"STUDIES ON CERTAIN ASPECTS OF ECOLOGY AND BIOLOGY OF TWO PALAEMONID PRAWNS, *Macrobrachium hendersoni hendersoni* (de Man) AND *Macrobrachium hendersoni cacharensis* (Tiwari)"

by

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ADDENDUM

to the Thesis
submitted in fulfilment of the requirements of the
degree of
DOCTOR OF PHILOSOPHY

to the
NORTH-EASTERN HILL UNIVERSITY
SHILLONG 793014, INDIA

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CERTIFICATE

I certify that the present ADDENDUM of the Thesis entitled "Studies on certain aspects of ecology and biology of two palaemonid prawns, *Macrobrachium hendersoni hendersoni* (de Man) and *Macrobrachium hendersoni cacharensis* (Tiwari)" submitted by Shri Nani Gopal Goswami embodies the record of original investigation carried out by him under my supervision.

A. R. Varman

Dated 19th March, 1985
Place: Shillong

Signature of the Supervisor

EXPLANATIONS ON THE "GENERAL COMMENT"

Regarding the statement "His preface and introduction .... neither is carried through".

It is true that in the 'Preface' and 'General Introduction,' fishery management and aquaculture potential are dealt with, but the idea of presenting such information was only to provide the necessary background for the present work. In this context the statement that the Thesis is open ended with unclear objectives is not justified since both in the preface (Page i) and in the general introduction (Page 1) there is a clear mention of what the present Thesis contains based on what has been done.

The criticism on the calculation of correlation coefficient is explained as below.

The purpose of such statistical calculations were to establish relationships only, and <u>not</u> for the erection of any a-posteriori hypothesis.

It is admitted that there are lacunae in the methods as presented in the Thesis. However, these lacunae do not refer to the methods employed <u>per se</u>, but only rather to their descriptions that were inadequate in details. This omission further happened because of the very simple nature of most methods employed in this study. However, the detailed descriptions of these methods are provided in the present Addendum.

The criticism by the examiner that "I am unable to find much innovative work in ..... of Macrobrachium" needs an explanation.

It may be pointed out that the present work is the first of its kind in the following respects:

i) The thesis deals with the ecology and biology of two endemic prawn species that are confined only to this part of India.

ii) The present work relates to the prawn fauna of altitudinal streams.

iii) While a great deal of information is available on Indian marine prawn species from a populational and fishery points of view, the present thesis employed an ecosystem approach for the study of the fresh water prawn species.

The above views are further augmented by the commendation of the present work by the other external examiner who is one of the current Indian experts. This examiner stated that "I am well aware that it is a first study of this kind in India from a lotic environment, from hill streams at high altitudes, of species which have become totally adapted to freshwaters throughout their life cycle and also with populations of such magnitude as to contribute, may be seasonally, to the commercial catches of these regions".

EXPLANATIONS ON THE "DETAILED COMMENT"

The General Introduction was considered too long. Accordingly, the distantly related topics like Review on Marine Works and Aquaculture have been omitted and revised as below.

1. General Introduction

Prawns have great significance in the life of mankind, being an important natural source of protein (Menu-Merqua and Morales, 1974) and providing certain other useful products (Sakthivel, 1976). In view of the ever increasing demand for shrimps both for local consumption and for export purposes, the Indian prawns have attracted the attention from a rapidly developing fishing industry as well as from biologists for scientific study. But most of the notable works in India include only the marine species.

Tiwari (1955) reported the taxonomy of more than 34 species of freshwater prawn of the genus Macrobrachium from Indian inland waters, inclusive of both lotic and lentic systems. But till now, the information available does not cover the biology of all these reported species. However, in the recent years, several Indian workers have contributed to a considerable amount of information on various aspects of selected freshwater species (Rajyalakshmi, 1961, 1966, 1980, a, b; Ibrahim, 1962; Raman, 1964; Pillai, 1965; Subrahmanyam, 1966; Gupta, 1967; Nagabhushanam and Vasantha, 1967, 1968;

Pandey, 1967; Rao, 1967; Tyagi and Prakash, 1967; Koshy, 1969, 1973; Nagabhushanam and Chinnayya, 1968; Rajyalakshmi et al., 1968; Rajyalakshmi and Ranadhir, 1969, 1974; Rasalan et al., 1969; Tiwari and Pillai, 1971; Pillai and Mohamed, 1973; Jalihal and Sankolli, 1975; Goswami et al., 1977; Katre, 1976; Katre and Reddy, 1977; Nagabhushanam and Jyoti, 1977; Murthy, 1978; Sharma and Tiwari, 1978; Ghate and Mulherkar, 1979; Nagabhushanam and Kulkarni, 1979, 1981; Sukumaran and Kutty, 1979; Murthy and Saxena, 1980; Anantharaman et al., 1981; Rao et al., 1981; Saxena and Murthy, 1981, 1982).

It is common knowledge that in order to understand the bionomics of locally available species, investigations on the basic ecology and biology of different species become imperative. Most of the investigations today take into account these view points depending upon the particular need of a region, state or even a country. As such a vast amount of literature on few selected freshwater prawns has accumulated over the years in different parts of the world (Schmitt, 1933; Gunter, 1937; Mori, 1939; Hedgneth, 1949; Holthuis, 1949; Riek, 1951; Maglhaes and Pintu, 1959; Parry, 1961; Johnson, 1963, 1966, 1967, 1968, 1973; Tobia, 1964; Lewis and Ward, 1965; Costa, 1966a, b, 1970; Lewis et al., 1966; Mistakidis, 1966; Carrillo, 1967; Antheunisse et al., 1968; Costlow, 1968; De La Cruz, 1968; Denne, 1968; Apollonio, 1969; Kwon and Uno, 1969; Choudhury, 1970; Chung, 1970; Fielder, 1970; Fujimura and Okamoto, 1970; Holthuis and Provenzano, 1970; Bailey and Crichton, 1971; Kamiguchi, 1972a, b; Yu and Mijake, 1972; Fujeno and Baba, 1973; Ruello *et al.*, 1973; Stoffel and Huschman, 1974; Wickins and Beard, 1974; Fielder *et al.*, 1975; McVey, 1975; Sandifer *et al.*, 1975; Ngoc-Ho, 1976; Martin, 1976; Thebault and Le Gal, 1978; Lee and Fielder, 1979, 1981, 1982a, b, 1983; Mcbride and Muguire, 1979; Beard and Wickins, 1980; Peebles, 1980; Yasuda and Kitoa, 1980; Fair and Fortner, 1981).

Keeping these in view, studies on certain aspects of the ecology and biology of two palaemonid prawns, *Macrobrachium hendersoni hendersoni* (de Man) and *Macrobrachium hendersoni cacharensis* (Tiwari) from the East Khasi Hills of Meghalaya, India, were undertaken. The present study includes the habitat structure, limnological parameters, population dynamics and their relationships. Other detailed biological studies include sexual dimorphism, maturation and spawning, brood size and reproductive efforts, larval development, food and feeding habits, digestive physiology and neuro-endocrine regulation of blood chloride.

Continuation of Explanations on other Comments

2. Study Area

- In page 27 of the Thesis Table 1 is given. Kindly read this Table 1 after the text explained in page 29.
- The recording of vegetational data using symbols (*, -, +, ++, +++) was followed after the quadrat method (Misra, 1968).
- All the species listed in Table 1 (Page 27) as macro-vegetation are terrestrial flora and as such only indirectly influence the functioning of the stream ecosystems.
- The overall criteria for selecting the study area was given in page 19 and this may kindly be referred. The criteria for choosing the sampling stations (A_1, A_2, A_3, B_1, B_2 and B_3) were detailed from page 29, of which the following two criteria were most prominent.
  - i) These were the perennial portion of the streams which could be sampled throughout the year by standard stream benthos techniques
  - ii) These stations were also found to have relatively adequate prawn populations.

- Regarding the sampling stations, detailed description on depth of water and width of stream at each station were not provided as these parameters were always variable during the annual cycle. However, some of the available data for a particular month (July 1980) is provided below.

The depth of the stations A_1, A_2, A_3, B_1, B_2 and B_3 were 0.60 m, 0.75 m, 0.80 m, 0.82 m, 1.0 m and 1.15 m while the width of the stations A_1, A_2, A_3, B_1, B_2 and B_3 were 8.0 m, 9.2 m, 6.5 m, 6.1 m, 7.2 m and 7.0 m respectively.

- <u>Description of Sampling Sites</u>: Though the sampling stations are described in detail commencing from page 29 of the Thesis (Section 2.8, Sampling Sites), it needs further clarity in the context of the querries raised.

Each sampling station (e.g. A_1, A_2, A_3, B_1, B_2 and B_3) covered a stretch of stream length. Thus, stations A_1, A_2, A_3, B_1, B_2 and B_3 were 18.0 m, 20.5 m, 25.0 m, 20.0 m, 18.0 m and 24.0 m long respectively.

- Page 29: Unit of Length: Please read 18.3 m instead of 60 ft.

3. Material and Methods

The descriptions of the methodology was considered to be inadequate. Accordingly details of the methods used are provided with a view to clarify the ambiguities.

3.1.1. Physico-chemical analysis:

Water samples for physico-chemical analysis were collected usually in the forenoon between 1000-1200 hrs and always at a distance of a metre away from the margin of the streams. Since the depth is a variable factor at each of the sampling stations, samples were always collected from close to the bottom to a height equivalent to the mouth diameter of a plastic bucket of 10-litre capacity. Such samples were obtained at monthly intervals for a period of two years from January 1979 to December 1980. Immediately after collection, each sample was passed through a 0.45 μ filter (Crowther and Hynes, 1977) and stored in a 500 ml plastic bottle. Various parameters were analysed and estimated on the same day.

In addition to the air and water temperature readings measured in the field using a mercury bulb thermometer, maximum and minimum air temperatures, relative humidity, rainfall and wind velocity of the area under study were collected regularly from the local metereological stations located close to the study areas. The metereological data were primarily collected to infer the overall influence on the study areas in addition to the specific parameters that were measured in each of the streams.

Turbidity was expressed as percentage volume of total suspended matter, transparency as Secchi disc readings (Welch, 1948) and the rate of water flow in cm^3/sec by using a metre tape, stop watch and a simple cork (Leitritz, 1959). pH and conductivity were measured with the use of a Toshniwal pH meter (Model CAT.CL-43) and Elico-conductivity bridge (Type CM-82) and the values expressed as pH units and µmhos/cm respectively.

For oxygen estimation, samples were taken directly from the bottom of the stream in glass bottles of 125 ml capacity and the dissolved oxygen fixed immediately. While sampling, care was taken not to disturb the bottom and air bubbles avoided. Modified Winkler's method (APHA, 1965) was employed for the oxygen estimation. Carbon dioxide content was determined using phenolphthalein indicator and N/44 NaOH, while total alkalinity was measured by using the Standard method (APHA, 1965). Nitrate Nitrogen was estimated by using phenol disulphonic acid method and Ammonia Nitrogen by Nessler's reagent method (Mackereth, 1963). Phosphate Phosphorus was determined by stannous chloride and molybdate method and chloride by Silver nitrate titration technique (APHA, 1965). Calcium and magnesium were estimated spectrophotometrically. Sodium and potassium ions were estimated by Flame photometry and oxidisable organic matter by Permanganate method. Silicate content was measured by Silico-molybdate method and total iron content by using the method after Mackereth (1963).

3.1.2. Phyto- and Zooplankton

The water samples for plankton analysis were collected from the same sites using the same procedures as for physico-chemical analysis. At each station, samples were collected in triplicate at monthly intervals for a period of two years (January, 1979 to December, 1980). Water sample was collected from the bottom by the 10-litre plastic bucket facing upstream. Each sample consisted of five buckets making up a total of 50 litres of water. The water thus collected was poured through a plankton net made of No. 25 xxx nylon bolting silk (60 μ mesh size). Finally, the actual sample of plankton and water was reduced to 50 ml of water and preserved by adding a few drops of Lugol's iodine. A Sedgwick rafter plankton counting cell of 1 ml capacity was used, having 1000 squares marked on its bottom (Utermohl, 1958). After a thorough stirring of the sample, one ml sub-sample was taken in the counting cell. Nine such sub-samples (three from each of the triplicate samples) were counted for the estimation of diversity and density of each group of plankton. However, for each sub-sample only 100 squares were counted. The average of these 100 counts for all the nine sub-samples were calculated and these values multiplied by a factor of 10 to make up for the 1000 squares. From this, the computation of the numbers of phyto- and Zooplankton per litre at different stations of the two streams was done by using the formula:

$$n = \left(\frac{a \times 1000}{l}\right) \times c$$

where, n = number of plankton/l of original water.

a = average number of plankton in all counts in the Sedgwick rafter cell.

c = volume of original concentration in ml.

l = volume of original water expressed in litre.

The data were presented in terms of percentage composition of the respective planktonic group.

The generic identification of phyto- and Zooplankton was done with the help of monographs after Smith (1950), Pennak (1953), Edmondson (1959) and Needham and Needham (1962).

General Clarification on the Comments Regarding Section 3.1.1. (Benthic organisms) and Section 3.2 (PRAWN POPULATION STUDY)

The author accepts the comments on the above items gratefully and offers clarity and explanation as given below. These explanations have also necessitated the change in the order of sequence. Thus Section 3.2 on prawn population study is presented first followed by Section 3.1.3. on benthic organisms. This is necessary since the sampling techniques of both these groups involved the same sampler.

3.2. PRAWN POPULATION STUDY

In the present study for the purpose of population analysis, prawns were collected at monthly intervals for the period January 1979 to December 1980. Animals were collected from five sites within each sampling station. The sampler used had a wrought iron frame of one metre square (length x breadth : 1.0 m x 1.0 m) and a height of 1.5 m. The top and the bottom of this box sampler were open, while three of its sides were covered with wire netting of 3.2 mm mesh size. The fourth side was fitted with a removable cloth net of similar mesh size with its tail end extending 1.5 m. length. This side of the sampler always faced opposite to the direction of the current. In actual sampling, the sampler was first firmly inserted on to the substratum thus enclosing an area of one square metre of stream bottom. Initially, all the prawns in the overlying water were scooped out by a hand net, while most others were collecting at the tail end of the cloth net. Further, in order to ensure effective sampling, all the boulders, pebbles on the substratum were also mannally disturbed with a view to dislodge the remaining animals.

All animals from the five sites in each station were pooled which comprised a single population sample. The animals were fixed in the field with 5% formalin and brought to the laboratory. The organisms in each sample were then measured and grouped into size categories and sexed. The population density was calculated per square metre of bottom by taking the mean of the total of the five sites in each Station, while the entire sample was used to estimate the sex ratio and length frequency measurements. The berried condition of females were also noted to distinguish the ovigerous from the non-ovigerous individuals.

Having explained the sampling procedure, it is necessary also to explain the discrepancies in Figs. 34-39 as pointed out by the examiner. The N values given in each of the figures (Figs. No. 34-39) refer only to the population density/m^2 while the actual histograms for the length frequency distribution were based on the entire sample from all the five sites in each station. The author regrets for having given the N values in the figures which represents the values per m^2 only without clarifying the above differences.

3.1.3. Benthic Organisms

Benthic samples were collected at monthly intervals for two year period (January 1979 to December 1980). The sampling stations in both streams and the five sites within each station were the same as for the prawn population study. However, in view of the anticipated diminutive size of most benthic organisms, a special dip net of 135 µ mesh size was employed. The net was placed within the box sampler referred earlier in Section 3.2 and most of the organisms in the various stones, pebbles and boulders were dislodged and caught by kicking and raking up the stream bottom.

Each sample thus obtained represents one square metre of the stream bottom. This method may be considered as a further modification of the modified kick sampling method of William and Hynes (1976). The animals collected were then fixed in 5% formalin. In the laboratory, the different groups of benthos were sorted out, counted and their percentage composition computed. Organisms were identified only upto genera wherever possible with the help of treatises of Pennak (1953), Edmondson (1959) and Needham and Needham (1962).

3.1.4. Vertebrate Fauna

The source of material for this study were mostly from the catches of the fishermen, while direct physical observations were always made to supplement the data. The collected material were fixed in 10% formalin and stored in 70% ethanol after the methods followed by Williams and Coad (1979). Preserved fishes were identified using the key in Day (1978), Hora (1951), Hubbs and Lagler (1964) and Scott and Crossman (1973).

3.3.1. Accessory Habitat Analysis

A number of depressions or in other words 'Supplementary habitats' were located adjacent to both the Umshing and Pongtung main streams. The length of the major axis, minor axis and depth of the depressions were measured with a metre tape. The analysis of their physico-chemical and biological properties were done by employing the same procedures as for the streams though no detailed graphs were presented to express the data. Also, no attempt was made to establish detailed correlations between the abiotic and prawn populations as in the case of the streams.

3.3.2. Condition Factor

Individual variations in length-weight relationships have been used to determine the "condition" (Le Cren, 1951). Such factors like 'condition', condition factor or Ponderal index have been calculated by using different formulae by various workers. However, in the present study, the 'condition factor' has been determined by using the following formula (Hile, 1936; Beckman, 1948):

$$K = \frac{W \times 10^5}{L^3}$$

where $\underline{K}$ = condition factor; $\underline{W}$ = dry weight of the prawn; and $\underline{L}$ = length of the prawn. The number 10^5 is a factor to bring the Ponderal index (K) to near unity (Carlander, 1970).

The examiner has questioned the validity of estimating the condition factor, while suggesting that it may be meaningful if dry weights of the animals are used for calculation. The author has omitted adding the word 'dry' in explaining the formula, whereas only dry weight was used in actual calculations. This omission is regretted. It is also true that apart from the present author, an earlier worker had determined the condition factors in another species of Macrobrachium (Rao, R.M. 1967. Studies on the biology of Macrobrachium rosenbergii (de Man) of the Hooghly estuary with notes on its fishery. Proc. Nat. Inst. Sci., Vol. 33(B), No. 5 & 6, 252-279).

4. Results

4.1.1. Physico-chemical analysis

Regarding the general comments by the examiner expressing concern about most of the physico-chemical analyses, a completely revised chapter on these aspects as provided above may kindly be referred.

4.1.2a. Phytoplankton

In page 58 of the Thesis (bottom 2 lines) it was reported that there is a distinct summer maxima and winter minima in all stations, while the examiner has inadvertently quoted "a distinct-summer minima".

Figs. 28-29 were given only as percentages, in order to give an over view of the phytoplankton composition, though the actual numbers are available with the author and are herewith presented in Annexure I. Further, the total phytoplankton data were used elsewhere (Table 13-18) when computing regression equations along with the prawn population data. A similar treatment of the data on Zooplankton and benthos was followed and their actual numbers are also appended in Annexure I.

4.1.2b. Zooplankton

The detailed description of sampling procedures given in Section 3.1.2 shows that the plankton sampling was done close to the bottom of the stream. Therefore, the occurrence of organisms like *Difflugia* and *Vorticella* could be explained as having originated from the bottom or from associated vegetation.

4.2.1. Seasonal fluctuation

- Comments refer mostly to correlations, although this aspect was not dealt with under this Section of the Thesis. Nevertheless, as pointed out at the very beginning of this Addendum (Page 1) correlations were worked out only to find out the degree of relationships among the various parameters and nothing more.
- Prawns of less than 20 mm length were never recorded at the sampling stations per se, though considerable numbers were caught in accessory habitats (please refer Fig. 41).

4.2.3. Length frequency distribution

Please refer to explanations provided under Section 3.2.

4.3.1. Accessory habitat analysis

During the rainy season (June-July), the depressions are filled with water from the main stream and serve as suitable places for the prawns to breed. As compared to males, the number of mature and berried females were always found to be higher in these habitats. During September, prawns less than 20 mm size occurred abundantly in these depressions (Fig. 41). This clearly shows that these depressions do serve as convenient places for egg laying and hatching of larvae. It was also observed that most of the juveniles were restless and had a tendency to escape out of these depressions. This probably indicates that most of the prawns ultimately swim back to the main stream when they reach 20 mm or more, before the drought actually sets in. As an evidence it may be mentioned that the author has noticed the streamward migration of juveniles on several occasions.

4.3.2. Condition factor

This aspect has already been explained in Section 3.3.2.

5. Discussion

The general criticism on the 'correlations' had already been explained earlier (Page 1) as to justify the need to establish relationship only.

2.1. Sexual dimorphism

The method for measurements of total length and carapace length was followed after the standard work of Truesdale and Mermilloid (1979) on Macrobrachium ohione (Smith) as it was felt adequate for the present study.

2.2. Maturation and spawning

Individuals of size frequency from 35.0 mm to 55.0 mm in *Macrobrachium hendersoni hendersoni* (de Man) and size range of 35.0 to 50.0 mm of *M. hendersoni aoharensis* (Tiwari) were used for calculating Gonad Index (GI) (Table 23). Animals in post breeding phase (Table 24) were never included in the above analysis.

2.5. Food and feeding habits

For calculation of Gastrosomatic Index (GSI), the whole gut was always used by dissecting out, whereas for the quantitative analysis of the food, only the foregut contents were considered. Such measurements were also employed by earlier workers (Venkatamaman, 1960; Marte, 1980).

2.6. Digestive physiology

pH indicator paper was always used to directly measure in all parts of the alimentary canal. However, some of these readings were confirmed and verified by a sophisticated pH meter with a very tiny electrode. Even in these cases, the washings of parts of the gut were only minimal just to remove the food particles if any.

4.6. Digestive physiology

The reference to appendages as parts of the alimentary canal was included unfortunately during typing and this error was overlooked. The author acknowledges this mistake. At the same time the lack of including the terms 'mouth' and 'oesophagus' may also be condoned as a gross omission.

Addendum: Dissolved Oxygen (Fig. 12)

The author is aware of the significance of dissolved oxygen fluctuations and the contributing factors as discussed in detail from page 130 to 131. However, the apparent supersaturated values in Fig. 12 could be due to any of the causative factors and difficult to pinpoint precisely. On re-examining the raw data, it is found that the June to September period was also the time of phytoplankton maxima (Annexure I). In addition to this, June to September period is also the high rainfall season with maximum flow rate. It is likely that anyone of the above causes could be attributed to the supersaturated condition, since precautionary measures were always taken while sampling for dissolved oxygen.

Finally, regarding the suggestion of the examiner to include an analytical section on the "recommendation for management or aquaculture", it may be pointed out that the main objective of this work was only to gather basic and fundamental data that may be of eventual use for aquacultural and management practices. Therefore the author feels reluctant at this stage to offer any recommendations which may sound far-fetched. Such recommendations are also unwarranted in view of the limited scope of the Title of the present Thesis. Nevertheless, ample discussions are provided for both sections of the Thesis and relationships established for the factors studied.

Please refer to the Thesis for all the literature cited in this Addendum.

ANNEXURE I

Data showing the total phytoplankton (unit/l), total zooplankton (unit/l) and total benthic organism (unit/m^2) at different staions.

Month	Station A_1			Station A_2			Station A_3			Station B_1			Station B_2			Station B_3		
	TP	TZ	TB	TP	TZ	TB	TP	TZ	TB	TP	TZ	TB	TP	TZ	TB	TP	TZ	TB
Jan. 1979	105	55	50	100	30	56	215	38	60	210	85	58	220	70	72	220	74	84
Feb.	80	25	76	88	22	76	185	24	46	375	40	82	340	35	100	350	34	104
Mar.	310	68	49	405	70	106	240	74	75	315	86	96	425	78	138	440	76	136
Apr.	206	110	115	210	115	108	320	120	96	425	150	120	460	144	150	480	130	150
May	300	52	94	310	56	100	410	58	114	540	68	104	625	60	138	640	62	158
Jun.	425	64	96	440	66	102	240	68	50	360	58	154	360	54	86	365	50	156
Jul.	410	58	90	420	62	92	360	63	72	410	60	142	380	58	90	390	55	124
Aug.	440	50	118	450	56	130	410	55	94	440	46	200	420	42	172	425	40	258
Sep.	320	48	142	330	52	144	450	51	114	580	48	140	440	45	174	450	44	66
Oct.	540	58	80	556	62	96	590	64	98	650	78	136	640	74	62	650	74	86
Nov.	290	48	120	310	58	108	390	60	56	410	65	138	440	66	70	452	69	138
Dec.	120	50	58	140	52	78	250	58	48	318	50	106	280	48	66	290	60	146
Jan. 1980	110	54	56	190	31	54	220	31	72	215	86	60	220	68	55	235	68	82
Feb.	82	26	80	90	24	78	180	22	64	382	42	78	210	34	64	348	32	104
Mar.	315	69	104	410	72	100	244	68	84	314	90	102	342	77	70	432	72	144
Apr.	210	112	118	208	120	134	330	110	142	440	152	114	420	142	66	475	125	148
May	298	58	102	315	60	116	420	48	154	546	70	106	555	58	70	638	60	146
Jun.	428	66	100	446	68	114	250	59	98	364	60	134	342	56	130	470	48	144
Jul.	412	57	98	418	64	106	367	60	120	425	62	132	364	62	106	380	52	132
Aug.	450	52	130	460	60	128	425	54	144	430	50	208	385	40	112	440	41	258
Sep.	340	50	156	328	50	142	460	48	168	572	52	220	415	45	198	450	48	216
Oct.	550	56	82	570	62	96	600	61	138	585	82	134	630	70	90	584	76	100
Nov.	300	70	120	320	72	126	392	80	114	424	60	132	432	56	118	378	60	134
Dec.	115	65	76	150	60	90	305	58	86	320	36	102	250	40	124	282	50	140

TP = Total phytoplankton; TZ = Total zooplankton; TB = Total Benthic organism.

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by

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DEPARTMENT OF ZOOLOGY
SCHOOL OF LIFE SCIENCES

Thesis submitted in fulfilment of the requirements of the degree of
DOCTOR OF PHILOSOPHY

to

THE NORTH-EASTERN HILL UNIVERSITY
SHILLONG-793014
INDIA

SEPTEMBER, 1983

Zoo
(Thesis)

To

my beloved

Parents

Phone : 3390

North-Eastern Hill University

Dr. A. RAGHU VARMAN
Reader in Zoology

DEPARTMENT OF ZOOLOGY
SCHOOL OF LIFE SCIENCES
SHILLONG - 793003

CERTIFICATE

I certify that the thesis entitled "Studies on certain aspects of ecology and biology of two palaemonid prawns, Macrobrachium hendersoni hendersoni (De Man) and Macrobrachium hendersoni cacharensis (Tiwari)" submitted by Mr. Nani Gopal Goswami, for the Degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong, embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. degree. This work has not been submitted for any Degree of any other university.

A. Raghu Varman

Dated 3. 9. 1983
Place: Shillong.

Signature of the Supervisor

Dr. A. Raghu Varman
School of Life Sciences
North-Eastern Hill University
Shillong 793003, Meghalaya

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Shillong,
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(NANI GOPAL GOSWAMI)

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PREFACE

India stands on the top in world shrimp production. Prawns are exported in different forms such as frozen, canned, dried, pickled, curry, meal, powder, bits, etc. As prawn is one of the most delicious food items, the per capita consumption of prawns in advanced countries is increasing year after year due to increase in buying power and increase in population.

India is exporting 49 items of marine products to 98 countries in the world (Sakthivel, 1976). India's export for the first time touched a remarkable figure in 1975 to the tune of 53,412 tonnes in quantity and Rs. 105 crores in value. Of the 49 items of marine products, frozen prawns are alone accounted for 88% (46,831 tonnes to the value of Rs. 94.34 crores). Of the 98 importing countries of Indian marine products, Japan and USA alone lift more than 90% of our products. In the coming years, some more European countries are likely to join the import race increasing further demand for prawns.

The cultivable inland water resources of India are vast but majority of them remain neglected. They are either not cultivated or if cultivated not effectively managed or exploited. Thus scientific management of prawn fisheries in impounded waters, assumes special significance as this can go a long way towards meeting the nutritional requirement of at least to our country when we are facing a shortage of even the cheap protein. In scientific prawn farming, aiming at maximising the production with minimum cost, utmost care is to be observed at every state, in which nursery rearing of seed occupies an important postion. The tender young ones of the cultivated prawn require special care and treatment before they are transported from the natural conditions to the new habitat of impoundments. The delicate larvae and post larvae may not readily adjust to the newly exposed conditions and undergo large scale of mortality due to changed physico-chemical and biotic environment. Thus, to employ scientific methods in rearing prawns, a thorough knowledge and understanding of their natural eco-system becomes imperative.

Meghalaya with its swift flowing streams and rivers offers an excellent scope for studies on available prawn species. The traditional practices of shifting cultivation termed "Jhum" which promotes denudation and soil erosion are the part of stresses to which the fauna of this region are usually subjected. In this context, an adequate knowledge of hydrological and biological parameters, in the first instance, is considered by the fishery workers as an essential pre-requisite for the better understanding of the respective faunal eco-system (Gupta, 1980).

There is a paucity of information on the ecology and biology of the fresh water shrimps of the indegenous species and particularly there is no work at all, on the prawns specific to the highlands of the North-Eastern part of India and knowledge on these, is of utmost importance, not only from the academic point of view, but its utility in increasing the technological efficiencies of the fishery enterpreneurs for evolving judicious management measures in prawn culture. Hence, a virtual absence of scientific knowledge on these aspects, promoted me to undertake the present investigation. It is, therefore, earnestly hoped that the information embodied in this dissertation, apart from its academic value, would have application and relevance to the socio-economic development of these areas of the country by evolving suitable pisciculture techniques.

The present study pertains to the specimens of Macrobrachium hendersoni hendersoni (de Man) from Umshing stream and Macrobrachium hendersoni cacharensis (Tiwari) from Pongtung stream collected during the period from January 1979 to December 1980. The results obtained during the present study are presented in this thesis entitled "Studies on certain aspects of ecology and biology of two palaemonid prawns, Macrobrachium hendersoni hendersoni (de Man) and Macrobrachium hendersoni cacharensis (Tiwari)".

GENERAL

INTRODUCTION

In the present day world, where the economy of a nation depends on judicious prospecting, conservation and proper management of renewable and non-renewable resources, the role of biological study is manifestly becoming significantly important. Today, the field of biology is no longer an academic subject only, as it concerns every one directly or indirectly related to food, energy crisis or pollution (Nasar, 1977).

Prawns have great significance in the life of mankind, being an important natural source of protein (Menu-Merqua and Morales, 1974) and providing certain other useful products (Sakthivel, 1976). In India, inland waters with potentialities of pisciculture is approximately 7.5 million hectares or in other words 2.34% of the total areas of the country (Biswas, 1982). Extensive researchers, in India, generally centres around the biology of only those species which are being used to stock in dams and lakes rather than exploring other cultivable natural resources.

The aim of any good fishery management is always to obtain the maximum sustained yield from a water body. This involves removal of yield equivalent to the amount produced each year and for this, it is necessary to understand first, the basic ecology and biology of any cultivable species. In relation to ecology, comparative physiologists ordinarily deal with functions which describe the relation between the organism and its medium or which delimit the environmental variation compatible with life. The tendency has therefore been to study physiological properties in relation to medium properties and to consider various internal states as "a function of the corresponding parameters in the environment" (Prosser, 1955).

The human race, at the moment, is confronted with the greatest crisis of finding adequate water resources for its multiferious use. While this may be a recent exigency of mankind, limnologists are concerned with the basic understanding of how plants and animals carry out their various life functions in relation to their environments. Such knowledge may be of ultimate value not only to understand the structural and functional dynamics underlying aquatic eco-systems, but also be of applied value in 'aquaculture programme' (Bhattacharaya, 1981).

'Aquaculture' is becoming of utmost key way in meeting the world wide demand for shrimps. Forster and Wickins (1972) described three basic types of aquaculture: (1) "extensive (low stocking densities) or free range" culture in very large outdoor aquasystem (2) "intensive (high stocking densities) outdoor culture in smaller, more controllable ponds, tanks or race ways" and (3) very intensive (high stocking densities with frequent croping) indoor culture in completely controlled environmental aqua-system". McSweeny (1977) further defined intensive culture as the "propogation and rearing of aquatic species in artificial systems which exhibit three characteristics: a high degree of environmental control; an artificial means to increase production significantly over natural or extensive systems; and minimal water requirements". Neal (1973) concluded that with a few exceptions, intensive cultivation of aquatic animals is much more likely to be commercially successful in coming years than extensive aquaculture. However, an economically practical technology for very intensive culture of crustaceans has not yet been demonstrated (Sandifer and Smith, 1978), although notable advances have been made in recent years (Mock *et al.*, 1973; Shigueno, 1975; Sandifer and Smith, 1977; Van Olst *et al.*, 1977; Salser *et al.*, 1978).

In view of the ever increasing demand for shrimps both for local consumption and for export purposes, the Indian prawns have been attracting attention from a rapidly developing fishing industry as well as from the zoologists. But, most of the notable works in India includes only the marine forms (Henderson and Matthai, 1910; Chopra, 1939; Nair, 1949; Gopalakrishnan, 1952; Kurian, 1952, 1953, 1954, 1964; Menon, 1952, 1954, 1961; Panikkar and Menon, 1956; John and Kuriyan, 1959; Bhimachar, 1962; George, 1962, 1964, 1966, 1967, 1968, 1969, 1970, 1972a, b; Sarojini, 1962; Subrahmanyam, 1962, 1963, 1965, 1966, 1967, 1968, Raman, 1964; Satija and Das, 1964; Madhayastha and Rangnekar, 1965; Cheriyan, 1966; Panikkar and

Jayaraman, 1966; Sebastian et al., 1966 ; Venugupala, 1966; Bhimachar and Tripathi, 1967; Kutty, 1967, 1969; Mohamed et al., 1967, 1968, 1969; Pandian, 1967; Ramamurthi and Scheer, 1967; George et al., 1968; James, 1969; Jones, 1969; Rasalan et al., 1969; Rangnekar and Madhayastha, 1970; Naidu and Boerema, 1972; Raje and Ranade, 1972; Kuttyamma, 1974; Pillai et al., 1975; Goswami et al., 1977).

Tiwari (1955) has already reported more than 34 species of freshwater prawn of the genus, Macrobrachium, from Indian inland water conditions (both lotic and lentic systems). But, till now, the information so far obtained on their ecology and biology, does not cover all these reported species. In the recent years, in India, considerable progress is being made on certain aspects of these species by several workers (Rajyalakshimi, 1961, 1966, 1980, a, b; Imbrahim, 1962; Raman, 1964 ; Pillai, 1965; Subrahmanyam, 1966; Gupta, 1967; Nagabhushanam and Vasantha, 1967, 1968; Pandey, 1967; Rao, 1967; Tyagi and Prakash, 1967; Koshy, 1969, 1973; Nagabhushanam and Chinnayya, 1968; Rajyalakshmi et al., 1968; Rajayalakshmi and Ranadhir, 1969, 1974; Rasalan et al., 1969; Tiwari and Pillai, 1971; Pillai and Mohamed, 1973; Jalihal and Sankolli, 1975; Goswami et al., 1977; Katre, 1976; Katre and Reddy, 1977; Nagabhushanam and Jyoti, 1977; Murthy, 1978; Sharma and Tiwari, 1978; Ghate and Mulherkar, 1979; Nagabhushanam and Kulkarni, 1979, 1981; Sukumaran and Kutty, 1979; Goswami et al., 1980, 1981, 1982, 1983a,b,c; Murthy and Saxena, 1980; Anantharaman et al., 1981; Rao et al., 1981; Saxena and Murthy, 1981, 1982; Goswami, 1982).

Although there is reason to be optimistic about the potential for eventual commercial production of prawns in environmental controlled systems, number of areas still require considerable research and development effort (Smith and Hopkins, 1977; Sandifer and Smith, 1978). Chief among these are prawn nutrition, behaviour, physiology, genetics, culture systems design and optimization, pilot plant demonstrations and economic feasibility analyses (Sandifer and Smith, 1978). Successful controlled environment culture of Macrobrachium, will require: the development of nutritionally complete cost effective rations; the determination and maintenance of optimal conditions for prawn survival and growth under crowded conditions; genetic manipulation to produce prawns better suited for intensive culture than essentially wild animals, we have today; reduced system costs, improved management techniques and greater production efficiency for M. rosenbergii (Sandifer and Smith, 1978). But, in order to find cultivable local varieties, firstly investigations on basic ecology and biology of unexplored species, becomes imperative.

Most of the investigations to-day take into account the above view points depending upon the particular need of a region, state or even a country. As such a vast amount of literature on freshwater prawns has accumulated over the years in different parts of the world (Schmitt, 1933; Gunter, 1937; Mori, 1939; Hedgneth, 1949; Holthuis, 1949; Riek, 1951; Maglhaes and Pintu, 1959; Parry, 1961; Johnson, 1963, 1966, 1967, 1968, 1973, Tobia, 1964; Lewis and Ward, 1965; Costa, 1966a, b, 1970; Lewis <u>et</u> <u>al</u>., 1966; Mistakidis, 1966; Carrillo, 1967; Hernandez, 1967; Ling, 1967, 1969; Uno and Nanba, 1967; Antheunisse *et al*., 1968; Costlow, 1968; De La Cruz, 1968; Denne, 1968; Apollonio, 1969; Kwon and Uno, 1969; Little, 1969; Misharev, 1969; Moore and Burn, 1969; Choudhury, 1970; Chung, 1970; Fielder, 1970; Fujimura and Okamoto, 1970; [illegible] Holthuis and Provenzano, 1970; Bailey and Crichton, 1971; Kamiguchi, 1972a, b; Yu and Mijake, 1972; Fujeno and Baba, 1973; Ruello *et al*., 1973; Stoffel and Hubschman, 1974; Wickins and Beard, 1974; Fielder *et al*., 1975; McVey, 1975; Sandifer *et al*., 1975; Ngoc-Ho, 1976; Martin, 1976; Thebault and Le Gal, 1978; Lee and Fielder, 1979, 1981, 1982a,b, 1983; Mcbride and Muguire, 1979; Beard and Wickins, 1980; Peebles, 1980; Yasuda and Kitoa, 1980; Fair and Fortner, 1981).

Based on the advances already made on the study of biology and also in the development of freshwater prawn farming techniques in several foreign countries like Japan, Taiwan, Phillipines, Thailand, Malayasia, United Kingdom, Australia and United States of America, the researches now required to be intensified in India, should also be centred around determination of the availability and distribution of seed of cultivable varieties and breeding of animals under controlled environmental conditions (De, 1977). But, in order to do so, firstly, it becomes necessary to understand the basic structure and function of their natural ecosystem. Secondly, it involves a thorough knowledge regarding their general biology. But, till now there is no work reported on the hill stream prawns of Meghalaya State, where subtropical climatic conditions prevail.

There are limited agricultural land in Meghalaya but 85% of the population subsists on agriculture. Apart from animal husbandry and mining of Sillimanite, coal, etc. there are no industries in Meghalaya. There is, however, plenty of rainfall and sufficient water bodies to develop prawn culture in this part of the country. Hence, introduction of prawn farming in these high lands would certainly help to grow a new occupation which will raise the economic status of small farmers.

Keeping these in view, studies on certain aspects of ecology and biology of two palaemonid prawns, *Macrobrachium hendersoni hendersoni* (de Man) from Umshing Stream, and *Macrobrachium hendersoni cacharensis* (Tiwari) from Pongtung Stream, East Khasi Hills of Meghalaya were undertaken. Ecological study includes their habitat structure - limnological analysis; population dynamics and certain aspects of their ecosystem. Biological study includes study of the male and female sexually dimorphic structures; muturation; reproductive cycles; brood size and reproductive efforts, larval development, food and feeding habits, digestive physiology and neuroendocrine-regulation of blood chloride. It is is hoped that the data presented from the investigation, could be of help for the basic understanding of a subtropical lotic ecosystem as well as the structural and functional aspects of prawn populations, in this region of our country.

GEOGRAPHICAL DISTRIBUTION:

Macrobrachium hendersoni hendersoni (de Man) is commonly available in the water bodies of East Khasi and Garo Hills of Meghalaya, India. Pillai and Biswas (1979) has also reported this species from the streams of Arunachal Pradesh and Manipur of North Eastern India. Macrobrachium hendersoni cacharensis (Tiwari) is distributed throughout the Khasi Hills of Meghalaya, Mikir Hills and Cachar district of Assam.

According to Tiwari (1955) the genus Macrobrachium had marine origin and has acquired freshwater habitat by immigration from the sea to the interior of land through rivers. The process of adaptation to freshwater is not yet complete, because many species are found in estauries and still depend on brackish water for breeding. But, at the same time, some of them became completely acclimatised to the hill stream conditions with several allopatric forms. Pillai

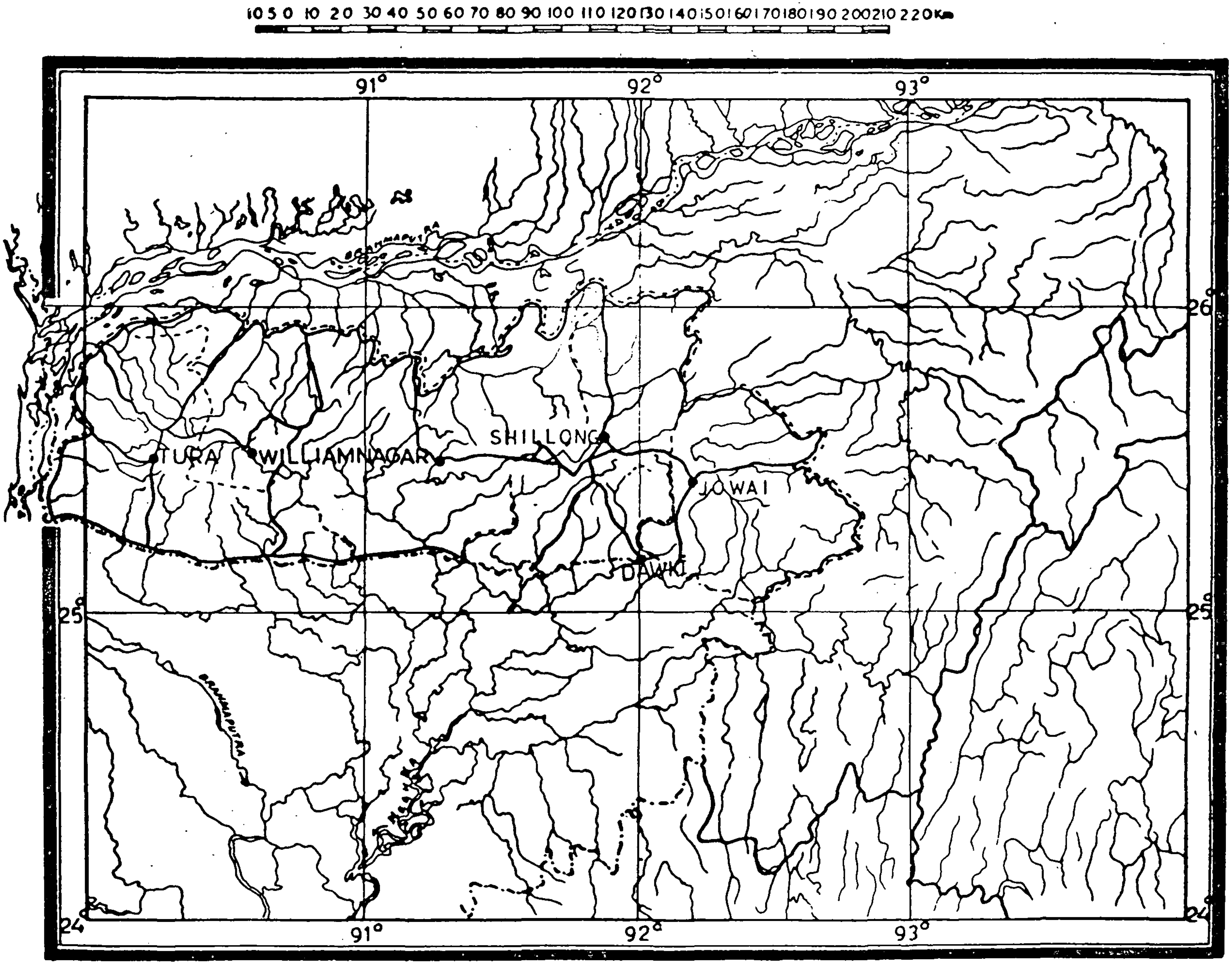

Fig. 1. Map showing the distribution of the lotic system of North-eastern India.

and Biswas (1979) have reported the occurrence of *Macrobrachium hendersoni*, *M. hendersoni hendersoni*, *M. assamensis*, *M. dayanum*, *M. lamarrei*, *M. choprai* and *M. birmarichum* from the North-Eastern regions of India.

It has been observed by the present author that the streams and rivers of North-Eastern regions of India meets with either river Brahmaputra or Megna river (Bangladesh) which ultimately ends into the Bay of Bengal (Fig. 1). The distribution patterns of the lotic system and the tendency of mass migration of palaemonid prawns (Hoglund, 1943; Forster, 1951; Ibrahim, 1962; Rajyalakshmi, 1961; Bimachar, 1965; Raman, 1965; Lee and Fielder, 1979) could be the further evidences to support "Inland migration hypothesis of *Macrobrachium*" after Tiwari (1955).

TAXONOMIC STATUS*

Phylum : Arthropoda; Class : Crustacea; Sub-Class : Malacostraca; Super order : Eucarida; Order : Decapoda; Super family : Palaemonida; Family : Palaemonidae; Sub-family : Palaemonienae; Genus : *Macrobrachium* Bate 1868.

Specimens : *Macrobrachium hendersoni hendersoni*
(de Man)
Macrobrachium hendersoni cacharensis
(Tiwari).

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*Prawns were identified by Dr. K.K. Tiwari, the leading Prawn Taxonomist, India.

Part - 1

ECOLOGY

1. INTRODUCTION

Ecological study of any group of organisms require an intimate knowledge of the nature of the environment in which they live, feed and reproduce (Gupta, 1980). The tempo of investigations in lotic-ecology has increased in recent years and considerable advances are being made (Berg, 1943; Burton and Odum, 1945; Berg et al., 1948; Fjerdingstad, 1950; Allen, 1951; Illies, 1952, 1964; Van Someren, 1945; Albrecht, 1953; Harrison and Elsworth, 1958; Oliff, 1960; Margalef, 1960; Allanson, 1961; Macan, 1961, 1962; Chorley, 1962; Minckley, 1963; Klinge and Ohle, 1964; Cummins, 1966, 1974; Minshall, 1967, 1968, 1978; Ulfstrand, 1968; Venkateswarlu and Jayanti, 1968; Venkateswaralu, 1969; Hynes, 1970, 1971; Imevbore, 1970; Coffman et al., 1971; Curry, 1972; Kaushik and Hynes, 1972; Ziemer, 1973; Webster, 1975; Fisher, 1977; Wallace et al., 1977; Platts, 1979).

This awareness has led to the concern over deterioration of water courses as a result of poor land utilization and their use as repositories for man's rejectamenta has stimulated research into the basic dynamics of the lotic environment and its biotic communities (Bishop, 1973). Before any assessment of pollution effects can be made, or national remedial action is suggested, there must be a sound detailed knowledge of the natural characteristics of regional water courses as a reference standard. This knowledge can be resulted only from investigating the whole drainage area as a unit ecosystem (Evan, 1956) rather than just the specific conditions in the system (Slack, 1955; Hynes, 1969).

From head waters to mouth, the physical variables within a lotic system present a continuous gradient of physical conditions. This gradient elicits a series of responses within the constituent populations resulting in a continuum of biotic adjustments and consistent patterns of loading, transport, utilization and storage of organic matter along the length of a lotic bodies (Vannote et al., 1980). Many communities can be thought of as continua consisting of mosaics of integrading population aggregates (Mc Intosh, 1967; Mills, 1969). Such a conceptualization is particularly appropriate to streams. Several workers have visualized streams as possessing assemblage of species which respond by this occurrences and relative abundances to the physical gradients present (Shelford, 1911; Thompson and Hunt, 1930; Ricker, 1934; Ide, 1935; Burton and Odum, 1945; Van Deusen, 1954; Huet, 1954, 1959; Slack, 1955; Minshall, 1968, 1978; Ziemer, 1973; Swanston et al., 1977; Platts, 1979).

Freshwater crustaceans like other freshwater animals keep their body fluids hyperosmotic to the medium (Robertson, 1960). They are faced with a continuous osmotic inflow of water which they have to excrete, and with the problem of active absorption of ions from a very dilute medium to replace those lost by outward diffusion and excretion. Starvation, temperature, state of maturity and stage in the molting cycle, may influence the level of internal ionic concentration in the freshwater crustaceans (Robertson, 1960). Many workers (Potts, 1954; Lockwood, 1961; Shaw and Sutcliffe, 1961, 1967) have studied the osmotic regulation of stream organisms under differing salinity levels but most of them considered only the sodium (Na^+) ions. Ammonia is the principal excretory product of crustacea (Hartenstein, 1970; Hochachka and Somero, 1973; Kinne, 1976) and its modes of toxicity as well as concentrations lethal to a variety of organism have been well documented (Warren, 1962; Campbell, 1973).

The supply of oxygen has a great influence on the distribution of aquatic animals (Ambuhl, 1959, 1961; Berg et al., 1959, 1962; Edwards, 1960; Eriksen, 1964, 1968). They investigated the relation of oxygen consumption to the oxygen concentration and tried to correlate the results to the natural distribution of the animals. Stephenson and Knight (1980) studied the effect of temperature and salinity on oxygen consumption of Macrobrachium rosenbergii (de Man). While many environmental disturbances have no readily detectable effect on aquatic invertebrates in the short term, they may prevent normal reproduction and cause eventual local extinction of a species (Lehmkuhl, 1979). Heavy metals and toxic substances may drastically reduce reproduction rates in species exposed to sublethal levels. Dissolved salts and pH affect organisms at abnormally high or low levels but most mechanisms are unknown (Lehmkuhl, 1979).

Very little precise information is available on the ecological significance and effects of nutrients and ions on aquatic life. Most life history disturbances result from excess of nutrients and ions rather than insufficiencies (Nduku **and Harrison, 1976**). On the other hand certain organisms appear to thrive over a rather wide range of concentrations (Hannon and Young, 1974). As even higher levels, most organisms are able to osmoregulate to a point but species begin to drop out as ion concentrations increase (Wichard et al., 1973, 1975; Tones, 1979). Drastic changes in physical features such as current velocity, water level fluctuations, substrates, etc. can eliminate sensitive species while allowing tolerant ones to thrive. Some information is available from studies of newly established "habitat hypothesis" that insects, worms, crustaceans and molluscs constantly invade new habitats from surrounding areas (Williams and Hynes, 1976). Competition and ability to reproduce in the new habitats soon moulds a new community. "Fine tunning" may occur through such processes as conditioning of water by another life stage. Both growth rates and natality are higher in water that has been conditioned by the presence of adults than in water where there are no adults (Williams and Hynes, 1976). Thus, various subtle aspects of life histories (e.g., fecundity, vagility and competitive ability) control community structure and composition in freshwater invertebrates.

Changes in current velocity and substrate act selectively on individual species and on individual life history stages. A sandy stream substrate, caused by a mining operation, formed an effective barrier to upstream movement in insect nymphs (Leudtke and Brusven, 1976). Smith and Sandifer (1976) increased production of tank-reared Macrobrachium rosenbergii through use of artificial substrates. Kovalak (1976) found an interaction between temperature and currents that influenced positioning of Glossosoma nigrior on brick substrates. Faunal changes in areas of siltation or altered current velocity are therefore predictable. But, more prcise studies on such relationship are needed.

The population of crustacean community in a particular habitat fluctuates to a greater or lesser extent in time and space. The study of such natural population, therefore, requires an intimate knowledge of the concepts of population and the environment in which they live. Gauge (1961) defined population as a collection of individuals persisting through a familiar but vaguely delimited time span within an ill defined area or space whereas their environment included the abiotic milieu -- the non-living organic matter, plants and animals -- inclusive of other members of the population. On the other hand, Solomon (1949) emphasised that population and environment are inseparable and every population requires a real ecological setting for its functioning, rather than an imaginary ecosystem minus the population, called the environment. By this statement he redefined the ecosystem concept originally proposed by Tansley (1935) to explain the inter-relationships between the functional aspects of a population and the sets of abiotic conditions. Such approach could be applied to study the population dynamics as a 'life system' which consists of the population itself and its effective environment wherein the external influences such as the biotic and abiotic factors are observed and measured.

The process of colonization is important for establishment and maintenance of diverse and stable communities. The ability of an established community, called an epicenter, to recolonize and impoverished area with regard to total number of species present becomes especially critical when the ecosystem exists under the strain of either a chronic or acute source of toxic stress (Cairns, Jr., et al., 1980). Filter feeding aquatic invertebrates occupies an important niche in functioning of stream ecosystems (Cummins, 1973 & 1975; Wallace et al., 1977). They capture and alter the composition of fine particulate organic matter in transport, thereby, influencing the food available to collector, and provide important energy subsidies to predators like shrimps. Filter-feeder can reduce the suspended organic load of streams (Chutter, 1963; Cushing, 1963; Hynes, 1971) and may form also another link in the processing of algae or detritus by consuming fine particulate faces produced by other components of the animal community (McCullough et al., 1977). Thus, identification of such component becomes imperative for the clear understanding of their ecosystem. Further, influence of man on any population, is also one of the important parametersin the content of ever increasing rate of urbanization and industrialization and needs consideration (Clark et al., 1978).

There are very limited works on the ecology of fresh water shrimp as a whole. Kubo (1948, 1950 a, b) made an ecological study on the Japanese fresh water shrimp, Palaemon nipponensis with special emphasis on items important for its propagation. With the development of aquaculture techniques, in the recent years, a considerable progress are being made on this aspects by several workers (Raman, 1964; Johnson, 1965, 1967;Allen, 1966; Coelho, 1966; Hughes, 1966; Baxter and Renfro, 1967; Couture, 1967; Aldrich et al., 1968; Ling, 1969; Truesdale, 1970; Truesdale and Mermilloid, 1979). Rajyalakshmi (1961, 1974, 1980) studied certain aspects of ecology of the Indian riverine prawn, Macrobrachium malcolmsonii. But, till now, no report is available on the ecology of the hill stream prawns from any part of India.

Keeping in view the above facts, the present study on the ecology of two palaemonid hill stream prawns, Macrobrachium hendersoni hendersoni (de Man) and Macrobrachium hendersoni cacharensis (Tiwari) was being undertaken. The study includes collection of information on the topography, climate, geology, lithology, vegetation cover and land use, nature of perturbations, the physico-chemical variables of the environment, seasonal biotic composition of the stream and also with major emphasis on the prawn population dynamics and their inter-relation with the various abiotic and biotic parameters of the environment.

2. STUDY AREA

2.1. GENERAL CONSIDERATION:

Umshing stream and Pongtung stream are, the two lotic water bodies selected for ecological studies of the prawns, Macrobrachium hendersoni hendersoni (de Man) and Macrobrachium hendersoni cacharensis (Tiwari). Criteria for selecting these two water systems were:

a. they comprise small perennial streams which could be sampled throughout the year by standard stream benthos techniques.

b. they were shallow and small enough to carry out a detailed study throughout the entire course.

c. the streams were proximate to the laboratories in comparison to other streams and it enabled rapid chemical analysis of the water samples.

d. the streams were free from gross organic pollution and chemical or industrial effluents.

e. the two streams have also an altitudinal difference.

f. both the streams were rich in prawn population.

2.2. TOPOGRAPHY:

Umshing stream (25°41' 06"N and 91°52' 27"E) is located near Barapani Dam, 25 kms from Shillong (East Khasi Hills), the capital of Meghalaya state (Fig. 2). Umshing stream originates at an altitude of 1514 m. and flow down to an altitude of 1050 m.

Pongtung stream (25°15' 00"N and 91°54' 15"E) is also located in Khasi Hills, 72 kms. from Shillong and is quite close

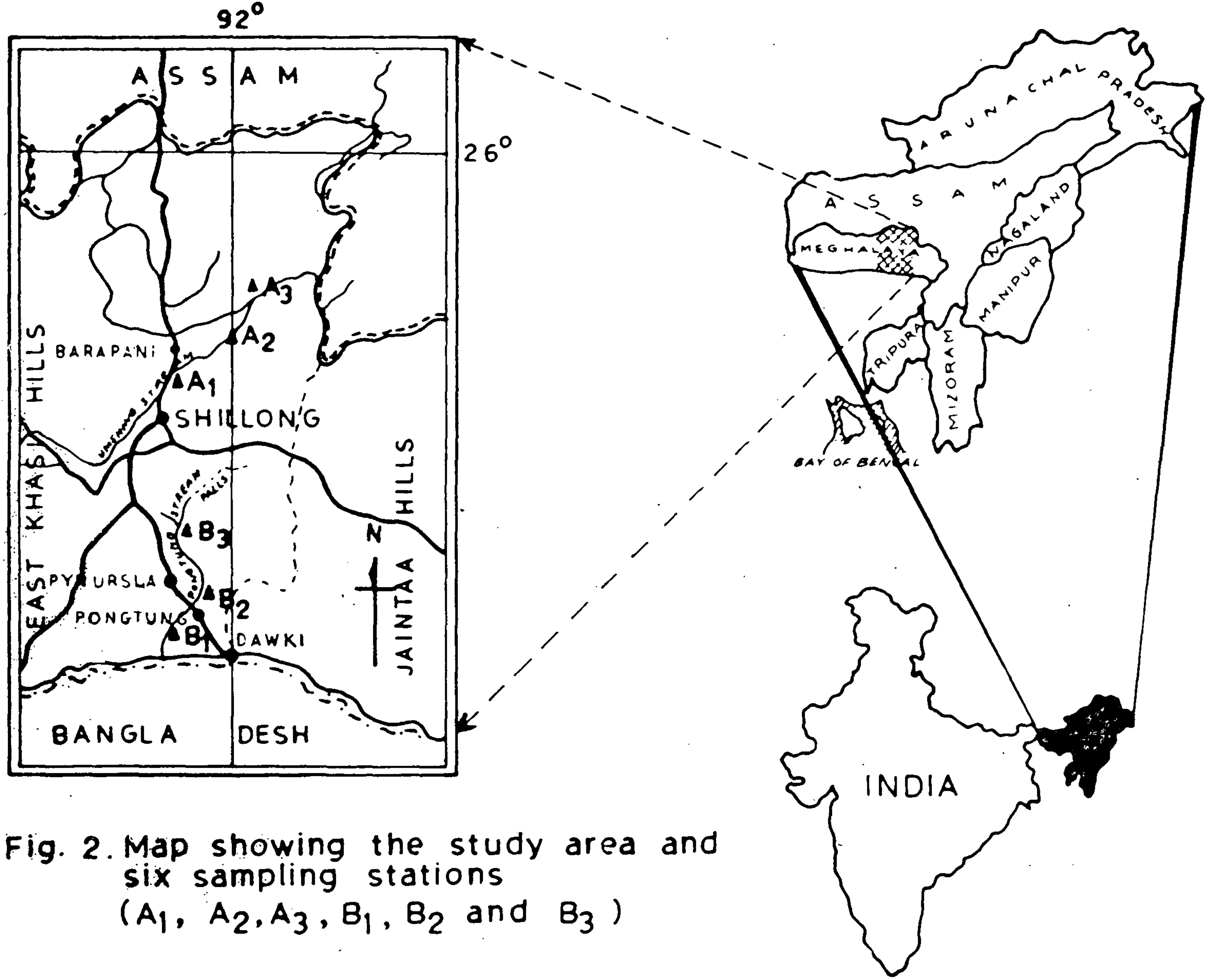


Fig. 2. Map showing the study area and six sampling stations (A_1, A_2, A_3, B_1, B_2 and B_3)

to the boarder areas of Bangladesh (Fig. 2). Pongtung stream originates at an altitude of 690 m. and flows down to an altitude of 610 m.

