POPULATION CHARACTERISTICS OF PRAWNS IN NATURAL AND SELECTIVE STOCKING SYSTEMS

Thesis Submitted in
Partial Fulfillment of the Requirement for the Degree of

Doctor of Philosophy
of

The Cochin University of Science and Technology

BY
E.M. ABDUSSAMAD, M.F.Sc.

भाकृअनुप
ICAR

Post-Graduate Programme in Mariculture

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
(ICAR)
KOCHI-682 014

June 2001

DECLARATION

I hereby declare that the thesis entitled, "**Population Characteristics of Prawns in Natural and Selective Stocking Systems**" has not previously formed the basis for the award of any degree, diploma, associateship or other similar titles or recognition.

Kochi-14
June-2001

E.M. ABDUSSAMAD
Scientist
C.M.F.R.I.

CERTIFICATE

This is to certify that the thesis entitled, "**Population Characteristics of Prawns in Natural and Selective Stocking Systems**" is the bonafied record of the research work carried out by Shri. E.M. Abdussamad, under my guidance and supervision at the Post-Graduate Programme in Mariculture, Central Marine Fisheries Research Institute (CMFRI) and that no part thereof has been presented for the award of any other degree.

Kochi-14
June-2001

Dr. N. Gopinatha Menon
(Supervising Guide)
Senior Scientist,
C.M.F.R.I.

Dedicated

to

My Parents

ACKNOWLEDGEMENT

I am deeply indebted to many, who rendered their help during the course of this study and preparation of this thesis in one way or another. I wish to put on record my sincere thanks to each and all of them.

First of all I am grateful to Dr. N. Gopinatha Menon, my supervising guide, who agreed at once to guide me without any hesitation, when Dr K. Alagaraja retired. I am grateful to him for his constant encouragement, support, critical evaluation of thesis and valuable suggestions.

I sincerely thank Dr. Mohan Joseph Modayil, Director, CMFRI, Kochi, for his constant encouragement and support.

I am equally thankful to Dr. K Alagaraja, Retired Principal Scientist and my former guide, under whose guidance and supervision I started this work. I am thankful to him for his guidance in experimental design, statistical analysis, interpretation of results, critical evaluation of thesis, constructive criticism and valuable suggestions.

I sincerely thank Dr. Paul Raj, Officer-In-Charge, Post-Graduate Programme in Mariculture, CMFRI, Kochi, his help, constant encouragement and support.

I am thankful to Dr. H. Mohamed Kasim, Senior Scientist, R.C. of CMFRI, Kakinada for his all hearted guidance in computer-based data processing and valuable suggestions.

I sincerely thank Dr. M. Devaraj, former Director, CMFRI, Kochi, for permitting part-time Ph.D. and also for his constant encouragement and support.

I also wish to record my sincere thanks to Dr. Shahul Hameed, former Director, School of Industrial Fisheries, Cochin University of Science and Technology (CUSAT), for his constant encouragement and guidance in matters related to University.

This work was done partly during the tenure of S.R.F. of ICAR, I am thankful to the COUNCIL for providing me the fellowship.

This work couldn't have been carried out without the active support of several shrimp farmers and farm workers. I ever thankful to them, for their co-operation by way of allowing sampling and providing me many vital informations.

I am thankful to my colleagues, especially Joseleen Jose, Scientist, CMFRI, Dr. M.K.Anil, Scientist, CMFRI, Dr. Sini Joys Mathew and Dr.C.H. Fernandez, who all rendered their help both in the field and laboratory in sample collection and laboratory studies.

I have to specially thank my family members, especially my wife and daughter, who suffered a lot during the course of this study. I sincerely acknowledge their silent suffering and whole-hearted co-operation.

I am ever thankful to PGPM staff, especially Mr. M. John (Retd. Superintendent) and Mr.Surendran, for their timely administrative and clerical help throughout.

My sincere thanks are also to Mr. Surendran, Mr. Soman and Mr Mathew, jeep drivers for their co-operation and help during field visits.

PREFACE

Penaeids are distributed widely in shallow tropical and sub-tropical waters and support to the fisheries production potential all along the Indian region. This being highly priced world over, there has been continuous attempt to increase the production through capture and culture. This has paved the way for irrational harvest from wild as well as environmental non-friendly culture, which ultimately lead to many resource/environmental maladies resulting in the collapse of shrimp culture world over. Moreover, their production is also reported to be dwindling from many traditional fishing grounds.

Cochin backwaters and the adjacent tidal ponds, where traditional prawn culture/fishing in vogue are part of such fishing grounds. Average prawn yield from the tidal fields of this area through traditional culture in 1950's been over 1180 kg/ha. Through 1960's and 1970's production level declined to 600-700 kg/ha and by eighties and nineties it has declined further to 300-620 kg/ha. In addition to the decline in production, economy of this fishery has further been affected by the decreased contribution of *P. indicus* in the catch. This decline in prawn production was attributed by many to man made stress on the ecosystem and stock on a bid to increase production.

The shrimp fishery is complex with regard to the life history of the species and nature and operation of different fisheries. Early life stages of penaeids occur close inshore and in estuaries and backwaters while as growth proceeds, they move offshore and the old and larger animals are found in relatively deep waters. Being the main target of traditional culture and capture fisheries, they are highly vulnerable to different means of exploitation during their early growth phase. Moreover, they are also susceptible to natural environmental changes and man-made changes like pollution and mangrove destruction. As such, optimum utilization of these resources requires good knowledge on the dynamics of individual species in the population. Such information points out what measures have to be adopted in each circumstance, to regulate the resources for maximum benefits.

In view of the importance of penaeid shrimps in the traditional fishery of backwaters and adjacent tidal ponds, this study is most appropriate, as it will provide vital scientific cues for the management of these resources during their nursery phase.

TABLE OF CONTENTS

General Introduction

GENERAL INTRODUCTION

Shrimps are extremely valuable resources, in view of their large domestic as well as export demand. Their high value emphasizes the importance of resource management, especially, since substantial increase in global shrimp production is not expected, to make most efficient use of the stocks in existing fisheries. However, shrimp management is somewhat different in concept than management of other fisheries, owing to its unique life history.

The important biological characteristic of penaeids is the presence of two distinct phases in their life cycle, involving postlarval and juvenile phase living close to inshore waters or in estuaries which serve as their nursery and an adult phase in deeper waters, where they mature and spawn. Different species spend variable amount of time, ranging from few weeks to several months in their nursery habitats.

The open estuary and tidal ponds of Cochin, where traditional prawn fisheries exist are ideal nurseries for prawns. Fishery of the tidal ponds involves trapping wild seeds during nursery phase and allowing them to feed naturally and grow till they emigrate when they are caught in filternets. Tidal ponds are generally extensive in nature with little or no management. These habitats, however, provide a potential and biologically healthy environment for the growth of prawns and fishes.

In seasonal ponds, paddy and prawn are cultivated alternately. Paddy is cultivated during monsoon, when salinity becomes low. After paddy harvesting in October, prawn and fish seeds are allowed to enter the field during high tides. Harvesting starts in November and is carried out for 6-7 days around every full and new moon. The process of trapping and filtration continue till the middle of April, when ponds are drained and the entire stocks were harvested. Perennial ponds are non-drainable and filtration is carried out round the year. However, occasional partial harvesting is resorted, when any calamities struck or large proportion of good-sized prawns encountered in the catch.

Shrimp fishery of tidal ponds is supported mainly by *M. dobsoni, P. indicus* and *M. monoceros*. Despite, having many biological features in common, like backwater nursery phase, variations are expected to occur in the degree to which the brackishwater environment is put to use by each species and their distribution.

In view of the importance of these habitats for shrimp fisheries, several studies have already been carried out on the ecology and related aspects (Menon and Raman, 1961; George, 1961; 1962a; 1962b; Banergy and George, 1967; Mohamed and Rao, 1971; Kuttyamma and Antony, 1975; Gopalan *et.al.* 1980; Muthu 1983; Mammen, 1984; Purushan and Rajendran, 1984; Jose *et.al.*, 1987). These studies provided considerable information on the ecology and some aspects of biology of major species. However, information on many vital aspects on the resource characteristics is still lacking.

Nursery areas being separate from adult habitats and its extreme vulnerability to natural environmental changes and human interference including fishing and habitat modifications, necessitated separate management practices for balanced utilisation of the resources. Living resources, being always in a dynamic state, such measures should be based on sound knowledge on the resource characteristics of individual species. Since, tidal ponds form part of the obligatory nursery grounds of penaeid shrimps, such information will be useful, not only for the management of tidal pond fishery, but for the backwaters as a whole.

In view of the above, this study was designed to understand more about postlarval recruitment, distribution, growth, mortality, emigration and yield of major species under different conditions. Purpose of this study is to develop scientific basis for management decision, through better understanding of the population, about which management decision has to be made.

Study materials for postlarval recruitment was obtained from set nets and liftnets; distribution, abundance and growth from liftnets and castnets and emigration from filternets and set nets. Yield data were collected by direct observations and from farmer's registers.

Results of the present study are presented in the forthcoming chapters. Study sites and characteristics are briefed in Chapter-1 and their hydrology in Chapter-2. Chapter-3 deals with postlarval ingression and recruitment and Chapter-4, distribution and abundance over time and space. Age and growth are dealt with in Chapter-5 and mortality in Chapter-6. Emigration of prawns is discussed in Chapter-7. Chapter-8 deals with length-weight relationship and condition factor, Chapter-9 sex ratio and sexual maturity and Chapter 10 yield. Summary, conclusion and references are provided in the order towards the end.

Study Area

Chapter-I

STUDY AREA

Study was conducted in eight tidal ponds located along the Cochin backwaters, towards north, south and east of bar mouth and at two open backwater sites. Tidal ponds, based on the prevailing management practices were classified as; i. perennial ponds-large and deep enclosures of 2 to 75 ha water spread and 1.0 to 4 m depth, ii. seasonal ponds without paddy rotation (Type-I seasonal ponds) -relatively small, shallow enclosures of 1 to 10 ha water spread and 1 to 2.5 m depth, iii. seasonal ponds with paddy rotation (Type-II seasonal ponds) - small, shallow enclosures of 1 to 4 ha water spread and 1 to 1.5 m depth and iv. modified extensive (selective stocking) ponds.

Tidal ponds for study were selected on the basis of mode of their operation and location. Two each of the tidal ponds were perennial, seasonal without paddy rotation, seasonal with paddy rotation and modified extensive in management (Fig 1.1). Physical features of the tidal ponds were given in Table 1.1.

One perennial (F1) and a Type-I seasonal pond (F3) was located at Edavanakkad, about 15 km north of bar mouth were selected. A similar selection (F2 and F4) was made at Panangad located about 16-17 km away from bar mouth. Type-II seasonal ponds were selected one each at Kannamali (F5) and Tripunithura (F6) about 12 and 20 km respectively from bar mouth. Stocking pond, F7 was located at Puthuvypeen, and F8 at Chellanam, about 6 and 22 km respectively from bar mouth.

Two stake net units in the open backwater near Panangad were also selected to monitor the emigration of prawns in the estuary.

Tidal ponds located at Panangad and Tripunithura along the inner upper regions of the backwaters had less marine influence when compared to other sites. Nearly freshwater condition prevails at these sites during peak monsoon and brackish during other season. Stocking pond at Chellanam has marine influence round the year due to its proximity to Anthakaranazhy. Tidal ponds invariably have muddy bottom, except for stocking pond F8 at Puthuvypeen, which had silty clay bottom.

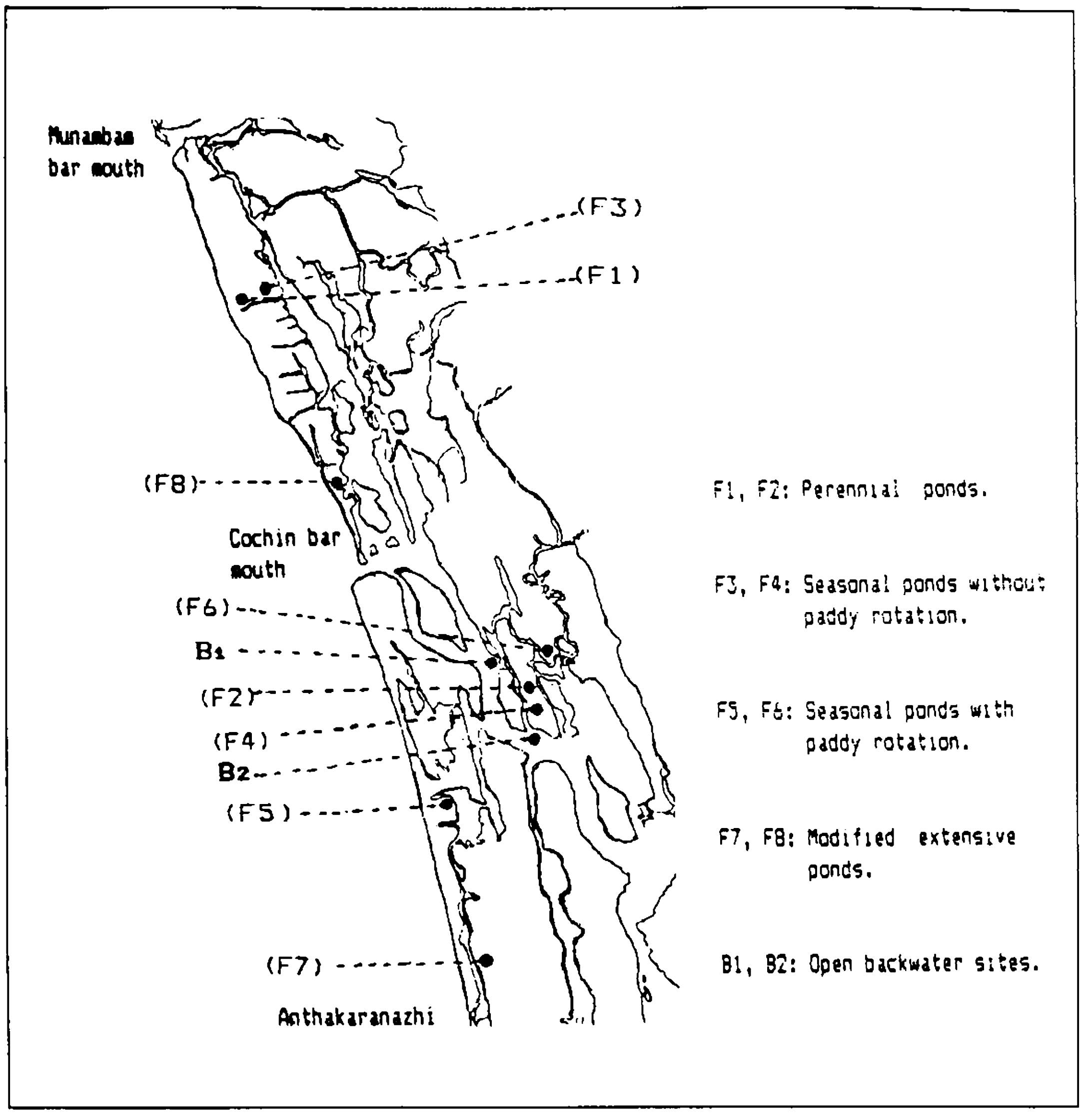


Fig 1.1.Site map showing location of the tidal ponds and open backwater sites.

Tidal ponds located at different gradients from bar mouth were chosen for the study, as they formed nursery areas for estuarine dependent penaeids and support all commercially important species. At the same time due to their location, these areas are exposed to varying levels of marine and freshwater influence and have different ecological conditions. These enable one to study in detail, the influence of varying ecological conditions on the biology of the species.

Table 1.1 Location, distance from bar mouth and physical features of the tidal ponds.

Type of Tidal Ponds	Location	Distance from Barmouth (Km)	Period of Operation (months)	Depth (m)	Water Spread Area (ha.)	Bottom Type	Rate of Water Exchange (%)
Perennial (F1)	**Edavanakkad**	15	12	1.0-3.5	74.0	**Muddy sand**	10
„ **(F2)**	**Panangad**	16	12	0.6-3.3	10.0	**Muddy sand**	20
Seasonal Type-I (F3)	**Edavanakkad**	15	8	0.5-2.3	7.5	**Muddy sand**	30
„ „ **(F4)**	**Panangad**	17	7	0.5-2.2	6.0	**Muddy sand**	35
Seasonal Type-II (F5)	**Kannamali**	12	8	0.6-1.8	2.0	**Muddy sand**	40
„„ **(F6)**	**Tripunithura**	20	7	0.4-1.8	2.4	**Muddy sand**	45
Stocking (F7)	**Chellanam**	22	12	0.9-1.5	2.3	**Muddy sand**	60
„„ **(F8)**	**Puthuvypeen**	6	12	0.8-1.5	2.8	**Silty clay**	45

Fig 1.2 A view of the perennial tidal pond, F1 at Edavanakkad.

Fig 1.3 A view of the perennial tidal pond, F2 at Panangad.

Fig 1.4 A view of the Type-I seasonal tidal pond F3, at Edavanakkad.

Fig 1.5 A view of the Type-I seasonal tidal pond, F4 at Panangad.

Fig 1.6 A view of the Type-II seasonal tidal pond, F5 at Kannamali.

Fig 1.7 A view of the Type-II seasonal tidal pond, F6 at Tripunithura.

Fig 1.8 A view of the selective stocking pond, F7 at Puthuvypeen.

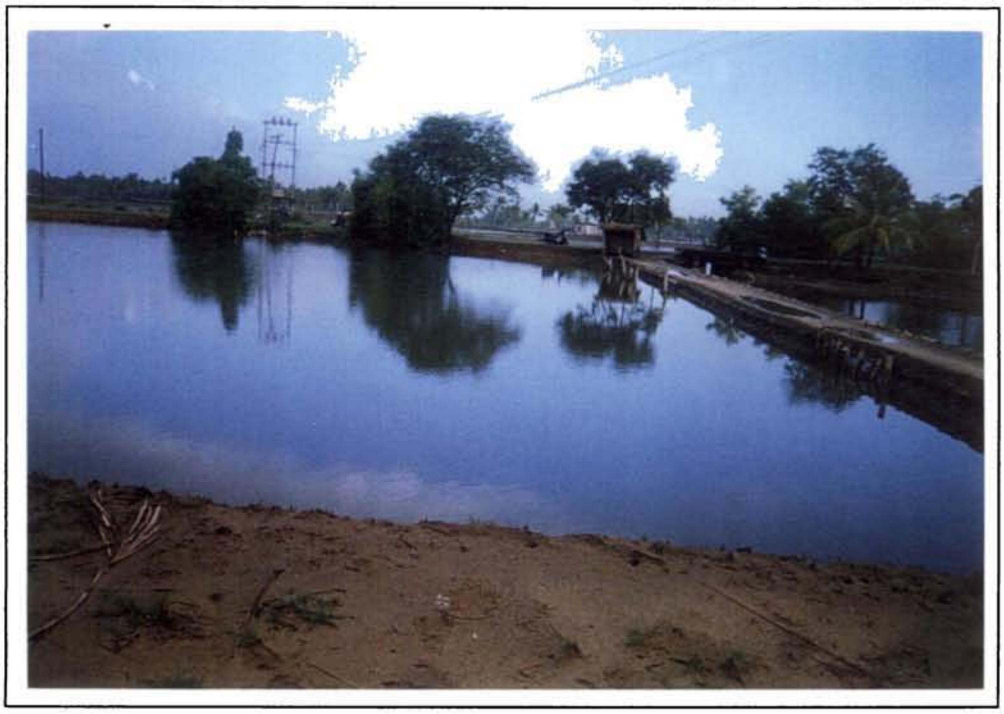


Fig 1.9 A view of the selective stocking pond, F8 at Chellanam

Fig 1.10 The experimental pond at Chellanam, used for predator free culture trial.

Fig 1.11 The stake net units in the open backwater near Panangad.

Fig 1.12 The process of "trapping in" post-larva into tidal ponds by freely letting in tidal water through sluice gate at high tide.

Fig 1.13 Thoombuvala (filtration net) used for harvesting emigrating prawns from tidal ponds.

Fig 1.14 Harvestig shrimp from perennial pond using filtration nets at sluice gate during ebb phase of spring tide.

Hydrology

Chapter-2

HYDROLOGY

INTRODUCTION

Hydrology plays vital role in determining postlarval recruitment, growth, survival, carrying capacity with an ultimate effect on production from the habitat. Measures of water quality variables such as salinity, temperature, pH, nutrients and productivity can be taken as an index of suitability of any habitat for the species concerned.

Tidal ponds, being connected to the main estuary either directly or by long chains of feeder canals are considered extensions of backwaters and estuaries. They experience wide fluctuations in hydrology over the seasons and provide a specific ecosystem distinct from open backwaters, due to lack of free mixing and inter-change with the main backwater ecosystem. In view of the importance of backwaters and adjacent tidal ponds for prawn and fish culture, number of studies have already been carried out on their ecology. Many studied seasonal changes in the ecology of open backwaters (Ramamritham and Jayaraman, 1963; Cheriyan, 1967; Qasim *et.al.*, 1969; Gopinathan, 1972; Gopinathan *et.al.*, 1974; Nair and Kutty, 1975; Nair *et.al.*, 1975; Pillai *et.al.*, 1975), whereas others described environmental characteristics of traditional prawn culture farms and adjacent fields (Paulinose *et.al.*, 1981; Gopinathan *et.al.*, 1982; Nair *et.al.*, 1982; 1988; Sankaranarayanan *et.al.*, 1982; Vasudevappa, 1992; Balasubrahmanyam *et.al.*, 1995). They correlated hydrology with the over all productivity of these habitats. Fast and Carpenter (1988) described significance of water depth on the environmental dynamics of shrimp ponds. Mrithunjayan and Thampi (1986) investigated the causes of pH fluctuation in prawn culture ponds over different seasons.

Most of the above studies, however, were general in nature and confined to short periods of time or to a limited area. So their usefulness in understanding the dynamics of shrimp stocks and yield characteristics is limited. The present study is aimed to understand more about the ecology of tidal ponds and to identify and quantify their impact on the dynamics of penaeid prawns during nursery and grow-out phase.

MATERIALS AND METHODS

Materials:

Materials for the study were collected from tidal ponds and backwaters at fortnightly intervals following standard procedures (Strickland and Parson, 1972). Air and water temperatures were measured on the spot by standard thermometer and turbidity by Secchi disc. These measurements and collection of hydrographic samples for laboratory analyses were made during morning hours.

Methods of Water Analysis:

Standard methods were used to study different water quality parameters as briefed in Table 2.1.

Table 2.1 Water quality variables and the standard procedures followed in the study.

Variables		Standard Procedures Followed In the study
Salinity	:	Knudsens titremetric method
Dissolved Oxygen		Standard Winklers method
Nitrate	:	Photometric method
Phosphate	:	Photometric method
Alkalinity	:	Titremetric method
Hardness		Titremetric method
pH		Electrometric method using ELICO digital pH meter; Model L1-122

Phytoplankton production was measured quantitatively by filteringpond water through bolting silk No. 20, 69 mesh/cm^2. During each sampling 100 litres of water was collected from different areas of the pond and filtered through the net. Concentrated samples were preserved immediately with 4% formalin to avoid grazing by zooplankton. Settlement volume was obtained by centrifuging these samples for 10 minutes.

The ecological data from the tidal ponds and backwaters were subjected to ANOVA and F-test (Snedecor and Cochran,1967).

RESULTS

Temperature:

Temperature fluctuation was more or less similar and showed no significant (P> 0.05) variation between tidal ponds (Fig. 2.1, Table 2.2). However, water temperature was relatively high in small shallow ponds during summer months than large deep ponds. Temperature was low, 27.5 to 29.0°C during monsoon and high 30.9 to 32.3 °C during pre-monsoon months. It gradually increased after monsoon and attained the peak by April. Annual temperature variation was small, between 2.7 and 4.4°C in tidal ponds, with a mean of 3.3 +/-0.6°C. It was minimum in perennial and maximum in seasonal ponds.

In open backwaters temperature was comparatively low throughout the year and ranged between 26.87°C in July and 29.4°C in April (Table 2.3). But seasonal fluctuations followed the same pattern as in tidal ponds.

Table 2.2 Annual range and mean (parentheses) of major water quality variables in different tidal ponds.

Hydrographic Parameters	TIDAL PONDS F1	F2	F3	F4	F5	F6	F7	F8
Wat. Temp (°C)	28.9-31.7 (29.53)	28.9-31.8 (29.96)	27.9-32.0 (29.82)	27.5-31.9 (30.01)	28.8-32.3 (30.62)	29.0-32.1 (30.46)	28.2-30.9 (29.96)	28.9-31.9 (29.81)
Salinity (ppt)	1.9-25.1 (11.97)	0.8-21.6 (8.23)	2.6-25.0 (12.50)	0.5-20.9 (8.57)	0.8-22.1 (10.05)	0.1-17.9 (8.15)	2.9-24.5 (12.21)	3.6-25.9 (13.21)
D.Oxygen (ppm)	3.8-5.3 (4.51)	4.1-5.9 (4.52)	3.7-5.0 (4.33)	3.9-4.7 (4.18)	4.1-5.0 (4.02)	3.9-4.6 (4.33)	3.9-5.4 (4.51)	4.0-5.3 (4.48)
Water pH	6.0-8.1 (7.02)	5.9-8.0 (6.95)	6.3-7.9 (7.15)	5.9-8.1 (7.11)	6.3-7.4 (7.05)	6.1-8.0 (7.21)	6.6-8.2 (7.38)	6.3-8.1 (7.28)
Soil pH	5.3-7.1 (6.59)	5.8-7.1 (6.50)	5.9-7.2 (6.66)	5.8-7.1 6.72)	6.0-7.1 (6.68)	6.3-7.4 (6.81)	6.8-7.7 (7.21)	6.6-7.5 (7.02)
Tot.Alkal (ppm)	61-279 (129.0)	42-233 (115.7)	43-247 (136.9)	38-230 (121.7)	47-245 (141.2)	31-210 (92.5)	54-256 (140.4)	38-250 (151.8)
Hardness (ppm)	375-3245 (1598.1)	124-2876 (1421.5)	313-3042 (1528.3)	371-2870 (1383.8)	344-3083 (1472.6)	124-2796 (1382.6)	242-3411 (1859.3)	402-3362 (1967.6)
NO3-N (µg at/l)	0.7-2.9 (1.44)	0.7-2.9 (1.66)	1.0-3.1 (1.70)	1.0-3.1 (1.68)	1.2-3.4 (1.87)	1.1-3.6 (1.82)	1.5-4.3 (2.77)	1.5-3.9 (2.56)
PO4-P (µg at/l)	0.8-3.1 (1.86)	1.0-2.9 (1.97)	0.9-2.9 (1.91)	1.1-3.7 (1.94)	1.0-3.7 (1.97)	1.2-3.2 (1.73)	1.2-4.4 (2.88)	1.3-3.9 (2.58)
Plankton (ml/m3)	0.8-2.9 (1.9)	1.6-4.1 (2.8)	1.7-4.1 (2.9)	1.9-4.6 (2.9)	2.1-4.8 (3.6)	2.3-4.3 (3.4)	2.1-6.2 (4.7)	2.1-5.7 (3.9)
Turbidity (*)	48-86 (69.9)	42-98 (68.4)	34-67 (50.8)	44-82 (63.9)	35-61 (47.7)	39-76 (57.7)	34-54 (42.6)	39-79 (53.8)

*- As Secchi disc visibility in (cm)

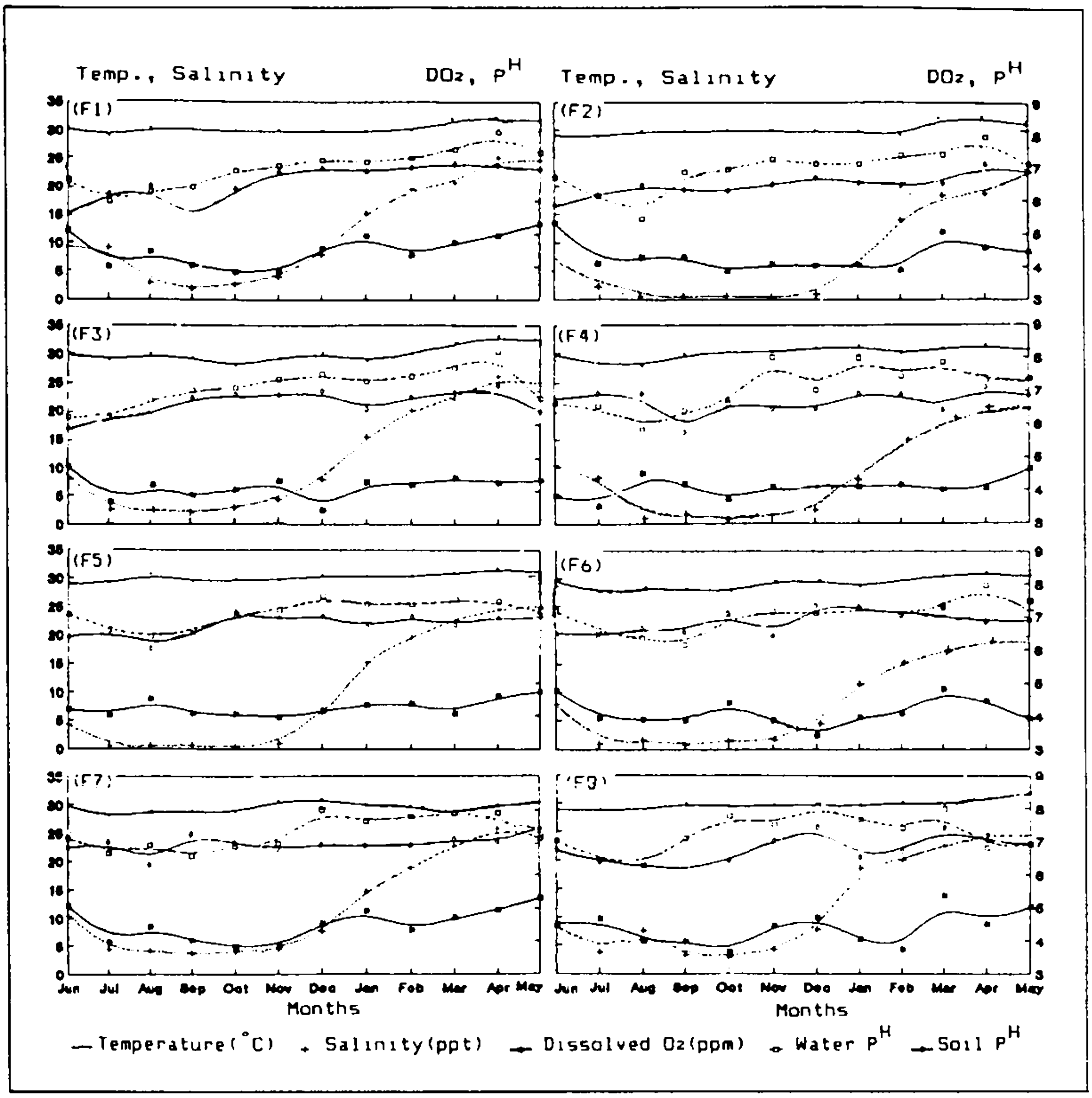


Fig 2.1. Seasonal fluctuations in temperature, salinity, dissolved oxygen and pH in tidal ponds.

Salinity:

Salinity varied in tidal ponds and open backwaters with location and season (Fig 2.1, Table 2.2, 2.3). It was relatively high in tidal ponds along the lower regions and low in that along the inner-upper regions. The high salinity range of 3.6 to 25.96‰ was recorded in tidal pond at Puthuvypeen, whereas, it was relatively low at Edavanakkad and Chellanam. It was the lowest 0.09 to 17.9‰ at Tripunithura with slightly high salinity at Panangad and Kannamali. It declined to the low of 0.09 to 3.6‰ during monsoon in tidal ponds respectively at Tripunithura and Puthuvypeen and to 1.04‰ in open backwaters by August. It gradually increased thereafter and reached the peak by pre-monsoon months. During May it was 17.9‰ in tidal pond at Tripunithura and 25.96‰ at Puthuvypeen and 25.8‰ in open backwater. The high saline condition persisted till June and there after it declined with the onset of south-west monsoon

Table 2.3 Seasonal fluctuation in the hydrographic conditions of open backwaters.

Parameters	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Mean
Water Temp. (°C)	27.2	26.9	27.8	28.4	27.9	28.7	29.9	28.2	28.8	29.1	29.4	29.7	28.4 (+/-0.78)
Salinity (ppt)	8.20	1.80	1.04	1.07	1.93	3.80	8.80	13.9	20.6	23.3	24.4	25.8	11.2 (+/-9.48)
Diss Oxygen (ppm)	4.90	4.82	5.73	5.32	4.90	4.63	5.70	4.28	4.35	5.01	4.80	4.21	4.89 (+/-0.48)
Water pH	8.30	7.23	7.90	8.40	8.36	7.23	8.20	7.80	8.40	8.60	7.98	7.99	8.03 (+/-0.42)
Nitrate-N (µg at./l)	2.13	2.25	1.87	2.99	2.79	2.99	2.19	1.92	1.41	2.06	1.91	2.01	2.21 (+/-0.57)
Phosphate-P (µg at./l)	2.09	3.47	3.60	2.95	3.61	3.98	4.06	2.84	2.69	2.96	2.57	2.72	3.15 (+/-0.76)
Plankton (ml/m^3)	1.52	0.94	1.04	1.22	1.46	1.72	2.26	2.06	2.68	2.46	3.64	2.94	2.00 (+/-0.79)

Dissolved Oxygen:

Wide fluctuation was observed in the oxygen content of tidal ponds and backwaters, but without any distinct spatial or seasonal pattern (Fig 2.1, Table 2.2, 2.3). It was relatively high, 4.48 and 4.52 ppm respectively in perennial and stocking ponds. In seasonal ponds it was low, between 4.13 and 4.33 ppm. Oxygen was consistently high in open backwaters (4.21 to 5.73 ppm), when compared to tidal ponds.

pH:

pH of soil and water in different tidal ponds showed no considerable variation (Fig 2.1, Table 2.2). The mean water pH of these habitats varied between 6.95 and 7.38. However, it varied between 5.86 and 8.19 over the season. It was low, 5.86 to 6.56 during August-September in tidal ponds. During other seasons it remained high, above 7.0. In open backwaters, pH was high throughout the year, where it fluctuated between 7.23 and 8.6 (Table 2.3). Seasonal fluctuation was relatively small in backwaters than tidal ponds.

pH of the pond soil was low compared to overlying water. In tidal ponds it ranged between 5.33 and 7.65 (Fig 2.1, Table 2.2). Soil pH followed almost the same pattern of seasonal fluctuation as of water. It was low during monsoon and high during other seasons. It was high in stocking ponds and low in perennial ponds.

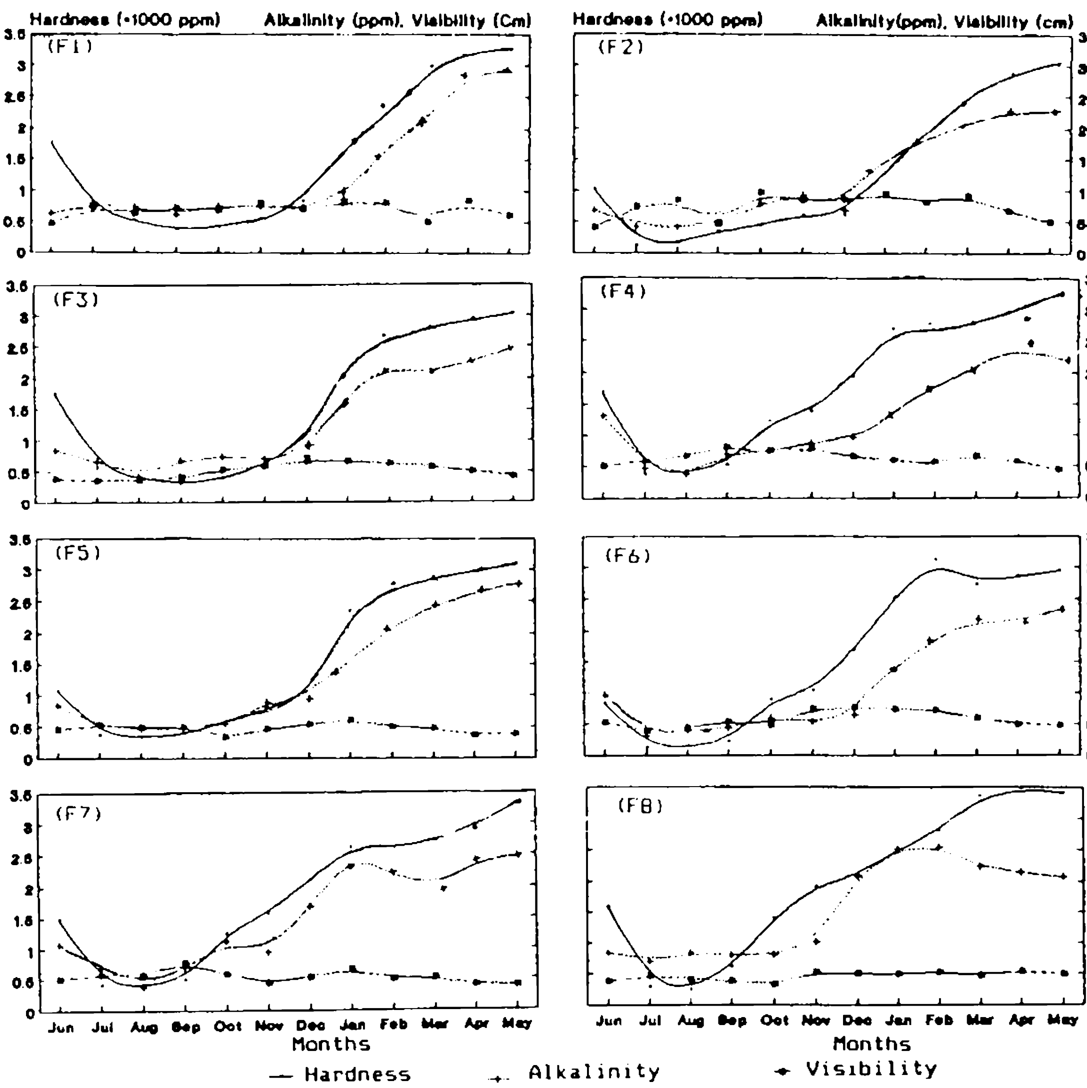


Fig 2.2 Seasonal fluctuations in total alkalinity, hardness and transparency in tidal ponds.

Total Alkalinity:

Alkalinity varied in different tidal ponds between 92.5 and 151.8 ppm (Fig 2.2, Table 2.2).

It was low in ponds located along inner-upper regions and high in ponds along lower regions of the backwaters. Seasonal variation was more pronounced ($P<0.01$) with low values during monsoon months. Thereafter it gradually increased to the peak by pre-monsoon months. Low values were recorded in August/September and high in April/May periods.

Hardness:

Hardness was relatively high in tidal ponds along the lower regions and along the upper regions of the backwaters (Fig 2.2, Table 2.2).. Seasonal variation was more pronounced with low hardness during monsoon and high during pre-monsoon months. It was low, 123.7 to 402.2 ppm during August-September and high, 2796.3 to 3426.0 during April/May.

Turbidity:

Turbidity was measured as secchi disc visibility. Turbidity was low, in perennial ponds as indicated by high, 68.4 to 69.9 cm visibility and high in stocking ponds with poor, 42.6 to 53.77cm visibility (Fig.2.2, Table 2.2). Wide variation was observed over seasons with high visibility, 54-98.3 cm during post-monsoon and low, 33.7 to 47.5 cm during pre-monsoon months.

Nutrients:

Nitrate:

Nitrate was high in stocking ponds, moderate in seasonal ponds and low in perennial (Fig. 2.3, Table 2.2). It ranged from 1.46 to 4.29 μg at./litre in stocking ponds and 0.99 and 3.54 in seasonal ponds. It was 0.69 to 2.94 μg at./litre in the perennial ponds and 1.41 to 2.99 in open backwaters (Table 2.3). Nitrate was relatively high during late monsoon and post-monsoon months and low during pre-monsoon months.

Phosphate:

Phosphate exhibited almost similar pattern of variation as nitrate (Fig. 2.3., Table 2.2, 2.3). It was high, 1.23 to 4.43 μg at./litre in stocking ponds and low, 0.76 to 3.08 in perennial ponds. It varied from 0.85 to 3.72 in seasonal ponds and 2.09 to 4.06 μg at./litre in open backwaters. It was high during late monsoon and post-monsoon and low during pre-monsoon months.

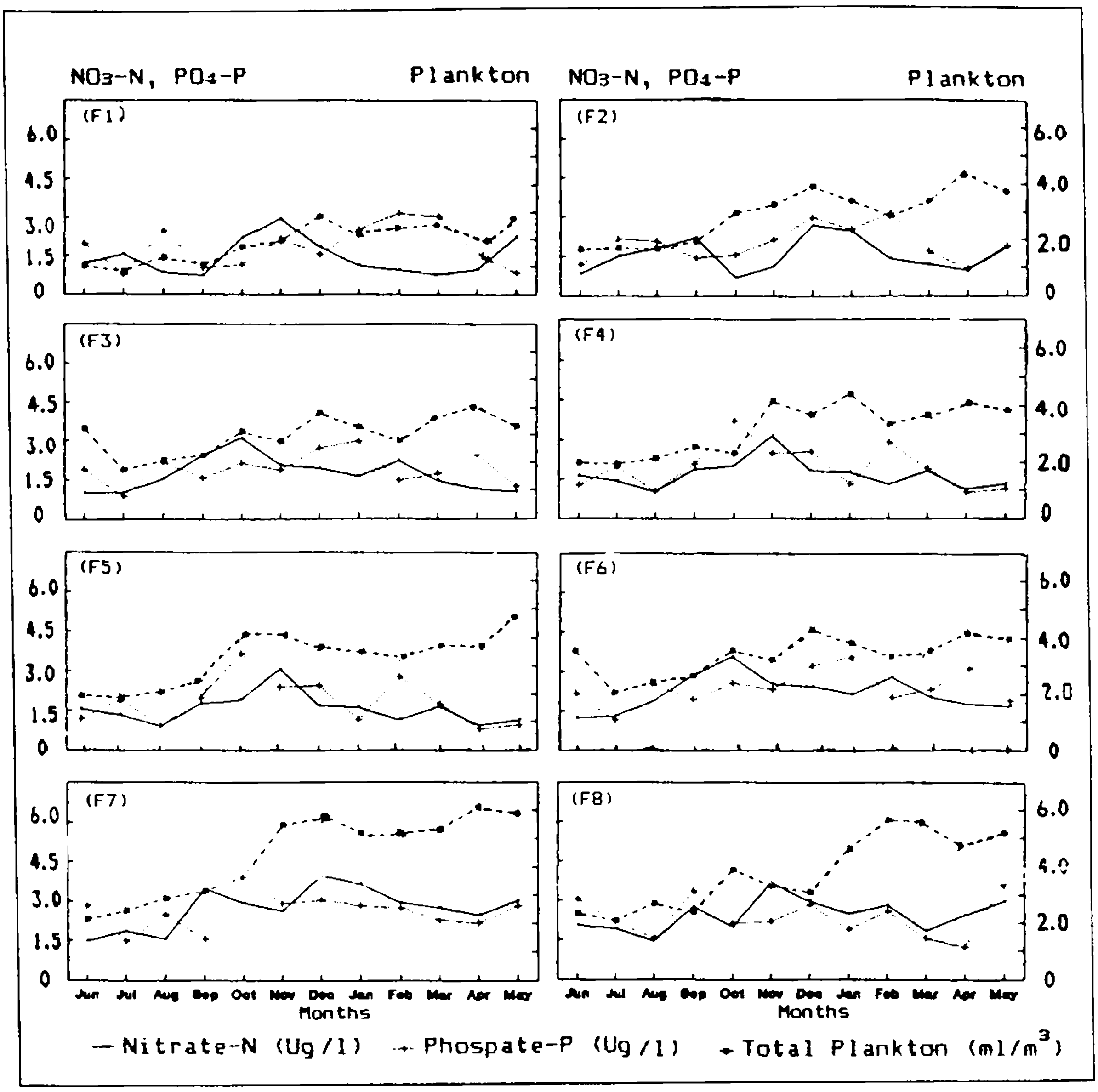


Fig 2.3 Seasonal fluctuations in nitrate, phosphate and total plankton production in tidal ponds.

Phytoplankton Production:

Phytoplankton production was high, 3.98 to 4.68 ml/m^3 of water in stocking ponds, moderate, 2.89 to 3.61 in seasonal and low, 1.97 to 2.76 in perennial ponds (Fig.2.3, Table 2.2, 2.3). In open backwaters, it was 2.0 ml/m^3 during the period. Seasonal fluctuation was very wide with low, 0.86 to 3.08 ml/m^3 during monsoon and high, 2.06 to 6.16 during pre-monsoon months in tidal ponds. In open backwaters it varied between 0.94 ml/m^3 in July and 3.64 in April.

DISCUSSION

Ecology of tidal ponds and open backwaters compared well with previous observations of Qasim *et.al.* (1969), Gopinathan *et.al.* (1974), Nair and Kutty, (1975) from open backwaters and of Gopinathan *et.al.* (1982), Nair *et.al.* (1988), Vasudevappa, (1992) and Balasubrahmanian *et.al.* (1995) from seasonal and perennial culture fields of the same area. Temperature of tidal ponds and open backwaters were well within the optimum range of 25-32°C for tropical species. Annual temperature fluctuation was also small, 2.7 to 4.4°C in tidal ponds and 2.83 °C in backwaters. This variation was very small compared to the earlier reports of Qasim *et.al.* (1969) from backwaters and Sankaranarayanan *et.al.* (1982) and Balasubrahmanian *et.al.* (1995) from tidal ponds. In the present study temperature was found to be relatively high in tidal ponds than open backwaters. Due to static nature of pond water, surface layers get heated up very fast during daytime. But in open backwater temperature disseminated to deeper layers due to continuous flow and mixing.

Wide spatial and seasonal fluctuations were observed in salinity during the study. Similar salinity fluctuations were reported from the same area by earlier workers also (Josanto, 1971; Qasim and Gopinathan, 1969; Gopinathan *et.al.*, 1974, Pillai *et.al.*, 1975). Salinity depends on the relative strength of riverine and marine influence prevailing at each area during time to time. Along the inner-upper regions, riverine influence is high compared to lower regions and hence have low saline condition. During monsoon riverine influence was so strong that nearly freshwater condition prevailed in open backwaters and tidal ponds, especially along inner-upper regions.

Fairly good dissolved oxygen was observed in tidal ponds and backwaters indicating stable and healthy environment. Increased photosynthetic activity due to better solar illumination produced comparatively high oxygen during summer months. In shallow seasonal ponds with paddy rotation, poor oxygen condition prevails due to decomposition of paddy and other organic remains. Nair *et.al.* (1988), also considered organic decomposition as the cause for low oxygen in seasonal ponds.

In tidal ponds soil and water pH fluctuated during different seasons, with small values during monsoon months. Such low pH conditions in tidal ponds during monsoon was also reported by, Paulinose *et.al.* (1981) and Mrithunjayan and Thampi (1986). Latter reported drastic drop in the pH from 7 to 4.5 after monsoon rain and attributed to leaching of acid sulphate compounds into ponds following heavy rains. Gopinathan *et.al.* (1982) observed fluctuation in the sediment pH, between 3.5 and 7 in prawn culture fields. According to them decomposition of weeds deposited in that area produced an almost acidic condition in the bottom soil. The low pH observed in the present study during monsoon might have caused by the leaching of acidic compounds from the nearby land areas. During early phase of monsoon, pond water maintains the pH at high levels, by making use of its natural buffering capacity. But, towards later stages due poor water exchange hypoxy condition will develop along bottom layers. Decomposition of organic compounds under low oxygen condition will produce organic acids and reduce the sediment pH. Moreover, the acidic land drainage will sink to bottom owing to its high density and modify bottom pH. Frequent application of lime maintained pH of stocking ponds at a high level. Land drainage has little impact on the pH of open backwaters, due to high dissolved oxygen and continuous mixing with seawater owing to tidal influence.

Alkalinity was always above 20 ppm in tidal ponds and above 100 ppm during most part of the year, which is considered to be the productive range. Alkalinity dropped below 100 ppm during monsoon months, when all other ecological conditions deteriorated.

Transparency was low during pre-monsoon and high during post-monsoon months, the respective periods of high and moderate plankton production. However, detailed evaluation of the seasonal variation in transparency and plankton production showed that, considerable amount of turbidity was caused by suspended particles and so it cannot be taken as a measure of productivity. The low transparency during pre-monsoon season resulted from high plankton population and of monsoon by suspended particles. But the variation between tidal ponds reflected variation in plankton production, as effect of suspended particles on turbidity is more or less same in all areas.

Nutrients of tidal ponds varied considerably. Nutrients in these habitats were derived mainly from replenishment through water exchange and regeneration from organic sediments. Due to large size, water exchange and hence replenishment of nutrients and organic compounds were low in perennial ponds. Being small in size, water exchange was relatively large in seasonal ponds and hence have large inputs of dissolved nutrients and particulate organic matters. In tidal ponds with paddy rotation part of nutrients were derived through decomposition of paddy remains.

Similar nutrient patterns were reported from seasonal and perennial ponds by Paulinose *et.al.* (1981) and Gopinathan *et.al.* (1982). They attributed these variations to differential water exchange and regeneration from paddy remains. Stocking ponds were superior in nutrient status, as they received large inputs from the supplementary feeds. Nutrient fluctuations, however, followed a common seasonal pattern. Increased nutrient utilisation by the large phytoplankton populations during pre-monsoon months reduced their availability. Availability was relatively large during post-monsoon months, due to better water exchange associated with increased trapping activities.

Phytoplankton production was high in stocking and Type-II seasonal ponds and low in perennial ponds. It closely followed nutrient abundance, but modified by prevailing ecological conditions of the habitat. The high productivity of pre-monsoon was the result of large nutrient abundance combined with stable environment and better solar illumination. Unfavourable conditions like low pH and fluctuating salinity resulted in low production during monsoon, when nutrients were not limiting. However, pond location has no effect on productivity, as suggested by some earlier workers (George *et.al.*, 1968 and Gopinathan *et.al.*, 1982).

Postlarval Ingression and Recruitment

Chapter-3

POSTLARVAL INGRESSION AND RECRUITMENT

INTRODUCTION

Postlarvae of penaeid prawns enter inland bays, estuaries and adjacent tidal ponds in large numbers with tidal waters and utilise this zone as nurseries. Since, traditional prawn fishery depends on these recruits, information on their recruitment and abundance is important in the context of management.

Considerable information is available on postlarval ingression into Cochin backwaters and adjacent areas (George, 1962a; Rao, 1972; George and Suseelan, 1982; Suseelan and Kathirvel, 1982; Thampi *et.al.*, 1982; Easo and Mathew 1989; Mathew and Selvaraj, 1993; Mathew *et.al.*, 1993), Korappuzha estuary (Menon, 1980), Kayamkulam lake (Kuttiyamma and Kurian, 1978), Kali estuary (Achuthankutty and Nair, 1983), estuaries of Goa (Goswami and George, 1978a; 1978b; Goswami and Goswami, 1992), Vellar estuary (Sampandam *et.al.*, 1982), Muthupet backwater (Mohan *et.al.*, 1995), Pulicat lake (Subrahmanyam and Rao, 1968; Rao and Krishnayya, 1974), Godavari estuary (Subrahmanyam and Ganapati, 1971), Chilka lake (Ramakrishnaiah, 1979) and in other estuaries of the world (Staple and Vance, 1985; Forbes and Benfield, 1986a).

The earlier reports showed considerable diel, tidal, lunar and seasonal periodicities in abundance and recruitment. The causes of such fluctuations were discussed by Mair (1980), Mair *et.al.*(1982) and D'Incao (1991). Postlarval behaviour, which enable ingression into nurseries was described by Garcia and Le Reste (1981) and Staples and Vance (1985) and that enable settlement by Hall (1962). Many described influence of prevailing environmental conditions on immigration (Gunter, 1961; Hughes, 1969; Barber and Lee, 1975; Mair, 1980; Coles and Greenwood, 1983; Laubier, 1989; Staples and Vance, 1985).

The above studies and reviews by Edwards (1978) and Garcia and Le Reste (1981) provided considerable information on various aspects of postlarval ingression, but only little is known on the basic dynamics which produce variation in these process. This study was designed to understand more on the processes involved in postlarval ingression and recruitment into backwaters and tidal ponds.

MATERIALS AND METHODS

Study Materials:

Postlarvae collected by setnets during immigration were used to study ingression and that by liftnets settlement and recruitment. Sampling frequency and sample sizes were decided as per Alagaraja (1984).

Sampling Migrating Postlarvae:

Migrating postlarvae were collected by a modified "set net" described by Staples and Vance (1985; 1986) and Haywood and Staples (1993), (Fig 3.1). It was a framed net of 50 * 50 cm mouth fitted with 1.2 m long body of fine meshed (1 mm) synthetic netting. Net was provided with a pair of hooks and a long handle. Hooks guide the net through a pair of poles, fixed vertically in the channel, while lowering and lifting in water. This maintained the mouth opening against current and also prevents the net from being carried away by currents. A calibrated flow meter measured the volume of water filtered by the net during sampling.

Fig 3.1 Sampling net used to collect migrating postlarvae.

Entire water column was sampled by lowering the net vertically from surface to bottom from a fixed platform. Net was operated in the intake channel, inside tidal pond, against incoming flood tide at the time of water intake. Postlarvae in the discharge water from tidal ponds were also sampled by operating the net in the outlet channel behind the filtration net in the same manner, during routine water exchange and filtration.

Sampling was stratified over a time scale, to examine variations in postlarval abundance and recruitment with diel, tidal and lunar phases. Sampling was carried out during day and night hours at weekly intervals for three months, to coincide with the changes in diel, tidal, and lunar phase. Three to four samples were collected during each sampling, covering different phases of the flood tide. Each collection was of 5-10 minute duration depending on the current speed. All other samples were collected at fortnightly intervals during flood tides at night. Materials used for the study are given Table 3.1.

Table 3.1 Materials used to study postlarval ingression and abundance at different tidal pond sites.

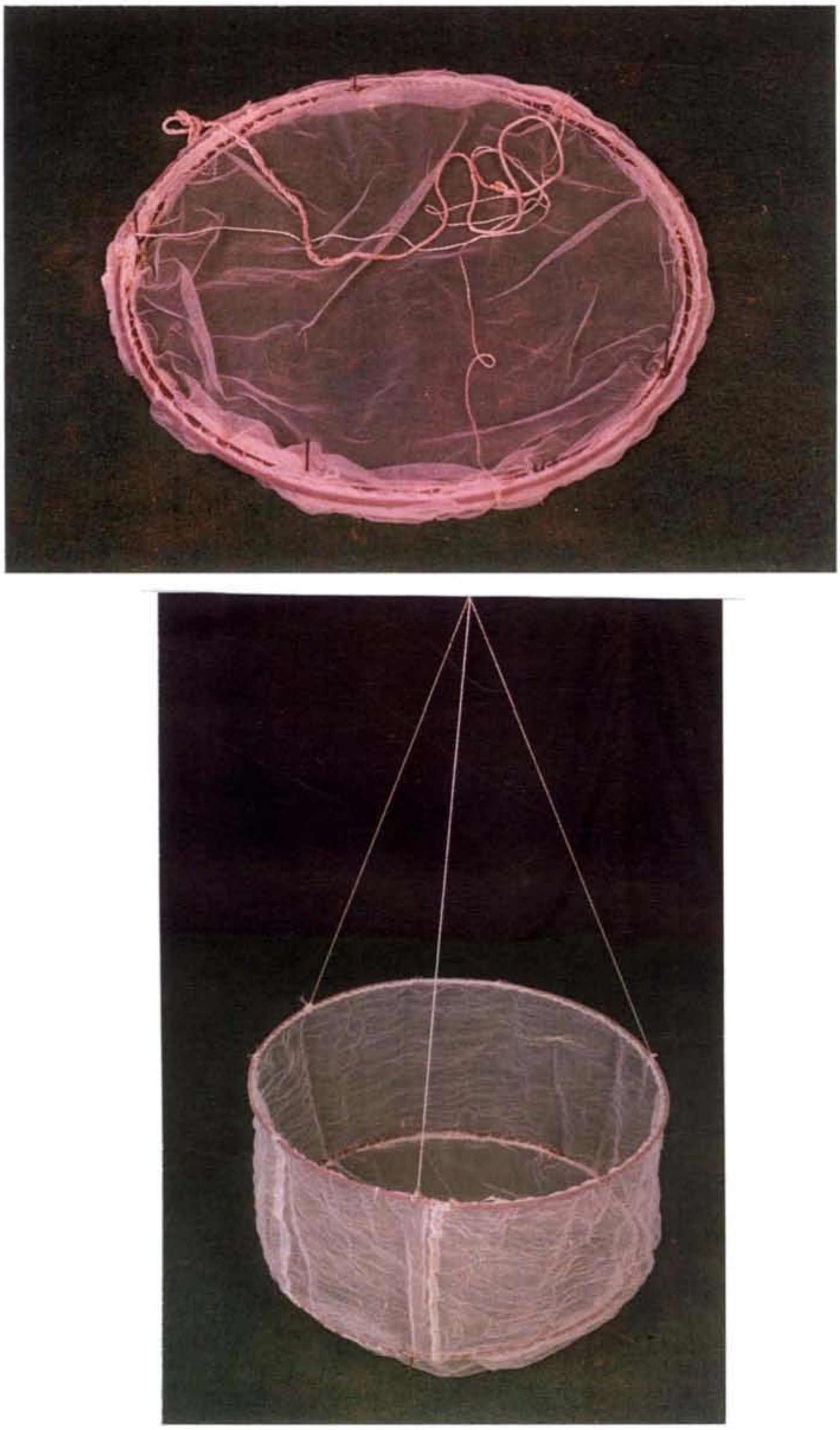
Tidal pond Site	*P. indicus*	*M. dobsoni*	*M. monoceros*	Other Species
F1	2924	6411	351	42
F2	2097	6029	312	29
F3	1462	3659	243	18
F4	1233	3506	207	14
F5	1026	3268	198	17
F6	812	3127	182	12

Sampling Resident Population:

Resident shrimps in tidal ponds were sampled by vertically lifting a circular liftnet (umbrella net), of 1.2 m diameter, fitted with 2 mm netting from the bottom as per Cheng and Chen (1990). The umbrella net proposed by them was modified by providing an additional vertical netting along the outer margin, to minimise the escape of shrimps while lifting (Fig 3.2). Following assumptions lend themselves in using liftnet samples for survival and population estimation;

(i) Liftnet samples with little or no disturbance to the surrounding areas, so different areas can be sampled with less bias.

(ii) Time allowed between setting and lifting the net is sufficient to stabilise the population disturbed during setting the net.



(a) set position

(b) Lifting position

Fig 3.2 Liftnet used for sampling resident shrimp population.

(iii) Along each depth zone species distributed uniformly at bottom and that liftnet capture all shrimps in the sampling area with minimum escape.

(iv) Mean catch per lift will provide an index of relative abundance of prawns.

Since much heterogeneity was expected in shrimp distribution with size, age and depth (Chamberlain *et.al.*, 1980; Easo and Mathew, 1989), entire pond area was divided into different depth strata, to weigh the population densities in each stratum. Sampling was done at fortnightly intervals from randomly selected points covering all depth strata proportionally. Nets were deployed at least two hours in advance prior to sampling. However, proportionate sampling could not be carried out in large holdings owing to practical difficulties in covering vast area. Materials used to study recruitment are given in Table 3.2.

Table 3.2 Materials used to study postlarval recruitment into different tidal ponds.

Species	F1	F2	F3	F4	F5	F6
P. indicus	1,223	808	525	646	497	473
M. dobsoni	4,209	3,387	2,212	2,182	2,417	2,244
M. monoceros	226	154	120	114	124	106

Methods of Analysis:

Materials were sorted out species-wise for each sampling days separately, counted and measured for total length, from tip of rostrum to telson, to the nearest 1.0 mm and weighed to the nearest 1.0 mg. The data so obtained were used to analyse basic diel, tidal, lunar and seasonal cycles of postlarval abundance and recruitment. Number of postlarvae caught per unit volume of water filtered by set net was estimated as an index of postlarval abundance and that in unit time of sampling as ingression rate, as suggested by Yokel *et.al.* (1969).

Materials from liftnet catches were used to study postlarval settlement and recruitment. Postlarvae and juveniles were segregated species-wise and counted separately. Relative abundance was estimated by summing up the catches of all lifts from each depth zones separately. The raised catches of each depth strata were then pooled for the entire pond area. Recruitment rate was estimated by dividing the number of new recruits with total area. New recruits were identified based on the size of the prawns in the immigrating population.

Statistical Methods:

Data were subjected to a variety of analyses and statistical tests to evaluate the influence of various biotic and abiotic factors on observed variations. These include hypothesis tests for means for paired observations, multiple regression analysis, analysis of variance and F-test (Snedecor and Cochran, 1967). Arc sin values were used, wherever necessary, to stabilise extreme variances in the percentage values.

RESULTS

Species Composition:

Postlarval recruits was constituted by *Metapenaeus dobsoni* (70.8-79%), *Penaeus indicus* (17.5-24.6%), *M. monoceros* (3.8-4.6%) and *P. monodon* (0.3-0.4%), (Table 3.3). *M. dobsoni* was most dominant at all areas (Fig 3.3). They constituted 26.7 (May) to 91% (October) of the total postlarvae recruited during different seasons. They dominated round the year except during April and May. Their composition was comparatively large, 72.6 to 79.0% along the inner upper regions than 70.8-72. 8% along lower regions of the backwaters.

P. indicus composition was small during monsoon and post-monsoon but dominated during pre-monsoon (Fig 3.3). They formed 6.2% of the total recruits in October and 60.3% in May. Their composition was comparatively small, 17.46-22.99% along the inner upper regions and large, 22.58-24.6% along the lower regions.

Table 3.3 Average annual abundance of different species (no/1000 m^3) and their percentage composition at different tidal pond sites.

Tidal pond	*P. indicus* (%)	*P. monodon* (%)	*M. dobsoni* (%)	*M. monoceros* (%)	Total (No.)
F1	22.95	0.31	72.78	3.96	387
F2	22.99	0.39	72.64	3.98	378
F3	24.61	0.29	70.76	4.34	418
F4	19.34	0.31	78.97	4.37	372
F5	22.58	0.43	72.42	4.57	374
F6	17.46	0.30	78.40	3.84	350

M. monoceros was totally absent in the recruits during August-September but represent 17.8% in April (Fig 3.3).. They exhibited an almost uniform abundance (3.84 to 4.57%) at different areas.

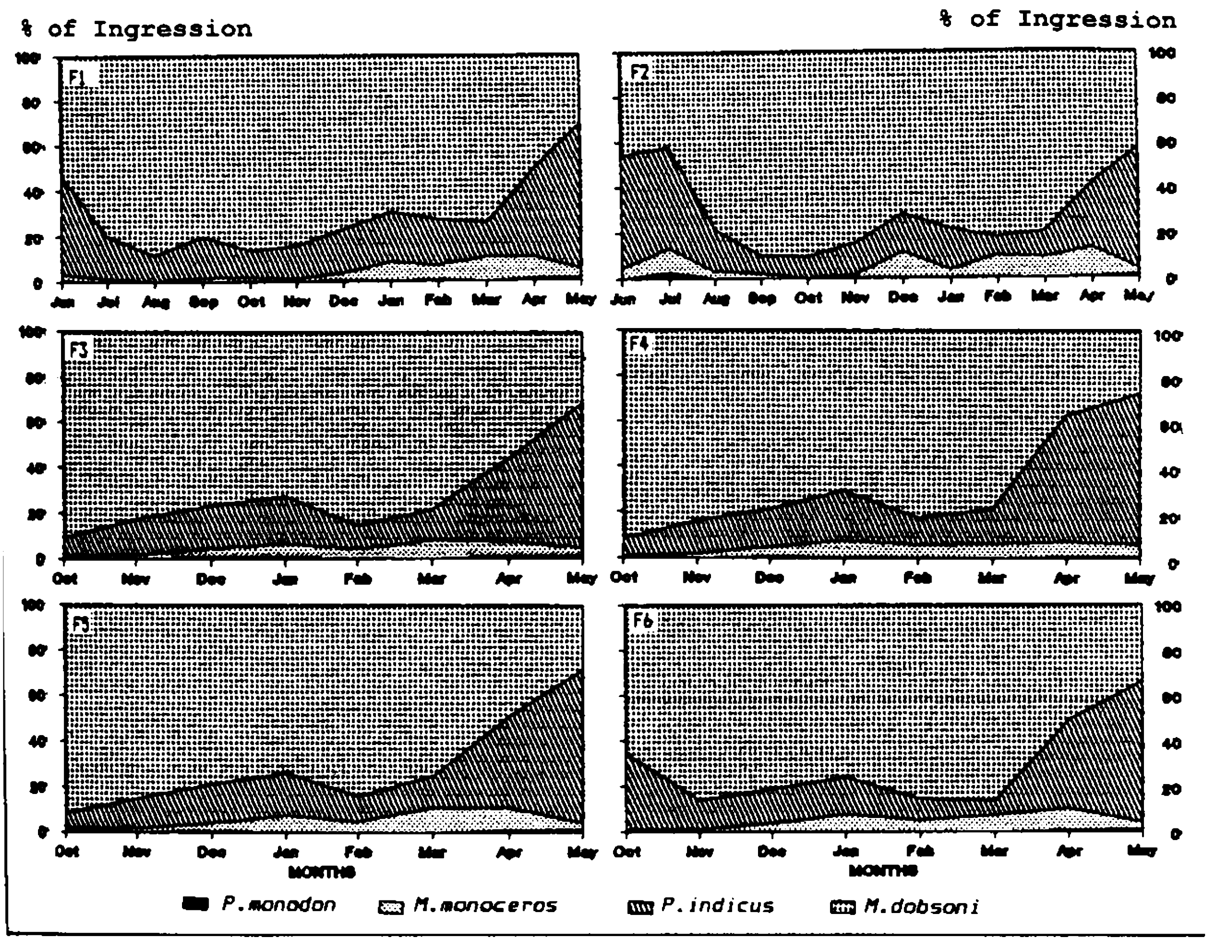


Fig 3.3 Seasonal variation in percentage composition of different species in the immigrating population tidal pond sites.

