INTENSIVE REARING OF POST-LARVAL *PENAEUS MONODON* FABRICIUS IN CONCRETE NURSERY TANKS.

By Matthew R.P. Briggs

Institute of Aquaculture, University of Stirling, Stirling, FK9 4LA, Scotland, U.K.

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Abstract

A system of twelve 25 m^3 concrete nursery tanks was used to investigate the parameters affecting the intensive nursery rearing of post-larval (PL_{15}) *Penaeus monodon* (Fabricius). The effects of habitats, substrates, dietary formulation and feeding rate on shrimp performance and system water quality were studied in two trials.

Results indicated that with water exchange at 20 % d^{-1}, the maximum stocking density of between 500 and 1,000 PL m^{-2} achievable in the absence of aeration could be increased to at least 2,000 m^{-2} with aeration. Increased stocking density led to concomitant increases in shrimp production (up to a maximum of 11.5 g $m^{-2}d^{-1}$), but decreases in individual growth rate and survival. Substrate, consisting of a 10 cm layer of riverine sand provided no advantage, but habitats comprising vertical mesh panels were beneficial to survival and production at high stocking density.

Analysis of the optimum feeding rates of a pelleted diet revealed that PL 15 to 50 would consume a maximum of between 30 and 60 % (depending upon post-larval age) of their wet body weight per day at four feeds per day. Increasing the feeding rate up to this level however, resulted in problems with system water quality.

A change in the reference diet to one containing higher levels of lipid, protein and dietary energy led to a decrease in shrimp production.

Results from these trials suggest that under certain conditions such intensive tank nurseries can be economically feasible and may contribute to a more efficient system for the intensive rearing of penaeid shrimp.

Introduction

The current trend in the culture of *Penaeus monodon* in most South East Asian countries, the major producers of this species, is for intensification of operations, designed to produce the maximum amount of shrimp per unit area, in order to generate maximum profits.

Such an intensive culture system, as used in countries such as Thailand, Indonesia and the Philippines includes the following stages:

STAGES IN THE INTENSIVE CULTURE CYCLE OF *P. MONODON*

1. *Broodstock* (Adult - Egg)

2. *Larval Rearing* (Egg - PL_{4-5})

3. *Primary Nursing* (PL_{4-5} - PL_{10-15})

4. *Secondary Nursing* (PL_{10-15} - PL_{30-50}) OPTIONAL

5. *Growout* (PL_{10-50} - 30-50g)

Currently, most farms stock PL_{10-15} directly into the growout ponds and omit the secondary nursery phase. This is because, the earlier the post-larvae are bought by the ongrowers, the cheaper they are, and since this is the established practice.

However, it is now evident that there are a number of problems with direct stocking of primary-nursed post-larvae. These include:

PROBLEMS WITH DIRECT STOCKING OF PL_{10-15}

1. Stress Resistance

Young post-larvae are intolerant of environmental stress and may not survive the transfer from the well controlled, optimum conditions of the hatchery into the grow-out ponds, particularly when the ponds are nearing the end of their useful life. This may result in unquantifiable mortality during ongrowing leading to inefficient and wasteful use of feed.

2. Predation

Younger, smaller post-larvae are more pelagic than older juveniles and are more susceptible to predation from fish, birds, insects and other predators and pests found in the grow-out ponds.

3. Inefficient Resource Utilization

The stocking of older post-larvae allows quicker growth to market size and hence shorter growout periods and more cycles per year. This also allows more economic use of land facilities by maintenance of high stocking densities at each phase of the culture cycle.

It is possible that the use of secondary nurseries may help to alleviate these problems. This work was thus part of a programme designed to investigate the potential of a secondary nursery phase in the intensive culture of *P. monodon*.

However, there are inherent disadvantages that would have to be overcome to make a secondary nursery phase viable, including:

DISADVANTAGES OF SECONDARY NURSERY CULTURE

1. Cost

Older, nursed post-larvae will necessarily cost more and ongrowers will have to be convinced of the advantages that they offer.

2. Size Range

Some forms of secondary nursery culture may result in a large range in size in a single batch of shrimp ready for stocking into the ponds - usually an undesirable situation.

3. Transportation Difficulties

Larger post-larvae have more developed rostral spines which are capable of puncturing plastic bags, so alternative methods of transportation to the pond site may be needed, such as transport in oxygenated tanks.

