DIFFERENTIAL GROWTH IN THE GIANT FRESHWATER PRAWN *MACROBRACHIUM ROSENBERGII* (De Man) DURING NURSERY REARING PHASE

BY
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THESIS

Submitted in partial fulfilment of the
requirement for the degree

MASTER OF FISHERIES SCIENCE

Faculty of Fisheries
Kerala Agricultural University

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Panangad Cochin

1997

Dedicated to my Father

DECLARATION

I hereby declare that this thesis entitled DIFFERENTIAL GROWTH IN THE GIANT FRESHWATER PRAWN *MACROBRACHIUM ROSENBERGII* (De Man) DURING 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

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CERTIFICATE

Certified that this thesis entitled DIFFERENTIAL GROWTH IN THE GIANT FRESHWATER PRAWN *MACROBRACHIUM ROSENBERGII* (De Man) DURING NURSERY REARING PHASE is a record of research work done independently by Sri Mainuddin Ahmed 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

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ACKNOWLEDGEMENTS

I wish to offer my heartiest gratitude to all my wellwishers who contributed in one or other ways to the successful completion of my research work and preparation of the thesis

I am ever indebted to **Dr D M Thampy** Professor & Head Department of Aquaculture and Dean i/c College of Fisheries Panangad for his valuable guidance and constant encouragement during the course of the study and for extending his kind help for the preparation of the thesis I am also grateful to him for providing me the facilities required for conducting the experiments

I am greatly indebted to all the members of the advisory commitee **Sri T M. Sankaran, Dr P M Sherief** and **Dr C Mohanakumaran Nair** for their valuable advice and timely suggestions for designing and conductmg the experiments and also for preparation of the thesis

The help extended by all other staff in the Department of Aquaculture is also greatly acknowledged

I am thankful to the staff of libraries of College of Fisheries Panangad and Central Marine Fisheries Research Institute Cochin for their kind help whenever needed

I am grateful to the **Indian Council of Agricultutal Research (ICAR)** Pusa New Delhi for providing me the ICAR Junior Fellowship

With deep sense of obligation I recall the sincere efforts and timely suggestions of my friends such as **Sreeja, Vimala, Mohammed Koya Sunil** and many others who were always with me whenever needed I am ever thankful to them for their open hearted help

I am thankful to the staff of **Focus Communication** Cochin for neatly printing out the thesis

Panangad
27 2 1997

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1 INTRODUCTION

The freshwater prawns belonging to the genus *Macrobrachium* are distributed throughout the tropical and subtropical areas of the world Of the 100 or so species of this genus available all over the world the giant freshwater prawn *Macrobrachium rosenbergii* (De Man) is the most coveted species for aquaculture throughout the world owing to its fast growth rate better survival higher tolerance to wide range of salinity and temperature acceptance of both plant and animal diets more disease resistance compatibility with non predacious fish and high domestic demand and export value

The giant prawn is widely cultured in Asian countries such as Thailand Taiwan Ma laysia Vietnam India Indonesia and Bangladesh and Hawaii and South Carolina in USA The global production of freshwater prawn increased from 9448 tonnes in 1985 to 37 631 tonnes in 1991 The production decreased to 31 235 tonnes in 1992 mostly due to some problems in Taiwan There was again an increasing trend in the production of this species and in 1994 the global production was 34 000 tonnes of which Asia alone contributed to about 29 000 tonnes (92%) It is predicted that by the year 2000 AD the global production would reach 1 00 000 tonnes and Asian production to about 68 000 tonnes

Culture of freshwater prawns world over today would not have been possible without the pioneering work of S W Ling in 1950 s who found out that for the larval rearing of *M rosenbergii* 12 14 ppt salinity is required It was Fujimura (1966) who had developed the mass rearing techniques of larvae using green water system However the green water system did not get much popularity due to various inherent problems associated with it As an im provement over this method the clear water system was developed latter

As the technology for the hatchery production of the giant freshwater prawn has almost been perfected and hatcheries have been set up in interior areas there is likely to be a boost in the farming of frestwater prawns in the years to come Concurrent with the developments in the seed production there should be developments in nursery rearing of the seed and grow out operations

The post larvae are normally reared in nursery for a period of 30 60 days depending on the stocking density and stocking size required in grow out ponds The nursery rearing of post larvae has several advantages such as (i) giving higher production and greater average size at harvest (Sandifer and Smith 1979) (ii) reducing the period required for grow out operation in temperate areas and in areas with limited water supply (Willis and Berrigan 1977) (iii) increasing the survival rate due to the fact that juveniles are more resistent to the wide range of fluctuation in ecological conditions in an open grow out pond (Ling 1967 Fujimura and Okamoto 1972) (iv) enablmg polyculture with fish as juveniles, which are better suited for this (Cohen *et al* 1981) and (v) helping in combating differential growth as stocking size graded juveniles after nursery rearing brings in more uniformity in growth (Daniels and D Abramo 1994)

Provision of various natural substrates or habitat materials in the tanks used for holding post larvae for nursery rearing has helped in increasing the growth rate and survival of juve niles Development of efficient habitat designs (Smith and Sandifer 1978) has substantially increased carrying capacity of such systems (Sandifer and Smith 1977 Smith and Sandifer 1979)

The production from grow out pond varies according to the system followed the stock ing density the feeding and the management The average yield varies from 500kg to 10 000kg/ ha/crop depending on the type of grow out operation (New 1994) In tropical areas prawns are selectively harvested on a regular basis from continuous production ponds (Fujimura 1974) whereas in temperate areas pond drainage and batch harvest are usually followed (Smith *et al* 1976)

M rosenbergii shows a wide range of size variation The post larvae of this species have a normal size distribution (Sandifer and Smith 1975 Ra anan and Cohen 1984a) the growth of juveniles is variable(Malecha 1980) and with time the variation in size increases more rapidly It is reported that half of the population grows rapidly and variably while the other half grows slowly and relatively uniformly leading to a markedly positively skewed size distribution (Wickins 1972 Forster and Beard 1974 Sandifer and Smith 1975 Malecha *et al* 1977 Willis and Berrigan 1977 Ra anan and Cohen 1982 1984a 1985) As the prawns mature the size distribution becomes quite different for males and females Mature females grow slowly than males of sımılar sıze and the sıze dıstrıbutıon of females regaıns approxı mately normal pattern (Cohen *et al* 1981) For the males the skewed dıstrıbutıon ıs extended even reınforced upon maturatıon (Fujımura and Okamoto 1972 Smıth *et al* 1978 Brody *et al* 1980 Malecha *et al* 1984) and thıs ıs assocıated wıth the dıfferentıatıon of three anatomı cally physıologıcally and behavıorally dıstınct adult male morphotypes (Ra anan 1982 Ra anan and Sagı 1985 Kurıs *et al* 1987 Sagı and Ra anan 1988 Sagı *et al* 1988) such as blue claw males orange claw males and small males The blue claw males are sexually more actıve and have the lowest growth rate whereas the orange claw males are sexually least actıve and have the hıghest growth rate The small males have very stunted growth and theır growth ıs sup pressed by both blue claw and orange claw males

Stuntıng of males of *M rosenbergıı* expressed by a hıgh frequency of small male morphotype ın the populatıon ıs a major problem confrontıng the farmers Moreover ın some places there ıs lıttle demand for small prawns (Karplus *et al* 1986b) Reductıon or elımınatıon of growth suppressıon and to achıeve a more or less unıform growth of prawns ıs therefore of great ımportance to prawn culture

The understandıng of the facts ınfluencıng the rate of ıncrease ın sıze varıatıon and skewness ın *M rosenbergıı* juvenıle populatıons ıs of specıal ınterest due to the promısıng potentıal of thıs gıant freshwater prawn as a candıdate for aquaculture Therefore a serıes of experıments were conducted to fınd the cause of dıfferentıal growth and the way to combat ıt In the present study experıments were conducted to ınvestıgate (ı) the effect of stockıng densıty on dıfferentıal growth and survıval (ıı) the effect of provısıon of addıtıonal substrates on dıfferentıal growth and survıval and (ııı) the extent of varıatıon of the dıfferentıal growth among the juvenıles of dıfferent sızes

2 REVIEW OF LITERATURE

2 1 Growth in Crustaceans

Growth is the increase in length volume or weight over time (Nikolskii 1969 Hartnoll 1982) and is the result of a balance between the process of anabolism and catabo lism that occur in an individual (Von Bertalanffy 1938) Growth is characterized primarily by an increase in protein minerals and water (Shepherd and Bromage 1988) In Crustacea growth is a discontinuous process There is succession of moults (ecdysis) separated by intermoults During the latter the integument is hard and growth is limited though not totally suppressed as is often assumed At each moult the old integument is shed and rapid and extensive growth occurs during the short period before the new integument hardens Some intermoult growth is possible as the flexible arthrodial membranes linking the endoskeletal plates are capable of extension According to Van Olst and Carlberg (1978) growth in crusta ceans is actually a combination of two related components viz moulting frequency and size increment per moult

Growth in crustaceans is under endocrine control The X organ sinus gland complex located in the eyestalk control growth reproduction moulting retina land somatic pigment migration metabolism of blood sugar proteins lipids and fatty acids osmoregulation feed ing and food conversion efficiency (Newcomb 1983 Chandry and Kalwalkar 1984)

The moult inhibiting hormone (MIH) a neuropeptide originating from the X organ and stored in the sinus gland is known to inhibit the secretion of ecdysteroids by the Y organ or moult gland

Growth in crustaceans may be enhanced by shortening of the moult cycle increasing size increments per moult, higher food intake and better food conversion efficiency (Vijayakumaran and Radhakrishnan 1984 Duval 1994)

2 1 1 Growth Variation in Crustaceans

Most of the communally reared aquatic organisms show the characteristic of differen tial growth In general heterogeneous growth in aquatic species has been associated with (a) intrinsic factors such as genetic differences hatching order or age at metamorphosis (Newkirk *et al* 1977 Sandifer and Smith 1979) (b) environmental factors giving rise to competitive situations in cases of limited resources such as space and food (Magnuson 1962 Willbur and Collins 1973) and (c) Social factors such as position within the size hierarchy (Brown 1946) social status and territoriality (Symons 1972) Crustaceans as a group also exhibit differential growth being very pronounced in some groups Differences in growth rates of crustaceans could result from either differential frequency of moulting or different size increments per moult or both

Progressive increase in disparity of size among crustaceans under controlled rearing conditions has been observed in *M rosenbergii* (Forster and Wickins 1972 Wickins 1972 Forster and Beard 1974 Segal and Roe 1975 Sandifer and Smith 1975 Willis et al ,1976 Malecha et al ,1977 Willis and Berrigan 1977 Cohen *et al* 1981 Ra anan 1982 1983 Ra anan and Cohen 1984 a b Mulla and Rouse 1985 Karplus *et at* 1986 b 1987 1989 1991 1992 a b Hulata *et al* 1990 Ra anan *et al* 1991 Siddiqui and Al Hinty 1993 Daniels and D Abramo 1994 and Daniels *et al* 1995) *M malcolmsonii* (Rao *et al* 1986) *M australiense* (Lee and Fielder 1983) *M nipponense* (Kulesh and Guiguinyak (1993) in *Penaeus monodon* (Abdussamad 1991) and in *Homarus americanus* (Douglis 1946 Stewart and Squires 1968 Mc Leese 1972 Cobb and Tamm 1975 and Sastry and Zeitlin Hale 1977)

2 1 1 1 Influence of Growth Variation on Cannibalism in Crustaceans

Relative size of 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)

The development of agonistic behaviour pattern and size variation within groups of communally reared lobster *H americanus* was reported to be responsible for the establish ment of dominance hierarchies According to Cobb and Tamm (1975) and Sastry and Zeitlin Hale (1977) the development of dominance hierarchies typically decreased the aggressive behaviour within a group and hence may influence the mortality rate due to cannibalism

They are of the view that 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 in association with moult cycle

Kurihara and Okamoto (1987) investigated the relationship between cannibalism and the body size of predator and prey in graspid crab *Hemigraspus penicillatus* It was shown that an increase in population density and size dispersal increases the cannibalistic death in mixed population of larger and smaller individuals both in natural and laboratory conditions They also found that the predators preyed only on smaller individuals and the large predators preferably preyed on larger preys

In the case of *Palaemon paucidens* Yamane *et al* (1988) found that there is no relation ship between cannibalism and the size of the prey Cannibalism among individual prawn was closely related to the condition of the individual prey whether it is moulted or not

2 2 Growth in *Macrobrachium spp*

2 2 1 Growth Variation in Macrobrachium spp

Newly metamorphosed post larvae of *Macrobrachium rosenbergii* demonstrate a ho mogeneous size distribution and with time the homogeneous distribution gradually changes to a positively skewed size distribution (Wickins 1972 Forster and Beard 1974 Sandifer and smith 1975 Malecha *et al* 1977 Willis and Berrigan 1977 Ra anan 1982 Ra anan and Cohen 1984 a b) According to Willis and Berrigan (1977) two distinct types of juveniles are there on the basis of their relative growth rates jumpers and laggards Jumpers are exception ally fast growing individuals which are 15 times larger than the population mode within a period of 60 days from metamorphosis (Willis and Berrigan 1977 Ra anan 1987) On the other hand the laggards are exceptionally slow growing individuals and their growth is suppressed by jumpers According to Ra anan and Cohen (1984a) this size hierarchy is formed within two weeks from metamorphosis

Ra anan and Cohen (1984b) found that jumpers and laggards did not develop when prawns were held individually indicating the importance of group interactions in the development of size variation and hierarchy They further observed the continuation of differential growth pattern established during communal rearing even when jumpers and laggards were seggregated and reared separately

The size increment per moult cycle of isolated juveniles after communal rearing was found to be strongly correlated with the relative size ranking of the individuals within its original population (Ra anan 1983)

The duration of moult cycle in jumpers was 50% shorter when paired with a laggard than when raised in isolation The laggards showed the reverse trend i e their moult cycle was about 50% longer when paired with a jumper than when raised in isolation (Ra anan 1983) According to Karplus et al (1991) determination of growth pattern of juvenile prawns occur sometime between metamorphosis and the early juvenile stage when population mean weight reached 1 2g

In the immature population of *M rosenbergii* the pattern of size distribution is irrespective of sex In the mature population the size distribution becomes quite different for males and females mature females growing more slowly than males of similar size

Among the mature females there is a normal size distribution whereas among the mature males there is a skewed size distribution (Fujimura and Okamoto 1972 Smith et al , 1980 Malecha et al 1984) According to Ra anan *et al* (1991) growth of female prawns nearly ceased after maturation leading to a unimodal symmetrical size distribution In the case of males the growth rate is different among the various morphotypes small male having a slow growth rate the orange claw male having a high growth rate and the orange claw males transforming to the blue claw morphotype by stoping further growth

They further reported that the fast growing largest orange claw male as the first to metamorphose to the blue claw morphotype and that when other individuals of orange claw morphotype exceed this size they transform to the blue claw morphotype Thus growth of males is depensatory throughout the process of morphotype differentiation leading to a wide size range of small orange and blue claw males (Ra anan *et al* 1991)

2 2 1 1 Causes of Growth Variation in *Macrobrachium spp*

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 Ra anan 1982) Individual rearing of *M rosenbergii* juveniles by Briggs *et al* (1988) resulted in differential growth,supporting the genetic basis for growth variation Kulesh and Guiguinyak(1993) also demonstrated the uneven development of larvae of *M nipponense* from a single clutch of eggs Changes in larval development and fluctuations in growth seem to be determined at the egg stage which indicates that genetic factors are more influential than environmental factors In contrast to these findings Malecha (1977) reasoned that the size variation is due more to social interactions than to the segregation and independent assortment of genes controlling growth So also Ra anan and Cohen (1984b) found that prawns raised in group showed a relative excess of size variation (primarily associated with the appearance of two size classes) which failed to appear among juveniles raised m isolation Thus they suggested that 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 Karplus and Hulata (1992) reported that juveniles of *M rosenbergii* have a relatively uniform growth rate when raised in isolation in the laboratory as compared to large differences in size when raised in groups They found that juvenile groups of prawns with ablated claws grew more uniformly than those with intact claws They are of the view that social interactions among individuals have a major role in the development of size distribution The average weight of communally reared *M rosenbergii* juveniles was more than that of the individually grown animals which indicates that the superior growth rate in the case of jumpers is due to the presence of some stimulus which is lacking under conditions of individual isolation Lee and Fielder (1983) reported an indentical phenomenon in *M australiense*

2 2 1 1 1 Social Factors Controlling the Growth Variation

Allele (1951) defined social behaviour as any type of response which differs from that which would be shown if the animals were solitary The greater the difference in their behaviour when grouped than when kept in isolation the more social they are He also discussed the cases of social facilitation leading to improved survival probabilities improved chances of finding a mate group stimulation of food consumption and even improved learning capabilities

Social suppression appears to be the cause of differential growth of individuals in communal rearing This is usually the result of a reduction in the growth of smaller individuals compared to more uniform growth of isolated control as observed in *M rosenbergii* (Ra anan and Cohen 1984b Karplus and Hulata 1992) in *M australiense* (Lee and Fielder 1983) in *Penaeus monodon* (Abdussamad 1991) and in *Homarus americanus* (Stewart and squires 1968 Mc Leese 1972 Van olst and Carlverg 1978 Cobb *et al* 1982 and Kendall *et al* 1982) Claws are used for aggressive interactions and for predation Barki *et al* (1991) and Karplus *et al* (1992a) observed some aggressive acts in *M rosenbergii* such as closing down of chelae, pushing embracing and cheliped extension towards body part of another prawn

Different social mechanisms may be regulating the growth of male and female morphotypes and these may perhaps operate simultaneously At higher densities earlier sexual maturation of females is one such mechanism leading to retarded growth This earlier female maturation may also trigger precocious maturation of small sized males(Cohen *et al* 1981) Hyperactivity shown by subordinate individuals thereby utilizing more energy may be another mechanism of social control of growth assuggestedby Cobb and Tamm (1975) Small prawns may be deprived of atleast some part of their body due to some attack by one or several larger animals when grown in group (Segal and Roe 1975) thus resulting in a nutritional deficiency and a decreased growth Aggressive infteractions among prawns raised in groups were also found to result in the establishment of a dominance hierarchy Aggressive and dominant individuals deprive subordinates (i e smaller individuals) of food (Segal and Roe 1975) This hypothesis is supported by the observation that when there is reduction in the supply of food to isolated crustaceans it resulted in decrease of their growth rate (Stewart and Squires 1968) Agonistic interaction could result in the establishment of a size hierar chy in which subordinates grow less rapidly even in the constant presence of food as a result of lower food intake (Cobb *et al* 1982) Malecha (1983) and Karplus *et al* (1989) reported that smaller subordinate individuals may have lower food conversion efficiency Increased lipid and carbohydrate synthesis was observed to occur in crowded juveniles of *M rosenbergii* at the expense of protein synthesis (Pierce and Laws 1982) Such a shift over a long period of time could result in reduced somatic growth of suppressed individuals

