

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

BY

ABDUSSAMAD E. M.



THESIS

Submitted in partial fulfilment of the
requirement for the degree

MASTER OF FISHERIES SCIENCE

Faculty of Fisheries

Kerala Agricultural University

Department of Aquaculture

COLLEGE OF FISHERIES

Panangad - Cochin


1991

To
My Parents
Brothers and Sisters



DECLARATION

I hereby declare that this thesis entitled "CANNIBALISM IN THE TIGER PRAWN PENAEUS MONODON FABRICIUS IN NURSERY REARING PHASE" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.



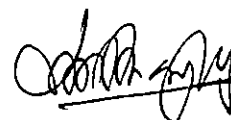
(ABDUSSAMAD . E.M)

Panangad,

4.2.1991.

CERTIFICATE

Certified that this thesis, entitled "CANNIBALISM IN THE TIGER PRAWN PENAEUS MONODON FABRICIUS IN NURSERY REARING PAHSE" is a record of research work done independently by Sri Abdussamad. E.M. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.



Dr. D.M. THAMPY
(Chairman, Advisory Board)
Professor & Head
Department of Aquaculture
College of Fisheries
Panangad

Panangad,

4.2.1991.

ACKNOWLEDGEMENTS

I wish to place on record my deep sense of gratitude to many persons who have contributed in one way or other to the successful completion of the research work and preparation of the thesis.

I am grateful to Dr. D.M. Thampy, Professor & Head, Department of Aquaculture, for his valuable guidance and constant encouragement during the course of the study. I am ever indebted to him for his valuable contributions in the conduct of the experiment as well as for the critical review of the manuscript and helpful suggestions.

I am greatly indebted to the members of the advisory committee, Sri T.M. Sankaran, Dr. P.M. Sherief and Sri C. Mohanakumaran Nair for their timely advise and suggestions rendered in the design of the experiments and in the preparation of the thesis.

I am grateful to Dr. M.J. Sebastian, Dean, College of Fisheries, for providing the facilities required for carrying out the work.

I also wish to extend my sincere thanks to all other staff in the Department of Aquaculture, for the help rendered during the course of the study.

With deep sense of obligation I recall the efforts of my friends, who were always with me when needed.

I am further greatly indebted to the Kerala Agricultural University for providing me with a fellowship during my study.

Panangad,
4.2.1991.

ABDUSSAMAD. E.M.

CONTENTS

	PAGE NO.
I INTRODUCTION	1
II REVIEW OF LITERATURE	
2.1 Cannibalism and its Ecological Importance	5
2.2 Cannibalism in Crustaceans	9
2.2.1 Cannibalism in the Tiger Prawn <u>Penaeus monodon</u>	10
2.2.2 Factors influencing cannibalism	11
III MATERIALS AND METHODS	24
IV RESULTS	
4.1 The Effect of Stocking Density on Cannibalism and Growth	33
4.2 The Effect of Providing Different Substrate Types in the Rearing Tanks on Cannibalism and Growth	40
4.3 The Effect of Feeding Frequency on Cannibalism	56
4.4 Cannibalism in the Juveniles	59
V DISCUSSION	
5.1 Effect of Stocking Density on Cannibalism and Growth	62
5.2 Effect of Providing Different Substrate Types in the Rearing Tanks on Cannibalism and Growth	67
5.3 Effect of Feeding Frequency on Cannibalism	70
5.4 Cannibalism in the Juveniles	72
5.5 Moulting and Cannibalism	73
VI SUMMARY	75
VII REFERENCES	79
VIII ABSTRACT	

LIST OF TABLES

TABLE		PAGE No.
1.	Proximate composition of the feed	26
2.	Percentage values of total mortality and cannibalism of <u>Penaeus monodon</u> post-larvae at various stocking densities during nursery rearing for a period of 35 days.	34
3.	Data on cannibalism of <u>P. monodon</u> post-larvae reared at various stocking densities over a period of 35 day recorded at weekly intervals.	37
4.	Analysis of variance table showing the effect of stocking density and age of post-larvae on cannibalism.	39
5.	Data of growth, survival and biomass production of <u>P. monodon</u> post-larvae at various stocking densities during the 35 day nursery rearing.	41
6.	Size distribution of <u>P. monodon</u> post-larvae after 35 day rearing at various stocking densities.	43
7.	Data of water quality parameters monitored during the study to evaluate the effect of stocking density on cannibalism and growth of <u>P. monodon</u> post-larvae.	45

8. Total mortality and cannibalism (Percentage) of P. monodon post-larvae reared with different substrate types in the rearing tanks, for a period of 35 days at a stocking density of 500/m². 47
9. Rate of cannibalism of P. monodon post-larvae, reared using different substrate types in the rearing tanks, at a stocking density of 500/m² recorded at weekly intervals over a 35 day period. 49
10. Analysis of variance table showing the effect of substrate types in the rearing tanks and age of P. monodon post-larvae on cannibalism. 52
11. Data of growth, survival and biomass production of P. monodon post-larvae reared in tanks with different substrate types for 35 days at a stocking density of 500 post-larvae/m². 53
12. Size distribution of P. monodon post-larvae after 35 day rearing with different substrate types in the rearing tanks. 54
13. Data of water quality parameters monitored during 35 day rearing of P. monodon post-larvae in tanks provided with different substrate types. 55

14. Effect of different feeding frequencies on total mortality and cannibalism of P. monodon post-larvae during 35 days rearing. 57
15. Data of total mortality and cannibalism of P. monodon juveniles of different sizes during 35 days rearing under laboratory conditions. 60

LIST OF PLATES AND FIGURES

PLATE		PAGE NO.
1.	Individual rearing system used to study the natural mortality.	27
2.	Different artificial substrates used in the rearing tanks (i) Polypropylene net frame, (ii) P.V.C. tube substratum and (iii) black polythene raffia.	30
FIGURE		
1.	Effect of stocking density on total mortality and cannibalism of <u>Penaeus monodon</u> post-larvae after nursery rearing for a period of 35 days.	35
2.	The rate of cannibalism observed on a weekly basis in <u>P. monodon</u> post-larvae reared at different stocking densities over a period of 35 days.	38
3.	Effect of various stocking densities on individual weight gain and biomass production of <u>P. monodon</u> post-larvae after nursery rearing for a period of 35 days.	42

4. Effect of stocking density on size distribution of P. monodon post-larvae after nursery rearing for a period of 35 days. 44
5. Effect of providing different types of substrates in the rearing tanks on total mortality and cannibalism of P. monodon post-larvae after nursery rearing for a period of 35 days. 48
6. Cannibalism in P. monodon post-larvae reared in tanks with different substrates, recorded at weekly intervals during nursery rearing for a period of 35 days. 50
7. Regression line showing the effect of feeding frequency on rate of cannibalism of P. monodon post-larvae. 58
8. Total mortality and cannibalism in P. monodon juveniles during a 35 day rearing. 61

I. INTRODUCTION

I. INTRODUCTION

Prawn and prawn products form prominent export commodities among marine products in India. Prawn fishery also plays a vital role in providing livelihood for thousands of families by way of offering employment opportunities. During the past several years there is no increase in the annual landings of prawns, despite increase in fishing effort. Infact there is a declining trend in the annual production (Silas, et al., 1981; CMFRI, 1990). The demand for prawn is however increasing in the world market. To meet this increased demand alternative methods for enhancing production will have to be evolved. Scientific farming of commercially important species of prawns appears to be the best alternative measure in this situation.

Prawn farming, the culture of prawns in impoundments, ponds and tanks has its origin in south-east Asia, where for centuries farmers raised incidental crops of wild shrimp in tidal fish ponds. Modern shrimp farming was born in the late 1970's and early 1980's, when fishermen and hatcherymen began supplying large quantities of juvenile shrimp to farmers.

In recent years there has been increased interest in the culture of marine prawns on a global basis. Although so many species of penaeid prawns are screened and cultured all over the world, the interest and most of the studies are concentrated only on a few species. This is based mainly on the relative larger size and better growth performance. The fast growing varieties yielding short term harvest are most suitable for intensive farming. Unfortunately most of these commercially important species display aggressive

and cannibalistic behaviour when reared at high densities (Smith and Sandifer, 1975).

Among the various species of penaeid prawns, the tiger prawn, Penaeus monodon is the best suited for brackishwater culture, from production and economic points of view (Verghese et al., 1975, 1982a; Aquacop, 1977; Eldani and Primavera, 1981; Rajyalakshmi, 1982). Owing to its fast growth rate (Subrahmanyam, 1973), omnivorous feeding habit (Aquacop, 1977), capacity to adapt to various culture systems (Alava and Lim, 1983) acceptance of artificial feed (Lee, 1971; Forster, 1972; Aquacop, 1977), hardiness to withstand environmental stress, wider distribution, largest size, ability to mature and reproduce in captivity and high fecundity, the tiger prawn is considered the most ideal species for commercial culture (Muthu et al., 1982; Hajra et al., 1988), and more so in the tropical countries with high water temperature, ranging from 25 - 35°C (Aquacop, 1977).

The tiger prawn culture has received considerable attention in recent years especially in countries like Taiwan, Philippines and Thailand. Culture experiments aimed at increasing the production of the tiger prawn were conducted mainly by manipulation of stocking density, fertilization, artificial feeding and combining with complementary species of fishes such as Chanos chanos and Mugil cephalus and prawns such as the sand shrimp, Metapenaeus monoceros and white shrimp, Penaeus indicus (Verghese et al., 1975, 1982b; Eldani and Primavera, 1981; Rajyalakshmi, 1982; Rajyalakshmi et al., 1982; Venketesan and Bose, 1982; Thampy et al., 1987, 1988) and in recent years by resorting to cage and pen culture and high-tech culture in recirculating

and flow-through systems (Apud et al., 1981; Liu and Mancebo, 1983; Maheswary, 1983; Natarajan et al., 1983; Krishnan et al., 1983; Chen et al., 1989; Wyban and Sweeny, 1989; Winas, 1990).

The tiger prawn Penaeus monodon is known to have better survival rate when grown from juvenile stage to marketable size in different culture systems. But when stocked as post-larvae the survival rate obtained has been reported to be comparatively low (Verghese, 1976; Siddharaju et al., 1980; Ravichandran et al., 1982). P. monodon is one of the major species being cultured in India and other south-east Asian countries, both in semi-intensive and intensive culture systems and its survival in the culture ponds is found to be 10-50% (Delmendo and Rabanal, 1956), 65% (Verghese et al., 1975), 18% (Tienkongrum and Manik, 1980), 30-68.4% (Ravichandran et al., 1982), 50% (Eldani and Primavera, 1981), 20-30% (Rajyalakshmi, 1982) and 30-80% (Aquacop, 1984) at various stocking densities. The causes of such low survival rate in culture systems were attributed to mortalities due to competition, intraspecific predation and increased cannibalistic tendencies due to high stocking density and lack of sufficient food and space (Rajyalakshmi, 1982; Aquacop, 1984), injury caused during repeated netting while restocking, sudden changes in the environmental condition such as temperature (Verghese et al., 1975) and pollution (Ravichandran et al., 1982). According to Bautista (1986), the main cause of low survival rate is the stress during moultings.

Cannibalism under high density culture conditions, has been recognized as a major problem only from mid 1970's. Cannibalism during larval and juvenile stages occurs in many important culturable species of fin-fishes

and shell-fishes. Although cannibalism may be useful for regulating population density and serve as a means of selection for individuals better adapted to artificial culture conditions, in terms of growth and survival, a reduction in the rate is necessary since excessive cannibalism may be disadvantageous to the survival and production of species under natural and artificial conditions.

Despite many nutritional and growth studies on P. monodon, there is very little information available on cannibalism during the post-larval and juvenile stages, periods of critical importance in its culture operations. Problems such as cannibalism and differential growth require urgent attention and further study, as combating these is a must for boosting the overall survival and production from the culture systems.

Successful commercial culture of the tiger prawn depends upon the solution of a variety of problems, including the development of nutritionally adequate and economically viable food ration, evolving suitable methods to reduce mortality caused by cannibalism and other agonistic interactions and providing optimal conditions for growth.

It is 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. In the present study the effect of varying the population density and feeding frequency and providing different shelter substrates in the rearing tanks, on the cannibalism during the early growth phase of P. monodon, was investigated.

II. REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

2.1 Cannibalism and its Ecological Importance

Intraspecific predation or cannibalism is a common phenomenon among both invertebrates (Fox, 1975a; Polis, 1981) and vertebrates (Packer and Pusey, 1984; Dominey and Blumer, 1984; Simon, 1984). Sastry and Zeitlin-Hale (1977) have defined cannibalism as any mortality due to group interactions among communally held populations. Cannibalism has also been defined as the killing and subsequent consumption of otherwise healthy conspecifics (Peebles, 1977; Koenekoop and Livdhal, 1980; Dominey and Blumer, 1984). Cannibalistic behaviour has often been considered as a laboratory artefact, with no consequences in the dynamics of natural populations. Information regarding the cannibalistic behaviour exhibited by different organisms, available in literature in a scattered manner, had been synthesized in the reviews by Fox (1975a), Polis (1981) and Dominey and Blumer (1984). Cannibalistic interaction may be very important to the understanding of some animal populations, as they play a role different from that of the interaction existing between competitors or from that between predators and prey.

Dominey and Blumer (1984) categorized cannibalism under three main heads, (a) filial cannibalism, cases in which the killer is the parent of the victim, (b) hetero cannibalism, cases in which the killer is not related to the victim and (c) sibling cannibalism, cases in which the killer will be the conspecific of the victim. Sibling cannibalism is an important source of early offspring mortality in many natural and laboratory populations.

Polis (1981), has mentioned three possibilities for the existence of cannibalism: (a) it has an adaptive significance, (b) it is a by-product of normal feeding response and (c) it is an abnormal response to stress. The adaptive significance of cannibalism according to him, is that it causes a reduction in intraspecific competition for the limited resource such as food and space. He has stated that the rate of cannibalism, will increase under stressful conditions such as starvation and limited space.

According to Hrdy (1979) an individual could gain from cannibalism in certain contexts such as (i) exploitation, wherein the killer directly benefits by consumption of its conspecifics as a food resource and (ii) resource competition, wherein the killer gaining access to the resource by acting as a source of mortality for potential competitor, in a resource limited environment.

Larval and juvenile cannibalism occur among important cultured species of fin-fishes such as in Esox lucius (Kipling and Frost, 1970; Giles et al., 1986), Dicentrarchus labrax (Kentouri, 1980), Anguilla anguilla (Degani and Levanon, 1983), Stizostideon vitreum (Loadman et al., 1986) and Clarias gariepinus (Hecht and Appelbaum, 1988) and in many species of crustaceans (Bovbjerg, 1953, 1956; Lowe, 1956; Hughes, 1966; Forster, 1970; Van Olst et al., 1975a, 1977; Bostford and Wikham, 1978; Carlberg et al., 1979; Ravichandran et al., 1982; Turpayeva et al., 1981; Legardere, 1982; Kurihara and Okomoto, 1987; Kurihara et al., 1988, 1989). As shown by many, cannibalism is neither rare nor it is explicable as an artefact of laboratory studies.

Many studies have been conducted to determine the ecological consequences and implications of cannibalism in natural communities and intensive culture systems. According to Fox, (1975a) and Polis (1981), the phenomenon of cannibalism is being reported in about 1,300 species. According to Fox, (1975b) and Loadman et al. (1986) cannibalism may have some ecological implications. As a biological phenomenon it can possibly be regarded as a specialized predatory strategy developed as a mechanism to ensure survival of fit individuals under harsh or unstable environmental conditions (Fox, 1975b). Cannibalism forms the principal food source, when potential prey is scarce in the environment (Munro, 1957). In short, when food is temporarily insufficient to support a population, cannibalism can ensure that atleast some animals would survive.

Eickwort (1973) and Crump (1983) suggested the evolution of cannibalism in terms of nutritional gains from the consumed conspecifics at key points in the life cycle of cannibals. Mertz and Roberston (1970), Degani et al. (1980) and Dionne (1985) seem to support this interpretation of ecological advantages of cannibalism. Their findings suggest that the energy inputs from cannibalism allow individuals either to survive short term reduction in food supply or to gain an important advantage in growth and development over non-cannibals. At the same time the cannibals require only minimum energy expenditure to get their prey, available in the same environment and obtain maximum returns to enhance growth and thus ensure a higher chance of survival (Dionne, 1985).

From the point of view of population dynamism cannibalism has been suggested as a unique and highly evolved predation strategy acting as a

density dependent population regulatory mechanism, particularly under conditions of nutritional limitation. In such conditions, cannibalism reduces competition within the population for limited food resources. Results to support this hypothesis have been obtained from investigations on natural population (Craig and Kipling, 1983; Kuriharà and Okomoto, 1987), as well as populations under controlled conditions (Kipling and Frost, 1970; Adelung, 1971; Giles et al., 1986). It is further supported by the results of many studies in species such as, Esox lucius (Hunt and Carbine, 1951; Mann, 1982), Lates calcarifer (Davis, 1985), Engraulis capensis (Brownell, 1985) and Perca fluviatilis (Goldspink and Goodwin, 1979).

Cannibalism is known to provide an ecological interaction with very real consequences on the relative fitness of cannibals and non-cannibals (Mertz and Robertson, 1970; Eickwort, 1973; Polis, 1981; Crump, 1983). Eickwort (1973) and Fox (1975b) hypothesized that a limited mortality rate from cannibalism may have selective advantage by increasing the fitness of survivors. According to Van Olst et al. (1977) cannibalism in mass rearing systems may serve as a process of selection, which eliminates those animals least well adapted to the artificial culture conditions in terms of growth and other characteristics which will be of survival value. Cannibalism may also act as a tool for selection for rapid growth rate in populations that are susceptible to intraspecific predation. Evidence to support this was provided by Segal and Roe (1975), who reported that in groups of M. rosenbergii more aggressive individuals grow faster than less aggressive ones. Furthermore, if this behaviour is exhibited in a heritable genetic basis it will be subjected to evolution through the process of natural selection

(Bobisud, 1976; Van Olst et al., 1977; Stenseth and Reed, 1978; Jones, 1982).

