Evaluation of economic efficiency and environmental impacts of a polyculture model (giant tiger prawn and mullet)

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I. Introduction

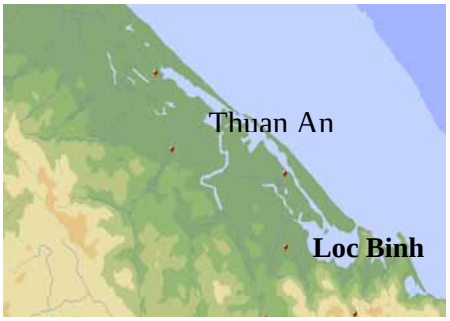

Fig 1. Study site in Tam Giang lagoon

Thua Thien Hue is one of the coastal provinces located in the central part of Vietnam, with a large and densely distributed lagoon system. Within the system, Tam Giang lagoon is recognized as the largest lagoon in Asia in terms of water surface with diverse aquatic species. Its unique form and physical characteristics have created a brackish water ecosystem with a diversity of resources (Phap et al., 2002). This is home to fishery resources, which provide foodstuff and livelihood for thirty-five percentages of province population (about thirty-five thousand inhabitants) living alongside the lagoon (Binh, 2005). However, due to the pressure of population growth, the over fishing, and the inharmonious development of economic operations in the same territory are resulting in the exhaustion of natural resources of Thua Thien Hue's lagoon system in general and Tam Giang lagoon in particular; the living conditions of the community of inhabitants living along the lagoon are being threatened. Aquaculture was introduced to Tam Giang lagoon in 1990s by government officials. It has been considered as an alternative to capture to improve the quality of and diversify the daily meals for the local people by the direct production of food and in the meanwhile, increase household incomes. Furthermore, the introduction of aquaculture also contributes to the decline of capture fisheries yield and thus reduces the exploitation pressure on lagoon resources. Finally, it generates employment opportunities in the lagoon communities in particular and Thua Thien Hue province in general.

In Loc Binh commune, located in the southern part of the lagoon, shrimp culture in ponds has been one of the major sources of livelihoods in recent years. Shrimp disease is the most serious problem that the farmers have been facing. Among solutions is using polyculture farming. The main principle of polyculture is utilizing species that feed at different levels of the food web to produce a balanced ecosystem. The concepts of carrying capacity in a hydrographical system, ecological balance between primary producers, primary and secondary consumers, and nutrient flow within an ecosystem are essential factors for the sustainable development of aquaculture. Aquatic plants and commercial species such as rabbit fish, mullet, grass carp, and clam are good candidates for polyculture. Mullet (Mugil cephalus) is a filter feeder, which usually swims near the top of the water in school and eats the scum of the water surface. Mullet can thrive on the Tam Giang lagoon conditions as they live in both fresh and saltwater. This fish is an ideal candidate to culture along with prawn. In 2006, a testing polyculture of shrimp and crab model was applied in this area (pilot farmer: Mr. Huynh Dau) and got successes. The farmers suggested that this aquaculture pattern should be multiplied in this area. However, crab is pathogen vector to shrimp

(e.g. white spot disease); that's why, crab should not be stocked into shrimp pond. Another model suggested by local farmers was the polyculture of shrimp (*P.monodon*) and fish (mullet) in which the densities of shrimp and fish are 5 units/m^2 and 0.1 unit/m^2, respectively. This model was applied in this commune in 2007 by IMOLA fund.

II. Objective

To evaluate the economic efficiency and environmental impacts of a polyculture model (giant tiger prawn and mullet).

III. Experimental Design

The experiment will be conducted in two ponds to investigate the effect of polyculture model (difference of species composition) on production and water quality management. Each experiment will be conducted in 1 culture period. All treatments will be carried out in a selected earthen pond in close consultation with farmers and provincial authorities. Followed are parameters from different treatments in the experiment. Data collection focused on the growth rate, environmental parameters, survival rate, yield, and economic evaluation.

The pilot model was designed as in the following table.

