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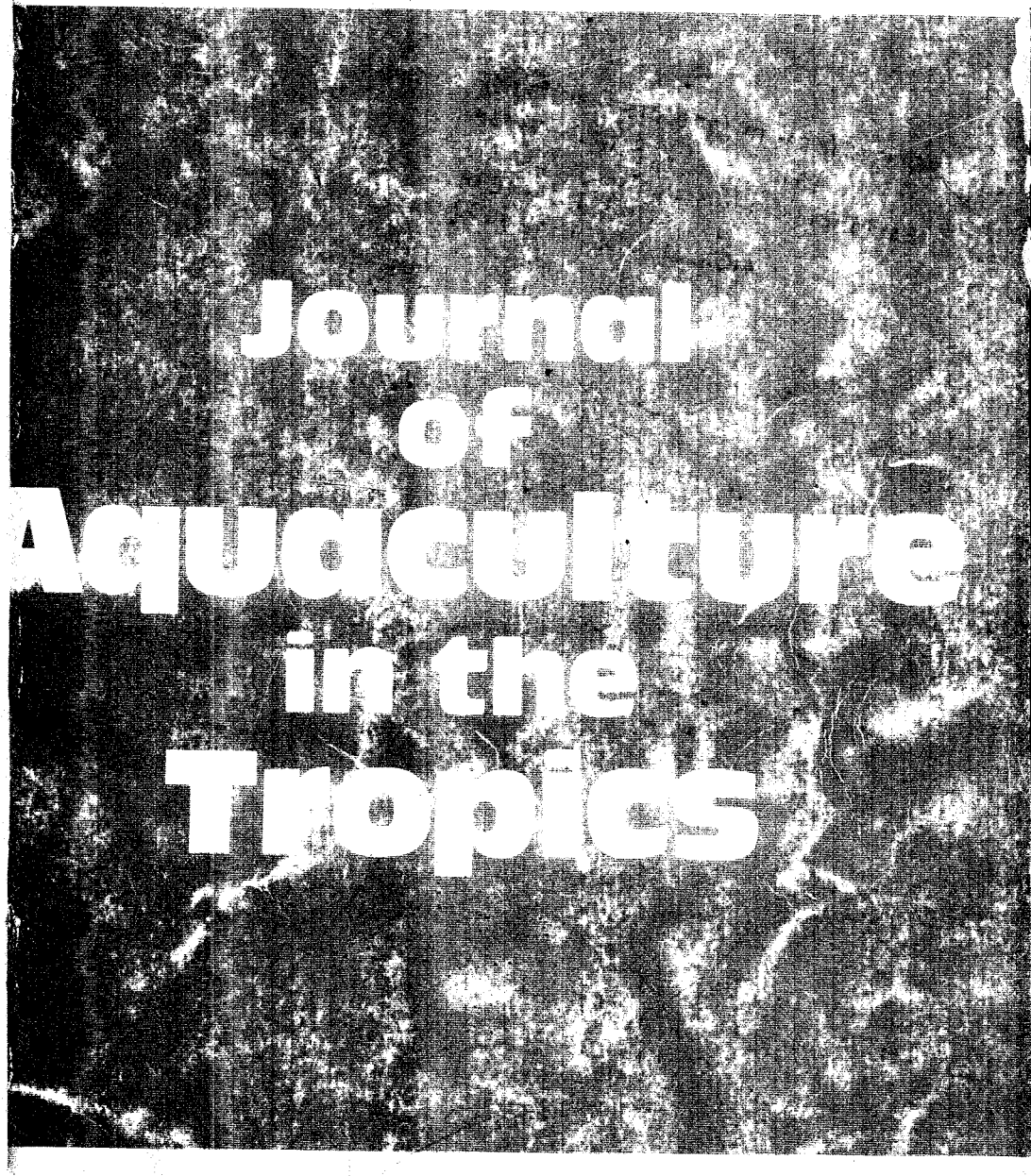

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A.A. BALKEMA

CANNIBALISM IN THE TIGER SHRIMP *PENAEUS MONODON* FABRICIUS IN NURSERY REARING PHASE

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ABSTRACT

Cannibalism among the post-larvae and juveniles of *Penaeus monodon* was found to be positively density dependent, significantly suppressed by shelter, and negatively correlated to food availability and feeding frequency. With the increase in population density there was an increase in the rate of cannibalism. Provision of different additional substrates in the rearing tanks was found to help in reducing cannibalism. Of the various substrates tested, clam shells and black polythene raffia were found to be the best for reducing cannibalism and increasing the carrying capacity. Feeding frequency was found to have great influence on cannibalism, which decreased with an increase in feeding frequency. In *P. monodon* post-larval cannibalism is mainly associated with attack made on animals undergoing moulting and is independent of the size of the victim. It is greater during the early post-larval phase and decreases towards the late post-larval and juvenile stages.

