EFFECT OF SALINITY ON FOOD INTAKE, CONVERSION EFFICIENCY AND GROWTH OF THE PRAWN METAPENAEUS MONOCEROS (FABRICIUS)

By

SURESH BABU C.

THESIS

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TO

MY PARENTS

AND BROTHERS

DECLARATION

I hereby declare that this thesis entitled "EFFECT OF SALINITY ON FOOD INTAKE, CONVERSION EFFICIENCY AND GROWTH OF THE PRAWN METAPENAEUS MONOCEROS (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.

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(Dr. D.M.THAMPY)
(Chairman, Advisory Board)
Professor and Head, Department of Aquaculture.

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I INTRODUCTION

I. INTRODUCTION

Prawn culture has shown tremendous development in the last two decades resulting in its becoming a new industry for both developed and developing countries. It is now practised extensively along the coasts of the Indo-Pacific region. The development of technology for the commercial culture of penaeid prawns has been rather slow, with most of the initial work being done in Japan. In recent years there is an increased tempo of development in the prawn farming sector, as a result of which new species and new areas are brought under culture. While the rate of growth in the capture fisheries sector between the years 1984 and 1987 was only 9 per cent, in the culture sector the growth rates were 25 and 27 per cent in 1987 and 1988 respectively (Ferdouse,1990). Of the total estimated world aquacultural production of 13.2 million tonnes in 1988 (Anon, 1990), prawns formed 0.56 million tonnes.

As an item of export, prawns have a prominent place in the world market, because of their limited supply. In India, prawn forms the major export item among the marine products and India had the distinction of being the world's largest prawn producing and exporting country until 1987.

Besides the overseas market potential, recent trends show a conspicuous rise in the domestic consumption of prawn in the country, which increased to 1,13,800 tonnes in 1987, from a mere 68,700 tonnes in 1967 (Ferdouse, 1990). Landings from the capture fisheries no longer seems capable of meeting these increasing demands for prawns, as the inshore waters are more or less fully exploited. This calls for enhancing prawn production through aquaculture.

Prawn culture is now gaining much importance in India. India's modest contribution of 23,500 tonnes towards the world production of cultured prawns in 1988 formed only 4.5 per cent, while the Asian countries together produced 85.2 per cent (Ferdouse, 1990). Although prawn farming is expanding in the country, the growth rate is significantly slow compared to most other Asian counterparts. Since we have vast areas at our disposal to be used for prawn farming, this lagging behind is not justifiable.

The existing prawn culture technology in India is extensive in nature because of the simple technology and low capital investments involved (Ferdouse,1990). Hitherto most of the farmers were to depend on wild seed stock, as the hatchery production of prawn seed was in its early stages of development. Now a few hatcheries have been set up for production of post-larvae of prawns such as *Penaeus monodon* and *P. indicus*. However, the adoption of high density intensive farming and the expansion of area under prawn culture leave the hatchery production of seed far below the requirement. The natural collection of seed could thus help in making available the seed for culture. Moreover, labour intensive development is of paramount importance to a developing country like India. In this context utilisation of the naturally available prawn seeds assume importance.

Penaeids of commercial significance in India include nearly a dozen species, the most important of which are *P. monodon*, *P. indicus*, *Metapenaeus monoceros*, *M. dobsoni*, *M. affinis*, *M. brevicornis* and *Parapenaeopsis stylifera* (George, 1968). The ability of the larvae and juveniles of these prawns (except that of *P. stylifera*) to adjust to the changes in salinity and temperature, and the naturally evolved life-history of most of these, which is preadapted to a juvenile growth phase in the low saline estuarine areas, make them ideally suited for cultivation in impounded waters (Rao, 1973). Once there arises a need of considering these species for commercial farming, the less dominant ones (species other than P. indicus and P.monodon) will be handicapped with lack of sufficient scientific information on their environmental and nutritional requirements.

Of the different cultivable varieties of prawns available in India, M. monoceros occurs in almost all backwaters and estuaries along the coasts of India and their juveniles contribute to a fishery in these waters (George, 1969; 1974; Achuthankutty and Nair, 1980). The species is able to tolerate wide fluctuations in salinity, feeds on different types of animal and vegetable matter and grows well in brackishwater ponds; sometimes in freshwater ponds also (Gopalakrishnan, 1973). The euryhaline habit and natural seed availability have contributed to its inclusion as a candidate species for aquaculture along with other dominant species of culturable prawns (Rao, 1973; Royan et al., 1977). M. monoceros is cultivated in Taiwan , the Philippines, Indonesia, Thailand, India and Pakistan (Gopalakrishnan, 1973). Chen (1976) and Tang (1986) have given accounts of the use of this species for culture in Taiwan both in monoculture and polyculture systems. In these regions this prawn is reported to have gained popularity as a table item, which could be produced at a much lesser cost. There is further scope for the development of its culture in the south and south-east Asian countries, especially in India.

Any attempt to culture an organism should be preceded by a detailed study of its biology, especially of its optimal environmental requirements. Brackishwater organisms are generally endowed with wide range of adaptability to withstand extreme fluctuations in physical conditions. Salinity perhaps, more than any other, is the single factor which characterises the brackishwater environment (George, 1968). Hence the implications of an animals salinity requirements to its relative suitability for intensive or extensive culture are obvious.

In most of the prawn culture operations carried out in India, supplementary feeding is not being resorted (Kurian, 1982). Qasim (1975) commented that the present yield of 500-1500 kg/ha/year from the extensive culture operations can be improved to 2500 kg/ha/year by giving artificial supplementary feeds. Hence it is highly desirable to develop cheaper and efficient prawn feeds so as to increase prawn production and to make prawn culture a profitable venture. Salinity is a factor that is known to influence the efficiency of a species to utilise the food given. As such it is necessary to understand the extent of influence of salinity on the feed utilisation by the cultured organism. It is more significant, because feeds comprise one of the largest items in the recurring expenditure of a prawn farm.

Most of the studies so far made on the prawn M.monoceros form only part of a general investigation on the biology of the species related to the fishery supported by them. But owing to its commercial importance and mounting aquacultural significance, there arises a need for more accurately defining its environmental requirements necessary for yielding optimum growth and food conversion efficiency.

Evaluating the responses of this species to fluctuations in salinity will provide valuable information of its environmental limitations, while utilising for aquacultural purpose. The present study is aimed at finding the effect of salinity on survival, food intake, growth and conversion efficiency of the prawn M. monoceros.

II REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

2.1 Distribution and Life-history

The prawn Metapenaeus monoceros has a wide distribution extending from South Africa through Mediterranean and Indian seas to Malaysia with Malacca strait as the eastern limit (Holthuis, 1980). But an earlier report by Ota (1949) had indicated its occurrence further east, in the inland bays on the western part of Japan. This species occurs all along the Indian coasts with the juveniles forming fishery of some significance in most of the estuaries on the west coast (Achuthankutty et al., 1977; George and Goswami, 1977; Kuttyamma, 1980 a; Achuthankutty and Nair, 1982; Trivedi et al., 1982; Suseelan and Kathirvel, 1983) as well as on the east coast (Subrahmanyam and Ganapati, 1971; Subrahmanyam, 1973; Evangeline et al., 1973; Suseelan, 1975; Lalithadevi, 1989). An account of the distribution of M. monoceros in the brackishwater environments of the maritime states of India has been given by George and Suseelan (1982). It is reported to occur throughout the year in the Ashtamudi lake, Cochin backwaters and the Korapuzha estuary in Kerala; Nethravathy and Aghanashini estuaries in Karnataka; the creeks of Bombay area in Maharashtra;

Narmada and Tapti estuaries in Gujarat; Manakkudy estuary, Malattar estuary, Killai backwaters, Kovelong backwaters and Pulicat lake in Tamilnadu, Godavari and Konada estuaries in Andhrapradesh and in the Chilka lake in Orissa. Besides, this species occurs occasionally in the Zuari and Mandovi estuaries in Goa; Rann of Kutch and the creeks in Gujarat and in the Hooghly Matlah estuarine system in West Bengal.

Life–histories of the members of the family penaeidae, in which family the majority of the important commercial prawns of tropical and subtropical waters are included, are broadly similar (Dall, 1981). The highly fecund females liberate the fertilised eggs demersally in offshore continental shelf waters. After about 1-2 weeks of larval existence, the post-larvae settle in shallow inshore waters, open estuaries or in some cases penetrate considerable distances up river systems to regions of very low salinity. As growth progresses the juvenile prawns tend to move into deeper waters and sexual maturity is usually attained in waters of oceanic salinity (Dall, 1981). However Panikkar and Iyer (1939); Dakin (1946); Muriel and Bennet (1952) and Gnanamuthu (1966) suggested the possibility of the prawn _M_. _monoceros_ breeding in coastal lakes. But later studies have indicated that it does not breed in brackishwaters (George, 1959;

Bishara, 1976). This prawn has been reported to breed in the sea throughout the year with two peaks, one from June to August and the other from October to December (George, 1962). The early larval history of the prawn is passed in inshore waters and at the late mysis stage, when about 3.0 mm in length, it enters estuarine areas and soon settles to the bottom. The size of M. monoceros caught from Cochin backwater ranges from 10 to 102 mm (George, 1962). It is known to occur as juveniles in most of the estuaries and backwaters of India with muddy bottom along the coastline and adults in the sea upto 50-60 m depth (George, 1969). George and George (1964) located a possible spawning area for this species off Cochin in the 50-60 m depth zone.

The movement of M. monoceros back to the sea has been reported to commence after it attains a length of about 100 mm in the estuarine environments in less than one year's time (George, 1959; 1969; Bishara, 1976). Mohamed and Rao (1971) reported that the minimum period of stay in the backwater and the size when they leave this ecosystem are 10 months and 85 mm respectively. Subrahmanyam (1973) while studying the fishery and biology of this species from the Godavari estuarine system observed that the prawn leaves estuary when it attains 45-50 mm in length.

Studies on the maturation and spawning of *M. monoceros* showed that the length at sexual maturity differs between the sexes and are reported as 24 mm CL in males and 26 mm CL in females (Ikematsu, 1959). The minimum size at first maturity of this species in Cochin region is reported to be 120 mm (George, 1969) and 118 mm (Nalini, 1976). The maximum size attained by *M. monoceros* is 180 mm (George, 1959). Fecundity varies between 1,55,000 at 146 mm and 3,38,000 at 175 mm (Nalini, 1976).

Raje and Ranade (1972) have given an account of the larval development of *M. monoceros* and this species has been successfully reared from egg to the post-larval stage in laboratory (Funada, 1966; Mohamed *et al*., 1978)

2.2 Food and Feeding

Penaeid prawns are omnivorous in their feeding habit and their gut contents largely include detritus of plant and animal origin (Panikkar and Menon, 1956). Laboratory experiments have shown that *M. monoceros* prefers muddy substratum and in nature also the species is abundant in such areas (Williams, 1958). Williams (1958) had pointed out that the abundance of organic detritus in such areas, which is the major constituent in the diet of the prawn, may be one of the reasons for such preference. Tiews *et al*. (1972) noticed slight regional and seasonal variations in kind and quality of the food consumed by *M. monoceros* and suggested that the diet composition is related to the availability of the food item within the selective feeding. Besides organic detritus, plant matter, small crustaceans and foraminiferan shells formed the main diet of *M. monoceros* in the Gautami estuary (Subrahmanyam, 1973). George (1974) suggested existence of food preferences to some extent in this species as there is selective feeding in different size groups. He observed that juveniles in the size range of 15-50 mm consume large quantities of detritus and in guts of specimens larger than 50 mm, detritus was found in lesser proportions.

Various workers have conducted feeding experiments with *M. monoceros* using natural food (detritus) and processed and compounded diets (Qasim and Easterson, 1974; Royan *et al*., 1977; Alfred *et al*., 1978; Sumitra-Vijayaraghavan *et al*., 1978; 1981). Attempts were also made by feeding *M. monoceros* with mangrove leaves (Ramadhas and Sumitra-Vijayaraghavan, 1979) and mangrove leaves at different stages of decomposition in combination with rice bran (Sumitra-Vijayaraghavan and Ramadhas, 1980), to find out the efficiency of energy utilization in this prawn. Maximum conversion efficiency was obtained in the prawns fed with completely decomposed mangrove leaves (Sumitra-Vijayaraghavan and Ramadhas, 1980).

Qasim and Easterson (1974) recorded high gross food conversion and assimilation efficiency when these prawns were fed with the estuarine detritus. Although in nature this prawn could survive well on low protein and low caloric diet such as detritus, Royan et al. (1977) pointed out that its growth can considerably be enhanced by compounded feeds especially where the protein level is about 60%. In support of this observation Alfred et al. (1978) obtained high assimilation but low conversion when compounded feeds of low protein and high carbohydrate content were fed to M. monoceros. Ramadhas and Sumitra-Vijayaraghavan (1979) found that the test diets prepared with mangrove leaves having a protein content of 8-18 per cent gave poor conversion efficiency. Kanazawa et al. (1981) reported that this species gives best growth with a diet containing 55 per cent casein.

Sumitra-Vijayaraghavan et al. (1978) observed that this prawn is able to convert maximum of the food into body tissue when it was fed with adult brine shrimp, detritus and trash fish among the different diets tested. Slaughter house waste was found as an efficient feed for this prawn by Sumitra-Vijayaraghavan *et al*. (1981). It is reported that in Taiwan, the sand shrimp *M. monoceros* in monoculture conditions are given animal protein feeds such as clam meat, trash fish and ground small shrimp together with feeds of plant origin such as peanut and soybean meal (Chen, 1976).

It is an established fact that a precise knowledge of the relationship between food requirement and body weight for a particular species and diet would be essential to avoid both over feeding and restricted growth through sub-maximum rations (Sedgwick, 1979). Sumitra-Vijayaraghavan *et al*. (1982) reported that *M. monoceros* showed 100 per cent survival at 7 per cent feeding level and above, whereas total mortality of the starved prawns was observed around 12th day. They recorded decrease in the final body weights when the prawns received a feeding level less than 7 per cent.

2.3 Growth

It was reported by Srivastava (1953) that *M. monoceros* attains a length of 102 mm in five months in the Gulf of Kutch area. A growth rate of 5 mm per month was worked out in the Cochin backwaters (George, 1959; Menon and Raman, 1961). George (1959) observed a higher growth rate of 7.98 mm per month in the lower size ranges of 3.0 to 60.0 mm. From the size frequency distribution of the juveniles in the Cochin backwaters, the growth rate of 6.72 mm per month was worked out compared to 9.88 mm per month in *M. dobsoni* (Mohamed and Rao, 1971). Preliminary observations made by Subrahmanyam and Ganapati (1971) on the rate of growth of the post-larval forms under laboratory conditions, showed that in the case of *M. monoceros* the average growth rate is 16 mm per month upto 30 mm; 22.8 mm per month between 30 and 60 mm and 4.5 mm per month between 60 and 99 mm. Rao (1972) found the average growth rate of this species as 0.325 mm per day in the size group 3.0 to 18.0 mm, while studying the larval growth of *M. monoceros* in laboratory. Subrahmanyam (1973) found that under laboratory conditions the average growth rate to be of 13 mm per month, while the estimated growth rate from size frequency distribution (Gautami estuary) ranged between 5 and 15 mm per month. In culture experiments conducted in the paddy fields adjoining the backwaters of Cochin, George (1975) recorded average growth rates of 0.47 mm per day in the case of *M. monoceros* in comparison to 0.35 mm for *M. dobsoni*, 0.38 mm for *M. affinis* and 0.49 mm for *Penaeus indicus.*

Chen (1976) reported that in culture ponds of Taiwan, the sand shrimp *M. monoceros* reaches marketable size of 5 to 10 g in about 50 days. The stocking density used there, ranges between 2,00,000 and 3,00,000 per hectare in monoculture situations and 60,000 and 1,00,000 per hectare when cultured with the milk fish (Chen, 1976).