Table 1. Experimental Design in Loc Binh

Models	Species	Density (units/m^2)	Size of fingerling (cm)	Feed
Polyculture (Treatment pond)	*P.monodon*	7	3 – 5	Artificial diet
	Mullet	0.1	8 - 10	
Monoculture (Control pond)	*P.monodon*	7	2 – 3	Artificial diet

Fig 2. Mullet fingerlings

Fig 3. Experimental pond

Pond preparation

- Pond area: 5,000 m^2
- Number of ponds for each model: 2 ponds

Procedure:

- Preparing the pond and clearing
- Dry the pond and get its bottom exposed in the sun for 3-5 days
- Liming: 500-600kg/ha 3 days after supplying water to 0.6 m height through a filter
- Fertilization: 15 kg NPK and 5 kg of Urea, 2kg of Phosphate
- After 3 days, supply water to 1.0m height
- Check the water quality parameters before stocking

Parameters will be measured:

Technical parameters

- Water quality (Dissolved oxygen (DO), pH, temperature, water color, Ammonia) by using test kit except for water color (by eye observation).
- Fish growth rate: fish sampling will be done monthly in order to determine the growth rate of the fish by recording the length and weight of a sample
- Shell growth rate (body weight)
- Fish health status: monitor fish activity, and unusual symptom and disease diagnosis
- Survival rate
- Economic analysis.

Socio- economical parameters

Inputs:
Costs: cage and pond making costs, material cost; fingerling cost; labour cost; interest cost, lime and medicine cost; feed cost

Outputs:
Growth performance (g/month) of each species; survival rates; income (aquaculture income, husbandry income, crop income, off-farm income); education levels; and others.

Feed, feeding and management

- During the first month of culture, fish and shrimp will be fed with macrophyte and artificial diet.
- Feeding rate: 20% of body weight for macrophyte and 10% of artificial diet. Amount of feed will be adjusted according to the fish growth, crab and shrimp as well as the number of fish, shrimp and crab in pond.
- Feeding twice per day.
- Water/ environment must be exchanged bimonthly.

Statistical analysis
Data will be analyzed by ANOVA using the General Linear Model in SPSS version 11.5.

IV. Results

1. Water quality in the experimental and control pond

Water environment parameters were daily measured; the fluctuation of all parameters was observed and presented in table 2.

Table 2. Water Environmental parameters

Parameters	Models			
	Polyculture		Monoculture	
	Mean	SD	Mean	SD
DO (mg O_2/L)	4,76	0,31	4,13	0,65
Temp. (^{0}C)	28,2	1,64	28,0	1,41
Salinity (‰)	17,0	1,00	17,5	1,20
pH	8,5	0,20	8,3	0,28
NH3 (mg/l)	<0,02	0,00	0,2	0,01
Alkalinity(KH+)	95	0,10	92	0.13

All water parameters were quite suitable for shrimp and mullet growth. pH, DO, salinity and alkalinity were in the optimal range for shrimp and mullet. The significant difference observed in two ponds was NH_3 amount. The NH_3 in monoculture pond (0.01 mg/L) was lower than in the control pond (0.2mg/L) ($p<0.05$). Other parameters were insignificantly different in two ponds. This implied that the organic matter could be utilized by mullet, which led to the decrease of total N and P in the environment; therefore, the amount of NH_3 was reduced in the polyculture pond.

2. Growth rate of mullet and shrimp in different ponds

The growth rate of shrimp and fish in the treatment and control ponds were regularly checked every 10 days. The growth rate of shrimp in the polyculture model was significantly higher compared to the growth rate of shrimp in monoculture ($p<0.05$) (Fig. 4). After 50 culture days, the weight of shrimp reached 8.5g in the polyculture pond.

