EFFECT OF LOW SALINITIES ON THE GROWTH AND SURVIVAL OF

PENAEUS MONODON **FABRICIUS**

BY

K. A. NAVAS

THESIS

Submitted in partial fulfilment of the requirement for the degree

MASTER OF FISHERIES SCIENCE

Faculty of Fisheries
Kerala Agricultural University

Department of Aquaculture
COLLEGE OF FISHERIES
Panangad - Cochin

1988

To My Parents

DECLARATION

I hereby declare that this thesis entitled "EFFECT OF LOW SALINITIES ON THE GROWTH AND SURVIVAL OF PENAEUS MONODON (FABRICIUS)" 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.

Panangad
23..4..1988.

K.A. NAVAS

CERTIFICATE

Certified that this thesis, entitled "EFFECT OF LOW SALINITIES ON THE GROWTH AND SURVIVAL OF PENAEUS MONODON (FABRICIUS)" is a record of research work done independently by Sri. K.A. Navas 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.

23/4/88

Panangad

23..4..1988.

Dr. M.J. Sebastian

Chairman, Advisory Board,
Dean, Faculty of Fisheries.

ACKNOWLEDGEMENTS

Many persons have contributed in one way or another to the completion of my thesis and I am grateful to all of them. Some of them have made critical and constructive contributions that warrant special mention.

I am fortunate to have benefitted from the incisive comments and friendly encouragement of my Adviser Dr. M.J. Sebastian (Dean of Faculty) at all stages of the research. I wish to thank him for his concern and support.

Dr. D.M. Thampy (Professor and Head of the Department of Aquaculture) provided invaluable technical advice and assistance for which I am most grateful.

The recommendations of Shri P.M. Sherief, Shri P.S. Mrithunjayan, Shri Syed Ismail Koya, Shri S. Krishnan, members of the Advisory Committee are greatly appreciated.

For helpful discussions on aspects of the research while in progress I would like to thank Drs. J. Rajasekharan Nair, Sajan George, I.S. Bright Singh (Faculty members) and Laxminarayanan (Scientist and Officer-in-charge, CIBA, Cochin).

My thanks are also due to Shri K.J. Joseph (Joint-Director, Regional Shrimp Hatchery, Azhicode) for the help in the procurement of the samples for the work and M/s Coastal Impex for typing this manuscript.

Sincere thanks go to my friends who were always there when needed. And finally I would like to thank my parents for their encouragement and for always having faith in me.

CONTENTS

PAGE

LIST OF FIGURES

LIST OF TABLES

TABLE PAGE

ANOVA - TABLE

PAGE

INTRODUCTION

INTRODUCTION

1.1 General

In India, prawn and prawn products account for about 83% of the foreign exchange earnings from the seafood export (Anonymous, 1986). However, the inconsistent trends in capture fisheries necessitate the identification and adoption of alternative methods for enhancing prawn production. Scientific farming of prawns appears to be the best alternative in the present context. This is important not only due to its potential for increasing production but also due to its scope for generating employment opportunities for the rural poor.

In the recent years, there has been an increased interest in the culture of marine prawns. Among the 74 species of penaeid prawns known to exist in the Indian region (Mohamed, 1973) Penaeus monodon (Fabricius) is considered the best species for culture purpose (Silas, 1980). This is by virtue of its fast growth, large size at maturity, high fecundity, hardiness to withstand environmental stress, wider distribution and capability to co-exist successfully under high population densities, in both mono and polyculture systems. For tropical countries with higher temperature of water, ranging from 25 to 35^{o}C, it is one of the best species for culture (Aquacop, 1977). It is one of the most important commercial prawns in the West Indo-Pacific region. Successful intensive farming of this species is practised in countries like the Philippines (Villadolid and Villaluz, 1950; Delmendo and Rasalan, 1956; Borja and Rasalan, 1968) Taiwan (Kubo, 1956; Chen, 1972; Liao and Huang 1972) and Indonesia (Alikunhi et al., 1975). In India selective culture of this species is highly recommended (Ghosh et al.,

1973; Subrahmanyam, 1973; Verghese et al., 1975). P. monodon, along with other species, support a traditional capture fishery in the paddy-fields and bheries of West Bengal. Cultural activities have been extended to a large number of private farms. Recently, attempts have been made to improve their culture practices by introducing modern technologies. Considerable progress has also been made in the country in the intensive culture of this species by experimental trials (Swaminathan, 1980).

1.2 Salinity and Biological Activity

The postlarvae of P. monodon as is the case with most of the commercially important penaeid prawns migrate into the estuaries and backwaters. In the brackishwaters, they grow rapidly into subadults and return to the sea. During their postlarval development, they encounter wide diurnal and seasonal variations in salinity of the environment.

The effect of salinity on marine and brackishwater organisms is of special importance. First, it represents an ecological master factor for most of the aquatic organisms. In tropical countries like India, salinity assumes greater importance as it influences the survival, growth, maturation, spawning and distribution of the animal. Salinity affects functional and structural responses of the animal through changes in

1) total osmo-concentration
2) relative proportion of solutes
3) co-efficient of absorption and saturation of dissolved gases
4) density and viscosity, through changes in surface tension and related parameters (Kinne, 1971).

Salinity also exerts an indirect effect by modifying the species composition of the ecosystem. This changes the biotic background for the

remaining forms (Kinne, 1964). However, salinity tolerance tend to decrease as test temperatures, concentrations of dissolved gases and other environmental factors become suboptimal. Besides, salinity tolerance may be subjected to significant intraspecific (inter-populations) differences, when populations occupy habitats with different salinity conditions viz, average salinities, extent and speed of salinity fluctuation (Kinne, 1971).

There are only few systematic studies and reports on the survival and growth of P. monodon along the South West Coast of India. Lack of prior knowledge on the levels and rates at which this species can adopt to lower salinities, has led in the past to unrealistic conclusions. Knowledge on these aspects has great implications in the culture of the species. While planning to undertake commercial farming of P. monodon, it was found that detailed information on the salinity tolerance of the postlarvae and juveniles, optimum salinity for maximum rate of survival and growth, effect of sudden fluctuation in salinity on the survival rate etc. would be very much useful.

Another reason for undertaking such a study was that postlarvae of P. monodon appear in the wild collections of prawn seed during the months from February to June (Thampy et al., 1980). The monsoon rains start atleast during the month of June in Kerala and as such the postlarvae collected in June could not be used in commercial farming. Seed collected in earlier months and grown in ponds would be in danger if salinity is such an important factor in the early development of this species. Moreover, for the proper maintenance of P. monodon postlarvae in nurseries and other holdings, it is necessary to have a clear idea of the environmental requirements, of which salinity tolerance is one of the most important.

In view of the above facts and in view of a lack of clear information on the aspects in question, a laboratory study was undertaken on the effect of low salinities on the growth and survival of postlarvae and juveniles of this prawn.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 Natural Distribution

Salinity is an important factor influencing the distribution of penaeids. Penaeus setiferus is more abundant at lower salinities than P. aztecus and P. duorarum (Williams, 1955; Gunter et al., 1964). All these three species have been found at salinities from less than 1 ppt (Gunter and Shell, 1958; Tabb et al., 1962; Gunter and Hall, 1963). The survival and growth of P. aztecus postlarvae in Barataria Bay were related to salinity (Amant et al., 1965). Preference for reduced salinities over seawater in postlarvae and early juveniles has been demonstrated experimentally for four species of penaeids from Western Mexico (Mair, 1980).

The availability of postlarvae of P. monodon fluctuated to a great extent according to change in the physico-chemical factors of the environment. The occurence and distribution of postlarvae of this species with reference to salinity in the various estuarine and brackishwater systems in India such as Hoogly-Matlah estuary (Verghese et al., 1979; Chakraborti et al., 1982) Kovelong backwaters (Rajendran and Sampath, 1975) Marakanam estuary (Bose and Venkatesan, 1982) Vellar estuary, (Ramaswamy and Pandian, 1985a) Ennore estuary (Vasudevan and Subrahmoniam, 1985) Pichavaran (Chandrasekaran and Natarajan, 1984) off Orissa coast (Rajyalakshmi et al., 1985) Pulicat lake (Raj, 1980; Raj and Raj, 1982a) and Cochin backwaters (Sebastian et al., 1980; Thampy et al., 1982) has been reported. Gunter et al. (1964) reported that increase in rainfall and consequent dilution of coastal waters might prove more favourable to the adult white shrimp. The heavy prawn catches in New

South Wales and Queensland during monsoon or immediately after monsoon may probably be due to the mass migration consequent upon the lowering of salinity (Racek, 1956; 1959). A similar observation of inverse correlation between the catches and salinity was also recorded from Pulicat lake. Declining salinity was conducive for survival and growth of postlarvae of P. monodon resulting in better catches (Rao and Gopalakrishnayya, 1974). A regression model, catch/net hour with salinity, show that salinity is a prominent factor in the prediction of P. monodon catch (Karmakar, 1982). Pearse and Gunter (1957) stated that young of many animals usually thought of as marine, required areas of low salinity for nursery grounds. The early stages required oceanic water, but the older larvae must reach bay water or perish.

However, some authors have felt salinity to be of less importance (Hoese, 1960; Broad, 1962). According to Lindner and Anderson (1956) size of young shrimp was correlated more with locality than salinity and concluded that salinity within a broad range was not important.

2.2 Osmoregulation

Crustacean osmoregulation studies have dealt primarily with salinity effects on the isosmotic and ionic properties of the haemolymph (Mantel and Farmer, 1983). Changes in water and ion concentration of haemolymph with the environment have been studied on a variety of penaeid species; P. indicus (Parado-Estepa et al., 1987) P. aztecus (Bishop et al., 1980; Howe et al., 1982) P. monodon (Cawthorne et al., 1983; Ferraris et al., 1986, 1987) Penaeids exposed to low salinities maintain blood osmolarity and ionic concentrations hyperosmotic and hypertonic to the external medium (Mangum

et al., 1976). Upon transfer to high salinity environments, blood ionic and osmotic concentrations increase due to efflux of water and inward movement of ions. Cell volume during hypersaline stress is regulated by an increase in intra-cellular free amino-acids, resulting in a decrease in ammonia excretion, indicating the greater use of endogenous ammonia to synthesize amino acids. (Mangum and Towle, 1977; Gilles, 1979) Crustaceans experience least osmotic stress and undergo best growth when placed in waters of isosmotic salinity (Panikkar, 1968).

In Crustaceans increased metabolic rate has been reported at salinities differing from the isosmotic point as indicative of the increased energy cost due to osmoregulation (Beadle, 1931; Lofts, 1956; Dehnel and Mc Caughran, 1964; Kutty et al., 1971). However, numerous reports that indicated either a decrease in metabolic rate in supra/subnormal salinities (Simmons and Knight, 1975) or no correlation between metabolic rate and salinity (Elfringham 1965; Mc Farland and Pickens, 1965) has led to difficulty in interpreting results of environmental changes on metabolic rate. Gunter et al. (1964) observed that adaptation to low salinity in penaeids is highly developed in younger stages while Panikkar (1968) has indicated that osmoregulation in dilute media is less effective in full-sized individuals especially in their reproductive phase. He considers this as one of the principal factors which forces them to migrate back to the sea. Mc Farland and Lee (1963) demonstrated that brown shrimp adults were better osmoregulators at higher salinity than at lower, with a greater tendency to isosmoticity when the external medium was below 18 ppt. Moulting interacted with salinity in inducing stress in penaeids. In culture systems high mortalities were observed when moulting coincided with large fluctuations in salinity. (Ferraris et al., 1987). However, dependence on external factors gradually declined in older moult stages. This suggests there is a reduction in integument

permeability and greater development of ion absorption or secretion mechanism as the exoskeleton hardened (Ferraris et al., 1987).

2.3 Growth and Survival

Zein-Eldin (1963) carried out pioneering works regarding the influence of salinity on the growth in prawns. He concluded that under conditions of constant temperature and restricted food supply Penaeus postlarvae survived and grew over a wide range of salinity (2-40 ppt). Zein Eldin and Aldrich (1965) observed salinity had little effect on either survival or growth of postlarvae of P. aztecus except at extreme temperatures. Jhonson and Fielding (1956) in attempts to rear shrimps in ponds noted that P. setiferus juveniles could be raised at 18.5 and 34 ppt salinity levels. Williams (1960) in experiments concerning the osmotic relationship of brown and pink shrimp found that temperature apparently had far more effect upon survival than did salinity. However, several experimental studies that followed revealed that salinity influenced the survival and growth of penaeid postlarvae and juveniles. (Grajcer and Neal, 1972; Nair and Kutty, 1975; Bhattacharya and Kewalramani, 1976; Kuttyamma, 1982; Lakshmikantham, 1982). Many others focussed on the cumulative effect of temperature and salinity on the survival, growth, food intake and food conversion efficiency (Venkataramaiah et al., 1975).

Kramer (1975) reported the influence of salinity on the lethal dissolved oxygen levels in prawns. Exposure to subnormal salinities resulted in reduced tolerance to other environmental factors like temperature, dissolved gases or hydrostatic pressure (Kinne, 1971). However, studies on the effect of salinity on the survival and growth of P. monodon are limited (Subrahmanyam, 1973; Verghese et al., 1975; Liao, 1977; Hideo, 1979; Motoh, 1981; Raj and Raj 1982b; Chakraborti et al., 1985a). There are few reports on the growth of P. monodon

adult in ponds of fluctuating physico-chemical conditions (Verghese et al., 1982; Pillai et al., 1984; Venkatesan and Joshua, 1984; Chakraborti et al., 1985b, 1986; Chen, 1985). Sebastian et al. (1980) reported that sudden drop in salinity of pond-waters was harmful for adults of P. monodon. Adults cultivated in the inundated paddy-fields of Kuttanad in Kerala under less than 1 ppt salinity grew well until the onset of the first monsoon rain with which all of them showed great stress and mass mortality of this species was recorded. On the contrary Das et al. (1982) reported that gradual increase or decrease in salinity did not affect the survival of the adults of this species. In culture systems, increasing salinity at ambient temperature was found to initiate moulting in P. monodon adults while decreasing salinity did not (Hag, 1984). Reyes (1985) reported the influence of salinity on hatching rate of eggs and survival from nauplius to zoea stage in this species.

There are only few systematic studies and reports on the survival and growth of the early stages of P. monodon under low saline conditions. Studies on tolerance of postlarvae/juveniles of this species to wide fluctuations in low salinities and lowest lethal salinity are lacking. In this study an attempt is made to improve the chances of postlarval survival by different levels of acclimation.

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Collection and Holding of Experimental Animals

Postlarvae/juveniles of P. monodon raised in the Regional Shrimp Hatchery of Department of Fisheries of Kerala at Azhicode were used as experimental material for the present study. The postlarvae were brought to the lab in oxygen-packed polythene seed transport bags. They ranged in size from 10-12 mm in total length and 3 - 4 mg in weight. A set of juveniles ranging from 25 - 35 mm in total length and weighing 180 - 260 mg was used for the growth experiments. These experiments were conducted in circular cement cisterns of 1 m diameter and 1 m depth (holding capacity 700 l). Tolerance experiments were carried out in cylindrical glass troughs of 10 l capacity (30 cm dia. x 15 cm ht).

The postlarvae/juveniles brought from the hatchery were acclimated to 25 ppt salinity in cement cisterns (pH 7.40 $\pm$ 0.36 and temperature of water 28^{o}C $\pm$ 0.5). The animals (buffer stock) in the acclimation tanks were fed with Tata's pelleted commercial prawn feed of 3 mm diameter ad libitum (Carbohydrate 47% ; Protein 30% ; Fat 7% ; Crude fibre 4-5% ; Moisture 10-12% ; Sand/Silica 2-3% ; Vitamins/Minerals trace). The leftover feed and faecal matter were siphoned out everyday.

3.2 Preliminary Tolerance Experiments

Five sets of experiments were conducted in this study. Animals were pre-acclimated to a particular salinity before releasing them to different test salinities.

3.2.1 Acclimation

Five different concentrations of acclimation salinity were selected (25, 20, 15, 10 and 5 ppt). The animals were transferred from the stock

tank and slowly acclimated to the respective acclimation salinity and then maintained for five days. Animals were fed ad libitum. Mortality during acclimation was negligible.

3.2.2 Tolerance in Test Salinity

From each acclimation salinity, fifteen numbers of postlarvae were transferred to cylindrical glass troughs containing 8 l of water of different test salinities (1.5 ± 0.5 : 4.5 ± 0.5 : 9.5 ± 0.5 : 14.5 ± 0.5 and 19.5 ± 0.5 ppt). The ratio of weight of the animals to the volume of medium was kept well below 2g/l (Duodoroff et al., 1951). The troughs were aerated intermittently and removable hideouts were provided to avoid cannibalism (Rajyalakshmi, 1982). Feed was given in small quantities for maintenance. Leftover feed and faecal matter were siphoned out everyday.

The animals were reared for 120 h at each test salinity. Frequent observations were made to record survival percentage. Dead animals were removed immediately. The experiments were carried out in duplicate.

