Bamboo Tray Module Mussel Farming

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Abstract: Mussel farming technologies such as staking and wigwam methods have been practiced in Maqueda Bay area in more than three decades already. They were observed to have no improvement in terms of production capacities due to inefficient use the bamboo poles as artificial substrate and could not withstand wind-induced waves due to typhoon. The Bamboo Tray Module was developed to improve farm productivity, efficient use of material and resistance to typhoons. This innovation has been tested in almost three years and compared its performance with the staking method in mussel farming. It was found out and concluded that the performance of the Bamboo Tray Module is more efficient in terms productivity, use of bamboo materials and resistant to typhoon and big waves compared to the staking and wigwam methods. This new technology in mussel farming will serve as an option to the recurring industry and environmental problem in Maqueda Bay area. Paradigm shift in mussel farming technology and policy redirection towards a sustainable environment were recommended.

Keywords: Mariculture, green mussel, typhoon resistant mussel farming method, cost-effective technology, productivity

1. Introduction

Mussel farming is the most productive form of saltwater aquaculture (Bardach et al., 1972) practiced not only in the Philippines but also in Europe, North America, China, Japan, India and Southeast Asian countries that have potential coastal waters. In the Philippines, mussel farming began in 1955 when the then Fisheries Commission (now the Bureau of Fisheries and Aquatic Resources or BFAR) set up a mussel demonstration farm in Binakayan, Cavite using bamboo poles that are staked to the bottom at a spacing of 2 meters (Aypa, 1990).

Mussel farming was introduced in Maqueda Bay by BFAR in 1975 due to the presence of green mussel, *Perna virides* spats. A research on mussel spats collection techniques in the municipal waters of Jiabong, Samar employing the staking or *tulos*, wigwam and hanging methods (Adora, 1978). Mussel test culture adopting the staking and wigwam methods were replicated in adjacent waters of Villareal and Laguimit bays (Villareal, Samar) and Cambatutay Bay (Tarangnan, Samar) using the bamboo poles and monofilament nylon as tying material with the mussel brood stocks. The result of such research paved the way for the dispersal of mussel brood stocks introduced in technology-demonstration farms established in these sites as strategy on resource enhancement which were consequently declared as the mussel-belt of the Province of Samar.

Since then, mussel farming became a significant fishery industry of the Province of Samar which supply fresh mussels to Manila market or even northern Mindanao (Baylon, 1990). Personal interviews from mussel traders revealed that Jiabong, Samar transport fresh mussels to Davao Provinces in Southern Mindanao while those in Villareal, Samar has already been transporting to Cebu City. Mussel farming became the main source of livelihood of 651 households in the province, with total mussel production reached 10,616 Metric Tons of fresh mussels valued at PhP43.245 Million pesos (BFAR, 2006). The Department of Trade of Trade and Industry – Region 8 has identified mussel as the OTOP of the Province of Samar due to the major employment it has generated (NSCB, 2006).

In the long period use of staking and wigwam methods most technology users complained on farm destruction after typhoon occurrences and the relatively low production of only 1-2 sacks (≈70-140 kgs) per 3 pcs (10m long) bamboo poles. No attempt has yet been made to evaluate the performances of mussel farming techniques. To address the above technology problems, a new technology in mussel farming was developed to improve farm economic efficiency and productivity and to mitigate impact of wind-induced waves from typhoons.

2. Objectives

This paper revealed the performance of bamboo tray module in mussel farming as the take-off point for its diffusion. Specifically, it aims to:

2.1 Reveal the technological framework of the innovation;
2.2 Discuss the strategies undertaken during the trial of the innovation;
2.3 Discuss procedures in the construction and establishment of the bamboo tray module, and
2.4 Compare the performance of the innovation with the staking methods.

3. Methodology

The design of the project was initially prepared and served as guide in its structural development. The technology trial was conducted in Cambatutay Bay, Tarangnan, Samar (Fig. 1) in coordination with the Local Government Unit. Community-folks identified by the LGU were involved in the new technology implementation and monitoring.

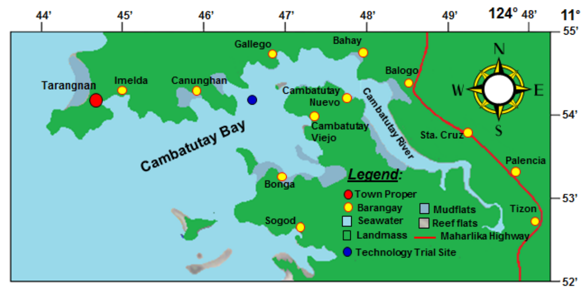

Fig.1 – Bamboo tray module farming experimental sites in Cambatutay Bay, Tarangnan, Samar Philippines

A total of 80 bamboo poles with an average length of 5.5m and 17cm average internodes circumference measured using the measuring tape and sharpened bolos were used in boring and in the construction of two (2) bamboo tray modules. The underwater monitoring was conducted monthly from November 2008 to June 2009 with the use of diving mask to determine the physical status of farm structure, size of mussel stocks. The stocks of the farm were harvested in July 2009 using a motor boat. During harvests, mussel productions from each bamboo pole utilized were weighed and recorded.