In recent years there has been increased interest in the culture of marine shrimps on a global basis. Among the various species of penaeid shrimps, the tiger shrimp, *Penaeus monodon*, is the best suited for aquaculture from production and economic points of view. It is known to have a better survival rate when grown from juvenile stage to marketable size in different culture systems. But when it is stocked as post-larvae, without nursery rearing, the survival rate has been reported to be comparatively low (Tiensongrusmee and Manik, 1980; Ravichandran *et al.*, 1982; Rajyalakshmi, 1982; Aquacop, 1984) and cannibalism is considered one of the causes of the low survival rate. Studies on cannibalism and its effect on the population structure of *P. monodon* are limited. There is a diversity of opinion about the aggressive and cannibalistic tendency of this species (Forster and Beard, 1974; Ravichandran *et al.*, 1982; Rajyalakshmi, 1982; Ferraris *et al.*, 1987; Navas, 1988; Pascual, 1988). In this context a series of laboratory studies were performed, to investigate the factors which influence cannibalism and to find out ways to combat it by understanding the ecological and behavioural implications.

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MATERIALS AND METHODS

Early post-larvae (PL7) of *P. monodon* of 9–11 mm size obtained from hatcheries were gradually acclimated to the laboratory rearing conditions before the start of the experiments. A series of mass rearing and individual rearing experiments were conducted for a period of five weeks. Parallel to all mass (communal) rearing experiments post-larvae from the same batch having same size and age were also reared individually in a series of glass containers of 1 litre capacity. Gentle aeration was provided and the shrimps were fed twice daily *ad libitum* on dry pelleted feed. Experiments were designed statistically adopting the principle of completely randomized design and observations made daily to record moulting, missing, and dead animals. Mortality among communally reared shrimps was considered total mortality which includes mortality due to water quality problems, disease, handling stress, and cannibalism, whereas the mortality observed among shrimps reared individually was considered natural mortality. All mortalities among mass-reared shrimps in excess of those observed in corresponding groups of individually held shrimps are attributed to be due to group interactions and considered mortality due to cannibalism.

Experiment I

The experiment to study the effect of population density on cannibalism was conducted in circular cement cisterns with epoxy coating, having 0.67 m^2 bottom area. The acclimated post-larvae having uniform initial size (11–13 mm and 0.005 g) were stocked at densities of 25, 50, 100, 200, 300, 400, and 500/m^2 of bottom area. Each treatment was replicated thrice.

Experiment II

Another experiment to study the impact of 'substrates' on cannibalism was conducted by stocking PL14 of 12–13 mm size at a density of 500/m^2 in circular fibreglass tanks having 0.22 m^2 bottom area, provided with different test substrates such as clam shells, round pebbles, frame made of PVC tubes having 2 cm inner diameter and 15 cm length, polypropylene net frame with vertical and horizontal resting places, black polythene raffia, and dried, seasoned casuarina twigs distributed freely in the bottom of the tank. Tanks without any additional substratum formed the control. All treatments were replicated thrice.

Experiment III

To determine the effect of feeding frequency on cannibalism another experiment was conducted in circular cement pots of 50 litre capacity by stocking PL15 of 12–13 mm size at 500/m^2. The feeding frequencies tried were once a day, twice a day, and thrice a day. Each treatment was replicated thrice.

Experiment IV

To study the cannibalism in the juvenile stage another experiment was conducted in rectangular plastic tanks of 70 litre capacity with juveniles after nursery phase

using different size groups of animals having the same age held as separate groups and one group consisting of various sizes put together. Four treatments with three replicates were conducted. The treatments used were 21–30 mm, 31–40 mm, 41–50 mm, and a mixed population of 21–50 mm.

The data collected were analysed and interpreted using standard statistical techniques. The percentage values were converted to arc sine values (θ) (using the formula $\theta = \sin^{-1} \sqrt{x/100}$, where x is the percentage values observed) and subjected to analysis of variance and F-test. Pairwise comparisons were also made using t test.

