
L_{25}	69.63
L_{50}	75.73
L_{75}	81
Maximum Length observed (mm)	192
M/K	1
E_{10}	0.451
E_{50}	0.32
E_{max}	0.54
Exploitation status (E/E_{10})	1.55
Exploitation status (E/E_{max})	1.29

* *values 1= fully exploited; >1= overexploited; <1= underexploited*

Growth

Considering the mean length (93. 28mm ± 24) of *S. varius* collected within the 38 months by the gleaners, indicates that majority gleaned by the fishermen in the area were small in sizes. If they were to grow at maximum size it will reached at 202mm in size with growth constant of 0.15 yr-1. Length–frequency analysis of the current data set yields a lifespan of intermediate estimate of 20 years. This result is comparable to the *S. spinosus* and *S. calcifer* from the Gulf of California (Cudney Bueno & Rowell 2008, Cota-Hernandez *et al.*, 2011) recorded the estimated asymptotic shell length (L^{∞}) of 180.7mm with growth rings to 10-14 years and 22 years for individuals of Ayangue, Ecuador (Mackensen 2013). This study suggests that this species are slow growing bivalves. Nevertheless, the K of this study was the same to the study of Cota-Hernandez *et al.* (2011) on the *S. calcifer* in the Gulf of California with the growth rate (k) of 0.15yr^{-1}.

The growth performance index (φ) of *S .varius* is 3.79. The GPI is proportional to the maximum rate of body mass increase during a lifetime (Herrmann *et al.,* 2008). This rate (φ) was within the values recorded in the shelled marine invertebrates from all latitudes and ranged between 2.2 to 4.7 (Wolff 1944). Aside, several studies on bivalves on its GPI (φ)) ranges from 3. 35-4. 24 (Defeo *et al.,* 1992; Fiori and Cazzaniga, 1999; Herrmann *et al.,* 2008). However, Herrmann *et al. (*2008) confirmed that growth performance index is habitat-specific from different areas into temperate and upwelling species.

Mortality and Exploitation Status

The high total mortality rate (Z) of 1.05yr^{-1}, with the fishing mortality (F) rate of 0.74yr^{-1} and natural mortality (M) about 0.3yr^{-1}. Mortality value of *S. varius* due to catchment is higher than natural catch which indicates that the stock of *S. varius* population in Lianga Bay was stressed. Factors inducing this tress are possibly by ecological and environmental aspects. King (1995) stated that many factors in sea environment might cause lower survival within the bivalve population, such as inappropriate condition, lack of food, competition, and mostly was due to predation. According to Welcomme (1985), natural mortality could be also due to predation, diseases, high temperature and low dissolved oxygen in the water. However, more studies are needed on this context.

Aside, the human impacts which lead to the overfished of the bivalves lead to the increase of the mortality rate. It was recorded that the maximum length observed is 192mm was collected in 2016. Aside, mostly of the collected samples were relatively large during the year 2016 and 2017. However, for the succeeding years (2018- 2019), it was observed that sizes collected in the wild abruptly decreased. This indicates that the gleaners collected the *S. varius* in smaller sizes. If collection of small size *S. varius* continues, this could definitely to recruitment overfishing. Further biological and ecological studies should be undertaken to carefully monitor S. *varius* exploitation and to put into practice fisheries management measures.

The *S. varius* fishery in Lianga Bay, Surigao del Sur was overexploited based on E_{max} (1.29). Aside, this study recorded the exploitation rates (E) of 0.7 which was higher than the optimum level of exploitation rate (E= 0.50). The unregulated, uncontrolled and constant harvest of the young and adult spiny oyster makes the resource exploited. In Mexico, and Ecuador, the Spondylid species have been overexploited throughout their geographic ranges (Cudney-Bueno and Turk Boyer 1998). Also, the depletion of *Spondylus* species affects also benthic biodiversity in the connection of Spondylids species as substratum for both epibionts species (Mackensen *et al.,* 2012).

Conclusion

This study concludes that the current status of stocks in *S. varius* in Lianga Bay Surigao del Sur is already exploited. The increased of fishing mortality over natural mortality, decreased of size of the catch, inflated current exploitation rates (E) of 0.7 which was higher than the optimum level of exploitation (E= 0.50). And the $E_{max,}$ and E10 were 1.29, and 1.55 respectively which interpreted as overexploited.

Recommendations

It is therefore to recommend for immediate action in ecological, economical and legal aspects in the fishery of *S. varius* in Lianga Bay Surigao del Sur. This study recommends to determine the reproductive biology of an organism as the basic remedy to formulate polices to protect and avoid over-exploitation of this marine invertebrate. Also, this study affirm to collect the *S. varius* individuals as possible to 100mm in size or size restrictions considering they are fully matured.

Aside, it can be facilitated the repopulation of exploited areas by establishing marine reserves, and seasonal closures. The use of aquaculture techniques in the sense of the development of restoration and stock enhancement programs of the natural population are promising alternatives for the recovery of Spondylid species.

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