

Mangrove-friendly Aquaculture Studies at the SEAFDEC Aquaculture Department

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Abstract

The SEAFDEC Aquaculture Department studies on mangrove-friendly aquaculture (MFA) can be categorized under two models: a) mangrove filters where mangrove forests are used to absorb effluents from high-density culture ponds, and b) aquasilviculture or the low-density culture of crabs, shrimp and fish integrated with mangroves. In a study using the first model, shrimp pond effluents were retained in an enclosed mangrove area prior to release to receiving waters. Nutrients and other water quality parameters, and bacterial levels were monitored in the untreated effluents and post-mangrove water.

In the second MFA model, mangrove pens and ponds installed in old growth and newly regenerating mangrove sites in Aklan, central Philippines were stocked with mud crab *Scylla olivacea/S. tranquebarica* and shrimp *Penaeus monodon*. Investment costs, survival and production, and cost-return analysis for the pens and ponds are reported in the paper. Aside from the aquasilviculture trials in collaboration with local government units, other activities in the Aklan mangrove sites are the survey and mapping of the 75-ha area in Ibajay, construction of a treehouse, and the educational use as field site by Coastal Resource Management trainees of SEAFDEC Aquaculture Department and field biology students of the University of the Philippines in the Visayas.

Introduction

Amidst the growing concern of international environmental non-government organizations (NGOs) over the ecological impacts of aquaculture, in early 1996 the SEAFDEC Council proactively mandated the Aquaculture Department to conduct studies on environment-friendly shrimp culture and to build up its expertise on mangroves. Under this initiative, a Mangrove-Friendly Aquaculture (MFA) Seminar-Workshop was organized in July 1999. The Workshop identified two MFA levels or models: a) mangrove as filters where the absorbing function of mangroves is used to process or treat effluents from high-density culture ponds, and b) aquasilviculture (or silvo-fisheries) where low-density culture ponds/pens are physically integrated with mangrove trees.

This paper reports on studies that fall under both MFA models.

Mangroves as Filters

The study site is located in Barangay Alacagan in the municipality of Banate, Iloilo. A second run (April-August 1999) of 15,000 *P. monodon* gave 41.2% survival rate, 6.98 g average body weight and 43 kg total production. Extraneous species such as *Metapenaeus/Penaeus* spp., tilapia, mudcrab and ambassids were abundant and contributed around two-thirds of total biomass, due to a lack of teaseed application. During the culture period, effluent water from a high-density (10 per m²) shrimp pond of 1500 m² was made to pass through a 1200 m² mangrove 'pond' for a few days prior to draining to Banate Bay. Water quality was measured inside the shrimp pond (pre-treatment of pond water) and in the mangrove pond (post-treatment) every two weeks.

Water in the shrimp pond (SP) showed significantly higher levels of NO₂, PO₄ and COD and lower dissolved oxygen compared with the mangrove pond (MP) (Figs. 1-2). Similar levels in the SP and MP were observed for temperature, salinity, NH₃, COD (sediment) and pH (Figs. 1-3). Levels of presumptive *Vibrio* and luminous bacteria increased throughout the culture period in the SP and in cultured shrimp (Table 1). In contrast, total bacterial counts remained constant in SP water but increased in the shrimp population. On the single date (29 April 1999) that the MP was monitored, luminous bacteria levels were one order of magnitude lower than in the SP. Overall, the lower levels of nutrients, COD, and luminous bacteria, and higher DO levels in the MP compared with the SP indicate nutrient assimilation and less organic matter, which are features related to the filtration function of mangrove trees.

