The Water and Sediment Quality of *Chanos chanos* Monoculture and *Chanos chanos* - *Gracilariopsis bailinae* Biculture in Pond

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ABSTRACT

A short-term study on the physical-chemical parameters in *Chanos chanos* monoculture and its biculture with *Gracilariopsis bailinae* indicated that the biculture might be advantageous for the growth of milkfish. Dissolved oxygen of the biculture and monoculture was not significantly different early in the morning. Oxygen produced by *G. bailinae* from late afternoon until evening was probably compensated by larger *C. chanos* that consumed more oxygen in the biculture. The afternoon DO of the biculture, however, was higher than that of the monoculture. There was no difference in pH readings between the monoculture and the biculture. Water temperature ranged from 23 - 39^{o}C, and salinity ranged from 14 - 42% for both monoculture and biculture. The presence of *G. bailinae* did not affect water pH, temperature, and salinity of the biculture pond.

During the culture period, phosphate in the water of the biculture decreased while it increased in the monoculture. The change in nitrate was insignificant for both monoculture and biculture. The ammonium decrease in the biculture was higher than that in the monoculture while the rise in phosphorus in the sediment was higher in the monoculture than in the biculture. The increase in nitrate and ammonia was higher in the monoculture sediments than in biculture sediments, but the difference was insignificant. Some of the phosphate and ammonium lost in the biculture pond may be attributed to the phosphorus and the nitrogen utilized by the red seaweed or stored in its tissues.

Chanos chanos grew better in biculture with *G. bailinae* as the effect of more favorable water and sediment quality in the pond during the culture period. Furthermore, the nutrients present in the pond water and sediment were probably utilized by *G. bailinae* for their growth or stored in their tissues.

Keywords: *Chanos chanos*, *Gracilariopsis bailinae*, water quality, sediment quality, monoculture, biculture.

INTRODUCTION

Milkfish (*Chanos chanos* Forsskål) culture using ponds, pens and cages is popular in the Philippines. Many aquaculturists today engage in high-density stocking to increase production. Such systems require supplemental feeding and may be stressful to the environment (Bagarinao, 1996). The limited area of the pond is prone to accumulation of certain nutrients from animal excreta and uneaten feeds both of which may become toxic to the reared organisms or lead to proliferation of pests or diseases. In the long run such conditions may contribute to the decline in the yield of the culture organisms as well as to the yield of other organisms in other bodies of water in the environs into which the pond drains.

It is hypothesized that the metabolic wastes and excess feed of *C. chanos* are used as source of nutrients for the photosynthetic processes of the agarophyte, *Gracilariopsis bailinae* Zhang *et* Xia. Previous studies have noted that *Gracilaria* spp. absorb ammonia produced in shrimp ponds (dela Cruz, 1995). Furthermore, *Gracilaria* spp. photosynthesize, therefore, produce oxygen that in effect accelerates oxidation of organic matter and utilizes ammonia. As a result, ammonia in the water will be reduced and dissolved oxygen will increase, leading to favorable conditions for the growth of *C. chanos*.

The biculture of seaweed and fish has not been adopted commercially in the Philippines. Supplemental income from the seaweed produced and reduced environmental impact are some of the advantages of this biculture technique (Hurtado-Ponce, 1993; Buschmann, 1996). Nowadays, environmental concerns are given high consideration in any technology development. This is important in aquaculture especially because the medium is in continuity with other bodies of water that can easily disperse substances such as nutrients and pesticides.

This study examines the effect of the biculture of *G. bailinae* with *C. chanos* on the water and sediment characteristics of the pond. It also presents the differences in the water quality and sediment quality of the pond for the culture of *C. chanos* alone, and the biculture of *C. chanos* and *G. bailinae*.

MATERIALS AND METHODS

The study was conducted in the fishponds of the Silliman University Marine Laboratory (SUML), Dumaguete City from February 3 to March 17, 1998. There were two treatments in the study: (1) the *C. chanos* monoculture, and (2) the *C. chanos*-*G. bailinae* biculture. Each treatment was replicated six times in $12m^2$ earthen ponds, which were further subdivided by netting material into three compartments. One compartment for all the replicates was measured, without replacement of experimental organisms, at two weeks interval. The first samples were referred to as series 1; the second series 2; and the third, series 3. Net production rates and growth rates of *C. chanos* were determined from the weights measured in every series. Water exchange between pond and incoming water occurred every other day during high tides.