The technology trial was further conducted in pre-identified sites of Maqueda Bay and Villareal Bay vicinities (Fig. 2) following similar procedures performed in the first trial, but with some corrective changes made. Two modules were established in each site using 50 poles of bamboo species *Bambusa blumeana* (Kabugawan) and *Dendrocalamus latiflorus* (Patong) per module measuring 7.5m long by 21cm average girth circumference. Polyester packing strap (Plate 2), 200m by 2.0cm width by 1.5mm thick was used as tying materials. The positions of the farms (Table 1) were determined after the establishment using the Global Positioning System (GPS) and water depths of each site was determined by actual sounding using rope and inventory of existing mussel farms, the corresponding technology adopted and the number of bamboo poles used was performed.

During the harvest of mussel stocks of each experimental set-up, sizes of mussel samples were measured using the foot rule and the total productions were recorded. Productions from the existing mussel farms were retrieved from the owners/operators. Results of this trial were compared with that of staking method and wigwam mussel farming techniques adopted in each site.

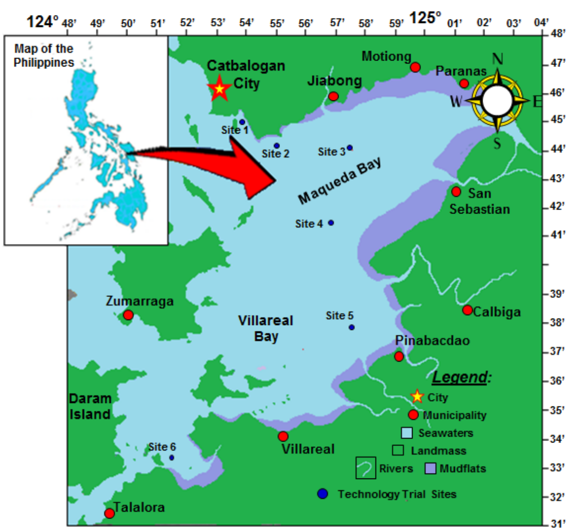

Fig.2 – Bamboo tray module farming experimental sites in Maqueda and Villareal Bay.

The efficiency performances of the two methods in terms material used was estimated by computing the submerged surfaces of the bamboo poles and the production was based on the quantity harvested per unit area. The data obtained were analyzed qualitatively using the univariate analysis. The resistance of the two techniques against inclement weather conditions was based on the observations noted during the trials. In addition, the technology environmental impacts were directly obtained from the technology adopters through field guided interviews. The information revealed in this paper is limited only on the outcome of the second trial, in which the primary intention was to verify and further test the viability of this new mussel farming technique in one production cycle in accordance with the prevailing environmental and climatic conditions during the period.

Table 1 – The specific locations, coordinates and respective water depth of experimental sites

Site №	Specific Sites and Positions (Barangay/Municipality)	Water Depth
1	Ibol, Catbalogan City 11° 44’ 21” N; 124° 55’ 12” E	4.57m
2	Pangdan, Catbalogan City 11° 44’ 27” N; 124° 54’ 03” E	4.57m
3	Jiabong, Samar 11° 43’ 45” N; 124° 57’ 00” E	4.57m
4	San Sebastian, Samar 11° 41’ 02” N; 124° 56’ 03” E	4.57m
5	Pinabacdao, Samar 11° 37’ 35” N; 124° 56’ 27” E	3.66m
6	Mallorga, Talalora, Samar 11° 33’ 00” N; 124° 52’ 00” E	2.44m

4. Results and Discussion

Fund availability was the major factor which contributed to the success of the technology innovation. This project is an outcome of BFAR’s plan to come-up a new on the advent of massive mussel mortalities that occurred in the early periods of 2008.

Project activities were undertaken through the collaboration of the regional and provincial offices of the Bureau of Fisheries and Aquatic Resources, a national government agency mandated for the management, protection, and conservation of fisheries and aquatic resources of the country, the Office of the Provincial Agriculturist in Samar and Local Government Units where the trial was undertaken. A proposal to implement a new mussel farming technology was submitted and fund for the Mussel Industry Rehabilitation Program was provided.

4.1 The Technology Framework

The framework of the bamboo tray module (Fig. 1) is anchored on the principle of sustainability of the mussel fishery, designed based on the ideas of the life history of mussel, ecological-sound, economic efficiency and resilience to typhoon towards enhancing farm productivity.

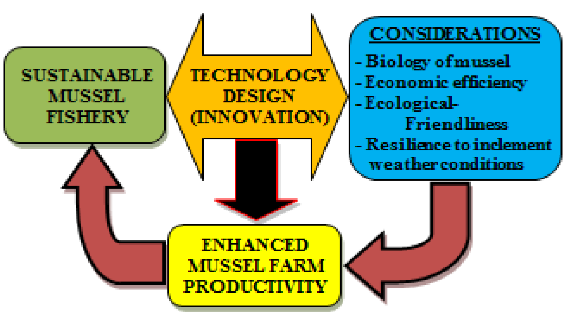

Figure 1 – Technology Framework of Bamboo Tray Module

The biology of green bay mussel, *Perna viridis* was very essential information in the design of the innovation. The behavior of this organism led to the idea of setting-up the structure in the mid-water column within which the mussel larvae (spats) dwell after they are spawned, undergo metamorphosis and settlement to the benthic habit within 8-12 days to as many as 20 days (Power et al., 2004)capable of secreting byssal threads (Tan, 1975; Siddall, 1980; Manoj and Appukuttan, 2003).