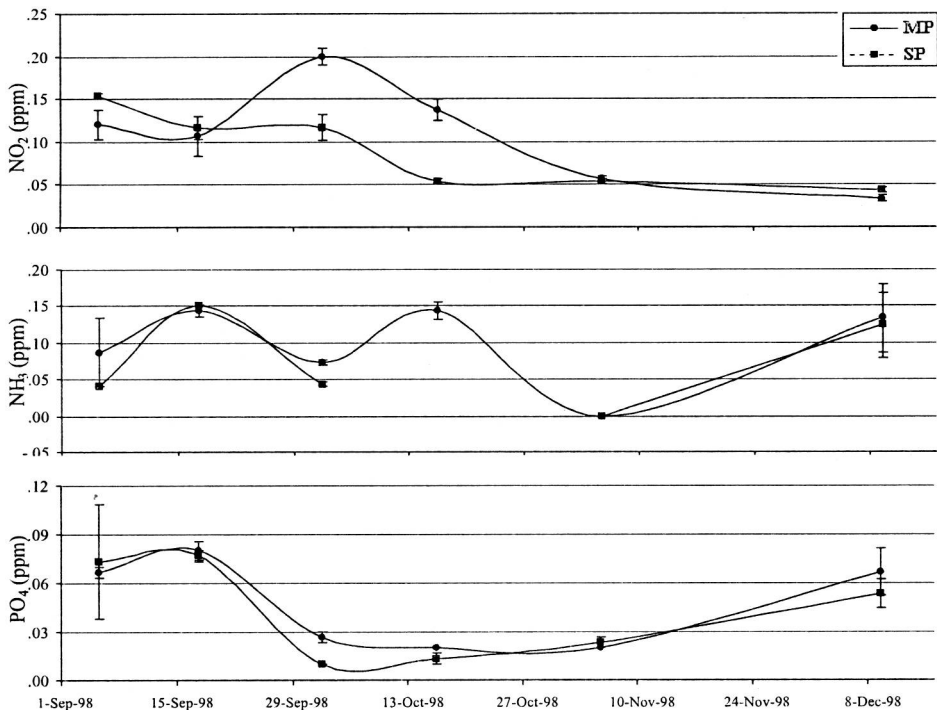


Figure 1. Nutrients in shrimp pond (SP) and mangrove pond (MP) water in Banate, Iloilo

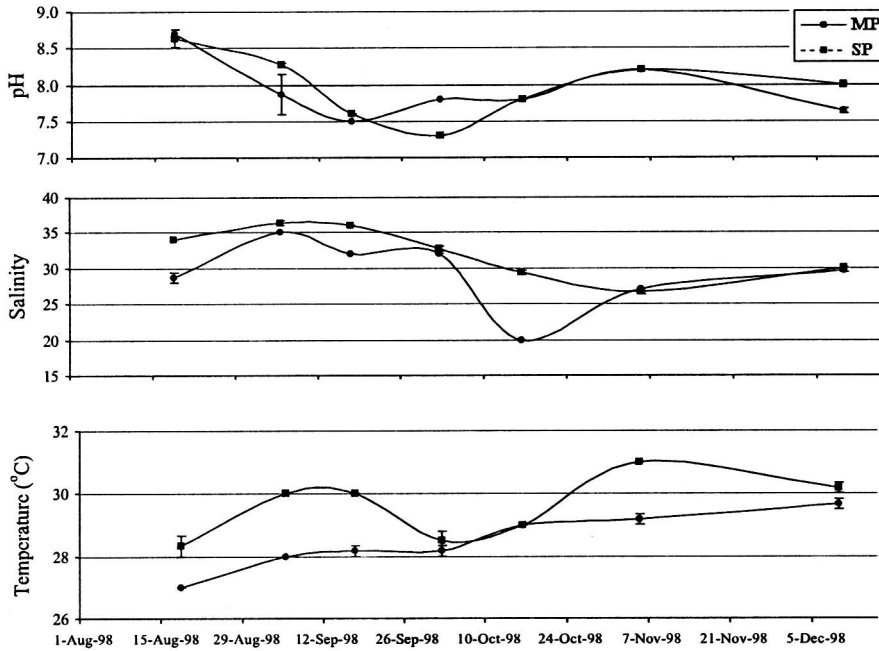


Figure 2. Physico-chemical measurements of shrimp pond (SP) and mangrove pond (MP) water in Banate, Iloilo