2.2 Cannibalism in Crustaceans

At present many decapod crustaceans are being intensively studied as possible candidates for aquaculture. Some of the major problems confronted for the development of commercial culture in the case of many species, are their aggressive and cannibalistic behaviour and social suppression of growth (Karplus et al., 1989). The aggressive and cannibalistic behaviour among cultivable crustaceans have been noticed by many workers (Ling and Merican, 1961; Forster and Wickins, 1972; Forster and Beard, 1974). In many of them, a high rate of mortality had been reported during the rearing operations (Van Olst et al., 1975a). The causes of mortality range from interspecific predation to intraspecific killing. It is widely recognised that an intraspecific prey-predator relationship, viz. cannibalism exists among most crustaceans and has been reported to be the most important cause of mortality in captive shrimps (Reeve, 1969; Forster, 1970; Smith and Sandifer, 1975; Van Olst et al., 1975a; Schulte, 1976).

Cannibalistic tendency has been reported among many of the culturable species such as Macrobrachium rosenbergii (Rao, 1965; Ling, 1969; Wickins, 1972b; Forster and Beard, 1974; Segal and Roe, 1975; Smith and Sandifer, 1975; Peebles, 1977; Karplus et al., 1989), M. idae (Nataraj, 1947; Shyama, 1987), Palaemon paucidens (Yamane et al., 1988), P. serratus (Forster, 1970), Penaeus duororum (Rickards, 1971), Crangon crangon (Legardere, 1982), Angasia armata (Sankolli et al., 1972), Homarus americanus (Van Olst et al., 1975a, 1977; Sastry and Zeitlin-Hale, 1977; Carlberg et al., 1979),

Homarus gammarus (Carlberg et al., 1979) Cambarellus shufeltii (Lowe, 1956), Orconectes virilis (Bovbjerg, 1953; 1956), Cancer magister (Bostford and Wikham, 1978), Helice tridens (Kurihara and Okomoto, 1987; Kurihara et al., 1989), Rhithropanopeus harissi (Turpayeva et al., 1981) and Ocypode ceratophthalmus (Hughes, 1966).

2.2.1 Cannibalism in the Tiger Prawn *Penaeus monodon*

Studies on cannibalism and its effect on the population structure of the tiger prawn, P. monodon is limited. There is a diversity of opinion about the aggressive and cannibalistic tendency of this species. According to Forster and Beard (1974), the tiger prawn is non-aggressive and can be packed closely together in small areas, where they would lie quite still and according to Aquacop (1977) is non-cannibalistic and accustomed to crowding. But their cannibalistic tendencies have been mentioned by many such as Subrahmanyam (1973); Vergheese et al. (1975), Ravichandran et al. (1982), Rajyalakshmi (1982), Aquacop (1984), Ferraris et al. (1987), Navas (1988) and Pascual (1988).

According to Subrahmanyam (1973), P. monodon in laboratory containers developed cannibalistic tendencies due to insufficient space. Vergheese et al. (1975) reported cannibalism as a major factor that adds to the mortality rate of the tiger prawn in rearing systems. According to them the moulted prawns become soft and sluggish and fall an easy prey to other active prawns and predators. Lack of food having sufficient nutrients may be a factor for the development of cannibalistic tendency and this has been found to attenuate when sufficient food is available in the environment.

According to Ravichandran et al. (1982) and Pasucual (1988) high population density and lack of sufficient food and space will induce cannibalism in P. monodon post-larvae in the nursery containers. Rajyalakshmi (1982) has stated that cannibalism poses a major problem in P. monodon culture systems. Occasional high mortalities of the tiger prawn post-larvae in the nursery ponds, just after stocking has been reported by Aquacop (1984) and this is attributed mainly to cannibalism.

In culture systems Ferraris et al. (1987) reported mortality of P. monodon juveniles due to cannibalism associated with moult cycle at low salinity levels. According to them when moulting occurs at very low salinity conditions, more energy and time are required to normalize haemolymph osmolarity, since they have to absorb ions against a higher ionic gradient. This, they say will prolong the time required for hardening the shell, and thus increase the vulnerability of animals to cannibalism and prolong their inability to forage for food. Navas (1988) also reported a higher rate of cannibalism at low salinity levels, which is in agreement to the observations of Ferraris et al. (1987).

2.2.2 Factors Influencing Cannibalism.

Various factors such as space, density, shelter, food, growth variation, moulting, environmental factors etc. are known to influence the evolution and expression of cannibalistic behaviour among different species of crustaceans.

2.2.2.1 Influence of Population Density, Space and Shelter on Cannibalism

The influence of available space, population density and shelter on cannibalism and growth of crustaceans, has been stressed by many such as Ling (1962), Reeve (1969), Forster (1970), Wickins (1972a), Smith and Sandifer (1975), Aiken and Waddy (1978), Carlberg et al. (1979), Kurihara and Okomoto (1987) and Kurihara et al. (1989). An organism requires certain minimum area for its survival and unrestricted growth. The area available to each individual varies with the population density, size and shape of the rearing tank, and availability of shelter substances.

Van Olst and Carlberg (1978) studied the effect of container size on survival of lobsters in mass rearing systems. According to them container size had a pronounced and significant effect on survival. Mortality increased markedly when the animal reached a certain critical size, which appeared to be dependent on container dimension. Mohamed (1983) observed that overcrowding of prawn post-larvae in hatchery containers leads to the development of cannibalistic tendencies due to inadequate space for the growing animals.

Cannibalism in crustaceans is a unique and highly evolved predation strategy acting as a density dependent population regulatory mechanism, especially under adverse environmental conditions (Aiken and Waddy, 1978; Kurihara and Okomoto, 1987). In mass rearing systems survival and growth of lobster, Homarus americanus (Aiken and Waddy, 1978) and the freshwater prawn, Macrobrachium rosenbergii (Sandifer and Smith, 1975) are inversely related to population density. Higher stocking densities resulted

in increased agonistic interactions indicated by increased injury, loss of claws and increased cannibalism at moult. In the mud crab, Helice tridens, Kurihara et al. (1988) have observed a density dependent cannibalism, wherein when the population density is greater than the carrying capacity of the system, larger individuals prey upon the smaller ones.

Kurihara and Okomoto (1987), investigated cannibalism and population dynamics of grapsid crab Hemigrapsus penicillatus both in the laboratory and natural conditions. This crab had shown territorial behaviour among individuals of the same size and shelter was found to be vital in avoiding cannibalism.

Use of artificial substrates for rearing different species of shrimps and lobsters has been examined by many workers. Forster (1970) studied the effect of adding horizontal artificial substrates to the rearing tanks of Palaemon serratus on cannibalism. He had obtained a higher survival rate in the tanks with artificial substrate as compared to control. The use of vertical screen substrate as a means of increasing production of tank reared pink shrimp Penaeus duorarum was tested by Rickards (1971), who found significantly higher growth and total yield in the tanks containing vertical substrates, but no difference in mortality. He has also examined the effect of different quantities of screened surface area on growth, mortality and production of pink shrimp, but no relation was apparent.

A direct relationship between growth and survival and the presence of shelter substrate was found in the case of M. rosenbergii by Smith and Sandifer (1975). They also found that survival and biomass production were

slightly higher among prawns reared in tanks with horizontal substrate configuration. Use of artificial substrates for rearing M. rosenbergii in ponds by Fujimura (1972) showed that use of such materials is not practical in intensive culture systems.

Provision of substrates in the lobster rearing system was effective in reducing cannibalism and assuring high carrying capacity (Mc Burney and Wilder, 1973; Van Olst et al., 1975a). Carlberg et al. (1979) evaluated the effect of different substrate types, shelter densities and stocking densities on the survival and rate of cannibalism in two lobsters viz. Homarus americanus and H. gammarus reared communally. It was found that the abundance of oriented refuges decrease mortality resulting from cannibalism among communally reared lobsters. According to them use of vertical substrate is preferred as it would allow lobsters to utilize the entire water column for refuge and is easy to maintain and harvest. They concluded that increased area for the escape of subordinates from attack and cannibalism by larger dominant lobsters might contribute to the increased survival.

2.2.2.2 Influence of Food Availability on Cannibalism

Existence of a relationship between food availability and cannibalism has been established by many. Nicholson (1933) stated cannibalistic habit as an indirect extension of cannibals foraging efficiency in a food limited situation, since the individual competitor consumed its conspecific ultimately for its benefit. It has been found that cannibalism occurred more frequently when alternate food items were unavailable in the rearing environment (Ling and Merican, 1961; Ravichandran et al., 1982). According to Ling and Merican (1961) cannibalism and hunger are directly related in Macrobrachium rosenbergii, but observed only among males of the population.

The occurrence of cannibalism in many crustaceans even in the presence of sufficient food in the rearing environment has been observed, but it occurred more frequently when alternate food items were unavailable (Van Olst et al., 1975a; Sastry and Zeitlin-Hale, 1977; Ravichandran et al., 1982).

The American lobster Homarus americanus is known to be aggressive and cannibalistic in nature (Shleeser, 1974; Van Olst et al., 1975a; Cobb, 1976; Aiken, 1977). In this, excessive cannibalism was observed even when food was abundant, shelter and refuges were plentiful and population density was relatively low. According to Van Olst et al. (1975a) survival was lower for low food dose levels and was substantially higher for high food dose levels among communally reared lobsters. According to them a certain minimum food level is necessary to reduce cannibalism in this species, but the degree of aggressive interaction is approximately the same regardless of food dose levels or substrate. This suggests that two different behaviour mechanisms exist for cannibalism and aggression, and that the tendency to cannibalise others is modulated by the level of hunger satiation. But the tendency to interact aggressively is a strong and constant drive independent of food level. Under conditions of hunger the aggression in agonistic encounters probably proceeds to cannibalism more often than under condition of satiation. According to Carlberg et al. (1979) cannibalism among communally reared lobsters can be minimised by providing ample quantities of nutritious and readily eaten food.

The giant freshwater prawn Macrobrachium rosenbergii according to Smith and Sandifer (1975) is aggressive and cannibalistic when reared at high densities. They found, feed utilization as less efficient and cannibalism

more apparent at a much smaller size among prawns reared in tanks without substrates. Segal and Roe (1975) and Peebles (1977) observed that even in the presence of excess feed in the rearing tank, well fed M. rosenbergii attack and cannibalise others invariably in association with moulting. Segal and Roe (1975) also reported that cannibalised animals were very rarely only completely consumed. In most cases the cannibalisation was limited to cutting of eyes, appendages and/or telson and consumption of small quantities of flesh from the cut ends. According to them both sexes indulged in cannibalism although larger males seem to be more aggressive.

According to Rajyalakshmi (1978), survival of crustaceans in the culture systems in general is controlled by several factors of which feed is the most important one. According to Yamane et al. (1988) the presence of bait will decrease the frequency of cannibalism, in Palaemon paucidens.

From several such studies it can be concluded that under controlled conditions food availability appears to be the most important factor determining the rate of cannibalism. In contrast, some such as Segal and Roe (1975) and Peebles (1977) have pointed out that food availability has no influence on cannibalism. According to them cannibalism would develop and exist in many populations independent of food availability.

2.2.2.3 Influence of Growth Variation on Cannibalism

Relative size of the individuals is reported to play an important role in determining the outcome of agonistic interactions and the rate of cannibalism (Allele and Douglas, 1945; Bovbjerg, 1960; Hughes, 1966; Peebles, 1978; Karplus et al., 1989). Variation in size and growth rate of individuals

was reported soon after metamorphosis of larvae into post-larvae, in most of the cannibalistic crustaceans such as Macrobrachium rosenbergii and Homarus americanus (Wickins, 1972b; Forster and Beard, 1974; Hedgecock and Nelson, 1978; Karplus et al., 1989).

The development of agonistic behaviour pattern and the size variation within groups of communally reared lobsters, H. americanus may allow establishment of dominance hierarchies. The establishment of dominance hierarchies typically decreased the aggressive behaviour within a group and hence may influence the mortality rate due to cannibalism (Cobb and Tamm, 1975; Sastry and Zeitlin-Hale, 1977). According to them development of dominance hierarchies reduces mortality rate due to group interactions.

According to Peebles (1978) relative size plays an important role in determining the outcome of agonistic interactions, which is measured as the body injury and mortality. Smaller prawns in the moulting stage incurred tangible body injury in a mixed population of large and small individuals. Cannibalism was observed by him among prawns of equal size also especially in association with moult cycle.

Kurihara and Okomoto (1987) investigated the relationship between cannibalism and the body size of predator and prey in grapsid crab, Hemigrapsus penicillatus. It was shown that an increase in population density and size dispersal increases the cannibalistic death in a population of larger and smaller individuals, both in natural and laboratory conditions. They also found that the predators preyed only on smaller individuals and that prey became larger with large male predators.

According to Yamane et al. (1988) there was no relationship between cannibalism and the size of the prawn prey in Palaemon paucidens. But cannibalism among individual prawn is closely related to the condition of the individual prey, whether it is moulted or not.

2.2.2.4 Moulting and Cannibalism

Moulting is an important event in the growth and development of crustaceans. It is a cyclical process involving hormonal and metabolic changes, which may directly or indirectly influence the activity, behaviour and survival (Passano, 1960; Waterman, 1961). Verghese et al. (1975), reported that P. monodon after moulting become soft and sluggish and fall an easy prey to other active individuals; larger prawns are often found to attack smaller ones. Such cannibalistic tendency associated with moulting has been reported in many crustaceans.

In M. rosenbergii this type of cannibalism occurs, the attack being made on the animals undergoing moult (Segal and Roe, 1975). Intra-specific killing in M. rosenbergii, according to Peebles (1977; 1978) followed a typical pattern. Generally a postmoult animal is attacked and the first appendages damaged are chelae or antennae, followed by other locomotory appendages and sensory systems. The rostrum and eye stalk are among the last body parts damaged. This moult related intra-specific aggressive behaviour which he called as 'MRIAB'; is a major cause of mortality and not cannibalism. Peebles (1978) reported that prawns of equal size were also susceptible to behaviourally related mortalities at two points in the moult cycle, late pre-moult and early post-moult.

Killing in cray fish, Orconectes virilis (Bovbjerg, 1953, 1956; Momot, 1967) and in other prawns (Shyama, 1987; Yamane et al., 1988) also have been reported to occur at the early post-moult. According to Shyama (1987), the prawn M. idella during moulting is inactive, soft and prone to predation and cannibalism. Cannibalism in the prawn Palaemon paucidens was found to be closely related to the moult cycle by Yamane et al. (1988). According to them post-moult prawns were vulnerable to cannibalism even under conditions of excess food. According to Harvey (1990) newly moulted crabs (Scylla serrata) are very soft and are extremely vulnerable to cannibalism.

Aiken and Waddy (1978) observed a significantly low survival rate among communally held lobster, Homarus americanus, during moult periods indicating that mortalities reported were those associated with cannibalism during the vulnerable period of moulting. Sastry and Zeitlin-Hale (1977), found that asynchronous moulting in the groups of communally reared American lobster, H. americanus, is a contributing factor to the higher mortality rate. According to them the high mortality rates could be reduced if all lobsters of a communally held group moulted synchronously. Results supporting this hypothesis have been obtained from studies on other species of crustaceans. Lowe (1956) found that cannibalism did not occur in groups of communally held freshwater crayfish, Cambarellus shufeltii, when they moulted synchronously.

It has been reported that in crowded tanks prawns and crabs such as Leander squilla (Schulte, 1976) and Carcinus maenas (Adelung, 1971) are able to delay the next moulting when larger specimens of the same

species are present, thereby escaping cannibalism.

2.2.2.5 Influence of Environmental Factors on Cannibalism

Survival and growth which together determine the ultimate yield in culture systems are influenced by a number of ecological parameters and managerial practices (Subrahmanyam, 1973; Ghosh et al., 1973; Verghese et al., 1975; Chakraborti et al., 1985). The environmental conditions determine the aggressive behaviour, the level and type of which ultimately govern the rate of cannibalism. It has been suggested that manipulation of environmental and/or physiological conditions influencing moulting might reduce mortality associated with cannibalism; by making moulting to occur more or less synchronously.

In the American lobster, Homarus americanus and in European lobster, H. gammarus, Carlberg et al. (1979) found that variation in photoperiod has a pronounced influence on cannibalism. The nocturnal locomotor activities of foraging and shelter exploration, which frequently resulted in agonistic encounters and cannibalism in H. americanus, H. gammarus and in other nocturnally active animals can be minimised by increasing the light period (Tamm and Cobb, 1976; Carlberg et al., 1979). However in a related study by Hand (1977) lobsters grown communally in dense algal culture, which prevented visual contact, resulted in lower mortality and fast growth rate. According to him this possibly was caused by preventing visual contact or any chemical communication between lobsters, thus reducing agonistic encounters.

Temperature is one of the major parameters influencing growth rate

and also of cannibalism in crustaceans. Lobsters cultured at elevated temperatures moult synchronously and so only fewer cannibalistic attacks take place (Ford et al., 1975).

2.2.3 Control of Cannibalism

In order to reduce cannibalism and to increase uniformity in growth, various experiments have been carried out in Homarus americanus (Aiken and Young-Lai, 1979, 1981; Kendall et al., 1982) and in Macrobrachium rosenbergii (Sandifer and Smith, 1975; Karplus et al., 1989). Several methods have been suggested to solve the problems of aggressiveness and cannibalism in crustaceans, when reared under crowded conditions. One such method is rearing the animals individually in separate rearing compartments, like that developed for the American lobster, H. americanus (Shleeser, 1974; Carlberg et al., 1979; Van Olst et al., 1977). Such individual segregation of animals is technically feasible but economically prohibitive (Smith and Sandifer, 1975).

Proper feeding was found to be helpful in minimising cannibalism (Van Olst et al., 1975a; Verghese et al., 1975; Rajyalakshmi, 1978; Carlberg et al., 1979). According to Van Olst et al. (1975a) a certain minimum amount of food is necessary to minimise cannibalism in American lobster. Verghese et al. (1975) and Rajyalakshmi (1978) suggested provision of adequate quantity of well balanced feed in the rearing systems for minimising aggressiveness and mortality due to cannibalism. According to Carlberg et al. (1979) providing ample quantities of nutritious and readily eaten food is essential for reducing cannibalism among communally reared lobsters.

Another effective method suggested by many workers to reduce mortality due to cannibalism and to increase the survival of cannibalistic crustaceans, is removing the fast growing dominant individuals from the rearing system. This is found to help acceleration of growth among the slow-growing individuals (Carlberg et al., 1979).

