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Rock Mounds as Rock Oyster *(Saccostrea cucullata von Born, 1778)* Bed in an Intertidal Zone

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Abstract: Rock oyster (*Saccostrea cucullata*) or "sisi" are mostly gleaned from natural beds usually in a distant island. This limits the access and put gleaners, mostly women to risks. There is high demand of rock oyster and supply from the wild is not enough. There are various methods that have been tested to improve supply of raw materials however there have been no success. The paper explored the use of rock mounds as oyster bed in the intertidal zone of Catbalogan City. The peak of spawning in the rock mounds occurred in May. The length-width measurements were ranging from L=1.50-5.99 and W=1.0-5.49 cm, respectively; with mean L = 3.815cm; mean W=3.003cm. With a total surface area of 322.85 m^2, it produced a biomass at ~ 38.243kgs. Dominance and diversity indices were determined from a total of 62 quadrat samples. Overall mean of rock oyster settlements was at 328.2/m^2 with 99% relative abundance from a total of 20,546 individual samples, rock mounds were considered as effective growing cultch. The results also showed that it created relatively new biotic community, but Shannon diversity index (H') ~0.071, and evenness index (e) ~0.028, showed <1.0, low value of indices of the community structure. Rock mounds are proven to be a better alternative in rock oyster farming. It was also found out that it also acted as coastal protection structure, serving as a breakwater.

Keywords: growing cultch, sustainable livelihood, gleaning, mangrove friendly mariculture, participatory community development

1. Introduction

Rock oyster (*Saccostrea cucullata von Born*, 1778) or locally known as *"sisi"* is an endemic mollusc in Samar. It is such a popular marine product wherein the salted form is a popular "pasalubong" item from the province. However, raw *sisi* gleaned from natural beds such as coral reef areas, mangrove forests, and estuarine areas in boulders (Patosa et.al., 2014) are not sufficient to respond to the demand. Furthermore, tidal cycle, rough seas, and distance was considered to be a problem for the gleaners, of which are mostly women. This limits the volume of collected rock oysters once the tide is high or as the sea level rises. Open access and competition in the exploitation of the rock oysters in natural beds also apparently exist among women gleaners not only because of their source of food but also of the increasing demand of "sisi" in the domestic market (ibid). Because of this, the National Economic Development Authority has funded a project to test farming methods to improve raw supply (Doncillo, et.al., 2010).

Although, there was an attempt to establish an artificial structure for growing rock oysters, but it was tested in Zumaraga, Samar under SSU-NEDA-KR2 project (Doncillo, et al., 2010), using of concrete hollow blocks, coco shells and other materials that can be utilized as substrates by oysters and hanging method. However, it was found to be socially unacceptable and considered unsustainable because the structures were destroyed by strong waves and blown by strong winds during the typhoon Pablo (Diocton, per com). An aquaculture technology that is disaster resilient, simple and efficient and socially acceptable is a welcome development for impoverished communities relying on wild catch for food and livelihood.

Rock mound is an artificial substratum, which comprises of sedimentary rocks (limestone) for the purpose of forming an artificial bed or a growing cultch for small rock oysters (*S. cucullata*, von Born, 1778). The rock mounds as oyster bed is locally known as "paniti-an". This can be a *sustainable livelihood* as defined by Ian Scoones:

A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermine the natural resource base (in Krantz, 2001).

It is a challenge for the women and other stakeholders to adopt good practices for governance of small scale and mangrove-friendly aquaculture technology, so that they can strive and claim "for food sovereignty and household/community well-being" (Charles, 2011).

Intertidal small rock oyster (*S. cucullata*, von Born, 1778) is the most important oysters of the family Ostreidae. Other genera of oysters include Ostrea and Crassostrea which are geographically distributed in tropics and sub-tropics, and commonly harvested from wild populations (Angell, 1986). "Sisi" usually attach and grow on the surfaces of rock, stones, seawalls, wharf's concrete post and wooden post, ship's sides, stem of mangrove and other substrates in the intertidal zone.

The attachment of mature oysters to natural substrata was by means of a combination of a modification of the prismatic outer- shell layer formed from within the periostracum and the pressing action of the mantle (Yamaguchi, 1994, in Harper, 1997). Harper (1997) confirmed that the attachment of the oyster *S. cucullata* to its natural habitat has the presence of crystalline calcareous cement. The cement shows a range of spherulitic and irregular blocky textures that are reminiscent of diagenetic cement fabrics. Their form suggested that the cement crystallizes from calcium carbonate-saturated liquor trapped between the underside of the shell and the substratum, with crystallites nucleating on all surfaces of the void.