3.3 Tolerance In Salinity Below 5 ppt

Tolerance of the postlarvae to very low salinities (4, 3, 2, 1 and 1 ppt) was studied after step-wise acclimation. The approach was to evaluate the improvement in survival of postlarvae at these very low salinities by a gradual change in salinity. Fifteen numbers of postlarvae were transferred to cylindrical glass troughs containing 8 l of water at lower salinities (4, 3, 2, 1 and 1 ppt) after step-wise acclimation. The animals were reared for 120 h at each salinity. Frequent observations were made to record survival. LC 50 after 120 h was recorded.

3.4 Lethal Salinity Studies

Three batches of ten animals each were subjected to gradually decreasing salinity from a pre-acclimation salinity of 20 ppt down to 2 ppt at 2 ppt intervals and from 2 ppt at still smaller intervals. The step-wise decrease in salinity was achieved by adding low saline water to the experimental containers. The animals were maintained at each salinity for a period of 24 h before the salinity was changed. Cumulative mortality at each salinity after a period of 24 h was observed. Dead animals were removed immediately. The salinity in which atleast 50 percent of the animals survived at the end of 24 h was considered within the tolerable range and rest as lethal.

3.5 Growth Experiment

Juveniles of *P. monodon* ranging from 180-250 mg from the buffer stock maintained at 25 ppt salinity were used for the study. The animals were slowly acclimated and released to different test salinities (1.5 ± 0.5 : 4.5 ± 0.5 : 9.5 ± 0.5 : 14.5 ± 0.5 and 19.5 ± 0.5 ppt as control). Lower salinities were prepared by diluting sea water with well water. About 120 l of water was maintained in each of these tanks. Twenty numbers of juveniles were introduced in each of these cement cisterns. After release, they were allowed 48 h to settle before the start of the experiment and monitoring of different parameters. The tanks were aerated intermittently to maintain sufficient oxygen concentration and provided with removable hideouts. Water in these tanks was changed partially every fortnight in order to prevent the lethal accumulation of metabolites and bacteria. Feeding was done with Tata's pelleted

commercial prawn feed of 3 mm diameter, ad libitum in the evening. The leftover feed and faecal matter were siphoned out everyday.

The prawns were reared for 56 days in water of the same salinity to which they were acclimated. Every fortnight, the animals were netted and weighed and the live weight was determined using a K-15 super analytical single pan balance (K. Roy & Co.) having a sensitivity of 0.01 mg. Minor variations that occured in the salinity during the course of the experiment were adjusted to specified levels. A duplicate experiment was also carried out.

All the above experiments were conducted at room temperature which ranged from 28 to 32°C. The temperature of water in the experimental containers during the course of the experiment ranged from 27 to 29°C.

3.6 Methods of Water Analysis

Salinity	:	Standard Argentotitric Method (Strickland and Parsons, 1968)
Dissolved Oxygen	:	Winkler's Method (Strickland and Parsons, 1968) Analysis was done within an hour of sampling.
Temperature	:	Mercury bulb Thermometer (0 to 50°C)
pH	:	Potentiometric Method using a Digital pH meter (ELICO - Model L1-122)
Alkalinity	:	Titrometric Method to Potentiometric end point (Strickland and Parsons, 1968)

Fig. A1 Cylindrical glass troughs used as experimental containers in tolerance studies. Size : 30x15 cm : Capacity : 10 l Troughs were filled with 8 l of test medium and aerated intermittently. Temperature of water in the troughs ranged from 27 to 29^{o}C.

Fig. A2 Cement cisterns used as experimental containers in growth studies. Size : 1x1 m : Capacity : 700 l. Cement cisterns were filled with 120 l of test medium and aerated intermittently. Temperature of water in the cisterns ranged from 27 to 29^{o}C.

Fig. A2

3.7 Sensory Evaluation

3.7.1 Sample Preparation

Animals of the growth experiments were used in this study. Prawns reared in different test salinities were harvested, peeled, deveined and cleaned. The samples were steam cooked seperately for ten minutes under normal pressure. Cooked samples were coded and served on white plastic plates. The cooked samples were held at $28^{o}C$ until evaluated by the taste panel.

3.7.2 Taste Panel Evaluation

A ten member taste panel was selected. Sensory evaluation utilizing an hedonic scale was used to evaluate the sensory characteristics (texture of flesh, flavour and overall quality). The scale consists of 6 scores from 0 to 6 in the ascending order (Table 15). Panelists were asked to make a judgement on the basis of their preference. Panelists were asked to rinse their mouth with distilled water between samples.

3.8 Statistical Analysis

Tolerance and growth data were subjected to Analysis of Variance (ANOVA). An F-test was performed to determine if difference between treatment (test salinity) means existed. If an F-value was found to be statistically significant, data was analysed by a Least Significance Difference (LSD) test. All possible differences between the means of each treatment were computed and compared to LSD. If the absolute value of the difference (d) was greater than the LSD ($|d| \geq LSD$), the difference was found to be significant at $P < 0.05$.

Results of experiment to determine Lethal Salinity (3.4) was verified using Probit analysis.

Analysis of the data was performed by a pre-written statistical RBD analysis on "VERSA IWS" of CP/M-86 Model.

RESULTS

RESULTS

4.1 Preliminary Tolerance Studies

Survival percentage of 10-12 mm size postlarvae in the different test salinities after pre-acclimation at indicated levels of salinity over 120 h exposure period is given in Table 6.

Postlarvae pre-acclimated at 25 ppt recorded a survival between 86.6 and 56.6% on sudden transfer (Table 1). Maximum survival was recorded at 14.5 ± 0.5 ppt and minimum at 4.5 ± 0.5 ppt. At 20 ppt pre-acclimation, survival ranged between 50 and 86.65% (Table 2). Maximum and minimum survival were recorded at 19.5 ± 0.5 and 4.5 ± 0.5 ppt respectively. Postlarvae pre-acclimated at 15 ppt recorded a maximum survival of 93.3% in 4.5 ± 0.5 and 19.5 ± 0.5 ppt and minimum of 79.95% at 14.5 ± 0.5 ppt (Table 3). Survival was uniform (93.3%) in all the tested conditions when the postlarvae were pre-acclimated at 10 ppt (Table 4). At 5 ppt pre-acclimation, survival of postlarvae ranged from 89.95 to 96.65% (Table 5). Survival was maximum at 9.5 ± 0.5 ppt and minimum at 4.5 ± 0.5 ppt and 14.5 ± 0.5 ppt. In all the above trials, complete mortality of the postlarvae was observed in less than 1 ppt test salinity within 2 h of their transfer, regardless of pre-acclimation.

4.1.1 Analysis

Survival values less than 1 ppt were not considered for analysis. There was no significant difference ($P \geq 0.05$) in the survival of postlarvae in different test salinities. (ANOVA - Table 6). Postlarvae acclimated at 25 ppt (ANOVA - Table 1) and 20 ppt (ANOVA - Table 2) showed highly significant variation in survival ($P < 0.001$) especially between 4 and 15 ppt.

Postlarvae showed less significant survival ($P < 0.05$) when pre-acclimated at 15 ppt (ANOVA - Table 3). There was no significant difference in survival ($P > 0.05$) when the postlarvae were pre-acclimated at 5 ppt (ANOVA - Table 5) and 10 ppt (ANOVA - Table 4).

4.2 Tolerance in Salinity Below 5 ppt

Postlarvae exhibited marked variation in survival when subjected to progressive dilutions below 5 ppt (Table 7). Survival percentage decreased with reduction is salinity levels, recording 93.3, 86.6, 86.65 and 59.5% in 4, 3, 2 and 1 ppt respectively (Fig. 1). In less than 1 ppt, the lowest survival was recorded (46.6%). This salinity was considered lethal (LC 50) for the postlarvae since mortality at the end of 120 h was more than 50%.

Analysis of variance showed highly significant difference in survival ($P < 0.001$) in less than 5 ppt levels of salinity (ANOVA - Table 7).

4.3 Lethal Salinity Studies

Postlarvae recorded cent percent survival upto the third day when salinity was gradually decreased from 20 to 16 ppt (Fig. 2). Postlarvae showed signs of mortality when the salinity reached 14 ppt (96.7% survival). Survival percentage decreased with step-wise reduction in salinity, recording 90, 86.7, 76.7, 66.7 and 53.34% at 8, 6, 2, 1 and 0.75 ppt respectively. At 0.5 ppt the survival was 53.34%. Salinity less than 0.5 ppt proved to be lethal for the postlarvae.

The above results were verified using probit analysis (Table 9). A probit regression line for the relation between the logarithmic salinity (dose = X) and mortality (Probit response = Y) was determined to be $Y = 5.982023 + 1.332194\ X$. The proportion responded among controls was

zero. LC 50 for the postlarvae was determined to be 0.5459 ppt with its upper and lower limits being 0.377 and 0.790 ppt respectively. LC 30 and LC 70 values determined were 1.3514 and 0.22055 ppt respectively.

4.4 Behavioural Observation

Animals exhibited abnormal behaviour in salinity less than 1 ppt. On sudden transfer, some of the postlarvae were seen jumping out of water to the sides of the containers. The postlarvae exhibited abnormal swimming pattern, swimming side-wise, with their body inclined to one side. These animals exhibited spiral movements and circular movements at the bottom of the container as well as in the water column. The stress conditions in animals at sub-optimal salinities were evident from the low rate of feeding and excretion of faecal matter. A high rate of cannibalism was observed at the extreme lower salinities.

4.5 Growth Studies

The growth of juveniles in different test salinities are given in Table 10 and Figure 3. Variation in the growth rate of juveniles in different test salinities are given in Table 11. Survival of juveniles recorded during the course of study is given in Table 12. Water quality parameters recorded are given in Table 14.

Graphical representations of growth rate variations in 1.5 $\pm$ 0.5 ppt reveal that from an initial increase of 4.43 mg/day to 8.95 mg/day, it dropped to 6.44 mg/day and remained steady, recording 6.63 mg/day (Fig. 5). In test salinities between 4 and 15 ppt, growth rate variations generally followed an increasing trend. The initial growth rate of 10.48 mg/day increased to 14.86 mg/day and later to 14.85 mg/day and

finally recorded 16.11 mg/day in 4.5 ± 0.5 ppt salinity. There was a gradual increase from an initial growth rate of 7.53 mg/day to 10.59 mg/day and then increased to 11.44 mg/day and finally recorded 13.30 mg/day in 9.5 ± 0.5 ppt salinity. In 14.5 ± 0.5 ppt there was a steady increase from 7.0 mg/day to 9.44 mg/day, 13.05 mg/day and 13.41 mg/day. However, in 19.5 ± 0.5 ppt, the initial increase in growth rate from 10.29 mg/day to 13.22 mg/day and 13.94 mg/day later declined to 12.74 mg/day towards the end of the experiment.

Biomass increase* New (1971) of the juveniles in the different test salinities are given in Table 13. Maximum biomass increase was recorded in 14.5 ± 0.5 ppt (18.77 g/m^2). See Figure 7. This was followed by 9.5 ± 0.5 ppt (16.15 g/m^2), 4.5 ± 0.5 ppt (15.03 g/m^2) and 19.5 ± 0.5 ppt (14.93 g/m^2). 1.5 ± 0.5 ppt salinity recorded the least of 1.54 g/m^2.

Summing up the whole results, overall growth rate was highest in 4.5 ± 0.5 ppt (16.11 mg/day/72.5% survival) followed by 14.5 ± 0.5 ppt (13.41 mg/day/100%) 9.5 ± 0.5 ppt (13.296 mg/day/90%) and 19.5 ± 0.5 ppt (12.74 mg/day/87.5%). See Figure 6. Overall growth rate was least in 1.5 ± 0.5 ppt (6.63 mg/day/50%).

4.5.1 Analysis

There was highly significant difference ($P < 0.001$) in the growth rate of the juveniles in different test salinities (ANOVA - Table 8). Mean values of growth rates of juveniles between 4 and 15 ppt did not differ

*$C = \frac{azy}{100} - bz$ where, a = av. final weight (g), b = av. initial weight (g), y = Survival percentage, z = Stocking density (nos/m^2), c = Biomass increase (g/m^2)

significantly ($P \leq 0.05$) from the control (19.5 ± 0.5 ppt). Variation in growth rate was highly significant ($P < 0.001$) among the different exposure periods. Variation in the 56-day survival of juveniles was also highly significant (ANOVA - Table 9). Mean values of survival between 1 and 5 ppt differed significantly ($P < 0.05$) from the control (19.5 ± 0.5 ppt).

4.6 Sensory Evaluation

Results of sensory evaluation at different salinities are shown in Tables 16, 18 and 20. The data involved were subjected to primary analysis to determine the Kendall's co-efficient of concordance (Sidney Siegel, 1956) to test the significant association in the judgements (Tables 17, 19 and 21). Only data of those sensory characteristics which were significant were subjected to analysis of variance.

Only in the case of flavour of cooked meat was there a significant association ($P < 0.05$) in the judgements (Table 17). The overall score of shrimps reared at 9.5 ± 0.5 ppt was better than those reared at other salinity levels (Table 17). A significant difference ($P < 0.01$) in cooked flavour was found between shrimps held at 1.5 ± 0.5 and 9.5 ± 0.5 ppt : 9.5 ± 0.5 and 14.5 ± 0.5 ppt and 14.5 ± 0.5 and 19.5 ± 0.5 ppt (ANOVA - Table 10).

Table 1. Survival percentage* of 10-12 mm size postlarvae of P. monodon in different test salinities over different exposure periods after acclimation at 25 ppt.

Test salinity levels (ppt)	Exposure periods (h)				
	24	48	72	96	120
Less than 1	-	-	-	-	-
4.5 ± 0.5	79	69.95	59.95	56.6	56.6
9.5 ± 0.5	96.65	93.3	76.65	76.65	69.95
14.5 ± 0.5	100	96.65	93.3	89.95	86.6
19.5 ± 0.5	100	96.65	93.3	89.95	83.3

* Each representative value is the average of two determinations for 15 animals per treatment.

ANOVA - TABLE 1

ANOVA for testing significance of survival of 10-12 mm size postlarvae of P. monodon in different test salinities (TS) over different exposure periods (EP) after acclimation at 25 ppt.

Source	S.S.	d.o.f.	M.S.	F-ratio
Test Salinity	1774.59	3	591.53	115.67 ***
Exposure Period	1103.45	4	275.86	53.94 ***
Error	61.37	12	5.11	

TS Means:		EP Means:	
TS1	53.696	EP1	80.7125
TS2	66.6816	EP2	72.6645
TS3	76.9396	EP3	65.459
TS4	76.3696	EP4	63.2325
		EP5	59.99

CD 5% for TS means comparison 3.116

CD 5% for EP means comparison 3.434

*** denotes significant at 0.1%

TS1 = 4.5 ± 0.5 ppt : TS2 = 9.5 ± 0.5 ppt

TS3 = 14.5 ± 0.5 ppt : TS4 = 19.5 ± 0.5 ppt

EP1 = 24 h : EP2 = 48 h : EP3 = 72 h : EP4 = 96 h

EP5 = 120 h

Since complete mortality of the postlarvae was observed in less than 1 ppt test salinity level, it was not considered for analysis.

The individual percentages (x) were transformed into arc size values ($\sin^{-1}\sqrt{\frac{X}{100}}$) for analysis.

Table 2. Survival percentage* of 10-12 mm size postlarvae of P. monodon in different test salinities levels over different exposure periods after acclimation at 20 ppt.

Test salinity levels (ppt)	Exposure periods (h)				
	24	48	72	96	120
Less than 1	-	-	-	-	-
4.5 ± 0.5	69.95	69.95	50	50	50
9.5 ± 0.5	93.3	93.3	89.95	86.6	80
14.5 ± 0.5	100	96.65	96.65	89.95	83.3
19.5 ± 0.5	100	100	96.65	89.95	86.65

* Each representative value is the average of two determinations for 15 animals per treatment.

ANOVA - TABLE 2

ANOVA for testing significance of survival of 10-12 mm size postlarvae of P. monodon in different test salinities (TS) over different exposure periods (EP) after acclimation at 20 ppt.

Source	S.S.	d.o.f.	M.S.	F-ratio
Test salinity	2814.56	3	938.19	73.07 ***
Exposure period	847.18	4	211.79	16.50 ***
Error	154.07	12	12.84	

TS Means:		EP Means:	
TS1	49.704	EP1	77.9395
TS2	70.6952	EP2	75.352
TS3	77.33	EP3	68.905
TS4	79.948	EP4	64.1425
		EP5	60.7075
CD 5% for TS means comparison			4.9405
CD 5% for EP means comparison			5.5209

*** denotes significant at 0.1%

TS1 = 4.5 ± 0.5 ppt : TS2 = 9.5 ± 0.5 ppt

TS3 = 14.5 ± 0.5 ppt : TS4 = 19.5 ± 0.5 ppt

EP1 = 24 h : EP2 = 48 h : EP3 = 72 h

EP4 = 96 h : EP5 = 120 h

Since complete mortality of the postlarvae was observed in less than 1 ppt test salinity level, it was not considered for analysis.