Diel Periodicity:

All species exhibited clear diel periodicity with high abundance and ingression during night hours (P<0.01), accounting 84.4% of the total recruitment (Fig 3.4, Table 3.4). Diurnal abundance and ingression vary among species. Comparatively strong nocturnal activity was displayed by *M. monoceros* with 90% of the ingression during night hours (T= -5.663, D.F. = 5, P = 0.0012). It was comparatively low, 84.6 and 82% respectively for *P. indicus* (T= -4.2118, D.F.= 5, P= 0.0042) and *M. dobsoni* (T= -4.5766, D.F. = 5, P= 0.002983).

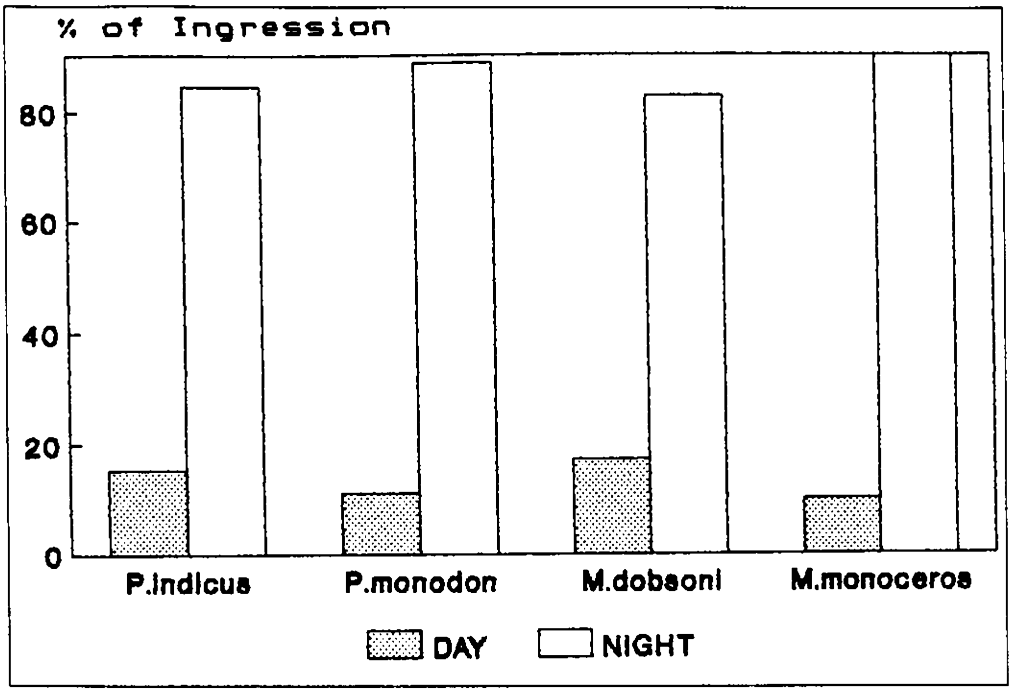


Fig 3.4 Effect of diel cycles on postlarval ingression.

Table 3.4 Diel, tidal and lunar periodicity in postlarval ingression rate (no 10 min^{-1}) into tidal ponds.

Particulars	*P. indicus*	*P. monodon*	*M. dobsoni*	*M. monoceros*	Total
a. Diel Cycle					
Day	10	2	30	2	44
(%)	(15.38)	(11.10)	(17.19)	(10.00)	(16.12)
Night	56	14	141	18	229
(%)	(84.62)	(88.90)	(82.81)	(90.00)	(83.88)
b. Tidal phase					
Spring Tide	76	8	220	12	317
(%)	(86.60)	(88.89)	(84.30)	(92.31)	(85.42)
Neap Tide	12	1	41	1	55
(%)	(13.40)	(11.11)	(15.70)	(7.69)	(14.58)
c. Lunar Phase					
New Moon	47	6	122	7	182
(%)	(53.40)	(66.67)	(46.74)	(53.84)	(49.06)
Full Moon	41	3	139	6	189
(%)	(46.60)	(33.33)	(53.26)	(46.16)	(50.94)

Tidal Periodicity:

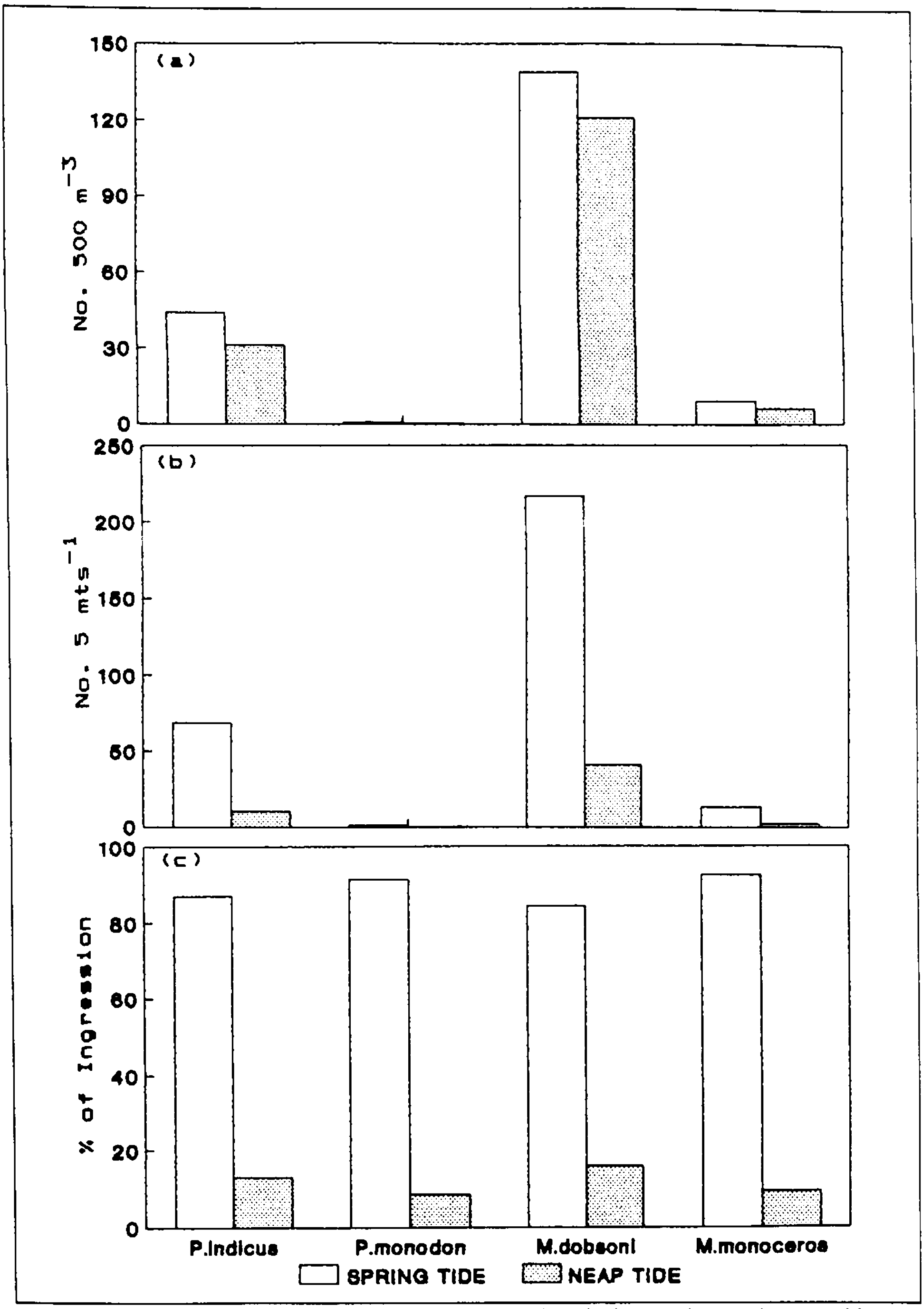


Fig 3.5 Ingression of postlarvae of different species during spring and neap tide, (a) abundance, (b) ingression rate and (c) % ingression.

All species exhibited considerable tidal variability with large ingression during spring tide (Fig 3.5, Table 3.4). Variation in the rate of ingression between spring and neap tide was very wide, whereas that of abundance was comparatively narrow.

Species differed in tidal periodicity (Fig 3.5, Table 3.4), but not at significant levels (P>0.05). In *P. indicus,* 86.6% of the ingression occurred during spring tide. Ingression rate was 76 and 12 postlarvae 5 min^{-1} respectively during spring and neap tide (T= -9.4789, D.F. = 5, P= 0.00011). Their abundance during these tides fluctuated between 44 and 31 postlarvae 500 m^{-3} of tidal water respectively. In *M. dobsoni,* more than 84% of the ingression occurred during spring tides (T= -3.5441, D.F. = 5, P = 0.00825). Their ingression rate varied between 220 and 41 and abundance between 139 and 121 during spring and neap tide respectively. *M. monoceros* also exhibited similar tidal periodicity with 92.3% of the ingression during spring tides. Their ingression rate was 12 and 1 and abundance, 9 and 6 respectively (T= -2.4665, D.F. = 5, P = 0.0284).

Lunar Periodicity:

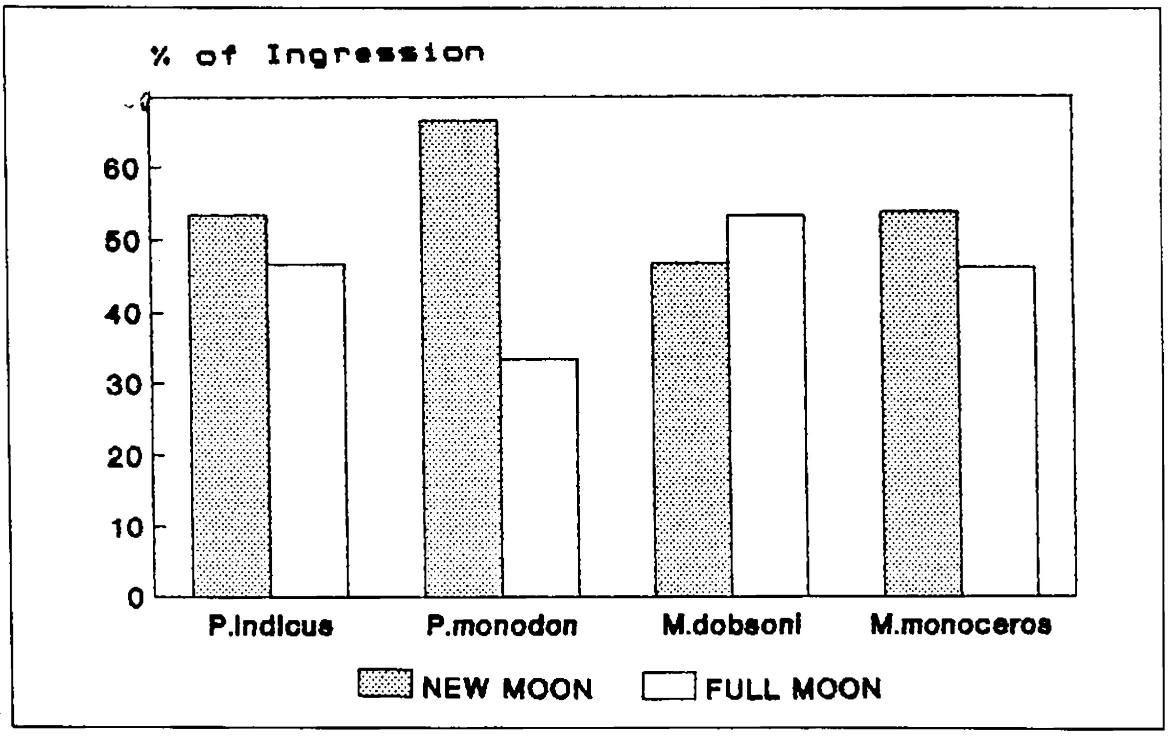


Fig 3.6 Percentage ingression of postlarvae during new moon and full moon phases.

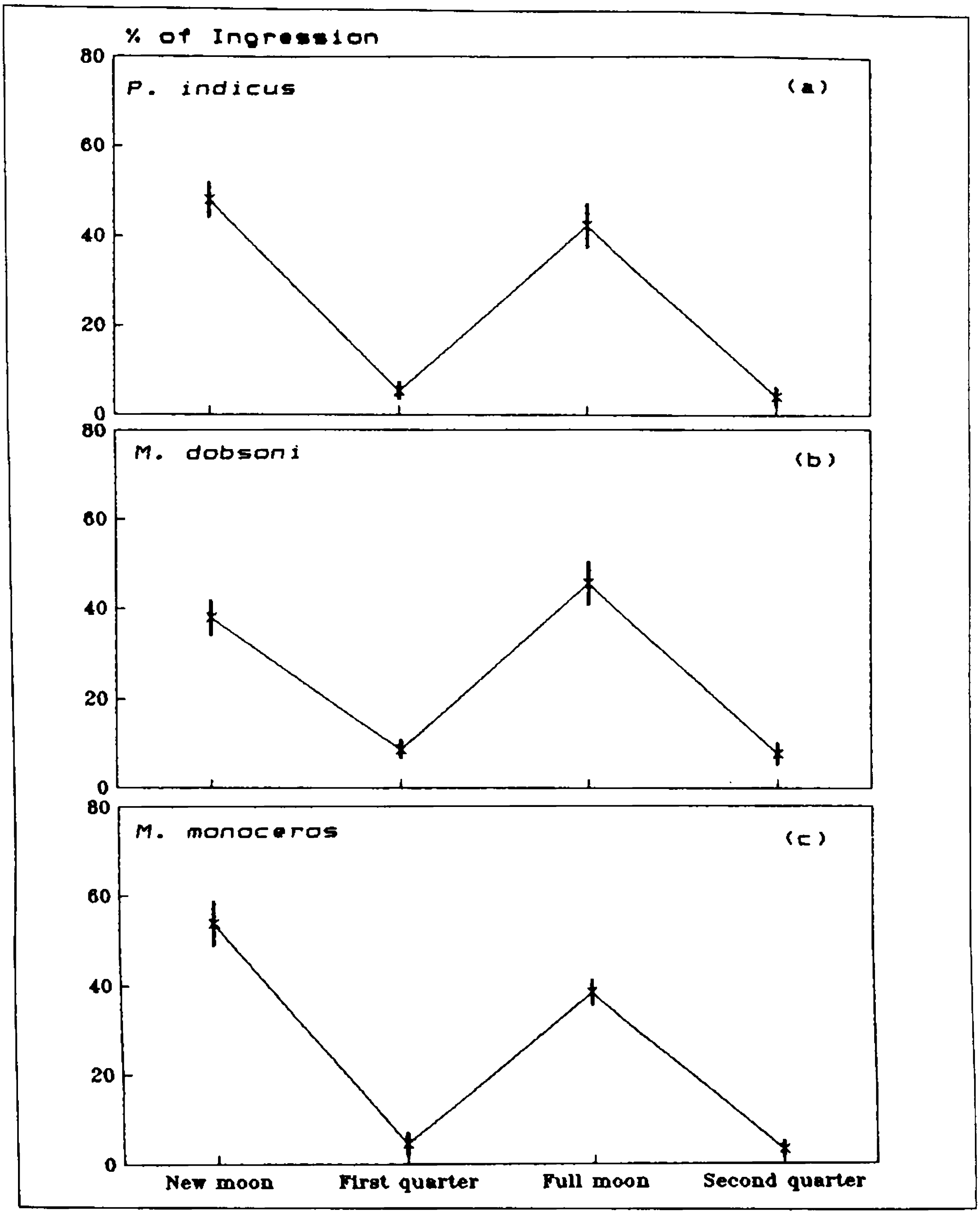


Fig 3.7 Percentage ingression of postlarvae during different quarters of the moon.

Lunar phases exerted considerable influence on abundance and ingression, with peaks at new and full moon phases (Fig 3.6, Table 3.4). In *P. indicus* (T= 3.177, D.F.= 5, P= 0.0123) and *M. monoceros* (T= -5.2243, D.F.= 5, P= 0.0017) peaks invariably associated with new moon phase, respectively accounting 53.4 and 53.8% of total ingression. Unlike these species, peaks coincides with full moon for *M. dobsoni* accounting 53.3% of their total ingression (T= -9.6746, D.F.= 5, P= 0.0001).

Ingression varied during different quarters of the moon also (Fig 3.7). First and third quarters respectively accounted 45.6 and 41.0% of the ingression in *P. indicus,* 38.84 and 45.5% in *M. dobsoni* and 48.6 and 41.9 in *M. monoceros.* Such differential abundance and ingression was observed between second and fourth quarters also.

Spatial Variation:

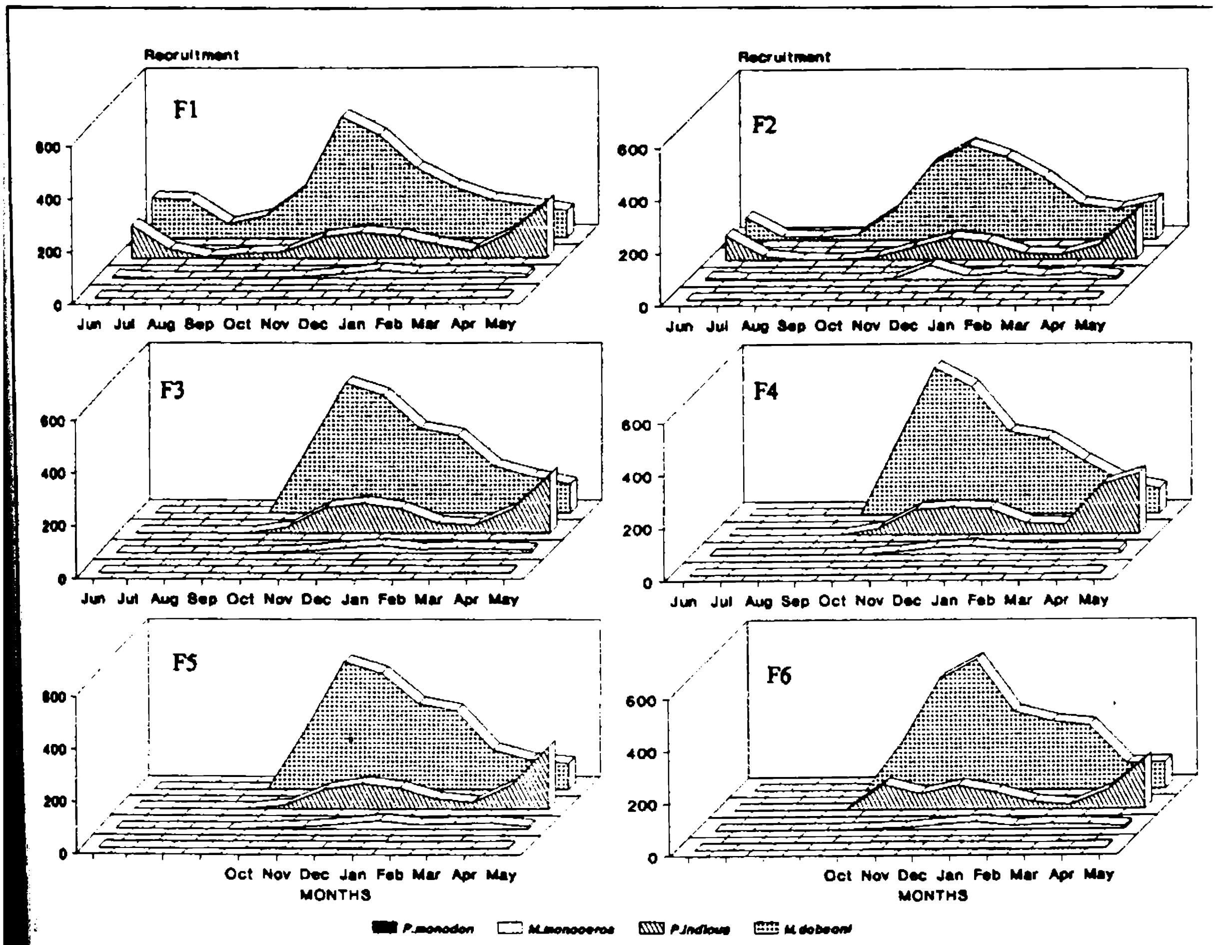


Fig 3.8 Species-wise abundance (no/1000 m^3) of postlarvae in tidal waters at different sites.

Abundance of ***P. indicus*** was small, 68 postlarvae 1000 m^{-3} of tidal water at Tripunithura, large, 103 at Edavanakkad (Fig 3.8). It was 84 at Kannamali and 88 at Panangad. During May the peak period of recruitment abundance varied between 163 at Tripunithura and 251 at Edavanakkad. At Kannamali it was 231 and at Panangad, 240.

Abundance of ***M. dobsoni*** was large, 296 at Edavanakkad and low, 266 at Tripunithura (Fig 3.8). It was 271 at Panangad and 276 at Kannamali. During peak periods (November/December) it varied between 489 at Tripunithura and 562 at Panangad. At Edavanakkad it was 504 and at Kannamali 497.

Abundance of ***M. monoceros*** varied between 16 postlarvae 1000 m^{-3} of tidal water at Edavanakkad and 10 at and Tripunithura with peaks of 32 and 29 during January respectively at these areas (Fig 3.8). The corresponding values were14 and 32 at Panangad and 13 and 29 at Kannamali.

Seasonal Periodicity:

P.indicus:

Major influx occurred during pre-monsoon months accounting 44.4% of the total ingression (Fig 3.8, 3.9a and 3.10a). It was 33.11 and 22.6% respectively during post-monsoon and monsoon months. Peak abundance of 163 to 240 postlarvae 1000 m^{-3} of tidal water was recorded in May and minimum of 0 to 8 in August. During peak monsoon, ingression was restricted to sites along the lower regions of e backwaters.

M. dobsoni:

Major influx, accounting 56.2% of the total ingression occurred during post-monsoon months, followed by 25.23 during pre-monsoon and 18.5% during monsoon months (Fig 3.8, 3.9b and 3.10b). Peak abundance of 405 to 562 postlarvae were observed in November and minimum of 11 to 37 in August.

M. monoceros:

Peak ingression occurred during pre-monsoon, followed by in post-monsoon months (Fig 3.8, 3.9c, 3.10c). It respectively accounted, 49.0 and 41.8% of the annual ingression, whereas monsoon ingression was only 9.2%. Peak abundance of 29 to 33 postlarvae were observed in April, whereas they were totally absent during August and September.

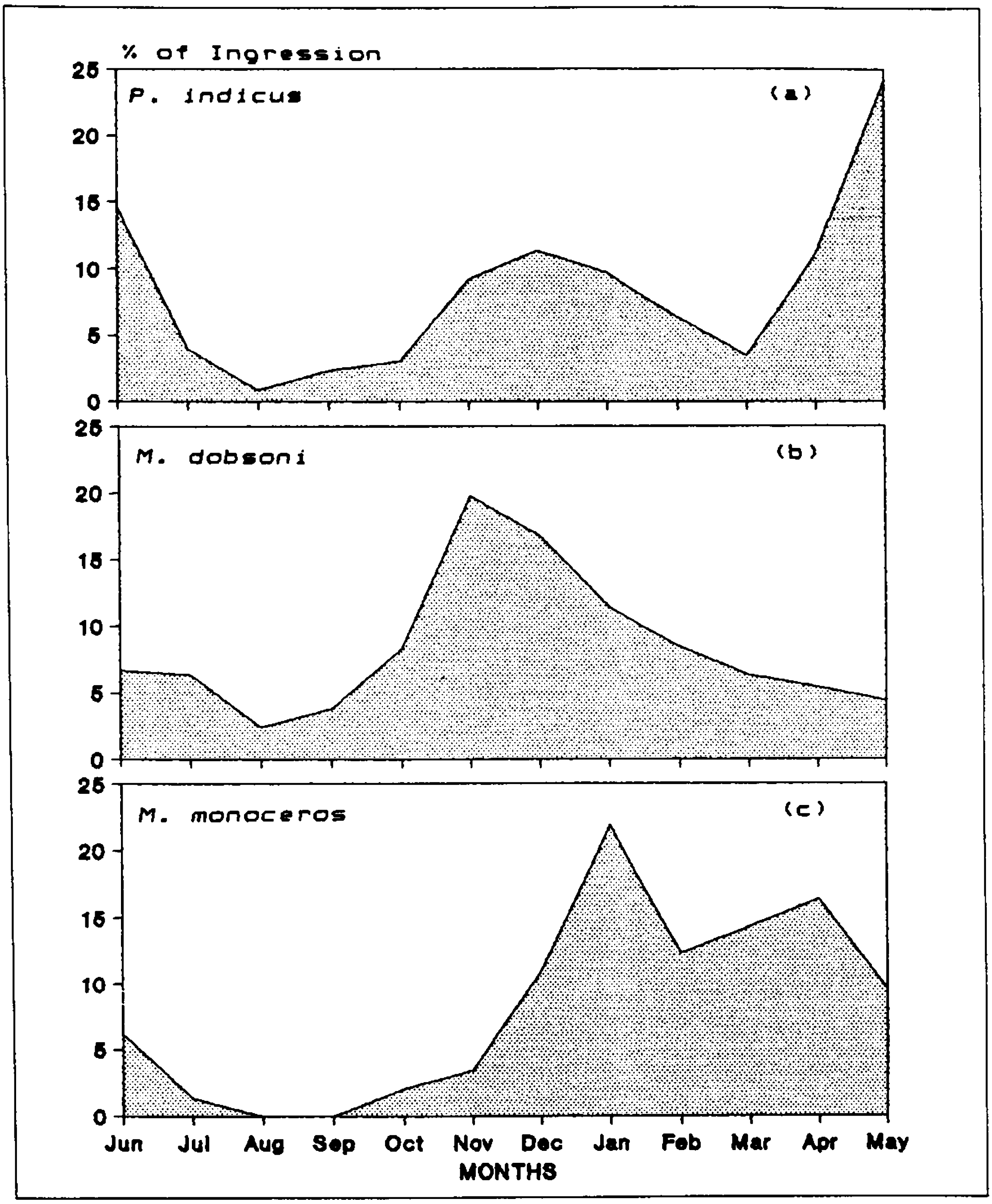


Fig 3.9 Seasonal pattern of postlarval ingression into perennial tidal ponds, a. *P. indicus*, *b. M. dobsoni* and *c. M. monoceros.*

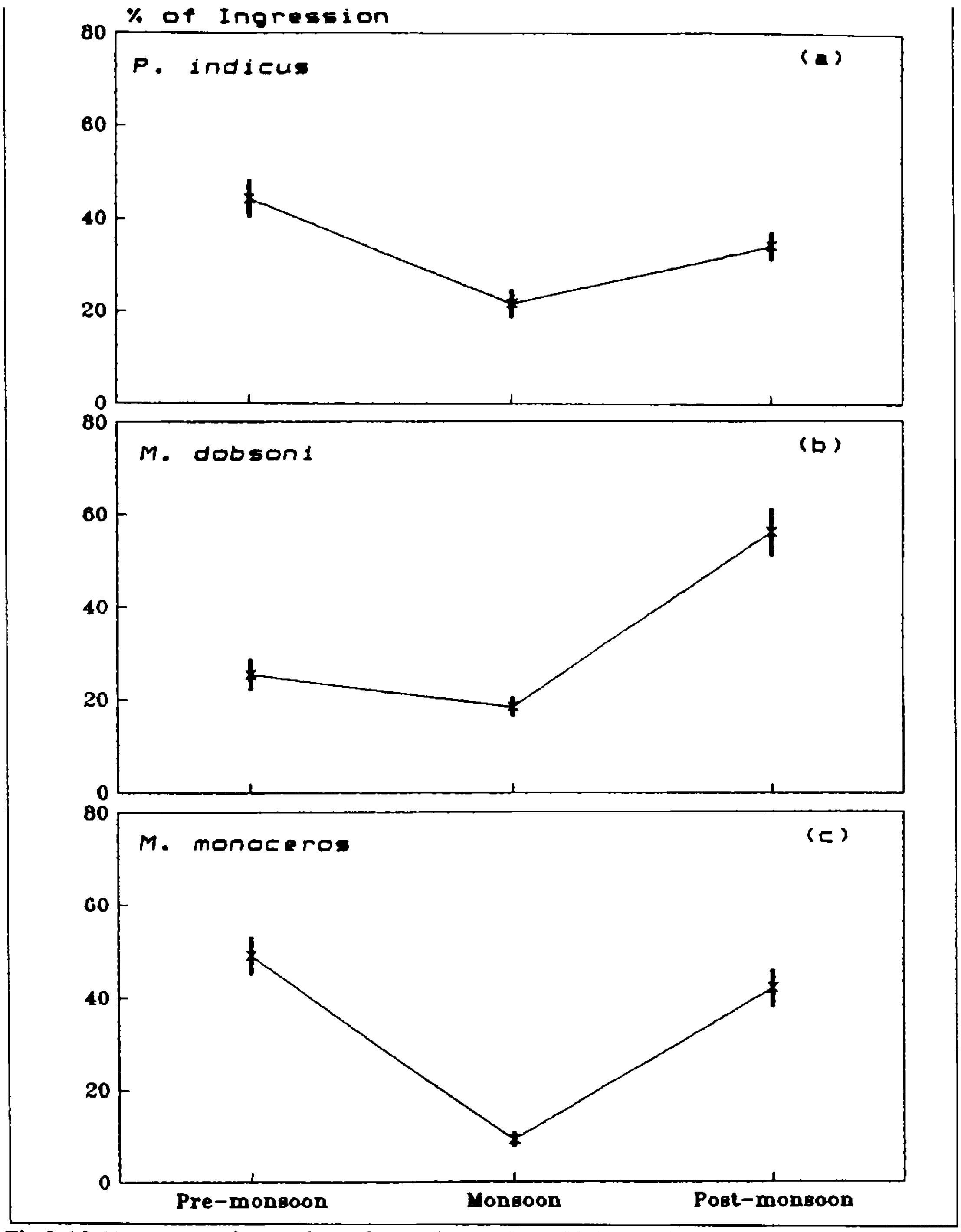


Fig 3.10 Percentage ingression of postlarvae into tidal ponds during different seasons a. *P. indicus,* b. *M. dobsoni* and c. *M. monoceros.*

Environmental Influence:

Several environmental factors were examined to evaluate their influence on the varia in postlarval ingression and the results are given in Table 3..5 for *P.indicus*, Table 3.6 foı *dobsoni* and Table 3.7 for *M. monoceros*. These tests showed no significant ($P>0.05$) influence for ecology on ingression. However, different factors together described 70.68% of the seasonal variation in *P. indicus*, 47.43 in *M. dobsoni* and 68.31% in *M. monoceros*.

Among the several factors, salinity produced maximum variation in ingression in all species. *M. dobsoni* was more abundant during the periods of medium salinity and *P. indicus* and *M. monoceros* during medium and high salinity. Abundance of all species declined during low saline periods.

Table 3.5 Multiple regression analysis and analysis of variance table for seasonal variation in *P. indicus* postlarval ingression and ecology of the habitat.

Variables	Reg. Coeff.	Std Error	t(df=5)	Prob.	Partial r^2
Temperature	-29.372	38.207	-0.769	0.4768	0.1057
Salinity	24.926	13.163	1.894	0.1168	0.4177
DO2	4.841	9.059	0.534	0.6161	0.0541
pH	-1.467	7.357	-0.199	0.8498	0.0079
Productivity	-32.672	36.015	-0.907	0.4059	0.1413
Turbidity	0.374	4.713	0.793	0.4637	0.1118
Constant	512.146				

Std. Error of Est.	60.0374	Adjusted R Squared	0.0365
R Squared	0.7068	Multiple R	0.8405

ANALYSIS OF VARIANCE TABLE

Source	SS	df	Mean Square	F Ratio	Prob.
Regression	23129.546	6	3854.924	2.352	0.1637
Residual	8194.9953	5	1638.999		
Total	31324.5394	11			

Table 3.6 Multiple regression analysis and analysis of variance table for seasonal variation in *M. dobsoni* postlarval ingression and ecology of the habitat.

Variables	Reg. Coeff.	Std Error	t(df=5)	Prob.	Partialr^2
Temperature	-98.374	94.729	-1.038	0.3466	0.1774
Salinity	11.9794	8.632	1.388	0.2146	0.2428
DO2	79.934	171.635	0.466	0.6609	0.0416
pH	-33.519	89.294	0.375	0.7228	0.0274
Productivity	254.567	249.383	1.021	0.3542	0.1724
Turbidity	-2.5722	12.703	-0.202	0.8475	0.0081
Constant	1303.6910				

Std. Error of Est.	148.8553	Adjusted R Squared	0.1312
R Squared	0.4743	Multiple R	0.6887

ANALYSIS OF VARIANCE TABLE

Source	SS	df	Mean Square	F Ratio	Prob.
Regression	91688.152	6	15281.359	0.966	0.4821
Residual	79096.066	5	15819.212		
Total	170784.217	11			

Table 3.7 Multiple regression analysis and analysis of variance table for seasonal variation in *M. monoceros* postlarval ingression and ecology of the habitat.

Variables	Reg. Coeff.	Std Error	t(df=5)	Prob.	Partial r^2
Temperature	55.079	69.225	0.796	0.4623	0.1124
Salinity	1.198	0.669	1.788	0.3346	0.3906
DO2	2.597	9.872	0.263	0.8031	0.0136
pH	-3.637	5.298	-6.862	0.5227	0.0861
Productivity	-105.066	102.812	-1.022	0.3537	0.1728
Turbidity	-0.198	0.339	-5.853	0.5837	0.0641
Constant	111.7090				

Std. Error of Est.	8.7262	Adjusted R Squared	0.3045
		R Squared	0.6838
		Multiple R	0.8269

ANALYSIS OF VARIANCE TABLE

Source	SS	df	Mean Square	F Ratio	Prob.
Regression	823.5174	6	137.253	1.802	0.2673
Residual	380.7326	5	76.147		
Total	1204.2503	11			

Size at Ingression:

Table 3.8 Seasonal variation in mean length and length range (in mm) of recruits of differen species at ingression.

	Species			
Months	*P. indicus*	*P. monodon*	*M. dobsoni*	*M. monoceros*
Jun	9.0-22.5 (12.23)	13.0-17.0 (14.62)	8.0-17.0 (12.94)	9.0-19.0 (12.47)
Jul	10.0-24.0 (14.34)	-	9.0-20.0 (12.27)	11.0-16.0 (13.81)
Aug	14.0-27.0 (15.41)	-	8.0-18.0 (12.64)	-
Sep	9.0-26.5 (14.33)	-	9.0-22.0 (14.23)	9.0-19.0 (14.21)
Oct	14.0-26.0 (12.02)	-	8.0-19.0 (12.87)	10.0-17.0 (12.87)
Nov	9.0-18.0 (11.04)	12.0-16.0 (14.22)	8.0-19.0 (9.93)	10.0-18.0 (10.97)
Dec	9.0-22.0 (13.22)	9.0-18.0 (14.84)	9.0-17.0 (10.09)	9.0-17.0 (10.84)
Jan	9.0-22.0 (12.46)	8.0-13.0 (11.63)	8.0-18.0 (10.23)	9.0-20.0 (11.81)
Feb	9.0-20.0 (12.37)	11.0-20.0 (13.89)	9.0-16.0 (11.52)	9.0-16.0 (10.91)
Mar	10.0-19.0 (13.14)	-	9.0-15.0 (10.49)	8.0-14.0 (10.98)
Apr	9.0-20.0 (12.84)	9.0-13.0 (10.41)	10.0-16.0 (11.01)	8.0-13.0 (9.84)
May	8.5-20.0 (10.86)	9.0-16.0 (11.26)	9.0-18.0 (10.43)	8.0-16.0 (10.43)

P. indicus, recruits were small, 10.9 mm in May, whereas they were relatively large, 12.23-18.4 mm during monsoon (Table 3.8). Size of *M. dobsoni* was small during post-monsoon and pre-monsoon months. They were small, 9.9 mm during November and large, 14.6 mm in August. *M. monoceros* recruits were small, 9.8-11.8 mm during post and pre-monsoon months and large, 12.5-17.8 mm during monsoon.

Postlarval Settlement:

Table 3.9 Seasonal variation in abundance of postlarvae (No 1000 m^{-3}) in the discharge water from tidal ponds.

	Tidal ponds					
Months	F1	F2	F3	F4	F5	F6
Jun	3	7	1	0	0	0
Jul	1	0	0	0	0	0
Aug	0	0	0	0	0	0
Sep	1	0	0	0	0	0
Oct	9	4	11	2	9	6
Nov	18	12	22	14	16	17
Dec	19	13	24	15	23	12
Jan	21	19	16	22	18	26
Feb	19	28	18	21	27	21
Mar	26	16	24	23	16	19
Apr	33	25	34	37	33	32
May	22	18	27	31	29	27

Postlarval abundance in discharge water from tidal ponds is given in Table 3.9. Proportion of postlarvae leaving the ponds were negligible compared to their abundance in the flood water and ingression rate, irrespective of time of the day, tide, lunar phase or season of the year. In the discharge water abundance varied between zero and 37/1000 m^3 during different seasons

Liftnet samples showed that postlarvae settled down to the bottom immediately after their entry into the tidal ponds. Their large concentrations were seen in shallow marginal areas with paddy remains and mangrove vegetations.

Recruitment Rate:

P. indicus:

During October-May recruitment rate varied from 27 (October) to 193 (May) postlarvae 100 m^{-2} of pond area with a mean recruitment of 85 in F1 and 110 to 355 with mean of 159 in F3 at Edavanakkad (Fig 3.11). The corresponding values were 23 to 285 and 116 in F2 and 38 to 325 and 147 in F4 at Panangad. In F5, at Kannamali it was 40 to 365 and in F6 at Tripunithura 20 to 328 with 143 and 123 as means. In perennial ponds recruitment was low between 13 and 16 postlarvae 100 m^{-2} of pond area during August/September.

Recruitment rate was influenced ($P<0.05$) by pond area, water exchange and distance from bar mouth (Table 3.10). It correlated negatively with area and distance and positively with water exchange.

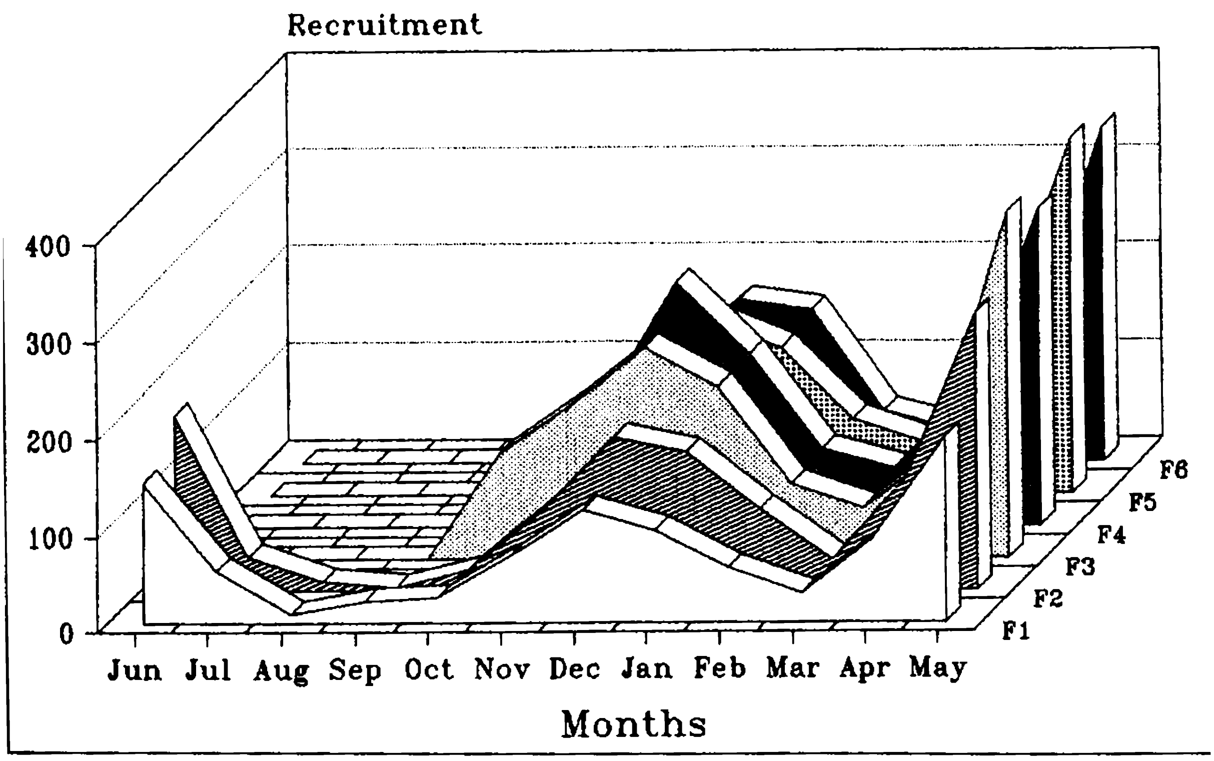


Fig 3.11 Seasonal variation in the recruitment rate (no/100 m^2) of *P. indicus* into different tidal ponds.

Table 3.10 Multiple regression analysis and analysis of variance table on recruitment rate of *P. indicus* and the physico-chemical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Area	-13.0902	1.0326	-11.999	0.05293	0.9931
Distance	-7.9942	0.3894	-20.911	0.03042	0.9977
Depth	3.9186	2.7950	1.402	0.29597	0.4957
Water Exchange	0.2418	0.0120	20.199	0.03149	0.9976
Salinity	9.2945	7.7843	1.194	0.35482	0.4163
Constant	-358.9763				

Std. Error of Est. = 0.1388

Adjusted R Squared = 0.9883
R Squared = 0.9897
Multiple R = 0.9939

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	69.0229	5	13.8046	716.34	0.0414
Residual	0.0193	1	0.0193		
Total	69.0421	6			

M. dobsoni:

During October-May, recruitment rate varied from 128 postlarvae 100 m^{-2} of pond area (May) to 430 (November/December), with a mean recruitment of 281 in F1 and 190 to 796, with mean of 488 in F3, at Edavanakkad (Fig 3.12). The corresponding values were 260 to 637 and 401in F1 and 215 to 804 and 488 in F4 at Panangad. In F5, at Kannamali it was 195 to 920 and in F6, at Tripunithura it was 185 to 870, with 513 and 516 respectively as mean recruitments. In perennial ponds recruitment was low, 75 and 21 postlarvae 100 m^{-2} of pond area respectively in Fl and F2 during August

Recruitment rate was influenced ($P<0.05$) by pond area, water exchange and distance from bar mouth (Table 3.11). It correlated negatively with area and distance and positively with water exchange.

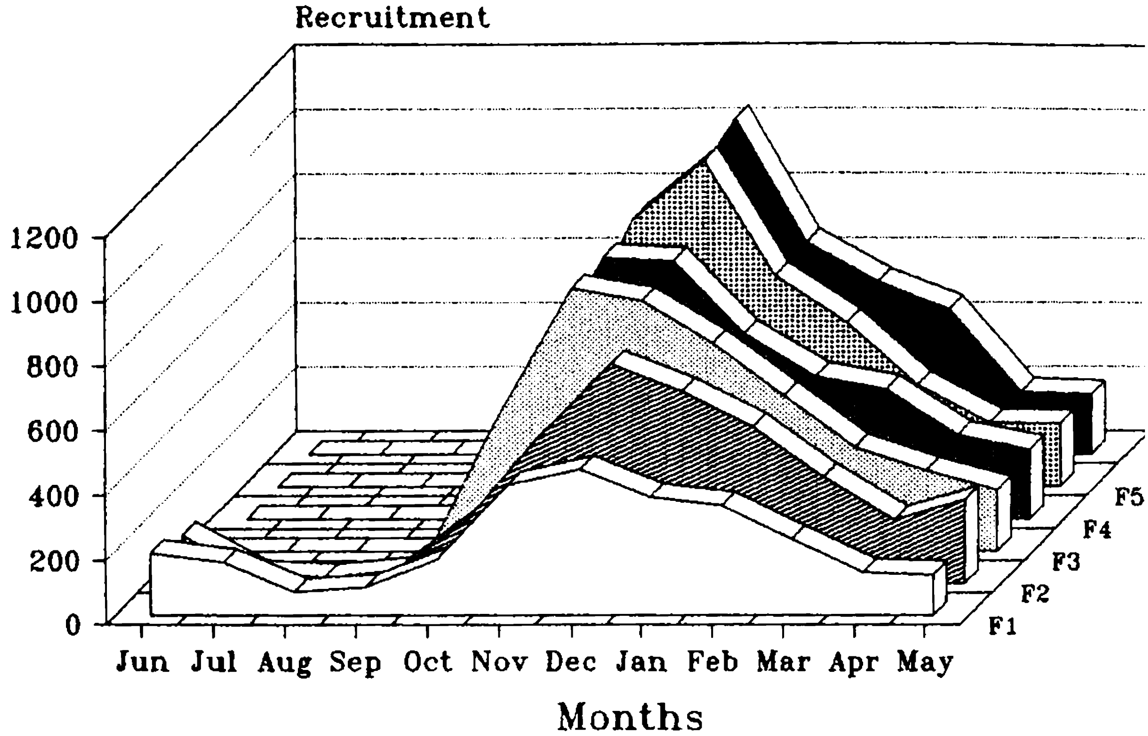


Fig 3.12 Seasonal variation in the recruitment rate (no/100 m^2) of *M.dobsoni* into diffe tidal ponds.

Table 3.11 Multiple regression analysis and analysis of variance table on the recruitment rat of *M. dobsoni* and physico-chemical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partialr^2
Area	-24.8453	0.4895	-50.760	0.01254	0.9996
Distance	-4.2487	0.6406	-6.632	0.09527	0.9778
Depth	-19.4867	10.8881	-1.790	0.21539	0.6156
Water exchange	0.1408	0.0042	33.607	0.01894	0.9991
Salinity	-0.2397	2.4225	-0.099	0.93021	0.0049
Constant	381.4896				

Std. Error of Est. = 0.0707

Adjusted R Squared = 0.9985
R Squared = 0.9987
Multiple R = 0.9997

ALYSISOF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	19.6171	5	3.9234	784.683	0.0327
Residual	0.0050	1	0.0050		
Total	19.6221	6			

M. monoceros:

Recruitment varied from 2 postlarvae 100 m^{-2} of pond area (October) to 38 (January), with 23 as mean in F1 and 5 to 45, with 26 as mean in F3, at Edavanakkad (Fig 3.13). It was 5 to 43, with 27 as mean in F2 and 6 to 45, with 29 as mean in F4 at Panangad. In F5, at Kannamali it was 4 to 63 and in F6 at Tripunithura 3 to 50, with 32.5 and 25.3 respectively as mean recruitments. In perennial ponds it was low during monsoon. There was no recruitment during August in F1 and during August-September in F2.

Recruitment was influenced ($P<0.05$) by pond area and water exchange (Table 3.12). It correlated negatively with the area and positively with water exchange

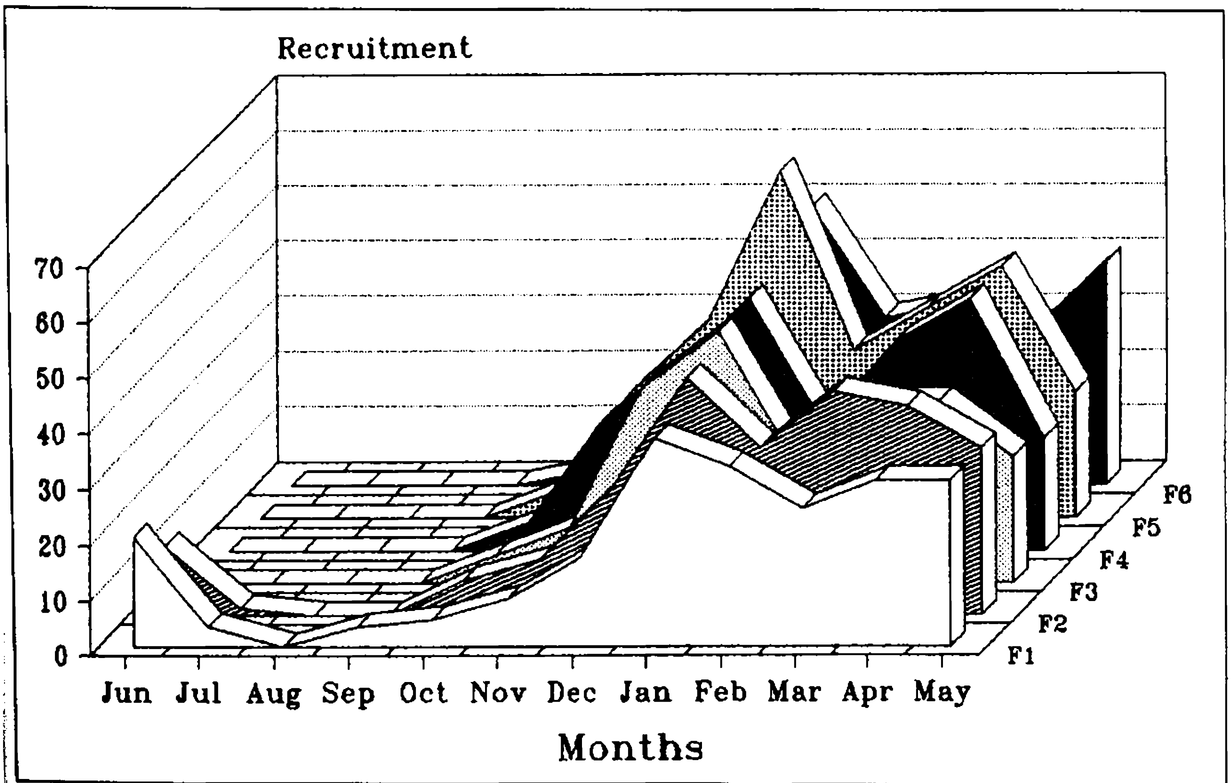


Fig 3.13 Seasonal variation in the recruitment rate (no/100 m^2) of *M. monoceros* into different tidal ponds.

Table 3.12 Multiple regression analysis and analysis of variance table on the recruitment rate of *M. monoceros* and physico-chemical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partialr^2
Area	-1.3648	0.0314	-43.489	0.01464	0.9995
Distance	-3.9186	2.7950	-1.402	0.29597	0.4957
Depth	-0.0150	0.2614	-0.057	0.95959	0.0016
Water exchange	9.6947	0.2278	42.567	0.01495	0.9994
Salinity	-0.4168	1.2864	-0.324	0.77699	0.0497
Constant	804.3680				

Std. Error of Est. = 0.4950

Adjusted R Squared = 0.9876
R Squared = 0.9861
Multiple R = 0.9968

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	608.8955	5	121.7791	495.22	0.04638
Residual	0.2450	1	0.2450		
Total	609.1405	6			

DISCUSSION

Considerable variation was observed in the ingression of postlarvae into tidal ponds. Recruitment of estuarine dependent species into these habitats was governed partly by the ability of young animals to negotiate inlets and by ambient ecological conditions (Staples and Vance, 1987). Laubier (1989) showed that, in nature, migration is controlled by variations in salinity, currents, nycthermal and tidal rhythms. In the present study also several basic recruitment patterns related to diel, tidal, lunar and seasonal rhythms and location of tidal ponds were observed.

Recruits were constituted by postlarvae of *M. dobsoni, P. indicus, M. monoceros* and *P. monodon.* Composition of the postlarvae in Cochin backwaters and adjacent areas are available from earlier reports (Rao, 1972; Suseelan and Kathirvel, 1982; Thampi *et.al.*, 1982; Easo and Mathew, 1989; Mathew *et.al.*, 1993). The composition reported by these workers showed marked variation among themselves and also with present observations. This may be due to differences in the period of observation, area of study and the sampling devices used. Suseelan and Kathirvel (1982) reported considerable variation in the composition of postlarvae collected by different gears, as they might have collected samples from different populations.

Composition of recruits fluctuated over the season and with location. Seasonal fluctuation depends entirely on the seasonality of species abundance. Composition was relatively large for *P. indicus* and *M. dobsoni* respectively along the lower and upper regions of backwater, the areas of high and low salinity. However, *M. monoceros* exhibited more or less uniform distribution at all areas. According to Zein Eldin and Aldrich (1965), salinity through its osmotic effect plays significant role in limiting organisms to specific environment. Though, postlarvae and juveniles are euryhaline, species differ in their salinity preference, resulting in differential distribution and hence have varying composition according to salinity range of each area. Such variations in spatial distribution of prawns with salinity were also available from several studies (George and Suseelan, 1982; Sampandam *et.al.*, 1982; Coles and Greenwood, 1983).

Abundance and ingression were influenced by diel cycles, with high nocturnal activity. Such increased nocturnal activities and abundance of larvae and postlarvae of penaeids has been reported by several workers (Tabb *et.al.*, 1962; Copeland and Truitt, 1966; Caillouet *et.al.*, 1968; Subrahmanyam and Rao, 1968; Subrahmanyam and Ganapati, 1971; Garcia, 1977a; Young and Carpenter, 1977; Goswamy and George, 1978a; Garcia and Le Reste, 1981; Goswami and Goswami, 1992). Goswami and George (1978a) observed more than 64% of the postlarval recruitment into the estuaries of Goa during night hours alone. However, Ramakrishnaiah (1979) observed no such variations in the ingression of *P. indicus* and *P. monodon* in Chilka lake and Staples and Vance (1985) in *Penaeus merguiensis* in Gulf of Carpentaria. However they observed strong nocturnal activity and abundance in *Metapenaeus* Spp.

Species varied in diel activity. *M. monoceros* exhibited relatively strong nocturnal abundance than *P. indicus* and *M. dobsoni*. James (1987), observed relatively strong nocturnal activity in *M. dobsoni* than *M. monoceros*.

Postlarval recruitment coincides with seawater ingression at high tides. Postlarvae migrate vertically in the water column during flood tide, in response to diel rhythms and move with tidal currents at night (Tabb *et.al.*, 1962; Roessler *et.al.*, 1969; Young and Carpenter, 1977; Goswami and George, 1978a; Garcia and Le Reste, 1981; Mair *et.al.*, 1982; Staples and Vance, 1985; Heron *et.al.*, 1993). Variations observed in abundance and recruitment rate with tide phases, further indicated clear influence for tidal cues, such change in tide heights and current speed on the strength of vertical migration. Chong (1979), reported that, in Straits of Malacca, postlarvae are responding more to tide height changes than to any other cues.

Only few postlarvae are found moving with the retreating tidal water. Hall (1962), Rao and Krishnayya (1974) and Venegas (1980) also observed more postlarvae in the inflowing water than outflowing waters from tidal ponds. It is possible that, they settle down, before flow of tide reverses and thus prevent themselves from being carried back by the retreating tides.

Abundance and ingression varied with moon phase. Recruitment occurred in pulsed manner, with two peaks, coinciding with every new and full moon. Since tide and lunar phases become synchronous, it is difficult to separate their effects from each other. However, numerical superiority of *P. indicus* and *M. monoceros* during new moon than full moon and that of *M. dobsoni* during full moon, despite similar influence of tidal signals indicated interaction between lunar and tidal cues. Many observed similar peaks in abundance of penaeid postlarvae during new moon phase (Roessler *et.al.*, 1969; Barber and Lee, 1975; Garcia, 1977a; Staples and Vance, 1985; Natarajan *et.al.*, 1986; Goswami and Goswami 1992). However, Subrahmanyam and Ganapati (1971) observed maximum abundance sometimes at full moon. But, in the case of *P. indicus, P. monodon* and *P. semisulcatus* Subrahmanyam and Rao (1968) observed no such variation in between different lunar phases. Analysis of the data shown that postlarval abundance was influenced mainly by tidal signals, but modified by lunar signals. The variations observed between moon phases appears to be triggered by prevailing light intensity at the time of flood tides, which modify postlarval behaviour and their abundance. Therefore, increased abundance and dispersal could be expected during new moon phase for species, which prefer darkness, and for others during full moon phase.

Ingression and abundance varied during different seasons. Similar seasonal variation as observed in the present study was reported by earlier workers from Cochin backwater areas (Rao, 1972; Kuttiyamma, 1975; Anon, 1980; George and Suseelan, 1982; Jose *et.al.*, 1987; Mathew *et.al.*, 1993; Mohan *et.al.*, 1995). Penaeids being continuous breeders, their postlarvae and juveniles are expected to be encountered in the estuaries throughout the year. Seasonal variation in reproduction is generally considered as the major cause of fluctuation in recruitment. Abundance of all species decreased during southwest monsoon. However, small prawns, which entered the tidal ponds and those stocked in the culture ponds thrive well during these periods. This indicated that, being an efficient osmoregulators with wide tolerance, environmental conditions cannot be considered limiting their abundance during monsoon. Present findings and earlier report of D'Incao (1991), showed that, decrease in seawater ingression in response to increased monsoon discharge might have acted as a physical barrier limiting the entry of postlarvae into the estuaries during this season.

Abundance and recruitment of postlarvae also varied with the location. As has been described above, these variations depends to a great extent on the prevailing tidal influence and to some extent on the salinity, fluctuations of which are found to have the potential to alter the population.

Variation was observed in the size of the recruits during different season. Similar variations in size of the recruits were reported by several workers (Copeland and Truitt, 1966; Garcia, 1977a; Le Reste, 1978). Garcia (1977a) and Staples and Vance (1985) attributed the advanced size and developmental stages of postlarvae at times to the prevalence of better conditions for larval growth and development. Variation in size observed in the study indicated the influence of prevailing ecology on postlarval ingression. Comparatively small size of the recruits during post and pre-monsoon periods suggested rapid migration from spawning grounds into nurseries. As has been discussed above, obstructions caused by freshwater discharge during monsoon prevent or considerably delay the entry of postlarvae into estuaries and hence have large size at recruitment.

Prawn fishery of tidal ponds and backwaters are highly complex due to continuous recruitment, emigration and prevalence of different means of fishing. Most of the recruits, which enter these habitats, emigrate at certain stages of their life and were caught in thoombuvala. Since only certain age/size groups alone will undergo emigration, the data obtained from filternet catches are likely to be non-representative of habitat population. Same is the case with other means of harvest also, as it is highly selective for species and size. So, such data cannot be used for studying vital population characteristics. Moreover, most of the common sampling methods are also not practical in tidal ponds, as farm operators have strong objections in using these devices as they fear that it will disturb pond bottom and cause emigration of small prawns. This necessitated special sampling designs and strategies to get precise information on recruitment and resident population. In this context the sampling techniques employed for this study was most appropriate. Selections of small mesh for the netting enabled postlarval and liftnet to catch almost all size ranges of prawns and so their catches were expected to provide most reliable information regarding migrating and resident population respectively.

Earlier workers also used similar nets (setnets) for sampling migrating prawns in estuaries

(Staples, 1980a; 1980b; Staples and Vance, 1985; 1986; Vance *et.al.*, 1996). According to Vance *et.al.* (1996) these devices are very useful for sampling prawns and fishes that move into and out of the inter-tidal areas.

Cheng and Chen (1990) used liftnet for sampling resident population and considered it as one of the most efficient technique for sampling prawns in enclosures. Although, as with other techniques, sampling efficiency is not 100%, they are less selective and the samples were assumed to be true representative of the population. So this data can be used for studying relative abundance, distribution, growth and mortality.

Distribution and Abundance

Chapter-4

DISTRIBUTION AND ABUNDANCE

INTRODUCTION

Penaeids are adapted to live within confined ecosystem, especially during their early phase of life. The success of the backwater prawn fishery depends entirely on the relative abundance of the concerned species. Reliable information on their abundance and distribution in these habitats are essential for efficient management decision.

Some information is available on the distribution of penaeids in backwater nurseries from earlier works (George, 1973; Kuttiyamma and Kurian, 1978; Anon, 1980; Suseelan and Kathirvel; 1982). Easo and Mathew (1989) described distribution and abundance of penaeids in Cochin backwaters with respect to depth and Benfield and Baker (1980) in coastal bays of Texas. Spatial segregation between different size groups of *M. dobsoni* was described by Achuthankutty (1988) and brown shrimp, *Crangon crangon* by Janssen and Kuipers (1980). Ecological aspects of spatial segregation between size and age groups have been discussed by many (Garcia and Le Reste, 1981; Garcia, 1984; Balasubrahmanyam *et.al.*, 1995).

Barring the above information on distribution of penaeids, only little is known on their abundance in relation to water spread area and depth of backwater nurseries and tidal ponds. This study envisages exploring more on distribution and abundance of penaeids in the tidal pond habitats in relation to the biological characteristics of species and nature of medium/habitat.

MATERIALS AND METHODS

Study Materials:

Materials collected from different depth zones of tidal ponds using liftnet as described in Chapter 3 were used to study abundance and distribution of prawns in tidal ponds. Materials used for the study are presented in Table 4.1.

Method of Analysis:

Materials from different depth strata were segregated according to size, counted and grouped into length classes of 5 mm interval. Relative abundance and distribution of prawns were analysed by summing up the catches of all lifts from each depth zones separately. Abundance per unit area was calculated by dividing the catch in number by the total sampling area as per Hutchins *et.al.* (1980). Catches from each depth strata were raised to the area and pooled month-wise to obtain monthly length frequency data.

Chi-square goodness of fit test was applied to evaluate discrepancies observed in the distribution of shrimps in different depth zone as per Snedecor and Cochran (1967). Factors influencing abundance and distribution of shrimps were evaluated by multiple regression analysis.

Table 4.1 The number and length range (mm) of different species used to study abundance and distribution in tidal ponds.

Tidal pond	*P. indicus* No.	*P. indicus* Size Range	*M. dobsoni* No.	*M. dobsoni* Size Range	*M.monoceros* No.	*M.monoceros* Size Range
F1.	2,902	10-172.0	8,977	9-105.5	471	9-120.9
F2	1,982	10-165.0	6,334	9-105.0	333	9-117.0
F3	1,231	10-150.5	3,515	9-90.0	251	9-103.0
F4	1,201	10-145.0	4,645	9-91.5	244	9-100.5
F5	1,149	10-142.5	5,144	9-89.0	269	9-98.5
F6	989	10-138.5	4,431	9-87.5	225	9-96.5

RESULTS

Distribution:

P. indicus:

Abundance per unit area was high in shallow marginal area up to 0.5 m depth (Table 4.2, Fig 4.1). 36.2 % of the population was found in this zone and was represented by prawns up to 120 mm. Postlarvae up to 20 mm (37.5%) and early juveniles of 20-40 mm (33.4%) dominated this zone. The 0.5-1.0 m zone accounted 33% of the population and was represented by prawns upto 160 mm. Juveniles of 20-80 mm dominated this zone. The 1.0-1.5 and 1.5-2.0 m zones respectively accounted 18.1 and 8.3% of the population dominated by 40-100 mm size groups. Large prawns up to 170 mm were observed in this region. Abundance of all size groups beyond this zone was only nominal. It was 3.1 and 1.4% respectively in 2.0-2.5 m and beyond that zone and was dominated by 60-100 mm population.

Table 4.2 Depth-wise abundance (no/100 m^2 area) of different size groups of *P. indicus* in tidal ponds.

Size range (mm)	Depth (cm) 0-50	50-100	100-150	150-200	200-250	>250	Total
0-20	418	143	2	0	0	0	563
20-40	373	245	48	24	5	0	695
40-60	193	214	139	63	14	3	626
60-80	86	195	131	50	28	14	504
80-100	38	160	164	54	26	14	456
100-120	8	42	50	36	12	4	152
120-140	0	13	17	16	4	3	53
140-160	0	5	7	9	2	2	25
>160	0	0	1	3	4	2	10
Total	1116	1017	559	255	95	42	3084

Chi-square Value	Table Value	d.f.	Probability
1182.36	63.69	40	0.010

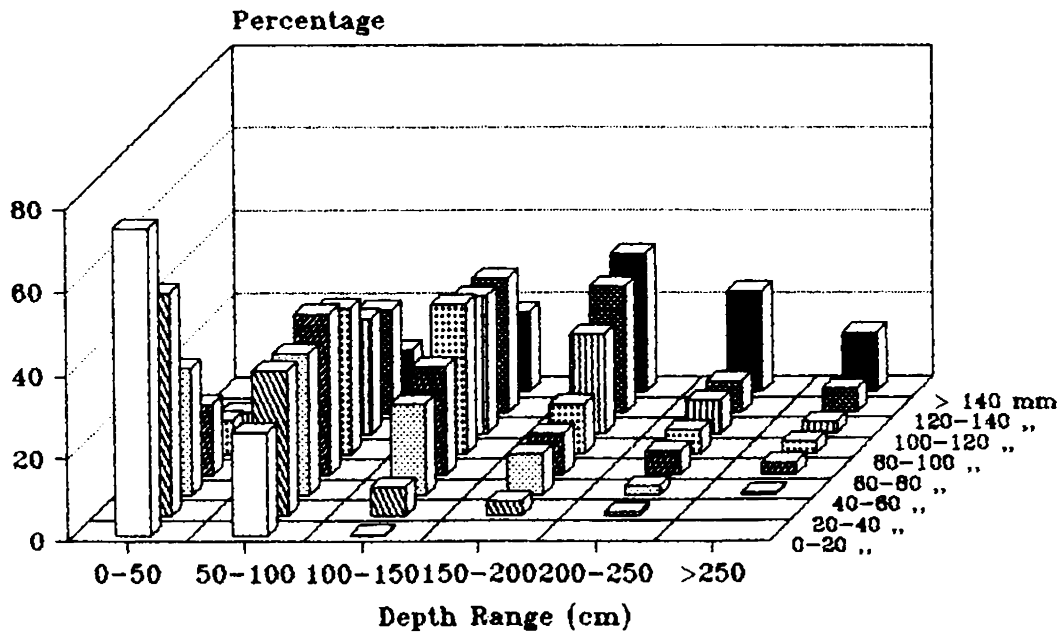


Fig 4.1.Percentage composition of a particular length group of *P. indicus* within different depth ranges of tidal ponds.

M. dobsoni:

Table 4.3 Depth-wise abundance (no/100 m^2 area) of different size groups of *M. dobsoni* in tidal ponds.