4. Growth Rate

Holding shrimp at high density in nurseries slows down their growth rate relative to what is achieved during the same time in a pond.

There are three main types of secondary nursery used currently, each with their own style of management. These are:

1. Earthen Ponds consisting of either small nursery ponds (0.1 ha) or sectioned-off production ponds.

In earth ponds, shrimp have been stocked at PL_{3-40} at 15-500 m^{-2} and reared for 25-45 days at survival rates of 40-90 %. Most studies in these systems have achieved production rates of < 2 g m^{-2} d^{-1} due to the low stocking densities used.

2. Net Cages/Pens

In cages densities from 10-10,000 m^{-2} have been tested, but usually PL_{5-25} are stocked at 100-3,000 m^{-2} and reared for 14-30 days at survival rates of 40-85 %. Most cage studies have realised production rates of < 10 g m^{-2} d^{-1}, again due to the low densities used.

3. Concrete/Wood/Fibreglass Tank Nurseries

In tank nurseries high stocking densities are used due to the more controllable water quality of these systems. Although densities of up to 12,000 m^{-2} have been used, densities commonly range from 500 - 6,000 m^{-2}. Shrimp are stocked at PL_{1-25} and ongrown for 15-30 days at survival rates of 30-90 %. Most studies have realised < 20 g m^{-2} d^{-1}, production generally increasing with increased stocking density.

This investigation was therefore set up utilising concrete nursery tanks to investigate the effects of various environmental, density and dietary changes on post-larval *P. monodon* production and system water quality.

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Materials and Methods

The experimental set-up consisted of a system of twelve 25 m^3 rectangular concrete nursery tanks situated at a research station in southern Thailand. Sea water at 30 °C and 20-30 ppt salinity was exchanged at 20-40 % tank volume d^{-1}, 24 h d^{-1}, and aeration provided 24h/d via a series of airstones.

Shrimp PL_{15} at 2-5 mg were obtained from a commercial hatchery, stocked into the tanks and ongrown for a period of 35 days to PL_{50} and sampled weekly for their growth, survival, feeding efficiency and production rates.

Water quality parameters of DO, temperature, pH, salinity and secchi depths were recorded twice daily and suspended solids, ammonia, nitrite and phosphate weekly.

The shrimp were fed only on a commercial pelleted ration four times/d, six days/week at between 10 and 60% wet body weight/d. The proximate analysis of the diets used in trials 4 and 5 are shown in Table 1.

[Insert Table 1]

5 trials have been completed to date investigating the effects of:

Stocking density (between 125 and 3,000 PL m^{-2})(trials 1 & 2)
Aeration (without air and with 2 levels of aeration)(trials 3-5)
Habitats (comprising vertically placed fine mesh panels increasing the wetted surface area (WSA) of the tanks by 40-160 %)(trials 2 & 4)
Substrates (comprising a 10 cm layer of coarse riverine sand)(trial 4)
Dietary Formulation (varying dietary protein, lipid and energy levels)(trial 5)
Feeding Rate (feeding shrimp between 10 and 60 % wet body wt/d)(trial 5)

The stress tolerance or quality of shrimp both before and after nursery rearing was also measured for each trial to test the significance of PL quality on subsequent nursery and pond ongrowing.

Also, nursed shrimp were ongrown in net cages for 10 weeks to analyze the effects of high density nursery culture on subsequent ongrowing performance.

Results and Discussion

Water quality

The water quality parameters measured were generally stable and within the optimum range for *P. monodon* culture and were largely unaffected the treatments used in these trials. Representative water quality measurements from trials 4 and 5 are shown in Table 2. However, of note were the following observations:

[Insert Table 2]

1. Dissolved Oxygen (DO)

DO levels became limiting without aeration when the stocking density was increased to > 1,000 PL/m^2

2. Water Exchange Rate

In the presence of aeration at 1-2 lps/tank, a water exchange rate of 20 %/d was capable of supporting a stocking density of up to 3,000 PL m^{-2} at low feeding rates. However, decreasing DO and increasing dissolved nutrient levels necessitated increasing the water exchange rate to 40 %/d at high feeding rates.

3. Algal Crashes

Algal crashes, leading to DO stress would occur in tanks, particularly without additional aeration, where secchi disc readings declined to < 40 cm. Secchi depths thus provided a good early warning sign of potential algal crashes.