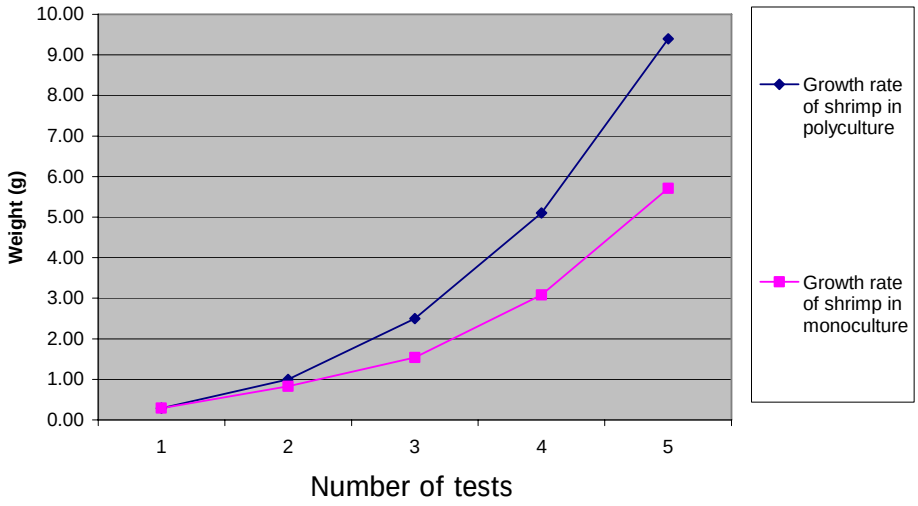

Fig 4. Growth rate of shrimp in polyculture and monoculture ponds

Mullet could reach to 1.6 g/day after 30 culture days (Fig.5). Mullet reached the highest growth rate after 40 culture days. The consequence of the sedimentation of uneaten feed and shrimp waste was to increase the organic matter in the pond and stimulated the development of phyto- and zoo-plankton. When the live feed was available in the pond, mullet had faster growth rate.

However, due to the bad weather (floods) in the second culture period, the experiment was collapsed in the middle of experimental process and all the parameters could not be measured. The impact of this model was unclear in both environmental and economic efficient aspects.

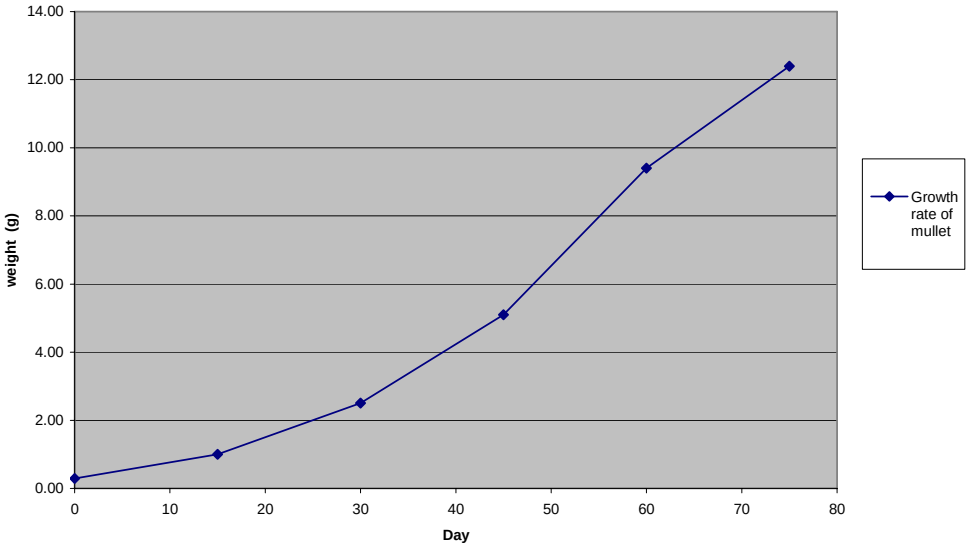

Fig 5. Growth rate of mullet in polyculture and monoculture ponds

3. Economic efficiency

Due to bad weather during this time (high floods), some mullets and shrimp escaped to the lagoon. As a result, the productivity was lessened. However, farmer also got some net profit in this model. The primary of economic efficiency of pilot was presented in table 3.

Table 3. The estimated economic efficiency of pilot

Items		Units	Quantity	Price	Amount
Sales	**Mullet**	kg	30	65,000	1,900,000
	P.monodon	kg	237	55,000	14,215,000
Total					**16,115,000**
		Fingerling	Feed	Other costs	
Purchases		7,200.000	5,000.000	1,000.000	**13,200,000**
Net Profit					**2,915,000**

The results of pilot showed that although the pilot did not succeed because of flood impact; however, the farmer got some profit from the pilot. At that time, farmer earned 2,915,000 VND from fish and shrimp retained in the pond. If this model had been carried out in the first culture period, the economic efficiency would have been higher.