In Philippine waters, the oyster species have been the subject of investigation. Angell (1986) reported that oyster culture of other species (e.g. *Crassostrea spp*. and *Perna viridis*) have been using various traditional methods such as: staking, lattice, hanging long-line and raft constructed with bamboo, shells and other materials. Delmendo (1994) reviewed the development of oyster (*Crassostrea spp*) farming, presented the history, described the traditional methods of culture, constraints and problems such as pollution in growing areas, and provided recommendations for expansion.

2. Objectives

This paper will present the potential of using rock mounds for growing rock oyster. It will also determine spawning month, estimate biomass of rock oyster produced and the diversity indices on the rock mounds.

3. Methodology

The study explores the performance of rock mounds as rock oyster bed. Direct observation was performed to collect data on biological and ecological aspects of the study. A pre identified site was selected as experimental station.

3.1 Study site assessment.

A study site assessment was conducted in the intertidal zone through an ocular survey or by walking along the entire shoreline to describe the biophysical features and record habitat types. The essential habitat types in the shoreline was recorded which consist of; e.g. soft or hard rock, sand, clay as in mangrove areas and soft to very soft clay, silt or mud as found along mangroves and other tidal areas (FAO, 2011). An aerial photography was produced to provide total coverage of the coast (Baker, Hartley and Dicks, 1987). Conduct of material needs assessment which includes the types of rocks, volume of rocks for the construction, sources of rock supply, quality, environmental impact (e.g. cause no negative effect in removing rock from the source), and the means of transport were all considered (FAO, 2011).

3.2 Construction of rock mounds

The project site was selected by the members of Ibol Rock Oyster Farmers Association (IROFA) together with other stakeholders in community. Criteria set on the project site selection were based on: local knowledge, accessibility, and availability of the construction materials.

Prior to the construction of rock mounds, elevation measurement of the existing substrates with the parental stock of rock oysters in nearby seashore was conducted using a meter stick, bamboo and a level hose with water. The height of the parent stock also served as basis for the height of the rock mounds to be constructed. Rock mounds comprising of sedimentary rocks (limestone) were used in the construction in an area near the mangroves with small creek, in exposed, compacted sandy-muddy substrates tidal flats.

3.3 Monitoring of spats

Monitoring of the oyster spat on the spat collector and rock mounds were undertaken to directly observed changes on the subject. Spat collectors were made of rectangular concrete tiles hanged between concrete posts. The spat collector served as growing cultch and also determined the spawning period of the oyster (Young and Traviña, 1983). The spats or shell of rock oyster were directly observed and identified on the rock mounds and spat collector to determine the setting or spatfall period.

3.4 Sampling

In a total surface area of 322.85 m^2, a total of 62 quadrat (area 1 m^2) samples were laid down randomly at four locations in the rock mounds: 1) facing seaward, 2) landward, 3) left column, and 4) right column. All species were identified, counted and recorded as total number in quadrat except: 1.) barnacles; 2.) hydroids, bryozoans, and spirorbids; 3.) sponges

(After: Baker, and Crothers, 1987). Results of the survey will require some form of statistical analysis. Mega-statistic program was used to determine one-way analysis of variance (ANOVA) for the variability of settlement, patchiness of the rock oysters on the rock mounds of 322.85 m² area.

Relative abundance or frequency of occurrence (number and %) of rock oyster on each quadrant sample and site were calculated as follows:

3.4.1 Relative abundance or frequency of occurrence of species

$$A\ (\%)\ \frac{No.of\ Collections\ of\ Species\ A}{Total\ number\ of\ samples\ observed} x100$$

3.4.2 Diversity and dominance indices

Species richness, relative abundance of rock oyster and density count of species were determined by direct observation and counting of the number of individuals present on the rock mound surfaces, crevices, cracks, and under overhangs. Odum (1971) and Baker, and Wolff (1987) provided some useful of indices of species structure in communities. They have suggested that Shannon-Wiener Index provides one of the best measures of community diversity.

3.4.3 Index of dominance (c)

$$\boldsymbol{c} = \sum \left(\frac{\boldsymbol{ni}}{\boldsymbol{N}}\right)^{\mathbf{2}}$$

Where ni = importance value for each species (number of individuals, biomas and so forth) and N = total important values.