Shrimp performance

Representative shrimp performance figures from trials 4 and 5 are shown in Table 3. The points of major interest regarding shrimp performance are as follows:

[Insert Table 3]

1. Stocking Density

In the absence of aeration, the maximum stocking density possible was 1,000 m^{-2}, while, with aeration at 1-2 lps/tank, this density could be increased to 2-3,000 m^{-2}.

In general, increases in stocking density led to significant increases in shrimp production (up to 12 g m^{-2} d^{-1} at 2,000 m^{-2}) (Figure 1).

[Insert Figure 1]

However, increases in stocking density led to significant decreases in individual growth rate (Figure 2) and survival (Figure 3).

[Insert Figure 2]
[Insert Figure 3]

Also, the food conversion efficiency ratio (FCE) declined from 0.93 to 1.53 at increased density.

Therefore, although production of shrimp biomass is enhanced by increasing density, fewer numbers of smaller shrimp will be produced so that the particular demands of the pond ongrowers will determine the most economically viable stocking densities.

2. Substrates

Substrates consisting of a 10 cm layer of sand conferred no advantage over bare concrete tank floors. Indeed, substrates resulted in slightly increased mortality due to siltation and the provision of an anoxic, inhospitable benthic environment (Figures 4 & 5).

[Insert Figure 4]
[Insert Figure 5]

Although this problem may be solved by more efficient filtration, the additional expense involved with providing and cleaning the substrate between production runs is likely to make their use unprofitable.

3. Habitats

At stocking densities of 500 m^{-2}, additional mesh habitats increasing the tanks WSA by up to 160 % had no effect on system water quality or shrimp production. However, when the density was increased to 2,000 m^{-2}, shrimp growth rate was unaffected, but survival was significantly increased from 41 to 55 %, and overall shrimp production was increased by 50 % over tanks without habitats (Figures 4 & 5).

The presence of habitats had this effect by increasing the amount of shelter available for shrimp during their delicate and susceptible moulting stage, hence reducing mortality due to cannibalism at high stocking density. Increased natural food production (for example filamentous algae), stimulated by the habitats, may have also helped enhance survival, production and feeding efficiency.

Similar results have previously been achieved by Sturmer and Lawrence with *Penaeus vannamei and P. stylirostris* using habitats increasing the WSA of nursery tanks by 270-300 %. The use of habitats may thus enhance the economic viability of tank nurseries primarily due to increased shrimp survival and production.

4. Feeding Rate

Analysis of the optimum feeding rate of a commercial pelleted diet revealed that post-larvae would consume up to 30-60 % of the wet body weight/d (depending upon age) at four feeds per day. Feeding at these levels however led to water quality problems. In addition, high feeding rates resulted in significantly decreased feeding efficiency, FCRs rose from 1.2 to between 3 and 4:1 as the feeding rate was increased from between 30-10 % to 60-30 % body wt/d (Figures 6 & 7).

[Insert Figure 6]
[Insert Figure 7]

Increased feeding rate also resulted in slightly increased growth and production of shrimp despite the poor feeding efficiency, due to increased food availability. It was not, however, able to significantly increase the survival rate.

5. Dietary Formulation

A change in the reference dietary formulation to one containing higher levels of lipid (11 as compared to 7 %), protein (53 as compared to 49 %) and total energy (4.3 compared to 4.1 Kcal/g) was inversely related to shrimp production, most likely due to the high dietary energy levels reducing feed intake. Previously published laboratory-based work, suggesting nutrient optima for post-larval *P. monodon* of 40-50 % protein, 7-9 % lipid and 20-40 % carbohydrate, thus seem consistent with these results from concrete nursery tanks where little natural feeding is available.

6. Stress Tests

A stress test on PL_{15} prior to secondary nursing and PL_{50} following nursing was done to analyze the effects of intensive nursery rearing on post-larval quality (Briggs, 1992).

The stress tests involved the transfer of post-larvae from normal conditions of 30 °C and 30 ppt salinity directly into water held at 20 °C and 10 ppt salinity. Shrimp were then left and survival counted after 1 hour to give a relative measure of shrimp quality.

Results indicated that:

1. PL_{15} shrimp survival varied significantly between batches of shrimp, indicating large variations in the quality of PL_{15} produced by a single hatchery.

2. The stress resistance (quality) of PL_{50} following secondary nursing was significantly better than that of PL_{15} prior to nursing. This suggests that nursed shrimp are more likely to survive transfer from the hatchery to the ongrowing ponds, and subsequent ongrowing, than are un-nursed PL_{15}.

