Adoption of Aquasilviculture Technology: A Positive Approach for Sustainable Fisheries and Mangrove Wetland Rehabilitation in Bataan, Philippines

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***Abstract*—The adoption of aquasilviculture technology project came into being after the implementation of the Philippine National Aquasilviculture Program in Bataan that aims (1) to continue rehabilitating the denuded mangrove areas, (2) to capacitate the coastal communities through training- seminars and livelihood provisions, and (3) to conserve native aquatic species through stock enhancement activities. Under this project, 863,930 mangrove propagules were planted covering an area of about 262 ha along the intertidal zone of six selected rehabilitation sites. Mean survival rate was ca. 56%. The mangrove rehabilitation program was participated by 1,329 fisher folks from the east coast of Bataan namely, Hermosa, Orani, Samal, Abucay, Limay and City of Balanga. The beneficiaries also established 48 units of aquasilviculture technology demonstration sites for the integrated fish-mangrove culture system using *Scylla serrata*, *Chanos chanos*, and saline-tolerant *Oreochromis mossambicus* as main cultured species. Stock enhancement through captive breeding had produced a total of about 1.03 billion larvae (mainly from *Portunus* sp. and *S. serrata*) from the community-based multi-species hatchery system. The produce was released in the wild for the purpose of increasing the potential fish catch of the fisher folks. A total of about Php 740, 654.40 was earned by the fisher folks in their aquasilviculture technology projects and PhP 5.59 million was given to them as compensation for their involvement in the three components of the program.**

***Index Terms*—aquasilviculture, fisher folks, hatchery, mangroves, milkfish**

I. Introduction

The decline in mangrove resources that serve as habitat for various fishery species had reach to 383,000 ha from 1918-1995 [1], which means that the Philippines had already lost 76.6% of its mangrove covered areas in less than a century, with an estimated deforestation rate of 4,432 ha/year between 1951 and 1988 [2]. This dilemma is brought about by habitat degradation and overexploitation by coastal dwellers, settlements conversion, agricultural runoff, salt beds, and industry [3]. Likewise, conversion of mangrove areas to aquaculture was attributed to the loss of around half of the 279,000 ha of mangroves forest from 1951-1988. Around 95% of the Philippine brackish water ponds in 1952-1987 were derived from mangroves [4]. The conversion to fishponds, prawn farms, salt ponds, reclamation and other forms of industrial development have reduced the mangrove area to 117,700 ha [1]. This very alarming loss of mangrove resources is causing deterioration of sea grass and coral reef ecosystem, and ultimately on the productivity of coastal fisheries [5].

The Government of the Republic of the Philippines, through Bureau of Fisheries and Aquatic Resources (BFAR) and Commission of Higher Education (CHED), and in collaboration with the Bataan Peninsula State University (BPSU) and local government units concerned, launched the Philippine National Aquasilviculture Program (PNAP) in Bataan to rehabilitate denuded mangrove areas, to capacitate the coastal communities through livelihood projects, and to conserve native aquatic species through stock enhancement program.

A. Site Selection and Validation

Priority areas for rehabilitation, aquasilviculture, and hatchery system were identified by the Department of Agriculture- BFAR, Department of Environment and Natural Resources (DENR), and the concerned Local Government Units (LGUs). The sites identified were validated in terms of: willingness of the community to participate (1); technical and ecological suitability (2); presence and abundance of mangrove species thriving in the area (3); and accessibility of the site (4). The six identified areas (also municipalities) were Hermosa, Orani, Samal, Abucay, Limay and Balanga City (Fig. 1).