3.4.4 Shannon index of general diversity (H)

$$H = - \sum \left(\frac{\boldsymbol{ni}}{\boldsymbol{N}}\right) \boldsymbol{ln} \left(\frac{\boldsymbol{ni}}{\boldsymbol{N}}\right) \text{ or } H = - \sum(\boldsymbol{Pi})\boldsymbol{ln}(\boldsymbol{ln}\ \boldsymbol{Pi})$$

where: Pi = importance probability for each species

3.4.5 Evenness index (e)

$$e = \frac{H}{\log S}$$

Where: H = Shannon index of general diversity, S = number of species

3.5 Length/width measurements

One hundred twenty (120) individual samples on length and width of rock oysters were collected. Sizes (length and width) of the rock oysters were measured using ruler. Length measurements of the shell of the rock oyster were done with the greatest measurement in an anteroposterior direction; this is approximately parallel with the axes of the hinge. While width of the shell was measured with the greatest measurement in a dorsoventral direction; this is usually approximately at right angle to the axis of the hinge and approximately at right angles to the length measurement (Laevastu, 1965). Collected length and width data was processed and analyzed to describe the rock oyster population.

3.6 Biomass estimate

Biomass may be expressed in various ways, e.g., wet weight of organisms, dry weight, ash-free dry weight, total nitrogen content, and calorific value. Ash free-dry is often considered as a reasonable compromise between usefulness of information and labor (Baker and Crothers, 1987).

However, the following procedure may be used for the determination of mean wet flesh weight of the chucked meat of small rock oysters, i.e. based on the overall mean of the quadrat survey results. The average number of small rock oyster meat were removed or chucked from their shells attached from the rock mounds. Placed in pale container and put wet sample in a strainer. Allow to loss water, and then weigh the sample.

Let the biomass estimate (B) A = total surface area under investigation from n rocks oyster/m² and let Ca (1) be the mean chucked meat (in wet flesh weight) of collected rock oyster no. i, i=1, 2, 3, .../n. The estimate then becomes:

$$B = A\frac{1}{n}\sum_{i=1}^{n} \overline{Ca}(1) = A\overline{Ca}$$

where: B = Biomass, total wet flesh weight of small rock oyster chucked meat; n = number of rock oysters per quadrat (area 1 m²); $\overline{Ca}$ = Mean wet weight of small rock oyster chucked meat in grams/m² ; A = Total surface area (m^2) under investigation

4. Results and Discussion

4.1 The experimental site profile

The experimental site was in an intertidal zone, about 300 m from the village of Ibol, Catbalogan City, Philippines with latitude of 11°45'18" N, and Longitude 124°50'36''. The seashore during low water is exposed, compacted of muddy-sandy substrates of tidal flats. A secondary growth of mangrove forest mostly *Avicennia* species found in the northeastern portion of about 8.4 m distance to the site. A small creek at about 36 m distance to the site cut-across into the intertidal zone which discharge a freshwater into the sea and influence the variability of the physico-chemical features of the area. With the presence of mangrove forest, this eventually promote harmoniously with the environmental integrity of the intertidal zone. They help to maintain water quality by filtering toxic pollutants, excess "plant nutrients" (Aypa and Baconguis, 2000), and sediments and by absorbing other pollutants. They also reduce storm damage and coastal erosion by absorbing waves and storing excess water produced by storms (Hatcher *et al.*, 1989; Miller and Spoolman, 2013).

Parent stock of rock oysters were observed and found in the coastline of some rocky area. On the west, is the Malatugawi Island, where natural bed of parent stock of oysters was also found, during spawning serves as sources of spawned trocophores and spats which could be readily transported by waves and tidal currents (i.e. during high tide or low tide), and possibly grow in the rock mounds.

The site selection must also take into consideration the quality of the coast. In as much as it is advantageous to set-up rock mounds near communities for easy management and gleaning activities, waste disposal will be an issue. Rock oysters are filter feeders and poor quality environment will make the harvested oyster potentially contaminated. In the study of Orale & Fabillar (2011), Catbalogan City (where the site of this study was made) has poor coastal quality condition due to poor waste management practices.

4.2 Rock mounds as oyster bed

Limestone was used as the rock mounds. A total of 50 m^3 of rocks were used in the construction of rock mounds. The mounds approximately about 1mx1mx0.4m have a total surface area of around 322.85 m^2. Each mound consists of

20 to 30 pieces having varied sizes and shapes.

Figure 1. Rock mounds

4.3 Rock oyster spat collector

A spat collector is an artificial or man-made substrate composed of any material that allows planktonic larvae or trochopore and spat stages of mollusks such as rock oyster to settle or grow. For this purpose, seven concrete posts were constructed. Each concrete post measuring of about 0.20 m x 0.20 m x 2.53m, with a base of 1 m x 1 x 0.20 m. Between the two concrete posts, 4 pieces of concrete tiles and each one measuring of about 0.15 m x 0.30 m x 0.025 m. The 4 pieces concrete tiles were hanged using a monofilament nylon twine # 300.