The individual percentages (x) were transformed into arc sine values ($\sin^{-1}\sqrt{\frac{x}{100}}$) for analysis

Table 3. Survival percentage* of 10-12 mm size postlarvae of P. monodon in different test salinities over different exposure periods after acclimation at 15 ppt.

Test Salinity levels (ppt)	Exposure periods (h)				
	24	48	72	96	120
Less than 1	-	-	-	-	-
4.5 ± 0.5	96.65	93.3	93.3	93.3	93.3
9.5 ± 0.5	100	89.95	89.95	89.95	89.95
14.5 ± 0.5	100	86.65	86.65	79.95	79.95
19.5 ± 0.5	100	100	96.65	96.65	93.3

* Each representative value is the average of two determinations for 15 animals per treatment.

ANOVA - TABLE 3

ANOVA for testing significance of survival of 10-12 mm size postlarvae of P. monodon in different test salinities (TS) over different exposure periods (EP) after acclimation at 15 ppt.

Source	S.S.	d.o.f.	M.S.	F-ratio
Test salinity	376.39	3	125.46	4.59 ***
Exposure period	619.60	4	154.90	5.66 ***
Error	328.30	12	27.36	

TS Means:		EP Means:	
TS1	75.33	EP1	86.6625
TS2	75.216	EP2	76.272
TS3	70.788	EP3	73.6845
TS4	82.859	EP4	72.392
		EP5	71.2290

CD 5% for TS means comparison 7.2118

CD 5% for EP means comparison 8.0591

* denotes significant at 5%

** denotes significant at 1%

TS1 = 4.5 ± 0.5 ppt : TS2 = 9.5 ± 0.5 ppt

TS3 = 14.5 ± 0.5 ppt : TS4 = 19.5 ± 0.5 ppt

EP1 = 24 h EP2 = 48 h EP3 = 72 h

EP4 = 96 h EP5 = 120 h

Since complete mortality of the postlarvae was observed in less than 1 ppt test salinity level, it was not considered for analysis.

The individual percentages (x) were transformed into arc sine values ($\text{Sin}^{-1}\sqrt{\frac{x}{100}}$) for analysis.

Table 4. Survival percentage* of 10-12 mm size postlarvae of P. monodon in different test salinities over different exposure periods after acclimation at 10 ppt.

Test Salinity levels (ppt)	Exposure periods (h)				
	24	48	72	96	120
Less than 1	-	-	-	-	-
4.5 ± 0.5	100	96.65	93.3	93.3	93.3
9.5 ± 0.5	100	100	96.65	93.3	93.3
14.5 ± 0.5	100	96.65	93.3	93.3	93.3
19.5 ± 0.5	100	96.65	93.3	93.3	93.3

* Each representative value is the average of two determinations for 15 animals per treatment.

ANOVA - TABLE 4

ANOVA for testing significance of survival of 10-12 mm size postlarvae of P. monodon in different test salinities over different exposure periods after acclimation at 10 ppt.

Source	S.S.	d.o.f.	M.S.	F-ratio
Test salinity	33.76	3	11.25	2.09 NS
Exposure period	675.48	4	168.87	31.36 ***
Error	64.61	12	5.38	

TS Means:		EP Means:	
TS1	78.888	EP1	90.0
TS2	81.889	EP2	82.0875
TS3	78.888	EP3	76.111
TS4	78.888	EP4	74.998
		EP5	74.998

CD 5% for TS means comparison 3.1979

CD 5% for EP means comparison 3.5759

NS = Non-significant

*** denotes significant at 0.1%

TS1 = 4.5 ± 0.5 ppt : TS2 = 9.5 ± 0.5 ppt

TS3 = 14.5 ± 0.5 ppt : TS4 = 19.5 ± 0.5 ppt

EP1 = 24 h EP2 = 48 h EP3 = 72 h

EP4 = 96 h EP5 = 120 h

Since complete mortality of the postlarvae was observed in less than 1 ppt test salinity level, it was not considered for analysis.

The individual percentages (x) were transformed into arc sine values ($\sin^{-1}\sqrt{\frac{x}{100}}$) for analysis.

Table 5. Survival percentage* of 10-12 mm size postlarvae of P. monodon in different test salinities over different exposure periods after acclimation at 5 ppt.

Test Salinity levels (ppt)	Exposure periods (h)				
	24	48	72	96	120
Less than 1	-	-	-	-	-
4.5 ± 0.5	100	96.65	96.65	93.3	89.95
9.5 ± 0.5	100	96.65	96.65	96.65	96.65
14.5 ± 0.5	100	96.65	93.3	93.3	89.95
19.5 ± 0.5	96.65	96.65	93.3	93.3	93.3

* Each representative value is the average of two determinations for 15 animals per treatment.

ANOVA - TABLE 5

ANOVA for testing significance of survival of 10-12 mm size postlarvae of P. monodon in different test salinities (TS) over different exposure (EP) periods after acclimation at 5 ppt.

Source	S.S.	d.o.f.	M.S.	F-ratio
Test Salinity	60.56	3	20.19	2.42 NS
Exposure Period	412.05	4	103.01	12.35 ***
Error	100.06	12	8.34	

TS Means:		EP Means:	
TS1	79.08	EP1	87.3625
TS2	81.56	EP2	79.45
TS3	78.19	EP3	77.224
TS4	76.78	EP4	76.111
		EP5	74.372

CD 5% for TS means comparison 3.9817

CD 5% for EP means comparison 4.44925

NS denotes non-significant

*** denotes significant at 0.1%

TS1 = 4.5 ± 0.5 ppt : TS2 = 9.5 ± 0.5 ppt

TS3 = 14.5 ± 0.5 ppt : TS4 =19.5 ± 0.5 ppt

EP1 = 24 h EP2 = 48 h EP3 = 72 h

EP4 = 96 h EP5 = 120 h

Since complete mortality of the postlarvae was observed in less than 1 ppt test salinity level it was not considered for analysis.

The individual percentages (x) were transformed into arc sine values ($\text{Sin}^{-1}\sqrt{\frac{x}{100}}$) for analysis.

Table 6. Survival percentage* of 10-12 mm size postlarvae of P. monodon in different test salinities over 120 h exposure period after acclimation at indicated salinities (compiled from the results of Tables 1, 2, 3, 4 and 5).

Acclimation salinity (ppt)	Test Salinity levels (ppt)			
	4.5 + 0.5	9.5 ± 0.5	14.5 ± 0.5	19.5 ± 0.5
5	89.95	96.65	89.95	93.3
10	93.3	93.3	93.3	93.3
15	93.3	89.95	79.95	93.3
20	50	80	83.3	86.65
25	56.6	69.95	86.6	83.3

* Each representative value is the average of two determinations for 15 animals per treatment.

ANOVA - TABLE 6

ANOVA for testing significance of 10-12 mm size P. monodon postlarvae surviving 120 h exposure period in different test salinities (TS) after acclimation at indicated salinities (AS)

Source	S.S.	d.o.f.	M.S.	F-ratio
Test salinity	184.44	3	61.43	1.21 NS
Acclimation salinity	256.63	4	189.16	3.73 *
Error	609.27	12	50.77	

TS Means:		AS Means:	
TS1	63.06	AS1	74.37
TS2	69.23	AS2	74.99
TS3	68.87	AS3	71.23
TS4	71.89	AS4	60.72
		AS5	59.99

CD 5% for TS means comparison 9.8198

CD 5% for AS means comparison 10.9836

NS denotes non-significant

* denotes significant at 5%

TS1 = 4.5 ± 0.5 ppt : TS2 = 9.5 ± 0.5 ppt

TS4 = 14.5 ± 0.5 ppt : TS4 = 19.5 ± 0.5 ppt

AS1 = 5 ppt AS2 = 10 ppt AS3 = 15 ppt

AS4 = 20 ppt AS5 = 25 ppt

Since complete mortality of the postlarvae was observed in less than 1 ppt test salinity level, it was not considered for analysis.

The individual percentage (x) were transformed into arc sine values ($\text{Sin}^{-1}\sqrt{\frac{x}{100}}$) for analysis.

Table 7. Survival percentage* of 10-12 mm size postlarvae of P. monodon in salinities below 5 ppt over different exposure periods after step-wise acclimation.

Test Salinity levels (ppt)	Exposure periods (h)				
	24	48	72	96	120
Less than 1	93.3	66.6	63.3	59.9	46.6
1	93.3	86.6	83.3	73.3	59.5
2	96.65	96.65	93.3	90	86.65
3	100	93.3	89.95	86.6	86.6
4	96.65	96.65	96.65	96.65	93.3

* Each representative value is the average of two determinations for 15 animals per treatment.

ANOVA - TABLE 7

ANOVA for testing significance of survival of 10-12 mm size of postlarvae of P. monodon in salinity levels (TS) below 5 ppt at different exposure periods (EP) after step-wise acclimation.

Source	S.S.	d.o.f.	M.S.	F-ratio
Salinity level	1868.87	4	467.22	19.58 ***
Exposure period	968.24	4	242.06	10.14 ***
Error	381.87	16	23.87	

TS Means:		EP Means:	
TS1	55.23359	EP1	79.77
TS2	63.73681	EP2	71.4076
TS3	74.8076	EP3	68.916
TS4	74.6796	EP4	65.81
TS5	73.5596	EP5	61.1068

CD 5% for TS means comparison 6.736164

CD 5% for EP means comparison 6.736164

*** denotes significant at 0.1%

TS1 = less than 1 ppt : TS2 = 1 ppt

TS3 = 2 ppt : TS4 = 3 ppt

TS5 = 4 ppt

The individual percentages (x) were transformed into arc sine values ($\text{Sin}^{-1}\sqrt{\frac{x}{100}}$) for analysis.

Table 8. Cumulative mortality of postlarvae of P. monodon exposed to salinity gradually decreasing from 20 ppt to 0.2 ppt.
(10 numbers per replicate)

Experimental period (days)	Salinity (ppt)	Replicates			Total number of animals present	Cumulative survival %	Cumulative mortality %
		1	2	3			
1	20	10	10	10	30	100	0
2	18	10	10	10	30	100	0
3	16	10	10	10	30	100	0
4	14	10	10	9	29	96.7	3.33
5	12	10	10	9	29	96.7	3.33
6	10	10	10	9	29	96.7	3.33
7	8	10	9	8	27	90.0	10
8	6	9	9	8	26	86.7	13.33
9	4	8	8	8	24	80	20
10	2	7	8	8	23	76.6	23.3
11	1	6	7	7	20	66.7	33.3
12	0.75	5	7	7	19	63.34	36.66
13	0.5	4	5	7	16	53.34	46.66
14	0.2	3	3	1	7	23.34	76.66

The animals were maintained at each salinity for 24 hours before the salinity was changed and cumulative mortality at each salinity after 24 h was observed.

Table 9. Probit analysis to determine the relation between logarithmic salinity level (dose = X) and mortality (probit response = Y) for the postlarvae of P. monodon for Exp. 3.2.4.

Proportion responded among controls	=	0
Intercept of probit regression line	=	5.982823
Slope of probit regression line	=	- 1.332194
Weighted mean of log dose (x)	=	1.262063
Weighted mean of probit response (y)	=	4.30071
Standard error	=	1
Standard error of slope	=	.1349906

Percent	Lower limit (ppt)	Lethal dose (ppt)	Upper limit (ppt)
30	1.801389	1.3514	1.013819
50	0.7900891	0.5459431	0.3772408
70	0.3656071	0.2205521	0.1330478
90	0.1243583	0.0595834	2.854801E-02

Table 10. Mean individual weight* (g) of juveniles of P. monodon surviving 56 days in different test salinities recorded at fortnightly intervals

Experimental period (days)	Test salinity levels (ppt)				
	1.5 ± 0.5	4.5 ± 0.5	9.5 ± 0.5	14.5 ± 0.5	19.5 ± 0.5
Initial	0.2483	0.1917	0.2412	0.1974	0.2143
14	0.3130	0.3384	0.3466	0.2954	0.3583
28	0.4990	0.6077	0.5376	0.4618	0.5486
42	0.5186	0.804	0.7117	0.7457	0.7998
56	0.6194	1.094	0.9858	0.9485	0.9275

* Individual values are the means of two determinations

Table 11. Growth rate variations (mg/day) of juveniles of P. monodon surviving 56 days in different test salinities recorded at fortnightly intervals.

Experimental period (days)	Test salinity levels (ppt)				
	1.5 ± 0.5	4.5 ± 0.5	9.5 ± 0.5	14.5 ± 0.5	19.5 ± 0.5
14	4.43	10.48	7.53	7.0	10.29
28	8.95	14.86	10.59	9.44	13.22
42	6.44	14.58	11.44	13.05	13.94
56	6.63	16.11	13.30	13.41	12.74

ANOVA - TABLE 8

ANOVA for testing significance of variations in growth rate of juveniles of *P. monodon* reared in different test salinities (TS)

Source	S.S.	d.o.f.	M.S.	F-ratio
Test salinity	123.26	4	30.815	18.96 ***
Exposure period	61.66	3	20.55	12.64 ***
Error	19.55	12	1.625	

TS Means:		EP Means:	
TS1	6.61	EP1	7.93
TS2	14.01	EP2	14.41
TS3	10.72	EP3	11.89
TS4	10.73	EP4	12.44
TS5	12.55		

CD 5% for comparison of TS means 1.965

CD 5% for comparison of EP means 1.7575

*** denotes significant at 0.1%

TS1 = 1.5 ± 0.5 ppt : TS2 = 4.5 ± 0.5 ppt

TS3 = 9.5 ± 0.5 ppt : TS4 = 14.5 ± 0.5 ppt

TS5 = 19.5 ± 0.5 ppt (control)

EP1 = 14 days : EP2 = 28 days : EP3 = 42 days

EP4 = 56 days

Table 12. 56-days survival (%)* of juveniles of P. monodon in different test salinities recorded at fortnightly intervals.

Experimental period (days)	Test salinity levels (ppt)				
	1.5 ± 0.5	4.5 ± 0.5	9.5 ± 0.5	14.5 ± 0.5	19.5 ± 0.5
Initial	100	100	100	100	100
14	80	85	100	100	100
28	70	55	95	100	100
42	50	55	90	100	95
56	50	50	90	100	75

* Individual values are the means of two determinations.

ANOVA - TABLE 9

ANOVA for testing significance of 56-day survival of juveniles of P. monodon in different test salinities (TS)

Source	S.S.	d.o.f.	M.S.	F-ratio
TS	3599.760	4	899.94	9.108 ***
EP	2310.805	4	577.70	5.8468 **
ERR	1580.895	16	98.8050	

TS Means:		EP Means:	
TS1	60.046	EP1	90.0
TS2	59.59	EP2	80.13
TS3	80.04	EP3	72.34
TS4	90.00	EP4	66.30
TS5	81.416	EP5	62.31

CD 5% for TS means comparison 13.39

CD 5% for EP means comparison 13.39

*** denotes significant at 0.10%

** denotes significant at 1%

TS1 = 1.5 ± 0.5 ppt : TS2 = 4.5 ± 0.5 ppt

TS3 = 9.5 ± 0.5 ppt : TS4 = 14.5 ± 0.5 ppt

TS5 = 19.5 ± 0.5 ppt (control)

EP1 = 14 days : EP2 = 28 days : EP3 = 42 days

EP4 = 56 days

The individual percentages (x) were transformed into arc sine values ($\text{Sin}^{-1}\sqrt{\frac{x}{100}}$) for analysis.

Table 13. Experimental values* for initial weight, stocking density, final weight and biomass increase of juveniles of P.monodon in growth experiment.