Increasing the available territory used for shelter and foraging is also suggested as a means for minimising the rate of cannibalism (Mc Burney and Wilder, 1973; Segal and Roe, 1975; Van Olst et al., 1975a; Smith and Sandifer, 1975; Carlberg et al., 1979; Rajyalakshmi, 1982; Kurihara and Okomoto, 1987). Addition of substrate could provide the growing animals with sufficient shelter and thus reduce aggressive encounters between individuals. Use of natural shelter substrates such as sticks, branches, gravel, shells, water plants and synthetic materials in the rearing tanks, has been suggested as a means of providing shelter for prawns, crabs, lobsters and other crustaceans for reducing aggressiveness and cannibalism (Ling, 1962; Reeve, 1969; Forster, 1970; Fujimura and Okomoto, 1970; Wickins, 1972a; Sandifer and Smith, 1974, 1975; Van Olst et al., 1975a; Peebles, 1979a; Carlberg et al., 1979; Kurihara and Okomoto, 1987; Kurihara et al., 1989).

As has been reported by Ford et al. (1975) increasing the water temperature for synchronising the moulting activity could be used for minimising cannibalism. Increasing the photoperiod in the case of nocturnal species to minimise foraging activity could also be used for reducing the rate of cannibalism (Tamm and Cobb, 1976; Carlberg et al., 1979).

In crustaceans, claws form the main defending and attacking organs

used during the aggressive bouts and in inter and intraspecific predation. Partial claw ablation or claw immobilization in cannibalistic crustaceans has been suggested by many workers, to increase their survival in mass rearing systems (Carlberg et al., 1979; Aiken and Young-Lai, 1979, 1981; Kendall et al., 1982; Karplus et al., 1989). By conducting chelotomy, dactylo-tomy and eyestak ablation on Scylla serrata, Natarajan and Thankaraj (1983) obtained higher survival rates, owing to the absence of cannibalism, suggesting that these techniques can be utilized for minimising cannibalism.

Aquacop (1984) suggested stocking the ponds with post-larvae or juvenile population having uniform size and age to avoid cannibalism among prawns in the culture system.

Smith and Sandifer (1975) suggested genetic selection for non-aggressive-ness and docility. Another approach is physiological manipulation to suppress or eliminate the pugnacious behaviour.

III. MATERIALS AND METHODS

III. MATERIALS AND METHODS

3.1 Experimental Animals

Early post-larvae of Penaeus monodon belonging to a single brood obtained from commercial hatcheries were used for the present study. The post-larvae were brought to the laboratory in oxygen filled polythene bags and reared in cement cisterns that were coated inside with epoxy resin.

3.3.1 Conditioning of the Experimental Animals

The post-larvae (P₇) brought from the hatcheries were gradually acclimated in cement cisterns to the experimental salinity (20 ppt) and other rearing conditions (pH 7.85 ± 0.30, water temperature 28 ± 0.5°C). In the acclimation tanks the prawns were initially fed ad libitum with chopped clam meat (Villorita cyprinoides) and gradually changed to specially prepared dry pellets. The left over feed and faecal matter were siphoned out daily as part of routine water exchange. To maintain the water quality, 20-30% of the water in the acclimation tanks was changed daily.

3.2 Feed Formulation

During the experiments the prawn post-larvae were fed exclusively with dry pelleted feed. The feed was formulated using ingredients such as dry clam meat powder (40%), groundnut oil cake (25%), rice bran (25%)

and tapioca powder (8%). These ingredients were mixed thoroughly with required amount of water (1.25 litre/kg of feed mixture) to make a dough and steamed for 30 minutes at atmospheric pressure in an autoclave. It was then pelletized (2 mm) after mixing with 2% of supplementary vitamin and mineral mixture and dried at 60°C over-night in hot air oven.

The proximate composition of the feed is given in the Table 1.

3.3 Experimental Procedure

The post-larvae (P₁₂) after acclimation were used for a series of mass rearing and individual rearing experiments. Each experiment was continued for a period of five weeks. During this period the animals were fed on dry pelleted feed. Uneaten feed and other solid wastes were siphoned out daily before feeding in the morning as part of routine cleaning and water exchange. Since feed consumption was found varying with size and moult cycle no attempt was made to calculate the feed intake of the animals (Observations).

For determining the natural mortality, parallel to all mass (communal) rearing experiments, post-larvae, from the same batch with uniform size were reared individually in a series of glass beakers (Plate 1). To reduce the light intensity in the individual rearing units, the sides of the glass beakers were covered with card board sheets. Aeration was provided as short burst of small air bubbles released through holes in the plastic tubes with tied ends. The experimental animals in the individual rearing

Table 1. Proximate Composition of the Feed

Components	Percentage
Crude protein	39.53
Crude fat	6.52
Ash	10.54
Crude fibre	8.4
Moisture	5.91



Plate 1. Individual rearing system used to study the natural mortality.

units were fed twice daily ad libitum. Solid wastes used to be removed daily as part of daily cleaning and water exchange.

Experiments were designed statistically adopting the principle of Completely Randomised Design (C.R.D.).

Observations were made daily to record moulting, missing and dead animals.

Mortality among communally reared prawns was considered as total mortality which include both natural mortality (mortality due to natural causes such as disease, handling stress etc.) and mortality due to cannibalism, whereas the mortality observed among prawns reared individually was considered as natural mortality. In the present study all mortalities among mass reared prawns in excess of those observed in corresponding groups of individually held prawns, were attributed to be due to group interactions and considered as mortality due to cannibalism. The percentage mortality of individually held Penaeus monodon post-larvae belonging to a particular group was subtracted from average percentage mortality of corresponding groups of communally held post-larvae, to determine the rate of cannibalism.

Although data on length as well as weight were collected, only weight changes are taken into account as growth indicator. Since growth is not a simple linear change, but a three dimensional increase, weight change is considered a more realistic indicator of growth (Segal and Roe, 1975).

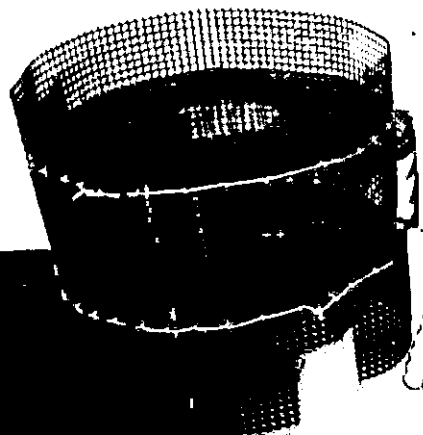
For maintaining the water quality 10-20% of the water was changed daily. Salinity was held nearly constant in each tank at a level of 20 ± 1 ppt and normal day and night photoperiod was given. Temperature and pH were monitored daily and oxygen levels once a week. Continuous mild aeration was provided to maintain optimum dissolved oxygen levels.

3.3.1 Study to Evaluate the Effect of Stocking Density on Cannibalism and Growth

This experiment was conducted in circular cement cisterns with epoxy resin coating, having 0.67m^2 bottom area. The tanks were filled with filtered brackishwater to a depth of 30 cm. Acclimated post-larvae having uniform initial size of 11-12 mm and 6 mg were stocked at densities of 25, 50, 100, 200, 300, 400 and $500/\text{m}^2$ of bottom area. Each treatment was replicated thrice. Animals were fed with pelleted feed ad libitum twice daily. Survival was determined once a week, when all animals were removed from the tanks and counted.

3.3.2 Study to Evaluate the Effect of Different Types of Additional Substrates in the Rearing Tank on Cannibalism and Growth

One experiment was conducted using circular fibre glass tank (75 litre capacity) having 0.22m^2 bottom area, provided with different test substrates, such as (i) clam shells of 3 to 6 cm size, (ii) round pebbles of more than 2 cm in diameter, (iii) frame made of PVC tubes having 2 cm inner diameter and 15 cm length, (iv) polypropylene net frame with vertical and horizontal



(i)



(ii)



(iii)

resting places, (v) black polythene raffia, and (vi) dried, seasoned casuarina twigs distributed in the bottom of the tank freely (Plate 2). Tank without any substratum, formed the control. All treatments were replicated thrice.

A stocking density of 500 post-larvae/m² of bottom area was used. Animals were fed with pelleted feed ad libitum twice daily. Survival was determined once a week.

3.3.3 Study to Evaluate the Effect of Feeding Frequency on Cannibalism

To determine the effect of feeding frequency on cannibalism and rate of survival an experiment was conducted in circular cement pots of 50 litre capacity. A stocking density of 300 post-larvae/m² of bottom area was used for this study. The feeding frequencies tried were (i) once a day (ii) twice a day and (iii) thrice a day. Each treatment was replicated thrice. In all cases after feeding ad libitum the left over food was removed in the next morning. Rate of survival was determined after 35 days.

3.3.4 Study to Evaluate the Extent of Cannibalism in the Juvenile Stages

Another experiment was conducted in rectangular plastic tanks with juveniles of P. monodon after the 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 replications were conducted. The treatments used were juveniles having 21-30 mm, 31-40 mm, 41-50 mm and a mixed population of juveniles of 21-50 mm size.

Animals were fed with dry pelleted feed ad libitum twice daily. The survival was determined after 35 days of rearing.

3.4 Methods of Water Analysis

The various water quality parameters were determined following the standard methods detailed below:

Dissolved Oxygen	: Standard Winklers Method (Strickland and Parsons, 1972)
Temperature	: Using mercury bulb thermometer with an accuracy of 0.1°C.
Salinity	: Using refractometer
pH	: Electrometric method using ELICO digital pH meter : Model LI - 122.

3.5 Statistical Analysis

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, wherever necessary, to assess which treatment differed from which, with regard to cannibalism.

IV. RESULTS

IV. RESULTS

4.1 The Effect of Stocking Density on Cannibalism and Growth

The results of the study to evaluate the effect of stocking density on total mortality and cannibalism of the post-larvae reared communally along with the one to find the mortality of the individually reared post-larvae, are given in Table 2 and Fig. 1. These values are expressed as percentages of the initial population.

The total mortality of the communally reared post-larvae was found to be higher for all treatments, than that of the individually reared post-larvae, during the 35 day rearing period (Vide Table 2). Total mortality was highest for the highest stocking density. The average total mortality of the post-larvae reared communally ranged from 11.76% at the lowest stocking density of $25/m^2$, to 27.26% at the highest stocking density of $500/m^2$, whereas only 10.7% (this has been taken as the natural mortality) of the post-larvae held individually, died during the same period.

From the Fig. 1, it can be seen that a significant 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 containers with the lowest population density ($25/m^2$) to 16.56% in those with the highest density ($500/m^2$), during the 35 day rearing period (Vide Table 2). Analysis of variance of mortality figures due to cannibalism at different stocking densities

Table 2. Percentage values of total mortality and cannibalism of Penaeus monodon post-larvae at various stocking densities during nursery rearing for a period of 35 days.

Stocking density (Nos/m ²)	Total mortality		Cannibalism **	
	Mean*	S.D.***	Mean*	S.D.***
25	11.76	0	1.06	0
50	13.72	1.386	3.02	1.386
100	16.90	1.864	6.20	1.864
200	20.88	1.576	10.18	1.576
300	22.39	0.812	11.69	0.812
400	24.00	1.374	13.30	1.374
500	27.26	1.383	16.56	1.383

* Average value of three replicates

** Cannibalism = Total mortality - Natural mortality
(Natural mortality = 10.7%)

*** S.D. - Standard Deviation.

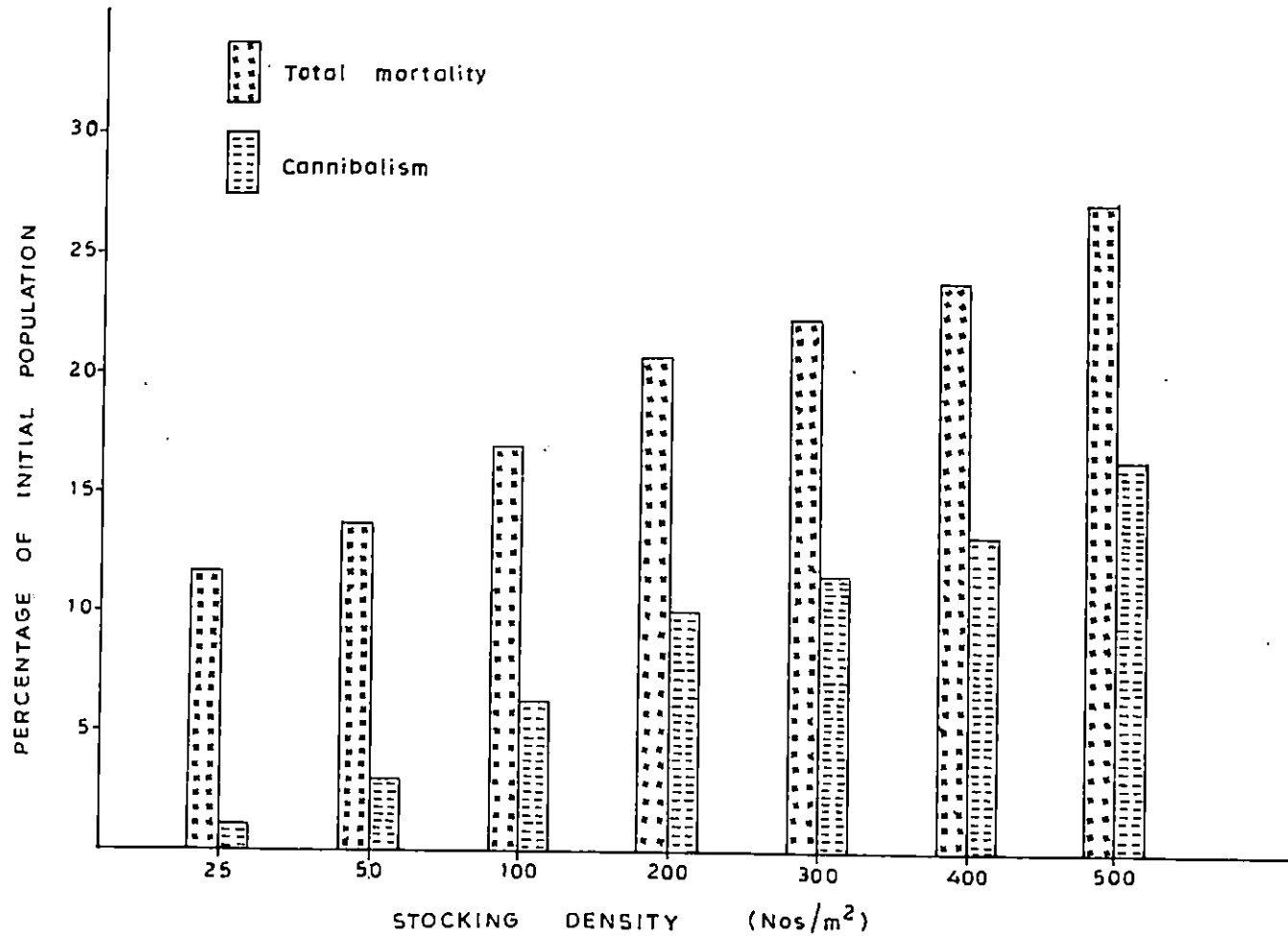


Fig. 1. Effect of stocking density on total mortality and cannibalism of Penaeus monodon post-larvae after nursery rearing for a period of 35 days.

indicated a significant ($P < 0.05$) effect for stocking densities on cannibalism, confirming that cannibalism is density dependent (Table 4). Pairwise comparison using t - test showed that the effect of stocking densities on cannibalism differed significantly with each other. These results further indicate that crowding promotes cannibalism.

Assessment done on a weekly basis showed that as the post-larvae grew older the mortality due to cannibalism decreased and the reduction in population density became slower, (Table 3 and Fig. 2). It could be seen that cannibalism has a negative relationship with the age of P. monodon post-larvae. At all densities cannibalism decreased at a relatively rapid, nearly constant rate, with age. At low stocking densities of 25, 50 and $100/m^2$ there was no cannibalism after 2nd, 3rd and 4th week respectively, whereas at higher densities of 200 - $500/m^2$ it persisted even at the end of the 5th week, although at a very low level (Vide Table 3). Statistical analysis (ANOVA) showed that age has a significant ($P < 0.05$) effect on the rate of cannibalism (Table 4).

It was observed that the early post-larvae moulted more frequently, about once a day whether held isolated or in groups. But as they grow older, the moulting frequency decreased and the intermoult period prolonged. With the beginning of differential growth the smaller prawns were found to moult only after prolonged intermoult period, whereas larger ones continued moulting, especially in association with water exchange. The newly moulted animals were found to take shelter in the dark corners of the tank. Cannibalism was found to be more when the victim is in the post-moult stage.

Table 3. Data on cannibalism of P. monodon post-larvae reared at various stocking densities over a period of 35 days, recorded at weekly intervals.

Age (Week)	I	II	III	IV	V	Total Cannibalism** (%)
Stocking Density (Nos/m ²)	Percentage Cannibalism					
25	0.53	0.53	0	0	0	1.06
50	1.33	1.33	0.36	0	0	3.02
100	3.09	1.60	1.09	0.42	0	6.20
200	4.33	2.84	1.85	0.95	0.21	10.18
300	5.75	3.92	1.27	0.71	0.04	11.69
400	7.07	3.09	1.72	1.09	0.33	13.30
500	7.97	4.28	2.10	1.70	0.51	16.56

* Each value is the average of three replicates.