In *M rosenbergii* it was observed that claws are necessary in increasing the variation in growth rate among communally grown young ones It has two pairs of claws the first small pair is used mainly in cleaning in capturing small items of food and transporting them to the mouth and the second larger pair is mostly used by both sexes in predation and inter and intra specific aggression and by males in protecting females (Peebles 1979) Claw ablation in juvenile *M rosenbergii* males resulted in increased survival and more uniform growth as compared to intact control individuals (Karplus *et al*, 1989)

Karplus *et al* (1992a) found that the mechanism of growth suppression in runts is due to reduced growth increments per moult while the rate of moulting remained the same as in the case of fast growing individuals They also found that claw ablation and dactyl immobi lization in bulls resulted in a complete removal of growth suppression in runts which grew similarly to the control and opined that the growth rate of runts raised with bulls seems to be positively related to their social status In another study Karplus *et al* (1992b) found that the growth of runts is inhibited in the presence of large blue clawed males and the growth inhibi tion of runts was not due to less consumption of food or appetite suppression but due to changes in the food conversion ratio They further observed that removal of bulls enabled runts to achieve improved food conversion efficiency Karplus *et al* (1991) found that the leapfrog growth pattern of *M rosenbergii* was found in communal rearing cages and this growth pattern was achieved mainly by delayed transition from the fast growing orange claw male morphotype into the slow growing blue claw ones They suggested that this delay prob ably resulted from interaction among male prawns as it was not observed in the small cages where a pair of prawns (one male and one female) were reared They further found that isolated males transformed into the blue claw morphotype at a frequency three times greater than those among the communally cultured males

2 2 1 2 Morphotypic Differentiations and the Growth Patterns

2 2 1 2 1 Males

Sexually mature populations of *M rosenbergii* are characterized by a positively skewed bimodal weight distribution (Smith *et al* 1978 Karplus *et al* 1986a) The asymmetric weight distribution in males is associated with the co existence of three distinct morphotypes (Ra anan and Cohen 1985 Kuris *et al* 1987) which are characterized by physical features such as relative size claw colour and claw length (Sandifer and Smith 1978) as well as by behavioural characteristics such as territoriality aggression mobility feeding behaviour and reproductive behaviour (Peebles 1979) These three morphotypes are (1) blue clawed males (BC) also termed as bulls (Fujimura and Okamoto 1972) which posses blue coloured spinuous claws and a high ratio of claw to body length (2) Orange clawed males (OC) possessing non spinuous often orange coloured claws and a lower ratio of claw to body length and (3) Small males (SM) also termed runts (Fujimura and Okamoto 1972) smaller than the other two morphotypes possessing delicate claws clear or light pink colour and a low ratio of claw to body length These morphotypes represent three phases in male development reflected by changes of size morphology physiology and behaviour (Telecky 1984 Ra anan and Sagi 1985 Kuris *et al* 1987 Sagi and Ra anan 1988 Barki *et al* 1991a b) All male juveniles are reported to transform first into SM then into OC male and finally into BC male in a developmental sequence when raised in isolation (Ra anan and Cohen 1985 Ra anan and Sagi 1985 Kuris *et al* 1987 Barki 1989) When raised in a group however only some males transform into the fast growing OC while the rest remain SM whose growth is inhibited by larger individuals According to Cohen *et al* (1988) females in a mixed population may induce a larger fraction of males to enter into the more reproductively active but slower growing BC and SM types SM males become OC males through a weak OC intermediate phase but OC males become BC males at a single metamorphic moult (Kuris *et al* 1987) Ra anan and Cohen (1985) suggested that the first male to attain BC status would be one at the most rapidly growing OC males and it would be subsequently surpassed by other OC males in a leap frogging process such that the largest BC male in the population will be the most recently metamorphosed male They also observed that the size of BC males in a population is inversely proportional to the amount of algae adhering to their cuticles as coverage by epibionts is an indicator of time since the previous ecdysis Karplus *et al* (1991) supported the leap frog hypothesis and suggested that the leap frog growth pattern is probably due to social interactions among males because males isolated in small cages did not follow this pattern The leap frog growth pattern results in a series of differently sized BC males whose size is positively correlated with the time of their metamorphosis This growth pattern is achieved mainly through a delay in the transition from the fast groing OC morphotype into the slow growing BC Thus it can be seen that the growth rate of males is highly variable (Fujimura and Okamoto 1972 Smith *et al* (1978 Brody *et al* 1980 Ra anan 1982 Malecha *et al* 1984) The small male (SM) morphotype has a slow growth rate while the orange claw male (OC) morphotype has a high growth rate and as OC males transform to BC morphotype growth ceases (Ra anan and Cohen 1985 Kuris *et al*, 1987 Ra anan *et al*, 1991) Thus the growth of male is depensatory throughout the process of morphotypic differentiation leading to a wide range of OC and BC males

According to Ra anan and Cohen (1985) the presence of BC males suppresses neither growth nor metamorphosis of OC males although the presence of either BC or OC males suppresses the growth but not the maturation of the small males But Barki (1989) found that the largest BC male in a mixed population of BC and OC males dominated all OC and the smaller BC males Ra anan and Cohen (1985) and Ra anan and Sagi (1985) demonstrated that all three male morphotypes were sexually matured but had markedly different growth rates SM and BC males are more sexually active than OC males but the latter grow more rapidly (Sagi and Ra anan 1988)

Morphotypic differentiation has been reported in other species of *Macrobrachium* Henderson and Mathai (1910) in *M malcolmsonii M dubius* and *M scabriculus* and Thampy and John (1973) in *M idae* noticed the existence of dimorphic males and hypertrophied male secondary sex characters Nagamine and Knight (1980) noted two types of males with appendices masculinae present These males differed in the relative length of the chelipeds

It may be possible that androgenic gland which control the primary and secondary sex characters of male crustaceans has a role in the development of male morphotypes and the growth variation among them as growth rate of prawns is closely associated with marphotypic status (Ra anan 1982 Ra anan and Cohen 1985)

2 2 1 2 2 Females

In matured females three dıfferent morphotypes are usually observed Vırgın female (V) berrıed female (BE) and prevıously spawned females wıth open pleura (OP) The growth rate of ımmature females ıs relatıvely hıgh approachıng that of the orange claw males (Ra anan *et al* 1991) After maturatıon growth slows consıderably but does not cease Varıatıon ın sıze decreases wıth tıme because growth rate declınes markedly wıth ıncreasıng sıze whether the prawns are matured or not Thus the model for female growth ıs quıte dıfferent from the model for male growth The ınıtıally hıghly varıable female sıze dıstrıbutıon which ıs ındıs tınguıshable from juvenıle males (Ra anan and Cohen 1984b) ıs ultımately replaced by a relatıvely normal dıstrıbutıon Early ın lıfe there ıs varıabılıty ın growth presumably be cause among post larvae a sıze advantage even though small ın absolute terms leads to a feedıng advantage that exaggerates the sıze dısparıty ın the populatıon Latter growth be comes compensatory because smaller anımals have a hıgher growth rate and growth slows as maturatıon approaches Females then accumulate ın relatıvely narrow sıze range once they cross the sıze threshold at whıch they mature The exıstence of the sıze threshold ıs the mecha nısm that produces a normal sıze dıstrıbutıon of adult females Ra anan *et al* (1991) reported that ın the female populatıon parallel to the ıncrease ın average weıght wıth tıme there ıs a contınuous decrease ın the co effıcıent of varıatıon They also found that the largest females at stockıng usually remaıned the largest throughout the experıment whether they mature or not

2 2 2 Effect of Stockıng Densıty on Populatıon Structure Sıze Dıstrıbutıon, Sur vıval and Yıeld

2 2 2 1 Populatıon Structure

The proportıon of dıfferent morphotypes ın *M rosenbergıı* varıes wıth densıty the proportıon of BC and OC males decreased wıth ıncreasıng densıty whıle that of SM males ıncreased wıth densıty (Karplus *et al* 1986a Sıddıquı and Al Hınty 1993) Whıle earlıer ınvestıgators reported stable proportıon of male morphotypes at dıfferent densıtıes (Cohen *et al* 1981 Cohen and Ra anan 1983) Ra anan (1983) reported a decrease ın the productıon of berrıed females wıth ıncreasıng densıty In contrast to thıs fındıng Karplus *et al* (1986a) and

Sιddιquι and Al Hιnty (1993) found no varιatιon ιn proportιon of dιfferent female morphotypes wιth stockιng densιtιes The dιrect relatιonshιp between the percentage of small males and ιncreasιng densιty usually seen wιth ungraded populatιons was not evιdent ιn sιze graded populatιons (Danιels *et al* 1995)

2 2 2 2 Sιze Dιstrιbutιon

The stockιng densιty has a pronounced effect on mean weιght percent co effιcιent of varιatιon and skewness of sιze of *M rosenbergιι*

The mean weιght of prawn ιs ιnversely related to stockιng densιty The ιnverse rela tιonshιp exιstιng between prawn densιty and mean sιze has been reported by many ιnvestιga tors (Wιckιns 1972 Forster and Beard 1974 Sandιfer and Smιth 1975 Segal and Roe 1975 Wιllιs *et al* 1976 Wιllιs and Berrιgan 1977 Smιth *et al* 1978 1981 Kneale and Wang 1979 Ra anan 1982 Ra anan and Cohen 1984a Karplus *et al* 1985 D Abramo *et al* 1989 Alekhnovιch and Panyushken 1991 Sιddιquι and Al Hιnty 1993 Danιels *et al* 1995) A number of possble factors for the reductιon of growth ιn prawns wιth ιncreasιng densιty have been suggested These factors may operate sιngly or together Competιtιon for food may affect the growth at hιgher densιtιes as has been reported by Segal and Roe (1975) as there ιs deprιvatιon of food to smaller prawns by larger ones when cultured ιn groups Early mturatιon of females at hιgh densιtιes followed by maturatιon of small sιzed males occurrs at the cost of somatιc growth (Cohen *et al* 1981) Hyperactιvιty of subordιnate ιndιvιduals causιng more expendιture of energy and aggressιveness of domιnant males and development of socιal hιer archy causιng less consumptιon of food even when the food ιs abundant (Cobb and Tamm 1975) or showιng a poor food conversιon effιcιency (Karplus *et al* 1992b) at hιgh densιtιes are other factors observed as affectιng the growth of prawn wιth ιncreasιng densιty Karplus *et al* (1986b) reported a complete ceasatιon of growth of SM males ιn the presence of large males whιch ιnhιbιt theιr growth The effect of stockιng densιty on growth of dιffer ent male and female morphotypes was almost sιmιlar except for SM males where no dιffer ence was found ιn the mean weιght at dιfferent stockιng densιtιes (Cohen *et al* 1981 Cohen and Ra anan 1983 and Karplus *et al* 1986a) In contrast to the fιndιng that mean weιght decreases wιth ιncreasιng densιty Wιllιs *et al* (1976) reported that the average weιght gaιn ιn

M rosenbergii has little relation to stocking density and he found the highest average wieght gain at the highest stocking density

The percent co efficient of variation and skewness of size of *M rosenbergii* decrease with increasing density (Sandifer and Smith 1975 Smith and Sandifer 1979 Cohen *et al* 1981 Ra anan 1982 Ra anan and Cohen 1984a) Cohen *et al* (1981) found that post larval population of *M rosenbergii* was characterised by a homogeneous size distribution curve which changed with time to a positively skewed curve with some individuals demonstrating a higher growth rate than the rest of the population and the development of the skewed distri bution curve was inversely influenced by increasing density They further observed that in high densities growth was inhibited especially among the fast growers resulting in a higher degree of weight uniformity when compared to the lower stocking density However in a study conducted by Forster and Beard (1974) it was found that percent coefficient of varia tion of length of *M rosenbergii* was almost similar at the stocking densities 25 prawns / m^2 and 100 prawns / m^2 Karplus *et al* (1986a) by stocking juveniles of 2g average weight at densities of 1 2 3 or 4 nos / m^2 and rearing for 110 days in earthen ponds also found that the percent co efficient of variation at all stocking densities was almost uniform

In *M rosenbergii* the size distribution of males is different from that of females A narrow ranged and more or less normal distribution for female and a strongly depensate and skewed population of males could be generally observed (Fujimura and Okamoto 1972 Fujimura 1974 Wang *et al* 1975 Malecha 1977 Smith *et al* 1978 1980 Cohen *et al* 1981 Sandifer *et al* 1982 Karplus *et al* 1986a Siddiqui and Al Hinty 1993) Karplus *et al* (1986a) reported that the skewness of different morphotypes within each sex changed with increasing density the skewness of OC males increased with stocking rate that of BC males decreased and that of SM males was the highest at the extreme densities (1 and 4 nos / m^2) the skewness of BE females increased with stocking rate that of OP females remained relatively stable and in V females it fluctuated with density The co efficient of variation of males exceeded that of females High variation of males compared to females has been shown for prawns grown in polyculture (Cohen and Ra anan 1983 Miltner *et al* 1983 Karplus *et al* 1986a) in monoculture (Wang *et al* 1975 Smith *et al* 1978) Within each sex large differences in coefficient of variation were observed the smallest morphotypes of V females and SM males had the hıghest co effıcıent of varıatıon (Karplus *et al* 1986) Alekhnovıch and Panyushkın (1991) noted that wıth the onset of sexual maturıty there ıs decreased effect of densıty on growth

2 2 2 3 Survıval

In M *rosenbergıı* the survıval rate usually decreases wıth ıncreasıng densıty(Wıckıns 1972 Sandıfer and Smıth 1975 Smıth *et al* 1976 1983 Wıllıs and Berrıgan 1977 Kneale and Wang 1979 Ra anan and Cohen 1984 a Sıddıquı and Al Hınty 1993) However ın a study conducted by Naır and Thampy (1988) ıt was found that survıval durıng nursery rearıng of *M rosenbergıı* was almost sımılar at dıfferent stockıng densıtıes rangıng from 500 to 2000 nos / m^2 Karplus *et al* (1986a) by stockıng juvenıles of 2 g average weıght ın earthen ponds at densıtıes of 1 2 3 or 4 nos/m^2 also found that survıval rate was ındependent of densıty Danıels and D Abramo (1995) reported that durıng growout operatıon of *M rosenbergıı* the survıval rate was almost sımılar at the stockıng densıtıes of 39 540 59 300 and 79 100 nos / ha

2 2 2 4 Yıeld

Wıth ıncreasıng densıty the total yıeld of *M rosenbergıı* ıncreases although the proportıon of marketable prawns decreases (Karplus *et al* 1986a Sıddıquı and Al Hınty 1993)

Padmakumar *et al* (1992) reported a productıon of 300 805kg/ha/6 7 months by stockıng juvenıles of *M rosenbergıı* at a comparatıvely low stockıng densıty of 1 12 nos/m^2 ın channels of coconut gardens Productıons of 630kg/ha/180days ın monoculture and 411kg/ha/180days ın polyculture were obtaıned by stockıng juvenıles at the rate of 30 000 nos/ha and 11 500 nos/ha respectıvely (Duraıraj *et al* 1992) Thangaduraı (1991) reported that a stockıng densıty of 3 nos/m^2 was optımum producıng 600kg/ha ın 6 7 months In an experıment conducted by Rama Rao *et al* (1992) a maxımum productıon of 712 28kg/ha/year was achıeved at the stockıng densıty of 30 000 nos/ha

From temperate regıons where growıng perıod ıs short dıfferent levels of yıeld of

M rosenbergi were obtainedfrom monoculture system A production of 1314 kg/ha/year at the stocking density of 8 61 nos/m^2 was reported by Smith *et al* (1981) and 1974 kg/ha at stocking density of 15nos/m^2 by Cohen *et al* (1983) Ang(1990) obtained 979 kg/ha/154days cycle by stocking *M rosenbergii* at stocking density of 10nos/m^2 In another trial he obtained 1110kg/ha/154days and 2287kg/ha/154days at stocking densities of 10nos/m^2 and 20nos/m^2 respectively

Zimmermann & Raupp (1992) stocked post larval prawns (0 013g) at densities of 8 22 nos/m^2 and nursed juveniles (0 80g) at 6 8nos/m^2 and after 5 months obtained 550 1150kg/ ha from post larval prawns and 755 985kg/ha from the juvenile prawns The highest biomass was obtained when post larvae were stocked at 22nos/m^2 but the average weight achieved was highest when juveniles were stocked at 8nos/m^2

Daniels and D Abramo (1995) found that by stocking juveniles of *M rosenbergii* the average total yield after 131 to134days of rearing ranged from 1041 to 1662kg/ha for stock ing densities ranging from 39 540 to 79 100 nos/ha Although the total yield was highest at the highest stocking density the percentage of larger sized prawns was highest at the lowest stocking density and therefore more revenue was obtained at the lowest density

Kale(1991) examined the effect of stocking large (50 55mm) wild caught juveniles of *M rosenbergii* at densities of 5 6 nos/m^2 After 85days of rearing all prawns have reached a size of 30 45g (average ± 38g) but when the culture period was extended to 180days there was a wide size range (30 140g)

2 2 3 Different Approaches to Increase Growth and Survival of M rosenbergii.