Size range (mm)	Depth (cm) 0-50	50-100	100-150	150-200	200-250	>250	Total
0-20	2070	1215	0	0	0	0	3285
20-40	1069	1497	911	122	0	0	3599
40-60	439	1000	893	209	58	12	2611
60-80	82	199	212	105	31	17	646
80-100	3	6	13	23	11	5	61
>100	0	1	2	3	2	1	9
Total	3663	3918	2031	462	102	35	10211

Chi-square Value	Table Value	d.f.	Probability
3431.63	44.31	25	0.010

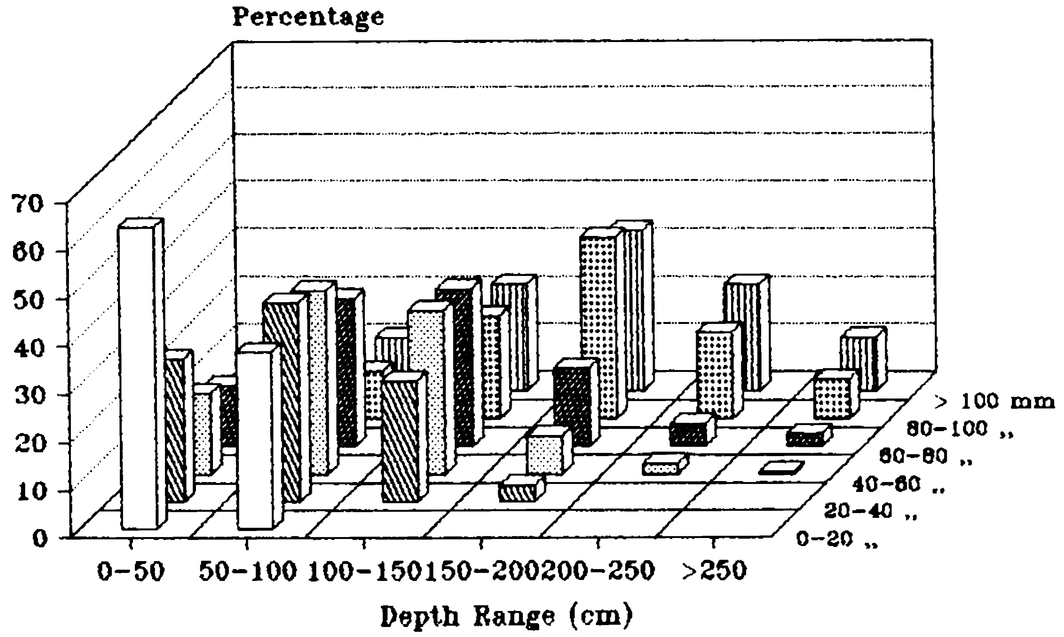


Fig 4.2 Percentage composition of a particular length group of *M. dobsoni* within different depth ranges of tidal ponds.

They were more abundant in shallow areas with large concentrations in 0.5-1.0 m zone accounting 38.4 % of the population, followed by 35.9% in 0.0-0.5 m zone (Table 4.3, Fig 4.2). Prawns up to 80 mm were observed in 0.0-0.5m zone and was dominated (56.5%) by small prawns of <20 mm. Juveniles of 20-40 mm were also abundant (29.2%) in this zone. All size groups were observed in the 0.5-1.0 m zone and were dominated by 20-60 mm prawns. 1.0-1.5 m zone accounted 19.9% of the total population. Beyond this depth abundance was very low of the order of 4.5, 1.0, 0.34% respectively in 1.5-2.0, 2.0-2.5 and >2.5 m zone.

M. monoceros:

They were distributed in relatively deeper areas than *P. indicus* and *M.dobsoni* (Table 4.4, Fig 4.3). They were more abundant (32.6%) in 0.5-1.0 m zone, followed by in 1.0-1.5 (24.13%) and in 0-0.5 m (21.4%) zones. 1.5-2.0, 2.0-2.5 and >2.5 deep zones respectively accounted 14.6, 5.9 and 1.5% of the population. 68.1% of the population in 0.0-0.5 m zone was represented by small ones of less than 20 mm and 23.3% by 20-40 mm. Large prawns up to 80 mm were observed in this zone. In the 0.5-1.0 m zone all size groups up to 120 mm were frequented. Small ones of less than 40 mm, constituted 63.2% of the population in this zone. 20-80 mm groups formed the main constituents in 1.0-1.5 m and 40-80 mm in 1.5-2.5 m zone. Beyond this depth 60-120 mm groups dominated.

Table 4.4 Depth-wise abundance (no/100 m^2 area) of different size groups of *M. monoceros* in tidal ponds.

Size range (mm)	Depth (cm) 0-50	50-100	100-150	150-200	200-250	>250	Total
0-20	79	59	0	0	0	0	138
20-40	27	53	45	13	0	0	138
40-60	7	35	31	19	9	1	102
60-80	3	18	34	24	10	2	91
80-100	0	10	16	14	7	2	49
100-120	0	2	5	9	5	2	23
>120	0	0	0	0	1	1	2
Total	116	177	131	79	32	8	543

Chi-square Value	Table Value	d.f.	Probability
398.55	50.89	30	0.010

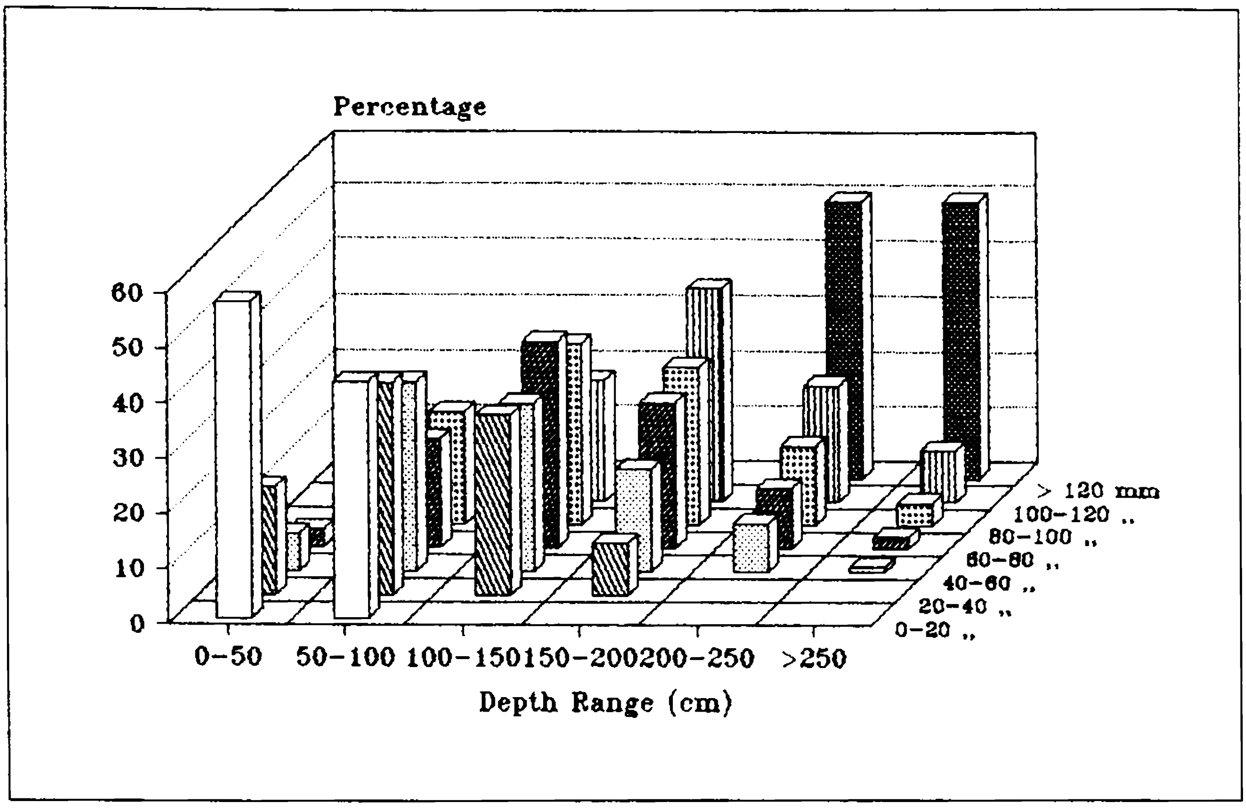


Fig 4.3 Percentage composition of a particular length group of *M. monoceros* in different depth ranges of tidal ponds.

Abundance:

Shrimp abundance and its seasonal fluctuations in tidal ponds are depicted respectively in Fig 4.4, 4.5 and 4.6, respectively for *P. indicus, M. dobsoni* and *M. monoceros* and results of statistical tests to evaluate the influence of ecology on seasonal variation in their abundance respectively in Table 4.5. Abundance was large during December-March and small during September-October. Abundance often exceeds 475-prawns/50 m^2 in perennial and 750 in seasonal ponds during peak periods. It declined to 0 to 48 prawns/50 m^2 respectively in these habitats during monsoon.

P.indicus:

Abundance was large in small tidal ponds and small in large ponds (Fig 4.4). In seasonal ponds it was small in F6 and large in F3 and F4. In perennial ponds it was respectively in F1 and F2. In seasonal ponds peak abundance of 155-173 prawns/50m^2 area was observed in May and in perennial ponds it was 183-193 in June. In the latter it was 104-151 during May. A second, small peak was observed in January with 78-128 prawns in perennial and 143-168 in seasonal tidal ponds. Abundance was low 8 to 20 during September-October in perennial ponds.

Statistical test showed no significant influence (P>0.05) for ecology on variation in the abundance of species over the season (Table 4.5). However, it described 83.1% of the fluctuation in abundance. Turbidity and salinity described maximum variations.

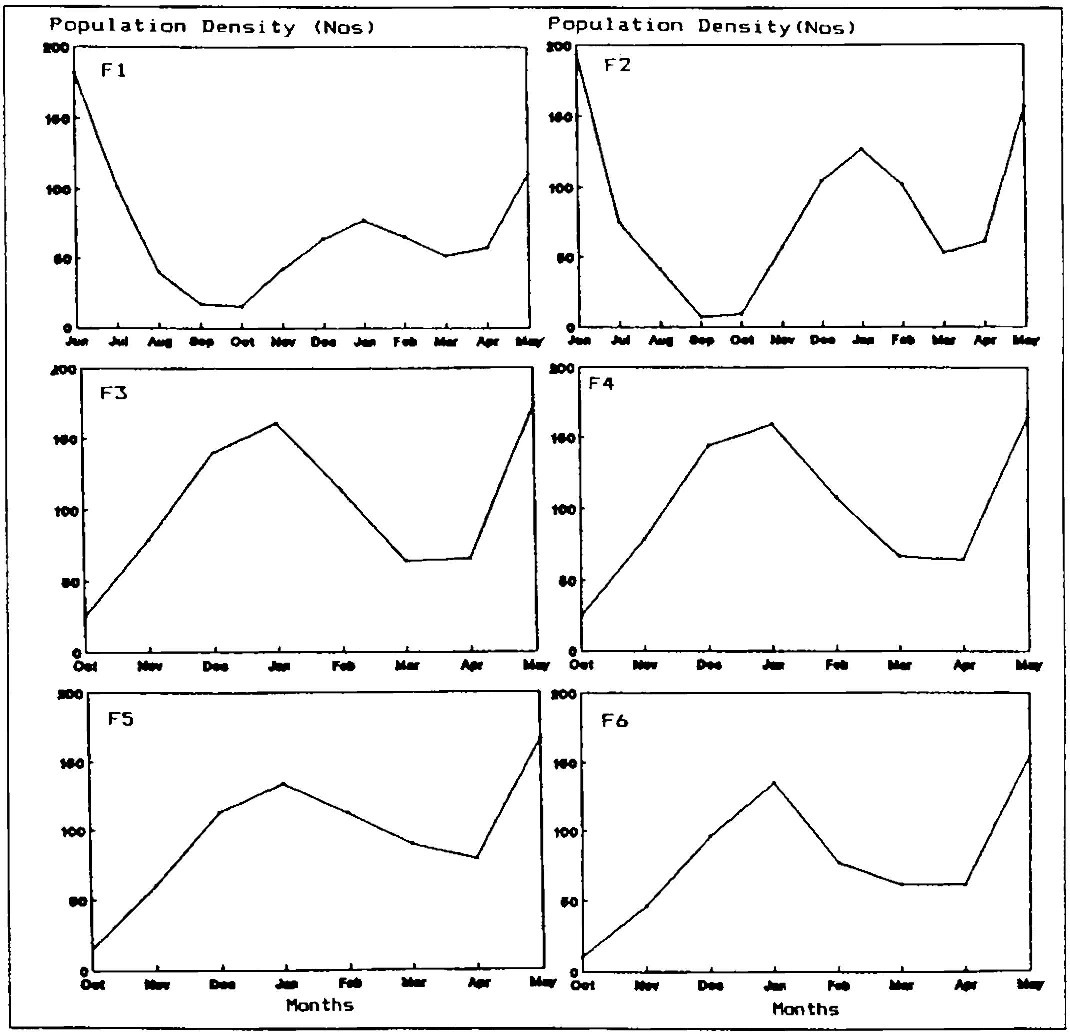


Fig 4.4 Monthwise abundance (no 50m^{-2} area) of *P. indicus* in different tidal ponds.

Table 4.5 Multiple regression and Analysis of Variance (ANOVA) Table for seasonal variation in *P. indicus* abundance and ecology.

Variables	Reg. Coeff.	Std Error	t(df=5)	Prob	Partial r^2
Temperature	-9.957	19.323	-0.515	0.6283	0.0504
Salinity	54.974	35.010	1.570	0.1774	0.3303
DO2	-3.008	3.721	0.808	0.4556	0.1156
pH	43.591	50.869	0.857	0.4306	0.1283
Productivity	-12.727	18.214	-0.699	0.5159	0.0890
Turbidity	-6.124	2.591	-2.364	0.0645	0.5277
Constant	301.022				

Std. Error of Est. 30.3635

Adjusted R Squared 0.6289
R Squared 0.8313
Multiple R 0.9118

ANALYSIS OF VARIANCE TABLE

Source	SS	df	Mean Square	F Ratio	Prob.
Regression	22715.1983	6	3785.8664	4.106	0.0713
Residual	4609.7184	5	921.9437		
Total	27324.9167	11			

M.dobsoni:

Table 4.6 Multiple regression and Analysis of Variance (ANOVA) Table for seasonal variation in the abundance of *M. dobsoni* and ecology.

Variables	Reg. Coeff.	STD Error	t(df=5)	Prob.	Partial r^2
Temperature	-59.4386	113.405	-0.524	0.6226	0.0521
Salinity	9.3980	21.837	0.430	0.6849	0.0357
DO2	-16.3056	205.473	-0.079	0.9398	0.0013
pH	120.0754	298.550	0.402	0.7042	0.0313
Productivity	-0.1129	106.898	-0.001	0.9992	$2.2*10^{-7}$
Turbidity	-0.6293	15.208	-0.041	0.9686	0.0003
Constant	1196.0774				

Std. Error of Est. 178.2028

Adjusted R Squared 0.3363
R Squared 0.3926
Multiple R 0.6266

ANALYSIS OF VARIANCE TABLE

Source	SS	df	Mean Square	F Ratio	Prob.
Regression	102630.4681	6	17105.078	0.539	0.7636
Residual	158781.1986	5	31756.239		
Total	261411.6667	11			

Among perennial ponds abundance was small in F1 and large in F2 (Fig 4.5). In seasonal ponds, it was low in F3 and F4 and high in F5 and F6. It fluctuated over the season with large abundance during November-February with peak of 394-650 prawns/50m^2 area in perennial and 600-698 in seasonal pond, in January. It declined thereafter to the low of 133-164 in seasonal ponds during May and 39-90 in perennial ponds during August-September. In perennial ponds abundance was 172-286 in May.

Statistical tests showed no significant influence (P>0.05) for ecology on variation in the abundance of the species over the season Table 4.6.

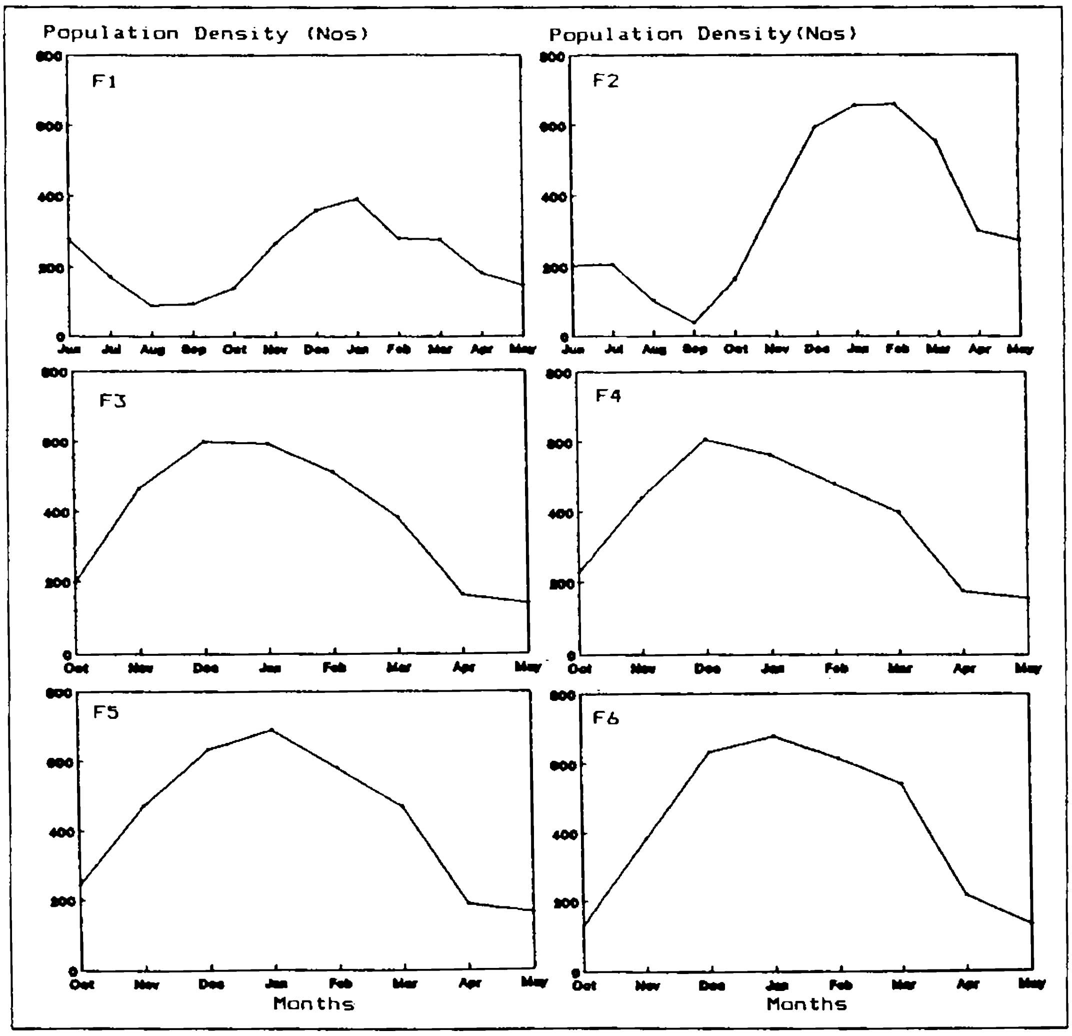


Fig 4.5 Monthwise abundance (no 50m^{-2} area) of *M. dobsoni* in different tidal ponds.

M.monoceros:

Abundance was low in large perennial pond, F1 and high in small seasonal ponds (Fig 4.6). Peak abundance of 22-33 prawns/50 m^2 pond area in perennial ponds and 33-38 in seasonal ponds was observed during February-March. It was low of 2-3 during September-October in perennial and October in seasonal ponds.

Ecology described 79.9% of the seasonal fluctuations in abundance but their influence was not significant (P>0.05), (Table 4.7). Salinity described maximum amount of variations in abundance.

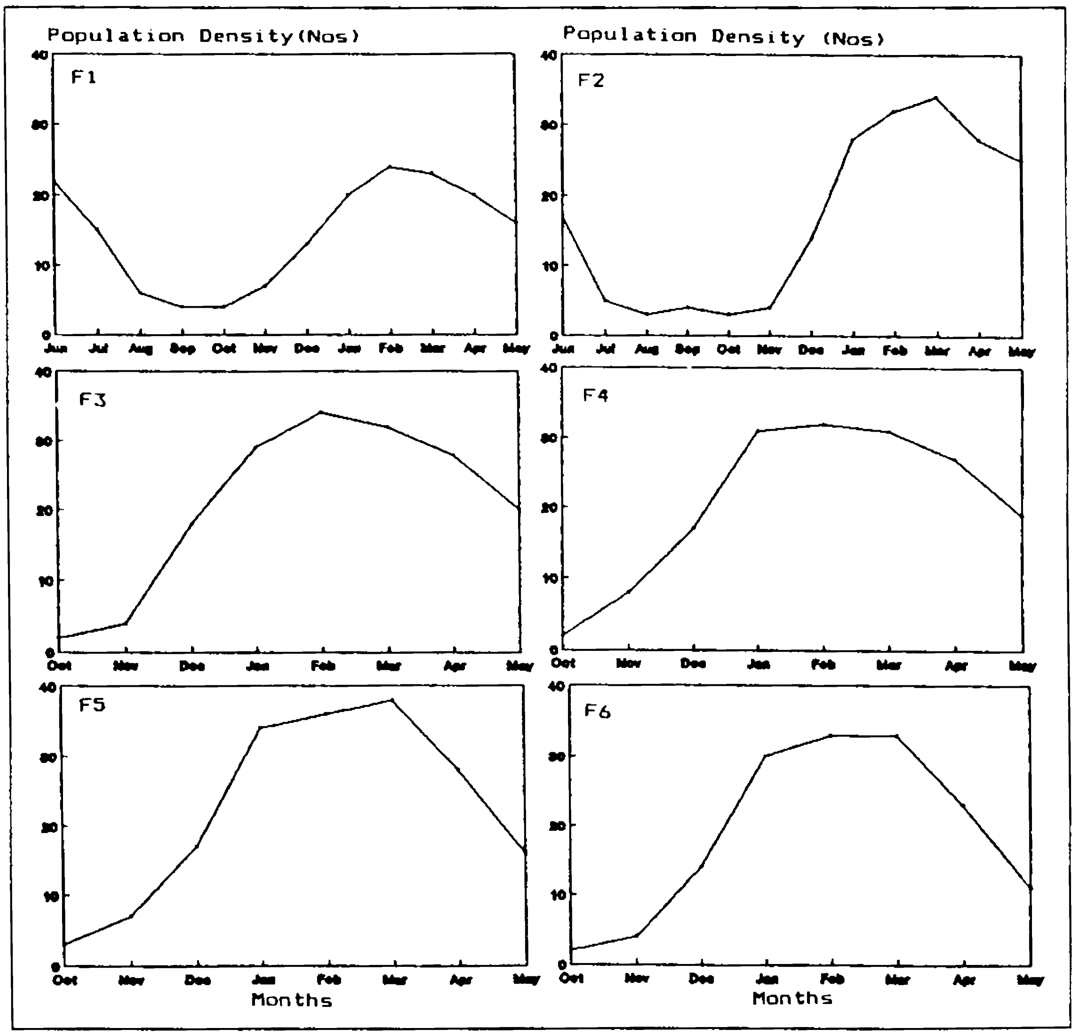


Fig 4.6 Monthwise abundance (no $50m^{-2}$ area) of *M. monoceros* in different tidal ponds.

Table 4.7 Multiple regression and Analysis of Variance (ANOVA) Table for seasonal variation in *M. monoceros* abundance and ecology.

Variables	Reg. Coeff.	STD Error	t(df=5)	Prob.	Partial r^2
Temperature	-0.3503	3.7437	0.094	0.9291	0.0017
Salinity	0.8201	0.7209	1.138	0.3068	0.2056
DO2	1.5816	6.7831	0.233	0.8249	0.0108
pH	-1.1389	9.8558	-0.116	0.9125	0.0027
Productivity	-0.0746	3.5290	-0.021	0.9840	$8.5*10^{-5}$
Turbidity	-0.0449	0.5020	-0.090	0.9322	0.0016
Constant	21.0886				

Std. Error of Est. 5.8829

Adjusted R Squared 0.5568
R Squared 0.7985
Multiple R 0.8936

ANALYSIS OF VARIANCE TABLE

Source	SS	df	Mean Square	F Ratio	Prob.
Regression	685.8756	6	114.3126	3.303	0.1054
Residual	173.0410	5	34.6082		
Total	858.9167	11			

DISCUSSION

Considerable heterogeneity was observed in distribution and abundance of shrimps in tidal ponds with respect to size and age. Small prawns were abundant along shallow areas and large ones in deeper areas. Many reported similar distribution pattern for *P. indicus, M. dobsoni* and *M. monoceros* (Achuthankutty, 1988; Easo and Mathew, 1989; Balasubrahmanyam *et.al.*, 1995), brown shrimp, *Crangon crangon* (Janssen and Kuipers, 1980) and *P. merguiensis* (Staples, 1980a; b; Garcia and Le Reste, 1981; Garcia, 1984). Achuthankutty (1988) attributed such differential distribution to changing physiological needs of shrimps with growth and changes in food preference. Balasubrahmanyam *et.al.* (1995), considered preference among large prawns for low temperature, as the probable cause for spatial segregation between different size groups. Garcia and Le Reste (1981), Garcia (1984) and Easo and Mathew (1989) opined that, for penaeids, which closely associated with the bottom, the substrate may have considerable influence in distribution. Postlarvae and early juveniles have wide tolerance for different environmental conditions than large shrimps and so will be available in large numbers along shallow marginal areas. But as grows, their tolerance limits get narrowed and accordingly they move to areas, where preferred conditions prevail. Such differential preference among size groups produced spatial segregation in the population.

Abundance was low for all species in deeper areas despite the prevalence of more stable environment there. This can be attributed to continuous emigration of large prawns from the habitat and also to prevailing sub-optimal conditions like relatively low dissolved oxygen and pH along the bottom layers of this zone.

Distribution pattern of shrimps suggested that spatial segregation between size groups act as a natural adaptation to minimise over-crowding, predation and intra-specific competition for food and space. This in turn help in the efficient utilisation of available habitat area and resources in tidal ponds.

The variation in abundance observed between tidal ponds linked with recruitment rate. As seen in Chapter 3 the low standing population in large perennial ponds can be attributed to low postlarval import into the habitat. Recruits, which enter these habitats, dispersed over wide area thus result in low abundance. Herke *et.al.* (1987; 1996) also attributed similar low abundance in weired tidal ponds than in the adjacent unweired ponds to reduced postlarval recruitment into the former due to low water exchange. As has been discussed in Chapter 3 location of tidal ponds also affect shrimp abundance.

Seasonal variation in shrimp abundance correlated directly with the strength and seasonality of postlarval recruitment, period of stay and juvenile emigration. Peak ingression immediately preceded the peak period of abundance and peak emigration the lean period. Similar fluctuation in seasonal abundance of *M. dobsoni* in perennial ponds was reported by Vasudevappa (1992), which according to the present findings followed the pattern of postlarval ingression and emigration.

Age and Growth

Chapter-5

AGE AND GROWTH

INTRODUCTION

Growth is three-dimensional increase in size of an organism over time. It depends directly on the suitability of the habitat for the organisms concerned in terms of environment, food and space availability. Information on growth helps to understand the dynamics of the population. It also formed the basis for understanding mortality or survival and other characteristics that determine yield. In view of the importance of penaeids in the traditional fishery and aquaculture, considerable work have been done by several, on the biology of major species and provided some information on their growth in the backwaters of Kerala (Menon, 1955; Gopinath, 1956; George, 1959; Menon and Raman, 1961; Banergy and George, 1967; Mohamed *et.al.*, 1967; George *et.al.*, 1968; Mohamed and Rao, 1971). Such informations are also available from estuaries of Goa (Achuthankutty and Nair, 1982; 1983; Achuthankutty and Parulekhar, 1986; Achuthankutty, 1988), Manakkudy estuary (Suseelan, 1975b), Ennur and Adayar estuary (Subrahmanyam, 1968), Godavari estuarine system (Subrahmanyam, 1972; 1973; Subrahmanyam and Ganapati, 1975; Devi, 1988), Chilka lake (Jhingran and Natarajan, 1966; Rao; 1967) and for related species from else where (Ford and St. Amant, 1971; Staples, 1980b; Alvarez *et.al.*, 1987; Rodriguez, 1987; Benfield *et.al.*, 1990; Haywood and Staples, 1993; Mohan and Siddeek, 1996). Many others added similar information for penaeids in tidal ponds (Menon, 1954; Hall, 1962; George, 1974; 1975; Le Reste and Marcille, 1976; Anon, 1978; Venegas, 1980; Paulinose *et.al.*, 1981; Knudsen *et.al.*, 1996), while reporting the fishery. Whereas others provided such information under different culture conditions (Sultan *et.al.*, 1973; Suseelan, 1975a; Muthu *et.al.*, 1981; Aravindhakshan *et.al.*, 1982; Jose *et.al.*, 1987; Lazarus and Nandakumaran, 1990; Vasudevappa, 1992).

Many estimated the residence period for penaeids in Cochin backwaters (Menon, 1954; 1955; George, 1959; 1962b; Mohamed and Rao, 1971), Chilka lake (Rao, 1967), estuaries of Goa (Achuthankutty and Nair, 1982; Achuthankutty, 1988), Godavari estuarine systems (Subrahmanyam, 1973) and in estuaries of other areas (Coles and Greenwood, 1983; Staples, 1983; Benfield *et.al.*, 1990; D'Incao, 1991). Others provided similar information for penaeids in tidal ponds also (Hall, 1962; Paulinose *et.al.*, 1981; Carpenter *et.al.*, 1986; George, 1974;

Vasudevappa, 1992).

A perusal of the literature reveals that the general pattern of shrimp growth is well known and reasonably consistent from area to area and species to species. However, further study is needed to gather accurate knowledge on growth to design and formulate specific management policies, like determination of optimum date to open the fishing season, etc.

The present study is an attempt to understand more on the growth characteristics of penaeids prawn in tidal ponds and adjacent backwater habitats with respect to ecology.

MATERIALS AND METHODS

Material:

The monthly length frequency data of resident shrimps from tidal ponds and backwaters and size increment data from culture trials were used for the study. Details of the materials used in the study were briefed in Table 5.1.

Table 5.1 Sample size and length ranges (mm) of different species from tidal ponds and backwaters used for the growth study.

Pond/Type	*P. indicus*		*M. dobsoni*		*M. monoceros*	
Habitat	No.	Length Range	No.	Length Range	No.	Length Range
Perennial (F1,F2)	4,884	10-172.0	15,311	9-105.5	804	9-120.5
Seasonal-TI (F3,F4)	2,432	10-150.5	8,160	9- 91.5	495	9-103.0
Seasonal-TII (F5,F6)	2,138	10-142.5	9,575	9- 89.0	494	9- 98.5
Stocking (F7,F8)	2,094	10-153.0	2,034	9-105.6	203	9-121.0
Backwater	853	10-136.5	3,684	9- 86.4	212	9- 98.5

Method of Study:

Modal class progression analysis was used to identify different recruits in the population and their growth in subsequent months as described by earlier workers (Bagenal, 1955; Pauly, 1982; 1983, Haywood and Staples, 1993). The modes recognised in monthly length frequency data were represented in the form of scatter diagram and the progression of modes were traced freehand through time. The average size increment against time obtained from modal progression was taken as growth. It was also estimated from the growth curves using ELEFAN-I programme

(Gayanilo *et.al.*, 1996) was also used to estimate growth parameters as described by Pinto (1986) for migrating juvenile population in nursery grounds. Growth obtained from the curves, which fitted through maximum number of peaks and troughs, were considered most reliable.

Growth of prawns under selective stocking conditions in farmers ponds were studied by direct measurement at fortnightly intervals. One growth trial of seven month duration was also conducted in two 0.05 ha ponds using postlarvae collected from backwaters. They were fed exclusively with clam meat through out the period.

Since all species remain in perennial tidal ponds for indefinitely long periods and attain maximum sizes, growth parameters were estimated for the population using ELEFAN-I programme (Gayanilo *et.al.*, 1996) as described by Pinto (1986). It was also estimated from Ford and Walford plot (Ford, 1933; Walford, 1936) using growth data from modal progression analysis. Growth of prawns in length were described by von Bertalanffy growth equation (Bertalanffy, 1938) as;

$$Lt = L\infty \ [1-e^{-k(t-to)}],$$

where;

Lt- Length at age t,

L∞- Maximum attainable size,

k- growth coefficient,

to- theoretical age at which animals would had zero length if it had always grown according to the above equation

A common "t_o" for the population of each species in backwaters and tidal ponds was estimated from von Bertalanffy plot (Bertalanffy, 1934) using the relation "–a/b"; where, "a" the constant and "b" regression coefficient. T_{max} was computed from fitted age-length equation, log t = a + b * log l, (where, t - age in months and l - length in mm). Since, growth vary under different habitat conditions, equations were fitted separately for the population from different tidal ponds and backwaters. The equations were fitted from log converted age-length data following linear analysis. Last age groups from each set of data were not considered for fitting the equation, to minimise error.

Multiple regression analysis (Snedecor and Cochran 1967) was employed to quantify influence of ecology on age and growth of prawns.

RESULTS

P. indicus:

Growth:

Growth in length was slow, 18.28 and 19.15 mm month^{-1} respectively in backwaters and perennial ponds and attained 122 and 129 mm in this habitats during the initial six month growth (Fig 5.1, 5.2, 5.3 Table 5.2). It was fast, 24.98 mm in stocking ponds and moderate 20.04 and 20.20 mm respectively in Type-I and Type-II seasonal ponds. In these habitat they attained 151, 145 and 141 mm respectively in 6 months.

They grown to a maximum size of 172 mm in perennial ponds in 14.4 months and 137 mm in backwaters in 9.2 months (Fig 5.1, 5.2). They attained 148.6 and 143.6 mm respectively in Type-I and Type-II seasonal ponds in 6.5 and 6.02 months. Under selective stocking conditions with feeding they attained 155 mm in 7 months.

Growth in weight also followed the same pattern as length (Table 5.3, Fig 5.3). It varied between 1.79 in open backwaters and 3.96 g month^{-1} in stocking ponds during the first six month. It was 2.16 g in perennial ponds and 3.58 and 3.22 g respectively in Type-I and Type-II seasonal ponds.

Results of the statistical tests showed that ecology and physical conditions of the habitat described 97% ($P<0.05$) of the growth variations in the species (Table 5.4). Productivity, water exchange and depth produced maximum variation.

Table 5.2 Average monthly length increment (mm) of *P. indicus* in tidal ponds and backwaters.

Age (months)	Perennial pond	Seasonal pond Type-I	Seasonal pond Type-II	Backwaters	Stocking pond
1	35.44	37.37	38.21	32.87	47.20
2	26.81	31.85	32.09	26.77	33.08
3	20.17	19.29	21.11	17.82	23.50
4	14.15	13.69	11.97	13.01	16.50
5	9.79	9.65	9.67	10.79	10.53
6	8.52	8.42	8.14	8.41	7.86
Mean for 6 months	19.15	20.04	20.20	18.28	24.98

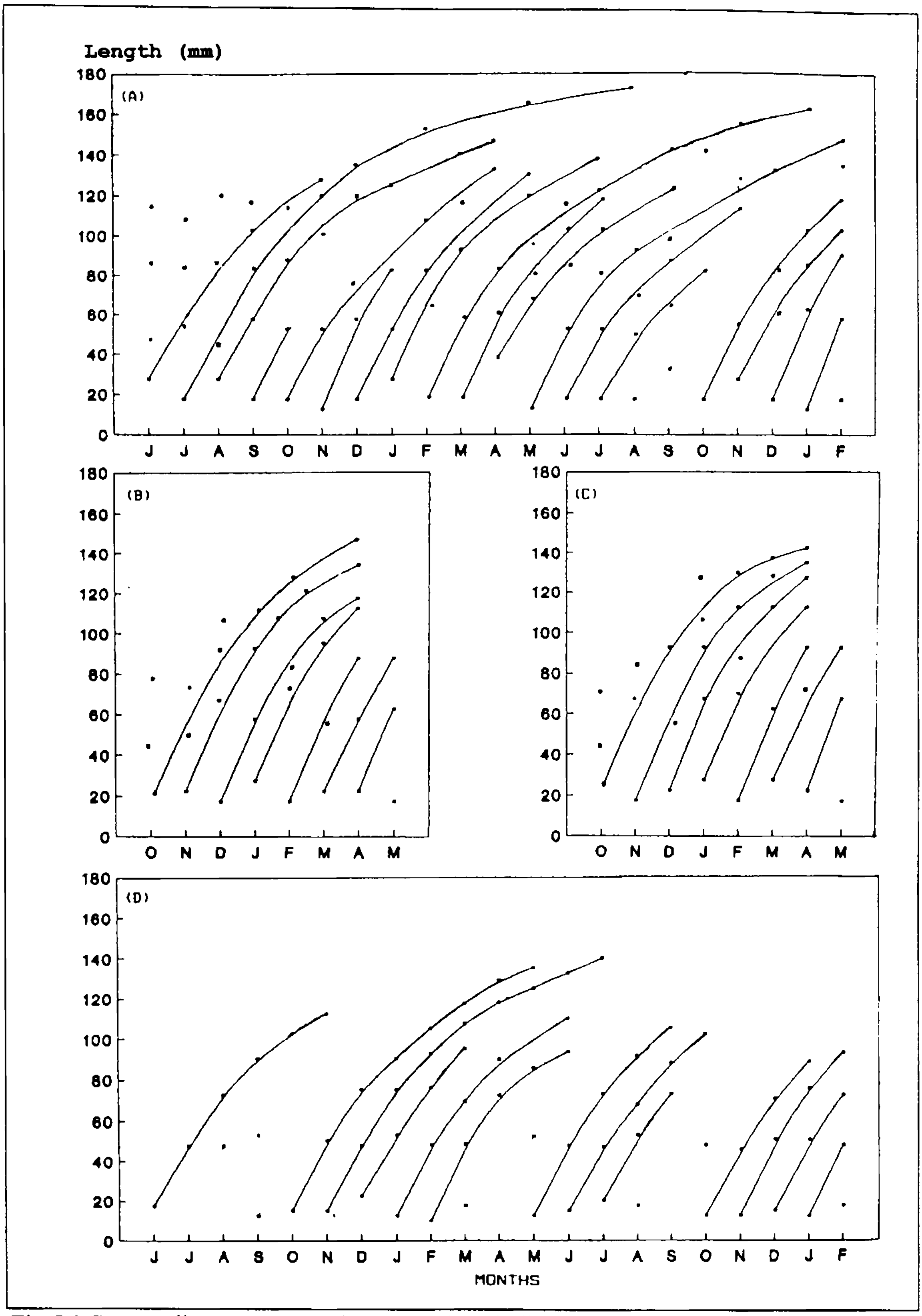


Fig 5.1 Scatter diagram on monthly modal length distribution and tracing of progression of mode in subsequent months free hand growth curves for *P. indicus* in tidal ponds and backwaters (A-Perennial pond, B- Seasonal Type-I, C- Seasonal Type-II and D-Open Backwaters).

Estimates of growth parameters of the species in perennial ponds by Ford-Walford and ELEFAN-I programme varied widely (Fig 5.2, 5.4, Table 5.5). The maximum attainable size ($L\infty$) is small, 175.45 mm by the former and large 179.5 mm by the latter. Growth co-efficient (K) also varied between 2.772 and 2.95.

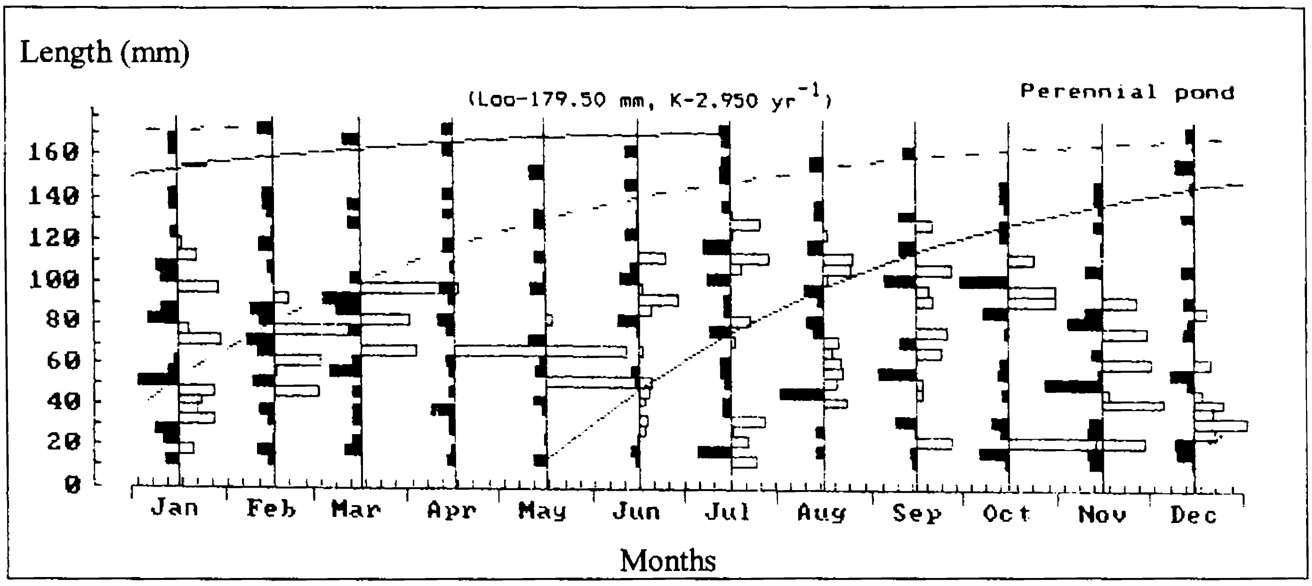


Fig 5.2 Restructured length frequency histogram and growth curves of *P. indicus* in tidal ponds and backwaters.

Table 5.3 Average monthly weight increment in grams of *P. indicus* in tidal ponds and backwaters.

Age (months)	Perennial pond	Seasonal Pond (T-I)	Seasonal Pond (T-II)	Backwaters	Stocking Pond
1	0.74	1.38	1.30	0.61	1.32
2	2.33	4.21	4.35	1.82	4.04
3	2.42	4.01	4.17	2.23	5.22
4	2.69	4.60	3.50	2.22	5.14
5	2.45	3.81	3.37	2.00	4.23
6	2.35	3.47	2.81	1.89	3.80
Mean for 6 months	2.16	3.58	3.22	1.79	3.96

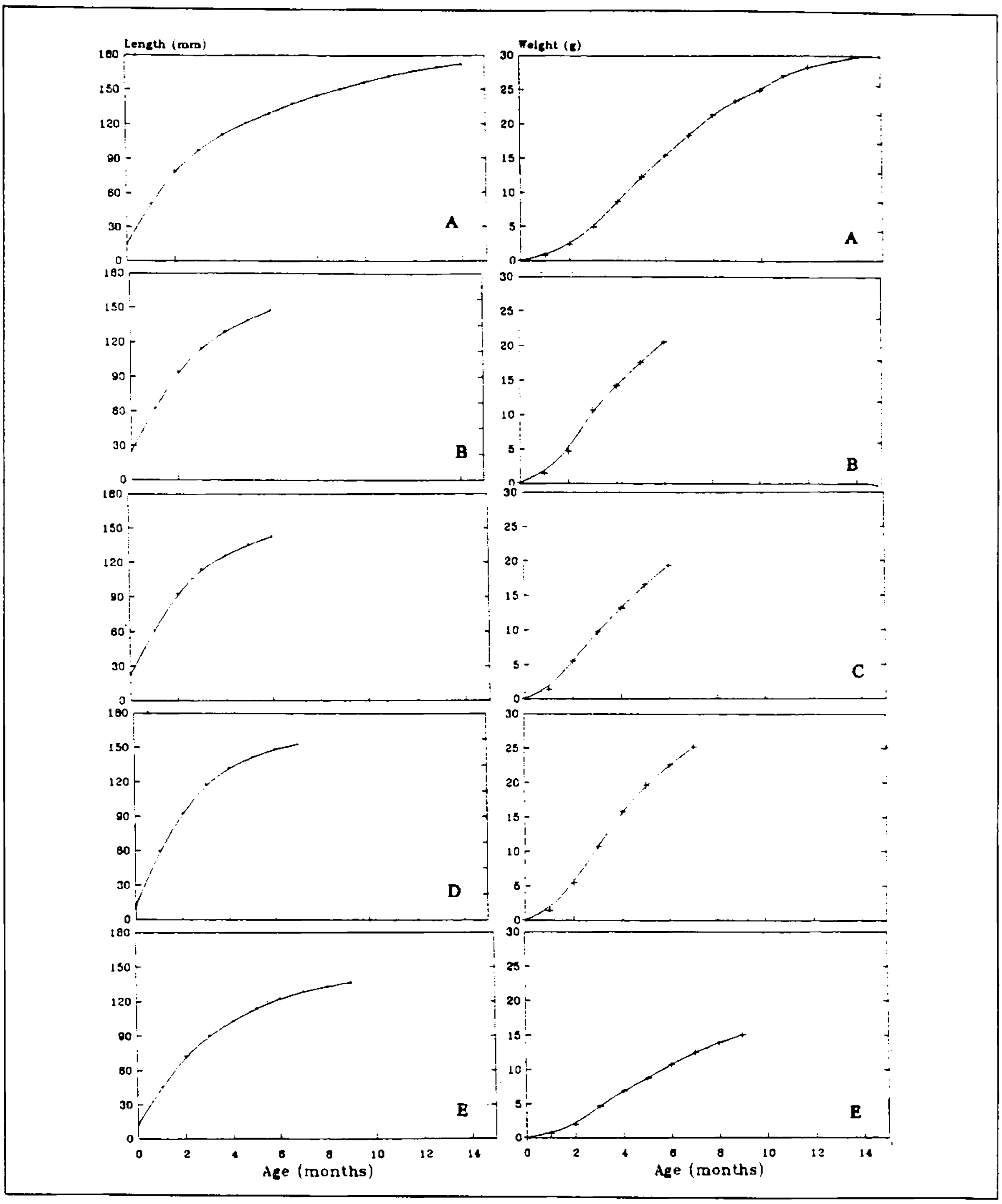


Fig 5.3 Growth curves of *P. indicus* in different tidal ponds and backwaters (A-Perennial pond, B-Seasonal Type-I, C-Seasonal Type-II, D-Stocking pond, E-Open Backwaters).

Table 5.4 Multiple regression and Analysis of variance table for growth of *P. indicus* and eco-physical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Salinity	0.0413	0.0696	0.593	0.61338	0.1495
Temperature	0.5663	0.6154	0.920	0.45462	0.2974
Area	0.0150	0.0148	1.012	0.41799	0.3387
Depth	-0.7849	0.6846	1.147	0.37021	0.3966
Water Exchange	0.1658	0.1369	1.211	0.34956	0.4231
Productivity	0.2221	0.1069	4.993	0.04714	0.9686
Constant	37.7252				

Std. Error of Est. = 0.4462

Adjusted R Squared = 0.8024
R Squared = 0.9702
Multiple R = 0.9850

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	23.1932	6	3.8655	19.415	0.0498
Residual	0.3982	2	0.1991		
Total	23.5914	8			

Table 5.5 Estimated growth parameters of *P. indicus* in perennial tidal ponds.

Method of Estimation	L∝ (mm)	K yr^{-1}	Rn
Ford-Walford Plot	175.45	2.772	-
ELEFAN-I	179.50	2.950	0.159
Mean	177.48	2.861	-

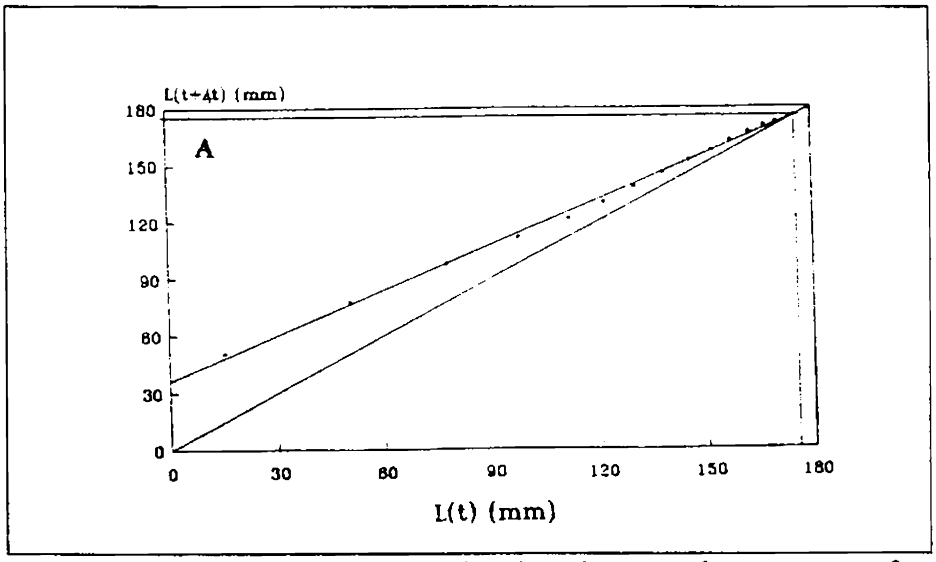


Fig 5.4 Ford-Walford plot for estimating the growth parameters of *P. indicus* in perennial pond.

Age and Residence Period:

In perennial ponds resident population was represented by 0-14+ month old prawns, where zero month group constituted 22.96% and 0-3+ group 72.67% (Table 5.6). Prawns of 9+ month and above represented 1.16% and 14+ groups only 0.05%. In seasonal ponds, they were represented by 0-6+ groups, where 0-3+ groups formed 94.11 and 95.27% respectively in Type-I and Type-II ponds. Zero month groups constituted 35.01 and 36.27% respectively in these habitats; whereas, 6+ groups 0.19 and 0.27%. In backwaters, they were represented by 0-9+ groups, where zero month groups formed 45.7%, 0-3+, 94.91% and 9+ groups 0.13%. Prawns of 6 month and above were very rare in this habitat.

Age at zero length (t_0) was estimated as –0.14 month and at recruitment as 0.25 (Table 5.8). Maximum age varied from 6.28 in Type-II seasonal pond to 14.63 months in perennial ponds. In the Type-I seasonal ponds it is 6.85 and in backwaters 9.46 months.

Their residence period was short, 6.02 months in Type-II seasonal ponds and long, 14.38 in perennial ponds (Table 5.9). In Type-I seasonal ponds it is 6.49 and in backwater 9.17 months.

Results of the statistical test to identify the factors influencing residence period of the species is given in Table 5.9 Ecology and physical conditions of the habitat together described 99.97% ($P<0.05$) of the variations in residence period. Depth, water exchange and temperature explain maximum variations.

Table 5.6 Age composition (percentage) of *P. indicus* population in tidal ponds and backwaters.

Age (months)	Perennial pond	Seasonal ponds Type-I	Seasonal ponds Type-II	Open Backwaters
0	22.96	35.01	36.27	45.70
1	19.59	27.32	27.33	25.62
2	16.64	20.02	20.30	15.81
3	13.48	11.76	11.37	7.78
4	9.79	4.27	3.52	2.68
5	6.53	1.42	0.95	1.21
6	4.37	0.19	0.27	0.64
7	2.69			0.25
8	1.79			0.19
9	1.00			0.13
10	0.47			
11	0.32			
12	0.21			
13	0.11			
14	0.05			

Table 5.7 Age-length relationship of *P. indicus* population in tidal ponds and backwaters.

Habitat	Age-length equation	r^2
Perennial Pond	Log t = - 4.70009 + 2.623657 * log l	0.9997
Type-I Seasonal Pond	Log t = - 3.68709 + 2.083419 * log l	0.9987
Type-II Seasonal Pond	Log t = - 4.04806 + 2.245704 * log l	0.9989
Open Backwater Pond	Log t = - 3.90065 + 2.226676 * log l	0.9765

Table 5.8 Age at different points of life and residence period (in months) of *P. indicus* in tidal ponds and backwater.

	Perennial pond	Seasonal pond Type-I	Seasonal pond Type-II	Backwaters
Maximum age (tmax)	14.63	6.85	6.28	9.46
Period of Stay	14.38	6.49	6.02	9.17
Age at zero length (t_0)	-0.14		Age at recruitment(tr)	0.25

Table 5.9 Multiple regression and Analysis of Variance table for residence period of *P. indicus* and eco-physical characteristics of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Temperature.	12.3902	1.0326	11.999	0.05293	0.9931
Area	0.0367	0.0075	4.915	0.12777	0.9603
Depth	8.1432	0.3894	20.911	0.03042	0.9977
Water Exchange	-0.2418	0.0120	-0.199	0.03149	0.9976
Productivity	-10.5235	1.2225	-8.608	0.07363	0.9867
Constant	-358.9763				

Std. Error of Est. = 0.1388

Adjusted R Squared = 0.9983
R Squared = 0.9997
Multiple R = 0.9999

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	69.0229	5	13.8046	716.336	0.0284
Residual	0.0193	1	0.0193		
Total	69.0421	6			

***M. dobsoni*:**

Growth:

Growth in length was fast, 15.24 mm month^{-1} during the initial six month in stocking ponds followed by 13.07 and 12.77 mm respectively in Type-II and Type-I seasonal ponds (Table 5.10, Fig 5.5, 5.6 and 5.7). During this period they attained 101.4 mm 88.9 and 87.9 respectively in these habitats. It was slow, 12.63 mm in perennial ponds and 11.81 in backwaters, where they respectively attained 86.73 and 81.4 mm during the same period.

They grown to a maximum size of 89.14 and 90.12 mm respectively in Type-I and Type-II seasonal ponds in 6.1 month and 86.45 mm in open backwater in 7.8 month (Fig 5.5, 5.6). In perennial ponds they attained 105.4 mm in 12.11 month. However, under selective culture conditions they had grown to 105.6 mm in 7 month.

Growth in weight varied between 0.561 g in open backwaters and 0.997 g month^{-1} in stocking ponds during the first six month (Table 5.11, Fig 5.7). It was 0.664 g in perennial ponds and 0709 and 0.791 g respectively in Type-I and Type-II seasonal ponds.

Results of the statistical test showed that ecology and physical conditions of the habitat described 97.2% ($P<0.05$) of the growth variation in different habitats (Table 5.12). Productivity, water exchange and depth produced maximum variations.

Table 5.10 Growth increment in length (mm month^{-1}) of *M. dobsoni* in tidal ponds and backwaters.

Age (months)	Perennial pond	Seasonal pond Type-I	Seasonal pond Type-II	Backwaters	Stocking pond
1	21.89	25.53	26.78	23.98	28.98
2	17.12	17.69	18.04	17.06	21.37
3	13.48	12.48	12.64	12.06	15.56
4	9.64	8.97	9.18	7.51	11.03
5	7.53	6.74	6.31	6.12	8.86
6	6.09	5.18	5.44	4.13	5.64
Mean	12.63	12.77	13.07	11.27	15.24

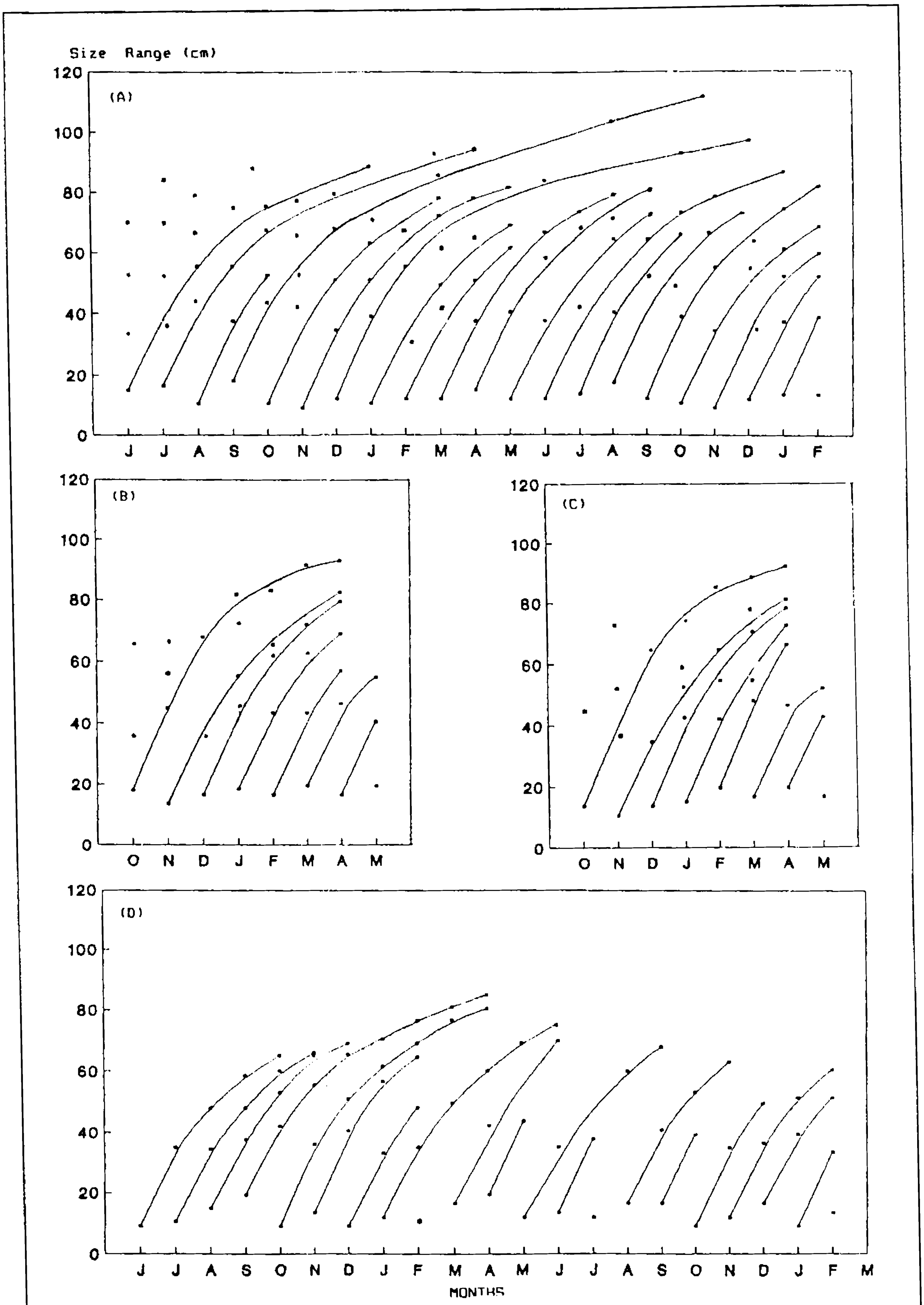


Fig 5.5 Scatter diagram on monthly modal length distribution and tracing of progression of mode in subsequent months free hand growth curves for *M.dobsoni* in tidal ponds and backwaters (A-Perennial pond, B- Seasonal Type-I, C- Seasonal Type-II and D-Open Backwaters).

Estimates of growth parameters for the species in perennial ponds by Ford-Walford. plot and ELEFAN-I varied slightly (Table 5.13, Fig 5.6, 5.8). The maximum attainable size (L∞) is small, 108.46 mm by former and large, 110.32 mm by the latter method. Estimates of growth co-efficient (K) also varied between 3.11 and 3.19 year^{-1} respectively by these methods.

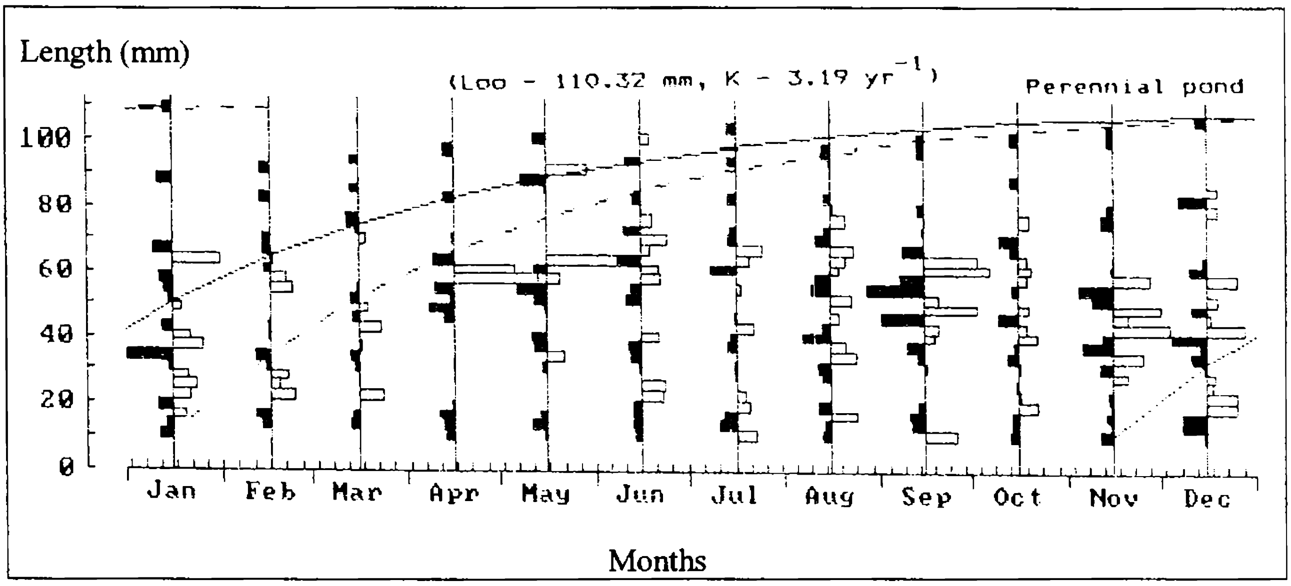


Fig 5.6 Restructured length frequency histogram and growth curves of *M.dobsoni* in tidal ponds and backwaters.

Table 5.11 Growth increment in weight (g month^{-1}) of *M. dobsoni* in tidal ponds and backwaters.

Age (months)	Perennial pond	Seasonal Pond (T-I)	Seasonal Pond (T-II)	Backwaters	Stocking Pond
1	0.471	0.656	0.671	0.562	0.733
2	0.723	0.813	0.945	0.782	1.076
3	0.792	0.834	0.874	0.599	1.517
4	0.788	0.774	0.903	0.594	1.192
5	0.540	0.584	0.710	0.363	0.982
6	0.669	0.593	0.214	0.464	0.484
Mean	0.664	0.709	0.719	0.561	0.997

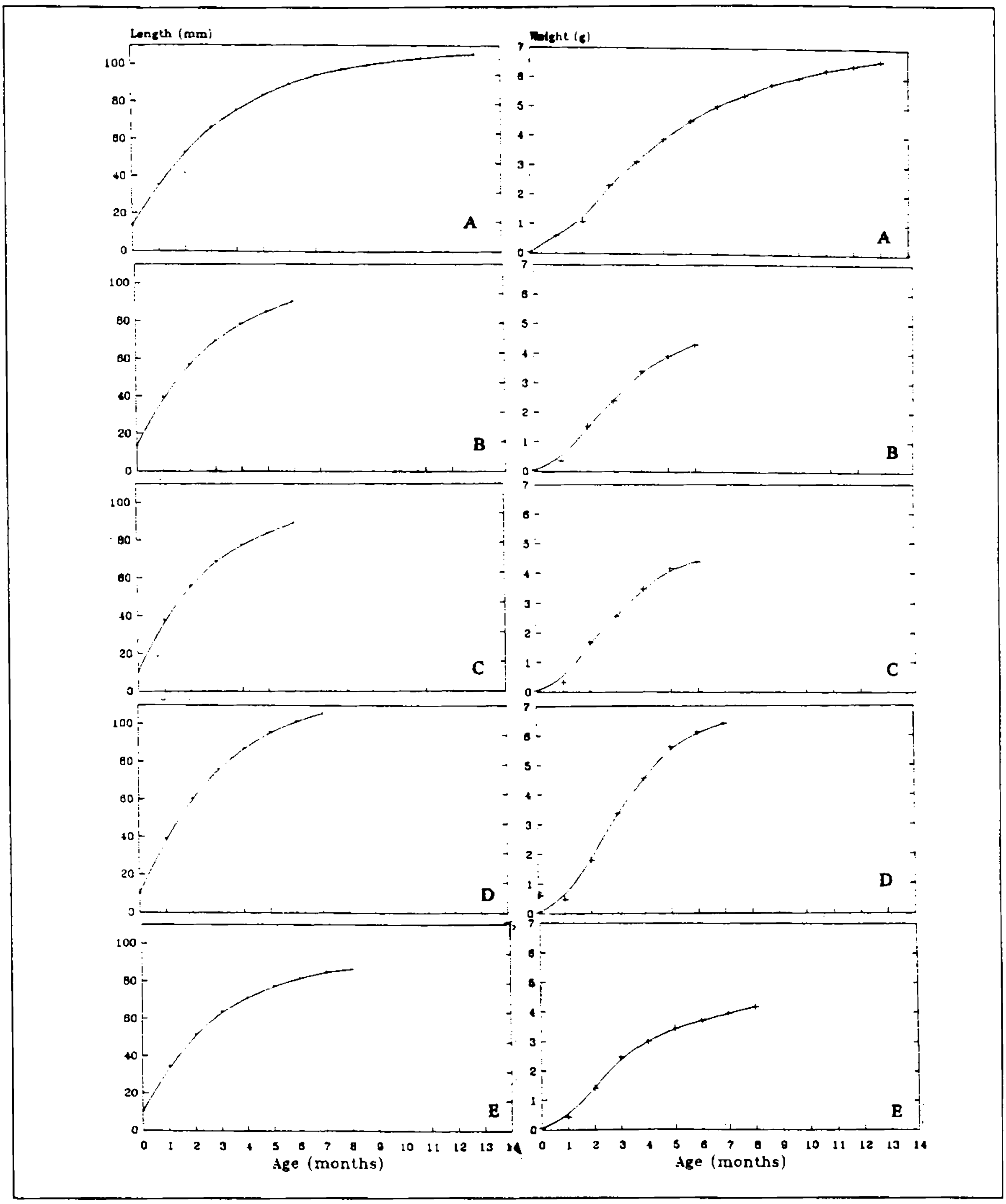


Fig 5.7 Growth curves of *M. dobsoni* in different tidal ponds and backwaters (A-Perennial pond, B-Seasonal Type-I, C-Seasonal Type-II, D-Stocking pond, E-Open Backwaters).