2.3. CLIMATE:

The region under study has a tropical monsoon climate with high rainfall (Figs. 3 & 4). In fact, Mawsynram, situated about 50 km. from Shillong records the World's heaviest rainfal rainfall, nearly 1400 cm. In the present study, based on temperature regimes, each annual cycle has been divided into four seasons:

I. Spring (March to May): dry and windy.
II. Summer and rainy season (June to September): warm period with high humidity.
III. Autumn (October to November): less windy, less warmer with average humidity.
IV. Winter (December to February): rainless period.

The summer temperature in Umshing areas goes as high as 27°C while in winter it falls down to 6°C. The summer maximum in Pongtung areas is 34.5°C and the winter minimum becomes 11.2°C.

Flash floods and spates in the streams during the rainy season due to high rainfall is quite frequent but permanent flooding of the drainage basin for longer period never occurs.

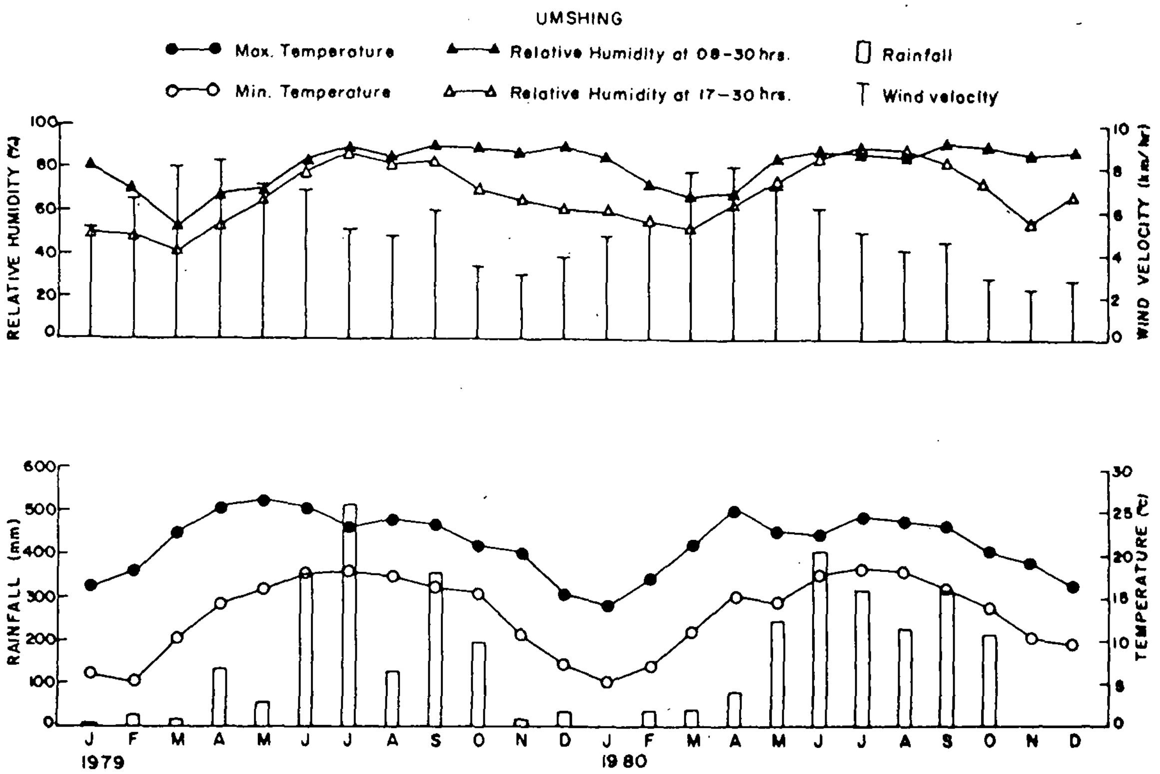


Fig. 3. Climatic aspects of Umshing area during the period of investigation.

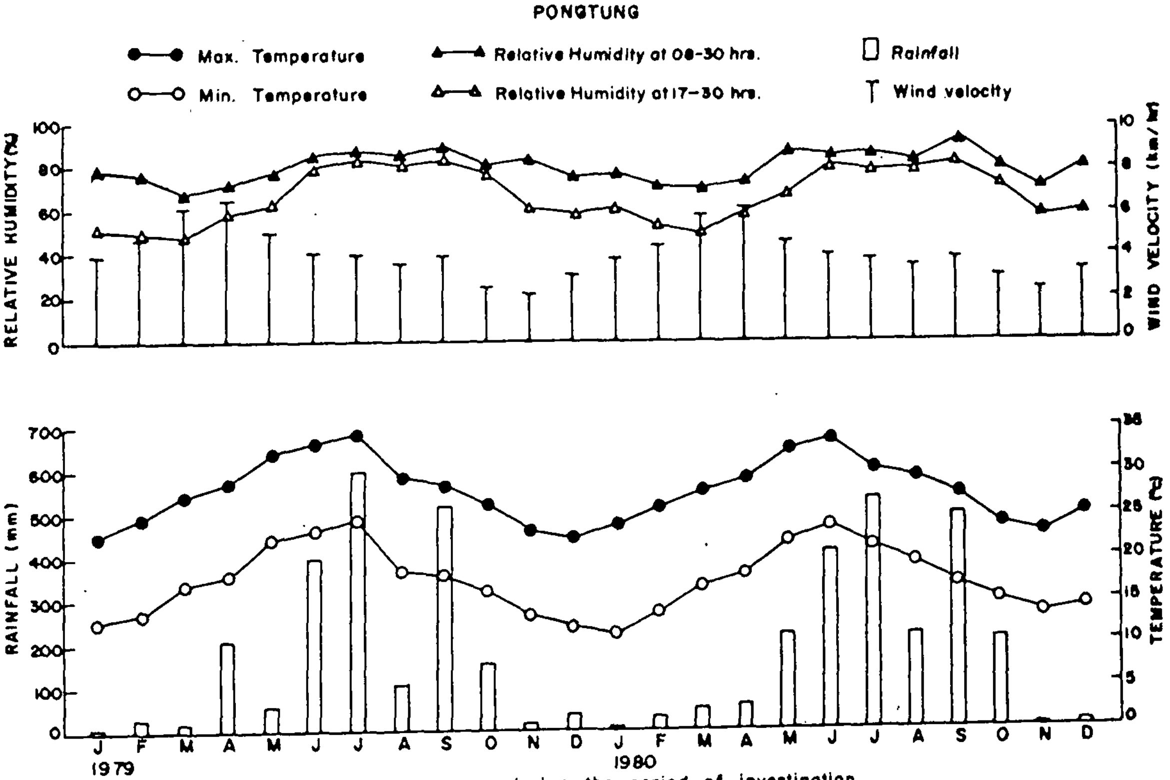


Fig. 4. Climatic aspects of Pongtung area during the period of investigation.

2.4. GEOLOGY:

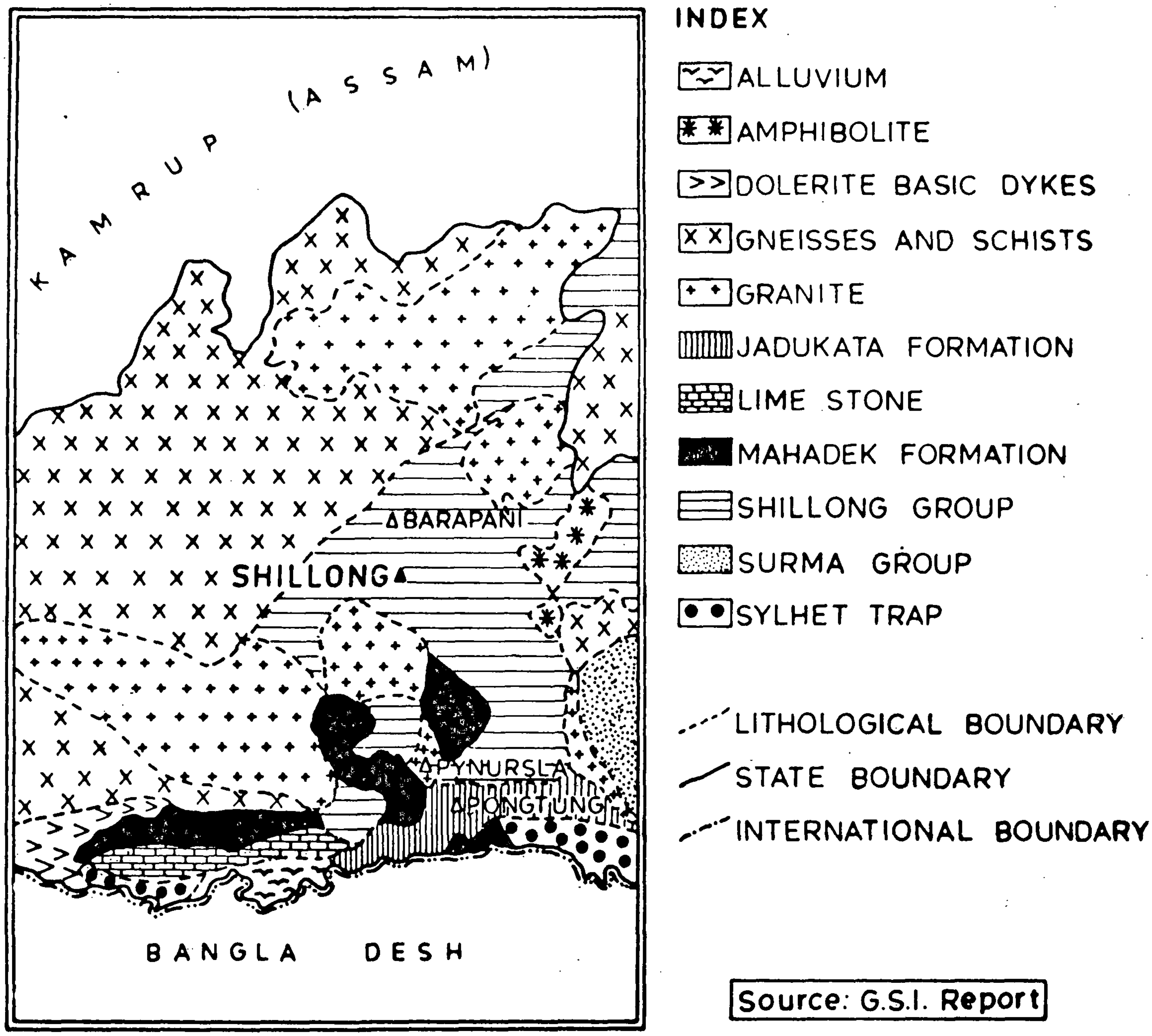
The highland comprising the Garo, Khasi, Jaintia and the detached Mikir Hills is known as the Shillong plateau which forms the North Easter part of the continental mass of India. Physiographically, it represents a remnant of an ancient plateau of Pre-cambrian Indian peninsular shield uplifted to its present height of 610 m. to 1544 m. above the sea level. The Karnel of the plateau is the exposed Archean gneisses and schists covered in this area by Pre-cambrian quartzites and phyllites. This was later marked by the intrusion of younger granites and basic/ultrabasic schists. This ancient pene-planned surface of the plateau is still preserved with marks of different cycles of denudation. It is hidden beneath the Mesozoic traps along the central, southern fringe and cretaceous, tertiary and post tertiary sediments. The polycyclic erosional surface at various levels indicate that the present physiographic configuration of the plateau was obtained through different geological events since Mesozoic to present study.

The tectonic history of the plateau begins with the effusion of plateau basalts (Sylhet traps) through fractures and faults in the basement and uplift and subsidence of the adjacent basement block. These were followed by upper cretaceous-tertiary sedimentation into the relatively down lifted portion along the faults. The tectonic force has been known to be vertically dominated and controlled by differential movements along the basement fractures. Further details of the tectonic theory is not discussed here as it is outside the purview of the present study.

2.5. LITHOLOGY:

The rocks around Barapani (Umshing stream) area are mainly of Shillong groups (D.G., G.S.I. Report, 1974) which consists rocks of both sandy (arenaceous) and clayey (argillaceous) nature (Fig. 5). The clayey rocks consists of phyllites, mica schists and carbon phyllite, while the sandy type includes green stones, granite and upper cretaceous sandstone. The sand stone are mainly coarse grained. The chemical composition of the rocks in terms of various oxides is as follows: SiO_2 : 51.94%; Al_2O_3 : 6.70%; TiO_2 : 6.64%; Na_2O : 1.10%; K_2O : 0.05%; CaO : 8.95%; MgO : 3.62%; and the rest includes other trace element oxides.

The rocks around Pongtung area (Fig. 5) are represented by conglomerate, sandstones and lime stones of Jadukata formation and Mahadek formation (D.G., G.S.I. Report, 1974). The Mahadaek formation includes felspathic sandstone, orcherous sandstone (yellowish brown) and glauconitic sand stone (light green in colour) with alternations of greenish brown shales and mud stones. Ferruginous sandstones are also present with clay bands containing coaly streaks and often decomposed plant matter (Datta, 1978). Boulders resembling conglomerate, shales,



Source: G.S.I. Report

Fig. 5. Lithological map of the study area.

mudstones, sandy lime stone and ferruginous concretions are profusely developed. Limestones were compact hard, clayey and compact algal types. The general compostion of the rocks in terms of the oxides is as follows: SiO_2: 47.0%; Al_2O_3: 11.0%; TiO_2: 4.25%; Na_2O: 2.3%; K_2O: 0.84%; CaO: 91.11%; MgO: 4.76% and rest includes other trace element oxides.

2.6. SOIL:

The soil varies all over the Meghalaya plateau in physico-chemical characters and fertility conditions. They are mostly lateritic type derived largely from granites, schist rocks and vary from sandy, red and clayey loam to sandy lime. The soils in the basin are more fertile than the upland soils since much of the bases and organic matter from the top soil of the latter gets washed away due to high rainfall. The sediments are mostly sandstones and shales (mud stones) and well defined fossiliferous limestones. The percentage of organic carbon is nearly 5 to 10 and the pH between 4.5 to 6.5.

2.7. VEGETATION AND GENERAL LAND USE:

The extent and type of ground cover in specific areas of the watershed exerts considerable influence on the hydrology and chemistry of the lotic system and has indirect effects on its biota through allochthonous organic production, temperature moderation and in denuded areas, by elevated removal rates of both inert and nutrients. A complete list of macrovegetation

Table 1: Distribution of bankside macro-vegetation (viz. trees, shrubs and grasses) at each station (*, rare; -, absent; +, present, ++, common; +++, abundant).

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
Artocarpus chaplasha	-	-	-	+	+	++
A. integrifolia	-	-	-	+	+	++
Bauhina sp.	-	-	-	*	+	++
Castonopsis sp.	-	-	-	*	+	++
Croton jofra	-	-	-	*	+	++
Eugenia tetragona	-	-	-	+	++	++
Ficus sp.	-	-	-	+	++	++
Litsea umbrosa	-	-	-	+	++	++
Lagerstromia parviflora	-	-	-	+	+	+
Pinus kesiya	+++	+++	++	-	-	-
Glochidion sp.	-	-	-	+	++	++
Quercus serrata	-	-	-	++	+++	+++
Rhododendron sp.	+	+	+	-	-	-
Schima wallichii	-	-	-	+	+	++
Terminalia sp.	-	-	-	*	+	++
Dendrocalamus spp.	++	++	++	++	+++	+++
Bambusa spp.	++	+	+	+	++	+++
Eupatorium spp.	++	++	++	-	-	-
Lantana camara	++	+++	++	++	++	++
Arundinella spp.	++	+++	++	++	++	++

cont'd.

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
Brunella sp.	++	++	+	-	-	-
Carex sp.	++	++	+	-	-	-
Cymbopagon citratus	++	+++	++	++	++	+++
Cyperus sp.	++	++	+	-	-	-
Fimbristylis sp.	++	+	+	-	-	-
Hypochaeris sp.	++	++	+	-	-	-
Imperata sp.	++	++	+	+	+	+
Osbeckia sp.	++	++	+	-	-	-
Panicum sp.	++	++	+	++	+++	+++
Polygonum sp.	++	++	+	+	++	++
Pogonotherum sp.	++	+	+	-	-	-
Rotella sp.	++	+	+	-	-	-
Rubus sp.	++	+	+	-	-	-
Saccharum sp.	-	-	-	*	++	+++
Scinpus sp.	++	+	+	-	-	-
Thysonolaena sp.	-	-	-	*	+	++

found near the stream bank are given in Table 1.

The head water of Umshing stream flows through thick forest and then about 5 km straight down through some agricultural land at the lower course where it also meets with outlet of the Barapani Dam. The agricultural lands are used infrequently for the cultivation of rice and certain other vegetables. Hand digging and cowdung manuring are the most commonly practised methods of farming. Stream Pongtung, on the other hand, flowing through steep hills for a distance of 6 km from its source, passes through a thick vegetation on its both banksides and finally rolls down in weak zone about 60 ft. straight forming a waterfall. The hill sides were not used for the agricultural purpose because of too many exposed rocks and gravels of various dimensions and the only human disturbance of **this** system is sport fishing which of course is a favourable practice of the people throughout this region.

2.8. SAMPLING SITES:

Stations for chemical and biological study are selected as such as it represents the most obvious areas of the stream. A very large number of sites i.e., sub-stations were selected from all the habitat under study and represented finally as a unique single sampling site. It was hoped that areas chosen would cover the main range of conditions found in the various zones. Six main sampling sites were selected, three from each stream, indicating A_1, A_2, A_3, and B_1, B_2 and B_3

(Figs. 6 & 7).

2.8.1. Station A_1:

Station A_1 is located on the upper region of the Umshing stream (Fig. 6a). Substrates were predominantly small boulders with stones, gravels and sand in between. Out of the emergent vegetation in the shallow areas *Lemna* sp. and ***Cerotophyllum*** **sp.** were the most dominant types (Table 2). Various mosses and liver wort grew on the larger rocks and boulders (Table 2). The vegetation cover of the bankside were mostly large trees, shrubs and patches of grasses. *Pinus kesiya*, *Rhododendron* sp., *Dendrocalamus hamiltonii*, *Lantana* sp., *Eupatorium* sp., *Cyperus* sp., *Panicum* sp., and *Rotella* sp. were the most dominant genera (Table 1). Over the period of investigation, considerable deepening of the unstable stream bed occurred at this station.

2.8.2. Station A_2:

It is in the middle region of the Umshing stream (Fig. 6b). Large boulders grossly characterize this study area but the substrates between these were sand, gravel and stones of variable dimensions. The bottom was stable over the study period with no visible channel alternation. Build up and erosion of gravel and sand beds during spates was evident, but in a short period the stream returned to the original configuration. The vegetation structure of the stream bank side is almost like that of Station A_1 (Table 1).

Fig. 6: Photographs showing the sampling sites, Umshing stream during early winter.

A : Station A_1

B : Station A_2

C : Station A_3

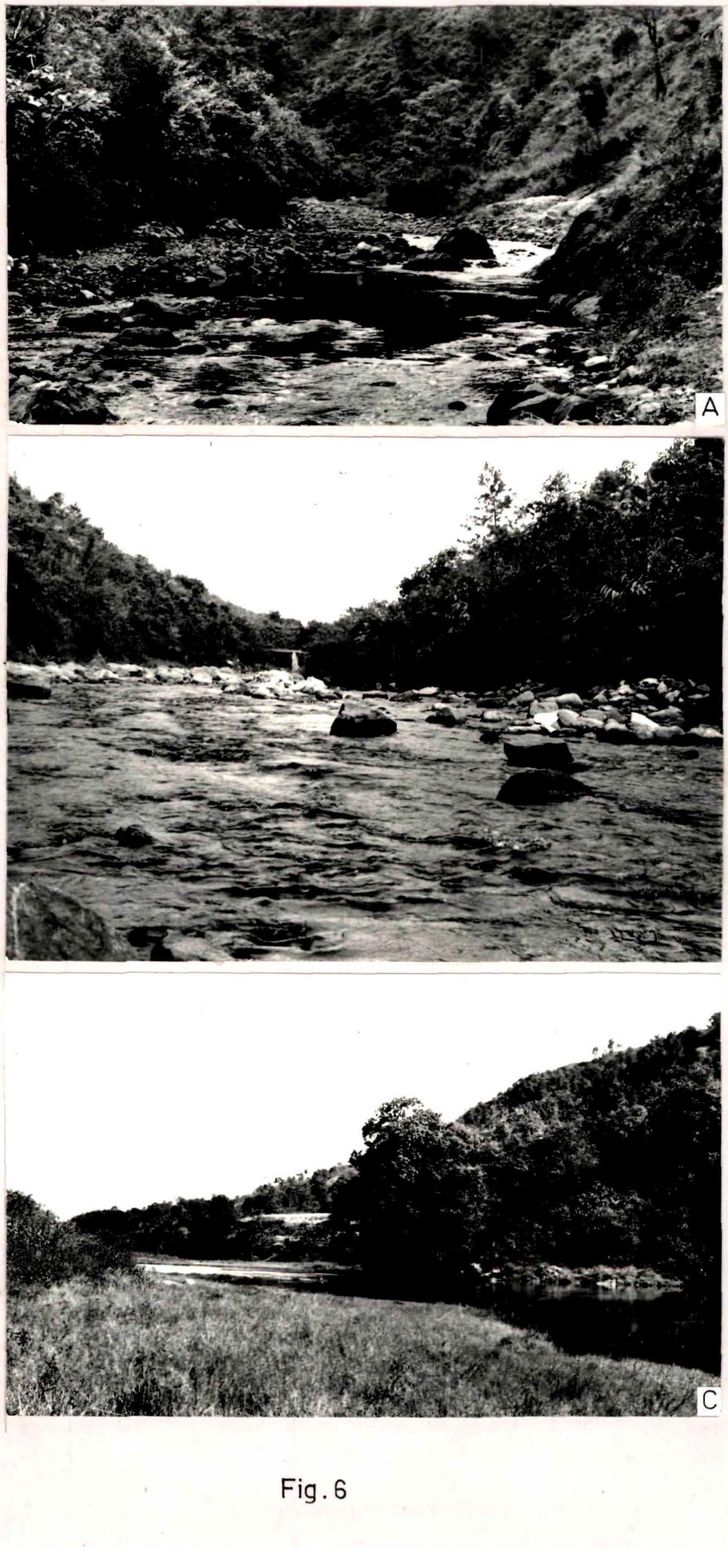


Fig. 6

Table 2: Aquatic vascular plant both submerged and emergent type and Bryophyta of the banks, boulder and bottom substratum at each stations (*, rare; -, absent; +, present; ++, common; +++, abundant)

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
VASCULAR PLANTS:						
Ceretophyllum sp.	++	+	+	+	+	*
Hydrilla sp.	*	*	+	+	+	++
Lemna spp.	++	+	+	+	+	+
Myriophyllum sp.	*	*	+	++	+	++
Ranunculus sp.	-	-	-	+	+	+
Wolffia sp.	*	-	*	+	+	+
BRYOPHYTA:						
Colistella sp.	+	+	+	+	+	++
Chiloscyphus sp.	+	+	+	*	+	+
Cladopodiella sp.	*	*	+	+	+	+
Frontinalis sp.	+	+	+	+	++	++
Himantocladium sp.	*	*	+	*	*	+
Leptodictylum sp.	+	*	+	*	+	+
Micromitrium sp.	+	+	+	+	+	++
Radula sp.	*	*	*	+	*	+
Ricoia spp,	*	*	*	+	+	++
Riccardia sp.	+	+	*	+	+	+

2.8.3. Station A_3:

It is in the lower course of the Umshing stream (Fig. 6c). Cyanophytes often formed thick layers on the bottom stones so that the substrate becomes too slippery to walk on. The substrate includes boulders of various dimensions and sand with organic deposits. Emergent and bankside vegetation is made up of largely weed species (Table 1). Canopy cover was scanty in comparison to station A_1 and A_2. Erosion of the banks occurred constantly with considerable loss of cultivated land in some places over the study period. As a result, highly unstable silt and mud banks build up in depositional areas.

2.8.4. Station B_1:

It is located on the upper region of the Pongtung stream (Fig. 7a). Stream bottom was marked by eroded rock bed. Substrates were predominantly small boulders of different dimension, organic deposits and sands. Emergent vegetation on the shallow areas includes Wolffia sp., Myriphyllum, Lemna sp. and Ranunculus sp. (Table 2). Various mosses and liver wort thrive on the rock bed and boulders (Table 2). The extreme upper part had less canopy cover and the marginal vegetation includes trees, shrubs and grasses of different varieties (Table 1).

2.8.5. Station B_2:

It is located on the middle region of the Pongtung

Fig. 7: Photographs showing the sampling sites, Pongtung stream during early summer.

A : Station B_1

B : Station B_2

C : Station B_3

Fig.7

stream (Fig. 7b). The bottom of the stream is marked by eroded rock bed. The substrates comprise large boulders and sand. Both the bank sides were thickly vegetated with trees, shrubs and grasses (Table 1). Shrubs were predominant and they reduce the intensity of the light over the water. The bottom were stable over the study period. Cyanophytes often formed thick layers on the bottom stones and made the stone surface quite slippery. Emergent and other aquatic flora of this station is given in the Table 2.

2.8.6. Station B_3:

It is located on the lower course of the Pongtung stream (Fig. 7c). There were outcropping of lime stone bed rocks and the normal substrates was sand in all areas with small egg sized stones in the faster flowing areas. Small clumps of Hydrilla grew as an emergent where sufficiently bottom condition were found in association with the bed rock. The marginal vegetation includes mostly trees and shrubs (Table 1). Mosses and liver wort are also found on the boulders and rock beds (Table 2). Considerable growth in short tufts of Cladosphora occurred on hard substrates in the stream and some free floating filamentous forms (Spirogyra sp.), formed mats in slack water areas between spates. Spouse diatoms and cynaphytes growth occurred on the riffle substrate. The bottom was relatively stable in spite of its sand gravel composition as flow was smooth with few obstructions to create turbulence. Canopy cover over the stream was complete with only about 5% available visible light reaching the water surface.

3. MATERIALS & METHODS

3.1. LIMNOLOGICAL STUDY (INDIVIDUAL LEVEL):

3.1.1. Physico-chemical analysis:

Water samples were collected during the middle of each month between 10 A.M. and 12 noon from January, 1979, to December, 1980. All the samples immediately after collection were passed through a 0.45 µ filter (Crowther and Hynes, 1977) and brought to the laboratory. Various parameters were analysed and estimated on the same day.

In addition to the air and water temperature readings which were measured in the field using a mercury bulb thermometer (Misra, 1968), maximum and minimum air temperature, relative humidity, rainfall and wind velocity of the area under consideration were collected regularly from the local metereological station during January 1979 to December, 1980.

Turbidity was measured as the percentage of total suspended matters, transparency by a Secchi disc (Welch, 1948) and the rate of water flow by using a metretape, stop watch and a simple cork (Leitritz, 1959). pH and conductivity were measured with the use of a Toshniwal pH meter (Model CAT. CL. -43) and Elico conductivity bridge (Type CM-82) respectively.

Dissolved oxygen was estimated by employing Winkler's method (APHA, 1965), Carbon dioxide by phenolphthalein - N/44 NaOH and total alkalinity using the standard method (APHA, 1965). Nitrate Nitrogen by Phenol di-sulphonic acid and ammonia nitrogen by Nessler's reagent (Mackereth, 1963). Phosphate-phosphorous by Stannous chloride and molybdate method, and chloride by mercuric nitrate titration technique (APHA, 1965). Calcium and Magnesium were estimated by Spectrophotometrically, sodium and potassium by Flamephotometry, oxidizable organic matter by permanganate method, silicate by silico-molybdate method and total iron were estimated by using the method after Mackereth (1963).

3.1.2. Phyto- and Zooplankton:

At each station, triplicate samples were collected monthly for a period of two years (January 1979 - December, 1980) by filtering a volume of 50 litres of water through a silk net of mesh size 25 µ. This was made to 50 ml and preserved by Lugol's iodine and were counted by Sedgwick rafter plankton counting cell after the method employed by Utermohl (1958) for all the organism present at random in 100 squares. The generic identification of phyto- and zooplanton was done with the help of the guideline after Smith (1950), Pennak (1953), Edmondson (1959) and Needham and Needham (1962). The counts were done in triplicate for each replicate of monthly sample, and an average count was recorded. The computation for the numbers of phyto- and zooplankton per litre at different stations of the stream was done by using the formula

$$n = \left(\frac{a.\ 1000}{l}\right).c$$

where, n = number of plankton/l of original water.
a = average number of plankton in all counts in Sedgwick rafter cell.
c = vol. of original concentration in ml.
l = vol. of original water expressed in litre.

The data were presented in terms of their percentage composition of the respective planktonic group.

3.1.3. Benthic organisms:

Animals were collected monthly for two years (January 1979 - December 1980) using a deep net of 135 μ mesh in a modified Kick sampling method (Williams and Hynes, 1976). This involved walking upstream while disturbing the substrate with the feet so that the dislodged animals were swept (by the current) into the net. By keeping the distances walked upstream constant, the sampling method was reasonably standard. In addition, other samples were taken from in and around aquatic vegetation in order to collect the more sparsely distributed and shy forms. The animal collected were fixed in 5% formalin and the result obtained after counting the different groups were presented as their percentage composition. The generic identification was done with the help of the guide line given after Pennak (1953), Edmondson (1959) and Needham and Needham (1962).

3.1.4. Vertebrate fauna:

The sources of material were the fisherman's catches. The collected materials were fixed in 10% formalin and stored in 70% ethanol (Williams and Coad, 1979). Preserved fishes were identified using the keys in Dey (1878), Hora (1951), Hubbs and Lagler (1964); Scott and Crossman (1973).

3.2 PRAWN POPULATION STUDY:

The monthly collection of the prawns for the purpose of their relative abundance were made for two years (January 1979 to December 1980) following the methods adopted by Truesdale and Mermilliod (1979) with certain modification because of their habitat difference. A seine hand net measuring 1.0 m x 1.0 m x 3.2 mm (mesh) hardware cloth was fixed to a square frame made of wrought iron with its mouth facing the current and unit area of substratum consisting of gravel, pebbles, boulders etc. were disturbed thoroughly so that the dislodged prawns were swept (by the current) into the placed net. A number of such sub-samples were taken from different areas under one of the sampling study site and comprise one population sample. In shallow stony beds, this method was found to be suitable. The samples collected were then fixed in 5% formalin and brought to the laboratory. If in each sample contained more than 50 prawns, at least 30 randomly selected individuals were sexed and measured; berried (ovigerous) females were also noted.

3.3. PRAWN ECOSYSTEM STUDY:

3.3.1. Accessory habitat analysis:

A number of depressions or rather 'supplementary habitat' have been located at the nearby surroundings of both the Umshing and Pongtung main stream. The detailed analysis of their physico-chemical and biological properties of the water and measurement of the depressions size have been made. The distribution of the prawn population in terms of their length, frequency and sex, was also noted.

3.3.2. Condition factor:

Individual variations from general length-weight relationship have been studied under the general name "condition" (Le Cren, 1951). Such changes in 'condition' have usually been analysed by means of a condition factor of Ponderal index, which has been calculated by using different formulae by various workers. However, in the present study, the 'condition factor' has been determined by using the following formula (Hile, 1936; Beckman, 1948):

$$K = \frac{W \times 10^5}{L^3}$$

where K = condition factor; W = weight of the prawn and L = length of the prawn under study. The number 10^5 is a factor to bring the Ponderal index (K) to near unity (Carlander, 1970).

3.3.3. Inter-relationship of prawn population density and different ecological parameters:

To study the inter-relation between prawn population density and different ecological parameters, the standard regression method has been employed with the formula:

$$Y = a + bx$$

where Y = population density; X = the ecological variables such as temperature, rainfall, dissolved oxygen etc.; a = a constant value to be determined and b = the regression co-efficient. The value of 'a' and 'b' were determined by the following formula:

$$b = \frac{\leq XY - n\,\bar{X}\,\bar{Y}}{\leq X^2 - n\,(\bar{X})^2}$$

where n = number of observations; $\bar{X}$ = mean of X and $\bar{Y}$ = mean of Y.

4. RESULTS

4.1. LIMNOLOGICAL ASPECT (INDIVIDUAL LEVEL):

4.1.1. Physico-chemical analysis:

The present investigation includes a study of twentyone physico-chemical factors for two years (January 1979 to December 1980) at six stations (A_1, A_2 & A_3 and B_1, B_2 & B_3), three each in two different streams (Umshing and Pongtung) having the altitudinal and climatic differences (Figs. 3 & 4) in them.

I. Rainfall: At both the study areas, the rainfall commenced in early April and continued upto October (Figs. 3 & 4). However the months of July and September experienced higher precipitation (average 511 mm/day) and January almost being the rainless period. Rainfall intensity was greater in Pongtung area (low elevation, 610 m) where short, heavy downpours were characteristic. At Umshing areas, precipitation was more frequent, but of lower intensity.

II. Water temperature: The water temperature showed a distinct summer maxima and winter minima with small differences caused by rain and prolonged cloudy weather but the peak and the fall were more prominant in Pongtung stream (Fig. 8). At Umshing stream, the water temperature varied from 10.0°C to 18.8°C whereas in Pongtung, it varied from 17.0°C to 32°C. Individually, the stations, A_1, A_2, A_3, B_1, B_2 and B_3 had a fluctuation range of 10.0 - 18.5°C, 10.0 - 18.0°C, 10.8 - 18.8°C, 18.0 - 32.0°C, 17.0 - 31.0°C and 17.3 - 31.5°C respectively (Fig. 8).

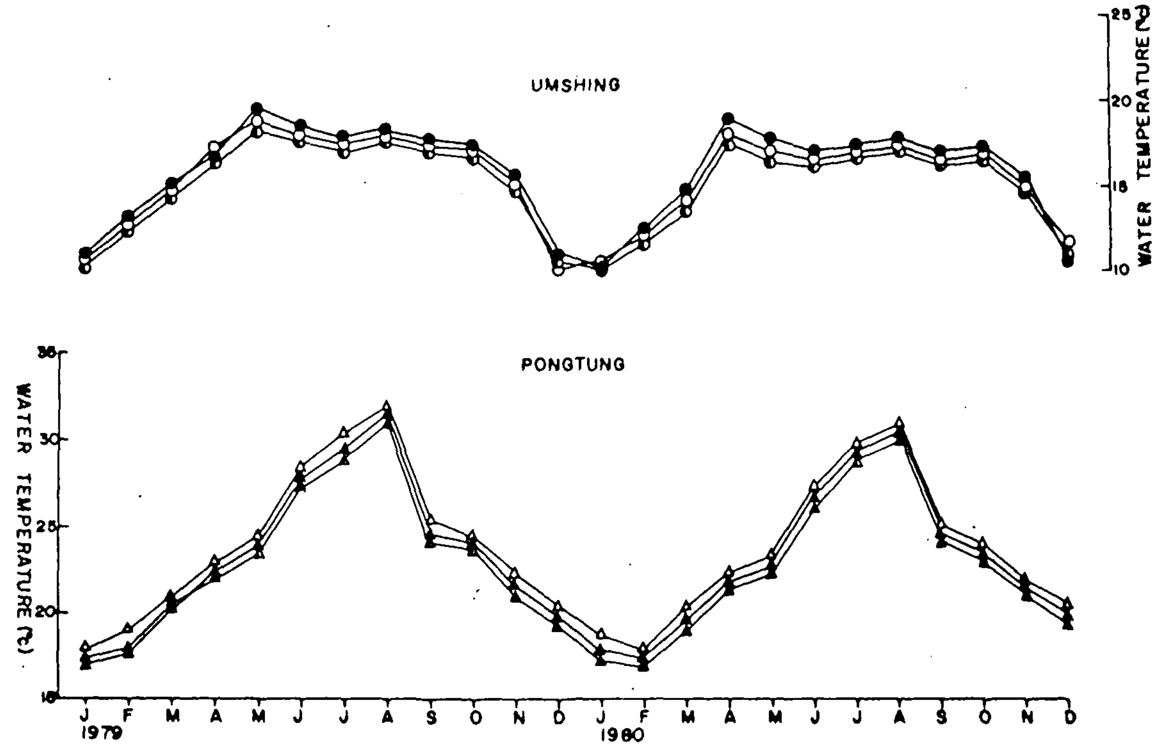


Fig. 8. Water temperature at six different stations: A_1 ○—○; A_2 ◐—◐; A_3 ●—●; B_1 △—△; B_2 ▲—▲; B_3 ▲—▲.

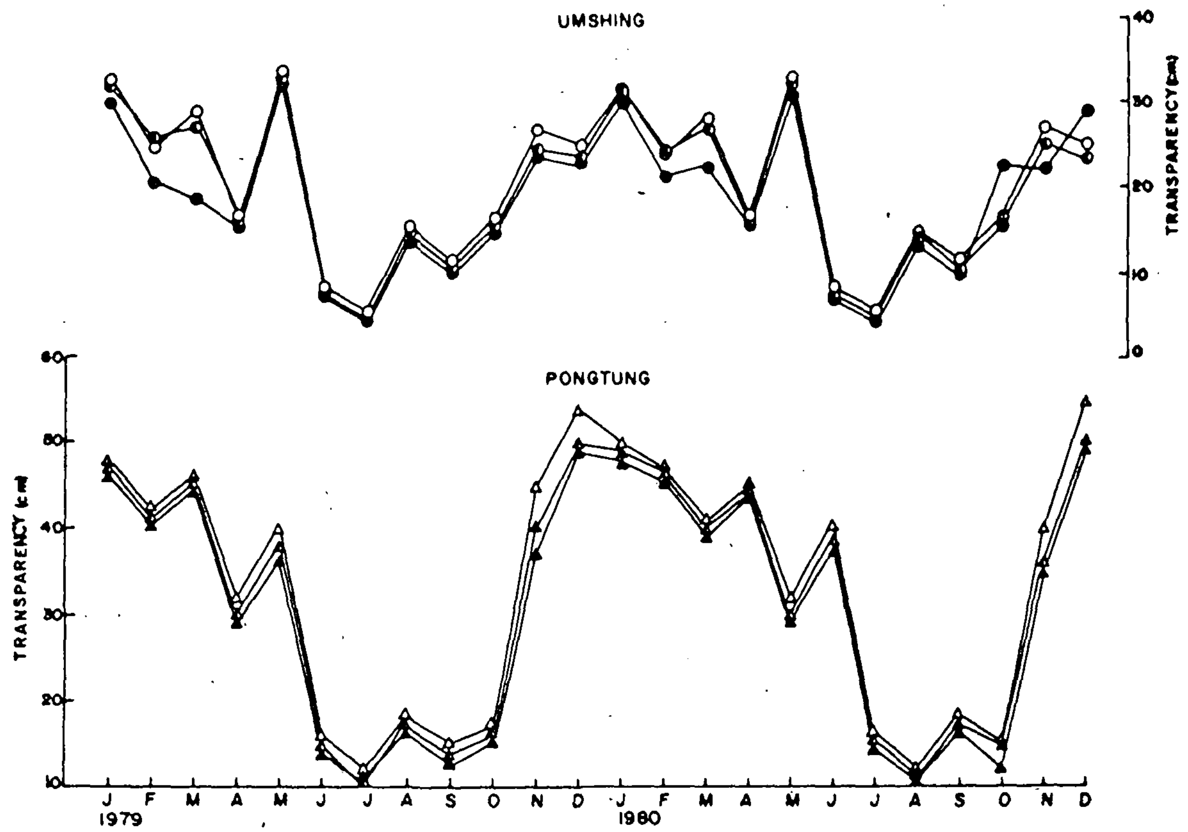


Fig. 9. Transparency values at six different stations: A_1 ○—○; A_2 ◐—◐; A_3 ●—●; B_1 △—△; B_2 ▲—▲; B_3 ▲—▲.

III. Transparency: It varied to the depth of 4.0 cm to 33.0 cm at Umshing stream and 10.0 cm to 55.0 cm in Pongtung stream. Station A_1, A_2, A_3, B_1, B_2 and B_3 showed the seccidisc reading in the range of 5.6 - 33.0 cm, 4.2 - 32.0 cm, 4.0 - 31.4 cm, 12.0 - 55.0 cm, 10.0 - 50.5 cm and 10.2 - 52.0 cm respectively (Fig. 9). The maximum transparency were recorded in the Upper regions (i.e., Station A_1 and B_1) of both the streams.

IV. Rate of water flow: It varied from 42.2 to 94.2 cm^3/sec in Umshing and 38.2 to 84.5 cm^3/sec at Pongtung stream. Station A_1,A_2,A_3,B_1,B_2 and B_3 had a fluctuation range of 42.2 - 88.2 cm^3/sec, 50.4 - 90.0 cm^3/sec, 52.0 - 94.2 cm^3/sec, 38.2 - 66.0 cm^3/sec, 41.5 - 70.6 cm^3/sec and 51.0 - 84.5 cm^3/sec respectively (Fig. 10).

V. Turbidity: It was maximum during the rainy season in all the stations. Comparatively, throughout the year Umshing stream was more turbid than Pongtung stream. The station A_3 experienced the maximum turbidity (96%) in July, 1979, than A_1 and A_2 while the station A_1 recorded the minimum of 8.5% in November, 1980. Out of B_1, B_2 and B_3 station B_3 recorded the maximum (80%) in July, 1979, and B_1, the minimum (8.0%) in November, 1979 (Fig. 11).

VI. Dissolved Oxygen: It showed September maxima in all the stations and fluctuated considerably throughout the year in the

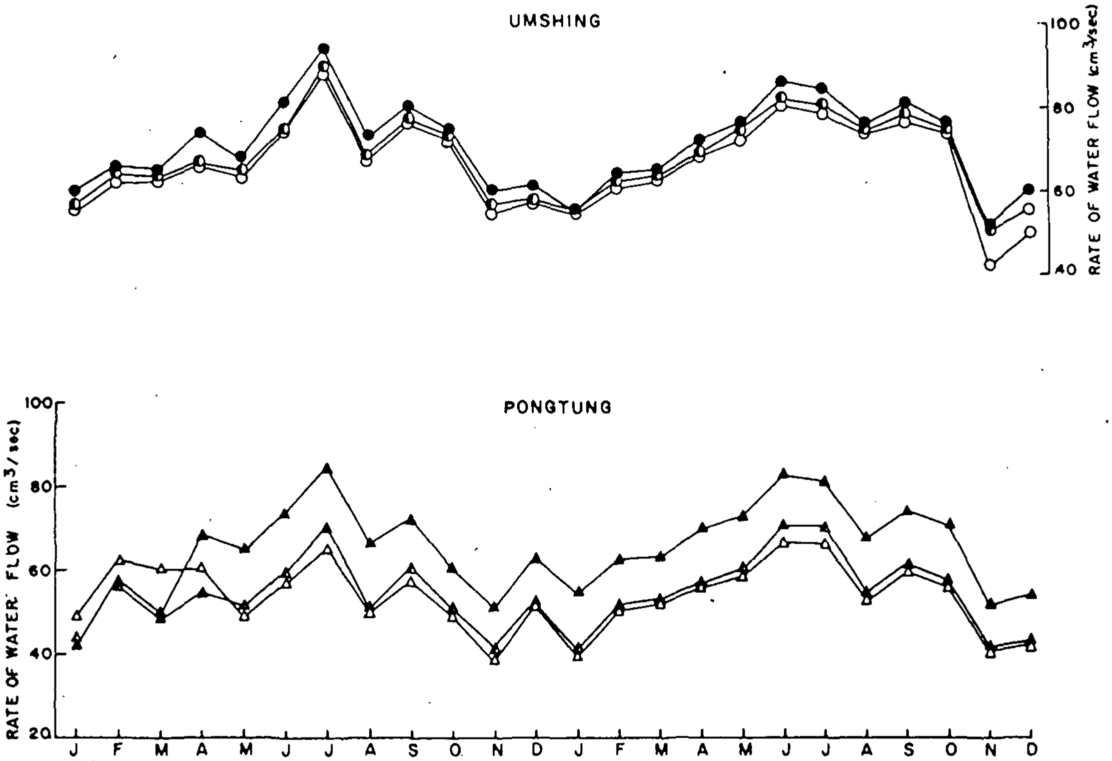


Fig. 10. Rate of water flow at six different stations: A₁ ○—○ ; A₂ ◐—◐ ; A₃ ●—● ; B₁ △—△ ; B₂ ▲—▲ ; B₃ ▲—▲ .

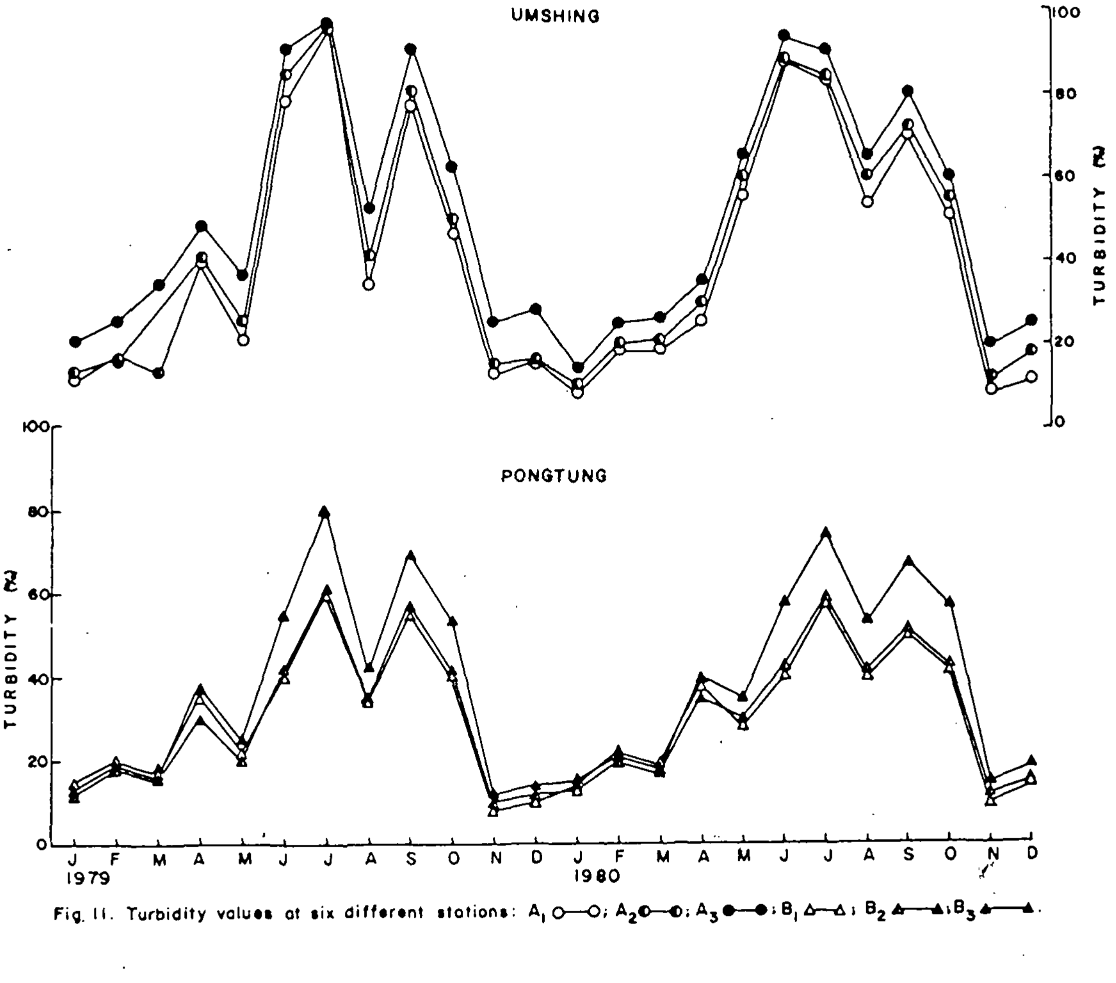


Fig. 11. Turbidity values at six different stations: A₁ ○—○ ; A₂ ◐—◐ ; A₃ ●—● ; B₁ △—△ ; B₂ ▲—▲ ; B₃ ▲—▲ .

range of 7.0 - 11.5 mg/l, 7.1 - 11.7 mg/l, 7.3 - 13.8 mg/l, 6.8 - 10.6 mg/l, 6.9 - 11.2 mg/l and 7.0 - 11.0 mg/l at the station A_1,A_2,A_3,B_1,B_2 and B_3 respectively (Fig. 12).

VII. Hydrogen ion concentration (pH): The pH of the water fluctuated considerably throughout the year. At Umshing, the pH varied from 5.7 to 7.3 but most of the months it was in acidic range only. Categorically, Station A_1 varied in the range of 5.8 - 6.9; A_2, 5.7 to 6.7; A_3, 6.1 to 7.3. But comparatively, the pH of Pongtung stream water was mostly leaning towards the alkaline range and fluctuated in the range of 5.8 - 6.8, 6.1 to 7.2 and 6.2 to 7.5 at the station B_1, B_2 and B_3 respectively (Fig. 13).

VIII. Carbon dioxide: It was varying in general from 1.8 to 5.0 mg/l. The station A_1,A_2,A_3,B_1,B_2 and B_3 had a fluctuating range of 2,4 - 5.0 mg/l, 2.6 - 4.85 mg/l, 1.8 - 4.6 mg/l, 3.0 - 4.9 mg/l, 2.7 - 4.65 mg/l and 2.4 - 4.6 mg/l respectively (Fig. 14). Station A_3 recorded a quite low carbon dioxide concentration (range 1.4 to 4.6 mg/l) during its first annual cycle.

IX. Specific conductivity: It ranged between 34.2 - 68.2 µmho/cm, 31.8 - 65.2 µmho/cm, 31.8 to 65.2 µmho/cm, 17.0 to 58.8 µmho/cm, 33.8 to 62.0 µmho/cm, 20.2 to 55.8 µmho/cm and 19.2 to 54.9 µmho/cm at the station A_1,A_2,A_3,B_1,B_2 and B_3 respectively (Fig. 15). During the first annual cycle, station A_3 experienced

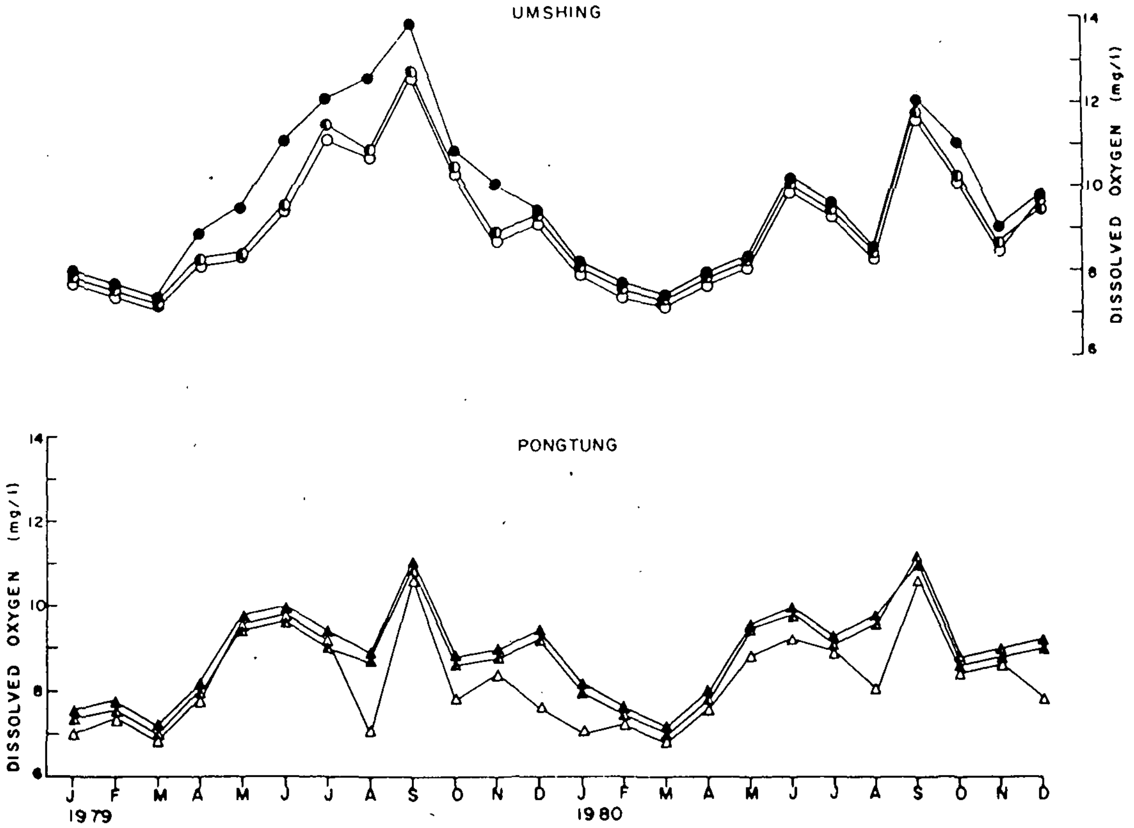


Fig. 12. Dissolved oxygen concentrations at six different stations: A_1 ○—○; A_2 ◐—◐; A_3 ●—●; B_1 △—△; B_2 ▲—▲; B_3 ▲—▲.

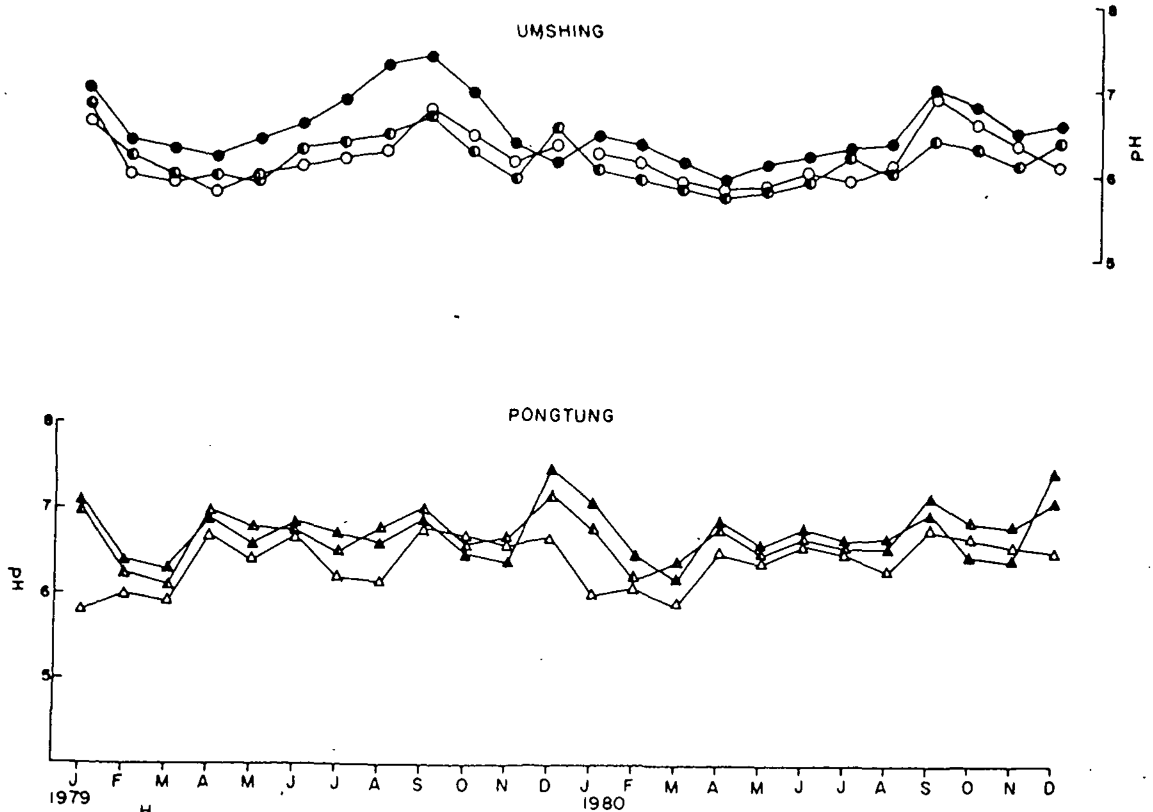


Fig. 13. P^H values at six different stations: A_1 ○—○ A_2 ◐—◐; A_3 ●—●; B_1 △—△ ; B_2 ▲—▲ ; B_3 ▲—▲.