V. Conclusions

- Growth rate of shrimp in polyculture model significant is higher compared to growth rate of shrimp in monoculture ($p<0.05$).
- Mullet can reach to 1.6 g/day after 30 culture days.
- NH_3 is significantly different between two models ($p<0,05$)
- Other parameters are insignificantly different between two models
- Bad weather (floods) affected the economic efficiency of the pilot

VI. Recommendation

- Polyculture (Tiger shrimp and mullet) is quite suitable for this area
- Stocking time should be considered at the time to carry out the pilot
- This pilot should be replicated to confirm the results
- Farmers should be supported with culture techniques.

Appendix

1. Growth rate of shrimp in polyculture pond

Culture day	0	15	30	45	60
shrimp 1	0.29	0.95	2.35	5.1	9.6
shrimp 2	0.25	1.05	2.45	5.05	9.4
shrimp 3	0.32	0.96	2.45	4.8	9.5
shrimp 4	0.29	0.98	2.55	4.9	9.2
shrimp 5	0.3	0.95	2.46	5.2	9.1
shrimp 6	0.3	0.96	2.46	5.25	9.8
shrimp 7	0.3	1.13	2.6	5.35	9.7
shrimp 8	0.27	1	2.53	4.95	9.2
shrimp 9	0.27	0.94	2.56	5.15	9.3
shrimp 10	0.32	1.03	2.54	5.2	9
Mean	0.29	1.00	2.50	5.10	9.38

2. Growth rate of shrimp in monoculture pond

Culture day	0	15	30	45	60
shrimp 1	0.29	0.85	1.45	3.1	5.4
shrimp 2	0.25	0.75	1.55	3	5.7
shrimp 3	0.32	0.86	1.55	2.8	5.9
shrimp 4	0.29	0.9	1.5	2.9	6
shrimp 5	0.3	0.8	1.46	3.3	6
shrimp 6	0.3	0.84	1.55	3.2	5.7
shrimp 7	0.3	0.78	1.6	3.3	5.9
shrimp 8	0.27	0.9	1.5	3.3	5.8
shrimp 9	0.27	0.84	1.65	2.9	5.5
shrimp 10	0.32	0.8	1.55	3	5.2
Mean		0.83	1.54	3.08	5.71

3. Growth rate of mullet

Culture day	0	15	30	45	65
Mullet 1	3.3	12.5	34.5	39.5	63.5
Mullet 2	3.2	12.5	32	39.5	62.5
Mullet 3	3.2	12	31.50	40.5	63.5
Mullet 4	3.3	13	34.5	40.5	64.5
Mullet 5	3	12	34.5	41.5	60
Mullet 6	3.5	12	33.5	38.5	62
Mullet 7	3.6	12.5	33	43.5	61
Mullet 8	3.4	12.5	32	39.5	60.5
Mullet 9	3.5	13.5	33.5	39	63.5
Mullet 10	3.4	12.5	33.5	37.5	64
Mean	3.3	12.5	33.3	40.0	62.5

4. Water parameters in mono and polyculture

Parameters	Oxy	Temp.	S%o	pH	NH3	KH
Polyculture pond						
1	4.7	28	17	8.2	0.01	90
2	4.8	30	17	8.5	0.01	95
3	4.5	28	15	8.7	0.15	97
4	4.9	29	15	8.5	0.15	97
5	4.7	28	19	8.5	0.01	95
6	4.8	26	18	8.7	0.01	98
7	4.9	28	16	8.7	0.15	95
8	4.76	28	17	8.5	0.1	95
Monoculture pond						
1	4.5	28	17	8	0.1	90
2	4.2	30	17	8.6	0.15	90
3	4.2	28	17	8.3	0.2	94
4	4	29	17	8	0.2	94
5	3.9	28	19	8.6	0.25	93
6	4	26	18	8.4	0.3	89
7	4	28	18	8.3	0.3	92
8	4.11	28	17.6	8.3	0	92