Table 5.12 Multiple regression and Analysis of Variance table for growth rate of *M. dobsoni* and eco-physical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Salinity	1.0186	1.8656	0.546	0.63996	0.1296
Temperature	0.3628	0.7158	0.507	0.66267	0.1138
Area	-0.0019	0.0172	-0.108	0.92405	0.0058
Depth	0.2379	0.1860	1.153	0.36795	0.3995
Water Exchange	0.0265	0.0229	1.279	0.32919	0.4500
Productivity	0.2539	0.1593	5.988	0.04496	0.9896
Constant	23.1856				

Std. Error of Est. = 0.5190

Adjusted R Squared = 0.8866
R Squared = 0.9716
Multiple R = 0.9857

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	63.1155	6	10.5193	22.410	0.0462
Residual	0.9388	2	0.4694		
Total	64.0543	8			

Table 5.13. Estimated growth parameters of *M. dobsoni* population in perennial tidal pond.

Method of Estimation	L∞ (mm)	K yr^{-1}	Rn
Ford-Walford Plot	108.46	3.107	-
ELEFAN-I	110.32	3.190	0.124
Mean	109.39	3.149	-

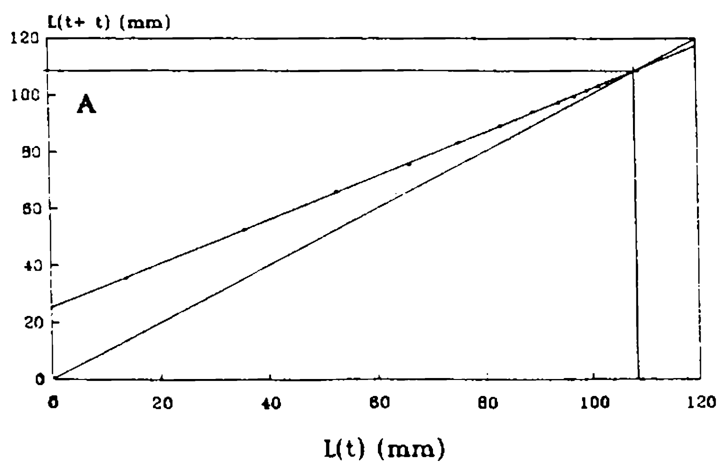


Fig 5.8 Ford-Walford plot for estimating the growth parameters of *M. dobbsoni* in perennial pond.

Age and Residence Period:

Age structure of the species in tidal ponds and backwaters were briefed in Table 5.14. Population was represented by 0 to 12+ month old prawns in perennial ponds, where, zero month group represented 1.03% and 12+ group 0.02%. 0-3+ month group constituted 87.54%, whereas 6+ and above age groups 1.32% of the population in this habitat. In seasonal ponds, they were represented by 0-6+ groups. 94.36% of the population in Type-I and 95.19% in Type-II ponds were constituted by 0-3+ groups, where 6+ group represent only 0.33 and 0.07% respectively. In backwaters they are represented by 0 to 8+ groups, with 97.13% being constituted by 0-3+ groups. 45.98% of the population in this habitat was constituted by zero and 0.11% by 8 month group.

Age-length relationship of the species in different tidal ponds and backwaters were given in Table 5.15 and the estimate of age at zero length (t_o), at recruitment (t_r), maximum age (t_{max}) and residence period in Table 5.16. Age at zero length (t_o) was estimated as –0.23 months and age at recruitment (t_r) as 0.28. Maximum age (t_{max}) varied from 6.3 months in seasonal ponds to 12.4 in perennial ponds, whereas it was 8.1 in open backwaters (Table 5.15, 5.16). Residence period was short 6.1 months in seasonal ponds, 7.8 in backwaters and 12.1 in perennial ponds.

Results of the statistical test showed that ecology and physical conditions of the habitat together described 99.98% ($P<0.05$) of the variation in age and residence period of the species (Table 5.17). Water exchange, depth and temperature produced maximum variation.

Table 5.14 Age structure of *M. dobsoni* population in tidal ponds and open backwaters.

Age (months)	Perennial pond	Seasonal ponds Type-I	Seasonal ponds Type-II	Open Backwaters
0	31.03	34.69	37.86	45.98
1	24.11	28.59	30.39	29.08
2	19.65	19.58	18.28	18.95
3	12.75	11.50	8.66	3.12
4	6.50	4.02	3.25	1.16
5	3.09	1.29	1.49	0.91
6	1.54	0.33	0.07	0.48
7	0.66			0.21
8	0.31			0.11
9	0.17			
10	0.10			
11	0.06			
12	0.02			

Table 5.15 Age-length relationship of *M.dobsoni* population in tidal ponds and backwaters.

Habitat	Age-length equation	r^2
Perennial Pond	Log t = -2.6968 + 1.8734 * log l	0.986
Type-I Seasonal Pond	Log t = -2.5057 + 1.6914 * log l	0.996
Type-II Seasonal Pond	Log t = -2.5065 + 1.6950 * log l	0.996
Open Backwater Pond	Log t = -2.4016 + 1.7232 * log l	0.990

Table 5.16 Age at different points of life and residence period (in months) of *M.dobsoni* in tidal ponds and backwater.

	Perennial Pond	Seasonal pond Type-I	Seasonal pond Type-II	Backwaters
Maximum age (tmax)	12.39	6.33	6.30	8.07
Period of Stay	12.11	6.07	6.13	7.84
Age at zero length (t_0)	-0.226		Age at recruitment(tr)	0.28

Table 5.17 Multiple regression and Analysis of variance table for residence period of *M. dobsoni* and eco-physical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Temperature	12.9701	0.6758	19.191	0.03314	0.9973
Area	-0.0622	0.0049	-12.719	0.04995	0.9939
Depth	8.0486	0.2639	30.504	0.02086	0.9989
Water Exchange	0.2357	0.0076	31.149	0.02043	0.9990
Productivity	-10.5956	0.8001	-13.242	0.04798	0.9943
Constant	-375.8814				

Std. Error of Est. = 0.0908

Adjusted R Squared = 0.9989
R Squared = 0.9998
Multiple R = 0.9999

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	45.2750	5	9.0550	1096.905	0.0229
Residual	0.0083	1	0.0083		
Total	45.2833	6			

***M. monoceros*:**

Growth:

Growth was fast, 19.69 mm month^{-1} in stocking ponds and slow, 15.79 mm in backwaters and respectively attained 108.6 and 90.9 mm during the initial five month period (Table 5.18, Fig 5.9, 5.10, 5.11). The corresponding values were 17.76 and 103.3 mm for perennial ponds and 17.23 and 98.2 mm for Type-I seasonal ponds. Growth was slow, 16.6 mm in Type-II seasonal ponds, where they attained 95.8 mm in 5 months.

In perennial ponds they attained a maximum size of 119.5 mm in 9 months and in backwaters 98.7 mm in 6.8 months (Fig 5.11). The corresponding values were 102.8 mm in 5.54 months in Type-I and 98.4 mm in 5.31 months in Type-II seasonal ponds. In stocking ponds they attained 121.2 mm in 7 months.

Growth in weight varied between 0.98 g month^{-1} in open backwater and 1.463 g in stocking ponds during the first five month (Table 5.19, Fig 5.11). It was 1.279 g in perennial ponds and 1.288 and 1.239 g respectively in Type-I and Type-II seasonal ponds.

Results of the statistical test showed that ecology and physical conditions of the habitat together described 98.5% ($P<0.05$) of growth variations in the species (Table 5.20). Productivity, water exchange and depth produced maximum variation.

Table 5.18 Growth increment in length (mm month^{-1}) of *M. monoceros* in tidal ponds and backwaters.

Age (months)	Perennial pond	Seasonal Pond (T-I)	Seasonal Pond (T-II)	Backwaters	Stocking Pond
1	29.13	32.09	31.32	28.55	34.06
2	21.15	22.22	21.68	19.63	24.23
3	17.45	15.02	14.25	14.41	18.39
4	12.49	9.95	9.04	9.51	12.17
5	8.56	6.89	6.71	6.85	9.58
Mean	17.76	17.23	16.60	15.79	19.69

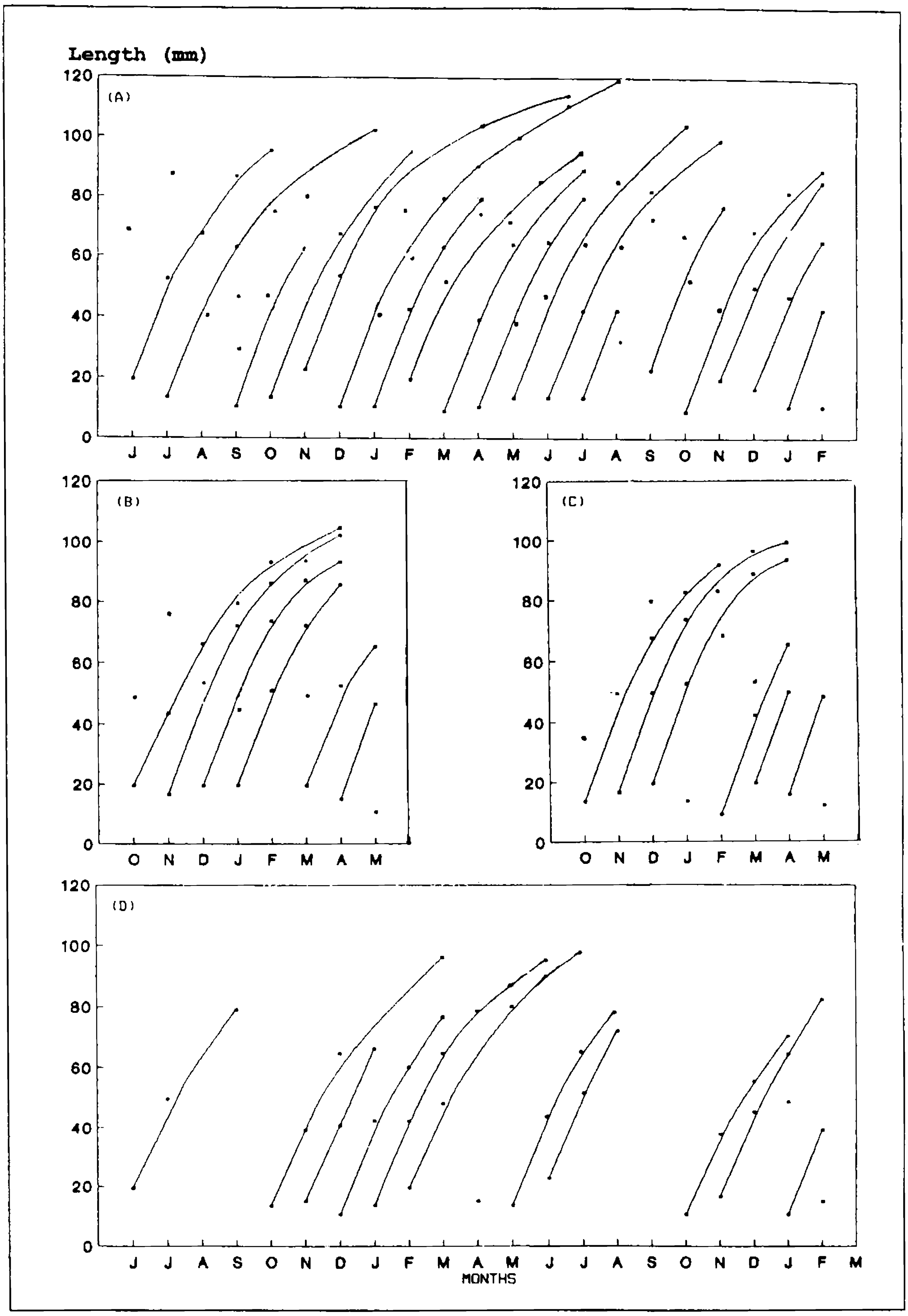


Fig 5.9 Scatter diagram on monthly modal length distribution and tracing of progression of mode in subsequent months free hand growth curves for ***M. monoceros*** in tidal ponds and backwaters (A-Perennial pond, B- Seasonal Type-I, C- Seasonal Type-II and D-Open Backwaters).

Estimates of maximum attainable size (L∞) was 126.04 mm by Ford-Walford plot and 127.05 by ELEFAN-I in perennial ponds (Table 5.21, Fig 5.10, 5.12). Growth coefficient (K) also varied between 3.821 and 3.58 respectively by these methods.

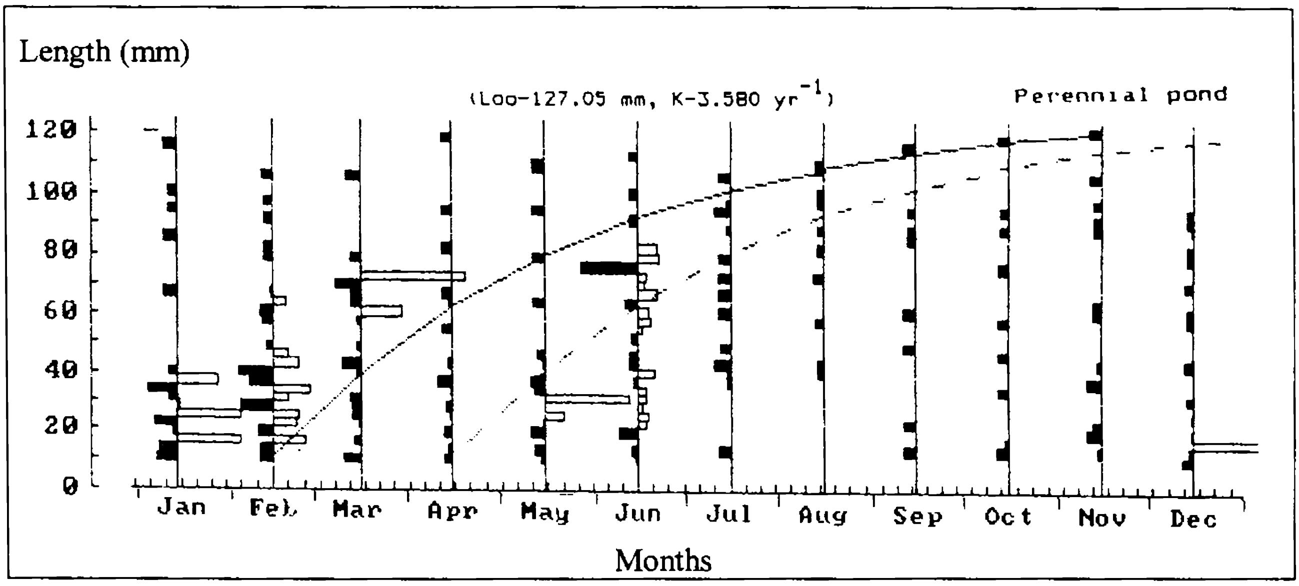


Fig 5.10 Restructured length frequency histogram and growth curves of ***M. monoceros*** in tidal ponds and backwaters.

Table 5.19 Growth increment in weight (g month^{-1}) of *M. monoceros* in tidal ponds and backwaters.

Age (months)	Perennial pond	Seasonal Pond (T-I)	Seasonal Pond (T-II)	Backwaters	Stocking Pond
1	0.948	1.162	0.990	0.711	1.064
2	1.374	1.817	1.522	1.141	1.617
3	1.393	1.615	1.708	1.028	2.492
4	1.195	0.979	0.828	0.795	1.415
5	1.353	0.867	1.147	0.863	1.327
Mean	1.279	1.288	1.239	0.908	1.463

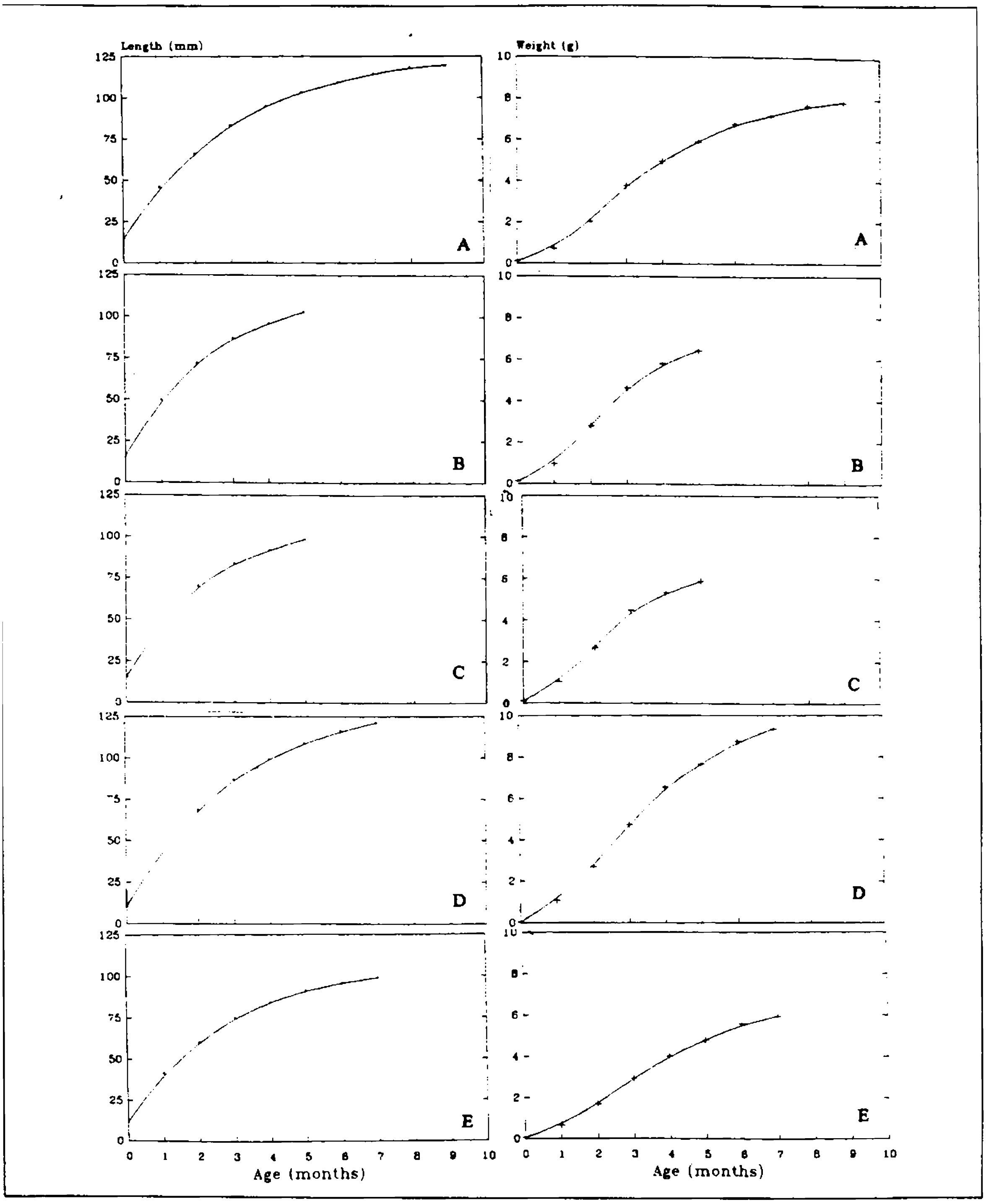


Fig 5.11 Growth curves of *M. monoceros* in different tidal ponds and backwaters (A-Perennial pond, B-Seasonal Type-I, C-Seasonal Type-II, D-Stocking pond, E-Open Backwaters).

Table 5.20 Multiple regression and Analysis of Variance table for growth rate of *M. monoceros* and eco-physical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Salinity	0.0176	0.0968	0.181	0.87279	0.0162
Temperature	0.3008	0.4839	0.622	0.59761	0.1619
Area	-0.0070	0.0104	-0.669	0.57250	0.1828
Depth	-1.4140	0.4350	-3.250	0.08304	0.8408
Water Exchange	0.0406	0.0139	3.274	0.08197	0.8428
Productivity	0.8673	0.2649	5.263	0.04882	0.9429
Constant	57.8993				

Std. Error of Est. = 0.3154

Adjusted R Squared = 0.8913
R Squared = 0.9851
Multiple R = 0.9925

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	16.2862	6	2.7144	27.280	0.034
Residual	0.1990	2	0.0995		
Total	16.4852	8			

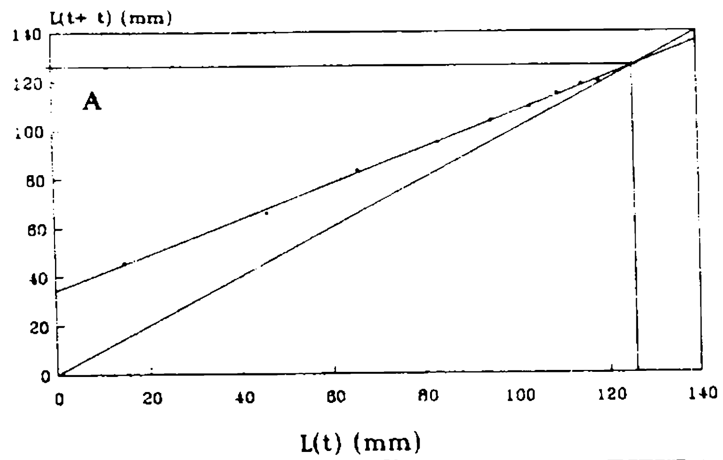


Fig 5.12 Ford-Walford plot for estimating the growth parameters of *M. monoceros* in perennial pond.

Table 5.21 Estimated growth parameters of *M. monoceros* population in perennial tidal pond.

Method of Estimation	L∝ (mm)	K yr^{-1}	Rn
Ford-Walford Plot	126.04	3.821	-
ELEFAN-I	127.05	3.580	0.128
Mean	126.55	3.701	-

Age and Residence Period:

In perennial ponds species was represented by 0 to 9+ month groups, where 0 to 3+ month groups constitute 81.9% of the population (Table 5.22). Zero month groups formed 26.3% of the population in this habitat, whereas 9+ groups only 0.24%. In seasonal ponds they are represented by 0 to 5+ groups. In Type-I seasonal ponds, 94.7% and in Type-II, 94.6% of the population was represented by 0-3+ groups. Zero month groups respectively constituted 32.9 and 31.9% of the population in these habitat. In backwaters population was represented by 0 to 6+ groups, where zero groups formed 63.9% and 0-3+ groups 96.9% of the population whereas 6+ groups represented only 0.5%.

Residence period was very short for the species compared to *P. indicus* and *M.dobsoni* (Table 5.27). They stayed for 5.54 and 5.31 months respectively in Type-I and Type II seasonal ponds. In perennial ponds it was 9.01 and in backwaters 6.77 months.

Results of the statistical tests showed that residence period was influenced by physical and ecological conditions of the habitat (Table 5.25). Depth, water exchange and temperature produced maximum variation.

Table 5.22 Annual age composition of *M. monoceros* in tidal ponds and backwaters.

Age (months)	Perennial pond	Seasonal ponds Type-I	Seasonal ponds Type-II	Open Backwaters
0	26.27	32.87	31.97	63.94
1	22.65	27.30	26.87	13.85
2	19.52	21.73	22.45	13.50
3	13.49	12.81	13.27	4.62
4	8.43	4.46	4.76	2.13
5	4.34	0.84	0.68	1.42
6	2.65			0.53
7	1.45			
8	0.96			
9	0.24			

Table 5.23 Age-length relationship of *M. monoceros* population in tidal ponds and backwaters.

Habitat	Age-length equation	r^2
Perennial Pond	Log t = -2.6830 + 1.7555 * log l	0.9886
Type-I Seasonal Pond	Log t = -2.6021 + 1.6725 * log l	0.9913
Type-II Seasonal Pond	Log t = -2.6270 + 1.6914 * log l	0.9922
Open Backwater Pond	Log t = -2.4563 + 1.6546 * log l	0.9602

Table 5.24 Age at different points of life and residence period (in months) of *M. monoceros* in tidal ponds and backwater.

	Perennial pond	Seasonal pond Type-I	Seasonal pond Type-II	Backwaters
Maximum age (tmax)	9.25	5.79	5.55	6.96
Period of Stay	9.01	5.54	5.31	6.77
Age at zero length (t_o)	-0.15	Age at Recruitment(t_r)	0.24	

Table 5.25 Multiple regression and Analysis of variance table for residence period of *M. monoceros* and eco-physical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Temperature	6.2899	0.4617	13.625	0.04664	0.9946
Area	-0.0289	0.0033	-8.671	0.07310	0.9869
Depth	4.2710	0.1802	23.696	0.02685	0.9982
Water Exchange	0.1213	0.0052	23.458	0.02712	0.9982
Productivity	-5.2923	0.5466	-9.683	0.06551	0.9894
Constant	-180.3245				

Std. Error of Est. = 0.0621

Adjusted R Squared = 0.9985
R Squared = 0.9997
Multiple R = 0.9999

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	14.9593	5	2.9919	776.697	0.0272
Residual	0.0039	1	0.0039		
Total	14.9631	6			

DISCUSSION

Growth was studied by tracing progression in size of the recruits over time. Among different methods, growth estimate by modal progression is most reliable, as it enable incorporation of growth by all identifiable recruits. Mark-recapture method, which frequently used for larger individuals (Linder and Anderson, 1956; Klima, 1964; Kutkhun, 1966), have been unsuccessful because small shrimps are difficult to mark (Klima, 1965; Farmer, 1981). So many resort to size frequency analysis for growth and mortality estimates (Neal, 1968; Berry, 1970; Garcia, 1977b; Parrack, 1981; Pauly *et.al.*, 1984; Minello *et.al.*, 1989; Haywood and staples, 1993). This method is potentially useful for growth estimation in nurseries, especially in tidal ponds, where postlarvae enter in pulses. So all major recruits could be easily identified and growth could be traced for several months. Moreover, there are little chances for overlapping growth of different recruits, as seasonal growth variation was not apparent, as in temperate waters.

Considerable information is available on the growth of major species from different habitats. Growth of *P. indicus* was reported to be very low, 10 to 16 mm month^{-1} in Cochin backwaters (George, 1962b; 1975; Mohamed and Rao, 1971), Mandovi estuary (Achuthankutty and Nair, 1983) and Ennore and Adayar estuary (Subrahmanyam, 1968). It was high, 36 mm in Chilka lake (Jhingran and Natarajan, 1969), 24.3 and 26.5 mm respectively for males and females in Manakkudy estuary (Suseelan, 1975b) and 27.5 to 32.5 mm in Godavari estuaries (Devi, 1988). Growth reported by Jhingran and Natarajan (1969), Suseelan (1975b) and Devi (1988) are in the same range as that observed in the present study. In St. Lucia estuary it varied from 4.61 to 28.2 mm month^{-1} depending on water temperature (Benfield *et.al.*, 1990). According to several others they grow at 6.7 to 34.9 mm month^{-1} under different farming conditions (Hall, 1962; Subrahmanyam and Rao, 1968; Sultan *et.al.*, 1973; George, 1975; Le Reste and Marcille, 1976; Paulinose *et.al.*, 1981: Muthu *et.al.*, 1981; Aravindhakshan *et.al.*, 1982), whereas, Jose *et.al.* (1987) reported much faster growth of 37 to 65 mm month^{-1} in pokkali fields under selective farming trials. A review by Champion (1983) on the earlier growth records of the species showed that they grow at 30 mm month^{-1}.

Still fast growth has been reported for allied species from other regions. Under natural conditions, growth of *P. setiferus* varied between 25 and 45 mm month^{-1} (Gunter, 1950: Linder and Anderson, 1956), whereas under culture conditions it was 63 mm (Johnson and Fielding, 1956). Another related species, *P. aztecus* grow at 42 to 51 mm month^{-1} in Louisiana waters (George, 1961; St.Amant *et.al.*, 1963).

M. dobsoni is the slow growing among the three species studied. They grow at 10-12 mm month^{-1} in Cochin backwaters (Menon, 1954; 1955; Banergy and George, 1967; George *et.al.* 1968; Mohamed and Rao, 1971; Suseelan, 1975a), 5 to 7.5 mm in Mandovi estuary (Achuthankutty and Nair, 1982; 1983; Achuthankutty, 1988) and 10 mm in Manakkudy estuary (Suseelan, 1975b). In tidal ponds of Cochin, their growth varied between 5 and 15 mm month^{-1} (George, 1974; 1975; Suseelan 1975a; Paulinose *et.al.* 1981; Vasudevappa, 1992). Under culture conditions, Muthu *et.al.* (1981), observed a growth of 17.7 mm month^{-1}, whereas, Lazarus and Nandakumaran (1990) observed 32 mm month^{-1} in polyethylene lined ponds during the initial growth period.

M. monoceros grows at 5 to 15 mm month^{-1} in Cochin backwaters (George, 1959; Mohamed and Rao, 1971; Menon and Raman, 1961), 8.3 mm in Mandovi estuary (Achuthankutty and Nair, 1982; 1983) and 5 to 18 mm in Godavari estuarine systems (Subrahmanyam, 1973; Devi, 1988). Under culture conditions, George (1959) observed only slow growth of 3.3 to 5 mm month^{-1} for the species, whereas, George (1975) reported fast growth of 13.8 mm. Under laboratory conditions, it varied between 4.5 to 28.8 mm month^{-1} during different phase of their life (George, 1959; Subrahmanyam and Ganapati, 1971; Subrahmanyam, 1973).

As seen above, growth of *P. indicus* was well within the range documented by earlier workers, whereas, that of *M. dobsoni* and *M. monoceros* was distinctly high. However, growth of all species varied in different habitats. It was moderate in Type-II seasonal ponds and slow in perennial ponds for *P. indicus* and *M. dobsoni*. Whereas, it was moderate in perennial ponds and slow in Type-II seasonal ponds for *M. monoceros*. It was fast for all species in stocking ponds. Johnson and Fielding (1956), Sriram *et.al.* (1987) and Jose, *et.al.* (1987) observed fast growths for penaeids in stocking ponds as observed in the present study. Food abundance coupled with better water exchange and low predation and competition especially during the initial growth phase provided ideal conditions for prawns to grow fast in stocking ponds. Despite many favourable conditions growth was comparatively slow in tidal ponds and open backwaters. As observed by Ingles (1957) and Moffet (1965), the apparent slow growth in these habitats are the result of heavy competition and predation. Continuous recruitment of postlarvae and juveniles of prawns and fishes produce persistent competition and predation, which obscured rapid growth.

Open backwaters were further characterised by strong currents and waves, which necessitated, diversion of considerable amount of energy for maintaining the position of the individuals in the habitat and thus produced poor growth.

In Type-II seasonal ponds paddy stumps offered suitable cover and refuge for young prawns and thus enhanced growth through increased food conversion, as demonstrated by Abdussamad and Thampy (1994) in *P. monodon.* Moreover, paddy stumps support growth of periphyton, an ideal food for postlarvae and also serves itself as food by microbial detrification. Increase in the nutritive value of mangrove foliage associated with such microbial decomposition was reported by Vijayaraghavan and Wafer (1983). But, unlike *P. indicus* and *M. dobsoni*, growth of *M. monoceros* was slow in these ponds. It may be due to shallow nature of this habitat, which is not conducive for this species with strong nocturnal activity.

Variation was also observed between the present growth estimate and that by earlier workers from similar habitats. This may be due to the variation in size, age and also the source of study materials used. Many used materials from stake nets and filtration nets for growth estimation. Since catches of these gears represent only emigrating populations, any shift in modal size in this gears reflect only fluctuation in habitat environment and not the growth. Moreover, many estimated growth for different size and age groups and as growth vary with life stages, such results cannot be compared with each other.

Maximum size observed for *P. indicus* is relatively large, whereas that of *M. dobsoni* and *M. monoceros* are in the range reported by earlier workers from similar habitats. *P. indicus* up to 137 mm was observed in open backwaters and 172 mm in perennial ponds. In seasonal ponds they attained much larger size than in backwaters. According to earlier workers they attain 95 to 130 mm in backwater environment (Menon, 1957; Menon and Raman, 1961; George, 1962b; Hall, 1962; Suseelan, 1975b; Anon, 1978; Ramakrishnaiah, 1979; Paulinose *et.al.*, 1981; George and Suseelan, 1982) and 145 mm in seasonal and 165 mm in perennial ponds of Cochin (Menon, 1954; George, 1974). In the tidal ponds of Singapore they attain 113.4 mm (Hall, 1962).

Maximum size of *M. dobsoni* varied between 86.5 mm in open backwaters and 105.4 mm in perennial ponds. They are reported to attain 70 mm in the estuaries of Goa (Achuthankutty and Nair, 1982; Achuthankutty, 1988) and Ashtamudi lake (Suseelan and Kathirvel, 1982) and 90-95 mm in Cochin backwaters and other areas (Banergy and George, 1967; George *et.al.*, 1968; Ramakrishnaiah, 1979; George and Suseelan, 1982; Mohamed and Rao, 1971). In seasonal ponds and perennial ponds of Cochin they respectively attain70 and 98-110 mm (George, 1974; Vasudevappa, 1992).

Maximum size of *M. monoceros* varied between 98.4 mm in Type-II seasonal ponds and 120.5 mm in perennial ponds. Many reported similar size distribution for the species from backwaters and adjacent fields. They attain 70 mm in Ashtamudi lake (Suseelan and Kathirvel, 1982), 100 mm in Godavari estuaries (Subrahmanyam, 1973), 80 mm in estuaries of Goa (Achuthankutty and Nair, 1982), 138 mm in Chilka lake (Ramakrishnaiah, 1979), 90 mm in Manakkudy estuary (Suseelan,1975b), 112 mm in Cochin backwaters (George, 1959, Mohamed and Rao, 1971) and 95 mm in seasonal and 120 in perennial tidal ponds (George, 1974).

Size of the prawns varied in different habitats owing to the variation in growth rate and period of stay. George (1974), attributed similar variation in the size of prawns to variation in residence period. Prawns either emigrate or being caught at an early age from seasonal ponds and backwaters and hence have relatively small individual size, whereas in perennial ponds they stay for long periods and attain large size. Carpenter *et.al.* (1986) also observed large prawns in deep ponds and attribute it to the prevalence of stable environment in these ponds.

Estimates of growth parameters by Ford-Walford Plot and ELEFAN-I programme varied. In the former case growth of all identifiable recruits were incorporated, where as latter identify and trace only one recruit at a time, even if several recruit were clearly visible in the population. However, $L\infty$ estimates are distinctly higher in all cases than Lmax, which always confirms to the Pauly's equation $L\infty = Lmax/0.95$.

Estimates of growth parameters for penaeids from similar habitats are limited, except for *M. dobsoni* from polyethylene lined experimental culture ponds (Lazarus and Nandakumaran, 1990) and from perennial ponds of Cochin (Vasudevappa, 1992). Lazarus and Nandakumaran (1990) estimated the $L\infty$ as 82.32 mm, for unsorted *M. dobsoni* population in polyethylene lined ponds whereas Vasudevappa (1992) estimated it as 90 to 105 mm for males and 105 to 107 mm for females in perennial ponds. These estimates are small compared to the present estimates from stocking ponds and perennial ponds.

The present estimates however, for all species are small, compared to that for marine population (Table 5.26). This is due to the occurrence of large age and size groups of prawns in the marine population.

Table 5.26 Range of estimates of growth parameters for *P. indicus, M. dobsoni* and *M. monoceros* population from marine environment.

Species	L∞ (mm)	K (yr^{-1})	to (months)
P. indicus	193.9-293.3	0.109-0.447	-0.190--1.286
M. dobsoni	109.1-144.6	0.120-1.890	-0.110--0.966
M. monoceros	178.4-216.2	0.972-1.680	-0.528--0.792

(Ref. Kurup and Rao, 1974; Ramamurthy *et.al.*, 1978; Devi, 1987; Sriraman *et.al.*, 1987; Rao and Krishnamoorthy, 1990; Jayawickrema and Jayakody, 1992; Rao, 1994)

Earlier estimates of growth coefficient (K) for *M. dobsoni* is very close to present estimate from similar habitats. Lazarus and Nandakumaran (1990) estimated it as 3.4664 in polyethylene lined culture ponds, whereas that by Vasudevappa (1992) ranged from 3.0 to 3.25 for males and 3.158 to 3.40 for females for the population in perennial ponds. However, these estimates are distinctly large compared to that of marine population (Table 5.26). Devaraj (1983) stated that longevity will be small for stocks with fast growth and large K. This support the present observation of fast growth and small longevity for prawns in tidal ponds and backwaters.

Resident population of penaeids in backwaters and tidal ponds were constituted mainly by small age groups, due to continuous recruitment of postlarvae and removal of advanced juveniles and pre-adults either by emigration or by fishing as they grows. Rate of such removal varies in different habitat and so the age composition also. Information on the age structure of penaeids in similar habitats is limited. Subrahmanyam (1973), observed similar age structure for *M. monoceros* in Godavari estuarine system as observed in the present study. According to them about 90 % of their estuarine population was represented by individuals of less than 4 month old.

Residence period was long for all species in perennial ponds, followed by in open backwaters and short in seasonal ponds. The present estimates though relatively large, are very close to that reported by earlier workers from similar habitat.

Residence period of *P. indicus* was 14.4 months in perennial ponds, 9.2 in open backwaters and 6.02 and 6.5 in seasonal ponds. Many reported it as one year for the species in Cochin backwaters (George, 1962b; Mohamed and Rao, 1971) and 7 months in Mandovi estuary (Achuthankutty and Nair, 1982). In St. Lucia estuary, it is 8 to 10 months, depending on water temperature (Benfield *et.al.*, 1990) and in the Singapore prawn ponds 10-12 months (Hall, 1962).

Residence period of *M. dobsoni* was 12.1 months in perennial ponds, 7.8 in open backwaters and around 6.07-6.13 months in seasonal ponds. Earlier workers estimated it as 6-12 months for the species in Cochin backwaters (Menon, 1954; 1955; Mohamed and Rao, 1971) and 6 months in Mandovi estuaries (Achuthankutty Nair, 1982; Achuthankutty, 1988). Vasudevappa (1992) estimated it as 8-13 months in the perennial ponds of Cochin depending on habitat condition.

M. monoceros spent 9.01 months in perennial ponds, 5.3 to 5.54 in seasonal ponds and 6.77 in backwaters. Many earlier workers reported it as 9 to 12 months in Cochin backwaters (Menon, 1954; 1955; George, 1959; Mohamed and Rao, 1971), 8 months in Mandovi estuaries (Achuthankutty and Nair,1982) and one year in Godavari estuaries (Subrahmanyam, 1973).

Residence period was influenced by the ecology of the habitat, especially depth, water exchange and temperature. The relatively long residence period in perennial ponds owed to stable and calm environment prevailing there, especially along deeper areas as discussed in chapters 5. The extreme diurnal fluctuations in the environment in seasonal ponds and physical disturbances in open backwaters forced the prawns to leave the habitat at an early age. The variations observed among species may be due to species specific differences in the biological and physiological requirements.

Mortality

Chapter-6

MORTALITY

INTRODUCTION

Different types of mortalities do occur in a population. This together with growth and abundance determine their yield. In the nursery habitats of shrimps different types of mortalities do exists, viz. natural and fishing. Part of the population also leaves the habitat by means of emigration. Emigrants as a whole from the tidal ponds were succumbed to filtration, whereas only part of them from open backwaters by different means of fishing. Reliable information on different mortalities operating in any population is important in understanding the stocks.

Attempts to correlate intensity of postlarval ingression into bays with subsequent offshore fishery by earlier workers (Berry and Baxter, 1969; Ford and St. Amant, 1971; Sutter and Christmas, 1983; Baxter and Sullivan, 1986) showed that, information on mortality of shrimps in their nurseries is one of the basic requirement in establishing such relationship and forecasting fishery. Although mortality estimates has been employed to assess stocks of fishes and prawns in the offshore fishing grounds, since the beginning of last century, such information for shrimps in their obligatory nursery habitats are scarce.

In the recent past some attempts were made to estimate the mortality of young shrimps in their nursery grounds. This include the mortality estimate during estuarine phase of *P. aztecus* in North Carolina (Mc Coy, 1972), *P. vannamei* (Edwards, 1977) and *P. aztecus* (Rothschild and Brunenmeister, 1984) in the coastal lagoons of Mexico, pink shrimp, *P. duorarum* in Terminose Lagoon, Mexico (Alvarez *et.al.*, 1987), *P. aztecus* in Galveston Bay (Minello *et.al.*, 1989), *P. merguiensis* in Embley river estuary, Gulf of Carpentaria (Haywood and Staples, 1993) and *P. setiferus* in marshy weired and unweired tidal ponds in Louisiana (Knudsen *et.al.*, 1996). In Cochin backwater area, though juveniles are being exploited by different means, no information is available on the mortality of different species.

This study was designed to examine different mortalities operating in the population of major penaeid species in tidal pond and open backwater nurseries and to understand the factors that regulate this processes. Results of this study will be useful in identifying critical life cycle stages that need special attention in the resource management. It may also aid in forecasting the offshore fishery by correlating mortality with recruitment, growth and emigration.

MATERIALS AND METHODS

Materials:

Data on recruitment, abundance, emigration, harvest and estimates of age were used for this study. The materials used in the present study are given below in Table 6.1.

Table 6.1 Consolidated recruitment, abundance, emigration and harvest data (no/ha habitat area) and estimates of age (month) used mortality estimates.

a. *P. indicus*

Habitat	Nr*	Ne*	Nc*	Ntmax*	tmax*	tr*
Per. Pond	99690	32697	12347	229	14.63	0.25
Seas. T-I	73726	27373	9191	599	6.85	0.36
Seas. T-II	51336	18581	8811	383	6.28	0.26
St. Pond	198399	0	144459	144459	8.00	1.00
Backwater	47946	0	0	207	9.46	0.29

b. *M. dobsoni*

Habitat	Nr*	Ne*	Nc*	Ntmax*	tmax*	tr*
Per. Pond	379911	148923	32756	254	12.39	0.28
Seas. T-I	358329	153093	36411	3458	6.33	0.26
Seas T-II	346207	147113	45269	669	6.30	0.17
St. Pond	322766	0	242546	242546	8.00	1.00
Backwater	287981	0	0	809	8.07	0.23

c. *M. monoceros*

Habitat	Nr*	Ne*	Nc*	Ntmax*	tmax*	tr*
Per. Pond	26226	9143	2887	241	9.25	0.24
Seas. T-I	24202	8409	3282	615	5.79	0.25
Seas. T-II	22211	8270	3308	473	5.55	0.24
St. Pond	53422	0	34554	34554	8.00	1.00
Backwater	5911	0	0	227	6.96	0.19

* Nr - no. of postlarvae recruited/unit area of the habitat during the year

Ne - no. of prawns emigrated from unit area of the habitat

Nc - no. of prawns caught from unit area of the habitat by fishing other than filtration,

Ntmax - no. of prawns in the habitat at tmax

tmax - maximum age of the prawns

tr - age at recruitment

Since earlier workers (Minello *et.al.*, 1989; Haywood and staples, 1993) attributed major part of the mortality in nursery grounds to predation, this hypothesis was tested through predator free culture experiments. As stocking ponds were considered free from predators and competitors, these trials were considered as predator free trial.

Total mortality was estimated by comparing change in density of recruits over time. Mortality due to emigration and other means of harvest were also estimated respectively from their relative representation in the harvest with respect to recruitment.

Instantaneous rate of total mortality (Z) was estimated as per Cushing (1968), using the relation;

$$Z = 1/(tn - t1) * \text{Loge}\,(Nt1/Ntn)$$

$$= 1/(tmax-tr) * \text{Loge}\,(Ntr/Ntmax)$$

Where;

Nt1- Number of prawns at an age of t1 in the population,

Ntr- Number of prawns at an age of tr in the population,

Ntn- Number of prawns at an age of tn in the population,

Ntmax-Number of prawns at an age of tmax in the population,

Tmax- Maximum age attained by the species in the habitat.

Fishing mortality include mortality due to different means of harvesting. Mortality due to filtration in tidal ponds was considered emigration mortality as the entire population emigrating from the habitats was caught by the filter net. Independent estimates of fishing mortality (F) and emigration mortality (Y) were obtained from the model for exploitation rate (U) proposed by Allen (1953) as below;

$$\text{Exploitation Rate (U)} = F * A / Z = \frac{\text{Annual catch in number}}{\text{Number at the beginning of the year}}$$

$$= \frac{\text{Total no caught during the year}}{\text{Total no recruited during the year}} = Nc/Nr$$

ie. $$= F * A / Z = F * (1-e^{-Z}) / Z = Nc / Nr$$

So, $$F = Nc * Z / Nr * (1 - e^{-Z})$$

Emigration mortality or emigration rate (Y) was obtained by replacing "Nc" with "Ne" .

$$Y = Nc * Z / Nr * (1 - e^{-Z})$$

Where,

F- Instantaneous rate of fishing mortality,

A- Mortality rate,

Z- Instantaneous rate of total mortality.

Natural mortality rate M was calculated directly from the Z and F values;

$$M = Z - F$$

In stocking ponds, population was in a virgin state and hence "F" up to the point of harvest will be zero and so natural mortality will be same as the total mortality for this period.

So, $$M = Z$$

Mortality due to predation was estimated by subtracting natural mortality of the respective species in stocking ponds from that of tidal ponds.

Mortality due to predation ! = Natural mortality in tidal ponds - Natural mortality in stocking ponds

The effect of salinity, prawn abundance, predator biomass, productivity, foliage cover and depth of the habitat on mortality were examined for significance by multiple regression.

RESULTS

P. indicus:

Natural mortality varied from, 27.2% in stocking to 54.8% in perennial ponds (Table 6.2, Fig 6.1). It was 50.4% in Type-I ponds and ponds 46.7% in Type-II seasonal ponds.

Mortality due to predation was high, 27.6% in perennial ponds, followed by 23.2% in Type-I and low, 19.5% in Type-II seasonal ponds. In perennial ponds, 32.8% of the recruits were caught during emigration and 12.4% by other means of fishing. The corresponding values were 37.1 and 12.5% respectively for Type-I seasonal pond and 36.2 and 17.2% for Type-II pond.

Table 6.2 Mode of operation of different mortalities in *P. indicus* population of tidal ponds.

		SOURCE OF MORTALITY			
Habitat	Natural	(Predation)	Fishing	Emigration (Filtration)	Total
Perennial	54.83	(27.64)	12.38	32.79	100.0
Seasonal-I	50.40	(23.21)	12.47	37.13	100.0
Seasonal-II	46.65	(19.46)	17.16	36.19	100.0
Stocking Ponds	27.19	0	0	0	27.19

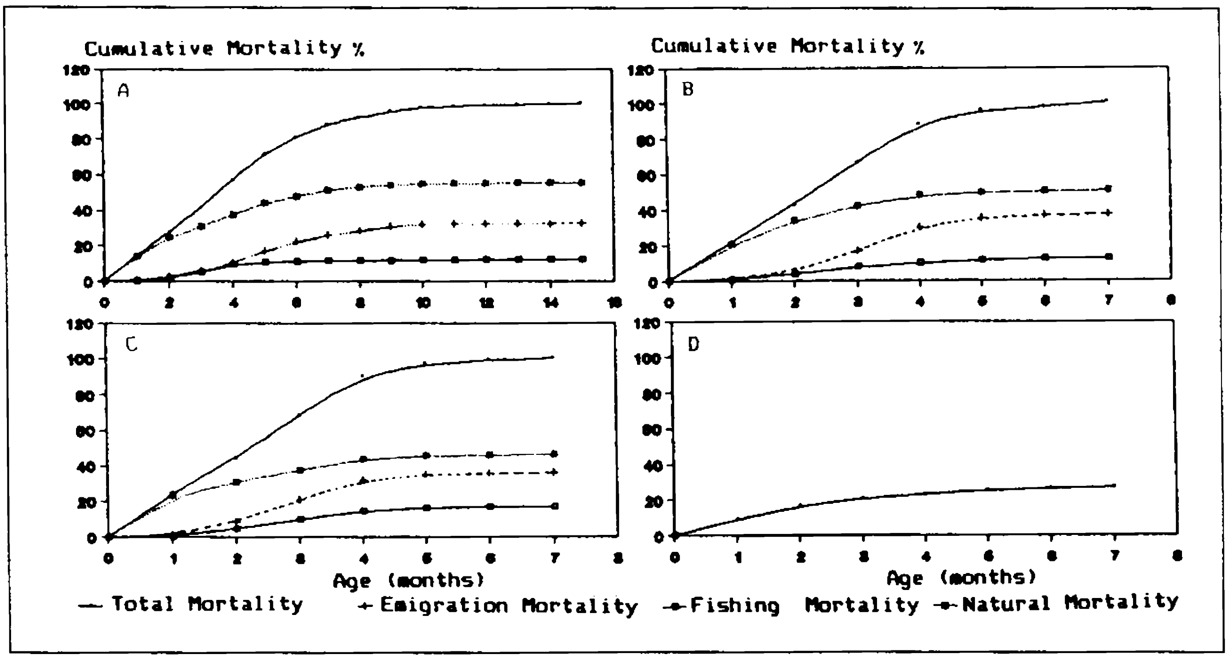


Fig 6.1 Mortality curves for *P. indicus* population in tidal ponds and socking ponds. A- Perennial pond, B Type-I seasonal pond, C- Type-II seasonal pond and D-Stocking pond.

Instantaneous rate of total mortality (Z) was high 9.763 in Type-II ponds and low, 5.072 in perennial ponds (Table 6.3). It was 8.898 in Type-I ponds and 7.051 in open backwaters.

Natural mortality (M) and fishing mortality (F) was small, 2.795 and 0.624 in perennial ponds and large, 4.55 and 1.676 respectively in Type-II ponds. The corresponding values were 4.486 and 1.109 respectively in Type-I ponds. Natural mortality was the lowest, 0.544 in stocking ponds. Mortality due to emigration was small, 1.653 in perennial ponds followed by 3.303 in Type-I seasonal ponds and large, 3.534 in Type-II seasonal ponds.

Statistical showed that mortality correlated positively with juvenile abundance (P=0.073) and predator biomass and negatively with foliage cover in the habitat, but was not statistically significant (P=0.1033) (Table 6.4).

Table 6.3 Annual instantaneous mortalities of *P. indicus* population in different habitats.

	TYPE OF MORTALITY			
Habitat	Natural (M)	Fishing (F)	Emigration (Y)	Total (Z=M+F+Y)
Perennial	2.7945	0.6242	1.6530	5.0717
Seasonal-I	4.4856	1.1090	3.3030	8.8977
Seasonal-II	4.5540	1.6757	3.5335	9.7631
Stocking ponds	0.5439	0.0000	0.0000	0.5439
Backwaters	-	-	-	7.0508

Table 6.4 Multiple regression and Analysis of Variance table to test the effect of different biophysical conditions of the habitat on natural mortality of *P. indicus* in tidal ponds.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Depth	2.5077	4.3386	0.578	0.66636	0.2504
Predator biomass	0.0750	0.0965	1.347	0.40644	0.6449
Productivity	-0.1960	0.2712	-0.723	0.60151	0.3432
Period of stay	0.7067	0.5245	0.777	0.57943	0.3765
Foliage cover	-0.1433	0.0513	-2.793	0.21885	0.8864
Shrimp density	0.0019	2.23E-04	8.662	0.07318	0.9868
CONSTANT	67.9046				

STD. ERROR OF EST. = 1.6798 ADJUSTED R SQUARED = 0.9787

R SQUARED = 0.9970 MULTIPLE R = 0.9985

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
REGRESSION	922.5996	6	153.7666	54.496	0.1033
RESIDUAL	2.8216	1	2.8216		
TOTAL	925.4212	7			

***M. dobsoni*:**

Natural mortality varied from 24.9% in stocking ponds to 52.3% in perennial ponds. It was 47.1 in Type-I ponds and 44.2% in Type-II seasonal ponds. Mortality due to predation was high, 27.4% in perennial ponds, followed by 22.3 in Type-I and low, 19.3% in Type-II seasonal ponds. In perennial ponds, 39.2% of the recruits were caught during emigration and 8.6% by other means of fishing. The corresponding values were 42.7 and 10.2 for Type-I seasonal pond and 42.5 and 13.3% for Type-II pond respectively.

Instantaneous rate of total mortality (Z) was high 12.23 in Type-II ponds and low, 7.243 in perennial ponds. It was 9.174 in Type-I ponds and 8.992 in open backwaters (Table 6.6). Natural mortality (M) and fishing mortality (F) was small, 3.785 and 0.620 respectively, in perennial ponds. It was large, 5.401 and 1.632 in Type-II ponds. The corresponding values were 4.321 and 0.933 in Type-I ponds. Natural mortality was the lowest, 0.490 in stocking ponds. Emigration mortality was small, 2.838 in perennial ponds, followed by 3.920 in Type-I seasonal ponds and large, 5.197 in Type-II seasonal ponds.

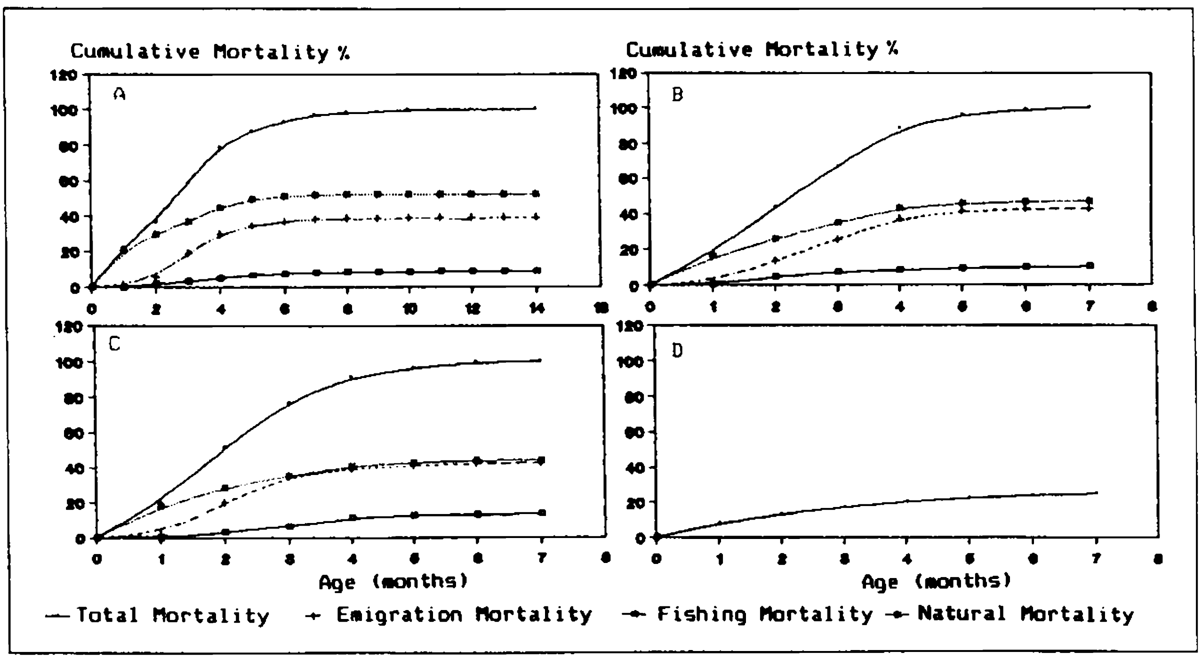


Fig 6.2 Mortality curves for *M. dobsoni* population in tidal ponds and socking ponds. A- Perennial pond, B Type-I seasonal pond, C- Type-II seasonal pond and D-Stocking pond.

Gn8216

Table 6.5 Mode of operation of different mortalities in *M. dobsoni* population of tidal ponds.

Habitat	Natural	SOURCE OF MORTALITY (Predation)	Fishing	Emigration (Filtration)	Total
Perennial	52.28	(27.43)	8.57	39.15	100.0
Seasonal-I	47.11	(22.26)	10.16	42.75	100.0
Seasonal-II	44.17	(19.32)	13.34	42.49	100.0
Stocking Ponds	24.85	0	0	0	24.85

Table 6.6 Annual instantaneous mortalities of *M. dobsoni* in tidal ponds and stocking ponds.

Habitat	Natural (M)	TYPE OF MORTALITY Fishing (F)	Emigration (Y)	Total (Z=M+F+Y)
Perennial	3.7851	0.6201	2.8376	7.2428
Seasonal-I	4.3210	0.9331	3.9199	9.1740
Seasonal-II	5.4013	1.6324	5.1974	12.2311
Stocking ponds	0.4898	0	0	0.4898
Backwaters	-	-	-	8.9922

Table 6.7 Multiple regression and Analysis of Variance table to test effect of different biophysical factors on natural the mortality of *M. dobsoni* in tidal ponds.

Variable	Regr. Coeff.	Std. Error	T(df=2)	Prob.	Partial r^2
Depth	18.1645	0.2320	0.167	0.89452	0.0272
Predator biomass	0.0032	0.0027	1.173	0.44937	0.5792
Productivity	0.6301	1.4528	0.434	0.73948	0.1583
Period of stay	1.3289	2.7851	0.477	0.71657	0.1855
Foliage cover	-0.0388	19.8445	-0.915	0.52812	0.4559
Shrimp density	0.1930	1.4166	2.368	0.25439	0.8486
CONSTANT	-77.2220				

STD. ERROR OF EST. = 8.9048

ADJUSTED R SQUARED = 0.3644
R SQUARED = 0.9092
MULTIPLE R = 0.9535

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
REGRESSION	794.0495	6	132.3416	4.669	0.3817
RESIDUAL	79.2963	1	79.2963		
TOTAL	873.3457	7			

Statistical tests showed that mortality correlated positively with juvenile abundance and predator biomass and negatively with foliage cover in the habitat, but was not statistically significant (P=0.3917), (Table 6.7).

M. monoceros:

Natural mortality varied from 35.3% in stocking ponds to 54.13% in perennial ponds (Table 6.8, Fig 6.3). It was 51.7 in Type-I seasonal ponds and 47.9% in Type-II ponds. Mortality due to predation was high, 18.8% in perennial ponds, followed by 16.4% in Type-I and low, 12.6% in Type-II seasonal ponds. In perennial ponds, 34.9% of the recruits were caught during emigration and 11.0% by other means of fishing. The corresponding values for Type-I seasonal pond was 34.8 and 13.6 and for Type-II seasonal pond was 37.2 and 14.9% respectively.

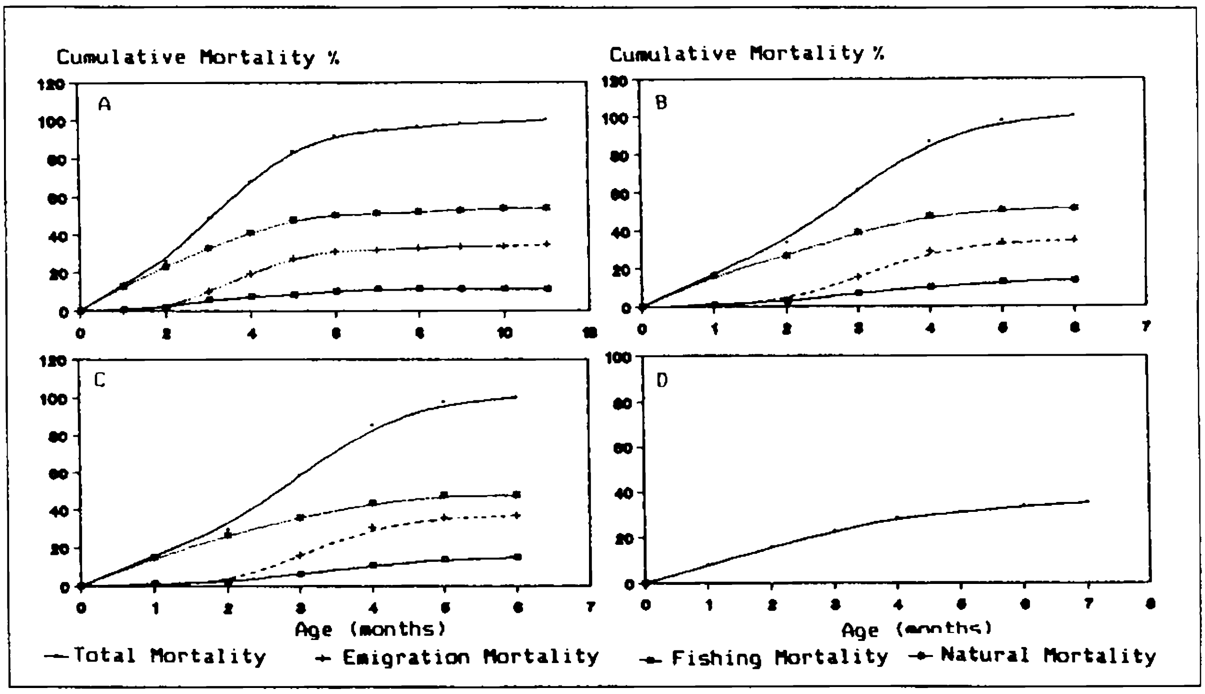


Fig 6.3 Mortality curves for *M. monoceros* population in tidal ponds and socking ponds. A- Perennial pond, B Type-I seasonal pond, C- Type-II seasonal pond and D-Stocking pond.

Instantaneous rate of total mortality (Z) was high, 8.701 in Type-II seasonal ponds and low, 5.775 in backwaters (Table 6.9). It was 7.954 in Type-I ponds and 6.248 in perennial ponds. The natural mortality (M) and fishing mortality (F) was small, 3.388 and 0.687 respectively, in perennial ponds. It was large, 4.166 and 1.296 in Type-II ponds. The corresponding values were 4.113 and 1.0781in Type-I ponds. Natural mortality was the lowest, 0.7469 in stocking ponds. Emigration mortality was small, 2.174 in perennial ponds, followed by 2.763 in Type-I seasonal ponds and large, 3.239 in Type-II seasonal ponds.

Table 6.8 Mode of operation of different mortalities in *M. monoceros* in tidal ponds.

Habitat	SOURCE OF MORTALITY Natural	(Predation)	Fishing	Emigration (Filtration)	Total
Perennial	54.13	(18.81)	11.01	34.86	100.0
Seasonal-I	51.69	(16.37)	13.56	34.75	100.0
Seasonal-II	47.88	(12.56)	14.89	37.23	100.0
Stocking Ponds	35.32	0	0	0	35.32

Table 6.9 Annual instantaneous mortalities of *M. monoceros* population in different habitats.

Habitat	TYPE OF MORTALITY Natural (M)	Fishing (F)	Emigration (Y)	Total (Z=M+F+Y)
Perennial	3.3876	0.6865	2.1741	6.2482
Seasonal-I	4.1131	1.0781	2.7627	7.9539
Seasonal-II	4.1661	1.2957	3.2392	8.7009
Stocking ponds	0.7469	0	0	0.7469
Backwaters	-	-	-	5.7751

Statistical test showed that mortality correlated positively with shrimp abundance ($P=0.03063$) and predator biomass ($P=0.26$) and negatively with foliage cover ($P=0.0735$) in the habitat (Table 6.10).

Table 6.10 Multiple regression and Analysis of variance table to test the effect of different biophysical factors on natural mortality of *M. monoceros* in tidal ponds.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Depth	-3.3544	1.4166	-2.368	0.25439	0.8486
Predator biomass	0.0728	0.0309	2.353	0.25584	0.8470
Productivity	-0.4714	0.0899	-5.243	0.11999	0.9649
Period of stay	0.4383	0.1743	2.515	0.24094	0.8635
Foliage cover	-0.1535	0.0178	-8.612	0.07359	0.9867
Shrimp density	0.0084	4.03E-04	20.765	0.03063	0.9977
CONSTANT	85.3112				

STD. ERROR OF EST. = 0.5588

ADJUSTED R SQUARED = 0.9950
R SQUARED = 0.9993
MULTIPLE R = 0.9996

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
REGRESSION	439.9999	6	73.3333	234.882	0.0499
RESIDUAL	0.3122	1	0.3122		
TOTAL	440.3122	7			

DISCUSSION

Mortality was relatively large for all species in tidal ponds and backwaters. Other field estimates available on juvenile mortality in estuarine nurseries of penaeids were also high. Mc Coy (1972) estimated the mortality of sub adult brown shrimp, *P. aztecus* in North Carolina as 52% for two week period. Other estimates for the same duration was 52% for *P. vannamei* (Edwards, 1977) and 4 to11% for brown shrimp, *P. aztecus* (Rothschild and Brunenmeister, 1984) in coastal lagoons of Mexico, 23 to 61% for brown shrimp, *P. aztecus* in Galveston Bay (Minello *et.al.*, 1989) and 63% for banana prawn, *P. merguiensis* in Gulf of Carpentaria (Haywood and Staples, 1993). In view of the short life span and presence of heavy competition and predation in nursery grounds, these estimates seems to be quite reasonable.

The weekly instantaneous natural mortality in tidal ponds ranged from 0.058 to 0.095 for *P. indicus*, 0.08 to 0.11 for *M. dobsoni* and 0.07 to 0.09 for *M. monoceros*. Other estimates of instantaneous natural mortality were much high, 0.57 wk^{-1} for *P. vannamei* in enclosures (Edwards, 1977), 0.3 to 0.76 for *P. aztecus* and 0.01 to 0.06 for *P. setiferus* (Laney, 1981), 0.19 to 0.41 for *P. aztecus* (Minello *et.al.*, 1989) and 0.23 to 0.94 for *P. merguiensis* (Haywood and Staples, 1993). These estimates seems to be much high, compared to the present estimates from tidal ponds, as they pertained to early juvenile phase, when most of the natural mortality do occur, as seen during the present study. Moreover, they were for open estuaries, where large mortalities can always be expected due to highly unstable environment.

Abiotic factors such as hypoxia, extremes of salinity and temperature or biotic factors such as predation, disease or limited food supply, may contribute to natural mortality of juvenile prawns in nurseries (Minello, *et.al.*, 1989; Haywood and Staples, 1993). Results from the present predator exclusion study showed predation as one of the major cause for mortality. It produced almost 50% of the natural mortality in *P. indicus* and *M. dobsoni* in tidal ponds. Dall *et.al.* (1990) also considered predation as the major cause of mortality in shrimp nurseries.

Natural mortality was relatively large during early phase of nursery life than later stages. Others also reported decline in natural mortality with time (Rothschild and Brunenmeister, 1984; Minello, *et.al.*, 1989; Haywood and staples, 1993) and attributed to decrease in the prawn-predator size ratio with age. Their study on food preference of common shrimp predators in estuarine nurseries showed that they prefer small prey. Since young prawns grow fast, will undergo frequent moulting and so chances of cannibalism is also high in a crowded population, as observed by Abdussamad and Thampy (1994) for the postlarvae and juveniles of tiger prawn, *P. monodon* in nurseries. But as grow, moulting frequency and aggregating tendency declines and move to deep, calmer waters and disperse over a much wider area, thus making them less vulnerable to predation and cannibalism.