	Test salinity levels (ppt)				
	1.5±0.5	4.5±0.5	9.5±0.5	14.5±0.5	19.5±0.5
Average initial wt. (g)	0.2483	0.1917	0.2412	0.1974	0.2143
Average final wt. (g)	0.6194	1.094	0.9858	0.9485	0.9275
Survival percentage	50	72.5	90	100	87.5
Stocking density (initial) nos/m^2	25	25	25	25	25
**Biomass increase (g/m^2)	1.535	15.0363	16.0505	18.7775	14.9316
Biomass increase/ day (mg/m^2/day)	27.410	268.504	288.40	335.31	266.635
Average daily gain (mg/day)	6.6267	16.1125	13.2964	13.4125	12.7357

* Individual values are the means of two determinations

** Biomass increase (New, 1971) $c = \frac{azy}{100} - bz$

Where a = av. final wt. (g)
b = av. initial wt. (g)
y = Survival percentage
z = Stocking density (nos/m^2)
c = Biomass increase (g/m^2)

Table 14. Average ($\bar{x}$) and standard deviation (S.D.) of water quality parameters monitored during 56-day survival of juveniles of P. monodon in cement cisterns (n = s)

Parameters	1.5 ± 0.5 ppt $\bar{X}$ ± S.D.	4.5 ± 0.5 ppt $\bar{X}$ ± S.D.	9.5 ± 0.5 ppt $\bar{X}$ ± S.D.	14.5 ± 0.5 ppt $\bar{X}$ ± S.D.	19.5 ± 0.5 ppt $\bar{X}$ ± S.D.
Air temperature (^{o}C)	30±0.63	30±0.63	30±0.63	30±0.63	30±0.63
Water temperature (^{o}C)	27.4±0.49	27.6±0.58	27.7±0.748	27.5±0.45	28.75±1.40
pH	7.44±0.32	7.544±0.31	7.57±0.32	7.402±0.33	7.26±0.24
Dissolved Oxygen (ppm)	5.46±0.70	4.64±2.37	5.54±0.79	4.942±0.68	6.48±1.40
Alkalinity (ppm)	34.75±2.86	67.8±17.79	65±12.537	67.6±15.12	65.2±14.96
Salinity (ppt)	1.202±0.34	4.89±0.46	10.62±0.67	15.16±0.88	19.43±0.63

Fig. 1 120-h survival (%) of postlarvae of P. monodon in salinities below 5 ppt. The lethal salinity (LC 50) for the postlarvae at a temperature of water between 27 to 29°C is indicated by.*

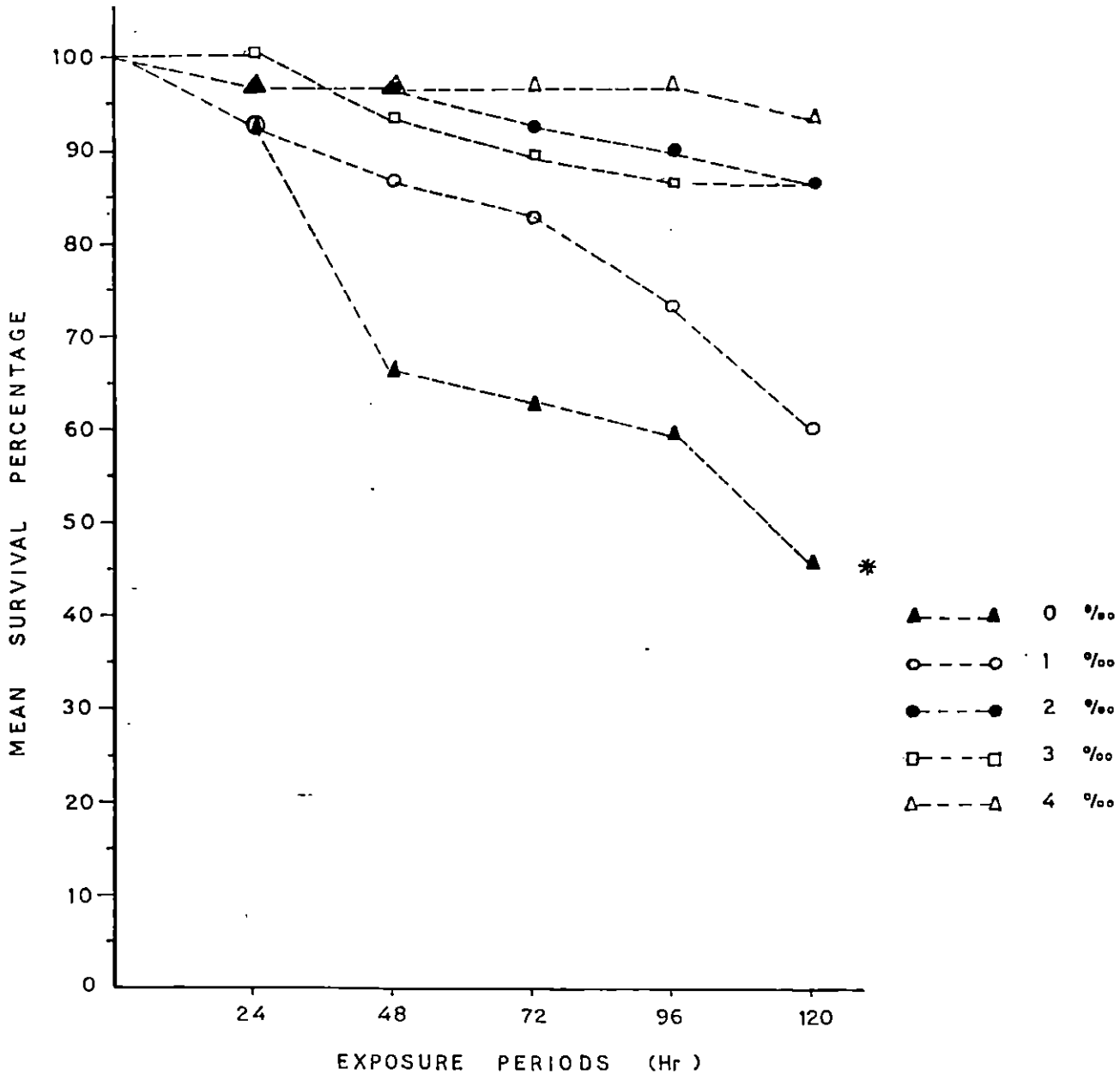
MEAN SURVIVAL PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
24
48
72
96
120
EXPOSURE PERIODS (Hr)
*
0 ‰
1 ‰
2 ‰
3 ‰
4 ‰

Fig. 1.

Fig. 2 Cumulative mortality (%) of postlarvae of P. monodon exposed to salinity gradually decreasing from 20 to 0.2 pppt.

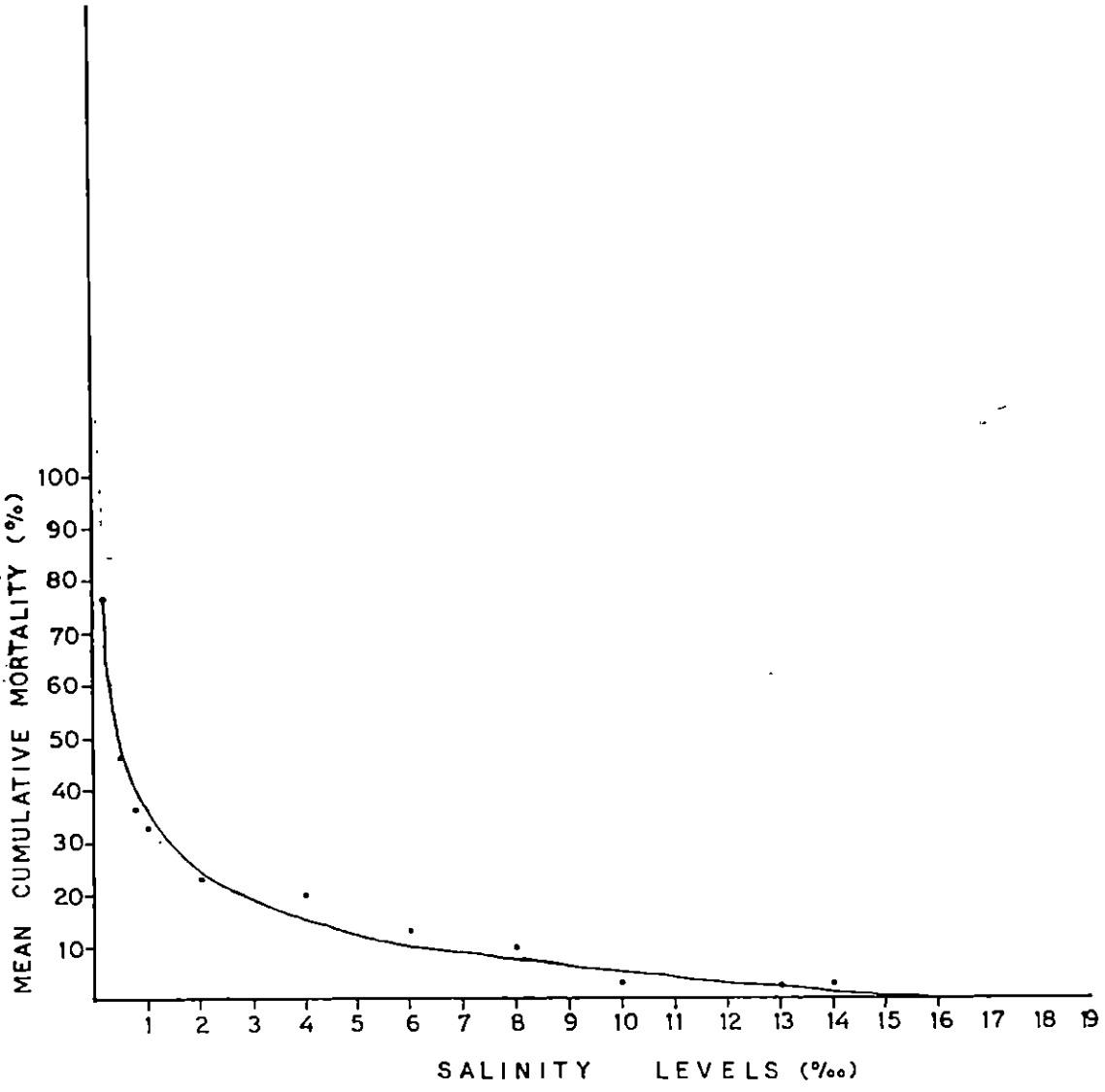
MEAN CUMULATIVE MORTALITY (%)
100
90
80
70
60
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
SALINITY LEVELS (‰)

Fig. 2.

Fig. 3 Growth of juveniles of P. monodon in different test salinities (length of experiment : 56 days). Under unrestricted food and constant levels of other growth factors.

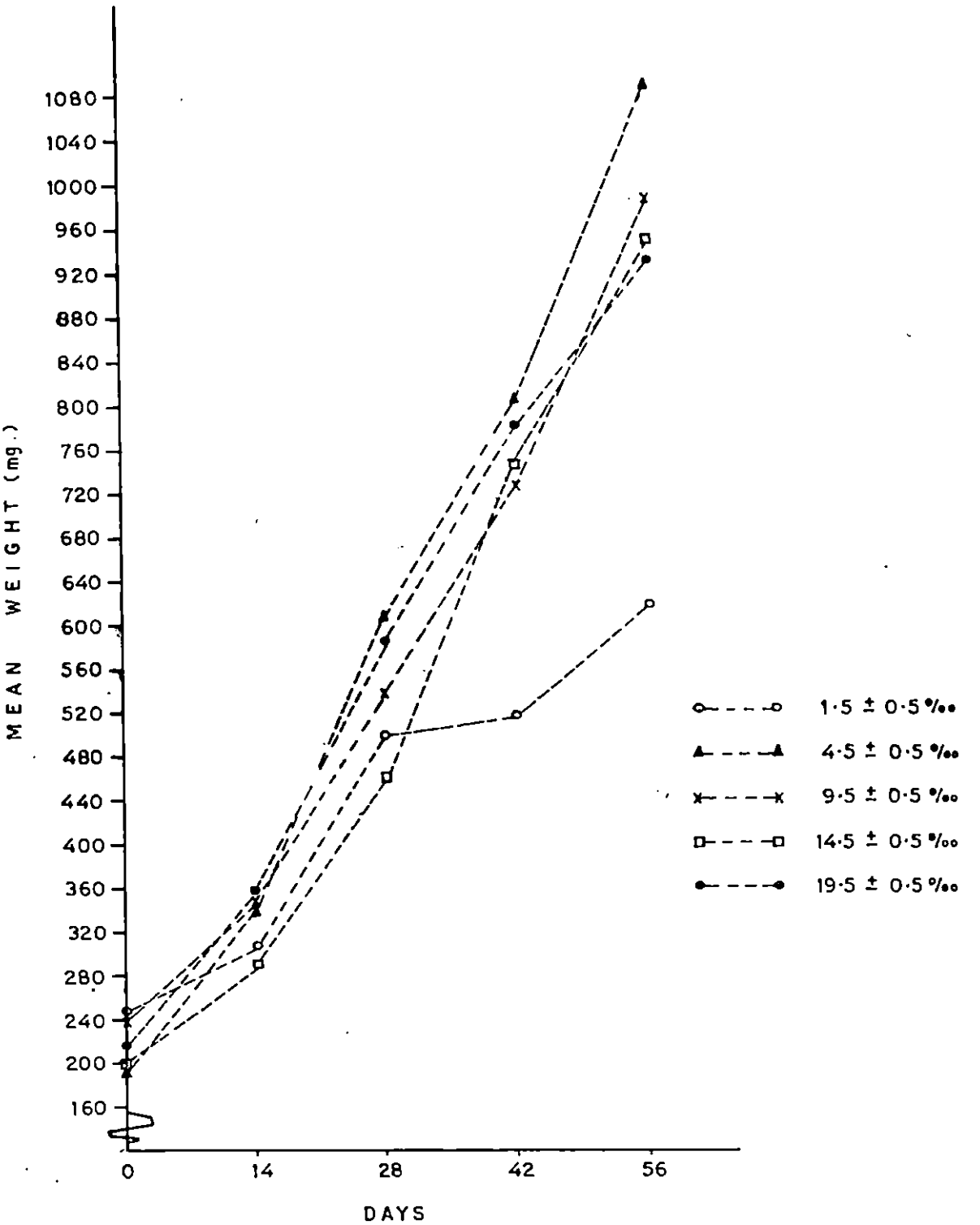
MEAN WEIGHT (mg.)
1080
1040
1000
960
920
880
840
800
760
720
680
640
600
560
520
480
440
400
360
320
280
240
200
160
0
14
28
42
56
DAYS
1·5 ± 0·5 ‰
4·5 ± 0·5 ‰
9·5 ± 0·5 ‰
14·5 ± 0·5 ‰
19·5 ± 0·5 ‰

Fig. 3.

Fig. 4 56 - day survival (%) of juveniles of P. monodon in different test salinities. Under unrestricted food and constant levels of other factors. Mean values that differ significantly from the control (19.5 ± 0.5 ppt) are indicated by*

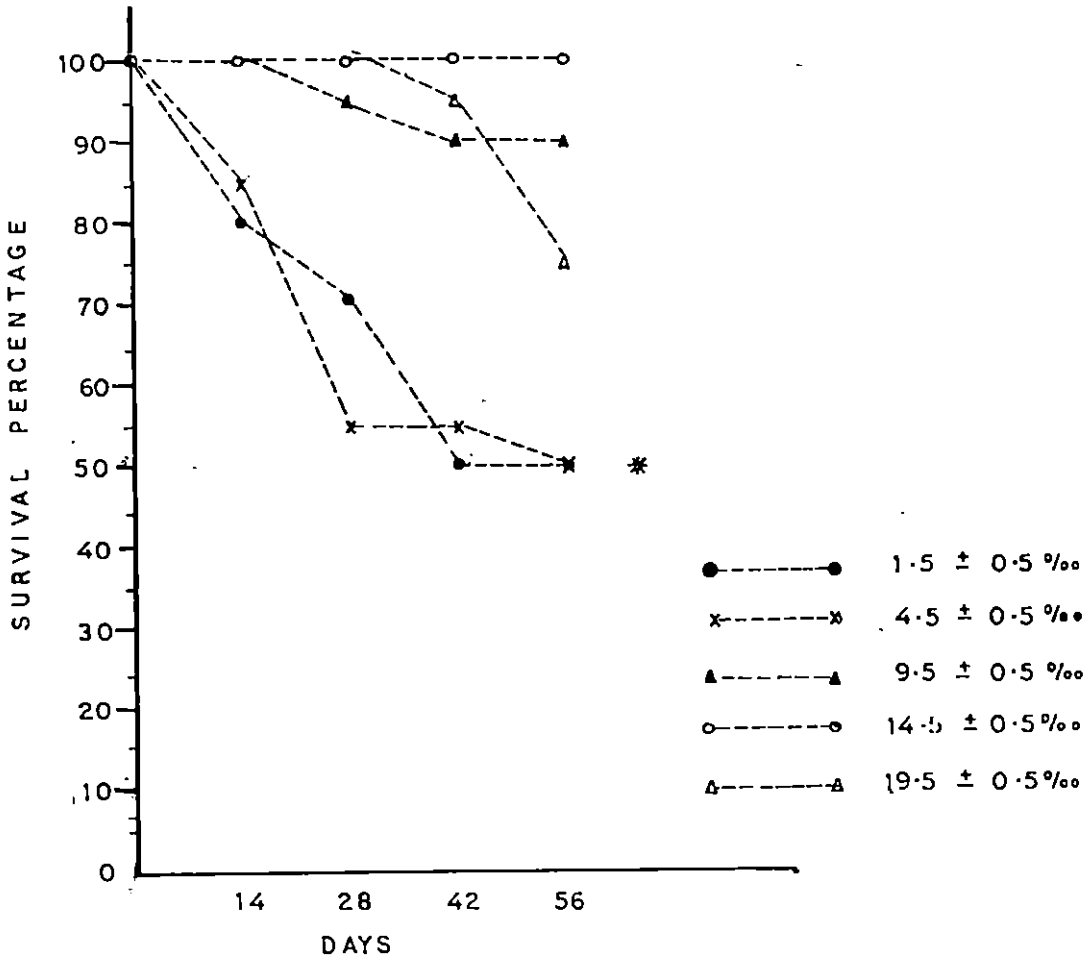
SURVIVAL PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
14
28
42
56
DAYS
1·5 ± 0·5 ‰
4·5 ± 0·5 ‰
9·5 ± 0·5 ‰
14·5 ± 0·5 ‰
19·5 ± 0·5 ‰

Fig. 4.