The main purpose of material used in mussel farming is for mussel spat collection, which also requires investment. The framework considered the economic efficiency of every material that is being utilized in the structure. Efficiency use of materials is translated in terms of their maximum area/spaces unto which mussel can attach. Since the full-length of bamboo poles is the material often used by most mussel farmers, setting them horizontally below and parallel to the sea surfaces is a noble idea that accord with the concept of economic efficiency of the bamboo tray mussel farm. No material is wasted and all surfaces of the bamboo serve as artificial hard substrate.

Environmentally- and ecologically-soundness are aspects considered in this innovation. These concepts are integrated in the design as the possible corrective measure for the current mussel farming practices. Staking and wigwam mussel farms impede water circulations and triggers siltation in a given area due to the abrupt variation of the surface slope, vertical velocities along the water column from bottom to surface during a tidal cycle. Due to bottom friction and to the vertical viscosity profile, velocities decrease from surface to bottom (Brenon et al., 2009). It has been found that staking method in mussel farming facilitates siltation (Guerrero, 2008). Setting the bamboo tray in mid-water column parallel to the sea surface with wide spaced posts will theoretically enhance water circulation.

Typhoon is one among the major threat to mussel farming. Its occurrence can severely damage mussel farms and loss of stocks. Huge wave occurrence is uncontrollable especially during inclement weathers and prevalence of seasonal winds. Waves in Maqueda Bay are generally wind-driven and large waves in the area are due to typhoons. Southwest monsoon (*Habagat*) is prevalent from mid-July to mid-September (Villanoy, 1990) which induces big waves in the area. Impact of waves is dependent on its height which is one-half of its length measured from one wave crest to the other as illustrated in Figure 2. The impact of waves is being triggered by the orbital motion of seawater particles that decreases with water depth. This led to the idea of setting the bamboo tray structure in the mid-water column 2-2.5m below the sea surface thereby significantly reducing its vulnerability to wave impact and making it resilient to typhoon.

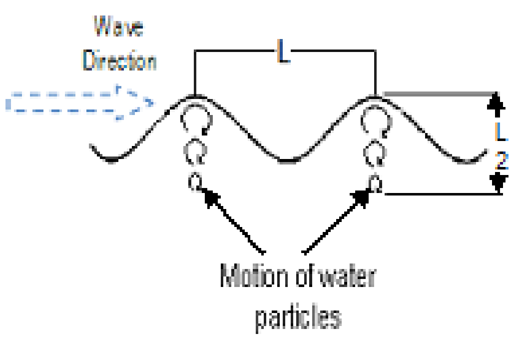

Figure 2 – Orbital motion of water particle (Ludman & Coch, 1981 as cited by Orale, 2011)

4.2 Implementation strategies

The technology trials of the bamboo tray module were successfully implemented by undertaking following the strategies below:

Inter-Agency Collaboration: Prior to project implementation, coordination with the Chief Executive and other concerned officials of the concerned Local Government Units was a protocol required under the provisions of Republic Act No. 7160 (Local Government Code of 1991) done through meeting. The need for collaboration, the role of communities in project implementation was clearly emphasized. Schedule of activities was formulated defining the specific dates and focal persons/entities concerned. After which, BFAR, LGU and fisher folks have entered into a Memorandum of Understanding (MOU) providing for the specific roles and function in the implementation. The LGU identified the technology beneficiaries and at the same time the adopters, the BFAR provided funding support, while the fisher folks took an active participation in the technology implementation. Fisheries personnel of OPA took charge in providing the technology innovation, conduct of training and supervision in the actual establishment of the project.

Community involvement – Among the identified attributes of Samar fisher folks is the poor responses to technological changes especially if it concerns of their livelihood. Most of them have this *wait and see attitude* in which people will not adapt to such changes unless proven by results. During the conduct of the bamboo tray module technology trial, the involvement of community folks was considered to serve as the immediate technology adapters, and to reduce project expenses in overseeing the structure. The community folks were involved on all activities required in one project cycle, which started from the procurement of local materials, project monitoring until harvesting of the crop. In this manner, fisherfolks have appreciated and grateful of being given the importance while gaining a *sense of ownership* on the project.

Hand-on Training – This activity is generally a basic requirement in any government program/project implementation. This was delivered only in every project location to fisherfolks involved to capacitate and appreciate the technology. The bottom-line of which is to develop fisherfolks' talent from within, as it has been recognized that most skills can be taught and that expertise can be developed on the job while helping them in increasing the job knowledge and skills and in inculcating the sense of team work, team spirit, and inter-team collaborations. The training was conducted in an informal manner through a hands-on demonstration. Fisherfolks were involved in the actual construction of bamboo trays and in the establishment of the structure at the identified farm site with the assistance of a fishery technician under the supervision and guidance of innovator/researcher.

Supervision in technology implementation and monitoring **-** The presence of the innovator is very essential during its implementation precisely because the technology innovation involves a process, which commences on the construction of the bamboo tray modules up to the modular farm establishment. The technology process was closely supervised so that lapses can be avoided during implementation. Technology monitoring is also very essential in looking into the state of technology especially on its effectiveness and efficiency in terms of spat collection and stability. The close supervision undertaken enabled the researcher to work with some workers in order to meet certain professional and personal objectives which together promote the best outcomes for participants and provided the opportunity to discuss on a one to one basis, share knowledge and ideas, thus ensuring that they feel supported and valued and that good practice and achievements are recognized. The same also provided the opportunity to discuss and identify areas for development through further training, observation of other more experienced staff, or other developmental activities. During regular monitoring, corrective measures were recorded and considered in subsequent replications.