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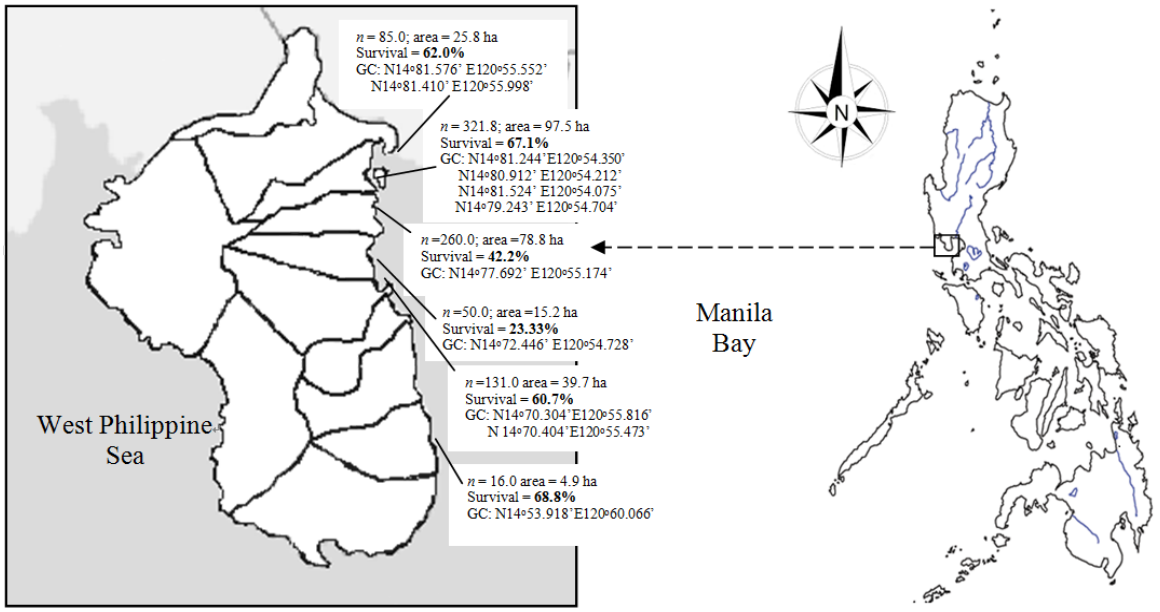

Figure 1. Map of Bataan, Philippines showing the number of mangrove propagules planted (in thousands), the area covered by the mangrove rehabilitation project (ha), and the survival rate (%) as of September 2015 in each of the selected rehabilitation site: Hermosa (1), Orani (2), Samal (3), Abucay (4), Balanga City (5), and Limay (6).

B. Mangrove Rehabilitation Project

Mature and healthy mangrove propagules (*Rhyzophora apiculata* and *R. mucronata*) were planted at a standard distance of 1.5m×2.0m between propagules at ca. 0.1m deep. A density of at least 3,000 mangrove propagules in every hectare was planted. The selected fisher folks were given PhP 1.50 to PhP 2.00 for every propagule planted; PhP 2.50 for each fully grown and live mangrove tree after one year from planting. To ensure the survival, the propagules were planted with corresponding tags and support bamboo stake (0.7m). Counting of survived propagules and number of leaves was done through visual inspection and manual counting. The rehabilitation project was started in June 2012.

C. Aquasilviculture

A standard 20m×50m design was followed to cover an area of 1,000m^2 aquasilviculture unit. Each unit was initially stocked with 500 tilapia (*O. mossambicus*) fingerlings, 300 mangrove (*S. serrata*) crablets, and 300 milkfish (*C. chanos*) fingerlings. The stocked species were grown to reach harvestable sizes under semi-intensive polyculture system. The projects also ensured that no more than 30% of the area for plantation was devoted to aquasilviculture. The chosen aquasilviculture locations varied from areas with surrounded by secondary forest stand with varying height and deciduousness to areas predominated with young mangroves. This project was started in January 2013.

The key beneficiaries for this project were chosen from the fisher folks who participated in the mangrove resources rehabilitation activities. The project was given to 28 fisher folk organizations (as oppose to individual beneficiaries) to equitably allocate among co-members the income derived from their aquasilviculture technology demonstration project. Aquaculture supplies and inputs including feeds, lime, fertilizers, cultured fish, nets, and among others were shouldered by the proponents.