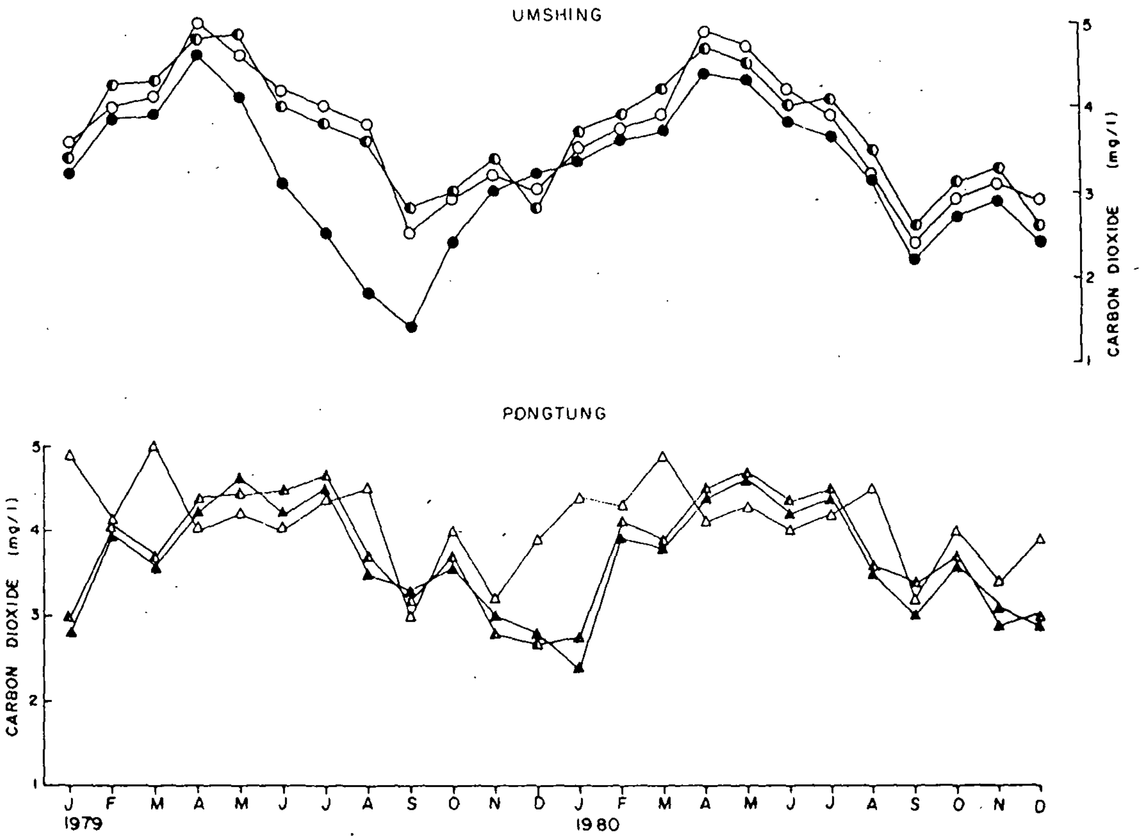


Fig. 14. Carbon dioxide values at six different stations: A_1 ○—○; A_2 ◐—◐; A_3 ●—●; B_1 △—△; B_2 ▲—▲; B_3 ▲—▲.

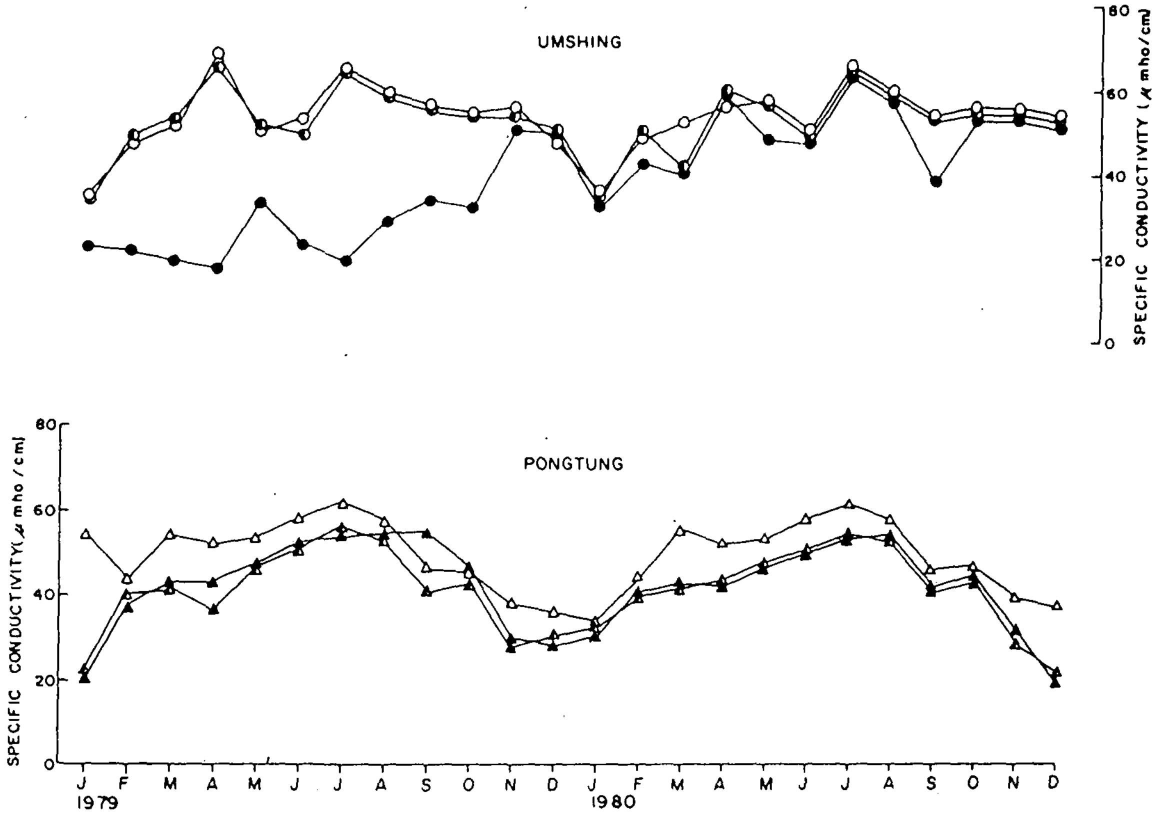


Fig. 15. Specific conductivity values at six different stations: A_1 ○—○; A_2 ◐—◐; A_3 ●—●; B_1 △—△; B_2 ▲—▲; B_3 ▲—▲.

a quite low condutivity (range, 17.0 - 52.8 µmho/cm).

X. Total Alkalinity: No phenolpthelein (carbonate) alkalinity but only methyl orange (bicarbonate) alkalinity was recorded at Umshing stream. However, both were recorded in Pongtung stream although former quantity was lesser than the later. Total alkalinity varied from 15 to 32.2 mg/l, 15.2 to 34.5 mg/l, 16.2 to 48.8 mg/l, 16.2 to 38.2 mg/l, 18.4 to 46.8 mg/l and 18.6 to 48.2 mg/l at the station A_1,A_2 ,A_3, B_1,B_2 and B_3 respectively (Fig. 16).

XI. Silicate: Comparatively Umshing stream recorded quite higher readings of silicate than Pongtung stream and in both, the higher values were noted during the rainy season (June - September). At station A_1,A_2,A_3, B_1,B_2 and B_3, it varied in the range of 3.8 - 6.1 mg/l, 4.15 - 6.5 mg/l, 4.35 - 7.6 mg/l, 2.1 - 3.9 mg/l, 2.5 - 4.0 mg/l and 2.63 - 4.25 mg/l respectively (Fig. 17).

XII. Phosphate-Phosphorous: It fluctuated in general from 0.24 mg/l to 1.10 mg/l and had a summer maxima and winter minima at all the stations. Phosphate-phosphorous content varied in the range of 0.30 - 0.90 mg/l, 0.31 - 0.85 mg/l, 0.40 - 1.30 mg/l, 0.42 - 0.98 mg/l, 0.24 - 0.92 mg/l and 0.30 - 1.10 mg/l at the station A_1,A_2,A_3,B_1,B_2 and B_3 respectively (Fig. 18). Station A_3 recorded the maximum phosphate phosphorous value (1.30 mg/l) in the month of June, 1979.

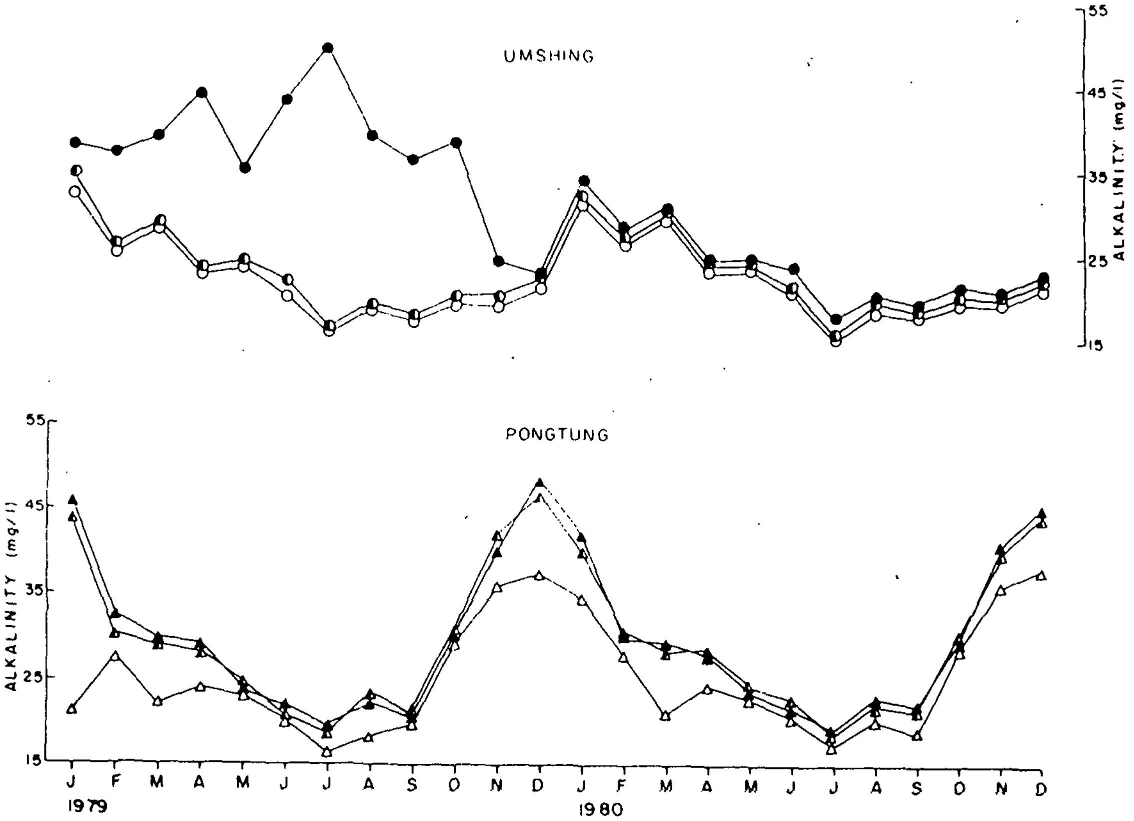


Fig. 16. Total Alkalinity values at six different stations: A_1 ○—○; A_2 ◐—◐; A_3 ●—●; B_1 △—△; B_2 ▲—▲; B_3 ▲—▲

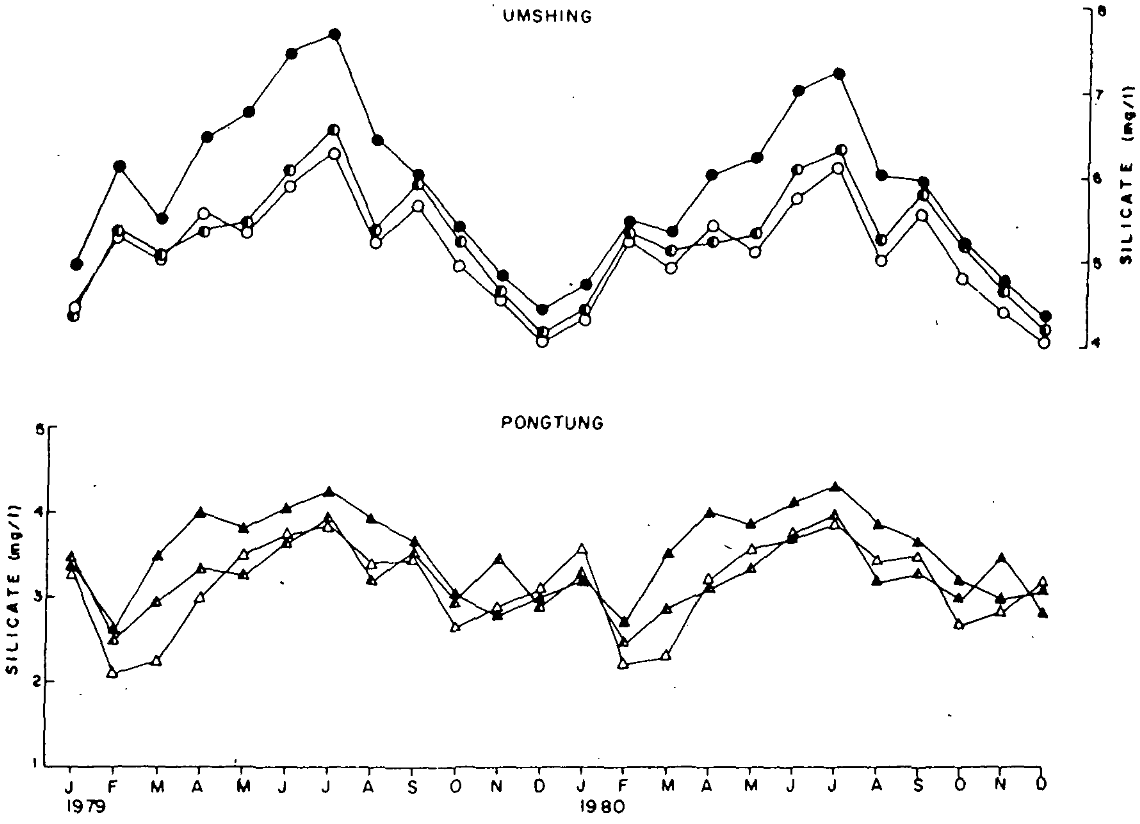


Fig. 17. Silicate concentrations at six different stations: A_1 ○—○; A_2 ◐—◐; A_3 ●—●; B_1 △—△; B_2 ▲—▲; B_3 ▲—▲.

XIII. Nitrate-nitrogen: It was varying in the range of 0.24 - 0.88 mg/l in all the stations. Categorically, it ranged 0.16 - 0.68 mg/l, 0.14 - 0.60 mg/l, 0.24 - 0.98 mg/l, 0.30 - 0.80 mg/l, 0.22 - 0.85 mg/l, and 0.25 - 0.88 mg/l at the station A_1, A_2, A_3, B_1, B_2 and B_3 respectively (Fig. 19). At the station A_3, the nitrate-nitrogen concentration was quite high (0.30 - 0.98 mg/l) during its first annual cycle.

XIV. Ammonia-nitrogen: It fluctuated in general from 0.05 mg/l to 0.094 mg/l. Individually, station $A_1, A_2, A_3, B_1, B_2, B_3$ recorded its fluctuation range of 0.05 - 0.081 mg/l, 0.044 - 0.085 mg/l, 0.05 - 0.094 mg/l, 0.052 - 0.09 mg/l, and 0.053 - 0.091 mg/l respectively (Fig. 20).

XV. Calcium: It was higher at all the stations of Pongtung stream than those of Umshing stream. At the station A_1, A_2, A_3, B_1, B_2 and B_3 the calcium concentration fluctuated in the range of 2.0 - 3.0 mg/l, 2.1 - 3.2 mg/l, 2.20 - 3.89 mg/l, 3.1 - 4.4 mg/l, 3.5 - 4.5 mg/l and 2.20 - 3.9 mg/l respectively (Fig. 21). Station A_3, recorded quite higher calcium value (3.0 - 3.9 mg/l) during the first annual cycle than station A_1 and A_2.

XVI. Magnesium: Station B_1, B_2 and B_3 accounted for the higher magnesium concentration than station A_1, A_2 and A_3 but station A_3, during its first annual cycle showed a sudden boost up (3.0 - 3.9 mg/l). At the station A_1, A_2 and A_3, it fluctuated from 0.51 - 1.30 mg/l, 0.58 - 1.38 mg/l and 0.84 - 2.64 mg/l

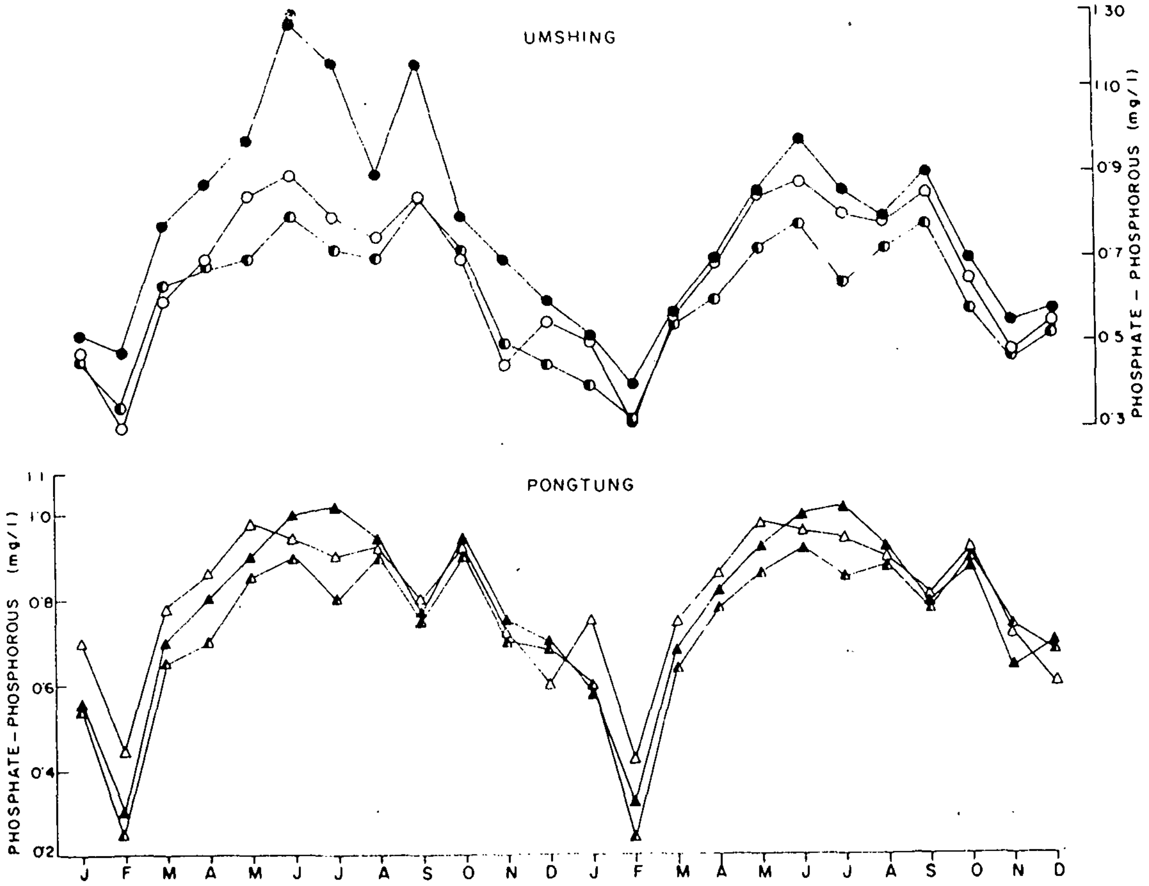


Fig. 18. Phosphate-phosphorous concentrations at six different stations: A_1 ○--○; A_2 ◐—◐; A_3 ●--●; B_1 △—△; B_2 ▲-▲; B_3 ▲-▲.

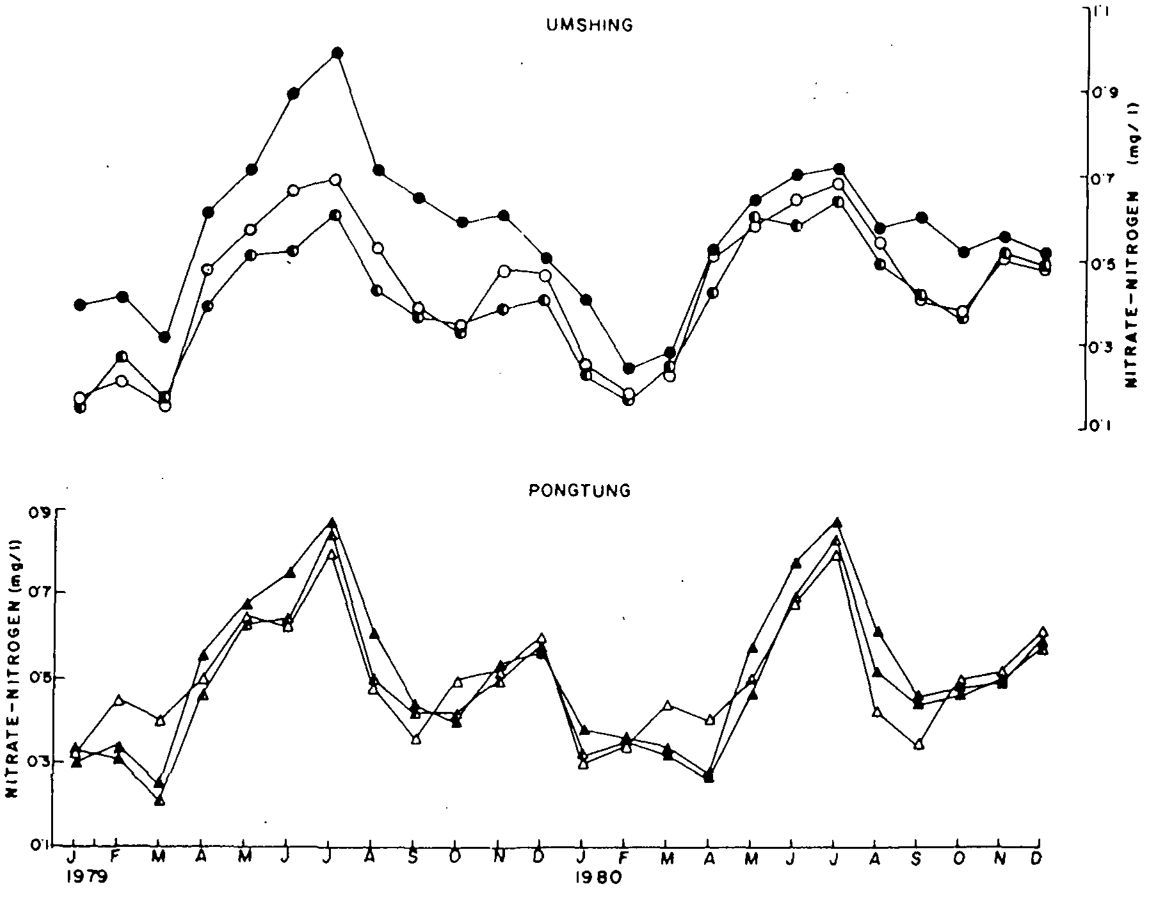


Fig. 19. Nitrate-nitrogen concentrations at six different stations: A_1 ○—○; A_2 ◐—◐; A_3 ●—●; B_1 △—△; B_2 ▲—▲; B_3 ▲—▲.

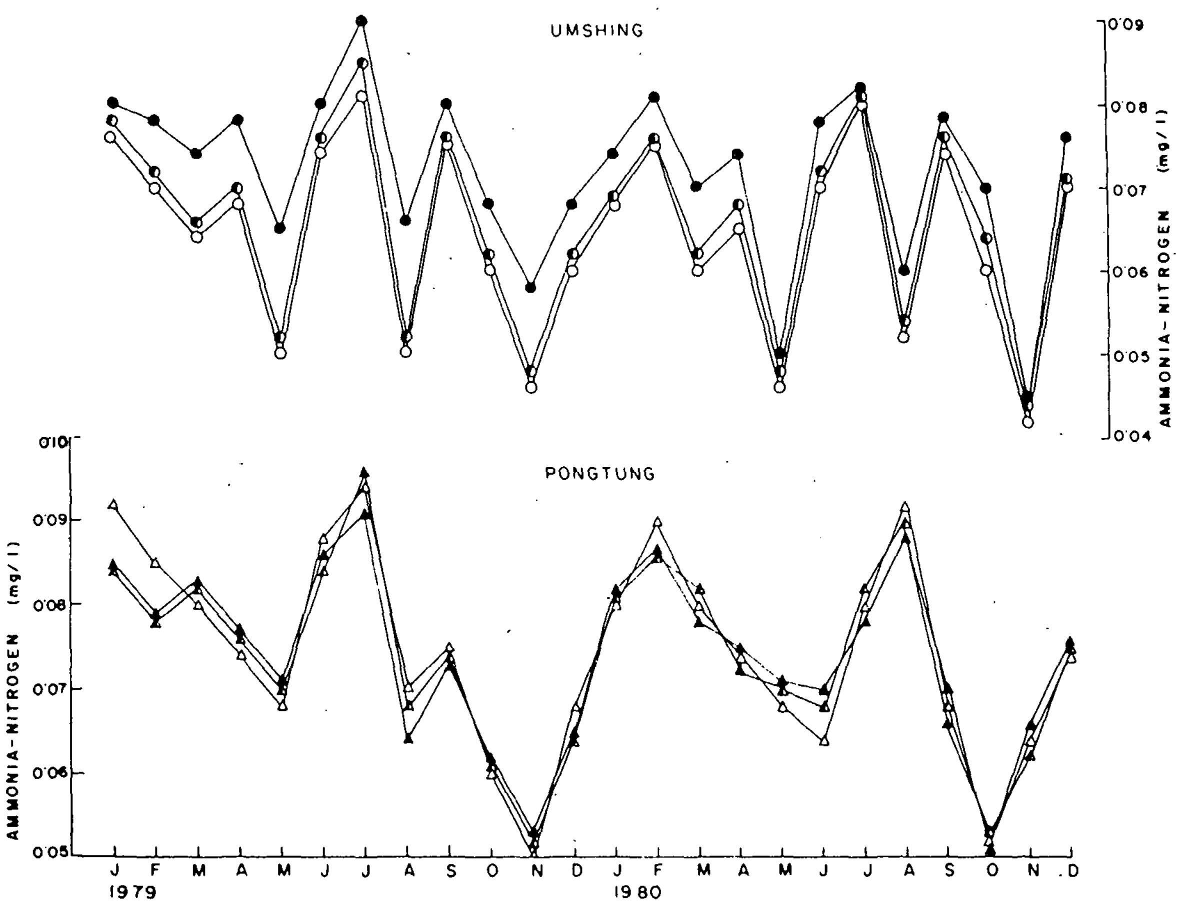


Fig. 20. Ammonia-nitrogen concentrations at six different stations: A_1○—○, A_2◐—◐, A_3●—●; B_1△—△; B_2▲—▲; B_3▲—▲.

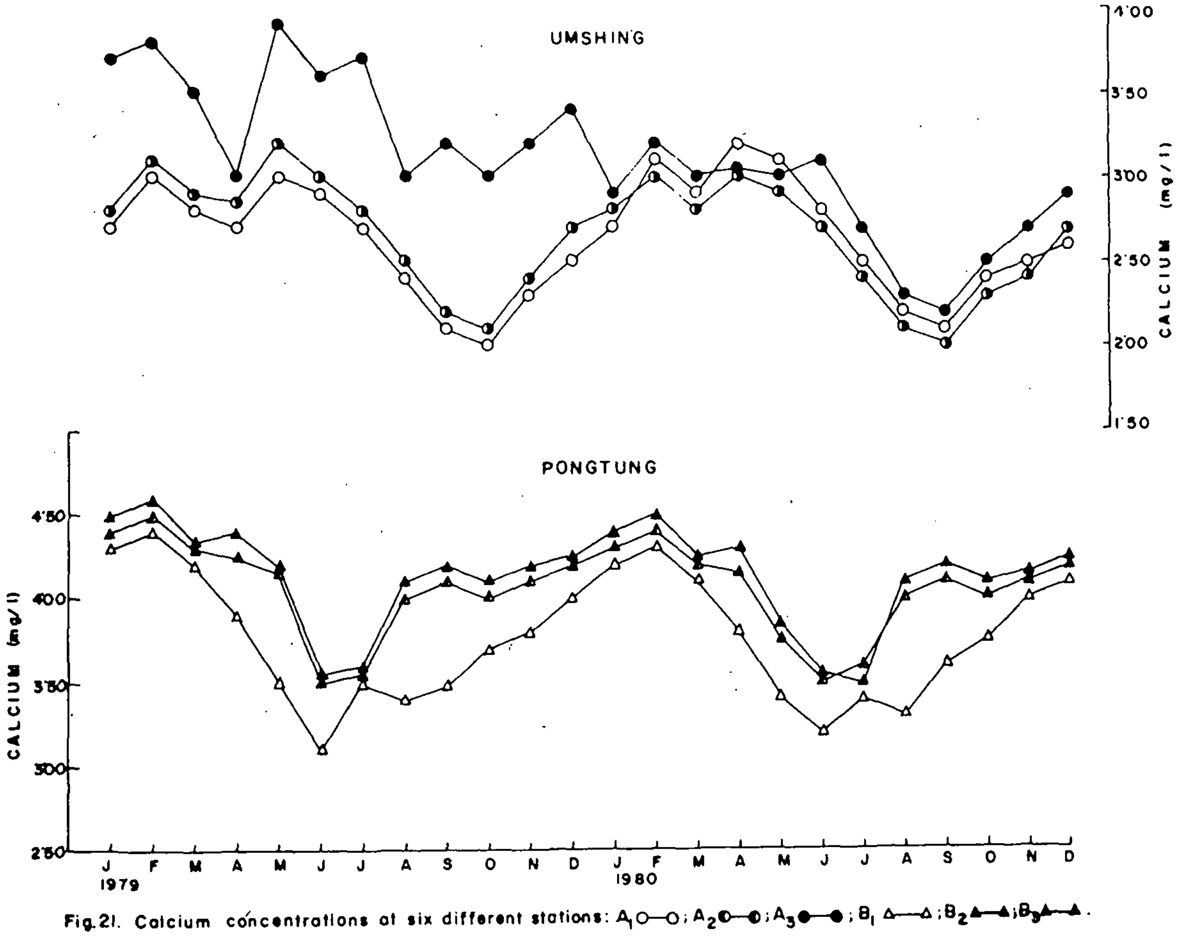


Fig. 21. Calcium concentrations at six different stations: A_1○—○; A_2◐—◐; A_3●—●; B_1 △—△; B_2▲—▲; B_3▲—▲.

respectively, whereas it ranged 1.0 - 2.3 mg/l, 1.20 - 2.4 mg/l and 1.24 - 2.8 mg/l at the station B_1,B_2 and B_3 respectively (Fig. 22).

XVII. Chloride: It showed seasonal fluctuation in all the stations and varied in the range of 0.4 - 1.0 mg/l, 0.44 - 1.20 ml/l, 0.50 - 1.35 mg/l, 0.40 - 1.10 mg/l, 0.35 - 1.15 mg/l and 0.38 - 1.18 mg/l at the station A_1, A_2, A_3, B_1, B_2 and B_3 respectively (Fig. 23).

XVIII. Sodium: It showed the winter maxima and the summer minima at all stations and fluctuated in the range of 1.6 - 3.6 mg/l, 1.68 - 3.68 mg/l, 1.95 - 4.0 mg/l, 1.7 - 3.3 mg/l, 2.1 - 3.86 mg/l, and 2.3 - 3.92 mg/l at stations A_1,A_2,A_3,B_1, B_2, and B_3 respectively (Fig. 24). Sodium content at the station A_3 was higher during the first annual cycle than the next cycle.

XIX. Potassium: It varied from 1.6 mg/l to 4.7 mg/l at Umshing stream and 1.7 mg/l to 4.0 mg/l at Pongtung stream. However, at station A_3 it showed comparatively higher potassium value during January 1979 - December 1980, than the preceeding annual cycle. Potassium concentration was fluctuating at stations A_1,A_2,A_3,B_1,B_2, and B_3 in the range of 1.6 - 4.0 mg/l, 1.7 - 4.1 mg/l, 1.90 - 4.7 mg/l, 1.7 - 3.4 mg/l, 2.4 - 3.8 mg/l and 2.5 - 4.0 mg/l respectively (Fig. 25).

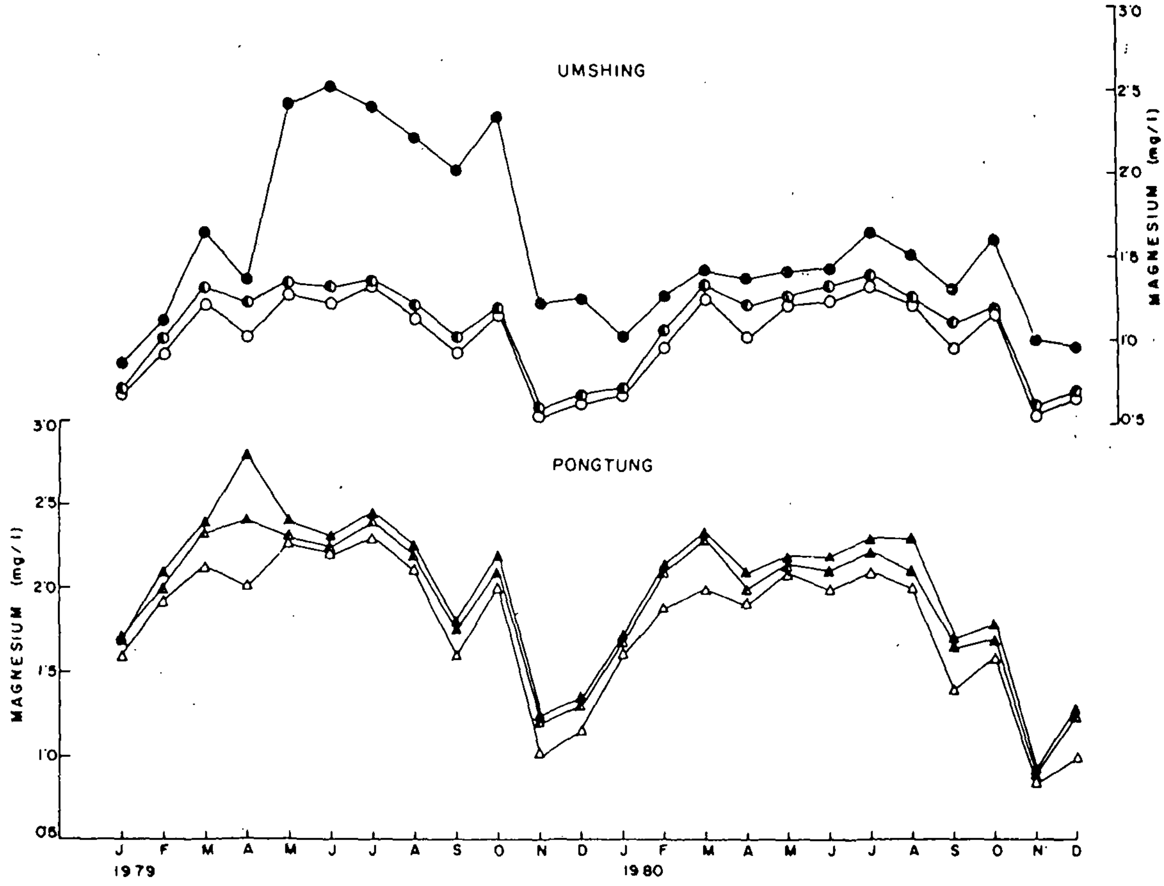


Fig. 22. Magnesium concentrations at six different stations: A_1 ○—○; A_2 ◐—◐; A_3 ●—●; B_1 △—△; B_2 ▲—▲; B_3 ▲—▲.

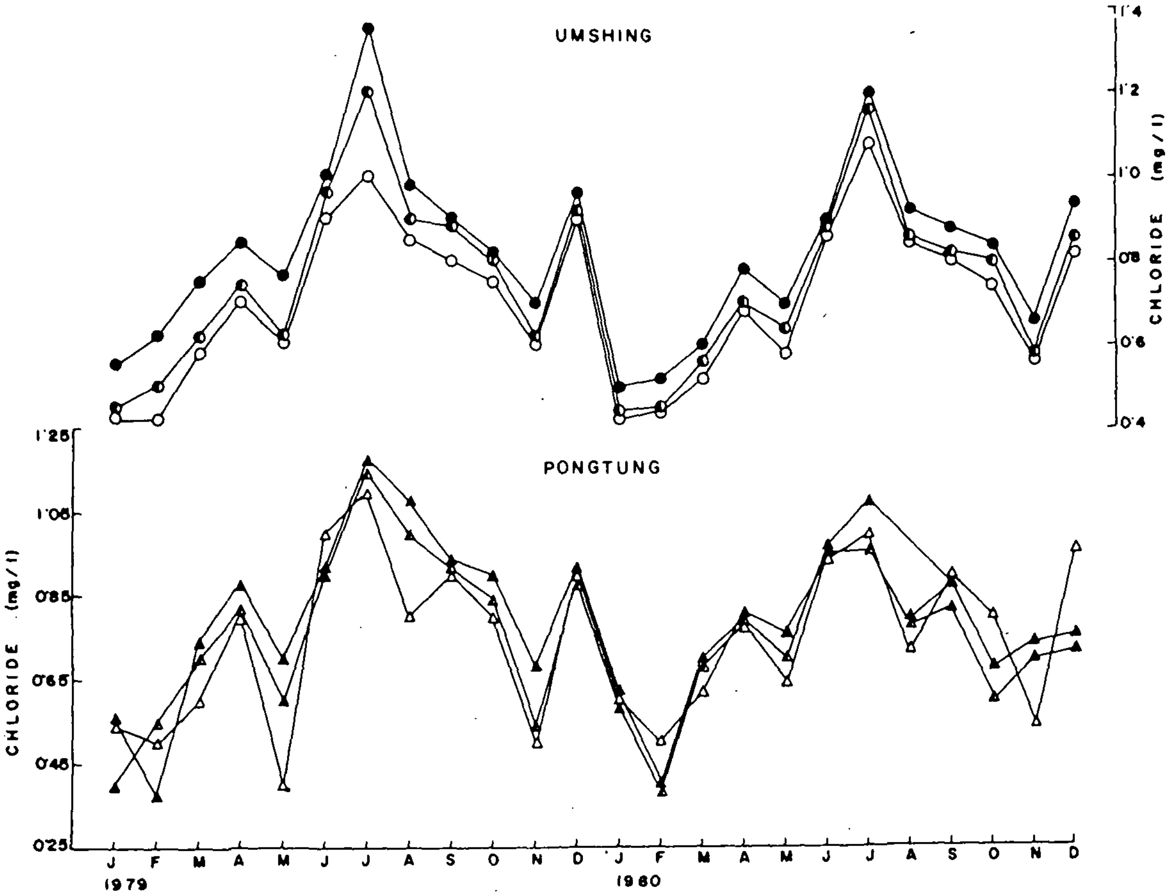


Fig. 23. Chloride ion content at six different stations: A_1 ○—○; A_2 ◐—◐; A_3 ●—●; B_1 △—△; B_2 ▲—▲; B_3 ▲—▲.

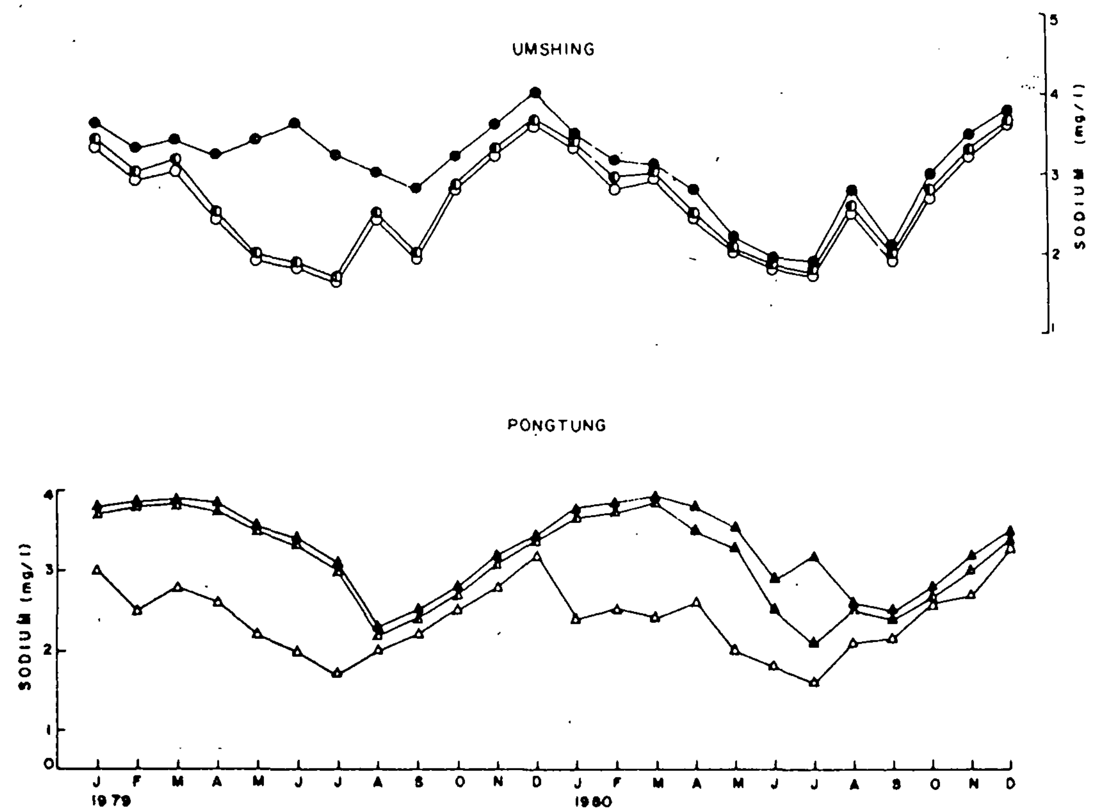


Fig. 24. Sodium concentrations at six different stations: A_1 ○—○ ; A_2 ◐—◐ ; A_3 ●—● ; B_1 △—△ ; B_2 ▲—▲ ; B_3 ▲—▲ .

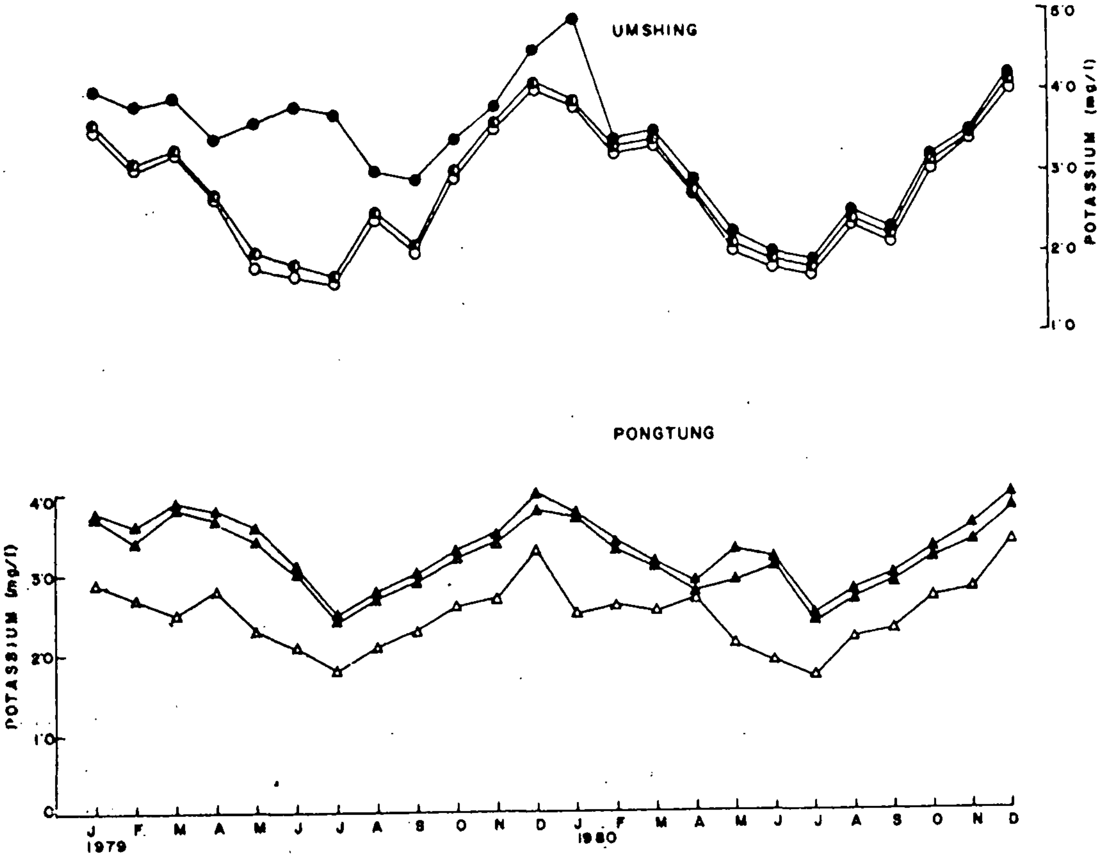


Fig. 25. Potassium concentrations at six different stations: A_1 ○—○ ; A_2 ◐—◐ ; A_3 ●—● ; B_1 △—△ ; B_2 ▲—▲ ; B_3 ▲—▲ .

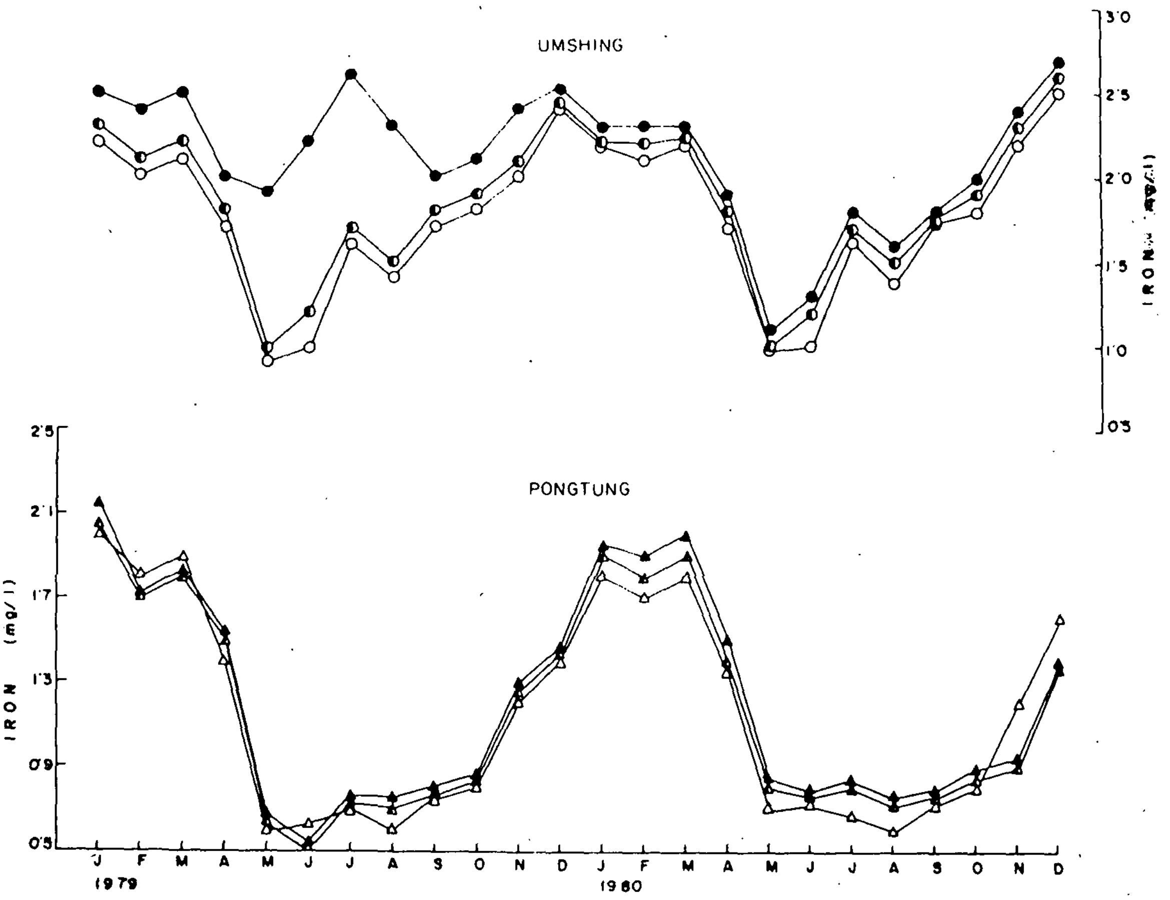


Fig. 26. Iron concentrations at six different stations : A_1 ○—○; A_2 ◐—◐; A_3 ●—●; B_1 △—△; B_2 ▲—▲; B_3 ▲—▲.

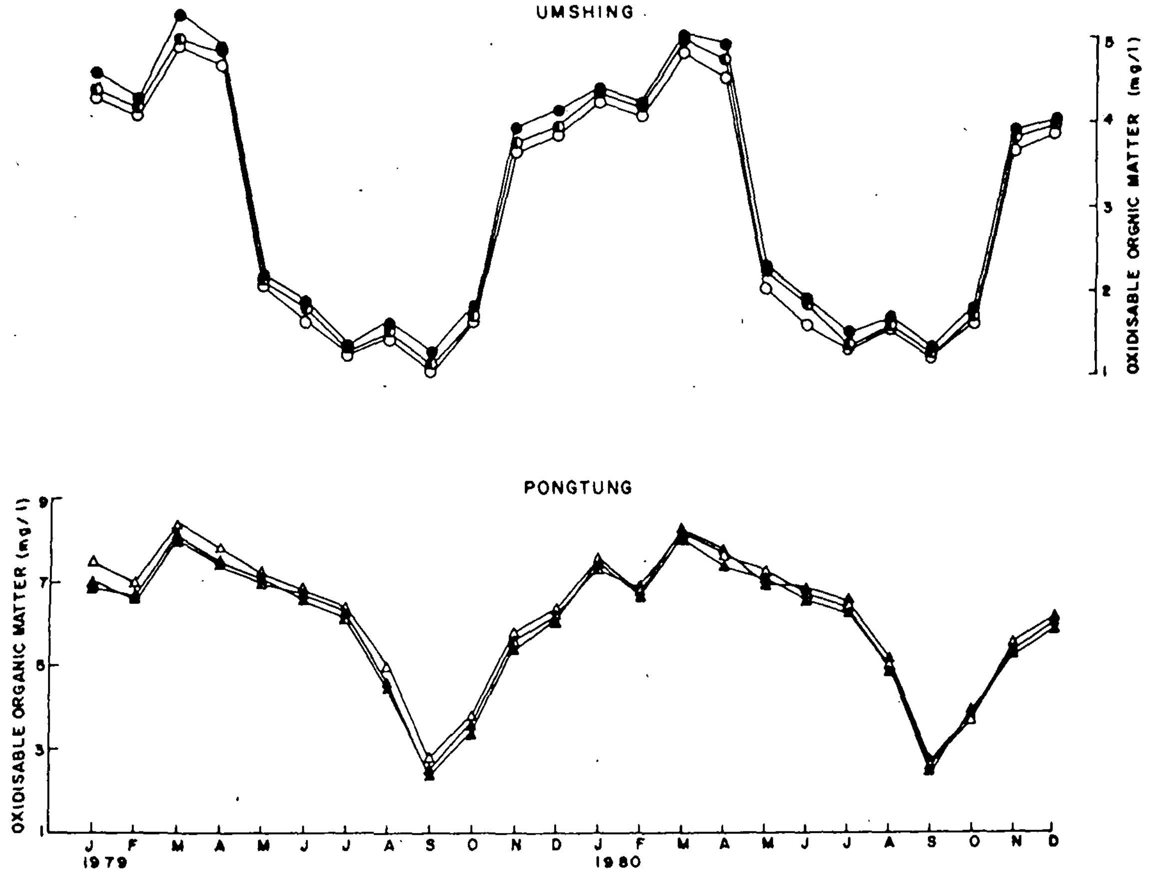


Fig. 27. Oxidisable organic matter values at six different stations: A_1 ○—○; A_2 ◐—◐; A_3 ●—●; B_1 △—△; B_2 ▲—▲; B_3 ▲—▲.

XX. **Iron:** Iron content did not follow any definite seasonal pattern. It varied from 0.9 to 2.5 mg/l, 0.98 to 2.6 mg/l, 1.1 - 2.7 mg/l, 0.6 to 2.0 mg/l, 0.5 to 2.05 mg/l and 0.54 to 2.10 mg/l at the station A_1, A_2, A_3, B_1, B_2 and B_3 respectively (Fig. 26).

XXI. Oxidisable Organic Matter: It was found higher at Pongtung stream than at Umshing stream and revealed winter maxima and summer minima at all the stations. At stations A_1, A_2, A_3, B_1, B_2 and B_3 it fluctuated in the range of 1.0 - 4.78 mg/l, 1.0 - 4.94 mg/l, 1.25 - 5.2 mg/l, 2.6 - 8.4 mg/l, 2.4 - 8.25 mg/l and 2.5 - 8.2 mg/l, respectively (Fig. 27).

4.1.2. Phyto- and Zooplankton:

In comparison to Pongtung stream, the plankton of Umshing stream is limited in mass and productive potential but relatively rich in diversity. Unfortunately, no detail diversity assessment of the natural assemblage was feasible because of the uneven mossaic growth patterns of certain algal flora and severe spate and erosion factors. Usually, flood-pools and small depressions in stream side boulders constitute a special habitat for the algal growth and also supports a considerable number of zooplankton.

4.1.2.a. Phytoplankton:

The total phytoplankton count showed a distinct summer maxima and winter minima at all stations. Based

Table 3: Distribution of phytoplankton taxa at each stations (*, rare; -, absent; +, present; ++, common; +++, abundant).

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
I. MYXOPHYCEAE:						
Chroococcaceae						
Aphanothece sp.	+	+	+	++	++	+
Gomphosphaeria sp.	+	+	+	++	+	+
Oscillatoriaceae						
Lyngbya spp.	+++	+++	++	+++	++	++
Plectonema sp.	+	+	+	+	+	+
Oscillatoria spp.	+	+	+	++	++	+
Schizothrix sp.	+	+	+	+	+	+
Nostocaceae						
Anabaena sp.	+	+	+	++	+	++
Nostoc sp.	+++	+	+	+++	++	+++
Rivulariaceae						
Calothrix sp.	++	+	+	++	++	++
Scytonemataceae						
Tolypothrix spp.	+++	++	+	+++	+	+
II.CHLOROPHYCEAE						
Palmellaceae						
Palmella sp.	+	+	+	+	+	+
Volvocaceae						
Euderina sp.	-	-	*	+	+	+
Gonium sp.	-	-	*	+	+	+
Hydrodictyaceae						
Pediastrum sp.	+	+	+	-	*	*

cont'd.

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
Characiaceae						
Dictyosphaerum sp.	+	++	++	+	+	++
Coclastraceae						
Coelastrum sp.	-	+	+	-	*	*
Oocystaceae						
Ankistrodismus spp.	+	++	++	++	+++	+++
Scenedesmaceae						
Actinastrium sp.	-	*	*	-	-	-
Scenedesmus spp.	*	+	+	+	+	++
Tetrastrum sp.	+	+	+	+	+	+
Ulotrichaceae						
Ulothrix spp.	+	++	++	++	+++	+++
Cladophoraceae						
Cladophora sp.	+	++	+++	+	+++	+++
Oedogoniaceae						
Oedogonium sp.	+	++	++	++	+++	+++
Zygnemataceae						
Spirogyra spp.	++	++	+++	+++	+++	+++
Zygnema sp.	+	+	+	+	+	++
Desmidiaceae						
Actinotaenium sp.	+	+	+	+	+	+
Cosmarium spp.	+	+	+	+	+++	+++
Closterium spp.	+	++	++	+	++	+++
Micrasterias sp.	+	+	+	+	+	++
Staureastrum sp.	+	+	+	+	+	+
Mesotaeniaceae						
Netrium sp.	+	+	+	-	-	-

cont'd.

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
III. DINOPHYCEAE:						
Gymnadiniaceae						
Gymnodinium sp.	+	+	+	++	++	++
Peridiniaceae						
Peridinium sp.	+	+	+	+	+	+
IV. CHRYSOPHYCEAE:						
Synuraceae						
Synura sp.	+	+	+	+	+	+
Glaebotrydiaceae						
Chlorobotrys sp.	+	+	+	-	-	-
Ochromonadaceae						
Ochromonas sp.	+	+	++	++	++	++
Dinobryon sp.	+	+	+	+	+	++
Pleurochloridaceae						
Botrydiopsis sp.	+	+	+	-	-	-
Rhizochrysidaceae						
Bitrichia sp.	+	+	+	-	-	-
Chrysidiastrum sp.	+	+	+	-	-	-
Mallomonadaceae						
Mallomonas spp.	+	+	++	++	++	++
V. RHODOPHYCEAE:						
Achrochaetiaceae						
Audoninella sp.	++	+	+	+	*	*
Batrachospermaceae						
Batrachospermum sp.	+	+	+	*	-	-
Lamaneaceae						
Lamanea sp.	++	+	+	+	+	+

cont'd.

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
VI. BACCILLARIOPHYCEAE:						
Coscinodiscaceae						
Melosira spp.	+++	++	+++	+	++	+++
Cyclotella sp.	+	+	+	-	-	*
Achnanthaceae						
Achnanthes spp.	+++	+++	+++	+++	+++	+++
Cymbellaceae						
Cymbella spp.	+	+	+	+	+	++
Amphora sp.	+	+	+	+	+	++
Naviculaceae						
Navicula spp.	+++	++	+++	++	++	++
Neidium sp.	-	-	*	+	+	+
Frustulia spp.	+	+	+	++	++	++
Pinularia spp.	++	+	++	++	++	++
Nitzschiaceae						
Nitzschia sp.	+	+	+++	+	+	+
Hantzschia sp.	-	-	*	*	+	+
Gomphonemaceae						
Gomphonema sp.	+++	+++	++	+++	+++	+++
Surirellaceae						
Surirella spp.	+	+	+++	++	++	++
Fragillariaceae						
Fragillaria spp.	+++	+++	+++	+++	+++	+++
Tabellaria spp.	+++	++	++	++	+	+
Synedra spp.	++	+	+++	*	++	++
Diatoma sp.	+	+	+	*	+	+

on their occurrence, the total phytoplankton was studied in detail into six categories viz. Myxophyceae, Chlorophyceae, Dinophyceae, Chrysophyceae, Rhodophyceae and Baccillariophyceae. In Table 3, the occurrence of each taxa per sub-community per station is given. Most notable was the dominance of the epilithic flora of Myxophyta, Baccilariophyta and Rhodophyta in Umshing stream and the dominance of epipelic flora of Chlorophyta, Dinophyta and Chrysophyta in Pongtung stream.

I. Myxophyceae: Myxophyceae occurred at all stations throughout the year with certain seasonal variation in terms of their percentage composition. At station A_1, A_2, A_3, Myxophyta contributed 5.0 to 17.5%, 7.0 to 19.0% and 7.0 to 20.0% whereas at station B_1, B_2 and B_3, they contributed 6.0 to 18.58%, 5.0 to 18.0% and 6.0 to 17.0% respectively towards their total phytoplankton composition (Figs. 28 & 29). The Myxophyte flora was surprisingly rich in the upper zone (station A_1 and B_1) of both the streams with Lyngbya sp., Nostoc sp., Calothrix sp. and Tolypothrix dominating the macroscopic assemblage (Table 3).