2.4 Effect of Salinity on Survival, Osmoregulation, Food intake, Growth and Conversion efficiency

According to Kinne (1971) salinity is one of the cardinal factors regulating the regional and geographical dispersal, species composition as well as the physiological activities of aquatic organisms. It is particularly relevant in the case of most of the commercially important penaeid prawns, in which the adults spawn offshore, in high salinity water, the young ones immigrate into bays and estuaries of moderate to low salinity for a period of rapid growth and then emigrate to the offshore areas (Hysmith and Colura, 1976).

Depending on the species, the time taken between hatching in the offshore waters and entry as post-larvae into the brackishwaters, varies among penaeids (George, 1968). Here salinity fluctuates greatly and the ability of the prawn to adapt to a constantly changing salinity is considered as a key factor determining survival (Ferraris et al., 1987).

The low saline conditions prevailing in the estuaries have been attributed to be primarily responsible for the entry of post-larval penaeids into the estuarine habitat (Gunter, 1950; Pearse and Gunter, 1957; Gunter, 1961; 1967; Achuthankutty and Nair, 1983), as this is reported to augment their growth by efficient conversion of food (Venkataramiah et al., 1972; Nair and Kutty, 1975). But there are results which point out that salinity alone in estuary may not form a decisive factor in their immigration and growth (Hoese, 1960; Broad, 1962; Achuthankutty, 1988). In the Australian estuaries, post-larval abundance of some species of penaeid prawns occur in wide salinity ranges and at times in very high salinity also (Young, 1978; Staples, 1979).

Salinity is considered as the most potent physical factor affecting life in tropical waters. Salinities in the backwaters of Cochin are found to vary from nearly 1.0 to 35.0 ppt during the course of an year (George _et al_., 1968).

2.4.1. Influence of Salinity on Survival.

Metapenaeids are considered to be much tolerant to variations in salinity. Panikkar and Menon (1956) remarked that among the penaeids, the most tolerant one to changes in salinity is _M. monoceros_ which occurs in seawater, brackishwater and in water that is nearly fresh.

Mortality in extreme low or high salinities appears to be primarily related to (i) critical disturbances in the overall water and mineral balance; (ii) direct osmotic damage of protein structure, cells and tissues; (iii) direct damage through significant deviation in relative proportion of solute and (iv) indirect damage caused by critical lowering of metabolic rate or activity or by disharmonising effects on the integrated methodology (Kinne, 1966).

Salinity tolerance studies by Kuttyamma (1980 b) have revealed that _M. monoceros_ together with _M. dobsoni_ and _P. indicus_ survive well in salinities 3 to 43 ppt and pointed out that there is not much significant difference in their tolerance capacity. According to George and Suseelan (1982), among the eight species of penaeid prawns commonly occurring in the Cochin backwaters, _P. indicus_, _P. monodon_, _M. monoceros_ and _M. dobsoni_ are the most tolerant to low salinity conditions thriving well in salinities below 5 ppt.

Weymouth _et al._ (1933) were the first to state the correlation between salinity and size of the organism in clear terms. Lindner and Anderson (1956) stated that correlations of the size of shrimp with a given salinity do not exist within certain wide ranges. According to Gunter (1961) the prawns which each year undergo large cyclic changes of salinity in connection with their life-histories, have developed physiological adjustments in response to the large osmotic and ionic changes involved. He suggested that the correlation is not with a given salinity but rather with the gradient as a whole.

Mc Farland and Lee (1963) demonstrated that the adults of the brown shrimp _Penaeus aztecus_ as better osmoregulators at higher salinity than at lower, with a greater tendency to isosmoticity when the external medium is below 18 ppt. Adults of the euryhaline species M. monoceros and M. bennettae have even better osmoregulatory abilities that P. setiferus and P. aztecus (Panikkar and Viswanathan, 1948; Dall, 1964). In contrast to the finding of Venkataramiah et al. (1974) that sensitivity to elevated salinity with increasing size in smaller juveniles of P.aztecus, there was no evidence of increasing sensitivity with increasing size in adults and sub adults of either P. setiferus or P. aztecus (Howe et al., 1982). Dall (1981) observed that there exists little difference in the osmoregulatory efficiency between juvenile and adult M. bennettae. Eventhough all stages of this species can tolerate salinities ranging from almost fresh to seawater, the post-larvae and juveniles are most abundant in localities with lowered salinities (Aziz and Greenwood 1981).

Generally the body size influences the osmoregulatory ability of many prawns such that improved regulation is shown by juveniles compared to adults (Gunter et al., 1964; Panikkar, 1968; Haefner, 1969; Castille and Lawrence, 1981 b; Kirkpatrick and Jones, 1985). Dall (1981) and Campbell and Jones (1989) are of the opinion that the adaptive nature of the size effect may be explained by different ontogenic habitat requirements of the species in question.

According to Kinne (1964) salinity tolerance of an organism generally depends on the salinity to which it is preacclimated. He reported that acclimation to low salinities tends to shift the lower lethal limit downwards and acclimation to higher salinities tends to shift upper limit upwards. This generalisation is found to be partially in agreement with the finding of Kuttyamma (1980 b) in the case of *M. monoceros* and *M. dobsoni*. Of the three salinity levels to which *M. monoceros* was acclimated, namely, 5, 15 and 30 ppt, she found that acclimation at 30 ppt only could help in shifting the upper lethal limit upwards and there was no difference in the lethal limit between those acclimated at 5 and 15 ppt. Aziz and Greenwood (1981) reported that juveniles of *M. bennettae* are able to tolerate salinities from 1.0 to 62.0 ppt and temperatures from 8.1 to 32.9°C irrespective of the salinity and temperature acclimation levels.

2.4.2. Influence of Salinity on Osmoregulation.

Among the penaeid prawns, *M. monoceros* is a species that has been extensively studied for its active regulation of chloride and osmotic behaviour by various authors (Panikkar, 1948; Panikkar and Viswanathan, 1948; Rao, 1958; Gnanamuthu, 1966).

Panikkar (1948) studied this prawn in comparison with other penaeids and found that it can survive the highest salinity ranges both low and high. Hypo-osmotic regulation has been established in M. monoceros (Panikkar and Viswanathan, 1948) and in a number of other penaeids in India (Panikkar, 1950) besides in P. aztecus and P. duorarum (Williams, 1960). Panikkar and Viswanathan (1948) have found that M. monoceros maintains the sodium chloride of the blood very close to the same value while the salinity fluctuates from 6 to 30 ppt.

Comparing two natural populations of the prawn M. monoceros in media of different salinities, Rao (1958) suggested that the pattern of response to osmotic stress in the oxygen consumption of this prawn depends on the salinity of the medium to which the animal is naturally adapted. Thus the prawns from the brackishwater habitat had a minimal rate of respiration in 50 per cent seawater, with increase in higher and lower salinities. On the other hand , the same species from the marine habitat showed the minimal rate in seawater. Gnanamuthu (1966) was of the opinion that the decrease of body volume in M. monoceros acclimated to dilute medium and the increase of body volume in concentrated medium, as well as the fluctuations in volume of prawn acclimated to anisosmotic media are features associated with the part played by fluid pressure in active regulation of water across the gut wall .

Tachycardia in response to salinity change is well documented in crustaceans (Spaargaren, 1973; 1974; DeFur and Mangum, 1979; Howe *et al.*, 1982). Dhage and Karunakaran (1976) reported variations in the heart beat of the prawn *M. monoceros* with reference to the changes in salinity, temperature and size. But studies on crustacean osmoregulation have dealt primarily with salinity effects on the osmotic and ionic properties of the hemolymph (Mantel and Farmer, 1983). In penaeids these responses by the hemolymph generally consist of hyper regulation in low salinities, and hypo regulation or conformity in higher salinities (Castille and Lawrence, 1981 a; Dall, 1981; Dall and Smith, 1981; Ferraris *et al.*, 1986). Changes in water and ion concentration 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.*, 1987). Cell volume during hyper saline stress is regulated by an increase in intracellular free aminoacids, resulting in a decrease in ammonia excretion, indicating the greater use of endogenous ammonia to synthesise aminoacids (Mangum and Towle, 1977; Gilles, 1979).

The salinity at which hemolymph osmolality becomes isosmotic with the external medium (isosmotic point) is often taken as a useful indicator of the adaptation of the osmoregulatory process of a species to its environment (Campbell and Jones, 1989). Crustaceans experience least osmotic stress and undergo best growth when placed in waters of isosmotic salinity (Panikkar, 1968).

There is a general lowering of the isosmotic point with life away from seawater and this is believed to be an essential adaptation to life in dilute saline conditions; since it results in reduction of the osmotic gradients across an animal and hence a decrease in osmotic work (Dorgelo, 1981). Most marine prawns are isosmotic around 35 ppt (Spaargaren, 1971; 1972); estuarine species between 21 and 27 ppt (Hagerman, 1971; Hagerman and Uglow, 1983) and fresh water species between 15 and 18 ppt (Denne, 1968; Moriera et al., 1983). But exception to this general pattern includes marine palaemonids which have isosmotic points below that of seawater (Kirkpatrick and Jones, 1985). However Campbell and Jones (1989) reported that the isosmotic point of a species is not necessarily fixed.

Isosmotic point expressed as percentage sodium chloride, of *M. monoceros* is 2.63 (Panikkar and Viswanathan, 1948). Dall (1981) found the isosmotic point as approximately 23 ppt for *M. bennettae*; 27 ppt for *P. merguiensis* adults and 24 ppt for *P. merguiensis* juveniles.

2.4.3. Influence of Salinity on Food intake, Growth and Conversion efficiency.

Information on the life-history of most of the penaeid prawns points to the profound influence of salinity on their food intake, conversion efficiency and growth. Although this fact has been generally accepted, knowledge on the influence of salinity on food intake and conversion efficiency among penaeid prawns is quite scanty . Most of the penaeids have broad salinity tolerance limits. But it is generally expected that best growth and food conversion occur in a relatively narrower salinity range, well within their tolerance limits, that is specific for each species (Kinne, 1971). 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; Iwata and Shigueno, 1980). However, numerous reports that indicated either a decrease in metabolic rate in supra or subnormal salinities (Simmons and Knight, 1975) or no correlation between metabolic rate and salinity (Elfringhan, 1965; Mc Farland and Pickens, 1965) have led to difficulty in interpreting results of environmental changes on metabolic rate.

Pioneering works regarding the influence of salinity on the growth in prawns were carried out by Zein-Eldin (1963). He concluded that under conditions of constant temperature and restricted food supply, penaeid post-larvae survived and grew over a wide range of salinity (2-40 ppt). Zein-Eldin and Aldrich (1965) observed that salinity had little effect on either survival or growth of post-larval P. aztecus except at extreme temperatures. Zein-Eldin and Griffith (1967) studied the effects of salinity and temperature on P. duorarum and P. setiferus from the gulf of Mexico. In experiments concerning the osmotic relationship of P. aztecus and P. duorarum, Williams (1960) found that temperature apparently had far more effect upon survival than did salinity. However, several experimental studies followed, revealed that salinity influenced the survival and growth of penaeid post-larvae and juveniles (Grajcer and Neal, 1972; Nair and Kutty, 1975; Verghese *et al*., 1975; Bhattacharya and Kewalramani, 1976; Kuttyamma, 1982; Lakshmikantham, 1982; Raj and Raj, 1982; Subramanian and Krishnamurthy, 1986). The cumulative effect of temperature, salinity and feeding levels on growth and food conversion efficiency was reported by Venkataramiah *et al*. (1972; 1975). Influence of salinity on food intake, conversion efficiency and biochemical composition of *P. indicus* was studied by Kalyanaraman (1984). He found that *P. indicus* of 13-14 mm TL requires an optimum salinity of 25 ppt and those of 26-32 mm TL, 20 ppt.

Chen (1976) reported that suitable water salinity for the culture of *M. monoceros* in ponds is 15 to 20 ppt, and that it is capable of growth even when salinity is as low as 10 ppt. Kuttyamma (1982) observed that *M. monoceros* grows maximum at 15 ppt in their post-larval stage and at 20 ppt salinity in the juvenile stage.

III MATERIALS AND METHODS

III. MATERIALS AND METHODS

3.1. Prawns

Juveniles of M. monoceros were collected from the tidal channels of the Fisheries station, Puduveypu, Kochi (Cochin) of the Kerala Agricultural University. They were transported to the laboratory at the College of Fisheries, Panangad in oxygen filled polythene bags.

The size group of prawns used for salinity tolerance studies, ranged between 35 and 70 mm in TL and 0.35 and 1.8 g in wet weight.

For the growth experiments different size groups of prawns were utilised. In the first experiment prawns with a wet weight of 0.4728 ± 0.0893 g (41.52 ± 6.48 mm TL) were used. For the second experiment the prawns were sorted into two size groups based on their wet weights, such that those with live weights 0.4996 ± 0.0695 g (42.13 ± 5.62 mm TL) formed the first group, whereas those having 1.5483 ± 0.1875 g (63.19 ± 5.16 mm TL) formed the second group.

3.2. Feed

A dry pelleted feed prepared using dry clam meat powder (40%), ground nut oil cake (25%), rice bran (25%) and tapioca powder (10%) was used for feeding the prawn during the growth study. The proximate composition of this feed is 35.50 per cent protein, 6.54 per cent fat, 9.75 per cent ash and 8.34 per cent moisture.

3.3. Containers

Rectangular perspex tanks of 28x16x30 cm dimensions were used for the salinity tolerance experiment, keeping 10 L of water. Growth studies were conducted in circular cement cisterns of 90 cm diameter and 60 cm height, coated on their interior with fibre-glass resin of light blue colour, keeping 100 L of water. (100 L of water filled the cisterns to a height of 16 cm).

3.4. Preparation of Saline Media

Seawater brought from the Kochi (Cochin) bar mouth area was used for the experiments. Low saline water was prepared by mixing filtered seawater and tap water in calculated proportions, found out using the formula

$$V = \frac{\text{Required Salinity}}{\text{Salinity of seawater}} \times 1000,$$ where V is the Volume of seawater to be diluted to make one litre of water of the required salinity.