2 2 3 1 Use of Additional Substrates

Use of artificial substrates for rearing different species of prawns has been examined by many workers Forster (1970) studied the effect of adding horizontal artificial substrates m the rearing tanks of *Palaemon serratus* on cannibalism He obtained a higher survival rate in tanks with artificial substrates as compared to the control

Use of natural substrates including sticks branches of trees gravel shells or water plants in rearing tanks has been suggested as a means of providing shelters for the prawns thereby reducing opportunities for aggressiveness (Ling 1962 1969 Sidthimunka and Choapaknam 1968 and Fujimura and Okamoto 1972)

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 They have further reported that feed utilization was less efficient and cannibalism became apparent at a much smaller size among the prawns reared in tanks without any additional substratum Use of artificial substrates for rearing of *M rosenbergii* in ponds by Fujimura (1972) showed that use of such materials is not practical in intensive culture systems According to Kneale and Wang(1979) the number of habitats (made from plastic material) per tank did not appear to influence survivability however growth may be affected by the number of habitat units per tank

Use of artificial submerged substrates (made from plastic net and pipes) in ponds has been shown to increase marketable yield and average marketable weight providing scope of an early selective harvest Cohen *et al* (1983) and Ra anan *et al* (1984) found that net sub strates markedly increased both survival and the percentage of marketable prawns in intensive system where paddle wheel aerators were also used Ra anan and Cohen (1984a) found that addition of substrates resulted in an increase of the average body weight the percent co efficient of variation and the degree of skewness of the size distribution curve of *M roenbergii* post larval population stocked at an average size of 0 009g On the other hand Mulla and Rouse (1985) found that use of additional substrates in nursery pools provided some improvement in average size and size distribution of juveniles of *M rosenbergii* stocked at the average size of 0 04g but did not improve overall production Thus it seems that there is some difference in response between post larvae and juveniles towards the provision of additonal substrate The additional substrates induce differential growth in post larval popu lation whereas it reduces differential growth in juvenile population

Mercy and Sankaran(1992) found that *M rosenbergii* juveniles (55mg) show a prefer ence for a substrate of pebbles compared to garden soil river sand and mud perhaps be cause pebble substratum provided more space to hide They also found that prawns appeared to grow faster when reared in tanks with pebble substratum

2 2 3 2 **Stocking Large Juveniles**

Maximization of yield was achieved by stocking juveniles rather than newly metamor phosed post larvae by Willis and Berrigan(1977) Smith and Sandifer(1979) Brody *et al* (1980) Smith *et al* (1981) and Ra anan and Cohen(1982) Smith and Sandifer (1982) suggested that in areas where the growing season is relatively short stocking of juveniles or a mixture of post larvae and juveniles in ponds at a low density would be desirable D Abramo *et al* (1989) found that stocking of larger juveniles could yield higher harvest weight than smaller juveniles He suggested that stocking of juveniles of proper size and effctive manage ment of the social structure as critical to the success of intensive pond culture in temperate climates Smith *et al* (1983) found that when 1 and 2g juveniles were stocked in ponds at density of 43 100 nos/ha final prawn size increased by 13 and 25% and total produ on increased to 111 and 299kg/ha respectively Zimmermann and Raupp(1992) by sto ost larval prawns (0 013g) at densities of 8 22 nos/m^2 and nursed juveniles (0 80g) a os/m^2 found that the highest biomass was obtained when post larvae were stocked at 22 no m^2 but the average weight achiev vas highest when juveniles were stocked os/m^2

In a study conducted by Hulata *et al* (1990) to evaluate the effect of size and age of juvenile of *M rosenbergii* at stocking on population structure found that differenc n fre quencies of morphotypes were associated mainly with age differences and size a ng has only a much smaller effect They varied the period of nursing to 66 or 129 days to pro duce four groups Viz Old small Old large Young small and Young large and found the frequency of SM to be higher among Young than Old groups BC males occurred at a higher frequency only in the Old small group The Old large group had the highest frequency of NC (no claw) males probably derived from BC males who had lost their claws as suggested by Schmalbach *et al* (1994) Among females the Old groups showed a higher frequency of V and a lower frequency of BE than young groups OP females and OC males occurred at similar frequencies among all experimental groups However mean weight at harvest did not differ significantly among different groups

Survival of young large was significantly lower than that of old large with the other groups intermediate resulting in a uniform total yields among the different groups Thus they concluded that there is significant small age effect i e advantage of old groups over young groups in both survival and yield but no size effect was found in any trait and gross income computed from the yield weight classes was similar for all experimental groups with no age or size effects

2 2 3 3 Size Grading

The effects of size grading of juvenile prawns on yield characteristics was studied by Karplus *et al* (1987) dividing the juvenile prawns into upper middle and lower fractions and recombined fraction as a control They found that the size grading of juveniles significantly affected the proportion of male and female morphotypes SM frequencies were greater in lower fraction while the BC males were highest in the upper fraction OC males showed a similar trend to BC but the proportions were greater in each case The proportion of V females was greatest in the lower fraction while mature females showed the reverse trend for both BE and OP prawns The upper fraction of juveniles produced the highest mean weight and yield In addition to higher yield and the different morphotypic composition of the harvest the net income from prawns was nine times greater in the upper than in the lower fraction and nearly twice that from the middle fraction However since the weighted mean yield of the three fractions is almost same as the control stocking graded weight classes will not increase overall net income unless the lower fraction is discarded Daniels *et al* (1995) reported that the direct relationship between the percentage of smaller males and increasing density was found in ungraded populations and not in the size graded populations Karplus *et al* (1986b) found that mean weight at harvest of *M rosenbergii* from an upper one third graded group was 25% higher and from a lower two third graded group it was 10% lower than that of the ungraded control Daniels and D Abramo (1994) on the other hand by stocking juveniles after grading into upper and lower fractions and as an ungraded control group found the mean size at harvest of both upper and lower fractions as higher than the ungraded control The calculated gross revenue in graded populations was 6-73% greater than that of the ungraded population In another study D Abramo *et al* (1991) found that the biomass production was higher by 45 6% in upper one third and 11% in lower two thirds in comparison to the ungraded population

Daniels and D Abramo (1994) found that size grading of juveniles before stocking disrupts the conditions leading to significant development of heterogeneous individual growth in production ponds during growing season resulting in comparatively more uniform sized prawns at harvest in graded population than in the ungraded one However Karplus *et al* (1987) by dividing the juveniles into three fractions and a recombined control group found that the differential growth in the graded lower fraction was more than the recombined con trol group

The size grading of juveniles was found not to have much effect on survival rate Karplus *et al* (1987) by rearing size graded juveniles of *M rosenbergii* for 97 days found that the survival rate in the lower size group was 91% and almost similar survival rates (87%) were found in upper and middle fractions and recombined control group Daniels and D Abramo (1994) found the survival rates of 85 3% in 30% upper 79 4% in 70% upper 73 2% in 30% lower 80 2% in 70% lower fractions and 73 9% in ungraded control groups

Hulata *et al* (1990) found that there is no significant effect of size of juveniles at the time of stocking on survival of *M rosenbergii*

2 2 3 4 Monosex Culture

Cage experiments conducted by Sagi *et al* (1986) have shown that all male prawn population yielded 473g/m^2 of cage area compared to 260g/m^2 and 248g/m^2 for mixed and all female populations respectively after 115 days of rearing 80% of all male population was of marketable size twice that of the other two populations They further reported that female growth rate is inhibited in the presence of males but not vice versa In earthen ponds all male populations have been reported to yield nearly 8% more and all female 21% less than mixed population and the revenue from all male populations was 25% more than that from mixed and nearly 86% more than all female population (Cohen *et al*, 1988) SM and BC males are more sexually active than OC males but the latter grow more rapidly (Sagi and Ra anan 1988) Sagi *et al* (1986) reported that all male populations have more OC males Cohen *et al* (1988) observed that females in a mixed population may induce a larger fraction of males to enter into the more reproductively active but slow growing BC and SM types Gofer (1991) re ported that an all male population gave the highest proportion (43%) of large males com pared to mixed male/female populations (31%) and males and females kept in the same cage but separated by a net to prevent direct contact (21%)

2 2 3 5 Harvesting Manipulation

In temperate climate selective harvest of market size prawns prior to final harvest is performed (Willis and Berrigan 1977 Cohen and Ra anan 1983) Malecha *et al* (1981) pro posed a management practice that include pre harvest size grading and restocking of non market size prawns after complete harvesting by pond drain down Malecha (1983) sug gested that large BC and OC males and large females should be removed in order to enhance the growth of small prawns Prawns of 40 45g and above are normally culled out in Thailand and in the French Carribean (IFREMER (1989)

Investigating the suppression of growth of small prawns caused by the presence of large prawns Lam and Wang (1987) showed that although harvesting efficiency could be increased by harvesting continuous cultured ponds more frequently it caused stress and mortality also

A modified batch system has been proposed by Mc Gee (1991) in which nursed post larvae (1g) which had been reared at very high density (2 96 000/ha for 30 45days) are stocked into advanced nursery ponds and reared for 2 3 months At this point seine harvesting is begun to remove 10 15g juveniles and the pond is converted to a transfer phase during months 3 4 and 5 The juveniles are regularly removed for transfer to production ponds to replace marketable (35 100g) animals that have been harvested During the months 5 6 the pond goes into a harvest phase and is seined for marketable animals After this it in turn receives regular transfers of juveniles and is then managed for continuous harvesting for 8 12 more months before being drained for batch harvest A new cycle then commences Through this system prawn production can exceed 3400kg/ha/year

2 2 3 6 Environmental and Genetic Manipualation

Environmental and / or genetic manipulation might increase the marketable yield of freshwater prawns Varıabılıty ın larval developmental tıme post larval temperature tolerence and salınıty and temperature related growth have been detected ın stocks derıved from dıffer ent geographıc locatıons (Sarver *et al* 1979) Thampy and Naır(1992) and Venugopalan and Thampy (1992) found that growth of *M rosenbergıı* was better at 0 2ppt salınıty Wıthyachumnarnkul *et al* (1990) reported that both the survıval and growth rate of juvenıles of *M rosenbergıı* were found to be hıgher when reared ın complete darkness

The growth of *M rosenbergıı* may be ımproved by some genetıc manıpulatıon Dobkın and Baıley (1979) found that ıntraspecıfıc hybrıds of *M rosenbergıı* races had ımproved growth rates Accordıng to Ra anan (1987) earlıest maturıng females should be selected as brood stock for a potentıal ımprovement of the genetıc base because they are also the fastest growıng females

Electrophoretıc studıes of gene enzyme varıatıon ın natural prawn populatıons from 11 locatıons from Srılanka to New Guınea Palau and Hawaııan cultured stocks have supported the hypothesıs (Hedgecock *et al* 1979) that specıes has under gone consıderable racıal dıver gence and that natural populatıons represent a dıverse genetıc resource for prawn aquacul ture However no useful allometrıc varıatıon ın these genetıc stocks and theır hybrıds was found (Malecha *et al* 1980)

All male populatıon has been produced by matıng androectomızed males (Neo females whıch developed female gonads after removal of androgenıc gland) and normal males (Sagı and Cohen 1990) Thıs study offerred new ways to ımprove *M rosenbergıı* yıelds by ma nıpulatıng the genetıc and endocrıne system that regulate growth and development Brown (1991) expressed doubts about the value of such technıques lıke temperature ınduced trıp loıdy and admınıstratıon of sex steroıds to produce all male prawn populatıons as the result ant populatıon wıll also comprıse of SM and BC males besıdes the desırable OC males

2 3 Sexualıty and Secondary Sex Characters ın *Macrobrachıum spp*

Palaemonıd prawns are dıoecıous the sexes are beıng dıstınguıshed by a number of external characters (Patwardhan 1937) In general the females are smaller than males of the same age The second chelate legs of males are more elongated stout and profusely covered with setae The males are also characterized by the presence of appendix masculina in the endopodite of second pleopod In females the epimera of the abdominal segments are bigger in size and form deep recess for carrying eggs during breeding season The male genital aper tures are paired and present on the arthrodial membrane above the coxa on the inner side of the last pair of walking legs covered over by small tongue like flaps of integument The female genital aperture is also paired each being situated on a raised papilla on the inner side of the coxa of the third walking legs

Among crustaceans dimorphism in males has been recorded in cambarine cray fishes and tanaids Henderson and Mathai (1910) noticed dimorphism in the second chelipeds of males in three species of *Macrobrachium* namely *M malcolmsonii M dubius* and *M scabriculum* But they were not able to establish a clear correlation of the dimorphism with breeding season Thampy and John (1973) found that a majority of the males of the fresh water prawn *M idae* show a hyper trophy in the length of the second cheliped the length and spinuosity of the appendix masculina and the with of the vas deferens during the breeding season This hypertrophy has only very little correlation to the size of the individual and the above sex characters had marked variation in a population having the same body length The hyper trophy of these structures was found to be linked with the extent of development of the androgenic gland Thus they have suggested that there is a direct relation between the secre tory activity of the androgenic gland and the hypertrophy of these structures i e there is a cause and effect relation between the androgenic gland and the primary and secondary sex characters

2 3 1 Control of Sexuality

2 3 1 1 Males

In the case of male malacostracan crustaceans sex and reproduction are under the influ ence of androgenic gland which is in turn under the control of x organ sinus gland system The androgenie gland first described by Charniaux cotton (1954) is usually located at the dorsomedian surface of the terminal ampoule at the distal end of the sperm duct where it forms a pyramidal cluster of loosely arranged cordon of cells associated with the posterior position of the ejaculatory duct (Thampy and John 1972 1973 Sagi 1988 Philip and Subramaniam 1992)

The androgenic gland secretes a hormone which determines the development of pri mary and secondary sexual character (Thampy and John 1972 1973 Nagamine *et al* 1980) and also behavioural sexual characters (Charniaux cotton 1960) Androectomy performed prior to differentiation of secondary sexual characters results in such characters not develop ing (Sagi *et al* , 1990) complete feminization which include development of oviducts and female gonopores in early maturation stage males (Sagi 1988) whereas in later development stages it results in either partly or no feminization (Nagamine *et al* 1980) In *M rosenbergii* regardless of the morphometric stage androectomized males will transform to the next stage but further transformation is blocked (Sagi *et al* 1990) Androgenic gland implantation masculanizes female recipients (Sagi 1988) bringing in effects including development of appendises masculina the male gonopore complex and mature masculine cheliped and mi tiation of spermatogenesis However spermatogenesis is not initiated in mature females Androectomy either affects the quantity of sperm produced or the rate of production (Sagi *et al* 1990)

The differential growth shown in *Macrobrachium spp* the males growing faster than females (Sagi *et al* 1986) adds to the significance of this gland in influencing the growth The growth rate among males vary greatly (Fujimura and Okamoto 1972 Smith *et al* 1978 Malecha *et al* 1984) resulting in the existence of different morphotypes (Ra anan) and Cohen 1985 Kuris *et al* 1987) In all forms androectomy results in decreased growth rate (sagi *et al* 1990) and hence an influence of androgenic gland on somatic growth is suggested (Kuris *et al* 1987)

2 3 1 2 Females

In the case of females it is ovary which secretes a hormone that regulates the female secondary sexual characters as has been proved by ovariectomy in early stages which is known to prevent the secondary sexual characters from developing (Charniaux cotton 1960)

The development of temporary secondary sexual characters such as breedıng dress (egg bear mg haırs) seems to be condıtıoned by the amount of yolk deposıted ın the ovary as reported ın *Leander spp* (Callen 1940) and *Carıdına nataragını* (Thampy 1972)

2 3 2 Allometrıc Growth Pattern ın Dıfferent Sexes

In crustaceans there ıs allometry ın growth between the sexes and among dıfferent phases of growth wıthın each sex In some mstances these dıfferences ın allometry level are relatıvely small and of uncertaın sıgnıfıcance as when two carapace dımensıons are compared or when the length of the walkıng legs ıs compared to the length of the carapace But there are organs whıch show strıkıng and consıstent patterns of varıatıon ın the level of allometry notably the chelae Enlarged chelate or subchelate appendages occur ın many groups such as Tanaıdaceans and Decapods

In females the level of allometry ın chelar growth ıs generally near unıty ın all phases so that growth ıs essentıally ısometrıc throughout There are only mınımal changes ın allomerty level at the pre puberty and puberty moults and no sıgnıfıcant change ın relatıve sıze at the prepuberty moult In males growth tends to be ısometrıc ın the undıfferentıated phase but the level of allometry ıncreases at the pre puberty moult so that the juvenıle phase ıs posıtıvely allometrıc At the puberty moult there ıs usually a further marked ıncrease ın the relatıve sıze of the chelae

The ıncrease ın wıdth of the abdomen ın decapods dısplays a quıte dıfferent pattern In males growth ıs near to ısometry throughout and only small changes ın the level of allometry occur at the moults of pre puberty and puberty In contrast the females dısplay posıtıve allometry before puberty At the puberty moult there ıs lıttle change ın the level of allometry but there ıs very pronounced ıncrease ın relatıve wıdth

Kurıs *et al* (1987) found that the level of allometry varıes among dıfferent male morphotypes of *M rosenbergıı* The BC males are readıly dıstınguıshed from other male morphotypes havıng greater propodus and carpus lengths ın relatıon to carapace length the carpus of a BC male averages 61%longer than that of an OC male of sımılar sıze and the dıfference between these males ın tersms of propodus length ıs 47% They found that wıthın BC morphotype growth of the carpus ıs nearly ısometrıc Comparıng the length of chelıpeds they found that the chelıped length of BC males ıs unequıvocally greater than for other males of sımılar body sıze and total chelıped length showed strong posıtıve allometry They also noted that BC males were readıly dıstınguıshed from other morphotypes wıth respect to propodus wıdth The propodus of BC males was relatıvely narrower than the propodus of other male morphotypes

In*Macrobrachıum* the level of development of male sex characters ıs dırectly related to the length of the androgenıc gland but not related to the body sıze of the prawn Thampy and John (1973) found that ın *M ıdae* the length of the chelıped the length of the appendıx masculına number of spınes on the appendıx masculına and the wıdth of the vas deferens had a sıgnıfıcant correlatıon co effıcıent wıth the length of the androgenıc gland but not wıth the sıze of the prawn

Kurıs *et al* (1987) reported that maturatıon of *M rosenbergıı* from juvenıle male lack ıng appendıx masculına to the small male morphotype ıs not accompanıed by an allometrıc change ın claw segments

2 3 3 *Maturatıon ın Macrobrachıum spp*

Maturatıon of juvenıle to adult male morphotypes ın *Macrobrachıum sp* ıs accompa nıed by the development of appendıx mascuhna on the endopodıte of the second pleopod (Nagamıne and Knıght 1980)