Vegetative cuttings of *G. bailinae* were broadcasted in the biculture treatment at 1,000 kg ha^{-1} one day ahead of *C. chanos* stocking. The stocking density of milkfish was 5,000ha^{-1}. The milkfish were given supplemental food (Tateh Bangus Feeds, Manila, Philippines) three times daily at 4.0 - 5.0% of the initial body weight, and adjusted accordingly every other week.

Temperature, pH and salinity were monitored daily at 1000-100h and 1500-1600h using an ordinary mercury thermometer, a portable pH meter Orion Research Model SA 250 (Orion Research Incorporated, USA), and a hand-held temperature compensated Reichert refractometer (Japan), respectively.

Dissolved oxygen was determined every seventh day of the week at 0600-0700h and 1500-1600h using Winkler's method. Water samples collected from each pond were filtered and stored in a freezer until the laboratory determination. Sediment samples were collected using an improvised pipe borer then air dried, powdered and sieved for laboratory analysis. Dissolved phosphate (PO_4), nitrate (NO_3), ammonium (NH_4) in the water, and phosphorus (P), nitrate (NO_3) and ammonia (NH_3) in the sediment were determined at the start and at the end of the study. Chemical analysis followed the methods in Grasshoff et al. (1983). Pond sediment particle size profile was determined using the methods prescribed by Dartnall & Jones (1986) and

English et al. (1994). Soil pH was determined every two weeks. Data were subjected to analysis of variance (ANOVA).

RESULTS

Water pH

The minimum and maximum morning pH in the pond compartments were recorded at 6.8 and 9.0, respectively. The initial morning pH ranged from 7.8 to 8.0. During the culture period, the weekly morning pH of the biculture treatment fluctuated from 8.1 to 8.3 while in the monoculture pH ranged from 8.2 to 8.3. The range of the afternoon pH was from 6.2 to 9.3. The initial afternoon pH was 8.1. In the biculture, pH varied from 7.9 to 8.3, and in the monoculture, the range was 7.9 to 8.4 (Fig. 1). Analysis of variance indicated no significant difference between the two treatments in both morning and afternoon pH readings.

Dissolved oxygen

The morning DO ranged from 0.1 to 6.6mg l^{-1}. Highest morning DO was recorded before the stocking of experimental organisms (4.5 to 5.1mg l^{-1}). For six weeks of culture, the DO of the biculture treatment fluctuated from 0.4 to 1.3mg l^{-1}, and for the monoculture treatment DO ranged from 0.6 to 1.3mg l^{-1}. The afternoon DO ranged from 4.4 to 19.3mg l^{-1}. Initial afternoon DO in the pond ranged from 10.6 to 11.9mg l^{-1}. During the culture period, the DO of the biculture fluctuated from 9.6 to 12.5mg l^{-1} while in the monoculture DO ranged from 6.4 to 7.2mg l^{-1} (Fig 2). No significant difference ($P>0.05$) was determined between the two treatments in the morning DO but significant difference ($P<0.05$) existed in the afternoon DO using ANOVA.

Phosphate

Chemical analysis of the water showed that the amount of PO_4 in the pond water decreased from 2.9 to 2.2µmol l^{-1} in the biculture treatment. In contrast, the monoculture treatment was found to increase from 2.9 to 4.0µmol l^{-1} (Fig. 3). Analysis of variance showed that the difference between the two treatments was significant ($P<0.05$).

Nitrate

The amount of NO_3 decreased from 1.9 to 1.3µmol l^{-1} in the biculture. On the contrary, in the monoculture treatment, a small increase of 0.1µmol l^{-1} was seen (Fig. 4). Analysis of variance revealed that the two treatments were not significantly different ($P>0.05$).

Ammonium

The amount of NH_4 lost in the biculture treatment was 1.7µmol l^{-1}, from 1.9 to 0.2µmol l^{-1} . On the other hand, in the monoculture, there was a decrease of 0.7µmol l^{-1} in NH_4 from 1.9 to 1.2µmol l^{-1} (Fig. 5). The amount of NH_4 lost in the biculture treatment was significantly higher ($P<0.05$) than that in the monoculture treatment using ANOVA.

Temperature

Morning pond water temperature ranged from 25 to 35°C while in the afternoon, it fluctuated from 22 to 39°C. Minimum-maximum temperature readings showed that the lowest water temperature was 22 to 29°C, and the highest was 32 to 39°C. There was no difference in water temperature between the monoculture and biculture ponds (Fig. 6).