RESULTS

Effect of stocking density on cannibalism

From Fig. 1 it can be seen that a positive relationship exists between the stocking density and the rate of cannibalism. High rate of cannibalism was associated with higher population densities and the loss due to cannibalism ranged from 1.06% in the lowest population density (25/m^2) to 16.56% in the highest density (500/m^2), during the 35-day rearing period. Analysis of variance of mortality figures due to cannibalism indicated a significant ($p < 0.05$) effect of stocking densities on cannibalism, confirming that cannibalism is density dependent. Pairwise comparisons using t test showed that the effects of stocking densities on cannibalism differed significantly with each other.

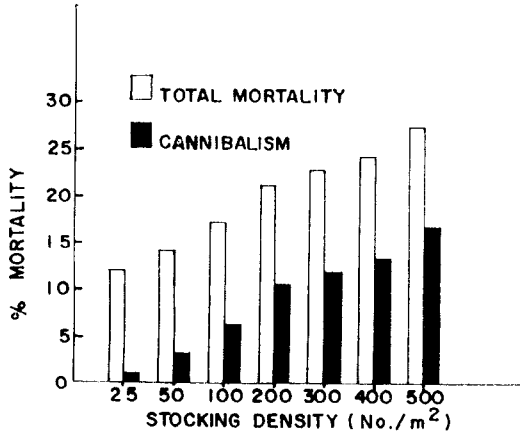

Fig. 1. Effect of stocking density on cannibalism

Effect of providing different substrate types in the rearing tanks on cannibalism

It can be seen from Fig. 2 that provision of substrates in the rearing tanks resulted in a decreased rate of cannibalism of communally reared *P. monodon* post-larvae. While 18.65% of the animals succumbed to cannibalism in the control tanks, the rate of cannibalism was considerably lower (5.3% to 10.17%) in tanks with different substrate types at the same population density. It could also be seen that cannibalism has a negative relationship with the age of *P. monodon* post-larvae, as at all densities, cannibalism decreased at a relatively rapid, nearly constant rate, with age (Figs. 3 and 4).

Effect of feeding frequency on cannibalism

The rate of cannibalism decreased with increased feeding frequency. The correlation coefficient showed a negative correlation between feeding frequency and cannibalism. The regression line (Fig. 5) depicted that the cannibalism can be brought to zero level theoretically if feeding frequency is increased to six times a day.

Cannibalism in the juvenile stage

The total mortality of *P. monodon* juveniles observed was of the order of 4.67–6.67%, which could be attributed mostly to natural mortality, as 4% mortality was observed in the rearing tanks with individual shrimps (Fig. 6). For the different size groups of juveniles stocked separately, the mortality due to cannibalism was only 0.67–1.35%. In the case of the group having different sizes (21–50 mm), it was slightly higher (2.67%).

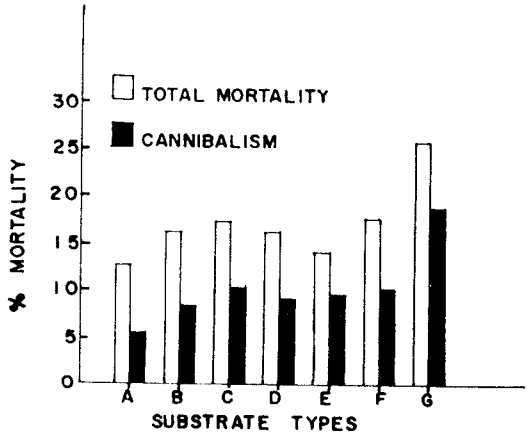

Fig. 2. Effect of different substrate types on cannibalism: (A) clam shell, (B) round pebbles, (C) PVC tube frame, (D) polypropylene net frame, (E) black polythene raffia, (F) twigs, (G) control

