Journal of Coastal Development ISSN: 1410-5217
Volume 4, Number 3, June 2001 : 107-116 Accredited: 69/Dikti/Kep/2000

EXPERIMENTAL STUDIES ON SHRIMP- GRACILLARIA POLYCULTURE SYSTEM

Effects of Gracillaria Density on Shrimp Sizes, Production, Survival And Growth Rate

Efficiency in Carbon Energy Conversion Into Harvestable Products Among Gracillaria Density

By: Munifatul Izzati, N .R. Nganro and N. Widyorini

ABSTRACT

This experiments was conducted as response to the serious negative impact of shrimp aquacultres into the environment. The shrimp-Gracillaria polyculture system was hypothesized to reduce excess pollutant in the shrimp pond. Variation in Gracillaria density was used as treatments. Two important aspects are discussed in this paper, that are the effect on shrimp productivity and efficiency in carbon energy conversion into harvestable products. There were significant evidences that the shrimp-Gracllaria polyculture system increase the sizes, total biomass, survival and growth rate of shrimp. The density of Gracillaria was positively correlated with all of those parameters. The carbon energy conversion was also significantly affected by Gracillaria density. The carbon energy conversion into harvestable products was more efficient if Gracillaria density was increased.

Keywords: Shrimp, *Gracillaria,* polyculture system, shrimp yield, carbon energy conversion.

I. INTRODUCTION

As the large archipelagic nation, Indonesia is highly dependent on fishery product to promote the economical growth. However, fish production is now declining due to the over exploitation. Thereby, the shrimp industry is an important alternative strategies for increasing export earning. The Indonesian government release policies to expand and intensify shrimp cultures. Since then, Indonesia was becoming one of the major shrimp world producers. Intensification of shrimp cultures involves the application of large scales, stocking density and feeding rate. The intensive shrimp culture system always creates problems associated with maintaining water quality and controlling disease (Kusumaatmadja, 1998). In this system, the increase of nutrient discharged into the surrounding water can be dramatically destroy local coastal environment. The environmental change, including eutrophication has led to the declining of shrimp production. The collapse of shrimp farm has left to the environmental, social and financial problems. Thereby, Smith and Brigg (1998) recommended to develop the shrimp culture systems that are both environmentally and economically sustainable.

1.1. The common environmental impact of intensive shrimp culture system:

The intensive shrimp culture system is usually practices as a large monoculture, high stock density and a very high nutrient feed to enhance the production. A large proportion of nutrient (80%) are not utilized

(Jones, 1995). Therefore, the large amount of nutrient is released into the environment. According to Smith and Briggs (1998), the excess of shrimp is the major source of organic matter (40-60%) in the pond. Decomposi-tion of organic matter by bacteria will increase the concentration of phyto-plankton, bacteria , nutrient and suspended solid in the water. As a consequence the water transparency will declining. This is the indication of eutrophication.

The large scale and intensive monoculture is the cause of eutrophication, oxygen depletion and pollution. The degradation of the surrounding water has led to the unsuitable and even unusable for other purposes including farther culturing and harvesting of natural stock (Kautsky et. al. 1995). Eutrophication is defined by Cole (1983) as the process of nutrient enrichment into the water environment. The visible indicator of eutrophication is the increase of water turbidity by phytoplankton blooming. The blooming of phytoplankton has been a problem since phytoplankton eventually crashes and causes oxygen depletion and severe stress to the shrimp.

1.1. The role of pytoplankton in aquaculture:

Phytoplankton is a micro aquatic plants that are dominant ecological factor in aquaculture ponds. They are the based of food chains, particularly in natural food dependent aquaculture. The abundance of aquatic plants increases in response to excessive food. As microscopic plants phytoplankton are suspended in the water. At moderate to high abundance phytoplankton discolor the water and make it turbid. This is called a phytoplankton bloom. The bloom of phytoplankton is always associated with the high nutrient loading. Following the bloom, phytoplank-ton will frequently crashes and followed by sudden massive die offs and will be sedimenting out of the water column.

Phytoplankton have unique role in shrimp pond ecosystem. They have positive and negative role at the same time. Because of their important role in ecosystem, altering quantity and quality of the micro aquatic plants is important factor in pond management.

As micro aquatic plants, phytoplankton is almost unremovable from the ecosystem Therefore, it is necessary to find a removable aquatic plant as an alternative solution. We proposed to investigated shrimp- seaweed polyculture to maintain the positive role and eliminate the negative role of phytoplankton. We have investigated shrimp-Gracillaria poly-culture system, analyzed the effect on shrimp production and calculated the efficiency in carbon energy conversion from shrimp food into harvestable products.