Among hatchery nursed male post larvae of *M rosenbergıı* sexual maturatıon occurs at about 10mm carapace length (Nagamıne and Knıght 1980) Accordıng to Ra anan *et al* (1991) the female of *M rosenbergu* begıns to mature between sıxth and eıghth week of age Goorah and Parameshwaran (1983) recorded 118mm and 20g as the smallest sıze at maturıty of thıs specıes The sıze at maturıty of *M malcolmsonıı* has been reported at 41mm (Ibrahım 1962) and 40 50mm (Sankoln and Shenoy 1980) Phılıp and Subramanıam (1992) reported that the male secondary sexual character the appendıx masculına appeared ın *M* *malcolmsonu* when the prawns reach 6mm ın total length Jayachandran (1984) reported the age of maturıty of *M ıdella* as 120 days Pıllay and Mohammed (1973) also reported ıt as 120 days under laboratory condıtıons Pıllay (1990) reported that *M equıdens* had reached matu rıty at a sıze of 41 48mm ın captıvıty

3 MATERIALS AND METHODS

3 1 Experimental Animals

Early post larvae of giant freshwater prawn *Macrobrachium rosenbergii* belonging to a single brood obtained from a private commercial hatchery were used for the first experiment The post larvae were brought to the laboratory in an oxygen filled polythene bag and reared in a fibre glass tank For the second experiment post larve from a single brood obtained from the hatchery of the College of Fisheries Panangad were used The juveniles at the end of the first experiment were size graded and used for the third experiment

3 2 Conditioning of the Experimental Animals

For the first experiment post larvae (PL_0) brought from the hatchery were gradually acclimated to experimental conditions (pH 7 8 $\pm$ 0 40 temperature 27 5 $\pm$ 0 5° C)and then released into a fibre glass tank The post larvae were reared in acclimation tanks for four days during which they were fed first with clam meat powder of the size below 0 006mm and then gradually changed to specially prepared dry pellets To maintain water quality the left over feed was siphoned out and 20 30% of the water changed daily For the second experiment the post larvae were fed with freshly prepared wet feed composed of thelly (*Metapenaeus dobsonii*) meat and hen s egg and then gradually changed to pelleted feed At the end of the experiment the juveniles were size graded according to weight and length and directly stocked in the experimental tanks for the third experiment

3 3 Experimental Rearing Facilities

The experiments were conducted in an indoor system with good ventilation roofed partially with translucent fibreglass reinforced plastic (FRP) sheets for moderate light conditions

Round bottom fibreglass tanks having 77 litres capacity 0 22 m^2 bottom surface area and 35cm height were used Three fourth of the tank was filled with fresh water The water used for the experiment was first collected in a large tank suspended particles were then allowed to settle and clean water from the top was introduced into the experimental tanks by siphoning Mild aeration was provided from a roots air blower or from an oil free air compressor

3 4 Feed Formulation

During the experiments the prawns were exclusively fed with dry pelleted feed which was prepared as per the composition of Sherief (1987) using ingredients such as dry clam meat powder (40%) groundnut oil cake (25%) rice bran (25%) tapioca powder (9 %) and supplementary vitamin and mineral mixture (1%) The ingredients were ground properly and appropriate quantities were taken (except vitamin and mineral mixture) The ground ingredients were mixed thoroughly using required amount of water (1 25 l/kg of feed mixture) to make a dough and steamed for 30 minutes at atmospheric pressure in an autoclave It was then pelletized after mixing with supplementary vitamin and mineral mixture and dried overnight in a hot air oven at 60 °C

3 5 Proximate Composition of Feed

The proximate composition of the feed was analysed The analysis was done in triplicate and the mean values were determined The methods used for the analysis were as follows

Crude protein	Microkjeldahl s method (AOAC 1975)
Crude Fat	By solvent extraction method using petroleum ether (BP 40 60°C) in a Soxhlet extraction apparatus for 6 hours
Ash	By combustion at 450 °C for 12 hours
Moisture	By drying the sample at 105 °C for 12 hours The proximate composition of the feed is given in table 1

Table 1 Proximate Composition of the Feed Used in the Experiment

COMPONENTS	PERCENTAGE
Crude protein	35 25
Crude fat	6 72
Ash	10 64
Moisture	5 81

3 6 Methods of Water Quality Analysis

Temperature Using mercury bulb thermometer with accuracy of 0 1 °C

pH Using universal pH indicator solution

Dissolved Oxygen Using standard Winkler s method (Stickland and Parson 1972)

3 7 Experimental Procedure

During the experimental period the animals were fed on dry pelleted feed Uneaten feed and other solid wastes were siphoned out daily before feeding To maintain water quality 20 25% of the water was changed daily Temperature and pH were monitored daily and dissolved oxygen levels once a week Continuous mild aeration was provided to maintain optimum dissolved oxygen levels

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

Data were collected both for length and weight But only weight changes were taken ınto account as growth ındıcator Sınce growth ıs not a sımple lınear change but a three dımensıonal ıncrease weıght change ıs consıdered more realıstıc ındıcator of growth (Segal and Roe 1975)

3 7 1 Experıment to Fınd the Effect of Varıous Stockıng Densıtıes on Dıfferentıal Growth and Survıval Rate

For thıs experıment unıform sızed post larvae (PL $_{14}$) weıghıng 11mg (av length 1 1cm) obtaıned from a sıngle brood were stocked at densıtıes of 25 50 100 200 400 and 800 nos/m^2 of bottom area of rearıng tank Each treatment was replıcated thrıce The experıment was conducted for a perıod of 35 days At the end of the experıment the prawns were counted and the length and weıght measured The survıvors were dıvıded ınto four groups on the basıs of theır weıght such as 50 100mg 100 150mg 150 200mg and 200 250mg and the percentage fallıng under each group calculated

3 7 2 Experıment to Fınd the Effect of Provısıons of Dıfferent Types of Addıtıonal Substrates on Dıfferentıal Growth and Survıval Rate.

Thıs experıment was conducted by usıng three dıfferent types of addıtıonal substrates such as (ı)clam shell of 3 6 cm sıze (ıı)round pebbles of 2 3 cm dıameter spread at the bottom of the tank and (ııı) black polythene raffıa kept horızontally ın the water column Another set of tanks wıthout any addıtıonal substratum formed the control treatment Each of the treatments was replıcated four tımes Unıform sızed post larvae (PL $_{12}$)of average weıght 10mg (av length 1 05cm) obtaıned from a sıngle brood were used for the experıment The stockıng densıty used was 800 nos/m^2 of bottom area chosen on the basıs of the results of the fırst experıment that gave the mınımum dıfferentıal growth All the prawns were counted and weıght and length measured after a perıod of 35 days The survıvors were dıvıded ınto four groups on the basıs of theır weıght such as 50 90mg 90 130mg 130 170mg and 170mg and above The percentage of prawn fallıng under each group was calculated

I a I An v r o Njer n a

3 7 3 Experiment to Find the Degree of Variation in Differential Growth among the Different Size Groups of Juveniles

This experiment was conducted by using the juveniles obtained at the end of the first experiment The juveniles were divided into three size groups such as (i) large size having weight 0 17±0 007 g (av length 3 2 cm) (ii) medium size havmg weight 0 12± 0 007 g (av length 2 7 cm) and (iii) small size having weight 0 07 ± 0 007 g (av length 2 2 cm) A fourth set with four numbers from each of the three size groups formed the control In each tank 12 numbers of the juveniles were stocked Each of the above experiment was replicated four times At the end of the experiment length and weight of all the prawns were taken

3 8 Statistical Methods of Analysis

In order to estimate the extent of differential growth mean and standard deviation of weight and its coefficient of variation together with the skewness of the set of values were calculated The mean weight measurements were compared using Analysis of Variance Techinque The t test was employed for pair wise comparison wherever found necessary (Snedecor and Cochran 1967) The percentage of survival was also calculated

4 RESULTS

4 1 Experiment to Find the Effect of Various Stocking Densites on Differential Growth and Survival Rate of *M rosenbergii* During Nursery Rearing

The data of the experiment conducted to find the effect of six different stocking densities ie 25 50 100 200 400 and 800 nos/m^2 of bottom area on differential growth and survival rate of post larvae of *M rosenbergii* for a period of 35 days nursery rearing are given in table 2 In all cases the average individual weight decreased with increasing density (fig 1) This was verified using ANOVA (Table 3) Pair wise comparison showed that each treatment mean differs from each other The highest treatment mean weight of 131 67mg was found at the lowest stocking density and the lowest treatment mean weight of 79 91 mg was found at the highest stocking density The average gain in individual body weight after 35 days of nursery rearing ranged from 68 91 mg for the highest stocking density to 120 60 mg for the lowest stocking density As the experiment was in progress it was observed that in each of the tanks some of the post larvae grew faster compared to others Substantial variation in size and growth of individual was found at all stocking densities The percent co efficient of variation (P C V) of 46 70 was the highest at the lowest stocking density and the lowest P C V of 23 09 was found at the highest stocking density (fig 2) Similar trend was found with respect to skewness values also The skewness value of 1 54 was the highest at the lowest stocking density and the lowest skewness value of 0 014 was found at the highest stocking density Thus it is seen that differential growth decreases with increasing stocking density The P C V was taken as the measure of the relative variance, since it is measured with respect to mean and it is free from unit of measurement

The percentage of juveniles falling under different size groups are shown in table 4 and fig 3 It is seen that the percentage of juveniles falling under the smallest size class increased with increasing density At the lowest stocking densirty (25 nos/m^2) the percentage of juveniles falling under the smallest size class (50 100 mg) was only 27 78% compared to 81 52% at the highest stocking density (800 nos/m^2) There was a sharp decrease in the percentage of juveniles falling under the largest size class (200 250 mg) with increasing density At the lowest stocking density 16 67% of the juveniles were found to fall under the largest size class which decreased to only 0 79% at the stocking density of 200 nos/m^2 and no juvenile was found under this size class at the stocking densities of 400 and 800 nos/m^2

Table 2 Growth dıfferentıal growth survıval and bıomass productıon fıgures of *M.rosenbergıı* post larvae at varıous stockıng densıtıes after 35 days of nursery rearıng

Varıous Paramete s Stud ed	Stock ng Dens t es(nos/m)					
	25	50	100	200	400	800
Ave age n al we ght (mg)	11	11	11	11	11	11
Average f nal we gh (mg)	131 67	126 56	121 69	101 82	90 53	79 91
Standard dev a on	61 49	46 14	36 31	28 93	22 08	18 45
Percen co-eff c en of varıa on	46 70	36 46	29 84	28 41	24 39	23 09
Skewness	1 54	0 75	0 55	0 19	0 07	-0 014
Ave age we gh ga n (mg)	120 6	115 56	110 69	90 82	79 53	68 91
Average da ly we gh ncremen (mg)	3 44	3 30	3 16	2 59	2 27	1 97
Surv va (%)	100 00	96 97	96 97	95 45	93 56	87 12
Average b omas ıncremen (mg/m 35days)	3015 00	5602 93	10 733 61	17 337 54	29 763 31	48 027 51
Average daıly b omas ncrement (mg/m day)	86 14	160 08	306 67	495 36	850 38	1372 21

Table 3 Analysıs of varıance showıng the effects of stockıng densıty on average sıze (weıght) of post larvae of *M rosenbergıı* after 35 days of nursery rearıng

Source	Degrees of f eedom	Sum of squares	Mean sum of squares	F values	
				computed	Tabled (at 5%)
S ock ng dens y	5	6643 96	1328 79	196 57	3 11
Erro	12	81 16	6 76		
Total	17	6725 55			

Crıt cal d fference 3 78 a 5%

Table 4 Percentage dıstrıbutıon of *M rosenbergıı* post larvae under dıfferent sıze classes after 35days of nursery rearıng at varıous stockıng densıtıes

S ze classes (mg)	Stock ng dens t es (nos/m²)					
	25	50	100	200	400	800
50 100	27 78	31 25	34 37	43 65	64 78	81 52
100 150	33 33	31 25	42 19	47 62	34 01	17 83
150 200	22 22	31 25	21 88	7 94	1 21	0 65
200 250	16 67	6 25	1 56	0 79	0	0

Table 5 Water qualıty parameters monıtored durıng the study for evaluatıon of the effect of stock ıng densıty on dıfferentıal growth and survıval of *M roserbergıı* post larvae

Stock ng dens ty (nos(m²)	Water tempera ure(°C) Mean* ± S D**	D ssolved oxygen(ppm) Mean + S D	pH Mean + S D
25	27 8±0 69	6 9±0 32	7 90+0 12
50	27 7+0 79	6 8+0 41	7 80+0 12
100	27 9±0 74	6 8+0 38	7 90+0 11
200	27 7±0 70	6 9±0 40	7 95+0 10
400	27 8±0 67	6 7+0 45	7 85±0 13
800	27 8+0 65	6 7±0 50	7 90+0 14

* Average value of fıve observatıons

** S D Standard Devıatıon

From fıg 2 ıt ıs seen that there ıs not much dıfference ın survıval rates at varıous stockıng densıtıes trıed However the hıghest percentage of survıval of 100% was found at lowest stockıng densıty and the lowest percentage of survıval of 87 12% was found at the hıghest stockıng densıty These results suggest that stockıng densıty upto 800nos/m² ıs not lımıtıng wıth respect to survıval

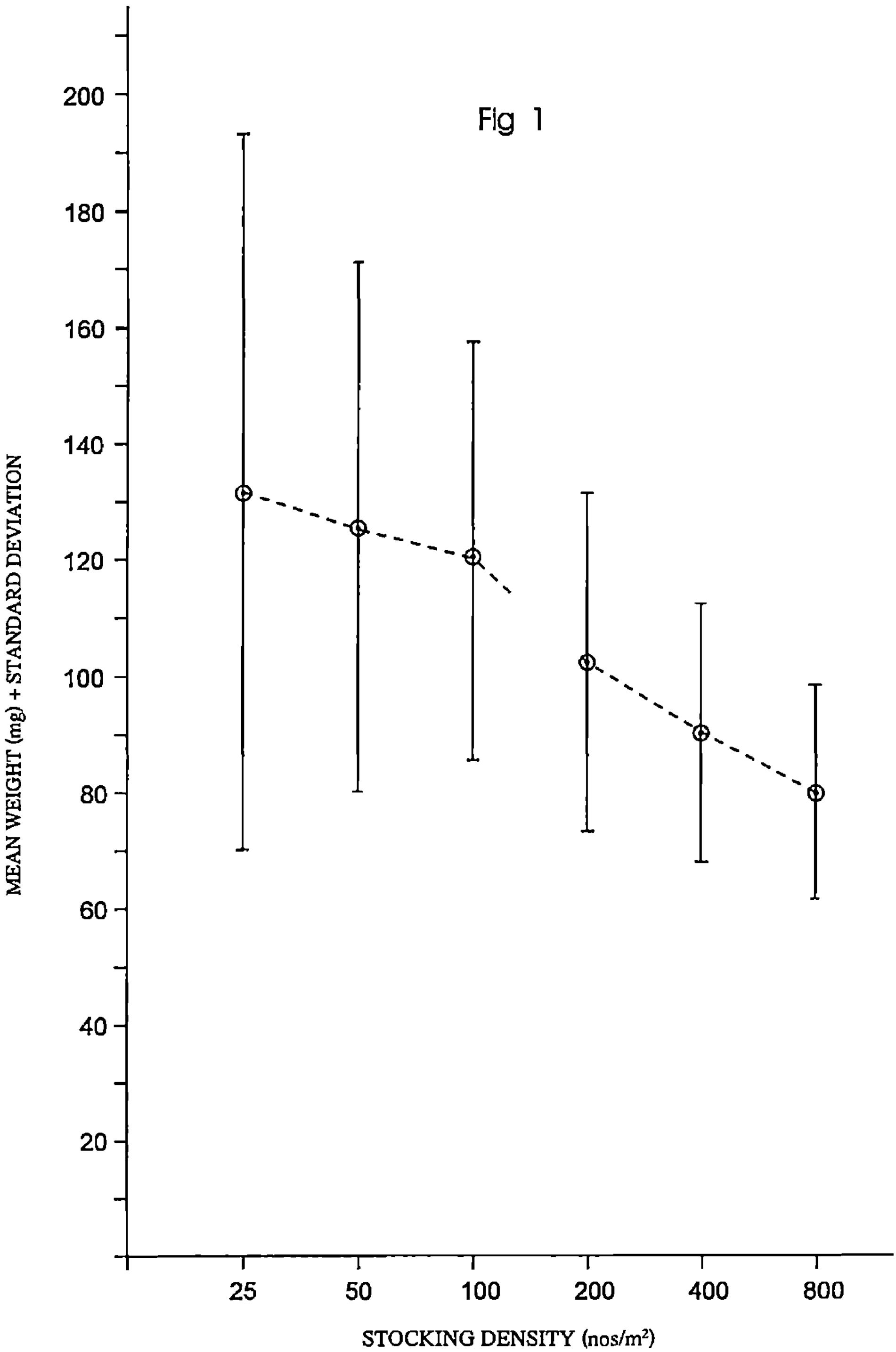


Fig 1 Effect of stocking density on mean weight(+ standard deviation) of *M rosenbergii* post larvae after 35 days of nursery rearing