Hyper saline water was prepared by freezing the seawater following the technique described by Shapiro (1961).

3.5. Experimental Procedure

3.5.1. Study to Evaluate the Effect of Salinity on Survival.

Salinity tolerance of the prawns was studied by abrupt transfer experiment. For this purpose, prawns of 35 - 70 mm TL were maintained at 25 ppt salinity - the average salinity of the site of collection - for 10 days, fed with the formulated pelleted feed. The tolerance experiment was conducted with five prawns in each perspex tank, keeping 10 L of water, with the test salinities, namely 0,5,10,15,20,25,30, 35, 40, 45 and 50 ppt.

Prawns acclimated at 25 ppt salinity were randomly selected and abruptly transferred to each test salinity level (5 prawns/tank). Aeration was provided in all the tanks during the course of the experiment (5 days).

The prawns were not fed during the experimental period. Prawns kept at 25 ppt salinity without feeding during the experimental period, served as the control group. Animals were considered dead when direct mechanical stimulation resulted in no appendage movement. The exact time of mortality of each prawn was recorded in all tanks. Dead animals were removed immediately. The experiment of salinity tolerance was replicated twice.

Probit analysis technique (Finney, 1971) was used for finding the 120 Hr. LC_{50} values, both lower and upper limits. Slope of the probit line, standard error and 95 per cent confidence limits were also calculated.

3.5.2. Study to Evaluate the Effect of Salinity on Food intake, Growth, Conversion efficiency and Assimilation efficiency.

Two experiments were conducted to evaluate the effect of salinity on food intake, growth, conversion efficiency and assimilation efficiency of *M. monoceros* juveniles.

In the first experiment, prawns with a wet weight of 0.4728 ± 0.0893 g were grown during August-September 1989, for 35 days. The test salinities selected on the basis of the salinity tolerance study were 5, 15, 25 and 35 ppt. All treatments were replicated thrice.

The second experiment, meant to find out whether there exist any variations in the food intake, growth, conversion efficiency and assimilation efficiency between prawns of two size groups, at different salinity levels, was carried out with prawns belonging to two size groups designated as group I and group II. The group I constituted those with a wet weight of 0.4996 ± 0.0695 g, whereas group II of 1.5483 ± 0.1875 g size. The test salinities for the experiment were selected on the basis of the results of the first experiment, according to which the best growth was observed in the salinity range of 25 - 35 ppt. Both groups (I and II) were reared for 30 days at 20, 25, 30 and 35 ppt salinities during November - December 1989. Each treatment was replicated twice.

The first experiment was divided into three growth periods, namely 0-15, 0-25 and 0-35 days, while in the second, the growth periods were 0-10, 0-20 and 0-30 days in both size groups.

In both experiments, uniform sized juveniles were sorted out, acclimated in the respective test salinity levels and were adapted to the experimental diet for 10 days before the start of the experiment.

The cement cisterns used for the growth studies were filled with 100 L of prepared water of required salinity to receive 10 prawns per tank. The prawns kept acclimated at different test salinities were starved for 24 hours in respective saline media to ensure complete gut evacuation. They were then carefully weighed in a monopan electric balance of sensitivity 0.01 mg and released into the experimental cisterns containing water with test salinity to which the prawns were acclimated. To find the initial wet weight and that at the end of each growth periods, all the prawns in each tank were weighed together and the average taken as the individual wet weight. The prawns were not fed on the day before weighing, in all growth periods.

The prawns were fed with the dry pelleted feed ad libitum, once daily. The left over food and the faecal matter collected from each tank every morning, were washed with freshwater to remove salt content and were separately dried and kept at 60°C in a hot air oven. At the end of each growth period these were weighed separately to estimate the food consumption and faecal output of the respective growth periods in each treatment.

During the experimental period, salinity, water level and the important water quality parameters (P^H, DO, Temperature and Total alkalinity) in each tank were monitored. The experimental medium was not changed but was aerated continuously for the entire duration of the experiments. The water quality parameters during the first experiment were : P^H : 8.01 ± 0.38; DO : 6.14 ± 0.54 ppm; temperature : 26.60 ± 0.26°C and total alkalinity : 60.60 ± 3.51 ppm. During the second experiment these were : P^H : 8.27 ± 0.43; DO : 6.12 ± 0.60 ppm; temperature : 26.90 ± 0.31°C and total alkalinity : 64.70 ± 5.60 ppm.

For each growth period in either experiments, food intake as percentage wet body weight per day, growth in terms of percentage weight increase, conversion efficiency and assimilation efficiency were calculated using the following formulae

(i) Percentage food intake =

$$\frac{\text{total food intake (dry weight) x 100}}{[(\text{initial + final prawn wet weight})/2]\text{x days}}$$

(ii) Percentage weight increase =

$$\frac{\text{weight at end of period-weight at beginning of period}}{\text{weight at beginning of period}}\text{x100}$$

(iii) Conversion efficiency =

$$\frac{\text{prawn wet weight gain} \times 100}{\text{food intake (dry weight)}}$$

(iv) Assimilation efficiency =

$$\frac{\text{food intake (dry weight)} - \text{faecal output (dry weight)} \times 100}{\text{food intake (dry weight)}}$$

All these values (percentages) were converted into their respective θ values by angular transformation (Snedecor and Cochran, 1967). This data was subjected to two-way analysis of variance (Gomez and Gomez, 1984). For pair wise comparisons of the significant salinity effects, Duncan's multiple range test was used (Gomez and Gomez, 1984). Comparison of the respective mean values of different parameters between group I and group II prawns, was done by t. - test.

At the beginning of the growth experiments, two prawns from each treatment were sacrificed for the determination of the initial water content and dry weight. At the end of the respective experiments all the prawns were killed for the determination of their final dry weight. This was used for computing the dry weight balance of the prawns as given by Royan *et al*. (1977), at different salinity levels in each growth experiment.

3.6. Determination of Water Quality Parameters

The following water quality parameters were analysed using the method mentioned against each.

Salinity : Mohr - Knudson titrimetric method (Strickland and Parsons, 1972)

Dissolved Oxygen : Standard Winkler's method (Strickland and Parsons, 1972)

Total Alkalinity : Acidimetric titration method (APHA *et al*., 1981)

P^H : Electrometric method using Elico digital PH meter, Model LI - 122

Temperature : Using a mercury bulb thermometer with an accuracy of 0.1°C.

IV RESULTS

IV. RESULTS

4.1. Effect of Salinity on Survival

M. monoceros juveniles acclimated to 25ppt salinity, when transferred abruptly to 0, 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 ppt salinities showed 100 per cent survival in salinities from 5 to 35 ppt and 100 per cent mortality in zero and 50 ppt. The abrupt transfer experiment with 25 ppt acclimated prawns, when repeated with narrower intervals in the lower and higher salinity levels, namely, 0,1,2,3,4,5-40, 42,44, 45 and 50 ppt, it was found that in the lower salinities ($<$ 5 ppt) mortality rate for 120 Hr. period was 10% at 4 ppt, 30% at 3 and 2 ppt and 50% at 1 ppt, whereas in the higher salinity range ($>$ 35 ppt) the mortality rates were 10%, 40%, 60% and 80% at 40, 42, 44 and 45 ppt respectively. The cumulative percentage mortality of this experiment is given in table 1.

The probit lines and LC_{50} values calculated for 120 Hr. period to find out the lower and higher lethal limits, together with their slopes, standard error and 95% confidence limits are given in figures 1, 2 and table 2. Probit analysis showed that M. monoceros juveniles acclimated

Table 1. Cumulative percentage mortality of 25 ppt acclimated M. monoceros juveniles transferred abruptly to various test salinities for a period of 120 Hr.

Exposure time (Hrs)	Test salinity levels (ppt)										
	0	1	2	3	4	5-35	40	42	44	45	50
24	100	20	0	0	0	0	0	0	0	10	100
48	100	30	10	10	0	0	0	0	20	20	100
72	100	40	20	10	0	0	0	20	30	30	100
96	100	40	20	10	0	0	0	30	40	40	100
120	100	50	30	30	10	0	10	40	60	80	100

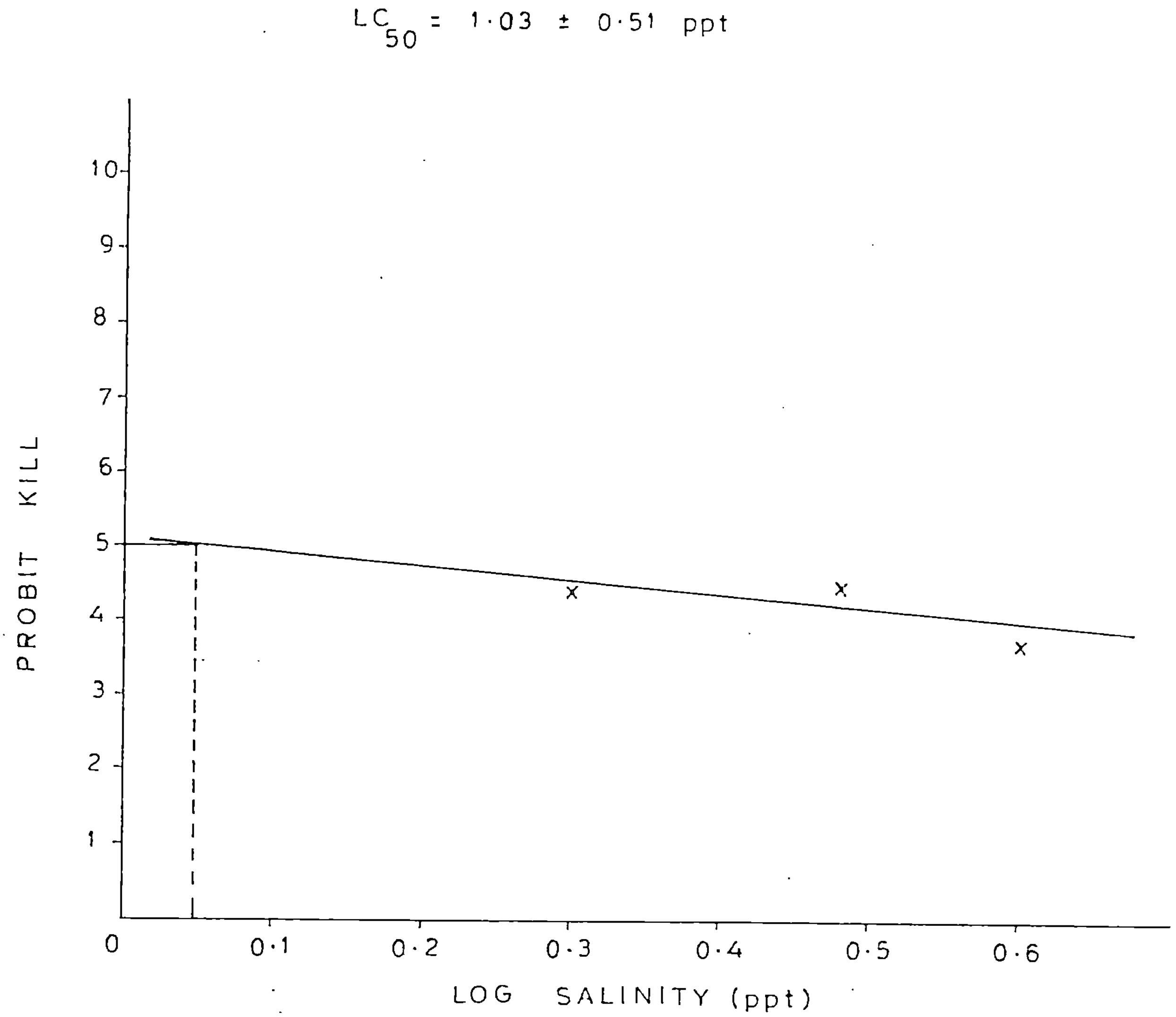

Fig.1 Probit line for M. monoceros juveniles abruptly transferred from 25 ppt salinity to different salinity levels for an exposure period of 120 Hr. showing lower LC_{50}.

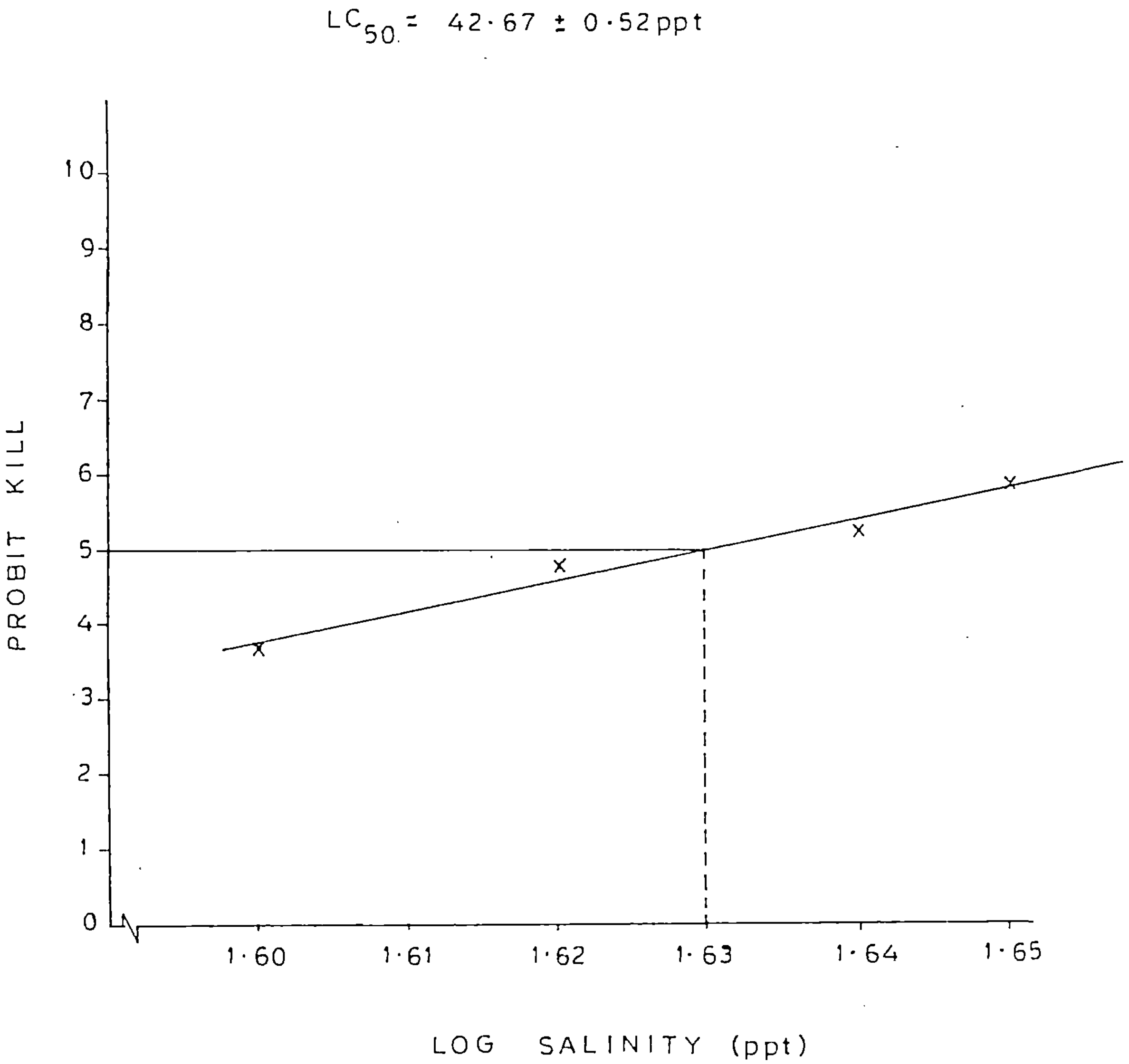

Fig.2 Probit line for M. monoceros juveniles abruptly transferred from 25 ppt salinity to different salinity levels for an exposure period of 120 Hr. showing upper LC_{50}.