Mortality varies due to variation in physical and biological conditions of different habitats. Despite high density, natural mortality was relatively low in seasonal ponds. Presence of refuge in the form of mangrove foliage and paddy stumps in these habitats protected young ones from predation and cannibalism to certain extent. Decreased juvenile mortality due to vegetative structures was reported by others also (Minello and Zimmerman, 1984; Minello *et.al.*, 1987; 1989; Abdussamad and Thampy, 1994). Predation related mortality was relatively low in *M. monoceros* than in other species as they either burrow in the bottom or take refuge. This substantiates the usefulness of refuge in nurseries for enhancing survival of shrimps.

Emigration

Chapter-7

EMIGRATION

INTRODUCTION

Penaeids, after estuarine phase of life migrate back to coastal waters for the remaining part of their life. At this stage, they support an important and extensive artisanal fishery by stationary gears in open backwaters and adjacent tidal ponds. As this fishery was supported by emigrating prawns, earlier reports on such fishery will provide some basic information on various aspects of emigration. Number of factors have been discussed by several to affect this fishery (Menon, 1951; Racek, 1959; Menon and Raman, 1961; Raman and Menon, 1963; Idyll, 1964; Idyll *et.al.*, 1964; Copeland, 1965; Subrahmanyam, 1965; 1966; 1967; De Bondy, 1968; Yokel *et.al.*, 1969; Hoestlandt, 1969; Staples and Vance, 1986; De Labretonne and Avault, 1971; George, 1974; Kuttyamma and Antony, 1975; Garcia, 1977; Le Reste, 1978; Lhomme 1979). Several investigated causal stimuli for emigration in prawns (Hildebrand and Gunter, 1953; Gunter and Hildebrand, 1954; Panikkar and Menon, 1956; Linder and Anderson, 1956; Racek, 1957; 1959; Gunter and Edwards, 1969; Hughes, 1969; 1972; Pullen and Trent, 1969; Munro, 1975; Boddekke *et.al.*, 1977; Glaister, 1978; Garcia and Le Reste, 1981; Chong, 1979; Benfield and Baker, 1980; Staples, 1980b; Dall, 1981; Achuthankutty and Nair, 1982; Chen, 1983; Coles and Greenwood, 1983; Matylewich and Mundy 1985; Rothlisberg *et.al.*, 1985; Forbes and Benfield, 1986b; Staples and Vance 1986; Jayakody and Costa, 1988; Laubier, 1989; Benfield *et.al.*, 1990).

Barring some information available on shrimp emigration from backwaters based on filternet fishery reported by the above workers and that from the migratory behaviour of Indian penaeids by Anon (1982) their emigration was very little understood from Indian waters. Present study envisaged to gather more information on the emigration of penaeids from tidal ponds and backwaters. Such information will be of immense use in the proper management of this fishery for better production.

MATERIALS AND METHODS

Emigration of prawns from tidal ponds and open backwaters were studied by monitoring the catches in filternets known respectively as thoombuvala (sluice gate net) and oonnivala (stake net). They are tapering conical nets, made of strong cotton or nylon threads with fine meshed code end. They are 4.5 to 5.0 m long and consists of 6 pieces. The first section of the net at mouth has 1.8 cm mesh, the following three sections have 0.7 cm and the cod end has 0.4 cm mesh.

Materials:

The catch and length-weight data of emigrating prawns collected from thoombuvala and oonnivala were used for this study. Catch data were collected directly on sampling day and from farm registers for remaining period of operation. Unsorted samples were collected at fortnightly intervals from thoombuvala and once in every month from oonnivala to study species composition, length, weight and other biological characteristics of species. Brief description of the materials used in the study is given in Table 7.1. Number of prawns emigrated from unit pond area were estimated for the sampling day from catch and length-weight data and then raised to monthly level. Monthly length frequency distribution of emigrants was also estimated in similar manner.

Table 7.1 Sample size used to study emigration pattern and biological characteristics of different species from tidal ponds and backwaters.

Habitat	Species		
	P. indicus	*M. dobsoni*	*M. monoceros*
F1	2,404	3,946	546
F2	2,312	4,809	463
F3	1,226	1,587	361
F4	1,190	1,780	451
F5	1,077	2,064	224
F6	1,421	2,224	352
Backwaters	1,646	3,372	474

Due to the absence of strong currents, filter nets could not be operated for a week between every consecutive spring tide phases. Further there was no fishing by these gears during daytime and so no data could be collected on day emigration also.

Method of Study:

Emigration rate is a fraction of total prawns recruited into a habitat during a year that emigrated during the same year. Since, all prawns that emigrated from tidal ponds were expected to be caught in thoombuvala, emigration rate is the same as the instantaneous rate of mortality due to emigration (Y) estimated in Chapter 6.

Size at emigration was derived from probability curve fitted from the length frequency distribution of emigrating population as below (Table 7.2);

Table 7.2 Derivation of probabilities for estimating length of prawns at emigration using length frequency distribution of emigrants and estimates of growth and mortality parameters.

Midpoint of Length Class	Number emigrated (Ni)	^t midpoint to midpoint (*a)	Emigration ((M+F)->Z)	Emigration (means)	Number available Ni/Pi (*b)	Probability P=Ni/(Ni/Pi)	Cumulative Probability (*d)
35	0	0.000	5.595	5.831	-	0.000	0.000
45	8	0.021	6.066	6.302	441	0.018	0.018
55	16	0.022	6.538	6.774	387	0.041	0.059
65	28	0.024	7.010	7.246	333	0.084	0.144
75	47	0.027	7.482	7.718	279	0.169	0.312
85	86	0.030	7.954	8.190	226	0.380	0.692
95	145	0.034	8.426	8.662	176	0.822	1.514
105	131	0.040	8.898		131 (*c)	1.000	2.514

Where,

M- Instantaneous rate of natural mortality,

F- Instantaneous rate of fishing mortality,

Z- Instantaneous rate of total mortality,

*a. Age was computed from fitted age-length equation as described in Chapter 5.

*b Computed from $N(i+1)/P(i+1) * e^{-Z\,\hat{}t}$

*c This is taken as total number of prawns available in that length class of the population which is fully ready for emigration.

*d Size of the emigrants corresponding to P = 0.5; ie., at 50% of the cumulated probabilities was obtained graphically from the probability curve. Age at emigration was then determined from the age-length equation.

Multiple regression and Analysis of variance were carried out to evaluate and quantify the influence of physico-chemical and biological factors on emigration. Paired observations were evaluated for significance by Hypothesis tests for means.

RESULTS

Species Composition:

M. dobsoni dominated the emigrants followed by *P. indicus* and *M. monoceros (*Fig 7.1, table 7.3, 7.4). *P. indicus* formed 16.7 to 20.8% of the total emigrants in perennial ponds and 10.9 to 15.4% in seasonal ponds. In perennial ponds *M. dobsoni* represented 72.2 to 76.6% and in seasonal ponds between 78.6 to 82.6%; where as *M. monoceros* accounted only 4.1 to 4.9% and 3.6 to 5.5% respectively in these habitat. *Macrobrachium idella* appeared during monsoon months, accounting 1.8 to 2.7% of the emigrants in perennial ponds and 4.3% in seasonal pond, F6 during October-January. But they are not observed among the emigrants from open backwaters.

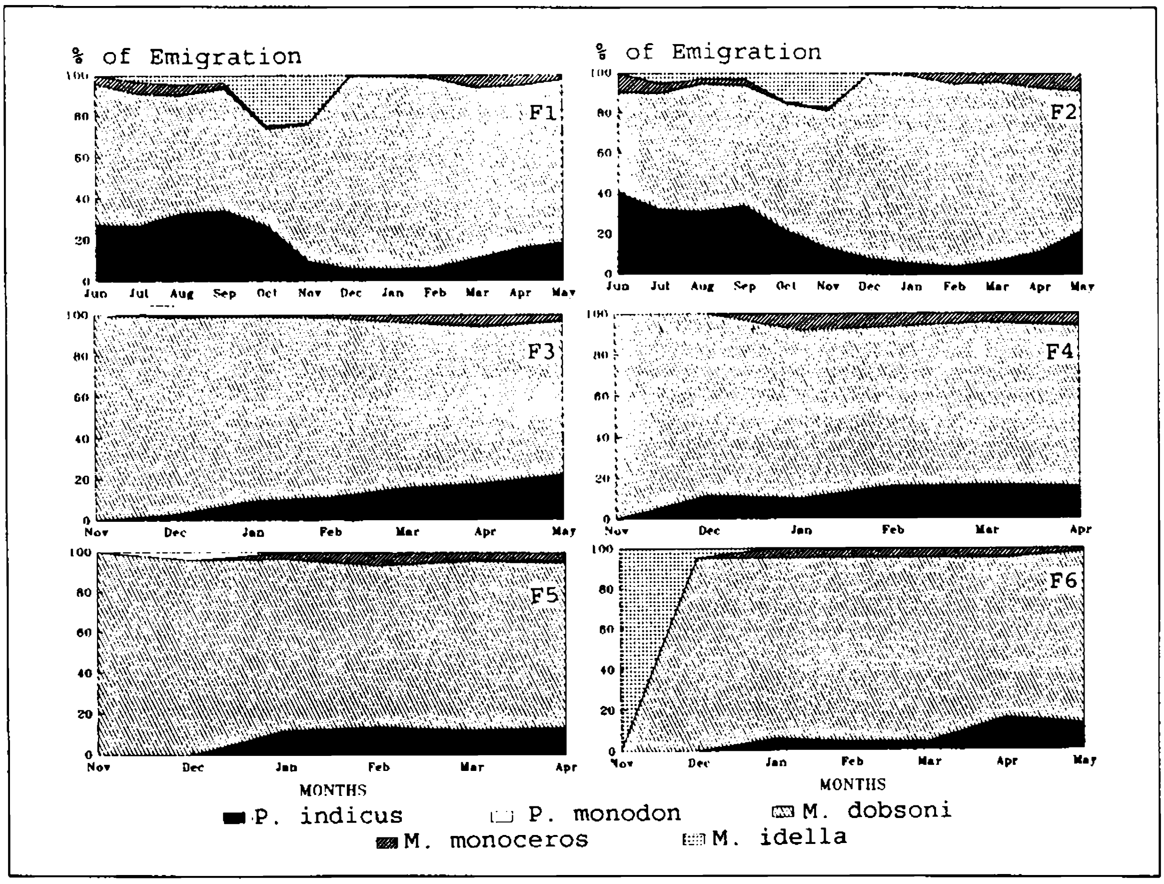


Fig 7.1 Seasonal variation in the composition of species in the emigrating prawn population from tidal ponds.

Table 7.3 Average percentage composition of species in the emigrating prawn population from tidal ponds and backwaters.

Habitat	*P. indicus*	*P. monodon*	*M. dobsoni*	*M. monoceros*	*M. idella*
F1	20.84	0.19	72.23	4.05	2.69
F2	16.67	0.10	76.57	4.85	1.81
F3	15.35	0.48	78.63	5.54	-
F4	14.46	0.25	81.73	3.56	-
F5	12.46	0.47	82.58	4.49	-
F6	10.93	0.25	80.61	3.97	4.24
Backwaters	15.83	0.10	79.64	4.43	-

Table 7.4 Seasonal variation in the percentage composition of emigrants from backwaters.

Months	*P. indicus*	*P. monodon*	*M. dobsoni*	*M. monoceros*
Jun	30.84	1.29	65.60	2.27
Jul	33.99	0.72	60.62	4.67
Aug	44.62	0.00	53.65	1.73
Sep	28.46	0.00	70.34	1.20
Oct	10.65	0.00	88.65	0.70
Nov	7.14	0.00	90.50	2.36
Dec	4.45	0.00	95.55	0.00
Jan	5.63	1.26	91.91	1.20
Feb	11.15	0.00	86.44	2.41
Mar	15.20	0.96	77.09	6.75
Apr	14.64	1.69	77.56	6.11
May	21.94	1.08	72.57	4.41

Composition of species also varied over the season (Fig 7.1, Table 7.4). *P. indicus* representation was relatively small during post and pre-monsoon months and large during monsoon. Their composition varied from 5.2 to 36.9% in perennial ponds, 0 to 22.0% in seasonal ponds and 4. 5 to 44.6% in backwaters. *M. dobsoni* representation varied from 54.9 to 93%, 50 to nearly 100%, 53.7 to 95.6% respectively in these habitat. Their representation was large during post-and pre-monsoon and small during monsoon. *M. monoceros* varied from 0.5 to 7% in perennial, 0.7 to 5.8% in seasonal ponds and 0 to 6.8 in backwaters, with large representation during pre-monsoon and low during post-monsoon months.

Emigration Rate:

P. indicus:

Emigration was large in seasonal ponds, where it varied between 2,768 and 5,284 no/ha/month respectively in F6 and F4 (Table 7.5). In perennial ponds it was between 2,275 in F1 and 3,174 in F2. Rate of emigration was high during monsoon and low during post-monsoon months.

Instantaneous rate of emigration (y) is small, 1.65in perennial ponds and large, 3.53 in Type-II seasonal ponds and 3.30 in Type-I seasonal ponds (Table 7.6).

Table 7.5 Seasonal variation in the emigration rate (no/ha of pond area) of *P. indicus* from tidal ponds.

Months	F1	F2	F3	F4	F5	F6
Jun	3406	3277				
Jul	4864	8490				
Aug	5662	6924				
Sep	3125	3445				
Oct	1162	1640				
Nov	486	794				
Dec	303	786	1101	506	349	
Jan	365	834	3030	1481	1439	687
Feb	811	1206	4673	4879	3853	904
Mar	1562	4096	6790	9207	6180	2121
Apr	3147	4930	8412	10349	8730	9923
May	2411	1667	4317			2975
Total	27304	38089	28323	26422	20551	16610
Monthly Mean	2275	3174	4721	5284	4110	2768

Table 7.6 Instantaneous rate of emigration of different species from tidal ponds.

Species	Perennial pond	Type-I Seasonal pond	Type-II Seasonal pond
P. indicus	1.6530	3.3030	3.5335
M. dobsoni	2.8376	3.9199	5.1974
M. monoceros	2.1741	2.7627	3.2392

M. dobsoni

Emigration was high from seasonal ponds (Table 7.7). It varied between, 22,691 no/ha/month in F5 and 26,347 in F6. It was relatively low, 9,117 o 15,703 respectively in perennial ponds F1 and F2. Emigration was low during monsoon and high during pre-monsoon months.

Table 7.7 Seasonal variation in the emigration rate (no./ha pond area) of *M. dobsoni* in tidal ponds.

Months	F1	F2	F3	F4	F5	F6
Jun	8598	7441				
Jul	11828	13235				
Aug	8585	14145				
Sep	6353	5807				
Oct	2046	5183				
Nov	3431	4821	5225	4508	3179	
Dec	4946	9240	18037	6425	6885	6382
Jan	5722	16887	32032	12054	11557	10963
Feb	11720	29221	34889	21503	19322	21528
Mar	15119	44485	34824	4462	44843	48362
Apr	20749	28258	36942	47922	50360	51275
May	10301	9726	13731			19569
Total	109398	188449	175680	136874	136146	158079
Monthly Mean	9117	15703	25092	22812	22691	26347

Instantaneous rate of emigration was small in perennial ponds and large in Type-II seasonal ponds (Table 7.7). It was 2.84 in perennial pond, 3.92 in Type-I seasonal ponds and 5.20 in Type-II seasonal ponds.

M. monoceros:

Emigration was high in seasonal ponds, between 1,096 no/ha/month in F3 and 2,049 in F4 (Table 7.8). It was low, 461 to 1,063 no/ha/month in perennial ponds. It was relatively low during late monsoon and early post-monsoon and high during pre-monsoon months.

Instantaneous rate of emigration was small, 2.17 in perennial ponds, large, 3.24 in Type-II seasonal ponds (Table 7.6). It was 2.76 in Type-I seasonal ponds.

Table 7.8 Seasonal variation in the emigration (no/ha pond area) of *M. monoceros* from tidal ponds.

Months	F1	F2	F3	F4	F5	F6
Jun	539	1392				
Jul	1028	1139				
Aug	725	509				
Sep	253	1073				
Oct	53	42				
Nov	49	74				
Dec	44	139	340			
Jan	52	302	383	1179	747	575
Feb	218	1632	523	1825	1692	1328
Mar	850	2888	1863	3110	2891	2071
Apr	1229	2847	2867	4130	3536	2883
May	488	721	599			818
Total	5528	12758	6575	10243	8865	7675
Monthly mean	461	1063	1096	2049	1773	1279

Diel Periodicity:

Emigration occurred mainly during night hours, with extremely large catches in filter nets than day. Variation was observed in emigration even during night hours, depending on the time of ebb tides (Table 7.9, Fig 7.2). More prawns emigrate, when ebb tides occurred during early hours of the night *(anthi)* than late hours *(pulari)* Preference for early hours of night for emigration was strong in *M. monoceros* (P=0.0121, T-5.6421, DF-5), with 60-73% of the emigration during *anthi*. In *P. indicus* 57.9 to 63.9% (P=0.001236, T-=5.6190, DF-5) and in *M. dobsoni* 52.4 to 63.3% (P=0.004092, T-4.2381, DF-5) of the emigration occurred during *anthi*.

Variation in species composition with the time of emigration is shown in Table 7.10. *M. dobsoni* representation was relatively large, 78.6 to 82.7% during late hours of the night and that of *M. monoceros* and *P. monodon* was large during early hours. *P. indicus* representation was more or less uniform irrespective of the time of emigration.

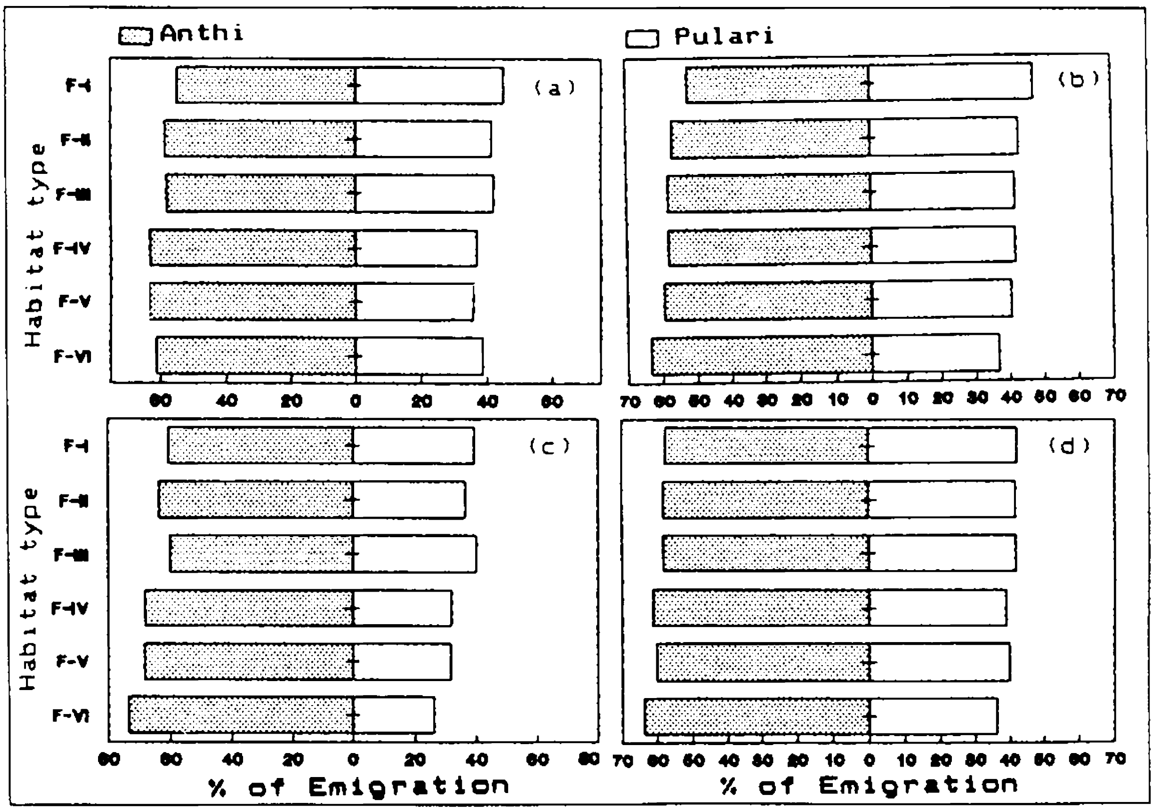


Fig 7.2 Percentage emigration of prawns from tidal ponds during *anthi* and *pulari thakkom*, a. *P. indicus*, b. *M. dobsoni*, c. *M. monoceros* and d. farm averages.

Table 7.9 Estimated emigration rate (no/ha of pond area/year) of prawns from tidal ponds during *anthi* and *pulari thakkom*.

Tidal Pond	SPECIES/THAKKOM					
	P. indicus		*M. dobsoni*		*M. monoceros*	
	Anthi	*Pulari*	*Anthi*	*Pulari*	*Anthi*	*Pulari*
F1	16,931	10,373	57,368	52,030	3,358	2,170
F2	22,343	15,746	107,736	80,713	8,119	4,639
F3	16,413	11,910	102,158	73,522	3,945	2,630
F4	16,194	10,228	86,655	50,219	7,547	2,696
F5	12,195	8,356	80,993	55,153	6,044	2,821
F6	10,496	6,114	91,986	66,093	5,244	2,431

Table 7.10 Variation in species composition (percentage) of emigrating population from tidal ponds during *anthi* (A) and *pulari* (P).

Habitat		*P. indicus*	*P. monodon*	*M .dobsoni*	*M. monoceros*	*M. idella*
F1	A	23.82	0.19	69.72	4.04	2.23
	P	16.24	0.20	78.60	3.07	1.89
F2	A	16.05	0.10	77.17	5.03	1.65
	P	14.78	0.07	79.30	4.17	1.68
F3	A	13.90	0.26	82.13	3.71	0.00
	P	14.79	0.13	81.63	3.45	0.00
F4	A	15.46	0.50	77.49	6.55	0.00
	P	12.99	0.49	81.74	4.78	0.00
F5	A	12.94	0.56	80.93	5.57	0.00
	P	12.97	0.42	82.69	3.92	0.00
F6	A	10.61	1.13	78.79	4.58	4.89
	P	12.40	0.66	81.60	2.88	2.46

Tidal and Lunar Periodicity:

Emigration varied with tidal and lunar phases, with peaks during spring tides of new and full moon (Fig 7.3, 7.4, Table 7.11). Distinct variation was also observed in emigration between new and full moon phases, with large peaks during dark phase. Hypothesis test for means showed significant variation in emigration between moon phases (P=0.00231, T- 8.1146, DF-5). Species also differed, with strong preference in *M. monoceros* towards new moon phases for emigration (P=0.0027, T-=7.8437, DF-5). New moon emigration in the species accounted 55.8 to 68.4% of the total emigration. In *P. indicus* it was 53.2 to 59.1% (P= 0.0439, T-7.0656, DF-5) and in *M. dobsoni* 50.9 to 58.99% (P=0.006592, T-3.7581, DF-5).

M. monoceros representation was relatively large, 4.1-6.7% during new moon than full moon phase (3.1-4.9%) and for *M. dobsoni* it was during full moon, 74.1-81.3% compared to 72.3-82.4% at new moon phase (Table 7.12). Whereas, no such variation was observed in the composition of *P. indicus* between moon phases.

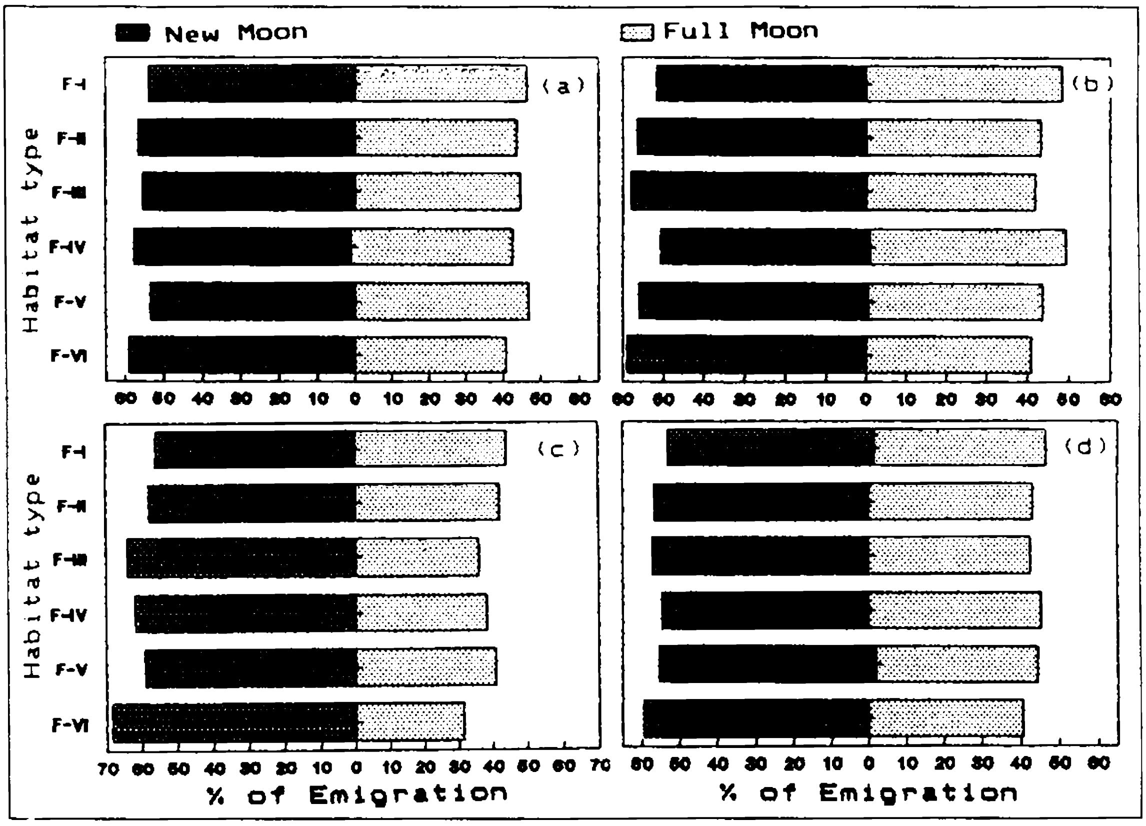


Fig 7.3 Percentage emigration of major species of prawns from tidal ponds during new and full moon phases a. *P. indicus*, b. *M. dobsoni*, c. *M. monoceros* and d. farm averages.

Table 7.11 Estimated emigration rate (no/ha. of habitat area/yr) of major species of penaeids from tidal ponds during different lunar phases.

Tidal pond	*P. indicus* New moon	*P. indicus* Full moon	*M. dobsoni* New moon	*M. dobsoni* Full moon	*M. monoceros* New moon	*M. monoceros* Full moon
F1	14,629	12,675	56,493	52,905	3,084	2,444
F2	21,456	16,633	106,530	81,919	7,373	5,385
F3	15,640	12,683	101,912	73,768	4,208	2,367
F4	15,626	10,796	80,742	56,132	7,008	3,235
F5	10,933	9,618	77,004	59,142	5,234	3,631
F6	9,540	7,069	80,399	77,680	4,733	2,942

Table 7.12 Variation in species composition (percentage) of emigrants from tidal ponds during new and full moon phases.

Habitat		*P. indicus*	*P. monodon*	*M .dobsoni*	*M. monoceros*	*M.idella*
F1	N	21.00	0.19	72.27	4.04	2.50
	F	20.01	0.20	74.14	3.60	2.05
F2	N	15.23	0.09	77.99	4.88	1.81
	F	15.86	0.10	77.87	4.55	1.62
F3	N	15.68	0.24	79.76	4.32	0.00
	F	15.84	0.16	80.92	3.08	0.00
F4	N	15.50	0.56	77.24	6.70	0.00
	F	13.36	0.42	81.30	4.92	0.00
F5	N	12.07	0.45	82.43	5.05	0.00
	F	14.00	1.20	80.20	4.60	0.00
F6	N	13.44	0.56	78.51	4.49	3.00
	F	11.09	0.59	80.95	3.08	4.29

Seasonal Pattern:

P. indicus:

Emigration was low during post-monsoon; thereafter it increased gradually to a small common peak in April in tidal ponds (Fig 7.4, Table 7.5). It decreased marginally in May and increased to the large peak in perennial ponds by August. In perennial ponds post-monsoon emigration accounted 8.5 to 10.6% of the total emigration, pre-monsoon 29.1 to 31.2 and monsoon 58.1 to 62.5% (Fig 7.4). In Seasonal ponds it occurred during November-May with 85% of the emigration during pre-monsoon. Ingression-emigration relationship (Fig 7.5) showed that juveniles from post-monsoon recruits leave the habitat during March-May and pre-monsoon recruits during June-September and produced two waves of emigration.

Statistical tests showed that seasonal variation in emigration directly correlated (P=0.048) with juvenile abundance and described 99.4% of the variation, whereas prevailing environmental conditions have no significant influence (Table 7.13). Salinity described only 54.8% of the observed variations.

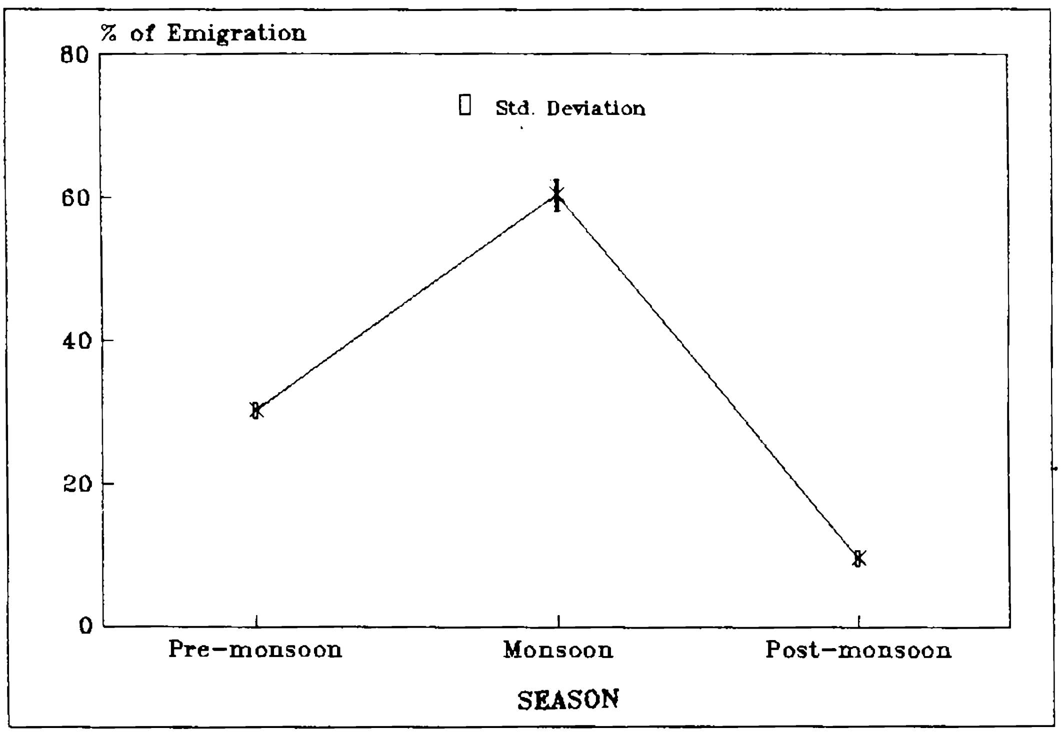


Fig 7.4 Emigration of *P. indicus* from perennial tidal ponds during monsoon, post-monsoon and pre-monsoon seasons.

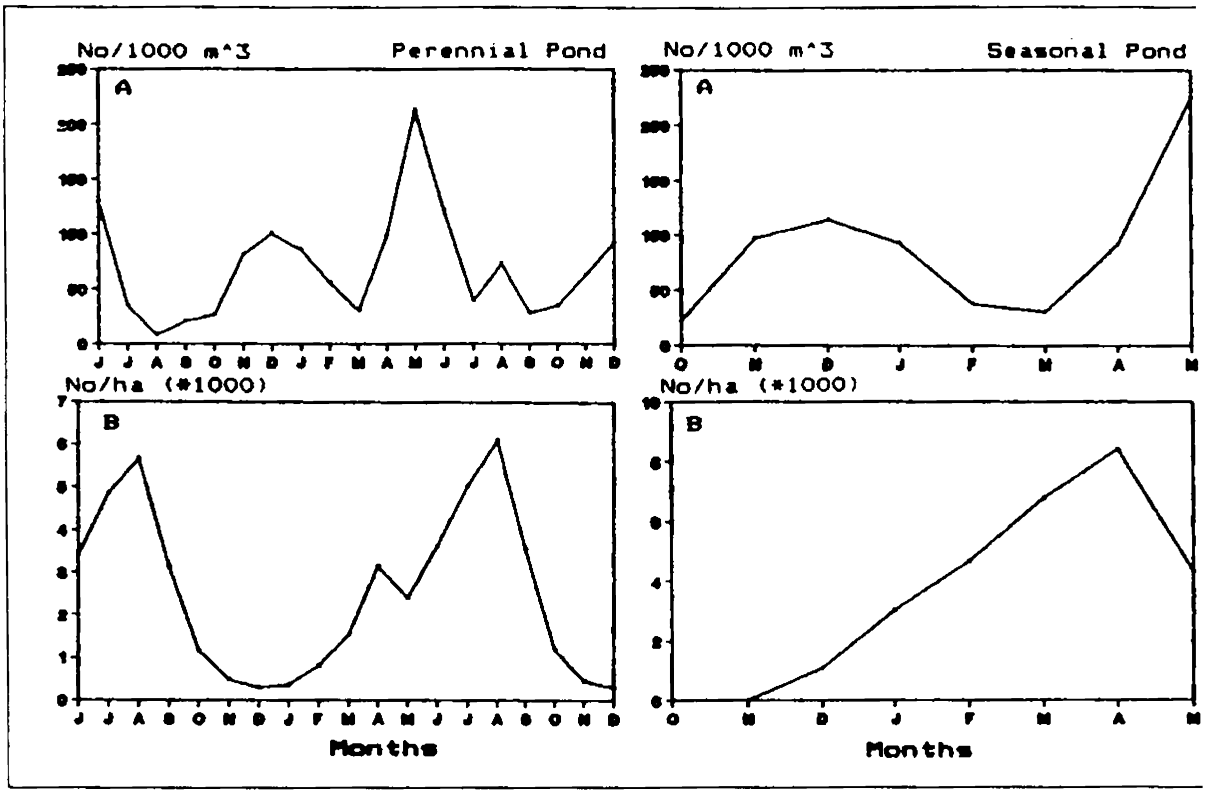


Fig 7.5 Ingression-emigration relationship of *P. indicus* in perennial and seasonal tidal ponds A- Ingression, B- Emigration.

Table 7.13 Multiple regression and Analysis of variance table for seasonal variation in emigration of *P. indicus* and eco-biological conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df=2)	Prob.	Partial r^2
Temperature	-1.1908	9.0987	-0.131	0.90097	0.0034
Salinity	-2.9903	1.2153	-2.461	0.05719	0.5477
DO2	24.5621	17.6361	1.393	0.22246	0.2795
pH	10.9620	16.2812	0.673	0.53062	0.0831
Juv. Abund.	10.5956	0.8001	13.242	0.04798	0.9943
Turbidity	1.8800	1.5661	1.200	0.28374	0.2237
Constant	151.6452				

Std. Error of Est. = 19.0309 Adjusted R Squared = 0.4607

R Squared = 0.9386 Multiple R = 0.9688

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	5577.0285	6	929.5048	5.036	0.0494
Residual	922.8602	5	184.5720		
Total	6499.8887	11			

M. dobsoni:

Emigration was low during post-monsoon, there after it increased gradually to the large peak by April (Table 7.7, Fig 7.6). It declined in May and then increased to a small peak by August in perennial ponds. In perennial ponds post-monsoon emigration accounted 14.8-19.1% of the total emigration, monsoon 21.6-32.3% and pre-monsoon 52.9 to 59.3%. In seasonal ponds post-monsoon emigration accounted 23.5 to 41.8% and pre-monsoon 58.2 to 76.5%.

Ingression-emigration relationship showed that juveniles from post-monsoon recruits produced a major wave of emigration during March-May and pre-monsoon recruits during July-August (Fig 7.7).

Results of the statistical tests showed that seasonal variation in emigration correlated directly (P=0.0304) with juvenile abundance and described 99.8% of the variation, whereas, environmental conditions have no significant (P>0.05) influence (Table 7.14). Salinity described only 48.3% of the observed variations.

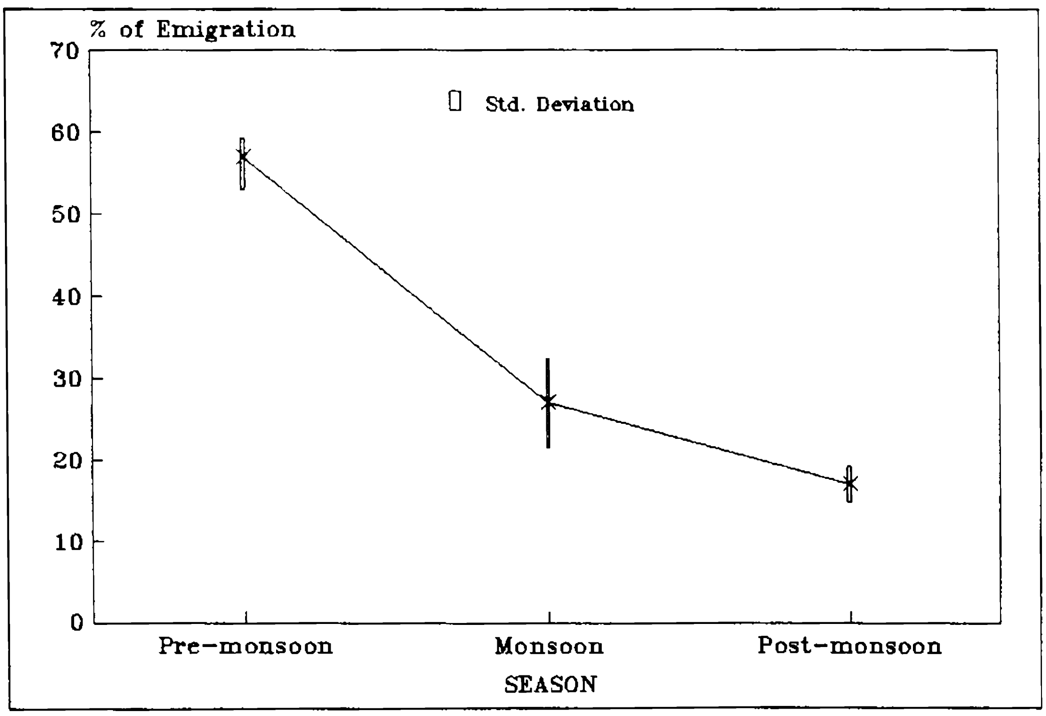


Fig 7.6 Emigration of *M. dobsoni* from perennial tidal ponds during different seasons.

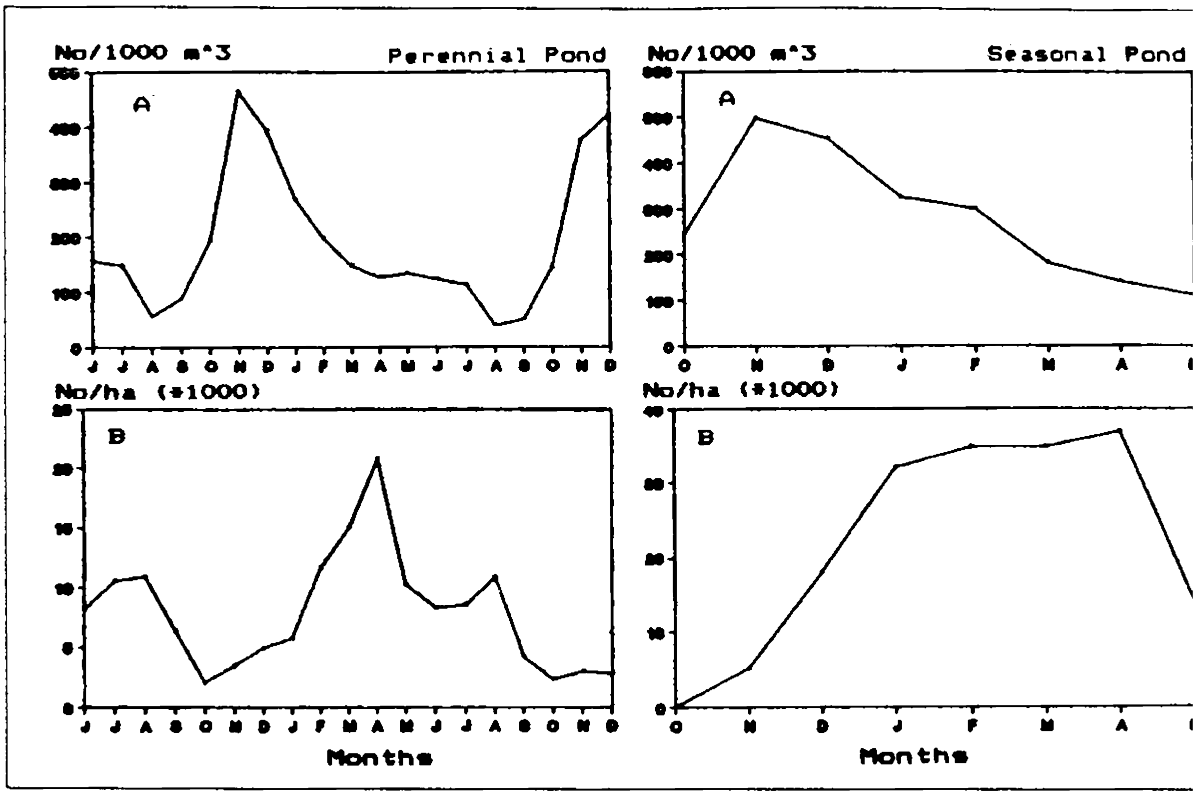


Fig 7.7 Ingression-emigration relationship of *M. dobsoni* in perennial and seasonal tidal poı
A-Ingression, B-Emigration.

Table 7.14 Multiple regression and Analysis of variance table for seasonal variation emigration of *M. dobsoni* and eco-biological conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df=2)	Prob.	Partial r^2
Temperature	2.7614	4.3072	0.641	0.54967	0.0760
Salinity	-1.2422	0.5753	-2.159	0.08327	0.4825
DO2	11.3642	8.3488	1.361	0.23159	0.2704
pH	1.4625	7.7074	0.190	0.85697	0.0071
Juv. Abund.	8.1432	0.3894	20.911	0.03042	0.9977
Turbidity	1.2189	0.7414	1.644	0.16108	0.3509
Constant	-83.3209				

Std. Error of Est. = 9.0091

Adjusted R Squared = 0.6126
R Squared = 0.9756
Multiple R = 0.9877

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	1899.0027	6	316.5005	5.900	0.0448
Residual	267.3771	5	53.4754		
Total	2166.3798	11			

M. monoceros:

Two peaks were observed in emigration; large during pre-monsoon and small during monsoon months (Fig 7.8, Table 7.8). Pre-monsoon emigration accounted 50.4 to 63.4, monsoon 32.2 to 46.1 and post-monsoon 3.6 to 4.4% of the total emigration from perennial ponds. In seasonal ponds 89 to 92.5% of emigration occurred during pre-monsoon.

Ingression-emigration relationship showed that juveniles from post-monsoon recruits emigrated during March-April and pre-monsoon recruits during June-August with respective peaks in April and July (Fig 7.9).

Results of the statistical tests showed that seasonal variation in emigration correlated directly (P=0.0455) with juvenile abundance and described 99.5% of the variation, whereas, environmental conditions have no significant (P>0.05) influence (Table 7.15). Salinity described only 54.42% of the observed variation.

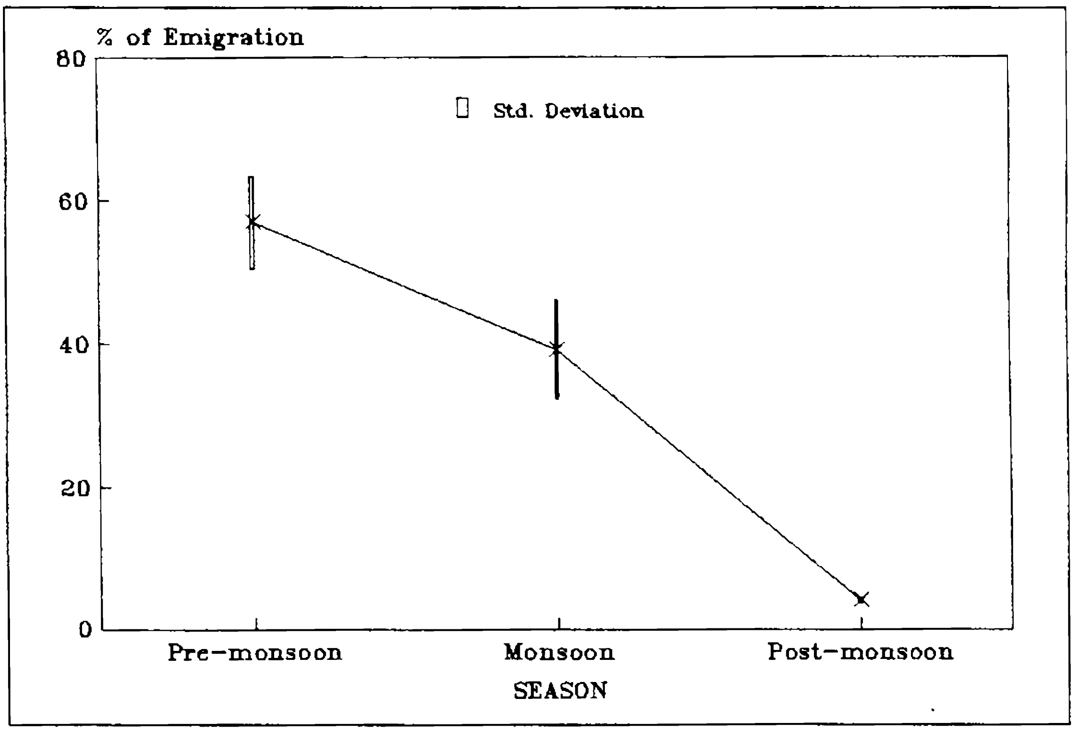


Fig 7.8 Emigration of *M. monoceros* from perennial tidal ponds during different seasons.

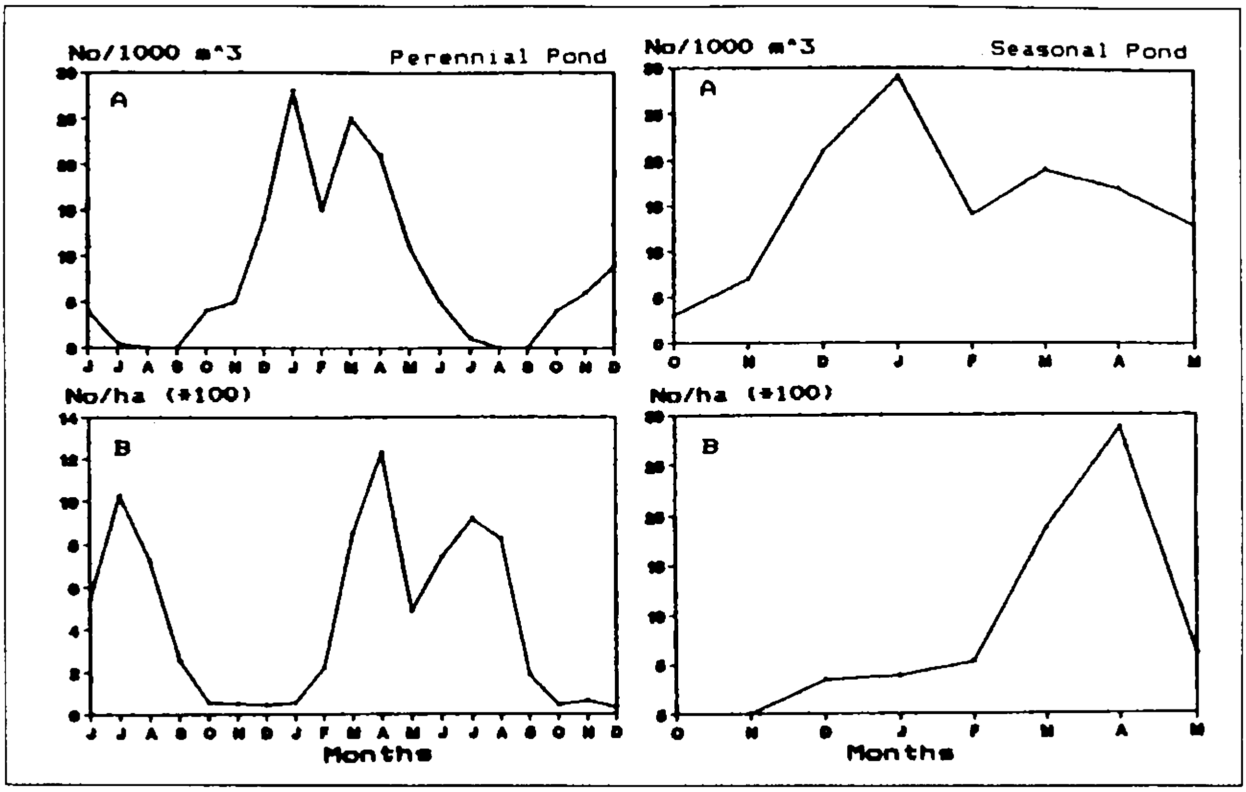


Fig 7.9 Ingression-emigration relationship of *M. monoceros* in perennial and seasonal tidal ponds, A-Ingression, B-Emigration.

Table 7.15 Multiple regression and Analysis of variance table for seasonal variation emigration of *M. monoceros* and eco-biological conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Temperature	0.2538	0.8424	0.301	0.77531	0.0178
Salinity	-0.2749	0.1125	-2.443	0.05842	0.5442
DO2	1.6149	1.6329	0.989	0.36809	0.1636
pH	0.4876	1.5075	0.323	0.75943	0.0205
Juv. Abund.	6.2899	0.4617	13.625	0.04664	0.9946
Turbidity	0.2216	0.1450	1.528	0.18694	0.3184
Constant	-3.9994				

Std. Error of Est. = 1.7620 Adjusted R squared = 0.5121

R Squared = 0.9563 Multiple R = 0.9779

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	54.4807	6	9.0801	5.393	0.0476
Residual	8.4184	5	1.6837		
Total	62.8991	11			

Size and Age:

P. indicus:

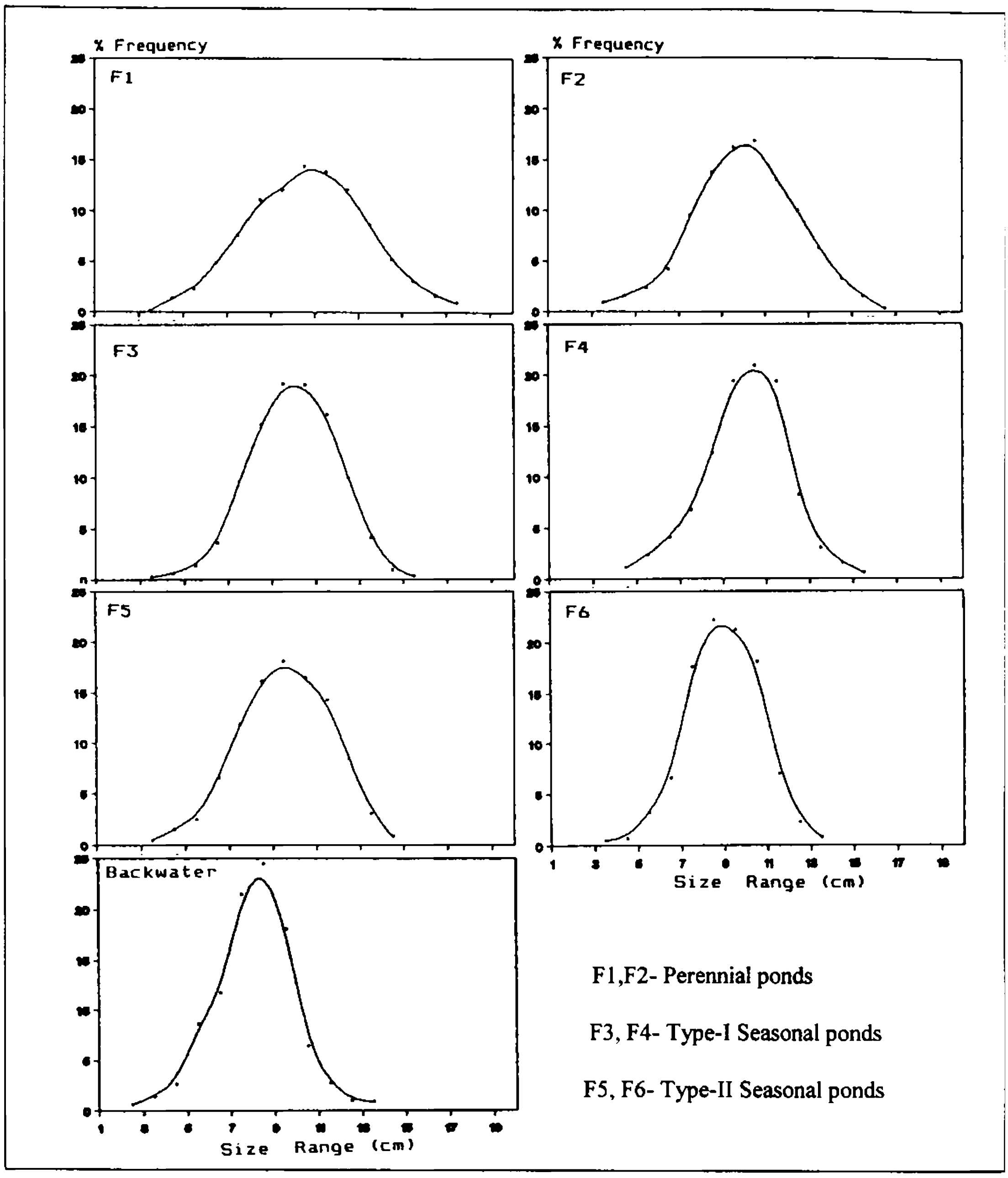


Fig 7.10 Annual length frequency (%) distribution of *P. indicus* emigrants from tidal ponds and backwaters.

Emigrants were 38.0 to 172.0 mm in perennial ponds, 38.0 to 147.6 mm in Type-I 38.5-142.7 mm in Type-II seasonal ponds and 28.5-136.6 mm in backwaters (Table 7.16, 7.10, 7.11). Most of them were 90.0 to 120.0 mm, 80.0 to 110.0, 70.0 to 90.0 and 60 to 80 respectively in these habitats. Small prawns of less than 60 mm were observed among the emigrants from tidal ponds during April and August-September. In open backwaters small prawns emigrated round the year with large abundance during June and July. They constituted 4.5-5% of the emigrants from perennial ponds, 3.5-8.5% from Type-I seasonal ponds, 5.0-5.5% from Type-II seasonal pond and 14.2% from backwaters.

Size of the species at first emigration varied from 95.0 to 96.6 mm in perennial ponds, 80.9 to 91.9 in Type-I and 81.7 to 89.3 in Type-II seasonal ponds (Fig 7.12, Table 7.16). Their age at first emigration (Table 7.15) was estimated as 3.1 to 3.2 months in perennial ponds, 1.9 to 2.6 Type-I seasonal ponds and 1.8 to 2.1 months for ~~and~~ Type-II seasonal ponds.

Table 7.16 Size and age structure of *P. indicus* emigrants from tidal ponds and backwaters.

Habitat	Size Range (mm)	Modal Class (mm)	Mean Length (mm)	Mean Age (months)	Mean Weight (g)	Size at First Emigration	Age at First Emigration
F1	38.0-172.2	100-110	107.0	3.76	9.60	96.59	3.19
F2	39.5-164.0	100-110	100.9	3.42	7.07	95.03	3.11
F3	38.0-147.6	90-100	99.9	2.72	7.50	80.86	1.92
F4	40.0-147.0	90-100	100.5	2.75	8.26	91.87	2.36
F5	39.5-142.7	90-100	95.7	2.34	8.09	89.34	2.07
F6	38.5-134.7	80-90	89.6	2.08	4.90	81.65	1.79
Back-Waters	28.5-136.6	80-90	83.6	2.89	4.66	-	-

Emigrating population was characterised by unimodal length distribution (Fig 7.10, 7.11). In perennial ponds annual modal length was 100-110 mm, where it fluctuated between 80-90 mm during August-September and 130-140 during March. It was 90-100 mm in seasonal ponds with small, 80-90 during December and 110-120 mm during March. Modal size was the smallest, 80-90 mm in F6, the small Type-II seasonal pond, where it was between 70-80 and 100-110 mm. In backwater it was 80-90 mm with small, 60-70 during August-September and large, 90-100 during March-May.

Results of the statistical tests (Table 7.17) showed that size of the emigrants from any habitat depend (P=0.0274), mainly on habitat conditions. It correlated directly with depth, water exchange and spread area of the habitat.

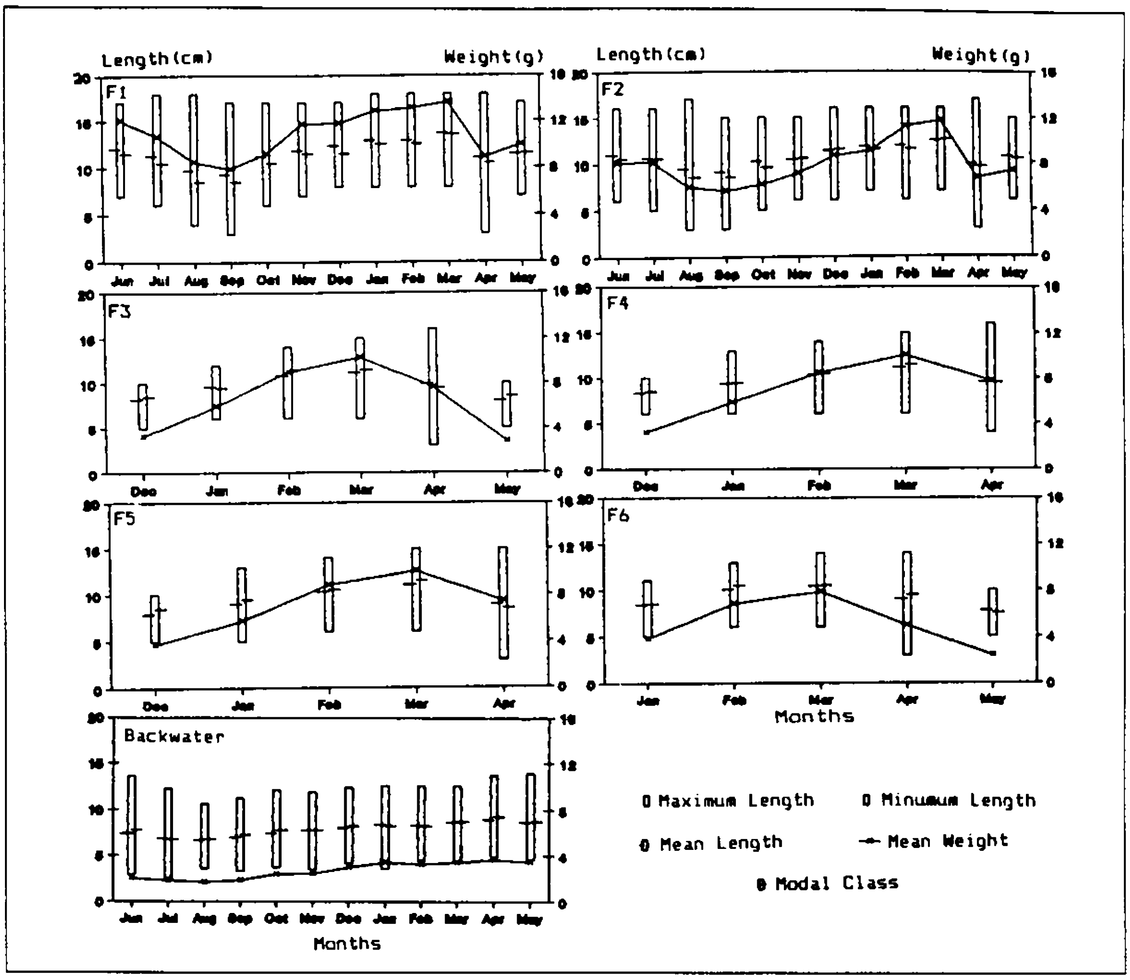


Fig 7.11 Seasonal fluctuation in size range, mean length, modal length and mean weight of *P. indicus* emigrants from tidal ponds and backwaters.

Table 7.17 Multiple regression and Analysis of variance table for variation in the size of *P. indicus* emigrants from different tidal ponds eco-physical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Area	0.3838	0.0152	25.178	0.02527	0.9984
Depth	4.2271	0.1106	38.212	0.01666	0.9993
Water exchange	-51.2965	1.6446	-31.190	0.02040	0.9990
Productivity	5.6783	0.6142	9.245	0.06860	0.9884
Salinity	0.6787	0.0711	9.551	0.06642	0.9892
Constant	366.1088				

Std. Error of Est. = 0.2404 — Adjusted R Squared = 0.9984

R Squared = 0.9997 — Multiple R = 0.9999

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	222.2893	5	44.4579	769.167	0.0274
Residual	0.0578	1	0.0578		
Total	222.3471	6			

Size of the emigrants were small (P<0.01) during September and large during March in perennial ponds (Table 7.18, Fig 7.11). In seasonal ponds, it was respectively during December and March and in backwaters during August and April.

Results of the statistical tests (Table 7.19) showed that seasonal variation in the size of the emigrants depend (P=0.0176) mainly on the prevailing environmental conditions during time to time. It correlated directly with salinity, which described 81.4% of variations.

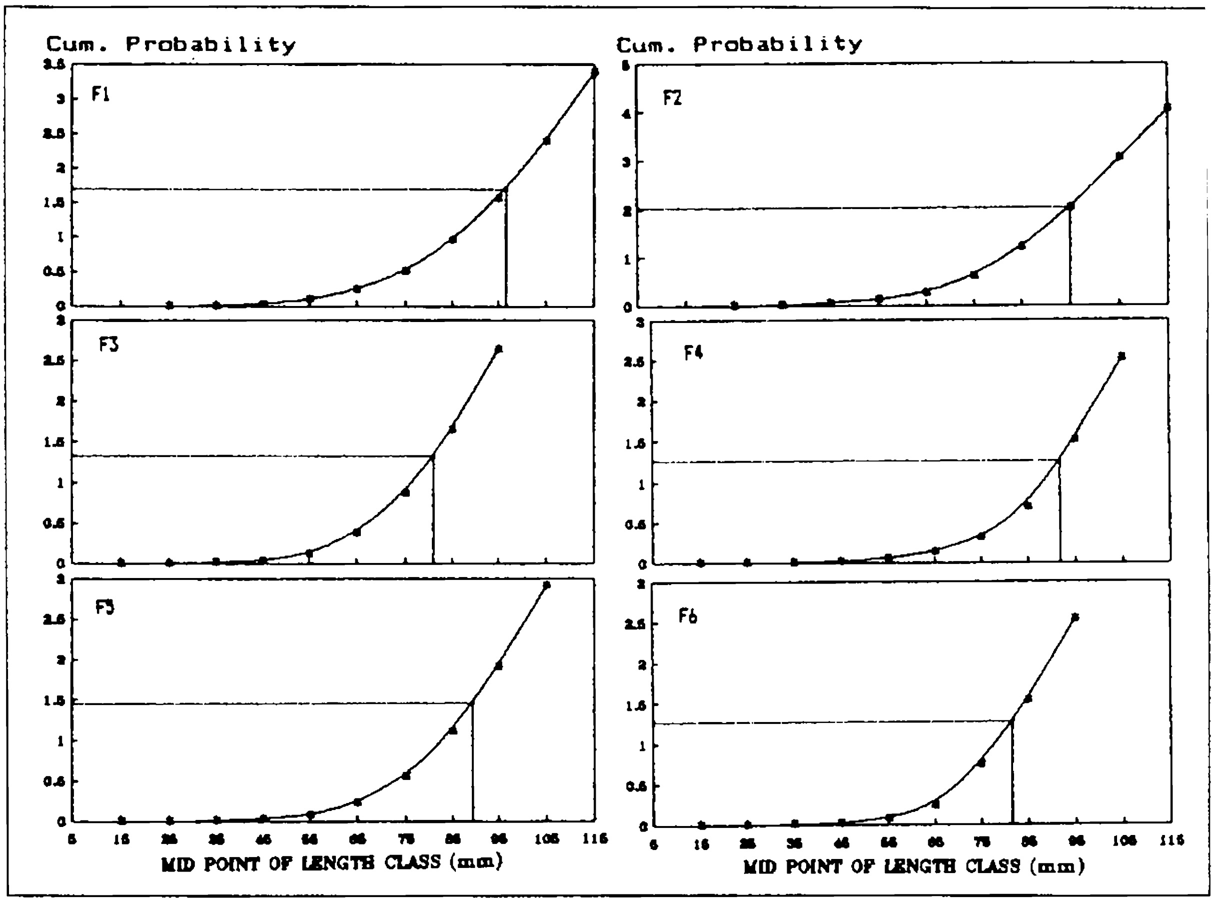


Fig 7.12 Probability curve showing length at emigration for *P. indicus* from tidal ponds.

Table 7.18 Analysis of variance table to test the significance of seasonal variation in size of *P. indicus* emigrants.