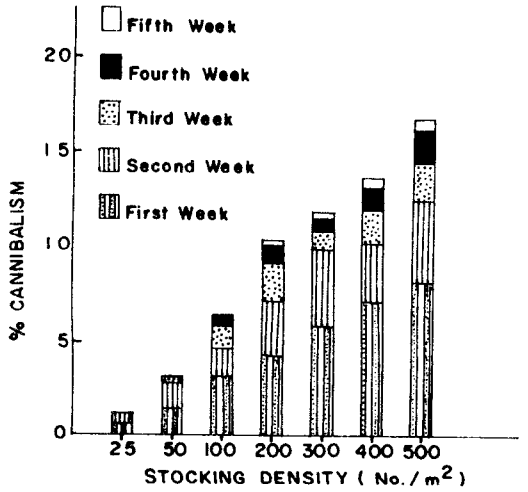

Fig. 3. Effect of age on cannibalism at various stocking densities

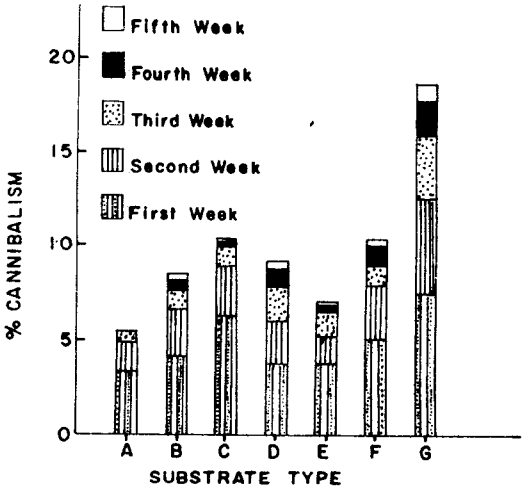

Fig. 4. Effect of age on cannibalism with different substrate types in the rearing tanks

DISCUSSION

Penaeus monodon is considered a cannibalistic species and heavy losses were reported during early growth phase in laboratories by Ravichandran *et al.* (1982), Ferraris *et al.* (1987), Navas (1988), and Pascual (1988). But according to Forster and Beard (1974) and Aquacop (1977) the tiger shrimp has been considered a quiet, highly compatible, and non-cannibalistic species withstanding high stocking densities and accustomed to crowding. This latter observation may not be correct as far as the post-larval stages are concerned as per the present study.

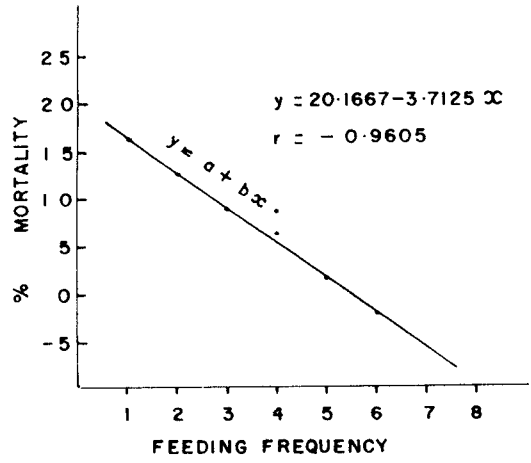

Fig. 5. Effect of feeding frequency on the rate of cannibalism

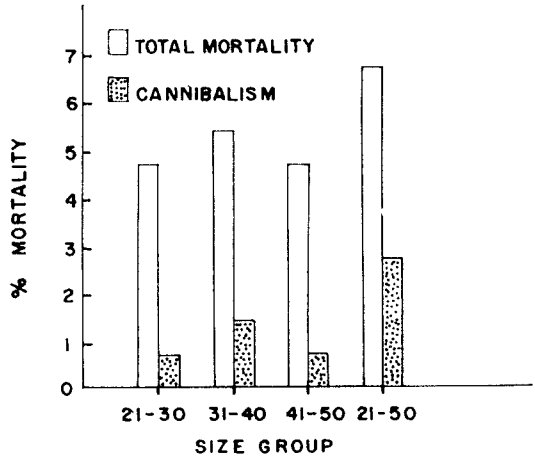

Fig. 6. Cannibalism in the juveniles

This study revealed that a positive relationship existed between cannibalism an stocking density. Such density-dependent cannibalism was also observed in *Mac robrachium rosenbergii* by Sandifer and Smith (1975). Ray and Chien (1992) re ported a negative correlation between stocking density and survival of *P. monodo* post-larvae in nursery ponds. Cannibalism, according to Kurihara *et al.* (1988 is a useful means of density-dependent population regulation in times of foo shortage. However, in the present study the post-larvae were fed *ad libitum* an thus food deficiency may not be the cause of cannibalism. Cannibalism in thi

experiment was observed even at low stocking densities in the presence of excess food and was found to reduce as the animals grew older, at all densities, even when the biomass was on the increase. Furthermore, *P. monodon* post-larvae showed a tendency to aggregate in the corners of the tanks, which may increase the chances of agonistic interactions, resulting in cannibalism even at very low stocking densities. This aggregating tendency, however, diminished as the post-larvae grew older, when they distributed more evenly in the tanks.