Table 2. The 120 Hr. LC_{50} values of *M. monoceros* juveniles acclimated in 25 ppt salinity and transferred abruptly to different test salinity levels.

	Slope	LC_{50} ± Standard error (ppt)	95% Confidence limits (ppt)	
			Lower limit	Upper limit
Lower LC_{50}	-1.6902	1.03 ± 0.51	0.00	2.22
Upper LC_{50}	-41.3833	42.67 ± 0.52	41.45	43.89

Table 3. Cumulative dry feed intake per individual prawn during the experimental period (35 days).

Salinity (ppt)	Growth period (days)			Mean daily intake (g)
	0-15	0-25	0-35	
5	0.6911	1.0330	1.2582	0.0359
15	0.6356	1.0585	1.3339	0.0381
25	0.9448	1.5906	2.1016	0.0600
35	0.6657	1.1353	1.5231	0.0435

at 25 ppt salinity could tolerate salinities ranging between 1.03 ± 0.51 ppt and 42.67 ± 0.52 ppt when transferred abruptly.

4.2. Effect of Salinity on Food intake, Growth, Conversion efficiency and Assimilation efficiency

The effect of salinity on food intake, growth, conversion efficiency and assimilation efficiency of M. monoceros juveniles (0.4728 ± 0.0893 g) conducted by rearing them in cement cisterns at 5, 15, 25 and 35 ppt salinities for 35 days formed the first experiment. In the second, all the above indices were found out in two size groups (group I : 0.4996 ± 0.0695 g and group II : 1.5483 ± 0.1875 g) of M. monoceros by growing them at 20, 25, 30 and 35 ppt salinities for 30 days.

4.2.1. Effect of Salinity on Food intake.

The cumulative dry feed intake and mean daily food intake of M. monoceros juveniles (first experiment) at 5,15, 25 and 35 ppt salinities are given in table 3. Food intake (as per cent of wet body weight) per day (table 4) was found to be not significantly different among the test salinity levels (table 5). But the food intake declined significantly ($P < 0.01$) with growth periods in all test salinity levels (tables 4 and 5).

Table 4. Food intake (expressed as per cent of wet body weight) per day of *M. monoceros* at different salinity levels and growing periods.

Salinity (ppt)	Growing period (days)		
	0 - 15	0 - 25	0 - 35
5	9.22	7.93	6.44
15	7.81	7.33	6.37
25	8.97	8.06	6.79
35	9.14	8.28	7.14

Each value is the mean of three replicates.

Table 5. 4x3 Analysis of variance of percentage food intake for salinity levels and growing periods.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Value	
				Computed	Tabular (1% level)
Between :					
Salinity levels	5.91	3	1.97	2.8244	4.718
Growing periods	30.62	2	15.31	21.9498	5.614
Interaction	1.42	6	0.2366	0.3392	3.667
Residual	16.74	24	0.6975		
Total	54.69	35			

Data subjected to angular transformation.

Details of the cumulative food intake and mean daily food intake of group I and group II prawns are given in tables 6 and 7 respectively. Group II prawns showed higher daily food intake than group I prawns due to their higher body weight. Percentage food intake of both group I (table 8) and group II (table 9) prawns when subjected to analysis of variance indicated no significant variation with salinity (tables 10 and 11). But it was observed that in group I prawns there is highly significant ($P < 0.01$) difference in the percentage food intake among the growth periods (tables 8 and 10); where it was found decreasing from the first growth period to the last growth period in all salinity levels. On the otherhand, in group II prawns, the percentage food intake did not vary significantly among the growth periods (tables 9 and 11).

The mean percentage food intake of group I prawns was found significantly higher ($P < 0.01$) than that of group II prawns (table 12) at the four experimental salinities.

The dry weight balance of M. monoceros in both experiments (tables 43, 44 and 45) revealed that food consumption/unit weight/day is more or less uniform in all treatments in the respective experiments.

Table 6. Cumulative dry feed intake per individual prawn (group I) during the experimental period (30 days).

Salinity (ppt)	Growth period (days)			Mean daily intake (g)
	0 - 10	0 - 20	0 - 30	
20	0.4969	1.0266	1.5084	0.0503
25	0.4437	0.9121	1.2597	0.0420
30	0.4771	1.0327	1.4929	0.0498
35	0.5060	1.0248	1.4069	0.0469

Table 7. Cumulative dry feed intake per individual prawn (groupII) during the experimental period (30 days).

Salinity (ppt)	Growth period (days)			Mean daily intake (g)
	0 - 10	0 - 20	0 - 30	
20	0.7910	1.5086	2.3526	0.0784
25	0.7574	1.3428	2.3724	0.0791
30	0.7827	1.3811	2.1912	0.0730
35	0.7535	1.3929	2.2659	0.0755

Table 8. Food intake (expressed as per cent of wet body weight) per day of *M. monoceros* (group I) at different salinity levels and growing periods.

Salinity (ppt)	Growing period (days)		
	0 - 10	0 - 20	0 - 30
20	7.8	6.86	6.20
25	9.33	8.54	7.39
30	7.69	7.55	6.83
35	8.39	7.70	6.68

Each value is the mean of two replicates.

Table 9. Food intake (expressed as per cent of wet body weight) per day of *M. monoceros* (group II) at different salinity levels and growing periods.

Salinity (ppt)	Growing period (days)		
	0 - 10	0 - 20	0 - 30
20	4.41	4.06	4.10
25	4.91	4.17	4.70
30	5.00	4.08	4.27
35	5.21	4.56	4.86

Each value is the mean of two replicates.

Table 10. 4x3 Analysis of variance of percentage food intake (group I) for salinity levels and growing periods.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Value	
				Computed	Tabular (1% level)
Between :					
Salinity levels	7.58	3	2.53	3.4858	5.953
Growing periods	10.91	2	5.46	7.5227	6.927
Interaction	0.82	6	0.1367	0.1883	4.821
Residual	8.71	12	0.7258		
Total	28.02	23			

Data subjected to angular transformation.

Table 11. 4x3 Analysis of variance of percentage food intake (group II) for salinity levels and growing periods.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Value	
				Computed	Tabular (1% level)
Between :					
Salinity levels	2.35	3	0.7833	0.4747	3.490
Growing periods	3.42	2	1.71	1.04	3.885
Interaction	0.5788	6	0.0965	0.0585	2.996
Residual	19.76	12	1.65		
Total	26.11	23			

Data subjected to angular transformation.

Table 12. Comparison of the percentage food intake between group I and group II prawns at different salinity levels by t - test.

Salinity (ppt)	Mean % food intake		t - value
	Group I	Group II	
20	6.95	4.19	8.8967 **
25	8.42	4.59	5.6591 **
30	7.35	4.45	8.3644 **
35	7.59	4.87	4.4135 **

** Significant at 1% level.

4.2.2. Effect of Salinity on Growth .

The mean wet weights at different growth intervals together with daily increment, mean percentage weight increase and survival of M. monoceros in the first stage of the experiment are given in table 13. The percentage weight increase in different salinity levels and growth periods is given in table 14. Two-way analysis of variance of the result (table 15) indicated, both the main effects to be highly significant ($P < 0.01$).

Pair wise comparison revealed that the mean percentage weight increase at 25 ppt salinity is significantly higher ($P < 0.05$) than that at 5 and 15 ppt salinities , but not from that at 35 ppt salinity (table 16). The percentage weight increase was not significantly different at 5, 15 and 35 ppt salinity levels.

Details of growth and survival of group I and group II prawns are presented in tables 17 and 18 respectively. The percentage weight increase in different salinity levels and growth periods of group I (table 19) and group II (table 21) prawns was subjected to two-way analysis of variance (tables 20 and 22). The analysis showed that eventhough percentage weight increase

Table 13. Mean individual weights of *M. monoceros* at 35 day period.

Salinity (ppt)	Initial g)	15th day (g)	25th day (g)	35th day (g)	
5	0.4273	0.5996	0.6402	0.7088	(
15	0.4740	0.6108	0.6821	0.7235	(
25	0.5724	0.8397	1.0148	1.2035	(
35	0.4174	0.5549	0.6787	0.8022	(

Table 14. Percentage weight increase of *M. monoceros* at different salinity levels and growing periods.

Salinity (ppt)	Growing period (days)		
	0 - 15	0 - 25	0 - 35
5	41.83	51.52	68.85
15	29.28	44.39	53.20
25	47.52	78.33	112.11
35	32.60	62.25	91.55

Each value is the mean of three replicates.

Table 15. 4x3 Analysis of variance of percentage weight increase for salinity levels and growing periods.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Value	
				Computed	Tabular (1% level)
Between :					
Salinity levels	4388.49	3	1462.83	10.7751	4.718
Growing periods	7286.35	2	3643.18	26.8354	5.614
Interaction	2463.90	6	410.65	3.0248	3.667
Residual	3258.15	24	135.76		
Total	17396.89	35			

Data subjected to angular transformation.

Table 16. Pair wise comparison of the percentage weight increase of *M. monoceros* at different salinity levels by Duncan's multiple range test.

Salinity (ppt)	Mean % weight increase	DMRT *
5	54.07	a
15	42.29	a
25	79.32	b
35	62.13	a b

* Any two means having a common letter are not significantly different at 5% level of significance.

Table 17. Mean individual weights of group I prawns at growth intervals over 30 day period.

Salinity (ppt)	Initial (g)	10th day (g)	20th day (g)	30th day (g)	Daily increment (g)	% weight increase	Survival (%)
20	0.5568	0.7187	0.9400	1.0665	0.0170	91.56	100
25	0.3967	0.5722	0.6801	0.7464	0.0117	88.15	100
30	0.5232	0.7167	0.8449	0.9350	0.0137	78.71	100
35	0.5218	0.6803	0.8127	0.8814	0.0120	68.92	95

Table 18. Mean individual weights of group II prawns at growth intervals over 30 day period.

Salinity (ppt)	Initial (g)	10th day (g)	20th day (g)	30th day (g)	Daily increment (g)	% weight increase	Surv-ival (%)
20	1.6940	1.8987	2.0197	2.1338	0.0147	25.96	100
25	1.4668	1.6555	1.8465	1.9603	0.0165	33.65	100
30	1.5330	1.6650	1.8481	1.9063	0.0124	24.35	100
35	1.4259	1.5110	1.6737	1.7105	0.0095	19.96	100

Table 19. Percentage weight increase of M. monoceros (group I) at different salinity levels and growing periods.

Salinity (ppt)	Growing period (days)		
	0 -10	0 - 20	0 - 30
20	29.47	70.52	93.66
25	44.16	71.62	88.70
30	37.09	61.60	78.92
35	31.65	56.65	70.22

Each value is the mean of two replicates.

Table 20. 4x3 Analysis of variance of percentage weight increase (group I) for salinity levels and growing periods.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Value	
				Computed	Tabular (5% level)
Between :					
Salinity levels	326.60	3	108.87	0.2749	3.490
Growing periods	5099.05	2	2549.53	6.4372	3.885
Interaction	459.35	6	76.56	0.1933	2.996
Residual	4752.77	12	396.06		
Total	10637.77	23			

Data subjected to angular transformation.

Table 21. Percentage weight increase of M. monoceros (group II) at different salinity levels and growing periods.

Salinity (ppt)	Growing period (days) 0 -10	0 - 20	0 - 30
20	12.15	19.26	25.94
25	13.57	27.39	35.82
30	8.35	19.97	23.85
35	6.34	17.87	20.37

Each value is the mean of two replicates.

Table 22. 4x3 Analysis of variance of percentage weight increase (group II) for salinity levels and growing periods.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Value Computed	Tabular (1% level)
Between :					
Salinity levels	207.85	3	69.28	1.9937	5.953
Growing periods	695.77	2	347.89	10.0112	6.927
Interaction	22.90	6	3.82	0.1099	4.821
Residual	416.96	12	34.75		
Total	1343.48	23			

Data subjected to angular transformation.

improved significantly with growth periods, it did not vary significantly among 20,25, 30 and 35 ppt salinities, both in group I and group II prawns.

The daily weight increment of both groups of prawns was more or less similar (tables 17 and 18). But the mean percentage weight increase in group I prawns in all test salinities was significantly higher than that in group II prawns (table 23).

The relative growth rate of prawns in the respective experiments, on dry weight basis, is also given in tables 43, 44, and 45.

4.2.3. Effect of Salinity on Conversion efficiency.

The wet weight gain divided by the amount of dry food consumed multiplied by 100 was used to express the conversion efficiency (CE) at four experimental salinities (table 24 and Fig.3) . From the analysis of variance (table 25) highly significant ($P < 0.01$) difference of CE could be observed among the salinity levels, but not among the growth periods.

Table 23. Comparison of the percentage weight increase between group I and and group II prawns at different salinity levels by t - test.

Salinity (ppt)	Mean % weight increase			
	Group I	Group II	t-value	
20	64.55	19.11	3.0668	*
25	68.16	25.59	4.1829	**
30	59.20	17.39	4.7867	**
35	52.84	14.86	2.8356	*

* Significant at 5% level; ** Significant at 1% level.

Table 24. Conversion efficiency of M. monoceros at different salinity levels and growing periods.

Salinity (ppt)	Growing period (days)		
	0 - 15	0 - 25	0 - 35
5	24.59	20.41	22.35
15	21.52	19.84	18.79
25	28.35	27.84	30.03
35	20.40	22.87	25.03

Each value is the mean of three replicates.

Table 25. 4x3 Analysis of variance of conversion efficiency for salinity levels and growing periods.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Value	
				Computed	Tabular (1% level)
Between :					
Salinity levels	168.14	3	56.05	7.7791	4.718
Growing periods	4.86	2	2.43	0.3370	5.614
Interaction	32.24	6	5.37	0.7448	3.667
Residual	172.92	24	7.21		
Total	378.16	35			

Data subjected to angular transformation.