II. Chlorophyceae: This group was available throughout the year and exhibited two peaks, one in May and other in October and had a winter fall in all the stations. At station A_1, A_2 and A_3, Chlorophyceae comprises 25.0 to 50.0%. 30.4 to 48.0%, and 28.0 to 46.0% while the station B_1, B_2 and B_3 comprise 35.4 to 65.25%, 36.0 to 60.0% and 38.0 to 60.0% of the total

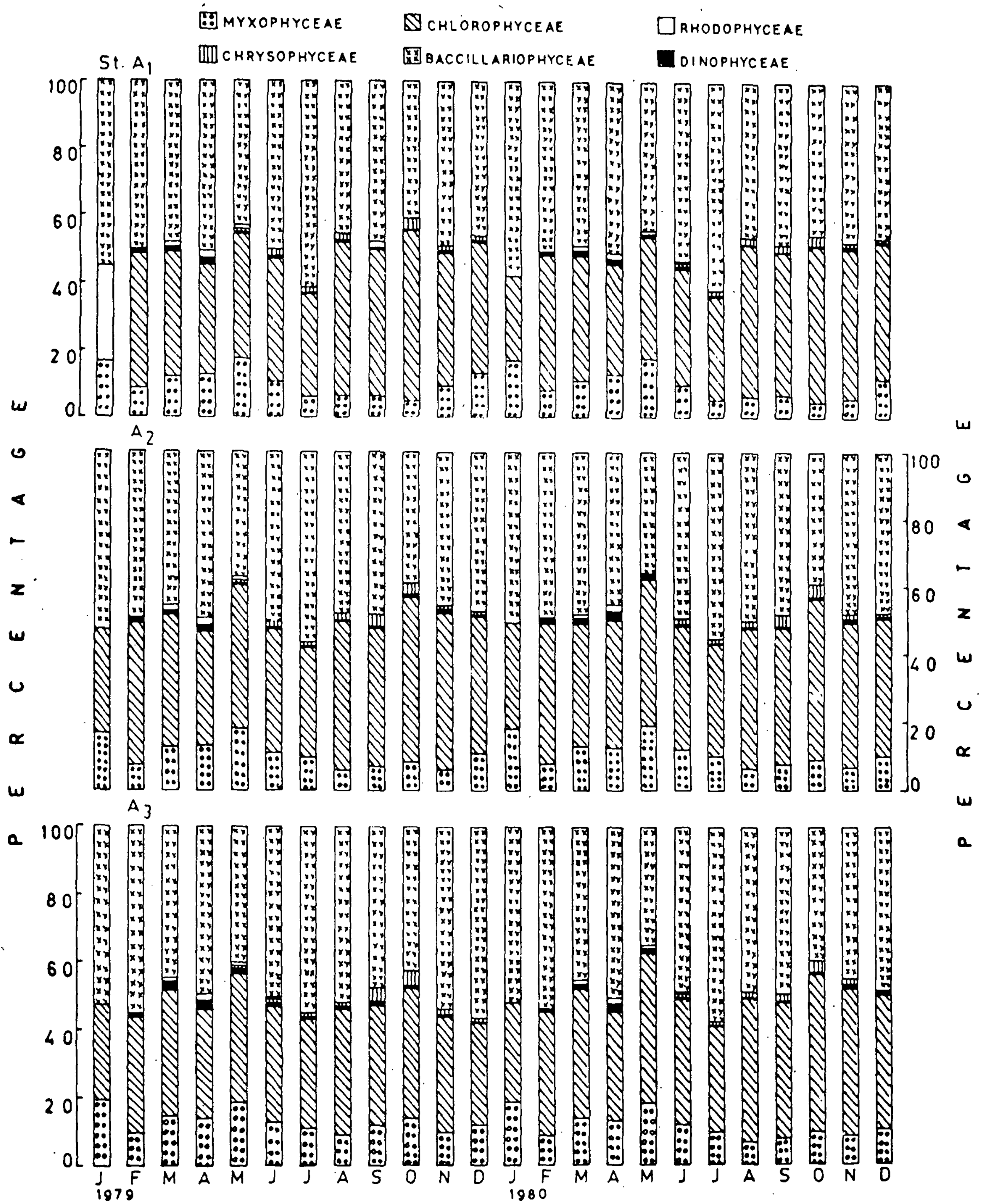


Fig. 28. Monthly fluctuations of the phytoplankton composition at Umshing stream.

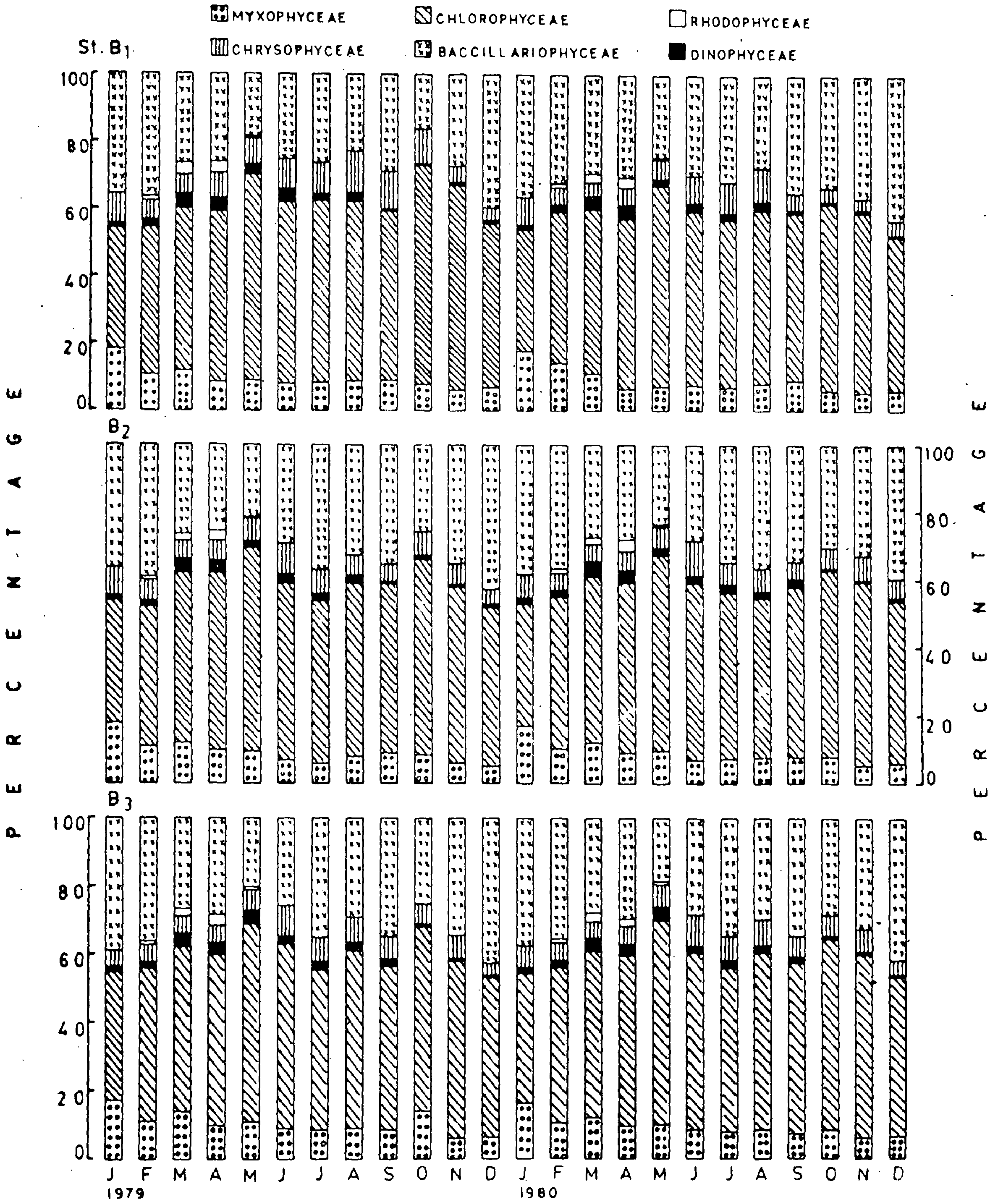


Fig. 29. Monthly fluctuations of the phytoplankton composition at Pongtung stream.

phytoplankton respectively (Figs. 28 & 29). The epipelic flora at the station A_1 and B_1 was scarce. Occasionally, Spirogyra developed small mats on muddy banks or sometimes on the boulders and rocky beds. The dominant chlorphytes include Spirogyra spp., Ulothrix spp. Oedogonium sp., Cladosphora sp., Ankistrodesmus spp., Closterium spp., Cosmarium spp. (Table 3).

III. Dinophyceae: This group showed the spring maxima and winter minima at all the stations. Dinophyceae represented only two genera viz. Gymnodinium and Peridinium, former being the more abundant type than the latter (Table 3). Dinophyceae contributed 0.3 to 2.0%, 0.3 to 2.7%, 0.2 to 3.5%, 0.5 to 4.41%, 0.5 to 4.3% and 0.5 to 4.2% in station $A_1, A_2, A_3. B_1, B_2$ and B_3 toward the total phytoplankton composition respectively (Figs. 28 & 29).

IV. Chrysophyceae: This group occurred throughout the year with summer maxima and winter minima in Pongtung stream. But in Umshing stream no chrysophytes were noted during January-April. However, a summer maxima was recorded. At the station A_1, A_2, A_3, B_1, B_2 and B_3 Chrysophyceae comprises 0.5 to 3.1%, 0.5 to 3.7%, 0.6 to 4.5%, 4.0 to 11.66%, 4.5 to 10.2% and 4.5 to 9.2% at statior A_1, A_2, A_3, B_1, B_2 and B_3 of the total phytoplankton (Figs. 28 & 29) respectively. Out of eight recorded genera of chrysophytes, Ochromonas and Mallomonas were the dominant type (Table 3).

V. Rhodophyceae: This group showed their occurrence, only in spring and contributed 0.2 to 1.82%, 0.4 to 2.1%, 0.4 to 2.0%, 0.5 to 3.6%, 0.5 to 3.2% and 0.8 to 3.5% at station A_1, A_2, A_3, B_1, B_2 and B_3 toward the total phytoplankton composition respectively (Fig. 28 & 29). Audoninella sp. was the only pre-dominant type in both the streams (Table 3).

VI. Baccillariophyceae: Baccillariophyceae occurred at all stations throughout the year with certain seasonal fluctuation. At station A_1, A_2 and A_3, Baccillariophyceae contributed 40.17% to 61.9%, 36.2 to 56.3%, 35.0 - 57.3% and in station B_1, B_2 and B_3 it contributed 16.3 to 46.0%, 21.2 to 42.6% and 20.2 to 42.7% toward its total phytoplankton composition (Figs. 28 & 29) respectively. Out of seventeen genera noted, Melosira, Achnanthes, Navicula, Pinularia, Gomphonema, Surirella and Fragellaria were the most dominant types (Table 3).

4.1.2.b. Zooplankton:

In association with the algae, considerable numbers of micro-consumers, i.e. Zooplankton were recorded. The total zooplankton count showed a distinct summer maxima and winter minima (Figs. 30 & 31). Based on their occurrence, the total zooplankton was studied in detail into five categories, viz. Protozoa, Rotifera, Ostracoda, Copepoda and Cladocera. In table 4, the distribution of each taxa per sub-community per station is given. Protozoans were the most dominant group,

Table 4: Distribution of Zooplankton at each station (*, rare; -, absent; +, present; ++, common; +++, abundant).

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
I. PROTOZOA						
Actinolophidae						
Actinolophus sp.	+	+	+	++	++	++
Macrogromiidae						
Actinospherium sp.	*	*	*	+	+	+
Didiniidae						
Didinium sp.	*	*	*	+	+	+
Podophryidae						
Podophrya sp.	*	*	*	+	+	+
Parmecium sp.	+	+	+	+	+	+
Vorticella sp.	+	+	+	+	+	+
Paulinellidae						
Euglypha sp.	++	+	++	++	+	+
Lecythium sp.	+	+	+	+	+	+
Tracheleuglypha sp.	+	+	+	+	+	+
Centropyxidae						
Centropyxis sp.	+	+	+	+++	++	++
Diffugia sp.	+	+	+	++	++	++
II. ROTIFERA:						
Brachionidae						
Brachionus sp.	*	*	*	+	+	+
Keratella sp.	*	+	+	++	++	++
Epiphanes sp.	-	-	-	*	*	*
Asplanchionidae						
Asplanchna sp.	*	*	*	+	+	+
Synchaetidae						
Synchaeta sp.	*	*	*	*	*	*
Polyarthra sp.	*	*	*	*	+	+
Lacanidae						
Lacane sp.	*	*	*	*	+	+
Trichaercidae						
Trichocerea sp.	-	-	-	-	-	*
Testudinellidae						
Testudinella sp.	*	*	*	*	+	+

cont'd.

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
III. OSTRACODA:						
Cypridae						
Cypris spp.	+	+	+	+	+	+
IV. COPEPODA:						
Cyclopidae						
Cyclops spp.	+	+	+	+	++	++
V. CLADOCERA:						
Moinidae						
Moina sp.	+	+	+	+	++	++
Daphnidae						
Daphnia sp.	+	+	+	+	++	++
Simocephalus sp.	*	*	*	+	+	+
Bosminidae						
Bosmina sp.	*	*	*	*	+	+
Chydoridae						
Acroperus sp.	-	-	-	*	*	*
Chydorus sp.	*	*	*	-	-	-

I. Protozoa: Protozoans were recorded in all stations throughout the year with certain seasonal variation in terms of their percentage compostion. In stations A_1, A_2 and A_3, these group contributed 22.0 to 58.33%, 20.0 to 52.0% and 22.0 to 50.0% whereas in station B_1, B_2 and B_3, contributed 34.0 to 62.5%, 34.0 to 52.0% and 38.0 to 52.0% respectively towards its total zooplankton composition (Figs. 30 & 31). Protozoans were comparatively richer in the upper zone (station A_1 and B_1) of both the streams than in the lower zone. The dominant protozoans were Actinolophus sp., Euglypha sp., Centrcpyxis sp. and Diffugia sp. (Table 4).

II. Rotifera: This group was available throughout the year and exhibited spring maxima and winter minima. At the station A_1, A_2 and A_3, Rotifera comprises 5.0 to 25.0%, 1.0 to 25.0% and 1.0 to 22.0% while the stations B_1, B_2 and B_3 comprise 14.58 to 27.69%, 15.0 to 30.0% and 15.0 to 28.0% of the total zooplankton (Figs. 30 & 31). In comparison to Umshing stream, the percentage composition of rotifera was always higher in Pongtung stream and, Asplancha sp., Keratella sp., Brachionus sp. were the dominant type (Table 4).

III. Ostracoda: This group occurred throughout the year with certain seasonal variation in terms of their percentage composition. Cypris spp. represented the single genus at all the stations and contributed 13.0 to 25.0%, 10.0 to 25.0%, 10.0 to 24.6%, 2.36 to 10.0%, 2.0 to 7.2% and 3.0 to 7.0% at

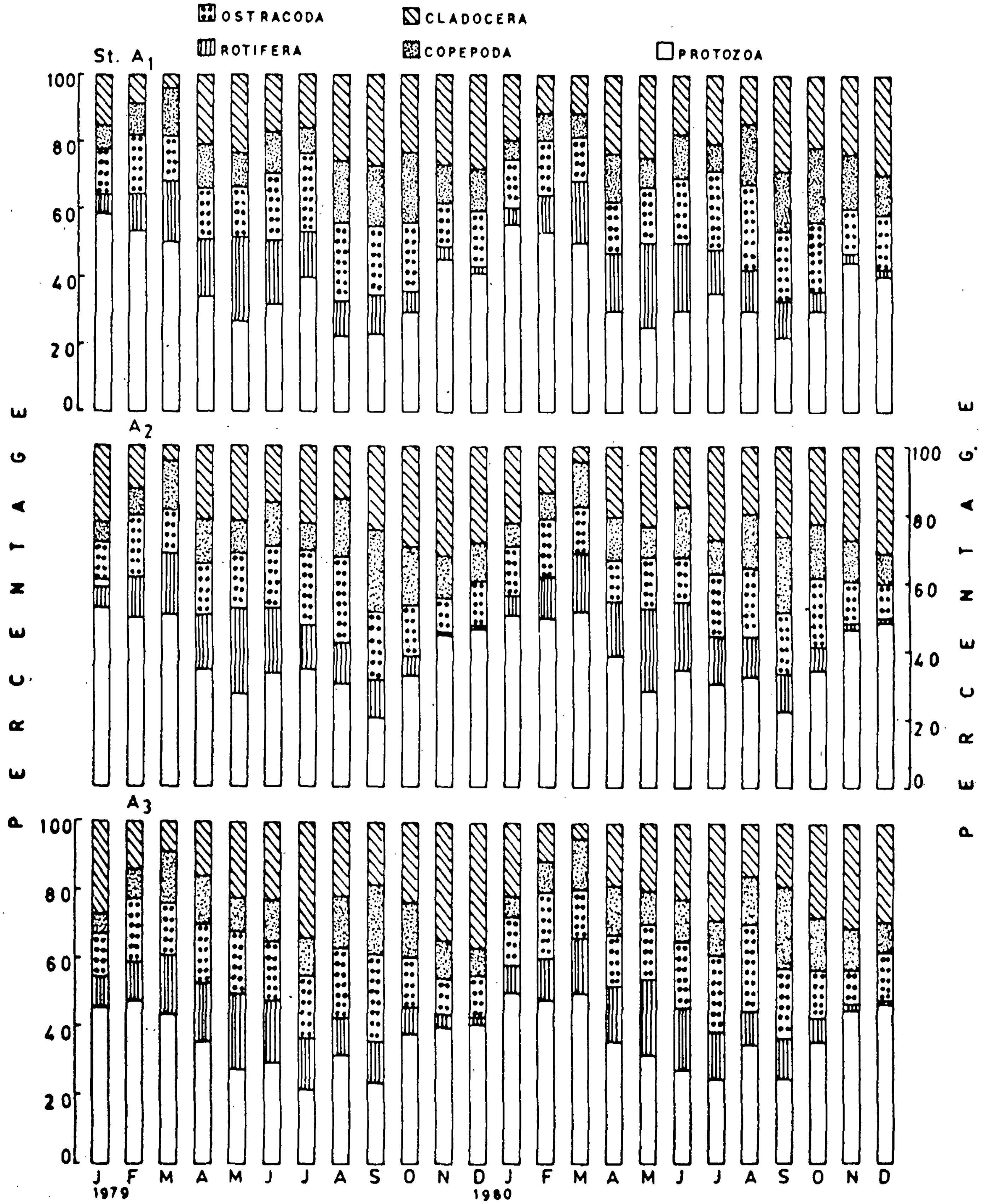


Fig. 30. Monthly fluctuations of the zooplankton composition at Umshing stream.

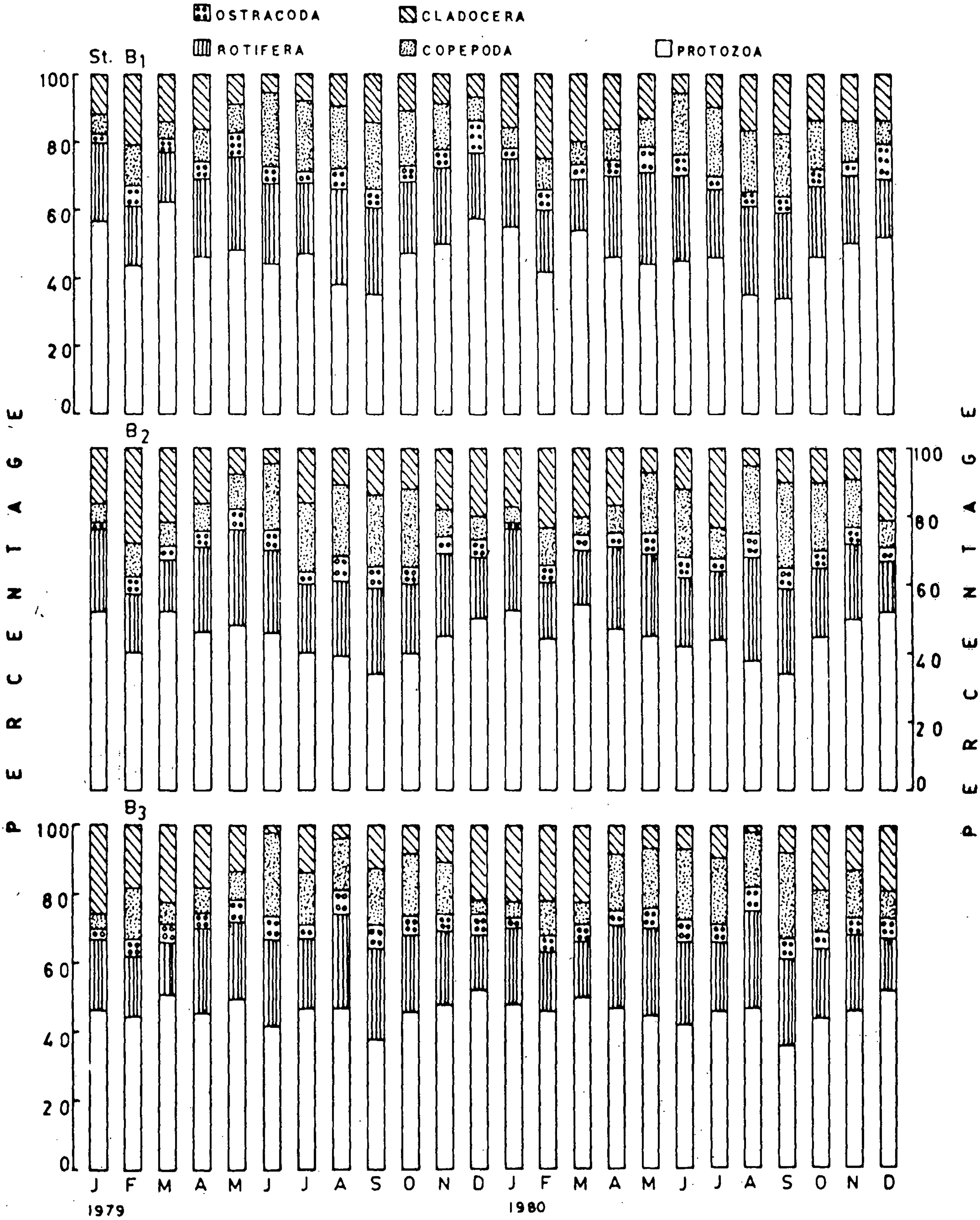


Fig. 31. Monthly fluctuations of the zooplankton composition at Pongtung stream.

stations A_1, A_2, A_3, B_1, B_2 and B_3 respectively towards the total zooplankton composition (Figs. 30 & 31).

IV. Copepoda: This group was recorded throughout the year with summer maxima and winter minima. Copepoda contributed 5.56 to 22.0%, 6.0 to 24.0%, 6.0 to 24.2%, 5.71 to 28.69%, 4.6 to 25.0% and 4.0 to 25.0% at the stations A_1, A_2, A_3, B_1, B_2 and B_3 respectively toward the total zooplankton composition (Figs. 30 & 31). Surprisingly, Cyclops was the single genus, representing the whole group (Table 4).

V. Cladocera: Cladocera occurred at all the stations throughout the year with certain seasonal fluctuation. Out of the six genera recorded, Moina sp. and Daphnia sp. were the dominant type (Table 4). At the stations A_1, A_2, A_3, B_1, B_2 and B_3, cladocera comprises 4.54 to 30.8%, 5.0 to 33.0%, 5.0 to 37.0%, 5.17 to 25.0%, 4.2 to 28.0% and 2.0 to 25.5% respectively of the total zooplankton composition (Figs. 30 & 31).

4.1.3. Benthic organism:

Pongtung stream supports a quite large number of benthic organisms throughout the year although there exists, in a certain range, the seasonal fluctuation too. The benthic fauna of Umshing stream on the other hand, is limited in mass and productive potential, but relatively rich in diversity. The benthic organism count showed, in general, a summer maxima

Table 5: Distribution of benthic organism at each **station** (*, rare; -, absent; +, present; ++, common; +++, abundant).

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
I. NEMATODA:						
Aphelenchoidae						
Labronema sp.	+	+	++	+++	+++	+++
Aphelenchoides sp.	*	*	*	+	+	+
Bastianudae						
Bastiania sp.	*	*	+	+	+	+
Diplogasteridae						
Diplogaster sp.	+	+	+	+	++	++
Plectidae						
Rhabdolaimus sp.	*	*	*	+	+	+
Anonchus sp.	*	*	*	+	+	+
Chronogaster sp.	+	+	+	++	++	+++
Triplylidae						
Alaimus sp.	*	*	*	-	-	-
Trilobus sp.	*	*	+	*	+	+
Dorylaimidae						
Actinolaimus sp.	*	*	+	*	+	+
Dorylaimus sp.	*	*	+	+	+	+
II. OLIGOCHAETA:						
Naididae						
Aulophorus sp.	*	*	*	*	*	*
Pristina sp.	*	*	*	*	*	*
Chaetogaster sp.	+	+	+	+	+	+
Branchiodrilus sp.	+	+	+	*	*	+
Allonais sp.	*	*	*	*	*	*
Stylaria sp.	*	*	*	++	++	++
Tubificidae						
Limnodrilus sp.	+	+	+	*	*	*
Bothrioneurum sp.	*	*	*	+	+	+
Megascolecidae						
Eukerria sp.	-	-	-	*	*	*
Pheretima sp.	*	*	*	++	++	++

cont'd.

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
III. DECAPODA:						
Palaemonidae						
Macrobrachium hendersoni hendersoni	++	++	++	-	-	-
M. hendersoni cacharensis	-	-	-	+++	+++	+++
M. dayanum	*	*	*	-	-	-
M. assamensis	-	-	-	*	*	*
Potamonidae						
Potamon sp.	*	*	*	*	*	*
Paratelphusa spp.	+	+	+	++	++	++
IV. INSECTA:						
Collembola						
Poduroidae (unidentified type)	*	*	+	*	*	*
Orthoptera						
Epilampridae(unidentified type)	*	*	+	*	*	*
Meghaloptera						
Corydalidae (unidentified type)	*	*	+	*	*	*
Ephemeroptera						
Baetidae						
Baetis spp.	++	++	++	+	+	+
Pseudocloen spp.	*	*	*	+	+	+
Caenidae						
Caenis spp.	+	+	+	+	+	+
Ephemerellidae						
Ephemerella spp.	-	-	*	*	*	*
Odonata:						
Protoneuridae						
Prodasineura spp.	+	*	*	*	*	*
Chlorocyphidae						
Rhinocypha spp.	+	*	*	-	-	-
Gomphidae						
Gomphidia sp.	*	*	*	-	-	-
Microgomphus sp.	*	*	*	*	-	-
Meghalogomphus sp.	*	*	*	*	*	-

cont'd.

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
Corduliidae						
Macromia spp.	*	*	-	-	-	-
Libellulidae						
Orthetrum sp.	*	*	-	-	-	-
Onchothemia sp.	*	*	-	-	-	-
Plecoptera						
Nemouridae						
Amphinemura sp.	*	*	*	*	-	-
Nemoura sp.	*	*	*	-	-	-
Perlidae						
Neoperla sp.	++	++	++	+	+	*
Etrocorema sp.	+	+	+	+	*	*
Hemipetra						
Hydrometridae						
Hydrometra sp.	+	+	*	+	*	*
Valiidae						
Rhagovelia sp.	++	++	+	*	*	*
Microvelia sp.	+	+	*	*	*	*
Gerridae						
Limnometra sp.	++	+	+	+	+	+
Metrocoris sp.	+	+	+	*	*	*
Corixidae						
Micronecta sp.	+	+	+	+	+	+
Nepidae						
Ranatra sp.	+	+	*	+	*	*
Trichoptera						
Psychomiudae						
Psychomyia sp.	*	*	*	+	*	*
Ecnomus spp.	*	*	*	+	+	+
Philopotamidae						
Chrimarra spp.	*	*	*	+	+	+
Rhyacophilidae						
Rhyacophila sp.	+	+	*	+	+	*
Leptoceridae						
Leptocella sp.	++	++	++	+	+	+
Oecetis spp.	++	+	+	+	+	+
Adicella spp.	+	+	*	++	+	*

cont'd.

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
Coleoptera						
Dytiscidae						
Hydrovatus sp.	*	*	*	+	+	+
Gyrinidae						
Orectochilus sp.	*	*	*	*	*	+
Psephenidae						
Psephenoides sp.	*	*	*	+	+	*
Psephenus sp.	*	*	*	+	+	+
Hydrophilidae						
Amphiops sp.	*	*	*	*	*	*
Enochrus sp.	*	*	*	+	+	+
Diptera						
Chironomidae						
Chironomus spp.	*	*	+	*	*	*
Tanytarsus spp.	*	*	*	*	*	*
Pentaneura spp.	*	*	*	*	*	*
Simuliidae						
Simulium spp.	*	*	*	+	+	+
Tipulidae						
Hexatoma sp.	*	*	*	+	+	+
Limonia sp.	*	*	*	+	+	+
V. GASTROPODA:						
Ampullaridae						
Pila spp.	+	+	+	+	+	+
Thiaridae						
Thiaria sp.	*	*	*	*	*	*
Melanoides sp.	*	*	*	*	*	*
Lymnaeidae						
Lymnea sp.	*	*	*	+	+	*
VI. MISCELLANEOUS:						
Bryozoa:						
Victorellidae						
Pottisiell sp.	*	*	*	*	*	*
Plumatellidae						
Plumatella sp.	*	*	*	*	*	*

cont'd.

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
Hydroidea						
Hydra sp.	-	-	*	*	-	-
Turbellaria						
Planariidae						
Dugesia sp.	-	-	*	-	*	*
Hirudinea						
Glossiphonidae						
Glossiphonia sp.	*	*	*	*	*	*
Helobdella sp.	-	-	*	*	*	*
Erpobdellidae						
Barbroonia sp.	-	-	-	*	*	*
Herpobdelloidea sp.	-	-	-	*	*	*
Acarina						
Torrenticolidae						
Hydrachnellid sp.	*	*	+	-	-	-
Hydracarina sp.	*	*	+	-	-	-

and winter minima (Figs. 32 & 33). Based on their occurrence, the benthic organisms were categorised into six groups viz. Nematoda, Oligochaeta, Decapoda, Insecta, Gastropoda and miscellaneous group. In Table 5, the distribution of each taxa per sub-community per station is given.

I. Nematoda: Nematoda occurred at all stations throughout the year with certain seasonal variation in terms of their percentage composition (Figs. 32 & 33). At the station A_1,A_2 and A_3, Nematoda contributed 5.88 to 24.0%, 10.0 to 25.0% and 10.0 to 24.0% whereas at stations B_1,B_2 and B_3, its population contributed 11.11 to 30,0%, 12.0 to 32.0% and 14.0 to 30.0% toward its total benthic composition respectively. In comparison to Umshing stream, Nematod population was higher in the Pongtung stream and mostly present along the bottom substrates of the forest leaf fall and other decidua. *Labronema* sp., *Diplogaster* and *Chronogaster* sp. represented the most abundant type (Table 5).

II. Oligochaeta: This group was absent during the winter and early spring and exhibited their peak availability during July at all stations. At the stations A_1,A_2,A_3,B_1,B_2, and B_3 the oligochaetes population comprise 2.7 to 16.0%, 5.0 to 17.0%, 4.0 to 18.0%, 4.0 to 13.0%, 4.0 to 19.0% and 4.0 to 18.0% of the total benthic composition respectively (Figs. 32 & 33). Out of the ten genera of oligochaetes recorded (Table 5), *Branchiodrilus* sp. and *Limnodrilus* sp. were the most dominant

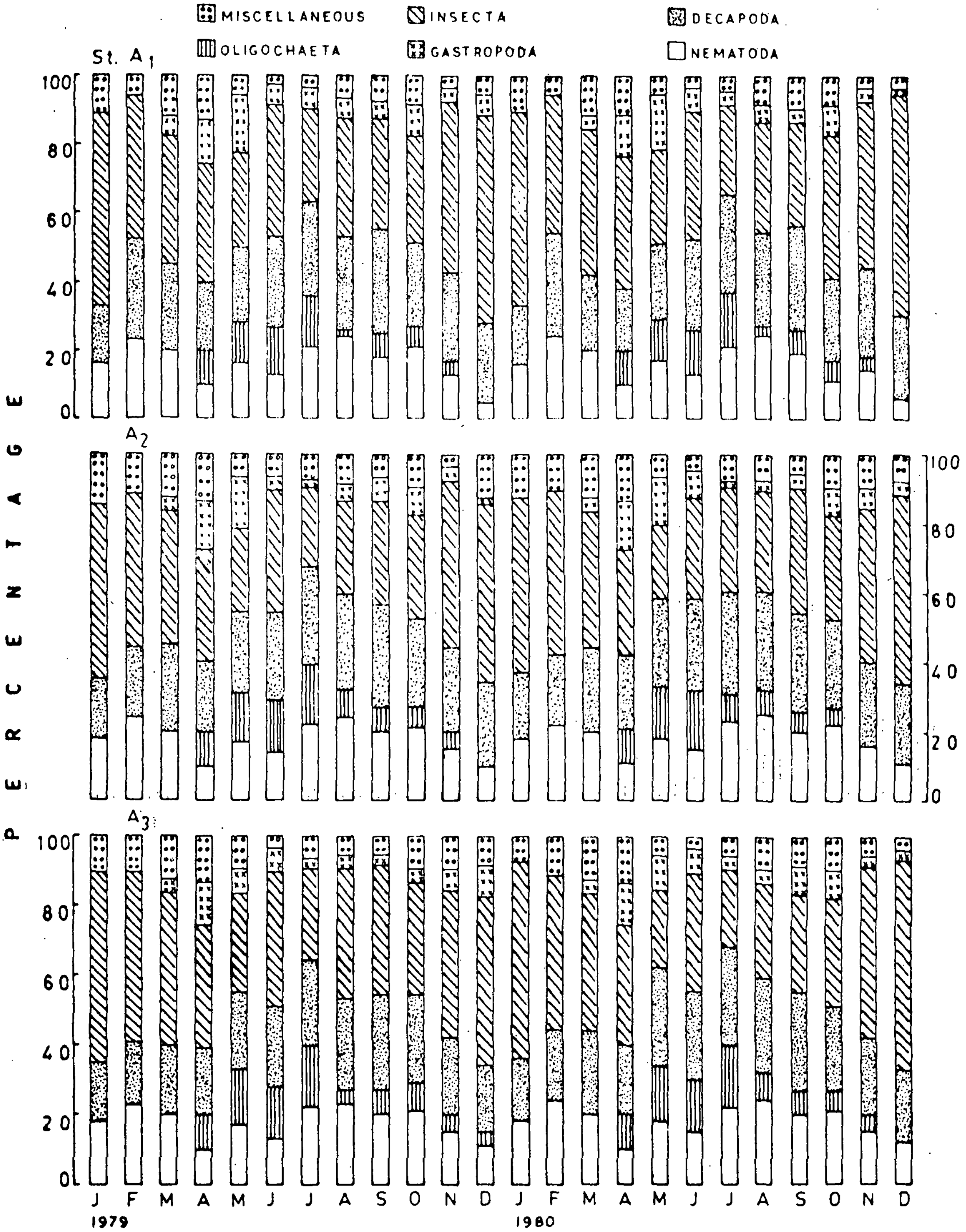


Fig. 32. Monthly fluctuations of the benthic organism composition at Umshing stream.

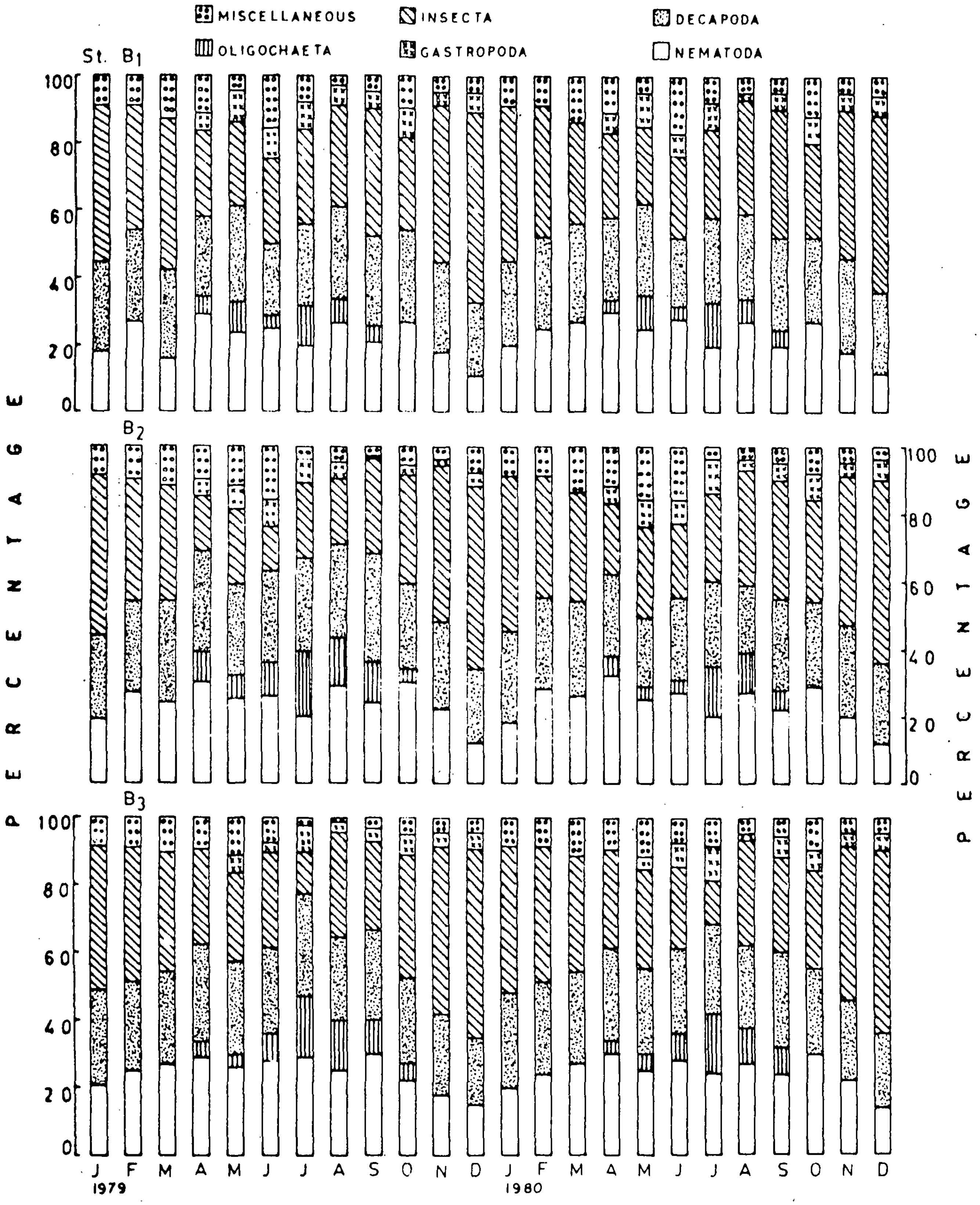


Fig. 33. Monthly fluctuations of the benthic organism composition at Pongtung stream.

type in Umshing stream whereas Pheretima sp. and Stylaria sp. in Pongtung stream and Chaetogaster sp. being the commonly dominant type (Table 5) in both the streams.

III. Decapoda: Decapoda were available throughout the year at all stations with summer maxima and winter minima. Prawns and crabs were the two types of Decapoda recorded (Table 5) and prawns of the genus, Macrobrachium sp. being the most abundant forms in both the streams. At the stations A_1, A_2, A_3, B_1, B_2 and B_3, the decapod population contributed 17.0 to 30.24%, 17.0 to 29.0%, 16.0 to 28.0%, 19.0 to 30.0%, 19.5 to 31.0%, 20.6 to 33.0% towards the total benthic composition respectively (Figs. 32 & 33).

IV. Insecta: This group occurred at all stations and exhibited Autumn and winter maxima, and spring and summer minima in terms of their total benthic composition. At the stations A_1,A_2,A_3,B_1,B_2 and B_3, insect population comprises 25.81 to 58.82%, 21.0 to 51.0%, 26.0 to 56.0%, 23.51 to 55.86%, 13.0 to 54.0% and 11.8 to 55.0% of the total benthos respectiely (Figs. 32 & 33). Out of insect group, Ephemeroptera, Plecoptera, Trichoptera and Diptera were the dominant orders in both the streams. But, at Umshing stream Hemipteran also posed to be important insect population (Table 5).

V. Gastropoda: This group was not recorded at all, in the months of January and February but in rest of the months, the Gastropod population fluctuated to a considerable extent

(Figs. 32 & 33). At the stations A_1, A_2,A_3,B_1,B_2 and B_3, the gastropod population contributed 2.0 to 16.13%, 2.0 to 15.0%, 3.0 to 12.0%, 2.0 to 8.5%, 1.0 to 8.0% and 2.0 to 8.0% toward the total benthic composition respectively. At the station A_3, Gastropods were **rather frequent** and Pila was the single genus found to be present at all stations (Table 5).

VI. Miscellaneous Group: Bryozoans, Hydroideans, Tuberllarians, Hirudineans and Acarineans noted not even periodically rather occassionally were categorised into miscellaneous group. Theyrepresented their populations almost throughout the year at least with a single sub-group and also contributed 4.0 to 12.5%, 4.0 to 15.0, 4.0 to 17.0%, 4,0 to 16.0% and 3.2 to 12.0% toward the total benthic composition at the stations A_1,A_2,A_3,B_1,B_2 and B_3 respectively (Figs. 32 & 33). Two types of aquatic mites were recorded regularly at the station A_3. The faunal composition and distribution of the miscellaneous group is given in the table 5.

4.1.4. Vertebrate fauna:

Frogs and fishes together comprise the recorded vertebrate fauna in both the stream. Pongtung stream comparatively supported a larger number of tadpole population (Rana spp.) during the rainy summer. On the other hand Umshing stream had relatively a larger number of fish population throughout the year. The distribution of the recorded vertebrate fauna in each station is given in Table 6.

Table 6: Distribution of vertebrate fauna at each station (*, rare; -, absent; +, present; ++, common; +++, abundant).

Taxa	Umshing stream			Pongtung stream		
	A_1	A_2	A_3	B_1	B_2	B_3
AMPHIBIA:						
Ranidae						
Rana spp.	+	+	+	++	++	++
PISCES:						
Cyprinidae:						
Danio dangila	-	*	*	+	++	+++
D. danio	-	*	*	++	++	++
Garra lissorhynchus	++	++	+++	-	-	-
G. gotyla	+	+	+	-	-	-
G. annadelei	++	++	++	-	-	-
Acrossocheilus sp.	*	*	+	-	*	*
Puntius sp.	*	*	*	*	+	+
Channidae						
Channa gachua	*	*	*	-	+	*
C. striata	*	+	+	-	+	+
C. stuwartii	*	+	+	-	+	+
C. orientalis	*	*	+	-	-	*
Siluridae						
Silurichthys sp.	*	*	+	*	+	+
Clariidae						
Clarias batrachus	*	*	*	*	+	+
Clarias sp.	+	+	+	+	+	+

4.2. PRAWN POPULATION STUDY:

4.2.1. Seasonal fluctuations:

Macrobrachium hendersoni hendersoni (de Man) and Macrobrachium hendersoni cacharensis (Tiwari) were **commonly** available in Umshing and Pongtung stream respectively. The population of both exhibited seasonal fluctuations in terms of their density and the maximum density being in the rainy summers and minimum in rainless winter. In comparison to M. hendersoni hendersoni, the population density of M. hendersoni cacharensis was higher throughout the study period.

M. HENDERSONI HENDERSONI

During the first annual cycle (January, 1979 - December, 1979) the catches of M. hendersoni hendersoni exhibited the maximum density of $64/m^2$, $67/m^2$ and $41/m^2$ in the month of September and minimum of $14/m^2$ in December, $19/m^2$ in April and $65/m^2$ in March while during the next annual cycle again in September showed the maximum of $70/m^2$, $65/m^2$ and $67/m^2$. But the minimum of $19/m^2$ and $20/m^2$, both in January, and $22/m^2$ in February and December were recorded at the stations A_1, A_2 and A_3 respectively (Figs. 34-36).

M. HENDERSONI CACHARENSIS

The catches of M. hendersoni cacharensis exhibited the maximum population density of $78/m^2$ and $87/m^2$ both in September and $104/m^2$ in August of the first annual cycle studied while $80/m^2$, $89/m^2$ both also in September and $102/m^2$ in August during the next annual cycle at stations B_1, B_2 and B_3 respeotively. The minimum density at all these stations was observed in the month of January (Figs. 37-39).

4.2.2. Sex ratio:

Both Umshing and Pongtung stream sites were dominated by males over the female members of M. hendersoni hendersoni and M. hendersoni cacharensis (Figs. 34-39) in terms of their population densities.

4.2.3. Length frequency distribution:

Length frequency distribution reveals the extent of structural and functional dynamicity of the prawn population and is closely associated with the breeding behaviour. All recorded data pertaining to length measurement falls under six categories viz. 20.0 - 30.0 mm, 30.1 - 40.0 mm, 40.1 - 50.0 mm, 50.1 - 60.0 mm, 60.1 - 70.0 mm and 70.1 - 80.0 mm. However, in Pongtung stream, prawns of size group 70.1 - 80.0 mm was completely absent. Males were dominant among all these size groups and also at all the sites under study.

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Among this population, female of the size groups 20.0 - 40.1 mm constitutes the juvenile group or rather pre-breeding group; 40.1 - 60.0 mm -- actively breeding group and 60.1 - 80.0 mm being the post breeding group. The ovigerous (berried) female size ranged between 40.1 - 60.0 mm and the density fluctuated during the period of early April to late September only. The young population of size group 20.0 - 30.1 mm were absent during March to May and the maximum availability was noted in later summer in both the annual cycles studied (Figs. 34-36). However, size group 31.0 - 40.1 mm was recorded throughout the year with their maximum abundance during the late summer and early winter and the minima were noted during early summer at all the sites under study. The principal breeding population (size group, 40.1 - 60.0 mm) was present throughout the year with their maxima during spring and early summer. The prawn catch in the month of May - June recorded the maximum berried female and the minimum usually being in August-September. The post breeding population (60.1 - 80.0 mm) also fluctuated considerably throughout the year.

At Station A_1: The population under size group 20.0 - 30.1 mm exhibited the peak (34.0%) in terms of their relative densities in September 1979. The size group 30.1 - 40.0 mm showed their maximum relative density (30.0%) in October 1979 and minimum (5.9%) in June 1980. The peak relative densities for the size groups 40.1 - 50.0 mm (38.0%) and 50.1 - 60.0 mm (31.8%) were noted both in April, 1979 and the fall being 12.9% and 13.3% in the month of October and January, 1979 respectively. The maximum ovigerous (16.0%) population was recorded in June 1980

(Fig. 34). The size group 60.1 - 70.0 mm and 70.1 - 80. 0 mm exhibited their peaks (20.0% and 25.0%) in terms of relative densities in the month of January 1979 and August 1980 respectively. However, in both the groups, the fall (3.1%) was noted in September, 1979 (Fig. 34).

At Station A_2: The population under size group 20.0 - 30.0 mm exhibited the peak (37.3%) in terms of their relative densities in September 1979. The maximum of 30.0% was noted in January 1980 for the size group 30.1 - 40.0 mm and minimum of 8.7% in May 1979 (Fig. 35). The size groups 40.1 - 50.0 mm and 50.1 - 60.0 mm showed their maximum relative densities (40.0% and 30.0%) in May 1979 and March, 1980 while the minimum (12.0% and 8.0%) being in the month of September and January 1979 respectively. The maximum ovigerous population (21.0%) was noted in May 1979 (Fig. 35). The peak relative densities for the size groups 60.1 - 70.0 mm and 70.1 - 80.0 mm recorded 21.9% and 26.7% in the month of June 1979 and May 1980 while the minimum were 6.6% and 5.0% in the month of May 1979 and June 1980 respectively.

At Station A_3: In comparison to Station A_1 and A_2, the overall population density throughout the two annual cycles under all size groups were lesser at station A_3. The size group 20.0 - 30.0 mm exhibited the peak (30.0%) in terms of their relative densities in October 1980. A maximum of 40.0% and minimum of 9.1% were noted for the size group 30.1 - 40.0 mm in the month

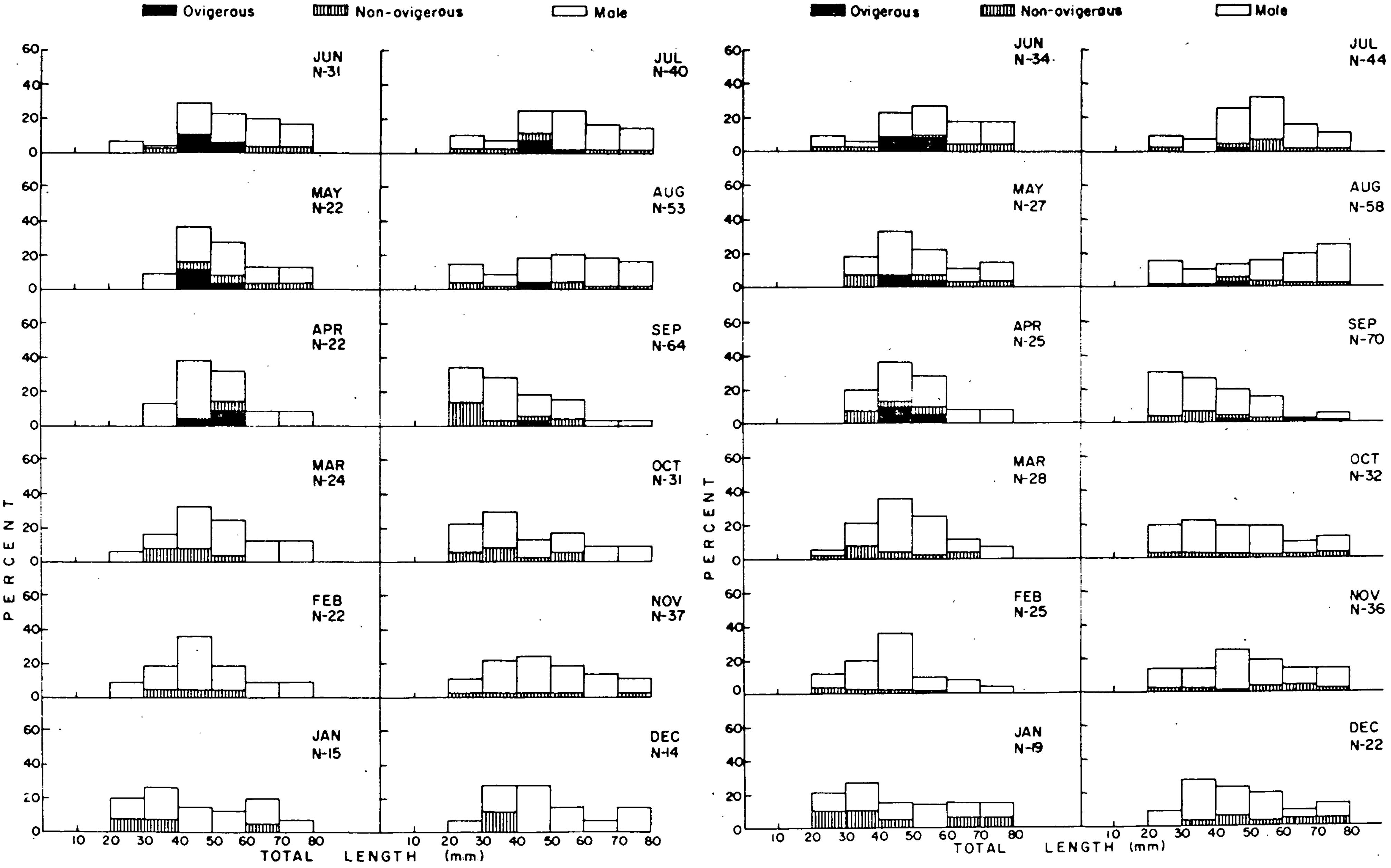

Fig. 34. Length frequency histograms of *Macrobrachium hendersoni hendersoni* (de Man) at station A_1 January, 1979— December, 1980.

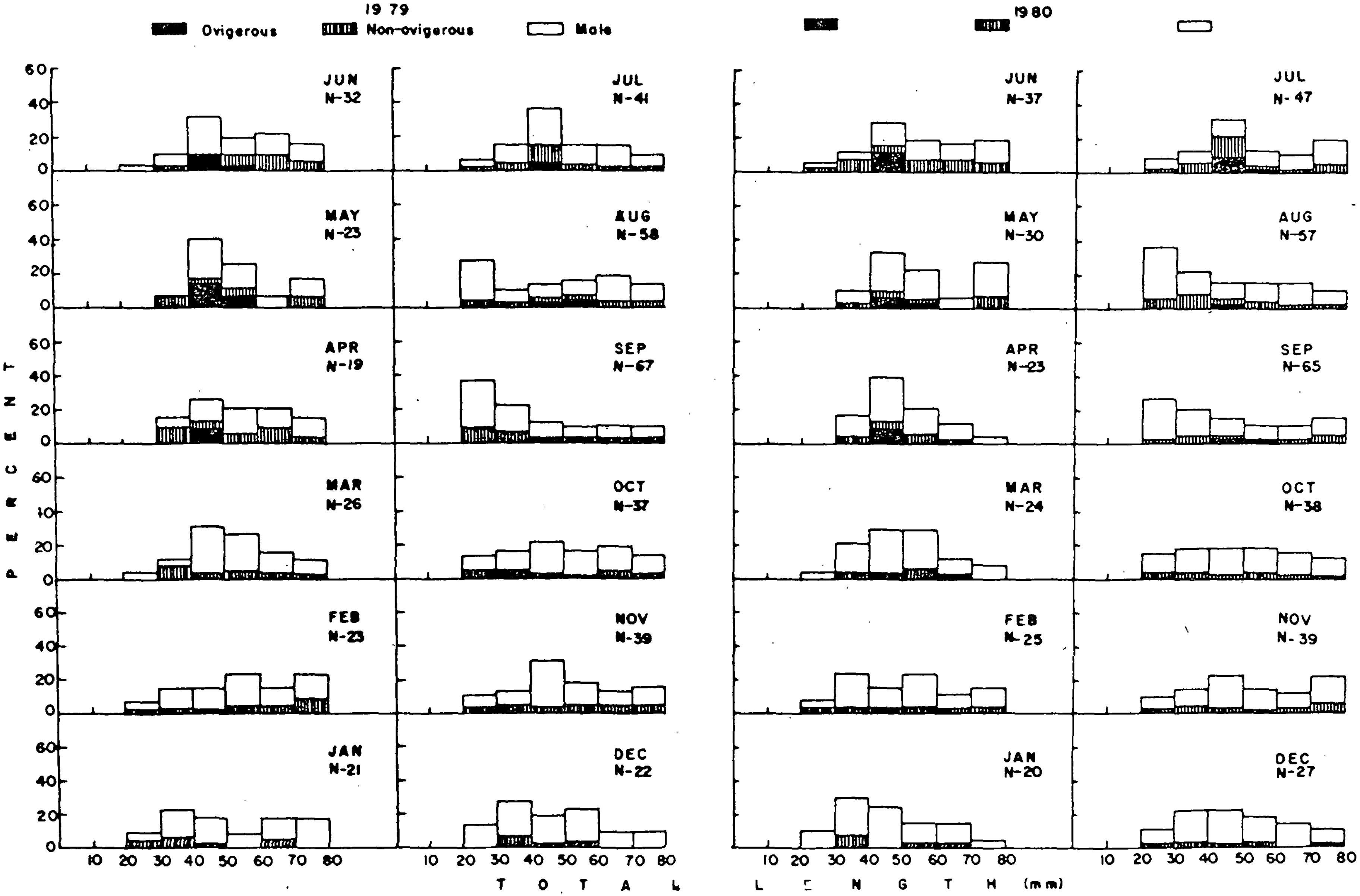

Fig. 35. Length frequency histograms of Macrobrachium hendersoni hendersoni (de Man) at station A_2, January, 1979 — December, 1980.

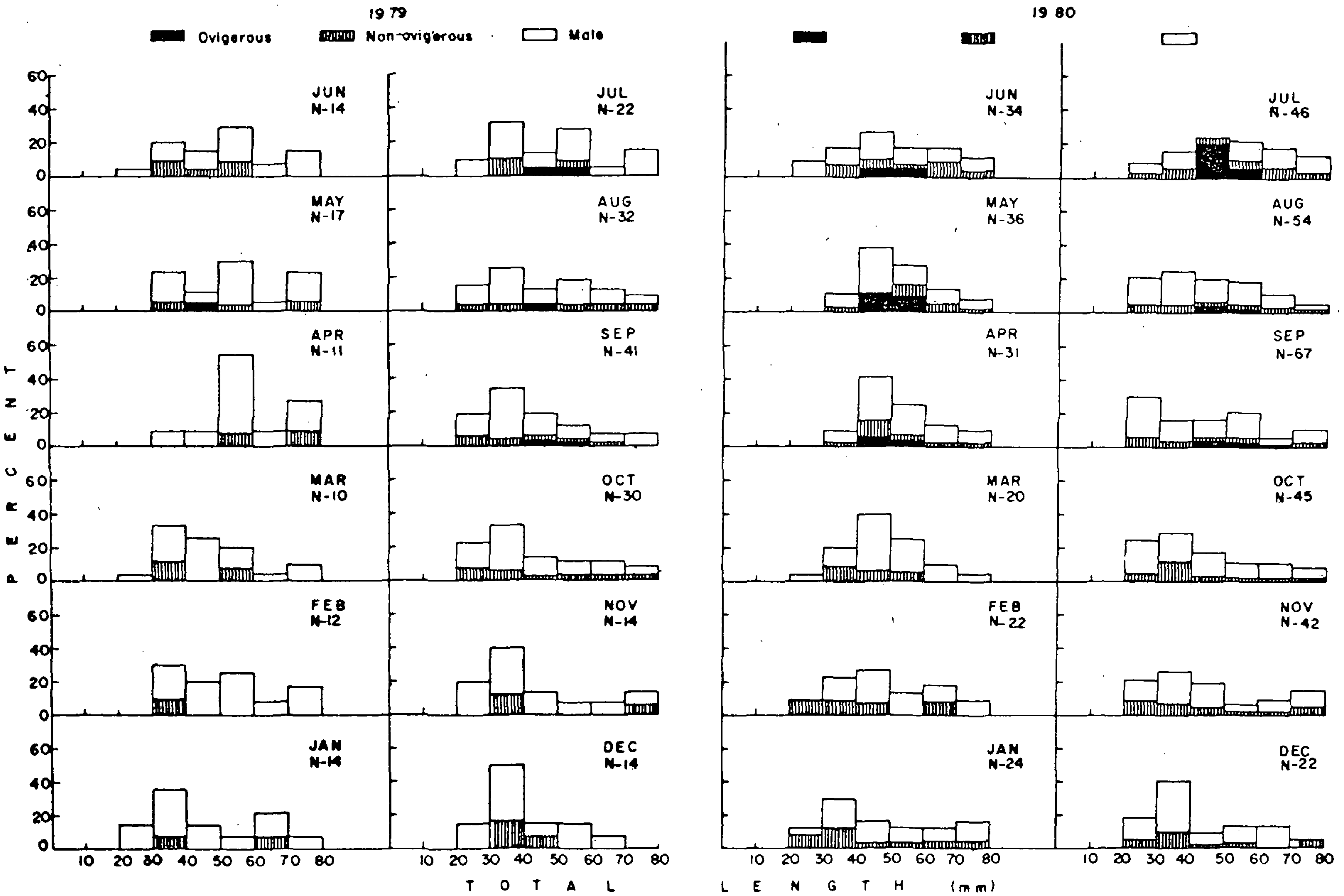

Fig. 36. Length frequency histograms of Macrobrachium hendersoni hendersoni (de Man) at station A_3, January, 1979 – December, 1980.

of December, and April 1979 respectively. The maximum relative density of ovigerous population was 25.0% in July 1980 and surprisingly, no ovigerous female was recorded among June 1979 catches. The maximum relative densities for the size groups 40.1 - 50.0 mm and 50.1 - 60.0 mm was 41.9% and 54.5% in the month of April 1980 and 1979 respectively (Fig. 36). The catches of February 1979 revealed complete absence of the prawn population under 40.1 - 50.0 mm size group. However, size group 50.1 - 60.0 mm recorded the minimum relative density of 6.6% in November 1979. The peak values (21.4% and 27.3%) in terms of their relative densities for the size group 60.1 - 70.0 mm and 70.1 - 80.0 mm were noted in January and April 1979 and complete absence were recorded in March and December 1979 respectively.