** Cannibalism at the end of 35 days rearing.

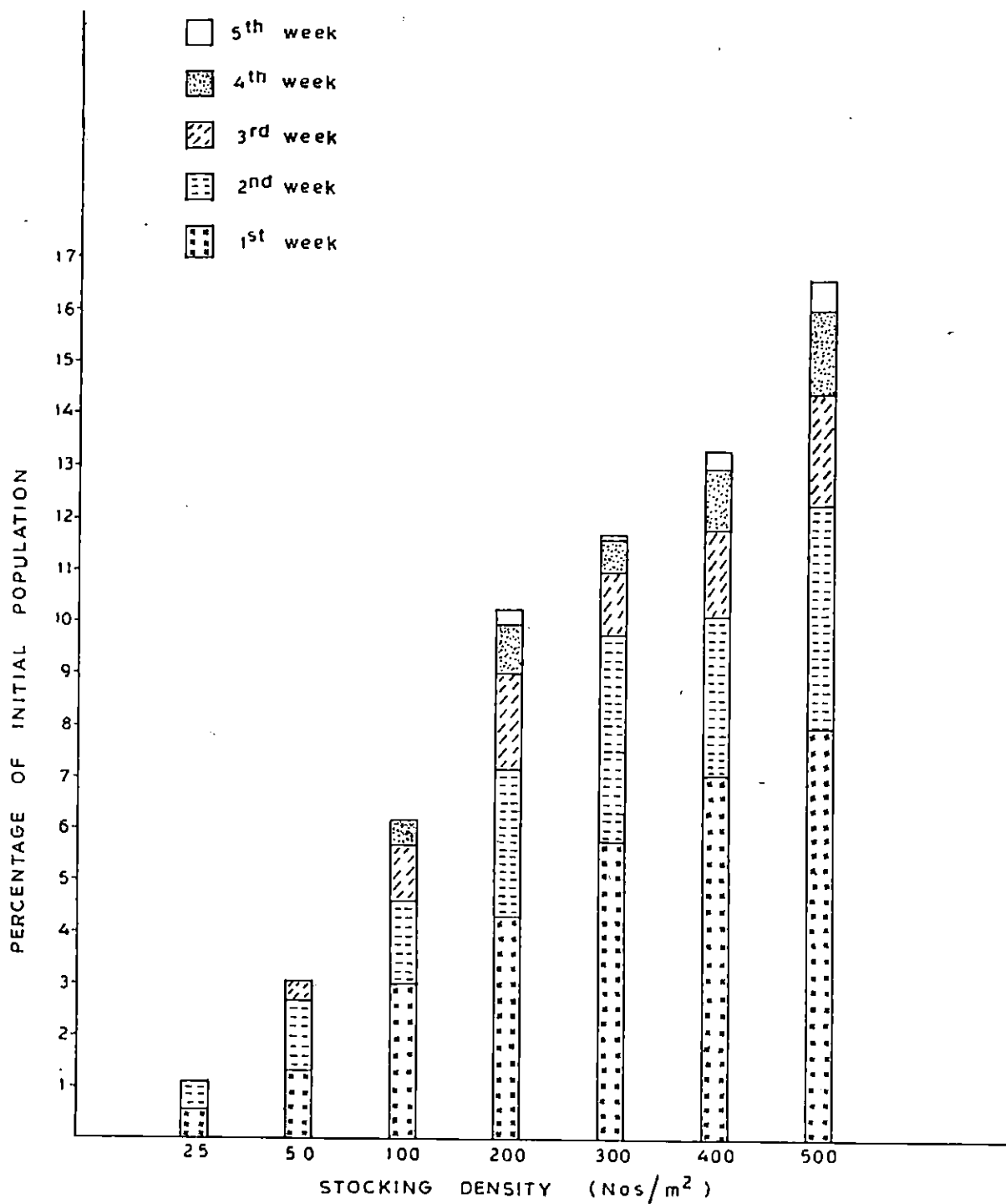


Fig. 2. The rate of cannibalism observed on a weekly basis in *Penaeus monodon* post-larvae reared at different stocking densities over a period of 35 days.

Table 4. Analysis of Variance table showing the effects of stocking density and age of post-larvae on cannibalism.

Source	Degrees of Freedom	Sum of squares	Mean sum of square	F - Values	
				Computed	Tabled (at 5%)
Stocking density	6	250.16	41.69	22.29*	2.51
Age	4	408.85	102.21	54.66*	2.78
Error	24	44.25	1.87		
Total	34	703.24			

* Denotes significant at 5% level

Treatment means

Stocking Density	Mean	Age	Mean
25	1.67	I	11.23
50	3.34	II	8.75
100	5.42	III	5.65
200	7.55	IV	3.94
300	7.55	V	1.59
400	8.47		
500	9.65		

Critical difference for comparing stocking densities - 1.48

Critical difference for comparing age - 1.25

It could be seen from the Table 5 and Fig. 3, that there exists a negative relationship between the population density and the growth of P. monodon post-larvae. Growth was most rapid at the lowest stocking density and its rate became lower as the population density was increased. The difference in growth was apparent by the first sampling and continued throughout the rearing period. The average gain in individual body weight during the 35 day rearing ranged from 67.04 mg for the highest density to 162.89 mg for the lowest density. The increment in biomass measured as mg/m^2 shows a direct relationship with the population density, the increment being the lowest for the lowest density and the highest for the highest density used (Table 5 and Fig. 3).

As the experiment was in progress it was observed that in each of the tanks some of the post-larvae grew faster and out-stripped others in growth. Substantial variation in size and growth rate of the individuals was found at all population densities (Table 6 and Fig. 4). This kind of differential growth although was there in all stocking densities, was more pronounced at higher stocking densities.

The physico-chemical parameters of the water, monitored during this study are presented in Table 7.

4.2 The Effect of Providing Different Substrate Types in the Rearing Tanks on Cannibalism and Growth

Results of the experiment to find the effect of providing different

Table 5. Data of growth, survival and biomass production of P. monodon post-larvae at various stocking densities during the 35 day nursery rearing.

Stocking density (Nos/m ²)	25	50	100	200	300	400	500
Average initial weight (mg)	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Average final weight (mg)	168.89	134.28	108.33	80.89	75.53	73.83	73.04
Average weight gain (mg)	162.89	128.28	102.33	74.89	69.53	67.83	67.04
Average daily weight increment (mg)	4.65	3.67	2.92	2.14	1.96	1.94	1.89
Survival (%)	88.24	86.28	83.10	79.12	77.61	76.0	72.74
Average Biomass increment (mg/m ² /35 day)	3593.3	5533.99	8503.62	11850.59	16188.67	20620.32	24382.45
Average Biomass increment (mg/m ² /day)	102.67	158.11	242.96	338.59	462.53	589.15	696.64

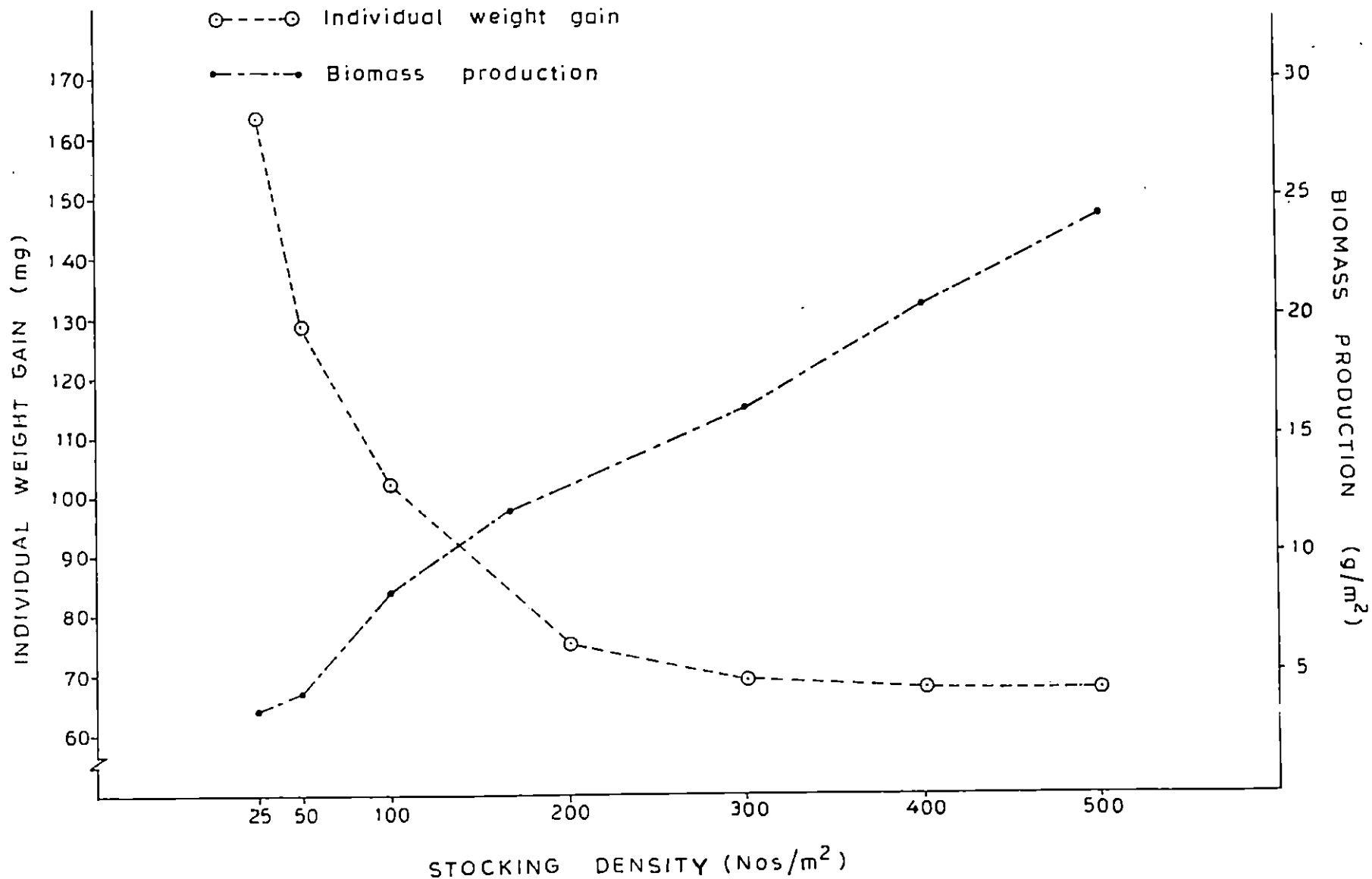


Fig. 3. Effect of various stocking densities on individual weight gain and biomass production of Penaeus monodon post-larvae after nursery rearing for a period of 35 days.

Table 6. Size distribution of P. monodon post-larvae after 35 day rearing at various stocking densities.

Stocking density (Nos/m ²)	25	50	100	200	300	400	500
Small prawns (%) (≤ 30 mm)*	13.3	36.7	51.8	81.13	85.26	86.57	87.18
Large prawns (%) (> 30 mm)*	86.67	63.3	48.2	18.87	14.74	13.43	12.82

* 30 mm is taken as the division line as the mean size of the post-larvae lies close to that figure (ie. 28.91 mm).

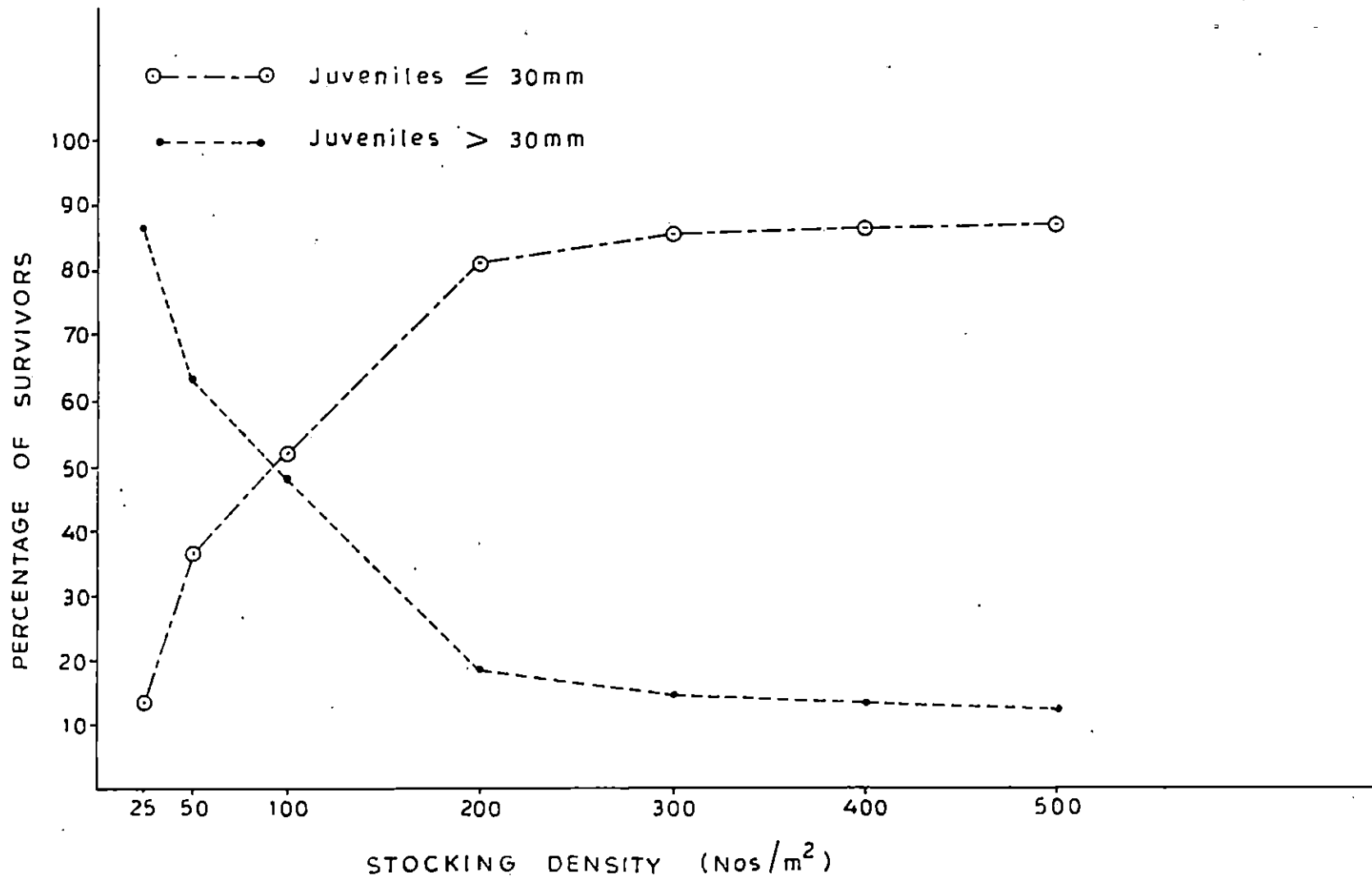


Fig. 4. Effect of stocking density on size distribution of *Penaeus monodon* post-larvae, after nursery rearing for a period of 35 days.

Table 7. Data of water quality parameters monitored during the study to evaluate the effect of stocking density on cannibalism and growth of P. monodon post-larvae.

Stocking density (Nos/m ²)	Water Temperature (°C)		Dissolved Oxygen (ppm)		pH		Salinity (ppt)	
	Mean**	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.
25	27.8	0.79	6.28	0.39	7.81	0.065	20.25	1.12
50	27.8	0.69	6.4	0.31	7.74	0.19	20.25	1.12
100	27.7	0.77	6.37	0.28	7.81	0.094	20.25	1.12
200	27.9	0.86	6.55	0.39	7.81	0.055	20.25	1.12
300	27.7	0.74	6.313	0.45	7.72	0.29	20.25	1.12
400	27.8	0.23	6.23	0.51	7.78	0.14	20.25	1.12
500	27.8	0.97	6.14	0.48	7.80	0.103	20.25	1.12
Individual rearing unit	27.5	0.90	5.93	1.54	7.75	0.015	20.25	1.12

* S.D. - Standard Deviation

** Average value of Five observations.

substrate types in the rearing tanks, on the rate of cannibalism are given in Table 8 and Fig. 5. It could be seen that provision of substrates in the rearing tanks resulted in a considerable increase in the survival rate and decrease in the cannibalism of communally reared P. monodon post-larvae. Cannibalism was significantly lower in all tanks containing substrates, compared to control. Within a period of 35 days, 18.65% of the animals succumbed to cannibalism in the control tanks without any substrates, whereas the rate of cannibalism was considerably lower in tanks with different substrate types at the same population density. The lowest rate of 5.3% was observed in those tanks with clam shells and the next higher value of 6.83% was recorded in those with black polythene raffia. The values in tanks containing round pebbles and polypropylene net frame were 8.65 and 8.95% respectively and the highest value of 10.17% was observed in tanks with P.V.C. tube substratum and twigs. Daily mortality due to cannibalism ranged from 0.152 to 0.291% in tanks with different substrates, whereas it was 0.533% in control tanks.

The effect of age of the post-larvae on cannibalism, could be found from the data given in Table 9 and represented in Fig. 6. From these the rate of cannibalism can be seen to have declined as the post-larvae grew older and reduced to negligible levels towards the end of the five week rearing period. This decline in the rate of cannibalism was not uniform in all treatments, it being more pronounced in tanks having clam shell substratum, wherein at the end of the third week it has reached zero level. It persisted at a very negligible level of 0.09% at the end of the 4th week in those tanks having black polythene raffia and P.V.C. tubes as additional

Table 8. Total mortality and cannibalism (percentage) of *P. monodon* post-larvae reared with different substrate types in the rearing tanks, for a period of 35 days, at a stocking density of 500/m².

Substrate types	Total mortality		Cannibalism	
	Mean*	S.D.	Mean*	S.D.
Control (A)	25.75	1.135	18.65	1.135
Black polythene raffia (B)	13.93	0.858	6.83	0.858
Clam shell (C)	12.40	1.124	5.30	1.124
Polypropylene net frame (D)	16.05	1.429	8.95	1.429
P.V.C. Tube substratum (E)	17.27	0.745	10.17	0.745
Round Pebbles (F)	15.75	1.527	8.65	1.527
Twigs (G)	17.27	1.486	10.17	1.486

Note: Natural mortality - 7.1%

* Average value of three replicates.