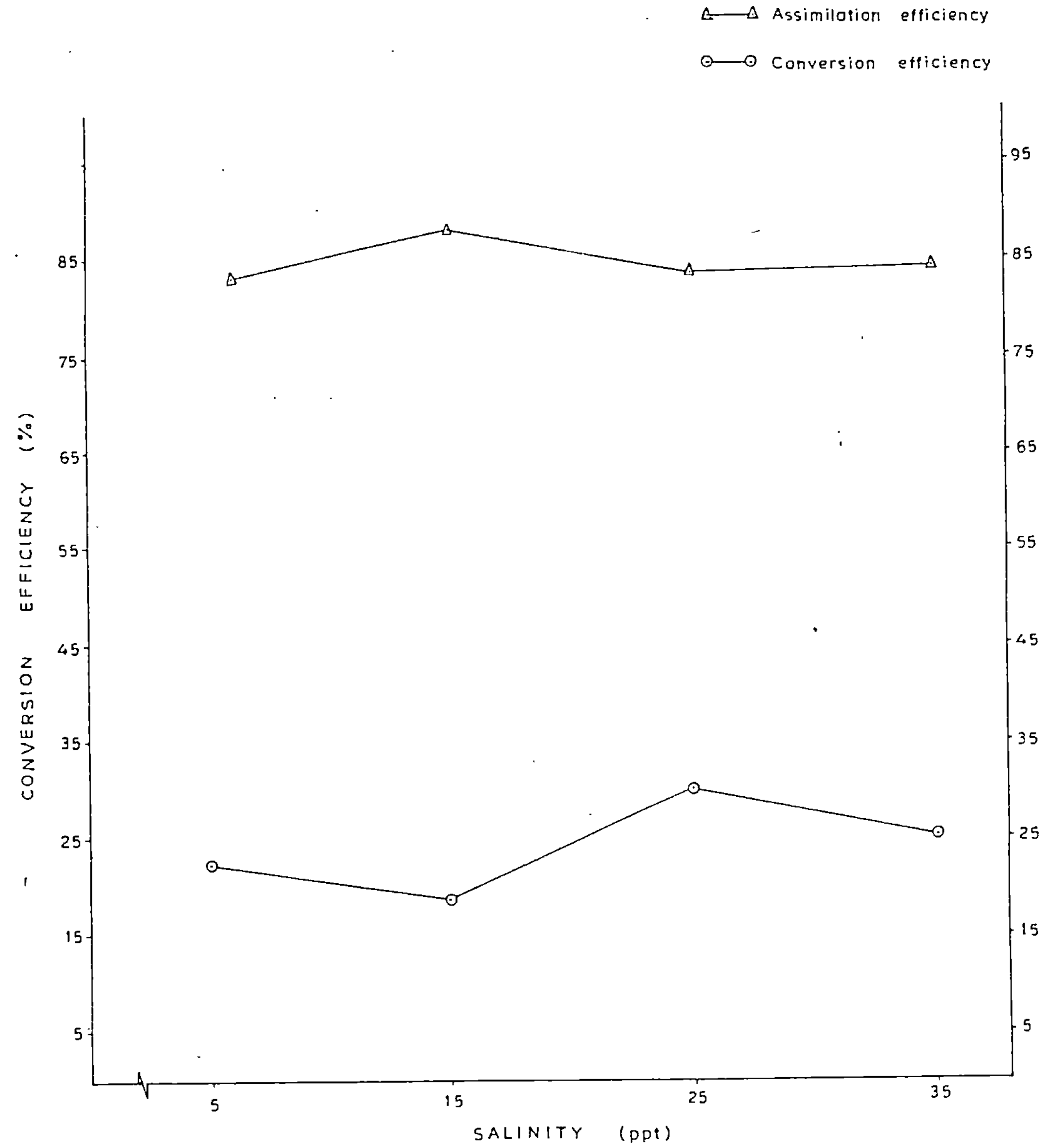

Fig.3 Conversion efficiency and assimilation efficiency of M. monoceros juveniles at test salinities in the first growth experiment.

Partition of the data between growth periods also showed a marked decline in mean food consumption for all treatments, accompanied by a corresponding reduction in growth rate which occurred over the first and last growth periods of the experiment (table 26) . But the efficiency of food conversion did not differ much between the first and last growth periods (tables 24 and 25).

The highest mean CE (28.74%) was recorded at 25 ppt salinity. Duncan's multiple range test showed that the mean CE at 25 ppt is significantly higher than that at 5, 15 and 35 ppt salinities while CE at these levels did not vary significantly among themselves (table 27).

Gross growth efficiency (K_1) was also calculated on dry weight basis (table 43). The K_1 values were more or less equal for prawns grown at 5 and 15 ppt salinities (3.03 and 3.64% respectively). Similarly the K_1 values in 25 and 35 ppt salinities were also comparable (7.40 and 6.33% respectively), but were conspicuously higher than the values obtained for lower salinity levels. The relative growth rate was also following a similar trend like the K_1 values among

Table 26. Percentage food intake and percentage weight increase of *M. monoceros* over three growth periods during the first experiment.

Salinity	% Food intake				% Weight increase			
	Growth period (days)				Growth period (days)			
(ppt)	0-15	15-25	25-35	Mean	0-15	15-25	25-35	Mean
5	9.22	5.61	3.22	6.02	41.83	6.85	11.50	20.06
15	7.81	6.53	3.93	6.09	29.28	11.75	6.07	15.70
25	8.97	6.99	4.64	6.87	47.52	20.87	18.92	29.10
35	9.14	7.60	5.23	7.32	32.50	22.46	17.90	24.29

Table 27. Pair wise comparison of the converison efficiency of M. monoceros at different salinity levels by Duncan's multiple range test.

Salinity (ppt)	Mean conversion efficiency	DMRT*
5	22.45	a
15	20.05	a
25	28.74	b
35	22.77	a

* Any two means having a common letter are not significantly different at 5% level of significance.

salinity levels, while the consumption/unit weight/day was almost uniform in the four test salinities.

CE of group I prawns at test salinities and growing periods are given in table 28 and figure 4. Analysis of variance showed that CE at different salinity levels and growth periods are not significantly different (table 29). However the results of CE in group II prawns (table 30 and Fig. 4) on analysis revealed that salinity has significant ($P < 0.05$) influence on CE but growth periods did not (table 31). Conversion efficiencies were comparable between 20 and 25 ppt as well as between 20 and 30 ppt salinities. Similarly, though a comparatively higher value of CE was recorded at 30 ppt salinity (18.56%) than the respective value at 35 ppt salinity (13.39%), they failed to differ statistically. But CE at 25 ppt was significantly higher than that at 30 and 35 ppt salinities (table 32). CE recorded at 35 ppt salinity was significantly lower in comparison to that at 20 and 25 ppt salinities.

The mean CE between group I and group II prawns at the four test salinities were compared using t-test (table 33). It was found that the respective CE values at 25 ppt salinity did not differ significantly.

Table 28. Conversion efficiency of *M. monoceros* (group I) at different salinity levels and growing periods.

Salinity (ppt)	Growing period (days)		
	0 - 10	0 - 20	0 - 30
20	32.77	37.19	33.72
25	40.17	31.05	27.76
30	41.07	31.19	27.71
35	31.69	28.42	24.78

Each value is the mean of two replicates.

Table 29. 4x3 Analysis of variance of conversion efficiency (group I) for salinity levels and growing periods.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Value	
				Computed	Tabular (5% level)
Between :					
Salinity levels	61.28	3	20.43	0.6290	3.490
Growing periods	96.13	2	48.07	1.4800	3.885
Interaction	61.57	6	10.26	0.3159	2.996
Residual	389.71	12	32.48		
Total	608.69	23			

Data subjected to angular transformation.

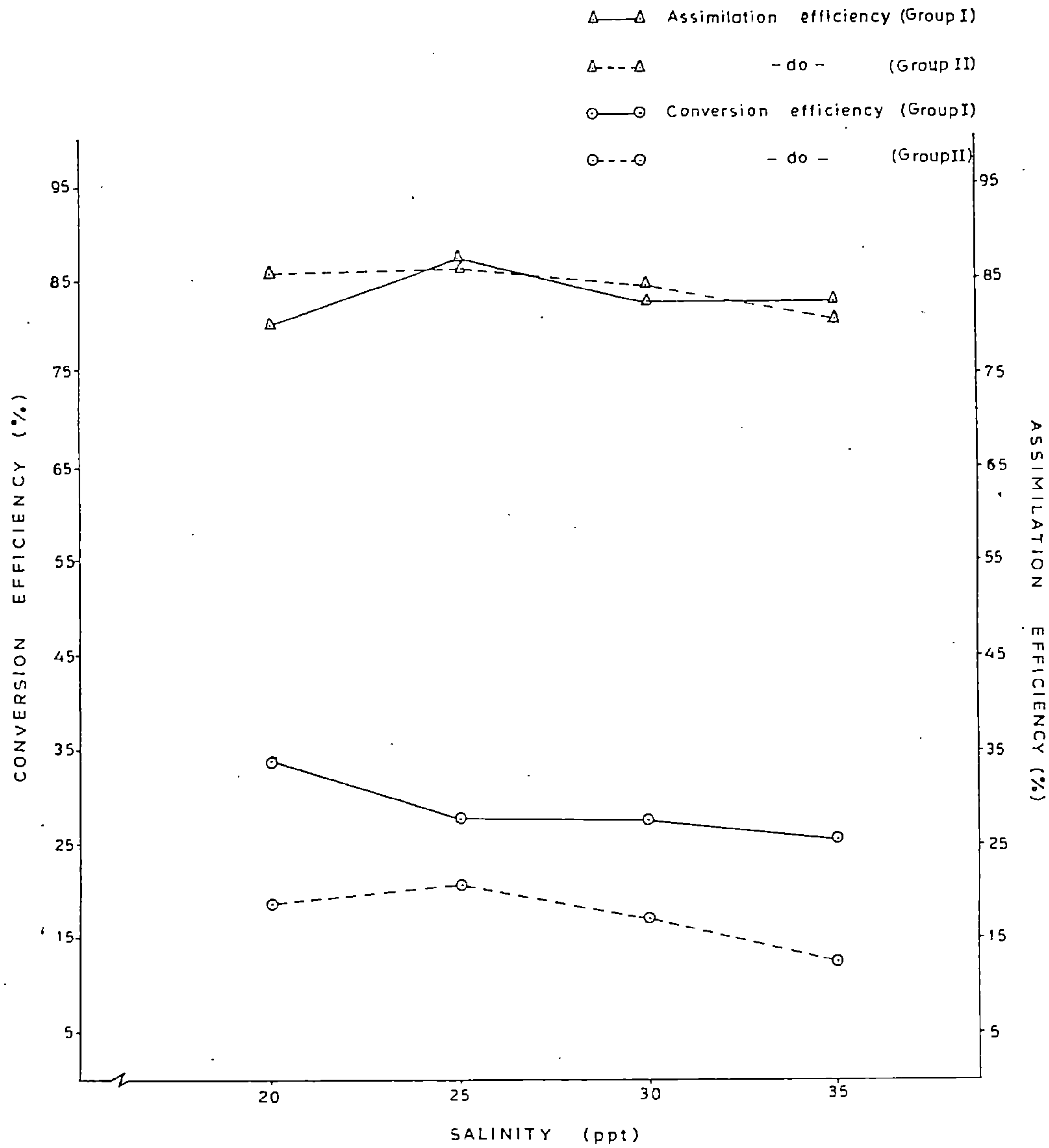

Fig.4. Conversion efficiency and assimilation efficiency of group I and group II _M_. _monoceros_ at test salinities.

Table 30. Conversion efficiency of *M. monoceros* (group II) at different salinity levels and growing periods.

Salinity (ppt)	Growing period (days) 0 - 10	0 - 20	0 - 30
20	25.98	21.69	18.67
25	25.36	28.10	20.81
30	16.87	22.14	16.69
35	10.17	17.53	12.47

Each value is the mean of two replicates.

Table 31. 4x3 Analysis of variance of conversion efficiency (group II) for salinity levels and growing periods.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Value Computed	Tabular (5% level)
Between :					
Salinity levels :	253.45	3	84.48	4.1842	3.490
Growing periods	59.51	2	29.76	1.4740	3.885
Interaction	59.27	6	9.88	0.4894	2.996
Residual	242.23	12	20.19		
Total	614.46	23			

Data subjected to angular transformation.

Table 32. Pair wise comparison of the conversion efficiency of group II prawns at different salinity levels by Duncan's multiple range test.

Salinity (ppt)	Mean conversion efficiency	DMRT*
20	22.11	a b
25	24.75	a
30	18.56	b c
35	13.39	c

* Any two means having a common letter are not significantly different at 5% level of significance.

Table 33. Comparison of the conversion efficiency between group I and group II prawns at different salinity levels by t-test.

Salinity	Mean conversion efficiency		
(ppt)	Group I	Group II	t-value
20	34.56	22.11	3.4071**
25	32.99	24.75	2.0983
30	33.32	18.56	3.8831**
35	28.29	13.39	2.9780*

* Significant at 5% level; ** Significant at 1% level.

But, at all other salinity levels, mean CE of group I prawns exceeded that of group II prawns.

The gross growth efficiency (K_1) values of group I and group II prawns were calculated on dry weight basis. In group I prawns K_1 values in 25,30 and 35 ppt salinities were almost uniform, while at 20 ppt salinity it was slightly higher (table 44). In the case of group II prawns, K_1 values at 20, 30 and 35 ppt salinities were comparable and at 25 ppt salinity it was higher (table 45). The results also showed that the K_1 values were higher for group I prawns than for group II prawns at all test salinity levels.

4.2.4. Effect of Salinity on Assimilation efficiency .

Assimilation efficiency of *M. monoceros* juveniles at four test salinity levels and three growing periods are given in table 34 and figure 3. Salinity is found to have a highly significant influence ($P < 0.01$) on assimilation efficiency but not growing periods (table 35). This was similar to the result of CE. But unlike CE, assimilation efficiency was relatively high (> 80%) in all test salinities and growth periods. Pair wise comparison showed that mean assimilation efficiency is

Table 34. Assimilation efficiency of M. monoceros at different salinity levels and growing periods.

Salinity (ppt)	Growing period (days)		
	0 - 15	0 - 25	0 - 35
5	85.58	85.15	83.38
15	89.99	89.71	88.20
25	76.69	80.08	83.53
35	82.80	84.41	84.27

Each value is the mean of three replicates.

Table 35. 4x3 Analysis of variance of assimilation efficiency for salinity levels and growing periods.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Value	
				Computed	Tabular (1% level)
Between :					
Salinity levels	244.54	3	81.51	13.0835	4.718
Growing periods	3.80	2	1.90	0.3050	5.614
Interaction	42.31	6	7.05	1.1316	3.667
Residual	149.47	24	6.23		
Total	440.12	35			

Data subjected to angular transformation.

comparatively higher at 5 and 15 ppt salinities (they were not significantly different from each other) compared to that at 25 and 35 ppt salinities (they were also not significantly different from each other) (table 36). But at the same time, mean assimilation efficiency at 5 ppt salinity was not higher than that at 35 ppt salinity.