II. MATERIAL AND METHOD

2.1. Study site:

This study was conducted in 12 m x 16 m of shrimp pond, belong to Coastal Research Development Laboratory, Dipo-negoro University, Jepara. The experiment was performed during August - December 2000. Using 12 of 1 m x l m x 1,2 m waterproved polyethilene enclosures, arranged inside the pond. The enclosures were hung from a strong plastic rope strung across the pond. Every enclosures was filled with approximately 1 m3 seawater that pumped from adjacent channel. The juvenil shrimp (PL-30) was stocked at density of 50 per enclosure.

2.2. Treatments:

The density of *Gracillaria* was varied at 1 kg /m^3, 2 kg /m^3 and 3 kg /m^3. Every treatment was replicated three times. Three enclosures without *Gracillaria* were used as controls

2.3. Water exchange:

Due to the collected data on nutrient content, there was no water exchange. The circulation was arrange in close system. Sea water was refilled weekly to reach the previous volume (1 m^3).

2.4. Food application:

Food pellet was given once a day. In the first 20 days the average food was given at 2 g /m^3 /day. For the next following 20 days was 5 g /m^3/ day and the last 20 days was 12 g /m3 /day. The total food given during the experiment (60 days) was 380 g /m3.

2.5. Data collection:

2.5.1. The total biomass, survival and growth rate of shrimp:

Shrimp total biomass and survival rate was recorded at the end of experiment, in the harvesting time. The shrimp total biomass was monitored by weighing of all of the harvested shrimp from every enclosure. The data of shrimp survival rate was collected from the number of survived shrimp per total stocked (in percent) in each enclosure. The growth rate of shrimp was monitored biweekly by sampling and measuring every individual weight and length of shrimp.

2.5.2. *Gracillaria* growth rate:

Growth rate of seaweed was monitored monthly by harvesting and weighing of all total biomass of seaweed in every enclosure. After weighing, the seaweed was hung back in the enclosure.

2.5.3. The carbon energy conversion:

The carbon energy was calculated by analyzes the carbon energy content in component of shrimp food, total shrimp productin and seaweed biomass. The energy content in every gram of each component was analyzedty born calorimeter. The carbon energy conversion in shrimp pond was determined by the percent of carbon energy converted from food pellet into harvestable products, shrimp and *Gracillaria.*

2.5.4. Statistical analyzes:

All collected data was analyzed using anova single factor. The difference among treatments was compared. Correlation among parameters was also statistically analyzed and compared.

III. RESULT AND DISCUSSION

3.1. Mean individual sizes (weight and length):

Table 1. mean individual weight (g) and length (cm) of harvested shrimp in different *Gracillaria* density

Gracillaria density	Mean individual Weight (g)	Standart Deviation	Mean Individual Length (cm)	Standart deviation
1 kg/m^3	3.43	0.9789	7.85	0.9789
	2.84	0.9271	7.48	0.7971
	3.24	1.1648	7.53	1.1025
Mean	3.06		7.61	
2 kg/m^3	3.74	1.5274	7.88	1.2091
	4.15	1.2831	8.32	1.0567
	3.99	1.5783	8.06	1.2831
Mean	3.94		8.09	
3 kg/m^3	3.92	1.3441	7.98	1.3441
	4.37	1.3741	8.28	1.3741
	4.14	1.4495	8.28	1.4495
Mean	4.12		8.23	
Controll (0 kg/m^3)	4.16	0.7831	8.20	1.0414
	3.32	1.8777	7.09	1.3199
	3.27	1.6643	7.39	1.6643
Mean	3.50		7.88	

Table 1. Table anova single factor of mean individual weight of harvested shrimp

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Group	51.0436	3	17.01453	6.8826	0.000163	2.6305
Within Group	860.293	348	2.4741			

As evidenced in table 1 to table 3 and showed by fig. 1 and fig. 2, the mean final weight and length in *shrimp- Gracillaria* polyculture was higher than in shrimp monoculture, even though not significantly different (p>O.05). There was a strong indication that *Gracillaria* density affect mean final sizes of shrimp. Statistical analyses indicated that the difference among treatment was highly significant, with p-value was less than 0.05 (p-v 1 .42E — 0,5). The *Gracillaria* density was positively correlated with mean final weight of shrimp (r = ± 0.94; p =227 n = 4) and mean final length (r = ± 0.953, p 0.195, n =3). Meaning that, an increase of *Gracillaria* density led to higher shrimp sizes.