Salinity

The range of morning pond salinity was from 14 to 42% and the afternoon salinity ranged from 14 to 44%. Generally, afternoon salinity (30.2%) was higher than morning salinity (29.8%). The salinity of the monoculture and biculture ponds were similar (Fig 7).

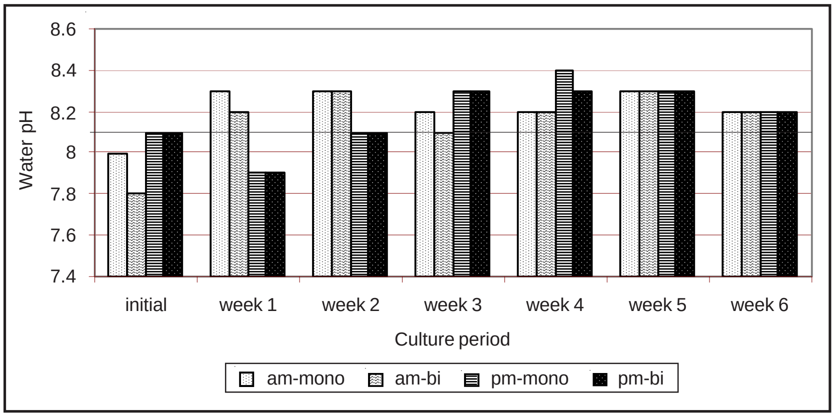

Figure 1. Comparison of the average pH between the ponds of *C. chanos* monoculture and *C. chanos* - *G. bailinae* biculture taken in the morning and afternoon from initial to six weeks of culture from February 3 to March 17, 1998 (mono = monoculture, bi = biculture, am = morning, pm = afternoon).

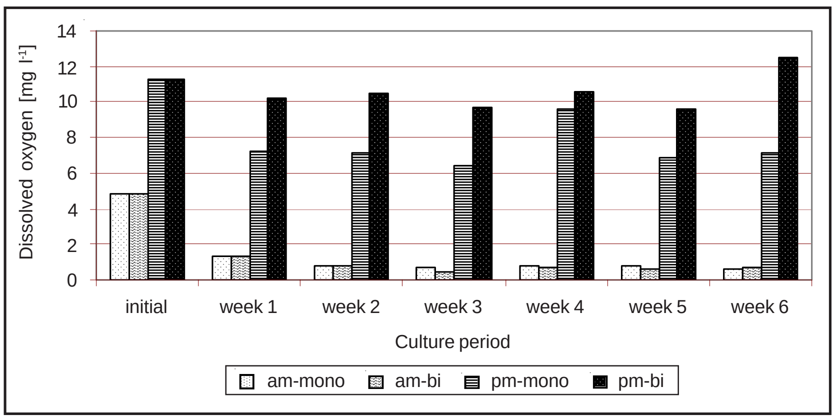

Figure 2. Comparison of the average dissolved oxygen between the ponds of *C. chanos* monoculture and *C. chanos* - *G. bailinae* biculture taken in the morning and afternoon from initial to six weeks of culture from February 3 to March 17, 1998 (mono = monoculture, bi = biculture, am = morning, pm = afternoon).

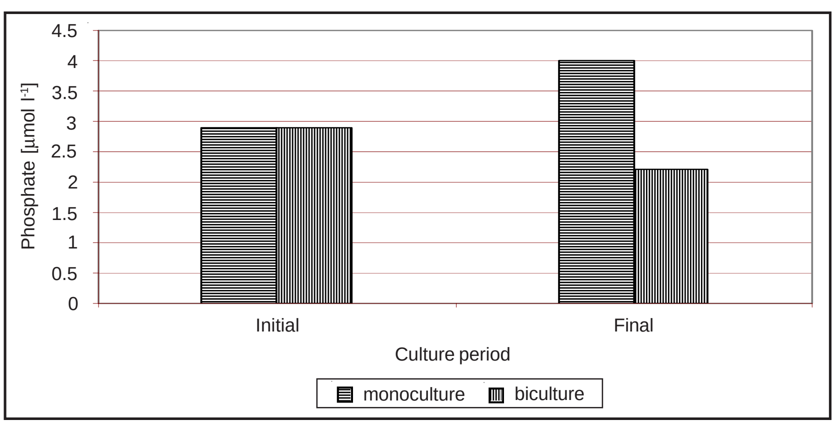

Figure 3. Comparison of the average phospate between the pond water of *C. chanos* monoculture and *C. chanos* - *G. bailanae* biculture taken before and after the culture period from February 3 to March 17, 1998.