3. Stocking poor quality PL_{15} may result in poor subsequent performance since, during the first 2 weeks of nursing, the poor quality PLs in nursery trial 1 increased in weight by 180 %, while those in nursery trial 2 increased by 775 %, and the high quality PLs stocked in nursery trial 3 increased in weight by 1,762 % over the same period. These results emphasise the importance of high quality PLs to subsequent production (Briggs, 1992).

7. Cage Ongrowing of Nursed Post-larvae

Two trials, taking different sized PL_{50} produced from the varying stocking density treatments of the nursery trials, and ongrowing them at a common density in net cages for 10 weeks showed that within 4-6 weeks, the initial size differences were compensated for by the increased growth rate of the smaller shrimp.

These results suggest that the growth potential of juvenile shrimp is not affected by the stunting occurring as a result of high density secondary nursing.

Conclusions

In conclusion, some comments can be made referring back to the potential disadvantages of nursery rearing.

1. Cost

Such an intensive nursery system would increase the cost of the seed stock by 30-50 % depending on the stocking density used. This has already been proved acceptable to filipino farmers who will pay 30 % more for quality tested PLs which result in > 90 % survival during pond ongrowing. Thus, a decision must be made as to the advantages in terms of increased land use efficiency, reduced grow-out time, greater control of stock and increased feeding efficiency as apposed to the increased expense.

2. Size Range

The size range is indeed increased, although some sorting of post-larvae may be possible prior to stocking which may ultimately reduce size variation in the harvested stock.

3. Transportation Difficulties

These still exist and may still represent a problem where large distances are involved.

4. Growth Rate

Although intensive nursery rearing does decrease the growth rate, this may be compensated for by the increased growth rate possible for stunted shrimp on introduction into the pond.

Under certain circumstances, intensive concrete nursery tanks may present an feasible and economically viable component of intensive shrimp culture. However, a slight extension of the primary nursery period, followed by stress testing of post-larvae produced so that only high quality seed are stocked, may offer an alternative method of maintaining high quality seed stock.

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Table 1: Proximate analysis (% dry weight) of diets.

Diet	Reference diet				Test diet	
	Trial 4		Trial 5			
Size	1	2	1	2	1	2
Crude Protein	51.1	49.8	48.9	49.2	52.2	53.0
Crude Lipid	4.2	3.6	7.4	7.2	11.1	11.3
Ash	17.2	17.8	15.8	16.0	17.6	16.8
Fibre	2.2	2.8	2.2	2.8	1.8	1.4
Moisture	11.4	12.0	8.9	10.2	10.2	10.3
Carbohydrate (by difference)	13.9	14.0	16.8	14.6	7.1	7.2
Total Energy $Kcal.g^{-1*}$	3.87	3.74	4.17	4.07	4.30	4.36
(mean)	3.80		4.12		4.33	
P:E ratio (mg $P.Kcal^{-1}$)	132	133	117	121	121	121
(mean)	133		119		121	
Lipid:Cho ratio	3.31	3.89	2.27	2.03	0.64	0.64
(mean)	3.60		2.15		0.64	

* Calculated Total Energy (T.E.) levels of Protein 5.65, Carbohydrate 4.20 and Lipid 9.45 $Kcalg^{-1}$.

Table 2: Mean water quality parameters of trials 4 and 5*.

Trial No.	4	4	4	4	4	5	5	5	5	5
Treatment (see key below)	1	2	3	4	5	1	2	3	4	5
Temperature (°C)	28.8	29.1	29.2	29.1	30.0	29.0	29.0	29.0	29.1	29.9
Salinity (°/∞)	32.7	32.7	32.7	32.7	32.1	32.5	32.5	32.5	32.5	31.7
pH	7.97	7.96	7.94	7.96	7.48	8.16	8.03	8.19	8.03	7.82
Dissolved Oxygen (% saturation)	98.2	100.3	100.7	100.7	83.0	97.0	82.8	96.2	84.3	78.0
Dissolved Oxygen ($mg.l^{-1}$)	6.3	6.5	6.4	6.5	4.9	6.3	5.4	6.3	5.5	4.1
Secchi depth (m)	0.64	0.66	0.66	0.65	0.46	0.74	0.66	0.71	0.68	0.61
Total ammonium ($ug.l^{-1}$)	1.7	1.0	1.4	1.0	0.7	2.1	14.1	2.0	17.8	0.4
Nitrite ($ug.l^{-1}$)	6.7	4.8	6.4	3.5	3.3	5.9	10.2	8.2	18.9	3.8
Dissolved phosphorus ($ug.l^{-1}$)	12.2	10.8	8.4	5.3	5.0	79.8	169.7	57.4	165.6	30.8
Suspended solids ($mg.l^{-1}$)	98.8	96.2	99.3	96.3	108.4	89.2	94.9	90.9	90.7	99.4