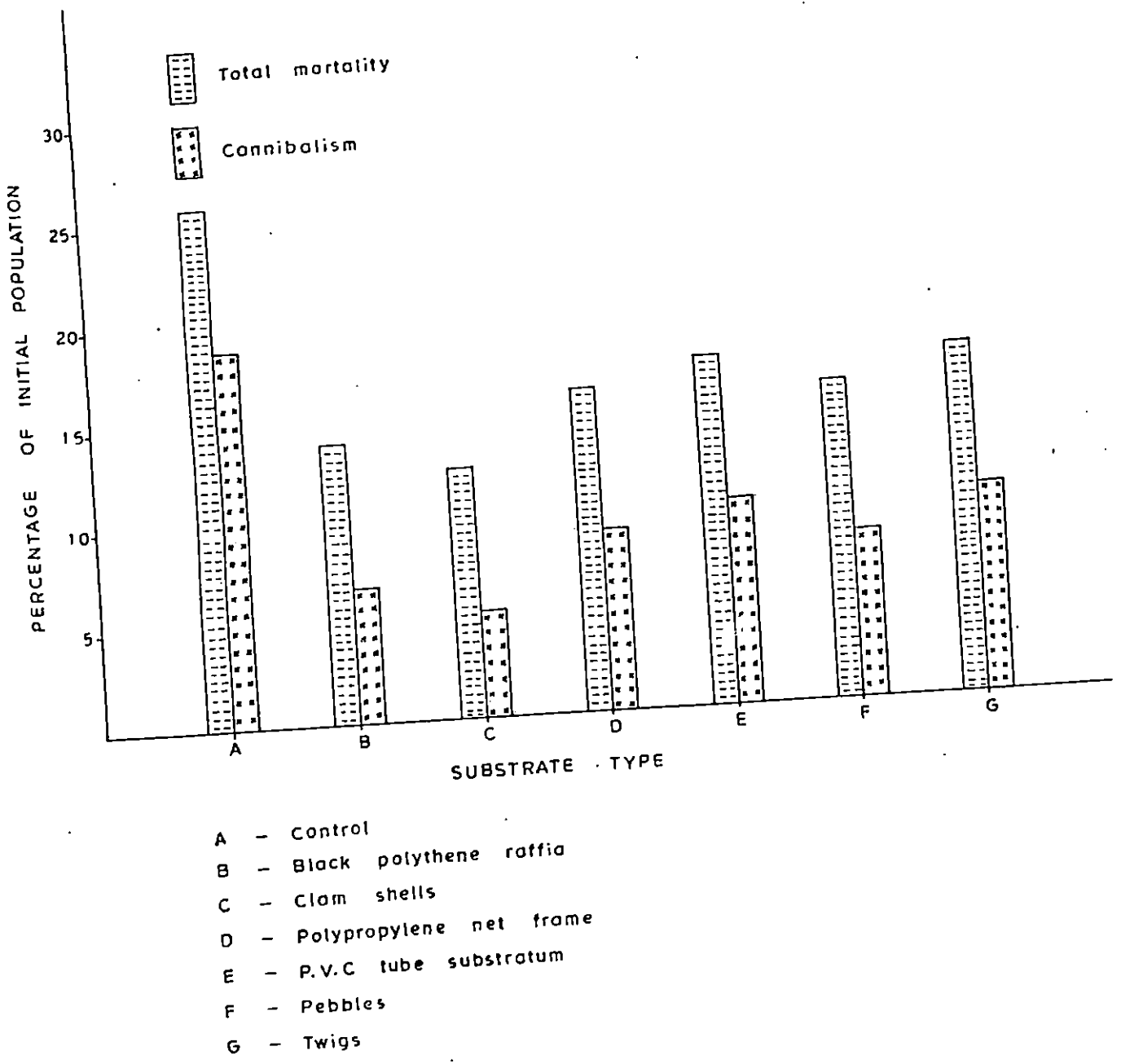


Fig. 5. Effect of providing different types of substrates in the rearing tanks on total mortality and cannibalism of Penaeus monodon post-larvae after nursery rearing for a period of 35 days.

Table 9. Rate of cannibalism of P. monodon post-larvae, reared using different substrate types in the rearing tanks, at a stocking density of 500/m² recorded at weekly intervals over a 35 day period.

Age (Week)	I	II	III	IV	V	Total Cannibalism %
Substrate Types	Percentage		Cannibalism *			
A	7.37	4.94	3.43	1.91	1.00	18.65
B	3.73	1.61	1.31	0.09	0.09	6.83
C	3.12	1.60	0.58	0	0	5.30
D	3.73	2.22	1.90	0.70	0.40	8.95
E	6.16	2.82	1.00	0.09	0.09	10.17
F	4.03	2.52	1.00	0.40	0.40	8.65
G	4.94	2.83	1.00	1.00	0.40	10.17

* Each value is the average of three replicates.

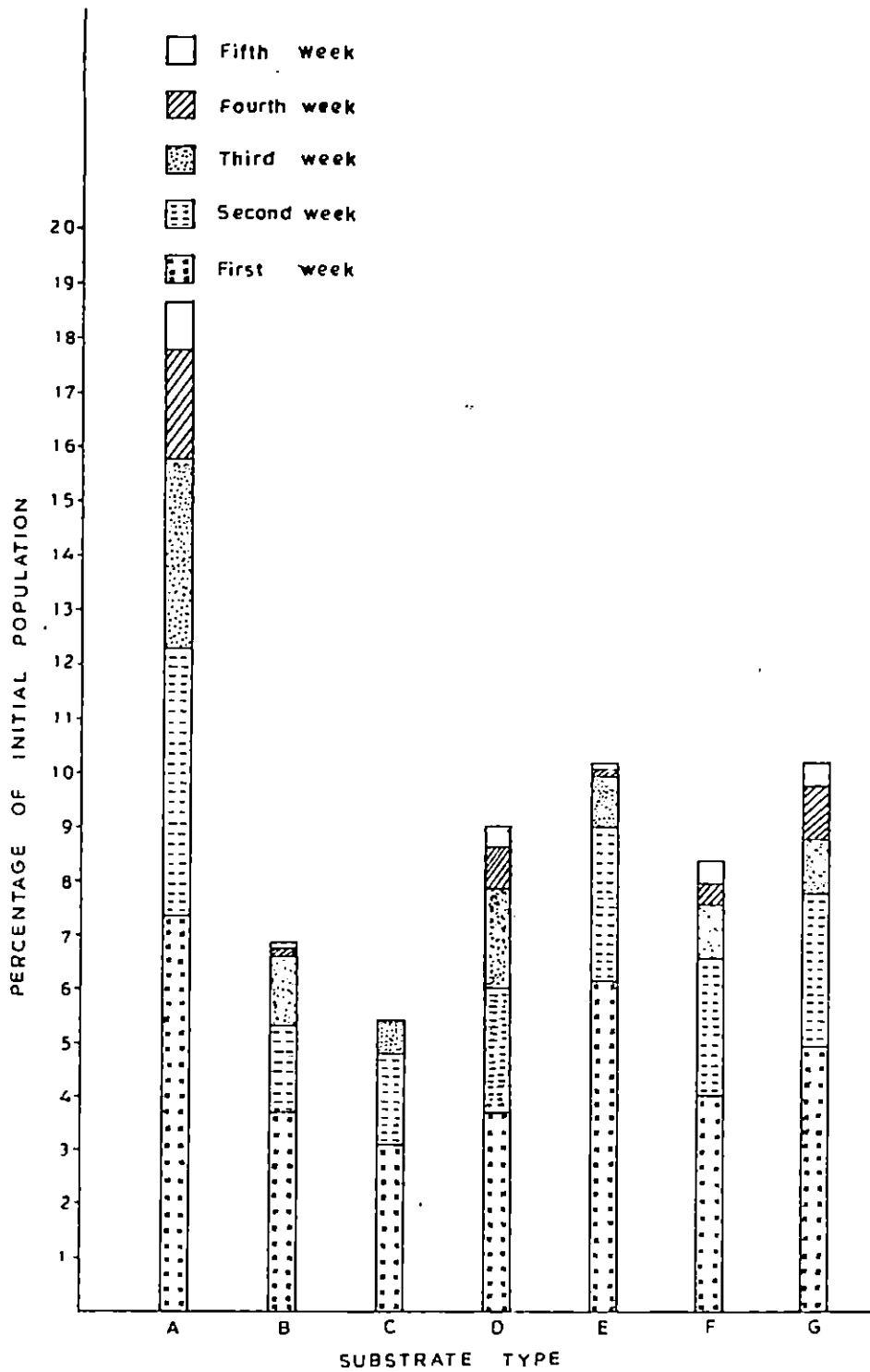
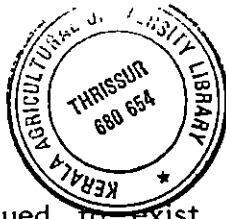


Fig. 6. Cannibalism in *Penaeus monodon* post-larvae reared in tanks with different substrates, recorded at weekly intervals during nursery rearing for a period of 35 days.



170302

51

substrates, whereas it continued to exist at a comparatively higher level of 1% at the end of 5th week, in the control tanks.

A two-way Analysis of Variance (ANOVA) was carried out for testing the statistical significance of providing different substrate types in the rearing tanks and the age of the P. monodon post-larvae on cannibalism (Table 10). The ANOVA showed that both factors, the substrate type and the age of the post-larvae have a significant effect on cannibalism in P. monodon ($P < 0.05$). Substrate types tested differed significantly with the control in terms of cannibalism.

Table 11 and 12 show that provision of different substrates in the rearing tanks of P. monodon post-larvae, influences the growth rate, it being high in tanks with some substrate than those without any additional substrate. Although there is significant variation in the growth rate of prawns between the control and experimental tanks, there is not much of a variation in the growth rate among the different substrates used. It was also observed that the addition of substrate in the rearing tank influences the size distribution of the post-larvae (Vide Table 12). The individual weight gain of the post-larvae was 79.95 mg for control and it ranged from 82.25 to 91.0 mg for various substrates tested, for a period of 35 days. Maximum growth was observed in tanks containing polypropylene net frame and minimum in tanks with pebble substratum. No correlation was observed between the growth rate and rate of cannibalism. The average biomass production measured as mg/m^2 in control tanks was 28,196.44 and it ranged from 34,647.81 to 38,197.25 in tanks with various substrates,

Table 10. Analysis of variance table showing the effect of substrate types in the rearing tanks and age of P. monodon post-larvae on cannibalism.

Source	Degrees of Freedom	Sum of square	Mean sum of square	F.- Value	
				Computed	Tabled(at 5%)
Substrate Type	6	110.50	18.42	16.8*	2.51
Age	4	439.23	109.80	100.19*	2.78
Error	24	26.3	1.09		
Total	34	576.03			

* Significant at 5% level.

Treatment means

Substrate type	Mean	Age	Mean
A	10.59	I	12.42
B	5.68	II	9.21
C	4.36	III	6.68
D	7.21	IV	3.65
E	6.64	V	2.86
F	6.74		
G	7.52		

Critical difference for comparing substrate types - 1.13

Critical difference for comparing age - 0.955

Table 11. Data of growth, survival and biomass production of P. monodon post-larvae reared in tanks with different substrate types for 35 days at a stocking density of 500 post-larvae/m².

Substrate types	A	B	C	D	E	F	G
Average initial weight (mg)	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Average final weight (mg)	81.95	93.15	88.6	97.0	95.95	88.25	92.45
Average weight gain (mg)	75.95	87.15	82.6	91.00	89.95	82.25	86.45
Weight increment/day (mg)	2.17	2.19	2.36	2.60	2.57	2.35	2.45
Survival (%)	74.25	86.07	87.6	83.95	82.73	84.25	82.73
Average biomass increment (mg/m ² /35 day)	28196.44	37496.29	36178.80	38197.25	37207.82	34647.81	35760.04
Average biomass increment (mg/m ² /day)	805.61	1071.32	1033.68	1091.35	1063.08	989.94	1021.71

Table 12. Size distribution of P. monodon post-larvae after 35 day rearing with different substrate types in the rearing tanks.

Substrate type	A	B	C	D	E	F	G
Small prawns (≤ 30 mm)*	85.37	76.84	80.20	73.92	74.73	80.65	76.92
Large prawns (> 30 mm)*	14.63	23.16	19.80	26.08	25.27	19.35	23.08

* 30 mm is taken as the division line for small and larger prawns, as mean size lies close to this figure (ie. 29.4 mm).

Table 13. Data of water quality parameters monitored during 35 day rearing of P. monodon post-larvae in tanks provided with different substrate types.

Substrate Type	Water Temperature (°C)		Dissolved Oxygen (ppm)		pH		Salinity (ppt)	
	Mean*	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
A	27.9	0.83	6.1	0.42	7.81	0.098	20.22	0.63
B	27.89	0.804	6.17	0.41	7.78	0.096	20.22	0.63
C	27.95	0.898	6.06	0.042	7.77	0.097	20.22	0.63
D	27.93	0.893	5.99	0.092	7.76	0.094	20.22	0.63
E	27.99	0.88	5.93	0.126	7.76	0.094	20.22	0.63
F	28.08	0.86	5.88	0.181	7.78	0.104	20.22	0.63
G	28.10	0.83	5.87	0.168	7.79	0.108	20.22	0.63
Individual rearing unit	27.83	0.92	5.62	0.246	7.77	0.120	19.87	0.81

* Average value of five observations.

over a rearing period of 35 days (Vide Table 11). Maximum biomass production was obtained in tanks with polypropylene net frame wherein the maximum increment of growth of 91.0 mg and an appreciably high survival rate of 83.95% were obtained.

The physico-chemical parameters of water monitored during the rearing experiment are given in Table 13.

4.3 The Effect of Feeding Frequency on Cannibalism

The results of the experiment conducted to find the effect of feeding frequency on cannibalism of P. monodon post-larvae are given in the Table 14. It was observed that the rate of cannibalism decreased as the feeding frequency was increased and the survival rate became proportionately high, when fed more frequently. Where the feeding frequency was less the decline in population was rapid, this being caused mainly by cannibalism and the population finally reached a relatively stable level of few animals, towards the later stages of rearing. Even in tanks where the feeding frequency was more, cannibalism was there, but at relatively low levels. The rate of cannibalism which was 17.075% when fed once a day declined to 11.5 and 9.65% levels when fed two and three times a day, respectively. Correlation coefficient showed a negative relationship between feeding frequency and cannibalism. In the regression line drawn (Fig. 7), it can be seen that, theoretically, cannibalism will be reduced to zero level, if feeding frequency is increased to 6 times a day.

Table 14. Effect of different feeding frequencies on total mortality and cannibalism of P. monodon post-larvae during 35 day rearing

Feeding Frequency	Total mortality (%)		Cannibalism (%)	
	Mean*	S.D.	Mean *	S.D.
Feeding once a day	27.75	5.55	17.075	5.55
Feeding twice a day	22.2	3.7	11.50	3.7
Feeding thrice a day	20.35	5.55	9.65	5.55

Note: Natural mortality - 10.7%

* Average value of three replicates.

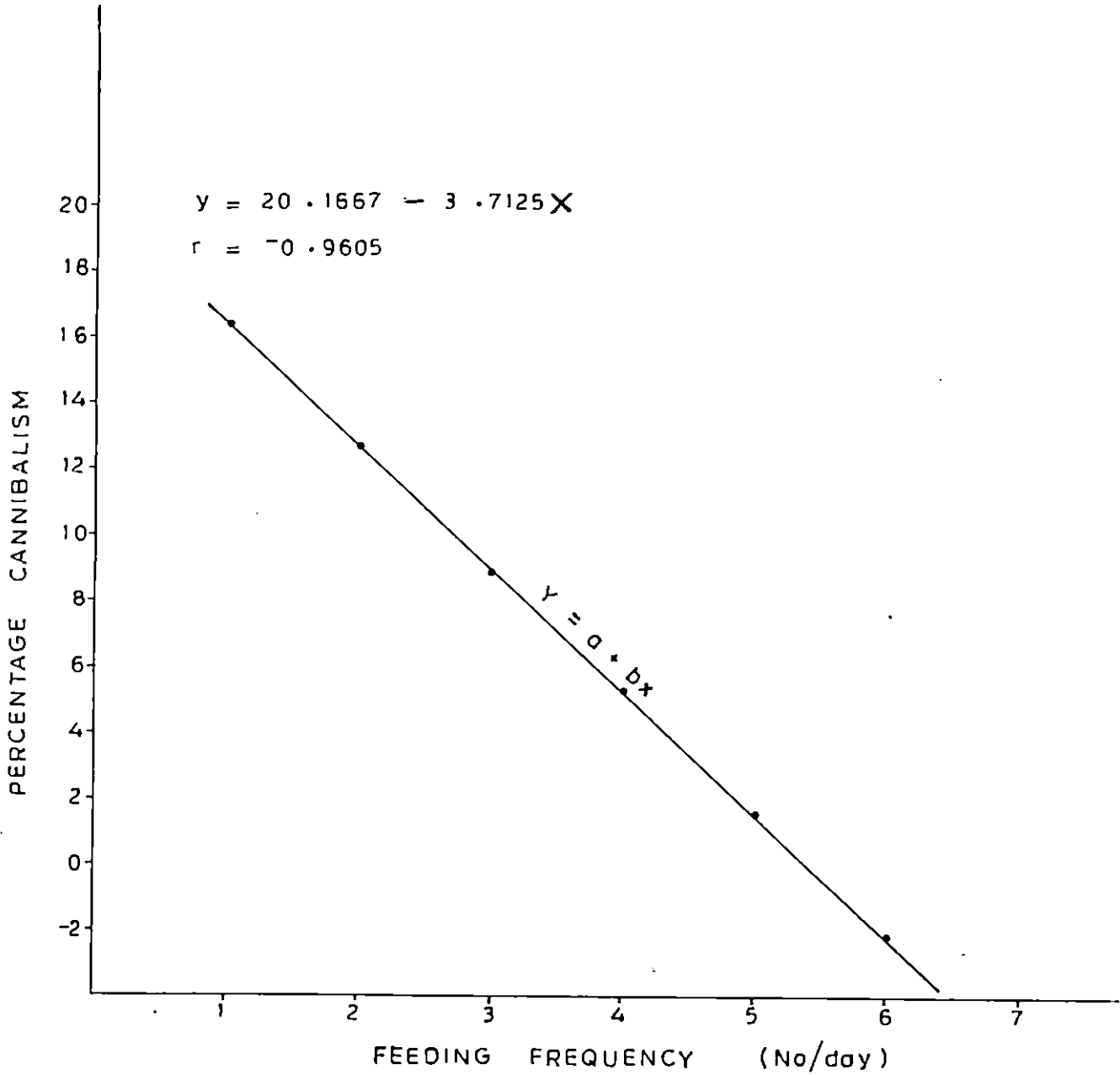


Fig. 7. Regression line showing the effect of feeding frequency on rate of cannibalism of Penaeus monodon post-larvae.