Sediment particle size

The grain size analysis using the Wentworth Grade Scale showed that the sediment was sandy mud. The principal grain component was fine to very fine sand, 62-250µm (45.3%), followed by very coarse to coarse sand, 500-200µm (22.3%), medium sand, 250-500µm (21.7%), and silt, 3.9-62µm (10.6%).

Sediment pH

The sediment pH ranged from 6.8 to 9.0. Initially the pH was 6.9. In the first series, the pH in the biculture was 8.9 and in the monoculture, it was 8.8. On the second and third series, both treatments had a pH of 8.3 and 8.5, respectively (Fig. 8).

Phosphorus

The amount of P in the sediment increased during the culture period from 301.4 to 312.1mol l^{-1} or an increase of 10.7mol l^{-1} in the biculture. The monoculture increased by 45.5mol l^{-1} from 271.6 to 346.9mol l^{-1} in P (Fig. 9). Analysis of variance showed that the increase in the amount of total P in the monoculture was significantly higher ($P<0.05$) than the biculture.

Nitrate

There was an increase in the amount of NO_3 in the sediment at the end of the study. The amount increased by 7.7mol l^{-1} from 26.2 to 33.9mol l^{-1} (Fig. 10). Analysis of variance revealed a significant ($P<0.05$) increase of NO_3 in the sediment; however, the two

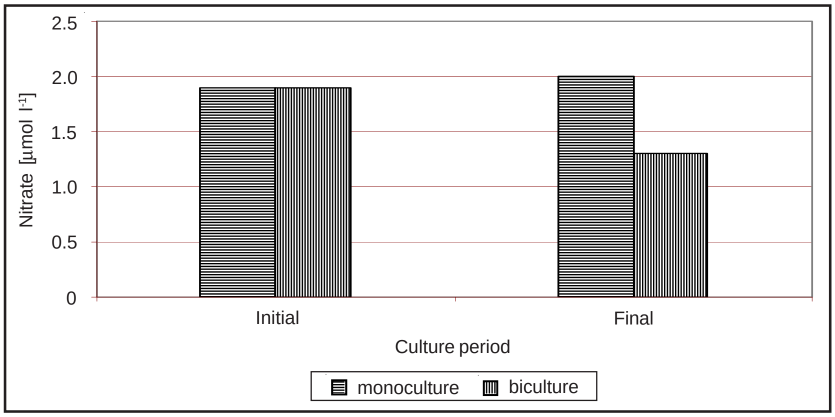

Figure 4. Comparison of the average nitrate between the pond water of *C.chanos monoculture* and *C. chanos - G. bailinae* biculture taken before and after the culture period from February 3 to March 17, 1998.

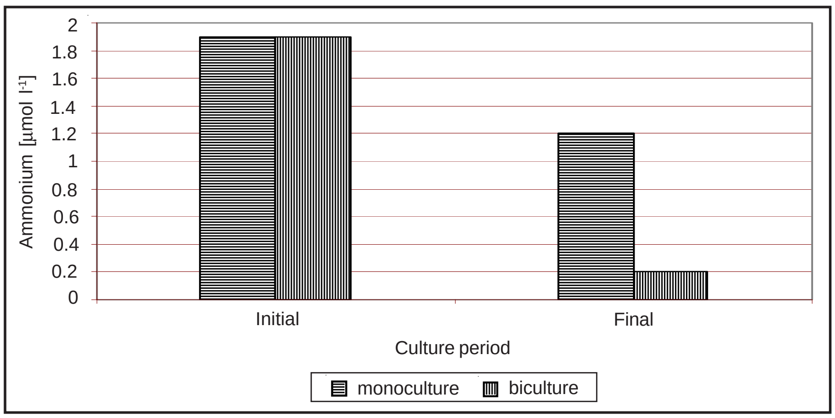

Figure 5. Comparison of the average ammonium between the pond water of *C. chanos* and *C. chanos - G. bailinae* biculture taken before and after the culture period from February 3 to March 17, 1998.