Figure 2. Rock oyster spat collector (L); part of rock mounds (R)

4.4 Monitoring of rock oyster spat

Monthly monitoring was conducted on the spat collector and rock mounds as to the presence or absence of spats settled. On the 9th day of May 2012, only some spats of barnacles or "tagimtimiw" were observed in the spat collector. Based on the local knowledge, after the occurrence of the spat of barnacles, rock oysters would follow to occur. On the 29th day of May, it was observed that numerous spats of rock oysters settled on the rough surfaces of rocks. This indicates a biological succession (Nybakken, 1982; Molles, 2006). The spat that settled on spat collector was measured using Vernier caliper, and the spat size was about less than 1mm. Ver (1986) reported that the age of spat stage in the larval development of oyster with length of 274µm- and height of 328 µm (i.e. *Crassostrea iredalei*) was about 20 days old. Thus, it is therefore safe to say that the spawning of the parent stock of rock oysters have occurred most probably on the month of April- May.

Spawning of *S. cucullata* Braley (1982) reported that the population of *S. cucullata* in Sasa Bay, Guam had low level of reproduction with three main peaks throughout the year, March-April until late June and November-December. In addition, Krishanakumari, *et al.* (1990) reported the spawning of the rock oyster (*S. cucullata*) in Bombay, Maharashtra, India, occurred during the premoonsoon, which is similar to the above mentioned findings. In comparison with the two areas, peak of spawning of rock oyster (*S. cucullata*) have occurred almost the same reproduction periodicity in the intertidal zone of the study area. This indicates that the rock oyster (*S. cucullata*) is geographically distributed in tropics and sub-tropics, and commonly harvested from wild populations (Angell, 1986).

Table 1. Total length –width frequency distribution and percentage (%) of small rock oysters in rock mounds (August 2013)

No	Class interval Low - High	Mid points cm	(L) N	(W) N	(L) %	(W) %
1	1.0 -1.49	1.25		1		0.83
2	1.5 – 1.99	1.75	1	8	0.83	6.70
3	2.0 – 2.49	2.25	5	17	4.17	14.12
4	2.5 – 2.99	2.75	9	37	7.50	30.83
5	3.0 – 3.49	3.25	33	29	27.50	24.20
6	3.5 - 3.99	3.75	35	16	29.17	13.33
7	4.0 – 4.49	4.25	16	7	13.33	5.83
8	4.5 - 4.99	4.75	14	4	11.67	3.33
9	5.0 – 5.49	5.25	4	1	3.33	0.83
10	5.5 – 5.99	5.75	3		2.50	
	N		120	120	100.00	100.00
	Mean		3.815	3.003		
	S^2=0.144		0.6628	0.0596		
	S=0.379		0.8141	0.7346		
	Relative S=0.117		0.2134	0.2446		
	Standard Error=0.03		0.0743	0.2232		

Table 2. Relative abundance in number and percentage of rock oyster and other organisms inhabiting the rock mounds constructed in the intertidal zone (October 2013)

No	Species	English name	Local name	Number	(%)
1	*Saccostrea cucullata*	Rock oyster	Sisi	20,350	99.09
2	*Patella sp.*	Limpet	Sadok-sadok	66	0.321
3	*Uca sp.*	Mangrove crab	Karas	47	0.228
4	*Noetia ponderosa*	Ponderous ark	Bu-o	30	0.146
5	*Nerita planospira*	Flat spire nerite snail	Sehi	19	0.093
6	*Anomalodiscus squamosus*	Squamose Venus	Bug-atan	7	0.034
7	*Zeuxis olivaceus*	Mitre-like Dog Whelk	Unknown	6	0.029
8	*Cantharus ringens*	Spiral snail	Halan	4	0.019
9	*Paphia amabilis*	Hard shell	Ponaw	4	0.019
10	*Saccostrea sp.*	Oyster	Polpol	4	0.019
	Total Summary			20,537	100.00
	Total number of species	10			
	Index of dominance (c)	1.149			
	Shannon index of diversity (H)	0.071			
	Evenness index (e)	0.0286			

However, on the first week of July monitoring, it was observed that another wave of new spats have set on the rock mounds. It is interesting to note however, that some spats that settled on the spat collectors become sexually mature and were identified as *C. eridalei* species or "talaba" (Figure 4). The *C. eridalei* is now considered as a potential commercially cultivable species in the study site.