Provision of incentives – There are plenty of evidences which suggest that incentive ensures worker a more relaxed and happier workplace and further can increase performance by up to 25% and reduces costs. Under this project, the efforts exerted/contributed by the fisher folks involved have been considered in the provision of incentives. However, the incentives given were not in the form of money. After the establishment, the ownership of modular farms was turned-over to the group of fisher folks emphasizing their role on the project including the submission of production records. After the harvest, the produce and the corresponding sales were given to fisherfolks as their incentive from the project. With this strategy, the sense of ownership has been inculcated in the fisherfolks and in like manner, enhanced their sense of responsibility on the project. This strategy further enhanced the fishers' self-satisfaction manifested by their action (gratefulness) and happy faces.

4.3 The experimental set-ups

The experimental set-ups generally being referred to in this report is the *Bamboo Tray Modules*, the new technological innovation in mussel farming that were subjected to test/trial. A total of ten (10) modules were established and distributed in six sites of Maqueda Bay and Villareal Bay vicinities (Table 1). The available materials extended to beneficiaries resulted to an uneven distribution of the experimental set-ups. This result was attributed to the number of modules allocated to every municipality.

Table 1 – The corresponding number of bamboo poles distributed and used for the construction of bamboo tray

Site Nº	Nº of BTM Established	Nº of Bamboo Poles Used
1	1	50
2	1	50
3	2	102
4	2	102
5	2	102
6	2	102
TOTAL	10	508

The structural plan: The plan of the bamboo tray module (Figure 4) is generally intended to deter if not reduce technological problems in mussel farming. Every set-up consisted of the bamboo tray, installed in water column and held elevated from the sea bottom by various staked posts evenly distributed throughout the tray structure for the distribution of weight loads.

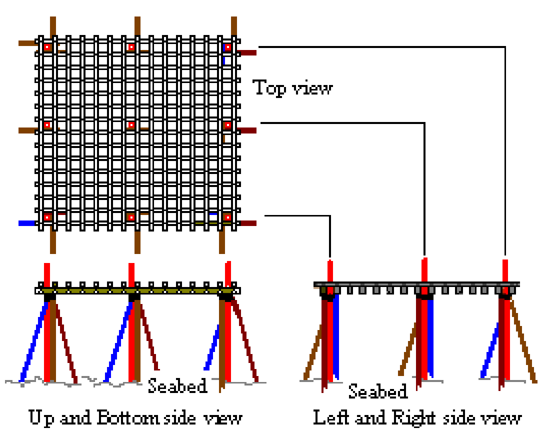

Figure 4 – Structural plan of the bamboo tray module

4.4 Construction and establishment

This section discusses the different activities involved in the construction and establishment of this new mussel farming technology. Undertaken through *bayanihan* system, the research implementation was successfully done following the procedures outlined.

4.4.1 Bamboo tray construction:

The construction of bamboo trays are undertaken at the shore through the hands-on demonstration training (Figure 5).

Figure 5 – The techno-demo training on bamboo tray construction

Generally, the number of bamboo poles being used in its construction largely depends on the lengths of available bamboo materials. Under this trial and in accordance with the structural plan, a total of thirty (30) pieces bamboo poles have been used in the construction of each bamboo tray. Fifteen (15) pieces of which were arranged vertically (in columns) at distance interval of 50 centimeters and over which were also 15 pieces arranged horizontally (in rows) at similar distances. One among the considerations during this stage was the tapering size of bamboo poles which has lighter weight along the smaller end than the basal portions. So that, positions of the basal (larger diameter) and the upper-end (smaller) portions of the bamboo poles were arranged alternately in order to achieve an even distribution of weights throughout the tray structure. After which, the cross-joint portions were manually tied (approximately 75-80 pound test) with splits of polyester plastic strap to form a tray-like structure called in this innovation as "*bamboo tray*" (Figure 6).

Figure 6: The bamboo tray

4.4.2 Farm establishment

After the fabrications were completed, all bamboo tray structures were brought manually (Plate 3) one at a time and allowed to float on the sea. The remaining bamboo poles were similarly carried one by one and directly loaded over the floating bamboo tray, secured in bundle with roped to prevent from slipping and subsequently towed to the identified farming site by motorboat.

Figure 7: Hauling of the fabricated bamboo trays for establishment

The establishments of the bamboo tray modules (farm set-ups) were carried out during lowest low tide to ensure that the structures are constantly submerged in the water column at any period. However, the timing of doing such caused delays in the establishments of experimental set-up (farms) since it had to wait for the low tide periods. Maximizing the use of time of the day and to mitigate delays, it was decided that the farm installation be done at any period during daytime. However, sounding of the area was determined first prior to the establishment. Water current direction of the area was likewise determined to have an idea where to position the diagonal support posts.

While the bamboo tray was floating, the main posts were initially staked firmly (penetrating about 1.5m) to the seabed along the inner four corners to prevent the structure from being drifted by water current. While the bamboo trays were quite top heavy on land, it was noted that they are highly buoyant in the water due to their closed vacuum hollow internodes. This condition provided difficulty to submerge and set-up the bamboo tray modules. As a solution to such problem, boring on bamboo poles (Figure 5) was done in a manner that will break the vacuum internodes and allow the entry of seawater and reduce buoyancy. However, holes were made only on larger culms (>20cm culm circumference). Boring holes on and below of the internodes close to the nodes in an alternate manner, did not significantly affect the tensile strength of the bamboo when used in mussel farming.