D. Community-Based Multi-Species Hatchery (CBMSH) System

The tank-based CBMSH system was designated in the available existing concrete tanks in BPSU Orani Campus, whilst the "lying-in" hatchery/nursery concept or cage-based hatchery/nursery modular systems (6m×2m×1.2m; effective water volume for rearing=24.0m^3) were constructed in Bagac and Orani, Bataan (Fig. 2). Bamboo poles were used as frame and support structures for the modules, while plastic drum were used as floats. The construction of modules was done in the June 2013.

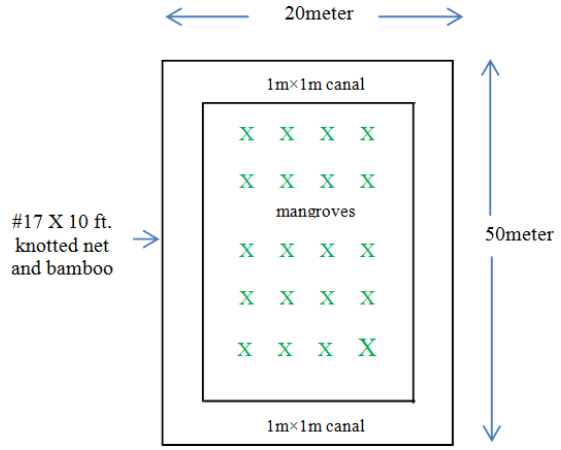

Figure 2. Layout of an "Aquasilvicuture Technology Demonstration Project" measuring 20 meter width by 50 meter length by 10 feet height fenced with #17 knotted net and bamboo poles.

Berried freshwater prawns, and mottled eels (10 pcs each species) were donated for the CBMSH in BPSU, while other fish species were procured from a reputable grow-out operators. Gravid species collected by fisher folks were reared in broodstock units (net size: 14;

effective water volume=8m^3). Net substrates were provided within the compartments to avoid cannibalism and predation. Some of the spawned fish larvae and crab zoea were transferred and reared in land-based hatchery, and others were nursed (only fish larvae) until they attained the stage where they can be released into the wild. Seined fish larvae and crab instar from the wild were directly nursed in separate nursery units (1mm-mesh size nets; effective water volume=2.0m^3). Two transition compartments (B-net; effective water volume=4m^3 each) were currently being used to grow captured immature *O. mossambicus* and *C. chanos* (unsexed) for potential broodstock. Breeders and juveniles in all CBMSH were fed *ad libitum* with commercial feeds.

II. Results and Discussion

A. Mangrove Rehabilitation Project

Fig. 1 presents the number of mangrove propagules planted, the area covered by the project, and the current percent survival as of September 2015. From the 863,930 mangrove propagules planted in six different sites, a very high survival rate (mean = ca. 86%) was documented in the first year implementation of the project. However, the occurrence of several strong typhoons and monsoon floods between 2013, 2014, and first half of 2015 negatively affected the rehabilitation project, causing a significant decline in the survival of the planted mangroves (mean = ca. 56%; range = 23.33%-68.8%) in all sites after 3-yr project implementation. Orani had the highest number of planted propagules (*n*=321,834), followed by Samal (*n*=260,000), and Balanga (*n*=130,950). The three sites comprised the 82.52% of the total number of planted propagules in all sites. Highest survival rate was achieved in Limay (68.8%), and these were followed by Orani (67.1%) and Balanga (60.7%). Overall, at least 480,910 propagules were survived after three years. A mean of nine leaves (range=5 to 12 leaves per plant) was observed from the 120 sampled mangroves. This signifies their good health status in the rehabilitation areas.