Treatment Key:

Trial No.	Treat-ment	Sytem	Stocking Density	Diet type	Habitats	Substrates	Feeding Rate
4	1	Tank	2,000 m^{-2}	Reference	0	0	Low
4	2	Tank	2,000 m^{-2}	Reference	0	10cm	Low
4	3	Tank	2,000 m^{-2}	Reference	3	0	Low
4	4	Tank	2,000 m^{-2}	Reference	3	10cm	Low
4	5	Canal	0 m^{-2}	0	0	0	0
5	1	Tank	2,000 m^{-2}	Reference	3	0	Low
5	2	Tank	2,000 m^{-2}	Reference	3	0	High
5	3	Tank	2,000 m^{-2}	Test	3	0	Low
5	4	Tank	2,000 m^{-2}	Test	3	0	High
5	5	Canal	0 m^{-2}	0	0	0	0

* Mean of 3 replicates for whole period of trial.

Table 3: Mean performance of shrimp in trials 4 and 5*.

Trial No.	4	4	4	4	5	5	5	5
Treatment (see key below)	1	2	3	4	1	2	3	4
Initial wt. (g)	0.0024	0.0024	0.0024	0.0024	0.0027	0.0027	0.0027	0.0027
Final wt. (g)	0.2731	0.2595	0.2568	0.3092	0.5106	0.5770	0.5090	0.5085
Final length (mm)	35.3	33.7	35.3	36.3	44.5	45.6	45.3	42.9
Total food fed (g)	7038.0	5838.4	8757.8	8439.4	9907.6	27743.7	9195.6	24880.2
Total protein fed(g)	3550.0	2944.9	4417.4	4256.8	4859.7	13608.3	4836.9	13087.0
FCR	1.30	1.27	1.26	1.25	1.23	2.87	1.26	3.92
PER	1.54	1.56	1.59	1.62	1.66	0.72	1.50	0.50
SGR (% body wt.d^{-1})	13.46	13.35	13.33	13.87	14.96	15.33	14.96	14.96
Survival (%)	40.66	36.94	54.81	45.47	32.41	35.22	29.08	26.19
Production(g $m^{-2}d^{-1}$)	6.08	5.25	7.88	7.85	9.17	11.46	8.30	7.47

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4	3	Tank	2,000 m^{-2}	Reference	3	0	Low
4	4	Tank	2,000 m^{-2}	Reference	3	10cm	Low
5	1	Tank	2,000 m^{-2}	Reference	3	0	Low
5	2	Tank	2,000 m^{-2}	Reference	3	0	High
5	3	Tank	2,000 m^{-2}	Test	3	0	Low
5	4	Tank	2,000 m^{-2}	Test	3	0	High

* Mean of 3 replicates for whole period of trial.

Figure 1. The effect of stocking density on mean shrimp production (± s.e.) after 35 days