From the dry weight balance of the prawns reared at 5, 15, 25 and 35 ppt salinities, assimilation efficiency and net growth efficiency (K_2) were also calculated (table 43). Eventhough high assimilation occurred in all salinity levels, K_2 values were relatively small ($<$ 10%). Within this, they showed similar trend as was observed in the case of K_1 values. K_2 values at 5 and 15 ppt as well as that at 25 and 35 ppt salinities were comparable each other. But the latter values (8.86 and 7.52% respectively) were almost twice that of the former (3.64 and 4.12% respectively). It could also be seen that K_1 and K_2 values at respective salinity levels did not differ much and K_2 values were only marginally higher than corresponding K_1 values.

Table 36. Pair wise comparison of the assimilation efficiency of M. monoceros at different salinity levels by Duncan's multiple range test.

Salinity (ppt)	Mean assimilation efficiency	DMRT*
5	84.70	a b
15	88.52	a
25	80.17	c
35	83.83	b c

* Any two means having a common letter are not significantly different at 5% level of significance.

Assimilation efficiency of group I prawns is given in table 37 and figure 4. On two-way analysis it was observed that salinity did not influence assimilation efficiency ($P > 0.05$). But there was a significant increase in the assimilation efficiency with growth periods ($P < 0.05$) (table 38). In the case of group II prawns, assimilation efficiency (table 39 and Fig.4) was significantly influenced ($P < 0.05$) by salinity, but did not vary among the growth periods (table 40). Pair wise comparison showed significantly lowest mean assimilation efficiency at 35 ppt salinity. But at 20, 25 and 30 ppt salinities mean assimilation efficiency values were higher and they did not differ significantly from each other (table 41). As obtained in the first experiment, assimilation efficiency was relatively high in both group I and group II prawns at all salinity levels. But the comparison of mean assimilation efficiency at each test salinity level between group I and group II prawns revealed that significant difference exists only at 20 ppt salinity (table 42). At 20 ppt salinity, group I prawns had lower assimilation efficiency (76.69%) than group II prawns (84.19%).

Table 37. Assimilation efficiency of M. monoceros (group I) at different salinity levels and growing periods.

Salinity (ppt)	Growing period (days)		
	0 - 10	0 - 20	0 - 30
20	71,71	79.01	80.24
25	83.69	87.06	87.71
30	73.53	80.99	86.77
35	75.33	82.48	83.05

Each value is the mean of two replicates.

Table 38. 4x3 Analysis of variance of assimilation efficiency (group I) for salinity levels and growing periods.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Value	
				Computed	Tabular (5% level)
Between :					
Salinity levels	142.19	3	47.40	2.6978	3.490
Growing periods	146.64	2	73.32	4.1730	3.885
Interaction	23.45	6	3.91	0.2225	2.996
Residual	210.83	12	17.57		
Total	523.11	23			

Data subjected to angular transformation.

Table 39. Assimilation efficiency of *M. monoceros* (group II) at different salinity levels and growing periods.

Salinity (ppt)	Growing period (days) 0 - 10	0 - 20	0 - 30
20	84.17	82.79	85.62
25	79.46	81.96	86.07
30	80.92	81.24	84.31
35	67.38	78.36	80.77

Each value is the mean of two replicates.

Table 40. 4x3 Analysis of variance of assimilation efficiency (group II) for salinity levels and growing periods.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Value Computed	Tabular (5% level)
Between :					
Salinity levels	130.59	3	43.53	3.8319	3.490
Growing periods	72.71	2	36.36	3.2007	3.885
Interaction	50.65	6	8.44	0.7430	2.996
Residual	136.29	12	11.36		
Total	390.24	23			

Data subjected to angular transformation.

Table 41. Pair wise comparison of the assimilation efficiency of group II prawns at different salinity levels by Duncan's multiple range test.

Salinity (ppt)	Mean assimilation efficiency	DMRT*
20	84.19	a
25	82.49	a b
30	82.15	a b
35	75.50	c

* Any two means having a common letter are not significantly different at 5% level of significance.

Table 42. Comparison of the assimilation efficiency between group I and group II prawns at different salinity levels by t-test.

Salinity (ppt)	Mean assimilation efficiency		t-value
	Group I	Group II	
20	76.99	84.19	3.2884**
25	86.15	82.49	1.3122
30	80.43	82.15	0.5129
35	80.28	75.50	1.0641

** Significant at 1% level.

The net growth efficiency (K_2) values in both groups were only slightly higher than their respective K_1 values at each test salinity level (tables 44 and 45). But as in the case of K_1 values, K_2 values in either size groups were not varying much among the four test salinity levels. However, the respective K_2 values of group I prawns were higher than that of group II prawns at all test salinity levels.

The percentage utilization of the total dry food consumed by the prawn for metabolism, production and faecal output in the test salinities for the first and second growth experiments, (calculated from the respective dry weight balance) are represented in figures 5 and 6 respectively. From the figure 5, it could be observed that, in the lower test salinity levels of 5 and 15 ppt, comparatively more food was utilised for metabolism than at 25 and 35 ppt.

Table 43. Dry weight balance of _M. monoceros_ after 35 days of growth at different salinity levels.

Salinity (ppt)	Initial weight w_1	Final weight w_2	Weighted mean w	Production p	Consumption c	Faecal output f	Relative growth rate p/w/30	Assimilation a	Metabolism r c-(p+f)	Assimilation efficiency a/c %	Gross growth efficiency k_1 p/c %	Net growth efficiency k_2 P/a %	Consumption/ unit weight/ day c/w/30
5	0.0935	0.1316	0.1126	0.0381	1.2582	0.2123	0.0097	1.0459	1.0078	83.13	3.03	3.64	0.3193
15	0.1037	0.1522	0.1280	0.0485	1.3340	0.1578	0.0108	1.1762	1.1277	88.17	3.64	4.12	0.2978
25	0.1252	0.2807	0.2030	0.1555	2.1016	0.3473	0.0219	1.7543	1.5988	83.47	7.40	8.86	0.2958
35	0.0913	0.1877	0.1395	0.0964	1.5231	0.2413	0.0197	1.2818	1.1854	84.16	6.33	7.52	0.3120

Values as g/animal.

Table 44 . Dry weight balance of *M. monoceros* (group I) after 30 days of growth at different salinity levels.

Salinity (ppt)	Initial weight w_1	Final weight w_2	Weighted mean w	Production p	Consumption c	Faecal output f	Relative growth rate p/w/30	Assimilation a	Metabolism r c-(p+f)	Assimilation efficiency a/c %	Gross growth efficiency k_1 p/c %	Net growth efficiency k_2 p/a %	Consumption/ unit weight/ day c/w/30
20	0.1534	0.2984	0.2259	0.1450	1.5084	0.2982	0.0214	1.2102	1.0652	80.23	9.61	11.98	0.2226
25	0.1093	0.2056	0.1575	0.0963	1.2597	0.1546	0.0204	1.1051	1.0088	87.73	7.64	8.71	0.2666
30	0.1441	0.2580	0.2011	0.1139	1.4929	0.2593	0.0189	1.2336	1.1197	82.63	7.63	9.23	0.2475
35	0.1438	0.2561	0.2000	0.1123	1.4069	0.2427	0.0187	1.1642	1.0519	82.75	7.98	9.65	0.2345

Values as g/animal .

Table 45. Dry weight balance of *M. monoceros* (group II) after 30 days of growth at different salinity levels.

Salinity (ppt)	Initial weight w_1	Final weight w_2	Weighted mean w	Production p	Consumption c	Faecal output f	Relative growth rate $p/w/30$	Assimilation a	Metabolism r $c-(p+f)$	Assimilation efficiency a/c %	Gross growth efficiency k_1 p/c %	Net growth efficiency k_2 p/a %	Consumption/ unit weight/ day $c/w/30$
20	0.4902	0.5981	0.5442	0.1079	2.3526	0.3390	0.0066	2.0136	1.9057	85.59	4.59	5.36	0.1441
25	0.4245	0.5673	0.4959	0.1428	2.3724	0.3306	0.0096	2.0418	1.8990	86.06	6.02	6.99	0.1595
30	0.4437	0.5340	0.4889	0.0903	2.1912±	0.3453	0.0062	1.8459	1.7556	84.24	4.12	4.89	0.1494
35	0.4127	0.5114	0.4621	0.0987	2.2660	0.4334	0.0071	1.8326	1.7339	80.87	4.36	5.39	0.1635

Values as g/animal.

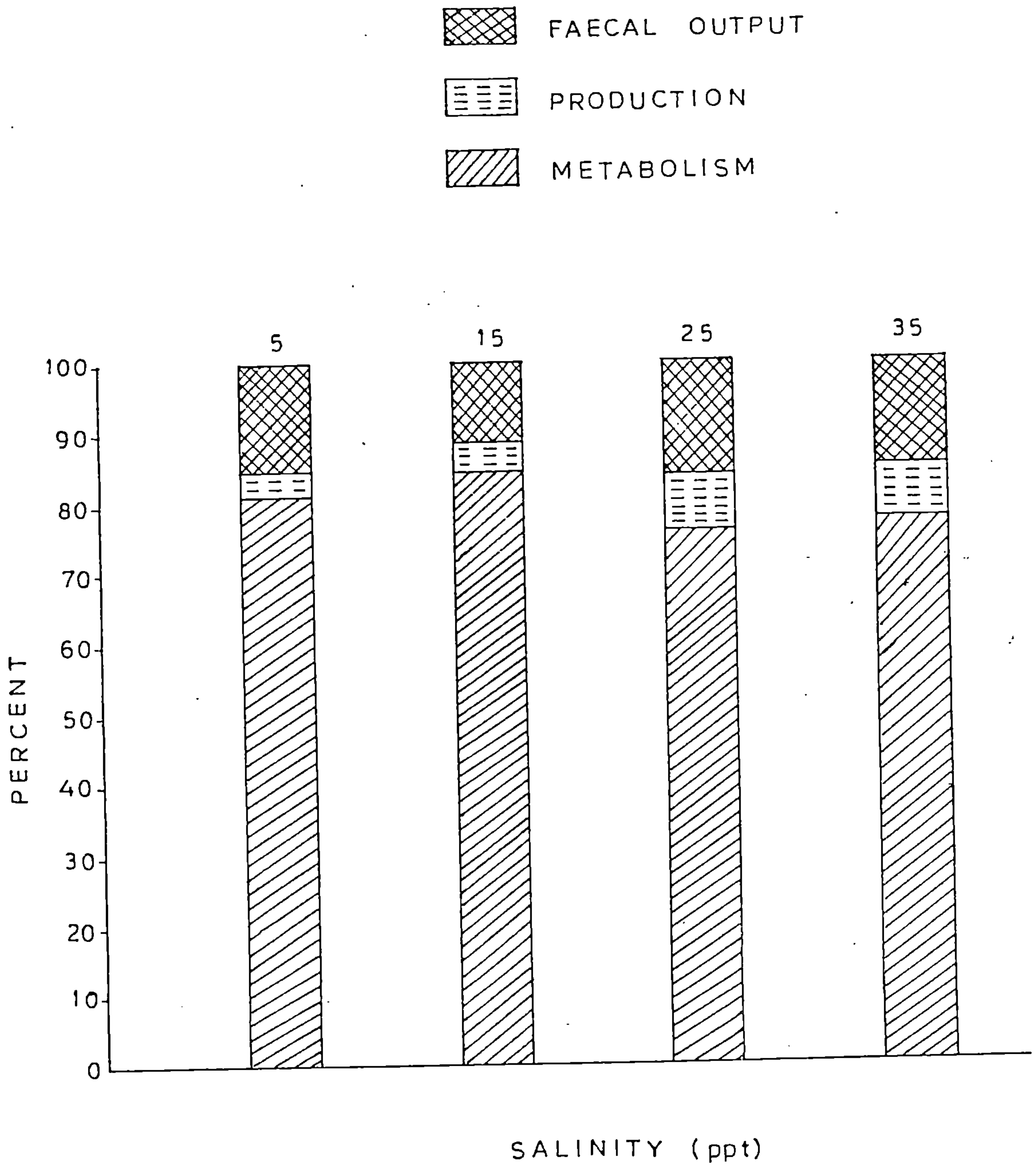

Fig.5 Percentage utilisation of food consumed for metabolism, production and faecal output by *M. monoceros* juveniles at test salinities in the first growth experiment.

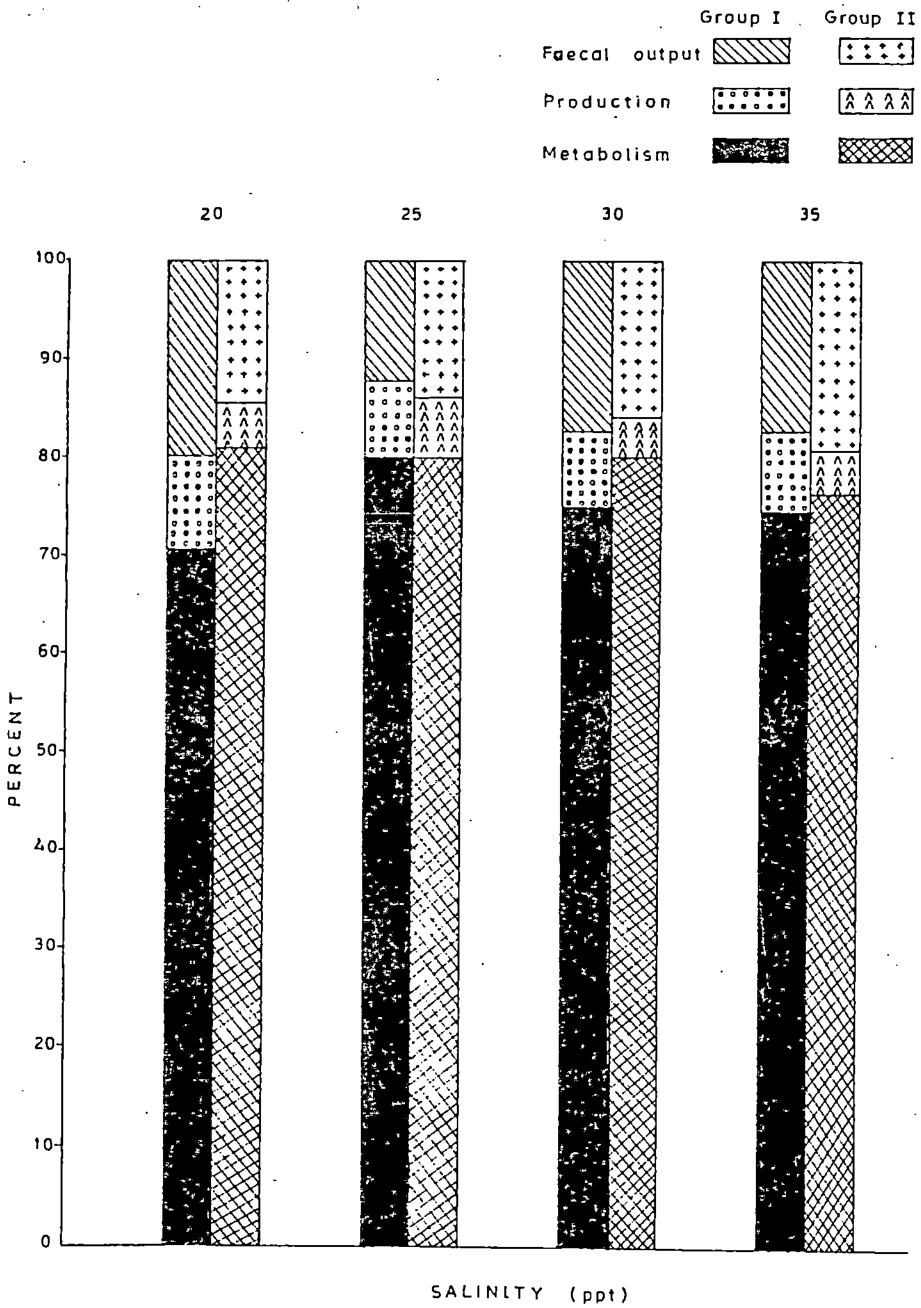

Fig.6. Percentage utilisation of food consumed for metabolism, production and faecal output by group I and group II *M. monoceros* at test salinities.