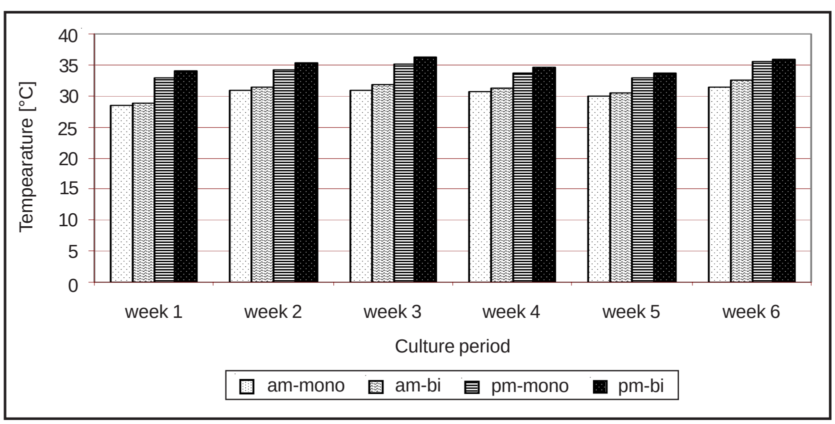

Figure 6. Comparison of the average water temperature between the ponds of *C.chanos* monoculture and *C. chanos - G. bailinae* biculture taken in the morning and afternoon from initial to six weeks of culture from February 3 to March 17, 1998 (mono = monoculture, bi = biculture, am = morning, pm = afternoon).

treatments have no significant difference ($P>0.05$).

Ammonia

The biculture treatment had higher NH_3 in the sediment at the start than at the end of the study. The difference was 3.7mol l^{-1} NH_3 from 33.8 to 30.1mol l^{-1}. In the monoculture, the increase was 1.0mol l^{-1} (Fig. 11). However, no significant difference ($P>0.05$) was shown by the two treatments.

Growth of *C. chanos*

Two-way ANOVA showed that the weight increment of *C. chanos* in the biculture treatment was significantly ($P<0.05$) greater than in the monoculture and that significant ($P<0.05$) differences exist between series. Weight increments of *C. chanos* were observed to increase with longer culture period (Table 1 & 2).

There was no significant difference ($P>0.05$) between the weight gained by milkfish in both monoculture and biculture treatments during the first two weeks of culture. After one month of culture until the end of the culture period, the milkfish cultured with the agarophyte had higher weight increment compared with those in monoculture.

In both the daily and the monthly net production rate estimates, ANOVA of logarithmically transformed data showed that the biculture treatment was significantly ($P<0.05$) higher than the monoculture. Net production rate after two weeks of culture did not

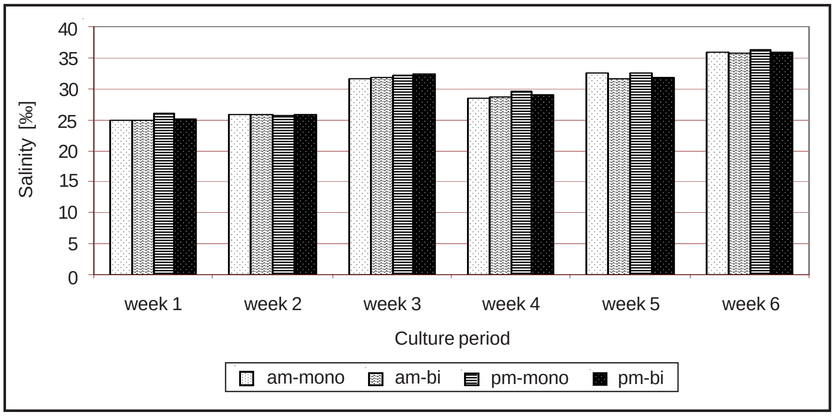

Figure 7. Comparison of the average salinity between the ponds of *C.chanos* monoculture and *C. chanos - G. bailinae* biculture taken in the morning and afternoon from initial to six weeks of culture from February 3 to March 17, 1998 (mono = monoculture, bi = biculture, am = morning, pm = afternoon).