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The female of M. hendersoni cacharensis, size group 20.0 - 40.0 mm constituted the juvenile population; 40.1 - 50.0 mm -- the actively breeding group. Unlike M. hendersoni hendersoni, this population includes ovigerous group ranging from 40.1 to 50.0 mm only and their relative density fluctuated during the period of early April to mid October (Figs. 37-39). The juvenile population under the size group 20.0 - 30.0 mm were absent in the month of April during both the annual cycles and also at all the sites under study. They exhibited their maximum relative densities during late summer.

The size group 30.1-40.0 mm recorded their maxima during mid summer and later winter and the minima being in the spring. The size group 40.1 - 50.0 mm exhibited in general a distinct peak in April a gradual declining relative densities right from summer to autumn. The size group 50.1 - 60.0 mm and 60.1 - 70.0 mm were abundant throughout the two annual cycles and fluctuated considerably at all the three sites under study. However, the maxima was noted during autumn to spring and minima in summer. Usually male were the most dominant sex group but still during breeding season the number of remale members increased proportionately to some extent.

At Station B_1: The juvenile under size group 20.0 mm - 30.0 mm recorded a distinct peak (40.0%) in terms of relative density in September 1980 and a complete absence during April in both the annual cycles. The peak (39.4%) for the size group 30.1 - 40.0 mm was recorded in October 1980 and a fall (6.0%) in April 1980 (Fig. 37). The size group 40.1 - 50.0 mm exhibited a clear peak (48.0%) and a fall of (10.0%) in November 1979. The ovigerous population of May 1979 recorded a maximum relative density of 18.0% and the minimum being 1.5% in October 1980. The size group 50.1 - 60.0 mm and 60.1 - 70.0 mm exhibited their peak values 41.0% and 38.0% in April and December 1980 and the fall 10.0% and 2.5% both being in October 1980 respectively.

At Station B_2: The juvenile population under size group 20.0 - 30.0 mm recorded their peak (30.0%) in terms of their relative density in September 1980 and during both the annual cycles they recorded their complete absence in the month of April (Fig. 38). The size group 30.1 - 40.0 mm noted their maximum relative density of 38.0% in September 1980 and a minimum of 6.4% in April 1979. The maximum value of 61.0% and minimum of 16.0% was recorded among the population of April 1979 and October 1980 catches. The maximum ovigerous relative density was noted in June 1979 and minimum of 4.1% in September 1979. The size group 50.1 - 60.0 mm and 60.1 - 70.0 mm were noted throughout the two annual cycles studied and exhibited the maximum relative densities (34.0% and 26.5%) in the month of May 1979 and December 1979 and a minimum of 4.0% and 4.5% in September and August 1979 respectively.

At Station B_3: The size group 20.0 - 30.0 mm represented their maximum relative density of 30.5% in August, 1979 and were completely absent in the month of April for both the annual cycles (Fig. 39). The peak values of 28.0% and 64.5% in the month of March and April 1980 and the fall (6.0% and 20.0%) in April 1979 and October 1980 respectively. The ovigerous population exhibited their maximum relative density in the month of May 1980 and the minimum of 2.5% in October 1980. The size group 50.1 - 60.0 mm and 60.1 - 70.0 mm recorded their maximum relative densities of 30.0% and 24.5% in the month of October 1979 and January 1979 and minimum of 6.2% and 7.0% in September 1980 and August 1980 respectively.

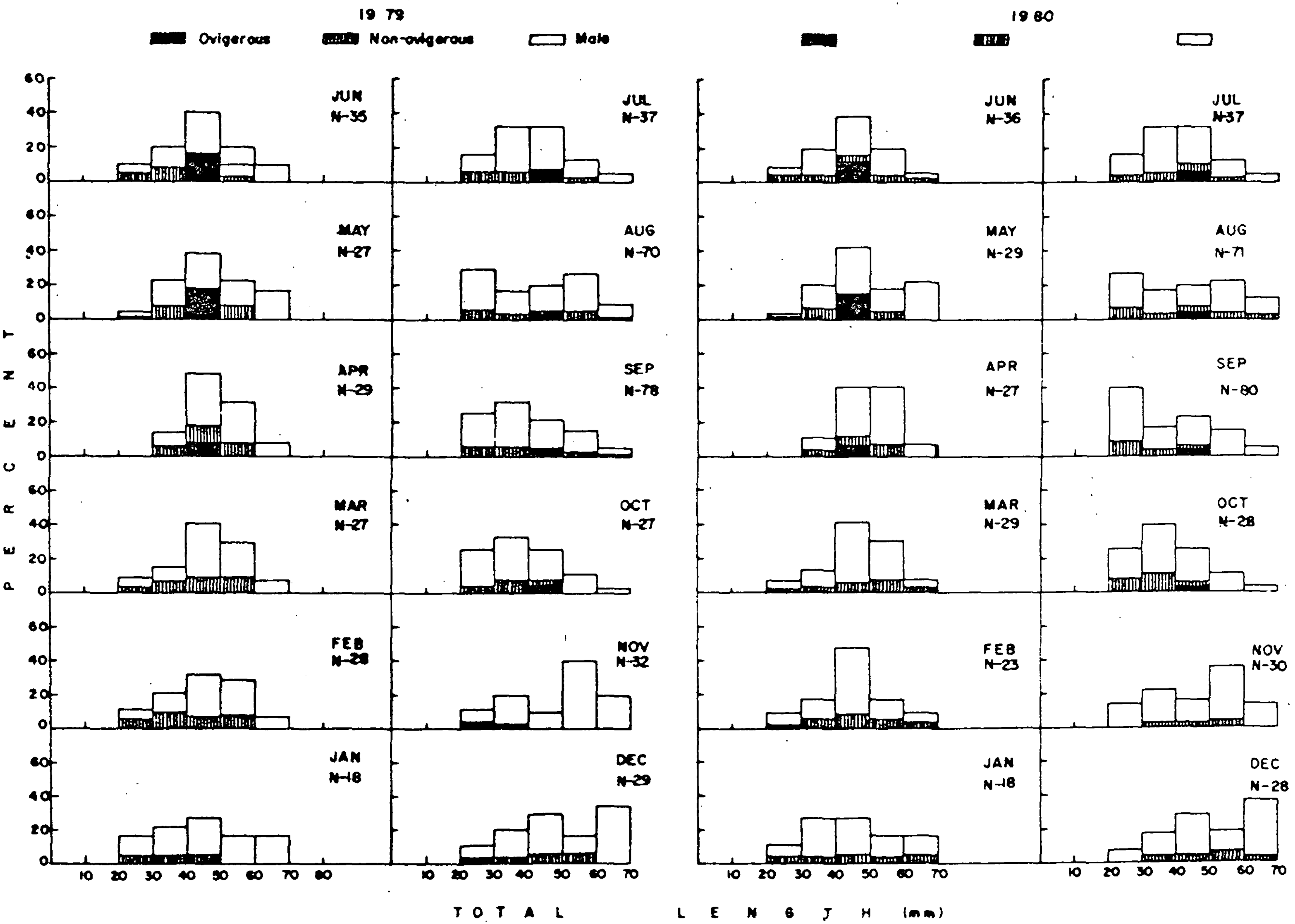

Fig. 37. Length frequency histograms, of Macrobrachium hendersoni cochensis (Tiwari) at station B₁, January, 1979 - December, 1980.

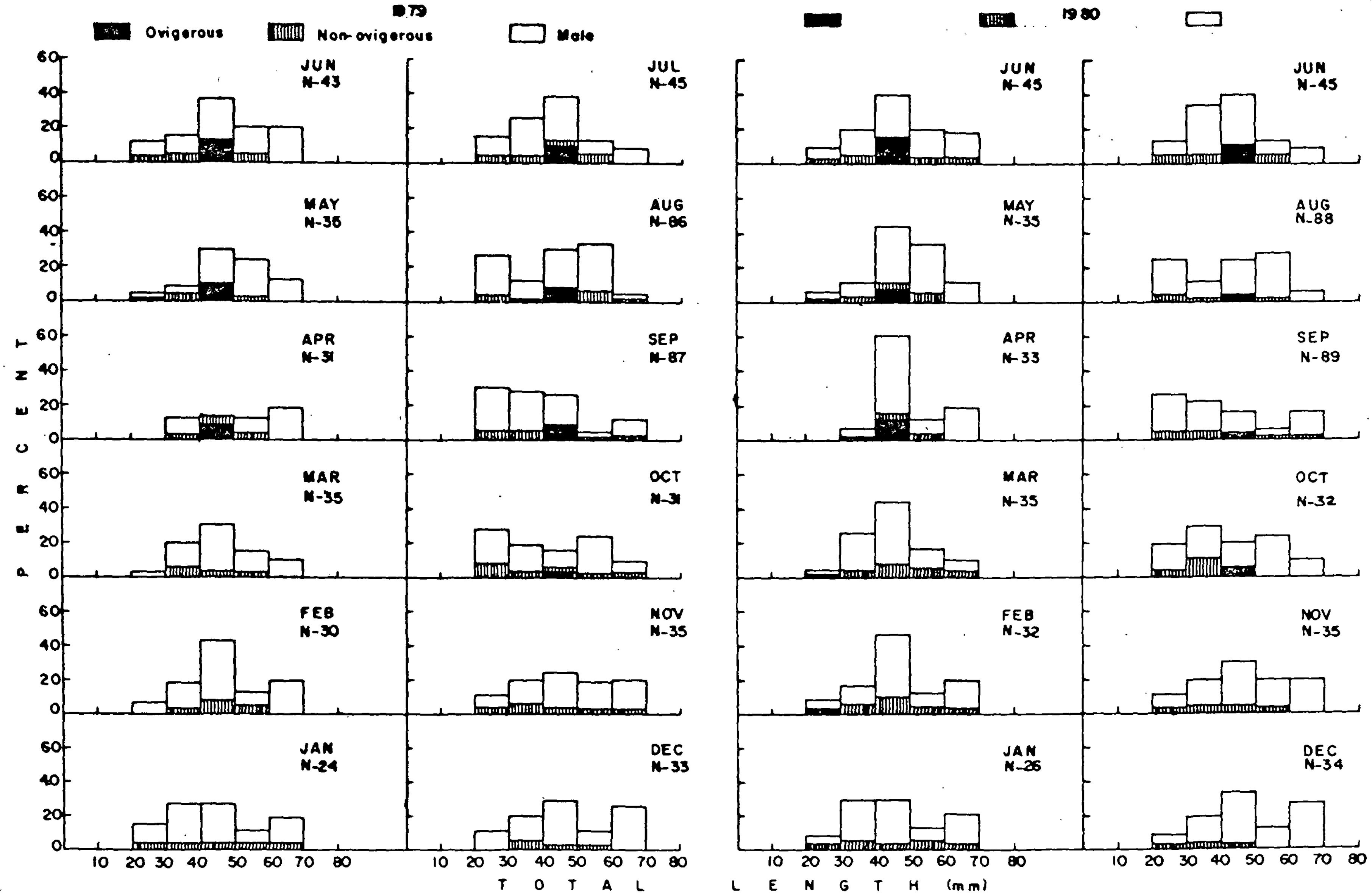

Fig. 38. Length frequency histograms of Macrobachium hendersoni cacherensis (Tiwari) at station B_2, January, 1979 – December, 1980.

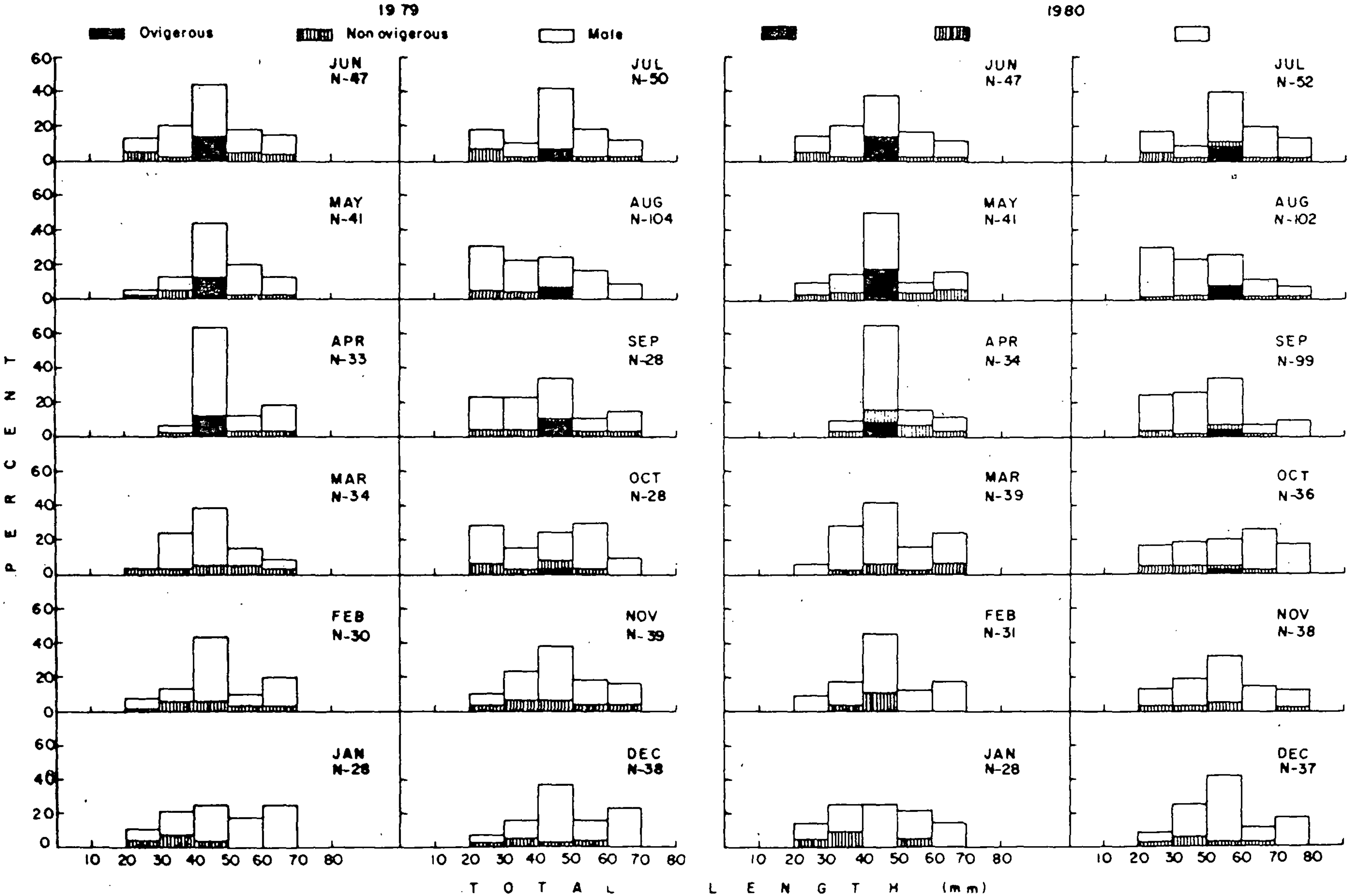

Fig. 39. Length frequency histograms of *Macrobrachium hendersoni Cocherensis* (Tiwari) at station B_3, January, 1979—December, 1980.

4.3 PRAWN ECOSYSTEM STUDY:

4.3.1. Accessory habitat analysis:

It was observed that M. hendersoni hendersoni and M. hendersoni cacharensis were also occurred or rather in a quite good numbers at the numerous depressions located at the nearby surroundings of both Umshing and Pongtung streams respectively (Fig. 40). During the early April, 1979 onward few large males were noted in each depression on the border stream bed and upto five sexually ripe females (i.e. bright yellow ovaries clearly discernible through the carapace) could be seen either within or on the periphery of the depressions. At the end of September 1979, these depressions were characterised by both young and mature population of different size groups (Fig. 41). Therefore, it was assumed that these depressions played some role during the 'breeding phase' of their life cycle. Most of these depressions remained dry during winter and spring season.

All depressions were one of the following types viz. circular, semicircular elliptical or irregular in shape and usually with the deepest area located in the centre. Depression sizes around Umshing stream ranged from 30.0 x 16.0 cm. to 135.4 x 135.0 cm with depth generally related to area and ranging from 5.2 to 17.5 cm (Table 7). Maximum ratio of depression diameter to depth was 7.72 : 1.0 and the ratio of the major axis to minor axis ranged from 1.0 to 2.5 (Table 7). Depression sizes around Pongtung stream ranged from 50.5 x 30.0

Fig. 40: Photographs showing the accessory habitat structure during winter.

A : Around Umshing stream

B : Around Pongtung stream

Fig. 40: C : Depicting the geomorphology of a typical habitat during winter

D : A typical habitat during rainy summer

Fig. 40

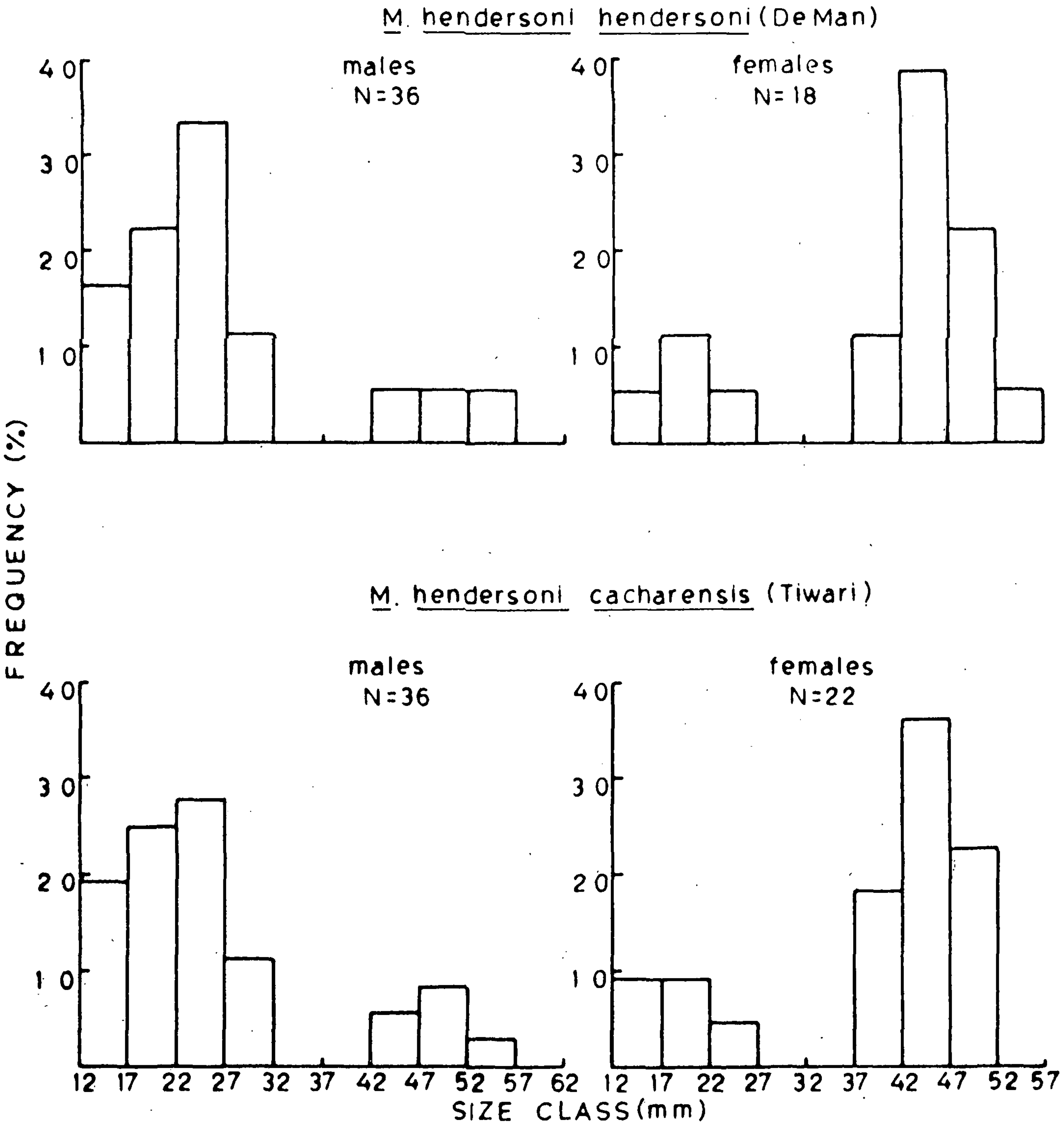

Fig.41 Size frequency distribution of male and female prawns at the accessory habitat during late summar.

Table 7: Characterization data for accessory habitat observed around Umshing Stream.

Sl. No.	Shape	Measurement data(cm)			Proportional data				
		Ma	Mi	D	Ma	: Mi	: D	Ma	: Mi
1.	Circular	135.4	135.0	17.5	7.72	: 7.72	: 1.00	1.00	: 1.00
2.	Circular	92.5	92.5	14.5	6.38	: 6.38	: 1.00	1.00	: 1.00
3.	Elliptical	92.0	45.6	10.2	9.03	: 4.47	: 1.00	2.00	: 1.00
4.	Semicircular	85.6	78.5	12.0	7.13	: 6.54	: 1.00	1.09	: 1.00
5.	Semicircular	81.2	75.2	12.5	6.50	: 6.02	: 1.00	1.08	: 1.00
6.	Elliptical	80.5	36.6	11.0	7.33	: 3.33	: 1.00	2.20	: 1.00
7.	Semicircular	60.0	24.0	10.0	6.00	: 2.40	: 1.00	2.50	: 1.00
8.	Irregular	52.0	21.0	9.0	5.78	: 2.33	: 1.00	2.48	: 1.00
9.	Semicircular	42.0	38.0	7.0	6.03	: 5.43	: 1.00	1.11	: 1.00
10.	Elliptical	30.0	16.0	5.1	5.79	: 3.08	: 1.00	1.88	: 1.00

Ma, Major axis; Mi, Minor axis;
D, Depth.

Table 8: Characterization data for accessory habitat observed around Pongtung Stream.

Sl. No.	Shape	Measurement data (cm)			Proportional data	
		Ma	Mi	D	Ma : Mi : D	Ma : Mi
1.	Circular	90.0	89.5	30.0	3.01 : 2.98 : 1.00	1.01 : 1.00
2.	Circular	84.0	84.0	29.5	2.85 : 2.85 : 1.00	1.00 : 1.00
3.	Circular	81.0	80.5	27.5	2.96 : 2.93 : 1.00	1.01 : 1.00
4.	Irregular	80.5	41.0	25.0	3.21 : 1.64 : 1.00	1.96 : 1.00
5.	Semicircular	72.0	69.2	24.0	3.00 : 2.88 : 1.00	1.04 : 1.00
6.	Elliptical	72.0	37.0	21.5	3.35 : 1.72 : 1.00	1.95 : 1.00
7.	Semicircular	65.0	63.5	22.5	2.88 : 2.82 : 1.00	1.02 : 1.00
8.	Elliptical	63.0	34.0	20.5	3.07 : 1.66 : 1.00	1.85 : 1.00
9.	Semicircular	60.0	57.2	20.4	2.94 : 2.80 : 1.00	1.05 : 1.00
10.	Elliptical	50.5	30.0	24.0	2.10 : 1.25 : 1.00	1.68 : 1.00

Ma, Major axis; Mi, Minor axis;

D, Depth.

Table 9: Physico-chemical conditions of the accessory habitat

Sl. No.	Parameters	Around Umshing Stream	Around Pongtung Stream
1.	Water temperatures(°C)	16.5 - 18.0	27.5 - 29.0
2.	Water level (cm)	5.2 - 17.5	20.4 - 30.0
3.	Transparency (cm)	5.2 - 17.5	20.4 - 30.0
4.	Rate of water flow (cm^3/sec.)	55.2 - 65.2	42.5 - 50.5
5.	Turbidity (%)	15.0 - 25.0	15.0 - 20.0
6.	pH	6.1 - 6.6	6.3 - 6.8
7.	Specific conductivity (µhmo/cm)	58.4 - 68.4	54.5 - 60.6
8.	Dissolved oxygen (mg/l)	10.0 - 12.5	9.0 - 11.5
9.	Carbon dioxide (mg/l)	3.8 - 4.4	3.6 - 4.2
10.	Total alkalinity (mg/l)	22.0 - 27.5	24.6 - 29.0
11.	Nitrate-nitrogen (mg/l)	0.52 - 0.60	0.58 - 0.65
12.	Ammonia-nitrogen (mg/l)	0.001- 0.006	0.003- 0.009
13.	Phosphate-phosphorous (mg/l)	0.70 - 0.86	0.75 - 0.90
14.	Chloride (mg/l)	0.60 - 0.65	0.63 - 0.69
15.	Calcium (mg/l)	2.5 - 3.5	3.0 - 4.0
16.	Magnesium (mg/l)	0.90 - 1.10	1.00 - 1.50
17.	Sodium (mg/l)	1.60 - 2.20	1.70 - 2.50
18.	Potassium (mg/l)	1.00 - 1.50	1.00 - 1.80
19.	Silicate (mg/l)	4.20 - 5.00	3.50 - 4.00
20.	Iron (mg/l)	0.90 - 1.30	0.60 - 1.00
21.	Oxidisable organic matter (mg/l)	0.04 - 0.09	0.09 - 0.12

Table 10: Biotic Composition of the accessory habitat (*, rare; -, absent; +, present; ++, common; +++, abundant).

	Biotic group	Umshing site	Pongtung site
A.	Total phytoplankton	+	++
1.	Myxophyceae	+	+
2.	Chlorophyceae	+	++
3.	Dinophyceae	*	+
4.	Chrysophyceae	+	+
5.	Rhodophyceae	-	-
6.	Baccillariophyceae	++	++
B.	Total zooplankton	+	+
1.	Protozoa	+	+
2.	Rotifera	*	+
3.	Ostracoda	+	*
4.	Copepoda	*	+
5.	Cladocera	*	+
C.	Total benthic organism	+	+
1.	Nematoda	+	+
2.	Oligochaeta	+	++
3.	Decapoda	++	+++
4.	Insecta	+	+
5.	Gastropoda	-	-
6.	Miscellaneous	*	*

cm to 90.0 x 89.5 cm with depth ranging from 20.4 to 30.0 cm (Table 8). Maximum ratio of depression diameter to depth was 2.98 : 1.0 and the ratio of the major axis to minor axis ranged from 1.0 to 1.96 (Table 8).

Water quality and the bottom textures in these depressions varied to some extent. The ranges of the physico-chemical propoerties of the water is given in the Table 9. The biotic composition of these accessory habitat also varied to a considerable extent and is summarised in the Table 10.

4.3.2 Condition Factor:

Monthwise averages of condition factor for four categories of population based on their size group have been calculated for the entire study period to elucidate the seasonal fluctuations and presented in Table 11 and 12. The 'K' factor exhibited its higher values for the young population than the mature and post mature group and also for males than the female populations of both _M._ _hendersoni_ _hendersoni_ and _M._ _hendersoni_ _cacharensis_. In all the four categories of these two populations, the 'K' factor represented its two peaks, one in Spring (May) and the other in later summer (September). However, apart from these, the male population have shown more frequent monthly fluctuations throughout the study period (Table 11 & 12).

Table 11: Monthly fluctuations in the condition factor of <u>M.</u> <u>hendersoni</u> <u>hendersoni</u>

Season	Month	SIZE GROUP (mm)						Ovigerous
		20.0 - 40.0		40.1 - 55.0		55.1 - 80.0		
		m	f	m	f	m	f	
Winter	Jan.'79	2.8674	2.4780	1.7842	1.2888	0.9548	0.8690	-
	Feb.	2.8875	2.4790	1.7892	1.2942	0.9628	0.8796	-
Spring	Mar.	2.8998	2.4879	1.7989	1.2953	0.9770	0.8905	-
	Apr.	2.9116	2.5874	1.8242	1.3024	0.9762	0.9198	1.5104
	May	2.9402	2.5984	1.8388	1.3021	0.9894	0.9196	1.5196
Summer	Jun.	2.9274	2.5952	1.8446	1.3112	0.9646	0.9108	1.5189
	Jul.	2.8919	2.4820	1.8266	1.3014	0.9602	0.9081	1.5186
	Aug.	2.8924	2.4916	1.8286	1.3164	0.9618	0.8998	1.5106
	Sep.	2.9042	2.5721	1.8292	1.3182	0.9815	0.9098	1.5192
Autumn	Oct.	2.9008	2.5689	1.8042	1.3005	0.9779	0.8684	-
	Nov.	2.8942	2.5226	1.7932	1.2985	0.9672	0.8509	-
Winter	Dec.	2.8742	2.5042	1.7856	1.2889	0.9642	0.8498	-
	Jan.'80	2.8733	2.4946	1.7850	1.2880	0.9689	0.8702	-
	Feb.	2.8784	2.4945	1.7852	1.2886	0.9644	0.8814	-
Spring	Mar.	2.9905	2.5078	1.7996	1.2965	0.9788	0.9098	-
	Apr.	2.9121	2.5887	1.8336	1.3042	0.9898	0.9142	1.5196
	May	2.9416	2.5982	1.8420	1.3198	0.9964	0.9210	1.5250
Summer	Jun.	2.9324	2.5831	1.8415	1.3142	0.9869	0.9110	1.5220
	Jul.	2.8921	2.5389	1.8292	1.3085	0.9809	0.9091	1.5198
	Aug.	2.9024	2.5408	1.8382	1.3105	0.9821	0.9094	1.5190
	Sep.	2.9076	2.5392	1.8398	1.3124	0.9832	0.9098	1.5210
Autumn	Oct.	2.9102	2.5401	1.8072	1.2990	0.9804	0.8940	-
	Nov.	2.9087	2.4988	1.8085	1.2900	0.9785	0.8812	-
Winter	Dec.	2.8766	2.4936	1.7962	1.2894	0.9762	0.8516	-

Table 12: Monthly fluctuations in the condition factor of M. hendersoni cacharensis

Season	Month	SIZE GROUP (mm)						Ovigerous
		20.0 - 40.0		40.1 - 50.0		50.1 - 70.0		
		m	f	m	f	m	f	
Winter	Jan'79	3.1003	2.0198	1.9646	1.3455	0.9798	0.9762	-
	Feb.	3.1979	2.1792	1.9742	1.3498	0.9852	0.9681	-
Spring	Mar.	3.3058	2.2644	1.9982	1.3918	0.9872	0.9720	-
	Apr.	3.3982	2.2856	2.0092	1.4102	0.9989	0.9742	1.6589
	May	3.4052	2.2950	2.0488	1.4766	1.0042	0.9842	1.6766
Summer	Jun.	3.3912	2.2742	2.0042	1.4780	0.9980	0.9722	1.6760
	Jul.	3.2129	2.1756	1.9879	1.4502	0.9624	0.9719	1.6592
	Aug.	3.2189	2.2142	1.9889	1.4681	0.9689	0.9728	1.6682
	Sep.	3.2426	2.2159	2.0014	1.4692	0.9824	0.9784	1.6694
Autumn	Oct.	3.0016	2.2140	1.8974	1.4589	0.9892	0.9766	1.6534
	Nov.	3.0981	2.1001	1.8866	1.4002	0.9820	0.9734	-
Winter	Dec.	3.0112	2.0089	1.8696	1.3686	0.9792	0.9689	-
	Jan.'80	3.0946	2.0182	1.9598	1.3428	0.9801	0.9676	-
	Feb.	3.1947	2.1142	1.9756	1.3489	0.9890	0.9735	-
Spring	Mar.	3.2158	2.1974	1.9989	1.3892	0.9896	0.9740	-
	Apr.	3.2927	2.2887	2.0102	1.3980	0.9972	0.9798	1.6602
	May	3.3846	2.2942	2.0514	1.4125	1.0012	0.9846	1.6698
Summer	Jun.	3.3918	2.2824	2.0104	1.4242	0.9986	0.9724	1.6752
	Jul.	3.2024	2.1856	2.0010	1.4054	0.9685	0.9717	1.6701
	Aug.	3.2115	2.2105	1.9942	1.4114	0.9704	0.9727	1.6681
	Sep.	3.2324	2.2192	2.0012	1.4401	0.9842	0.9786	1.6692
Autumn	Oct.	3.1102	2.2150	1.9116	1.4008	0.9888	0.9765	1.6501
	Nov.	3.0992	2.1142	1.8892	1.3996	0.9870	0.9730	-
Winter	Dec.	3.0134	2.0112	1.8765	1.3672	0.9789	0.9692	-

4.3.3. Inter-relationship of prawn population density and different ecological parameters:

The correlation co-efficients and regression equations of the prawn population densities at different sites of Umshing and Pongtung streams with then prevailed respective twenty one physico-chemical parameters and twenty biotic parameters were summarised in the Table 13, 14, 15, 16, 17 & 18.

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I. Total density versus

i) Physico-chemical variables : Rainfall, water temperature, rate of water flow, turbidity, dissolved oxygen, phosphate-phosphorous and chloride concentration exhibited significantly positive correlation while water transparency, total alkalinity, sodium, potassium and oxidisable organic matter content revealed significantly negative correlation (Table 13-15).

ii) Biotic variables: Total phytoplankton, zooplankton as well as benthic organism have shown distinct significantly positive correlation and particularly correlation with Chlorophyta, Chrysophyta, Baccillariophyta, Ostracoda, Copepoda, Cladocera, Nematoda, Decapoda, Insecta are found to be positively significant (Table 13-15).

II. Population density (size group, 20.0 - 40.0 mm) versus

i) Physico-chemical variables: Water turbidity, dissolved oxygen exhibited significantly positive correlation while oxidisable organic matter only resulted significantly negative correlation. But sodium, potassium and ammonia-nitrogen have shown significantly negative correlation at the Station A_3 (Table 13-15).

ii) Biotic variables: Total phytoplankton and zooplankton revealed significantly positive correlation while total benthic organisms have shown a significantly negative correlation. Categorically correlations with Chlorophyta, Chrysophyta, Baccillariophyta, Ostracoda, Copepoda, Cladocera, Nematoda, and Insecta resulted positively significant, while Rhodophyta and miscellaneous resulted significantly negative correlations (Table 13-15).

III. Population density (size group, 40.1 - 55.0 mm) versus

i) Physico-chemical variables: Rainfall, water temperature, rate of water flow, turbidity, dissolved oxygen, silicate phosphate-phosphorous, nitrate-nitrogen, magnesium and chloride content have shown significantly postive correlations. But water transparency, sodium, potassium, iron and oxidisable organic matter content exhibited negatively significant correlations (Table 13-15).

Specific conductivity exhibited a positive and the total alkalinity showed a negative significant correlation at both the stations A_1 and A_2 but their r-values were not significant at the Station A_3 (Table 13-15).

ii) Biotic variables: Total phytoplankton, zooplankton and benthic organisms revealed positively significant correlations and particularly Myxophyta, Baccillariophyta, Ostracoda, Oligochaeta and Decapoda exhibited significantly positive r-values (Table 13-15).

IV. Population density (size group, 55.1 - 80.0 mm) versus

i) Physico-chemical variables: Correlations with rainfall, water temperature, dissolved oxygen, phosphate-phosphorous and chloride content resulted significantly positive r-values (Table 13-15). But water transparency, sodium, and potassium concentrations resulted into negatively significant correlations. Ammonia-nitrogen also showed a negatively significant r-value (-0.6714) at the station A_3.

ii) Biotic variables: Total phytoplankton, zooplankton and benthic organism have shown distinctly positive significant correlations. More categorically, Chlorophyta, Chrysophyta, Baccallariophyta, Ostracoda, Copepoda, Cladocera, Nematoda, Decapoda, Insecta and Gastropoda groups (Table 13-15). Miscellaneous groups exhibited negatively significant r-values (Table 13-15).

Table 13: Correlation co-efficients (r) and regression equations (y) of *Macrobrachium hendersoni hendersoni* (De Man) population versus various ecological parameters at Station A_1 (Umshing Stream)

Parameter (x)	Total density (y)	Size group:			Ovigerous (y)
		20.0–40.0 mm (y)	40.1–60.0 mm (y)	60.1–80.0 mm (y)	
Rainfall	r=0.5879 y=0.0562x+24.0398	r=0.3530 y=0.0211x+6.6373	r=0.5403 y=0.0155x+10.3972	r=0.4568 y=0.0142x+6.5301	r=0.4847 y=0.0048x+0.7744
Water temperature	r=0.5659 y=3.0869x-14.5344	r=0.2145 y=0.7227x-1.2724	r=0.7776 y=1.2596x-6.6069	r=0.5408 y=0.9412x-5.7960	r=0.7312 y=0.4072x-4.7575
Transparency	r=-0.6002 y=-9.9147x+52.5584	r=-0.3457 y=-0.3760x+17.3323	r=-0.5621 y=-0.2940x+18.6143	r=-0.5412 y=-0.3046x+14.7362	r=-0.5149 y=-0.0926x+3.3471
Rate of water flow	r=0.5222 y=0.7242x-15.4841	r=0.3008 y=0.3163x-11.3323	r=0.5872 y=0.2971x-7.1234	r=0.3752 y=0.2582x-8.6091	r=0.5015 y=0.0376x-3.7360
Turbidity	r=0.5983 y=0.3080x+20.3731	r=0.4522 y=0.2582x-8.6091	r=0.5286 y=0.0872x+9.4334	r=0.3860 y=0.1324x+4.7981	r=0.5045 y=0.0396x-3.7360
Dissolved oxygen	r=0.6471 y=6.6258x-25.9998	r=0.7717 y=4.8329x-33.7035	r=0.5115 y=0.9382x+4.2976	r=0.4942 y=1.5992x-5.7400	r=0.5142 y=0.2888x-1.1019
pH	r=0.3953 y=19.4519x-87.2453	r=0.3523 y=27.1716x-157.4985	r=-0.452 y=-7.8523x+61.1073	r=0.1254 y=2.3394x-5.7402	r=-0.3178 y=-1.8984x+13.1908
Carbon dioxide	r=-0.4147 y=-8.3727x+63.4431	r=-0.4323 y=-9.9945x+47.1462	r=0.3454 y=2.2672x+4.2855	r=-0.0598 y=-0.4217x+10.2409	r=0.3806 y=1.0843-2.5481
Specific conductivity	r=0.3987 y=0.9112x-16.6116	r=0.1855 y=0.2086x-1.2648	r=0.7635 y=0.4129x-9.2208	r=0.4492 y=0.2610x-5-2209	r=0.5207 y=0.0968x-3.6514
Total alkalinity	r=-0.6565 y=-2.1118x+78.9398	r=-0.4199 y=-0.8997x+29.4327	r=-0.6547 y=-0.6747x+27.4473	r=-0.4364 y=-0.5938x+21.6016	r=-0.4079 y=-1.4453x+4.6485
Silicate	r=0.2443 y=5.8157x+3.1788	r=0.1271 y=2.0740x-7.8928	r=0.6392 y=5.0164x-12.9427	r=0.3249 y=2.7393x-5.3632	r=0.5274 y=1.4228x-5.7815
Phosphate phosphorus	r=0.5398 y=44.1269x+3.9155	r=0.2020 y=10.9815x+2.6678	r=0.5240 y=13.6976x+3.8122	r=0.4951 y=13.6826x-0.2042	r=0.8137 y=7.3081x-3.2685
Nitrate nitrogen	r=0.3085 y=27.0726x+21.0333	r=-0.0882 y=-4.940x+11.8917	r=0.6663 y=17.9447x+5.2730	r=0.4422 y=12.7926x+3.3364	r=0.7048 y=6.5253x-1.2188
Ammonia nitrogen	r=-0.0269 y=-3.4529x+34.9369	r=0.1109 y=9.6904x-3.5345	r=-0.1665 y=6.9986x-17.2901	r=-0.1238 y=-5.5855x+12.2972	r=-0.0372 y=-0.5384x+1.8499
Calcium	r=-0.3829 y=-14.715x+41.5513	r=-0.3425 y=-22.7118x+68.6949	r=0.1817 y=2.6237x+5.4501	r=-0.2454 y=-3.8851x+18.6467	r=0.2996 y=1.3051x-2.4007
Magnesium	r=0.2667 y=15.0516x+17.7370	r=-0.1434 y=-0.5320x+15.0650	r=0.5565 y=9.9287x+2.9867	r=0.3688 y=7.0683x+1.7162	r=0.5639 y=3.4593x-1.9016
Chloride	r=0.4682 y=36.2426x+7.3083	r=0.1828 y=9.6486x+2.9988	r=0.4718 y=11.9788x+4.2649	r=0.4859 y=13.2525x-0.7205	r=0.4926 y=4.3001x-1.5459
Sodium	r=-0.5493 y=-12.9583x+66.0220	r=-0.2053 y=-3.1546x+17.9564	r=-0.7009 y=-5.1795x+26.0874	r=-0.5062 y=-4.0187x+19.0149	r=-0.7662 y=-1.9469x-6.5132
Potassium	r=-0.5545 y=-10.6243x+61.7261	r=-0.1653 y=-2.1113x+15.5075	r=-0.6859 y=-0.4213x+24.0741	r=-0.5092 y=-3.3594x+17.6951	r=-0.7783 y=-1.6437x+5.9175
Iron	r=-0.3256 y=-10.5163x+51.2082	r=0.0540 y=1.1913x+7.7703	r=-0.4728 y=-4.9413x+21.3397	r=-0.4404 y=-5.0135x+17.3483	r=-0.8518 y=-3.1031x-6.8735
Oxidisable organic matter	r=-0.7027 y=-7.3981x+53.7329	r=-0.5028 y=-3.4880x-19.6579	r=-0.4701 y=-1.5685x+17.1681	r=-0.6387 y=-2.2895x+15.1154	r=-0.5366 y=-0.6155x+3.2337
Total phytoplankton	r=0.7936 y=0.0615x+14.4235	r=0.5979 y=0.0390x-1.7076	r=0.5445 y=0.0171x+7.6953	r=0.6086 y=0.0206x+2.5968	r=0.4312 y=0.0046x+0.1236
Myxophyceae	r=0.1467 y=0.2448x+28.1517	r=0.0831 y=0.0766x+7.7887	r=0.4631 y=0.2052x+7.2754	r=0.2213 y=0.1054x+5.8561	r=0.6637 y=0.1011x-1.1973
Chlorophyceae	r=0.7676 y=0.1606x+12.5515	r=0.6929 y=0.0971x-1.4749	r=0.3537 y=0.0238x+9.9732	r=0.5472 y=0.0396x+4.0531	r=0.2845 y=0.0066x-10.7323
Dinophyceae	r=0.0149 y=0.1505x+30.8862	r=-0.1913 y=-1.2909x+12.9531	r=0.4132 y=1.5351x+9.0401	r=-0.0268 y=-0.0936x+6.0872	r=0.3058 y=0.3411x+0.6756
Chrysophyceae	r=0.7083 y=2.0880x+21.5054	r=0.6521 y=1.2878x+3.8233	r=0.2607 y=0.2471x+11.5940	r=0.5417 y=0.5528x+6.0872	r=0.2106 y=0.0688x+1.1789
Rhodophyceae	r=-0.3446 y=-2.8510x+34.3386	r=-0.4842 y=-2.4063x+12.4401	r=0.1549 y=0.4130x+12.3024	r=-0.2996 y=-0.8578x+9.5959	r=0.3399 y=0.3115x+1.1625
Bacillariophyceae	r=0.8078 y=0.1704x+7.3456	r=0.5720 y=0.0808x-1.5068	r=0.6272 y=0.0462x+6.7679	r=0.6428 y=0.0469x+2.0827	r=0.4754 y=0.0111x-5.8244
Total zooplankton	r=0.7099 y=0.9851x-23.4206	r=0.4842 y=0.4513x-15.2160	r=0.5615 y=0.2517x-1.2206	r=0.5856 y=0.2819x-6.9839	r=0.6652 y=0.1027x-4.1989
Protozoa	r=-0.4362 y=-0.2242x+75.7195	r=-04205 y=-1.4459x+38.5121	r=-0.0662 y=-0.1097x-14.9267	r=-0.3859 y=-0.6864x+22.2805	r=-0.5876 y=-0.3345x+8.1341
Rotifera	r=0.1421 y=0.4546x+28.2571	r=-0.1338 y=-0.2868x+11.7219	r=0.4241 y=0.5092x+9.3972	r=0.2097 y=0.2322x+7.1380	r=0.7477 y=0.2751x-0.2882
Ostracoda	r=0.7631 y=3.4487x-3.8126	r=0.5003 y=1.5148x-5.5673	r=0.5581 y=0.8126x+4.4878	r=0.7167 y=1.1213x-2.7332	r=0.5652 y=0.2830x-1.3774
Copepoda	r=0.7079 y=2.9160x+9.1365	r=0.6818 y=1.8813x-4.4336	r=0.2669 y=0.3542x+10.0637	r=0.4773 y=0.6805x+3.5064	r=0.2723 y=0.1242x+0.5579
Cladocera	r=0.5968 y=1.7073x+11.9001	r=0.5589 y=1.0712x-2.3077	r=0.2108 y=0.1949x+10.5496	r=0.4460 y=0.4416x+3.6609	r=0.4106 y=0.1556x-2.6241
Total Benthic organism	r=0.8227 y=1.5039x-10.8611	r=-0.5541 y=-0.5834x+1.9536	r=0.5726 y=0.3373x-2.3055	r=0.6522 y=0.4127x-2.8889	r=0.6466 y=0.1309x-2.1667
Nematoda	r=0.8032 y=5.09x+6.2231	r=0.5647 y=2.3973x-1.9536	r=0.5041 y=1.0291x+7.6901	r=0.7385 y=1.6636x+0.4874	r=0.3962 y=0.2781x+0.1325
Oligochaeta	r=0.3359 y=2.5454x+26.1591	r=0.0773 y=0.4288x+9.0112	r=0.6072 y=1.6185x+9.6478	r=0.2617 y=0.7494x+7.2302	r=0.6651 y=0.6095x+3.8182
Decapoda	r=0.9011 y=5.7099x-8.2437	r=0.6171 y=2.6198x-8.2874	r=0.6909 y=1.4195x+2.9933	r=0.7657 y=1.6794x-2.9497	r=0.6001 y=0.4212x-1.4132
Insecta	r=0.6974 y=6.4x-32.75	r=0.4807 y=0.0171x+10.1469	r=0.1465 y=0.4334x+8.4167	r=0.5562 y=1.7667x-9.0	r=0.3279 y=0.3334x-1.8333
Gastropoda	r=0.4194 y=4.0307x+19.8296	r=0.3403 y=2.4552x+2.6722	r=0.3728 y=0.8148x+10.3732	r=0.4162 y=0.9772x+5.8164	r=0.4068 y=0.3733x+0.4112
Miscellaneous group	r=0.0452 y=0.1505x+30.8862	r=-0.4850 y=-3.9236x+16.0458	r=-0.2297 y=-0.8389x+13.7288	r=-0.5098 y=-1.9999x+10.9999	r=0.0981 y=0.1198x+1.3705

Table 14: Correlation co-efficients (r) and regression equations (y) of Macrobrachium hendersoni hendersoni (De Man) population versus various ecological parameters at Station A_2 (Umshing Stream)

Parameter (x)	Total density (y)	Size group:			Ovigerous (y)
		20.0-40.0 mm (y)	40.1-60.0 mm (y)	60.1-80.0 mm (y)	
Rainfall	r=0.5823 y=0.0586x+24.8454	r=0.3573 y=0.02256x+8.0950	r=0.5148 y=0.0145x+11.0603	r=0.4678 y=0.0097x+8.7829	r=0.5729 y=0.0064x+0.8631
Water temperature	r=0.5742 y=3.4468x-17.5542	r=0.2141 y=0.8367x-2.0304	r=0.6759 y=1.1978x-4.5978	r=0.4678 y=0.7652x-1.2096	r=0.8729 y=0.5641x-6.6144
Transparency	r=-0.5936 y=-1.0382x+53.6972	r=-0.4086 y=-0.4741x+19.5311	r=-0.4859 y=-0.2518x+18.0465	r=-0.5136 y=-0.2496x+15.0056	r=-0.5298 y=-0.1092x+3.9153
Rate of water flow	r=0.5373 y=0.8469x-24.0112	r=0.3036 y=0.3370x-12.4494	r=0.5588 y=0.2764x-5.5812	r=0.3738 y=0.1734x-1.5676	r=0.5672 y=0.1117x-3.4464
Turbidity	r=0.6078 y=0.3283x+19.9452	r=0.4789 y=0.1389x+4.8427	r=0.4967 y=0.0782x+10.0653	r=0.4272 y=0.0631x+7.6805	r=0.6376 y=0.0399x+0.2057
Dissolved oxygen	r=0.6693 y=7.1075x-30.2704	r=0.7508 y=4.8473x-34.0553	r=0.4842 y=0.1226x+1.9776	r=0.5074 y=1.3725x-2.3656	r=0.4562 y=0.3847x-1.7028
pH	r=0.4147 y=21.3544x-96.8319	r=0.2771 y=19.1788x-108.0894	r=-0.3231 y=-4.7947x+42.8973	r=0.3886 y=5.4105x-23.2052	r=-0.3472 y=-0.2052x+3.1026
Carbon dioxide	r=-0.3566 y=-8.1547x+64.1835	r=-0.4186 y=-9.2902x+45.3383	r=0.0549 y=0.03684x+11.8686	r=-0.3213 y=-2.0215x+17.8308	r10.3836 y=1.0242x-2.0076
Specific conductivity	r=0.4243 y=0.8103x-8.8878	r=0.2421 y=0.3063x-5.6251	r=0.5831 y=0.3294x-4.0921	r=0.2364 y=0.1253x+3.6512	r=0.4980 y=0.0921x-3.0241
Total alkalinity	r=-0.6547 y=-2.1236x+81.9661	r=-0.4204 y=-0.9915x+33.0239	r=-0.6971 y=-0.6561x+28.1547	r=-0.4087 y=-0.3608x+18.4481	r=-0.4351 y=-0.1630x+5.5377
Silicate	r=0.3536 y=8.5981x-11.1166	r=0.2421 y=2.1456x-6.9245	r=0.5948 y=4.1738x-8.6450	r=0.3097 y=2.0331x-0.4459	r=0.6403 y=1.7888x-7.5508
Phosphate phosphorus	r=0.6311 y=65.0250x-5.3025	r=0.4109 y=28.8978x-7.4889	r=0.4934 y=15.4929x+3.6056	r=0.4589 y=12.3411x+2.5676	r=0.7642 y=0.5538x-4.1139
Nitrate nitrogen	r=0.3229 y=34.5169x+20.0826	r=0.0272 y=2.1481x+9.7057	r=0.6421 y=22.5390x+4.8917	r=0.1626 y=5.3547x+8.2642	r=0.7298 y=10.2006x-1.9494
Ammonia nitrogen	r=-0.0332 y=-4.3871x+36.7779	r=0.2713 y=2.2817x+8.9692	r=-0.2839 y=-10.6624+20.4027	r=-0.1219 y=-4.2959x+13.1318	r=-0.0332 y=-0.4976x+2.1671
Calcium	r=-0.2342 y=-12,3456x+76.4256	r=-0.4127 y=-20.5461x+51.2164	r=-0.1927 y=-2,6745x+15.4268	r=-0.3427 y=-0.4271x+17.5232	r=0.3127 y=1.6452x-3.4672
Magnesium	r=0.2339 y=13.4718x+19.3816	r=-0.1231 y=-4.6811x+15.4854	r=0.4586 y=7.2812x+5.4955	r=0.1486 y=2.3694x+7.7265	r=0.6854 y=4.6351x-3.1030
Chloride	r=0.4857 y=31.7878x+10.1098	r=0.3065 y=15.0107x-9.9573	r=0.5463 y=11.9484x+4.0995	r=0.5464 y=10.3199x+2.6562	r=0.5117 y=4.4557x-1.5791
Sodium	r=-0.5201 y=-12.6490x+67.3898	r=-0.2089 y=-3.3118x+19.2736	r=-0.5081 y=-0.3596x+22.7779	r=-0.4531 y=-2.1453x+15.9333	r=-0.5863 y=-0.6436x+3.8065
Potassium	r=-0.5651 y=-11.5722x+66.5906	r=-0.2047 y=-2.8190x+18.3627	r=-0.5240 y=-3.2002x+22.1759	r=-0.4674 y=-2.1197x-16.1626	r=-0.8463 y=-2.0721x+7.6125
Iron	r=-0.3560 y=-12.3047x+56.4939	r=0.0133 y=0.3225x+9.9113	r=-0.4838 y=-5.2330x+22.8002	r=-0.3001 y=-3.0453x-15.8078	r=-0.9259 y=-3.9872x+9.1101
Oxidisable orgnic matter	r=-0.7410 y=-8.0790x+57.7115	r=-0.5449 y=-3.9491x+22.0349	r=-0.5465 y=-1.7685x+18.4155	r=-0.6342 y=-1.9254x+15.8738	r=-0.6190 y=-0.7975x+4.1627
Total phytoplankton	r=0.7762 y=0.0794x+10.9317	r=0.5954 y=0.0409x-1.1.5909	r=0.5728 y=0.0175x+8.0551	r=0.5978 y=0.0172x+5.1641	r=0.4233 y=0.0059x+0.0646
Myxophyceae	r=0.1977 y=0.2757x+26.6474	r=0.1012 y=0.0982x+7.8826	r=0.4720 y=0.1611x+8.9542	r=0.0405 y=0.0164x+9.8104	r=0.6881 y=0.1186x-1.3301
Chlorophyceae	r=0.7852 y=0.1665x+14.6089	r=0.6579 y=0.0971x-0.7955	r=0.4413 y=0.0291x+9.8670	r=0.6553 y=0.0404x+5.5374	r=0.3264 y=0.0085x+0.8
Dinophyceae	r=-0.1376 y=-1.4046x+37.3946	r=-0.2403 y=-1.7056x+14.6221	r=0.2247 y=0.7123x-11.5284	r=-0.1584 y=-0.4113x+11.2441	r=0.2491 y=0.3144x+1.0736
Chrysophyceae	r=0.7652 y=2.2809x+=3 5635	r=0.6258 y=0.13004x+4.4311	r=0.4226 y=0.3922x-11.4197	r-0.6758 y=0.5883x+7.5045	r=0.2918 y=0.1078x+1.3303
Rhodophyceae	r=-0.4683 y=-3.9277x+35.2551	r=-0.3829 y=-2.6411x+13.3611	r=-0.6502 y=-0.1693x+13.4334	r=-0.4574 y=-1.1173x+11.4604	r=-0.3241 y=-0.3295x+1.4762
Bacillariophyceae	r=0.7668 y=0.1641x+10.9982	r=0.5873 y=0.0873x-1.7497	r=0.6096 y=0.0404x+7.5724	r=0.5807 y=0.0361x+5.1755	r=0.5228 y=0.0138x-0.1055
Total zooplankton	r=0.6829 y=0.9632x-19.4586	r=0.5188 y=0.5088x-17.7390	r=0.5380 y=0.2356x+0.1724	r=0.5325 y=0.2187x-1.8919	r=0.7252 y=0.1264x-5.1839
Protozoa	r=-0.4555 y=-2.3728x+81.0609	r=-0.5166 y=-1.8710x+47.6097	r=0.0937 y=0.1525x+10.2439	r=-0.4305 y=-0.6533x+23.2073	r=-0.5001 y=-0.3275x+2.3293
Rotifera	r=0.0249 y=0.0809x+33.4667	r=-0.1015 y=-0.2288x+12.0064	r=0.2906 y=0.2926x+11.3236	r=0.0182 y=0.0172x+10.1366	r=0.7898 y=0.3165x-0.2507
Ostracoda	r=0.7694 y=3.5256x-1.8436	r=0.5838 y=1.8598x-8.4084	r=0.5428 y=0.7722x+5.3989	r=0.6695 y=0.8935x+1.1659	r=0.6187 y=0.3504x-1.7291
Copepoda	r=0.7351 y=3.0688x+10.728	r=0.6488 y=1.8836x-3.7839	r=0.3380 y=0.4381x+9.9272	r=0.6142 y=0.7470x+4.4847	r=0.2754 y=0.1421x+0.7558
Cladocera	r=0.6378 y=1.8498x+13.0345	r=0.6250 y=1.2602X-3.7829	r=0.2158 y=0.1943x+11.0469	r=0.4679 y=0.3952x+5.7705	r=0.4050 y=0.1738x-1.3714
Total Benthic organism	r=0.7738 y=1.4338x-6.1481	r=-0.6385 y=-0.227x+12.5370	r=0.4759 y=0.2738x+5.5833	r=0.6249 y=0.3373x+0.8055	r=0.6583 y=0.1507x-2.3889
Nematoda	r=0.7968 y=5.1178x+8.8371	r=0.6209 y=2.7735x-3.1364	r=0.4562 y=0.9099x+8.7761	r=0.7667 y=1.4344x+3.1973	r=0.4170 y=0.3311x+0.2053
Oligochaeta	r=0.2326 y=1.9503x+30.2618	r=0.0441 y=0.2573x+10.0067	r=0.5436 y=1.4153x+10.5372	r=0.1136 y=0.2776x+9.7176	r=0.7796 y=0.8081x+0.2844
Decapoda	r=0.8554 y=5.8816x-7.6616	r=0.6637 y=2.9642x-10.0026	r=0.6236 y=1.2437x+4.6476	r=0.6987 y=1.3072x+1.2079	r=0.6171 y=0.4904x-1.5562
Insecta	r=0.7381 y=6.8667x-34.6667	r=0.7318 y=4.7333x-36.8333	r=0.1269 y=0.3667x+9.5833	r=0.6520 y=1.7667x-7.4166	r=0.2319 y=0.2667x-8.3333
Gastropoda	r=0.3442 y=4.1542x+21.8907	r=0.3024 y=2.4855x+3.2503	r=0.3518 y=0.7511x+11.0591	r=0.4569 y=0.9150x+7.5811	r=0.2942 y=0.5422x+1.5442
Miscellaneous groups	r=-0.6498 y=-1.9831x+43.3135	r=-0.5474 y=-4.3728x+15.6016	r=-0.4332 y=-1.6525x-15.1779	r=-0.5849 y=1.9576x+12.5338	r=-0.0238 y=-0.0388x+1.8728