4.4 Cannibalism in the Juveniles

The results of the study conducted to examine whether any cannibalism exists in the tiger prawn P. monodon during the juvenile stage, are given in Table 15 and Fig. 8. The survival rate obtained for the juveniles, of 3 different size groups and one mixed group after 35 day rearing, was much higher being in the range of 93.33 to 95.53%. The total mortality observed was of the order of 4.67 - 6.67%, which could be accounted mostly to natural mortality, as 4% mortality was observed in the individual rearing units. The mortality due to cannibalism was only 0.67 - 1.35% for the different size groups of juveniles stocked separately, whereas in the case of the fourth group having different sizes (21 - 50mm) put together, it was slightly higher being 2.67%.

Table 15. Data of total mortality and cannibalism of P. monodon juveniles of different sizes during 35 day rearing under laboratory conditions.

Size group (Total length) (mm)	Total mortality (%)		Cannibalism (%)	
	Mean *	S.D.	Mean *	S.D.
21 - 33	4.67	2.0	0.67	2.0
31 - 40	5.35	1.4	1.35	1.4
41 - 50	4.67	0.665	0.67	0.665
21 - 50 (Mixed size group)	6.67	1.335	2.67	1.335

Note: Natural mortality - 4%

* Average value of three replicates.

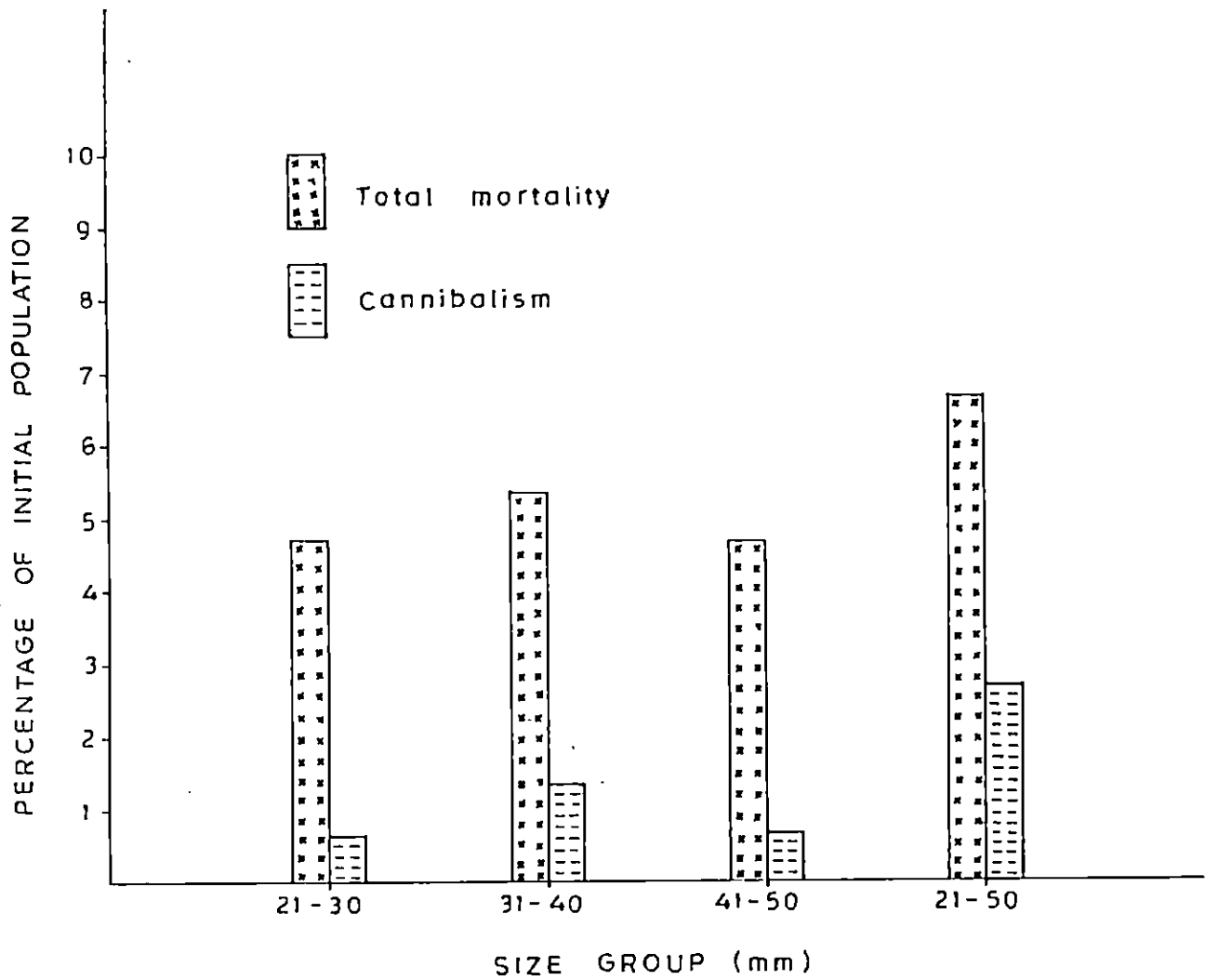


Fig. 8. Total mortality and cannibalism in Penaeus monodon juveniles during a 35 day rearing.

V. DISCUSSION

V. DISCUSSION

The present study on cannibalism in Penaeus monodon has revealed that when post-larvae are reared communally the rate of mortality is quite high than when reared individually. The mortality in the communal rearing tanks in excess of those observed in corresponding groups of individually reared post-larvae is considered to be due to group interactions and has been attributed to cannibalism. The tiger prawn, P. monodon is considered as a cannibalistic species and heavy losses are reported during rearing operations by Verghese et al. (1975), Ravichandran et al. (1982), Rajyalakshmi (1982) and Ferraris et al. (1987). But according to Forster and Beard (1974) and Aquacop (1977) the tiger prawn has been considered as a quiet, highly compatible and non-cannibalistic species withstanding high stocking densities and accustomed to crowding. This finding could be correct only with regard to juvenile stages when cannibalism is reduced to negligible levels as per the present study, wherein the rate of cannibalism has become negligible in the juvenile stages.

5.1 Effect of Stocking Density on Cannibalism and Growth

Stocking density was found as one of the most important factors influencing the rate of cannibalism in the tiger prawn P. monodon post-larvae. A positive relationship between the rate of cannibalism and stocking density was observed in the present study; ie. the mortality due to cannibalism increased with increasing stocking density. Such density dependent cannibalism

was observed in other species of crustaceans such as in Macrobrachium rosenbergii (Sandifer and Smith, 1975), Homarus americanus (Aiken and Waddy, 1978) and Hemigrapsus penicillatus (Kurihara and Okomoto, 1987). In the rearing tanks their survival was observed to vary inversely with population density. In the mud crab, Helice tridens, Kurihara et al. (1988) observed that if the population density becomes greater than the carrying capacity of the system, the animals responded by increasing the rate of cannibalism, thereby reducing the population density to the optimum levels.

At higher densities, P. monodon post-larvae were found to encounter agonistically with their conspecifics more frequently, so that the chances of cannibalism are more. It is possible as suggested by Dunham (1972) that some chemicals released by the animals in the holding containers, especially in association with moulting may mediate the social interactions of the post-larvae. According to him a pheromone produced by lobsters mediate social interactions.

Cannibalism according to Fox (1975b) and Pearre (1982) is a useful means of density dependent population regulation in times of food stress. Although cannibalism among individuals may be aggravated due to non-availability of food, in the present study the post-larvae were fed ad libitum and as such food deficiency may not be stated as a cause of cannibalism. In this case cannibalism was observed even at comparatively low stocking densities in the presence of excess food and was found to diminish towards the later stages as the animals grew older, at all densities, even when

the biomass was on the increase. In the rearing tanks P. monodon post-larvae were found to show 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 diminished as the post-larvae grew older, and found to distribute more evenly in the rearing tanks.

Survival rate obtained in the present study is comparatively high at all stocking densities, than those reported from many nursery rearing trials with P. monodon post-larvae. Siddharaju et al. (1980) obtained a survival of 60 and 85% at stocking densities of 400 and 200/m² respectively during 35 day rearing, while in a series of nursery rearing trials, Tabbu (1984) reported only very low survival rates of 41.62, 67.44 and 52.14% at stocking densities of 50, 100 and 150/m² over a period of 45 days. Ravichandran et al. (1982) at a comparatively low stocking density of 2.5 and 15 post-larvae/m² reported survival rates of 68.4 and 31% respectively during 30 days of nursery rearing. At densities of 50 to 200 post-larvae/m² Aquacop (1984) obtained survival rates of only less than 50%. The comparatively higher survival rate obtained in the present study may be due to better rearing conditions such as proper feeding with balanced diet and the better water quality conditions maintained, during the rearing period.

Adoption of a suitable stocking density is important in checking the losses due to cannibalism without affecting much the operational cost. In the present study, when different densities ranging from 25-500 post-larvae/m² were tried rates of survival ranging from 88.24 to 72.74% were

obtained after 35 days of rearing. To fix the optimum stocking density, besides 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.

Growth rate of P. monodon post-larvae is found to be affected by the stocking density. Growth of the post-larvae in rearing tanks was inversely related to population density. Reduced growth rate at high densities would be resulted from either lengthening of intermoult period or a reduction in the weight increment per moult. According to Van Olst and Carlberg (1978) growth in crustaceans is actually a combination of two related components viz., moulting frequency and size increment per moult. Analysis of the data of the present study revealed that both the components of growth appeared to be influenced by population density. In other words under conditions of limited space animals exhibit both lengthened intermoult period and reduced weight increment per moult. The combined effect of these two components caused a reduction in growth over time at high stocking densities. Sandifer and Smith (1975) found growth in M. rosenbergii also to be density dependent, with a relatively slow growth rate at higher densities.

In groups under controlled laboratory conditions the post-larvae grew at an uneven rate producing increasing disparity in size towards the later stages of rearing. The progressive increase in disparity of size is a well known natural phenomenon, among crustaceans under controlled rearing

conditions and has been observed in others such as M. rosenbergii (Forster and Wickins, 1972; Wickins, 1972b; Segal and Roe, 1975; Karplus et al., 1986, 1989), M. malcolmsonii (Rao et al., 1986) and Homarus americanus (Douglass, 1946; Stewart and Squires, 1968; Mc Leese, 1972; Cobb and Tamm, 1975; and Sastry and Zeitlin-Hale, 1977).

Variation in the growth rate observed in the present study was found to be due to the interaction of various intrinsic and extrinsic factors. In the initial stage, because of the uniform size and age of the post-larvae, each individual has an equal chance to grow. Since each individual in a group experiences the same rearing condition it is clear that a sizeable proportion of the variation in the growth rate may be due to additive genetic factors. The disparity in growth observed even at very low stocking density in the rearing tank seems to support this interpretation of genetic basis of differential growth. In M. rosenbergii although the average growth is inversely related to density, the variation in size is believed to be influenced by intrinsic rather than extrinsic factors (Sandifer and Smith, 1975 and Raanan, 1982). Individual rearing of M. rosenbergii juveniles by Briggs et al. (1988) resulted in differential growth supporting the genetic basis for growth variation. But according to Raanan and Cohen (1984a, b) the variation in size in M. rosenbergii is due to the interaction within the prawn group, than it is by genetic difference in growth potential of individual prawns. In H. americanus according to Hedgecock and Nelson (1978) upto 30% of the variation appears to be heritable, but culture system-family by system interactions and density difference within and between systems also contribute substantially to growth rate variation.

The development of disparity in size as a direct function of population density and the more uniform growth of isolated controls noted in the present study indicate that a large proportion of variation in growth rate may be influenced by some extrinsic factors which persist in the rearing tanks. In groups, variation in the time of moulting of the same aged post-larvae may occur because of competition for food and space, other group interactions, environmental influences, population density and innate genetic variability.

5.2 Effect of Providing Different Substrate Types in the Rearing Tanks on Cannibalism and Growth

The presence of some additional substrates in the rearing tanks was found to influence the rate of cannibalism in P. monodon post-larvae (Vide Table 8). A notable increase in the survival and sizeable decrease in the cannibalism of communally reared post-larvae, were observed when additional substrates were provided in the rearing tanks. Similar observations were also made in other species of prawns such as Macrobrachium rosenbergii by Smith and Sandifer (1975) and Palaemon serratus by Forster (1970) and the lobster Homarus americanus by Van. Olst et al. (1975a). Smith and Sandifer (1975) reported faster growth and higher survival among M. rosenbergii in tanks containing shelter substrates than those reared in tanks not containing 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. Van Olst et al. (1975a) also found the provision of such shelter substrates in the rearing tanks of the lobster

Homarus americanus, reducing the number of social encounters that lead to fighting and cannibalism.

The present study in P. monodon post-larvae, with different substrate types in the rearing tanks, has indicated that relatively high post-larval density could be maintained, with minimal level of cannibalism, if suitable substrates are provided in the rearing tanks. The prawns 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 mostly were found taking refuge in the shelter substrates, thereby escaping from cannibalism by other active individuals in the group. The maximum survival of 87.6% in the present experiment was recorded in the tanks where clam shells were provided which probably offer the maximum shelter space among the different substrates used. The black polythene raffia which has given a survival of 86.07% also provides lot of shelter space for the post-larvae to hide during moulting. The black coloured polypropylene net frame which has provided an additional vertical space has given a survival of 83.95%. This has also given the maximum growth as well as the highest biomass production. It can be seen that vertical space actually helps the use of entire water column efficiently, to secure more places of refuge and thus provide a better environment. The usefulness of additional substrates in rearing tanks had been stressed by Smith and Sandifer (1975) while working on M. rosenbergii and Carlberg et al. (1979) working on lobsters such as H. americanus and H. gammarus, having this phenomenon of cannibalism.

It is not very clear as to how cannibalism is being initiated, and whether

the attackers get any cues from the moulting or moulted animals. P. monodon after moulting is soft and sluggish in movement. Their sluggish movement may attract the attention of other active animals which often initiated 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 other active ones. Further, it was observed that the cannibalism was least in the tanks where clam shells were provided, which perhaps give more hiding space followed by black polythene raffia. In the grapsid crab, Hemigrapsus penicillatus, Kurihara and Okomoto (1987) also observed visual contact of individuals leading to aggressive encounters and cannibalism. Provision of shelter for the smaller individuals was found helpful in avoiding cannibalism in this crab.

The results of the experiment providing different kinds of substrates indicate that certain types of shelters are very effective in reducing cannibalism. Thus clam shells and black polythene raffia were found to be most effective in minimising cannibalism. Probably any substrate which provides sufficient hiding place would be of value. In one study on Homarus americanus Van Olst et al. (1975a) found oyster shell to be the best shelter substrate for reducing cannibalism and assuring high carrying capacity compared to other substrates tested such as beach sand, rounded beach rock and P.V.C. tubing. Use of natural or artificial shelter substrate was suggested in high density rearing of post-larvae and also in the intensive culture systems for prawns (Ling, 1962; Reeve, 1969; Forster, 1970; Sandifer and Smith, 1974; Smith and Sandifer, 1975) lobsters, (Carlberg et al., 1979) and crabs (Kurihara and Okomoto, 1987).

Provision of shelter substrates in the rearing tanks was also observed to influence the growth rate of P. monodon post-larvae. Animals reared in tanks with different substrate types grew rather fast compared to those without any shelter substrate. In the presence of shelter substrates, the animals were found to cling to the substrate and remain quiet and motionless most of the time compared to animals in the control tanks and were not easily affected by slight disturbances. Thus the food taken would be channelled more for growth than for maintenance. In tanks without substrate the animals need a higher maintenance energy which may account for the significantly lower growth rate. Rickards (1971) obtained significantly higher growth and yield for Penaeus duororum reared in tanks with shelter substrates. So also fast growth and high yield were obtained for M. rosenbergii reared in tanks with shelter substrates by Wickins (1972b). According to Smith and Sandifer (1975), the fast growth of animals reared in tanks with shelter substrates was due to more efficient feed utilization among prawns.

Development of disparity in size was also observed in this study. Considerable variation in the differential growth between substrate tanks and control tanks was observed in the present study. This observation supports the fact that, differential growth in P. monodon post-larvae is influenced by some extrinsic factors. The patterns of differential growth in the control tank and that observed in the earlier stocking density study at a density of 500 post-larvae/m², are comparable.

5.3 Effect of Feeding Frequency on Cannibalism

Food availability and feeding frequency are the important factors

influencing cannibalism in P. monodon post-larvae. It could be seen that the rate of cannibalism decreased as the feeding frequency increased. But the cannibalistic tendency was found to develop and exist even when sufficient food was there 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). In that species well fed animals were found to attack and cannibalize 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 American lobster Homarus americanus, Van Olst et al. (1975b) made similar observations and according to them a certain minimum food level is necessary to reduce cannibalism in the rearing tanks. Similarly in the case of Palaemon paucidens Yamane et al. (1988) found that the presence of bait in the rearing tank helped in reducing the frequency of cannibalism.

Under conditions of limited food supply, the cannibalistic response increased as a result of greater number of contacts between animals while searching for food. This suggests that cannibalism could be suppressed by increasing the food density and feeding frequency, as high as is practically possible. This would increase the ratio of food particles to the potential prey and the relative possibility of a predator encountering a conspecific would decline. Observations on the feeding behaviour of P. monodon post-

larvae showed that they always prefer fresh diet rather than the remnants of the previous ration. Thus by increasing the feeding frequency, it was possible to satiate the animals easily. This has provided them with fresh feed at all times and is more beneficial than providing large quantities of feed as a single dose at one time.

Feeding the P. monodon post-larvae 3 times a day does not seem enough to prevent cannibalism completely. So during weaning periods from live feed to commercial feed, the period when usually high rate of cannibalism is noticed, the post-larvae will have to be fed more frequently ad libitum as practically as possible.

5.4 Cannibalism in the Juveniles

The rate of cannibalism was found to be so 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 many, such as Forster and Beard (1974), Maheswary (1983), Chen et al. (1989), Wyban and Sweany (1989) and Winas (1990) during intensive culture trials with P. monodon, wherein they got higher survival rate when stocked with juveniles.