3.2. Shrimp survival rate

Table 4. The shrimp survival rate among *Gracillaria* density:

Treatments : Gracillaria density	Replication no	Shrimp survival rate (%)
1 kg	1	24
	2	56

	3	44
Mean		41.33
2 kg	1 2 3	100 78 74
Mean		84
3 kg	1 2 3	96 66 58
Mean		73.33
Controls (0 kg)	1 2 3	24 66 66
Mean		52

Table 5. Table anova single factor of shrimp survival rate

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Group	4246.67	3	1415.556	3.829276	0.057206	4.006618
Within Group	2957.333	8	369.6667			

The survival rate of shrimp in polyculture wa higher than in monoculture. The difference was not statistically significant (p>0.05). The density of *Gracillaria* was almost significantly influenced the shrimp survival rate (p-v = 0.057206). There was a positive correlation between *Gracillaria* density and shrimp survival rate. The higher *Gracillaria* density, the shrimp survival rate was higher too (r = 0.52 ; p = 0.65 ; n = 3)

3.3. Shrimp Production:

Table 6. Data of shrimp production

Gracillaria density	Replication no	Mean individual shrimp weight (g)	# of survived shrimp	Shrimp total biomass (kg/ha)
1 kg / m^3	1 2 3	3.48 2.83 3.24	12 28 22	417.66 792.40 712.80
Mean			20.66	640.95
2 kg / m^3	1 2 3	2.77 3.98 3.57	50 39 37	1380.50 1552.20 1320.90
Mean			42	1417.59
3 kg /m^3	1 2 3	3.9 4.25 4.14	48 33 29	1872.00 1402.50 1200.60
			36.66	1491.70
Controls 0 kg / m^3	1 2 3	4.16 3.18 2.75	12 33 33	499.20 1049.40 907.75
Mean			26.00	818.78

Table 7. Table of anova single factor on shrimp production

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Group	2350228	3	783409.5	10.9554	0.003319	4.06618
Within Group	572072.1	8	71509.01			
Total	2922301	11				

In compare to monoculture, shrimp production in polyculture was 53% higher. The difference was not statistically significant ($p>0.05$). The Gracillaria density was significantly affect shrimp production (p-value = 0.003319). There was a positive correlation between Gracillaria density and shrimp total biomass (r = + 0,998 ; p = 0.098 ; n =). Srimph production increase with an increase of *Gracillaria* density.

3.4. Shrimp growth rate

Shrimp-*Gracillaria* polyculture facilitated a better growth rate compared to shrimp monoculture. At *Gracillaria* density of 2 kg/m^2 and 3 kg/m^2 the growth of shrimp was at the best rate. The growth rate shrimp at 1 kg/m^2 of *Gracillaria* density was declining at the end of rearing period.

Table 8. Data of shrimp growth rate during cultivation period:

Treatments : *Gracillaria* density	Mean of shrimp individual weight at different cultivation period (weeks)									
	0 weeks		2 weeks		4 week		6 weeks		8 weeks	
	weight	±SD	weight	±SD	weight	±SD	weight	±SD	weight	±SD
1 kg / m^3	0.06	0.0002	0.50	0.14	1.24	0.37	2.64	0.43	3.43	0.9789
			0.60	0.24	1.14	0.28	2.44	0.18	2.84	0.7971
			0.60	0.29	1.52	0.39	2.64	0.25	3.24	1.1025
Mean	0.06		0.56		1.43		2.57		3.06	
2 kg / m^3	0.06	0.0002	0.28	0.13	1.44	0.38	3.36	1.11	2.77	1.2091
			0.58	0.29	1.19	0.34	2.48	0.35	3.98	1.0567
			0.44	0.39	1.20	0.26	2.78	0.47	3.57	1.2831
Mean	0.06		0.43		1.29		2.87		3.94	
3 kg /m^3	0.06	0.0002	0.34	0.11	1.4	0.61	2.38	0.59	3.92	1.3441
			0.44	0.002	1.48	0.37	2.72	0.49	4.25	1.3741
			0.50	0.002	1.36	0.45	3.38	0.90	4.14	1.4495
	0.06		0.42		1.25		2.83		4.13	
Controls 0 kg / m^3	0.06	0.0002	0.52	0.10	1.50	0.48	2.90	0.19	4.16	1.0414
			0.52	0.002	0.84	0.39	1.26	0.57	3.18	1.3199
			0.50	0.15	0.84	0.57	1.15	0.83	2.75	1.6643
Mean	0.06		0.45		0.96		1.80		3.51	