It is generally accepted that holes, cuts and notches reduce the ultimate strength of bamboo culm. If hole is made in a culm, this should be as close as possible to the node, paying particular attention to the direction of the applied force. Whenever possible holes should be round or radiused rather than square cut as these are less likely to propagate splits.

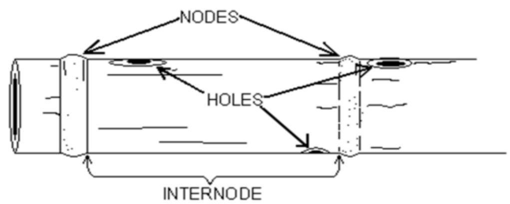

Fig. 8: Illustrated boring of holes on every bamboo pole

Boring on the culms greatly reduced the buoyancy and made easy for implementers to set-up the bamboo tray structures. By putting more weight loads, it sunk to appropriate water depth and secured by divers to the main vertical posts in a flat lying position below and parallel to the sea surface. Five (5) additional main vertical posts were also staked at the mid-inner sides of the bamboo tray structure at equal distances of 3.75m to ensure even weight loads distribution in each post. The bamboo tray structure is elevated 3.0m from the seabed in sites 1-4, 2.5m in site 5 and 2m in site 6. Additional four diagonal support posts (staked at 45° angle relative to posts) were provided at every post, properly secured to each main vertical post and bamboo tray to counteract the cyclical water currents velocities and to strengthen structural resistance against severe water movements.

The whole set-up is called “bamboo tray module” shown in Figure 9. The bamboo posts extending above the sea-surface were finally cut and used in the subsequent bamboo trays fabrication and only one extending post maybe retained (as marker) to reduce the impacts from strong winds and big waves. The size or width of the bamboo tray generally depends on the lengths of bamboo poles used. In this set-up however, a total of 50-51 pieces of 7.5m long bamboo poles were used which occupied an area of 56.25 sq. m.

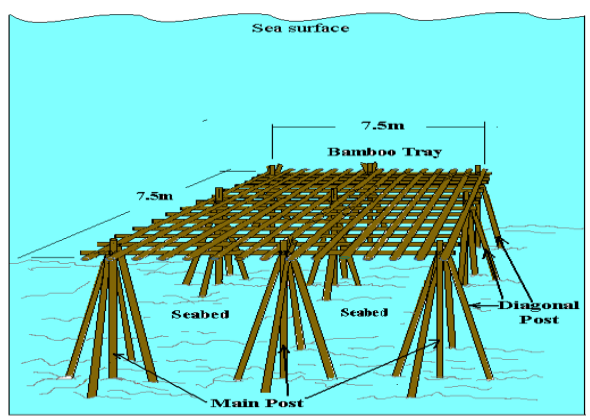

Fig. 9: The Bamboo Tray Module set-up

The experimental farms establishment was not synchronized (Table 2) due to the fact that the materials procurement primarily depends on the availability of funds and delivery of bamboo poles. What is essential however, are that the dates of establishment which serve as the basis as to when the harvesting are done. Mussel farm operation and practices also vary with sites.

Table 2 – The dates of experimental set-up establishments and harvest

Sites	Schedule Dates of Activities	
	Establishment	Harvested
1	November 9, 2009	April 27, 2010
2	October 20, 2009	July 27, 2010
3	June 15, 2009	July 30, 2010
4	November 17, 2009	April 10, 2010
5	January 17, 2010	September 6, 2010
6	December 7, 2009	April 8, 2010

In some areas of the Philippines, selective harvesting is being practiced that result in two or more cropping within the 6–8 months of the culture period. However, the harvesting is dependent also to the demands of buyers in terms of volume and size of the crops. In mussel farming however, it is more appropriate to harvest the crops after 7-8 months so that mussels are given first the opportunity to spawn and at the same time achieve good harvests.

4.5 Technology performance

Mussel farming techniques are differentiated by most authors and researchers in terms of their types/designs, purpose and performance. These criteria are very essential in technology selection especially if it concern socio-economic activity. The comparative analysis was focused on the concept of economic efficiency, productivity and resilience to inclement weather which are generally the basic technological problems noted in the area.

4.5.1 Economic efficiency**.**

This is a broad term that implies an economic state in which every resource is optimally allocated to serve in the best way while minimizing waste and inefficiency. Its phases include allocational efficiency and production efficiency which are achieved when a product is created at its lowest average total cost (Investopedia. com, 2011). This occurs in a situation in which a given state of technology generate a larger total welfare from the available resources also called “allocative efficiency” which indicates a "just the right balance between pain and gain" has been achieved (Business Dictionary, 2011). For the economist’s point of view, economic efficiency is measured not by the relationship between the physical quantities of ends and means, but by the relationship between the value of the ends and the value of the means (Heyne, 2011). This aspect was analyzed on the utilization of bamboo poles in mussel farming.

*(a) Allocation efficiency***.** Investors and mussel farmers oftentimes do some project analysis especially if it involves relatively larger investment. The bulk of investment in mussel farming usually goes to the direct costs such as: procurement of bamboo poles, tying materials and labor. When bamboo poles are installed in mussel-belt areas, it is expected to serve as artificial substrates for settling mussel spats. The efficient use of bamboo poles was analyzed based on their respective settling spaces of the farm set-ups. The concern of allocational efficiency is the effective dispersion of capital to the most productive opportunity/ies, the aspect in which the economic efficiency focuses on both farming technique. It is expected that when bamboo poles are used in mussel farming must serve its purpose.