Table 15: Coreelation coeefficients (r) and regression equations (y) of Macrobrachium hendersoni hendersoni (De Man) population versus various ecological parameters at Station A_3 (Umshing Stream)

Parameter (y)	Total density (y)	Size group:			Ovigerous (y)
		20.0-40.0 mm (y)	40.1-60.0 mm (y)	60.1-80.0 mm (y)	
Rainfall	r=0.6388 y=0.0629x+27.0451	r=0.3464 y=0.0131x+7.1099	r=0.6763 y=0.0128x+4.6511	r=0.5834 y=0.2890x+0.3898	r=0.6095 y=0.0826x+0.7520
Water temperature	r=0.6331 y=3.330x-14.8569	r=0.2082 y=0.4772x+1.6267	r=0.7038 y=0.8091x-0.0576	r=0.5666 y=0.4734x-3.2304	r=0.6875 y=0.5665x-6.8509
Transparency	r=90.6208 y=-1.1670x+60.2012	r=-0.3331 y=-0.2531x+13.4521	r=-0.6600 y=-0.2286x+10.5310	r=-0.5159 y=-0.0591x+5.1994	r=-0.5503 y=-0.1503x+4.5945
Rate of water flow	r=0.5307 y=0.6776x-11.2228	r=0.2589 y=0.1627x-2.5981	r=0.7121 y=0.2243x-4.5297	r=0.3420 y=0.0742x-1.4549	r=0.6688 y=0.1512x-8.8577
Turbidity	r=0.6559 y=0.3293x+20.4784	r=0.5666 y=0.4734x-3.2304	r=0.6605 y=0.0859x+2.7434	r=0.4086 y=0.0936x+4.3558	r=0.6418 y=0.0528x-0.6694
Dissolved oxygen	r=0.7021 y=7.0641x-26.9841	r=0.7051 y=2.1910x+12.8789	r=0.8407 y=1.3101x-6.5508	r=0.6351 y=0.7193x-3.0444	r=0.5179 y=0.5785x-3.7991
pH	r=0.3546 y=25.9420x-128.5771	r=0.3478 y=11.4082x-66.1158	r=0.3153 y=5.473x-22.4928	r=0.3031 y=4.4665x-25.2751	r=0.2368 y=1.2954x-6.5421
Carbon dioxide	r=-0.4001 y=-8.3471x+64.8101	r=-0.3761 y=-5.8964x+27.2826	r=-0.3476 y=-2.1857x+13.3319	r=-0.3890 y=-1.4451x-8.6293	r=-0.1251 y=0.3027x+2.9346
Specific conductivity	r=0.2626 y=0.4023x-17.07201	r=0.3261 y=0.1823x+3.7832	r=0.2501 y=0.0421x-7.8077	r=0.2763 y=0.0156x-4.6189	r=-0.3632 y=-0.0730x+4.1222
Total alkalinity	r=-0.7531 y=-2.1766x+87.9957	r=-0.1372 y=-0.1173x-13.4367	r=-0.3077 y=-0.1681+0.2050	r=0.2841 y=0.8853x+0.8819	r=0.3954 y=0.1829x-4.7867
Silicate	r=0.2927 y=4.7216x+10.2352	r=-0.1862 y=-1.1734x+16.0557	r=0.6896 y=1.2325x-7.4008	r=0.3810 y=0.8506x-0.9228	r=0.8052 y=1.8256x-8.8569
Phosphate phosphorus	r=0.6671 y=51.5309x+1.274	r=0.2147 y=4.8619x+4.8534	r=0.7228 y=8.2058x-5.5579	r=0.4794 y=2.3054x+2.1609	r=0.7546 y=6.140x-3.3414
Nitrate nitrogen	r=0.4089 y=58.7265x+6.1831	r=0.1158 y=3.7306x+6.8262	r=0.4767 y=7.7122x+1.9431	r=0.3403 y=3.9963x+1.7489	r=0.7902 y=9.1476x-3.5345
Ammonium nitrogen	r=-0.1447 y=-18.8752x+50.1764	r=-0.6252 y=-2.0681x+17.2877	r=-0.2529 y=-9.5372x+5.4579	r=-0.6714 y=-1.0445x+7.3785	r=-0.5434 y=-0.8335x+4.5632
Calcium	r=-0.4914 y=-15.7660x+73.7006	r=-0.4425 y=-9.2061x+40.5376	r=-0.4229 y=-4.1086x+20.6212	r=-0.4536 y=-3.2033x+15.1114	r=0.2246 y=2.2465x-4.6785
Magnesium	r=0.3998 y=25.3063x+3.5333	r=0.2909 y=2.9479x+3.8115	r=0.6960 y=3.5383x+0.2556	r=0.4103 y=1.7011x+1.1245	r=0.6432 y=2.3433x-2.1907
Chloride	r=0.5269 y=37.8494x+7.1417	r=0.1193 y=3.8911x+5.6624	r=0.5529 y=9.0488x-1.3772	r=0.4801 y=0.9525x+3.3292	r=0.5985 y=7.0193x-4.1714
Sodium	r=-0.5343 y=-12.0018x+70.7019	r=-0.4866 y=-9.7896x-41.9601	r=-0.8049 y=-0.8127x+33.8587	r=-0.7150 y=-5.2441x+20.4082	r=-0.8245 y=-2.3441x+9.8723
Potassium	r=-0.6084 y=-10.0114x+67.2430	r=-0.6252 y=-2.6681x+17.2877	r=-0.8234 y=-6.5526x+28.6754	r=-0.8328 y=-0.4497x+30.4082	r=-07245 y=-6.4497x+10.3827
Iron	r=-0.4404 y=-13.6072x+63.6096	r=-0.1781 y=-4.771x+19.9842	r=-0.5038 y=-6.7684x+22.0491	r=-0.4795 y=-0.4682x+14.8667	r=-0.5386 y=-3.2603x+9.4498
Oxidisable organic matter	r=-0.8080 y=-8.2243x+62.2271	r=-0.6252 y=-2.0681x+17.2877	r=-0.7766 y=-1.6621x+11.6943	r=-0.6714 y=-1.0445x+7.3785	r=-0.5434 y=-0.8335x+4.5632
Total phyto-plankton	r=0.8596 y=0.0606x+2.2375	r=0.6909 y=0.0294x+0.5439	r=0.9441 y=0.0201x+0.7319	r=0.6569 y=0.0067x+1.9665	r=0.4271 y=0.0063x+0.1328
Myxophyceae	r=0.2287 y=0.2198x+13.9725	r=-0.0396 y=-0.0229x+9.6960	r=0.5701 y=0.1658x+2.1610	r=0.3106 y=0.0656x+2.4151	r=0.5391 y=0.1123x-9.9700
Chlorophyceae	r=0.9162 y=0.1338x+12.9725	r=0.8074 y=0.0712x+0.7918	r=0.4387 y=0.0379x+2.1606	r=0.7578 y=0.0243x+1.3294	r=0.2275 y=0.0072x+1.1526
Dinophyceae	r=-0.2749 y=-1.9331x+24.505	r=-0.4010 y=-1.7023x+13.1973	r=0.0769 y=0.1638x+6.1872	r=-0.1513 y=-2.341x+4.7324	r=0.3156 y=0.4816x+0.8361
Chrysophyceae	r=0.9247 y=1.9036x+10.9495	r=0.8674 y=1.0779x+4.0527	r=0.4356 y=0.4896x+4.2981	r=0.7264 y=0.3291x+2.6307	r=0.2156 y=0.0963x+1.5504
Rhodophyceae	r=-0.4259 y=-2.4604x+22.4988	r=-0.6220 y=-2.1693x+11.4334	r=-0.0244 y=-0.0428x+6.6297	r=-0.1740 y=-0.2212x+4.4063	r=0.2593 y=0.3251x+1.6478
Bacoillariophyceae	r=0.7645 y=0.1126x+4.0371	r=0.5846 y=0.0519x+1.7907	r=0.7281 y=0.0413x+0.7773	r=0.6013 y=0.0193x+1.4320	r=0.5010 y=0.0161x-0.2465
Total zooplankton	r=0.7454 y=0.7241x-20.3563	r=0.5415 y=0.3176x-8.5448	r=0.8661 y=0.2547x-7.5574	r=0.6701 y=0.1433x-3.7862	r=0.6142 y=0.1129x-5.1873
Protozoa	r=-0.5632 y=-2.0211x+59.9146	r=-0.3659 y=-0.7926x+24.8048	r=-0.4334 y=-0.6881x+20.2317	r=-0.3706 y=-0.5296x+14.6707	r=-0.4627 y=-0.3135x+8.2195
Rotifera	r=0.0221 y=0.0493x+19.5089	r=0.2690 y=0.3628x+11.4718	r=-0.4187 y=-0.2831x+4.7192	r=0.2045 y=0.1006x+3.5046	r=0.6768 y=0.3281x-1.5963
Ostracoda	r=0.7901 y=2.4932x-5.5148	r=0.6316 y=1.2035x-3.1522	r=0.8363 y=0.7991x-1.5417	r=0.6829 y=0.4743x-0.6563	r=0.5786 y=0.3962x-2.0282
Copepoda	r=0.8339 y=2.3934x+1.6452	r=0.7712 y=1.3391x-1.0716	r=0.4396 y=0.6440x+1.6989	r=0.6667 y=0.4219	r=0.1936 y=0.1208x-1.0834
Cladocera	r=0.7471 y=1.4924x+2.9190	r=0.6223 y=0.7505x+0.5772	r=0.4159 y=0.4330x+1.6754	r=0.6731 y=0.2958x+0.8132	r=0.3811 y=0.1652x+0.1274
Total Benthic organism	r=0.7803 y=0.9960x+13.9725	r=-0.5492 y=0.4232x+2.7685	r=0.9583 y=0.3703x-3.7870	r=07156 y=0.2011x-1.4629	r=0.5991 y=0.1123x-9.9700
Nematoda	r=0.8076 y=3.5735x+2.2635	r=0.6193 y=1.6543x+0.9496	r=0.8374 y=1.1218x+1.0675	r=0.7861 y=0.7655x+0.4028	r=0.3641 y=0.3496x+0.2807
Oligochaeta	r=0.2478 y=1.4311x+17.0902	r=0.0239 y=0.0835x+8.9232	r=0.5667 y=0.9909x+4.6839	r=0.2592 y=0.3296x+3.5349	r=0.7131 y=0.8939x+0.2867
Decapoda	r=0.7753 y=3.4304x-3.8940	r=0.5836 y=1.5589x-1.6993	r=0.9085 y=1.2172x-1.8357	r=0.6556 y=0.6384x-2.4901	r=0.5794 y=0.5562x-1.8476
Insecta	r=0.5931 y=3.8001x-18.6667	r=0.5773 y=2.2333x-13.2501	r=0.3846 y=1.0334x-3.7506	r=0.4682 y=0.6421x-1.8333	r=0.2877 y=0.4x-2.0001
Gastropoda	r=0.3421 y=3.7298x+8.9544	r=0.4572 y=1.6585x+4.2458	r=0.4211 y=1.2488x+2.9408	r=0.5201 y=0.8042x+1.8209	r=0.3893 y=0.4006x+0.8315
Miscellaneous group	r=-0.6532 y=-5.1694x+25.8644	r=-0.4520 y=-3.0569x+13.1864	r=-0.2452 y=-0.8422x+7.5423	r=-0.4184 y=-0.7284x+5.0169	r=-0.0421 y=1.0451x+0.2867

V. Population density of ovigerous female versus

i) Physico-chemical variables: Rainfall, water temperature, rate of water flow, turbidity, dissolved oxygen, silicate, phosphate-phosphorous, nitrate-nitrogen, magnessium, and chloride content have shown significantly positive correlations Specific conductivity also resulted negatively significant r-values at A_1 and A_2 (Table 13-15). Correlations with water transparency, sodium, potassium, iron and oxidisable organic matter content resulted significantly negative, and at the station A_3, ammonia-nitrogen also resulted a negatively significant r-value (-0.5434).

ii) Biotic variables: Total zooplankton and benthic organisms have shown positively significant correlation. Myxophyta, Baccillariophyta, Rotifera, Ostracoda, Oligochaeta and Decapoda exhibited positively significant correlations. Correlation with Protozoa resulted significantly negative r-values (Table 13-15).

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I. Total density versus

i) Physico-chemical variables: Rainfall, water temperature, turbidity, dissolved oxygen and chloride concentration have shown positively significant correlations while correlations with water transparency, total alkalinity, sodium, potassium, iron, oxidisable organic matter content resulted into significantly negative r-values (Table 16-18).

ii) Biotic variables: Total phytoplankton, zooplankton and benthic organisms have shown significantly positive correlations and also categorically Myxophyta, Chlorophyta, Chrysophyta, Baccillariophyta, Rotifera, Ostracoda, Copepoda, Nematoda, Oligochaeta, Decapoda, Insecta and Gastropoda group.

II. Population density (size group, 20.0 - 40.0 mm) versus

i) Physico-chemical variables: Water temperature, turbidity, and dissolved oxygen exhibited significantly positive correlations while sodium, potassium, iron and oxidisable organic matter resulted into negatively significant r-values (Table 16-18).

ii) Biotic variables: Total phytoplankton and zooplankton have shown positively significant correlations. Categorically correlations with Myxophyta, Chlorophyta, Chrysophyta, Baccillariophyta, Rotifera, Ostracoda, Copepoda, Insecta resulted significantly positive r-values while Rhodophyta and also Miscellaneous group resulted into negatively significant r-values (Table 16-18).

III. Population density (size group, 40.1 - 50.0 mm) versus

i) Physico-chemical variables: Rainfall, water temperature, rate of water flow, turbidity, dissolved oxygen, specific conductivity, silicate phosphate-phosphorous and chloride concentration exhibited significantly positive correlation. Nitrate-nitrogen showed its positively significant correlation ($r = +0.4805$) at the station B_3. Correlations with water

Table 16: Correlation co-efficients (r) and regression equations (y) of *Macrobrachium hendersoni cacharensis* (Tiwari) population versus various ecological parameters at Station B_1 (Pongtung Stream)

Parameter (x)	Total density (y)	Size group:			Ovigerous (y)
		20.0-40.0 mm (y)	40.1-50.0 mm (y)	50.1-70.0 mm (y)	
Rainfall	r=0.4821 y=0.0587x+28.0878	r=0.3892 y=0.0312x+10.3975	r=0.4652 y=0.0118x+10.3302	r=-0.0035 y=-0.0013x+9.6667	r=0.5677 y=0.0085x+0.7085
Water temperature	r=0.6119 y=2.6414x-26.7763	r=0.5333 y=1.4715x-20.6689	r=0.5497 y=0.4778x+4.7309	r=0.4821 y=0.5429x-3.4323	r=0.8426 y=0.4340x-8.5542
Transparency	r=-0.5676 y=-0.6297x+57.2281	r=0.2230 y=0.0722x+7.5233	r=-0.4651 y=-0.0911x+15.0345	r=-0.5548 y=-0.3946x+27.9897	r=-0.6501 y=-0.0863x+4.7936
Rate of water flow	r=0.2227 y=0.4919x+10.0669	r=-0.0308 y=-0.0478x+17.4177	r=0.5623 y=0.1302x+4.9731	r=0.1130 y=0.0811x+5.2882	r=0.4923 y=0.0566x-1.1402
Turbidity	r=0.5453 y=0.6216x-29.3980	r=0.5729 y=0.4089x+2.7014	r=0.4522 y=0.0926x+9.2522	r=-0.3014 y=-0.0971x+12.8956	r=0.5516 y=0.0735x-0.2636
Dissolved oxygen	r=0.5007 y=7.9765x-29.3980	r=0.4763 y=4.0286x-18.4031	r=0.6094 y=1.8567x-3.3181	r=0.4854 y=1.4261x+0.4026	r=0.5182 y=0.9301x-5.7418
pH	r=0.3232 y=18.3645x-81.1194	r=0.2852 y=9.7102x-47.2312	r=0.2965 y=6.1029x-27.0076	r=0.1068 y=0.1656x+20.2501	r=0.0484 y=1.1295x-5.3027
Carbon dioxide	r=-0.3486 y=-11.8826x+84.7965	r=-0.4203 y=-9.9280x+55.4557	r=0.2158 y=2.7064x+23.0739	r=-0.1746 y=-0.5962x+10.2429	r=0.0401 y=0.1547x+1.2856
Specific conductivity	r=0.2060 y=0.4281x+15.7261	r=0.0049 y=0.0073x+14.4629	r=0.4724 y=0.0779x+8.1007	r=0.1121 y=0.0421x+9.2782	r=0.6993 y=0.1967x-7.9323
Total alkalinity	r=-0.4697 y=-1.2602x-68.2395	r=-0.3110 y=-0.5651x+28.7479	r=-0.4546 y=-0.1303x+15.2093	r=0.0429 y=0.0462x+11.4429	r=-0.6296 y=-0.2136x+7.1747
Silicate	r=0.3582 y=11.8409x-0.8452	r=0.3285 y=7.2125x-7.5495	r=0.4933 y=3.4105x+1.4158	r=0.3422 y=4.2674x-0.6426	r=0.7504 y=3.0752x-7.6267
Phosphate phosphorus	r=0.2481 y=28.6321x+13.4573	r=0.1837 y=14.0506x+3.6865	r=0.4685 y=8.8740x+4.9599	r=0.0042 y=0.6422x+37.4224	r=0.7104 y=10.1383x-6.1264
Nitrate nitrogen	r=0.1296 y=16.8998x+44.8671	r=-0.1808 y=-17.0001x+23.6580	r=0.3171 y=9.0512x+7.3234	r=0.2704 y=5.4262x+8.3527	r=0.5246 y=8.8324x-2.6472
Ammonia nitrogen	r=0.0071 y=1.0742x+35.5730	r=-0.1239 y=-11.4434x+23.4540	r=0.0067 y=0.1822x+11.8642	r=-0.2426 y=-4.2423x+7.4632	r=-0.2765 y=-4.7652x+1.6731
Calcium	r=-0.2728 y=-6.2043x+16.3840	r=-0.2031 y=-3.8311x+30.6461	r=-0.3551 y=-1.5138x+18.2483	r=0.0246 y=0.0452x+8.4231	r=-0.5473 y=-1.3829x+7.6246
Magnesium	r=0.0181 y=0.7761x+36.9926	r=-0.0854 y=-2.4488x+19.3676	r=0.1571 y=1.4022x+9.3965	r=-0.1764 y=-0.8462x+14.1026	r=0.5934 y=3.1758x-3.9640
Chloride	r=0.5524 y=36.8906x+8.5687	r=0.3809 y=21.2084x-7.9022	r=0.4917 y=7.9628x+5.7358	r=0.2627 y=1.4526x+7.2342	r=0.4892 y=4.4710x-1.3769
Sodium	r=-0.4206 y=-17.2088x+77.7334	r=-0.4521 y=-12.2392x+44.9214	r=0.4525 y=-3.8579x+21.4841	r=-0.2674 y=-0.9345x+14.7229	r=-0.8294 y=-0.4191x+12.2186
Potassium	r=-0.3911 y=-16.8226x+18.0956	r=-0.4322 y=-12.7775x+46.8836	r=-0.3735 y=-3.4774x+20.7226	r=-0.1674 y=-0.8149x+15.2321	r=-0.7748 y=-4.2755x+12.6411
Iron	r=-0.5651 y=-20.5394x+59.87	r=-0.5242 y=-11.8196x+28.3864	r=-0.5645 y=-4.007x+16.5921	r=-0.2232 y=-0.4265x+11.2942	r=-0.7522 y=-3.1654x+5.5463
Oxidisable organic matter	r=-0.7034 y=-7.7392x+84.9710	r=-0.8629 y=-6.2343x+54.2654	r=-0.4518 y=-0.3226x+14.0408	r=-0.1467 y=-1.4232x+17.8427	r=-0.4565 y=-0.1301x+2.7400
Total phytoplankton	r=-0.6524 y=0.0442x+18.9827	r=0.6056 y=0.0586x-5.8947	r=0.4927 y=0.0151x+6.6898	r=0.1124 y=0.0456x+10.2319	r=0.6089 y=0.0112x-1.9729
Myxophyceae	r=0.5982 y=1.0021x+10.6430	r=0.6402 y=0.7389x-9.4932	r=0.4768 y=0.1617x+7.0123	r=0.2346 y=0.2749x+14.2361	r=0.6540 y=0.1504x-2.7221
Chlorophyceae	r=0.5142 y=0.1345x+11.3916	r=0.5756 y=0.0853x-1.6552	r=0.5931 y=0.1834x+8.4537	r=0.5122 y=0.0451x+14.2264	r=0.5361 y=0.0148x-0.9491
Dinophyceae	r=-0.3940 y=-4.8341x+46.9617	r=0.0417 y=0.1179x+13.9389	r=0.5433 y=0.4831x+8.3363	r=0.1104 y=1.6741x+7.2267	r=0.7839 y=0.4091x-1.1515
Chrysophyceae	r=0.5206 y=6.8820x+12.5229	r=0.7677 y=0.3180x+0.4713	r=0.4942 y=0.0643x+9.6768	r=0.1670 y=0.4262x+10.2324	r=0.5682 y=0.0551x-0.0683
Rhodophyceae	r=-0.5782 y=-2.5169x+40.8951	r=-0.4901 y=-1.6932x+18.3609	r=0.0470 y=0.05115x+11.8934	r=-0.1122 y=-0.0894x+17.4264	r=-0.1349 y=-0.0871x+2.0979
Bacillariophyceae	r=0.4872 y=5.0162x+14.5858	r=0.5591 y=0.3021x-7.6216	r=0.6521 y=0.1109x+3.7521	r=0.4942 y=0.8042x-4.2237	r=0.7943 y=0.0801x-4.0379
Total zooplankton	r=0.4965 y=2.7397x+7.7331	r=0.5835 y=0.6526x-17.6351	r=0.4847 y=0.1355x+5.2587	r=0.0942 y=0.623x+11.3242	r=0.5822 y=0.1215x-4.1295
Protozoa	r=-0.1299 y=-0.5014x+45.7843	r=0.0008 y=0.0019x+14.7858	r=0.0447 y=0.0359x+11.1458	r=-0.0782 y=-0.0827x+17.4255	r=0.1906 y=0.0909x-0.2424
Rotifera	r=0.4652 y=1.6549+10.3264	r=0.6664 y=2.3019x-10.6792	r=0.4834 y=0.5258x+6.1716	r=0.3322 y=0.1421x+7.4236	r=0.7599 y=0.4889x-3.5136
Ostracoda	r=0.5645 y=1.6549x+11.3124	r=0.4573 y=5.5140x+0.5887	r=0.5787 y=2.4673x+5.6262	r=0.4624 y=1.6642x+7.9144	r=0.3810 y=0.9626x-0.5702
Copepoda	r=0.4524 y=0.0178x+2.7734	r=0.6788 y=1.9591x+1.1190	r=0.4877 y=0.3979x+9.2142	r=0.1136 y=0.0452x+12.3266	r=0.6532 y=0.3520x-0.5476
Cladc	r=0.3264 y=2.8404x+26.6877	r=0.4239 y=3.8876x-5.2528	r=0.0288 y=0.0674x+11.6516	r=0.2112 y=3.2411+9.2468	r=-0.1176 y=-0.1629x+2.7584
Total benthic organism	r=0.4949 y=0.6554x+15.2862	r=0.3847 y=0.7640x+2.0358	r=0.6323 y=0.4261x+5.3233	r=0.4642 y=0.1554x+7.7742	r=0.9521 y=0.3803x-4.0425
Nematoda	r=0.5291 y=2.2025x-9.2187	r=0.3954 y=2.8709x+4.7849	r=0.4797 y=1.0967x+11.0763	r=0.4634 y=3.2421x+11.2466	r=0.3577 y=0.8167x+1.1679
Oligochaeta	r=0.4998 y=1.5372x+10.9861	r=0.3018 y=3.5714x+11.8571	r=0.4870 y=1.6285x+10.6428	r=0.4422 y=1.3212x+7.4215	r=0.8084 y=1.4581x-3.3083
Decapoda	r=0.7369 y=1.8330x-10.7793	r=0.4935 y=3.6563x+1.7312	r=0.5057 y=1.4801x+6.6960	r=0.4206 y=0.5824x+5.6725	r=0.8406 y=1.6581x-3.6083
Insecta	r=0.4806 y=0.4534x+8.9046	r=0.6456 y=5.2989x-12.9863	r=0.5584 y=1.4433x+4.4226	r=0.6670 y=0.9456x+2.5627	r=0.6796 y=1.0412x-3.3498
Gastropoda	r=0.4552 y=3.8126x+19.3929	r=0.3162 y=4.2807x+8.0561	r=0.6578 y=2.8037x+7.5607	r=0.1527 y=0.3748x+9.9456	r=0.6917 y=1.7476x-0.8504
Miscellaneous group	r=-0.4232 y=-2.4776x+48.7320	r=-0.4527 y=-0.4625x+20.7251	r=0.2616 y=1.0076x+11.0763	r=0.0524 y=0.0452x+11.5424	r=0.3577 y=0.8167x+1.1679

Table 17: Correlation co-efficients (r) and regression equations (y) of *Macrobrachium hendersoni cacharensis* (Tiwari) population versus various ecological parameters at Station B_2 (Pongtung Stream)

Parameter (x)	Total density (y)	Size group: 20.0-40.0 mm (y)	Size group: 40.1-50.0 mm (y)	Size group: 50.1-70.0 mm (y)	Ovigerous (y)
Rainfall	r=0.4702 y=0.0651x+34.4742	r=0.2714 y=0.0193x+9.5871	r=0.5000 y=0.0297x+15.1146	r=-0.0912 y=-0.0013x+10.3516	r=0.8644 y=0.0642x+0.4627
Water temperature	r=0.6583 y=3.2756x-31.0855	r=0.4923 y=1.2489x-16.4642	r=0.7696 y=1.6196x-18.3778	r=0.4856 y=0.0028x+10.1016	r=0.8124 y=0.3527x-5.2437
Transparency	r=-0.5769 y=-0.7622x+67.6225	r=0.2739 y=0.0396x+8.9673	r=-0.6664 y=-0.4016x+31.4741	r=-0.5621 y=-0.4063x+24.6165	r=-0.8426 y=-0.0745x+3.4639
Rate of water flow	r=0.3247 y=0.7778x+1.5088	r=0.1876 y=0.2682x-1.9903	r=0.5221 y=0.1425x+4.7242	r=0.0719 y=0.0205x+9.0683	r=0.6527 y=0.0942x-1.1327
Turbidity	r=0.5688 y=0.6967x+22.2278	r=0.5260 y=0.2369x+3.8952	r=0.6447 y=0.3205x+9.8101	r=-0.2049 y=-0.0245x+10.8964	r=0.7423 y=0.3427x-3.2742
Dissolved oxygen	r=0.6322 y=11.7314x-59.2276	r=0.5839 y=5.8620x-38.8173	r=0.5709 y=4.6390x-21.0051	r=0.4758 y=0.1485x+8.8744	r=0.5427 y=0.8427x-4.2452
pH	r=0.2173 y=14.8699x-56.3390	r=0.3024 y=10.0428x-55.2886	r=0.0686 y=1.9000x+6.5398	r=-0.0407 y=-0.2714x+11.9942	r=0.1244 y=0.3142x-6.4234
Carbon-dioxide	r=-0.0533 y=-0.1660x+49.9385	r=-0.13052 y=-4.8227x+30.3423	r=0.3173 y=4.1802x+3.7239	r=-0.1843 y= 0.5834x+12.3453	r=0.1144 y=0.1754x-1.8457
Specific conductivity	r=0.4080 y=0.8007x+11.0219	r=0.2323 y=0.2193x+3.5816	r=0.6685 y=0.5278x-1.7319	r=-0.1332 y=-0.0251x+11.1687	r=0.6274 y=0.1142x-2.5674
Total alkalinity	r=-0.5418 y=-1.2907x+32.0028	r=-0.3291 y=-0.3721x+23.3918	r=-0.7956 y=-0.7518x+41.8123	r=0.0379 y=0.0086x+9.9076	r=-0.8842 y=-0.1574x+5.2647
Silicate	r=0.1549 y=8.0998x+17.2238	r=0.1509 y=4.1812x-1.2903	r=0.5155 y=7.2901x-4.4206	r=-0.0013 y=-0.0075x+10.4129	r=0.7452 y=2.3543x-6.2475
Phosphate-phosphorus	r=0.3507 y=40.0002x+16.5044	r=0.3050 y=17.5361x-0.3949	r=0.4565 y=20.8574x+4.1769	r=-0.1609 y=-1.8537x+11.5122	r=0.6427 y=0.2747x-3.2071
Nitrate-nitrogen	r=0.1647 y=14.9218x+37.7640	r=0.0023 y=0.1451x+12.2624	r=0.2793 y=14.7299x+12.1401	r=0.0022 y=0.2834x+10.0276	r=0.6144 y=7.4567x-3.4471
Ammonia-nitrogen	r=0.0924 y=18.1946x+30.2930	r=-0.1912 y=-18.7154x+26.1048	r=-0.1657 y=-13.5278x+9.3791	r=0.0818 y=1.5736x+9.0021	r=-0.2427 y=4.2752x+1.5232
Calcium	r=-0.4208 y=-7.1849x+79.6896	r=-0.1918 y=-6.8614x+40.3793	r=-0.4117 y=-12.2809x+69.5315	r=0.0104 y=0.0746x+9.8618	r=-0.4252 y=-1.2437x+6.3421
Magnesium	r=0.0569 y=2.4187x+38.9169	r=-0.1753 y=-4.5364x+21.3911	r=0.3821 y=8.2454x+2.8699	r=-0.1870 y=-0.9697x+12.1029	r=0.5565 y=3.2555x-3.7425
Chloride	r=0.5158 y=52.0866x+4.7318	r=0.4326 y=19.1831x-2.2139	r=0.6040 y=22.3664x+2.4094	r=0.1690 y=1.5023x+9.0274	r=0.4562 y=4.3272x+1.5127
Sodium	r=-0.7142 y=-26.4054x+127.0420	r=-0.8971 y=-17.4321x+68.5819	r=-0.6384 y=-10.3448x+52.6954	r=0.1432 y=0.5576x+8.3684	r=-0.9245 y=-0.5147x+11.5245
Potassium	r=-0.5681 y=-27.1994x+130.3841	r=-0.5956 y=-14.0264x+58.4451	r=-0.6792 y=-13.3369x+63.1786	r=0.1301 y=0.6141x+8.1479	r=-0.7427 y=-5.3241x+9.2546
Iron	r=-0.5292 y=-22.0839x+69.1919	r=-0.4547 y=-0.0352x+22.7991	r=-0.6439 y=-10.8861x+31.8343	r=0.1442 y=0.5857x+9.4940	r=-0.6845 y=-3.2417x+6.2431
Oxidisable organic matter	r=-0.6410 y=-8.0040x+92.7913	r=-0.8583 y=-5.4252x44.9979	r=-0.4673 y=-2.3576x+33.5283	r=0.3642 y=0.4613x+7.389	r=-0.4451 y=-0.1502x+3.4251
Total phytoplankton	r=0.6306 y=0.1058x+5.5437	r=0.5389 y=0.0484x-5.0178	r=0.7448 y=0.05341x+0.4707	r=0.1295 y=0.0022x+10.9549	r=0.5042 y=0.01142x-1.7423
Myxophyceae	r=0.6878 y=1.4678x-2.3396	r=0.5922 y=0.6476x-7.6361	r=0.8008 y=0.7304x-3.1873	r=0.2361 y=0.0517x+11.7623	r=0.6451 y=0.1321x-2.4526
Chlorophyceae	r=0.5344 y=0.1371x+16.4086	r=0.5239 y=0.0689x-0.9857	r=0.5927 y=0.0649x+6.7677	r=0.4646 y=0.0085x+11.8207	r=0.5327 y=0.0452x-0.9789
Dinophyceae	r=0.3139 y=1.5351x+31.2749	r=-0.0279 y=-0.0699x+12.8637	r=0.6438 y=1.3452x+9.1317	r=0.2172 y=0.1075x+9.3418	r=0.5271 y=0.4152x-0.5174
Chrysophyceae	r=0.7143 y=0.6415x+19.7674	r=0.7407 y=0.3409x+0.0031	r=0.6879 y=0.2641x+9.8049	r=-0.2949 y=-0.0272x+11.1480	r=0.6421 y=0.2542x-0.2040
Baccillariophyceae	r=-0.3088 y=-1.8472x+46.7651	r=-0.5297 y=-1.6238x+15.7163	r=-0.0552 y=-0.1412x+19.6275	r=0.1883 y=0.1156x+9.9237	r=-0.1021 y=-0.0741x+2.0412
Total zooplankton	r=0.6047 y=1.1711x-15.3456	r=0.5646 y=0.5604x-15.5457	r=0.6188 y=0.5121x-6.1463	r=0.1289 y=0.0256x+11.4425	r=0.6412 y=0.1415x-3.4567
Protozoa	r=0.0196 y=0.0869x+40.8525	r=-0.0017 y=-0.0039x+12.4282	r=0.0591 y=0.1118x+16.6759	r=-0.0132 y=-0.0006x+10.3090	r=0.1452 y=0.0842x-0.2541
Rotifera	r=0.7437 y=4.4486x-6.3883	r=0.6806 y=2.0864x-10.7912	r=0.7579 y=1.8332x-0.6796	r=-0.1684 y=-0.1035x+11.3134	r=0.7241 y=0.4521x-0.4157
Ostracoda	r=0.5243 y=12.2897x+11.1682	r=0.4637 y=5.5700x-2.0561	r=0.5210 y=2.7452x+6.2341	r=0.4652 y=0.5421x+8.7664	r=0.3942 y=0.7457x-0.3127
Copepoda	r=0.6542 y=0.3270x+20.0238	r=0.6485 y=1.7107x+0.5011	r=0.6638 y=1.4184x+9.4047	r=-0.1292 y=-0.0663x+10.6309	r=0.5578 y=0.4274x-0.4527
Cladocera	r=0.3708 y=4.5408x+18.6989	r=0.4032 y=2.5306x-1.1632	r=0.3432 y=1.7959x+9.7551	r=-0.2353 y=-0.2959x+11.7448	r=0.2054 y=0.2152x-1.2352
Total Benthic organism	r=0.6009 y=2.0408x+8.9031	r=0.3292 y=0.5729x+2.7834	r=0.8263 y=1.1994x-0.6562	r=0.4895 y=0.0487x+9.3556	r=0.8121 y=0.3741x-4.0421
Nematoda	r=0.5317 y=6.2983x+18.2482	r=0.2469 y=1.4988x+6.4630	r=0.7771 y=3.9332x+3.9284	r=0.4536 y=0.0191x+10.0952	r=0.6144 y=0.5241x+1.5274
Oligochaeta	r=0.4552 y=9.3286x+35.1428	r=0.2258 y=2.3714x+10.3571	r=0.6819 y=5.9714x+14.3571	r=0.0135 y=0.0286x+10.1428	r=0.7142 y=1.3546x-3.4137
Decapoda	r=0.6504 y=8.8857x+5.1523	r=0.4972 y=2.7809x+0.5142	r=0.8483 y=5.9714x+14.3571	r=0.0678 y=0.0954x+9.7619	r=0.8507 y=2.1041x-2.4127
Insecta	r=0.8113 y=11.9264x-20.6912	r=0.6480 y=4.8823x-13.7058	r=0.8482 y=4.9524x-1.7143	r=0.4981 y=0.6764x+6.5588	r=0.6671 y=0.8147x-2.4272
Gastropoda	r=0.4870 y=10.4375x+28.9998	r=0.4239 y=4.6562x+6.1250	r=0.5903 y=5.4063x+14.1250	r=-0.1987 y=-0.4375x+10.7499	r=0.6142 y=1.2412x-0.9127
Miscellaneous group	r=-0.2750 y=-4.8125x+47.7292	r=-0.4878 y=-4.3750x+16.7083	r=0.0084 y=0.0625x+19.2708	r=0.1739 y=0.3125x+9.8542	r=0.4024 y=0.2417x-1.1425

Table 18: Correlation co-efficients (r) and regression equations (y) of *Macrobrachium hendersoni gachorensis* (Tiwari) population versus various ecological parameters at Station B_3 (Pongtung Stream)

Parameter (x)	Total density (y)	Size group:			Ovigerous (y)
		20.0-40.0 mm (y)	40.1-50.0 mm (y)	50.1-70.0 mm (y)	
Rainfall	r=0.4571 y=0.0753x+37.6805	r=0.2132 y=0.0234x+12.1681	r=0.5045 y=0.0295x+16.4723	r=0.1123 y=0.0023x+11.1785	r=0.7767 y=0.0928x+0.4310
Water temperature	r=0.6819 y=3.9499x-43.3635	r=0.5949 y=2.2209x-36.3252	r=0.7752 y=1.5386x-15.2491	r=0.4879 y=0.1272x+8.5306	r=0.8392 y=0.3402x-6.1923
Transparency	r=-0.5758 y=-0.9188x+76.2273	r=-0.0258 y=0.0052x+11.6539	r=-0.6645 y=-0.3991x+32.2973	r=-0.5448 y=-0.6164x+33.4288	r=-0.8029 y=-0.0988x+4.6257
Rate of water flow	r=0.3399 y=0.9065x-10.4834	r=0.0838 y=0.4068x-10.0961	r=0.6507 y=0.4959x-10.5376	r=0.2361 y=0.0613x+7.6396	r=0.8328 y=0.1296x-6.4091
Turbidity	r=0.5481 y=0.6016x+25.5133	r=0.4802 y=0.3016x+4.5132	r=0.6017 y=0.2242x+12.4985	r=0.1398 y=0.0178x+10.8525	r=0.7797 y=0.0593x-4.1357
Dissolved oxygen	r=0.6134 y=14.2657x-78.1027	r=0.4574 y=7.0597x-46.9786	r=0.6426 y=5.2754x-26.0206	r=0.4628 y=1.2955x+0.0341	r=0.6222 y=1.0434x-7.4844
pH	r=0.0628 y=4.4420x+18.4726	r=0.0028 y=0.1354x+14.5887	r=-0.0861 y=-2.2312x+35.6806	r=0.3673 y=1.2657x+3.3033	r=0.0493 y=0.2611x-7.4157
Cabon dioxide	r=-0.0881 y=-3.3703x+60.7189	r=-0.2401 y=-0.6361x+38.8393	r=0.3121 y=4.3989x+4.5189	r=-0.2034 y=-0.9778x+15.0892	r=0.4404 y=1.8439x-5.0190
Specific conductivity	r=0.4289 y=1.1629x-0.0213	r=0.4158 y=0.6314x-10.7960	r=0.7905 y=0.5579x-2.5664	r=0.1090 y=0.0262x+10.4076	r=0.7883 y=0.1136x-2.9828
Total alkalinity	r=-0.5259 y=-1.4305x+91.3728	r=-0.3948 y=-0.6694x+35.6604	r=-0.7694 y=-0.6939x+41.5668	r=-0.1198 y=-0.367x+12.6082	r=-0.8134 y=-0.1498x+6.2634
Silicate	r=0.3793 y=18.4566x-17.0381	r=0.2057 y=6.4396x-7.0872	r=0.6134 y=10.2104x-15.1462	r=0.3739 y=2.1221x+4.0566	r=0.8274 y=2.8132x-8.1173
Phosphate phosphorus	r=0.3597 y=40.0902x+14.5944	r=0.2472 y=19.2034x+0.3773	r=0.5164 y=21.3349x+3.8654	r=0.0369 y=0.5206x+41.0906	r=0.7455 y=6.2914x-3.2045
Nitrate nitrogen	r=0.1047 y=11.9213x+37.7010	r=0.1018 y=9.0426x+10.7315	r=0.4805 y=22.7008x+8.7109	r=0.1467 y=2.3634x+10.2552	r=0.7853 y=7.5783x-2.2412
Ammonia nitrogen	r=0.0921 y=18.1916x+30.2730	r=-0.2617 y=-38.3843x+43.9683	r=-0.0012 y=-0.0933x+20.7359	r=-0.2028 y=-5.3934x+7.4998	r=-0.3626 y=-5.7786x+2.5358
Calcium	r=-0.4288 y=-7.1719x+79.5890	r=-0.1704 y=-9.0231x+53.1413	r=-0.4365 y=-12.5787x+73.1411	r=-0.0589 y=-0.5662x+13.8621	r=-0.7944 y=-4.5709x+20.8183
Magnesium	r=0.0742 y=4.3023x+39.7306	r=-0.1256 y=-4.4610x+24.8049	r=0.2726 y=5.1507x+9.9230	r=-0.1553 y=-1.0071x+13.5872	r=0.5129 y=1.9798x-2.3795
Chloride	r=0.5431 y=67.8705x-5.5255	r=0.4332 y=36.4552x-14.4540	r=0.6220 y=24.9588x+0.1592	r=0.3153 y=4.3478x+7.9130	r=0.7853 y=7.5783x-2.2412
Sodium	r=-0.8255 y=-39.2902x+178.7203	r=-0.8885 y=-27.3146x+105.8661	r=-0.6601 y=-10.7925x+56.3718	r=-0.2566 y=-1.4311x+16.2351	r=-0.4569 y=-0.1392x+6.3573
Potassium	r=-0.5778 y=-32.4872x+156.3139	r=-0.6267 y=-22.3907x+94.7028	r=-0.6573 y=-12.4909x+63.1776	r=-0.1078 y=-0.6984x+13.8769	r=-0.7357 y=-2.855x+11.4699
Iron	r=-0.4820 y=-27.4229x+81.0883	r=-0.4620 y=14.2620x+32.2460	r=-0.7059 y=-11.5900x+34.2752	r=-0.1455 y=-0.8145x12.4563	r=-0.8287 y=-2.7793x+5.0134
Oxidisable organic matter	r=-0.6448 y=-9.7990x+108.3738	r=-0.7559 y=-7.4387x+60.4115	r=-0.4509 y=-2.3601x+34.9153	r=-0.0967 y=-0.7726x+12.5422	r=-0.4522 y=-0.2376x+3.1848
Total phytoplankton	r=0.7242 y=0.1121x+6.4274	r=0.5226 y=0.0694x-9.0212	r=0.7645 y=0.0540x+1.5882	r=0.0944 y=0.0027x+10.6961	r=0.7126 y=0.0102x-1.8825
Myxophyceae	r=0.6532 y=1.2141x-2.1142	r=0.5893 y=0.9956x-15.1995	r=0.7681 y=0.6863x-0.4972	r=0.2724 y=0.0827x+8.9488	r=0.7469 y=0.1371x-2.4779
Chlorophyceae	r=0.5427 y=0.1345x+11.4567	r=0.4885 y=0.0992x-3.6861	r=0.6391 y=0.0691x+7.3173	r=0.5018 y=0.0006x+11.4870	r=0.6514 y=0.01435x-1.0274
Dinophyceae	r=0.2152 y=1.4566x+14.5279	r=0.1216 y=0.4709x+11.9288	r=0.6194 y=1.2753x+10.9956	r=0.4218 y=0.0854x+10.8523	r=0.7512 y=0.3159x-0.6462
Chrysophyceae	r=0.6845 y=0.5674x+17.4523	r=0.7024 y=0.4995x-2.5241	r=0.6902 y=0.2610x+11.2471	r=0.1500 y=0.0193x+10.8018	r=0.6996 y=0.0541x-0.2004
Rhodophyceae	r=-0.2127 y=-1.6749x+44.5273	r=-0.4587 y=-2.1728x+20.0267	r=-0.0802 y=-0.2021x+21.0816	r=-0.1403 y=-0.1205x+11.7510	r=-0.1668 y=-0.0858x+1.9287
Bacillariophyceae	r=0.7127 y=0.7452x-3.4251	r=0.4524 y=0.3469x-11.0721	r=0.7965 y=0.3249x-4.2161	r=0.4976 y=0.0275x+9.3950	r=0.7603 y=0.0634x-3.1016
Total zooplankton	r=0.6425 y=1.1121x-13.2427	r=0.5824 y=0.8930x-28.9274	r=0.6214 y=0.5067x-4.5463	r=0.0894 y=0.0248x-10.2622	r=0.6629 y=0.1104x-3.7439
Protozoa	r=0.1022 y=0.0942x+42.4567	r=0.0969 y=0.0339x+14.6933	r=0.0729 y=0.1358x+17.4398	r=-0.0974 y=-0.0619x+12.9712	r=0.2336 y=0.0889x-0.3616
Rotifera	r=0.6456 y=3.3245x-7.4232	r=0.7410 y=3.509x-23.3962	r=0.7723 y=1.9452x-0.8929	r=0.2338 y=0.2008x+9.2738	r=0.7712 y=0.3962x-2.6415
Ostracoda	r=0.5142 y=11.2746x+9.2432	r=0.5106 y=9.4766x-8.9813	r=0.4923 y=4.8598x+8.1121	r=0.4865 y=1.4018x+7.8785	r=0.3198 y=0.6448x+0.0841
Copepoda	r=0.4867 y=0.3143x+11.6742	r=0.6214 y=2.4592x-1.7143	r=0.6665 y=1.4031x+10.8452	r=0.0923 y=0.0663x+11.0357	r=0.7593 y=0.3265x-0.5357
Cladocera	r=0.3843 y=3.5617x+19.2431	r=0.3504 y=3.3979x-2.6224	r=0.2572 y=1.3265x+13.5918	r=0.0848 y=0.0764x+10.8692	r=-0.0581 y=-0.0612x+2.0765
Total Benthic organism	r=0.6224 y=2.0546x+8.4252	r=0.3527 y=1.2174x-4.7904	r=0.8112 y=1.1601x+1.3312	r=0.4676 y=0.1695x+8.6742	r=0.9107 y=0.2661x-2.6348
Nematoda	r=0.5421 y=5.4672x+15.4232	r=0.3985 y=3.7375x+0.8616	r=0.7387 y=3.6849x+6.2338	r=0.4768 y=3.0071x+10.3221	r=0.8081 y=0.8234x-1.4749
Oligochaeta	r=0.4926 y=7.3567x+32.4254	r=0.3381 y=5.4851x+10.9285	r=0.6787 y=5.8517x+15.7857	r=0.4016 y=1.4261x+9.4086	r=0.8023 y=1.4142x+0.5714
Decapoda	r=0.7145 y=7.7456x+6.2432	r=0.5335 y=5.7714x-9.0285	r=0.8212 y=4.7238x+0.5905	r=0.4206 y=0.6667x+8.6671	r=0.8497 y=1.1762x-3.0528
Insecta	r=0.8456 y=10.562x+24.5645	r=0.7237 y=8.1443x-27.2577	r=0.7854 y=4.7010x-4.0137	r=0.7373 y=1.5052x+3.5979	r=0.5931 y=0.7524x-2.2512
Gastropoda	r=0.4654 y=11.3261x+25.2487	r=-0.2927 y=-1.1620x+20.2449	r=0.6372 y=5.7521x+12.9984	r=0.1218 y=0.3751x+10.9998	r=0.8136 y=1.4998x-0.2496
Miscellaneous group	r=-0.3219 y=-3.2421x+45.8292	r=-0.4511 y=-6.2500x+21.7500	r=-0.085 y=-0.0625x+20.7292	r=0.0307 y=0.0333x+10.5333	r=0.4152 y=0.6252x+1.1252

transparency, total alkalinity, sodium, potassium, iron and oxidisable organic matter content resulted into significantly negative r-values (Table 16-18).

ii) Biotic variables: Total phytoplankton, zooplankton and benthic organisms exhibited positively significant correlations and more particularly Myxophyta, Chlorophyta, Dinophyta, Chrysophyta, Baccallariophyta, Rotifera, Ostracoda, Copepoda, Nematoda, Oligochaeta, Decapoda, Insecta and Gastropoda groups.

IV. Population density (size groups, 50.1 - 70.0 mm) versus

i) Physico-chemical variables: Water temperature and dissolved oxygen have shown significantly positive correlation whereas the water transparency was significantly the negative.

ii) Biotic variables: Although total phytoplankton and zooplankton revealed positive correlation but were not significant while total benthic organism exhibited a significantly positive r-values (Table 16-18). Chlorophyta, Baccillariophyta, Ostracoda, Nematoda and Insecta resulted categorically positive significant r-values (Table 16-18).

V. Population density of ovigerous female versus

i) Physico-chemical variables: Rainfall, water temperature, rate of waterflow, turbidity, dissolved oxygen, specific conductivity, silicate, phosphate-phosphorous, nitrate-nitrogen, magnesium and chloride concentration exhibited significantly positive correlations while water transparency, total alkalinity, sodium, potassium, iron and also oxidisable organic matter content have shown significantly negative r-values (Table 16-18).

ii) Biotic variables: Correlations with total phytoplankton, zooplankton and benthic organisms resulted significantly positive r-values and more categorically with Myxophyta, Chlorophyta, Dinophyta, Chrysophyta, Baccillariophyta, Rotifera, Copepoda, Nematoda, Oligochaeta, Decapoda, Insecta and Gastropoda groups.

5. DISCUSSION

There are a number of environmental properties which in various ways make up the ecological factors of the local macrohabitat. To understand the ecology of fresh water hill stream prawns and the interpretation of data at population level in lotic system is often a complex task because of the multitude of both abiotic and biotic factors which control the population and the extent to which these factors operate differ considerably from one region to another. Shifting (jhum) cultivation which is the predominant form of agricultural practice among the local people involves clear cutting of forest, followed by burning of the slash and cultivation on steep slopes, affects the amount of water passing through to the sub-soil; dissolved substances and particulate matter being extensively lost through run off, and also owing to blow off ash from the burnt site due to strong wind (Toky and Ramakrishnan, 1981 a & b). This creates a direct instability of the abiotic parameters and an indirect transitional state of the aqua-system as a whole and are the part of stresses to which biotic group of this region are usually subjected. The rate of metabolism of invertabrates is influenced by a wide variety of environmental stimuli (Nelson _et al._, 1977). It is the nature of these physiological responses to environmental factors which will determine the biological fitness of individuals of a population and which will ultimately define the distributional limits of the species. The collective environmental limits imposed by these responses determine the fundamental niche of an organism, while the interactions of environmental and biotic factors circumscribe the N-dimensional realized niche as defined by Hutchinson (1958).

The horizontal and longitudinal distribution among the stream animals are closely related as most taxa select a micro habitat by optimizing the complex of local factors determining niche while being restricted to a physically distinct zone either by inability to tolerate extremes of one or a combination of those factors as they change with location. Examination of the physiological responses of individuals to specific environmental regimes allows the delineation of casual relationships underlying the distribution of a species (Fry, 1947).

Temperature and altitude difference are considered by many authors to account for most longitudinal and successional distribution patterns (Ide, 1935; Sprules, 1947; Schmitz, 1954; Macan, 1958, 1961, 1962; Illies, 1961; Minckley, 1963; Kamler, 1967; Minshall and Kuchne, 1969; Hynes, 1970). The general climatic condition of Umshing area do show some uniqueness and being different in many respect from that of Pongtung area. Thus, the vegetational composition is also quite different, former being dominated by the conifer, Pinus kesiya and major portion of allochthonous input into the stream through leaf fall, from the various shrubs and grasses like Eupatorium spp., Carex sp., Cyperus sp., Rotella sp. etc. while later being dominated by the broad leaf, Artocarpus sp., Eugenia sp., Ficus sp. and the leaf fall from the various shrubs and grasses like Quercus sp., Glochidion sp., Saccharum sp., Panicum sp. etc.

(Table 1).

Table 2 shows the various macrophytes including mosses of Umshing and Pongtung streams. A notable feature about these plant communities is that they do not occur everywhere. Their decay provides soil-building material and they trap silt and build up mud banks (Hynes, 1974). These macrophytes might contribute to some extent to the fluctuations of the physico-chemical conditions of the streams (Nasar and Datta Munshi, 1974). The Umshing stream supported comparatively lesser number of macrophytes which needs to be explained. It has been found that pH is generally low resulting in acidic medium with low buffering capacity. Further, the allelopathic effects of the coniferous vegetation on other plants are well known (Berg *et al.*, 1980). At Umshing area, air temperature shows considerable fluctuation through falling within a lower range as comparable to Pongtung area where higher temperature values are noted throughout the year (Figs. 3 & 4). This may be effected by the altitudinal difference of the study areas (Hynes, 1970).

High rainfall and steep gradient in the course of the streams result in periodic spates which also facilitate the filling up of the accessory habitat for the principal breeding prawn populations. The significant positive relationship between breeding group and rainfall is due to a chain of events as Rajayalakshmi (1980a) also reported for *Macrobrachium* malcolmsonii. The steep relief of the upper area might have been expected to promote more rapid run-off than the gentle slopes of the low land area, but this factor appeared to be encountered by the effects of vegetation-cover on the water retention capacity. Many workers (Hoover, 1944; Delfs, 1956; Rutter, 1958; Bullard, 1965; Binns, 1969; Gray and Edington, 1969; Bochkov, 1970; Likens et al., 1970) have discussed the problems of increased run-off from areas where natural cover has been removed. The rainfall in the upper reaches consequently results rise in water level and also increase in dissolved oxygen and dilution of nutrients to an optimum level. This could be attributed to their significant positive relationship with the prawn population. Sometime, due to heavy precipitation, the primary productivity of the lotic system decreases and consequently the system looses the capability of supporting proportionate quantities of secondary producers. This could be attributed to the negative relationship with post-mature group of M. hendersoni cacharensis. As Goswami et al. (1983b)reported in M. hendersoni cacharensis that the juveniles are having higher ecological amplitude in terms of their oxygen requirements; the positive relationship with rainfall (Table 13-18) could be explained in the same way.

In aquatic ecosystems, temperature is generally considered to be the major environmental properties which limit the distribution of invertebrates (George, 1969; Kinne, 1971). Variations in water temperature during and following rain are slight. The cooling effects of intense rain and increased heat loss to wind in suface layer are quickly dissipated by turbulence. Elevation of the mean water temperature of the stream by 0.5 - 1.5°C because of surface run-off occurred on several occasions, when the shower was short and intense and followed a day of sunshine. These increases were transitory as losses to the relatively cooler air soon modified their effect (Bishop, 1973). The major factors affecting stream temperature by the difference between the warming effects of radiation, absorption and the cooling effect of the air (Ricker, 1934) and for tropical stream in particular, the type of substrate (lithological) and degree of exposure to direct sunlight (Geijskes, 1942). This could be attributed to the frequently observed higher water temperature than the air temperature in Pongtung stream.

Each organism has a maximum and a minimum environmental temperature between which life is possible but beyond which conditions are lethal (Lehmkuhl, 1979). Even for individual species, these temperature limits are not absolutely fixed, since they may vary with different individuals, with different sexes, with different life history stages, with different physiological states, and in different parts of the geographical range (Lakshmi *et al.*, 1978; Venkatachari and Ambore, 1979). *Macrobrachium rosenbergii* is found in habitats of about 25°C in Malaya (Johnson, 1967) and from 27 to 34°C in India (John, 1957; Rao, 1967). In the present study, for *M. hendersoni hendersoni*, the water temperature range recorded, is 10 to 19°C while for M. hendersoni cacharensis is 17 to 32°C. M. hendersoni cacharensis revealed a distinct temperature dependent situation (Tables 16-18) but in M. hendersoni hendersoni, for the juvenile group, it did not show to a significant extent. This could be an advance step by this population in order to adapt themselves to a newly invaded ecological set up. Statistically significant correlations of the population density with water temperature also reflects their seasonal abundance (Truesdale and Mermilliod, 1979). Dugan et al. (1975) reported moulting cycle occurred more frequently in Palaemon paucidens at high temperature while even increased photo-period did not affect the intermoult duration. The reproductive cycle in M. australiense was found to be more sensitive to changes in water temperature than to other environmental factors (Lee and Fielder, 1981).

One of the most obvious and familiar properties of water is its transparency. Natural waters manifest great differences in the degree to which sunlight can illuminate them. Many natural water as also noted in the present study, show seasonal and irregular variations, due to several possible causes viz. intensity of illumination at the surface, angle of contact of light with surface, dissolved materials, suspended solids etc. (Welch, 1952). In certain turbid lotic system, the decrease of light by suspended silt is in excess of 90% in the first 25 mm of water depth (Welch, 1952). These also explain the difference in the transparency values in Umshing and Pontung stream. Light exerts a very profound influence upon a whole series of biological phenomenon in water. Most species of *Macrobrachium* are reported to be nocturnal in habits (Patwardan, 1937; Ling, 1969), In the present study, it was also noted for *M. hendersoni hendersoni* and *M. hendersoni cacharensis* and in fact they also exhibited a significant negative correlation with transparency values (Tables 13-18). The prawn population are found to be sensitive to the higher intensities of sunlight and usually avoid them during day hours by seeking shelter under boulders having algal "moss back" or under the shade of aquatic macrophytes. The insignificant role of transparency with juvenile population reflects their incomplete growth stage where pigmentation, hardening of chitinous coverings, gonodal maturations etc. are still in progress as Wickens (1972) while working with *P. serratus* reported that the growth and development of larvae was inhibited by long periods of darkness.