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Treatment	13.806	4	3.451	4.673	7.94E-03
Block	42.707	5	8.541	11.565	2.39E-05
Error	14.771	20	0.739		
Total	71.284	29			

Table 7.19 Multiple regression and Analysis of variance table on seasonal fluctuation In the size of *P. indicus* emigrants and variation in the physico-chemical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Temperature	0.0263	0.2747	0.096	0.92754	0.0018
Salinity	0.1716	0.0367	4.676	0.00545	0.8139
DO2	0.5941	0.5326	1.116	0.31530	0.1993
PH	0.1556	0.4916	0.316	0.76442	0.0196
Productivity	0.2145	0.2747	0.781	0.47023	0.1087
Turbidity	0.0093	0.0473	0.198	0.85120	0.0077
Constant	5.2313				

Std. Error of Est. = 0.5747

Adjusted R Squared = 0.7976
R Squared = 0.9080
Multiple R = 0.9529

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	16.3006	6	2.7168	8.227	0.0176
Residual	1.6512	5	0.3302		
Total	17.9518	11			

M. dobsoni:

Emigrants were constituted by 36.0 to 105.4 mm prawns from perennial ponds, 32.5 to 90.1 and 32.5 to 89.1 respectively from Type-I and Type-II seasonal ponds and 27.5 to 86.4 mm in backwaters (Fig 7.13, 7.14, Table 7.20). More than 50% of the emigrants were represented by 5.5 to 7.5 mm groups in perennial, 5.0 to 6.5 in seasonal ponds and 5.5 to 7.0 mm in backwaters. Small prawns of less than 50 mm were observed among emigrants from tidal ponds during April and August-September and round the year from backwaters. They constituted 7.0 to 10.3% in perennial ponds, 14.2 to 20.3 and 14.4 to 21.2% respectively in Type-I and Type-II seasonal ponds and 19.8% in backwaters. Emigrants were relatively large during pre-monsoon and small during monsoon months.

Size of the species at emigration was large, 59.7 to 64.4 mm in perennial ponds, 55.8 to 59.4 in Type-I seasonal ponds and 51.7 to 58.7 mm in Type-II seasonal ponds (Fig 7.15, Table 7.20).

Their age at emigration varied from 2.8 to 3.2 months in perennial ponds, 2.1 to 2.4 in Type-I seasonal pond and 1.9 to 2.3 in Type-II seasonal ponds.

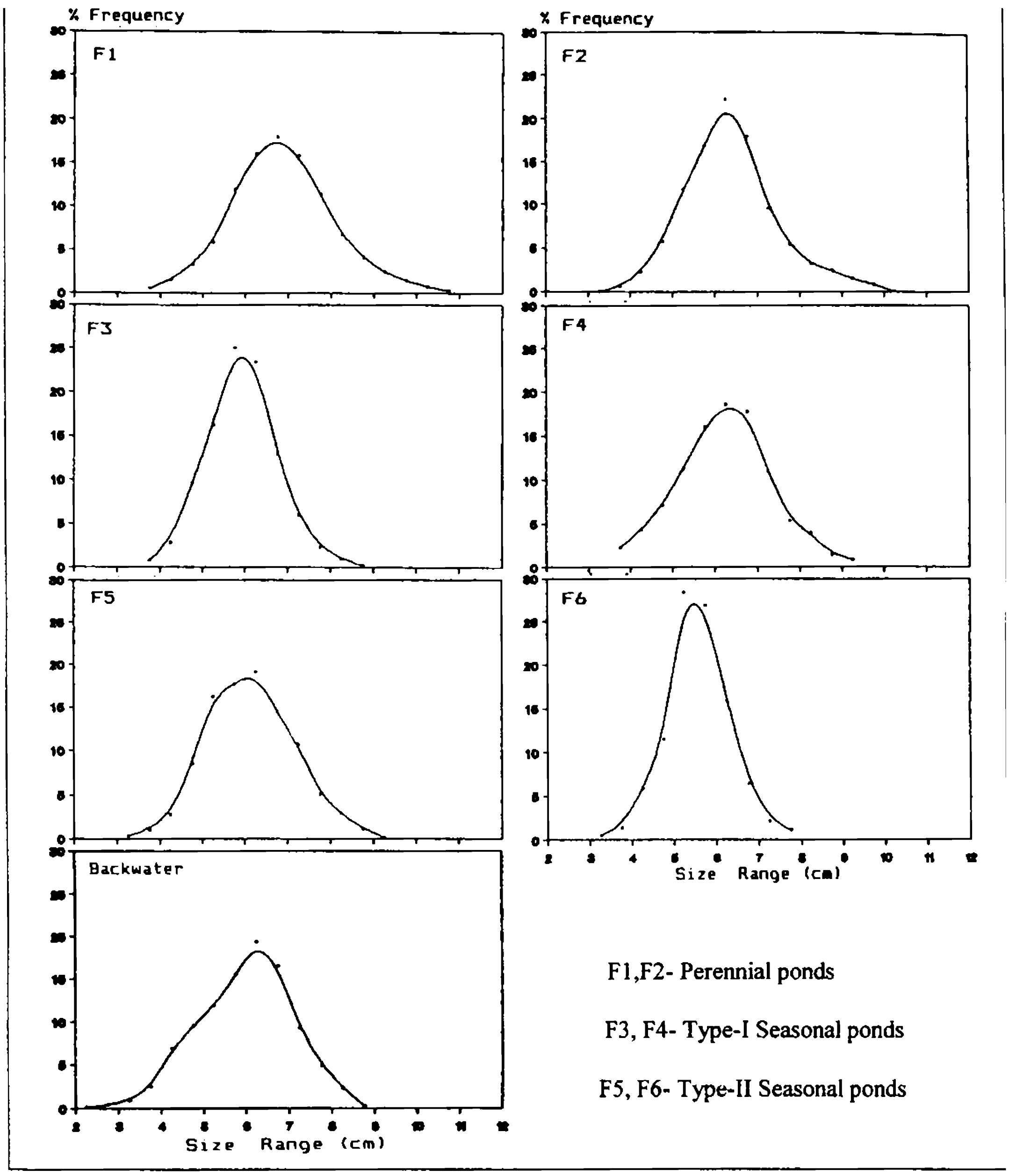


Fig 7.13 Annual length frequency (%) distribution of *M. dobsoni* emigrants from tic ponds and backwaters.

Modal size was large, 60-65 mm in perennial ponds, where it fluctuated between, : and 70-75 mm respectively during August-September and January and March (Fig 7.14, ' 7.20). It was 60-65 and 55-60 mm respectively in Type-I and Type-II seasonal ponds small, 50-55 during November and large, 65-70 during March. The corresponding valu€ backwater was 55-60 mm with small, 50-55 during July and large, 65-70 during March-M

Table 7.20 Size and age structure of *M. dobsoni* emigrants from tidal ponds and backwaters.

Habitat	Size Range (mm)	Modal Class (mm)	Mean Length (mm)	Mean Age (months)	Mean Weight (g)	Size at First Emigration	Age at First Emigration
F1	37.5-105.4	65-70	69.4	3.61	2.05	64.38	3.16
F2	36.0-103.8	60-65	63.7	3.10	2.00	59.71	2.78
F3	33.0- 89.1	55-60	59.3	2.36	1.55	55.76	2.13
F4	32.5- 90.1	60-65	62.2	2.57	1.57	59.37	2.37
F5	33.0- 89.1	60-65	61.3	2.52	1.57	58.67	2.34
F6	32.5- 79.5	50-55	55.6	2.13	1.49	51.74	1.90
Back-Waters	27.5- 86.4	55-60	58.7	2.85	1.50	-	-

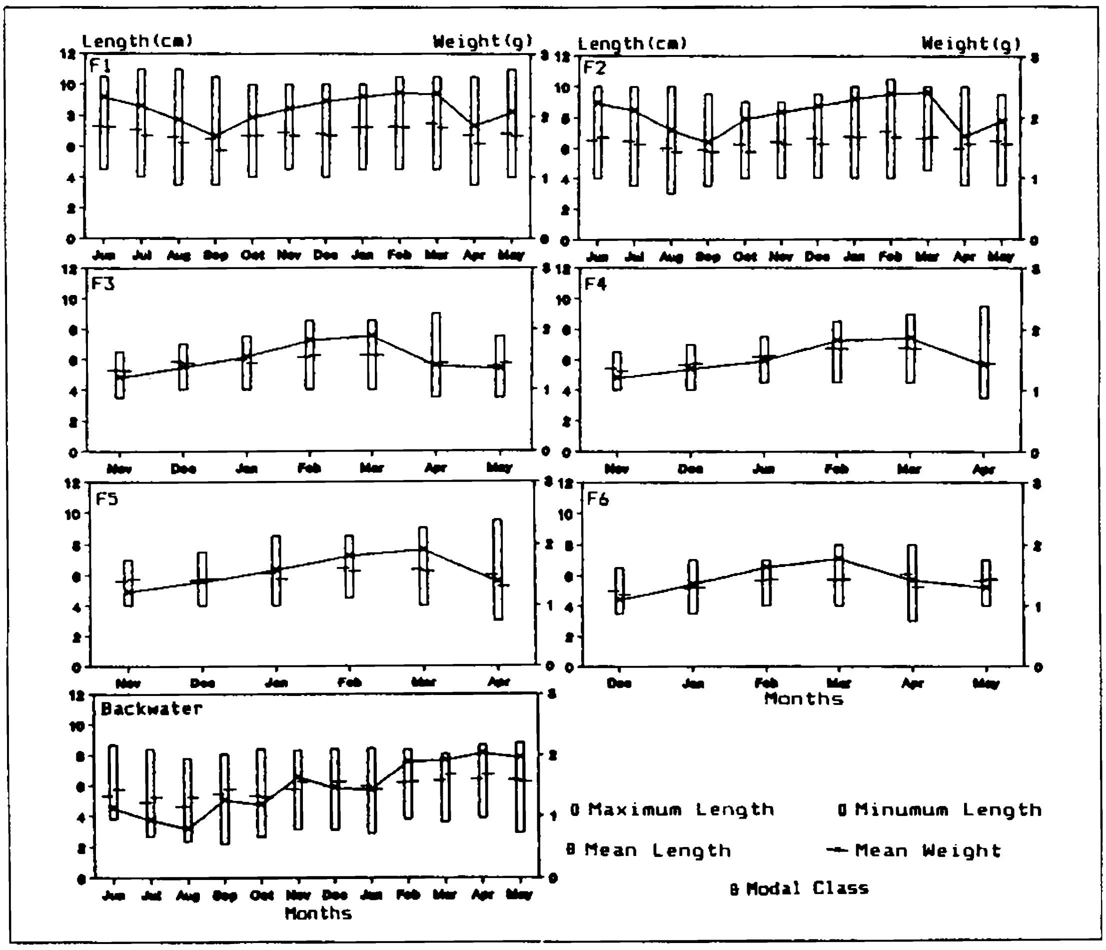


Fig 7.14 Seasonal variations in size range, mean length, mean weight and modal size of *M. dobsoni* emigrants from tidal ponds and backwaters.

Results of the statistical tests showed that size of emigrants depend on habitat conditions (P=0.0253), (Table 7.21). It described 99.98% of the observed variations. Depth, water exchange and pond area has maximum influence on the size of the emigrants.

Size of the emigrant was small (P<0.01) during September in perennial ponds and November in Seasonal ponds (Fig 7.14, Table 7.22).). It was large during February/March in these habitats. Whereas it was small during August and large during March in backwaters.

Results of the statistical tests (Table 7.23) showed that environmental conditions have no significant influence on seasonal variation in the size of the species at emigration (P>0.05). However, salinity fluctuation described 55.4% of the observed variations in size.

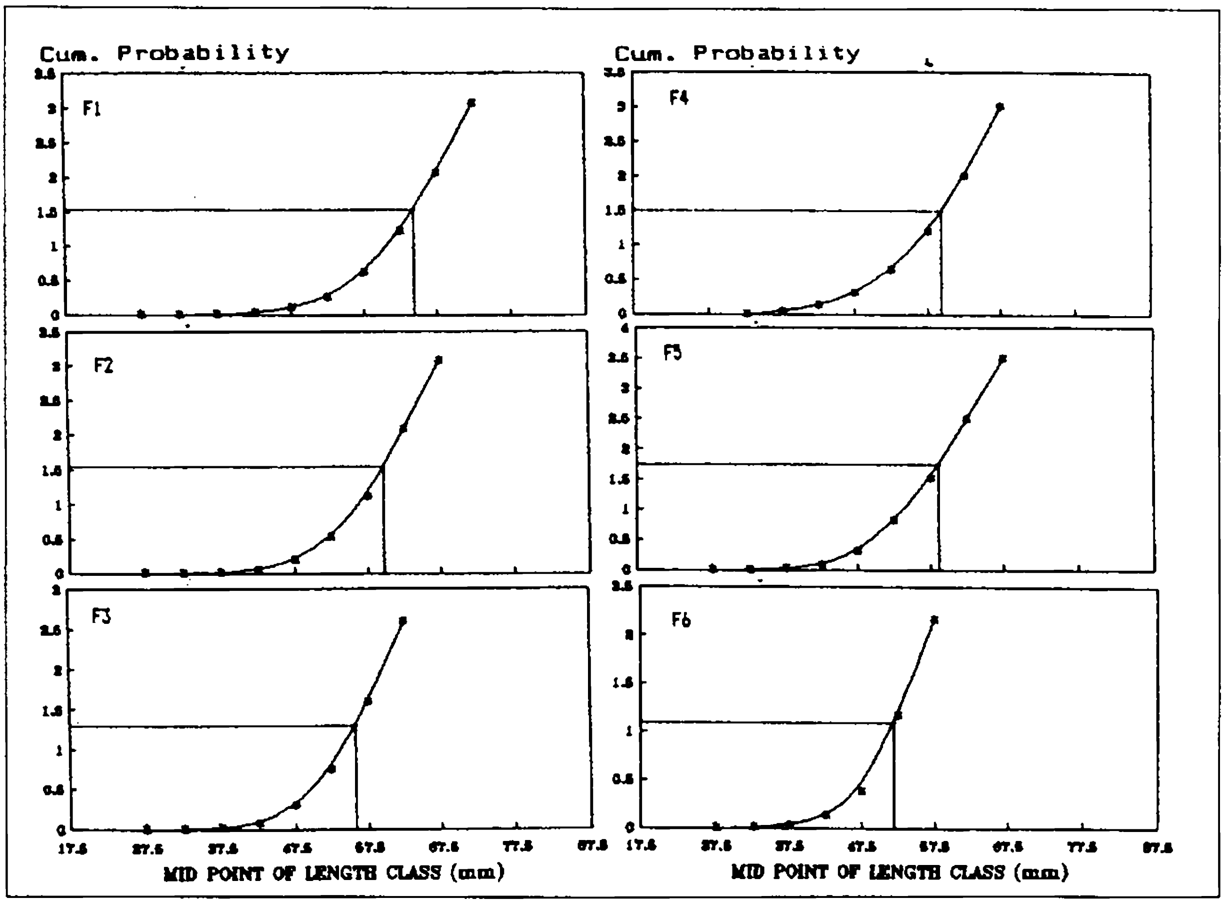


Fig 7.15 Probability curve showing length at emigration for *M. dobsoni* from tidal ponds.

Table 7.21 Multiple regression and Analysis of variance table on variation in the size of *M. dobsoni* emigrants and eco- physical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Area	0.1550	0.0084	18.489	0.03440	0.9971
Depth	37.2699	0.9789	38.072	0.01672	0.9993
Water exchange	-3.1033	0.0719	-43.171	0.01474	0.9995
Productivity	14.0440	1.2812	10.962	0.05792	0.9917
Salinity	17.9117	1.1658	15.365	0.04138	0.9958
Constant	738.5901				

Std. Error of Est. = 0.1414

Adjusted R Squared = 0.9987
R Squared = 0.9998
Multiple R = 0.9999

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob
Regression	89.7304	5	17.9461	897.304	0.0253
Residual	0.0200	1	0.0200		
Total	89.7504	6			

Table 7.22 Analysis of variance table to test the significance of seasonal variation in the size of emigrating population of *M. dobsoni* from different habitats.

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Treatment	3.022	6	0.504	4.068	4.22E-03
Block	13.191	5	2.638	21.308	4.68E-05
Error	3.715	30	0.124		
Total	19.928	41			

Table 7.23 Multiple regression and Analysis of variance table on seasonal fluctuation in the size of *M. dobsoni* emigrants and variation in the physico-chemical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Temperature	0.0318	0.1173	0.271	0.79731	0.0145
Salinity	0.0391	0.0157	2.494	0.05488	0.5544
DO2	0.2013	0.2273	0.886	0.41636	0.1356
pH	0.0455	0.2099	0.217	0.83701	0.0093
Productivity	0.1051	0.1173	0.896	0.41125	0.1384
Turbidity	0.0031	0.0202	0.154	0.88359	0.0047
Constant	5.8325				

Std. Error of Est. = 0.2453

Adjusted R Squared = 0.3824
R Squared = 0.7193
Multiple R = 0.8481

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	0.7709	6	0.1285	2.135	0.2114
Residual	0.3009	5	0.0602		
Total	1.0719	11			

***M. monoceros*:**

Emigrants were large, 37.5 to 119.6 mm in perennial ponds, 34.0 to 102.8 in Type-I, 33.0 to 98.4 in Type-II seasonal ponds and 26.0 to 98.7 mm in backwaters (Table 7.24, Fig 7.16, 7.17). They were constituted mainly by 70 to 90, 65 to 80, 60 to 80, 60 to 75 mm length groups respectively in these habitats. Small prawns of less than 60 mm were migrated in large numbers during April and August/September from tidal ponds and through out the year from backwaters. They constituted 8.4-10.6% of the emigrants from perennial and 17.5-27.6 from Type-I seasonal ponds, 22.1-39.8% from Type-II seasonal ponds and 30.2% from backwaters.

Size of the species at emigration was large, 77.9 to 78.4mm in perennial ponds, 61.2 to 62.9 mm in Type-I and 58.9 to 68.2 mm in Type-II seasonal ponds (Fig 7.18, Table 7.24). Age at emigration was large, 2.94 to 2.98 months in perennial ponds, 1.73 to 1.81 in Type-I and 1.70 to 2.19 in Type-II seasonal ponds.

Modal sizes of the emigrants were large, 80-85 mm in perennial ponds, where it varied between 70-75 mm during September and 85-90 mm during January-February and June (Fig 7.17 Table 7.24). It was 60-65 mm in seasonal ponds with small during December-January and large during April. The corresponding values were 65-70 mm with small, 55-60 August-September and large, 75-80 during May for backwater emigrants. Results of the st tests showed that size of the emigrants depends on habitat condition (P=0.0177) which de 99.99% of the observed variance (Table 7.25).

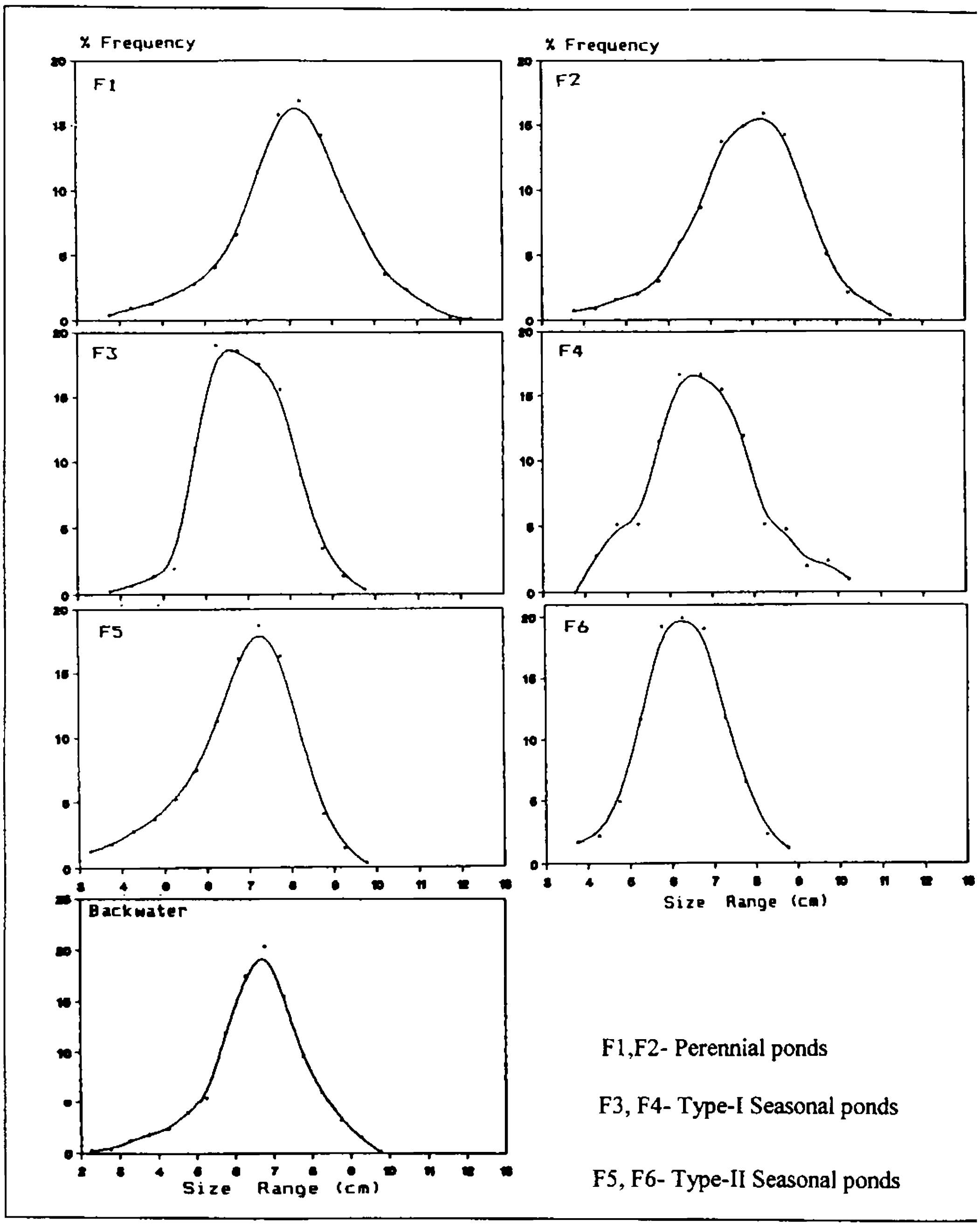


Fig 7.16 Annual length frequency (%) distribution of *M. monoceros* emigrants fro tidal ponds and backwaters.

Table 7.24 Size and age structure of *M. monoceros* emigrants from tidal ponds and backwaters.

Habitat	Size Range (mm)	Modal Class (mm)	Mean Length (mm)	Mean Age (months)	Mean Weight (g)	Size at First Emigration	Age at First Emigration
F1	38.5-119.6	80-85	81.10	3.17	3.87	78.37	2.98
F2	37.5-108.5	80-85	78.60	2.99	3.39	77.88	2.94
F3	36.0- 98.9	60-65	69.60	2.16	3.02	61.15	1.73
F4	34.0-102.8	65-70	68.20	2.08	3.11	62.93	1.81
F5	34.0- 98.4	70-75	68.30	2.19	3.18	68.28	2.19
F6	33.0- 88.7	60-65	62.60	1.90	2.17	58.93	1.70
Back-water	26.0- 98.7	65-70	60.42	2.14	2.01	-	-

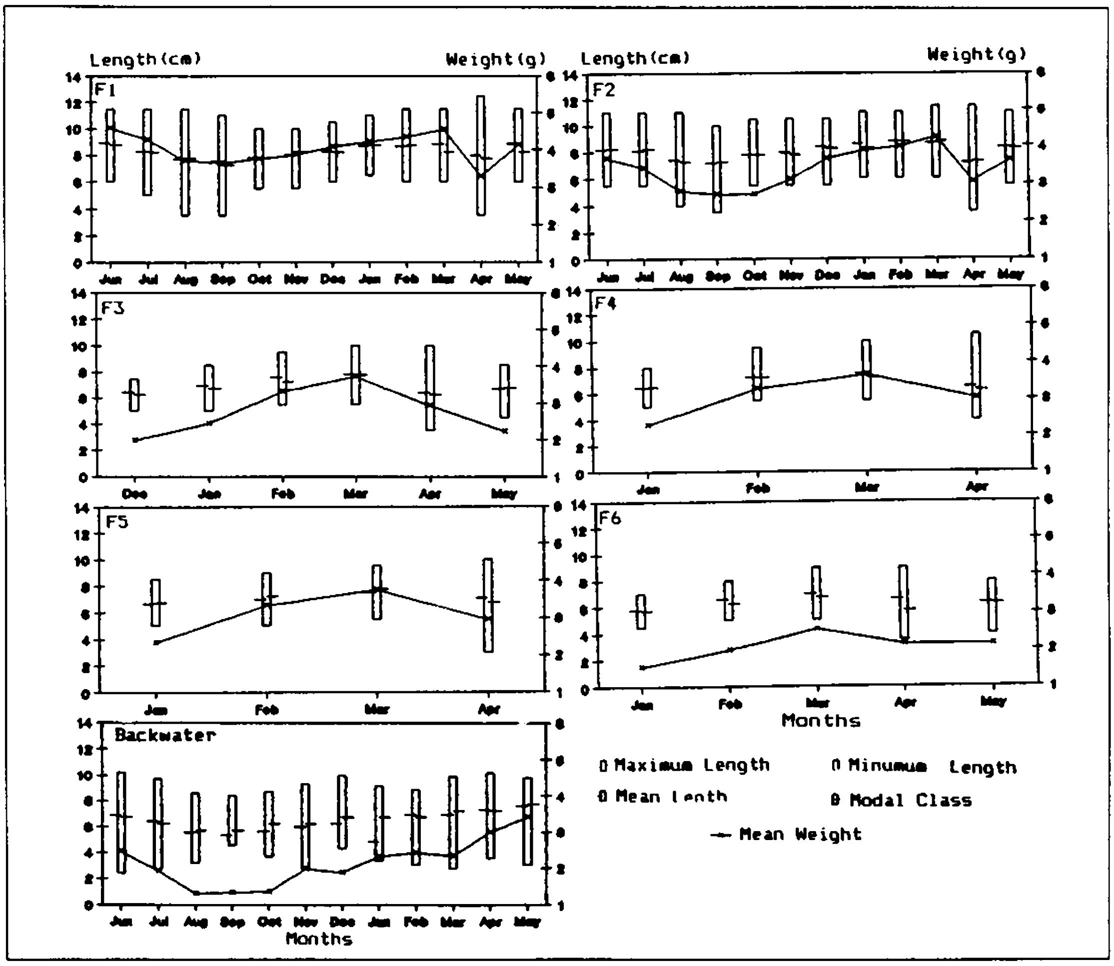


Fig 7.17 Seasonal variation in size range, mean length, mean weight and modal size of the emigrating population of *M. monoceros* from tidal ponds and backwaters.

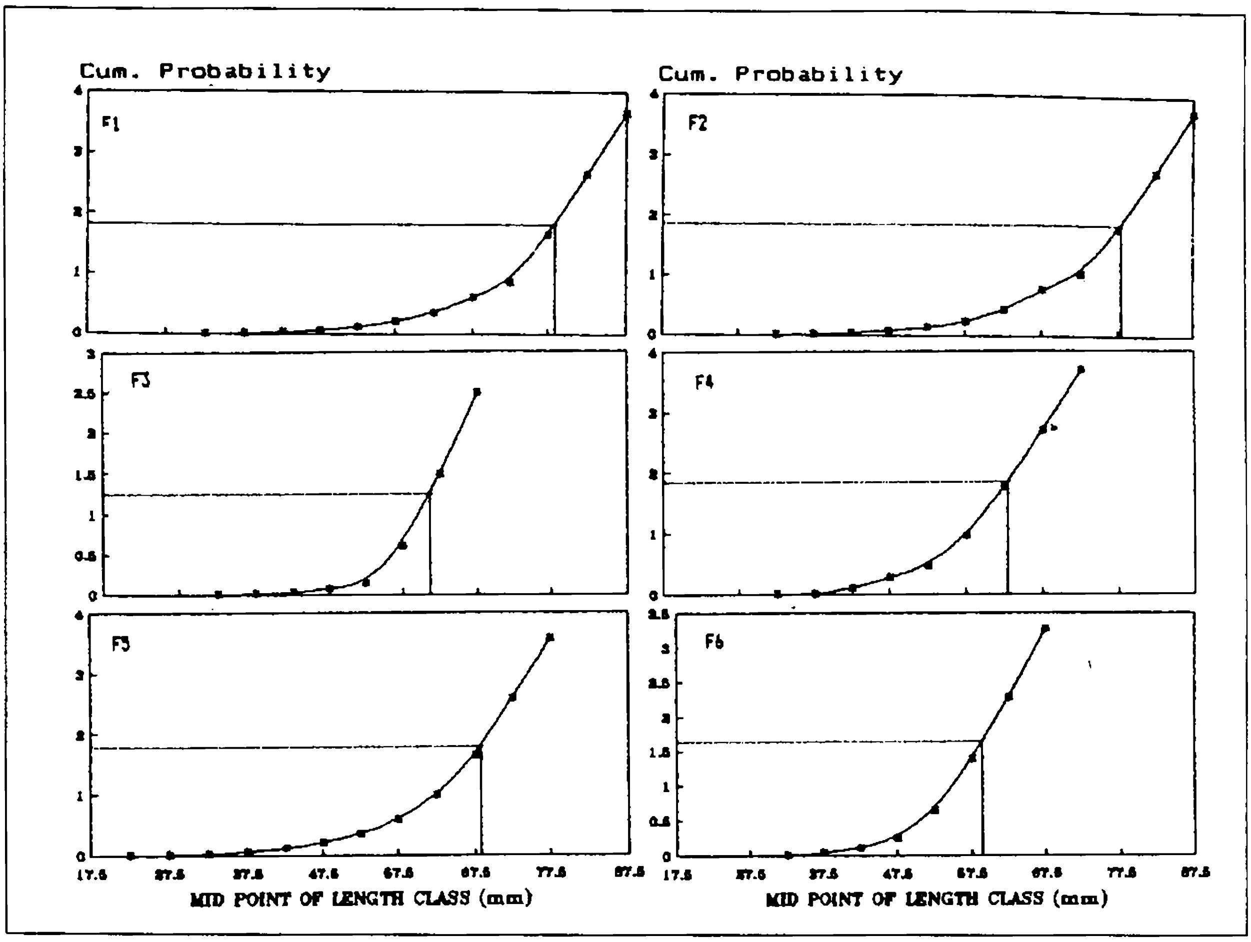


Fig 7.18 Probability curve showing length at emigration for *M. monoceros* from tidal ponds.

Table 7.25 Multiple regression and Analysis of variance table on variation in the size of *M. monoceros* emigrants in different tidal ponds and eco-physical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Area	0.2073	0.0126	16.518	0.03849	0.9963
Depth	15.8065	0.5058	31.249	0.02037	0.9990
Water exchange	-2.1110	0.0911	-23.172	0.02746	0.9981
Productivity	3.8527	1.3544	2.845	0.21521	0.8900
Salinity	0.2985	0.0585	5.101	0.12324	0.9630
Constant	93.5956				

Std. Error of Est. = 0.1980

Adjusted R Squared = 0.9993
R Squared = 0.9999
Multiple R = 0.9999

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	360.0526	5	72.0105	1837.003	0.0177
Residual	0.0392	1	0.0392		
Total	360.0918	6			

Size of the emigrants were small during September and large during February/March in perennial ponds ($P<0.01$), (Fig 7.17, Table 7.26). It was respectively during December and March in seasonal ponds and April/May and September in backwaters.

Results of the statistical tests showed environmental conditions, have significant ($P<0.01$) influence on seasonal variations in the size of emigrants (Table 7.27). They described 93.4% of the observed variations. Salinity described maximum observed variation.

Table 7.26 Analysis of variance table to test the significance of seasonal variation in the size of emigrating population of *M. monoceros* from different habitats

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Treatment	2.886	4	0.721	5.051	5.594E-03
Block	17.221	5	3.444	24.112	7.840E-05
Error	2.857	20	0.143		
Total	22.964	29			

Table 7.27 Multiple regression and Analysis of variance table for seasonal fluctuation in the size of the emigrants of *M. monoceros* and variation in the physico-chemical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Temperature	0.0497	0.0151	3.295	0.02160	0.6846
Salinity	0.0491	0.0117	4.190	0.00857	0.7784
DO2	0.1686	0.1700	0.992	0.36688	0.1644
PH	0.1431	0.1569	0.912	0.40370	0.1426
Productivity	0.2418	0.0877	2.758	0.03992	0.6034
Turbidity	0.1611	0.0877	1.837	0.12570	0.4028
Constant	12.8470				

Std. Error of Est. = 0.1834

Adjusted R Squared = 0.8558
R Squared = 0.9344
Multiple R = 0.9667

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	2.3979	6	0.3997	11.877	7.88e-03
Residual	0.1682	5	0.0336		
Total	2.5662	11			

DISCUSSION

Considerable similarities were observed in the emigration of different species from tidal ponds and backwaters, despite variability on various aspects. Many factors influence and modify emigration and composition of emigrants from these habitats.

Composition of emigrants varied with relatively large representation of *P. indicus* in tidal ponds along the lower regions of backwaters. Whereas, *M. dobsoni* was relatively more numerous in tidal ponds along the inner upper regions. Composition also varied with location This reflected spatial variation in the composition of recruits. Coles and Greenwood (1983) reported similar differential recruitment and juvenile abundance for species like *Penaeus plebejus, Metapenaeus bennettae* and *Metapenaeus macleayi* in the Noosa river estuary Australia. Emigrants from seasonal ponds were dominated by *M. dobsoni*, as they receive only post-monsoon recruits dominated by them. Whereas, perennial ponds receive pre-monsoon recruits dominated by *P. indicus* and so, have their better representation in the emigrating population.

Emigration rate correlated directly with juvenile abundance. Earlier workers also correlated emigration rate with juvenile abundance (Staples and Vance 1986, 1987). According to them rate of emigration depends on the density of juveniles in the habitat at the time of emigration.

Instantaneous rate of emigration demonstrated, how fast prawns complete their emigration from the habitats. Small emigration rate indicated slow emigration of prawns over a long span of time from perennial ponds and large values, rapid emigration from seasonal ponds. This was supported by large age for emigrants in perennial ponds and small in seasonal ponds and backwaters.

Emigration is almost nocturnal in prawns . Shrimps in general, are active at night and take refuge or stay buried in sediments during day. Reflecting this active rhythm, catches were generally high in filternets at night. Such diel variation in penaeid emigration and prawn catches has been demonstrated by earlier workers (Idyll, 1964; Idyll *et.al.*, 1964; Subrahmanyam, 1965; De Bondy, 1968; Yokel, *et.al.*, 1969; Hoestlandt, 1969; De Labretonne and Avault, 1971; Garcia, 1977; Staples and Vance, 1986). However, Subrahmanyam (1965) did not observed such diel variation for penaeids except in *M. monoceros*, in Godavari estuaries and Le Reste (1978) for *P. indicus* in Madagaskar.

Rate of emigration and composition of emigrants varied even during night with time, with large emigration during early hours in the night. As seen above, after low profile activities during day, prawns become more active by dusk in search of food and for other biological requirements. If ebb tide coincide this period more prawns will emigrate. With the advancement of night, their activities subside and so relatively small numbers of prawns emigrate, if it occur late in the night. Such biological activities and diurnal rhythm may vary for species and produce variation in species composition, if emigration occurred at different time.

Prawns emigrate at ebb phase of high tides, with large emigration during spring tides. Earlier workers also reported similar pattern of emigration in penaeids from estuarine habitats (Idyll *et.al.*, 1964; Yokel, *et.al.*, 1969; De Bondy, 1968; Hoestlandt, 1968; De Labretonne and Avault, 1971; Garcia, 1977; Le Reste, 1978; Lhomme 1979). The most widely accepted explanation for higher emigration during these periods is strong water currents, resulting in increased water volume filtered by filter nets. Moreover, present observation indicated considerable influence for tide height and current speed on emigration rates, as indicated by increased abundance of juveniles in the water column at ebb phase of spring tides than neap tides. Juveniles migrate vertically in the water column in response to diel phase, current speed and direction and move with tidal currents. Such vertical movement in prawns as a possible precursor of horizontal displacement was suggested by (De Labretonne and Avault, 1971) and Coles and Greenwood (1983). It was also supported by the well-documented emigration movements of *P. duorarum* (Beerdsley, 1970; King, 1971) and *P. merguiensis* (Staples and Vance, 1986; Haywood and Staples, 1993) with retreating tidal currents. It may be the change in direction and speed of current in tidal ponds and coupled with it the salinity change in back waters govern vertical migration.

Emigration varied with lunar cycle, with peaks at new and full moon phases. Many linked fluctuations in emigration and their catches in inland tidal systems with lunar phases (Racek, 1959; Menon and Raman, 1961; Raman and Menon, 1963; Copeland, 1965; Subrahmanyam, 1965; 1966; 1967; De Bondy, 1968; Yokel *et.al.*, 1969; Garcia, 1977) and attributed large juvenile catches at new and full moon to strong tidal influence. Since, tidal and lunar phases of the area are synchronous, spring tides always coincide with new and full moon phases and made it difficult to separate the lunar influence from tidal influence. A close examination of the data indicated strong correlation for emigration with tide than lunar influence. Such large influence for tides on emigration was also reported by Staples and Vance (1986) for *P. merguiensis* in Gulf of Carpentaria.

Emigration was relatively high at new moon than at full moon phase. Since there is no apparent variation in tide patterns and its occurrence between moon phases, it may be the prevailing light levels, which produce variation. Being nocturnal, activity of prawns will be intense if nights become dark and so large emigrations at new moon phase. Earlier workers also observed large emigration during new moon phase (Racek, 1959; Subrahmanyam, 1965; 1967; Boddekke *et.al.*, 1977; Staples and Vance, 1986). According to Subrahmanyam (1967) and Staples and Vance (1986) juvenile emigration will peaked up if there is no moon light at ebb tide. However, Racek (1959) and Boddekke *et.al.*(1977) attributed it to moulting stages of prawns. They argued that sensitivity of shrimps to migrational stimuli depends on moulting stages and as moulting occur around full moon, migration is inhibited during that period.

Composition of emigrants also varied with lunar phase. As discussed in earlier chapters, species differ in their light preference. Accordingly species specific variation can be expected in emigration and composition with moon phase.

Prawns emigrated round the year and exhibited considerable seasonal fluctuations. It followed the generalised seasonal pattern with two peaks out lined by Garcia (1985) for penaeids. Menon (1954) and Menon and Raman (1961) observed two peaks in the fishery of *P. indicus* in tidal ponds, one in April and another in August-September, pertained to two peak waves of emigration as observed in the present study. Based on stake net fishery Kuttyamma and Antony (1975) demonstrated peaks in emigration from Cochin backwaters. The ingression-juvenile abundance-emigration relationship demonstrated cyclic emigration pattern for species. Peak abundance of advanced juveniles preceded each waves of emigration. Similar pattern of recruitment-emigration relationship was observed for *P. indicus* in Chilka lake (Jhingran and Natarajan, 1969; Ramakrishnaiah, 1979), Pulicat lake (Rao and Krishnayya, 1974), Singapore prawn ponds (Hall, 1962), estuaries of Madagaskar (Le Reste, 1978) and St. Lucia estuary (Benfield *et.al.*, 1990) and for *P. merguiensis* in Gulf of Carpentaria, Australia (Rothlisberg *et.al.*, 1985).

Size and age of the emigrants varied widely in different habitats. However, it was well within the range reported by earlier workers from seasonal and perennial tidal ponds (Hall, 1962; George, 1974; Vasudevappa, 1992), Cochin backwater (Panikkar and Menon, 1956; George, 1959; 1962b; Menon, 1961; Menon and Raman, 1961; Mohamed and Rao, 1971), Pulicat lake (Rao and Krishnayya, 1974), Chilka lake (Kemp, 1915; Rao, 1967; Subrahmanyam, 1967; Ramakrishnaiah, 1979) Godavari estuary (Ganapati and Subrahmanyam, 1964; Subrahmanyam, 1964; 1965; 1966; 1973), Mandovi estuary of Goa (Achuthankutty and Nair, 1983; Achuthankutty, 1988) and else where (Benfield *et.al.*, 1990; Jayakody and Costa, 1988).

Size of the emigrants depends on the nature of the habitat, as it determines growth and period of stay. As discussed in earlier chapters, perennial ponds provide stable environment for growth and prolonged stay of prawns and hence have large size for emigrants. Despite fast growth, prawns emigrate after short stay from seasonal ponds and hence have small size for emigrants. However, despite relatively long stay, sizes of the emigrants were small in backwaters due to slow growth..

Barring occasional emigration of small prawns, a clear seasonal pattern could be seen in the size of the emigrants. Size was small during low saline and large during high saline periods, thus demonstrated salinity dependent size variation. Many reported similar salinity dependent seasonal fluctuation in the size of emigrants of several species from estuaries and lagoons (Tabb *et.al.*, 1962; St. Amant *et.al.*, 1965; Yokel *et.al.*, 1969; Pullen and Trent, 1969; Parker, 1970; Garcia, 1977; Ruello, 1973; Kuttyamma and Antony, 1975; Le Reste, 1978; Lhomme, 1979; Benfield and Baker, 1980; Dall, 1981, Staples, 1980b; Staples and Vance, 1986). As discussed earlier, postlarvae and early juveniles could tolerate near freshwater condition, whereas advanced juveniles have very narrow tolerance limits. Large prawns respond to declining salinity by moving out of the field early, whereas small juveniles remain in the habitat to continue their growth. However, they also emigrate from the habitat with further decline in salinity.

All species emigrate at an age of about 2 months from seasonal ponds and backwaters and above 3 months from perennial ponds. Fast growth of prawns, in these habitats would justify their small age at emigration. Many estimated the age of prawns at emigration in backwaters and tidal ponds as 6 months for *P. indicus*, 3-10 months for *M. dobsoni* 5-10 for *M. monoceros* (Menon, 1955; 1957; George, 1959; 1970; Mohamed and Rao, 1971, Achuthankutty and Nair, 1983; Vasudevappa, 1992). These estimates are on the higher side, as they were based on the size of emigrants and average growth rate of the species reported from else where, without considering their fast growth during early nursery phase (Vasudevappa, 1992). The estimate of 3 months for *M. dobsoni* from perennial ponds by George (1970) and Vasudevappa (1992) are almost same as the present estimate, as they considered fast growth of prawns during their early nursery phase.

In nature many factors trigger migration in shrimps (Garcia, 1977) and may interact as is the case with regard their influence on behaviour (Zein-Eldin and Aldrich, 1965). Shrimps being highly sensitive to the environment in which they live, many attribute considerable influence for ecology in eliciting emigration. Several considered declining water temperature as the driving force in emigration (Linder and Anderson, 1956; Racek, 1959; Glaister, 1978; Garcia and Le Reste, 1981; Coles and Greenwood,1983; Benfield *et.al.*, 1990). Seasonal variation in temperature during the present study was very narrow, to have any direct influence on emigration. However, low temperature always coincided with declining salinity and other ecological conditions and so, some synergistic effect with other factors can be expected.

In areas, where seasonal temperature variation is small, but rainfall is seasonal, Garcia and Le Reste, (1981) considered rainfall as the major driving force for emigration. Many considered salinity as the causal stimuli as they observed an inverse relationship between salinity and juvenile catches (Hildebrand and Gunter, 1953; Gunter and Hildebrand, 1954; Racek, 1957; 1959; Menon and Raman, 1961; Banergy and Roychoudhary, 1966; Subrahmanyam, 1967; Gunter and Edwards, 1969; Hughes, 1969; Rao and Krishnayya, 1974; Kuttyamma and Antony, 1975; Benfield and Baker, 1980; Staple, 1980b; Dall, 1981; Garcia and Le Reste, 1981; Coles and Greenwood, 1983; Rothlisberg *et.al.*, 1985; Forbes and Benfield, 1986b; Staples and Vance 1986; Jayakody and Costa, 1988; Laubier, 1989). They attributed large prawn catches during monsoon or immediately after monsoon to mass emigration owing to osmotic stress, consequent upon lowering of salinity. However, present observations fails to agree fully with the above hypothesis on salinity influence, as juveniles of all species having varying size and age emigrate in large numbers even against positive salinity gradient.

Disturbances in the habitat may force prawns of all sizes to leave their habitat, as evidenced from large waves of emigration from tidal ponds during April and August-September due to intense fishing activities and absence of the same from backwater during the same period. It is further demonstrated by increased emigration from backwaters than tidal ponds immediately after the onset of monsoon. Similar rainfall related emigrations were observed for penaeids in Indian estuaries (Panikkar and Menon, 1956; Achuthankutty and Nair, 1982), banana prawn, *P. merguiensis* in Gulf of Carpentaria, Australia (Staples, 1979; 1980a; 1980b) and school prawn, *Metapenaeus macleayi* in Hunter river estuary, Australia (Ruello, 1973). They attributed this to mechanical flushing by increased river flow and subsequent disturbances of bottom sediment.

As discussed above, emigration correlated directly with juvenile abundance. Presence of large number of prawns in the habitat exert considerable stress on individuals by increasing inter and intra-specific competition. Matylewich and Mundy (1985) considered such biotic factors as one of the driving force in shrimp emigration.

It was seen that, except during periods of extreme habitat disturbances and instability, prawns emigrate selectively, after attaining particular size and developing secondary sex characters only. So it can be assumed that, it may be some biological instincts, which is set in the animals and become active at certain stages of their life, to have most ideal environment to suit their metabolic/physiological requirement is the driving force in emigration. As most of the emigrants were with well-developed secondary sex structures, the biological instinct can be presumed to be the urge for sexual maturation. Coles and Greenwood (1983), suggested onset of sexual maturity coupled with environmental changes as migratory stimuli in prawns. So urge sexual maturation can be considered as the basic stimuli for emigration, whereas factors like habitat environment, competition and predation have only interactive role in modifying patterns and timings.

Length-Weight Relationship and Condtion Factor

Chapter-8

LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR

INTRODUCTION

Animals grow in size, with time and the growth pattern varies considerably in different animal groups and also in different individuals. Growth in length and weight of the individuals in a population generally follows a definite pattern. However, it may vary with the living conditions and hence has the potential to influence length-weight relationship and robustness of the individuals. Informations on these aspects are useful in assessing the suitability of habitats for the species concerned. Extensive information is available on the length-weight relationship of several species of penaeids from Chilka lake (Rao, 1967), Cochin backwaters and adjacent tidal ponds (George, 1959; Nair *et.al.*, 1982; Devi *et.al.*, 1983, Vasudevappa, 1992) and estuaries of Goa (Achuthankutty and Parulekar, 1986) etc.

Condition factor is another biological tool, which can be used as a reliable index for assessing the well being and robustness of the individuals. Usefulness of condition factor for penaeids in different habitat is indicated in Nair *et.al.* (1982) and Devi *et.al.* (1983). They discussed the influence of environmental conditions and related aspects on the condition of P. *indicus* and *M. dobsoni* under laboratory and natural conditions. Variation in condition factor with growth and seasons for *P. semisulcatus* were discussed by Thomas (1977) and for *P. kerathuruz*, by Rodriguez (1987). However, information on this aspect of penaeids from tidal ponds and backwater nurseries is limited.

Present study aimed to compare length and weight relationship and condition factor of penaeids in different tidal ponds and backwaters. This study will be useful in understanding the influence of various habitat conditions on well being of species and help in better management of the culture practices and fishery.

MATERIALS AND METHODS

Data on length and wet weight of prawns covering all available size groups collected from tidal ponds and backwaters using liftnets, filternets and castnets were used for this study. Pooled habitat-wise data for the entire study period were used to fit the equation. Materials used for the study are shown in Table 8.1.

Table 8.1 Length range and sample size of prawns from tidal ponds and backwaters used to wok out the length-weight equation.

Species	Habitat				
	Perennial Pond	Seasonal pond (Type-I)	Seasonal pond (Type-II)	Stocking Pond	Backwaters
P. indicus					
Length Range-mm	10.0-172.0	9.0-147.5	9.0-142.5	11.0-153.0	9.0-136.5
No.	947	866	753	603	653
M. dobsoni					
Length Range-mm	9.5-105.5	9.5-90.0	9.0-89.0	10.0-105.5	9.0-86.5
No.	1424	1053	851	790	866
M. monoceros					
Length Range-mm	10.5-120.0	9.5-102.5	10.0-98.0	12.0-120.0	9.5-98.5
No.	584	335	343	203	162

Length-weight equations were computed as per Sparre (1986) following linear analysis by converting the length and weight data into log values. In order to test any variation in length-weight relationship due to variation in habitat condition, equations were fitted separately for prawns from different tidal ponds and backwaters. The fitted equations were then tested for significance by analysis of covariance (Snedecor and Cochran, 1967). The equation on length-weight relationship is given by;

$$\text{Log } W = a + b * \log L$$

Where; W- weight in grams,

L- total length in mm,

a - constant,

b - regression coefficient.

The well being and robustness of prawns in different medium/habitats were compared using relative condition factor (Kn), as per Le Cren (1951). It was computed from the relation;

$$Kn = W / \hat{w}.$$

Where; W - observed weight

^w - calculated weight

^w was estimated from length-weight equation. To enable more realistic comparison between different habitats the mean of estimated weights of prawns from different habitats were used as ^w.

RESULTS

Length-Weight Relationship:

P. indicus:

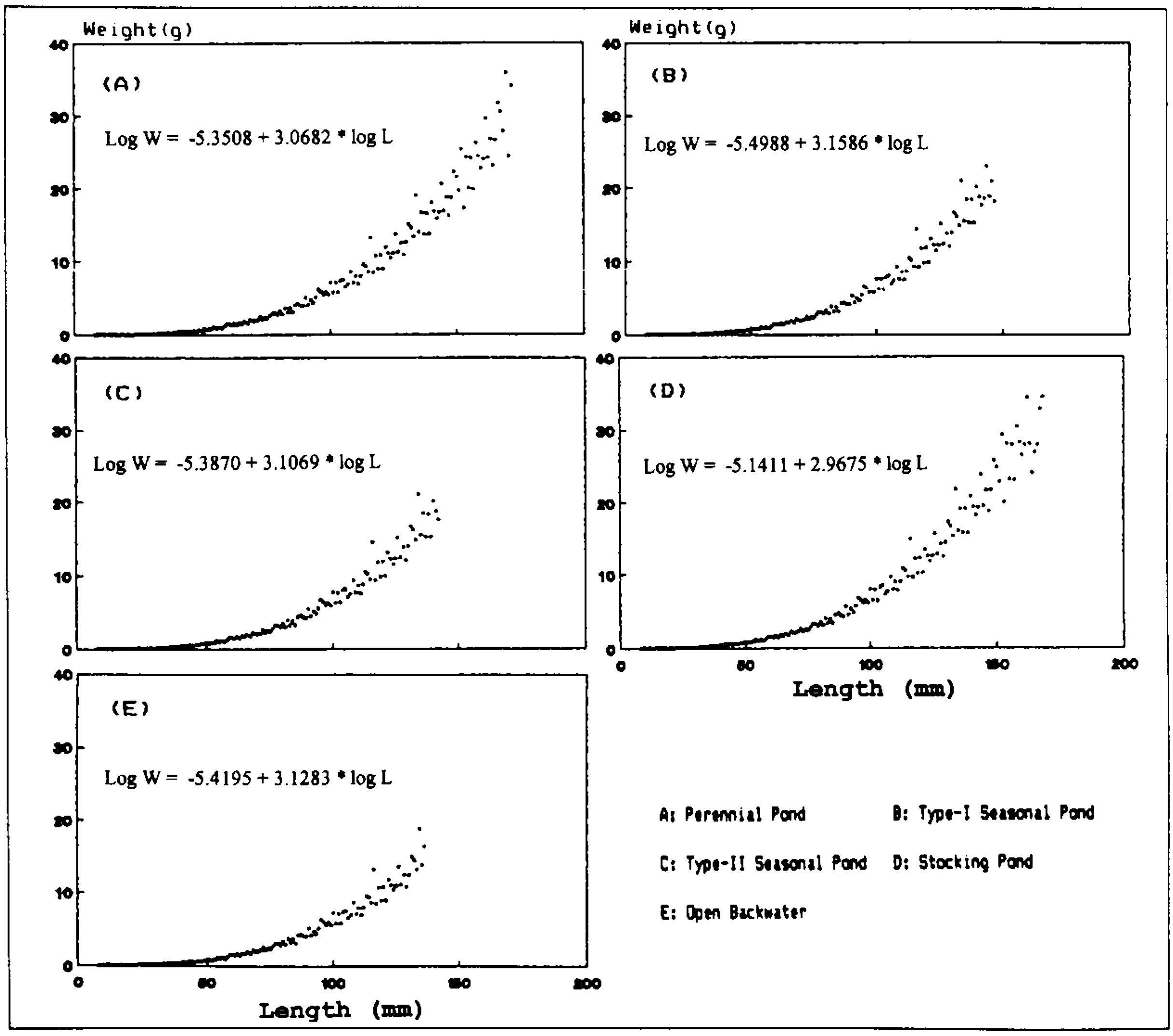


Fig 8.1 Scatter diagram representing length-weight relation of *P. indicus* from different tidal ponds and backwaters.

Length-weight relationship of the species in different tidal ponds and backwaters varied significantly (P<0.01), (Fig 8.1, Table 8.2). Prawns of the same length were relatively heavy in stocking ponds than their counter parts in other tidal ponds and backwaters. They were light in perennial ponds and backwaters and moderately heavy in seasonal ponds.

Table 8.2 Covariance analysis of significance for length-weight equation of *P. indicus* from different habitats.

						Deviation from regression		
Source	D.F.	Ex^2	Exy	Ey^2	Redn	D.F.	SS	MSS
Between Habitats (T)	4	89907.6	22941.6	6120.7				
Error (E)	1465	2736341.0	416194.1	84760.9	63302.6	1464	21458.3	14.657
T + E	1469	2826248.6	439135.7	90881.6	68231.9	1468	22649.8	
						4	1191.5	297.87
			F Ratio = 20.32 (df.4, 1464)**,				Table F-3.32	

** - Highly significant at 1% level

M. dobsoni:

Species from different tidal ponds and backwaters varied significantly (P<0.01) in their length-weight relationship (Fig. 8.2, Table 8.3). They were relatively heavy in stocking ponds, followed by in Type-II seasonal ponds, moderately heavy in Type-I and perennial ponds and light in backwaters.

Table 8.3 Covariance analysis of significance for length-weight equation of *M. dobsoni* from different habitats.

						Deviation from regression		
Source	D.F.	Ex^2	Exy	Ey^2	Redn	D.F.	SS	MSS
Between Habitats (T)	4	15888.7	1281.3	105.8				
Error (E)	873	579695.4	34721.5	2247.4	2079.7	872	167.7	0.192
T + E	877	595584.1	36002.8	2353.1	2176.4	876	176.8	
						4	9.1	2.276
			F Ratio = 11.83 (df.4, 872)**,				Table F-3.34	

** - Highly significant at 1% level

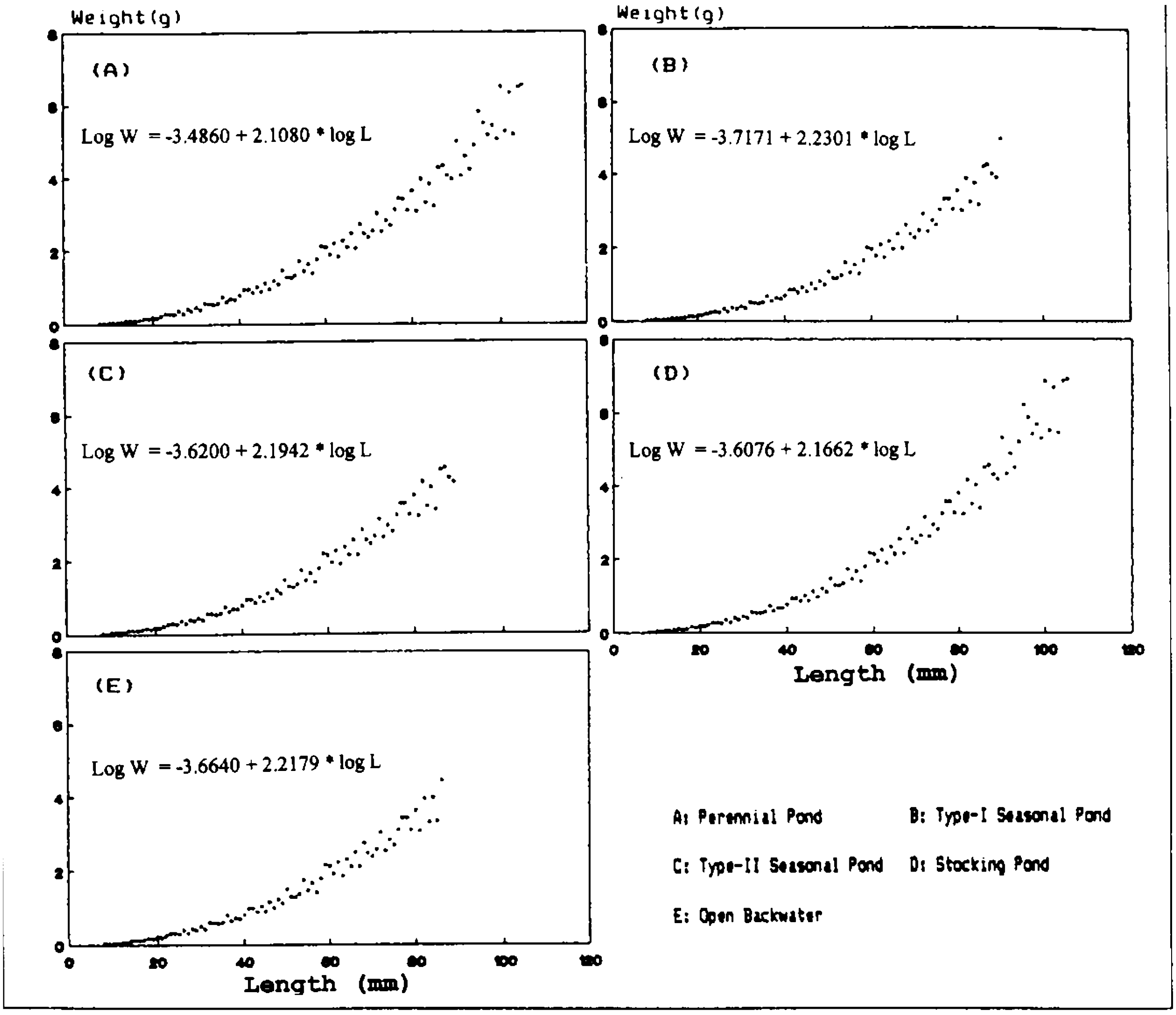


Fig 8.2 Scatter diagram representing length-weight relation of *M. dobsoni* from different tidal ponds and backwaters.

M. monoceros:

Species in different tidal ponds and backwaters varied significantly ($P<0.01$) in their length-weight relationship (Fig. 8.3, Table 8.4). They were relatively heavy in stocking ponds followed by perennial ponds. Whereas, they were light in Type-II seasonal ponds and moderately heavy in Type-I seasonal ponds and backwaters.

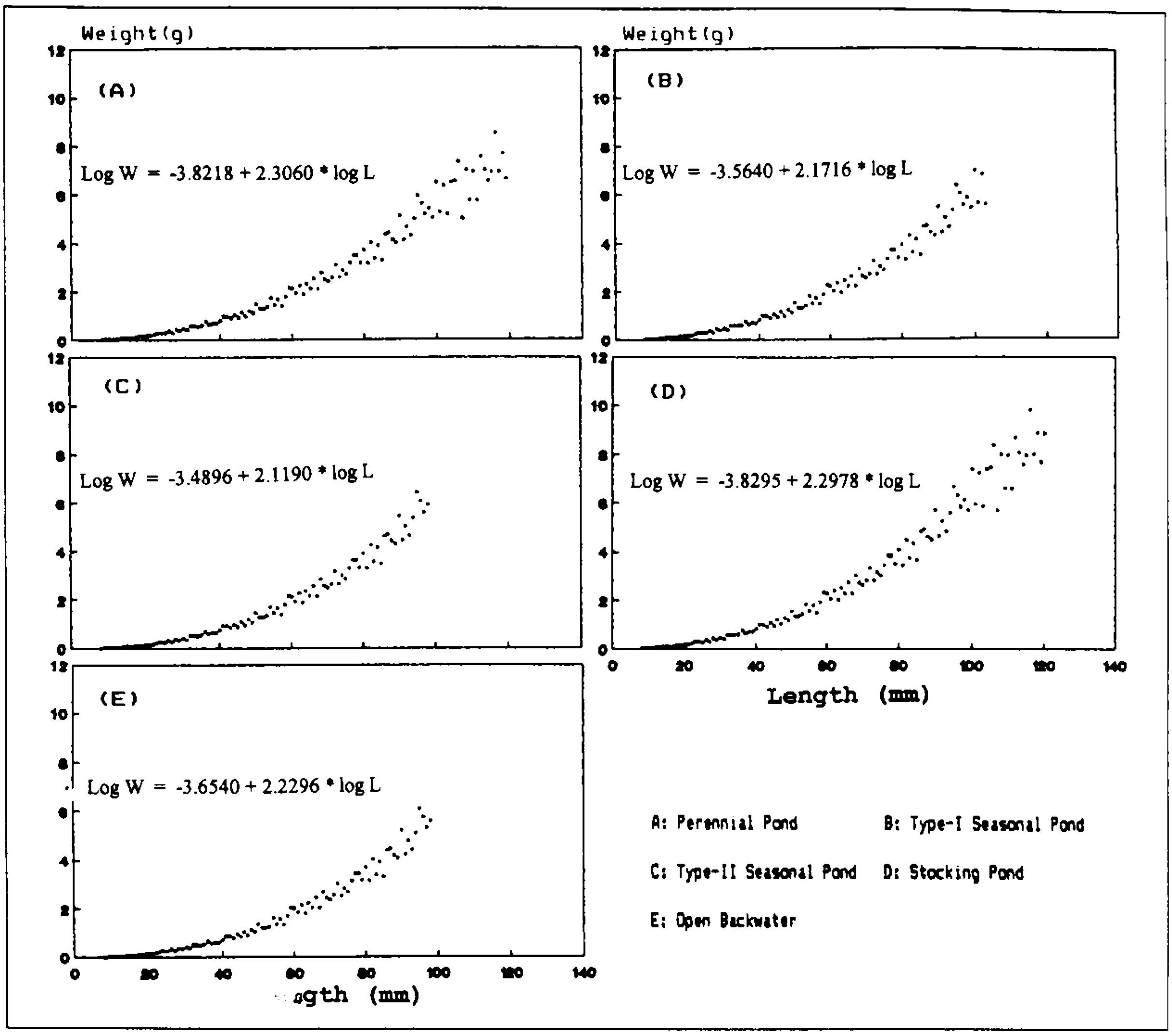


Fig 8.3 Scatter diagram representing length-weight relation of *M. monoceros* from different tidal ponds and backwaters.

Table 8.4 Covariance analysis of significance for length-weight equation of *M. monoceros* from different habitats.

Source	D.F.	Ex^2	Exy	Ey^2	Deviation from regression Redn	D.F.	SS	MSS
Between Habitats (T)	4	24727.0	2412.2	250.1				
Error (E)	999	867792.8	61687.1	4725.9	4385.0	998	340.8	0.342
T + E	1003	892519.8	64099.3	4976.0	4603.5	1002	372.5	
						4	31.6	7.902

F Ratio = 23.14 (df.4, 998)**, Table F-3.34

** - Highly significant at 1% level

Relative Condition Factor (Kn):

***P.indicus*:**

Condition factor varied in different habitat and during different seasons (Fig 8.4). It was small, 0.908 and 0.929, respectively in perennial ponds and backwaters and large, 1.04 in stocking ponds. It varied from 0.83 to 0.95 in perennial ponds, 0.86 to 0.95 in backwaters and 0.89 to 1.15 in stocking ponds over the season. It was 0.964 and 0.976 respectively in Type-I and Type-II seasonal ponds. In the former it varied from 0.93 to 1.04 and in the latter 0.93 to 1.06. It was small during monsoon, large during post-monsoon and pre-monsoon.

Ecology and physical conditions of the habitat have significant ($P<0.01$) influence on condition factor (Table 8.5). These factors together described 99.7% of the variation between habitats. Productivity and depth of the habitats described maximum variation.

Table 8.5 Multiple regression and Analysis of Variance Table for condition factor of *P. indicus* and eco-physical characteristics of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Area	-0.00031	0.00018	-1.697	0.23172	0.5902
Depth	0.08360	0.00850	9.835	0.01018	0.9797
Water Exchange	0.00094	0.00025	3.847	0.06141	0.8810
Productivity	0.06050	0.00470	12.992	0.00587	0.9883
Salinity	0.0026	0.00170	1.549	0.26147	0.5454
Temperature	0.0175	0.00760	2.296	C.14855	0.7250
Constant	0.7398				

Std. Error of Est. = 0.0055 Adjusted R Squared = 0.9907
R Squared = 0.9977 Multiple R = 0.9988

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	0.02650	6	0.00440	143.657	0.00693
Residual	0.00001	2	0.00003		
Total	0.02650	8			

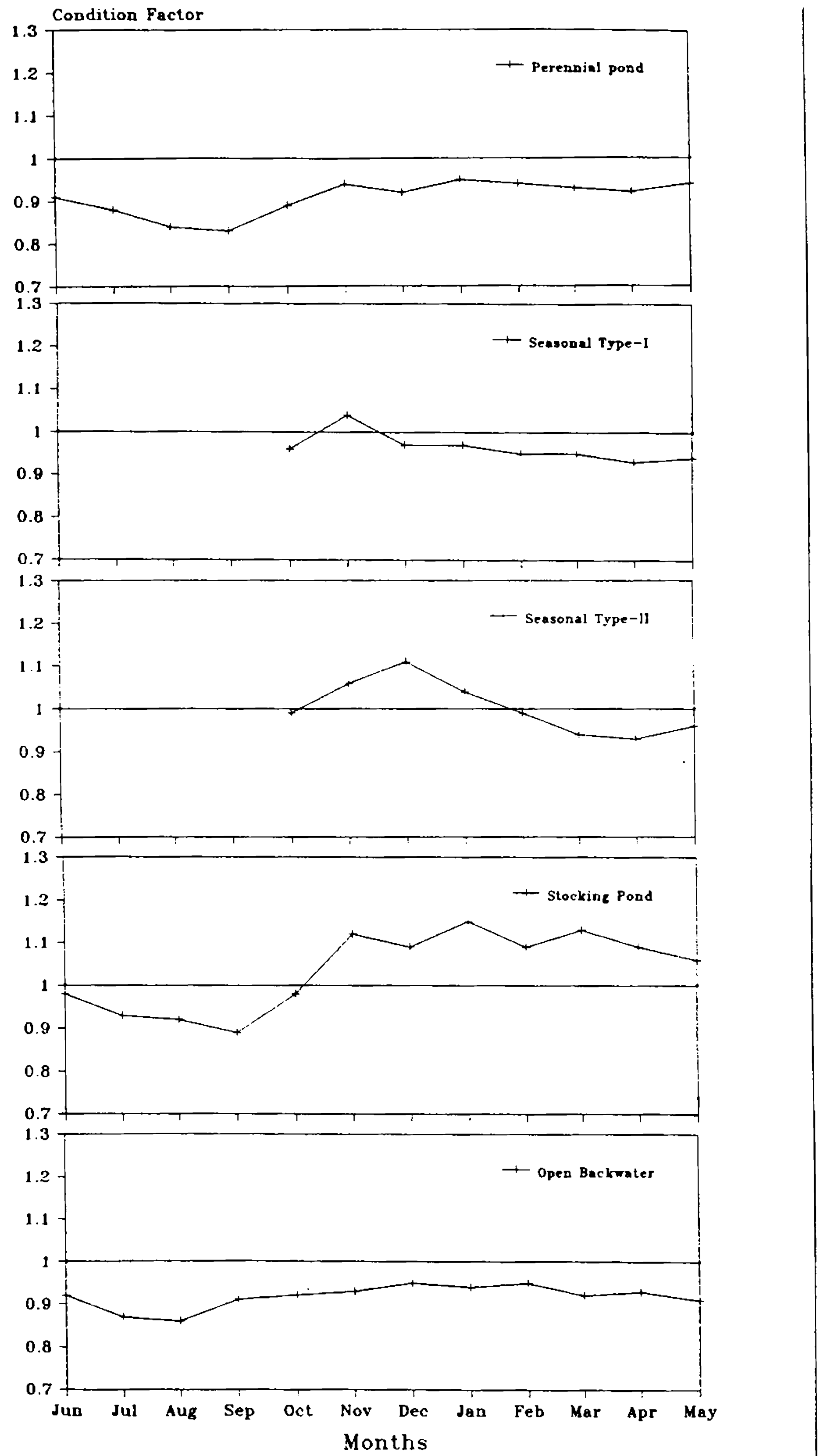


Fig 8.4 Monthly variation in the relative condition factor of *P. indicus* in tidal ponds and backwater.