To avoid biased results, the quantity of materials used was standardized at 51 pieces of bamboo poles which were the total quantity actually utilized in the bamboo tray module establishment. Prior to farm establishment, each bamboo pole has an estimated surface area of 1.575m^2 suggesting an estimated total surface area of 80.325m^2 for each mussel farm.

The practice of mussel farming methods in the Philippines generally varies with site. In Manila Bay (Binakayan, Cavite) and Tinagong Dagat (Batan, Aklan) Bay, the 4–6 m long bamboo poles are stake firmly into the seabed in rows, 0.5–1 m apart during low tide in areas about 3.0 m deep and above. In areas where water current is strong, bamboo poles are kept in place by nailing long horizontal bamboo supports between rows (Aypa, 1990). In Maqueda Bay, bamboo poles are stake into 1.5m deep of the seabed arranged in rows at 1.5m distance between bamboo poles and 2.0m between rows. The outcome of the farm set-up resulted for almost all bamboo poles in staking method to extend more or less 2.0m and in wigwams 1.5m above sea surfaces especially at low tides as shown in Figure 10. In contrast, no portion of the bamboo tray module can be seen extending above sea-surface. Except the buried portions of the posts, the whole structure is fully submerged in the water column fully utilizing all bamboo surfaces as settling spaces for mussel spats.

Figure 10: The staking mussel farm in Jiabong, Samar along Maqueda Bay (above) and wigwam mussel farm in Villareal Bay along Brgy Pacao, Villareal, Samar (below)

Obviously, only the 11 horizontally positioned bamboo poles are totally submerged out of the 51 pieces used in staking method (Figure 11) and the 40 pieces of which are staked to the seabed with portion extending more or less 2m above the sea surface. Portions of the bamboo that extend above sea surfaces clearly manifests direct losses estimated at more or less 20% in bamboo poles investment. As a rule of thumb in any business, wastage of materials for production purposes should be minimized or if possible avoided. Aside from those that extend above sea surfaces, portions of bamboo poles buried in the seabed are considered as additional direct loss of production cost.

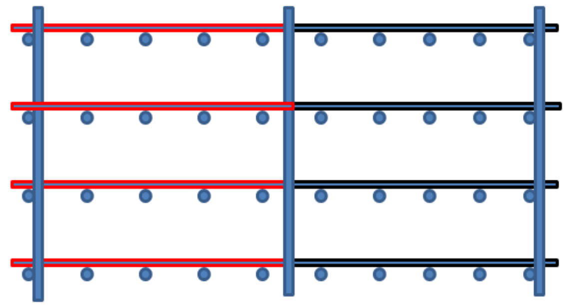

Figure 11 – Top view of the schematic arrangement in the set-up of 51 bamboo poles staking mussel farm in Maqueda Bay

The data in Table 3 shows that the efficiency of bamboo poles is relatively lower in staking and wigwam method than in the bamboo tray module.

Table 3 – The comparative efficiency use of bamboo poles in different mussel farm set-ups

Variables	Farming Techniques	
	Staking	Bamboo Tray
Mean surface area (m^2)	0.999	1.519
Total surface area (m^2)	50.925	77.490
Efficiency Use (%)	63.400	96.470

The poor efficiency on bamboo poles use in staking wigwam is attributed to the fact that about 36.60% (16.8m^2) of the total surfaces of bamboo poles did not serve its purpose. In the bamboo tray module, only the buried portion of the posts estimated at

Table 4 – The comparative production efficiency analyses of mussel farming methods

Sites	Staking			Bamboo Tray		
	No. of Bamboo Poles Used (Pcs)	Total Production (Kg)	Mean Production Per Bamboo Pole (Kg)	No. of Bamboo Poles Used (Pcs)	Total Production (Kg)	Mean Production Per Bamboo Pole (Kg)
1	122	5,983	49.04	50	2,793	55.85
2	211	8,897	42.17	50	3,510	68.82
3	969	41,855	43.40	102	6,961	68.24
4	-	-	-	102	6,263	61.41
5	341	14,728	43.19	102	7,291	71.48
6	276	12,213	44.25	102	6,580	64.51
Total	1,919	83,676	43.60	508	33,397	65.74

3.53% (2.835m^2) of the total bamboo surfaces were considered as ineffective areas while extending above sea surfaces. The result further suggests that the efficiency use of bamboo poles in bamboo tray module set-up is higher by 33.07% that can be translated into 26.5635m^2 settling spaces compared to that of staking method.

(b) Production efficiency: High production is usually attributed to productivity, which from the economist point of view, is a measure of output from a production process, per unit of input (Hickman, 1989). Production in mussel farming is usually attributed to the availability of mussel spats in an area. Absence or indeterminately small mussel population is due to some factors which would result to less production. In fact, there are also some areas within Maqueda Bay where two or more among the various farms installed in one site can have lower harvest than the others. Such result oftentimes is attributed with the timing in mussel farm establishment with mussel spat fall. This condition simply requires knowledge and understanding on the life history of mussel (*tahong*) which includes the spawning period in an area and its behavior at certain stage are necessary to attain high production. This information would enable mussel farmer to have timing in establishing farm with the mussel spat fall and to have the chance of attaining high farm production.