Fig. 5 Effect of low salinity on the growth rate of juveniles of P. monodon under laboratory conditions (length of experiment : 56 days). Under unrestricted food and constant levels of other growth factors. Mean values that differ significantly from the control (19.5 ± 0.5 ppt) are indicated by*

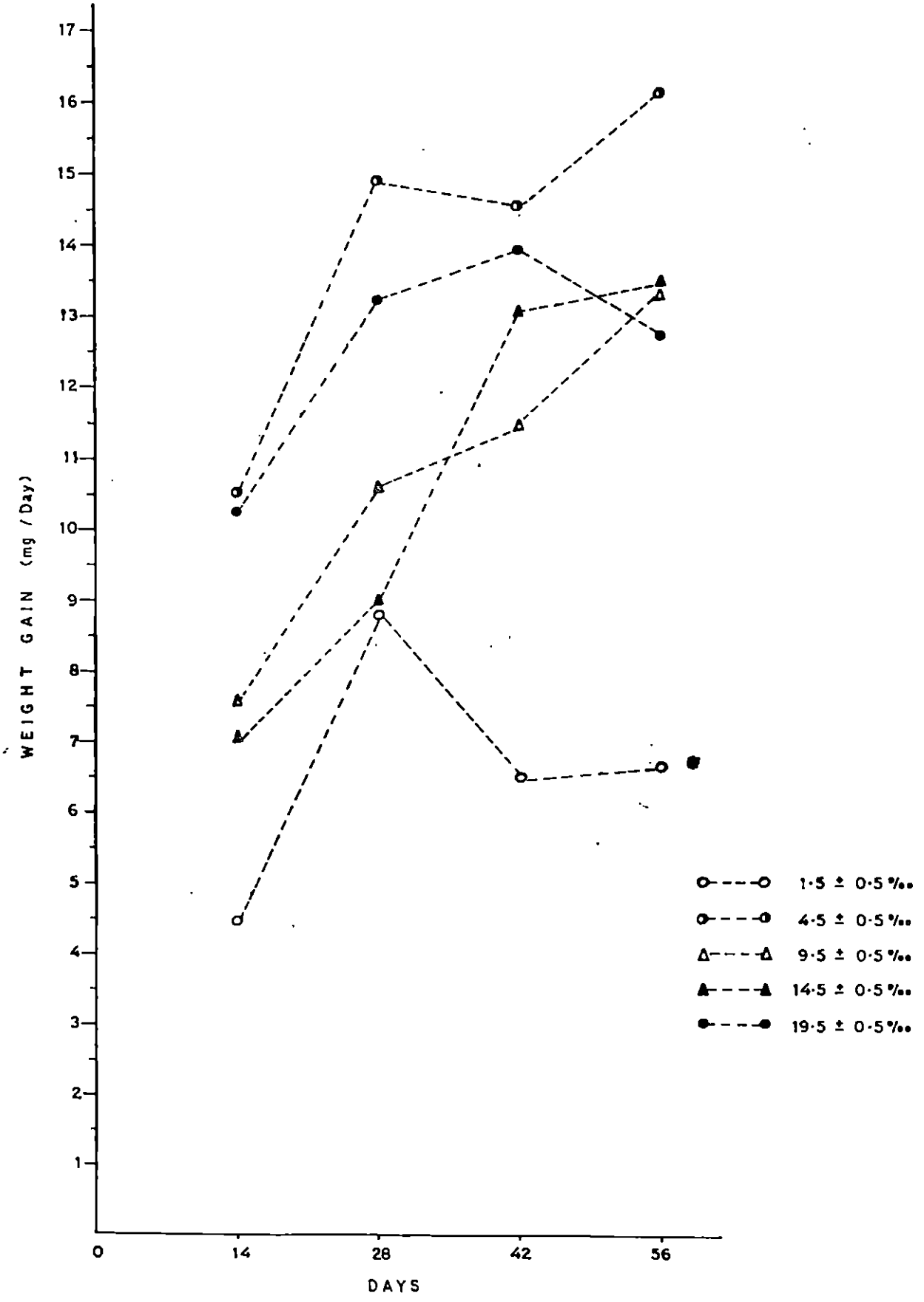
WEIGHT GAIN (mg / Day)
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
14
28
42
56
DAYS
1·5 ± 0·5 ‰
4·5 ± 0·5 ‰
9·5 ± 0·5 ‰
14·5 ± 0·5 ‰
19·5 ± 0·5 ‰

Fig. 5.

Fig. 6 Average growth rate of juveniles of P. monodon surviving 56 days in different test salinities. Mean values that differ significantly from the control (19.5 ± 0.5 ppt) are indicated by*

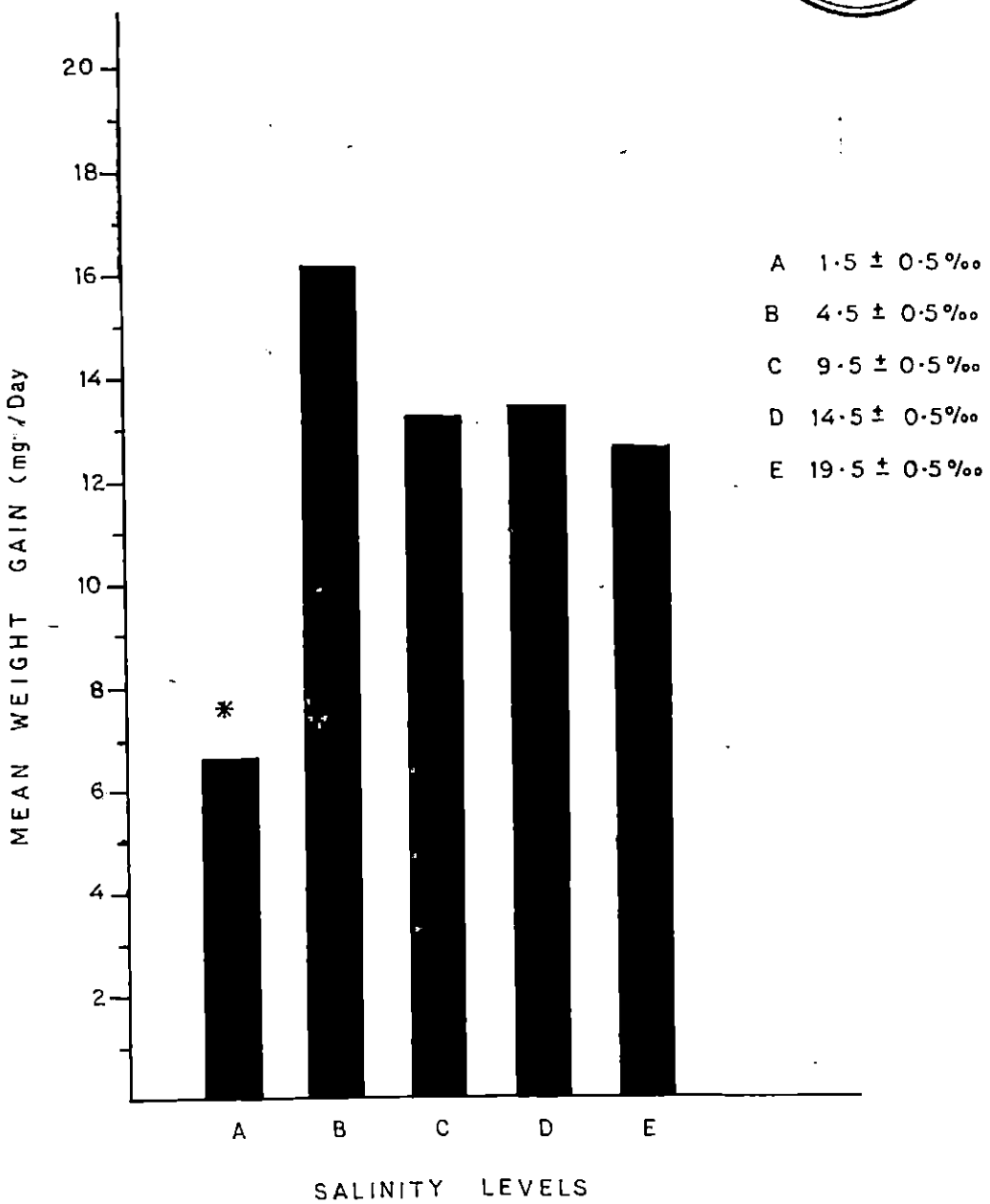

Fig. 6.

Fig. 7 Effect of low salinity on the biomass increase of juveniles of P. monodon in the laboratory (length of experiment : 56 days).

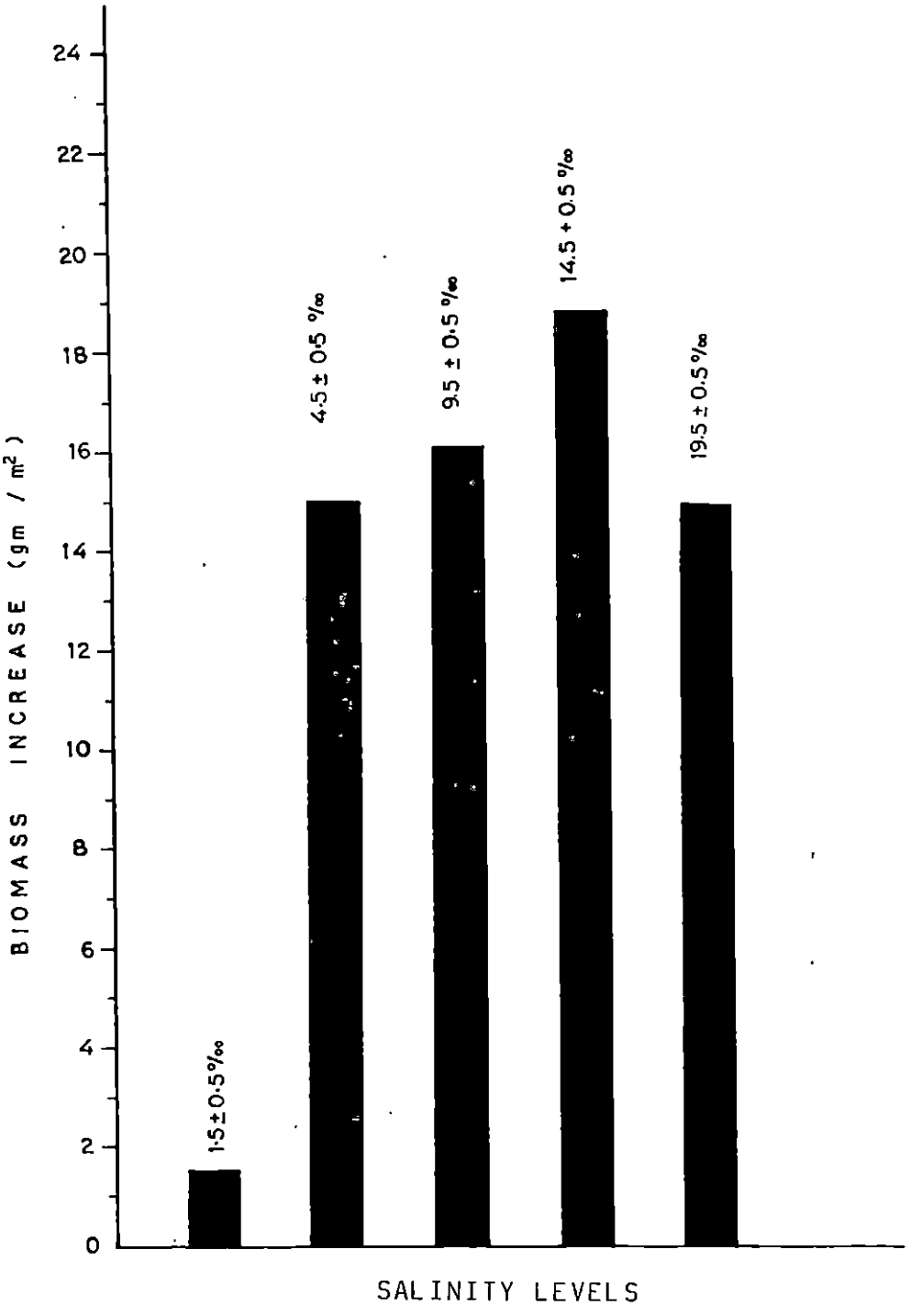
BIOMASS INCREASE (gm / m²)
0
2
4
6
8
10
12
14
16
18
20
22
24
1·5±0·5‰
4·5 ± 0·5 ‰
9·5 ± 0·5 ‰
14·5 + 0·5 ‰
19·5 ± 0·5 ‰
SALINITY LEVELS

Fig: 7.

Table 15. Model of taste panel evaluation sheet

Sample ..... Date.....

Name of the judge .....

Kindly evaluate the given coded samples on the basis of your preference by placing the appropriate score against each quality characteristic.

Quality rating	Scale
Excellent	6
Good	5
Moderate	4
Fair	3
Slightly poor	2
Poor	1
Very bad	0

Quality characteristics	Sample code				
	A	B	C	D	E
Cooked flavour					
Cooked texture					
Overall quality					

Table 16. Taste panel evaluation sheet for flavour of cooked meat of P. monodon reared in different test salinities.

Taste Panel	Samples				
	A	B	C	D	D
	1.5 ± 0.5 (ppt)	4.5±0.5 (ppt)	9.5±0.5 (ppt)	14.5±0.5 (ppt)	19.5±0.5 (ppt)
1	4	5	5	3	2
2	5	5	5	4	4
3	4	4	5	2	5
4	4	4	4	4	3
5	3	5	6	3	6
6	2	2	5	1	5
7	2	1	5	2	4
8	4	4	4	4	5
9	4	5	4	4	5
10	4	4	4	3	5

Table 17. Kendall's co-efficient of concordance (Sidney Segel, 1956) to test significance in association among judgements for flavour of cooked meat of shrimps reared in different test salinities.

Taste panel	Samples				
	A	B	C	D	E
	1.5 ± 0.5 (ppt)	4.5 ± 0.5 (ppt)	9.5 ± 0.5 (ppt)	14.5 ± 0.5 (ppt)	19.5 ± 0.5 (ppt)
1	3	4.5	4.5	2	1
2	4	4	4	1.5	1.5
3	2.5	2.5	9.5	1	4.5
4	3.5	3.5	3.5	3.5	1
5	1.5	3	4.5	1.5	4.5
6	2.5	2.5	4.5	1	4.5
7	2.5	1	5	2.5	4
8	2.5	2.5	2.5	2.5	5
9	2	4.5	2	2	4.5
10	3	3	3	1	5
**	27	31	38	18.5	35.5

Kendall's coefficient of concordance (W) = 0.2365*

*denotes significant at 5%

Individual values given are the ranks in ascending order of preference.

**denotes the total of individual ranks in a particular sample.

ANOVA - TABLE 10

ANOVA for testing significance of variation in flavour of cooked meat of P. monodon samples reared in different test salinities.

Source	S.S.	d.o.f.	M.S.	F-ratio
Between Tr.	17.88	4	4.47	3.89 *
Error	51.8	45	1.15	

TR Means

T1	3.6
T2	3.9
T3	4.7
T4	3.0
T5	4.4

CD 5% for Tr means comparison 0.97

* denotes significant at 5%

T1 = mean panel score for samples at 1.5 ± 0.5 ppt (n=10)
T2 = mean panel score for samples at 4.5 ± 0.5 ppt (n=10)
T3 = mean panel score for samples at 9.5 ± 0.5 ppt (n=10)
T4 = mean panel score for samples at 14.5 ± 0.5 ppt (n=10)
T5 = mean panel score for samples at 19.5 ± 0.5 ppt (n=10)

Table 18. Taste panel evaluation sheet for texture of cooked meat of P. monodon reared in different test salinities.

Taste Panel	Samples				
	A	B	C	D	E
	1.5±0.5 (ppt)	4.5±0.5 (ppt)	9.5±0.5 (ppt)	14.5±0.5 (ppt)	19.5±0.5 (ppt)
1	5	5	5	3	2
2	4	4	4	2	3
3	4	4	4	5	5
4	5	5	4	5	3
5	4	3	5	3	5
6	3	3	5	1	4
7	1	2	5	1	3
8	5	4	4	4	4
9	3	4	5	2	4
10	4	5	4	2	5

Table 19. Kendall's co-efficient of concordance to test significance in association among judgements for texture cooked meat of shrimp reared in different salinities.

Taste panel	Samples				
	A	B	C	D	E
	1.5 ± 0.5 (ppt)	4.5 ± 0.5 (ppt)	9.5 ± 0.5 (ppt)	14.5 ± 0.5 (ppt)	19.5 ± 0.5 (ppt)
1	4	4	4	2	1
2	4	4	4	1	2
3	2	2	2	4.5	4.5
4	4	4	2	4	1
5	3	1.5	4.5	1.5	4.5
6	2.5	2.5	5	1	4
7	1.5	3	5	1.5	4
8	5	2.5	2.5	2.5	2.5
9	2	3.5	5	1	3.5
10	2.5	4.5	2.5	1	4.5
**	30.5	31.5	36.5	20	31.5

Kendall's co-efficient of concordance (W) = 0.147 NS

NS denotes non-significant.