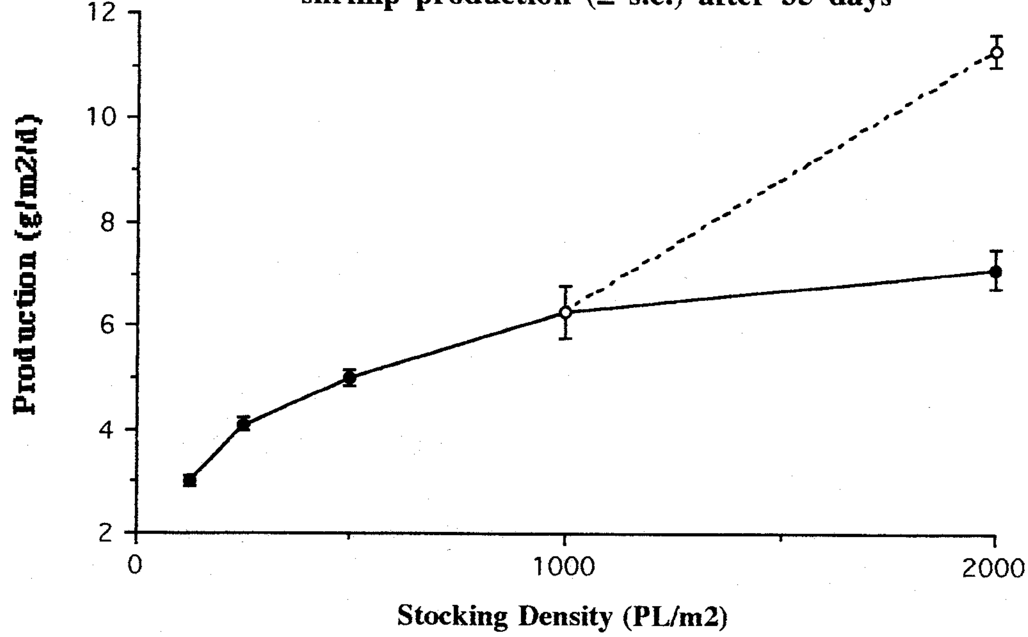

Figure 2. The effect of stocking density on mean shrimp weight (±s.e.) after 35 days.

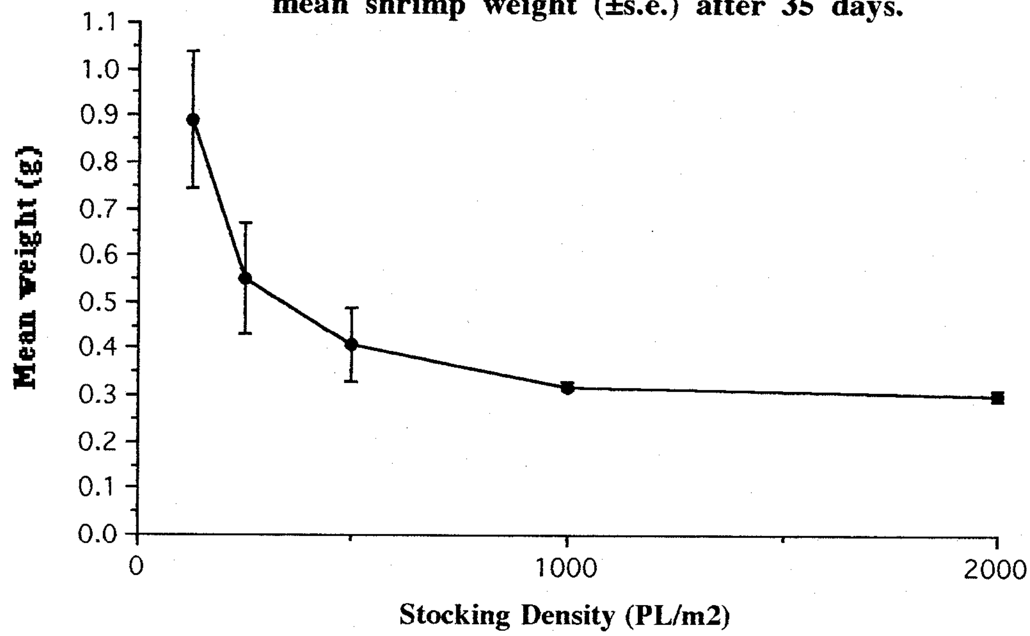

Figure 3. The effect of stocking density on mean shrimp survival (± s.e.) after 35 days.