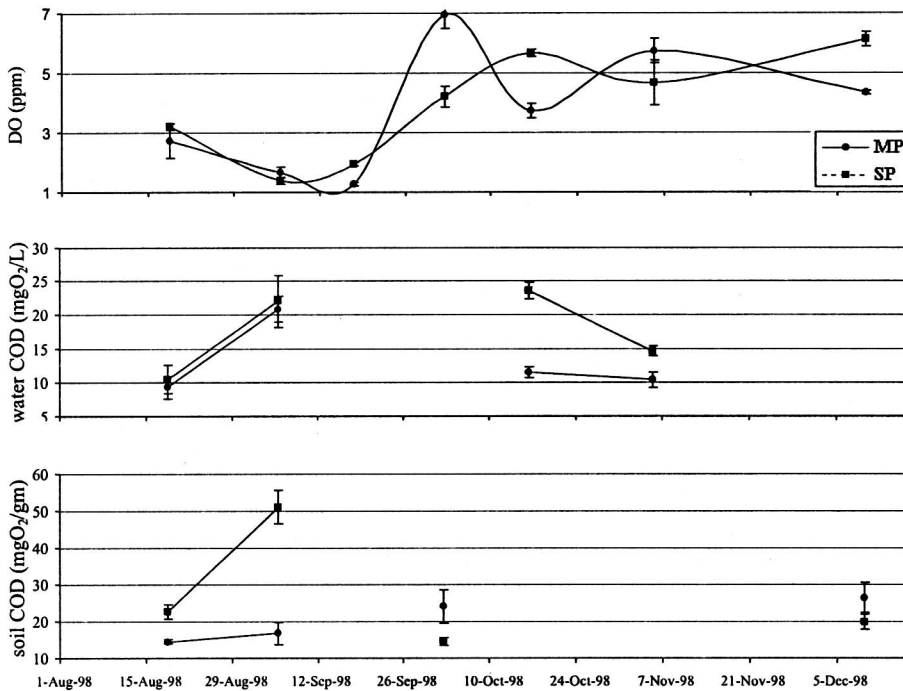


Figure 3. Physico-chemical measurements of shrimp pond (SP) and mangrove pond (MP) water and sediment in Banate, Iloilo

Table 1. Bacterial levels (cfu per ml) in pond water (shrimp pond and mangrove pond) and in shrimp in Banate, Iloilo

	Total plate count	Presumptive <i>Vibro</i>	Luminous bacteria
Shrimp pond water			
07 April 1999	3.2 x 10 ³	1.0 x 10 ¹	0.0
29 April 1999	2.0 x 10 ³	1.8 x 10 ³	3.1 x 10 ²
17 May 1999	3.6 x 10 ³	6.9 x 10 ²	2.1 x 10 ¹
09 June 1999	1.2 x 10 ³	5.3 x 10 ²	2.5 x 10 ¹
01 July 1999	3.9 x 10 ³	7.1 x 10 ²	3.0 x 10 ¹
12 Aug 1999	3.8 x 10 ³	1.4 x 10 ³	8.5 x 10 ¹
Mangrove pond water			
29 April 1999	7.4 x 10 ²	2.0 x 10 ²	2.0 x 10 ¹
Shrimp <i>P. monodon</i>			
10 April 1999	5.6 x 10 ³ to 1.4 x 10 ⁴	5.7 x 10 ³	0.0
01 July 1999	3.6 x 10 ⁶	4.0 x 10 ⁵	7.0 x 10 ⁴
12 August 1999	1.3 x 10 ⁷	4.1 x 10 ⁶	1.9 x 10 ⁴

Table 2. Growth of *Rhizophora* seedlings in mangrove pond and in control pond in Banate, Iloilo

	Mangrove pond		Control (natural mangrove)	
	Mean height (cm)	Mean no. leaves	Mean height (cm)	Mean no. leaves
05 June 1998	26.81	—	18.86	—
10 July 1998	50.48	8.28	25.14	—
03 September 1998	50.41	7.17	41.55	5.13
02 October 1998	56.63	—	48.77	—
12 November 1998	60.67	9.60	54.97	6.38
09 December 1998	63.75	11.79	58.86	7.17
28 July 1999	78.82	—	71.77	—

Rhizophora propagules were planted inside the MP and in adjacent natural mangrove areas. As shown in Table 2, seedlings had significantly higher growth in the MP (55.4 cm height, 9 leaves) compared to the SP (45.7 cm height, 6 leaves). The faster growth of mangrove seedlings inside the MP compared with control areas provide indirect evidence of utilization of nutrients (drained from the SP effluents) by the seedlings.

Aquasilviculture

Aquaculture that is integrated with the mangrove ecosystem may be located in the sub-tidal waterways as in the farming of seaweeds, bivalves and fish in netpens or cages, or in the intertidal mangrove forest itself as in mangrove ponds and pens. This report will be limited to the latter as the culture of seaweeds and fish is covered elsewhere in this volume.