Although, the incidence of mortality of propagules was attributed primarily to natural calamities, and irresponsible coastal fishing (beach netting, and dredging), deliberate destruction of none concerned individuals or intruders was also a contributory factor in the decline of planted propagules. To compensate for the loss, replanting was done by the project beneficiaries, and frequent visitation and periodic patrolling was conducted. Moreover, signage and banners were also been placed in the sites to alarm/inform other fisher folks about the on-going rehabilitation program in their respective area.

B. Aquasilviculture

The aquasilviculture technology demonstration projects were able to produce a total net income of about PhP 740, 654.40 during the first cycle of operation in 2013 (Table I). The operations for the year 2014, and 2015 were about to commence when typhoons and monsoon floods affected the on-going commercial aquasilviculture operations including that of the prospective cooperators and adjacent fishponds operators. Setting up the project in the selected areas was further delayed, and thus the data for such years were not available. Even so, the project remained to be profitable under favorable condition.

TABLE I. Stocking Density, Reported Harvest and Income of the Beneficiaries from the Aquasilviculture Projects

Beneficiary Organization of Fisher Folks	No. of Aquasilviculture Unit	**Stocking Density**			**Harvest (pcs)**		**Yield (kg)**		**Net Sale (PhP)**
		Scylla serrata	*Chanos Chanos*	*Oreochromis mossambicus*	*Scylla serrata*	*Chanos Chanos*	*Penaeus* sp.**	*Portunus* sp. and other crabs**	
1. KAMMANCE	1	300	300	500	85	58.0	13.3	12.7	26,052.00
2. MFARMC	2	600	600	1000	178	40.0	17.0	13.0	11,913.00
3. SAMAKA	1	300	300	500	296	41.0	11.0	22.5	19,670.00
4. SMT	1	300	300	500	42	22.5	24.5	27.0	24,200.00
5. SMW	1	300	300	500	258	12.9	16.0	20.0	21,250.00
6. SAMADU	1	300	300	500	212	46.0	21.0	27.0	23,550.00
7. SMPL	5	1500	1500	500	198	38.0	26.2	19.0	46,260.00
8. SAMANA	1	300	300	500	324	54.0	19.5	28.0	30,050.00
9. MMAKISIG	1	300	300	500	170	39.0	18.0	24.0	24,590.00
10. GAMACA	1	300	300	500	232	51.0	25.0	16.5	27,180.00
11. SMPB	1	300	300	500	123	11.2	9.3	16.0	15,047.00
12. KAKAMPI	1	300	300	500	234	66.0	24.0	34.0	28,180.00
13. PUFIDECO	1	300	300	500	102	8.8	11.1	8.6	11,787.40
14. SMP	1	300	300	500	265	17.5	4.3	25.0	23,550.00
15. SAMAKA*	1	550	-	-	-	-	-	-	
16. Hermosa MFARMC	18	5,400	5,400	-	2592	660	-	-	299,160.00
17. Samal MFARMC	7	-	10,000	-	-	1433	-	-	78,830.00
18. Limay MFARMC	3	1000	1000	-	244	700	-	-	29,385.00
								Gross Income =	740,654.40

*Stocks had escaped when nets were destroyed.
**Non-target stock/by-catch

Due to the eco-climatic predicament, adoption of climate-resilient aquasilviculture operation shall be in utmost concern. Reinforcement of fences and embankments, and improvement in canal systems are some measures that can minimize the magnitude of damage brought by flooding and strong currents to mangrove propagules and cultured species.