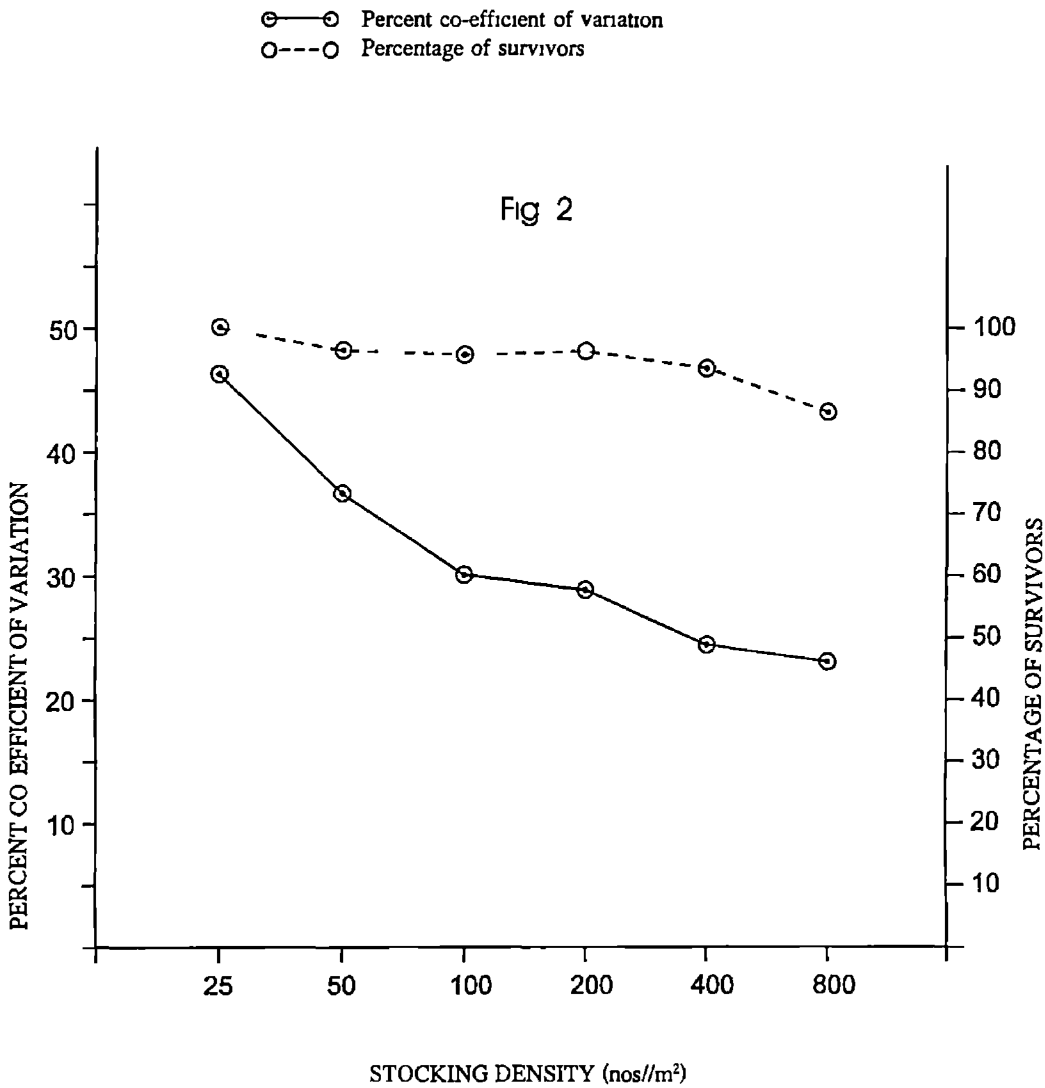


Fig 2 Effect of various stocking densities on percent co-efficient of variation and percentage of survival of *M rosenbergii* post larvae after 35 days of nursery rearing

Fig 3

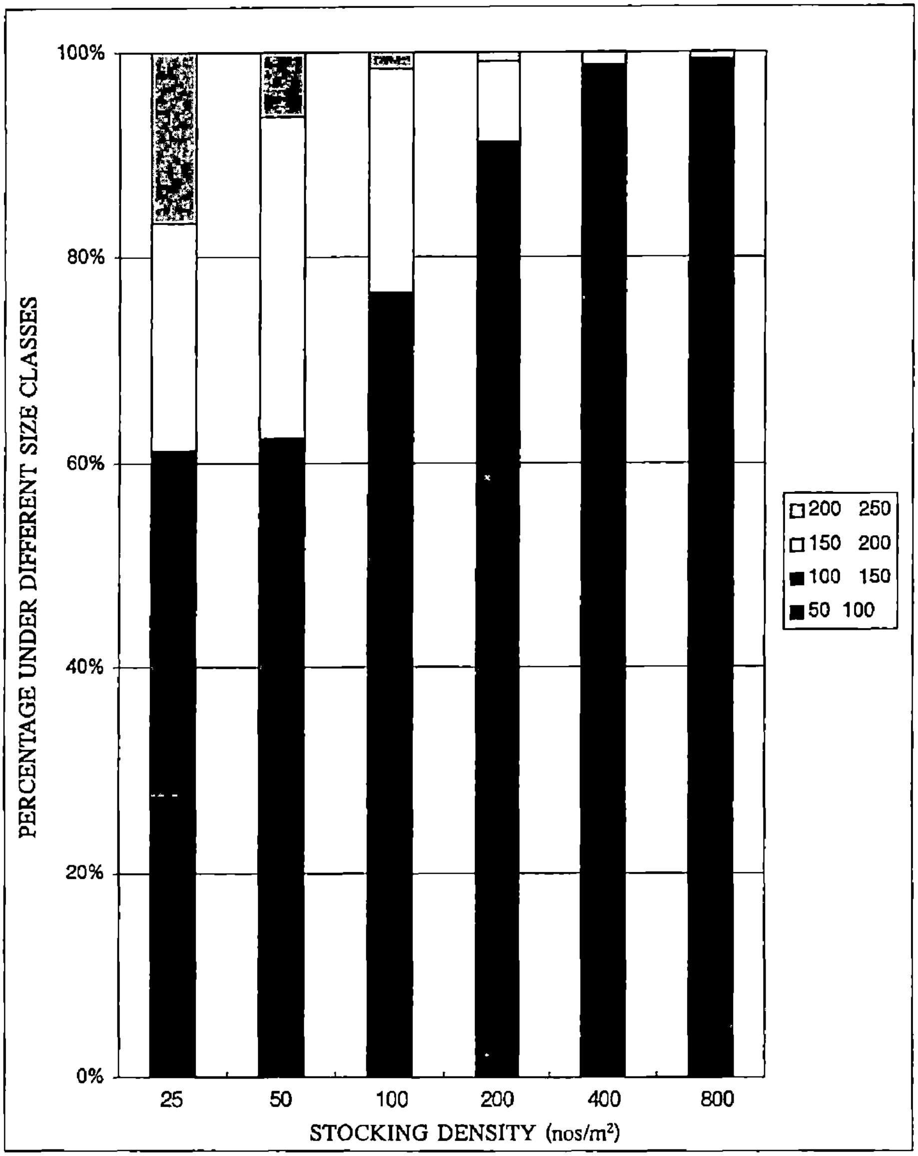


Fig 3 Effect of stocking density on size class of *M rosenbergii* post larvae after 35 days of nursery rearing

Fig 4

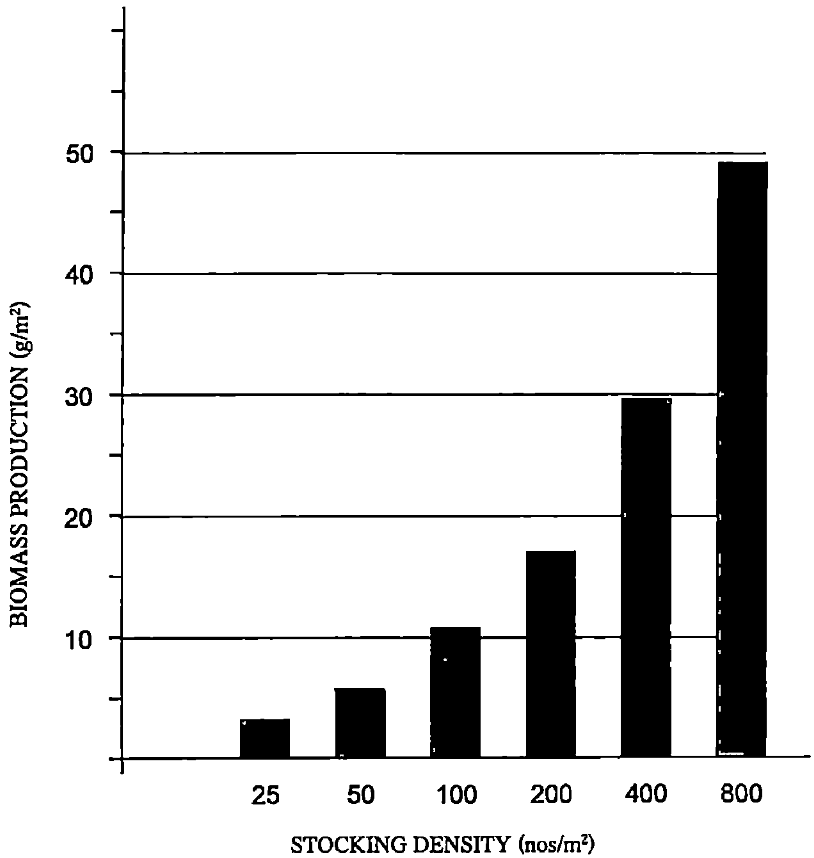


Fig 4 Effect of stocking density on biomass production of *M rosenbergii* post larvae after 35 days of nursery rearing

The total biomass production values of juveniles at various stocking densities at the end of 35 days of nursery rearing are shown in fig 4 It is seen that the biomass production of juveniles in creased with increasing stocking density The highest biomass production of 48 027 5mg was found at the highest stocking density and the lowest biomass production of 3015mg was found at the lowest stocking density

The water quality parameters monitored during this study are shown in table 5

4 2 Experiment to Find the Effect of Provision of Different Types of Additional Substrates on Differential Growth and Survival Rates of *M.rosenbergii* During Nursery Rearing

The results of the experiment to find the effect of providing different substrate types in the rearing tanks on differential growth and survival rates of juveniles of *M.rosenbergii* are shown in table 6 It can be seen that provision of additional substrates in the rearing tanks influenced the growth rate (fig 5) After 35 days of nursery rearing the lowest mean weight of 98 37 mg was found in the tank without any additional substratum Among the various substrates used clam shell was found to be the best in enhancing growth of the juveniles of *M rosenbergii* With clam shell the mean weight at harvest was 111 38 mg compared to the figures of 105 64 mg and 104 50 mg in the tanks with black polythene raffia and round pebbles respectively Comparison using ANOVA(table 7) showed that there is significant difference in mean weight of juveniles between the treatments with additional substrates and the one without any additional substratum The mean weight of the juveniles in the tanks with clam shell was also found to be significantaly higher than the mean weight of the juveniles in the tanks with round pebbles and black polythene raffia as additional substrates

The percent co efficient of variation (P C V) of the mean weight of juveniles found were 32 92 in tanks with round pebbles 31 50 in tanks with black polythene raffia and 30 21 in tanks with clam shell as additional substrates These were comparitively higher than the P C V of 28 63 in tanks without any additional substratum (fig6) Similarly skewness values were also higher for the treatment with additional substrates than the treatment without any additional substratum Thus the provision of additional substrates could not combat the differential growth rather it led to an increase in the differential growth

Table 6 Growth dıfferentıal growth survıval and bıomass productıon of *M.rosenbergıı* post larvae reared ın tanks wıth dıfferent types of addıtıonal substrates for 35 days at a stockıng densıty of 800 post larvae/m²

Varıous parameters studıed	Substrate types			
	Control	Round pebble	Clam shell	Black polythene raff a
Average ın t al we gh (mg)	10	10	10	10
Ave age f nal we ght(mg)	98 37	104 50	111 38	105 64
Standard dev at on	26 67	34 4	33 65	33 28
Percent co-eff c ent of varıatıon	28 63	32 92	30 21	31 50
Skewness	0 130	0 567	0 487	0 320
Average we gh ga n(mg)	88 37	94 50	101 38	95 64
Ave age da ly we ght ncrement(mg)	2 52	2 7	2 90	2 73
Surv val(%)	70 74	80 40	83 38	77 41
Average B omass ncrement(mg/m²/35day)	50010 35	60782 4	67624 52	59227 94
Average B omass ncrement (mg/m²/day)	1428 87	1736 64	1932 13	1692 23

Table 7 Analysıs of varıance showıng the effects of dıfferent types of addıtıonal substrates on average sıze (weıght) of post larvae of *M.rosenbergıı* after 35 days of nursery rearıng

Source	Degrees of f eedom	Sum of squa es	Mean sum of squares	F values	
				compu ed	Tab ed (a 5%)
Subs a e type	3	345 97	115 32	7 81	3 49
Erro	12	177 20	14 77		
To al	15	523 17			

Crı ca D fference 4 84 at 5%

Table 8 Percentage dıstrıbutıon of *M.rosenbergıı* post larvae to dıfferent sıze classes after 35 days of nursery rearıng wıth dıfferent types of addıtıonal substrates

S ze classes(mg)	Substrate types			
	Control	Round pebbles	Clam shell	Black polythene raff a
50 90	42 66	41 70	27 60	34 13
90 130	45 11	38 87	47 87	46 79
130 170	10 60	12 72	18 57	14 13
170 and above	1 63	6 71	5 96	4 95

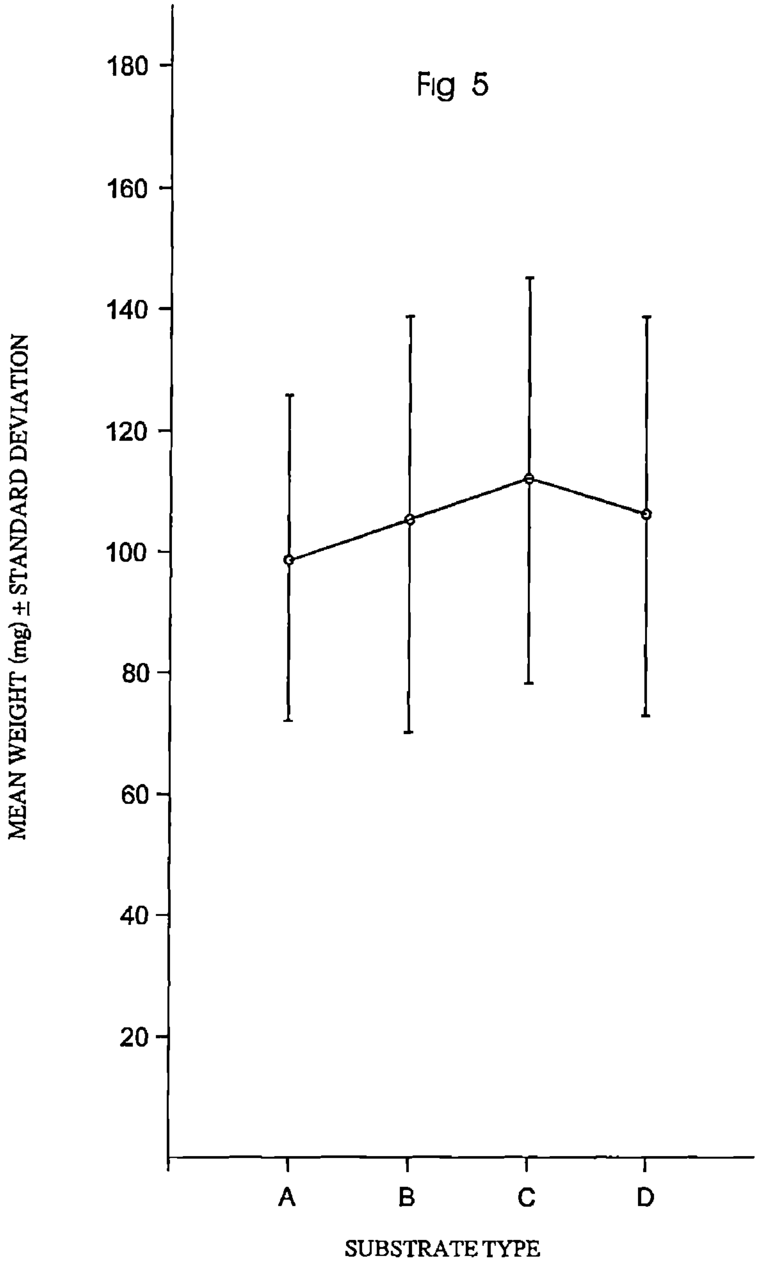
Table 9 Water qualıty parameters monıtored durıng 35 day nursery rearıng of *M rosenbergıı* post larvae ın tanks provıded wıth dıfferent substrate types

Substrate type	Water temperature(°C) Mean *±S D **	D ssolved oxygen(ppm) Mean±S D	PH Mean+S D
Control	27 5 ±0 85	6 8 + 0 40	7 6 + 0 15
Round pebble	27 9 + 0 81	6 5 + 0 38	7 8 + 0 12
Clam shell	27 6 + 0 83	6 6 + 0 37	7 8 + 0 094
Black Polythene raff a	28 0 + 0 88	6 7 ± 0 41	7 7 + 0 14

* Average value of fıve observatıons

** S D Standard Devıatıon

From table 8 and fıg 7 ıt can be seen that percentages of juvenıles fallıng under smallest sıze class were 42 66% ın tank wıthout any addıtıonal substratum 41 70% ın tanks wıth round pebbles 34 13% ın tanks wıth black polythene raffıa and 27 60% ın tanks wıth clam shell as addı tıonal substrates It ıs also seen that percent of juvenıles fallıng under the largest sıze class were 1 63% ın tanks wıthout any addıtıonal substratum and 4 95% 5 96% and 6 71% ın tanks wıth black polythene raffıa clam shell and round pebbles respectıvely as addıtıonal substrates Thus from the above results ıt ıs found that provısıon of addıtıonal substrates leads to a decrease ın the percentage of juvenıles fallıng under the smallest sıze class and an ıncrease ın the percentage of juvenıle fallıng



A Control
B Round pebble
C Clam shell
D Black polythene raffia

Fig 5 Effect of providing different types of substrates in the rearing tanks on mean weight (± standard deviation) of *M rosenbergii* post larvae after 35 days of nursery rearing