V DISCUSSION

V. DISCUSSION

5.1. Effect of Salinity on Survival

Results of the experiment of abrupt transfer to different salinity grades could confirm the highly efficient osmoregulatory ability of M. monoceros juveniles. When the prawns acclimated at 25 ppt salinity were transferred to lower and higher salinity levels, 100 per cent survival was obtained between 5 and 35 ppt salinities. Although the prawns could not survive at zero ppt or 50 ppt salinity levels, it could be seen that they have very wide salinity tolerance, as revealed from the present studies, wherein the lower and higher lethal salinities were 1.03 ± 0.51 and 42.67 ± 0.52 ppt respectively. This is in conformation to the observation of Kuttyamma (1980 b) who reported the respective lower and higher lethal salinities of M. monoceros as 2 and 42 ppt for the prawns acclimated at 5 ppt; 2 and 41 ppt for those acclimated at 15 ppt and 3 and 43 ppt for the prawns acclimated at 30 ppt salinity.

Juveniles of penaeid prawns are known to have such wide adaptation to varying salinity levels. Thus the juveniles of M. macleayi were found (Ruello,

1971) to be able to tolerate a drop in salinity of as much as 30 ppt within 30 hours. Zein-Eldin anf Griffith (1967) found the post-larvae of *Penaeus aztecus* and *P. setiferus* tolerating a salinity range of 2 to 40 ppt with 90-100 per cent survival. Such wide salinity tolerances have been found in the juveniles of *P. monodon* where it is 0-52 ppt (Motoh, 1982) and in *P. japonicus* where it is 19-52 ppt (Hudinaga, 1942). *M. bennettae* was found to be a highly efficient osmoregulator (Dall, 1981), capable of tolerating salinities from 1 to 62 ppt (Aziz and Greenwood, 1981).

M. monoceros has its juvenile stages spent in the estuaries until they return to sea after attaining a length of about 100 mm (George, 1959). Thus it is expected to have a wide salinity tolerance, as suggested by Dall (1981) that species with stages inhabiting estuaries where salinity may be low, would be efficient osmoregulators. Salinity in the estuaries is subjected to wide fluctuations and it is reported to vary from 1.0 ppt to 35.0 ppt in the Cochin backwaters during the course of an year (George *et al*., 1968). Result of the present study shows that *M. monoceros* has the capacity to withstand these variations successfully.

The lower lethal limit obtained for *M. monoceros* in the present study is 1.03 ± 0.51 ppt. But, comparatively a higher value of 3 ppt was reported as the lower lethal limit of this prawn by Kuttyamma (1980 b), when prawns acclimated at 30 ppt salinity were used for the experiment. When prawns acclimated at 5 ppt as well as 15 ppt were used, the lower limit she could observe was 2 ppt. The occurrence of M. monoceros in areas having lower salinity levels than what has been observed in the laboratory is reported by George and Suseelan (1982), who found it penetrating into the zone of very low salinity (0.6 to 2.6 ppt). Similar observations were reported in the case of some other penaeids also. For example Penaeus aztecus was collected from water with salinity lower than the level it can tolerate in the laboratory (Gunter and Hall, 1963; Christmas and Langley, 1973; Venkataramiah et al., 1974). Dall (1958) observed post-larval M. bennettae occurring in the Brisbane river at salinities as low as 0.22 ppt, which was found to be below the lower lethal level of 1.0 ppt shown by their juveniles in the laboratory studies conducted by Aziz and Greenwood (1981). Pearse and Gunter (1957) have stated that once an animal has adjusted to salinity changes, its range of tolerance may exceed the usual environmental changes, so that it could survive unusual conditions. This explains the occurrence of M. monoceros at lower salinity levels than what it could tolerate in the laboratory. Further, it is well understood that extrapolation of laboratory tolerance studies to predict species distribution in nature need not be precise, since in nature they are subjected to a variety of environmental changes, besides salinity, and the organism in turn respond to the total resulting stimulus or stress rather than to single environmental entities (Aziz and Greenwood, 1981). However, the result of the present salinity tolerance study gives confirmatory evidence to the ability of M. monoceros juveniles to survive the highest salinity ranges, both low as well as high as opined by Panikkar (1948).

5.2. Effect of Salinity on Food intake

The results of the present investigation show that food consumption of M.monoceros juveniles is not influenced by salinity within the range of 5-35 ppt. It may be due to the fact that these levels are well within the tolerance range of this highly euryhaline prawn. A relatively higher daily mean intake of food by prawns in 25 ppt salinity may be due to their higher initial wet weight (Vide table 3). But it can be seen that the daily food intake expressed as the percentage of the wet body weight is more or less uniform at all experimental salinities. This is supported by the result obtained on dry weight basis also, wherein the consumption per unit weight per day ranged between 0.2958 g and 0.3193 g among the treatments. In the present study the respective feeding levels when calculated as percentage initial body weight per day are found to be 8.41, 8.04, 10.49 and 10.43 at 5, 15, 25 and 35 ppt salinities, falling well within the range reported by Sumitra-Vijayaraghavan _et_ _al_. (1982). She reported the feeding level of juvenile _M_. _monoceros_ of 0.35 - 0.48 g size as 15 per cent for maximum growth and that when below 7 per cent, the final body weight decreased.

The marked declining trend as seen from the comparison of the percentage food intake between first and last growth period, at all salinities in the present experiment (Vide tables 4 and 26) could be a normal reaction to increased size of the prawns. At all test salinities, the prawns achieved appreciable weight increase during the 35 day experimental period which obviously mean an increase in their average weight with growth period. Hence there is a decrease in consumption per unit weight with increasing body weights though it could be seen that the variation among the different salinities tested is not quite significant.

The percentage food intake of group I (smaller) prawns (0.4728 ± 0.0893 g) in the second experiment is not influenced by salinity variations within the range of 20-35 ppt. This is similar to the result of the first experiment where a wider salinity range (5-35 ppt) failed to bring in any variation in the food intake of prawns having comparable body weight (0.4996 ± 0.0695 g). So also it is to be noted that salinity levels ranging between 20 and 35 ppt were not able to influence any significant variation in the percentage food intake of larger prawns (1.5483 ± 0.1875 g) that constituted group II.

The percentage food intake was found declining with growth periods in group I prawns but not in the case of group II prawns. This decrease in consumption per unit weight of group I prawns is due to the increase in body weight with growth periods, while in group II prawns the weight increment with growth periods is not sufficient to cause a significant reduction in percentage food consumption. This is better explained by the comparison of the percentage weight increase between group I and group II prawns (Vide table 23).

In both experiments, it is seen that salinity is not influencing food intake. In this respect, the results of the present study differed from that of Kalyanaraman (1984), who found that the food intake of *Penaeus indicus* is salinity dependent. In two size groups of *P. indicus* having 13-14 mm TL and 26-32 mm TL respectively, he recorded maximum food consumption at 25 ppt and 20 ppt salinities; but in both size groups least food intake occurred at 5 ppt salinity. This difference in response between *M. monoceros* and *P. indicus* may be due to the better adaptation to salinity, exhibited by the former species.

From the comparison of food intake between group I and group II prawns, it can be seen that at all test salinities, group II prawns consumed more food per day. But owing to a higher body weight of group II prawns, their percentage food intake was significantly lower than that of group I prawns. This is in conformity with the observations of Sushchenya and Khmeleva (1967) that under a given set of conditions, the food intake of crustaceans increases with increase in body weight and of Katre and Reddy (1977) that in *Palaemon lamarrei*, larger prawns consumed more food per day than smaller prawns, but when the daily food intake is expressed as a percentage of body weight, the rate of food intake is found to be inversely proportional to the body size.

5.3. Effect of Salinity on Growth

Growth of *M. monoceros* juveniles is found to be influenced by salinity and is significantly different among the four salinities tested namely, 5, 15, 25 and 35 ppt . Percentage weight increase recorded at 25 ppt salinity is significantly higher than those at lower salinity levels but is comparable with that at 35 ppt salinity. The highest daily increment of 0.018 g was recorded at 25 ppt salinity.

The available information on the growth rate of this species is related to field conditions not considering the effect of different salinities. Moreover the growth rates are mostly studied on the basis of measurements of increase in length or are based on the length frequency distribution of the prawns in their respective habitats. This makes it difficult to compare earlier observations with the absolute increase in weight gained by the prawns at different salinities in the present study. Kuttyamma (1982) reported maximum growth of *M. monoceros* juveniles at 20 ppt salinity during laboratory studies for a period of one month. But when they were grown for a prolonged period of one year, she found 25 ppt as the optimum salinity for growth. Such a shift in salinity requirement is quite justifiable for a prawn like *M. monoceros* which goes back to the sea after spending a considerable period in the estuaries during their early stages. During the juvenile phase when they are cultured, they have a preference for lower salinities. The most suitable salinity range for the pond culture of *M. monoceros* in Taiwan is reported as 15-20 ppt (Chen, 1976).

Salinity is reported to influence the growth of most of the penaeids as they pass through an estuarine phase during their nursery stage and a marine phase as they begin to breed. The fact that most of the penaeids do have a wide tolerance range need not mean that the whole range is quite suitable for growth. The statement of Kinne (1971) that 'in most of the euryhaline invertebrates, growth is restricted to a narrower range than survival', must be true in the case of *M. monoceros* also. Raj and Raj (1982) observed 25 ppt as the best salinity for growth in *P. indicus* and *P. monodon*, while

Subramanian and Krishnamurthy (1986) reported it as 23 ppt. In the case of *P. indicus* Nair and Kutty (1975) reported the optimum salinity for growth as 30 ppt. Kuttyamma (1982) obtained maximum growth of post-larvae of *P. indicus* at 20 ppt salinity and that of the juveniles at 25 ppt. The maximum growth of post-larvae of *M. dobsoni* was noticed at 15 ppt and that of the juveniles at 20 ppt salinity (Kuttyamma, 1982). Hysmith and Colura (1976) have shown *P. aztecus* and *P. setiferus* as growing best at 15 ppt salinity. Higher salinity levels are also found to be preferred by certain penaeid prawns especially those which do not show migration towards estuaries; for example, 23-47 ppt in the case of *Penaeus japonicus* (Imai, 1977) and 25-45 ppt in the case of *P. latisulcatus* (Ramaswamy and Pandian, 1985). It could be seen that all these salinity levels are somewhere in the middle of their tolerance range.

The percentage weight increase of group I and group II prawns have shown that within the range of 20-35 ppt, there is no significant variation in the influence of salinity on growth, although there is slight variation in the growth performance between these two groups. In the first group, the percentage weight increase is maximum at 20 ppt salinity whereas in the second group, the maximum percentage weight increase is recorded at 25 ppt salinity. Both the size groups of *M. monoceros* juveniles can be said to have more or less comparable growth rates among the test salinities. Comparison of the mean percentage weight increase between group I and group II prawns shows that it is significantly higher in the former, evidently indicating better growth rate in smaller prawns. George (1959) also observed that in *M. monoceros* growth rate is lower in larger specimens. In *M. brevicornis*, Rajyalakshmi (1961) reported the specific growth rate being highest in the young and it decreases with size. In *Penaeus vannamei* also, growth was negatively correlated with size, with a marked decrease in growth rate occurring at about 28 mm carapace length (Menz and Blake, 1980).

5.4. Effect of Salinity on Conversion efficiency

The efficiency with which *M. monoceros* juveniles converted food material into body substance is significantly influenced by salinity as shown by the present experiment. The maximum conversion efficiency of 28.74% has been recorded at 25 ppt, while the values are comparable at all other test salinity levels (20.05% - 22.77%). Results also indicate that conversion efficiency remains uniform throughout the growth periods.

The mean food consumption and growth rates show a declining trend over growth periods in all treatments (Vide table 26) . Since the efficiency of feed conversion does not differ much with growth periods, retardation of growth could have resulted only from the reduced food intake.

Gross growth efficiency (K_1) calculated on dry weight basis, was found to range between 3.03 and 7.40%. The K_1 values at 5 and 15 ppt salinities are 3.03 and 3.64% respectively whereas at 25 and 35 ppt salinities the values are much higher, being 7.40 and 6.33% respectively. This shows that the prawns are able to convert food material into body tissue better at higher salinity levels of 25-35 ppt . Since the consumption per unit weight per day is more or less uniform at all salinity levels, the difference in K_1 values has resulted entirely due to the variation in relative growth rate with salinity, as K_1 is production divided by consumption (Vide table 43).

The data on growth and conversion efficiency show that M. monoceros juveniles require an optimum salinity of about 25 ppt. Though the data show that growth is comparable between 25 and 35 ppt salinities, it could be seen that conversion efficiency is significantly higher at 25 ppt. In the case of P. indicus best growth and conversion efficiency were reported to be obtained at 25 ppt and 20 ppt salinities respectively for prawns with 13-14 mm TL and 26-32 mm TL (Kalyanaraman, 1984). Similarly Hysmith and Colura (1976) found 21 ppt as the best salinity for the production of brown shrimp, P. aztecus, while it was 15 ppt for the white shrimp, P. setiferus.

The results of the second experiment show that there is no significant difference in conversion efficiency among the test salinities, in the case of group I prawns. But it is found varying significantly among the four test salinities in group II prawns. Conversion efficiency is comparable between 20 and 25 ppt as well as between 20 and 30 ppt salinities. Although not statistically significant, a better conversion efficiency value (18.56%) was recorded at 30 ppt as compared to that obtained at 35 ppt (13.39%). The conversion efficiency values at 20 and 25 ppt salinities are significantly higher in comparison to that at 35 ppt. Similarly, at 25 ppt salinity, conversion efficiency is higher than that obtained at 30 and 35 ppt salinities. It is also to be noted that the efficiency of food conversion does not vary among the growth periods in both groups.