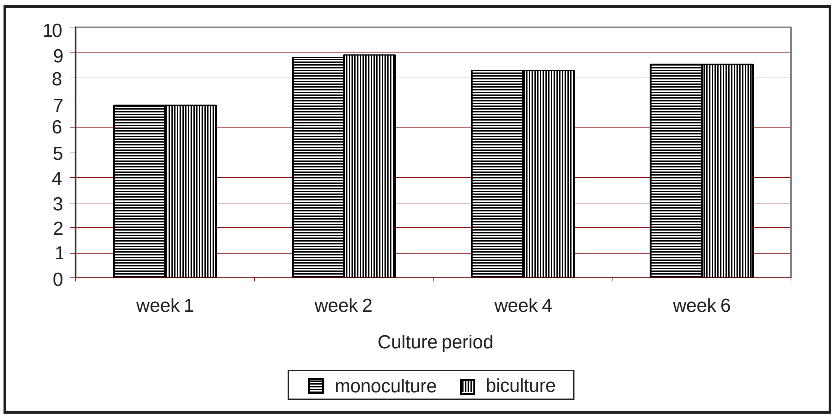

Figure 8. Comparison of the average pH between the pond sediment of *C. chanos* monoculture and *C. chanos - G. bailinae* biculture taken once every two weeks period from February 3 to March 17, 1998.

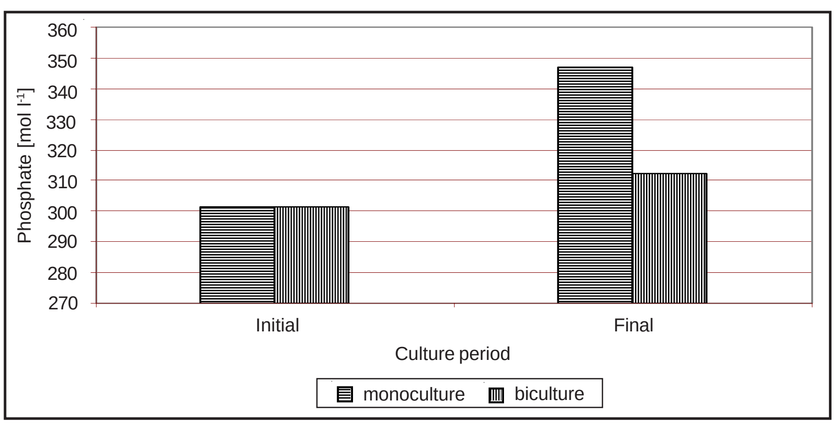

Figure 9. Comparison of the average phosphorus between the pond sediment of *C. chanos* monoculture and *C. chanos - G. bailinae* biculture taken once every two weeks period from February 3 to March 17, 1998.

vary significantly (P>0.05) from those cultured for four weeks or six weeks in both the monoculture and biculture. The net production rate in the biculture decreased with time. Highest net production rate was obtained during the first two weeks while lowest was obtained in the sixth week (Table 2).

Both the biculture and monoculture treatments obtained the fastest growth rate during the first two weeks of culture. The growth rates of the biculture were significantly (P<0.05) higher than those of the monoculture. Moreover, there were significant differences (P<0.05) between the culture time series. Comparison of means using Duncan's multiple range test (DMRT) revealed that growth rates in the biculture increased with time. However, the monoculture mean growth rates in all series were statistically similar.

DISCUSSION

Growth performance of *Chanos chanos* was higher in the biculture than in the monoculture. Several physical and chemical parameters most likely contributed to this.

The dissolved oxygen content probably influenced the growth performance of *C. chanos*. The early morning DO of the two treatments did not differ, but the afternoon DO in the biculture was usually higher than that in the monoculture. Afternoon DO may represent most of the oxygen produced by photosynthesizing algae, including the cultured *G. bailinae*, that started to build-up from mid-

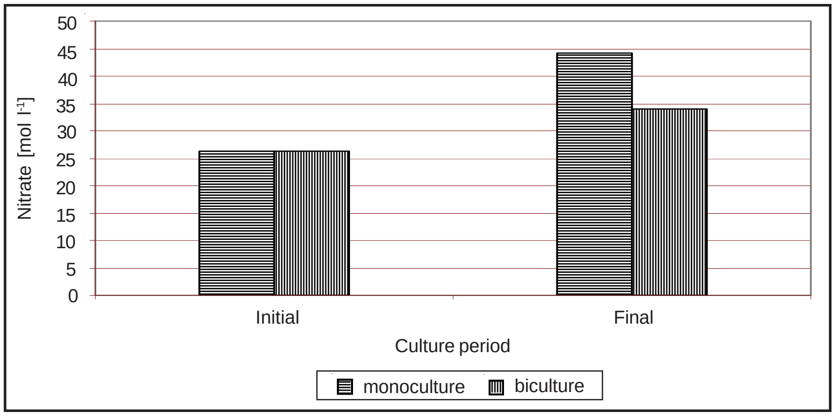

Figure 10. Comparison of the average nitrate between the pond sediment of *C. chanos* monoculture and *C. chanos* - *G. bailinae* biculture taken before and after the culture period from February 3 to March 17, 1998.