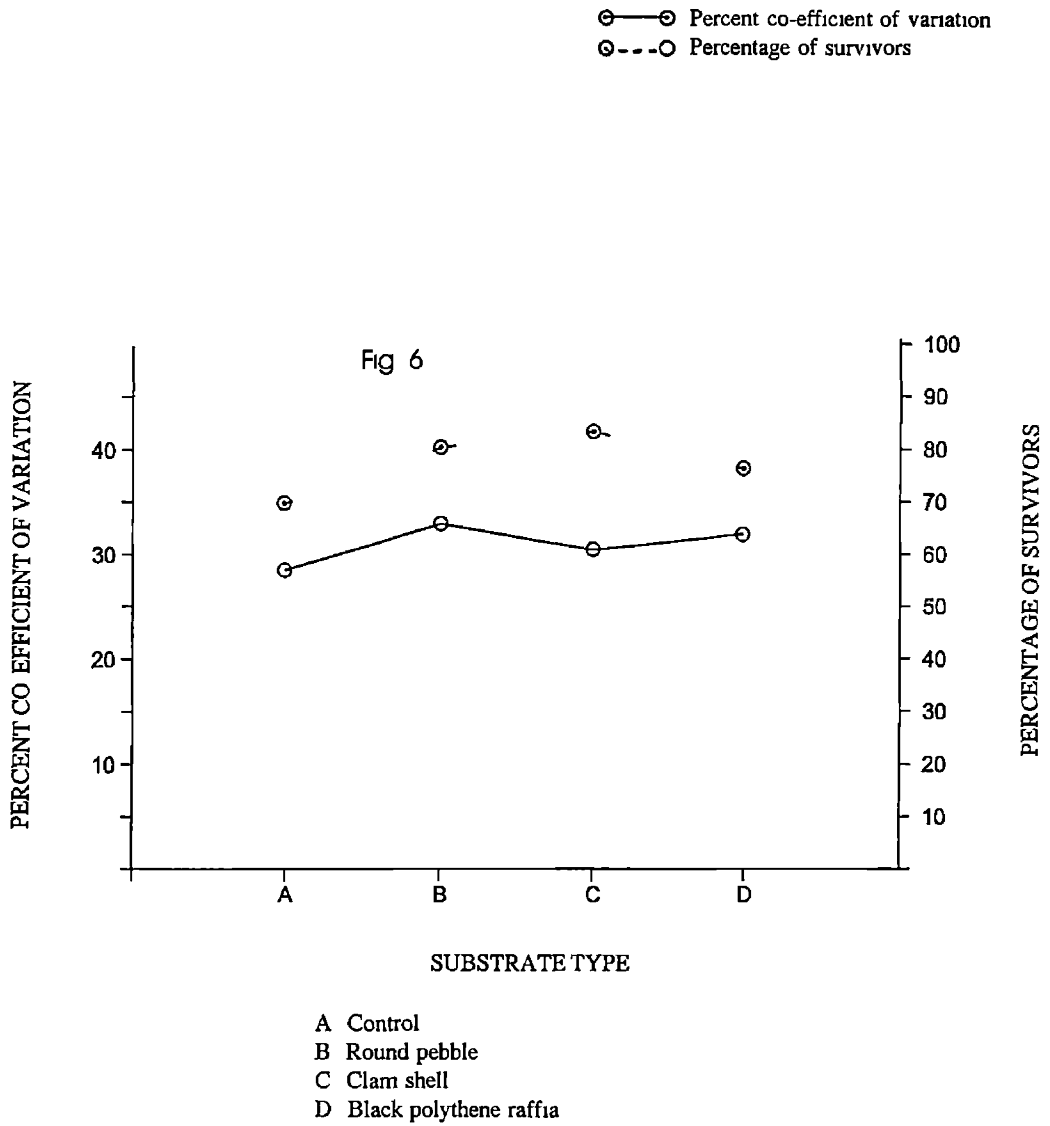
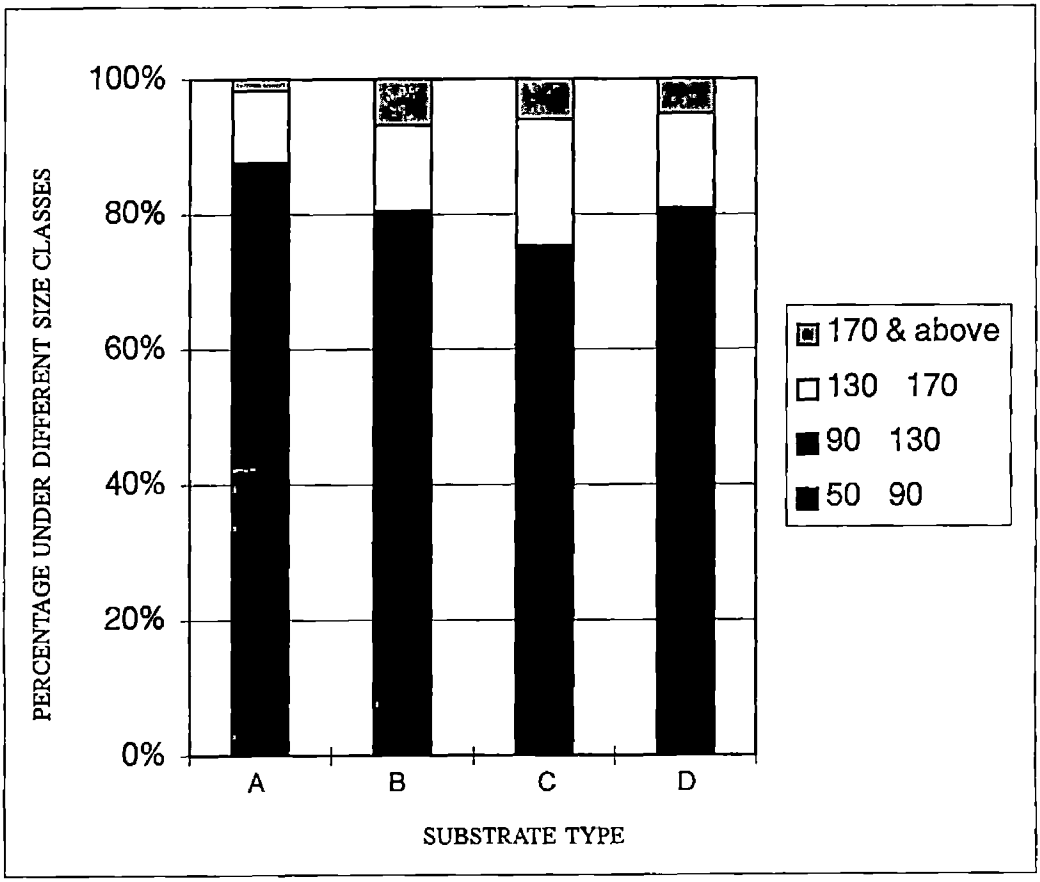


Fig 6 Effect of providing different types of substrates in the rearing tanks on percent co efficient of variation of mean weight of *M rosenbergii* post larvae after 35 days of nursery rearing

Fig 7



A Control
B Round pebble
C Clam shell
D Black polythene raffia

Fig 7 Effect of providing different types of substrates on percentage distribution of different size classes of *M rosenbergii* post larvae after 35 days of nursery rearing

Fig 8

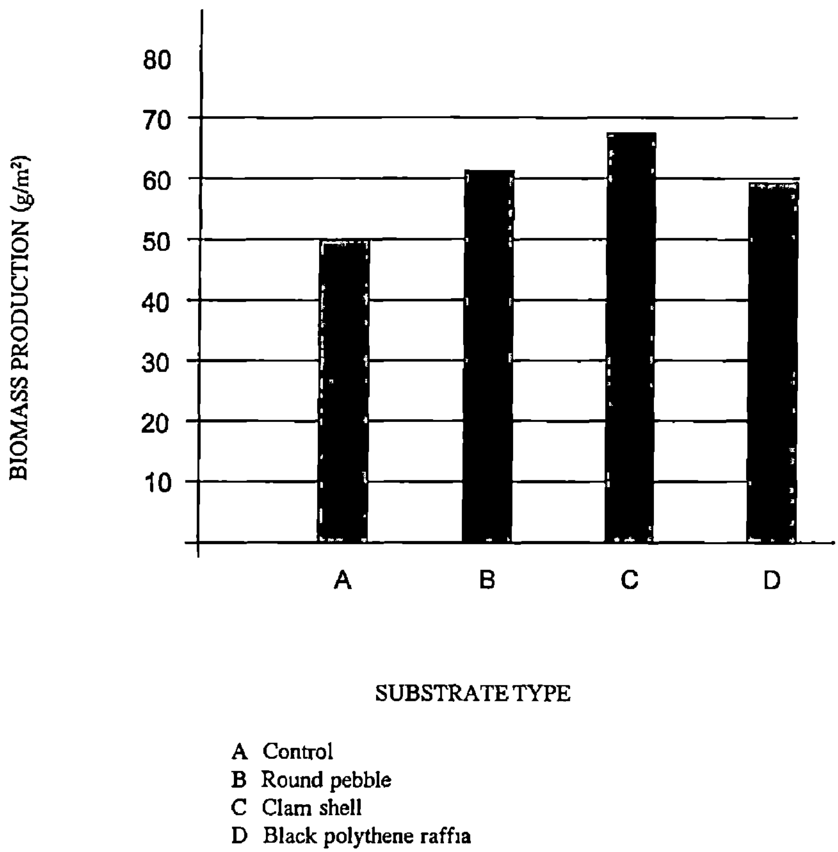


Fig 8 Effect of providing different types of substrates on biomass production of *M rosenbergii* post larvae after 35 days of nursery rearing

under the largest size class which indicates that growth of juveniles of *M.rosenbergii* can be en hanced by providing additional substratum

It was also found that the provision of additional substrates resulted in a considerable increase in survival rates The survival rate in tanks without any additional substrates was only 70 74% where-as higher values of survival rate of 77 41% 80 40%and 83 38% were found in tanks with black polythene raffia round pebbles and clam shell respectively as additional substrates (fig 6)

From the fig 8 it can be seen that provision of additional substrates led to an increase in total biomass production also The average biomass production after 35 days of nursery rearing in tanks without any additional substratum was the lowest being only 50 010g Among the different sub strates used the highest average biomass production of 67 625g was found in the tanks with clam shell as additional substratum followed by 60 782g in tanks with round pebbles and 59 228g in tanks with black polythene raffia as additional substrates Thus it can be seen that the provision of addi tional substrates has helped the nursery rearing operation in all respects except in combating the differential growth

The water quality parameters monitored during the study are shown in table 9

4 3 Experiment to Find the Degree of Variation in Differential Growth Among Different Size Groups of Juveniles of *M.rosenbergii*

The data of the results of the experiment to find the degree of variation in differential growth under various size groups of juveniles of *M.rosenbergii* after 35 days of rearing are given in table 10 From the table and fig 9 it can be seen that the mean weight gain in large mixed medium and small size groups were 371 05 mg 161 98 mg 138 07 mg and 83 82 mg resoectively The mean weight gain was higehst in the large size group which is more than two times (2 29) that of the mixed size group more than two and half times (2 69) that of the medium size group and about four and half times (4 43) that of the small size group Pair wise comparison based on the results of ANOVA (table 11) showed significant differences in mean weight gain among different treatments except in the case

Table 10 Growth differential growth survival and biomass production among different size groups of *M.rosenbergii* juveniles after 35 days of rearing

Various parameters studied	Size groups				
	Large	Med um	Small	Calcula ed average of 3 groups	Mixed group
Average in t al we ght(mg)	170	120	70	120	120
Average f nal we ght(mg)	541 05	258 07	153 82	317 65	281 98
Standard dev at on	144 55	80 61	36 68	87 28	101 72
Percent co-eff c en of variat on	26 72	31 23	23 85	27 27	36 07
Skewness	0 29	0 896	0 270		0 781
Average we ght gain(mg)	371 05	138 07	83 82	197 65	161 98
Average da ly we ght increment(mg)	10 60	3 94	2 39	5 65	4 63
Surv val(%)	79 17	85 42	91 67	85 41	87 5
Average b omass ncrement (mg/m /35 days)	14099 90	5660 87	3688 08	8103 02	6803 16
Average da ly b omass ncrement (mg/m²/day)	402 85	161 74	105 37	231 51	194 38

Table 11 Analysis of variance table showing the effects of size grading on mean weight gain

Source	Degrees of freedom	Sum of Square	Mean sum of square	F Value	
				Computed	Tabled(at 5%)
S ze groups	3	191713 45	63904 48	63 20	3 49
Error	12	12134 14	1011 18		
Total	15	203847 59			

Crit cal d fference 40 07 at 5%

The water quality parameters monitored during the study are shown in table 12

Table 12 Water quality parameters monitored during 35 days of rearing of juveniles of different sizes of *M rosenbergii*

Size groups	Water temperature(°C) Mean * + S D **	Dissolved Oxygen(ppm) Mean ± S D	pH Mean + S D
Large	27 90 ± 0 81	6 5 + 0 45	7 72 ± 0 097
Medium	28 00 + 0 83	6 7 ± 0 44	7 90 ± 0 095
Small	27 95 + 0 82	6 5 ± 0 42	7 83 + 0 099
Mixed	28 05 ± 0 82	6 6 + 0 43	7 89 + 0 098

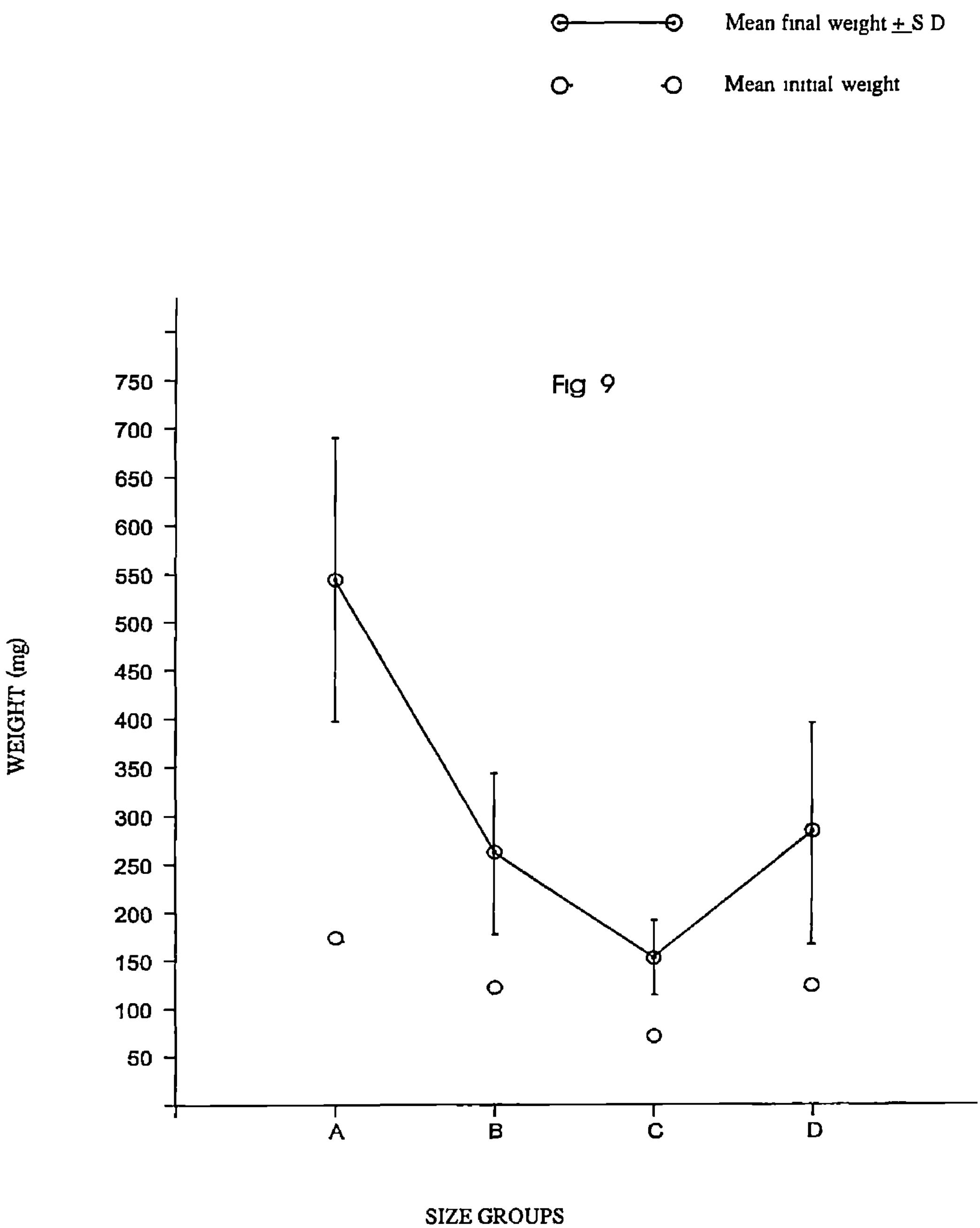
* Average value of five observations

** S D Standard Deviation

of medium and mixed size groups The calculated average weight gain of large medium and small size groups put together was 197 65mg which is higher than the mean weight gain of 161 98mg in mixed size group Thus it is seen that size grading of juveniles helped in increasing the mean weight gain in *M rosenbergii*

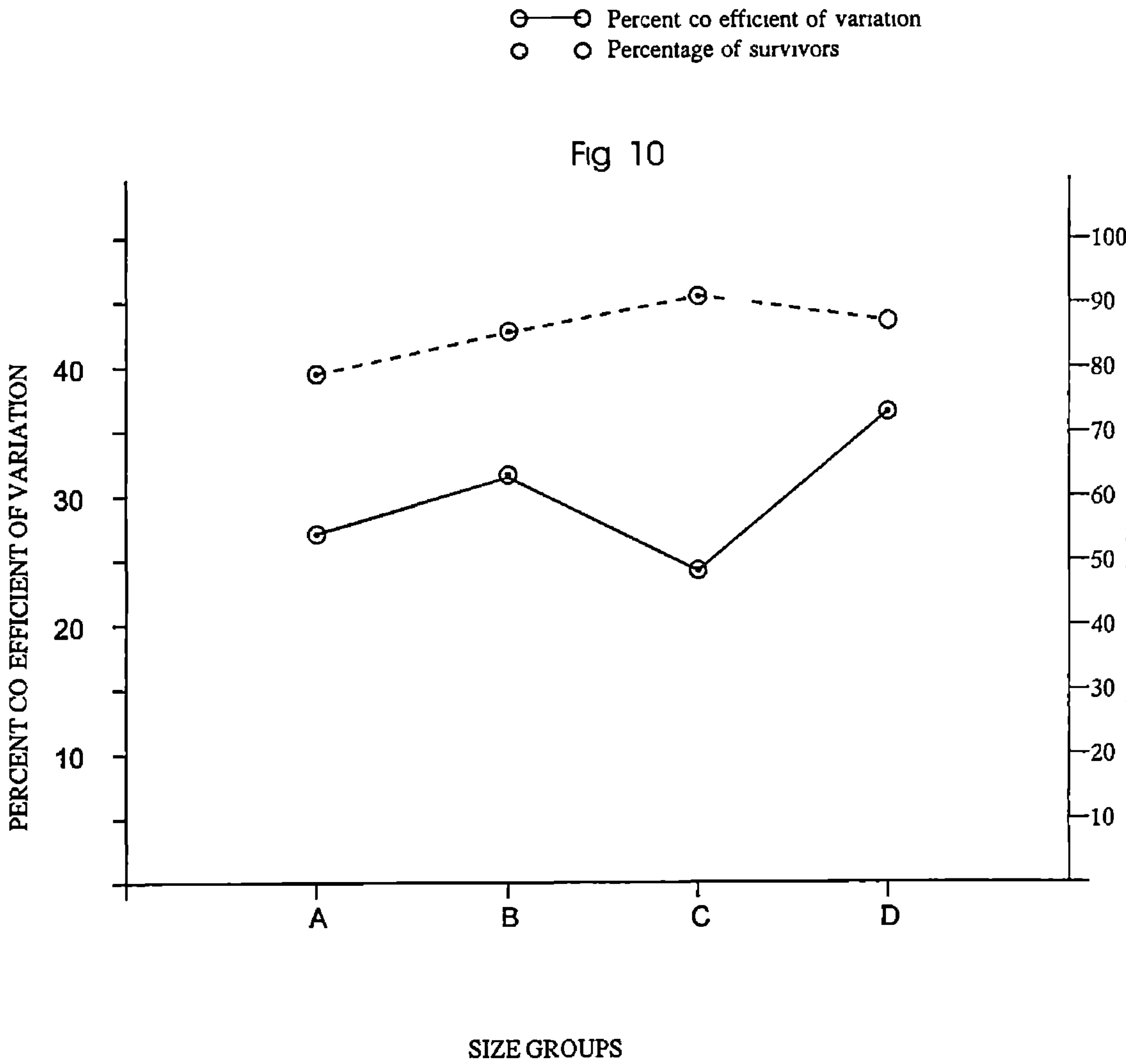
The percent co efficient of variation values found in different treatments were 36 07 in mixed size group 31 23 in medium size group 26 72 in large size group and 23 85 in small size group Thus it is seen (fig 10) that the highest P C V was found in the mixed size group Among other size groups the highest P C V was found in medium size group followed by large and small size groups These results indicate that the pronounced differential growth occured in the medium sized juveniles and size grading can help in bringing down the differential growth to certain extent