M. dobsoni:

Condition Factor was small, 0.937 in backwaters, followed by 0.941 in perennial ponds 0.984 and 0.997 respectively in Type-I and Type-II seasonal ponds and large, 1.043 in stocking ponds (Fig 8.5). It varied from 0.89 to 0.98 in backwaters, 0.88 to 0.99 in perennial ponds, 0.98 to 1.14 in stocking ponds and 0.94 to 1.11 and 0.96 to 1.12 respectively in Type-I and Type-II seasonal ponds over the seasons. Condition factor was large during post-monsoon and small during monsoon months.

Ecology and physical features o f the habitat described 98.98% (P<0.05) of the variation in condition factor of the species (Table 8.6). Productivity and depth described maximum variation.

Table 8.6 Multiple regression and Analysis of Variance Table for condition factor of *M. dobsoni* and eco-physical characteristics of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Area	-0.00011	0.00084	-0.130	0.90829	0.0084
Depth	0.12140	0.03900	5.118	0.04931	0.8999
Water Exchange	0.00160	0.00110	1.430	0.28900	0.5055
Productivity	0.06660	0.02130	5.121	0.04899	0.9011
Salinity	0.00370	0.00780	0.471	0.68422	0.0997
Temperature	0.00200	0.03500	0.057	0.95949	0.0016
Constant	1.53340				

Std. Error of Est. = 0.0254

Adjusted R Squared = 0.8378
R Squared = 0.9898
Multiple R = 0.9929

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	0.2337	6	0.03890	24.348	0.0428
Residual	0.0032	2	0.0016		
Total	0.2369	8			

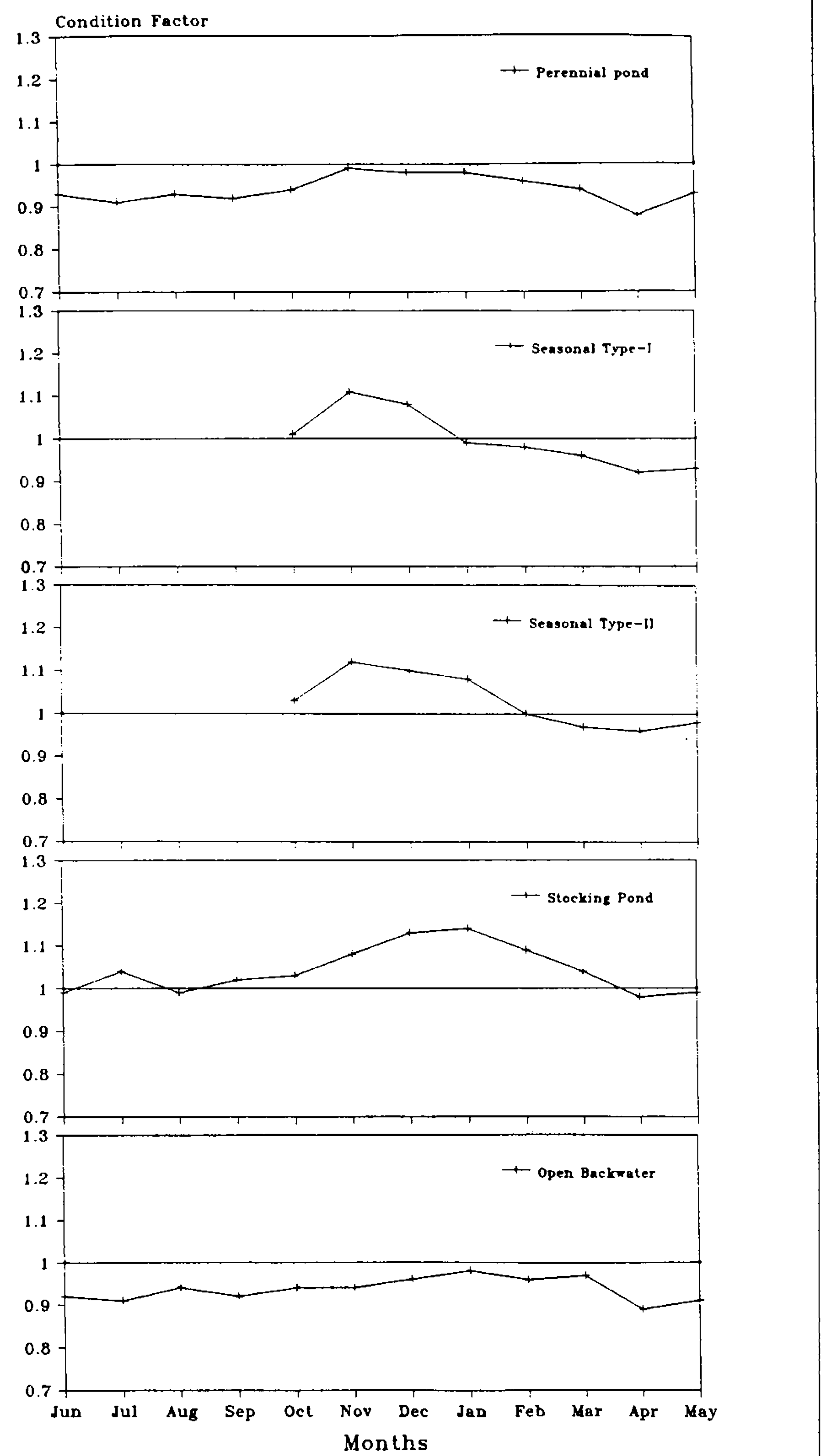


Fig 8.5 Monthly variation in the relative condition factor of *M.dobsoni* in tidal ponds and backwater.

M. monoceros:

Condition factor was small, 0.949 in Type-I seasonal ponds followed by 0.953 in backwaters and large, 1.02 in stocking ponds (Fig 8.6). It varied from 0.91 to 1.05, 0.89 to 1.0 and 0.94 to1.12 respectively in these habitats over the season. It was moderate, 0.96 in Type-II seasonal ponds and 0.975 in perennial ponds, where it varied respectively, from 0.91 to 1.04 and 0.92 to 1.02. It was small during monsoon, moderate during pre-monsoon and large during post-monsoon .

Ecological and physical conditions of the habitat described 97.89% ($P<0.05$) of variation in condition factor (Table 8.7). Depth ($P=0.042$) and productivity ($P=0.108$) described maximum variations.

Table 8.7 Multiple regression and Analysis of Variance Table for condition factor of *M. monoceros* and eco-physical characteristics of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Area	0.00002	0.00089	0.019	0.98679	0.00017
Depth	0.1147	0.04120	6.385	0.04414	0.90731
Water Exchange	0.0023	0.00120	1.909	0.19647	0.64570
Productivity	0.0369	0.02250	1.639	0.24286	0.57330
Salinity	0.0086	0.00820	1.045	0.40557	0.35330
Temperature	0.0440	0.03700	1.188	0.35671	0.41380
Constant	2.8162				

Std. Error of Est. = 0.0268   Adjusted R Squared = 0.8640
R Squared = 0.9789   Multiple R = 0.9894

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	0.9138	6	0.1523	21.302	0.0489
Residual	0.0143	2	0.0072		
Total	0.9281	8			

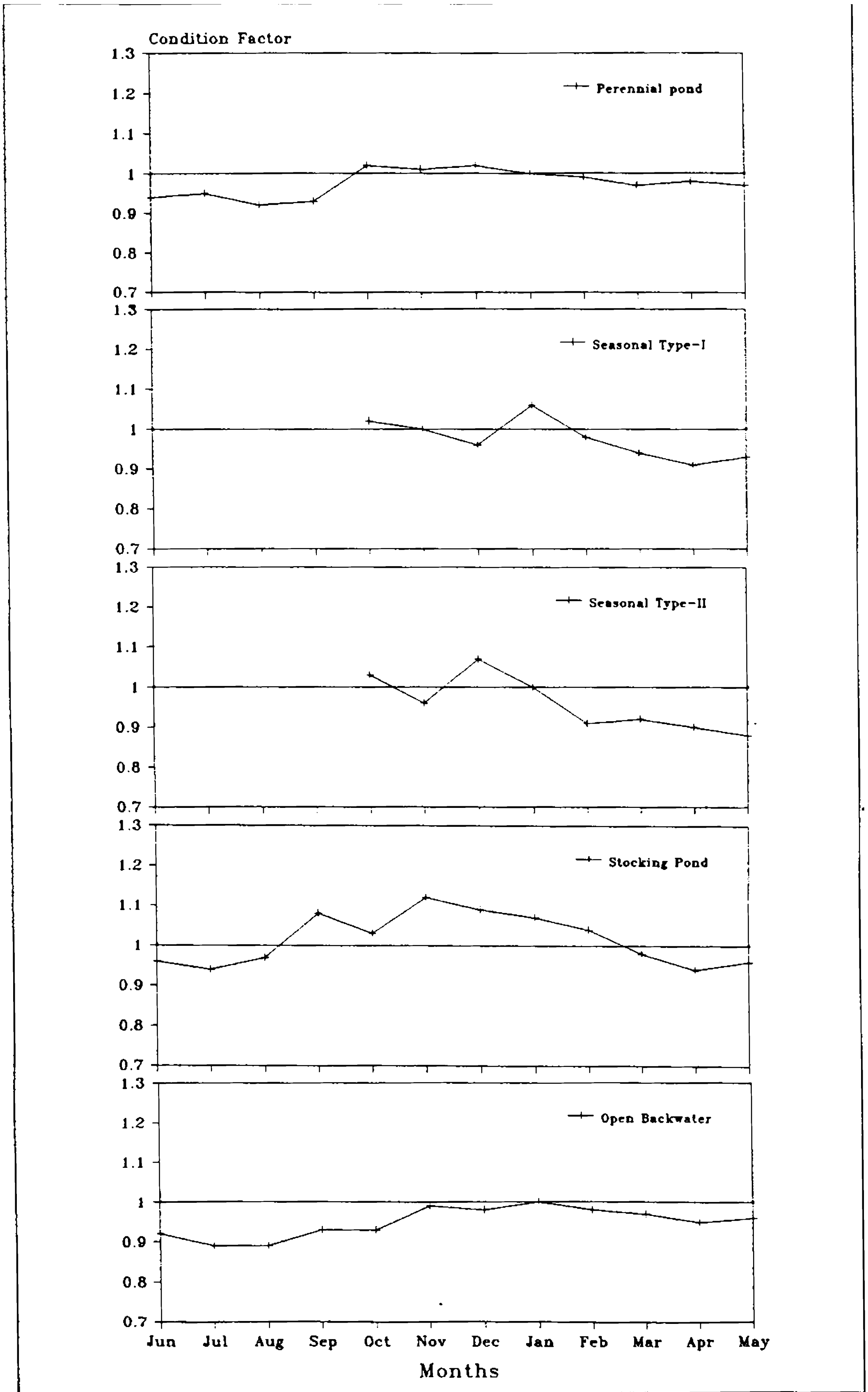


Fig 8.6 Monthly variation in the relative condition factor of *M. monoceros* in different tidal ponds and backwater.

DISCUSSION

Length-weight relationship of prawns from different habitats and areas were expected to follow a uniform relationship under normal environmental conditions. However, in the present study it varied for all species in different habitats. Individuals of *P. indicus* and *M. dobsoni* were relatively heavy in stocking ponds, light in perennial ponds and backwaters and moderately heavy in seasonal ponds. *M. monoceros* was heavy in stocking ponds and perennial ponds, moderately heavy in Type-1 seasonal ponds and backwaters and light in Type-II seasonal ponds. These fluctuations can be attributed to differential growth in prawns caused by variation in biotic and abiotic conditions of the habitats, to which the animal is exposed. A perusal of literature showed variation in the length-weight relationship of prawns from different habitats and areas. According to Devi *et.al.*, (1983), such variations can be expected in the length-weight relationship in nature, due to extraneous factors, such as food abundance and quality. So it can be assumed that factors which affect growth of prawns, have similar influence on their length-weight relationship also. However, according to Nair *et.al.* (1982), food availability and feeding regime have no effect on the length-weight relationship of *P. indicus* and *M. dobsoni* under laboratory conditions.

Relative condition factor of prawns also varied for population from different habitats. It is high for prawns in stocking ponds and low in tidal ponds and backwaters. This indicated that condition factor vary with habitat environment. Experimental evidences to support the environmental influence, including food quality are available from the reports of Nair *et.al.* (1982) and Devi *et.al.* (1983). In laboratory trials, Nair *et.al.* (1982) observed that condition factor of *P. indicus* and *M. dobsoni* remain unaffected by feeding levels, but obtained only small values. In another comparative study, Devi *et.al.* (1983) observed large condition factor for these species from open backwaters of Cochin. They attributed this to favourable environmental conditions, especially balanced natural food in the habitat. In the present study, fluctuations observed in condition factor correlated with productivity and food availability. According to Hall (1962), varied food in the natural environment is a complete diet and their abundance in adequate quantity determines condition of the prawns. Despite calm and stable environment, perennial pond habitats were characterised by poor living conditions, owing to low productivity and high predation and competition. In contrast, seasonal ponds have comparatively high natural productivity, organic detritus and low predation and competition and hence have large condition factor. Comparatively low or virtual absence of predation and competition coupled with adequate food supply in stocking ponds provided most favourable conditions for the growth of prawns and hence have large condition factor. As discussed earlier, open backwater habitats though lack many disadvantages of tidal ponds have low condition factor as prawns have to divert considerable amount of energy for maintaining their position.

The relatively large condition factor for *M. monoceros* in perennial ponds and small in seasonal ponds indicated that behaviour of prawns that govern habitat preference and distribution have considerable influence on their growth and condition factor also. As discussed earlier, being strongly nocturnal, they prefer deep waters. So despite better food availability their growth and condition factor become small in seasonal ponds.

It is further seen that condition factor of prawns fluctuated over the season, with poor condition during monsoon and better during post-monsoon months. These fluctuations linked mainly with environmental conditions, as evidenced from large seasonal variations in the condition factor of prawns even in stocking ponds, despite adequate food supply. Rodriguez (1987) also observed similar seasonal fluctuations in the condition of *P. kerathuruz* and attributed it to temperature fluctuations. Despite high productivity and stable environment, condition factor was small during pre-monsoon months due to comparatively high standing population and high salinity. In contrast, monsoon is characterised by low water temperature, pH, productivity and low and highly fluctuating salinity. These sub-optimal conditions might have adverse effect on the physiology of prawns, as seen from large scale soft-shelling and weight loss in *P. indicus* and so have small condition factor.

Large condition factor of *M. dobsoni* suggested that they are more adapted for these habitats than *P. indicus* and *M. monoceros*. Based on the condition factor, Devi *et.al.* (1983) also made similar conclusions that backwater environment is more favourable for *M. dobsoni*, than *P. indicus*. From the present findings it is seen that condition factor can be used as index to evaluate suitability of habitats for different species.

Sex Ratio and Sexual Maturity

Chapter-9

SEX RATIO AND SEXUAL MATURITY

INTRODUCTION

Sex ratio and gonadal conditions are important factors having considerable biological significance. Information on these is essential for proper understanding of sexual maturity, spawning season, spawning frequency, fecundity, recruitment patterns and migratory movements. Gonadal development has profound influence on growth and also on behavioural changes of species. This varies depending on species, geographical location and ambient environmental conditions. Clear understanding of these aspects will aid in formulating sound strategies for proper management of the fishery of the species concerned.

Reproductive biology of commercially important penaeids of the area has been studied in detail. Considerable information is also available on gonadal development and sex ratio of penaeids in tidal ponds and backwaters from earlier woks (Menon, 1951; 1957; Rajyalakshmi, 1961; Rao 1967; Rao and Kathirvel, 1973; Paulinose *et.al.*, 1981; Silas *et.al.*, 1982; Vasudevappa, 1992). Some information was also provided by Mohamed (1970), while reviewing biological data of penaeids. Present study envisages understanding more on sex ratio and gonadal maturity of major species in tidal ponds and backwaters in order to explain various discrepancies observed on sex ratio and related aspects.

MATERIALS AND METHODS

Unsorted samples of resident and emigrating population of prawns collected respectively from liftnet and filter net catches were used to study sex ratio. Males and females were identified as described by George and Rao (1968). Details of the materials used for the study are given in Table 9.1.

Pooled samples of resident and emigrating population of prawns collected from liftnet and filternet were used to study gonadal development and sexual maturity. Since, gonadal development of males could not be easily differentiated by visual examination as of females, latter alone were used for maturity stage study. Sample size and length range of the materials used for the study is given in Table 9.2.

Variations observed in sex ratio with size were tested for statistical significance by Chi-square test as per Snedecor and Cochran (1967).

Table 9.1 Number of prawns examined to study sex ratio of prawns in tidal ponds and backwaters.

Species	Perennial pond	Seasonal T-I pond	Seasonal T-II pond	Backwaters
Resident prawns				
P. indicus	1634	849	757	878
M. dobsoni	2337	1084	1175	1238
M. monoceros	528	356	314	379
Emigrating prawns				
P. indicus	1868	1046	869	1043
M. dobsoni	2364	1086	1237	1485
M. monoceros	586	427	329	312

Table 9.2 Sample size (number) of pooled female prawns and their length ranges examined to study gonadal development in tidal ponds and backwaters.

Species/ Size range	Perennial ponds	Seasonal T-I ponds	Seasonal T-II ponds	Backwaters
P. indicus (>80 mm)	788	486	393	572
M. dobsoni (>55 mm)	1012	475	437	821
M. monoceros (>65 mm)	296	208	186	199

RESULTS

Sex Ratio:

P. indicus:

Females outnumbered males in the resident populations in all habitats (Fig 9.1). They represented 54.3% of the population in perennial ponds, 54.1% in Type-I seasonal ponds, 53.2% in Type-II seasonal ponds and 52.3% in backwaters. In small length groups, males and females represented almost equally, but male representation decreased gradually with size. In large length groups, they constituted, 25% in perennial ponds, 33.3 to 40.4% in seasonal ponds and 42.5% in backwaters. Sex ratio of resident population of the species varied significantly ($P<0.05$) with size in all habitats (Table 9.3).

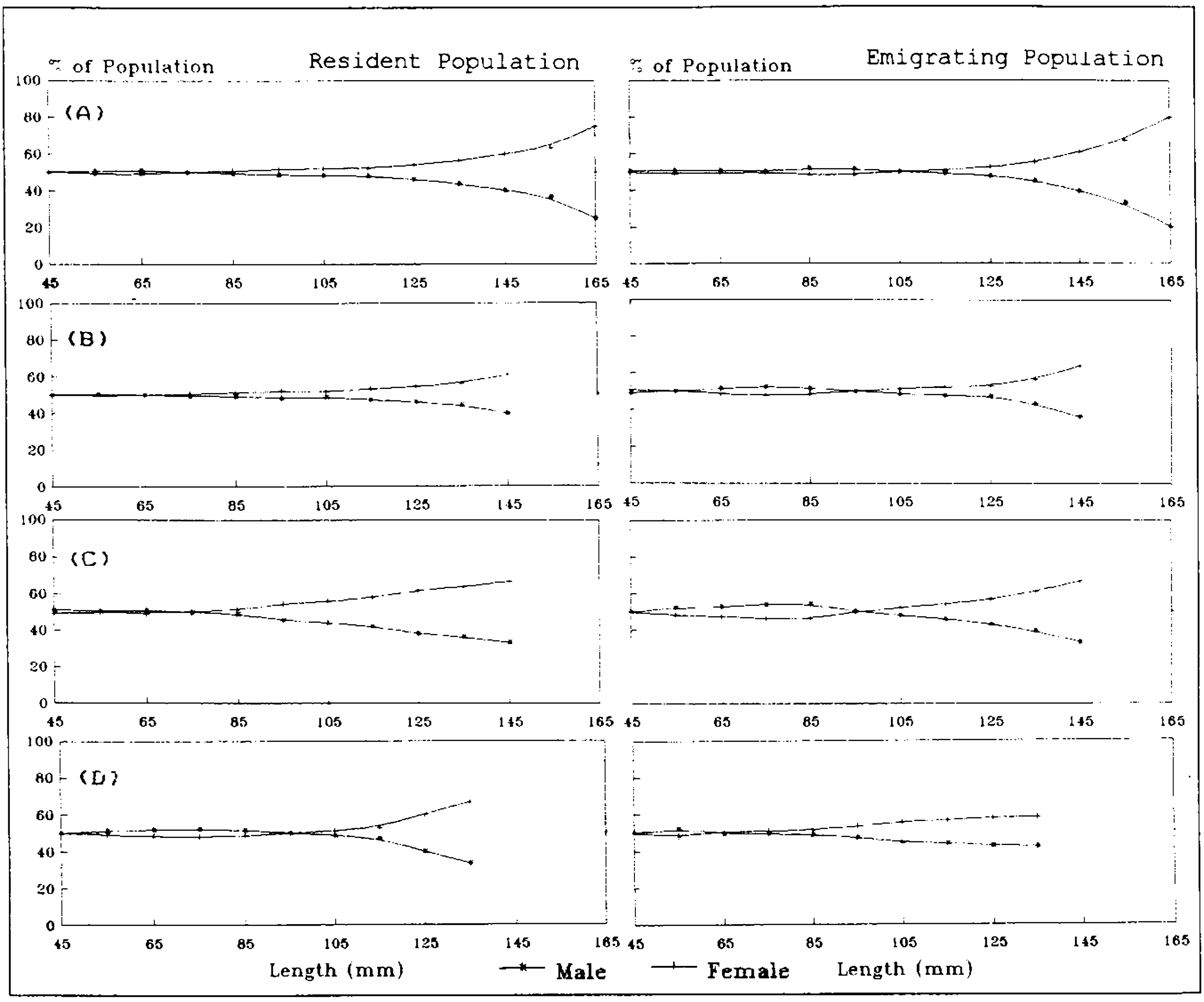


Fig 9.1 Percentage composition of males and females in different length groups of emigrating population of *P. indicus* from tidal ponds and backwaters. A-Perennial pond, B-Type-I seasonal pond, C-Type-II seasonal pond and D- Open backwaters.

In the emigrating population, males represented 51.5% in Type-I seasonal pond, 50.8% in backwaters, 49.8% in perennial and, 48.3% in Type-II seasonal ponds (Fig 9.1). Males outnumbered females in small length groups, up to 100 mm in perennial ponds and 90 mm in seasonal ponds and backwaters. Their representation decreased sharply there after with size. In large length groups male representation was very low, 20% in perennial ponds, 33.3% in Type-II seasonal ponds and 36% in Type-I seasonal ponds and 33.3% in backwaters.

Sex ratio of emigrating population varied significantly ($P<0.05$) with length only in perennial ponds and backwaters (Table 9.3).

Table 9.3 Chi-square values to test the significance of variation in sex ratio of resident and emigrating population of *P. indicus* in different length groups.

	Perennial Pond	Seasonal Pond (Type-I)	Seasonal Pond (Type-II)	Backwaters
D.F	12	10	10	9
Residents	27.28**	18.32*	19.15*	23.31**
Emigrants	23.22*	14.64	16.03	21.20*
Reference value (5%)	21.03	18.31	18.31	14.68
Reference value (1%)	26.22	23.21	23.31	21.67

* - significant at 5% level. ** - significant at 1% level.

M. dobsoni:

Females dominated resident population of the species (Fig 9.2). They constituted 56.2% of the population in backwaters, 55.8% in perennial ponds, 54.1% in Type-I seasonal ponds and 53.5% in Type-II seasonal ponds. Males and females represented almost equally in small length groups. But male representation decreased with size. In large length groups they represented only 0 to 25% in different habitats.

Sex ratio of resident population of the species varied significantly ($P<0.05$) with size from different habitats, except in Type-II seasonal ponds (Table 9.4).

Females dominated the emigrating population from all habitats, except in perennial ponds (Fig 9.2). Females constituted 52% in Type-I seasonal ponds, 51.0% in backwaters, 50.9% in Type-II seasonal ponds and 49.4% in perennial ponds. Males outnumbered females in small length groups up to 70 mm in tidal ponds and 60 mm in backwaters. Their representation declined sharply, thereafter, with size. In large length groups, it was only 0 to 37%in different habitats.

Sex ratio of emigrants varied significantly with size ($P<0.05$) only in perennial ponds and Type-II seasonal ponds (Table 9.4).

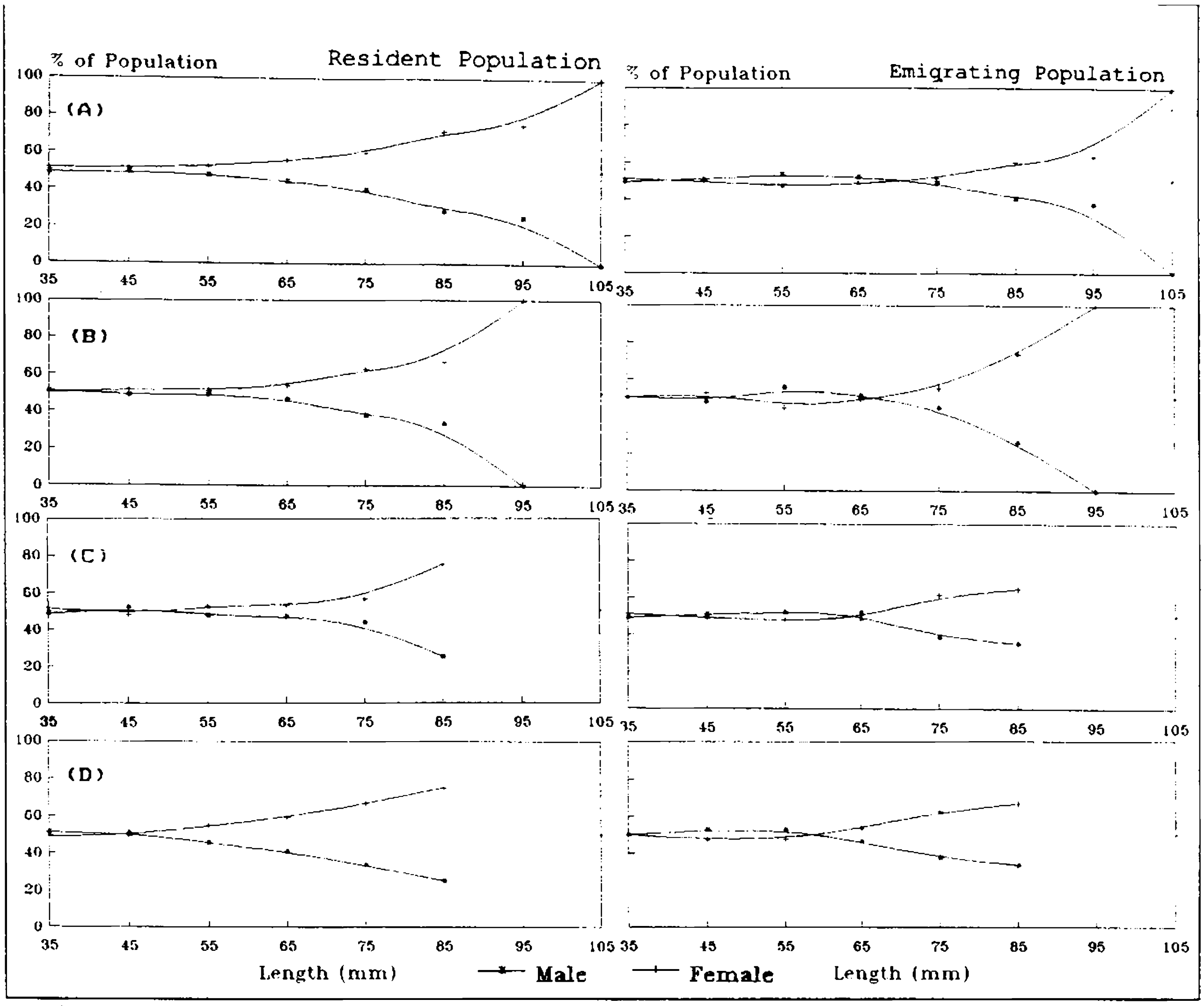


Fig 9.2 Percentage composition of males and females in different length groups of emigrating population of *M. dobsoni* from tidal ponds and backwaters. A-Perennial pond, B-Type-I seasonal pond, C-Type-II seasonal pond and D- Open backwaters.

Table 9.4 Chi-square values to test the significance of variation in sex ratio of resident and emigrating population of *M. dobsoni* from different length groups.

	Perennial Pond	Seasonal Pond (Type-I)	Seasonal Pond (Type-II)	Backwaters
D.F	7	6	5	5
Resident	21.40*	14.44*	8.64	15.59*
Emigrants	14.88*	10.90	11.16*	10.11
Reference! (5%)	14.07	12.59	11.07	11.07
Values ! (1%)	18.48	16.81	15.09	15.09

* - significant at 5% level. ** - significant at 1% level.

***M. monoceros*:**

Females dominated the resident population of the species (Fig 9.3). They constituted 55.6% in perennial ponds, 55.0% in Type-II seasonal ponds, 54.9% in Type-I seasonal ponds 52.2% in backwaters. Males and females represented almost equally in small length groups. But male representation decreased with size. In large length groups they represented 31.1 to 40.0% of the population in tidal ponds and 42.6% in backwaters.

Significant variation was observed in the sex ratio of resident population of species with size ($P<0.05$) in all habitats (Table 9.5).

Females outnumbered males in the emigrating population of the species in Type-I seasonal pond and backwaters (Fig 9.3). They represented 51.0% and 51.5% of the population respectively from these habitats. Whereas males dominated in perennial ponds (50.18%) and Type-II seasonal ponds (50.45%). Both sexes represented almost equally in the smaller length groups of emigrants. Male representation increased initially and outnumbered females till 70 mm length in seasonal ponds and backwaters and 80 mm in perennial ponds. Their representation decreased there after with size. In large length groups, it was very small, 9.1to 25% in tidal ponds and 33.3% in backwaters.

Sex ratio varied significantly ($P<0.05$) with the size of emigrants from all habitats (Table 9.5).

Table 9.5 Chi-square values to test the significance of variation in sex ratio of resident and emigrating population of *M. monoceros* from different length groups.

	Perennial Pond	Seasonal Pond (Type-I)	Seasonal Pond (Type-II)	Backwaters
D.F	8	7	6	6
Resident	23.48*	15.59*	13.37*	13.52*
Emigrants	17.56*	15.65*	13.23*	14.46*
Reference! (5%)	15.51	14.07	12.59	12.59
values ! (1%)	20.09	18.48	16.81	16.81

* - significant at 5% level. ** - significant at 1% level.

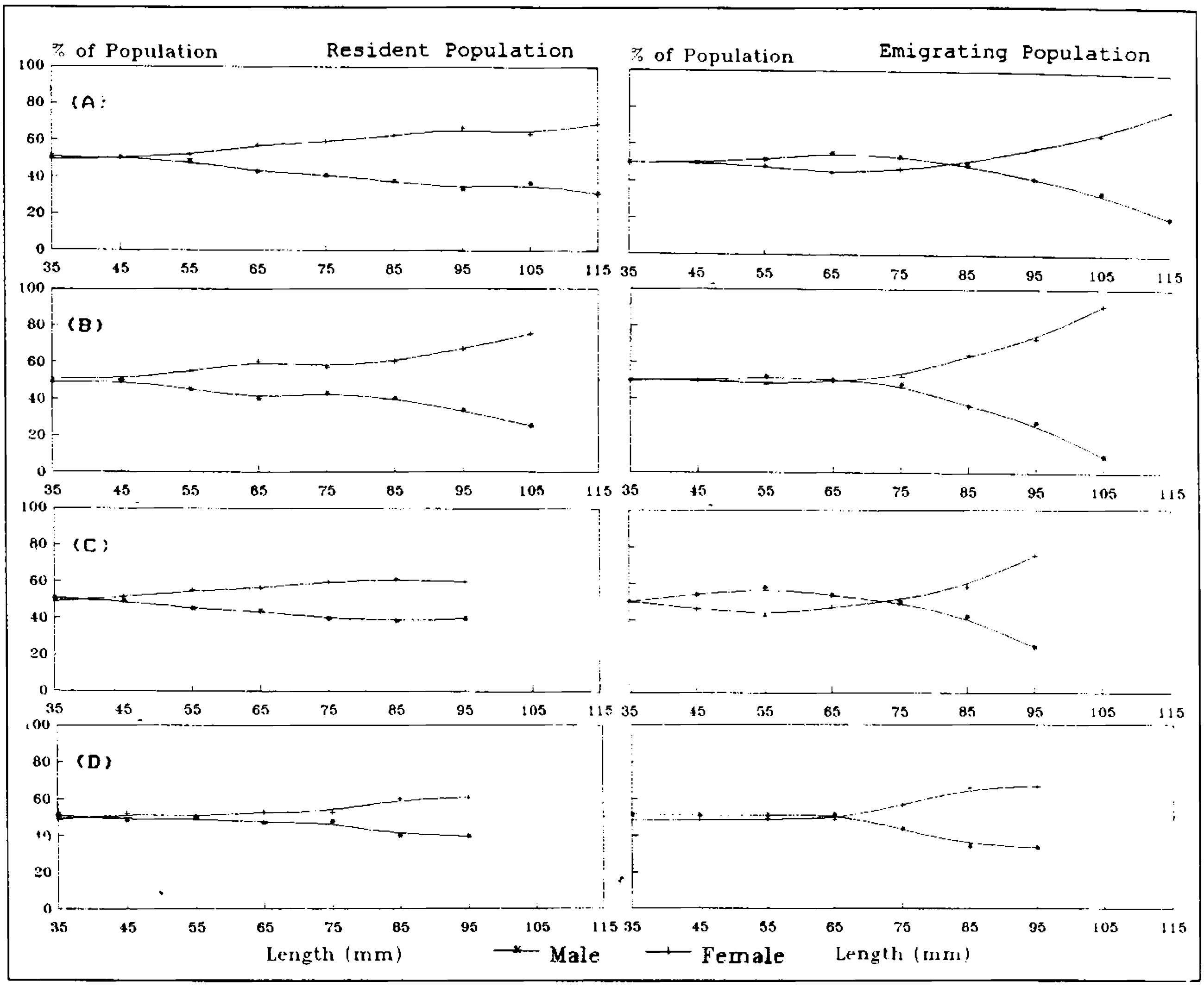


Fig 9.3 Percentage composition of males and females in different length groups of emigrating population of *M. monoceros* from tidal ponds and backwaters. A-Perennial pond, B-Type-I seasonal pond, C-Type-II seasonal pond and D- Open backwaters.

Sexual Maturity:

***P. indicus*:**

They were constituted by sexually immature individuals in tidal ponds and backwaters (Table 9.6). Barring small proportion of prawns with gonads at stage II in perennial ponds (0.63%) and backwaters (0.17%) during peak saline periods, all were at stage-I without any development (Table 9.7). However, fully developed external genitalia were observed in prawns above 110 mm length from all habitats.

Table 9.6 Number and percentage occurrence of different maturity stages of *P. indicus* in tidal ponds and backwaters.

Stage of Maturity	Perennial Pond		Seasonal T-I Pond		Seasonal T-II Pond		Backwaters	
	(No)	(%)	(No)	(%)	(No)	(%)	(No)	(%)
I	783	99.4	486	100.0	393	100.0	571	99.8
II	5	0.6	-		-		1	0.2
III	-		-		-		-	
IV	-		-		-		-	
V	-		-		-		-	

Table 9.7 Seasonality in the occurrence of different maturity stages of *P. indicus* in tidal ponds and backwaters.

Months	Perennial Pond	Seasonal T-I Pond	Seasonal T-II Pond	Backwaters
Jan	I	I	I	I
Feb	I	I	I	I
Mar	I - II	I	I	I
Apr	I - II	I	I	I
May	I - II	I	I	I -II
Jun	I	-	-	I
Jul	I	-	-	I
Aug	I	-	-	I
Sep	I	-	-	I
Oct	I	I	I	I
Nov	I	I	I	I
Dec	I	I	I	I

M. dobsoni

The number and percentage occurrence of different maturity stages of the species in the population is given in Table 9.8 and its seasonality in occurrence in Table 9.9. They were ɜpresented mainly by prawns with immature gonads in all habitats (Table 9.8). Small proportion f prawns with gonads at stage-III was occurred in Type-I seasonal ponds and up to stage-IV in erennial ponds during April-June (Table 9.9). They constituted 0.21% of the total population ı the former and 0.89% in the latter. However, males with sperm sacs at the base of fifth pair of eriopods and first pleopods were observed in large numbers in all habitats.

'able 9.8 Number and percentage occurrence of different maturity stages of *M. dobsoni* in tidal ponds and backwaters.

Stage of maturity	Perennial Pond		Seasonal T-I Pond		Seasonal T-II Pond		Backwaters	
	(No)	(%)	(No)	(%)	(No)	(%)	(No)	(%)
I	974	96.3	468	98.5	432	98.9	815	99.3
II	29	2.9	6	1.3	5	1.1	6	0.7
III	7	0.7	1	0.2	-		-	
IV	2	0.2	-		-		-	
V	-		-		-		-	

Table 9.9 Seasonality in the occurrence of different maturity stages of *M. dobsoni* in tidal ponds and backwaters.

Months	Perennial Pond	Seasonal T-I Pond	Seasonal T-II Pond	Backwaters
Jan	I	I	I	I
Feb	I - II	I	I	I
Mar	I - II	I - II	I - II	I - II
Apr	I - III	I - III	I - II	I - II
May	I - IV	I - II	I - II	I - II
Jun	I - IV	-	-	I
Jul	I	-	-	I
Aug	I	-	-	I
Sep	I	-	-	I
Oct	I	I	I	I
Nov	I	I	I	I
Dec	I	I	I	I

The number and percentage occurrence of different maturity stages in the population is iven in Table 9.10 and its seasonality of occurrence in Table 9.11. No trace of gonadal evelopment was observed in this species. Individuals with gonads at stage-I represented opulation of the species in different habitats. However, well-developed external genitalia were bserved in large individuals above 90 mm length.

'able 9.10 Number and percentage occurrence of different maturity stages of *M. monoceros* in tidal ponds and backwaters.

Stage of maturity	Perennial Pond		Seasonal T-I Pond		Seasonal T-II Pond		Backwaters	
	(No)	(%)	(No)	(%)	(No)	(%)	(No)	(%)
I	296	100.0	208	100.0	186	100.0	99	100.0
II	-		-		-		-	
III	-		-		-		-	
IV	-		-		-		-	
V	-		-		-		-	

'able 9.11 Seasonality in the occurrence of different maturity stages of *M. monoceros* in tidal ponds and backwaters.

Months	Perennial Pond	Seasonal T-I Pond	Seasonal T-II Pond	Backwaters
Feb	I	I	I	I
Mar	I	I	I	I
Apr	I	I	I	I
May	I	I	I	I
Jun	I	-	-	I
Jul	I	-	-	I
Aug	I	-	-	I
Sep	I	-	-	I
Oct	I	I	I	I
Nov	I	I	I	I
Dec	I	I	I	I

DISCUSSION

Considerable information is available on sex ratio of penaeids from backwater habitats. However, a review of biological data by Mohamed (1970), showed considerable disparity in the data provided by different authors. Signoret (1972), stated that females predominated the population of all penaeid species in nature. Devi (1988) also observed female dominance in the penaeid populations from Godavari estuary. However, many reported sex ratio of penaeid species under normal conditions as unity (Menon, 1957; Subrahmanyam, 1973; Subrahmanyam and Ganapati, 1975; Garcia, 1974; Paulinose *et.al.*, 1981). The present study also showed sex ratio of the three species as near unity, as indicated by the equal representation of both sexes in small length groups of resident and emigrating population and in the emigrating population as a whole.

Considerable anomalies were observed in the sex ratio of prawns with size. Decline in relative representation of males in resident population with size was noticed for all species, while in the case of emigrants it increased initially up to certain length and thereafter declined sharply. Many reported similar fluctuation in sex ratio of *P. indicus* and *P. monodon* (Rao, 1967; Subrahmanyam, 1973; Devi, 1988). All of them reported comparatively large representation for females in advanced length groups. The reason for such fluctuation in the male : female ratio with size is selective emigration of sexes according to their age and phase of growth. The continuos decline in male representation in resident population with size and their simultaneous increase in representation in the respective length groups of emigrating population, observed in the present study, indicated that males leave these habitats much earlier than females.. Marsoedi and Greenwood (1990), also observed similar differential emigration between males and females of *Metapenaeus macleayi* and attributed to low salinity tolerance among males. Rao (1967) also suggested the possibility of an early emigration of males to sea from nursery habitat.

Immature individuals constituted *P. indicus* and *M. monoceros* population in backwaters and tidal ponds. Mainly immature individuals along with small numbers of early maturing females and matured males represented *M. dobsoni* population in these habitats. Menon (1951) observed fully matured males and impregnated, but immature females of *M. dobsoni* in Cochin backwaters. While several others reported mature females with ripe ovaries in the backwaters (Rao and Kathirvel (1973) and in perennial culture ponds of Vypeen island (George, 1974; Silas *et.al.*, 1982; Vasudevappa, 1992). Among the three species it appears that, attainment of sexual maturity is quite common among the males of *M. dobsoni*, whereas in females, the chances of maturation are relatively low, as proportion of animals even in early maturing stage in the population is found to be relatively meagre.

Yield

YIELD

INTRODUCTION

Prawn fishery in seasonal and perennial tidal ponds of Cochin backwaters, of Kerala, famous for their productivity is practised even today by the age-old method of filtration. Many reviewed their fishery and economics at various points of time (Panikkar, 1937; Menon, 1954; Pillay, 1954; Gopinath, 1956; Kesteven and Job, 1957; George *et.al*, 1968; George, 1974; Gopalan *et.al*, 1980; Purushan and Rajendran, 1984; Jose *et.al*, 1987; Nasser and Noble, 1992).

Considerable information is available on tidal pond fishery from earlier works. While reporting the status of this fishery, many reported dwindling nature of prawn production from these habitats and attributed it to man made stress on the ecosystem and stock. According to Menon (1954) and Gopinath (1956) average prawn yield from tidal fields through traditional culture in 1950's were over 1180 kg/ha. Through 1960's and 1970's production level declined to 600-700 kg/ha (Gopalan *et.al*, 1980; Mammen, 1984). According to Purushan and Rajendran (1984), Purushan (1996) and Sathiadas *et.al* (1989) the yield has declined further to 300-620 kg/ha. In addition to the decline in production, economy of this fishery has further been affected by the decreased contribution of *P. indicus* in the catch (Muthu, 1983; Jose *et.al*, 1987).

The present study envisaged to gather more information on the yield characteristics of penaeids from tidal ponds and to examine different factors, which affect the production.

MATERIALS AND METHODS

Shrimps were harvested from tidal ponds by filtration using thoombuvala regularly for 6-7 days around every full and new moon. In seasonal ponds this process of filtration continue till the middle of April, when ponds are drained and the entire stocks were harvested by castnetting and hand picking. Perennial ponds are non-drainable and filtration is carried out round the year. However, occasional partial harvesting by cast netting, seine netting and hand picking is resorted, when any calamities struck or large proportion of good-sized prawns encountered in the catch.

Species-wise catch data by different means of harvests, from tidal ponds were used for the study. Data were collected by direct observation during sampling days and from farm registers for the remaining periods. Catches were pooled month-wise and then to annual level, to study different patterns in prawn production.

Data were subjected to various statistical tests to evaluate the influence of different factors governing the yield.

RESULTS

Prawn Yield:

Fishery was constituted by *P. indicus, P. monodon, M. dobsoni, M. monoceros* and *M. idella* (Table 10.1, Fig 10.1). Annual yield was high, 920 to 1,650 kg/ha/yr from stocking ponds, followed by 716.3 to 925.6 kg/ha from perennial ponds, 629.5 to 650.8 kg/ha from Type-I and 464.9 to 589.1 kg/ha from Type-II seasonal ponds. Production per unit time of operation was relatively high in seasonal ponds than perennial ponds. It was 89.9 to 108.5 kg/ha/month in Type-I seasonal ponds, 66.3 to 94.4 kg/ha/month in Type-II seasonal ponds and 59.7 to 77.1 kg/ha/month in perennial ponds.

Table 10.1 Species-wise average annual prawn yield (kg/ha) from tidal ponds and stocking ponds (average for two years).

Habitat	*P. indicus*	*P. monodon*	*M. dobsoni*	*M. monoceros*	*M. idella*	Total
F1*	362.50	12.91	272.95	29.76	38.15	716.27
F2*	352.49	7.85	466.13	45.77	53.36	925.60
F3 ***	267.34	6.93	327.33	27.87	-	629.47
F4**	304.32	10.81	291.35	44.32	-	650.81
F5**	229.13	8.70	291.30	36.52	-	565.65
F6 ***	125.44	3.51	306.14	21.93	7.89	464.91
F7 *	1,650.00	-	-	-	-	1,650.00
F8 *	920.00	-	-	-	-	920.00

*-yield during 12 month operation
**-yield during 6 month operation
***-yield during 7 month operation

P. indicus:

Annual production was 920 to 1,650 kg/ha/yr from selective farming, 352.5 to 362.5 kg/ha from perennial ponds, 267.3 to 304.3 kg from Type-I and 125.4 to 229.1 kg from Type-II seasonal ponds (Fig 10.2, Table 10.1). Production per unit time of operation was 38.2 to 50.7 kg/ha/month in Type-I seasonal ponds, 17.9 to 38.2 kg/ha/month in Type-II seasonal ponds and 29.37 to 30.2 kg/ha/month in perennial ponds.

Their representation was comparatively large in the catches from perennial ponds than seasonal ponds and backwaters (Fig 10.2, Table 10.1). They constituted 38.1 to 50.6% in perennial ponds, 42.5 to 46.8% in Type-I and 27.0 to 40.5% in Type-II seasonal ponds and 42.1% in backwaters.

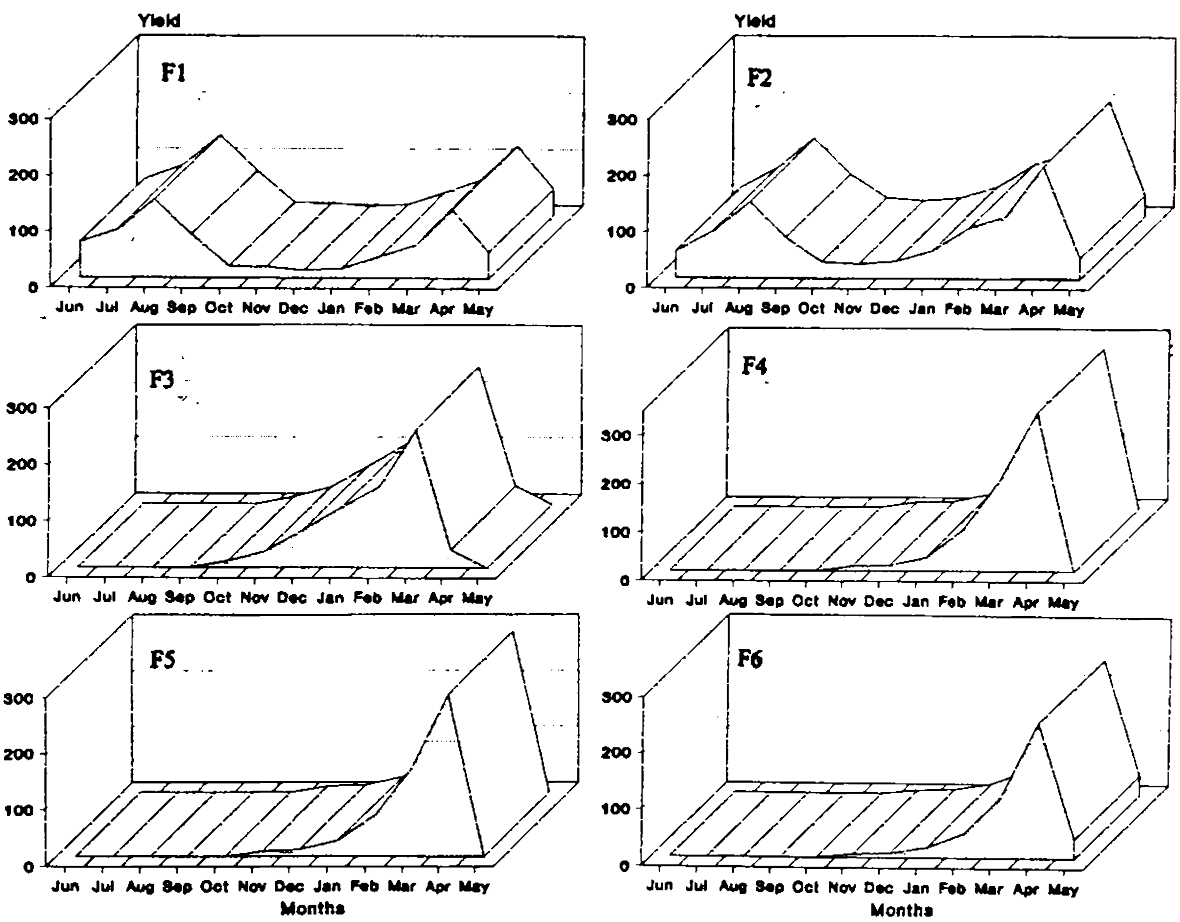


Fig 10.1 Month-wise average total prawn yield (kg/ha) from different tidal ponds.

M dobsoni:

Annual yield was 273.0 to 466.1 kg/ha in perennial ponds, 291.4 to 327.3 kg in Type-I and 291.3 to 306.14 in Type-II seasonal ponds (Table 10.1, Fig 10.2). Production per unit time of operation was 46.7 to 48.6 kg/ha/month in Type-I seasonal ponds, 43.7 to 48.6 kg/ha/month in Type-II seasonal ponds and 22.7 to 38.8 kg/ha/month in perennial ponds.

Their representation was large in seasonal pods and backwaters (Fig 10.2, Table 10.1). It was 38.0 to 50.4 %in perennial ponds, 44.8 to 52.0% in Type-I seasonal ponds, 51.5 to 65.9% in Type-II Seasonal ponds and 53.4% in backwaters.

M. monoceros:

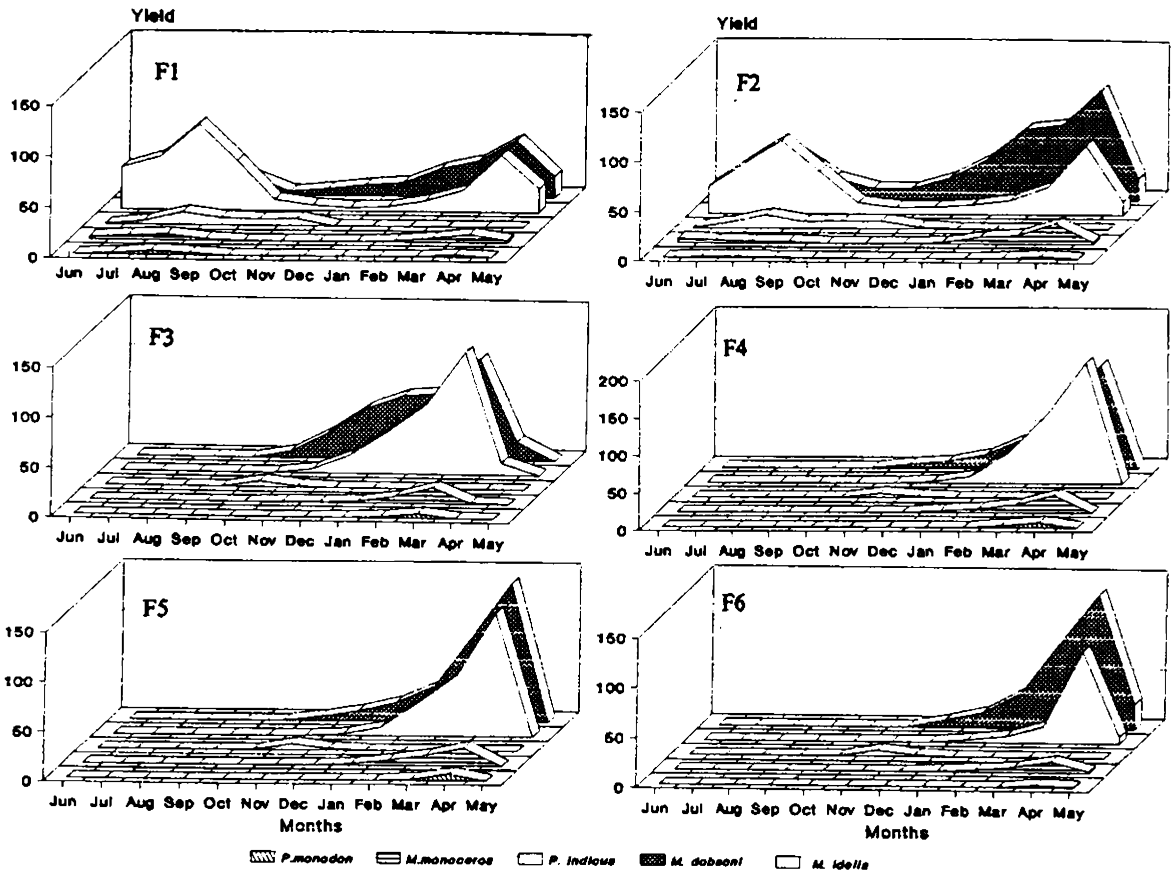
Annual yield was high, 29.8 to 45.8 kg/ha in perennial ponds, followed by 27.9 to 44.3 kg/ha in Type-I and 21.9 to 36.5 kg/ha in Type-II seasonal ponds (Table 10.1, Fig 10.2). Production per unit time of operation was 4.0 to 7.4 kg/ha/month in Type-I seasonal ponds, 3.1 to 6.1 kg/ha in Type-II seasonal ponds and 2.5 to 3.8 kg/ha in perennial ponds.

Their representation was large in seasonal ponds (Fig 10.2, Table 10.1). It was 4.2-4.9% in perennial ponds, 4.5-6.8% in Type-I seasonal ponds, 4.5-6.7% in Type-II seasonal ponds and 4.2% in backwaters.

Statistical analysis indicated that yield of species from tidal ponds differed significantly from each other (Table 10.2). Further statistical tests showed that yield from these habitats were affected by the physical and ecological conditions of the habitat ($P<0.05$), (Table 10.3, 10.4, and 10.5). Pond area, water exchange and productivity explained maximum amount of variation in production. Yield correlated negatively with pond area.

Table 10.2 Analysis of variance table to test the significance of prawn yield from different tidal ponds.

Source	Sum of Square	D.F.	Mean Square	F Ratio	Probability
Habitat	16785.7	5	3357.14	29.43	1.03E-10
Species	1026456.7	4	256614.18	2249.36	0.00E+00
Interaction	57926.1	20	2896.30	25.39	1.30E-13
Error	3422.5	30	114.08		
Total	1104591.0	59			



Figs 10.2 Month-wise average yield (kg/ha) of different species from tidal ponds.

Table 10.3 Multiple regression and Analysis of variance table of *P. indicus* yield from tidal ponds and eco-physical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Area	-1.3648	0.0314	-43.489	0.01464	0.9995
Depth	47.8773	1.2646	37.860	0.01681	0.9993
Water exchange	151.7402	3.3860	44.814	0.01420	0.9995
Productivity	9.6947	0.2278	42.567	0.01495	0.9994
Salinity	4.1088	0.1463	28.082	0.02266	0.9987
Temperature	3.71 E-11	8.86E-08	4.2E-04	0.99973	1.76E-07
Constant	804.3680				

Std. Error of Est. = 0.4950 Adjusted R Squared = 0.9976
R Squared = 0.9996 Multiple R = 0.9998

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	618.8955	5	123.7791	505.221	0.0338
Residual	0.2450	1	0.2450		
Total	619.1405	6			

'able 10.4 Multiple regression and Analysis of variance table of *M. dobsoni* yield from tidal ponds and eco-physical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Area	-0.4557	0.0202	-22.584	0.02817	0.9980
Depth	7.0E-12	7.07E-08	9.9E-05	0.99994	9.80E-09
Water exchange	31.9876	2.4369	13.126	0.04841	0.9942
Productivity	1.8721	0.1684	11.114	0.05713	0.9920
Salinity	1.2066	0.1058	11.408	0.05566	0.9924
Temperature	7.8364	0.8317	9.422	0.06732	0.9889
Constant	404.0671				

Std. Error of Est. = 0.3536 Adjusted R Squared = 0.9986
R Squared = 0.9998 Multiple R = 0.9999

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	530.1609	5	106.0322	848.258	0.0261
Residual	0.1250	1	0.1250		
Total	530.2859	6			

[able 10.5 Multiple regression and Analysis of variance table of *M. monoceros* yield from tidal ponds and eco-physical conditions of the habitat.

Variable	Regr. Coeff.	Std. Error	T(df= 2)	Prob.	Partial r^2
Area	-24.8453	0.4895	-50.760	0.01254	0.9996
Depth	4.2487	0.6406	6.632	0.09527	0.9778
Water exchange	1.6916	0.0359	-47.066	0.01352	0.9995
Productivity	0.1408	0.0042	-33.607	0.01894	0.9991
Temperature	9.2470	0.5829	-15.864	0.04008	0.9960
Salinity	0.3316	0.0209	15.864	0.04008	0.9960
Constant	381.4896				

Std. Error of Est. = 0.0707 Adjusted R Squared = 0.9985
R Squared = 0.9997 Multiple R = 0.9999

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F Ratio	Prob.
Regression	19.6171	5	3.9234	784.683	0.0271
Residual	0.0050	1	0.0050		
Total	19.6221	6			

ιonal Pattern:

Considerable Seasonality was observed in prawn yield from tidal ponds (Fig 10.1, 10.3) ıl prawn yield varied considerably over the season. 83.6 to 93.1% of the catches in Type-I 92.8 to 92.4 in Type-II seasonal ponds were realised during pre-monsoon months alone. In ınnial ponds 37.1 to 50.9 of the catches were realised during monsoon, 9.1 to 14.9% during -monsoon and 40.0 to 48.0% during pre-monsoon.

P. indicus:

In perennial ponds, monsoon catch accounted for 54.5 to 62.3% of the total catch and pre-monsoon 31.3 to 36.2% (Table 10.6). In seasonal ponds 91.9 to 100% of the catches were realised during pre-monsoon alone.

M. dobsoni:

In perennial ponds monsoon catches accounted for 22.9 to 35.4% of the total catch and pre-monsoon 51.63 to 59.4% (Table 10.7) . In seasonal ponds 94.3 to 100% of the catches were realised during pre-monsoon alone.

M. monoceros:

In perennial ponds monsoon catches accounted for 22.7 to 47.5% of the total catch and pre-monsoon 49.9 to 73.3% (Table 10.8) . In seasonal ponds 91.9 to 100% of the catches were realised during pre-monsoon alone.

Table 10.6 Percentage of annual yield of *P. indicus* from tidal ponds during different seasons.

Habitat		Monsoon	Post-monsoon	Pre-monsoon
Perennial	(F1)	62.28	6.40	31.32
	(F2)	54.45	9.35	36.20
Seasonal TI	(F3)	-	8.08	91.92
	(F4)	-	0.53	99.47
Seasonal TII	(F5)	-	0.57	99.43
	(F6)	-	-	100.00

Table 10.7 Percentage of annual yield of *M. dobsoni* from tidal ponds during different seasons.

Habitat		Monsoon	Post-monsoon	Pre-monsoon
Perennial	(F1)	35.37	13.00	51.63
	(F2)	22.90	17.73	59.37
Seasonal TI	(F3)	-	8.08	91.92
	(F4)	-	4.83	95.17
Seasonal TII	(F5)	-	4.62	95.38
	(F6)	-	-	100.00

Table 10.8 Percentage of annual yield of *M. monoceros* from tidal ponds during different season.

Habitat		Monsoon	Post-monsoon	Pre-monsoon
Perennial	(F1)	47.49	2.64	49.87
	(F2)	22.69	3.99	73.32
Seasonal TI	(F3)	-	5.74	94.26
	(F4)	-	-	100.00
Seasonal TII	(F5)	-	-	100.00
	(F6)	-	-	100.00

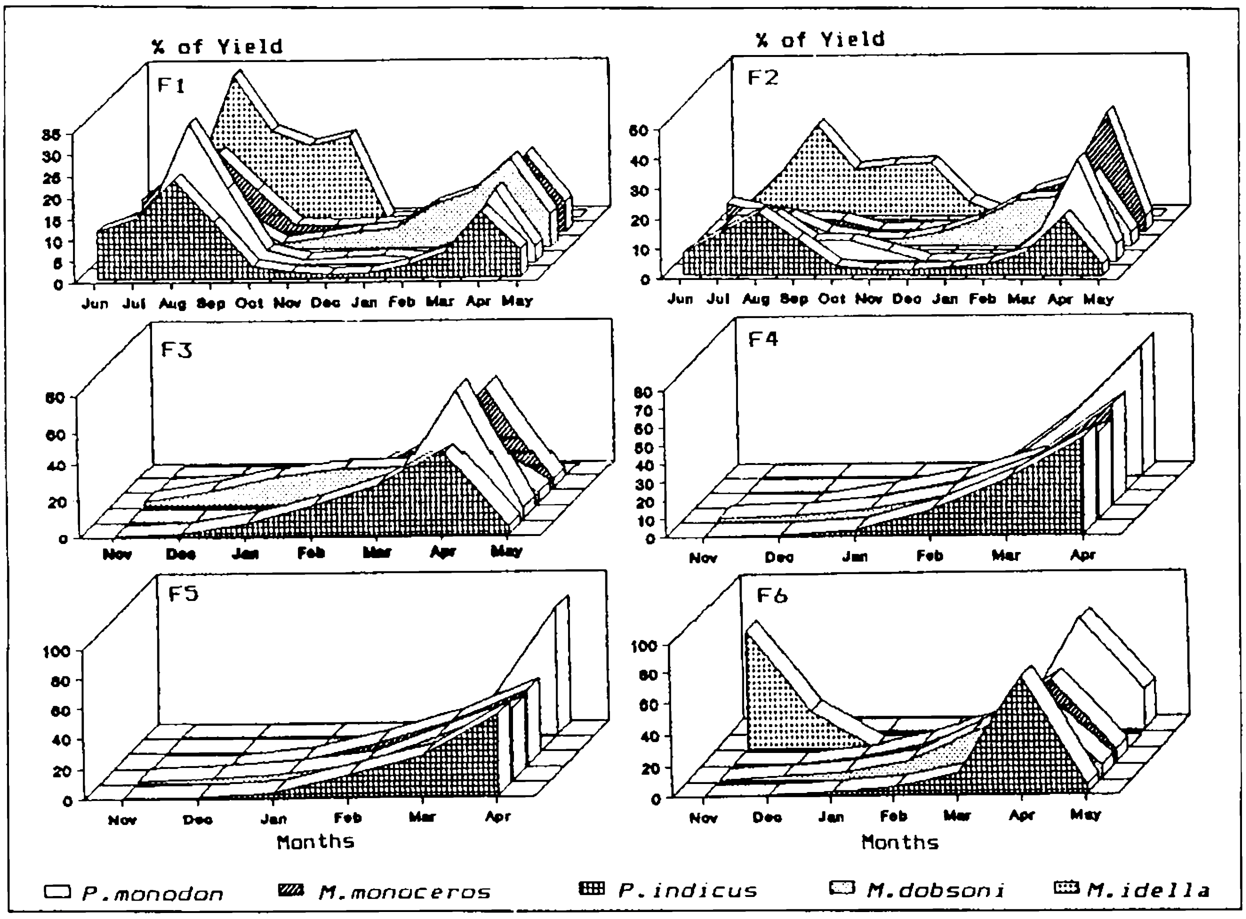


Fig 10.3 Month-wise percentage yield of different species of prawns from tidal ponds.

DISCUSSION

Prawn production from tidal ponds was almost within the ranges as reported by earlier workers from the same area (George *et.al*, 1968; George, 1974; Nasser and Noble, 1992). However, yield varied considerably in different tidal ponds. Sathiadas *et.al* (1989) and Purushan (1996) attributed farm to farm variation in production to location of tidal ponds. According to them production decrease with distance from bar mouth. Sathiadas *et.al* (1989), reported a production of 620 kg/ha/yr from ponds located within 5 km from bar mouth and less than 260 kg beyond 15 km. In the present study also production varied with the location, but it was much high compared to their reports. Present study indicated that variation in recruitment, growth and period of operation produced most of the farm to farm variation in production.