Individual values given are the ranks in ascending order of preference.

**denotes the total of individual ranks in a particular sample.

Table 20. Taste panel evaluation sheet for overall quality of cooked meat of P. monodon reared in different test salinities.

Taste panel	Samples				
	A	B	C	D	E
	1.5 ± 0.5 (ppt)	4.5 ± 0.5 (ppt)	9.5 ± 0.5 (ppt)	14.5 ± 0.5 (ppt)	19.5 ± 0.5 (ppt)
1	4	5	5	3	2
2	5	5	5	3	4
3	4	4	4	3	5
4	4	5	4	5	3
5	3	3	5	3	5
6	3	2	5	1	4
7	2	1	5	2	4
8	4	4	4	4	5
9	4	5	4	4	5
10	4	4	4	3	5

Table 21. Kendall's co-efficient of concordance to test significance in association among judgements for overall quality of cooked meat of shrimps reared in different salinities.

Taste Panel	Samples				
	A	B	C	D	E
	1.5 ± 0.5 (ppt)	4.5 ± 0.5 (ppt)	9.5 ± 0.5 (ppt)	14.5 ± 0.5 (ppt)	19.5 ± 0.5 (ppt)
1	3	4.5	4.5	2	1
2	4	4	4	1	2
3	3	3	3	1	5
4	2.5	4.5	2.5	4.5	1
5	2	2	4.5	2	4.5
6	3	2	5	1	4
7	2.5	1	5	2.5	4
8	2.5	2.5	2.5	2.5	5
9	2	4.5	2	2	4.5
10	3	3	3	1	5
**	27.5	31	36	19.5	36

Kendall's co-efficient of concordance (W) = 0.1535 NS

NS denotes non-significant

Individual values given are the ranks in ascending order of preference.

**denotes the total of individual ranks in a particulars sample.

Table 22. Salinity preference of some penaeids

Species	Stage	Salinity (ppt)	Author
Penaeus aztecus	larvae	28-20	Cook (1970)
- do -	Juvenile	32	Grajcer and Neal (1973)
- do -	(13-20 mm)	8.5-17	Venkataramaiah et al. (1975)
P. indicus	Postlarvae	10	Nair and Kutty (1975)
	Juvenile	30	-do-
	Postlarvae	21-28	Bhattacharya and Kewalramani (1976)
	8-19 mm	10-25	Lakshmikantham (1982)
	13-15 mm	5-35	-do-
	15-19 mm	5-40	-do-
	Postlarvae	20	Kuttyamma (1982)
	Juvenile	25	-do-
	Juvenile	5-15	Raj and Raj (1982)
P. japonicus	Embryonic	27-39	Takeo Imai (1977)
	Early juvenile	23-47	-do-
P. merguiensis	Postlarvae	25	Beard et al. (1977)
P. (Melicertus) latisulcatus	Juvenile	25-45	Ramaswamy and Pandian (1985b)
P. monodon	Juveniles	15-20	Hideo (1979)
	Juveniles	10-25	Manik et al. (1979)
	Juveniles	5-15	Raj and Raj (1982)
	Postlarvae	7-10	Rajyalakshmi (1982)
	Juveniles	15-25	Chen (1984)
	Juveniles	4-20	Present study

DISCUSSION

DISCUSSION

5.1. Salinity Tolerance

The interpretations of observations on salinity and shrimp abundance in nature is rather difficult because some factors like temperature, light, substrate, food supply, vegetative cover and pollution vary frequently independent of changes in salinity (Zein-Eldin and Aldrich, 1965). For this reason, controlled environment studies in the laboratory were employed for salinity tolerance studies.

It was observed that for the postlarvae, fluctuations in salinities ranging from 4 to 20 ppt, were not a significant factor ($P \leq 0.05$) influencing the survival (ANOVA Table 6). However, a marked reduction in tolerance to salinity below 4 ppt was observed. A general reduction in survival in salinity levels below 1 ppt on sudden transfer regardless of acclimation salinities suggest a strong salinity effect. (Table 6). The excellent survival of the postlarvae upto 24 h in salinity ranging from 1 to 20 ppt suggested a short term tolerance to this salinity range while the survival in different test salinities for 120 h regardless of acclimation salinities confirmed the wide range of tolerance to salinity ranging from 4 to 20 ppt. Complete mortality was observed at salinity less than 1 ppt. Mortality at this test salinity was presumably the result of the immediate stress caused by changes in the salinity levels. However, the stress of salinity acclimation do not seem to explain the poorer survival (56.6 to 69.95%) of postlarvae between 4 and 10 ppt when they were acclimated at 25 ppt (Table 1).

The higher rate of mortality at low salinity levels can be due to lethal salinity level. According to Manik et al.(1979) at low salinity, the shrimps could maintain their osmotic and ionic balance by decreasing the rate of water transport across the gut, as well as the rate of sodium and chloride extrusion through gills. The animal can survive only when the cells are able to tolerate the decreased haemolymph sodium and chloride concentrations. When this becomes too little for

the cells to maintain ionic balance, the shrimps would die. This may be a factor that caused mortality of postlarvae in this trial. Moreover, the stress would make some of the animals weak and susceptible to predation. In culture systems, Ferraris et al. (1987) observed that mortality of the juveniles of P. monodon occured when moulting coincided with salinity fluctuations. When moulting occured at very low salinity levels, more energy and time were required to normalize haemolymph osmolarity. This long time interval increased the vulnerability of the animal to cannibalism and prolongs their inability to forage for food.

Chakraborti et al. (1985a) reported a 76 to 100% survival for postlarvae of P. monodon when acclimated to different salinities, viz. 25, 20, 15, 10 and 5 ppt and directly transferred to salinities ranging between 3 to 30 ppt. Survival was between 2 to 4% below 2 ppt. He suggested salinity above 3 ppt should be maintained in brackishwater impoundments during the monsoon since long exposure to salinity lower than 3 ppt causes heavy mortality. Result of the present study also demonstrated a similar effect.

The effect of step-wise acclimation in extending ranges of postlarval tolerance is clearly shown in fig. 1. When the changing rate of salinity was 2 ppt per day while from 2 ppt onwards, it was done at still smaller intervals, 53.34% of postlarvae survived in 0.5 ppt salinity (Fig. 2). Comparing this result with those, when the postlarvae were pre-acclimated at different salinities and then introduced suddenly into the different test salinities (Table 6), it can be seen that a gradual changing condition permitted better survival than did sudden changes. There are similar reports of 40-64% survival of postlarvae of P. monodon in salinity less than 1 ppt when the changing rate of salinity was done 1-2 ppt per day (Motoh, 1981; Chakraborti et al., 1985a). Analysis of probit regression line for the relation between the logarithmic salinity level (dose = X) and mortality (probit response = Y) was found to be $Y = 5.982023 + 1.332194 X$ (Table 9). This implies that lowest lethal salinity (LC 50) for the postlarvae is 0.5459 ppt with its upper and lower

limit being 0.3772 and 0.7901 ppt respectively. LC 30 and LC 70 lethal salinities were 1.3514 and 0.2206 ppt respectively. These results can explain how postlarvae of P. monodon can penetrate into and survive extreme low salinities in the natural environment.

5.1.1. Biological and Ecological Implications.

Commercially important shrimps of the genus Penaeus spawn at the sea, migrate into the estuarine areas as postlarvae, remain in less saline estuaries until they approach maturity and then return to the sea (Subrahmanyan and Rao, 1968; Subrahmanyam and Ganapati, 1975). A number of authors have emphasized the requirement of low salinities by postlarvae and juveniles of Penaeus for better survival and growth in nursery areas (Gunter, 1950; Pearse and Gunter, 1957; Gunter et al., 1964). Preference for reduced salinities over seawater in postlarvae and early juveniles had been demonstrated experimentally for Penaeus vannamei, P. stylirostris, P. californiensis and P. brevirostris from Western Mexico (Mair, 1980). A few penaeids sp. like P. aztecus, P. setiferus and P. duorarum have been recorded at salinities less than 1 ppt (Gunter and Shell 1959; Tabb et al., 1962; Gunter and Hall, 1963). Large numbers of the postlarvae of P. aztecus were collected from Louisiana waters within 0.8 to 5.99 ppt(Wengert, 1972). Reports on the occurence of the postlarvae of P. monodon in very low salinity (less than 1 ppt) are available (Manik et al.,1979; Raj and Raj, 1982a). In Marakanam estuary, Bose and Venkatesan (1982) encountered postlarvae of P. monodon in salinity ranging from 1.3 to 2.0 ppt. According to Thampy et al. (1982) owing to its capacity to tolerate low salinity conditions the percentage availability of the postlarvae of P. monodon in the Cochin backwaters could have been more in the monsoon but for the turbidity of water and silting of beds during the rainy season which could be adversely affecting the survival of the postlarval recruitment just prior to the start of the South-West monsoon. George

and Suseelan (1982) reported the postlarvae of this species to thrive well in salinities below 5 ppt and encountered the postlarvae in all gradients of salinity in the Godavari and Konade estuaries along the east cost of India. Thus, the ecological distribution of juveniles and postlarvae of P. monodon correlates well with its ability to osmoregulate in very low salinity levels as obtained in this study.

Temperature influences salinity tolerance in penaeids either independently (Williams, 1960) or in combination with salinity (Zein-Eldin and Aldrich, 1965). Usually salinity tolerance tends to decrease as temperature becomes sub - or supra - optimal (Kinne, 1971). The temperature variation noticed in the present study was 27 to 29^{o}C which is the normal temperature range found in most of the brackishwater nursery grounds. This temperature range is characteristic of tropical regions and is relatively stable in the inshore and estuarine region. This makes it possible for the postlarvae to withstand wide range of salinities in nature.

5.2. Growth Studies

The objective of this study was to determine the range of low salinities (below 20 ppt) for favourable growth of the prawns, which might give an insight into the growth rate under natural conditions. In order to analyse and understand growth phenomenon, it is convenient to consider short growth periods for arbitrarily defined time periods (Webb, 1978).

The result of the growth experiment conducted in the present study indicated that low salinities had a highly significant ($P < 0.001$) influence on the growth of juveniles of P. monodon (ANOVA - Table 8). Juveniles recorded maximum growth rate of 6.63 mg/day in 4.5 $\pm$ 0.5 ppt while between 9 and 20 ppt growth rate varied from 12.74 to 13.41 mg/day (Fig. 6). Mean values of growth rates of juveniles between 4 and 15 ppt did not differ significantly ($P > 0.05$) from the

control (19.5 ± 0.5 ppt).

In brackishwater ponds in the Philippines, juveniles of P. monodon grew to about 50 - 100 g under 10 to 20 ppt (Hideo, 1979) while in Indonesia Manik et al. (1979) recorded better growth and production of juveniles of this species in salinity ranging between 15 and 20 ppt. In West Bengal, Verghese et al. (1975) observed a growth rate of 4.36 g/month for this species when salinity of the pond water varied from 5.44 to 36.5 ppt. Reports on the optimum growth of P. monodon during culture in grow - out ponds when exposed in salinities ranging between 5 and 20 ppt (Sundararajan et al., 1979; Sebastian et al., 1980) correlate well with results of this study that optimum growth may be maintained by juveniles of P. monodon over a range of 4 to 20 ppt salinity.

Manik et al. (1979) reported that within the salinity range from 15 to 20 ppt, there was no discernible effect on growth rate of juveniles of P. monodon when food was sufficient. In the present study, mean values of growth rate of juveniles between 4 and 15 ppt did not differ significantly ($P \nless 0.05$) with the control (19.5 ± 0.5 ppt).

Observations of better growth rate in lower salinities had been reported in other penaeids too (Nair and Kutty, 1975; Venkataramaiah et al., 1975).

The superior growth rate and biomass increase obtained in this study for juveniles in salinties between 4 and 20 ppt comparing with those in 1.5 ± 0.5 ppt may be due to their better efficiency of consumption and utilization. Both consumption and utilization of food for growth depend to a lesser extend on salinity concentrations (Paloheimo and Dickie, 1966 a, b; Warren and Davis, 1967). Based on comprehensive studies on P. aztecus Venkataramaiah et al. (1975) observed better food conversion efficiency in 8.5 and 17 ppt salinities compared to higher

salinities. They recorded faster metamorphosis of postlarvae into juveniles in 18.5 ppt than in higher salinities. Better growth of juveniles may also be due to the consistent growth rate associated with higher moulting frequency in salinities between 4 and 20 ppt (Mintardjo et al., 1979 as given in Manik et al., 1979). However, Hag (1984) had noticed that higher salinity (40 to 45 ppt) favoured moulting in P. monodon under laboratory conditions while decreasing salinity did not induce moulting. Salinity also influences the burying behaviour of prawns (Lakshmi et al., 1976). Greater number of shrimps, buried in low (8.5 and 17 ppt) than in higher salinity (Venkataramaiah et al., 1975). The implication is that burying is a means of conserving energy, that can be diverted for growth. Reports of low respiratory rates in low salinities and high rates in high salinities indicated the corresponding low or high energy demands in the respective media (Equasa, 1961; Venkataramaiah et al., 1975).

The poor growth rate of juveniles in 1.5 ± 0.5 ppt (Fig. 6) indicated that although the juveniles could be grown in a wide range of low salinities, weight increment was poor in very low salinities. This poor growth rate at very low salinities may be due to the stress undergone and the increase in energy cost due to osmoregulation (Kutty et al., 1971). In culture systems with very low salinity, growth rate of juveniles of P. monodon was very poor because of lesser moulting frequency and smaller growth increment with each moult (Manik et al., 1979). Similar reports of adverse effect of low salinity on growth of juveniles of this species in the laboratory (Subrahmanyam, 1973) and in ponds with saline soil and freshwater are available (Venkatesan and Joshua, 1984).

There are few reports of faster growth rate of P. monodon in culture systems when salinity of pond water was gradually increasing. (Verghese et al., 1982; Chakraborti et al., 1985b). The animals referred to in these cases were larger-sized individuals and belonged to the size-group 13-17 cm. Animals of this size-

groups are on the verge of their spawning migration to the sea (Rao, 1967; Jhingran, 1975). Hence a gradual change to stenohalinity is to be expected alongwith other physiological changes. Faster growth rate observed by Verghese et al. (1982) and Chakraborti et al. (1985b) at the increasing phase of salinity of pond-water seems to suggest such a gradual change in this species. Gunter et al. (1964) pointed out that the adaptation to low salinity is highly developed in younger stages while Panikkar (1968) had indicated that osmoregulation in dilute media is less effective in full-sized individuals, especially in their reproductive phase.

The decrease in survival rate of juveniles held at 19.5 ± 0.5 ppt (Fig. 4) is unexplainable. Mortality was recorded during the latter days of the experiment. If this decreased survival represented a longterm effect of the stress of low salinity it is strange that such a decrease did not occur among groups held at even lower salinities. Besides the preliminary tolerance studies had indicated that the animal survive well at 19.5 ± 0.5 ppt (Table 6).

Based on comprehensive studies on P. aztecus, Venkataramaiah et al. (1975) stated that although the juveniles of P. aztecus survived a wide salinity range, the best growth and survival were observed in optimum salinity of 8.5 and 17 ppt. Kinne (1971) also stated that in most of the euryhaline invertebrates, growth is restricted to a significantly narrower range of salinity when compared to survival. The present study shows that though juveniles of P. monodon could tolerate very low salinity upto 1 ppt (Fig. 4) their growth rate was optimal beyond 4 ppt.

5.3. Sensory Evaluations

Flavour of fish and shellfish is derived from extractable compounds which may be divided into two broad categories. The first category contains the nitrogenous compounds which include free amino acids, nucleotides and related compounds. The

second category is comprised of non-nitrogenous compounds such as organic acids, sugars and inorganic constituents. Of the nitrogenous compounds free amino acids predominate the majority of crustaceans. Together with quarternary ammonium bases, free amino acids comprise nearly 90% of the total extractable nitrogen in Molluscan and Crustacean tissues (Konosu and Yamaguchi, 1982).

Free amino acids have been implicated as being responsible for the characteristic flavour of fish and shellfish (Simudu and Hujita, 1954; Hashimoto, 1965). In addition to free amino acids, inorganic ions such as Na^+ and Cl^- have also been found to contribute significantly to the flavour of marine products (Hayashi et al., 1981). In penaeid shrimp free amino acids (Mc Coid et al., 1984) as well as Na^+ and Cl^- (Castille and Lawrence, 1981) have been shown to influence osmoregulation. Since these same compounds impart flavour characteristic of marine food products, manipulation of the flavour intensity in penaeid shrimp may be possible through changes in environmental salinity.

In the present study a significant difference ($P<0.05$) in flavour was observed in the shrimp meat with salinity variations (ANOVA Table 10). The overall taste panel score for flavour of cooked meat of shrimps held at 9.5 $\pm$ 0.5 ppt was better than those grown at lower salinity levels (Table 16). The significant difference in this flavour intensity can possibly be associated with variations in the tissue free amino acid concentration.