Rate of water flow is dependent on drainage gradient, rain fall conditions, depths and an additional complication is the drag effect of high silt load (Bishop, 1973). The dependence of suspended and bed loads on current velocity has been summarised by Einsele (1960). Douglas (1969) demonstrated that in spite of high precipitation levels in the tropics denudation may proceed more slowly than in areas with great rainfall fluctuation. The main cause for this is the protection given to the soils by plant cover and the stabilizing effect of roots and leaf litter. According to a time-worn statement, the lotic fauna is composed typically of animals whose dissolved oxygen demand is such that it can be fulfilled only by the highly oxygenated waters of the stream (Hynes, 1970). In M. hendersoni cacharensis, the actively breeding populations exhibited significant dependency on the rate of water flow which probably reflects their metabolic state but in M. hendersoni hendersoni in spite of actively breeding population, even the total population also shows dependency. This could be explained as a process of adaptation rather than short term physiological responses to the oscillation in the rate of water flow. In Pongtung stream, the current conditions at large vary from turbulant rapids to those in which the rate of water flow is virtually imperceptible, exhibiting all intergrades from the very swift rushing waters in narrow channels to the situations which are apparently lenthic and this was reflected in terms of their just positive relationship with total density, juvenile and post mature group of M. hendersoni cacharensis (Tables 16-18).

Turbidity is a condition of water resulting from the presence of suspended matters. In common parlance, water is turbid only when its load of suspended matters is conspicuous, but as a matter of fact, all natural water contains suspended materials, and, therefore all are turbid Welch, 1952). Differences in turbidity of Umshing and Pongtung stream could be attributed to the geomorphology of the stream bed and also to the rate of water flow (Welch, 1952; Bishop, 1973). Douglas

(1969) also reported that erosive process which results in turbidity takes place in two forms under tropical forest: sub-surface flow through the weathered soil mantle and surface run-off. The former is more prominant in the stable undisturbed forest on steep slopes and is responsible for much of the dissolved loads derived from the parent lithology and its soil cap. In addition, it carries the finer clay particles down through the interstitial spaces of the larger sand particles. Surface run-off is also a factor in the forest and becomes increasingly more important as ground cover is removed. The chief erosional agents as found in Umshing stream are chemical weathering that causes the break down of most lithologies to sand sized particle with the release of dissolved salts, particularly silica to the ground water and the intense rainfall in short interval loosens and carries large suspended load to the mouth part of the Umiam river. These high sediment loads affect channel capacity in the lower courses and more flooding is indicated. Bishop (1973) reported for Gombak river that the similar typical situation might have both direct and indirect effects on the faunal composition. It is noted in the present study that due to flood, all the depressions around the main stream gets filled with water and with course sand and small gravels a special bottom condition is made suitable for the actively breeding prawn population. Due to turbidity and running condition of water, the juvenile, mature and also the berried prawn population maintain themselves hidden and consequently get rid of predators as well as from the cannibalistic attitude of their post-mature group (Ling, 1969; Wickens, 1972). This is why, probably, the correlation value recorded insignificant and even to the extent of negative with the post-mature prawn population (Tables 13-18).

Many animals, notably many invertebrates can live only in well-aerated water, but it is not the actual amount of dissolved oxygen which matters so much as the percentage saturation (Hynes, 1974). Oxygen is not very soluble in water, and its solubility depends on the temperature (Stephenson and Knight, 1981). In a swift upland stream the movement and turbulence of the water rapidly replenishes any oxygen used and the water remains saturated. According to Welch (1952) the important factors which have to do with the level of dissolved oxygen concentration in lotic system are: character of stream flow, slope of channel, temperature, release by chlorophyll-bearing plants, oxygen consumed in respiration of the biota and oxygen consumed in the decay of organic deposits on the bottom. These factors also could be attributed to the difference in oxygen concentration of Umshing and Pongtung streams. Many workers (Berg, 1952; Eriksen, 1964; Konstantinov, 1971) investigated the relation of the oxygen consumption to the oxygen concentration of the habitat and tried to correlate the results to the natural distribution of the aquatic animals. Goswami _et al_. (1983b) reported that the most optimum dissolved oxygen level for _M. hendersoni_ *cacharensis* from Pongtung stream condition to be 9.5 - 10.0 mg/l. This condition of the water is noted during May-July and also in September for Pongtung stream. However, the higher oxygen values throughout the year, is an added advantage for *M. hendersoni hendersoni* in Umshing stream as they are also highly dependent on dissolved oxygen concentration (Table 13-15). The juvenile of *M. hendersoni cacharensis* can withstand comparatively more fluctuation in the oxygen concentration (Goswami *et al.*, 1983a).

Each organism has its toleration range of pH terminated by a maximum and minimum, and possess an optimum at some intermediate position (Welch, 1952). Knowledge concerning the limiting effects of pH is in a very unsatisfactory state. In a sense that every species has some where its extremes of tolerance of acidity and alkalinity (Prosser and Brown, 1961). The literature contains numerous positive contentions that pH is an important limiting factor for certain organism. The same conception is noted in the present study for both *M. hendersoni hendersoni* and *M. hendersoni cacharensis* (Tables 13-18). In addition to the possible direct action of pH as a factor, it may also serve as an index of certain existing conditions in water. For example, the proper determination of pH may in addition to give a measure of the concentration of the ionised hydrogen, yield indirect information on the free carbon dioxide, alkalinity, dissolved oxygen, organic loads, dissolved solid contents etc. (Welch, 1952). Ling (1963) reported the pH range of 7.0 to 8.0 being most suitable for

M. rosenbergii. Truesdale and Mermilliod (1979) recorded the pH range of 6.20 to 8.40 for the riverine prawn, M. ohione. In the present study for M. hendersoni hendersoni the pH range of 5.7 to 7.3 and for M. hendersoni cacharensis the range being 5.8 to 7.5, is noted in their natural habitat. During the actively breeding season, the pH range for M. hendersoni hendersoni varies in the range of 5.7 to 7.0 and in the case of M. hendersoni cacharensis in the range of 6.20 to 7.05. This reveals their leaning towards the acidic range of pH. Hynes (1974) reported that when water flows from non-calcareous rocks, such as slates, or granite, very little calcium is present in solution; the water is therefore, soft and may be acidic. Acidity occurs particularly where the landscape is peaty because the water is quite unbuffered, the acids added from the peat are not neutralised and in physico-chemical term the pH is lowered. Welch (1952) noted ground water seepages and springs at the base of the foot hills had pH values as low as 5.0 so that partial neutralization of such contribution much occurs further. All these causal aspects could be attributed to the pH differences in Umshing and Pongtung streams.

The free carbon dioxide concentration which exhibits negative correlation with both M. hendersoni hendersoni and M. hendersoni cacharensis population depends on the interaction of the various biotic and abiotic variables of the system. King and Heath (1967) have shown that the leaching of newly fallen litter of deciduous trees has great effects in accelerating litter break down through increased palatability to the nearby soil organisms. They attributed this effect to the removal of polyphenols from the leaves by leaching. Kowal (1969) reported the importance of leaching and fungal inhibition to pine needle decomposition. Ricker (1937) explained that carbon dioxide concentration is also interdependent on lithology and soil type, rate of water flow, temperature, oxygen concentration, type of floral and faunal composition in the waterbody etc.

Specific conductivity data indicated the ionic condition of both the streams. Seasonal differences at each station is caused mainly by variations in the ionic composition of the precipitation and the diluting effects of large volumes of rain (Welch, 1952; Sioli, 1969 and Likens et al., 1970). Slack & Feltz (1968) recorded higher conductivity and drop in pH as a result of increased leachate from fallen leaves. A similar situation is noted at the station A_1 and B_1 which also accounted for higher higher conductivity values than remaining respective stations. Truesdale and Mermilliod (1979) reported the specific conductivity varying in the range of 250.0 to 470.0 µmhos/cm in the natural habitat of the riverine prawn, Macrobrachium ohione. In the present study, for M. hendersoni hendersoni and M. hendersoni cacharensis, the conductivity value noted, are comparatively low varying in the range of 17.0 to 68.2 µmho/cm (Fig. 15). During the breeding season it varies from 48.0 to 65.8 µmho/cm in Umshing stream and 40.6 to 62.0 umho/cm in Pongtung stream and this higher requirement for conductivity in comparison to the rest of the year reflected through their significantly positive correlations with actively breeding populations. At the station A_3, a comparatively low conductivity values (17.0 - 33.2 µmho/cm) during the first annual cycle adversely affected the ovigerous population of M. hendersoni hendersoni (Fig. 36), as also reflected in their 'r' values (Table 13-15).

Weak acids and weak bases have greater buffer action in preventing rapid changes in pH because of the fact that the initial ionization is low. Water containing large amounts of dissolved matters are most likely to show high buffer effects, while low buffer effect is to be expected in waters very low in dissolved materials or rather organic colloids (Kleerekoper, 1955). This could be attributed to the higher alkalinity values at stations A_3 and B_3. Johonson (1967) showed that for many local waters, no direct correlation between alkalinity and calcium content exists based on the fact that the pH buffering system also be dependent on silica concentrations. The data on alkalinity show considerable variable with time probably as a result of dilution during periods of high rain and high flow just prior to the sampling date as also reported by Hynes (1970) and Bishop (1973) for some other lotic system. Total alkalinity values are low compared to many fresh waters, but are similar to those reported from some areas of the Amazon basin (Marlier, 1954) and the Sai Buri River (Kobayashi, 1959). Total alkalinity of the medium has shown highly negative role in terms of prawn population density (Tables 13-18), showing thereby that higher the alkalinity lesser the population. Similarly basic ions present like calcium, sodium, potassium, iron, ammonium, etc. have been shown negative effects and is discussed separately.

Natural waters commonly contain silicon dioxide in some form of soluble silicate and silica may also exist in certain waters in colloidal form (Welch, 1952). The high mobility of silica from igneous rock has been described by Kobayashi (1969) for Japanese river system. The primary products of silicate hydrolysis have different solubilities, the bases being much more soluble. These highly mobile products are, therefore, preferentially lost to the drainage water, leaving the acid hydrolystate. This is also responsible for the partial explanation for the near neutral pH of water in certain months (Bishop, 1973). The differences in the silica concentration in Umshing and Pongtung streams could be attributed to the lithological differences (Wang and Evans, 1969) and run-off (Däuglas, 1969). Hobbs and Hall Jr. (1974) explained the role of silica and siltation in Procambarus acutissimus and established their positive relationship although some earlier workers thought of their detrimental status. Data of the present study reveal that silicate plays a significant positive role for the actively breeding prawn population. Probably, silica plays some important role in their breeding physiology.

The low phosphate-phosphorous values reveals that the most free phosphate was quickly taken up by the expanded root to the macro-vegetation of the bank side (Kemp, 1968) and by the aquatic macrophytes as well as algal crop. In addition, it also reflects the allochthonous input (Andrews and Minshall, 1979). The role of phosphate-phosphorous in limnological study is well documented (Stewart and Rohlich, 1967; Vollenweider, 1968; Shanon and Brezonick, 1972; Golterman, 1975). The amount of phosphate-phosphorous in natural water is small and since phytoplankton requires an adequate supply of phosphate-phosphorous, it is now generally regarded as a limiting factor (Shanon and Brezonick, 1972). The positive correlation of prawn population and phosphate-phosphorous could be an indirect net work of 'prawn population and phytoplankton relationship' or could be the direct buffering machanism by them to maintain a suitable pH range for the actively breeding population. The dissolved nitrogen compounds in water do not originate from bed rock materials under the wet conditions of tropical rain forest (Bishop, 1973); rather they result from biological processes that also determine their formation (Klinge and Ohle, 1964). Usually the nitrogen richness in water is also attributed to animal origin. The phenomenon is emphasized by the fact that dead organic matter decomposes in water to form complex protein that get converted to nitrogenous organic matter and finally into nitrates by bacterial activity (Zafer, 1964). Some of the nitrate and probably most of the ammonia were derived from the rain, presumably from intense electrical activity, but the remainder likely had botanical origin (Bishop, 1973). A considerable development of blue green algae was evident (Table 3) and these are undoubtedly associated with nitrogen fixing bacteria. These florestic elements must continually contribute considerable concentrations of nitrate-nitrogen by 'trickling fertilization' (Klinge and Ohle, 1964) but specially during the periods of heavy rain other possible sources are directly leaching from plants (Nye, 1961) or from fallen leaves in the stream which give up some nitrogen as leachate immediately after entering the water (Hynes and Kaushik, 1969). The significant positive correlation (Tables 13-18) of nitrate-nitrogen with actively breeding prawn population could be explained in the light of their conductivity relationship as free nitrate radicals also known to boast up the conductivity values.

Ammonia is the principal excretory product of Crustacea (Hartenstein, 1970; Hochachka and Somero, 1973; Kinne, 1976) and its modes of toxicity as well as concentrations lethal to variety of organisms have well documented (Warren, 1962; Campbell, 1973). In aquatic habitat, organisms rely on rapid diffusion of NH_3 across the gill membrane (Fromm and Gillete, 1968) or exchange transport of NH_4^+ with Na^+ (Maetz and Garcia-Romeu, 1964; Campbell, 1973; Mangum and Towle, 1977) to avoid themselves of this toxicant. As external NH_3 concentration increases, the rate of diffusion outward from an animal decreases and toxcity ensures when tolerable body loads are exceeded. Consequently, the toxicity of ammonia to aquatic organisms is generally credited to the NH_3 molecule (Ellis, 1937; Wuhrmann and Workers, 1948; Downing and Merkens, 1955; Spotte, 1970; Hampson, 1976), despite the evidence that NH_4^+

adversely affects some physiological functions (Shaw, 1960; Maetz, 1972; Campbell, 1973). This also could be attributed to the negatively shown correlation co-efficient values of all the size groups of both M. hendersoni hendersoni and M. hendersoni cacharensis. The chemistry of ammonia in solution has been discussed by Whitefield (1974) and Colt and Tchobanoglous (1976). The proportion of total ammonia existing as NH_3 is dependent on temperature and ionic strength of the medium but primarily on the pH of the solution (Warren, 1962; Truessell, 1972; Skarheim, 1973; Whitefield, 1974). Calculations by these authors show that the NH_3 increases as pH rises. In the present study, monthly data on ammonia-nitrogen and pH values also reveals similar conception. Armstrong et al.(1978) reported that in M. rosenbergii toxicity of ammonia was not only due solely to the ammonia molecule. In solutions of different pH and equal NH_3 concentrations, survival was greatly reduced as NH_4^+ levels increased and they also concluded that ammonia will not pose a substantial threat in adequately managed system.

The differences in the concentration of calcium and magnesium of Umshing and Pongtung streams could be attributed to their lithological set-up (Gorbet, 1964) and the decomposing leaf leachates may also add to some extent (Thomas, 1970). Under William's (1964) classification (following Ohle, 1934), waters with less than 2.5 mg/l of calcium are considered extremely poor. Johnson (1967) found that most Southern Malaya waters fell into this category and some had calcium concentrations an order of magnitude lower than the minimum 0.10 mg/l.

The rivers studied in Tahiland by Kobayashi (1959) generally had higher calcium concentration (mean 20 mg/l.) and did not support any prawn population. But, in southern most Malaya Peninsular stream, he recorded a mean of 1.9 mg/l and also two species of *Macrobrachium* was found to be abundant. The extreme values of calcium and magnesium concentration at the station A_3 during the first annual cycle can be attributed to the "impact of jhum cultivation" at the bankside (Fig. 6c) and heavy run-off during the rain (Ramakrishnan and Toky, 1981). Sources of calcium for post-molt calcification of the exoskeleton in crustacea include: 1) free-ionic calcium in the water, 2) 2) calcium in food, and 3) stored body calcium available from blood, hepatopancreas and gastroliths (Travis, 1965; Huner *et al.*, 1978). Ryhamen (1962) felt that gastroliths and other body source of calcium served the function of initial hardener for mouth parts to permit, *Astacus astacus* to feed and thereby obtain calcium from its food. Data from the present study reveal that during the breeding season (April-September), calcium concentrations was diluted to an average of 2.15 mg/l and 3.48 mg/l at Umshing and Pongtung stream respectively. Huner *et al.* (1978) reported that the presence of excess dissolved calcium in the surrounding medium did not increase the uptake of calcium in *Procambarus clarkii*. This also could be attributed to the negative r-values noted for both *M. hendersoni hendersoni* and *M. hendersoni cacharensis*. Nduku and Harrison (1976) rightly commented "most life history disturbances result from excess nutrients and ions rather than insufficiencies". Magnesium concentration exhibited mean dilution of 1.13 mg/l and 2.07 mg/l during April-September reflecting thereby the optimum values for the actively breeding population. In berried females, the pleopods showed constant movements and this frequency of movement increases as the time for hatching becomes nearer (Sharma and Tiwari, 1978). The role of magnesium as an essential co-factor in the locomotory physiology of certain animals have been studied (Prosser, 1973), Martin (1976) reported magnesium to be the essential for laying eggs in Cancer irroratus.

The summer peaks of chloride concentration are generally associated with high discharge, high temperature, higher evaporation rate (Hanes et al., 1970; Kunkle, 1972; Smith, 1974) and the winter peak is associated with low rainfall and discharge (Bishop, 1973). Both Umshing and Pongtung streams exhibited lesser chloride concentration as reported by Bishop, 1973 for Gombak river (5-12 mg/l) which also supported four species of Macrobrachium. In the present study, the acid radicals irrespective of the nature of ions have shown positive effects and also to the level of significant in some cases (Table 13-18). The chloride content exhibited positively significant role. The genus Macrobrachium had marine origin (Tiwari, 1955) and are still in the process of adapting themselves to the newly invaded inland conditions and the key role of chloride also appears to support the same. However, sodium ion present in the medium is much higher in proportion to chloride ion. It has been reported that Na^+ is bound as it passes through the soil but Cl^- ions pass freely to the water table (Huchinson, 1970; Van de Voorde et al., 1973). The sodium and potassium concentration in the stream water are related to accumulation of mineralisation product (as reflected from their lithological set up), soil leachates (Bishop, 1973) and run-off (Toky and Ramakrishnan, 1981a, b). It may be worthwhile noting here that Dendrocalamus hamiltonii which comprise a part of the bank side vegetation (Table 1), is a heavy accumulator of potassium (Toky and Ramakrishnan, 1982 a & b).

Toky and Ramakrishnan (1981a) reported that subsequent to slash and burn of the forested fallow and during shifting agriculture (Jhum) in the North-Eastern Hill areas of India, the system loses much of its capacity to hold soil nutrients. Various losses occur through wind blow of ash and also through run-off. The chemistry of the ash and the amounts of run-off and percolation water, are related to the length of the jhum cycle, owing to the type of vegetation that is slashed and burnt. On the bank side of the station A_3, a similar situation was observed and consequently during the first annual cycle (January-December, 1979), the nutrient level (Ca^{++}, Mg^{++}, K^+, Na^+, NO_3^-, PO_4^- etc.) exhibited comparatively their higher values. Both Umshing and Pongtung streams have shown relatively higher sodium and potassium concentration than their probable acid radical concentrations. Probably, they exist in some complex form and perhaps also these ions might have exceeded the optimum concentration limit. This could be attributed to their negative correlations with both M. hendersoni hendersoni and M. hendersoni cacharensis (Tables 15-18). During rainy season, the dilution factor could provide an optimum condition for the prawn population which was reflected by their high population densities (Figs. 34-39).

The fluctuation in iron content reveals primarily the discharge pattern (Bishop, 1973). The immobility of iron in tropical soils has been discussed by Richards (1957), Sioli (1968a) and unless considerable concentrations of electrolytes and humic colloids are present (Shapiro, 1966), these elements tend to remain static as sesqui-oxides in the lotosol soils. Low iron concentrations were detectable throughout the sampling period. In water-logged accumulations of leaf detritus and humus, where decomposition may produce anaerobic conditions, iron is reduced and solubilized (Bishop, 1973). In Umshing stream, where sand bars were constantly being shifted and some pyritic material was available from the local schist formation and accounted for the higher iron concentration than Pongtung stream (Bishop, 1973). During April-October, the iron concentration were diluted to an average of 1.38 mg/l and 0.78 mg/l in Umshing and Pongtung streams respectively and this was reflected in their correlation co-efficients (Tables 13-18). That is, M. hendersoni hendersoni and M. hendersoni cacharensis grow better in the medium of low iron concentration.

High values of oxidisable organic matter noticed during winter and spring presumably due to reduced precipitation and water-logged condition which gets diluted or rather washed off with the commencement of rainy season. Oxidisable organic matter exhibits higher values of biological oxygen demand (Bishop, 1973) and this also could be attributed to their significantly negative role with both M. hendersoni hendersoni and M. hendersoni cacharensis which are also dependent on dissolved oxygen concentration. Seki et al.,(1969) and Hynes (1970) reported that leachates from leaves contribute considerable concentrations of inorganic and organic materials to the water (10-25% of initial dry weight in the first three days). These dissolved fractions are particularly important in the impoverished waters found in tropical streams and there is growing evidence that these nutrients are rapidly incorporated either de novo through physical phenomena or by microbial flocculation actively, into particulate organic components.

The characteristic algae of swift streams are those possessing the so called hold fast cells or other structures which make it possible for them to adhere to various kinds of supports on the bottom and to remain there in the face of strong current (Tiffany, 1938). So far as is known, all natural waters, irrespective of latitude, altitude and physico-chemical characters, are in the vast majority of instances, normal supporters of plankton although they may differ in many respects (Welch, 1952). The records (Table 3) of various epilethic, epiphytic and epipelic alga in the present study is found to be common with those noted for the Gombak river by

Bishop (1973). Table 3 shows the record of ten genera of Myxophyceae, twenty one genera of Chlorophyceae, two genera of Dinophyceae, eight genera of Chrysophyceae, three genera of Rhodophyceae and seventeen genera of Baccillariophyceae. However, it is suspected that few members of phytoplankton could possibly be omitted in our records because of their periodic occurrence. So, these stream systems nevertheless seem to be poor in diversity as compared to other tropical or sub-tropical streams or small rivers (Hynes, 1970). High turbidity hinder light penetration, but at shallow depth, this is not a notable factor (Bishop, 1973) as also reflected from the noted florestic composition of the present study. However, in these reaches, whenever a stable substrate eroded clean of deposited material is found, substantial epilithic and epiphytic growth occurs and during modal periods, a considerable transient epipelic community often develops. Presence of Cynaophytes and diatoms like Nitzschia indicates possible enrichment (Bishop, 1973), although the over-all dominance of Chlorophytes in the algal community is indicative of oligotrophy which agrees with other workers (Patrick, 1957; Cushing, 1964; Hynes, 1970). During spring months brown mat of diatom and green patches of Chlorophytes always developed on all the stream substates. As a whole, filamentous chlorophyceae viz. Oedogonium, Spirogyra, Cladophora, Ulothrix were abundant to some extent in these stream systems compared to their occassional presence in the river Gombak of Malayasia (Bishop, 1973). Steuer (1910) regarded the lotic plankton

(Potamoplankton) as an ecological group of organisms (biocoenose) living and breeding in running water and consisting principally of diatoms like *Melosira*, *Synedra*, *Fragillaria* so on which are also noted in the present study (Table 3). However, **Steur** commented that the lotic plankton is not a special community of organisms adapted exclusively for life in running water.

The significant positive correlations of *M. hendersoni hendersoni* and *M. hendersoni cacharensis* with total phytoplankton could probably reveals this key role in proper maintainance of the optimum conditions for the prawn population as Welch (1952) rightly commented that certain phytoplankton can also modify a given ecological condition. Fritsch (1929) and Minckley (1963) reported that the growth of genus *Phormidium* was associated with high calcium concentration of the aquamedium. The density dependent relationship of *M. hendersoni hendersoni* with particular reference to post breeding group versus total phytoplankton highlights their 'food habit' rather than regulation by the "river continuum concept" after Vannote *et al.* (1980). Dense algal growths on the exoskeleton were observed mostly among the male populatio of both *M. hendersoni hendersoni* and *M. hendersoni cacharensi* collected from their natural habitat. No females with epibio were observed either at this time (July-October, 1980) or later. Prawns displaying this "moss back" condition were sluggish, poor in health and occassionally "blind" (Goswami *et al.*, 1982, 1983c).

Identification of the algal covering showed that it was primarily consisted of chlorophytes (*Oedogonium* sp., *Spirogyra* sp., *Ulothrix* sp.) with cyanophyte (*Nostoc* sp. and *Lyngbya* sp.), the secondary dominant. In *M. hendersoni cacharensis*, this infection was rather severe among the post mature group and probably, this was reflected in their r-values. It was also observed that, this algal association which leads to functional "blindness" resulted in death due to bird predation as on occassion heavily infested prawns could be seen in the boarder areas of the stream even during day light hours.

It was seen that generally an oligotrophic assemblage of plankton was prevalent in the system. However, presence of *Scendesmus* was also indicative of 'eutropic' state (Thapa, 1981). The replacement of *Scendesmus* during winter is attributed to the fact that the seston is capable of releasing more nutrients for the faster intrinsic growth rate of this group. *Lemanea* sp. and *Batrachospermum* sp. also occur during the spring. Welch (1952) also reported these species from a turbulent rapid hill stream but presence of these Rhodophytes does not have positive bearings to the prawn population. Most of the Dinophyta and Chrysophyta noted in the present study comply with the findings of Gupta (1980) from certain hill stream of Meghalaya and the dependency of the prawn population (Table 13-18) to the later group could probably highlights their food relation.

The intrinsic growth of Baccillariophyceae which also possesses a seasonal trend of fluctuation is similar to Scendesmaceae. It is therefore, possible that the presence or absence of particular species of phytoplankton in a habitat could be attributed to the nutrient budget of the system (Margalef, 1958 & 1968). The increase in amplitude of the turn over rates during the seasons could be explained by the altered diversity of phytoplankton population and by decrease of total biomass (Javarnicky and Komarkava, 1973). The aspect of 'productive system' could possibly be extended to the present streams as it is very well documented that green algae and diatoms are more efficient producers than blue green algae and dinoflagellates (Findenegy, 1965 and Pyrina, 1966). Lellak (1965) rightly stated that absence of these producer group may create a vacuum in the food-web link which will reduce the population size of the consumer group including the benthic fauna. This type of dependency is also clear in the present study (Table 13-18) for both _M. hendersoni hendersoni_ and _M. hendersoni cacharensis_. The critical environmental factors precipitating species-specific period of maximum growth and reduction are important to a total understanding of phytoplankton succession (Dozier and Beuchamp, 1978). It is therefore, felt that the field rhythms as observed in the present study could probably be a compromise between forced oscillations in the environment and an inherent rhythmicity in the potential of the organism (Enright, 1970).

Data of the correlation co-efficient value reveal the dependency of both M. hendersoni hendersoni and M. hendersoni cacharensis on total zooplankton population. This could be assigned to their food relationship (Ling, 1969; Nelson et al., 1977. Zooplankton are also well known as reservoir of various essential vitamins (Copping, 1934; Wald, 1941; Waterman, 1960). In the present study, eleven genera of portozoa, nine genera of Rotifera, single genus of Ostracoda and Copepoda, and six genera of Cladocera are recorded (Table 4). William and Hynes (1976) also recorded a large number of Ostracoda, Copepoda, Cladocera and Rotifera from two temporary Canadian stream. Bishop (1973) also reported a good number of zooplankton from a Malayan river and surprisingly most of them were found to be in common with the present findings.

The negatively shown correlationsof both M. hendersoni hendersoni and M. hendersoni cacharensis with Protozoa group is not glearly understood. The winter blooms of Protozoa as noted in the present study are also known for other Indian impoundments (Michael, 1968). However, the density and the period of occurrence of individual protozoan species was reported to vary during different seasons (Wesenburg-Lund, 1939; Welch, 1952; Davis, 1955). Pennak (1953) suggested the optimum temperature range for the growth of protozoan to be 16° to 25°C and in present study. Probably this explains the occurrence of protozoan throughout the year. Further, the amount of available food has been regarded as another factor controlling seasonal blooms in Protozoa (Bamforth, 1958; Michael, 1968) although no direct evidence is available from this study. The Rotifera recorded maxima during spring in Umshing stream. Such a pattern was also observed earlier from other Indian situation (Das and Srivastava, 1956; Vasisht and Dhir, 1970; Tandon and Singh, 1972; Vasisht and Sharma, 1975; Sharma, 1978). The summer maxima of rotifera group in Pongtung stream is comparable to the findings of George (1961, 1968). M, hendersoni cacharensis was more dependent on rotifera than M. hendersoni hendersoni. The cleanliness of water is known to depend directly on the quantity of Rotifera (Thapa, 1981). Rotifera are also known to feed largely by sedimenting seston particles into their mouth orifice by means of the pulsating action of their corneal cilia (Hutchinson, 1967). Moreover, the reproductive rate of rotifera is related strongly to the quality and abundance of food as well as temperature (Edmondson, 1946, 1965). However, the dependency shown by the ovigerous prawn population (Table 13-18) on the rotifers is not clearly understood. Ostracoda and Copepoda, though represented by single genus (Table 4) have shown considerable impact on the prawn population (Tables 13-18). The peak exhibited by the copepod and ostracod population may be indicative of their active period of reproduction as was suggested by Michael (1968), Mathew (1972) and Sharma (1978). Further, the comparatively higher temperature during April till October (Fig. 8) is thought to be the another factor favouring their reproductive activities as temperature has already been shown to have a direct relationship with copepod populations (Sharma, 1978). Cladocera exhibited a positive correlation with the prawn population (Tables 13-18) and particularly the prawn, M. hendersoni hendersoni have shown their significant dependency on the cladoceran population. Many cladoceran species are known to serve as food for the cultivable prawn varieties (Ling, 1969; Smith et al., 1977). Documentation of an increase in metabolic rate following ingestion has been made for a few aquatic invertebrates (Nelson et al., 1977). Cladoceran are also well known as reservior for certain specific vitamins (Fluckiger and Fluck, 1950) and their precursor was found to be the detritus (Fox, 1937; Fox et al., 1944).

The bethic invertebrate community of undertaken lotic ecosystem is, with some specific exceptions, a remarkably conservative assemblage of types that recur in a similar biotopes regardless of geographical location. Similar environmental niches (physical/chemical/biotic) harbour analogous taxa, often of the same familial or generic group, wherever such habitat are found (Botosaneanu, 1960; Illies, 1961; Hynes, 1970). Structurally, the community parallels that found in more temperate streams with the notable difference that species diversity in many groups is greater and the population of any particular species comparatively smaller. Asynchronous and non-seasonal life cycles combine to keep population densities low and this, with the variety of relatively constant, but not necessarily stable, micro-habitats available, permits multiple congeneric combinations or groups of unrelated invertebrates apparently exploiting the same feeding niches to occur. Under these conditions of reduced density-dependent interaction, some species are able to exist in a biotope and even successfully complete their life cycles under marginally suitable conditions. Both M. hendersoni hendersoni and M. hendersoni cacharensis exhibited significantly positive correlation with the total benthic organisms. The significantly negative r-values (Table 13-15) exhibited by the juvenile of M. hendersoni hendersoni could be attributed to the predation pressure (Ling, 1969; Smith et al., 1977). Bishop (1973) also rightly commented for lotic ecosystem that under seasonal conditions, with temporal fluctuations in resources and demographic pressures, weaker groups would easily be eliminated if they cannot expand their niche easily. In the present study, the bethic organism recorded include eleven genera of namatodes, ten genera of oligochaetes, three genera of decapods, forty three identified and three unidentified genera of Insects, four genera of gastropodes and ten genera of miscellaneous groups (Table 5). It was observed that most of the recorded benthic organisms in the present study were in common as noted by Bishop (1973) for Gombak river. In the present study, it is also possible that certain genera might have remained uncollected due to their periodic occurrence which did not coincide with our field collection hour.

Both *M. hendersoni hendersoni* and *M. hendersoni cacharensis* have been noted to be dependent on nematode group (Table 13-18). The exact reason for their dependency other than 'food relation' (Subramanyam, 1963; Kuttyamma, 1974) is not clear from the present study. The diplogasterid type of nematodes appeared to be restricted to the bottom substrates. Horizontal and longitudinal distribution of stream benthic animals are closely related as most taxa select a micro-habitat by optimising the complex of local factors determining niche while being restricted to a physically distinct zone either by inability to tolerate extremes of one or a combination of those factors as they change with location (Bishop, 1973). If transients are disregarded, the community found at location has reached a compromise with the habitat conditions and in most cases it can be assumed that if a species is not present, it has failed to find a satisfactory niche. This situation is represented by their rare occurrence (Table 5). Data on the r-values (Tables 13-18) reveal that both *M. hendersoni hendersoni* and *M. hendersoni cacharensis* exhibited positive relationship with Oligochaetes, this probably reflects their food relationship (Dall, 1968), but the significant relationship of the actively breeding population further explains their choice in terms of their food preference. Kennedy (1966) has shown that *Limnodrilus hoffmeisteri* cannot reproduce asexually as in some Tubificidae (Brinkhurst, 1964) but that sexual stages are normally present continuously in a population, particularly at temperature exceeding 15°C. Most oligochates are indiscriminate particulate feeders utilizing different components of the organic susbstate either directly or through a symbiotic microflora or fauna (Brinkhurst and Kennedy, 1965). Population density difference between erosional and depositional substrates were never pronounced even in the upper stream. So the physical nature and porosity of the sediments were apparently subsidiary to food availability and other biotic factors in determining occurrence (Bishop, 1973).

In the present study, *Macrobrachium hendersoni hendersoni* and *M. hendersoni cacharensis* exhibited positive correlation with the decapods. One reason for this could be that under this decapod group even the count of *M. hendersoni hendersoni* and *M. hendersoni cacharensis* are included. Mizuno and Mori (1970) reported the riverine *M. malayanus* and *M. pilimanus* from the bank side root niches, between and beneath boulders and where current flow was stabilized, on open depositional gravels and sands. The crabs, *Paratelphusa* spp. were found only in the upper forested reaches more frequently and also collected in torrential sections hidding in rock holes beneath stable boulders. Surprisingly, they were very often also noted to be associated with prawn population but the exact causal aspect is not clear from the present study. Karunakaran (1969) also reported certain crab species associated with *M. geron* from a similar stream from Singapore Island. Diets of the African potamonids have been fully described (William *et al.*, 1961; William, 1962, 1965) and may be summarized as primarily herbivorous but incorporating upto 30% invertebrate foods. It is possible that the remaining unused food particles after the crabs' fed are utilized by the associated prawn population.

The significantly positive correlation (Table 13-18) exhibited by both M. hendersoni hendersoni and M. hendersoni cacharensis with Insect groups needs detailed explanation. Collembola were a minor element of the benthos at all stations that probably feeding on detritus or its microflora. The main habitat of the Ephemeropteran members was on both erosional and depositional substrates although nymphs also occurred on stones in the current from where they able to filter the flow for detritus with their hair-fringed femora and tibiae (Jones, 1950). The limiting factor was probably substrate instability as the food supply did not change appreciably. However, the increase in suspended inorganic material that might hinder feeding, altitude and shade (i.e. temperature) may be important too (Bishop, 1973). The actively swimming nymphs of Baetis spp. were facultatively herbivorous grazing on periphyton and collecting detritus primarily from clean stones in currents (Jones, 1950; Hynes, 1961; Chapman and Demory, 1963; Costa and Fernando, 1967). At all stations, they were a major component of the insect fauna. Small baetids were commonly found in the interstitial spaces of the gravels, presumably feeding on the microflora growing there as described by Brown (1961) and Minkley (1963) and prawns were also noted to be associated with them. Gut content analysis (given detail in Part 2 of the thesis) of *Macrobrachium hendersoni hendersoni* and *M. hendersoni cacharensis* reveal that insects comprise of a good fraction of the ingested food items. This could be attributed to their significantly positive r-values (Tables 13-18). The larval biotopes of the Odonates collected revealed its benthic habits. The rare assemblage of Gomphids were burrowers, found in sand-gravel substrates, usually in depositional areas, but often extending into regions classified as riffles which, at the micro-habitat level where direct current effects are not a factor but substrate cover appeared to be the principal factors, determining the nymphal distribution. Food supply would appear not to be an important factor as the ephemeropteran prey species preferred by most Odonates (Bishop, 1973) were readily available at all localities, as well as accessary tripchopteran and plecopteran larvae and nymphs for the 'Clingers' and 'hinders' and Chironomidae and/or oligochaetes for the 'burrowers' also noted to be present in the system (Table 5).

The females of both *M. hendersoni hendersoni* and *M. hendersoni cacharensis* are reported to carry eggs of *Ramphocorixa* sp. and *Micronecta* sp. (Goswami *et al.*, 1982, 1983c). These eggs supported on pedicels were usually located on the posterior portions of the Cephalothorax although some were also deposited laterally on the first two abdominal segments. The deposition of these aquatic insect eggs appears to have been random with respect to stage in the reproductive cycle and size of prawns (Goswami *et al.*, 1982, 1983c). No detrimental effects associated with the infestation were noted. Forbes (1876) first noted a relationship of *Ramphocorixa acuminata* with cray fish. Abbott (1912) provided a full description of the egg deposition by this species on the cray fish, *Cambarus immunis* in Kanas. Hungerford (1919) believed eggs were deposited on those areas of the cray fish most likely to receive aeration by water currents from the gills. This peculiar relationship between the water boatman, *Ramphocorixa* and the cray fish is believed to be one of the adaptations (Klotts, 1966). However, two small adult male prawns (mean size 2.8 cm) of ten accidentally stocked into the brood stock aquarium (Goswami et al., 1982, 1983c) did harbour eggs of *Ramphocorixa* sp. The occurrence of *Ramphocorixa* and *Micronecta* eggs on prawns does not appear to be a physiological problem. Infested prawns were in good health and responded normally to stimuli. Under stream condition, it is suspected that once the eggs hatch, the new insects may serve as a source of supplemented food for the prawns.

Among the benthic community of both Umshing and Pongtung streams notably in the insect orders Ephemeroptera, Plecoptera and Diptera, a number of potentially competitive taxa co-exist. If the generally accepted premise, that co-existing species are separated ecologically (De Bach, 1966) holds for lotic communities (Ide, 1936; Botosaneanu, 1960; Illies, 1961;

Macan, 1962; Ulfstrand, 1968; Grant and Mackay, 1969) thereby the segregating machanisms operate. Brinkhurst (1969) reported that co-habiting oligochaetes of different genera had specific baterial flora and hence selective enzymes in their gut that enabled exploitation of different parts of the available organic food. Further, in an elegant series of experiments on three sympatric tubicids, Brinkhurst and Chua (1969) showed that there was no difference in food ingested, but that expleited bacterial species were different for each worm species and that one of the worms could even assimilate amino acids directly from the mud. It is possible that by ingestion of Oligochaetes, prawns also maintain bacterial flora in their digestive gut which provides a symbiotic relationship in the digestion of detritus, cellulose etc. Yasuda and Kitoa (1979) reported three bacterial flora i.e. Vibrio spp., Pseudomonas spp. and Acromonas sp. in the digestive tract of prawns, Penaeus japonicus. Complementary feeding niches may be common in benthic organisms but determination of these for the herbivorous (particularly detritivorous) and euryphagous forms pose considerable difficulties and has not yet been tackled sufficiently. For carnivores, size-selective predation at both intra specific and related species levels has been demonstrated by Sheldon (1969) and Dodson (1970). Segregation of similar taxa at either inter or intra-generic levels to maximize the exploitation of seasonally available food resources was unnecessary as both algal and detrital food were in continuous supply.

In the context of the Umshing and Pongtung fauna, much of the discussion may be academic, as to a degree, these mechanisms are all density dependent. But population of benthic fauna (Ephemeroptera, Palaemonidae, Plecoptera, Hemiptera and Trichoptera perhaps excepted) probably rarely attain stability for long enough to build densities upto a level where contact interactions become common. Many species are facultatively polyphagous and occur throughout the year in all instars so that there may be ecological overlap, but insufficient pressure from demand for limiting micro-habitats, restricted to food supply or temporal conditions to necessitate either homo- or heterogeneric segregation in the aquatic stages. Similar, was the case with the prawn population also. If environmental resources are not limiting, as it likely, the need for adult temporal segregation which is probably an adaptation to ensure maximum exploitation of biotic resources over the extended long term immature stage, is no longer present. This explanation was also found to be true for both _M. hendersoni hendersoni_ and _M. hendersoni cacharensis_. Dittmar (1955) and Ulfstrand (1968) have commented that in disturbed biotopes where communities are not in steady state considerable interspecific ecological overlap may be expected.

The gastropod fauna of the upper water shed was extremely poor, probably limited by availability of suitable calcium, stable substrates and food (Bishop, 1973). After only slight physico-chemical modification of the biotope in the lower course, both diversity and population density increased considerably. Occassional individuals were collected from diatom-covered rocks in the current and from trailing vegetation but never more than two specimens were collected at any site in spite of diligent searching. The prefered food was attached algae. The significantly positive correlation exhibited by M. hendersoni cacharensis with the gastropods was not clear but possibly due to calcium requirement of the prawns (Subramanyam, 1963). The miscellaneous group exhibited either negative correlations or insignificantly positive correlation (Tables 13-18) in some cases with both M. hendersoni hendersoni and M. hendersoni cacharensis. This may be due to their periodic occurrence which possibly overlap the ecological niche of the prawn population or probably sometimes contribute themselves as supplementary food to the prawn population. Turberllaria are normally carnivorous (Dittmar, 1955; Hynes, 1961; Macan, 1962) and the probable diet was small may fly nymphs, oligochaetes or chironomid larvae. The glossiphonids preyed on gastropods and other invertebrates (Harding and Moore, 1927). In Pongtung stream, egg cases and young were sometimes collected attached to the stones, but the rare Herbdelloidea sp. was obtained exclusively in bank areas. This species was also recorded by Harding and Moore (1927) as a predator of crustaceans. Two genera of mites for terrestrial litter and forest canopy group (Bishop, 1973) occurred sometimes quite regularly at station A_3. This could be attributed to the run-off and jhum cycle of the bankside (Vatsauliya, 1982). However, their exact role in the prawn ecology is not very clear.

The riffle community of the upper zone of Umshing stream may tentatively be considered as a climax in that, as it is composed of numerous relatively small population. Out of the forest zone, this community, with a decrease in species and large increases in the number of few taxa, becomes increasingly disclimatic as a result of the abiotic factors discussed. This introduces the analogous situation, discussed by Minckley (1963) and he found in many rivers in which a stable or mature community with specific adaptation and stenopic forms is present in the young eroding part of a water course, while a faunal disclimax of eurytopic forms is present in the mature base levelled reaches. Populations of immatures extent during stable periods when both detritic and algal food are available undoubtedly develop at a more rapid pace than those hatched out into or subjected to denuded or impoverished substrates following a period of spates. The Pongtung stream is analogous to the situation in temperate rivers where diet preferences and optimal growth periods are adjusted to the seasonal availability of food; algal grazers develop most rapidly in phototrophic periods of summer and detrivores in winter and early spring when leaf-fall materials are most abundant (Hynes, 1961; Ulfstrand, 1968). Here where light and leaf fall are not seasonal, both categories of food vary in abundance together, in response to discharge conditions. For predators like prawns, regulation of growth rate might also be influenced indirectly by the availability of prey animals; however, as most aquatic females have larger reproductive periods, the short-term effects on population density might not be important (Bishop, 1973). In these contexts, some comparable environmental parameters as discussed already could be of more significance.

No detailed study of food niches was undertaken partly because of lack of time but also because specific investigations of that nature was of little relevance as the nomenclature of the organisms could not be organised at our convenience. In addition, as the research of a number of workers on various orders (e.g. Levanidov, 1949; Brown, 1960, 1961; Brinkhurst and Chua, 1969) have shown, food ingested may not necessarily be utilized, so that without data on digestive efficiencies enumeration of gut contents as done in many studies may be a fallacious exercise (Mecan and Cummins, 1964). In the present study, considering the prawn ecosystem aspect, three categories of food were immediately evident: 1) autochthonous periphytic algae particularly the epilithos of the riffles;
2) allochthonous particulate matter originating as terrestrial detritus and the dependent population of micro-consumers and degraders that may be more important than the leaf products themselves; this food resources was ubiquitously available from the seston, in substrate intertices or in accumulations in areas of reduced current; 3) animal foods whose distribution was secondarily controlled by the occurrence of 1) and 2). Gunter (1937) reported that the prawns Macrobrachium ohione are voracious and attack catfish confined to live-boxes. Hay (1882) commented on the importance of river shrimps in lotic food

chains. Speaking of river shrimp in the Mississipi River near Vicksburg, Mississipi, Hay (1882) stated: "Considering their size and abounding numbers, river shrimp must constitute an important part of the food of the fishes of these waters". Concurrent but priliminary studies of fish food-habits in the Atchafalaya Basin (Bryan *et al.*, 1975) revealed that *M. ohione* was an important food item of flathead cat fish, *Pylodictis olivaris*, the white bass, *Morone chrysops* and the southern flounder, *Paralichthys lethostigma*. Goswami and Majhi (1981) reported also the importance of *Macrobrachium* spp. in the feeding ecology of *Danio dangila* in Pongtung stream, Meghalaya. Roy (1979) stated the position of *Macrobrachium* spp. in the food chain of *Rana lissorhynchus* which also supported the view of Hay (1882). From the data on the distribution of the vertebrate fauna in the present study and considering the foregoing discussion, it is possible that both *M. hendersoni hendersoni* and *M. hendersoni cacharensis* play a key role in their respective lotic ecosystem.

Ruello *et al.*, (1973) reported that a male *M. australiense* of 7 cm. in length, constructed a 10 cm diameter and 3 cm deep saucer-shaped depression in an aquarium. They further described active use of the 'breeding nest' in courtship and mating in this species. Similar shaped but larger depressions have been observed in indoor aquaria containing bottom gravel particles (size 1-6 mm) and the housing large, *M. rosenbergii* culture pond in Florida (R. Wulff, personal communication). Willis and Berrigan (1976) noted that prawns utilized cray fish burrows in the banks and that males constructed their breeding depressions in a Florida pond and the sexually mature females have been observed in and around active breeding depressions. Similarly, mating behaviour has been observed (Sandifer and Smith, 1978) in an artificially managed tank.

Information on the occurrence, characteristics and importance of accessory habitat reported here, is first of this kind from hill stream condition and unique in many ways. The major difference is that, although the accessory habitat serve the purpose of breeding these are comparatively stable structures provided in the nature itself with the process of denudation by the running water and active weathering. So, this provides an added advantage to the prawn population. The large male prawns were often observed surrounded by as many as sixteen sexually ripe females. It is believed that the male will mate with some if not all the females after each complete her premating moult (Smith and Sandifer, 1979). Water quality data reveal their optimum ranges during the breeding season and in fact they deviated to a considerable extent from the main stream conditions.

Data from Tables 11 and 12 reveal that there are seasonal fluctuations in the 'K' values (condition factor) of both M. hendersoni hendersoni and M. hendersoni cacharensis and it was also expressed among the different size groups. The variations in the condition factor may be attributed to different factors, such as food availability, gonadal maturity and abiotic factors of the system, as has also been suggested for fishes by many workers (Le Cren, 1951; Jhingran, 1972; Bashirullah, 1975). According to them, knowledge about the changes in the 'K' values with the increase in length may yield evidences reflecting the size at different maturity, while the seasonal fluctuations may reflect the spawning cycle as the 'K' is influenced by its gonadal condition (Biswas, 1982). However, in the present study, it has been seen that the smaller size groups of both _M. hendersoni hendersoni_ and _M. hendersoni cacharensis_ have higher condition values indicating juveniles have better "condition". The result further suggests that the increase in the weight of the body due to the weight of maturing gonads followed by a decrease due to spawning, is also reflected in the 'K' values of the prawn populations. Weatherly (1972) stated that even among the members of one population sampled on a single date, there may be considerable variation in the 'K' values which is further supported by the results obtained in the present study. According to him, animal population displays considerable changes in average condition, reflecting normal seasonal fluctuations in their metabolic balance and in the maturation pattern and subsequent release of reproductive products. Analyses of the 'K' values also reveal that male prawns are having better 'condition' than the female. In other way, females exhibit narrow ecological amplitude than the males in both _M. hendersoni hendersoni_ and _M. hendersoni_ *cacharensis* which was also reflected in the co-efficient correlation (r) values as the ovigerous females showed dependency to a larger number of ecological parameters.

Part - 2

BIOLOGY

1. INTRODUCTION

Macrobrachium hendersoni hendersoni (de Man) and *Macrobrachium hendersoni cacharensis* (Tiwari) are the two commonly available palaemonid prawns in the lotic (or Semilotic) water bodies of Khasi Hills, Meghalaya (Pillai and Biswas, 1979). They can be an economically important fishery potentials (Goswami et al., 1983 a,b) but remained thoroughly unexplored till date and even the basic biology, has not been worked out.

The taxonomy of the freshwater prawns belonging to the genus, *Macrobrachium* Bate, is mainly based on the form, armature and proportions of different segments of the second chelipeds, in addition to the rostrum. The specific characters shown by the second legs are often developed only in full grown males. Lack of sufficient data on the problem of age and sex variation has resulted in some confusion, which can partly be solved by morphometric analysis of measurable parameters at different stages of growth (Koshy, 1979). The problem of relative growth in shrimps have received the attention of biologists since long time (Huxley, 1932; Thompson, 1942; Mishra, 1958; Johnson, 1960; Koshy, 1969, 1973; Nagamine and Knight, 1980; Morizur *et al.*, 1981; Rodrigues, 1981; Curzon *et al.*, 1982; Lee and Fielder, 1982). But, a detailed study of the male and female sexually dimorphic structure of prawns from the lotic water bodies is still lacking.

During the breeding period, the integument of the female undergoes important modifications characterized by the presence of extra setae for the purpose of egg bearing (Antheunnisse *et* al., 1968; Nagamine and Knight, 1980). This special breeding dress comes into being at the moult preceding copulation and ovulation, and is lost at the moult after hatching.

Such a breeding dress is found among the members of Palaemonidae and throughout the Caridea (Yonge, 1955). In this connection, Sollaud (1923) distinguished between permanent and periodic secondary sexual characters; the former persisting after sexual maturity, the later appearing only during the berried intermoult period. Among the permanent secondary sexual characters included in the females, are 1) the enlargement of the epimera of the three anterior abdominal segments 2) the enlargement of the external parts of the same segments 3) the lengthening of the three anterior pairs of pleopods by the addition of a para coxa and 4) the development of a flange on the basipodite of the three anterior pleopods. Only the special setae of the breeding intermoult, were termed periodical. Surprisingly, these important changes during the breeding period of the Natantia remained unobserved for a long period. Ehrenbaum (1890) working on Crangon, mentioned the appearance of certain setae exclusively during the berried intermoult period and Mortensen (1897) reported a single breeding character of Palaemon adspersus Rathke i.e., the long plumose setae on the endopodites of the first pleopods. Nothing more was published on this phenomenon until the simultaneous papers of Gurney (1923) and Sollaud (1923), later by Hoglund (1943) and recently, by Antheunisse et al. (1968) and Nagamine and Knight (1980).

As recently pointed out by Kaur (1981) that for proper fishery management, a thorough knowledge of maturation cycle and depletion of gonads is of utmost importance as it is essential to understand and predict the annual changes that the population undergoes. From these studies a variety of inferences could be drawn, such as the rate of regeneration of stocks and determination of ecological factors which led to synchronization of breeding activity. Similarly, information on such related aspects as fecundity, size at first maturity etc. are also pertinent and all these aspects should be taken into consideration for successful aquaculture programme. According to Corbin (1948) and Simpson (1951), the number of eggs produced by an animal must be known, if survival is to be estimated and the data pertaining to fecundity are also useful in determining the density dependent factor affecting population size. The control of the reproductive cycle of an animal of commercial interest is an important prerequisite for programming its culture (Lumare, 1979). This is also true for the penaeid shrimps where artificial induction of spawning has been successfully tried by controlling certain environmental parameters (Laubier-Bonichon and Laubier, 1976; Beard et al., 1977; Laubier-Bonichon, 1978) as well as by applying special treatments to the females. Such treatments could be control of photoperiod (Lee and Fielder, 1982), thermal stimulation (Shigueno, 1975; Lumare, 1976; San Feliu et al., 1976) and eye stalk ablation (Idyll, 1971; Alikunhi et al., 1975; Arnstein and Beard, 1975; Lumare, 1979). The length-weight relationship in a few species of Macrobrachium has been studied (Katre, 1976; Rajyalakshmi, 1980). Koshy and Tiwari (1975) studied the relation between clutch size and female size in M. dayanum and M. lamarrei. Kamita (1961) stated that the number of eggs carried by a female is closely related to the size of the mother shrimp. Nishino (1980) reported that egg size of Palaemon paucidens is almost constant regardless of their body sizes within a population but differs among the populations having geographical differences in them. Brood size increases with body size, however, relative brood size is almost similar within a population; Relative brood weight is almost similar in a population and mean relative brood size is almost inversely proportional to mean eggs size. But, to understand all these aspects under hill stream conditions, the detailed study on M. hendersoni hendersoni and M. hendersoni cacharensis becomes imperative.

More than thirty four species of the Palaemonid prawns of the genus Macrobrachium Bate, 1868, have been reported from the inland and estaurine waters of India (Tiwari, 1955) and out of these only in five species, the larval development has been studied in detail viz. M. lamarrei (H. Milne Edwards, 1837) by Rajyalakshmi (1961) and Sharma and Tiwari (1978); M. malcolmsonii (H. Milne Edwards, 1837) by Kewalramani et al. (1971); M. idella (Hilgendorf, 1898) by Pillai and Mohamed (1973); M. hendersodayanum (Tiwari, 1952) by Jalihal and Sankolli (1975); M. kistnensis by Nagabhushanam and Kulkarni

(1979). In addition, Das (1935) reported on the larval stages of M. lamarrei. There were also some records on the larval stages of M. rosenbergii (de Man, 1879) and M. rude (Heller, 1862) by Menon (1938) and of embryonic development in M. idae by Nataraj (1947) and Aier (1949).

One important aspect of the biology of any species which is relevant to the success of any aquaculture operation is a knowledge of its food and feeding habits. The nature and amount of food the organism takes in, the time of feeding, the effect of various environmental factors on its feeding behaviour and the relationship between feeding activity and the onset of gonadal maturation are some of the information needed to achieve optimum utilization of food given to the organism being cultured (Marte, 1982). Prawns have been described by many authors as omnivorous scavengers which feed on a variety of benthic organisms including large quantities of organic detritus, silt, and sand (Patwardhan, 1937; Chopra, 1939; Gopalkrishnan, 1952; Panikkar, 1952; William, 1955, 1958; Eldred et al., 1961; Hall, 1962; Subramanyam, 1963; Dall, 1967, 1968; Warren and Sheldon, 1967; Hughes, 1968; George, 1972; Rodriquez and Naylor, 1972; Thomas, 1972; Kuttyamma, 1974; New, 1976; Tiews et al., 1976; Primavera et al., 1979; Truesdale and Mermilliod, 1979; Marte, 1980, 1982; Rajyalakshmi, 1980b). But, none of these studies include the reports on the prawns collected from hill stream condition.

The anatomy of the crustacean alimentary canal has been widely studied (Biedermann, 1911; Jordan, 1913; Yonge, 1924; Balss, 1926; Haslar, 1935; Von Buddenbrook, 1956). Among the best recent descriptions with clear illustrations are those of Patwardan (1935) and Reddy (1935), who have studied many forms and therefore have been able to consider the evolution of the gastric mill. In Malacostraca the digestive juice is produced almost entirely by the cells of the hepatopancreas and transported from there to the stomach. In lower forms its production presumably takes place in both the hepatopancreas and the midgut although experimental evidence is lacking on this point.

The neuroendocrine control of osmoregulation is demonstrated in a very few crustaceans (Kamemoto, 1976). Several earlier workers studied mainly the neuroendocrine control of water and total osmo-concentrations. But chloride ion regulation is an index of osmoregulatory abilities of the animal (Prosser, 1973) and hence the neuroendocrine control of chloride concentration is a better approach to understand the mechanism of osmoregulation.

Keeping in view the above facts, the presently undertaken study on the biology of two palemonid hill stream prawns Macrobrachium hendersoni hendersoni (de Man) and Macrobrachium hendersoni cacharensis (Tiwari), include reports on the male and female sexually dimorphic structures; maturation and spawning; brood size and reproductive efforts; larval development; food and feeding habits; certain aspects of digestive physiology and neuroendocrine regulation of blood chloride.

Fig. 42: Photographs of the two palaemonid prawns

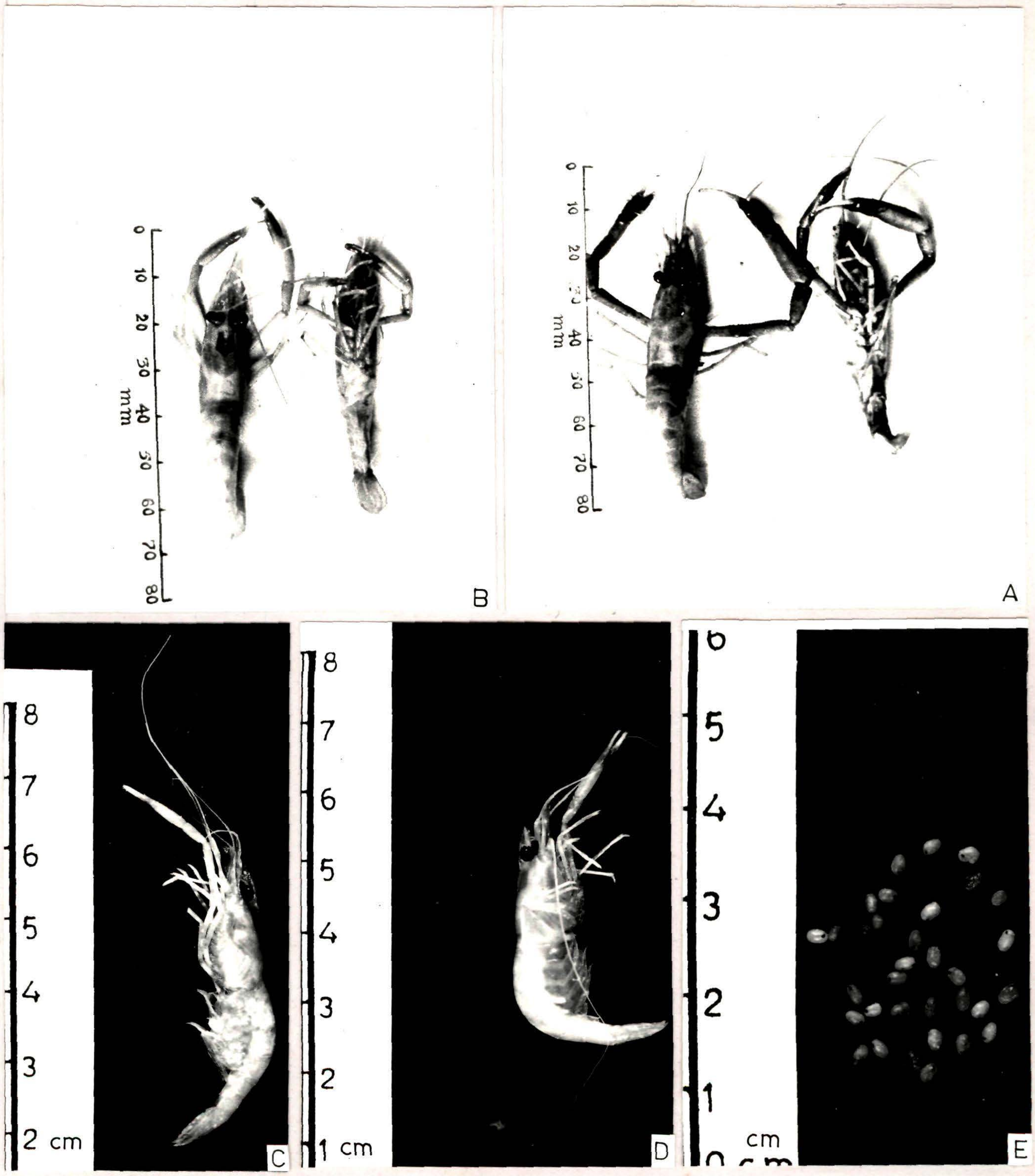
A: *M. hendersoni hendersoni* male (dorsal and ventral view of preserved specimen).