3.5. Carbon energy conversion from shrimp food into harvestable products (shrimp + *Gracillaria*)

3.5.1. The energy content in the main ecosystem component:

Name of component	Carbon energy content (cal / g) component
Shrimp food	3969.46
Shrimp	4184.75
Gracillaria	**2362.37**

3.5.2. The total carbon energy in shrimp:

Table 10. Data of total carbon energy in shrimp

Gracillaria density	Replication no	Total biomass (g fresh weight)	Total biomass (g dry weight)	Total carbon energy
1 kg / m^3	1	41.76	12.528	52393.070
	2	79.24	23.772	99465.565

	3	71.25	21.384	89469.955
Mean			19.22	80444.842
2 kg / m^3	1	138.05	41.550	173876.360
	2	155.22	46.566	194841.960
	3	132.09	39.627	165591.32
Mean				178103.21
3 kg /m^3	1	187.20	56.160	235015.560
	2	140.25	42.075	176073.35
		120.09	36.270	150726.32
				187271.74
Controls 0 kg / m^3	1	49.92	14.976	62645.707
	2	104.94	31.482	131735.930
	3	9.75	27.225	113908.890
Mean				104563.500

3.5.3. The total carbon energy in *Gracillaria*:

Table 11. Data of total carbon energy in *Gracillaria*

Gracillaria density	Replication no	Total biomass (g fresh weight)	Total biomass (g dry weight)	Total carbon energy
1 kg / m^3	1	4200	420	992124.00
	2	3900	390	921648.00
	3	3030	303	715767.8/1
2 kg / m^3	1	4950	495	1169323.60
	2	3950	395	933096.65
	3	4300	430	1015776.10
3 kg /m^3	1	4900	490	1157512.30
	2	4350	435	1027587.40
		4750	475	1122078.20
Controls 0 kg / m^3	1	0	0	0
	2	0	0	0
	3	0	0	0

3.5.4.The total carbon energy conversion:

Table 12. Data of total carbon energy conversion

Gracillaria density	Replication no	Total C energy in shrimp food 318x3969.46	Total C energy in shrimp	Total C energy in Gracillaria	Total C energy in Shrimp + Gracillaria	Total C Energy conversion
1 kg / m^3	1	1262288.2	52393.070	992124.00	1044517.0	82.75
	2	1262288.2	99465.565	921648.00	1091589.5	86.47

	3	1262288.2	89469.955	715767.81	805237.7	63.79
Mean		1262288.2	80444.842	876513.3	980448.1	77.67
2 kg / m^3	1	1262288.2	173876.360	1169323.60	1343199.9	106.41
	2	1262288.2	194841.960	933096.65	1157938.6	89.36
	3	1262288.2	165591.32	1015776.10	1181367.4	93.59
Mean		1262288.2	178103.21	1049399	1220109	96.44
3 kg /m^3	1	1262288.2	235015.560	1157512.30	1627543.3	128.94
	2	1262288.2	176073.35	1027587.40	1203660.7	95.35
	3	1262288.2	150726.32	1122078.20	1272804.3	100.83
Mean		1262288.2	187271.74	1102393	1401490	108.37
Controls 0 kg / m^3	1	1262288.2	62645.707	0	62645.707	4.96
	2	1262288.2	131735.930	0	131735.930	10.44
	3	1262288.2	113908.890	0	113908.890	9.02
Mean			104563.500	0	102763.5	8.14

Table 13. Table of anova single factor on carbon energy conversion

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Group	18593.01	3	6197.669	51.46758	1.42E-05	4.06618
Within Group	963.3511	8	120.4189			
Total	19556.36	11				

The carbon energy conversion from shrimp food into harvestable products in polyculture was higher than in monoculture. The difference of carbon energy conversion between polyculture and monoculture was highly significant (p = 1.28E-05). The density of *Gracillaria* affect carbon energy conversion. The difference of energy conversion among *Gracillaria* density was highly significant (p = 1,42E-0,5). There was a strong positive correlation between *Gracillaria* density and carbon energy conversion (r=0.999; p = 0.03 3; n = 3). Therefore, the carbon energy conversion increase with an increase of *Gracillaria* density.

IV. DISCUSSION

Shrimp-*Gracillaria* polyculture resulted in higher shrimp production, as indicated by paramaters of shrimp individual sizes, total biomass, survival and growth rate. The carbon energy conversion from shrimp food into harvestable product of shrimp and *Gracillaria* was also significantly higher in polycultures compared to monocultures.