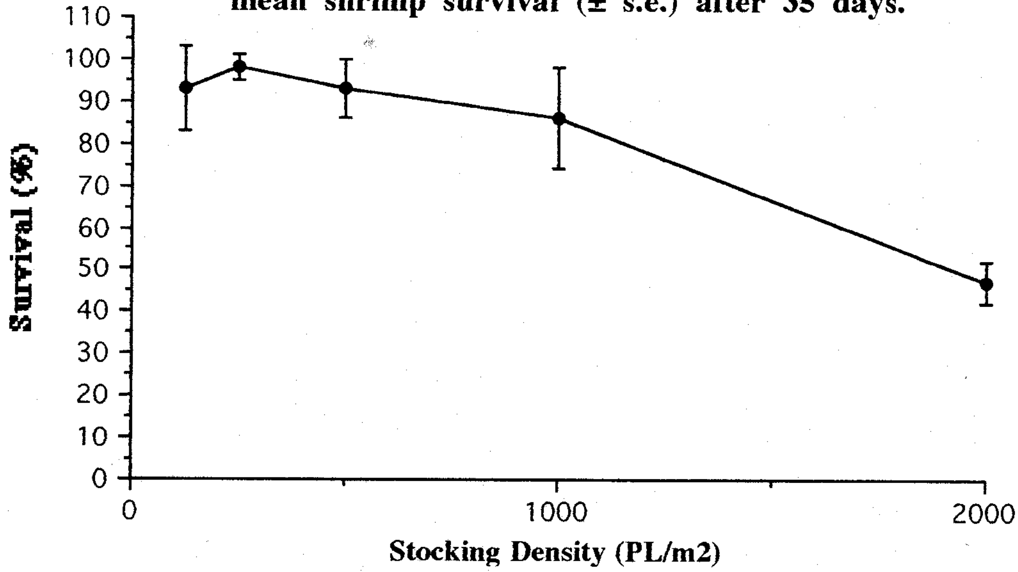

Figure 4. The effect of substrates and habitats on mean survival (±s.e.)

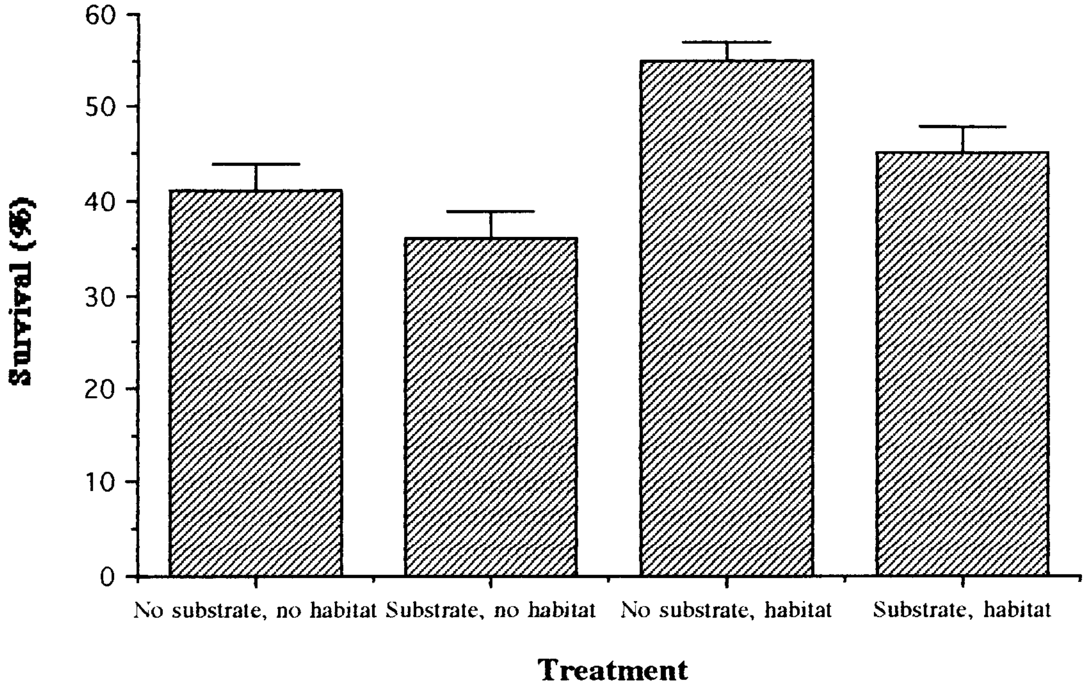

Figure 5. The effect of substrates and habitats on mean production (±s.e.)