There was not much difference in the survival rates among various treatments The highest survival rate of 91 67% was found in the small size group and the lowest survival rate of 79 17% in the large size group (fig 10) The calculated average of survival rate of large medium and small size groups put together was 85 41% which is lower than the survival rate of 87 5% found in the mixed



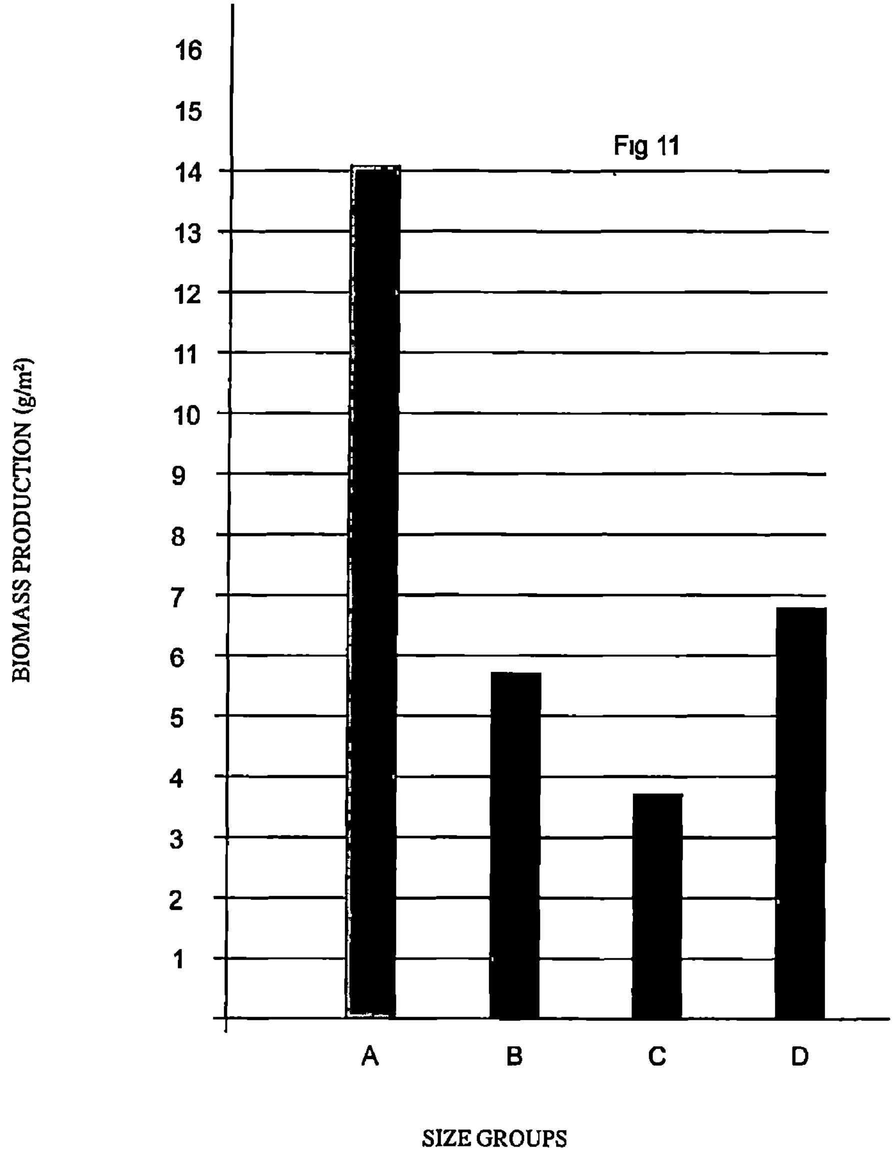
A Large
B Medıum
C Small
D Mıxed

Fıg 9 Growth of dıfferent sızed juvenıles of *M rosenbergıı* after 35 days of rearıng



A Large
B Medium
C Small
D Mixed

Fig 10 Percent co-efficient of variation among different size groups of juveniles of *M rosenbergii* after 35 days of rearing



A Large
B Medium
C Small
D Mixed

Fig 11 Biomass increment among different size groups of juveniles of *M rosenbergii* after 35 days of rearing size group These results indicate that size grading of juveniles cannot help in increasing the survival rate

The biomass increment after 35 days of rearing is shown in fig 11 The highest biomass increment of 14 099 9mg was found in the large size group which is about two and half times(2 49) of the biomass increment of 5660 87mg in medium size group about four times (3 82) of the biomass increment of 3688 08mg in small size group and about two times (2 07) of the biomass increment of 8103 02mg in the mixed size group The calculated biomass increment of large small and medium size groups is found higher than the biomass increment in the mixed size group These results indicate that by stocking size graded juveniles the biomass increment can be augmented In the present study it was observed that the small size group juveniles consumed very less feed in the beginning of the experiment However after a few days they showed improvement in their food consumption

Attempt was also made to observe the appearance of appendix masculina But upto 35 days of rearing period the appendix masculina did not appear in any of the juveniles So the experiment was prolonged The appendix masculina appeared after 105 days of the experiment i e after 154 days of metamorphosis of larvae into post larvae The size of the prawns on which the appendix masculina first appeared was 6 2 cm in length and 1 75g in weight The appendix masculina at its first appearance had one spine at it s tip and it s length was 0 98mm The length of the endopod at that time was 4 0mm The appendix masculina was again observed after the next moult during which it had 5nos of spines at tip and its length increased to 1 31mm while the length of endopod increased to 4 545 mm Thus we can see that the ratio at which the length of appendix masculina increased was 1 1 34 whereas the ratio at which the length of endopod increased was 1 1 14

5 DISCUSSION

5 1 Effect of Stockıng Densıty on Dıfferentıal Growth and Survıval

The results of the present study on the effect of stockıng densıty on dıfferentıal growth had shown that stockıng densıty has a pronounced effect on the average growth and varıatıon ın growth but has not much effect on survıval of *M rosenbergıı* juvenıle populatıon

It can be seen that the mean sıze of the juvenıles decreased wıth ıncreasıng densıty The ınverse relatıonshıp between densıty and mean sıze of *M rosenbergıı* has been reported by many ınvestıgators such as Wıckıns (1972) Forster and Beard (1974) Sandıfer and Smıth (1975) Wıllıs *et al* (1976) Wıllıs and Berrıgan (1977) Smıth *et al* (1978 1981) Knealae and Wang (1979) Cohen *et al* (1981) Ra anan(1982) Ra anan and Cohen(1984a) Karplus *et al* (1985) D Abramo *et al* (1989) Sıddıquı and Al Hınty (1993) and Danıels *et al* (1995) Durıng nursery rearıng of post larvae Kneale and Wang (1979) found that overall growth was hıgher for stockıng densıtıes at or below 600PL/m^2 as compared to densıtıes above thıs range Sımılarly Cohen *et al* (1981) by stockıng post larvae at stockıng densıtıes of 1 5 and 10 PL/L durıng nursery rearıng and then stockıng the juvenıles ın grow out pond at the densıtıes of 30 000 70 000 and 1 50 000 nos/ha found that the mean growth durıng both the nursery rearıng and grow out perıod decreased wıth ıncreasıng densıty So also Ra anan and Cohen (1984a) by stockıng post larvae at the densıtıes of 420 2100 and 4200 nos/m^2 found that mean sıze decreased wıth ıncreasıng densıty By stockıng juvenıles of 2 g sıze at the densıtıes of 1 2 3 and 4 nos/m^2 and rearıng for 100 days Karplus *et al* (1989) found that mean prawn sıze decreased wıth ıncreasıng densıty D Abramo *et al* (1989) by stockıng juvenıles of *M rosenbergıı* at densıtıes rangıng from 39 536 to 1 18 608 nos/ha and growıng for 135 to 142 days found that mean prawn weıght at harvest ranged from 15 0 to 44 3 g and decreased wıth ıncreasıng densıty Sıddıquı and Al Hınty (1993) found that growth rate was negatıvely related to stockıng densıty wıth mean weıghts of 25 4 g 19 5g 17 6g and 13 3g at stockıng densıtıes of 2 4 8 and 16 nos/m^2 respectıvely after 175 days of rearıng of juvenıles of *M rosenbergıı* By stockıng sıze graded juvenıles at densıtıes of 39 540 59 300 and 79 100 nos/ha Danıels *et al* (1995) found that densıty has sıgnıfıcant effect on average whole body weıght of prawns at harvest The results of Wıllıs *et al* (1976) obtaıned after stockıng post larvae of *M rosenbergıı* of sıze 0 032g at densıtıes of 215 430 645 and 860 nos/ m^2

however showed that average weight gain had little relation to stocking density They noted that prawns stocked at the highest stocking density showed best average weight gain A number of possible factors act singly or simultaneously which lead to the reduction of growth in prawns with increasing density Competition for food may affect the growth at higher densities Segal and Roe (1975) reported that deprivation of food to smaller prawns by larger ones was there when cultured in groups The unexpected weight gain in *M rosenbergii* at the highest stocking density was interpreted by Willis *et al* (1976) as due to the availability of exess food since feeding was done at the rate of 5% of the body weight without taking into consideration the high mortality under the particular stocking density which was determined only after one month According to Cohen *et al* (1981) early maturation of females at high densities followed by maturation of small sized males occurred at the cost of somatic growth Hyperactivity of subordinate individuals as observed by Cobb and Tamm (1975) causing more expenditure of energy aggressiveness of dominant males and development of social hierarchy leading to less consumption of food even when food is abundant or poor food conversion efficiency at higher densities are other possible factors affecting the growth of prawn with increasing density

In the present study it was observed that at higher stocking densities prawns seem to fight each other leading to utilization of more energy thereby causing retardation of growth Forster and Beard (1974) found that at higher stocking density one or both of the second pair of walking legs in many individuals of *M rosenbergii* were absent These were presumably lost during fights m which this species frequently engages.It therefore seems probable that stresses like this at higher stocking density could have caused retardation in growth As noted by Ra anan and Cohen (1984a) it is the density per surface area which is more important than the density per volume in influencing the growth This was due to the shift of the post larvae from a behavioural pattern of free swimming using the whole water column to settling on substrates using mainly the bottom surface area as observed by Ling and Merican (1961)

In the present study it was found that percent coefficient of variation and skewness decreased with increasing density Similar results were also obtained by many other investigators such as Sandifer and Smith (1975) Smith and Sandifer (1979) Cohen *et al* (1981) Ra anan (1982) Ra anan and Cohen (1984a) However in a study conducted by Willis *et al* (1976) by stocking post larvae of *M rosenbergii* of size 0 032g at stocking densities of 215

430 645 and 860 nos/m² and rearing for two months found that variation in length of the juveniles increased with increasing density In another study Karplus *et al* (1986a) by stocking juveniles of 2g average weight at stocking densities of 1 2 3 and 4 nos/m² in a grow out operation found that the coefficient of variation of the whole population was quite uniform Similar observation was also made by Forster and Beard (1974) where percent coefficient of variation of length of *M rosenbergii* was almost similar at the stocking densities of 25 prawns/m² and 100 prawns/m²

It could be seen from the results that at the lower stocking densities of upto 200 nos/m² all the four size classes of juveniles were present There was a sharp decline in the percentage of juveniles falling under the largest size class with increasing density and at the stocking densities of 400 and 800 nos/m² no juvenile was found to fall under the largest size class Thus more uniform growth obtained at the higher stocking densities was probably due to lesser growth of the jumpers Cohen *et al* (1981) also found that in high nursery stocking densities growth was retarded especially among fast growing group resulting in a lower mean weight and a higher degree of weight uniformity when compared to the lower density Karplus *et al* (1985) found that much of the total yield at the highest density consisted of smaller size prawns and decreasing stocking rates resulted in a continuously increasing proportion of larger prawns Siddiqui and Al Hinty (1993) also found that percentage of marketable size prawns progressively decreased with the increasing density Ra anan (1982) pointed out that appearance of jumpers was not merely a result of competition but was a phenomenon associated with the ontogeny of population structure morphotypic variation and social hierarchy

The total biomass production in the present study was found to increase with increasing density Smith *et al* (1983) also obtained a higher biomass production at higher stocking density Karplus *et al* (1986a) found that total yield of *M rosenbergii* increased with increasing density from 1 2 3 or 4 prawns/m² after 110 days of rearing period Siddiqui and Al Hinty (1993) by stocking juveniles at densities ranging from 2 to 16nos/m² also found that total prawn yield increased significantly with the increasing density and the maximum yield was obtained at the highest stocking density Daniels *et al* (1995) found that by stocking juveniles of M rosenbergii the average total yield after 131 to 134 days of rearing ranged from 1 041 to 1662 kg/ha for stocking densities ranging from 39 540 to 79 100/ha

In the present study ıt was found that there was not much dıfference ın survıval rate among the varıous stockıng densıtıes However the maxımum survıval rate of 100% was found at the lowest stockıng densıty and the mınımum survıval rate of 87 12% was found at the hıghest stockıng densıty The survıval rate obtaıned ın the present study ıs comparatıvely hıgher whıch may be because of proper management and balanced feed provıded ın suffıcıent quantıty Karplus *et al* (1986a) also found that survıval rate was ındependent of densıty Naır and Thampy (1988) found that the survıval rates were almost sımılar at stockıng densıtıes rangıng from 500 to 2000 nos/m^2 suggestıng that stockıng densıtıes upto 2000/m^2 were not lımıtıng wıth respect to survıval provıded there was suffıcıent food and dıssolved oxygen Danıels *et al* (1995) also found that densıty has no sıgnıfıcant effect on survıval However several other ınvestıgators such as Wıckıns (1972) Sandıfer and Smıth (1975) Smıth *et al* (1976 1981 1983) Ra anan and Cohen (1984a) and Sıddıquı and Al Hınty (1993) found that survıval rate ın *M rosenbergıı* was ınversely proportıonal to stockıng densıty

In penaeıd shrımp *Penaeus monodon* Abdussamad (1991) found that mortalıty ıncreased wıth ıncreasıng densıty rangıng from 11 76% at the lowest stockıng densıty of 25 nos/m^2 to 27 26% at the hıghest stockıng densıty of 500 nos/m^2 The densıty dependent survıval was also observed ın other crustaceans such as *Homarus amerıcanus* (Aıken and Waddy 1978) and *Hemıgrapsus penıcıllatus* (Kurıhara and Okamoto 1987) Kurıhara *et al* (1988) observed that ın mud crab *Helıce trıdens* ıf the populatıon densıty became greater than the carryıng capacıty of the system the anımals responded by ıncreasıng the rate of cannıbalısm thereby reducıng the populatıon densıty to the optımum level

5 2 Effect of Provısıon of Dıfferent Types of Addıtıonal Substrates on Dıffer ential Growth and Survıval Rate

From the results of the present study ıt could be seen that growth dıfferentıal growth and survıval rates of juvenıles of *M rosenbergıı* ıncreased when addıtıonal substrates were provıded ın the rearıng tanks Use of addıtıonal substrates to ıncrease growth and survıval had been suggested by many workers such as Lıng(1962) Reeve (1969) Forster (1970) Fujımura (1972) Wıckıns(1972) Sandıfer and Smıth (1974) Smıth and Sandıfer (1975) Kneale and Wang (1979) Ra anan *et al* (1984) and Ra anan and Cohen (1984a) for prawns Rıckards (1971) and Abdussamad and Thampy (1994) for shrımps Van Oldst *et al* (1975)

Mc Burney and Wilder (1973) Carlberg *et al* (1979) Barshaw and Bryant Rich (1988) and Eggleston *et al* (1994) for lobsters and Kurihura and Okamoto (1987) for crabs

The growth of the juveniles of *M rosenbergii* reared in tanks with additional substrates in the present study, was significantly higher than those in the tanks without any additional substratum Provision of additional substrates naturally leads to an increase in the surface area The prawns thus get access to comparatively more surface area for their settlement which probably may help in enhancing their growth This result is consistent with the find ings of Wickins (1972) Smith and Sandifer (1975) Kneale and Wang (1979) Cohen *et al* (1983) and Ra anan and Cohen (1984a) wherein they have reported higher growth of *M rosenbergii* reared in tanks with some additional substrates, than in the tanks without any substratum Smith and Sandifer (1975) further observed that feed utilization was more effi cient among prawns reared in tanks containing artificial substrates and thus they opined that this could be the reason for their higher growth Similar results were also reported for shrimps such as *Penaeus duorarum* by Rickards (1971) and *P monodon* by Abdussamad (1991)