The higher shrimp yield in polyculture was primarily attributed to an ecological role of *Gracillaria* . As an aquatic plants, *Gracillaria* has a dominant ecological factors in shrimp ponds. In pond ecosystem, aquatic plants serves as the based of the food chain. The food for fish and crustacean originates entirely from plant production (Boyd, 1990). In intensive culture systems primarily on additional feeding, plants are less important as food supplier. However, in this type of ecosystem, aquatic plant may function in maintaining the natural food chain that produce natural food for shrimp. The existence of natural food for shrimp in the ecosystem may resulted in higher shrimp production.

It is hypothesize that if the *Gracillaria* was absence from the shrimp pond, phytoplankton was domi-nant. The domination of phytoplankton in shrimp pond causes several problems. According to Neon et. al. (1991), phytoplankton was periodically crashes driven by zooplankton and nutrient limitation. Consequently, oxygen consumption was increased and concentration of ammonia in the water was also increased.

This condition may led to the lower shrimp production. On the other hand, *Gracillaria* has been known to have capability in removing ammonia from ecosystem (Neon et. al. ; Troell et. al. 1997; Bird, 1982).

The presence of *Gracillaria* in the shrimp pond may replace a positive role and eliminate the negative role of phytoplankton. From the economical point of view, *Gracillaria* is on of the commercially valuable of seaweeds. This alga produce agar that was widely used as stabilizing agent in many industrial product,- such as ice cream, toothpaste and cosmetics. Therefore, *shrimp-Gracillaria* polyculture produce two commercial products all at once, i.e. shrimp and agar. It can be concluded that *shrimp-Gracillaria* polyculture is promising cultivation technique to be practiced in the future.

V. CONCLUSIONS

Shrimp-*Gracillaria* polyculture resulted in significantly higher shrimp individual sizes, total biomass, survival and growth rate. The carbon energy conversion from shrimp food into harvestable products in *shrimp-Gracillaria* polycultures were also significantly higher in polyculture than in shrimp monoculture. *Gracillaria* density was positively correlated with shrimp productivity and efficiency in carbon energy conversion. Shrimp productivity and carbon energy conversion were increase with an increase of *Gracillaria* density. The high commercially valuable of *Gracillaria* resulted in twofold advantages for shrimp farmer. *Shrimp-Gracillaria* polyculture system is a promising shrimp cultivation method to be practiced in the future.

REFERENCES

Bird, K. T. (1982): Nitrogen allocation and storage patterns in *Gracillaria tikvihiae* (Rhodophyta). J. Phycol 18: 344-348.

Boyd, C.E. (1990): Water Quality in Ponds for Aquaculture. Birmingham Publishing Co. Birmingham, Alabama.

Cole, G.A. *(1983):* Textbook of Limnology. Third edition. Waveland Press. Inc. Illinois, USA.

Hansen L.S. and T.H. Blackburn (1992): Effect of algal bloom deposition on sediment respiration fluxes. Marine Biology 1 12: 147- 152.

Jones, A. (1995): Manipulation of prawn farm effluent flow rate and residence time and density of biofilters to optimise filtration efficiency of oysters *(Saccostrea commersialis).*

Kautsky, N., M. Troell and C. Folke (1995) : Ecological engineering for increased production and environ-mental improvement in open sea aquaculture. Department of System Ecology, Stockholm University, Sweden.

Kusumastanto, T., C.M. Jolly and C. Bailey (1998): A multiperiod programming evaluation of brackishwater shrimp aquaculture development in Indonesia 1989/1990-1998/1999. Aqua-culture 159: 3 *17-331*

Neori, A., M.D. Krom, S.P Ellner, C.E. Boyd, D. Popper, R. Rabinovith, P.J. Davison, O. Dvir, D. Zuber, M. Ucko, D. Angel and H. Gordin (1996): Seaweed biofilter as regulator of water quality in

integrated fish-seaweed culture units. Aquaculture 141: 183-199.

Smith, S.J.F. and M.R.D. Briggs (1998): Nutient budgets in intensive shrimp ponds: implications for sustainability. Aquaculture 164: 117-133.

Troell, M., C. Hailing, A. Nilson, A.h. Buschmann, N. Kautsky and L. Kautsky (1997): Integrated marine cultivation of *Gracillaria chilensis (Gracillariale.s; Rhodophyta)* and Salmon cages for reduced environmental impact and increased economic output. Aquaculture 156: 45 - 61.