Catches were large in seasonal ponds over a small unit of time when considering actual period of operation. Menon (1954) attributed it to rich organic detritus and better biological conditions owing to the presence of paddy stumps in the field. As discussed in earlier chapters, natural productivity, food availability, recruitment rate, juvenile abundance and growth were large in small ponds and so better yield can be expected from seasonal ponds. Moreover, as described by Nasser and Noble (1992) and as discussed in earlier chapters competition, predation and natural mortalities were relatively low in seasonal ponds and so have high retrieval rate and yield. This was further substantiated by increased production from stocking ponds.

A review of earlier reports (Menon, 1954; Gopinath, 1956; George *et.al*, 1968; George, 1974; Sathiadas *et.al*, 1989; Nasser and Noble, 1992), showed that prawn production varied from year to year in seasonal and perennial ponds, with a gradual decline in the yield over the years. According to these reports production from seasonal ponds declined from over 1180 kg/ha/yr during 1950's to 300-620 kg during 1990's. During the present study it was 630 kg/ha from seasonal ponds of the same area. Informations on recruitment and ecology of these habitats were not adequate to scientifically interpret these reports, as it spread over a very long span of years. It is possible that extensive use of backwaters for several activities like navigation, fishing and increased discharge of domestic and industrial sewage's into this ecosystem might have adversely affected postlarval recruitment.

Composition of species in the catch, showed wide variation in different habitats, which conform well to the composition of postlarval recruits of the area. *P. indicus* representation was comparatively large in perennial ponds than in seasonal ponds. Many reported similar relatively large representation for the species in the catches from perennial ponds than seasonal ponds (Muthu, 1983; Jose *et.al*, 1987; Sathiadas *et.al*, 1989; Nasser and Noble, 1992; Purushan, 1996). The present observation and that of Mathew *et.al* (1993) and Purushan (1996) indicated substantial increase in the composition of *P. indicus* in all habitats compared to previous reports.

Summary

SUMMARY

Present work deals with the various aspects of population characteristics of *Penaeus indicus, Metapenaeus dobsoni* and *Metapenaeus monoceros* during their nursery phase in tidal ponds and adjacent backwaters.

Study Area:

* Tidal ponds where prawn fishery invogue, were categorised based on the management practices as perennial, seasonal without paddy rotation (Type-I), seasonal with paddy rotation (Type-II) and selective stocking ponds. Two perennial and Type-I seasonal ponds, one each at Edavanakkad and Panangad, were selected for study. Type-II seasonal ponds were located at Kannamali and Tripunithura and stocking ponds at Puthuvypeen and Chellanam. Two open backwater sites near Panangad and Thevara were also selected for the study. These areas experience varying levels of tidal and freshwater influences. So this selection enabled to understand the effects of varying physical and ecological conditions on the dynamics of penaeids during their nursery phase in tidal ponds.

* Postlarval ingression, recruitment, distribution, abundance, growth, mortality, emigration other biological characteristics and yield of *P. indicus, M. dobsoni* and *M. monoceros*, in tidal ponds and backwaters were studied.

Hydrology:

* Hydrology of tidal ponds varied with location, but showed a common seasonal pattern. Seasonal variation in temperature was very small. It fluctuated between 27.5 to 32.3°C in tidal ponds and 26.9 to 29.9°C in open backwaters.

* Marked variation was observed in salinity over space and time. Salinity was high in areas near bar mouth and it decreases with the distance. It fluctuated over the season between 0.1 and 25.9‰ in tidal ponds and 1.07 and 25.9‰ in open backwaters.

* Dissolved oxygen content of the water was fairly good in all habitats. pH fluctuated over the

season, with low values during monsoon and high during other seasons. Hardness and alkalinity were low during monsoon and high during pre-monsoon. Turbidity was low in perennial ponds and high in stocking ponds. It varied over the seasons and was low during pre-monsoon and high during post-monsoon.

* Dissolved nutrients and productivity were high in stocking ponds, seasonal ponds, while the values were low in perennial ponds and backwaters. Phytoplankton production was high in stocking ponds, moderate in seasonal ponds and low in perennial ponds least in backwaters.

Ingression and Recruitment:

* Considerable diel, tidal, lunar and seasonal periodicity was observed in abundance, ingression and recruitment of postlarvae. Ingression occurs mainly during night hours at flood tides. On an average about 84% of the total ingression occur during night hours alone. It also followed a 14/28-day cycle with peaks coincided with alternate spring tides of full and new moon. Abundance and ingression peaked up during spring tides at night for all species. Lunar phase which coincide with tide phases have modifying effect on postlarval abundance and ingression through variation in light intensity.

* Ingression and recruitment of major species occurred through out the year with well-defined individual peaks for each species. It was during post-monsoon for *M. dobsoni*, pre-monsoon for *P. indicus* and late post-monsoon and early pre-monsoon season for *M. monoceros*. It was low for all species during monsoon. Seasonal fluctuation in abundance and ingression relate directly with the spawning periodicity of individual species.

* Postlarval recruits were constituted by *M. dobsoni* (70.8-79%), *P. indicus* (17.5-24.6%), *M. monoceros* (3.8-4.6%) and *P. monodon* (<1%). Composition varied with the location and also over the seasons. Composition of *P indicus* was relatively large in areas near bar mouth and that of *M. dobsoni* in areas away from the bar mouth.

* Abundance and recruitment was comparatively large for all species in areas located near bar mouth. Marine influence played the key role in determining abundance, composition and

distribution of the species over time and space. Southwest monsoon and the freshwater discharge that followed, have considerable impact on ingression and recruitment rate.

* Postlarvae once entered the tidal ponds or suitable nursery areas settle down immediately and will not leave the habitat along with receding tidal waters, till they attain 2-3 month old.

* Rate of recruitment into tidal ponds was negatively correlated with the size of the pond and distance from bar mouth and positively with water exchange.

* Size of the recruits was comparatively small during the peak recruitment period and large during monsoon for all species.

Distribution and Abundance:

* Considerable heterogeneity was observed in the distribution and abundance of shrimps in tidal ponds with respect to depth. Postlarvae and juveniles were found along shallow marginal areas closely associated with mangroves vegetation, while large prawns were restricted mainly to deep areas.

* Spatial segregation between different size groups were caused by the change in the metabolic/physiological requirement of shrimps with growth and the associated shift in preference to different environmental conditions. Such spatial segregation will minimise over-crowding, intra-specific competition and predation and also enable better utilization of resources in a habitat with continuous recruitment of small prawns.

* Shrimp abundance in tidal pond was determined by the factors affecting recruitment rate. Shrimp abundance correlated directly with rate of recruitment and water exchange and inversely on habitat area. Relative abundance was large in small ponds.

* Abundance varied over the season with peaks during January-May and it linked with the strength and seasonality of postlarval recruitment, period of stay and juvenile emigration.

Growth and Age:

* Growth of shrimps were estimated by integrated modal progression and ELEFAN programme from length-frequency distribution of resident prawns.

* Growth of all species varied in different habitats mainly due to variation in productivity and food availability. Growth was fast in stocking ponds for all species, moderate in tidal ponds and slow in backwaters. Among tidal ponds it was fast in Type-II seasonal ponds, followed by in Type-I ponds and slow in perennial ponds for *P.indicus* and *M.dobsoni*. For *M. monoceros* it was fast in perennial ponds, followed by in Type-I ponds and slow in Type-II seasonal ponds. Growth variation was caused by ecology of the habitat, particularly food availability.

* Prawns attain large size in perennial ponds, followed by in seasonal ponds and small in backwaters

* Estimates of $L\infty$ based on length frequency data for prawns in perennial pond was 177.5 mm for *P. indicus*, 109.4 mm for *M. dobsoni* and 126.6 mm for *M. monoceros*. Growth coefficient (K) was 2.861 for *P. indicus*, 3.149 for *M. dobsoni* and 3.701for *M. monoceros.*

* Prawns stay for comparatively long periods in perennial due to the prevalence of calm and stable environment than in seasonal ponds and backwaters. Residence period of *P. indicus* was 14.4 months in perennial ponds6.0 to 6.5 months in seasonal ponds and 9.2 months in backwaters. It was 12.1, 6.1 and 7.8 months respectively in these habitats for *M. dobsoni* and 9.01, 5.3 to 5.4 and 6.8 months for *M. monoceros.*

Mortality

* Mortality was estimated from length frequency data, based on change in relative density of successive age groups. In tidal ponds mortality due to natural causes ranged from 46.7 to 54.8% for *P. indicus*, 44.2 to 52.3% for *M. dobsoni* and 47.9 to 54.1% for *M. monoceros*. Natural mortality was relatively high during early phase of nursery life than later stage.

* Instantaneous rate of natural mortality (annual) in tidal ponds ranged from 2.7945 to 4.554 for *P. indicus*, 3.7851 to 5.4013 for *M. dobsoni* and 3.3876 to 4.1661 for *M. monoceros*. Instantaneous rate of total mortality (annual) in tidal ponds ranged from 5.0717 to 9.7631 for *P. indicus*, 7.2428 to 12.2311 for *M. dobsoni* and 6.2482 to 8.7009 for *M. monoceros*. Whereas, it was 7.0508, 8.9922 and 5.7751 respectively for these species in open backwaters.

* Mortality in different habitats varies with the physico-chemical and biological characteristics of the habitat.

Emigration

* Like postlarval ingression, considerable diel, tidal, lunar and seasonal fluctuations were observed in emigration of prawns. Emigration was almost nocturnal in prawns. Rate of emigration and composition of emigrants varied with time of migration. It was large, during early hours than late hours in the night. Preference for early hours for emigration was strong in *M. monoceros* than other species. Large pulses of emigration always coincided with spring tides with major peak during new moon. Peak emigration of *P. indicus* occurred during monsoon months, whereas that of *M. dobsoni* and *M. monoceros* during pre-monsoon.

* Rate of emigration was relatively large for all species from small tidal ponds. It correlated directly with juvenile density at the time of emigration and was modified by the prevailing environmental conditions. Instantaneous rate of emigration was also large in seasonal ponds and small in perennial ponds.

* The basic stimulus for emigration is urge for sexual maturation in prawns. This coupled with other ecological changes in the habitat cause various patterns in migration.

* Composition of emigrants varied from different habitats. *P. indicus* representation was relatively large in the emigrants from perennial and *M. dobsoni* from seasonal tidal ponds.

* Emigrants were relatively large in perennial ponds and small in open backwaters. Size of the

emigrants was large during pre-monsoon and small during monsoon. Major part of the recruits emigrates at an age of about 2 months from seasonal ponds, 1 to 2 months from backwaters and above 3 months from perennial ponds.

Length-Weight Relationship and Condition Factor:

* The length-weight relationship varied with habitat. *P. indicus* and *M. dobsoni* of same length was relatively heavy in stocking ponds and light in perennial ponds and backwaters, whereas *M. monoceros* was relatively heavy in stocking ponds and light in Type-II seasonal ponds.

* Relative condition factor and so robustness was large in stocking ponds and small in perennial ponds and backwaters for *P. indicus* and *M. dobsoni,* whereas it was small in Type-I seasonal pond for *M. monoceros.* Robustness and well-being of prawns varied over the season, with poor condition during monsoon and better during post-monsoon period

* Condition factor suggested that *M. dobsoni* is well suited for these habitats than other species studied.

Sex Ratio AND Sexual Maturity:

* Sex ratio and gonadal maturity of species in resident and emigrating populations were analysed separately to correlate it with the biological and behavioural changes. On an average sex ratio of all species were near unity. In small length groups males and females represent almost equally, whereas in large length groups females dominate.

* Males of all species emigrate at an early age from these habitats, thus resulting in considerable anomalies in the sex ratio in resident and emigrating population with size.

* Immature individuals represented *P. indicus* and *M. monoceros* in these habitats. *M. dobsoni* males attain full sexual maturity in the study area whereas the chances of full sexual maturation in females are relatively low.

Yield:

* The estimated prawn yield was 716.3 to 925.6 kg/ha in perennial ponds and 464.9 to 650.81 kg/ha in seasonal ponds. Whereas in short time scale harvests it was large in small seasonal ponds. Yield correlated positively with recruitment rate and productivity in tidal ponds and inversely with the size and distance from bar mouth. *P. indicus* composition was comparatively large in the catches from perennial ponds.

- More than 90% of the catches from seasonal ponds and 40-48% from perennial ponds were realized during pre-monsoon months, whereas, 37 to 51% of the catches in the latter were realized during monsoon months

Conclusion

CONCLUSION

Importance of the present study is to suggest scientific basis for the management of penaeid resources in tidal ponds and backwaters, based on their biological characteristics to ensure better yield. The fundamental issue in the management of backwater and tidal pond prawn fishery is the lack of proper understanding of the resources characteristics of major species in these habitats. Based on the findings, the following measures are proposed on a broader perspective.

- Improvement of nursery habitats with due consideration for biological requirements of the resource will ensure better growth, survival and abundance of the stock.

  - Close association of postlarvae and young juveniles with mangroves and paddy remains suggested establishment and preservation of mangrove vegetation in shallow marginal areas of tidal ponds and backwaters. It will attract more prawns and ensure optimum densities. The mangrove foliage and paddy remains besides acting themselves as refuge and food, provide additional area for the growth of periphyton, an ideal natural food for young shrimps, and enhance their growth and survival.

  - Large size of prawns in the deep perennial ponds due to relatively long residence period suggest that, by providing deep trenches in shallow tidal ponds, emigration can be delayed and can ensure large size at harvest.

  - Since tidal currents being the transporting agent for postlarvae and juveniles, recruitment in to tidal ponds can be improved by increasing tidal exchange by way of (i) increasing the number and size of water intake structures and (ii) dividing large holdings in to small units with independent access to open water body. Copious in water exchange will further improve productivity, food abundance and other living conditions in the habitat.

- Minimum size of the shrimps at harvest from backwaters and tidal ponds has to be stipulated especially for commercial species like *P. indicus*. Mesh size of filternets has to be regulated to ensure the escape of small prawns in a mixed population. This, if strictly enforced, at least during pre-monsoon and early monsoon months, the peak periods of emigration, will produce fruitful results.

- Seasonal closure of fishing will be effective in improving the size of the shrimp at harvest. Since there is seasonality in the recruitment and emigration of prawns, closure of fishing during periods when large number of small prawns emigrate, will prevent destruction of under sized population. Large number of small juveniles leave open backwaters immediately after the onset of monsoon. Operation of stake nets has to be controlled during this periods. But while considering the economic impact of such closure on traditional sector, mesh size regulation and size at harvest is better advocated.
- If shrimps were allowed to grow larger before being caught, will ensure better returns. In tidal ponds the present practice is to start harvest by October end or by November. If the first harvest delayed till January or February, more number of large prawns can be expected in the catch.
- *P. indicus* recruits enter their backwater nurseries mainly during pre-monsoon months. In seasonal ponds, they were harvested before attaining preferred market size, by the middle of April. If the period of fishing operation in seasonal ponds extended till June, instead of April, their growth potential can be exploited much effectively.
- Shallow areas in open backwaters with mangrove vegetation have to be protected against destruction and fishing operations be strictly regulated, as postlarvae and early juveniles aggregate in large numbers in this area and use it as their nurseries.
- The recruitment, growth and emigration data of prawns from their nurseries can be used successfully for fishery forecasting. By projecting juvenile growth forward through time, it is possible to establish, which cohort contributes to offshore fishery each year. So, by interpreting the recruitment and growth data of species in their nurseries with offshore catch data, fishery can be forecasted successfully.

References

REFERENCES

Abdussamad, E.M. and D.M Thampi, 1994. Cannibalism in the tiger shrimp, *Penaeus monodon* Fabricius in nursery rearing phase. *J. Aqua. Trop.*, 9: 67-75.

Achuthankutty, C.T. 1988. Nursery life of the marine prawn *Metapenaeus dobsoni* (Miers) in the Mandovi estuary along Goa coast of India. *Indian J. Mar. Sc.*, 17(4): 313-316.

Achuthankutty, C.T. and S.R.S. Nair 1982. Penaeid prawn population and fry resources in a mangrove swamp of goa, India. *Proc. Symp. Coastal Aquacult., Part-I:. Prawn Culture,* 1: 190-195.

Achuthankutty, C.T. and S.R.S. Nair 1983. Larval migration and growth of marine prawns in the estuarine habitat. *Mahasagar,* 16(2): 243-250.

Achuthankutty, C.T. and A.H. Parulekar 1986. Growth of penaeid prawns in Goa waters. *Indian J. Mar. Sci.,* 15: 117-120.

Alagaraja, K. 1984. Simple methods for the estimation of parameters for assessing exploited fish stocks. *Indian J. Fish.*, 31: 177-208.

Allen, K. R. 1953. A method for computing the optimum size limit for a Fishery. *Nature,* 172(4370): 210.

Alvarez, N.F., G.A. Garcia and L.A. Soto 1987. Growth and mortality of estuarine stages of pink shrimp, *Penaeus (Farfantepenaeus) duorarum* Burkenroad, 1939 in Terminose Lagoon, Campeche, Mexico. *An. Inst. Cienc. Marlimnol. Univ. Nac. Auton. Mex.,* 14 (20): 207-220.

Anon 1978. Intensive culture of prawns in a perennial field. *CMFRI, News letter,* (No. 7): 10pp.

Anon 1980. Assessment of fry resources of cultivable prawns at selected centres in Kerala and Karnataka. *CMFRI, Project Report,* 84pp.

Anon 1982. New light on the migration of the Indian white prawn *Penaeus indicus*. *Mar. Fish. Infor. Serv., T & E Ser., No.* 45: 1-9.

Aravindhakshan, P.N., V.T. Paulinose, T. Balasubrahmanian, P.G. Menon and M. Krishnankutty 1982. On the growth of *Penaeus indicus* experimented in cages at different densities in a selected nursery ground. *Proc. Symp. Coastal Aquacult.*, Part-I: 398-402.

Bagenal, T.B. 1955. The growth rate of the long rough dab, *Hippoglossoides platessoides* (Fab). *J. Mar. Biol. Assoc. U.K.,* 34: 297-311.

Balasubrahmanian, T. M. Viswakumar and P. Venugopal 1995. Ecological evaluation of two prawn culture fields in the Cochin backwater, based on pre-monsoon diurnal observations. *J. Mar. Biol. Assoc. India*, 37(1-2): 212-220.

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

Banerji, S.K. and M.J. George 1967. Size distribution and growth of *Metapenaeus dobsoni* (Miers) and their effect on the trawler catches off Kerala. *Proc. Symp. Crustacea*, Part II: 634-648.

Barber, M.E. and C.P. Lee 1975. Preliminary analysis of physical factors influencing the ingress of planktonic king prawn (*Penaeus plebejus*) postlarvae into the Morten Bay. *First Australian Natl. Prawn Seminar*, 1: 45-53.

Baxter, K.N. and L.F. Sullivan 1986. Predicting offshore brown shrimp catches from early inshore stages. *In* A.M. Landry Jr. and L.F. Klima, editors. Proceedings of shrimp yield workshop. Texas A&M Sea Grant Publication TAMU-SG-86-110, College station. Pages 22-36.

Beardsley, G.L. 1970. Distribution of migrating juvenile pink shrimp, *Penaeus duorarum duorarum* Burkenroad, in Buttonwood canal, Everglade National Park, Florida. *Trans. Am. Fish. Soc.*, 99: 401-408.

Benfield, R.L. and W.B. Baker, Jr. 1980. Studies of shrimp population on selected bays of Texas. *Manage. Data Ser. Tex. Parks Wildl. Dept.*, pp 104.

Benfield, M.C., J.R. Bosscheieter and A.T. Forbes 1990. Growth and emigration of *Penaeus indicus* H.Milne-Edwards (Crustacea: Decapoda: Penaeidae) in the St. Lucia Estuary, Southern Africa. *Fish. Bull.*, 88 (1): 21-28.

Berry, R.J. 1970. Shrimp mortality rates derived from fisheries statistics. *Proc. Gulf. Carrib. Fish. Inst.*, 22: 66-78.

Berry, R.J. and K.N. Baxter 1969. Predicting brown shrimp abundance in the Northwestern Gulf of Mexico. *FAO Fish. Rep.*, 57(3): 775-798.

Bertalanffy, L. von 1934. Untersuchungen ubar die Gesetzlich-keiten deswachstums I. Allgemeire Grudlagen der Theorie. *Roux. Arch. Ebtwicklungsmech.*, 131: 613-652.

Bertalanffy, L. von 1938. quantitative theory of organic growth (Inquiries on growth and laws). *Hum. Biol.*, 10 (2): 181-213.

Boddekke, R., R. Dijkema and M.E. Simelink 1977. The patterned migration of shrimp populations: a complete study of *Crangon crangon* and *Penaeus schmitti*. *FAO Fish. Rep.*, 200: 31-49.

Caillouet, C.W. Jr., W.S. Perret and J.R. Dugas 1968. Diel fluctuation in the catch of postlarval brown shrimp, *Penaeus aztecus* Ives with the Renfro beam trawl. *Bull. Mar.*

Sc., 20(3): 711-770.

Carpenter, K.E., A.W. Fast, V.L. Corre, J.W. Woessner and R.L. Janeo 1986. The effect of water depth and circulation on the water quality and production of *Penaeus monodon* in earthen ponds. *Proc. First Asian Fish. forum., pp.* 21-24.

Chamberlain, G.W., D.L. Hutchins, A.L. Lawrence and J.C. Parker 1980. Winter culture of *Penaeus vannamei* in ponds receiving thermal effluent at different rates. *Proc. World Maricult. Soc.*, 11: 30-43.

Champion, H.F.B. 1983. The reproductive biology of *Penaeus indicus* with notes on its autecology. *M.S. Thesis, Rand Afrkkans Univ., Johannasburg*, 160 pp.

Chen, Y.L. 1983. Emigration of penaeid shrimp from the once-through cooling lake of Cedar Bayou steam electric generation station, Baytown, Texas. *Ph.D. diss., Texas A&M Univ. College station,* 187 pp.

Cheng C.S. and L. Chen 1990. Growth characteristics and relationship among body length, body weight and tail weight of *Penaeus monodon* from a culture environment in Taiwan. *J. Aquacult.*, 91: 253-263.

Cheriyan, P.V. 1967. Hydrographical studies in and around Cochin Harbour. *Bull. Dept. Mar. Biol. Oceanogr. Univ. Kerala,* 3: 9-17.

Chong, V.C. 1979. The biology of the white prawn *Penaeus merguiensis* de Man (Crustacea: Penaeidae) in the pulau Angsa-Klang Strait waters (Straits of Malacca). *M.S. Thesis, Univ. of Malaysia, Kaulalampur,* (Abstract).

Coles, R.G. and J.G. Greenwood 1983. Seasonal movement and size distribution of three commercially important Australian prawn species (Crustacea: Penaeidae) within an estuarine system. *Aust. J. Mar. Freshwat. Res.*, 34(5): 727-743.

Copeland, B.J. 1965. Fauna of Aransas Pass Inlet, Texas. Emigration as shown by tide trap collections. *Publ. Inst. Mar. Sci. Univ. Tex.*, 10: 9-21.

Copeland, B.J. and M.V. Truitt 1966. Fauna of the Aransas Pass inlet Texas. Part 2. Penaeid shrimp postlarvae. *Texas J. Sc.*, 18(1): 65-75.

Cushing, D.H. 1968. Fishery biology. A study in population dynamics. *Univ. Wisconsin Press, Madison. Wis.*, 200 pp.

Dall, W. 1981. Osmoregulatory ability and juvenile habitat preference in some penaeid prawns. *J. Exp. Mar. Biol. Ecol.*, 54: 55-64.

Dall, W., B.J. Hill, P.C. Rothlisberg and D.J. Staples 1990. The biology of the penaeidae. In: Baxter, J.H.S. and Southward, A.J. (eds.) Advances in Marine Biology, Vol. 27: Academic press London, p. 1-498.

De Bondy, E.T. 1968. Observations Sur'la biologie de *Penaeus duorarum* au Senegal. *Doc. Sci. Provis. Cent. Rech. Oceanogr. Dakar-Thiaroye,* 16: 50 pp.

De La Bretonne, L.W. and J.W. Avault Jr. 1971. Movements of brown shrimp, *Penaeus aztecus* and white shrimp, *Penaeus setiferus*, over weirs and marshes of south Louisiana. *Proc. Ann. Conf. Southeast Game. Fish. Comm.*, 25: 651-654.

Devaraj, M. 1983. Fish population dynamics. *Course Manual, CIFE (ICAR)*, 98 pp.

Devi, C.B.L., K.K.K.C. Nair, T. Balasubrahmanian, T.C. Gopalakrishnan, P.N. Aravindhakshan and M.K. Kutty 1983. Length-Weight relationship and condition factor of *Penaeus indicus* and *Metapenaeus dobsoni* in the Cochin backwater. Mahasagar, 16: 399-402.

Devi, S.L. 1987. Growth and population dynamics of three penaeid prawns, in the trawling grounds of Kakinada. *Indian J. Fish.*, 34:245-264.

Devi, S.L. 1988. Observation on the fishery and biology of penaeid prawns from Godavari estuary. *Indian J. Fish.*, 35: 52-63.

D'Incao, F. 1991. *Penaeus paulensis*. Fishery and biology in the Patos Lagoon. *Atlantica,* 13(1): 159-169.

Easo, S. and K.J. Mathew 1989. Seasonal variation in the abundance of penaeid prawn seed in relation to environmental parameters in the seed grounds of Cochin backwaters. *Indian J. Fish.*, 36(2): 125-132.

Edwards, R.R.C. 1977. Field experiments on growth and mortality of *Penaeus vannamei* in a Mexican coastal lagoon complex. *Estuarine and Coastal Mar. Sci.*, 5: 107-121.

Edwards, R.R.C. 1978. The fishery and fisheries biology of penaeid shrimp on the Pacific coast of Mexico. *Oceanogr. Mar. Biol. A. Rev.*, 16: 145-180.

Farmer, A.S. 1981. A review of crustacean marking methods with particular reference to penaeid shrimp. *Kuwait Bull. Mar Sci.*, 2: 167-183.

Fast, A.W. and K.E. Carpenter 1988. Effect of water depth and artificial mixing on dynamics of philippines brackishwater ponds. *Aquacult. Eng.*, 7(5): 349-361.

Forbes, A.T. and M.C. Benfield 1986a. Tidal behaviour of postlarval penaeid prawns (Crustacea: Decapoda: Penaeidae) in south east African estuary. *J. Exp. Mar. Biol. Ecol.*, 102(1): 23-34.

Forbes, A.T. and M.C. Benfield 1986b. penaeid prawns in the St.Lucia lake system: Post-larval recruitment and the bait fishery. *S. Afr. J. Zool.*, 21(3): 224-228.

Ford, E. 1933. An account of the herring investigations conducted at plymouth during the year from 1924 to 1933. *J. Mar. Biol. Assoc. U.K.,* 19: 305-384.

Ford, T.B. and L.S. St. Amant 1971. Management guidelines for predicting brown shrimp, *Penaeus aztecus*, production in Louisiana. *Proc. Gulf. Carrib. Fish. Inst.,* 23: 149-160.

Galois, R. 1975. Biology, ecology and dynamics of the lagoon phase of *Penaeus duorarum* in the Ivory coast. *Cocteur en Oceanogr. Biol.,* 120pp. (Abstract).

Ganapati, P.N. and M. Subrahmanyam 1964. The prawn fishery in Godavari estuary. *J. Zool. Soc., India.* 16(1&2): 11-20.

Garcia, S. 1974. Biologie de *Penaeus duorarum notialis* en Cote d'Ivoire, IV Relation entre la repartition et les conditions du milieu. Etude des variations du sex ratio. *Doc. Sci. Centre Rech. Oceanogr. Abidjan.,* 5(3-4): 1-39.

Garcia, S. 1977a. Les migrations descrevettes penaeids tropicales. *Oceanis,* 1977: 465-380.

Garcia, S. 1977b. Biologie et. dynamicques des populations de crevette rose *Penaeus duorarum notialis* Perez Farfente, 1967, en cote d' Ivoire. Trav. Doc. OSTROM, 79: 221pp.

Garcia, S. 1984. A note on environmental aspects of penaeid shrimp biology and dynamics. Gulland , J.A. and B.J. Rothschild (Eds). In *Penaeid Shrimp- Their Biology and Management,* pp. 268-271.

Garcia, S. 1985. Reproduction, stock assessment models and population parameters in exploited penaeid shrimp populations. In Rothlisberg, P.C. et. al. (eds). *Second Australian National Prawn Seminar,* p. 139-158.

Garcia, S. and L. Le Reste 1981. Life Cycle, dynamics, exploitation and management of coastal penaeid shrimp stocks. *FAO Fish. Tech. Rep.,* 203: 215pp.

Gayanilo, F.C. Jr., P. Sparre and D. Pauly 1996. The FAO-ICLARM Stock Assessment Tools (FISAT), Users guide. *FAO, Computerised Information Series (Fisheries),* No. 8, Rome, FAO 1995, 126 pp.

George, K.V. 1974. Some aspects of prawn culture in the seasonal and perennial fields of Vypeen island. *Indian J. Fish.,* 21: 1-19.

George, M.J. 1959. Notes on the bionomics of the prawn *Metapenaeus monoceros* Fabricius. *Indian J. Fish.,* 6: 268-279.

George, M.J. 1961. Preliminary observations on the recruitment of postlarvae and growth of juveniles of the brown shrimp, *Penaeus aztecus* Ives in Barataria Bay. *9th Biennial report. 1960-61, Louisiana Wild life and Fisheries Commission,* 160-163.

George, M.J. 1962a. On the breeding of penaeids and the recruitment of their postlarvae into the backwaters of Cochin. *Indian J. Fish.*, 9: 110-116.

George, M.J. 1962b. Observations on the size groups of *Penaeus indicus* (Milne Edwards) in the commercial catches of different nets from the backwaters of Cochin. *Indian J. Fish.*, 9: 468-475.

George, M.J. 1970. Synopsis of biological data on the penaeid prawn, *Metapenaeus dobsoni* (Miers). *FAO, Fish. Rep.*, 57: 1335-1358.

George, M.J. 1973. The influence of backwaters and estuaries on marine prawn resources. *Proc. Symp. Living Res. Sea Around India.*, pages 563-569.

George, M.J. 1975. Observations on the growth in certain penaeid prawns studied in prawn culture experiments in paddy fields. *Bull. Dept. Mar. Sci. Univ. Cochin,* 7: 41-55.

George, M.J., K.H. Mohamed and N.N. Pillai 1968. Observation on the paddy field prawn filtration of Kerala, India. *FAO Fish. Rep.*, 57(2): 427-442.

George, M.J. and P.V. Rao 1968. Observations on the development of the external genitalia in some Indian penaeid prawns. *J. mar. Biol. Assoc. India,* 10 (1): 52-70.

George, M.J. and C. Suseelan 1982. Distribution of species of prawns in the backwaters and estuaries of India withreference to coastal aquaculture. *Proc. Symp. Coastal Aquacult.*, 1: 273-284.

Glaister, J.P. 1978. The impact of river discharge on distribution and production of the school prawn *Metapenaeus macleayi* (Haswell). (Crustacea:Penaeidae) inthe Clarence rtiver. *Aust. J. Mar. Freshwat, Res.*, 29: 311-323.

Gopalan, U.K. Purushan, K.S. and T.S.S. Rao 1980. Case studies on the economics of an improved method of paddy field shrimp culture in Vypeen Island, Kerala, *Proc. Symp. Shrimp farming, Bombay.*, 175-186

Gopinath, K. 1956. Prawn culture in the rice fields of Travancore Cochin, India. *Proc. Indo-Pac. Fish. Counc. 6th Session.* 18: 419-424.

Gopinatahan, C.P. 1972. Seasonal abundance of phytoplankton in the Cochin backwater. *J. Mar. Biol. Assoc. India,* 14(2): 568-575.

Gopinathan C.P., P.V.R. Nair and A.K.K. Nair 1974. Studies on the phytoplankton of Cochin backwaters, a tropical estuary. *Indian J. Fish.*, 21(2): 501-513.

Gopinatahan, C.P., P.V.R. Nair, V.K. Pillai, P.P. Pillai, M. Vijayakumar and V.K. Balachandran 1982. Environmental characteristics of seasonal and perennial prawn culture fields in the estuarine system of Cochin. *Proc. Symp. Coastal Aquacult., Part I. Prawn Cult.*, 1: 369-382.

Goswami, S.C. and M.J. George 1978a. Diel variation in the occurrence of penaeid larvae in estuarine and nearshore waters of Goa. *Indian J. Mar. Sci.,* 7: 33-38.

Goswami, S.C. and M.J. George 1978b. Seasonal abundance of penaeid prawn larvae and postlarvae in the coastal waters of Goa, up to 50m depth zone. *Indian J. Mar. Sci.,* 7: 110-115.

Goswami, S.C. and U. Goswami 1992. Lunar, diel and tidal variability in penaeid prawn larval abundance in the Mandovi estuary, Goa. *Indian J. Mar. Sci.,* 21: 21-25.

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

Gunter, G. 1961. Some relations of estuarine organisms to salinity. *Limnol. Oceanogr.,* 6: 182-190.

Gunter, G. and J.C. Edwards 1969. The relation of rainfall and freshwater drainage to the population of penaeid shrimp (*Penaeus fluviatilis* Say and *Penaeus aztecus* Ives) in Texas and Louisiana waters. *FAO Fish. Rep.,* 57(3): 875-892.

Gunter, G. and H. Hildebrand 1954. The relation of total rainfall of the state and catch of the marine shrimp, *Penaeus setiferus*, in Texas waters. *Bull. Mar. Sc. Gulf. Carribb.,* 4(2): 95-103.

Hall, D.N.F. 1962. Observation on the taxonomy and biology of some Indo-west Pacific penaeidae (Crustacea: Decapoda). *Fish. Publ. Colon. Off.,* 17: 229pp.

Haywood, M.D.E. and D.J. Staples 1993. Field estimates of growth and mortality of juvenile banana prawn (*Penaeus merguiensis*). *Mar. Biol.,* 116: 407-416.

Herke, W.H., B.D. Rogers, V.L. Wright and W.H. Bradshaw 1996. Postlarval *Penaeus aztecus* and *Penaeus setiferus* transport into and distribution within adjacent weired and unweired ponds. *Wetlands,* 16(2): 197-207.

Herke, W.H., M.W. Wengert and M.E. Lagory 1987. Abundance of young brown shrimp in natural and semi-impounded marshy nursery areas: Relation to temperature ands salinity. *Northeast Gulf. Sci.,* 9(7): 9-28.

Heron, M.L., H.X. Wang and D.J. Staples 1993. Transport process affecting banana prawn postlarvae in the estuaries of Gulf of Carpentaria. *Proc. Boeda Workshop on Larval Dispersal and Recruitment.* In. P. Sammarco (Ed.) Coastal and estuarine studies. American Geophysical Union, Washington D.C.

Hildebrand, H. and G. Gunter 1953. Correlation of rainfall with Texas catch of white shrimp, *Penaeus setiferus* (L). *Trans. Am. Fish. Soc.,* 82: 151-155.

Hoestlandt, H. 1969. Recherches sur le cycle biologique de la crevette *Penaeus duorarum* Burkenroad 1939, au Dahomey. *FAO Fish. Rep.*, 57(3): 687-708.

Hughes, D.A. 1969 Response of salinity changes as a tidal transport mechanism of pink shrimp *Penaeus duorarum. Biol Bull. Mar. Bil. Lab., Woods Hole,* 136: 43-53.

Hughes, D.A. 1972. On the endogenous control of tide associated displacements of pink shrimp, *Penaeus duorarum* Burkenroad. *Biol. Bull., (Woods Hole).* 142: 271-280.

Hutchins, D.L. G.W. Chamberlain and J.C. Parker 1980. Estimation of shrimp population in experimental ponds using mark-recapture and stratified random sampling methods. *Proc. Annu. Meet. World Maricult. Soc.,* 11:142-150.

Idyll, C.P. 1964. The juvenile phase of the life history of the shrimp, *Penaeus duorarum* in the Everglade Notional Park nursery grounds. *Circ. USFWS.,* (183): 83-85.

Idyll, C.P., E.S. Iverson and B. Yokel 1964. Movements of juvenile pink shrimp in the Everglade Notional Park, Florida. *Proc. Gulf. Carrib. Fish. Inst.,* 16: 51-52.

Ingle, R.M. 1957. Intermittent shrimp sampling in Apalachicola Bay with biological notes and regulatory applications. *Proc. Gulf Caribb. Fish. Inst.,* 9: 6-17.

James, D.B. 1987. Diurnal variation in the abundance of penaeid prawn postlarvae in the Ennore estuary, near Madras. *J. Mar. Biol. Assoc., India,* 29: 250-256.

Janssen, G.M. and B.R. Kuipers 1980. On tidal migration in the shrimp, *Crangon crangon. Neth. J. Sea Res.,* 1493/4): 339-348.

Jayakody, D.S. and H.H. Costa 1988.. Population dynamics of Indian shrimp (*penaeus indicus* Milne Edwards) on the west coast of Srilanka. *Asian Fish. Soc.,* 1(2): 135-146.

Jayawickrema, S.J.C. and Jayakody, D.S. 1992. Population dynamics of *Penaeus indicus* (H. Milne Edwards) in the west coast of Srilanka. *J. Mar. Biol. Assoc. India,* 34(3): 94-102.

Jhingran, V.G. and A.V. Natarajan 1966. Final report of the fisheries of the Chilka lake (1957-1965). *Bull. Cent. Inl Fish. Res. Inst. Barrackpore.* No. 8. Mimeo.

Jhingran, V.G. and A.V. Natarajan 1969. A study of the fisheries and fish populations of Chilka lake during the period 1957-1965. *J. Inl. Fish. Soc. India,* 1: 49-126.

Johnson, M.C. and J.R. Fielding 1956. Propagation of the white shrimp, *Penaeus setiferus* (Linn.), in captivity. *Tulane Studies in Zoology,* 4 (6): 175-190.

Josanto, V. 1971. The bottom salinity characters and factors that influence the salt water penetration in the Vembanad lake. *Bull. Dept. Mar. Biol. Oceanogr.,* 5: 1-16.

Jose, M.M., P.M. Mathew and S. Jose 1987. Feasibility and economic viability of selective culture of *Penaeus indicus* in pokkali fields. *Proc. Natl. Sem. Est. Manag.,*: 379-381.

Kemp, S. 1915. Fauna of the Chilka lake: Crustacea-Decapoda. *Mem. Indian Mus.,* 5(3): 199-325.

Kesteven, G.L. and T.J. Job 1957. Shrimp culture in Asia and Far East; a preliminary review. *Proc. Gulf. Carribb. Fish. Inst.,* 10: 49-68.

King, B.D. 1971. Study of migratory pattern of fish and shellfish through a natural pass. *Tex. Parks. Wildl. Tech. Ser.,* 9: 1-54

Klima, E.F. 1964. Mark-recapture experiments with brown and white shrimps in the northern Gulf of Mexico. *Proc. Gulf. Carribb. Inst.,* 16: 52-64.

Klima, E.F. 1965. Evaluation of biological stains, ink and fluorescent pigments as marks for shrimp. *U.S. Fish and Wildlife Service, Special scientific Report-Fisheries,* 511: 1-8.

Knudsen, E.E., B.D. Rogers, R.F. Paille, W.H. Herke and J.P. Geagham 1996. Juvenile white shrimp growth, mortality and emigration in weired and unweired Louisiana marsh ponds. *N. Am. J. Fish. Manage.,* 16 (3): 640-652.

Kurup, N.S. and P.V. Rao 1974. Population characteristics and exploitation of the important marine prawns of Ambalapuzha, Kerala. *Indian J. Fish.,* 21: 183-211.

Kutkhun, J.H. 1966. Dynamics of a penaeid shrimp population and management implications. *U.S. Fish and Wildlife Service, Fish. Bull.,* 65: 313-338.

Kuttiyamma, V.J. 1975. Studies on the relative abundance and seasonal variation in the occurrence of the postlarvae of three species of penaeid prawn in Cochin backwaters. *Bull. Dept. Mar.Sc. Univ. Cochin,* 7(1): 213-219.

Kuttiyamma, V.J. and A. Antony 1975. Observations on the relative abundance, size variation and sex difference on the penaeid prawns in the Cochin backwaters. *Bull. Dep. Mar. Sc. Uni. Cochin,* 7(3): 503-510.

Kuttiyamma, V.J. and C.V. Kurian 1978. Prawn fishery resources in the Kayamkulam lake. *Proc. First Natl. Symp. Shrimp Farming, Bombay,* 1: 49-53.

Laney, R.W. 1981. Population dynamics of penaeid shrimp in two North Carolina tidal creeks. Doctoral dissertation. Graduate Faculty of North Carolina State University, Raleigh.

Laubier, A. 1989. The migrations of penaeid prawns. *OCEANIS (DOC. OCEANOGR.)* 15(2): 121-127.

Lazarus, S. and K. Nandakumaran 1990. Observation on the growth of *Metapenaeus dobsoni* (Miers) in the polyethylene film lined ponds at Calicut beach. *Indian J. Fish.,* 37: 31-36.

Le Cren, E.D. 1951. The length-weight relationship and seasonal cycle in gonadal weight and condition in the perch (*Perca fluviatilis*). *J. Anim. Ecol.,* 20: 201-219.

Le Reste, L. 1978. Biology d'une population de crevettes, *Penaeus indicus* H.Milne Edwards. Sur la cote nord-ouest de Madagaskar. . *Trav. Doc. ORSTOM* 99: 291 pp. (Abstract).

Le Reste, L. and J. Marcille 1976. Biologie de la crevette *Penaeus indicus* H.Milne Edwards, a Madagascar, Croissance recruitment, migration, reproduction, mortalite. *Cah. ORSTOM Ser. Oceanogr.,* 14: 109-127.

Lhome, F. 1979. Biologie et dyanamique de *Penaeus duorarum notialis* au Senegal. Partie 3 Reproduction. *Doc. Sci. CentreRech. Oceanogr. Dakar-Thiaroye,* (69): 34 pp.

Linder, M.J. and W.W. Anderson, 1956. Growth migrations, spawning and size distribution of shrimp, *Penaeus setiferus. U.S. Fish and Wildlife Serv., Fish. Bull.,* 106:553-645.

Mair, J.Mc.D. 1980. Salinity and water type preference of four species of postlarval shrimp (*Penaeus*) from west Mexico. *J Exp. Mar. Biol. Ecol.,* 45(1): 69-82.

Mair, J.Mc.D., J.L. Watkins and D.I. Williams 1982. Factors affecting the immigration of postlarval penaeid shrimps into a Mexican lagoon system. *Oceanologica Acta,* No. SP. 339-345.

Mammen, T.A. 1984. Kerala Fisheries-Brackishwater Fisheries. *Fishing Chimes,* 4: 4.

Marsoedi, and J.G. Greenwood 1990. Environmental factors influencing the distribution of penaeid shrimps in asub-tropical estuary in Queensland, Australia. *Proc. Second Asian Fish. Forum,* 2: 373-376.

Mathew, P.M., M.M. Jose, P.S. Mrithunjayan and S. Jose 1993. Cultivable prawn and fish seed resources of Cochin bar mouth area. *J. Mar. Biol. Ass. India,* 35: 87-94.

Mathew, S.S. and G.S.D. Selvaraj 1993. Size distribution and abundance of cultivable penaeid prawns in Cochin backwaters during southwest monsoon. *CMFRI Spl. Publ.,* 53:148-151.

Matylewich, M.A. and P.R. Mundy 1985. Evaluation of the relevance of some environmental factors to the estimation of migratory timings and yield for the brown shrimp of Pamlico Sound, North Carolina. *N. Am. J. Fish. manage.,* 5: 197-209.

McCoy, E.G. 1972. Dynamics of North Carolina commercial shrimp populations. *North Carolina Department of Natural and Economic Resources. Special Scientific report, 21. Raleigh.*

Menon, M.K. 1951. The life history and bionomics of an Indian penaeid prawn, *Metapenaeus dobsoni* Miers. *Proc. Indo-Pacific Fish. Counc.,* 3: 80-93.

Menon, M.K. 1954. On the paddy field prawn fishery of Travancore-Cochin and an experiment in prawn culture. *ProcIndo-Pacific Fish. Counc.*, 5: 1-5.

Menon, M. K. 1955. Notes on the bionomics and Fishery of the prawn, *Metapenaeus dobsoni* Miers on the south-west coast of India. *Indian J. Fish.*, 2: 41-56.

Menon, M.K. 1957. Contributions to the biology of penaeid prawns of the south-west coast of India. I. Sex ratio and movements. *Indian J. Fish.*, 4: 62-74.

Menon, M.K. 1980. Observations on the occurrence of penaeid postlarvae in Korapuzha estuary. *Indian J. Fish.*, 27(1-2): 236-244.

Menon, M.K. and K. Raman, 1961. Observation on the fishery of the Cochin backwaters with special reference to stake net catches. *Indian J. Fish.*, 8: 1-23.

Minello, T.J. and Zimmerman, R.J. 1984. Selection for brown shrimp, *Penaeus aztecus*, as prey by the spotted seatrout, *Cynoscion nebulosus*. *Contributions in Marine Science*, 27: 159-167.

Minello, T.J., Zimmerman, R.J. and E.X. Martinez 1987. Fish predation on juvenile brown shrimp, *Penaeus aztecus*: effect of turbidity and substratum on predation rates. *U.S. National Marine Fisheries Service. Fishery Bulletin*, 85: 59-70.

Minello, T.J., Zimmerman, R.J. and E.X. Martinez 1989. Mortality of young brown shrimp, *Penaeus aztecus* in estuarine nurseries. *Trans. Am. Fish. Soc.*, 118: 693-708.

Moffet, A.W. (1965). A study of the Texas shrimp populations. *Proj. Rep. Coast. Fish., Tex. Parks and Wild life Dept.*, (1965): 1-30.

Mohamed, K.H. 1970. Synopsis of biological data on the Indian prawn, *Penaeus indicus* (H. Milne Edwards). *FAO Fish. Rep.*, 57: 1267-1288.

Mohamed, K.H. and P.V. Rao 1971. Estuarine phase in the life history of the commercial prawns of the west coast of India. *J. Mar. Biol. Assoc. India*, 13: 149-161.

Mohamed, K.H., P.V. Rao and m.J. George 1967. Postlarvae of penaeid prawns of the south-west coast of India, with a key to their identification. *FAO Fish. Rep.*, 57 (2): 487-504.

Mohan, R., V. Selvam and J. Azariah 1995. Temporal distribution and abundance of shrimp postlarvae and juveniles in the mangroves of Muthupet, Tamilnadu, india. *Proc. Asia-Pacific Symp. Mangrove Ecosys.*, 295: 183-191.

Mohan, R. and M.S.M. Siddeek 1996. Habitat preference, distribution and growth of postlarvae, juvenile and pre-adult Indian white shrimp, *Penaeus indicus* H. Milne Edwards, in Ghubat Hasish Bay, Gulf of Masirah, Sultanate of Oman. *Fish. Manage.*

Ecol., 3 (2): 165-174.

Mrithunjayan, P.S. and D.M. Thampi 1986. Leaching of soil from the bunds as a factor responsible for the lowering of pH of water in brackishwater ponds. *Proc. Symp. Coastal Aquacult., Part IV,*: 1131-1135.

Munro, I.S.R. 1975. Biology of the banana prawn (*Penaeus merguiensis*) in the south-east corner of the Gulf of Carpentaria. In: Young, P.C. (Ed) First National Prawn Seminar, Australian Govt. Publishing Service, Canberra, P. 60-78.

Muthu, M.S. 1983. Prawn culture in Kerala. *Industrial Fisheries Association Annual, University of Cochin,* pp. 9-12

Muthu, M.S., N.N. Pillai, K.V. George and S. Lekshmi 1981. Growth of the Indian white prawn, *Penaeus indicus* in relation to stocking density. *J. Mar. Biol. Assoc. India* 23: 205-208.

Nair, P.V.R., K.J. Joseph, V.K. Balachandran and V.K. Pillai 1975. A study on the primary production in the Vembanad lake. *Bull. Dept. Mar. Sci., Univ. Cochin.*, 7(1): 161-170.

Nair, S.R.S., H.K. Iyer, C.B.L. Devi and M.K. Kutty 1982. Studies on the growth of Penaeid prawns. 1. Length-weight relationship and condition factor In *Penaeus indicus* and *Metapenaeus dobsoni* under different levels of feeding. *Mahasagar,* 15: 95-104.

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

Nair, K.K.C., V.N. Sankaranarayanan, T.C. Gopalakrishnan, T. Balasubramanian, C.B.L. Devi, P.N. Aravindakshan and M.K. Kutty 1988. Environmental conditions of some paddy cum prawn culture fields of Cochin backwaters, south-west coast of India. *Indian J. Mar. Sci.*, 7(1): 24-30.

Nasser, A.K.V. and A. Noble 1992. Economics of prawn culture in Vypeen, Kerala, with emphasis on some little known facts. *Proc. Workshop on Aquaculture economics. Special Publication 7. Asian Fish. Soc., Indian Branch,* 55-64.

Natarajan, R., Chandrasekharan, V.S. and S. Shanmugam 1986. Observation on the ingress and abundance of postlarvae of the penaeid prawn, *Penaeus indicus* in Parangipettai, India, coastal waters. *In: Biology of Benthic Marine Organisms. Techniques and Methods as Applied to the Indian Ocean.,* no. 12: 365-372.

Neal, R.A. 1968. An application of the virtual population technique to penaeid shrimp. *Proc. Annu. Conf. Southeast Assoc. Game Fish. Comm.*, 21: 264.

Panikkar, N.K. 1937. Prawn industry of the Malabar coast. *J. Bombay Nat. Hist. Soc.,* 39(2):

343-353.

Panikkar, N.K. and M.K. Menon 1956. Prawn fisheries of India. *Proc. Indo-Pacif. Fish. Counc.*, 6(3): 328-344.

Parker, J.C. 1970. Distribution of juvenile brown shrimp, *Penaeus aztecus*, growth in the northern Gulf of Mexico. *Fish. Bull. NOAA/NMFS*, 76(4): 827-837.

Parrack, M.L. 1981. Some aspects of brown shrimp exploitation in Northern Gulf of Mexico. *Proc. Workshop Scientific basis for the manage. Pen. Shrimp, Florida*, Nov. 1981. 50 pp (Mimeo).

Paulinose, V.T., T. Balasubramanian, P.N. Aravindakshan, P.G. Menon and M.K. Kutty 1981. Some aspects of prawn ecology in Cochin backwaters. *Mahasagar*, 14(2): 123-133.

Pauly, D. 1982. Studying single species dynamics in tropical multispecies context. In: *Theory and Management of Tropical Fisheries*. D. Pauly and G.I. Murphy (Eds.). Proceedings ICLARM/CSIRO *Workshop on the Theory and Management of multispecies Stocks.* 12-21 January 1981, Cronulla, Australia, P 33-70.

Pauly, D. 1983. Some simple methods for the assessment of tropical fish stocks. *FAO Fish. Tech. Pap.*, No. 234, 52pp.

Pauly, D., J. Ingles and R. Neal 1984. Application to shrimp stocks of objective methods for the estimation of growth, mortality and recruitment related parameters from length-frequency data (ELEFAN 1&2). In: Gulland, J.A. and B.J. Rothschild (Eds), Penaeid Shrimp-their Biology and Management. pp 230-234.

Pillai, V.K., K.J. Joseph and A.K.K. Nair 1975. The plankton production in the Vembanad lake and adjacent backwaters in relation to the environmental parameters. *Bull. Dept. Mar. Sci., Univ. Cochin*, 7(1): 137-150

Pillay, T.V.R 1954. The ecology of a brackishwater bheri with special reference to the fish culture practices and the biotic interactions. *Proc. Nat. Inst. Sci., India*, 20(4): 399-427.

Pinto, L. 1986. Use of ELEFAN programme for emigrating species. *ICLARM. FISHBYTE*, 4(1): 14-15.

Pullen, E.J. and W.L. Trent 1969. White shrimp emigration in relation to size, sex, temperature and salinity. *FAO Fish. Rep.*, 57(3): 1001-1014.

Purushan, K.S. 1996. Traditional methods of prawn farming in India-Different farming systems, Merits and demerits-Evaluation of production-Economics and its scope for avocation and rural development. *Seafood Export Journal*, 27(3): 11-15.

Purushan, K.S. and C.G. Rajendran 1984. Prawn production in Kerala, budding or withering

?. *Seafood Export Journal*, 16(11): 1-4.

Qasim, S.Z. and C.K. Gopinatahan 1969. Tidal cycle and environmental features of Cochin backwater, a tropical estuary. *Proc. Indian Acad. Sci.*, 69B: 336-348.

Qasim, S.Z., S. Wellerhaus, P.M.A. Bhattathiri and S.A.H. Abidi 1969. Organic production in a tropical estuary. *Proc. Indian Acad. Sci.*, 69: 51-94.

Racek, A.A. 1957. Penaeid prawn fisheries of Australia with special reference to New South Wales. *Res. Bull. State Fish. Dept., N.S.W.*, No. 3.

Racek, A.A. 1959. Prawn investigation in eastern Australia. *Res. Bull. No., 3, State Fish. N.S.W.*, (6): 57pp.

Rajyalakshmi, T. 1961. Observations on the biology and fishery of *Metapenaeus brevicornis* (M.Edw.) in the Hoobly estuarine system. *Indian J. Fish.*, 8: 383-402.

Ramakrishnaiah, M. 1979. Observation on postlarval incursion and fishery of penaeid prawns in Chilka lake. *J. Inland. Fish. Soc. India*, 11(2): 31-40.

Ramamritham, C.P. and R. Jayaraman 1963. Some aspects of the hydro-biological conditions of the backwaters around Willigton Island (Cochin). *J. Mar.Biol. Assoc. India*, 5(2): 170-177.

Ramamurthy, S., G. Annigeri and N.S. Kurup 1978. Resource assessment of the penaeid prawn, *Metapenaeus dobsoni* (Miers) along the Mangalore coast. *Indian J. Fish.*, 25: 52-66.

Raman, K. and M.K. Menon 1963. A preliminary note on experiment in paddy field prawn fishery. *Indian J. Fish.*, 10: 33-39.

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

Rao, G.S. 1994. Mortality rates and stock assessment of *Metapenaeus monoceros* along the Kakinada coast. *J. Mar. Biol. Assoc. India*, 36: 1-18.

Rao, G.S. and Krishnamoorthy, 1990. Age and growth of *Metapenaeus monoceros* (Fabricius) along the Kakinadacoast. *J. Mar. Biol. Assoc. India*, 32: 154-161.

Rao, K.J. and C. Krishnayya 1974. Penaeid prawn catches from the Pulicat lake in relation to ingress of postlarvae and lake in relation to lake hydrography. *Indian J. Fish.*, 21(2): 445-453.

Rao, P.V. 1972. Seasonal abundance of larvae and postlarvae of the commercially important penaeid prawns in the inshore waters of Cochin. *Indian J. Fish.*, 19: 86-96.

Rao, P.V. and M. Kathirvel 1973. On the breeding of penaeid prawn, *Metapenaeus dobsoni* in the brackish water medium. *Indian J. Fish.,* 20(1): 228-230.

Rodriguez, A. 1987. Biology of shrimp, *Penaeus kerathuruz* (Forskal, 1775) from Gulf of Cadiz. 3. Biometry age and growth. *Invest. Persq. (Barc.),* 51 (1): 23-37.

Roessler, M.A., A.C. Jones and J.L. Munro 1969. Larval and postlarval penaeid shrimp, *Penaeus duorarum*, south Florida. *FAO Fish. rep.,* 57(3): 859-866.

Rothlisberg, P.C., Staples D.J. and P.J. Cocoss 1985. A review of the life history of the banana prawn, *Penaeus merguiensis* in the Gulf of Carpentaria. In' Second Australian National Prawn Seminar. (Eds. P.C. Rothlisberg, B.J. Hill and D.J. Staples) pp.125-136.

Rothschild, B.J. and S.L. Brunenmeister 1984. The dynamics and management of shrimp in the northern gulf of mexico. In: Gulland, J.A. and B.J. Rothschild (Eds), Penaeid shrimp- their biology and management. pp 145-172.

Ruello, N.V. 1973. The influence of rainfall on the distribution and abundance of the school prawn, *Metapenaeus macleayi* in the Hunter river region (Australia). *Mar. Biol.,* 23: 221-228.

Sampandam, K.P., L. Lawrence and J. Noble 1982. Some observations on penaeid prawn seed resources in the Vellar estuarine system, (Porto novo). *Proc. Symp. Coast Aquacult.,* Part 1: 308-311.

Sankaranarayanan, V.N., S. Kumaran, T. Balasubramanian, S. Rosamma and S.U. Panampunnayil 1982. Studies on the environmental conditions of tidal ponds in the Ramanthuruthu Island (Cochin). *Proc. Symp. Coastal Aquacult., Part I: Prawn Cult.,* 1: 362-368.

Sathiadas, R., K.K.P. Panikkar, U.K. Satyavan and T. Jacob 1989. Economic evaluation of paddy-prawn integrated farming in Kerala. *Seafood Export J.,* 21(11): 9-21.

Signoret, M. 1972. Ecological researches and distribution of the penaeid shrimps of the Lagoon de Terminos, Campeche (Mexico) during one year. *Sci. de la Mer. et de I- Environment.*

Silas E.G., M.S. Muthu, N.N. Pillai and K.V. George 1982. Breeding of the marine prawn, *Metapenaeus dobsoni* in brackishwater ponds. *J. Mar. Biol. Assoc. India,* 24(1-2): 147-149.

Snedecor, G.W. and W.G. Cochran 1967. Statistical Methods. Oxford and IBH Publishing Co., New Delhi, 593 pp.

Sparre, P. 1986. Introduction to tropical fish stock assessment. *FAO/DANIDA Project, Training in Fish Stock Assessment,* (I-III Edition).

Sriraman, K.S., S. Ajmalkhan and R. Natarjan 1987. Age and growth of *Penaeus indicus*

Milne Edwards of Porto Novo Coast. *Proc. Natl. Sem. Est. Manag.*, Trivandrum (1987), pp. 377-378.

St. Amant, L.S., G.L. Broom and T.B. Ford 1965. Studies of the brown shrimp, *Penaeus aztecus*, in Barataria Bay, Louisiana, 1962-65. *Proc. Gulf. Caribb. Fish Inst.*, 18: 1-16

St. Amant, L.S., K.C. Corkum and J.G. Broom 1963. Studies on the growth dynamics of the brown shrimp, *Penaeus aztecus*, in Louisiana waters. *Proc. Gulf. Caribb. Fish Inst.*, 15: 14-26.

Staples, D.J. 1979. Seasonal migration pattern of postlarval and juvenile banana prawns, *Penaeus merguiensis* de Man in the major rivers of the Gulf of Carpentaria, Australia. *Aust. J. Mar. Freshwat. Res.*, 30: 143-157.

Staples, D.J. 1980a. Ecology of juvenile and adolescent bananaprawns, *Penaeus merguiensis* in a mangrove estuary and adjacent offshore areas of the Gulf of Carpentaria. I. Immigration and settlement of postlarvae. *Aust. J. Mar. Freshwat. Res.*, 31: 635-652.

Staples, D.J. 1980b. Ecology of juvenile and adolescent banana prawns, *Penaeus merguiensis* in a mangrove estuary and adjacent offshore areas of the Gulf of Carpentaria. II. Emigration, population structure and growth of juveniles. *Aust. J. Mar. Freshwat. Res.*, 31: 653-665.

Staples, D.J. 1983. Habitat requirements of juvenile prawns. In the *Potential of Aquaculture in Queensland.* Pollock, B.R. and R.H. Quinn (eds.) pp. 87-102.

Staples, D.J. and D.J. Vance 1985. Short term and long term influences on the immigration of postlarval banana prawns *Penaeus merguiensis* into mangrove estuary of the Gulf of Carpentaria, Australia. *Mar. Ecol. Prog. Ser.*, 23: 15-29.

Staples, D.J. and D J. Vance 1986. Emigration of juvenile banana prawn *Penaeus merguiensis* from a mangrove estuary and recruitment to offshore areas in the wet dry tropics of the Gulf of Carpentaria, Australia. *Mar. Ecol. Prog. Ser.*, 27: 239-252.

Staples, D.J. and D.J. Vance 1987. Comparative recruitment of the banana prawn *Penaeus merguiensis* in five estuaries of the south-eastern Gulf of Carpentaria, Australia. *Aust. J. Mar. Freshwat. Res.*, 38: 29-45.

Strickland, J.D.H. and T.R. Parson 1972. A practical handbook of sea water analysis. *Fish. Res. Bd. Canada*, 167: 311pp.

Subrahmanyam, M. 1964. Fluctuations in prawn landings in the Godavari estuarine system. *Proc. Indo-Pacif. Fish. Counc. 11th Sess., C/70/Sym.* 36:1-12.

Subrahmanyam, M. 1965. Lunar, diurnal and tidal periodicity in relation to prawn abundance and migration in Godavari estuarine systems. *Fish. Tech.*, 2(1): 26-41.

Subrahmanyam, M. 1966. Fluctuations in prawn landings. in the Godavari estuarine system. *Proc. IPFC,* 11: 44-51.

Subrahmanyam, M. 1967. Further observations on the lunar periodicity in relation to the prawn abundance in the Godavari estuarine system. *J. Mar. Biol. Assoc. India.,* 9: 111-115.

Subrahmanyam, M. 1968. Preliminary observations on age and growth in *Penaeus indicus* from Ennur and Adayar estuaries. *Indian J. Vet. Sci.,* 38(4): 764-767.

Subrahmanyam, M. 1972. Growth in the Indian prawn,*Penaeus indicus* and possibility of its culture in the Godavari estuarine system. *Seafood Export Journal,* 4(11): 9-10.

Subrahmanyam, M. 1973. Fishery and biology of *Metapenaeus monoceros* from the Godavari estuarine system *Indian J. Fish.,* 20: 95-107.

Subrahmanyam, M. and P.N. Ganapati 1971. Observations on the postlarval prawns from the Godavari estuarine system with a note on their role in capture and culture fisheries. *J. Mar. Biol. Assoc. India,* 13(2): 195-202.

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

Subrahmanyam, M. and K.J. Rao 1968. Observations on the postlarval prawns (Penaeidae) in the Pulicat lake with notes on their utilization in capture and culture fisheries. *Proc. Indo-Pacific Fish. counc.,* 13: 113-127.

Sultan, K.M.M., R. Soundararaj and T. Franklin 1973. Shrimp culture made easy. *Proc. Sem. Maricult. Mechan. Fish., Madras* (1972) pp. 103-104.

Suseelan, C. 1975a. The prawn culture practices in salt-pan reservoirs at Manakkudy, near Cape Comerin. *Bull. Dept. Mar. Sci. Univ. Cochin.* 7: 477-486.

Suseelan, C. 1975b. Resource and exploitation of juvenile penaeid prawn from Manakkudy estuary. *Indian J. Fish.,* 22: 96-106.

Suseelan, C and M. Kathirvel 1982. A study on the prawns of Ashtamudi backwaters in Kerala with special reference to penaeids. *Indian J. Fish.,* 29: 71-78.

Suseelan, C and M. Kathirvel 1982. Prawn seed calenders of Cochin backwaters. *Proc. Symp. Coastal Aquacult.,* Part 1: 173-182.

Sutter, F.C.III. and J.Y. Christmas 1983. Multilinear models for the prediction of brown shrimp harvest in Mississippi waters. *Gulf Research Reports.* 7: 205-210.

Tabb, D.C., D.L. Dubrow and A.E. Jones 1962. Studies on the biology of the pink shrimp,

G 8216

Penaeus duorarum (Burk), in Everglades National park, Florida. *Tech. Ser. Fla. Board Conserv., Mar. Lab. Univ. Miami,* 37 (Abstract)

Thampi, D.M., M.J. Sebastian, E.A. Suseela and C.J. Rajendran 1982. Relative abundance and distribution of the postlarvae and juveniles of *Penaeus monodon* Fabricius in the Cochin backwaters and the prospects of their utilization in culture fisheries. *Proc. Symp. Coastal Aquacult.,* Part 1: 223-228.

Thomas, M.M. 1977. Age, growth, length-weight relationship and relative condition factor of *Penaeus semisulcatus* De Han. *Indian J. Fish.,* 22: 133-142.

Vance, D.J., M.D.E. Haywood, D.S. Heales and S.J. Staples 1996. Seasonal and annual variation in the abundance of postlarval and juvenile grooved tiger prawn, *Penaeus semisulcatus* and environmental variation in the Embley River, Australia, a six year study. *Mar. Ecol. Prog. Ser.* 13: (1/3):43-55.

Vasudevappa, C. 1992. Growth and reproduction of the penaeid prawn, *Metapenaeus dobsoni* (Miers) in brackishwater environment. *Ph.D. Thesis (Submitted to the Cochin Univ. Sci. Tech.),* 316pp.

Venegas, J.L.G. 1980. Observations on shrimp filtrations in trapping systems at "El Puyegue" Chametla, south Sinaloa, Mexico. *Dept. Pesca, Mexico city (Mexico).* 1: 1519 1541.

Vijayaraghavan, S. and S. Wafar 1983. Further studies in using mangrove foliage as a prawn feed. *Mahasagar,* 16: 309-316.

Walford, L.A. 1936. A new graphic method of describing the growth of animals. *Biol. Bull.,* 90: 141-147.

Wang, X. 1995. Tidal fonts and their influence on prawn postlarvae immigration in Albatros Bay, The Gulf of Carpentaria, Australia. *Chin. J. Oceanol. Limnol.,* 13(2): 147-154.

Yokel, B.I., Iverson, E.S. and C.P. Idyll 1969. Prediction of the success of commercial shrimp fishing on the Tortugas grounds, based on enumeration of emigration of emigrants from the Everglade National Park estuary. *FAO Fish. Rep.,* 57: 1027-1040.

Young, P.C. and S.M. Carpenter 1977. Recruitment of postlarve penaeid prawns to nursery areas in Morten Bay, Queensland. *Aust. J. Mar. Freshwat. Res.,* 28: 745-773.

Zein-Eldin, Z.P. and D.V. Aldrich, 1965. Growth and survival of *penaeus aztecus* under controlled condition of temperature and salinity. *Biol. Bull., Mar. Biol. Lab. Woods Hole.* 129: 199-216.