In collaboration with the local government or people's association, the SEAFDEC Aquaculture Department has mangrove pond and pen culture study sites located in old growth and regenerating

Table 3. Comparison between New Buswang, Kalibo and Bugtong Bato, Ibajay mangrove-aquaculture sites in Aklan

Trait	New Buswang, Kalibo	Bugtong Bato, Ibajay	
Mangrove growth	Regenerating	Old growth	Old growth
Culture system	Pen	Pen	Pond
Compartment size (m ²)	200	300	1400
Culture species	Mud crab	Mud crab, milkfish	Mud crab, shrimp
Linkage	People's organization	Local government	Local government

Table 4. Investment cost for 200 m² pens of mud crab *Scylla serrata* in Kalibo, Aklan (1 Philippine Peso, ₱ = 40 US Dollar)

	Stocking density		Feed	
	0.5 / m ²	1.5 / m ²	Salted fish	Mixed
Total variable cost ^a	₱ 5,275	₱ 5,275	₱ 5,275	₱ 5,275
Capital cost ^b	1,822	4,900	3,423	3,153
Interest in capital	211	211	211	211
Depreciation ^c	26	26	26	26
Total fixed cost	237	237	237	237
Total operation cost	2,059	5,137	3,660	3,390
Total investment	7,334	10,412	8,935	8,665

^aseed, feed, etc., ^bbamboo, nylon, PVC, etc., ^c8% per annum

Table 5. Production and cost-return analysis per crop for mud crab *Scylla serrata* in 200 m² pens in Kalibo, Aklan

	Stocking density		Feed	
	0.5/m ²	1.5/m ²	Salted fish	Mixed
Survival (%)	56	33	44	45
FCR	5.30	7.60	6.70	6.20
Mean body weight (g)	317.40	316.40	310.00	324.00
Production (kg per pen)	17.80	31.30	23.60	25.60
Total revenues (₱)*	5,509	9,715	7,313	7,924
Less: Operational cost (₱)	2,059	5,137	3,660	3,390
Net revenue (₱)	3,450	4,578	3,653	4,534
Production cost per kg (₱)	116	264	155	133
ROI (%)	65	87	69	86

* Price per kg: ₱ 350.00 female, ₱ 270.00 male, ₱ 310.00 mixed sexes (in Philippine Peso, ₱)

Table 6. Investment cost for 300 m² pens of mud crab *Scylla tranquebarica* in Ibayay, Aklan (in Philippine Peso, ₱)

	Male	Female	Mixed
Total variable cost ^a	P 10,704	P 10,260	P 10,221
Capital cost ^b	9,011	9,011	9,011
Interest in capital	360	360	360
Depreciation ^c	45	45	45
Total fixed cost	405	405	405
Total operating cost	11,109	10,665	10,626
Total investment	20,120	19,676	19,637

^aseed, feed, etc., ^bbamboo, nylon, PVC, etc., ^c8% per annum

Table 7. Production and cost-return analysis per crop for mud crab *Scylla tranquebarica* in 300 m² pens in Ibayay, Aklan

	Male	Female	Mixed Sex
Survival (%)	69	60	52
FCR	7.70	7.30	7.20
Mean body weight (g)	190.20	191.30	216.70
Production (kg per pen)	79	69	68
Total revenue (P)	15,800	16,560	15,640
Less: Operation cost (P)	11,109	10,665	10,626
Net revenue (P)	4,691	5,895	5,014
Production cost per kg (P)	141	155	156
ROI (%)	52	65	56

mangrove sites (Table 3).

Mangrove pens, Kalibo, Aklan - In a regenerating mangrove site (a few naturally growing *Avicennia* and *Sonneratia*, planted *Rhizophora*), 200 m² pens made of nylon net on a bamboo framework were installed. Investment costs are found in Table 4.

Mud crab *Scylla serrata* juveniles were stocked in a 2x2 factorial experiment (two densities: 0.5 and 1.5/m² and two feeds: salted fish and mixed 25% salted fish plus 75% salted brown mussel). Survival, production and cost-return analysis are found in Table 5 (statistical analysis showed no interaction between stocking density and feed so data were pooled). Although 1.5 per m² density gave a lower survival rate and higher FCR compared with 0.5 per m², it has a higher production, gross and net revenue and ROI (Table 5). On the other hand, feeding with salted fish alone and mixed salted fish-mussel gave similar survival, food conversion (FCR) and production rates.