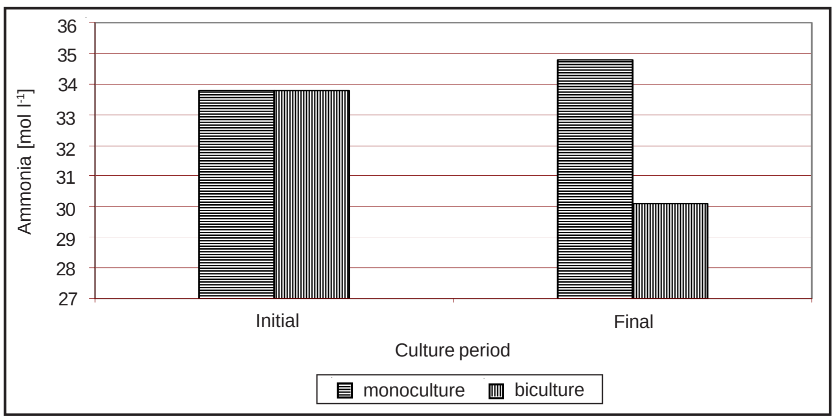

Figure 11. Comparison of the average ammonia between the pond sediment of *C. chanos* monoculture and *C. chanos* - *G. bailinae* biculture taken before and after the culture period from February 3 to March 17, 1998.

Basis of Comparison	Biculture	Monoculture
Overall weight increment	↑	↓
Weight increment with longer culture period	↑	↓
Daily net production rate	↑	↓
Monthly net production rate	↑	↓
Overall growth rate	↑	↓
Growth rate with longer culture period	↑	↓

Table 1. Comparison of the performance of *Chanos chanos* in monoculture and biculture with *Gracilariopsis bailinae* based on analysis of variance from February 3 to March 17, 1998 (↑ = higher, ↓ = lower).

morning till late afternoon. With higher DO and additional food source from the epiphytic organisms of the agarophyte, the milkfish in the biculture treatment benefited and probably converted to higher weight. Higher DO in the biculture was probably caused by the photosynthetic activity of *G. bailinae* (Fig. 2). Lower DO in the pond early in the morning may have been caused by several respiring organisms present in the sediment and water.

Dissolved oxygen greatly affects growth and production of milkfish through its direct effect on feed consumption and metabolism, and indirect effect on environmental parameters (dela Vega, 1996). Bagarinao (1996) reported that fish grew favorably when DO was maintained at 5 or >5mg l^{-1} but grew slowly at DO <5mg l^{-1}. In this study, however, all readings are still within the range of 5.0mg l^{-1} but the biculture were much higher than those of the monoculture. Further study is needed to elucidate this matter.

Carbon dioxide and ions in equilibrium with photosynthesizing organisms largely influence changes in water pH. Thus, pH is low at dawn and high in the afternoon (dela Vega, 1996). Water pH (9 to 10) in ponds recorded by Haglund & Pedersen (1993) was higher than reported in this study (7.5 to 8.5). Nevertheless, the results here were very near to what Santelices & Doty (1989) suggested (pH 8.1) for pond culture of *Gracilaria* spp.

Nelson et al. (1980) found that *Gracilaria edulis* and *Gracilaria arcuata* have the capability of removing ammonia from seawater. Likewise, *Gracilaria tenuistipitata*

Treatment/ Series	Initial Weight (g)	Final Weight (g)	Weight Increment* (g)	Net Production* Rate ($g\ m^{-2}\ day^{-1}$)	Net Production* Rate ($kg\ ha^{-2}\ mo^{-1}$)	Growth Rate ($\%\ day^{-1}$)
Biculture, Series 1	11.0 ± 1.2	27.7 ± 2.3	16.7 ± 2.0[dc]	0.9 ± 0.1[a]	262.9 ± 90.3[a]	6.2 ± 0.6[a]
Biculture, Series 2	12.7 ± 1.7	46.8 ± 4.1	34.1 ± 3.5[b]	0.6 ± 0.1[a]	182.8 ± 18.7[a]	4.8 ± 0.5[a]
Biculture, Series 3	15.8 ± 1.7	68.8 ± 5.4	53.1 ± 4.7[a]	0.6 ± 0.1[a]	174.8 ± 18.4[a]	3.3 ± 0.2[c]
Monoculture, Series 1	14.1 ± 1.0	23.1 ± 1.8	9.0 ± 1.2[d]	0.3 ± 0.04[b]	95.8 ± 13.0[b]	3.3 ± 0.4[c]
Monoculture, Series 2	16.4 ± 1.4	38.1 ± 2.4	21.7 ± 1.9[c]	0.39 ± 0.03[b]	116.2 ± 10.3[b]	2.89 ± 0.2[c]
Monoculture, Series 3	17.6 ± 1.8	56.3 ± 5.5	38.8 ± 4.2[b]	0.46 ± 0.05[b]	138.5 ± 14.8[b]	2.61 ± 0.2[b]