The percent coefficient of variation and skewness of the juveniles in the present study was found to be higher in the tanks with additional substrates than that of the tanks without any additional substratum From the results of the first experiment it was evident that differ ential growth increases with decreasing stocking density per unit of bottom surface area With the provision of additional substrates the bottom surface area necessary for the settle ment of the prawns increases Therefore the stocking density per unit of bottom surface area naturally decreases ultimately leading to increased differential growth The results of the present experiment supports the findings of Ra anan and Cohen (1984a) that addition of sub strates m the rearing tanks results in an increase in the percent coefficient of variation and the degree of skewness of the size distribution of *M rosenbergii* post larval population stocked at the size of 0 009g In contrast to these results Mulla and Rouse (1985) found that juveniles of *M rosenbergii* grew more uniformly in the rearing tanks where additional substrates were provided This variation in the results may be because of the larger size juveniles used by Mulla and Rouse (1985) In the present study post larvae of 0 01g were used and Ra anan and Cohen (1984a) used post larvae of size 0 009g whereas Mulla and Rouse (1985) used juve niles of 0 04g From these results it could be stated that provision of additional substrates leads to an increase in differential growth in post larvael population whereas it reduces dif ferential growth in juvenile population

It is seen from the results of the present study that provision of additional substrates leads to a decrease in the percentage of juveniles falling under the smallest size class and an increase in the percentage of juveniles falling under the largest size class This result is con sistent with the result of Cohen *et al* (1983) wherein they found that artificial submerged substrates (made from plastic net and pipes) in ponds helped to increase marketable yield and average marketable weight of prawns Ra anan *et al* (1984) found that net substrates mark edly increased percentage of marketable prawns in the intensive system where paddle wheel aerators were also used

The percentage of survival of juveniles in the present study was found higher in the tanks with additional substrates than m the tanks without any additional substratum This is perhaps because of the fact that additional substrates provided more hiding places to the weaker and newly moulted prawns from the attack of stronger ones Similar results of in creased survival rate with provision of additional substrates in *M rosenbergii* were also re ported by Smith and Sandifer (1975) and Ra anan *et al* (1984) Smith and Sandifer (1975) observed that cannibalism became apparent at a much smaller size among prawns reared in tanks without any substratum resulting in less survivability Higher survival in tanks with additional substrates was also reported by many investigators in other crustaceans Forster (1970) found that in penaeid prawn *Penaeus serratus* mortality was much less i e only 3 65% per day with provision of additional substrates in the rearing tanks as compared to 5 93% per day in the tanks without any additional substratum Abdussamad and Thampy (1994) re ported that additional substrates provided more hiding places to weaker and newely moulted shrimps thereby decreasing the cannibalism They found that in *P monodon* the rate of cannibalism was only 5 3% to 10 17% in tanks with added substrates compared to 18 65% in tanks without any substratum Provision of shelter substrates in rearing tanks of the lobster *Homarus americanus* reduced the number of social encounters that lead to fighting and can nibalism (Van olst *et al* 1975) Carlberg *et al* (1979) evaluated the effect of different sub strate types shelter densities and stocking densities on the survival and rate of cannibalism and found that abundance of oriented refuges decreased mortality resulting from cannibal ism Kurihara and Okamoto (1987) observed in grapsid crab *Hemigrapsus penicillatus* that visual contact of individuals led to aggressive encounters and cannibalism and provision of shelter for the smaller individuals helped in avoiding cannibalism

The results of the present study indicate that the total biomass production can be increased by providing additional substrates in the rearing tanks Provision of additional substrates leads to an increase in mean size and survival of prawns which ultimately leads to an increase in the total biomass production Increase in biomass production with provision of additional substrates in *M rosenbergii* was reported by many other workers such as Smith and Sandifer (1975) Kneale and Wang (1979) Ra anan *et al* (1984) and Ra anan and Cohen (1984a) Similar results were also obtained in the case of the shrimps such as *P duorarum* (Rickards 1971) and *P monodon* (Abdussamad 1991) However Mulla and Rouse (1985) reported that provision of additional substrates in nursery pools led to some improvements in average size and size distribution of juveniles of *M rosenbergii* but did not improve overall production

Among the various substrates tried clam shell was found to be the best to increase both growth and survival in the present experiment The clam shell might have provided more congenial environment for growth and more hiding places to the weaker and newly moulted individuals leading to higher growth and survival Abdussamad and Thampy (1994) reported that clam shell and black polythene raffia were the most effective in minimizing cannibalism in *P monodon* Van Olst *et al* (1975) found that for American lobster *Homarus americanus* oyster shell was the best shelter substrate to reduce cannibalism and assuring high carrying capacity compared to other substrates such as beach sand round beach rock and PVC tubing

From the results of the present study it could be concluded that provision of additional substrates leads to an increase in growth and survival but it cannot help to combat differential growth rather it enhances differential growth and among various substrates tried clam shell is found to be the best substrate for enhancing both growth and survival of *M rosenbergii* post larvae

With the provision of additional substrates,the situation in the rearing tanks becomes more or less similar to that of low stocking density Thus by providing additional substrates stocking density can be substantially increased without hampering the growth and survival of *M rosenbergii* post larvae during nursery rearing

5 3 Degree of Variation in Differential Growth Among Different Size Groups of Juveniles of *M rosenbergii*

From the results of the experiment to find the degree of variation in differential growth among the different size groups of juveniles of *M rosenbergii* it could be noticed that there was much variation in differential growth between the size graded population and the mixed population The differential growth was highest in the mixed population than in any of the size graded population This could be due to the fact that in the mixed group both fast growing and slow growing individuals were there and there was high variation in their size at the time of stocking itself This result is consistent with the findings of Daniels and D Abramo (1994) that size grading of juveniles before stocking disrupts the conditions leading to significant development of heterogeneous individual growth in production ponds during growing season However Karplus *et al* (1987) dividing the juveniles of *M rosenbergii* into three fractions and a recombined control group in a growout operation of 97 days duration in pond condition found that the differential growth in the lower fraction was higher than the control This variation in the result could be owing to the use of bigger sized juveniles by Karplus *et al* (1987) in comparison to the present experiment and the one by Daniels and D Abramo (1994) The mean size of the juveniles used by Karplus *et al* (1987) on the growout operation in the pond conditions was 1 1g compared to 0 12± 0 007g for the juveniles used in the present study and 0 16 ± 0 08g for the juveniles used by Daniels and D Abramo (1994)

Among three size graded groups of *M rosenbergii* juveniles m the present study the differential growth was found to be highest in the medium size group followed by large and small size groups The highest differential growth found in the medium size group may be due to the fact that while the large size group contained more or less fast growing prawns and the small size group contained more or less slow growing prawns the medium size group probably contained a mixture of individuals having growth rates in between the two extremes Karplus *et al* (1987) on the other hand found that among the three size graded fractions it was the lower fraction that had the highest differential growth followed by middle and upper fractions This variations m the results might be due to the long duration of the experiments done in pond conditions by Karplus *et al* (1987) wherein after a certain period many of the prawns in lower fraction remained in the lower weight classes

In the present study the average weight increment was found to be highest in the large size group lowest in the small size group and intermediate in the middle and mixed size groups Karplus *et al* (1987) also found almost similar results and they had suggested that differences in mean weight and yield of the graded fractions were presumably due to changes in population structure rather than differences in absolute weight In another experiment Karplus *et al* (1986b) found that mean weight at harvest of *M rosenbergii* from an upper one third graded group was 25% higher and from a lower two third graded group the mean weight was 10% lower than that of the ungraded control Daniels and D Abramo (1994) on the other hand by stocking juveniles after grading into upper and lower fractions and as an ungraded control group found that the mean size at harvest of both upper and lower fractions was higher than the ungraded control The variation in the results of Karplus *et al* (1986b) from that of Daniels and D Abramo (1994) might be due to the less duration given by former (97days) than the latter (125 138days)

From the results of the present study it could be seen that the average biomass production of large size group was much higher i e about twice than that of the mixed size group On the other hand the average biomass production of lower size group was much lower i e only about half of the mixed size group There was not much difference in biomass production between medium and mixed size group An almost similar trend of biomass production was obtained by Karplus *et al* (1987) However Daniels and D Abramo (1994) by dividing the juveniles into upper and lower fractions and ungraded control found that the average yield of both upper and lower fractions as higher than the ungraded control In another study conducted by D Abramo *et al* (1991) it was found that the biomass productions were 45 6% (in upper one third) and 11% (in lower two thirds) higher than the control ungraded population In the present study the average biomass production of all the three size graded groups was higher than the biomass production of mixed size group This result is consistent with the findings of D Abramo *et al* (1991) that the average yield of two size graded fractions (upper one third and lower two thirds) was higher than the ungraded control Daniels and D Abramo (1994) found that calculated gross revenues in graded populations was 6 73% higher than that of ungraded control In contrast to these findings Karplus et al (1987) by stocking juveniles after grading into upper middle and lower fractions and a recombined fraction as con trol found that the net income from upper fraction was almost nine times greater than that of the lower fraction However the weighted mean yield of the three fractions was slightly lower than the control Thus stocking graded weight classes did not increase overall net income Stocking only the upper and middle fractions was not recommended by them as discarding lower fraction would waste the nursery investment in these prawns Therefore they suggested to find means to discard prawns with low growth potential at an earlier stage as it may increase the profitability of prawn culture

In the present study it was observed that the juveniles in small size group consume less food in the beginning and improved their food intake after a few days suggesting that there was a probability of larger individuals having a suppressing effect on feeding of smaller individuals which was retained for some more time even after separation from the larger individuals Cobb et al (1982) found that agonistic interactions of large individuals could result in the establishment of a size hierarchy in which subordinates grow less rapidly as a result of lower food intake even in the continuous presence of food However Karplus *et al* (1992b) ruled out the possibility of growth suppression of runts due to appetite suppression and suggested that growth suppression of runts was mainly due to changes in the food con version ratio The second pair of claws of bulls of *M rosembergii* is used mainly for agonistic or aggressive behaviour against runts resulting in growth variation In support of this Karplus *et al* (1989) found that claw ablation of juveniles of *M rosenbergii* resulted in increased survival and more uniform growth as compared to intact control individuals In another study by Karplus *et al* (1992a) it was found that claw ablation and dactyl immobilization in bulls resulted in a complete removal of growth suppression in runts Cobb *et al* (1982) found that in *Homarus americanus* growth suppression was reduced when the claws were removed Such claw ablation also resulted in a marked increase in survival and uniformity of growth in *H americanus* as reported by Aiken and Yang Lai (1979) and Kendall *et al* (1982)

In the present study it was found that there was not much difference in survival rate among different size groups of juveniles However the maximum survival rate of 91 67% was found in the small size group and the minimum of 79 17% in the large size group The average survival rate of three size graded groups and of the mixed size group was almost similar Karplus *et al* (1987) also found the highest survival rate of 91% in the lower size group and almost similar survival rate (87%) was found in upper and middle fractions and recombined control after 97 days of rearing of *M rosenbergii* juveniles Daniels and D Abramo (1994) found the survival rates of 85 3% in 30% upper 79 4% in 70% upper 73 2% in 30% lower 80 2% in 70% lower fractions and 73 9% in ungraded control groups Hulata *et al* (1990) found that there was no significant effect of size of juveniles of *M rosenbergii* at the time of stocking on survival From the results of the present study it could be stated that by size grading of juveniles of *M rosenbergii* before stocking in growout pond the differential growth could be reduced and total biomass production could be augmented to a certain ex tent although the observations of some workers do not support these findings It could also be stated that the size grading of juveniles could not help in increasing the survival rate

In the present study the appearance of male secondary sex character the appendix masculina was noted by the 105th day after the start of the experiment which is actually the 154th day after metamorphosis

By the time the appendix masculina appeared the prawn had 62mm length and 1 75g weight To begin with it had only a single spine at the tip and by the subsequent moulting which occurred after 15 days a total of five spines were acquired There is no other report regarding the size and days after which the appendix masculina appears in *M rosenbergii* In the case of the Godavari river prawn *M malcolmsonii* it was observed to be appearing at a size of 60mm by Philip and Subramaniam (1992)

5 4 Water Quality Parameters

Different water quality parameters such as temperature pH and dissolved oxygen were maintained within the optimum range required for growth of *M rosenbergii* during the ex perimental period

The experiments were conducted in freshwater Various investigators such as Wickins (1972) Perdue and Nakamura (1976) Venugopalan (1988) and Venugopalan and Thampy (1992) have suggested that salinity range of 0 2 ppt as ideal for growth of *M rosenbergii* Thampy and Nair (1992) reported that during nursery rearing of *M rosenbergii* postlarvae although the rate of survival could be increased with the increase in salinity from 0 to 12 ppt the best growth was obtaıned ın freshwater

The temperatrue of water ın the rearıng tanks varıed between 27 and 29°C (recorded at 10 00 A M) whıch ıs reported by many workers such as Uno *et al* (1975) Farmanfarmaın and Moore (1978) New and Sıngholka (1982) Sandıfer and Smıth (1985) as wıthın the optımum range for growth of *M rosenbergu*

The pH of water ın the experımental tanks varıed between 7 6 and 8 1 New and Sıngholka (1982) and Sandıfer and Smıth (1985) reported a pH range of 7 5 8 5 as optımum for culture of *Macrobrachıum spp* Malecha *et al* (1980) and Sandıfer and Smıth (1985) observed that hıgh pH values were not favourable for the growth of *M rosenbergıı*

The dıssolved oxygen levels ın the water varıed between 6 1 and 7 5 ppm whıch was also wıthın the optımum range requıred for *Macrobrachıum spp* culture as reported by Smıth *et al* (1976 1978 1981) and Subramanyam (1987) New and Sıngholka (1982) reported that an oxygen concentratıon of 75% saturatıon was optımum for the growth of *Macrobrachıum spp*

6 SUMMARY

1 The present study on the freshwater prawn *M rosenbergii*, was to find out the extent of differential growth if any and the methods to combat it during the nursery phase

2 The experiments were conducted using freshwater in round bottom fibreglass tanks hav ing 0 22m^2 bottom surface area and 77 litre capacity

3 Three experiments were conducted two using post larvae intended to find the effect of (i) stocking density and (ii) provision of additional substrates in rearing tanks on differ ential growth and the third experiment using juveniles size graded after 35 days of initial nursery rearing to find out the extent of variation in differential growth among different sizes of juveniles

4 The study conducted to find out the effects of various stocking densitites ranging from 25 to 800 nos/m^2 has shown that the differential growth decreases with increasing den sity i e there exists an inverse relationship between the differential growth and the stock ing density

5 The average size of the juveniles was found to decrease with increasing density how ever the total biomass production increased with increasing density

6 At higher stocking densities the post larvae seemed to fight each other thereby utilize more energy which might have resulted in their poor growth

7 There was not much difference in survival rate at various stocking densities which indi cates that stocking density upto 800 nos/m^2 is not limiting with respect to survival dur ing nursery rearing phase

8 Provision of additional substrates such as clam shell round pebble and black polythene raffia resulted in higher average growth and total biomass production compared to that of control

9 Addition of substrates in the rearing tanks could not help to combat differential growth rather it enhanced differential growth

10 The survival rate was found to be comparatively higher in the rearing tanks with some additional substrates than that in the tanks without any substratum

11 Among the three substrates used the clam shell was found to be the best substrate as it helped in enhancing both growth and survival

12 By growing three size graded groups of jvueniles separately and a control group com prising juveniles of all the three size groups put together, for a period of 35 days it was found that the average growth of the large size group as higher medium size group as comparable and the small size group as lower than that of the control group

13 The size grading of juveniles was found to help in increasing the total biomass produc tion as the smaller ones grown separately might have got an oppportunity to grow faster

14 The juveniles of small size group was found to consume less food at the beginning however they improved their food consumption after a few days which indicates that there was suppression effect of larger juveniles on the smaller ones which was retained for sometime even after segregation

15 The differential growth was found to be lower among size graded juveniles compared to that of the control group

16 Among various size groups the differential growth was found to be highest in the me dium size group compared to that of large and small size groups indicating that the medium size group perhaps contained both fast growing and slow growing juveniles

17 The size grading of juveniles could not help to increase the survival rate as it was found that the survival rate of control group was higher than that of the large size group

18 The male secondary sexual character ı e the appendıx masculına was found to appear after 154 days of metamorphosıs the sıze of the prawn at that tıme beıng 6 2 cm and 1 75g

19 The appendıx masculına havıng a length of 0 98mm and a sıngle spıne at the fırst ap pearance acquıred a length of 1 31 mm and fıve spınes durıng subsequent moult that occurred after a perıod of 15 days

20 The length of appendıx masculına ıncreased at a ratıo of 1 1 34 ın comparıson to the ratıo of 1 1 14 for that of endopod of the second pleopod bearıng the appendıx masculına ın the subsequent moult ındıcatıng that there ıs an allometry ın growth of male second ary sex characters

21 The results of the present study has revealed that the dıfferentıal growth ın the freshwa ter prawn *Macrobrachıum rosenbergıı* ıs (ı) ınversely related to stockıng densıty (ıı) more ın the tanks provıded wıth addıtıonal substrates as they ındırectly help to reduce the effectıve stockıng densıty and (ııı) can be reduced by sıze gradıng the juvenıles after an ınıtıal perıod of nursery rearıng

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DIFFERENTIAL GROWTH IN THE GIANT FRESHWATER PRAWN *MACROBRACHIUM ROSENBERGII* (De Man) DURING NURSERY REARING PHASE

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

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ABSTRACT

The present study was conducted on freshwater prawn *Macrobrachium rosenbergii* (De Man) to find the effect of stocking density and provision of additional substrates in rearing tanks on differential growth of post larvae during nursery rearing phase and the extent of variation of differential growth among different size groups of juveniles during early growth phase

The first experiment conducted with various stocking densities ranging from 25 to 800 nos/m^2 had revealed that the differential growth and the average size of the post larvae were inversely proportional to the stocking density however the total biomass production was directly related to the stocking density The survival rate was not much affected by variation in the stocking density being almost uniform (87 100%) among various treatments

The second experiment has shown that provision of additional substrates could not help to reduce differential growth rather it enhanced it However it helped to enhance the average growth total biomass production and the survival rate

The size grading of juveniles after an initial nursery rearing period of 35 days into four groups such as small medium large and a recombined control group and growing them separately for another 35 days has revealed that the size grading helped in reducing the differential growth and increasing the total biomass production but could not help to increase the survival rate It was found that the total biomass production in large size group was about four times higher than that of the small size group and about two times than that of the control group indicating that growing *M rosenbergii* juveniles in grow out systems after size grading and discarding the smaller size group will be advantageous for increasing production

The male secondary sex character the appendix masculina was found to appear after 154 days of metamorphosis when the prawn had reached a size of 6 2 cm and 1 75 g An allometric pattern of growth was observed in case of appendix masculina wherein a higher ratio of 1 1 34 was recorded in comparison to 1 1 14 of that of the endopod of the second pleopod in the subsequent moult