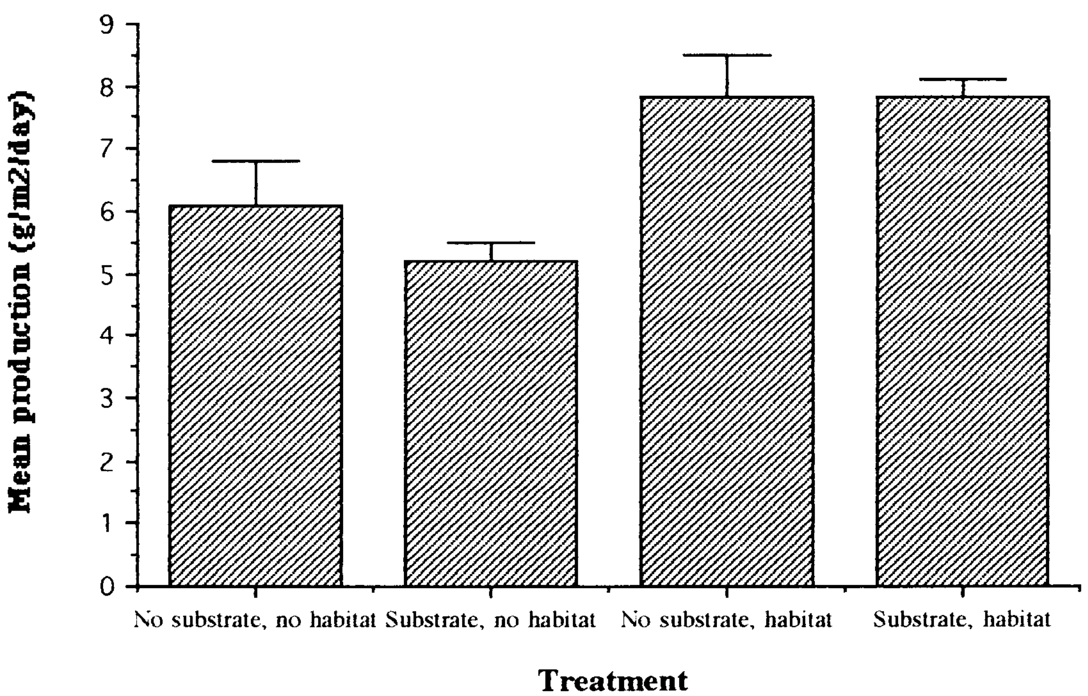

Figure 6. The effect of feeding rate and diet on mean FCR (±s.e.)

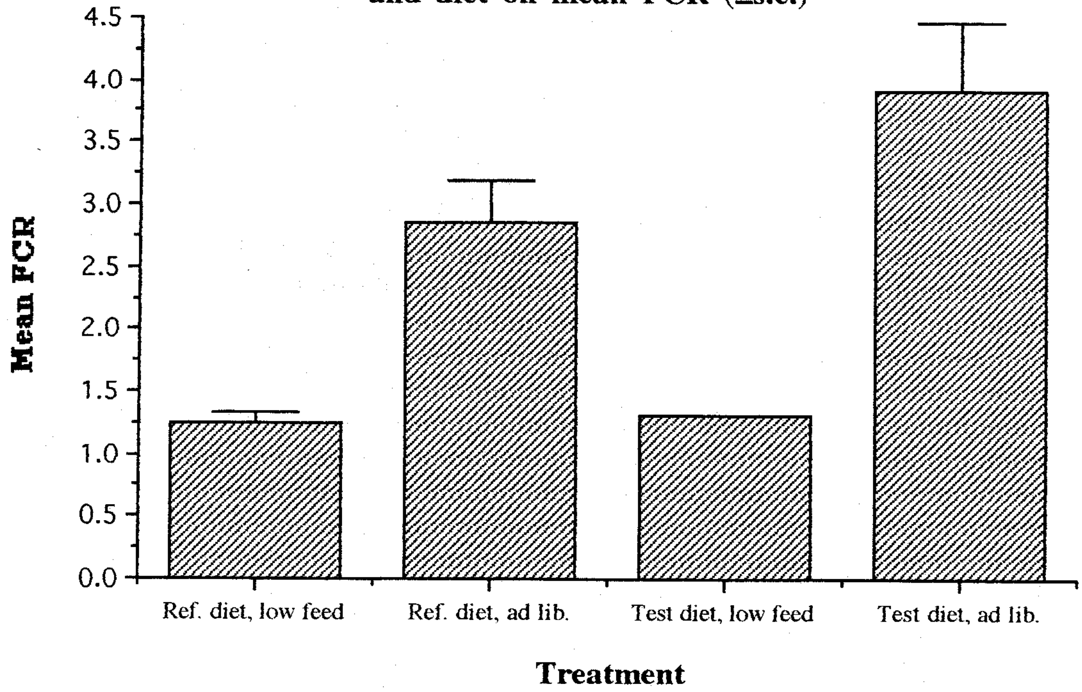

Figure 7. The effect of feeding rate and diet on mean production (± s.e.)