* Means having common letter superscript are not significantly different at P = 0.05.

Table 2. Mean (±SE) initial weight, final weight, weight increment, net production rate, and growth rate of *Chanos chanos* in monoculture and biculture ponds from February 3 to March 17, 1998 (n = 12).

was found to remove NO_3^-, NH_4^+, and PO_4^{3-} (Haglund & Pedersen, 1993). Results of the study show that the removal of PO_4 and NH_4 in the biculture of *C. chanos* and *G. bailinae* was significantly higher than in the monoculture (Figs. 4 & 5).

The phosphorus from the sediment is a good source of phosphorus for phytoplankton and algal growth. Ammonia, ammonium, nitrite and nitrate are inorganic forms of nitrogen used by photosynthetic organisms. The range of P and N for average to high fish production has been reported by dela Vega (1996) to be 30 to >60 mol l^{-1} and 250 - 750 mol l^{-1}, respectively. The fish production referred to here relates to natural food production. The monoculture of milkfish increased the quantity of total P in the pond soil. The amount of nitrogen in the form of nitrate and ammonia in this study is lower than the optimum range given above. The nutrients in the sediment are probably accumulated through time from fish excreta and other inputs.

The maximum growth rates of *C. chanos* in the biculture of this study are higher (6.2% day^{-1}) than those obtained in 500m^2 ponds stocked at 7,000ha^{-1} (2.1% day^{-1}) (Sumagaysay & Borlongan, 1995). The culture system, area, and stocking density are different. Biculture with *G. bailinae* probably improved the growth performance of *C. chanos*. Milkfish cultured with the red alga obtained higher mean growth rate (3.19% day^{-1}) than monoculture (1.57% day^{-1}) did. The biculture of fish and macroalga has synergistic interaction, and the culture medium is favorable to both organisms.

It has been documented that feeding the cultured fish increases production and profits. However, nutrients and organic matter from excess feeds and feces can cause rapid deterioration of water quality (Feed Dev't. Section, 1994). Cruz (1996a) claimed that the direction of the milkfish aquaculture in the Philippines is towards intensification. It should be considered, though, that high-density culture systems have ecological limits (Bagarinao, 1996). In line with this, it is relevant to look for an alternative milkfish culture system that will be economically and ecologically viable for a longer period. The simultaneous culture of milkfish and the agarophyte may be an alternative method to minimize, if not prevent pollution in the pond and the coastal waters.

Environmental conditions in the culture pond are significant because these may have some effect on the physiology of fish, its appetite and growth (Chiba, 1986). For example, it has been noted that the ideal feeding temperature for milkfish is at 28-34^{o}C (Cruz, 1996b). Chiu et al. (1986) observed that peak feeding of *C. chanos* occurs during the day and stop feeding when DO is below 1.5mg l^{-1}.

CONCLUSIONS

Dissolved oxygen in the monoculture of *C. chanos* was significantly lower than in the biculture of *C. chanos* and *G. bailinae* during afternoon. The biculture significantly lost higher phosphate and ammonia from the culture medium compared to the *C. chanos* monoculture. On the other hand, the monoculture of *C. chanos* accumulated a higher amount of total phosphorus in the pond sediment than the biculture treatment. In general, *C. chanos* grew better in biculture with *G. bailinae*.

RECOMMENDATIONS

Results on the biculture of *G. bailinae* and *C. chanos* look promising. Pilot testing of this farming system is, therefore, recommended using longer culture periods and larger ponds. Management measures to minimize proliferation of opportunistic green algae and epiphytes should be developed to produce good quality *G. bailinae*. The recommended procedure is to grow the milkfish for two months before stocking the red alga and there should be a regular monitoring of water quality for management purposes.

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