4.5 Length-width frequency of small rock oysters

Table 1 shows the total length-width frequency distribution and percentage data

Figure 3. Spats of rock oyster settled on the rocks

of the small rock oyster collected in the experimental rock oyster mounds. It indicates that the small rock oysters with length ranges from 1.5-5.75 cm and at about 3.75 cm or between 3.50-3.99 cm has the greatest number and percentage (n = 35; 39.17%). Biostatistics methods were used to compute for mean length-width, variance, standard deviation, standard error. The results showed that mean length of rock oyster was found at 3.815 cm, and the width was at 3.003 cm. Variance (S^2) of length and width were at 0.6628; 0.0595 respectively. The values of standard deviation (S) was computed at 0.8141; 0.7346 for length and width, respectively. Standard error of the length-width frequency of rock oysters were computed at 0.0743 and 0.223.

The length-width data of small rock oysters was plotted on a graph had shown a significant result, as the length increases width also increases (Figure 4). Generally, this means that the small rock oysters belong to same cohort that have settled or set on the rock mounds on May 2012.

4.5 Relative abundance and diversity indices

Table 2 lists the species in abundance at the rock mounds where *S. cucullata* records the most abundant with 20,350 counts (or 99% of the total species), followed *Patella sp.* with 66 (or 0.03%), and *Uca sp.* with 47 (or 0.02%). The total count of all the species is 20,537 comprising 10 different species, 9 consisting of mollusks, and one (1) crustacean. It was observed that six (6) mangrove plants species identified as the *Avicennia alba and Rhizophora apiculata* have grown within the rock mounds. It indicates a low value of Shannon diversity index *(H)* ~ 0.071 and evenness index (e) of 0.0286. But created relatively new biotic community structure and coastal habitat for other organisms, hence biodiversity may be improved.

Figure 4. Village women gleaning rock oyster from the rock mounds.

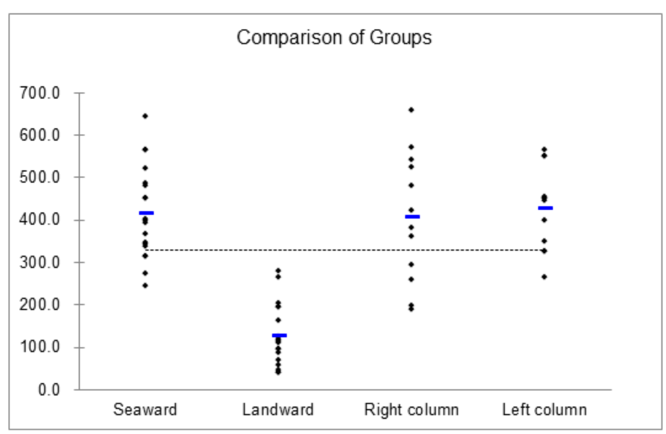

Figure 5. Oyster count and mean in four sides of the study area

The highest settlement of oysters is the left column location with a mean of 427.9/m^2, followed by seaward with 4.16, and right column with 407, and the lowest is the landward location with 127.4. The overall mean of the rock oyster settlement is 328.2/m^2.

4.6 Biomass estimate

Figure 5 shows the scatter plot and the different mean values (blue dash in the figure) of rock oyster per m^2 from four locations with overall mean ~ 328.2 rock oyster/m^2 is considered preliminary. This value is used as basis to estimate biomass in wet weight ~354.11 grams/m^2. With total surface area of 322.85 m^2, the biomass estimate ~38.243 kg. In one (1) hectare surface area, the projected yield is 3.541 metric tons.

5. Conclusion and Recommendation

Rock mounds as oyster bed is considered as mangrove friendly-aquaculture and effective growing cultch for small rock oysters having 99% of the relative abundance. It created a new biotic community in the intertidal zone. It indicates an index of dominance of 1.149, by *S. cucullata*, but Shannon diversity index (H') ~0.071 and evenness index (e) ~ 0.0286, showed a low values of indices of the community structure.

The small rock oysters spawned in the month of April-May; Indicates that the *S. cucullata* is geographically distributed in the tropics and subtropics. The overall mean of 328.2/m^2 serve as basis for biomass estimate. With the total surface area 108 m^2. The biomass estimate in wet weight ~38.243 kg. The length-width measurements of small rock oysters ranges from L=1.50-5.99 and W=1.0-5.49 cm, respectively; mean L = 3.815cm, W=3.003cm and considered as preliminary values. Most of rock oyster settled on the side facing the sea and less on the landward side.

Data shows that rock mounds as oyster bed is promising and can be a good source of livelihood for the community.

Further studies on how to improve efficiency of rock mounds needs to be explored. The siltation/deposition of eroded soil carried by runoff water, strength of rock mounds to waves and the circulation of water must be studied.

6. Bibliography

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