Free amino acids were reported to vary with salinity in the muscle and hepatopancreas of Penaeus kerathurus (Richard and Ceccaldi, 1974). Muscle and blood of crabs and lobsters became enriched with free amino acids when the animals transferred from brackishwater to full marine water (Duchateau and Florkin, 1961). Larserre and Gilles (1971) observed an immense decrease in muscle free amino acid content of euryhaline intertidal teleosts Crenimugil labrosus and

Paralichthyes lethostisma upon transfer from seawater to freshwater. A higher amount of free amino acids was observed in P. vannamei held at higher salinities than those held at relatively lower salinities (Papadapoulos and Finne, 1986).

Free amino acids especially glycine have been shown to be a major contributing factor to the sweet taste of shrimp. In taste panel observations in Metapenaeus dobsoni Rangaswamy et al. (1970) found that glycine contributed to the sweet flavour, where as glutamic acid, leucine and proline conferred a general desirable flavour. Konosu et al. (1960) reported a flavour enhancing effect when free amino acids other than histidine in combination with inosinic acid were added to dried bonito tuna preparation. Glycine is responsible for the sweet flavour of fresh shrimp (Simudu and Hujita, 1954; Hashimoto, 1965) where as Histidine contributed to a 'meaty' characteristic flavour (Simudu et al., 1953). However, in the present trial no attempt was made to analyse the variation in individual amino acid composition in the different samples. The general preference stated by the taste panel for samples at 9.5 $\pm$ 0.5 ppt can possibly be due to the increase in their concentration of flavour enhancing amino acids. However, a low score was described for flavour of cooked meat of shrimps held at 14.5 $\pm$ 0.5 ppt (Table 16). It has been observed that although the total free amino acid content increased with increasing salinities, the relative contribution of individual free amino acid to the total amino acid pool was not constant. Molar percentage of glycine and serine/ threonine varied randomly with salinity, with the concentration of arginine and proline inversely related to salinity (Mc Coid et al., 1984). Hence the lower preference by the taste panel for samples at 14.5 $\pm$ 0.5 ppt can be justified on the basis of inference stated by Mc Coid et al. (1984).

Similar observations of variation in flavour intensity in P. vannamei with variation in salinity have been reported by Papadapoulos and Finne (1986). They

observed a significant flavour difference between shrimps held at 10 and 50 ppt and not at 10 and 30 ppt. However, in the present trial, a significant flavour difference was observed between 1.5 $\pm$ 0.5 and 9.5 $\pm$ 0.5 ppt: 9.5 $\pm$ 0.5 and 14.5 $\pm$ 0.5 ppt and 14.5 $\pm$ 0.5 and 19.5 $\pm$ 0.5 ppt (ANOVA Table 10).

The present study throws light on the possibility of the influence of environmental salinity on the flavour of cultured penaeid shrimp. Since free amino acids are major osmoeffectors in shrimps and also primary flavour producers in marine products, "more flavourable" shrimp can be produced by manipulating environmental salinity. Although priority factor in prawn culture is promoting growth and adding to total production, salinity manipulations in order to improve flavour may be done only within permissible limits.

SUMMARY

SUMMARY

The effect of low salinity upon growth and survival of postlarvae/ juveniles of P. monodon (Fabricius) was studied under controlled conditions. Test salinities ranged from 1 to 20 ppt.

6.1. Tolerance Studies

1. Large fluctuations in salinities ranging from 4 to 20 ppt did not influence the survival of postlarvae significantly ($P \leq 0.05$).
2. Postlarvae showed excellent survival for 24 h in salinities ranging from 1 to 20 ppt suggesting a short-term tolerance to a wide range of salinity.
3. Complete mortality of postlarvae at salinity less than 1 ppt within 24 hours regardless of acclimation at 5, 10, 15, 20 or 25 ppt suggested a strong salinity effect.
4. Step-wise acclimation extended the range of postlarval tolerances. Such a gradual change permitted better survival at 'critical levels' of salinity (less than 4 ppt).
5. A probit regression line for the relation between the logarithmic salinity level (dose = X) and mortality (probit response = Y) was determined as $Y = 5.982023 + 1.332194\ X$. The lowest lethal salinity (LC 50) at normal conditions of temperature for the postlarvae was 0.5479 ppt with its upper and lower limit as 0.377 and 0.790 ppt respectively.
6. Postlarvae exhibited abnormal behaviour at salinities less than 1 ppt. Feeding and excretion of faecal matter was low at this salinity. Abnormal swimming behaviour such as jumping out, swimming side-wise, spiral and circular movements was also exihibited
7. A higher rate of cannibalism was observed at suboptimal salinities.

6.2 Growth Studies

8. Within the range of 4 to 20 ppt, salinity had no significant effect ($P \nless 0.05$) on the growth rate of the juveniles. Below 4 ppt salinity, growth rate of the juveniles was retarded ($P < 0.001$).

9. Eventhough postlarvae survived 0.5 to 20 ppt salinities growth was restricted to 4 to 20 ppt range.

6.3 Sensory Evaluation

10. Flavour of cooked meat of shrimps differed significantly ($P < 0.05$) with variation in salinity.

11. Overall taste panel score for flavour of cooked meat of shrimps held at 9.5 ± 0.5 ppt was better than those grown at lower salinity levels.

12. The possibility of the influence of salinity on flavour of cultured shrimps is suggested.

REFERENCES

REFERENCES

Alikunhi, K.H., Budiono, M., Adisukresno, S. and Busman, S. (1975) Preliminary observation on survival, growth and production of Penaeus monodon Fabricius and Penaeus merguiensis De Man in shallow brackishwater ponds. Bull. Shrimp Cult. Res. Cent., 1 (2) : 47-55.

* Aquacop (1977) Reproduction in captivity and growth of Penaeus monodon, Fabricius in Polynesia. Proc. World Maricult. Soc., 8 : 927-945.

* Amant, L.S. St., Broom, J.G. and Ford, T.B. (1965) Studies of the Brown shrimp Penaeus aztecus in Barataria Bay Lousisiana. 1962 - 1965. Proc. Gulf Carib. Fish. Inst., 18 : 1 - 17.

Anonymous (1986) Statistics of Marine Products Exports. Marine Products Exports Development Authority India.

Banerjee, A.C. and Roychoudhury, N.C. (1966) Observations on some physico-chemical features of the Chilka lake. Indian J. Fish., 13 (1 & 2) : 395 - 429.

* Beadle, L.C. (1931) The effect of salinity changes on the water content and respiration of marine invertebrates. J. exp. Biol., 8 : 211 - 227.

Beard, T.W., Wickens, J.F. and Arnstein, D.R. (1977) The breeding and growing of Penaeus merguiensis De Man in laboratory recirculation systems. Aquaculture, 10 (3) : 275 - 289.

Bhattacharya, S.S. and Kewalramani, H.G. (1976) Salinity and temperature tolerance of postlarvae Penaeus indicus. J. Ind. Fish. Assoc., 6 (182) : 105 - 113.

Bishop, J., Gossilink, J. and Stone, J. (1980) Oxygen consumption and haemolymph osmolality of brown shrimp, Penaeus aztecus. Fish. Bull., 78 : 741-757

Borja, P.C. and Rasalan, S.B. (1968) A review of the culture of Sugpo Penaeus monodon Fabricius in the Philippines. F A O Fish. Rep.,57(2) : 111-124.

Bose Victor Chandra, S. and Venkatesan, V. (1982) Prawn and fish seed resources of Marakanam estuary. Proc. Symp. Coastal Aquaculture, 1 : 196-201.

* Broad, A.C. (1962) Environmental requirements of shrimp. 3rd seminar on Biological Problems in Water Pollution, U.S. Public Health Service : I (Abstract).

Castille, F. Jr. and Lawrence, A. (1981) The effect of salinity on the osmotic, sodium and chloride concentrations in the haemolymph of euryhaline shrimp of the genus Penaeus. Comp. Biochem. Physiol.,68A(1) : 75-80.

Cawthorne, D.F., Beard, T., Davenport, J. and Wickens, J.F. (1983) Response of Juvenile Penaeus monodon Fabricius to natural and artificial seawater of low salinity. Aquaculture, 32 : 165 - 174.

Chakraborti, R.K., Bhowmick, M.L. and Halder, D.D. (1985a) Effect of change in salinity on the survival of Penaeus monodon (Fabricius) postlarvae. Indian J. Fish., 33 (4) : 484-487.

Chakraborti, R.K., De, D.K. and Subrahmanyam, M. (1982) Observations on the availability of bagda Penaeus monodon (Fabricius) and chapra P. indicus (H. Milne Edwards) seed in the Hoogly estuary around Nurpur and Uluberia, West Bengal. Sci. & Cult., 48 : 142-144.

Chakraborti, R.K., Halder, D.D., Das, N.K., Mandal, S.K. and Bhowmick, M.L. (1986) Growth of Penaeus monodon Fabricius under different environmental conditions. Aquaculture, 51 (3 & 4) : 189-194.

Chakraborti, R.K., Ravichandran, P., Halder, D.D., Mandal, S.K. and Sanfui, D. (1985b) Some physico-chemical characteristics of Kakdwip brackishwater ponds and their influence on the survival, growth and production of Penaeus monodon (Fabricius). Indian J. Fish., 32 (2) : 224-235.

Chandrasekaran, V.S. and Natarajan, R. (1984) Abundance and distribution of juveniles of penaeid prawns in Pichavaran mangrove, south east coast of India. First International Conference on the Culture of Penaeid/ Shrimps, Iloilo City : 74 (Abstract).

Chen, H.C. (1985) Water quality criteria for farming the grass shrimp Penaeus monodon. Proc. First International Conference on the Culture of Penaeid Prawns/Shrimps, Iloilo City : 165.

Chen, T.P. (1972) Status and problems of coastal aquaculture in Taiwan. In: Coastal Aquaculture in the Indo - Pacific Region. T.V.R. Pillay (Ed) Fishing News Books Ltd., London : 68 - 73.

* Cook, H.L. (1970) Larval culture in Report Bureau Comm. Fish. Bio. Lab. Galveston, Texas. U.S. Cir. Fish. Widl. Serv., 343 : 5 - 6.

Das, N.K., Chakraborti, N.M. and Halder, D.D. (1982) Experiments on mixed prawn farming in brackishwater pond at Kakdwip. Proc. Symp. Coastal Aquaculture, 1 : 129 - 133.

Dehnel, P.A. and Mc Caughran, D.A. (1964) Gill tissue respiration in two species of estuarine crabs. Comp. Biochem. Physiol., 13 : 233 - 259.

Delmendo, M.N. and Rabanal, H.P. (1956) Cultivation of "Sugpo" (Jumbo tiger Shrimp) Penaeus monodon Fabricius in the Philippines. Proc. Indo - Pacific Fish. Coun., 6 (3) : 424 - 431.

* Duchateau - Bosson, Gh. and Florkin, M. (1961) Changes in intra-cellular concentration of free amino acids as a factor of euryhalinity in the cray-fish Astacus astacus. Comp. Biochem. Physiol., 3 : 245 - 249.

* Duodoroff, P.B., Anderson, G., Burdick, G.E., Galtsoff, P.S., Hart, W.B., Patrick, R., Strong, E.R., Strong, E.B., Surben, E.W. and Vanhorn, W.M. (1951) Bioassay methods for the evaluation of acute toxicity of industrial waters to fish. Sewage and Industrial Wastes, 23 : 1380 - 1397.

* Elfringham, S.K. (1965) The respiration of Limnoria (Isopoda) in relation to salinity. J. mar. biol. Ass. U.K., 45 : 145 - 152.

* Equasa, S. (1961) Studies on the respiration of the 'Kuruma' prawn, Penaeus japonicus Bate. II Preliminary experiments on its oxygen consumption. Bull. Jap. Soc. Sci. Fish., 27 : 650 - 659.

Ferraris, R.P., Parado - Estepa, F.D., De Jesus, E.G. and Ladja, J.M. (1987) Osmotic and chloride regulation in the haemolymph of the tiger prawn Penaeus monodon during moulting in various salinities. Mar. Biol., 95 : 377 - 385.

Ferraris, R.P., Parado - Estepa, F.D., Ladja, J.M. and De Jesus, E.G. (1986) Effect of salinity on the osmotic, chloride, total protein and calcium concentrations in the haemolymph of prawn Penaeus monodon (Fabricius). Comp. Biochem. Physiol., 83 A (4) : 701 - 708.

George, M.J. and Suseelan, C. (1982) Distribution of species of prawn in the backwaters and estuaries of India with special reference to coastal aquaculture. Proc. Symp. Coastal Aquaculture, 1 : 273 - 284.

Ghosh, A.N., Das, N.K. and Mazumder, H.S. (1973) Pilot observations on the culture of prawns in brackishwater ponds at Kakdwip, West Bengal. Proc. Seminar on Mariculture and Mechanised Fish. Madras,: 86 - 88.

Gilles, R. (1979) Intracellular organic osmotic effectors . In : Mechanism of Osmoregulation in Animals. John Willey & Sons, New York : 111 - 156.

* Grajcer, D. and Neal, R. (1972) Growth of hatchery reared Penaeus aztecus on experimental diets. Proc. World Maricult. Soc., 3 : 461 - 470.

* Gunter, G. (1950) Seasonal population changes and distribution as related to salinity of certain invertebrates of the Texas coast, including the commercial shrimp. Publ. Inst. Mar. Sci., 1 (2) : 7 - 51.

* Gunter, G., Christmas, J.Y. and Killibrew, R. (1964) Some relations of salinity to population distribution of motile estuarine organisms with special reference to penaeid shrimp. Ecology, 45 : 181 - 185.

Gunter, G. and Hall, G.E. (1963) Biological investigations of the St. Lucie estuary (Florida) in connection with Lake Okeechobee discharges through the St. Lucie canal. Gulf Res. Rep., 1 (5) : 189 - 307.

* Gunter, G. and Shell, W.E. Jr. (1958) A study of an estuarine area with water level control in the Louisiana marsh. Proc. La. Acad. Sci., 21 : 5 -34.

Hag El, E.A. (1984) On the possibility of prawn pond culture in Sudan. First International Conference on Culture of Penaeid Prawns/Shrimps Iloilo City, Paper No. 15 (Abstract).

Hashimoto, Y. (1965) Taste producing substances in marine products. In : The Technology of Fish Utilization. R. Kreuzer (Ed) Fishing News Books Ltd, London, England : p 57.

Hayashi, T., Yamaguchi, K. and Konosu, S. (1981) Sensory analysis of taste active components in the extracts of boiled snow crab meat. J. Food Sci., 46 : 479 - 483.

Hideo Mochizuki, (1979) The present prawn culture in the Philippines. Aquacult. Dept. S.E. Asian Fish. Dev. Centre, Tigbauan, Iloilo City.

* Hoese, H.D. (1960) Juvenile penaeid shrimp in shallow Gulf of Mexico. Ecology, 41 : 592 - 593.

Howe, N., Quast, W. and Cooper, L. (1982) Lethal and sublethal effects of a simulated salt brine effluents on adults and subadults of the shrimps Penaeus setiferus and P. aztecus. Mar. Biol., 68 : 37 - 47.

Jhingran, V.G. (1975) Some aspects of brackishwater aquaculture in India. Bull. Dept. Mar. Sci., Univ. Cochin, 7 (1) : 25 - 29.

* Jhonson, M.C. and Fielding, J.R. (1956) Propogation of the white shrimp Penaeus setiferus (Linn.) in captivity. Tulane Stud. Zool.,4(6) : 175-190.

Karmakar, H.C. (1982) A regression model for the prediction of availability of Penaeus monodon seed. Proc. Symp. Coastal Aquaculture, 1 : 206-210.

* Kinne, O. (1964) The effect of temperature and salinity on marine and brackishwater animals. II. Salinity. Oceanogr. mar. Biol., 2 : 281-339.

Kinne, O. (1971) Salinity. In : Marine Ecology.Kinne, O. (Ed) Willey Interscience, London, New York, Sydney, Toronto, 1 (2) : 683 - 1033.

* Konosu, S., Maeda, Y. and Fujita, T. (1960) Evaluation of Inosinic acid and free amino acid as tasting substances in the Katsuwobushi stock. Bull. Jap. Soc. Sci. Fish., 26 (1) : 45.

Konosu, S. and Yamaguchi, K. (1982) The flavour components of fish and shell fish, In : Chemistry and Biochemistry of Marine Food Products. Avi Publishing Co., Inc., West Port, CT : pp 367.

* Kramer, G.L. (1975) Studies on the lethal dissolved oxygen levels for young brown shrimp, Penaeus aztecus Ives. Proc. World Maricult. Soc., 6 : 157 - 170.

Kubo, I. (1956) A review of the biology and systematics of shrimps and prawns of Japan. Proc. Indo - Pacific Fish. Coun., 6 (3) : 387 - 398.

Kutty, M.N., Murugapoopathy, G. and Krishnan, T.S. (1971) Influence of salinity and temperature on the oxygen consumption in young juveniles of Indian Prawn Penaeus indicus. Mar. Biol., 11 : 125 - 131.