C. CBMSH System

Table II shows the species currently being maintained in CBMSHs, number of broodfish, and the estimated larvae and juveniles produced from 2013 until 2014. An estimated 778.5 million blue crabs (*Portunus* sp.) eggs and 248 million zoea of mangrove crab (*S. serrata*) were spawned in the cage-based hatcheries. The latter, together with ca. 4 million zoea of *Scylla* sp. were released in the open sea to increase their natural populations. Due to limited area for larval rearing, some *O. mossambicus* larvae and juveniles, and *S. serrata* instar stage were brought to tank-based nursery area for nursery and some were used for research. A combined summation of about 2,000 juveniles of *O. mossambicus* and *O. niloticus* were disseminated to fisher folks and coastal beneficiaries, whilst some were used for research and instructional purposes (laboratory fish). Fish species such as *C. chanos, Lates calcalifer, Anguilla* sp., and *Scatophagus argus* did not spawn during the early phase of captivity. One effective technique to induce spawn them in captivity is through adoption of hormonal induction method [6], albeit this method requires further upgrade and provision of additional facilities particularly in cage-based system. Similarly, domestication, spawning, and larval rearing success are highly dependent on the availability of live foods in the facilities, and thus up-scaled natural food production should be included in CBMSH operation.

TABLE II. FISH COMPOSITION, NUMBER OF BROODSTOCK, AND ESTIMATED TOTAL NUMBER OF LARVAE AND JUVENILES PRODUCED IN THREE COMMUNITY-BASED MULTI-SPECIES HATCHERY SYSTEMS

Species	Hatchery Location	Number of Broodstock	Estimated total number of larvae and juveniles produced
*Scylla serrata**	Orani	124	248,000,000
Portunus sp.**	Orani, Bagac	1, 557	778,500,000
Scylla sp.*	Orani, Bagac	2	4,000,000
Scylla tranquebarica	Orani	10	
Chanos chanos	BPSU, Orani	4	
Lates calcalifer	BPSU	4	
Oreochromis mossambicus	BPSU, Orani	25	1,800
Oreochromis niloticus	BPSU	25	600
Anguilla sp.	BPSU	10	
Scatophagus argus	BPSU, Orani	60	
Macrobrachium rosenbergii	BPSU	10	
Total			**1,030,502,400**

*Estimated for an average of 2M eggs/mass of gravid mud crab [7]
**Estimated for an average of 0.5M eggs/mass of gravid blue crab [8]

An estimated 778.5 Million larvae and juveniles from 1, 557 berried blue crabs [7] and 252 Million larvae and juveniles of mud crabs from 126 berried mudcrabs [8] were produced during the first 1.5 years of stock enhancement as a support activity of the project. Although high spawning rate was achieved within 1.5 years of operation, the high survival of larvae in the wild remains vague. Even so, if the ideal 1.0% of the total 1.03 billion larvae will survive, and become adults, this means that around 10.3 million of these species will be growing in the wild and can be harvested by the fisher folks. To determine its positive impacts, studies on catch per unit effort for *Portunus* sp. and *Scylla* sp. shall be done to quantify the increase in catch of fisher folks in the areas.

Establishment of CBMSH and related enclosure systems in every area (municipality) in Bataan would provide a temporary refuge for some fish/crustacean populations through the establishment of both ex-situ and in-situ captive breeding programs. The breeding program under the CBMSH operation should focus on the target species itself to guarantee that a viable population exists, while there is continuing threat (high fishing pressure, and mangrove habitat degradation) to the wild stocks.

III. CONCLUSION

With the adoption of aquasilviculture technology as a strategy for mangrove wetland rehabilitation, which was participated by 1, 329 fisher folks in Bataan, Philippines a total of 863,930 mangrove propagules were planted covering an area of about 262 ha along the intertidal zone in six selected rehabilitation sites with a mean survival rate of c.a. 56% after three years. Aside from earning Php 740, 654.40 from the sales of harvested grown fishes in their aquasilviculture projects, a total of about PhP 5.59 million was given to the fisher folks as compensation for their involvement in the three components of the program. The aquasilviculture technology is hoped to expand the current mangrove forest cover, which consequently improve the fishery resources in various wetlands of Bataan. Although at its third year of implementation, those additional mangroves are expected to improve local fishery resources and our collaborative effort in adopting the aquasilviculture technology could serve as a model for initiating further conservation strategies on Philippine mangrove forest in other critical wetlands.

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