Mangrove pens, Ibayay, Aklan - Located in a primary forest in Barangay Bugtong Bato, the pens have similar construction as in Kalibo but the dikes were higher, the canals deeper (to

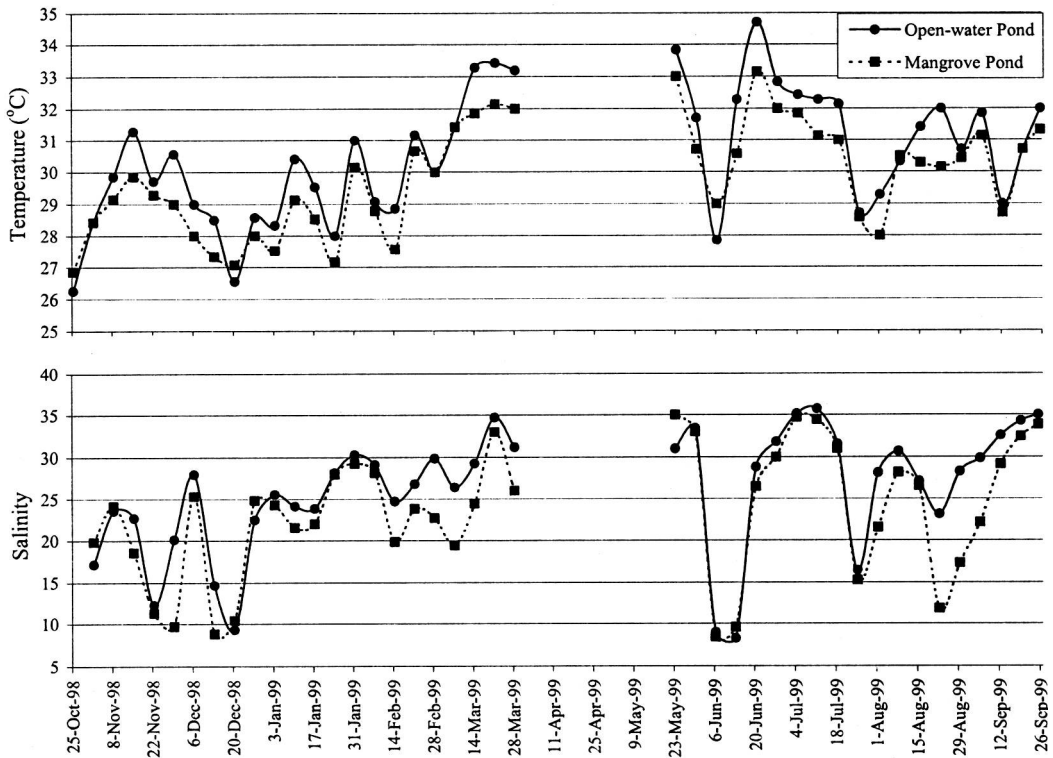


Figure 4. Weekly means of water temperature and salinity in Pond B (open water) and C (mangrove pond) in Bugtong Bato, Ibabay, Aklan

Table 8. Mud crab *Scylla olivacea*/*S. tranquebarica* culture in 1,400 m² mangrove pond in Bugtong Bato, Ibabay, Aklan

	Run 1	Run 2	Projected
Total pond area (m ²)	1,400	1,400	5,000
Stocking density (number per m ²)	0.65	0.40	0.50
Initial stock (number)	910	580	2,500
Final stock (number)	366	213	1,250
Survival rate (%)	40.2 ^a	36.7 ^b	50.0
Mean body weight (g)	210	142	220
Production (kg per crop)	76.9	30.2	275
FCR	8:1	7.4:1	6:1

^aLeaking gate, ^bChelipeds removed

Table 9. Projected investment cost of mud crab culture in 5,000 m² mangrove pond in Ibajay, Aklan (in Philippine Peso, P)

Capital cost			
Diking (675 m ³ x P40 per m ³)		P 27,000	
Gate		10,000	
Net enclosure		5,000	
Miscellaneous		<u>500</u>	
Total capital cost		P 37,775	P 42,500
Operating cost			
Variable cost			
Crab juveniles, 2500 x P3.50		P 8,750	
Feed (<i>kohol</i>), 825 kg x P7.00/kg		5,775	
Feed (fish), 825 kg x P15.00/kg		12,375	
Lime, teaseed, etc.		<u>1,000</u>	
Subtotal		P 27,900	
Fixed Cost			
Interest on capital ^a		P 633	
Depreciation ^b 40			
Subtotal		P 673	
Total operating cost		<u>P 28,573</u>	
Total investment		P 71,073	