The lower rate of cannibalism in the juvenile stage may be associated with acclimation of animals with the new rearing conditions and pelleted feed and decreased moulting frequency with long intermoult period. But

the limited rate of mortality due to cannibalism existing during this stage, may be taking place when an individual in the group becomes weak or injured. Similar interpretations were also made by Sastry and Zeitlin-Hale (1977) in the case of American lobster, Homarus americanus, where cannibalism among larger individuals was observed only during moulting.

5.5 Moulting and Cannibalism

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. Similar moult related cannibalism was also observed in Palaemon paucidens by Yamane et al. (1988), where cannibalism was closely associated with the condition of individual prey, whether moulted or not and there was no relationship with the size of the prey and predators. Cannibalism associated with moulting was also observed in other species of crustaceans such as the giant fresh water prawn Macrobrachium rosenbergii (Segal and Roe, 1975; Peebles, 1977, 1978) and the fresh water crayfish, Cambarellus shufeltii (Lowe, 1956). In the juvenile American lobster, Homarus americanus, Sastry and Zeitlin-Hale (1977) observed a significantly lower survival during moult periods indicating that mortalities are associated with cannibalism during vulnerable periods of moulting and that mortality increases as moulting within the group becomes asynchronous.

As the post-larvae grew older cannibalism was found to decrease at a relatively rapid nearly constant rate (Vide Table 3 and 9). Although

the cannibalism would be expected to increase with increasing biomass and asynchronous moulting, the increased survival rate in the later stage may be due to decreased moulting frequency, prolonged intermolt period and avoidance or delayed moulting by smaller individuals in the group. Thus Schulte (1976) in the prawn Leander squilla and Adelung (1971) in the crab Carcinus maenas found smaller individuals to delay their next moulting when larger individuals were present, thereby escaping cannibalism. 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 Cambarellus shufeltii and Sastry and Zeitlin-Hale (1977) in H. americanus. But in P. monodon post-larvae when in a group, asynchronous moulting is common. Variation in the time of moulting of post-larvae with same age and size may occur because of the innate genetic variability, competition for food and space, group interactions and other factors such as water quality, population density and availability of shelter substrates in the rearing tank. Environmental and physiological manipulation of moulting in lobsters, were suggested by Sastry and Zeitlin-Hale (1977) for reducing cannibalism. Water temperature was found to be one parameter, quite efficient in controlling cannibalism, in lobsters. Lobsters cultured at elevated temperatures had more synchronous moulting and therefore fewer cannibalistic attacks occurred (Ford et al., 1975). In P. monodon mass moulting was found associated with water exchange. So frequent water exchange at regular intervals in the nursery tanks can be used for synchronising moulting.

VI SUMMARY

1. The phenomenon of cannibalism existing among the post-larvae of the tiger prawn Penaeus monodon Fabricius has been studied to find, the different factors influencing it and the methods to control it.
2. The effects of varying the stocking density, provision of different additional substrates in the rearing tank and of varying the feeding frequency, on cannibalism were investigated.
3. To study the extent of cannibalism during later stages, juveniles were segregated size-wise and reared separately, and as mixed group having all the sizes put together.
4. To investigate the level of natural mortality, animals were reared individually in glass beakers giving more or less similar rearing conditions.
5. Total mortality of communally reared post-larvae was found to be higher in all the experiments than that noticed in corresponding groups of individually reared post-larvae, suggesting that cannibalism is responsible for increased mortality.
6. The rate of cannibalism was found to increase with increasing population density ie. there exists a positive relationship between stocking density and the rate of cannibalism.
7. Early post-larvae of P. monodon show a tendency to aggregate in the corners of the rearing tanks and this tendency diminished as the post-larvae grew older and found to disperse more evenly in the rearing tanks towards later stages.

VI. SUMMARY

8. The rate of growth of post-larvae was found to be low at higher densities compared to that at lower densities.
9. Noticeable increase in the survival and decrease in the rate of cannibalism of communally reared post-larvae were obtained when shelter substrates were provided in the rearing tanks.
10. Weak and newly moulted animals were found to take refuge in the shelter substrates provided, thus escaping cannibalism.
11. A certain level of cannibalism was observed even in the presence of shelter substrates in the rearing tanks.
12. Among the various shelter substrates tested, clam shells and black polythene raffia were found to be very effective in reducing cannibalism in P. monodon post-larvae.
13. Slightly higher growth rate was obtained for the animals which were reared in tanks with shelter substrate, compared to those reared in tanks without any shelter.
14. It was found that as the feeding frequency is increased the rate of survival increased, showing that by increasing the feeding frequency, the rate of cannibalism could be reduced.
15. The regression line drawn for feeding frequency against the rate of cannibalism showed theoretical possibilities of bringing down the cannibalism to zero levels if the feeding frequency is increased 6 or more times a day.

16. Post-larvae were found to prefer fresh diet rather than remnants of previous ration.
17. Most of the mortalities due to cannibalism among communally reared P. monodon post-larvae were found to be associated with attack made on newly moulted animals irrespective of the size of the victim.
18. Early post-larvae moulted more frequently about once a day; but as they grew older, the moulting frequency decreased and intermoult period prolonged.
19. High rate of cannibalism was observed during the early post-larval phase when they moulted more frequently.
20. As the post-larvae grew older cannibalism decreased at a relatively rapid nearly constant rate and reduced to very low levels as they attain the juvenile stage.
21. When reared communally the post-larvae were found to grow at an uneven rate and showed disparity in size towards the later stages.
22. With the beginning of differential growth the smaller prawns were found to delay their moulting, whereas the larger ones continued moulting, especially in association with water exchange.
23. Segregation of larger individuals from the group was found to trigger the growth of smaller individuals, suggesting that segregation of animals, according to size after the nursery phase, may help to achieve uniform growth in grow-out ponds.

24. The rate of survival obtained for juveniles in the present study was much higher, showing that in juveniles cannibalism doesnot form a major cause of mortality, under well fed conditions.

VII. REFERENCES

VII REFERENCES

- *Adelung, D. (1971) Untersuchungen zur Hautungsphysiologie der dekapoden Krabben am Beispiel der Strandkrabbe, Carcinus maenas Helgolander. Wiss. Meeres Unters., 22: 66-119.
- *Aiken, D.E. (1977) Moulting and growth in decapod crustaceans with particular reference to lobster, Homarus americanus. Proc. Workshop on lobster and Rock lobster Ecology and Physiology, (Australia, Circular No. 7): 41-75.
- Aiken, D.E. and Waddy, S.L. (1978) Space, density and growth of lobsters (Homarus americanus). Proc. World Maricult. Soc., 9: 461-467.
- Aiken, D.E. and Young-Lai, W.W. (1979) Cheliped ablation and immobilization: methods for improving survival and growth of juvenile American lobsters in communal culture tanks. Proc. World Maricult. Soc., 10: 159-161.
- Aiken, D.E. and Young-Lai, W.W. (1981) Dactylotomy, chelotomy and dactylostasis. Methods for enhancing survival and growth of small lobsters (Homarus americanus) in communal conditions. Aquaculture, 22: 45-52.
- Alava, V.R. and Lim, C. (1983) The quantitative dietary protein requirements of Penaeus monodon juveniles in a controlled environment. Aquaculture, 30: 53-61.

- *Allele, W.C. and Douglas, M.B. (1945) A dominance order in the hermit crab, Pagurus longicarpus Say. Ecology, 26: 411-412.
- Apud, F.D., Gonzalez, K. and Deatras, N. (1981) Survival, growth and production of Penaeus monodon Fabricius at different stocking densities in earthen ponds with flow-through system and supplemental feeding. Fish. Res. J. Philippines, 6(2): 1-9.
- Aquacop (1977) Reproduction in captivity and growth of Penaeus monodon Fabricius in Polynesia. Proc. World Maricult. Soc., 8: 927-945.
- Aquacop (1984) Review of ten years of experimental penaeid shrimp culture in Tahiti, New Calidonia (S. Pacific). Proc. World Maricult. Soc., 15: 73-91.
- Bautista, M.N. (1986) The response of Penaeus monodon juveniles to varying protein/energy ratios in test diet. Aquaculture, 53: 229-242.
- *Bobisud, L.E. (1976) Cannibalism as an evolutionary stable strategy. Bull. Math. Biol., 38: 359-368.
- Bostford, L.W. and Wikham, D.E. (1978) Behaviour of age specific density dependent models and the northern california Dungeness crab (Cancer magister) fishery. J. Fish. Res. Bd. Canada, 35: 833-843.
- Bovbjerg, R.V. (1953) Dominance order in the cray fish Orconectes virilis (Hagen). Physiol. Zool., 26: 173-178.

- Bovbjerg, R.V. (1956) Some factors affecting aggressive behaviour in cray fish. Physiol. Zool., 29: 127-136.
- Bovbjerg, R.A. (1960) Behavioural ecology of the crab, Pachygrapsus crassipes. Ecology, 41: 668-672.
- Briggs, M.R.P., Jauncey, K. and Brown, J.H. (1988) The cholesterol and lecithine requirements of juvenile prawn (Macrobrachium rosenbergii) fed semipurified diets. Aquaculture, 70: 121-129.
- Brownell, C.L. (1985) Laboratory analysis of cannibalism by larvae of the Cape anchovy Engraulis capensis. Tras. Am. Fish. Soc., 114: 512-518.
- Carlberg, J.M., Van Olst, J.C. and Ford, R.F. (1979) Potential for commercial rearing of the nephropid lobsters (Homarus sp.). Proc. World Maricult. Soc., 10: 840-853.
- Chakraborti, R.K., Ravichandran, P., Halder, D.D., Mandal, S.K. and Sanfui, D. (1985) The physicochemical characteristics of some brackish-water ponds and their influence on the survival, growth and production of Penaeus monodon (Fabricius), Indian J. Fish., 32(2): 224-235.
- Chen, J.C., Liu, P.C. and Lin, Y.T. (1989) Culture of Penaeus monodon in an intensified system in Taiwan. Aquaculture, 77: 319-328.
- CMFRI (1990) Central Marine Fisheries Research Institute Annual, Cochin (Indian Council of Agricultural Research) Annual Report 1989-1990.
- *Cobb, J.S. (1976) The American lobster: The biology of Homarus americanus University of Rhode Island, Sea Grand Publication : pp. 32.

- Cobb, J.S. and Tamm, G.R. (1975) Dominance status and molt order in lobsters (Homarus americanus Milne Edward). Mar. Beh. Physiol., 3: 119-124.
- Craig, J.F. and Kipling, C. (1983) Reproduction effort versus the environment, case histories of Windermere perch, Perca fluviatilis L., and pike, Esox lucius L. J. Fish. Biol., 22: 713-727.
- Crump, M.L. (1983) Opportunistic cannibalism by amphibian larvae in temporary aquatic environments. Am. Nat., 121: 281-287.
- Davis, T.L.O. (1985) The food of barramundi, Lates calcarifer (Bloch), in coastal and inland waters of Van Diemen Gulf and the Gulf of Carpentaria Australia. J. Fish. Biol., 26: 669-682.
- Degani, G., Goldenberg, S. and Warburg, M.R. (1980) Cannibalistic phenomenon in Salamandra salamandra larvae in certain water bodies and under experimental conditions. Hydrobiologia, 75: 123-128.
- Degani, G. and Levanon, D. (1983) The influence of low density on food adaptation, cannibalism and growth of eels (Anguilla anguilla). BAMIDGEH, 35(2): 53-60.
- Delmendo, M.N. and Rabanal, H.R. (1956) Cultivation of 'Sugpo' (jumbo tiger shrimp), Penaeus monodon Fabricius in the Philippines. Proc. Indo-Pacific Fish. Coun., 6(23): 424-431.
- Dionne, M. (1985) Cannibalism, food availability and reproduction in the mosquito fish (Gambusia affinis): A laboratory experiment. Am. Nat., 126(1): 16-23.

- Dominey, W.J. and Blumer, L.S. (1984) Cannibalism of early life stages in fishes. In Hausfater, G. and Blaffer, S.H. (Editors). Infanticide : Comp. Evol. Persp., Aldine Publ. Co., N.Y. : 43-64.
- *Douglass, M.B. (1946) Some evidence of dominance - subordinate relationships among lobsters. Anat. Rec., 9: 553.
- Dunham, P.J. (1972) Some effects of group housing upon the aggressive behaviour of the lobster Homarus americanus. J. Fish. Res. Bd. Canada, 29: 598-601.
- Eickwort, K.R. (1973) Cannibalism and kin selection in Labidomera elivicolis (Coleoptera : chrysomelidae). Am. Nat., 107: 452-453.
- Eldani, A. and Primavera, J.H. (1981) Effect of different stocking combination on growth, production and survival of milk fish (Chanos chanos Forskal) and prawn (Penaeus monodon Fabricius) in poly culture in brackishwater ponds. Aquaculture, 23: 59-72.
- Ferraris, R.P., Parado-Esteva, F.D., De Jesus, E.G. and Ladja, J.M. (1987) Osmotic and chloride regulation in the haemolymph of the tiger prawn, Penaeus monodon during moulting in various salinities. Mar. Biol., 95: 377-385.
- Ford, R.F., Van Olst, J.C., Carlberg, J.M., Dorband, W.R. and Johnson, R.R. (1975) Beneficial use of thermal effluent in lobster culture. Proc. World Maricult. Soc., 6: 509-519.

- *Forster, J.R.M. (1970) Further studies on the culture of the prawn Palaemon serratus Pennant, with emphasis on the post-larval stages. Ministry of Agriculture, Fisheries and Food, Fishery Investigation Series II, 26(6): 1-39.
- Forster, J.R.M. (1972) Studies on the compounded diets for prawns. Proc. World Maricult. Soc., 3: 389-402.
- Forster, J.R.M. and Beard, T.W. (1974) Experiment to assess the suitability of nine species of prawns for intensive cultivation. Aquaculture, 3(4): 355-368.
- *Forster, J.R.M. and Wickins, J.F. (1972) Prawn culture in the United Kingdom, its status and potential. Laboratory Leaflet, No. 27. Fisheries Experimental Station, Conwy, Great Britain, 32 pp.
- *Fox, L.R. (1975a) Cannibalism in natural population. Ann. Rev. Ecol. Syst., 6: 87-106.
- Fox, L.R. (1975b) Factors influencing cannibalism, a mechanism of population limitation in the predator Notonecta hoffmanis. Ecology, 56: 933-941.
- *Fujimura, T. (1972) Development of a prawn culture industry. Annual Report from Hawaii Department of Land and Natural Resources, 6 pp.
- *Fujimura, T. and Okomoto, H. (1970) Notes on progress made in developing a mass culture technique for Macrobrachium rosenbergii in Hawaii. Indo-Pac. Fish. Coun., 14th Session (FAO) Bangkok, 10 pp

- Ghosh, A.N., Das, N.K. and Mzumdar, H.S. (1973) Pilot observations on the culture of prawns in brackishwater ponds at Kakdwip, West Bengal. Proc. Sem. Maricult. Mech. Fishing., Madras, India.: 86-88.
- Giles, N., Wright, R.M. and Nord, M.E. (1986) Cannibalism in pike fry Esox lucius L.: Some experiment with fry densities. J. Fish. Biol., 29(1): 107-113.
- Goldspink, C.R. and Goodwin, D. (1979) A note on the age composition, growth rate and food of perch, Perca fluviatilis (L.) in four eutrophic lakes, England. J. Fish. Biol., 14: 489-505.
- Hajra, A., Ghosh, A. and Mandal, S.K. (1988) Biochemical studies on the determination of optimum dietary protein to energy ratio for tiger prawn, Penaeus monodon (Fabricius) juveniles. Aquaculture, 71: 71-79.
- *Hand, C. (1977) Development of aquaculture systems. University of California Sea Grant Programme Publication, (No. 58): 97 pp.
- Harvey, M. (1990) Mud crab culture in Thailand. INFOFISH International 6/90: 53-54.
- Hecht, T. and Appelbaum, T. (1988) Observation on intraspecific aggression and coeval sibling cannibalism by larval and juvenile Clarias gariepinus (Claridae : Pisces) under controlled conditions. J. Zool., 214(1): 21-44.

- Hedgecock, D. and Nelson, K. (1978) Components of growth rate variation among laboratory cultured lobsters (Homarus americanus). Proc. World. Maricult. Soc., 9: 125-136.
- *Hrdy, S.B. (1979) Infanticides among animals : A review classification, and examination of the implications for the reproductive strategies of females. Ethol. Sociobiol., 1: 13-40.
- Hughes, D.A. (1966) Behavioural and ecological investigations of the crab Ocypode ceratophthalmus (Crustacea : Ocypodidae). J. Zool., 150: 129-143.
- Hunt, B.P. and Carbine, W.F. (1951) Food of young pike, Esox lucius L. and associated fishes in Peterson's ditches Houghton Lake, Michigan. Trans. Am. Fish. Soc., 80: 67-83.
- Jones, J.S. (1982) On cannibalism and kins. Nature, 229: 202-203.
- Karplus, I., Haluta, G., Wholfarth, G.W. and Halevy, A. (1986) The effect of density of Macrobrachium rosenbergii raised in earthen ponds on their population structure and weight distribution. Aquaculture, 52: 307-320.
- Karplus, I., Samsonov, E., Haluta, G. and Milstein, A. (1989) Social control of growth in Macrobrachium rosenbergii. The effect of claw ablation on survival and growth of communally raised prawns. Aquaculture, 80: 325-335.

- Kendall, R.A., Van Olst, J.C. and Carlberg, J.M. (1982) Effects of chelae immobilization on growth and survivorship for individually and communally raised lobsters, Homarus americanus. Aqua-culture, 29: 359-372.
- Kentouri, M. (1980) Rearing of larvae of seabass (Dicentrarchus labrax) using frozen zooplankton organisms: Preliminary results. Aqua-culture, 21: 171-180.
- Kipling, C. and Frost, W.E. (1970) A study of the mortality, population numbers, year class strengths, production and food consumption of pike, Esox lucius L., in Windermere from 1944-1962. J. Anim. Ecol., 39: 115-158.
- *Koenekoop, R.K. and Livdhal, T.P. (1980) Cannibalism among Aedes triseriatus larvae. Ecol. Entomol., 11(1): 111-114.
- Krishnan, P., Shaick Jalaluddin, R. and Jayasundari, K. (1983) Studies on the penaeid prawn farming in floating and fixed cages in the brackishwaters of Kovalam. Proc. Natl. Sem. Cage and Pen. Culture, Tuticorin: 89-93.
- Kurihara, Y. and Okomoto, K. (1987) Cannibalism in a grapsid crab, Hemigrapsus penicillatus. Mar. Ecol., 41(2): 123-127.
- Kurihara, Y., Okomoto, K. and Takeda, S. (1989) Preference of the grapsid crab, Hemigrapsus penicillatus (De Hann) for an appropriate aperture. Mar. Beh. Physiol., 14(3): 169-179.