Spawning of green mussels, *Perna viridis* also vary geographically. The *spat fall* coincide with the monsoon seasons, but capable of reproducing year-round in some locations (Stephen and Shetty, 1981; Walter, 1982). In Malaysia, mussel spawning occurs in response to environmental factors such as high food levels, temperature fluctuations, and physical disturbance (Aypa, 1990) that occurs twice a year between early spring and late autumn (Rajagopal et al., 1998) which is closely related to the monsoon seasons and occurred twice a year during March and April and October and November (Sivalingam, 1977) although spawning in Johore Straits, Malaysia occurs throughout the year (Rajagopal et al., 1998).

In the Philippines, green mussel also spawns year-round, the peak period of spawning and settling is during April and May and again in September to October (Walter, 1982). However, it also varies geographically but normally occurs every two months. The peak spat fall season in Manila Bay (Bacoor) occurs during April to

May and October to November; February to March and September in Eastern Panay; and January to March and July to September in Negros Occidental (IIRR, 1995) while most mussel farmers in Maqueda Bay and Villareal Bay establish their farms during the months of May to June and November to January.

The productivity of mussel farm has relationship to the number of bamboo poles as the major input as spat collector in the production process. However, this case occurs only in staking and wigwam methods but not in bamboo tray module. Table 4 shows that staking method used so many bamboo poles, but had relatively low production efficiency. In contrast, the few numbers of bamboo poles used in bamboo tray module have higher production suggesting higher production efficiency compared to staking and wigwam mussel farms.

The production efficiency of the bamboo tray mussel farms varied with site. The highest farm production efficiency was recorded in Site 5 (waters of Pinabacdao, Samar) where the average production difference was 65.50% (28.29kg/pole) than in the staking method. In site 2 (coastal waters of Pangdan, Catbalogan City), the new method had an average production of 68.82 kg/pole higher by 63.20% (26.65 kg/pole) than in the staking method. The site 4 of San Sebastian and site 5 in Pinabacdao, Samar are new sites for mussel farming and expansion of the mussel-belt area. The least mean production observed in Site 1 (Brgy. Ibol, Catbalogan, Samar) is attributed to the small sizes of the harvested mussels. Instead of having them cultured within seven to eight months, the farmers-beneficiaries harvested the mussel after six months only at an average size of 4.10cm which resulted to relatively low production.

Mussel has two distinct stages, the free swimming mussel spat and the most critical is the larvae called *trochophore* stage which requires possible settling habit. Larvae of green mussel settle on hard submerged surfaces and form large masses (McGuire and Stevely, 2009) which apparently require wider spaces on which the organisms can settle/habit and ultimately grow to marketable and matured sizes. At this premise, mussel farm production is precisely dependent on the area of settling space. This recent observations justifies the fact that although it is necessary to have more bamboo poles for mussel settling habits, it is essentially more efficient to have wider settling space in mussel farming as illustrated by the results of this trial. The result of the pooled production data suggests that wider farm does not necessarily mean to have higher volume of crop production irrespective of the area occupied. The staking method which occupies a relatively wider area ($81m^2$) has lesser production compared to the $56.25m^2$ occupied by the bamboo tray module.

The result shows that the production performance of bamboo tray module was higher by 50.78% (1,129.14 Kg) and 47.63% (117.33 MT) in estimated production per hectare compared to the staking method. The estimated bamboo poles requirement per hectare and biomass production are almost similar. The estimated production of bamboo tray module in this trial was very high, higher in production performance per cropping among the different mussel farming models reported elsewhere. The world's average productivity of mussel farms is 7.4 MT per hectare, while the mussel farm productivity in New Zealand is 9.85MT per hectare (Loyd, 2003), although it was reported that the New Zealand mussel industry had an average annual yield for a mussel farm using longlines of over 27 MT per hectare in 2002 (Jeffs, 2003). The mussel farming in Greece, floating long-line systems constitute today the industry's standard producing nominally 100 tons per hectare (Theodorou et al., 2010). A Dutch mussel farmer was able to achieve 10MT per hectare, while the new method that uses only 2,000 bamboo poles for hanging the polyethylene net (4-inch mesh) yielded only more than 30 tons of mussels per hectare (Guerrero, 2008).

(c) Resilience against inclement weather: One among the identified threats to mussel farming is the typhoon with effects that can be in an indirect or direct manner but definitely results to damage or destruction of properties most especially on structures at sea because of its strong winds. Waves are created by the force of wind moving across the sea surface. Wind-driven waves become more destructive to mussel farms when their length ranges between 2-3m. The impact of its force is being triggered by the oscillating motion of water particles towards its direction. The Philippine Atmospheric and Geophysical, Astronomical Services Administration (PAGASA) Office in Catbalogan City indicated an average of 21 typhoons annually almost 2 typhoons monthly that struck Samar mussel belts from 2005 to 2010.

Apart from wind and rain, the other destructive component of typhoons (or cyclones) has been its *storm surge*. This in itself has several components. Firstly, lower than normal atmospheric pressure near its centre raises the sea level. Secondly, strong winds blowing from the sea to the land generate large waves. These latter effects are most pronounced to the left track of the tropical cyclone where its movement adds to the wind strength. If all these coincide with high tides, the effect of storm surge is increased (McDavitt, 2011). The energy developed by the huge waves is proportional to water bodies that range and amplitude of oscillation. This energy is divided into two parts, which practically are the same: a potential energy, which causes deformation of the sea surface, and a kinetic energy or movement due to displacement of the particles. The large sea waves that form re-growth by the force of strong winds greatly increase their height, mass and speed of advance. If the depth is small, the kinetic energy is transported with a speed that depends on certain characteristics of the wave. It has been estimated that a wave height of 7.50 meters on the level of calm waters and 150 meters wavelength, propagating with a speed of 15 meters per second delivers an output of 700 horsepower per meter crest. Wave of the same features had 1-km wide develop the considerable power of 700,000 horsepower, which explains the disastrous effects the sea storms (Solar Energy, 2010).