^a 8% per annum, ^b 0.5% per annum

Table 10. Partial cost-return analysis of mud crab culture in 5,000m² mangrove pond in Bugtong Bato, Ibajay, Aklan (in Philippine Peso, P)

Total harvest (kg)	275
Total revenues (kg x P250 per kg)	P 68,750
LESS: Operating cost	28,573
Net revenues	40,177
Total investment	71,073
Revenue per kg	250
Production cost per kg	241
ROI (%)	57

hold 0.8-1.0 m water depth), and the compartments bigger at 300 m². Tables 6 and 7 show investment costs, and production and cost-return analysis, respectively, for all-male, all-female and mixed sex stocking of *S. tranquebarica*.

Although mixed sexes have lowest survival (52%), the highest body weight (216.7 g) gave a production similar to the all-female treatment (Table 7). All-male treatment has the highest survival and production but the lower price for males (P270 per kg vs. P350 per kg for females) gave lower net revenue and ROI compared with the other treatments.

Mangrove pond, Ibajay, Aklan - A mangrove “pond” was constructed in a patch of old growth forest in Barangay Bugtong Bato by deepening the natural canals and piling the excavated soil to mounds created by the mud lobster. Dikes enclosed an area of 1400 m² and a wooden gate was installed for tidal water exchange. Interestingly, water temperature and salinity levels were consistently lower in the mangrove pond because of the canopy shading compared to an adjacent open-water pond (Fig. 4).

Locally sourced crab juveniles of the species *Scylla olivacea* and *S. tranquebarica* were stocked at 0.4-0.65 per m² and fed the golden apple snail *Pomacea canaliculata* (*kohol*) or chopped salted fish sometimes combined with copra meal. Low survival (37-40%) in the first two runs may be traced to a leaking gate (and escape of small juveniles) and removal of whole chelipeds, respectively (Table 8). The smaller size and production in Run 2 compared with Run 1 (142 vs. 210 g body weight; 30 vs. 77 kg per crop) can be traced to the total removal of both chelipeds prior to stocking. Hence, energy was first diverted to limb replacement before growth.

Based on capital cost of P42,500 for a 5,000 m² pond and operating cost of P28,573 at 0.5 per m² stocking density, 50% survival rate and 6:1 FCR based on Run 1 and 2 (Tables 8 and 9), partial cost-return analysis gave a total revenue of P68,750, net revenue of P40,177 and ROI of 57% for the 5,000 m² mangrove pond (Table 10).

Conclusion and Recommendations

Results of the Banate, Iloilo study indicate some mitigating effects of passing effluents from shrimp ponds through mangrove forests (before draining to receiving waters) in terms of assimilation of nutrients from the effluents. There is a need for follow-up studies in sites with a wider mangrove area (compared with the 20-m band found in the Banate site) that incorporate regular monitoring of luminous bacteria in shrimp ponds and in the receiving waters of mangrove forests.

The aquasilviculture trials in Ibajay, Aklan had some un-intended “negative”, albeit valuable, results. Mortality of some *Avicennia* and *Sonneratia* trees and saplings in the pens, and to a lesser degree in the pond, was traced to a) stress from prolonged flooding or inundation (of the pneumatophores or mangrove roots), and b) direct cutting of the major mangrove roots during pond/pen construction. In contrast, both the natural *Avicennia* and *Sonneratia* and planted *Rhizophora* in the Kalibo, Aklan pens were healthy and fast-growing. In this latter site, very little of the hydrology was altered. These results point to the double challenge of aquasilviculture - to meet the biophysical needs not only of the cultured animal (e.g. crabs, shrimp) but the mangrove trees as well.

Nevertheless, the promising ROI, net revenues and other financial indicators point to a way by which local villagers can obtain fishery products for sale or domestic consumption while conserving the mangrove trees. The aquasilviculture project is in collaboration with local government units (Barangay Bugtong Bato and Ibajay municipality) in Aklan. Aside from this project, a treehouse has also been constructed on old growth *Avicennia* trees in the site. The Ibajay mangroves have been an educational tool as site for the practical exercises of Sustainable Aquaculture and Coastal Resource Management trainees of SEAFDEC and field biology students of University of the Philippines in the Visayas.