- Kurihara, Y., Sekimoto, K. and Miyata, M. (1988) Wandering behaviour of the mud crab, Helice tridens related to evasion of cannibalism. Mar. Ecol., 49(1-2): 41-50.
- Lee, D. (1971) Studies on the protein utilization related to growth of Penaeus monodon Fabricius. Aquaculture, 1(4): 1-13.
- Legardere, J.P. (1982) Effect of noise on growth and reproduction of Crangon crangon in rearing tanks. Mar. Biol., 71(2): 177-185.
- *Ling, S.W. (1962) Studies on the rearing of larvae and juveniles and culturing of adults of Macrobrachium rosenbergii (de Man). Indo-Pac. Fish. Coun. Curr. Affairs Bull. (FAO), 35: 1-11.
- Ling, S.W. (1969) The general biology and development of Macrobrachium rosenbergii (de Man). Proc. World Scient. Conf. Biol. Cult. Shrimp and Prawns (FAO) 57(3): 589-606.
- *Ling, S.W. and Merican, A.B.O. (1961) Notes on the life and habits of the adults and larval stages of Macrobrachium rosenbergii (de Man). Proc. Indo-Pac. Fish. Coun., 9: 55-60.
- Liu, M.S. and Mancebo, V.J. (1983) Pond culture of Penaeus monodon in the Philippines : Survival, growth and yield using commercial formulated feed. Proc. World Maricult. Soc., 14: 75-85.
- Loadman, N.L., Modie, G.E.E. and Mathias, J.A. (1986) Significance of cannibalism in larval walley (Stizostedion vitreum). Can. J. Fish. Aquat. Sci., 43(3): 613-618.

- *Lowe, M.E. (1956) Dominance-sub-ordinance relationship in the cray fish Cambarellus shufeltii. Tulane Stud. Zool., 4: 139-170.
- Maheswari, R.U. (1983) Studies on the cage culture of prawns, Penaeus indicus and Penaeus monodon. Proc. Natl. Semi. Cage and Pen Culture, Tuticorin : 95-98.
- Mann, R.H.K. (1982) The annual food consumption and prey preferences of pike (Esox lucius) in the River Frome, Dorset. J. Anim. Ecol., 51: 81-95.
- *Mc Burney, D.R. and Wilder, D.G. (1973) Survival and conditions of lobsters in a tide pond related to feeding cover and stock density. Fish. Res. Bd. Canada, St Andrews, N.B. Technical Report Number 377, 599 pp.
- Mc Leese, D.W. (1972) Effect of several factors upon the growth of American lobster (Homarus americanus) in captivity. J. Fish. Res. Bd. Canada, 29: 1725-1730.
- Mertz, D.B. and Robertson, J.R. (1970) Some development consequences of handling, egg eating and population density for flour beetle larvae. Ecology, 51: 989-998.
- Mohamed, K.H. (1983) Hatchery production of prawn seed. Proc. Natl. Symp. Shrimp Seed production and Hatch. Management, Cochin: 117-137.
- *Momot, W.T. (1967) Population dynamics and productivity of the cray fish Orconectes virilis in a marl lake. Am. Midl. Nat., 78: 55-81.

- *Munro, W. R. (1957) The pike of loch Choin. Freshwat. Salmon Fish. Res., Scottish Home Department, 16 pp.
- Muthu, M.S., Kathirvel, M., Vedavyasa, P. and Pillai, N.N. (1982) Research progress in the culture of penaeid prawn along the coast of Indian ocean and Indo-Pacific. Proc. Symp. Coastal Aquaculture, 1: 1-11.
- *Nataraj, S. (1947) Preliminary observations on the bionomics, reproduction and embryonic stages of Palaemon idae Heller. Rec. Indian, 45(1): 89-96.
- Natarajan, P., Sundararaj, V. and Kuthalingam, M.D.K. (1983) Review on cage and pen culture. Proc. Natl. Sem. Cage and Pen Culture, Tuticorin: 1-4.
- Natarajan, P. and Thangaraj, G.S. (1983) Studies on the growth of edible crab, Scylla serrata in a barackishwater cage. Proc. Natl. Sem. Cage and Pen Culture, Turicorin: 107-110.
- Navas, K.A. (1988) Effect of low salinities on the growth and survival of Penaeus monodon Fabricius. M.F.Sc. Thesis, Submitted to the Kerala Agricultural University, 82 pp.
- * Nicholson, A.J. (1933) The balance of animal populations. J. Anim. Ecol., 2: 132-178.

- Packer, C. and Pusey, A.E. (1984) Infanticide in carnivores. In: Hausfater, G. and Blaffer, S.H. (Editors). Infanticide : Comp. Evol. Persp. Aldine Publ. Co., N.Y., : 31-42.
- Pascual, F.P. (1988) Nutrition. In : Biology and culture of Penaeus monodon. Brackishwater Aquaculture Informative System, South East Asian Fisheries Development Centre, Tigbaun, Iloilo, Philippines, : 119-137.
- Passano, L.M. (1960) Molting and its control. In: Waterman, T.H. (Editor) The physiology of crustacea, Vol.1. Metabolism and Growth. Academic Press Newyork, : 473-536.
- Pearre, S. (Jr.) (1982) Feeding by chaetognath : Aspects of inter and intra-specific predation. Mar. Ecol., 7(1): 33-45.
- Peebles, J.B. (1977) Notes on mortality, cannibalism and competition in Macrobrachium rosenbergii. In : J.A. Hanson and H.L. Goodwin (Editors). Shrimp and Prawn Farming in the Western Hemisphere Dowden, Hutchinson and Ross Inc., : 266-271.
- Peebles, B. (1978) Molting and mortality in Macrobrachium rosenbergii. Proc. World Maricult. Soc., 9: 39-46.
- Peebles, B. (1979a) Moulting movement and dispersion in the freshwater prawn Macrobrachium rosenbergii. J. Fish. Res. Bd. Canada, 36: 1080-1088.

- Peebles, B. (1979b) The role of prior residence and relative size in competition for shelter by the Malaysian prawn, Macrobrachium rosenbergii. Fish. Bull., 76(4): 905-911.
- *Polis, G.A. (1981) The evolution and dynamics of intraspecific competition. Ann. Rev. Ecol. Syst., 12: 225-251.
- *Ra'anan, Z. (1982) The ontogeny of social structure of the freshwater prawn Macrobrachium rosenbergii. Ph.D. Thesis, Submitted to the Hebrew University, Jeruzalem, Israel, 101 pp. (Abstract).
- Ra'anan, Z. and Cohen, D. (1984a) The effect of group interactions on the development of size distribution in Macrobrachium rosenbergii (de Man) juvenile population. Biol. Bull., 166(1): 22-31.
- Ra'anan, Z. and Cohen, D. (1984b) Characterization of size distribution development in the fresh water prawn Macrobrachium rosenbergii (de Man) juvenile populations. Crustaceana, 46(3): 271-282.
- Rajyalakshmi, T. (1978) Food and feeding in prawn, in hatcheries and intensive rearing systems. Proc. Indian Sc. Nat. Acad., 46(1): 63-71.
- Rajyalakshmi, T. (1982) Some aspects of prawn culture with particular reference to tiger prawn Penaeus monodon Fabricius. Proc. Symp. Coastal Aquaculture, 1: 63-70.

- Rajyalakshmi, T., Pillai, S.M., Roy, A.K. and Varghese, P.U. (1982) Studies on the rearing of Penaeus monodon Fabricius in brackishwater ponds using pelleted feeds. J. Inland Fish. Soc. India., 14(1): 28-37.
- Rao, R.M. (1965) Breeding behaviour in Macrobrachium rosenbergii (de Man). Fish. Tech., 2(1): 19-25.
- Rao, K.G., Reddy, O.R., Rama Rao, P.V.A.N. and Ramakrishna, R. (1986) Monoculture of Indian freshwater prawn, Macrobrachium malcolmsonii (Milne Edwards). Aquaculture, 53: 67-73.
- Ravichandran, P., Verghese, P.U., Karmakar, H.C. and Rajyalakshmi, T. (1982) Effect of stocking density and size of Penaeus monodon Fabricius post-larvae in nursery rearing experiment. Proc. Symp. Coastal Aquaculture, 1: 412-413.
- *Reeve, M.R. (1969) The laboratory culture of the prawn, Palaemon serratus. Fish. Invest. London, Ser. II., 26(1): 1-38.
- Rickards, W.L. (1971) Studies of the use of vertical substrate for improving production of pink shrimp Penaeus duororum Burkenroad. University of Miami Sea Grant Technical Bulletin, No. 10: 152.
- Sandifer, P.A. and Smith, T.I.J. (1974) Development of a crustacean mariculture programme at south Carolinas Marine Resource Research Institute. Proc. World Maricult. Soc., 5: 431-442.

- Sandifer, P.A. and Smith, T.I.J. (1975) Effect of population density on growth and survival of Macrobrachium rosenbergii reared in recirculating water management systems. Proc. World Maricult. Soc., 6: 43-54.
- Sankolli, K.N., Shenoy, S.S. and Neelakantan, B. (1972) On the occurrence of Lipolycid prawn Angasia armata (Paulson) (Decapoda: Crustacea) in Bombay waters, its cannibalistic tendencies and its larvae. J. Bombay Nat. Hist. Soc., 69(2): 369-377.
- Sastry, A.N. and Zeitlin-Hale, L. (1977) Survival of communally reared larval and juvenile lobsters, Homarus americanus. Mar. Biol., 39: 297-303.
- *Schulte, E.H. (1976) The laboratory culture of the palaemonid prawn, Leander squilla. In: Personne, G. and Jaspers, E. (Editors), Tenth European Symp. Mar. Biol. Maricult. (University Press, Wetteran, Belgium), 1: 437-454.
- Segal, E. and Roe, A. (1975) Growth and behaviour of post-juvenile Macrobrachium rosenbergii (de Man) in close confinement. Proc. World Maricult. Soc., 6: 67-88.
- Shleeser, R.A. (1974) Studies of the effects of feeding frequency and space on the growth of the American lobster Homarus americanus. Proc. World Maricult. Soc., 5: 149-156.
- Shyama, S.K. (1987) Studies on moulting and reproduction in the prawn, Macrobrachium idella (Heller). Mahasagar, 20(1): 15-21.

- Sidharaju, S., Sultan, K.M.M. and Menon, V.R. (1980) Nursery rearing of post-larvae of two commercially important penaeid prawns in Nylon cages. Proc. Symp. Coastal Aquaculture, 1: 403-405.
- Silas, E.G., George, M.J. and Jacob, T. (1981) A review of the shrimp fisheries of India. A scientific basis for the management of the resources. Workshop on the Scientific basis for the Management of Penaeid Shrimp. Key West, Florida, USA.
- *Simon, M.P. (1984) The influence of conspecifics on egg and larval mortality in amphibians. In: Hausfater, G. and Blaffer, S.H. (Editors) Infanticide: Comp. Evol. Persp. Aldine Publ. Co., N.Y., : 65-86.
- Smith, T.I.J. and Sandifer, P.A. (1975) Increased production of tank reared Macrobrachium rosenbergii through use of artificial substrates. Proc. World Maricult. Soc., 6: 55-66.
- *Stenseth, N. and Reed, J. (1978) A comment on Bobisud's paper on the evolution of cannibalism. Bull. Math. Biol., 40: 541-545.
- Stewart, J.E. and Squires, H.J. (1968) Adverse conditions as inhibitors of ecdysis in the lobster, Homarus americanus. J. Fish. Res. Bd. Canada, 25(9): 1763-1774.
- Strickland, J.D.H. and Parsons, T.R. (1972) A practical handbook of sea water analysis. Bull. Fish. Res. Bd. Can., 167 2nd Edition pp. 311.
- Subrahmanyam, M. (1973) Growth of Penaeus monodon Fabricius under laboratory conditions. Indian J. Mar. Sc., 2(1): 63-65.
- Tabbu, N.S. (1984) Growth and survival of Penaeus monodon post-larvae with different feeding regimes and stocking densities in earthen brackishwater nursery ponds. Proc. First Inter. Nat. Conf. Cul. Penaeid Prawns/Shrimps (Abstract) : 180.

- Tamm, G.R. and Cobb, J.S. (1976) Diel ecdysis rhythms in juvenile lobsters, Homarus americanus. J. Fish. Res. Bd. Canada, 33: 819-821.
- Thampy, D.M., Susheela Jose, Koya, M.S.S.I. and Mohan, M.V. (1987) Utilization of brackishwater area of Kerala by adoption of triple cropping with penaeid prawns and fish. Presented in the seminar on Fisheries Research and Development in Kerala, Dept. of Aquatic Biology and Fisheries University of Kerala (in press).
- Thampy, D.M., Susheela Jose, Mohan, M.V. and Koya, M.S.S.I. (1988) Short term biculture of tiger prawn, Penaeus monodon Fabricius and milk fish Chanos chanos Forskal in low saline pond. The First Indian Fisheries Forum, Proc. Asian Fish. Soc., Indian Branch, Manglore, : 139-141.
- Tiensongrusmee, B. and Manik, R. (1980) Semi-intensive monoculture of the tiger shrimp. Bull. Brackishwater Aquacul. Development Centre, Japara, 6(1-2): 396-403.
- *Turpayeva, Ye. P., Galperin, M.V. and Chugay, V.V. (1981) Elimination losses in a developing population of Rhithropanopeus harrisi tridentatus. OCEANOL. Acad. Sci., U.S.S.R., 21(6) : 767-771.
- Van Olst, J.C. and Carlberg, J.M. (1978) The effect of container size and transparency on growth and survival of lobsters cultured individually. Proc. World Maricult. Soc., 9: 469-479.

- Van Olst, J.C., Carlberg, J.M. and Ford, R.F. (1975a) Effect of substrate types and other factors on the growth, survival and cannibalism of juvenile Homarus americanus in mass rearing systems. Proc. World Maricult. Soc., 6: 261-274.
- Van Olst, J.C., Carlberg, J.M. and Ford, R.F. (1977) A description of intensive culture systems for the American lobster (Homarus americanus) and other cannibalistic crustaceans. Proc. World Maricult. Soc., 8: 271-292.
- *Van Olst, J.C., Ford, R.F., Carlberg, J.M. and Dorband, W.R. (1975b) Use of thermal effluent in culturing the American lobster. In Power Plant Waste Heat Utilization in Aquaculture, Workshop 1. PSE & G Company Newark, New Jersey: 71-100.
- Venketesan, V. and Bose, V.C.S. (1982) Observation on the culture of tiger prawn Penaeus monodon Fabricius in brackishwater ponds. Proc. Symp. Coastal Aquaculture, 1: 146-150.
- Verghese, P.U. (1976) Nursery rearing of the brackishwater prawn post-larvae and fish seeds. Report of the Training Course on the Culture of Brackishwater Fishes and Prawns : 16-17.
- Verghese, P.U., Ghosh, A.N. and Das, P.B. (1975) On growth survival and production of jumbo tiger prawn Penaeus monodon (Fabricius) in brackishwater ponds. Bull. Dept. Mar. Sc., Univ. Cochin, 7(4): 781-789.
- Verghese, P.U., Ravichandran, P. and Pillai, S.M. (1982a) Growth and production of Penaeus monodon Fabricius in short term field rearing experiments, (Abstract). Proc. Symp. Coastal Aquaculture, 1: 419.

- Verghese, P.U., Verghese, A.G., Chandran, K.K., Thomas, A. and John, S. (1982b) Improved prawn production through selective stocking. Proc. Symp. Coastal Aquaculture, 1: 388-392.
- *Waterman, T.H. (1961) Comparative physiology. In: Waterman, T.H. (Eds). The Physiology of Crustacea, Vol. 2. Sense organs, Integration and Behaviour. Academic Press, New York, pp. 681.
- *Wickins, J.F. (1972a) Developments in the laboratory culture of the common prawn Palaemon serratus Pennant. Fish. Invest. London, Ser. II, 27(2): 435-507.
- *Wickins, J.F. (1972b) Experiments on the culture of the spot prawn, Pandalus platyceros. Brandt and giant fresh water prawn Macrobrachium rosenbergii (de Man) Fish. Invest. London, Ser. II, 27(5): 1-23.
- Winas, S.T. (1990) Pen culture technique for marine shrimp in Thailand. INFOFISH International, 2/90: 38-40.
- Wyban, T.A. and Sweeney, T.N. (1989) Intensive shrimp growout trials in a round pond. Aquaculture, 76: 215-225.
- *Yamane, T., Litaka, Y. and Flores, E. (1988) Cannibalistic behaviour of striped prawn, Palaemon paucidens in captivity. Mem. Fac. Agric. Kinki. Uni./Kinkidai No Kiyo., No. 21: 25-34.

* Originals are not referred.



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

BY

ABDUSSAMAD E. M.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the
requirement for the degree

MASTER OF FISHERIES SCIENCE

Faculty of Fisheries

Kerala Agricultural University

Department of Aquaculture

COLLEGE OF FISHERIES

Panangad - Cochin

1991

ABSTRACT

Factors influencing the rate of cannibalism in the post-larvae and juveniles of Penaeus monodon, were investigated under laboratory conditions. Cannibalism 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 shelters suitable for reducing cannibalism and assuring high carrying capacity. Feeding frequency was found to have greatest influence on cannibalism, which decreased with increase in feeding frequency.

In P. monodon post-larvae cannibalism is invariably associated with attack made on animals undergoing moulting and is independent on the size of the victim. A high rate of cannibalism was observed during the early post-larval phase and it progressively decreased towards the late post-larval stage and juvenile stage, may be due to the decreased moulting frequency and acclimation to new rearing conditions and artificial feed.

Substantial variation in size and growth rate was observed among individuals at all stocking densities. The marked difference in individual growth rate observed within the group could be due to the interaction of various intrinsic and extrinsic factors.