From the data on percentage food intake and percentage weight increase, it can be seen that the respective values are significantly higher in the case of group I prawns than group II at all test salinities. A similar trend is observed with respect to the conversion efficiency values also. Statistical analysis showed higher conversion efficiency values in group I prawns at all test salinities except at 25 ppt. Eventhough there is an apparent difference in the absolute values of conversion efficiency at 25 ppt between group I and group II prawns (32.99 and 24.75% respectively), they are not significantly different from each other (Vide table 33).

5.5. Effect of Salinity on Assimilation efficiency

Salinity is found to have a highly significant influence on the assimilation efficiency of M.

monoceros juveniles. Comparable assimilation efficiencies are obtained between 5 and 15 ppt, 25 and 35 ppt as well as between 5 and 35 ppt salinities. It is seen that mean assimilation efficiency obtained at 25 ppt (80.10%) is significantly lower than that at 5 and 15 ppt salinities.

Net growth efficiency (K_2) calculated from the dry weight balance shows a pattern similar to that of K_1 values. These values at higher salinities (25 and 35 ppt) are more than those at lower salinities (5 and 15 ppt).

Results of the first growth experiment in general highlight the better performance of M. monoceros juveniles at 25 ppt salinity. Eventhough growth and assimilation efficiency values are comparable between 25 and 35 ppt salinities, prawns show higher conversion efficiency at 25 ppt. Similarly, at 25 ppt, they have higher growth and conversion efficiency than at lower test salinities (5 and 15 ppt), even with a significantly lower assimilation efficiency. Since food intake is uniform throughout these four salinity levels, this invariably indicates that, of the total consumption, prawns in lower salinities utilised more food for metabolism rather than for production (Vide Fig.5). It is also to be noted that either growth, conversion efficiency or assimilation efficiency, are not different between 5 and 15 ppt as well as between 5 and 35 ppt salinities. Likewise, prawns at 15 ppt salinity have growth and conversion efficiency comparable to that at 35 ppt salinity, despite a significantly higher assimilation efficiency (at 15 ppt).

As the case of conversion efficiency, in group I prawns, salinity does not influence assimilation efficiency too. The K_2 values also vary little among the test salinities. But salinity significantly influences the assimilation efficiency of group II prawns. Lowest mean assimilation value (75.50%) is recorded at 35 ppt while at all other test salinities it is more than 80% and are comparable with each other. At 35 ppt salinity group II prawns exhibited lesser efficiency in the case of food conversion also. Moreover, the difference between K_1 and K_2 values of group II prawns at this salinity level is comparatively more, due to an increased faecal output (Vide Fig. 6).

Assimilation efficiency values are found comparable between group I and group II prawns at 25, 30 and 35 ppt salinities. At 20 ppt salinity, though assimilation efficiency is observed to be lower in group I prawns than in group II prawns, the former group has significantly higher percentage food intake, percentage weight increase and conversion efficiency. Moreover, it is also to be noted that assimilation efficiency is not influenced by salinity in group I prawns and hence comparable among the test salinities.

The K_2 values of group I prawns, as can be expected, are higher than that of group II prawns at all salinity levels. Both K_1 and K_2 values are comparatively higher at 20 ppt salinity in group I prawns whereas they are higher at 25 ppt salinity in group II prawns. K_1 and K_2 values remain more or less uniform at all other test salinities in either groups. This trend seems very apparent on dry weight basis, but is neither supported by the conversion efficiency values calculated on wet weight basis nor could be analysed statistically.

A wide variation has been reported to be present in the K_1, K_2 and assimilation efficiency values (0.3 to 30%; 0.4 to 38% and 64 to 93 % respectively) in the prawn, M. monoceros

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(Sumitra-Vijayaraghavan et al., 1978). In the present study the respective values fall within these ranges, and the K_1 values do not vary greatly from K_2 values. As Qasim and Easterson (1974) pointed out, it can be due to the readily assimilable form of the food consumed by the prawns and little loss through defaecation. Generally in either groups of prawns, at all salinities conversion efficiencies (K_1 and K_2) are found comparatively low while assimilation efficiency is uniformly constant and high. Similar results were reported for *M. monoceros* by Alfred et al. (1978); Sumitra-Vijayaraghavan et al. (1978) and Ramadhas and Sumitra-Vijayaraghavan (1979) in different feeding experiments. The high assimilation and low conversion can be traced to low protein content of the diet provided to the prawns, which may indicate that adequate nitrogen is not available for body building (Alfred et al., 1978). Royan et al. (1977) have shown that an optimum level of 60% protein is required and at levels above or below this, growth and conversion efficiency are suppressed in *M. monoceros*. The pelleted feed used in the present study has a protein content of 35.50% only. This indicates that *M. monoceros* needs relatively a high protein diet than that required by *P. indicus* (43% : Colvin, 1976) and *P. monodon* (46% : Lee, 1971; 35% : Bages and Sloane, 1981). It is well established that protein requirement varies with individual species of prawn (New, 1976). Deshimaru and Shigeno (1972) demonstrated that the most rapid growth with *P. japonicus* occurred when test diets contained more than 60% crude protein.

Differences in protein requirement may be associated with differences in feeding habits. For example, *M. monoceros* remain buried in mud during day time and uncover themselves at night to feed (Qasim and Easterson, 1974; Joshi *et al.*, 1979), a habit exhibited by *P. japonicus* also (Deshimaru and Shigeno, 1972). Moreover, it is likely that their natural feeding habit is also reflected in their energy budget. Examination of gut contents by George (1974) showed that *M. monoceros* below 50 mm in length consume large quantities of detritus whereas those with more than 50 mm length, consume less of it and the food largely includes animal matter. Thus Qasim and Easterson (1974) obtained high K_1 and K_2 values of 35 and 36% respectively for *M. monoceros* fed on detritus, in the size range of 17-20 mm, while in larger specimens (41-46mm) K_1 and K_2 values were reduced to 10.5 and 11.7% respectively. They could also observe a shift in the feeding habit of this prawn, with larger ones developing carnivorous tendencies. These changes in food habits associated with size (age) of M. monoceros can be due to the change in its quantitative as well as qualitative protein requirements.

The nutritional consequences of changes in salinity are often overlooked, although there exists a complex relationship between salinity and the ratios between energy sources (Provasoli, 1976). In Artemia, it is demonstrated that at high salinities, non-essential aminoacids takeover the role of energy sources, that the carbohydrates and lipids play at lower salinities (Hernandorena, 1974).

All these indicate that the K_1 and K_2 values are food quality dependent. However, the same feed being given to prawns at all test salinities in both experiments, the validity of the results obtained in the present study, on a relative basis, cannot be doubted.

VI SUMMARY

VI. SUMMARY

1. The objective of the present study is to find out the effect of salinity on survival, growth, food intake, conversion efficiency and assimilation efficiency of the juveniles of the prawn *Metapenaeus monoceros.*

2. The study to evaluate the effect of salinity on survival was carried out in perspex tanks of 28 x 16 x 30 cm, with 5 prawns/tank, containing 10 L of water.

3. The prawns acclimated at 25 ppt salinity for 10 days were abruptly transferred to 0, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 42, 44, 45 and 50 ppt levels to find out the LC_{50} values for 120 Hr. period.

4. Cent per cent mortality was recorded at zero and 50 ppt, while there was 100% survival at 5-35 ppt salinity levels, during the 120 Hr. experimental period.

5. Probit analysis technique was used to estimate the LC_{50} values. The lower and higher LC_{50} values

for 120 Hr. period were 1.03 ± 0.51 and 42.67 ± 0.52 ppt respectively, which indicated the wide salinity tolerance range of this species.

6. In order to evaluate the effect of salinity on food intake, growth, conversion efficiency and assimilation efficiency, two experiments were conducted in cement cisterns, having 90 cm diameter and 60 cm height with 100 L of water, keeping 10 prawns in each tank.

7. The prawns in both of the growth experiments were fed daily with a prepared pelleted feed having 35.50% protein, *ad libitum*. The feed remnants and excreta were collected, dried at 60°C and later used for the estimation of food intake and growth efficiencies.

8. The water in the experimental tanks was not exchanged but was aerated throughout the course of the experiments and the water quality parameters were monitored.

9. The percentage food intake, percentage weight increase, conversion efficiency (%) and assimilation

efficiency (%) at different salinity levels and growth periods were subjected to two-way ANOVA (after angular transformation of the respective percentage values) in both experiments.

10. In the first growth experiment _M_. _monoceros_ juveniles (0.4728 ± 0.0893 g wet weight and 41.52 ± 6.48 mm TL) were grown at 5, 15, 25 and 35 ppt salinities for 35 days with 0-15, 0-25 and 0-35 days as the three growth periods, each treatment being replicated thrice.

11. The influence of salinity on food intake of the prawns was not significantly different within the tested salinity levels between 5 and 35 ppt. But percentage weight increase, conversion efficiency and assimilation efficiency were significantly different among the salinity levels tested.

12. The percentage weight increase was higher at 25 ppt than at 5 and 15 ppt levels, but was comparable to that at 35 ppt salinity.

13. Prawns showed highest conversion efficiency at 25 ppt, while the values were comparable at all other salinity levels tested (5, 15 and 35 ppt).

14. The partition of the data among growth periods revealed a declining trend for percentage weight increase associated with a corresponding decrease in percentage food intake.

15. Assimilation efficiency was found comparable between 5 and 15 ppt, 5 and 35 ppt as well as between 25 and 35 ppt salinities. However, at 25 ppt, it was significantly lower than that at 5 and 15 ppt. Similarly, a significantly lower assimilation efficiency value was recorded at 35 ppt compared to that at 15 ppt salinity.

16. The growth efficiency values on dry weight basis (K_1 and K_2) were comparatively lower in the lower test salinity levels (5 and 15 ppt) than in the higher test salinity levels (25 and 35 ppt).

17. Prawns at 25 ppt salinity showed highest conversion efficiency even with a significantly lower assimilation efficiency, which may be due to the prawn utilising more energy for body building than for metabolism at 25 ppt.

18. The second growth experiment intended to compare the food intake, growth, conversion efficiency and assimilation efficiency between two size groups of M. monoceros, designated as group I and group II prawns respectively was conducted at 20, 25, 30 and 35 ppt salinities for 30 days, with 0-10, 0-20 and 0-30 days as the three growth periods. Each treatment was replicated twice.

19. In group I prawns (smaller size group) the effects of salinity on food intake, percentage weight increase, conversion efficiency and assimilation efficiency were not significantly different among the four salinity levels tested.

20. In group II prawns (larger size group) also the influence of salinity on food intake and percentage weight increase was not significantly different. However, conversion efficiency and assimilation efficiency were significantly influenced by salinity.

21. Conversion efficiency value was higher at 25 ppt than at 30 and 35 ppt, while it was comparable

between 20 and 25 ppt, 20 and 30 ppt and between 30 and 35 ppt salinities. However, conversion efficiency value recorded at 35 ppt was significantly lower when compared to that at 20 and 25 ppt salinity levels.

22. Assimilation efficiency values recorded at 20, 25 and 30 ppt for the group II prawns were found comparable, but it was significantly lower at 35 ppt salinity.

23. Comparison between group I and group II prawns showed significantly higher percentage food intake and percentage weight increase in the former at all test salinity levels.

24. Conversion efficiency values were also higher in group I prawns at all salinities excepting 25 ppt, at which it was comparable with that of group II.

25. Assimilation efficiency was comparable at all test salinity levels between the two size groups, except for a lower value at 20 ppt in group I.

26. The growth efficiency values calculated on the dry weight basis (K_1 and K_2) were higher in group I prawns than group II at all test salinity levels. However, the K_1 as well as the K_2 values were more or less uniform among the treatments in either size groups.

27. Even with a comparatively high assimilation at all salinity levels, prawns showed lower growth efficiencies (K_1 and K_2) in the present experiment with the feed having a protein content of 35.50%, indicating a still higher level of protein requirement in the feed for M. monoceros juveniles.

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VII. REFERENCES

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EFFECT OF SALINITY ON FOOD INTAKE, CONVERSION EFFICIENCY AND GROWTH OF THE PRAWN METAPENAEUS MONOCEROS (FABRICIUS)

By

SURESH BABU C.

ABSTRACT OF A THESIS

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ABSTRACT

Salinity tolerance of the juveniles of the prawn Metapenaeus monoceros (Fabricius) was found out by abrupt exposure to high and low salinity levels after acclimation at 25 ppt salinity. 100% mortality was recorded both at zero and 50 ppt and no mortality between 5 and 35 ppt. The lower and higher LC_{50} values for 120 Hr. period were 1.03 ± 0.51 and 42.67 ± 0.52 ppt respectively. The juveniles with mean wet weight of 0.4728 ± 0.0893 g (41.52 ± 6.48 mm TL) were grown at 5, 15, 25 and 35 ppt salinities for 35 days (first experiment), to find out the effect of salinity on food intake, growth, conversion efficiency and assimilation efficiency. Food intake was found uniform throughout the test salinity levels. Growth and assimilation efficiency were comparable between 25 and 35 ppt but conversion efficiency was higher at 25 ppt salinity. Similarly, growth and conversion efficiency were higher at 25 ppt than at the lower test salinities (5 and 15 ppt), even with a significantly lower assimilation efficiency. Growth, conversion efficiency and assimilation efficiency were not significantly different between 5 and 15 ppt as well as between 5 and 35 ppt salinities. Prawns at 15 ppt showed growth and conversion efficiency comparable to

that at 35 ppt though assimilation efficiency was more at 15 ppt salinity.

In the second growth experiment M. monoceros juveniles of mean wet weight of 0.4996 ± 0.0695 g (42.13 ± 5.62 mm TL) and of 1.5483 ± 0.1875 g (63.19 ± 5.16 mm TL) designated as group I and group II respectively were grown at 20, 25, 30 and 35 ppt salinities for 30 days, to compare food intake, growth, conversion efficiency and assimilation efficiency between the two size groups. In the group I prawns, food intake, growth, conversion efficiency and assimilation efficiency were comparable among the four test salinities. This was the case with group II prawns also with respect to food intake and growth. In group II prawns conversion efficiency was significantly higher at 25 ppt than at 30 and 35 ppt, and significantly lower at 35 ppt than at 20 and 25 ppt salinities. Comparable conversion efficiency was obtained between 20 and 25 ppt, 20 and 30 ppt and between 30 and 35 ppt salinities. The lowest assimilation efficiency was recorded at 35 ppt while at all other test salinities, it was more or less uniform.

The comparison between group I and group II prawns showed that the percentage food intake and percentage weight increase were higher in group I prawns. They also showed higher conversion efficiency at 20, 30 and 35 ppt salinities, but the value for 25 ppt was comparable to that of group II prawns. Assimilation efficiency of the two size groups were not different among 25, 30 and 35 ppt salinities but at 20 ppt, group I prawns had lesser assimilation efficiency than group II prawns. The dry weight balance, in both growth experiments, showed high assimilation efficiency and comparatively low growth efficiency (K_1 and K_2) values in all treatments, indicating higher protein requirement in the diet for M. monoceros.