Kuttyamma, V.J. (1982) The effect of salinity on the growth of some penaeid prawns. Bull. Dept. Mar. Sci., Univ. Cochin, 13 (1) : 1 - 34.

Lakshmi, G.J., Venkataramaiah, A. and Gunter, G. (1976) Effect of salinity and photoperiod on the burying behaviour of Brown shrimp Penaeus aztecus Ives. Aquaculture, 8 : 327 - 336.

Lakshmikantham, K.P. (1982) Salinity tolerance of postlarvae of Penaeus indicus H. Milne Edwards. (unpublished thesis) Univ. Cochin.

* Larserre, B. and Gilles, R. (1971) Modification of the amino acid pool in the parietal muscle of the two euryhaline teleosts during osmotic adjustments. Experimentia, 27 : 1434.

Liao, I.C. (1977) A culture study on grass prawn Penaeus monodon in Taiwan, the patterns, the problems and the prospects. J. Fish. Soc. Taiwan, 5 (2) : 143 - 161.

Liao, I.C. and Huang, T.L. (1972) Experiments on the propagation and culture of prawns in Taiwan. In : Coastal Aquaculture in the Indo-Pacific Region, T.V.R. Pillay (Ed) Fishing News Books Ltd., London : 328 - 354.

* Lindner, M.J. and Anderson, W.W. (1956) Growth, migrations, spawning and size distribution of shrimp, Penaeus setiferus. U.S. Fish and Wildl. Serv., Fish. Bull., 56 : 555 - 645.

* Lofts, B. (1956) The effects of salinity changes on the respiratory rate of the prawn Palaemonetes varians (Leach) J. exp. Biol., 33 : 730 - 736.

Mair, J. McD. (1980) Salinity and water type preferences of four species of postlarval shrimp (Penaeus) from West Mexico. J. exp. mar. Biol. Ecol., 45 (1) : 69 - 82.

Mangum, C.P., Silverthorn, S., Harris, J., Towle, D. and Krall, A. (1976) The relationship between blood pH, ammonia excretion and adaptation to low salinity in the blue crab Callinectes sapidus. J. Exp. Zool., 195 : 129 - 136.

* Mangum, C.P. and Towle, D. (1977) Physiological adaptations to unstable environments. Amer. Sci., 65 : 67 - 75.

Manik, R., Adisukresno, S. and Tiensongrusmee, B. (1979) The effect of high salinity on growth and survival of the giant tiger shrimp under cultivation in the earth pond. Bull. Brackishwat. Aquacult. Dev. Cent., 5 (1 & 2) : 351 - 361.

Mantel, L. and Farmer, L. (1983) Osmotic and ionic regulation. In : The Biology of Crustacea. E.B. Dorothy (Ed) Academic Press, New York, 5 : 53-161.

Mc Coid, V., Miget, R. and Finne, G. (1984) Effect of environmental salinity on the free amino acid composition and concentration in penaeid shrimp. J. Food Sci., 49 (2) : 327 - 330.

* Mc Farland, W.N. and Lee, B.D. (1963) Osmotic and ionic concentrations of penaeidean shrimps of the Texas coast. Bull. Mar. Sci. Gulf Caribb., 13 : 391 - 417.

* Mc Farland, W.N. and Pickens, P.E. (1965) The effect of season, temperature and salinity on standard and active oxygen consumption of the grass shrimp Palaemonetes vulgaris (Saiy). Can. J. Zool., 43 : 571 - 858.

Mohamed, K.H. (1973) Penaeid prawn resources of India. Proc. Symp. Living Resources of the Seas Around India, : 548 - 556.

Motoh, H. (1981) Studies on the fisheries biology of the giant tiger prawn Penaeus monodon in Philippines. Tech. Rep. Aquacult. Dept. S.E. Asian Fish.Dev. Centre, (7) : 128.

Nair, S.R.S. and Kutty, M.K. (1975) Notes on the varying effects of salinity on the growth of the juveniles of Penaeus indicus from the Cochin backwaters. Bull. Dept. Mar. Sci., Univ. Cochin, 7 (1) : 181 - 184.

New, M.B. (1976) A review of dietary studies with shrimps and prawns. Aquaculture, 9 (2) : 101 - 144.

Paloheimo, J.E. and Dickie, L.M. (1966a) Food and growth of fishes. II Effect of food and temperature on the relation between metabolism and body weight. J. Fish. Res. Bd. Canada, 23 : 869 - 908.

Paloheimo, J.E. and Dickie, L.M. (1966b) III Relation among food, body size and growth efficiency. J. Fish. Res. Bd. Canada, 23 : 1209 - 1248.

Panikkar, N.K. (1968) Osmotic behaviour of shrimps and prawns in relation to their biology and culture. FAO Fish. Rep., 57 (2) : 527 - 538.

Papadapoulos, L.S. and Finne, G. (1986) Effect of environmental salinity on sensory characteristics of penaeid shrimp. J. Food Sci., 51 (3) : 812 - 814.

Parado-Estepa, F.D., Ferraris, R.P., Ladja, J.M. and De Jesus, E.G. (1987) Response of intermoult Penaeus indicus to large fluctuations in environmental salinity. Aquaculture, 64 : 175 - 184.

* Pearse, A.S. and Gunter, G. (1957) Salinity. Mem. geol. Soc. Am., 67(1) : 129-157.

Racek, A.A. (1956) Penaeid prawn fisheries of Australia with special reference to New South Wales. Proc. Indo - Pacific Fish. Coun., 6 (2 & 3) : 347-359.

* Racek, A.A. (1959) Prawn investigations in Eastern Australia. Res. Bull. State Fish. N.S.W., 6 : 1 - 57.

Raj, P.J.S. (1980) Pulicat lake as a giant pond for prawn culture under rural science and technology. Proc. First Nat. Symp. Shrimp Farming, Bombay : 227 - 229.

Raj, R.P. and Raj, P.J.S. (1982a) Distribution and ecology of postlarvae of the genus Penaeus in the Pulicat lake. Proc. Symp. Coastal Aquaculture, 1 : 415.

Raj, R.P. and Raj, P.J.S. (1982b) Effect of salinity on growth and survival of three species of penaeid prawns. Proc. Symp. Coastal Aquaculture, 1 : 236 - 243.

Rajendran, A.D.I. and Sampath, V. (1975) The prospects of prawn culture in Kovelong backwaters of Tamil Nadu coast. Bull. Dept. Mar. Sci., Univ. Cochin, 7 (3) : 487 - 501.

Rajyalakshmi, T. (1982) Some aspects of prawn culture with particular reference to tiger prawn Penaeus monodon Fabricius. Proc. Symp. Coastal Aquaculture, 1 : 63 - 70.

Rajyalakshmi, T., Pillai, S.M. and Ravindran, P. (1985) The biology of Penaeus monodon off Orissa coast, India in the context of occurence of natural broodstock. Proc. First International Conference on the Culture of Penaeid Prawns/Shrimps, Iloilo City : 175.

Ramaswamy, A. and Pandian, P. Al. (1985a) Recruitment of postlarval penaeid prawns in the Vellar estuary, South India. Proc. First International Conference on Culture of Penaeid Prawns/Shrimps, Iloilo City : 177.

Ramaswamy, A. and Pandian, P. Al. (1985b) Environmental physiology of the prawn Penaeus (Melicertus) latisulcatus. Proc. First International Conference on Culture of Penaeid Prawns/Shrimps, Iloilo City : 177.

* Rangaswamy, J.R., and Lahiry, N.L. (1970) Free amino acid pattern in Indian shrimp (Metapenaeus dobsoni) J. Agric. Food Chem., 18 : 298.

Rao, A.V.P. (1967) Some observations on the biology of Penaeus indicus H. Milne Edwards and Penaeus monodon Fabricius from the Chilka lake. Indian J. Fish., 14 (1 & 2) : 251 - 270.

Rao, K.J. and Gopalakrishnayya, C.H. (1974) Penaeid prawn catches from Pulicat lake in relation to ingress of postlarvae and lake hydrography. Indian J. Fish., 21 (1) : 445 - 453.

Reyes, E.P. (1985) Effect of temperature and salinity on the hatching of eggs and larval development of Sugpo, Penaeus monodon. Proc. First International Conference on Culture of Penaeid Prawns/Shrimps, Iloilo City : 177.

* Richard, P. and Ceccaldi, H.J. (1974) Variation in free amino acid in the muscle and hepatopancreas of Penaeus kerathurus (Forskal) in relation to diluted seawater. 9th Europ. Mar. Biol. Symp. Oban U.K.

Sebastian, M.J., Thampy, D.M. and Rajendran, C.G. (1980) Preliminary experiments in tiger prawn culture and a report on seed prospecting of penaeid prawns in Kerala backwaters. Proc. First Nat. Symp. Shrimp Farming, Bombay : 205 - 208.

Sidney Siegel (1956) Non-Parametric Statistics for Behavioural Sciences. International Student Edition Mc Graw Hill, Kogakusha Ltd., pp 365.

Silas, E.G. (1980) Status of prawn culture in India and strategy for its future development. Proc. First Nat. Symp. Shrimp Farming, Bombay : 209 - 218.

* Simmons, M.A. and Knight, A.W. (1975) Respiratory response of Neomysis intermedia (Crustacea : Mysidaceae) to changes in salinity, temperature and season. Comp. Biochem. Physiol., 50 (A) : 181 - 193.

* Simudu, W., Hibiki, S., Sibata, S. and Takeda, K. (1953) Studies on muscle of aquatic animals. XVI: Distribution of extractive nitrogen in muscle of several kinds of Gastropods. Bull. Jap. Soc. Sci. Fish, 19 : 871.

* Simudu, W. and Hujita, M. (1954) Studies on muscle of aquatic animals. XVII : On glycine content in extractive of shrimp with special reference to their taste. Bull. Jap. Soc. Sci. Fish., 20 (8) : 720.

Snedecor, W.G.and Cochran, W.G. (1967) Statistical Methods. Oxford 8 IBH Publishing Co. pp 593.

Strickland, J.O.H. and Parsons, T.R. (1968) A. Practical Handbook of Seawater Analysis. Fish. Res. Bd. Canada, 167 : 310.

Subrahmanyam, M. (1973) Experimental studies on growth in Penaeus monodon (Fabricius) Proc. Seminar on Mariculture and Mechanised Fish., Madras : 70 - 73.

Subrahmanyam, M. and Ganapati, P.N. (1975) The biology of the prawn Penaeus monodon Fabricius from the Godavari estuarine system. Bull. Dept. Mar. Sci., Univ. Cochin, 7 (3) : 653 - 670.

Subrahmanyam, M. and Rao, K.J. (1968) Observation on the postlarvae prawns (Penaeidea) in the Pulicat lake with notes on their utilization in capture and culture fisheries. Proc. Indo. Pacific Fish. Coun., 13 (2) : 113 - 127.

Sundararajan, D., Bose, V.S. and Venkatesan, V. (1979) Monoculture of tiger prawn Penaeus monodon Fabricius in a brackishwater pond at Madras. Aquaculture, 16 (1) : 73 - 75.

Swaminathan, M.S. (1980) Shrimp farming - A new dimension to the scientific utilisation of our aquatic wealth. Proc. First Nat. Symp. Shrimp Farming, Bombay : 1 - 10.

* Tabb, D.C., Dubrow, D.L. and Manning, R.B. (1962) The ecology of northern Florida Bay and adjacent estuaries. Tech. Ser. Fla. Board Conserv., 39 : 1 - 79.

Takeo Imai (1977) Biological research on prawns - Tolerance to salinity. In : Aquaculture In Shallow Seas : Progress in Shallow Sea Culture. Oxford & IBH Publishing Co: 453.

Thampy, D.M., Sebastian, M.J., Suseela Abraham and Rajendran, C.G. (1982) Relative abundance and distribution of postlarvae and juveniles of Penaeus monodon Fabricius in the Cochin backwaters and the prospects of the utilisation in culture fisheries. Proc. Symp. Coastal Aquaculture, 1 : 238 - 228.

Vasudevan, S. and Subramoniam, T. (1985) Seasonal abundance of penaeid prawn seed in Ennore estuary Madras in relation to hydrography and lunar phase. Proc. First International Conference on the Culture of Penaeid Prawns/Shrimps, Iloilo City : 175.

Venkataramaiah, A., Lakshmi, G.J. and Gunter, G. (1975) A review of the effects of some environmental and nutritional factors on brown shrimp, Penaeus aztecus Ives in laboratory culture. Proc. 10th Europ. Symp. Mar. Biol., Ostend, Belgium, 1 : 523 - 542.

Venkatesan, V. and Joshua, K. (1984) Observations on the growth, survival and production of tiger prawn Penaeus monodon Fabricius in freshwater ponds with saline soil. First International Conference on Culture of Penaeid Prawns/Shrimps, Iloilo City : 104 (Abstract).

Verghese, P.U., Ghosh, A.N. and Das, P.B. (1975) On growth, survival and production of Jumbo Tiger Prawn Penaeus monodon (Fabricius) in brackishwater ponds. Bull. Dept. Mar. Sci., Univ. Cochin, 7 (4) : 781 - 789.

* Verghese, P.U., Hardial Singh., Karmakar, H.C. and Ravichandran, P. (1979) Abundance of tiger prawn Penaeus monodon Fabricius in Muriganga estuary at Kakdwip, West Bengal. Proc. 66th Ind. Sci. Cong., : 247 (Abstract).

Verghese, P.U., Ravichandran, P. and Pillai, S.M. (1982) Growth and production of Penaeus monodon Fabricius in short term field rearing experiments. Proc. Symp.Coastal Aquaculture, 1 : (Abstract).

* Villadolid, D.V. and Villaluz, D.K. (1950) The cultivation of Sugpo (Penaeus monodon Fabricius) in the Philippines. Philipp. J. Fish., 1 (1) : 55-65.

Warren,C.E. and Davis, G.E. (1967) Laboratory studies on the feeding bioenergetics and growth of fish. In : The Biological Basis of Freshwater Fish Production. S.D. Gerking (Ed) London : Blackwell scientific Publication : 175 - 214.

Webb, P.W. (1978) Partitioning of energy into metabolism and growth. In : Ecology of Freshwater Fish Production. S.D. Gerking (Ed) London : Blackwell scientific Publications : 184 - 214.

* Wengert, M.W. Jr. (1972) Dynamics of the brown shrimp Penaeus aztecus Ives. 1891, in the estuarine area of Marsh Island, Louisiana in 1971. M.S. Thesis, Louisiana State Univ., Baton Rouge, Louisiana, U.S.A. 94pp.

* Williams, A.B. (1955) A contribution to the life histories of commercial shrimp (Penaeidea) in North Carolina. Bull. Mar. Sci. Gulf Caribb., : 116-146.

Williams, A.B. (1960) The influence of temperature on osmotic regulation in two species of estuary shrimps (Penaeus spp.) Biol. Bull. mar. biol. Lab., Woods Hole, 119 (3) : 560 - 571.

Zein - Eldin, Z.P. (1963) Effect of salinity on growth of postlarvae penaeid shrimp. Biol. Bull. mar. biol. Lab., Woods Hole, 125 (1) : 188 - 196.

Zein - Eldin, Z.P. and Aldrich, D.V. (1965) Growth and survival of postlarvae of of Penaeus aztecus under controlled codtions of temperature and salinity. Biol. Bull. mar. biol. Lab., Woods Hole, 129 (1) : 199 - 216.

ABSTRACT

Growth and survival of P. monodon are influenced by a number of ecological factors (Chakraborti et al., 1986) salinity being one of the most important of them. Knowledge on the tolerance of this species to low salinity conditions has great implications in its culture especially in extending its culture to low saline fields.

In the present study, the postlarvae were subjected to wide fluctuations in salinity ranging from 1 to 20 ppt. The influence of gradual acclimation in improving ranges of tolerance of postlarvae was studied. The lowest lethal salinity (LC 50) was determined by step-wise reduction of salinity. Salinity in which more than 50% mortality occured at the end of 120 h was considered lethal. Growth of juveniles in different test salinities ranging from 1 to 20 ppt for a period of 56 days was undertaken.

Preliminary tolerance studies indicated that fluctuations in salinity ranging from 4 to 20 ppt did not influence the survival of postlarvae significantly ($P > 0.05$). Gradual acclimation extended the range of tolerance. A probit regression line for the relation between the logarithmic salinity level (dose=X) and mortality (probit response=Y) was found to be $Y=5.982023+1.332194X$. The lowest lethal salinity (LC 50) was 0.5479 ppt with its upper and lower limits being 0.377 and 0.790 ppt respectively. Postlarvae exhibited abnormal behaviour and higher rate of cannibalism at suboptimal salinities.

Low salinities had a highly significant influence on the growth of juveniles ($P < 0.001$). However, mean values of growth rate between 4 and 15 ppt did not differ significantly ($P > 0.05$) from the control (19.5±0.5 ppt).

Shrimps reared in different test salinities were subjected to sensory evaluation. Flavour of cooked meat of shrimps differed significantly with variation in salinities ($P \leq 0.05$). The overall taste panel score was highest at 9.5 $\pm$ 0.5 ppt. The possibility of the influence of salinity on flavour of cultured shrimps is suggested.