In 2009, 20 typhoons entered the Philippine area of responsibility (Typhoon Watch, 2009), and typhoon "Santi" were among which that landfall over Aurora-Quezon area and parts of Luzon had still a meager impact on mussel farms in Maqueda bay. Reports of the Agricultural Technologists for Fisheries from the mussel farming municipalities in the area indicated that some of the mussel farms have been damaged. It was during the occurrence of typhoon "Basyang" with maximum sustained winds of 120 kph and gustiness up to 150 kph (ABS-CBN News, 2010) occurred last July 11-18, 2010. The waves along the directly affected waters were exceptionally high, while the sea completely covered with long white patches of foam. Edges of wave crests blown into froth (Cruiser-Charter.Net, 2010). Storm surge generally 4-5 ft (1.22-1.52m) above normal can cause coastal road flooding and minor

Table 7 – Impact of typhoon *Basyang* on mussel farms along Maqueda Bay and Villareal Bay

Farm Sites/ Stations	BEFORE THE TYPHOON				AFTER THE TYPHOON				Percentage (%) of Bamboo Poles Remained After the Typhoons	
	Inventory of Farms Models		Total number of Bamboo poles used		Inventory of Farms Models		Total number of Bamboo poles used			
	Staking Method	Bamboo Tray Modules	Staking Method	Bamboo Tray Modules	Staking Method	Bamboo Tray Modules	Staking Method	Bamboo Tray Modules	Staking Method	Bamboo Tray Modules
1	2	1	300	50	2	1	122	harvested	40.67	harvested
2	3	1	600	50	3	1	211	50	35.17	100.00
3	13	2	2,750	102	13	2	969	102	35.24	100.00
4	-	2	-	102	-	2	-	harvested	-	harvested
5	1	2	500	102	1	2	341	102	68.20	100.00
6	1	2	350	102	1	2	276	harvested	78.86	harvested
Total	20	10	4,500	508	20	10	1,919	254	42.64	100.00

pier damage (Marine Waypoints.com, 2010). Although the same typhoon did not directly hit Maqueda Bay, it posed a major threat to coastal areas, related to the storm surge threat (Preece, Undated). During these periods, the seas of Western Samar were rough to very rough due to the proximity of the said typhoon. For some valid reasons, the experimental farms in Stations 1, 4 and 6 have been harvested prior to the occurrence of the same typhoon although the crops were yet of smaller sizes. The resiliency of the mussel farms in Sites 2, 3 and 5 were observed after the occurrence of relatively severe sea conditions.

All mussel farms installed and not harvested prior to the occurrence of typhoon "Basyang" were heavily damaged. Table 7 reflects the impact of the aforesaid typhoon in the vicinities of Maqueda Bay and Villareal Bay. High damages were noted in sites 2 and 3 where the total number of farms suffered more than 64% damages. However, much damage in terms of quantity was noted in Stn 3 (Jiabong, Samar) wherein 64.76% (1,781 pieces of bamboo poles) lost out of the initial counts, while in Stn 2 (Pangdan, Catbalogan City) 64.83% but only 389 pieces out the initial inventory. In totality, about 57.36% (2,581 pieces of bamboo poles) in the staking method were lost due to typhoon.

In contrast, the physical structures of bamboo tray modules remained intact after exposure to big waves due to typhoon. However, one of the two modules established in Site 5 (Pinabacdao, Samar) partially damage but the bamboo poles were still complete. The damage was due to improper tying wherein some of tying materials loosened, which was repaired immediately. The resiliency of the bamboo tray mussel farms to typhoons is attributed to how the modules are set-up. The design of the technology has considered the anatomy of waves shown in Figure 2.

Data in Table 7 suggests how resistant the new mussel farming innovation was. Their performance against inclement weather can be explained by their being fully submerged in the water column to depths within which the effect of wind-induced waves is greatly reduced. It has been mentioned that portions in the set-up of staking method were extending above sea surface and are therefore vulnerable to the impact of strong winds and big waves. This is the weakness of this method in mussel farming. Long period of exposure of any stationary object/structure at sea to the combined forces of typhoon and big waves would definitely result to destruction. Submerging the bamboo tray structure to 1.83m the water deep based at lowest low tide greatly reduced effect of strong winds and big waves on the experimental farms, which makes this mussel farm model resistant to inclement weather conditions.

5. Conclusion and Recommendation

5.1 Conclusion

The bamboo tray module farming outranked the performance of the traditional farming methods specifically the staking and wigwam methods. The new method pooled production is about 50% higher than the staking method. The bamboo tray module was also proven to be more climate change-proof technology which is not affected by strong waves. Furthermore, the bamboo tray module will result into better water circulation in the mussel-built area.

5.2 Recommendations

There is a need to document the improvement of water circulation and sediment accumulation through a real-time monitoring set-up. A policy on shifting from the old mussel farming to the new farming method is also necessary.

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