Adoption of a suitable stocking density is therefore important in checking the losses due to cannibalism. To fix the optimum stocking density, the rate of survival, the growth rate, size, and health of the juveniles obtained and the economics of operation will have to be taken into consideration.

A notable decrease in the cannibalism of communally reared post-larvae was observed when additional substrates were provided in the rearing tanks. Smith and Sandifer (1975) reported faster growth and higher survival among *M. rosenbergii* in tanks containing shelter substrates than in those reared in tanks without substrates. In *Palaemon serratus*, Forster (1970) observed a mortality rate of 3.65% per day in those tanks with substrates as compared to 5.93% per day in the control tanks. The present study has indicated that relatively high post-larval density could be maintained, with minimal level of cannibalism, if suitable and sufficient substrates are provided in the rearing tanks. The shrimps were found to take refuge in the interspace of shelter substrates or spend most of the time resting on the edges of the substrate. The weak and newly moulted animals also could take shelter here and thereby escape from cannibalism. It is not very clear how cannibalism is initiated or whether the attackers get any cues from the moulting or just moulted animals. After moulting, those animals become very soft and sluggish and thus may attract the attention of other active animals which often initiate attack. The increased survival rate in the tanks with shelter substrate may be due to the reduction of visual contact between the moulted weak animals and the active ones. The results of the experiment indicated that the clam shells and black polythene raffia were most effective in minimizing cannibalism. Probably any substrate which provides sufficient hiding place would be of value.

Food availability and feeding frequency seem to be important factors influencing cannibalism in *P. monodon* post-larvae. It was found that the rate of cannibalism decreased as the feeding frequency increased. But the cannibalistic tendency developed and existed even when there was sufficient food in the rearing tanks. So hunger may not be the driving force in the development of cannibalism in *P. monodon*. Similar observations were made in the giant freshwater prawn *M. rosenbergii* by Segal and Roe (1975) and Peebles (1977), who found that well-fed animals attacked and cannibalized their conspecifics, invariably in association with moulting, and did so even in the presence of sufficient food. But according to Ling and Merican (1961) cannibalism and hunger are directly related in *M. rosenbergii*. It was also observed that cannibalism occurs more frequently under conditions of limited food supply than under conditions of sufficient food. In the case of *Palaemon paucidens*, Yamane *et al.* (1988) found that the presence of bait in the rearing tank helped to reduce the frequency of cannibalism. Under

conditions of limited food supply, the cannibalistic response increased as a result of increased rate of contacts between animals while searching for food. This suggests that cannibalism could be suppressed by increasing the food density and feeding frequency. Feeding the post-larvae three times a day does not seem enough to prevent cannibalism completely. So during weaning periods from live feed to commercial feed, the period when a high rate of cannibalism is usually noticed, the post-larvae will have to be fed more frequently at *ad libitum* level.

The rate of cannibalism was found to be low among the juveniles of *P. monodon* even in high densities under well-fed conditions, suggesting that it is not a major cause of mortality. This observation supports the results of Forster and Beard (1974), Chen *et al.* (1989), Wyban and Sweeney (1989), and Winas (1990) during intensive culture trials with *P. monodon*, wherein they got higher survival rate when stocked with juveniles. The decreased rate of cannibalism in the juvenile stage may be associated with the faster acclimation of animals with the new rearing conditions and comparatively low moulting frequency with long intermoult period. However, the low rate of mortality due to cannibalism existing during this stage may be attributed to the presence of weaker or injured individuals.

Most of the mortalities due to cannibalism among communally reared *P. monodon* post-larvae in the present study were found to be associated with attack made on weak or newly moulted animals irrespective of the size of the victim. Cannibalism associated with moulting was also observed in other species of crustaceans such as the giant freshwater prawn, *M. rosenbergii* (Segal and Roe, 1975; Peebles, 1977, 1978), the freshwater crayfish, *Cambarellus shufeltii* (Lowe, 1956), and *Palaemon paucidens* (Yamane *et al.*, 1988). As the post-larvae grew older cannibalism was found to decrease at a relatively rapid rate. Mortalities due to cannibalism associated with moult cycle could be reduced if all individuals of the group moulted synchronously as observed by Lowe (1956) in the case of *C. shufeltii.* In *P. monodon* post-larvae in a group, asynchronous moulting is common. However, mass moulting of *P. monodon* was found to be associated with water exchange in this study. Frequent water exchange at regular intervals in the nursery tanks can be used for synchronizing moulting.

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