B: *M. hendersoni cacharensis* male (dorsal and ventral view of preserved specimen)

C: Ovigerous female of *M. hendersoni hendersoni*

D: Ovigerous female of *M. hendersoni cacharensis*

E: Eggs of the broad pouch carried by a female.



B
0 10 20 30 40 50 60 70 80
mm
A
0 10 20 30 40 50 60 70 80
mm
C
8 7 6 5 4 3 2 cm
D
8 7 6 5 4 3 2 1 cm
E
6 5 4 3 2 1 0 cm

Fig.42

2. MATERIALS & METHODS

The monthly collection (January, 1979 to December, 1980) of Macrobrachium hendersoni hendersoni (de Man) from Umshing stream and Macrobrachium hendersoni cacharensis (Tiwari) from Pongtung stream for the purpose of their ecological studies as already mentioned in Part I of the thesis, constitutes the prawn materials for the present study. Seven hundred males and three hundred females were subjected to detailed biometrical analyses. Measurements of structures were taken closer to 0.1 mm with the aid of an ocular micrometer mounted on a dissecting microscope or somtimes with a vernier calliper. The relationships have been studied for different size groups and also for different sexes.

2.1. Sexual Dimorphism:

Total length was measured from the tip of the rostrum to the tip of the telson and carapace length from the base of the right eye stalk to the midregion of the posterior edge of the carapace (Truesdale and Mermilliodes, 1979). The larger of the two chelipeds was used in all cases. Seven articles comprise the chelipeds and are named starting from the base distally: coxa, basis, ischium, merus, carpus, propodus, and dactylus. In the genus Macrobrachium, the coxa and basis contribute little to overall cheliped length and therefore were ignored. Lengths of the five distal articles were taken as each article's lateral side. The exopod and endopod of the left first pleopod of males and females were measured from their origin on the protopodite to their tips. In instances where the left pleopod was damaged, the right pleopod was substituted. The appendices musculinae and internae, which are found on the endopods of the second pair of pleopod of males, were measured from their origin on the endopod to their tip.

The right second abdominal pleuron of males and females was measured at its widest point to study development of the female abdominal brood chamber. Relative growth can be described by the allometric growth equation $y = ax^b$, where y is the variable dimension, x is the reference dimension, 'a' is the y-intercept, and 'b' is the relative growth rate (Huxley, 1927). A logarithmic transformation of the allometric growth equation allows one to describe growth in terms of linear equations. Thus, the data were plotted on a log;log scale, the regression were calculated by the method of 'least squares'. Data, above and below an obvious break in the plot, were treated separately, if so doing increased the fit of the regression equation to the plotted data, regressions for males and females were tested for similarity of slopes/or intercepts by the students' 't' test at $P = 0.05$ and 0.01 (Smilie, 1966). Additionally, during the daily operation of our culturing facility, numerous instances of mating and agression were observed. These observations aided in interpreting the function of the sexual structures.

2.2 Maturation and Spawning:

In order to study the gonadal cycle, histological preparations were made. Different regions of testes and ovaries were fixed in Bouin's fluid. Routine type of paraffin sections of 6-7 µm thickness were cut and stained with Delafield's haemotoxylin and using eosin-counterstain in all cases. Heidenhain's Azan, Mallory's triple stain and periodic acid Schiff (PAS) were also used. The 'maturity index' or 'Gonad index' was also calculated using the formula (Giese, 1959).

$$\text{Gonad Index (GI)} = \frac{\text{Weight of the gonad}}{\text{Weight of the animal}} \times 100$$

2.3. Brood size and reproductive efforts:

Brood size is the measure of the number of eggs carried by a female at one time (Nishino, 1980). The eggs from each berried female which were not artificially injured, shrunk or bursting on hatching, were removed and their numbers were also noted. The length and width of the eggs were measured under microscope to the nearest of 0.1 mm. The body length and width of right second abdominal pleuron of each mother prawn was also measured to the nearest of 0.01 mm. The wet weight with and without eggs carried by a female prawn was calculated as the ratio of brood size to the berried female body weight. The egg size is calculated by employing the formula: Egg size = $[\text{length (mm)}] \times [\text{width (mm)}]^2$ and called egg volume for convenience' sake (Nishino, 1980). The relative brood weight is calculated as the ratio of weight of eggs carried by a female to the berried female body weight. The numbers of ovigerous and ovipositing setae on the first pleopods of the female was counted under microscope and correlated with their respective brood sizes.

2.4. Larval development:

Living berried females of M. *hendersoni hendersoni* were collected from Umshing stream and M. *hendersoni cacharensis* from Pongtung stream and kept in laboratory aquaria containing water from their respective habitat. The aquasystems were maintained under continuous water circulation and aeration. The investigations were carried out in two seasons. The first set of observations was made in early May, 1979 and the second was conducted in late September, 1979.

The berried females were fed with cut pieces of earthworm and sometimes with cooked rice. The unconsumed food matter were removed about half an hour after feeding was over, to avoid fouling of water. Females in advanced stages of berry were kept singly in glass jars of one litre capacity and containing water from the original habitat. After hatchings were over, the larvae were removed from the jars and spent females transferred to another aquarium.

Rearing of larvae was carried out in glass beakers of 250 ml. capacity. Two to three larvae were kept in one beaker with about 150 ml. of stream water and covered on top with fine muslin cloth to prevent dust particles from setting in the beakers. A few example of each larval stage preserved in neutral formalin mixed with glycerine (9:1). Exuviae were also collected and preserved likewise. Measurements were also made with ocular micrometer on preserved larvae.

Appendages were dissected and mounted in polyvinyl alcohol-lectophenol mixture. Appendages dissected from larval exuviae gave good results. All the drawings were made with camera-lucida and measurements were recorded in millimeters.

2.5. Food and feeding habits:

Food and feeding habits of M. hedersoni hendersoni and M. hendersoni cacharensis were studied by examining a total of 592 and 628 digestive tracts respectively. The guts were removed from the specimens after measuring and weighing each prawn and were preserved in 5% formalin for subsequent analysis. The preserved guts were later uncoiled, cleaned off and their weight were recorded. The feeding intensity or the gastro-somatic index (G.S.I.) has been calculated by employing the following formula (Desai, 1970):

$$\text{G.S.I.} \quad \frac{\text{Weight of the gut}}{\text{Total weight of the animal}} \times 100$$

Different workers have adopted different methods in analysing the gut contents. Job (1940) followed the 'volumetric method' whereas Bapat and Lal (1950) estimated the percentages of the various food items of some inshore fishes by eye assessment. Hynes (1950) studied the stomach contents of freshwater stickle backs by the 'points method'. Bhimachar and George (1952) conbined both 'points method' and 'number method'. As Pillai (1952) has suggested, the method to be adopted depends entirely on the particular diet of an animal, Venkataraman (1960) employed the 'points method' with certain modifications. In the present study, the quantitative analysis of foregut contents was made by employing visual estimate method as followed by Venkataraman (1960) and Marte (1980). Gut contents were examined microscopically for food organisms to determine their frequency of occurrence. Identification was based on skeletal remains.

2.6. Digestive physiology:

The study on the digestive physiology was made only on Macrobrachium hendersoni hendersoni (de Man). Living specimens of M. hendersoni hendersoni was collected from the Umshing stream and were reared in the aquarium for about fifteen days with continuous water circulation and proper aeration. Some of the live prawns were dissected to measure the pH in different regions of the alimentary canal of normal feeding prawns. The different parts of the gut were separated and thoroughly washed to clear them of any food contents. The pH of the gut was measured both by pH indicator paper and pH meter. The pH measurements were also made in thr prawns which were starved for about 72 hours and also in those which were first starved and then fed on some selected diets.

For qualitative estimation of enzymes, the digestive juices were collected by canula method (Tyagi and Prakash, 1967) from different parts of the gut. However, the canula could not be inserted into the intestine, rectum and hepatopancreas. In such cases, these parts were separated and their extracts were prepared according to the method described by Krishna (1955). To investigate the place of secretion, the extracts and digestive juices of different parts of the gut were incubated with different substrates (Tyagi and Prakash, 1967). The incubated solutions were tested for the different enzymes after different time intervals. The amylase and protease activities have been studied and confirmed employing the methods used by (Krishna, 1955, 1958) and Shukla and Upadhyaya (1978) respectively and for lipase, Baldwin and Bell (1955) method as followed by Tyagi and Prakash (1967) were adopted.

2.7. Neuroendocrine-regulation of blood chloride:

The freshwater prawn, M. hendersoni hendersoni (size 2.85 ± 0.35 g) were collected from Umshing stream and were reared in the laboratory. Eye stalks were ablated by making a deep incision at their bases, with a sharp blade and the aqueous extracts of the eye stalks were prepared to give a final concentration of a pair of eye stalks/0.25 ml and 0.2 ml. of clear supernatant was injected into each animal. Sendroy's modified method (1942) was used to estimate the blood chloride content in the normal, eye stalkless and eye stalk-extract injected animals. All animals were maintained in tap water.

3. RESULTS

3.1. SEXUAL DIMORPHISM:

In both *Macrobrachium hendersoni hendersoni* and *M. hendersoni cacharensis*, the presence of appendices masculinae and the gonopore are the first external evidences of sexual dimorphism to be seen in both sexes. In the second abdominal appendages of male, the appendix interna gives off on its inner side an additional process called appendix masculine lying in between the appendix interna and endopodite (Fig. 43). As with several other species of caridean prawns, the male gonopores occur on the medial surface of the arthrodial membrane between the coxae of the fifth pereiopods and the sternum and are covered by gonopore flaps (Fig. 43). Male gonopores were not found without their associated gonopore flaps, although in earlier stage of development, the flaps looked more like nipples, The female gonopores appeared as oval apertures on the medial surface of the coxae of the third pereiopods and are covered with a thin membrane that can be pushed inward with a fine, blunt dissecting needle.

Reproductive setae which are developed almost simultaneous with the brood chamber development, were also the evidences of sexual dimorphism. The setae are divided into two functional categories: Ovigerous and ovipositing setae. Ovigerous setae, to which eggs are attached for brooding, are characteristically thick, long, and wiry and are found on the medial surfaces and bases of the protopodites of the first through fourth pleopods. These setae are formed only on

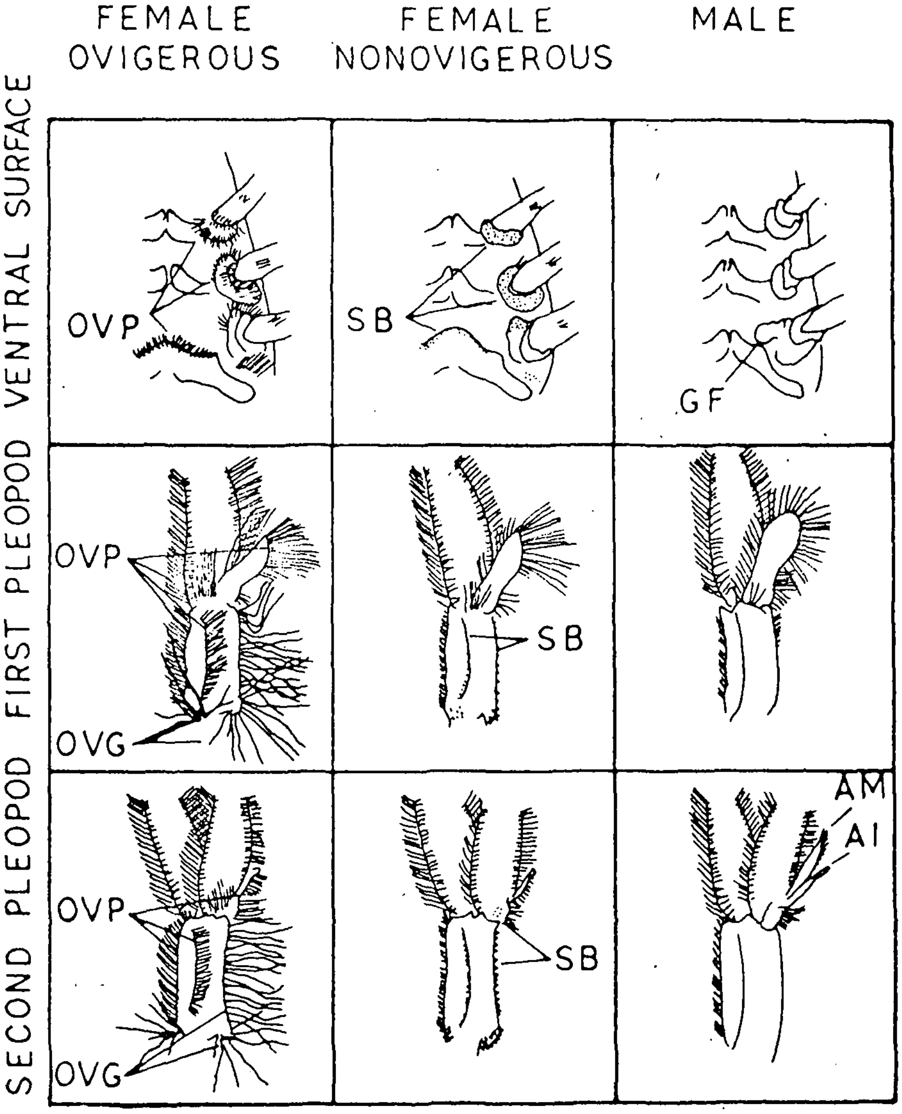


Fig. 43. Diagrammatic representation of sexual dimorphism on the ventral surface and the first and second pleopods of sexually mature male and female prawn and differences between ovigerous and nonovigerous females. Tips of the exopods and, in the second pleopods, the endopods have been deleted. AI, appendix interna; AM, appendix interna; AM, appendix masculina; GF, gonopore flap; OVG, ovigerous setae; OVP, ovipositing setae; SB, setal buds.

preparturial moults and are thus termed temporary setae. On non-parturial moults, their past or future presence is evidenced by their buds which appear as conical projeotions (Fig. 43). Ovipositing setae, which aid in propelling, guiding, or containing newly laid eggs, are found on the coxae of the third, fourth, and fifth pereiopods, the posterior sternum of the cephalothorax, the endopods of the pleopods, the appendices internae (although they may be absent in the appendices of the fifth pleopods in smaller females), and on the lateral edges and sides of the protopodites. Unlike ovigerous setae, some ovipositing setal groups are permanent whereas others are temporary (Fig. 43). Permanent ovipositing setae usually show a decrease in length on non-parturial moults which may be substantial in some cases, e.g., the ovipositing setae on the lateral edge and sides of the protopodites.

The sexual structures described above are not meant to be exhaustive. Other noted sexual dimporphism are in the relative growth of the body size, certain articular ratios of the chelipods, ratio of exopod and endopod length, second pleuron width etc.

3.1.1. Total length-carapace length relationship:

A highly significantly positive correlation between total length (TL) and carapace length (CL) is indicated by the high r-values (Tables 19, 20). The total length are plotted against the carapace length (Fig. 44) and the calculated parabolic equations are as follows:

M. hendersoni hendersoni

♂ : $TL = 2.3009\ CL^{1.0168}$
(TL : 20.0-40.0 mm)

♀ : $TL = 2.6388\ CL^{0.9738}$
(TL : 20.0-40.0 mm)

♂ : $TL = 2.4333\ CL^{0.9945}$
(TL : 40.1-55.0 mm)

♀ : $TL = 2.4860\ CL^{0.9967}$
(TL : 40.1-55.0 mm)

♂ : $TL = 2.6959\ CL^{0.9642}$
(TL : 55.1-80.0 mm)

♀ : $TL = 2.4474\ CL^{1.0014}$
(TL : 55.1-80.0 mm)

M. hendersoni cacharensis

♂ : $TL = 3.7914\ CL^{0.8184}$
(TL : 20.0-40.1 mm)

♀ : $TL = 2.4088\ CL^{1.0139}$
(TL : 20.0-40.1 mm)

♂ : $TL = 2.2131\ CL^{1.0215}$
(TL : 40.1-50.0 mm)

♀ : $TL = 4.1419\ CL^{0.8223}$
(TL : 40.1-50.0 mm)

♂ : $TL = 2.8132\ CL^{0.9413}$
(TL : 50.1-70.0 mm)

♀ : $TL = 2.6761\ CL^{0.9774}$
(TL : 50.1-70.0 mm)

3.1.2. Total length-body weight relationship:

The total length (TL) and body weight (W) exhibited significantly positive correlations and the regression equations are given in tables 19 and 20. The total length and body weight are plotted (Fig. 44) and their parabolic relationship calculated are as follows:

M. hendersoni hendersoni

♂ : $TL = 37.6097\ W^{1.3754}$
(TL : 20.0-40.0 mm)

♀ : $TL = 33.4888\ W^{1.0130}$
(TL : 20.0-40.0 mm)

♂ : $TL = 29.4103\ W^{0.9983}$
(TL : 40.1-55.0 mm)

♀ : $TL = 33.1665\ W^{1.0116}$
(TL : 40.1-55.0 mm)

M. hendersoni cacharensis

♂ : $TL = 10.6807\ W^{0.4095}$
(TL : 20.0-40.0 mm)

♀ : $TL = 32.2626\ W^{1.006}$
(TL : 20.0-40.0 mm)

♂ : $TL = 27.6312\ W^{1.0098}$
(TL : 40.1-50.0 mm)

♀ : $TL = 32.2552\ W^{1.0007}$
(TL : 40.1-50.0 mm)

♀ : $TL = 29.8469\ W^{0.9996}$
(berried)

♂ : $TL = 29.6825\ W^{0.9856}$
(TL : 55.0-80.0 mm)

♀ : $TL = 33.3734\ W^{0.9977}$
(TL : 55.0-80.0 mm)

♀ : $TL = 30.2482\ W^{1.0049}$
(berried)

♂ : $TL = 27.7651\ W^{1.006}$
(TL : 50.1-70.0 mm)

♀ : $TL = 32.3147\ W^{0.9969}$
(TL : 50.1-70.0 mm)

3.1.3. Total length-pleuron width relationship:

The total length (TL) and pleuron width (PL) exhibited significantly positive correlations and their regression equations are given in tables 19 and 20. In both _M. hendersoni hendersoni_ and _M. hendersoni cacharensis_, sexual dimorphism in relation to their pleuron width was evident (Tables 19, 20). And, also their relationship has been obtained by plotting the total length against pleuron width (Fig. 44) and the parabolic equations derived are as follows:

M. hendersoni hendersoni

♂ : $TL = 78.0369\ PL^{1.0130}$
(TL : 20.0-40.0 mm)

♀ : $TL = 45.2689\ PL^{0.9456}$
(TL : 20.0-40.0 mm)

♂ : $TL = 75.9451\ PL^{0.9779}$
(TL : 40.1-55.0 mm)

♀ : $TL = 41.6677\ PL^{0.9334}$
(TL : 40.1-1-55 mm)

♂ : $TL = 76.3484\ PL^{0.9673}$
(TL : 55.1-80.0 mm)

♀ : $TL = 66.8960\ PL^{1.0012}$
(TL : 55.1-80.0 mm)

M. hendersoni cacharensis

♂ : $TL = 81.7335\ PL^{0.9855}$
(TL : 20.0-40.0 mm)

♀ : $TL = 59.3198\ PL^{0.7354}$
(TL : 20.0-40.0 mm)

♂ : $TL = 81.5455\ PL^{0.9615}$
(TL : 40.1-50.0 mm)

♀ : $TL = 67.2357\ PL^{0.9293}$
(TL : 40.1-50.0 mm)

♂ : $TL = 83.6373\ PL^{0.9689}$
(TL : 50.1-70.0 mm)

♀ : $TL = 65.2379\ PL^{0.5777}$
(TL : 50.1-70.0 mm)

3.1.4. Merus-Ischium relationship:

The merus (M) and ischium (I) length exhibited significantly positive correlations and their regression equations are shown in tables 21 and 22. In both *M. hendersoni hendersoni* and *M. hendersoni cacharensis*, the sexual dimorphism in relation to the growth of merus and ischium length was evident (Tables 19, 20). By plotting the merus length against ischium length their parabolic relationship has been shown (Fig. 45) and the equations derived are as follows:

M. hendersoni hendersoni	*M. hendersoni cacharensis*
♂ : $M = 1.3928\ I^{0.9894}$ (TL : 20.0-40.0 mm)	♂ : $M = 1.3690\ I^{0.9881}$ (TL : 20.0-40.0 mm)
♀ : $M = 1.511\ I^{1.1716}$ (TL : 20.0-40.0 mm)	♀ : $M = 1.2014\ I^{1.006}$ (TL : 20.0-40.0 mm)
♂ : $M = 1.1956\ I^{0.8606}$ (TL : 40.1-55.0 mm)	♂ : $M = 1.0723\ I^{0.7179}$ (TL : 40.1-50.0 mm)
♀ : $M = 1.3381\ I^{1.0238}$ (TL : 40.1-55.0 mm)	♀ : $M = 0.7027\ I^{0.2648}$ (TL : 40.1-50.0 mm)
♂ : $M = 1.4148\ I^{1.0080}$ (TL : 55.1-80.0 mm)	♂ : $M = 1.0018\ I^{0.4936}$ (TL : 50.1-70.0 mm)
♀ : $M = 1.3577\ I^{1.0661}$ (TL : 55.1-80.0 mm)	♀ : $M = 1.1347\ I^{0.8965}$ (TL : 50.1-70.0 mm)

3.1.5. Merus-Carpus relationship:

The merus (M) and carpus (C) length exhibited significantly positive correlations and their regression equations are given in tables 21 and 22. The post-breeding group (50.1-70.0 mm) of *M. hendersoni cacharensis* exhibited distinct sexual dimorphism in relation to their relative growth of the merus and carpus length (Table 20). The parabolic relationship of their observed values were noted by plotting them (Fig. 45) and the equations derived are as follows:

M. hendersoni hendersoni	*M. hendersoni cacharensis*
♂: $M = 1.3474\ C^{0.9261}$ (TL : 20.0-40.0 mm)	♂: $M = 1.3110\ C^{0.9121}$ (TL : 20.0-40.0 mm)
♀: $M = 1.4388\ C^{1.0151}$ (TL : 20.0-40.0 mm)	♀: $M = 1.3753\ C^{0.9641}$ (TL : 20.0-40.0 mm)
♂: $M = 1.7726\ C^{1.4719}$ (TL : 40.1-55.0 mm)	♂: $M = 1.2145\ C^{0.8135}$ (TL : 40.1-50.0 mm)
♀: $M = 1.3567\ C^{0.9269}$ (TL : 40.1-55.0 mm)	♀: $M = 1.3574\ C^{0.9454}$ (TL : 40.1-50.0 mm)
♂: $M = 1.4401\ C^{0.9863}$ (TL : 55.1-80.0 mm)	♂: $M = 5.9927\ C^{0.4857}$ (TL : 50.1-70.0 mm)
♀: $M = 1.4112\ C^{1.0009}$ (TL : 55.1-80.0 mm)	♀: $M = 3.9774\ C^{0.6817}$ (TL : 50.1-70.0 mm)

3.1.6. Propodus-Carpus relationship:

The propodus (P) and carpus (C) length-exhibited significantly positive correlations and the sexual dimorphism was evident in all the size groups (Tables 21, 22). By plotting their observed values, the parabolic relationship has been noted (Fig. 45) and the equations derived are as follows:

M. hendersoni hendersoni	*M. hendersoni cacharensis*
♂: $P = 1.5307\ C^{0.9148}$ (TL : 20.0-40.0 mm)	♂: $P = 0.5933\ C^{0.9350}$ (TL : 20.0-40.0 mm)
♀: $P = 1.5090\ C^{1.0064}$ (TL : 20.0-40.0 mm)	♀: $P = 1.4494\ C^{0.9714}$ (TL : 20.0-40.0 mm)

♂: $P = 0.8504\ C^{-0.0937}$
(TL : 40.1-55.0 mm)

♀: $P = 1.5195\ C^{1.0162}$
(TL : 40.1-55.0 mm)

♂: $P = 1.6512\ C^{0.9260}$
(TL : 55.1-70.0 mm)

♀: $P = 1.5018\ C^{1.0222}$
(TL : 55.1-70.0 mm)

♂: $P = 0.9156\ C^{0.2786}$
(TL : 40.1-50.0 mm)

♀: $P = 1.9661\ C^{1.2861}$
(TL : 40.1-50.0 mm)

♂: $P = 1.5509\ C^{0.5858}$
(TL : 50.0-70.0 mm)

♀: $P = 7.5248\ C^{0.7020}$
(TL : 50.0-70.0 mm)

3.1.7. Propodus-dactylus relationship:

The propodus (P) and dactylus (D) length exhibited significantly positive correlations and the regression equations are given in tables 21 and 22. The parabolic relationship has been obtained by plotting their observed values (Fig. 46) and the equations derived are as follows:

M. hendersoni hendersoni

♂ : $P = 0.8652\ D^{0.9148}$
(TL : 20.0-40.0 mm)

♀ : $P = 0.8360\ D^{0.9892}$
(TL : 20.0-40.0 mm)

♂ : $P = 0.8958\ D^{0.0532}$
(TL : 40.1-55.0 mm)

♀ : $P = 0.8656\ D^{1.0436}$
(TL : 40.1-55.0 mm)

♂ : $P = 0.9247\ D^{0.9218}$
(TL : 55.1-80.0 mm)

♀ : $P = 0.1466\ D^{1.0177}$
(TL : 55.1-80.0 mm)

M. hendersoni cacharensis

♂: $P = 0.7938\ D^{1.0019}$
(TL : 20.0-40.0 mm)

♀: $P = 0.2674\ D^{1.0134}$
(TL : 20.0-40.0 mm)

♂: $P = 0.7914\ D^{0.9707}$
(TL : 40.1-50.0 mm)

♀ : $P = 0.2841\ D^{1.0354}$
(TL : 40.1-50.0 mm)

♂: $P = 0.7917\ D^{1.0112}$
(TL : 50.1-70.0 mm)

♀: $P = 0.2449\ D^{0.9922}$
(TL : 50.1-70.0 mm)

Table 19: Regression statistics for the linear regression (Log Y = Log a + b Log X) for comparing the relationship between certain indicator structures in male and female, *M. hendersoni hendersoni*

X	Y	Sex	Size group (mm)	a	b	r
Carapace length	Total length	M	20.0-40.0	0.3619	1.0168	0.996**
		F	20.0-40.0	0.4214	0.9738	0.9997
		M	40.1-55.0	0.3862	0.9954	0.9998**
		F	40.1-55.0	0.3855	0.9967	0.9998
		M	55.1-80.0	0.4307	0.9642	0.9988**
		F	55.1-80.0	0.3887	1.0014	0.9998
Body weight	Total length	M	20.0-40.0	1.5753	1.3754	0.9560**
		F	20.0-40.0	1.5249	1.0117	0.9978
		M	40.1-55.0	1.4685	0.9983	0.9999**
		F	40.1-55.0	1.5207	1.0116	0.9997
		M	55.1-80.0	1.4725	0.9856	0.9985**
		F	55.1-80.0	1.5234	0.9977	0.9999
Pleuron width	Total length	M	20.0-40.0	1.8923	1.0130	0.9993**
		F	20.0-40.0	1.6558	0.9456	0.9774
		M	40.1-55.0	1.8805	0.9779	0.9676***
		F	40.1-55.0	1.6198	0.9334	0.9989
		M	55.1-80.0	1.8828	0.9673	0.9994**
		F	55.1-80.0	1.8254	1.0012	0.9993
Endopod length	Exopod length	M	20.0-40.0	0.3219	0.9265	0.9915**
		F	20.0-40.0	0.2328	0.8568	0.9531
		M	40.1-55.0	0.3627	0.9713	0.9895***
		F	40.1-55.0	0.0226	0.6416	0.9467
		M	55.1-80.0	0.3805	1.0016	0.9968***
		F	55.1-80.0	0.2161	1.0473	0.9989

r = correlation co-efficient; * = no significant difference between sexes; ** = Significant difference between sexes, $P \ll 0.05$; *** = Significant differences between sexes, $P \ll 0.01$. M = Male; F = Female.

Table 20: Regression statistics for the linear regression (Log Y = Log a + b Log X) for comparing the relationship between certain indicator structures in male and female, *M. hendersoni cacharensis*

X	Y	Sex	Size group (mm)	a	b	r
Carapace length	Total length	M	20.0-40.0	0.5788	0.8184	0.7950**
		F	20.0-40.0	0.3818	1.0139	0.9996
		M	40.1-50.0	0.3450	1.0215	0.8976**
		F	40.1-50.0	0.6172	0.8223	0.9709
		M	50.1-70.0	0.4492	0.9413	0.9835**
		F	50.1-70.0	0.4275	0.9774	0.9986
Body weight	Total length	M	20.0-40.0	1.0286	0.4095	0.9976**
		F	20.0-40.0	1.5087	1.0006	0.9998
		M	40.1-50.0	1.4414	1.0098	0.9996**
		F	40.1-50.0	1.5086	1.0007	0.9998
		M	50.1-70.0	1.4435	1.0006	0.9995**
		F	50.1-70.0	1.5094	0.9969	0.9998
Pleuron width	Total length	M	20.0-40.0	1.9124	0.9855	0.9997*
		F	20.0-40.0	1.7732	0.7354	0.9708
		M	40.1-50.0	1.9114	0.9615	0.9945***
		F	40.1-50.0	1.8276	0.9293	0.9706
		M	50.1-70.0	1.9224	0.9689	0.9692**
		F	50.1-70.0	1.8145	0.5777	0.6897
Endopod length	Exopod length	M	20.0-40.0	-0.2048	0.2959	0.9469***
		F	20.0-40.0	0.2790	0.9274	0.9968
		M	40.1-50.0	-0.1462	0.2512	0.9948***
		F	40.1-50.0	-0.0306	0.4137	0.6263
		M	50.1-70.0	0.0413	0.4708	0.8762**
		F	50.1-70.0	0.1770	0.7149	0.9734

r = correlation co-efficient; * = no significant difference between sexes; ** = Significant difference between sexes, $P \ll 0.05$; *** = Significant difference between sexes, $P \ll 0.01$. M = Male; F = Female.

Table 21: **Regression statistics for the linear regressions (Log Y = Log a + b Log X) for comparing the relationship between the length of four distal articles of the Chelipeds in male and female, *M. hendersoni hendersoni***

X	Y	Sex	Size group (mm)	a	b	r
Ischium length	Merus length	M	20.0-40.0	0.1439	0.9894	0.9997*
		F	20.0-40.0	0.1793	1.1716	0.9959
		M	40.1-55.0	0.0776	0.8606	0.4880**
		F	40.1-55.0	0.1265	1.0238	0.9676
		M	55.1-80.0	0.1507	1.0080	0.9989*
		F	55.1-80.0	0.1328	1.0661	0.9990
Carpus length	Merus length	M	20.0-40.0	0.1295	0.9261	0.9944*
		F	20.0-40.0	0.1580	1.0151	0.9993
		M	40.1-55.0	0.2486	1.4719	0.5662*
		F	40.1-55.0	0.1325	0.9269	0.9684
		M	55.1-80.0	0.1584	0.9863	0.9969*
		F	55.1-80.0	0.1496	1.0009	0.9991
Carpus length	Propodus length	M	20.0-40.0	0.1849	0.9148	0.9822**
		F	20.0-40.0	0.1787	1.0064	0.9997
		M	40.1-55.0	-0.0704	-0.0937	-0.3390***
		F	40.1-55.0	0.1817	1.0162	0.9994
		M	55.1-80.0	0.2178	0.9260	0.7658***
		F	55.1-80.0	0.1766	1.0222	0.9957
Dactylus length	Propodus length	M	20.0-40.0	-0.0629	1.0946	0.9850**
		F	20.0-40.0	-0.0778	0.9892	0.9998
		M	40.1-55.0	-0.0478	0.9532	0.9884*
		F	40.1-55.0	-0.0627	1.0436	0.9631
		M	55.1-80.0	-0.0340	0.9218	0.9801**
		F	55.1-80.0	-0.8338	1.0177	0.9979

r = correlation co-efficient; * = no significant difference between sexes; ** = significant difference between sexes, $P << 0.05$; *** = significant difference between sexes, $P << 0.01$. M = Male; F = Female.

Table 22: **Regression statistics for the linear regressions (Log Y = Log a + b Log X) for comparing the relationship between the length of four distal articles of the Chelipeds in male and female, M. hendersoni cacharensis**

X	Y	Sex	Size group (mm)	a	b	r
Ischium length	Merus length	M	20.0-40.0	0.1364	0.9881	0.9985**
		F	20.0-40.0	0.0797	1.0006	0.9994
		M	40.1-50.0	0.0303	0.7179	0.9734***
		F	40.1-50.0	-0.1532	0.2648	0.4810
		M	50.1-70.0	0.0008	0.4936	0.8014***
		F	50.1-70.0	0.0549	0.8965	0.9944
Carpus length	Merus length	M	20.0-40.0	0.1176	0.9121	0.9943*
		F	20.0-40.0	0.1384	0.9641	0.9977
		M	40.1-50.0	0.0844	0.8135	0.9586*
		F	40.1-50.0	0.1327	0.9454	0.9411
		M	50.1-70.0	0.7776	0.4857	0.7579*
		F	50.1-70.0	0.5996	0.6817	0.9529
Carpus length	Propodus length	M	20.0-40.0	-0.2267	0.9350	0.9962**
		F	20.0-40.0	0.1612	0.9714	0.9989
		M	40.1-50.0	-0.0383	0.2786	0.4386**
		F	40.1-50.0	0.2936	1.2861	0.7516
		M	50.1-70.0	0.1906	0.5858	0.7062***
		F	50.1-70.0	0.8765	0.7020	0.9620
Dactylus length	Propodus length	M	20.0-40.0	-0.1003	1.0019	0.9994**
		F	20.0-40.0	-0.5728	1.0134	0.9995
		M	40.1-50.0	-0.1016	0.9707	0.9981**
		F	40.1-50.0	-0.5465	1.0354	0.9971
		M	50.1-70.0	-0.1014	1.0112	0.9996***
		F	50.1-70.0	-0.6110	0.9922	0.9964

r = correlation co-efficient; * = no significant difference between sexes; ** = significant difference between sexes, $P << 0.05$; *** = significant difference between sexes, $P << 0.01$. M = Male; F = Female.

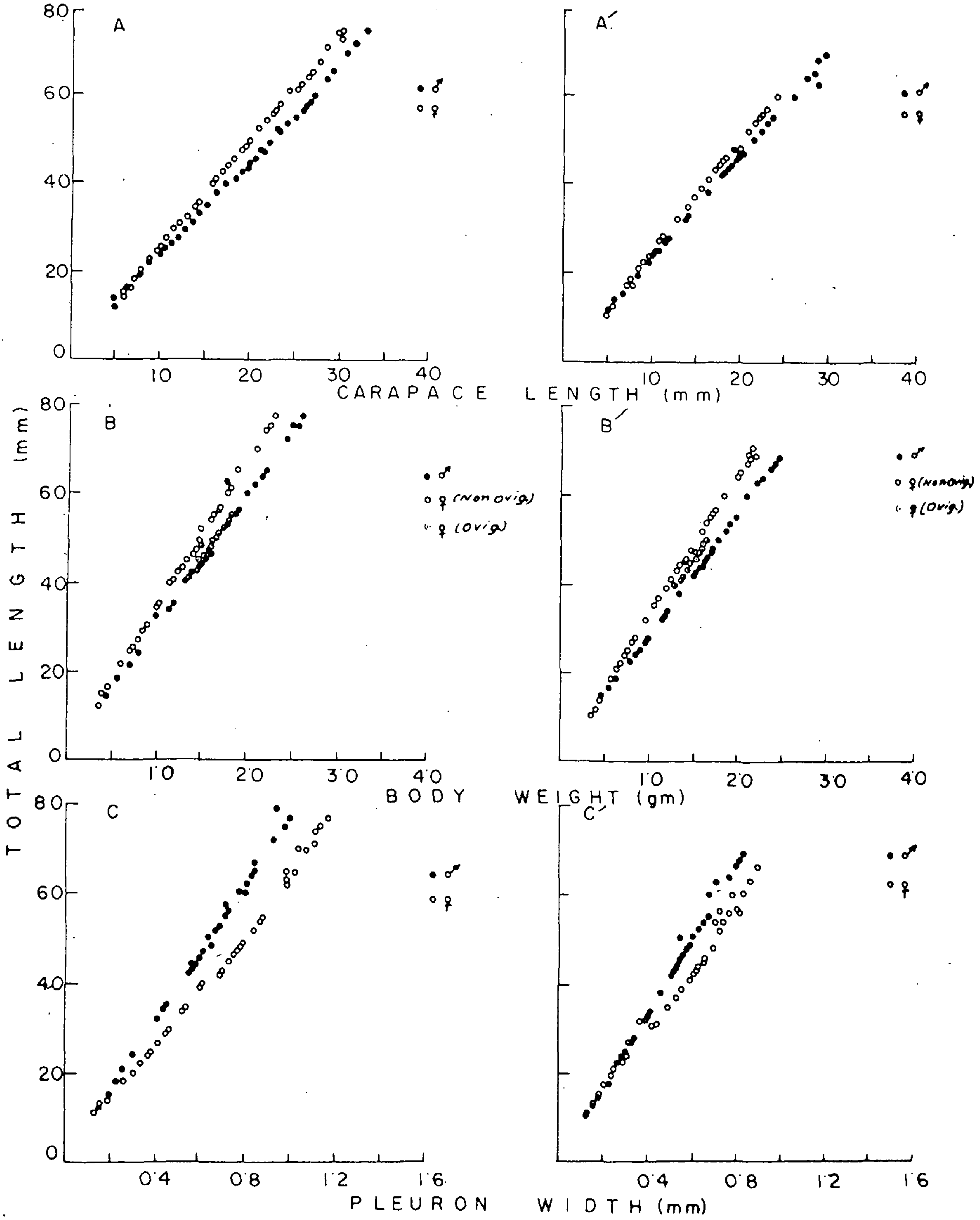


Fig. 44. Sexual dimorphism in the relative growth of total length to carapace length, body weight and pleuron width of M. hendersoni hendersoni (A,B,C,) and M. hendersoni cacharensis (A′,B′,C′).

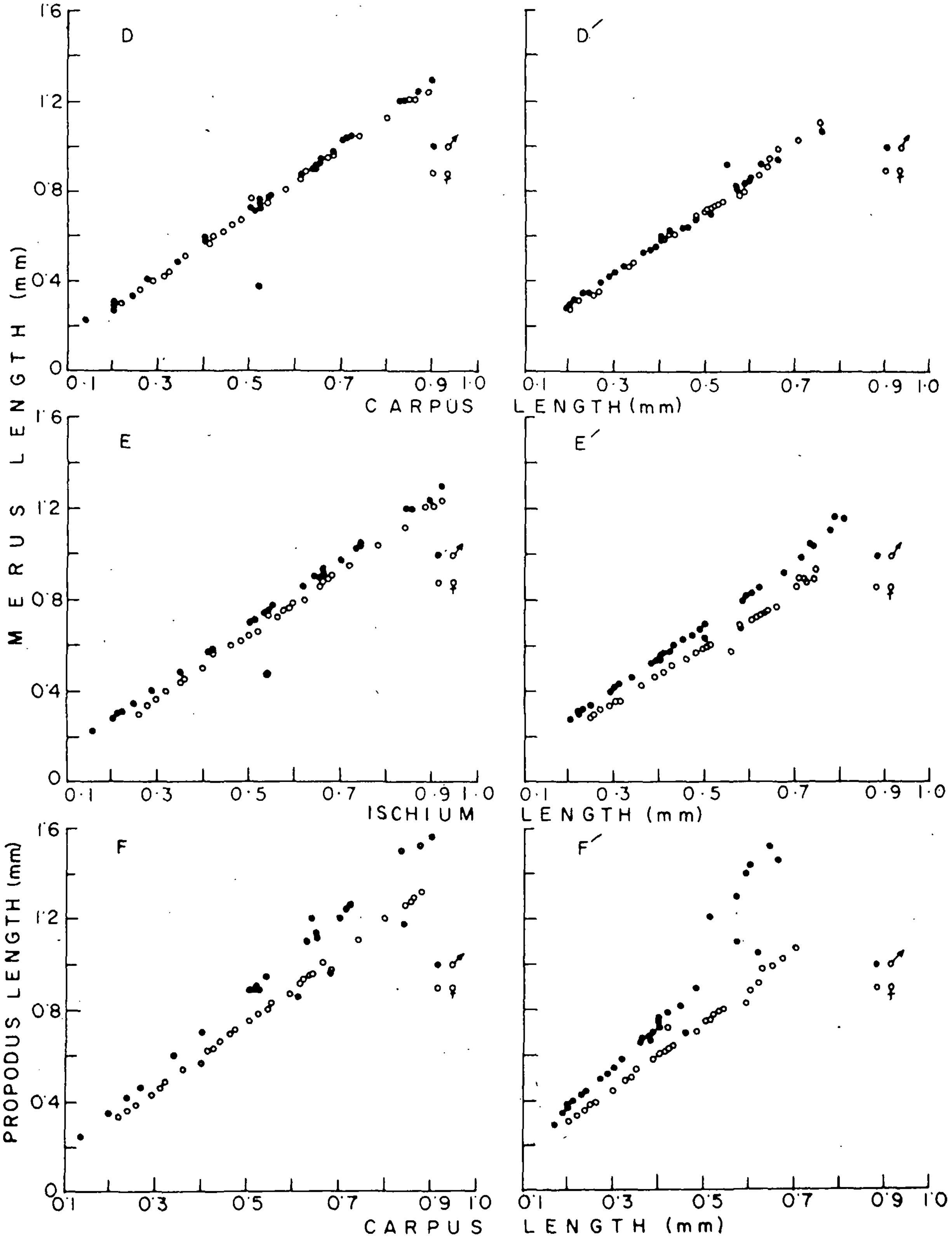


Fig.45.Sexual dimorphism in the length of the distal joints of the cheliped of *M. hendersoni hendersoni* (D,E,F,) and *M. hendersoni cacharensis* (D′,E′,F′)

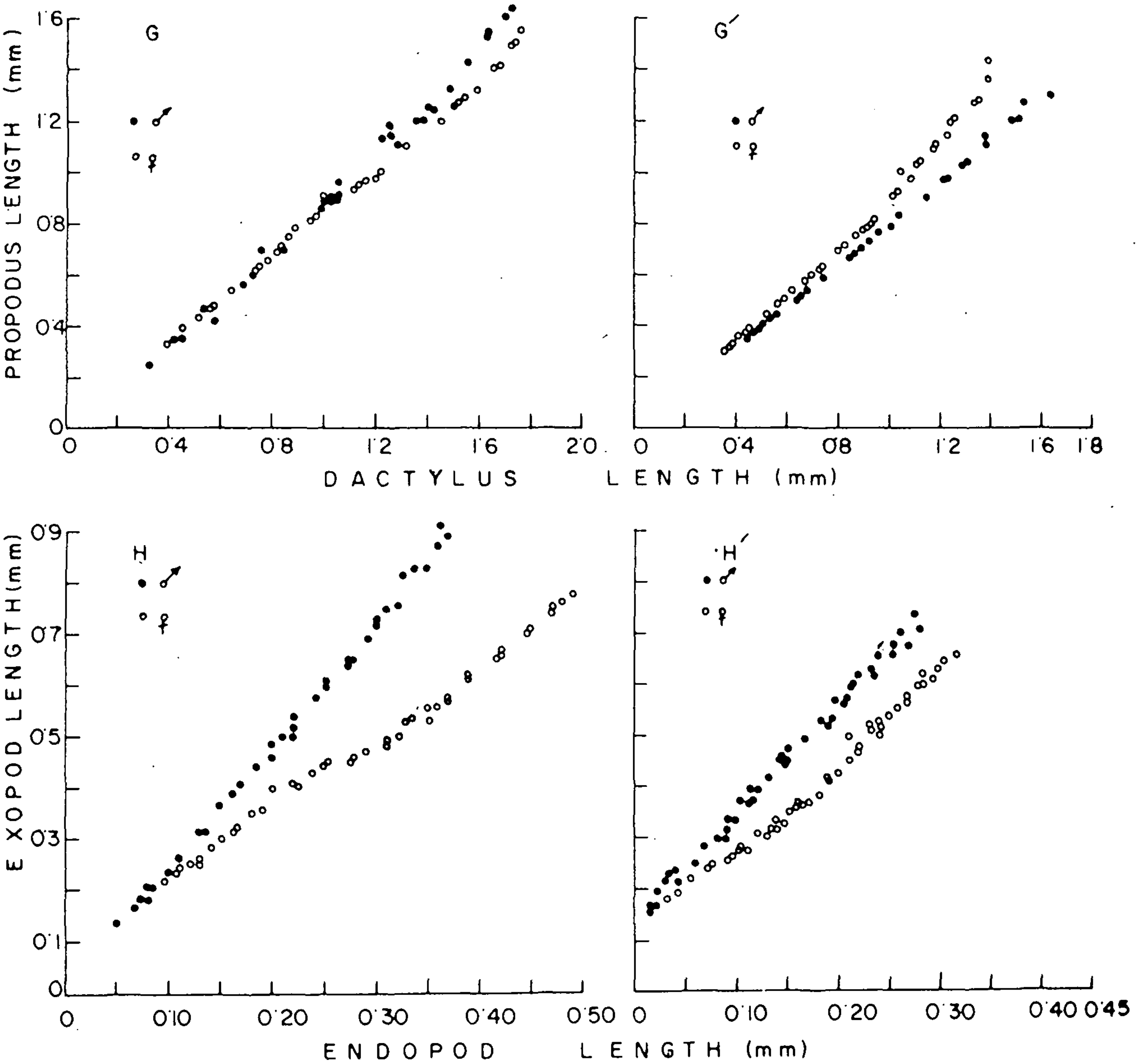


Fig. 46. Sexual dimorphism in the relative length of the propodus and dactylus and the expopod and endopod of *M. hendersoni hendersoni* (G,H) and *M. hendersoni cacharensis* (G′,H′).

3.1.8. Exopod-Endopod relationship:

The exopod (Ex) and endopod (En) length exhibited significantly positive correlations and their regression equations are shown in tables 19 and 20. In both *M. hendersoni hendersoni* and *M. hendersoni cacharensis*, sexual dimorphism in relation to the relative growth of exopod and endopod were evident (Tables 19, 20). By plotting the exopod and endopod length, a parabolic relationship has been noted (Fig. 46) and the equations derived are as follows:

M. hendersoni hendersoni	*M. hendersoni cacharensis*
♂ : $Ex = 2.0984\ En^{0.9265}$ (TL : 20.0-40.0 mm)	♂ : $Ex = 0.6240\ En^{0.2959}$ (TL : 20.0-40.0 mm)
♀ : $Ex = 1.7092\ En^{0.8568}$ (TL : 20.0-40.0 mm)	♀ : $Ex = 1.9011\ En^{0.9274}$ (TL : 20.0-40.0 mm)
♂ : $Ex = 2.3052\ En^{0.9713}$ (TL : 40.1-55.0 mm)	♂ : $Ex = 0.7142\ En^{0.2512}$ (TL : 40.1-50.0 mm)
♀ : $Ex = 1.0534\ En^{0.6416}$ (TL : 40.1-55.0 mm)	♀ : $Ex = 0.9320\ En^{0.4137}$ (TL : 40.1-50.0 mm)
♂ : $Ex = 2.4016\ En^{1.0016}$ (TL : 55.1-80.0 mm)	♂ : $Ex = 1.0997\ En^{0.4708}$ (TL : 50.1-70.0 mm)
♀ : $Ex = 1.6448\ En^{1.0473}$ (TL : 55.1-80.0 mm)	♀ : $Ex = 1.5031\ En^{0.7149}$ (TL : 50.1-70.0 mm)

3.2. MATURITY AND SPAWNING:

3.2.1. Gonadal Cycle:

The histomorphological features of reproductive system of both *M. hendersoni hendersoni* and *M. hendersoni cacharensis* show close similarity. So, it is described commonly.

I. Male Gonad (Testis):

I.a. Morphology:

Bilobed testes are situated immediately beneath the heart whereas some part of it lies above the hinder border, dorsal to the hepatopancreas. In a mature prawn the testes extend anteriorly as far as the renal sac and posteriorly as far as the first abdominal segment. At their anterior ends, the two testes meet together and fuse to form a common lobe, while posteriorly they remain separate, although lying close together. Apart from the middle of their length they diverse from each other leaving a gap for the passage of the cardio-pyloric strand. From the posterior end of each testis originates a vas deferens, which runs for a short distance into the substance of the testis before coming out of it (Fig. 47B). The two vas differentia form a pair of long convoluted ducts, each of which forms a closely winding coil immediately after its origin, the coiled portion lying on the dorsal surface of the hepatopancreas. Beyond the coil, each vas deferens descends vertically downwards between the thoracic wall on the outer side and the flexor muscles of the abdomen on the inner (Fig. 47A). On reaching near the coxa of the last pair of walking legs, the vas deferens form a small club-shaped swelling, the vasicula seminalis, in which the spermatozoa are stored in the form of white compact bodies called the spermatophores.

Fig. 47: Diagrammatic representation of gonad morphology in *M. hendersoni hendersoni* (de Man)

A: Male lateral view : c., coxa of the fifth walking leg; c.s., cardiac stomach; f.m., flexor muscles of the abdomen extending into the thorax; h. heart; h.p., hepatopancreas; r.s., renal sac; s., cardio-pyloric strand; t., testis; v.d., vas deferns; v.s., vesicula seminalis.

B: Dorsal view of testis : c., coxa; f., flap covering the male genital pore; m.g.p., male genital pore; m.g.p., male genital pore; t., testis; v.d., vas deferens; v.s., vesicula seminalis.

C: Female lateral view : c., coxa of the third walking leg; c.s., cardiac stomach; f.m., abdominal flexor muscles extending into the thorax; h., heart; h.p., hepatopancreas; o., ovary; o.d., oviduct; r.s., renalsac.

D: Dorsal view of ovary : c., coxa; c.s., median gap for cardiopyloric strand; f.p, female genital pore; ov., ovary; ov.d., oviduct; s., sternum.

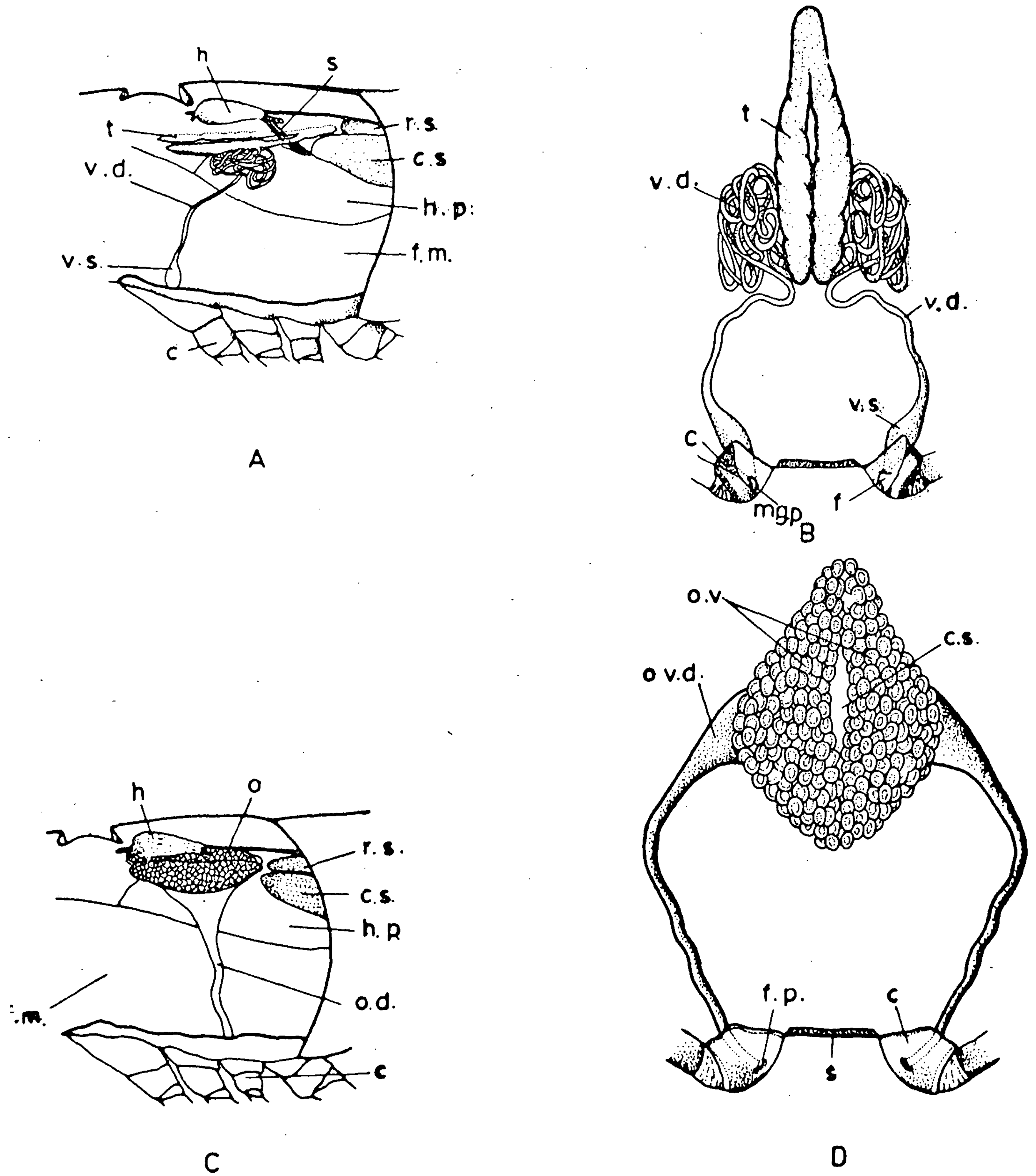

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Fig. 47

I.b. Histology of testis:

Each testis is made up of numerous convoluted siminiferous tubules of varying sizes, held together by a thin layer of connective tissue. The intertubular space contains a few blood vessels. Each tubule is covered by a thin layer of connective tissue, and in a transverse sections shows two distinct areas, the germinative region and the lumen (Fig. 48.1). Different tubules in the same section consist of germcells in different stages of development (Fig. 49. 6-7). Tubules at posterior region of testes become narrow and have small or no germinal area, while their lumen is fully of sperms. The tubules appear to be continuous, opening directly into the vas deferens. In spermatogenesis, the sperm mother cells or primary spermatogonia are the germ cells of first stage and are the largest of all. Each spermatogonium contains a thin rim of cytoplasm around a vesicular nucleus containing peripheral chromatin granules (Fig. 48.3). The number of primary spermatogonia gradually increase soon after spawning (April - September), becoming abundant during November and December (Fig. 50.11). Most of them later on divide mitotically and give rise to the secondary spermatogonia that will differentiate into spermatocytes, but a few remain undifferentiated till sperm formation and spermiation. These are the resting spermatogonia which divide soon after spermiation and supply a new crop of germ cells for the next breeding season. The secondary spermatogonia are smaller than the primary ones and chromatin granules distributed homgeneously in nucleoplasm. These cells undergo mitotic division so that a large number of primary spermatocytes are formed. Furthermore, a tubule at any time contains either spermatocytes or spermatids.

I.c. Seasonal Cycle:

The annual testicular cycle of *M. hendersoni hendersoni* can be divided into the following four stages on the basis of histomorphological characters:

Stage I (October to December): The size and weight of testes gradually decreases reaching a minimum value in October and December (Fig. 54). The testes are thin and translucant during these periods. Some of the tubules have large number of spermatogonia and few residual sperms (Figs. 48.3; 50.10). Spermatogenesis still continues to exist in some of the tubules, but the number of spermatocytes and spermatids decreases gradually and finally absent during December. This indicates gradual ceasation of spermatogenesis in testes. The spermatogonia greatly increased in most of the tubules in October and were in preponderance during November and December (Fig. 50.11). During this period the dimension of tubules decrease and the wall of tubules becomes thick and undulated.

Stage II (January to March): The spermatogenesis begins during January and February with an accompanying increase in size, weight and their walls become comparatively thin. They contain a few primary spermatogonia and a large number of secondary spermatogonia. The primary and secondary spermatocytes are produced in some of the tubules. A few residual sperms are still retained in the lumen of the tubules and almost disappear in March. During March the spermatogonial population decreases and actively dividing primary and secondary spermatocytes become dominating cells in the tubules. In a few tubules spermatids are formed but sperms are not yet developed.

Stage III (April-May): The testes have greatly increased in their size and weight, being maximum during April (Fig. 54). They appear turgid and opaque and their wall becomes so thin that the seminiferous tubules are visible. The vas deferens also appears swollen, opaque and highly coiled and when ruptured the seminal fluid does not ooze out from it. This stage is characterised by spermatogenetic and spermiogenetic activity. Spermatids and sperms are in preponderance (Fig. 49.7). Sperms are developed for the first time in April and tubules fully packed with sperms are seen in April and May. Owing to this the tubules are greatly enlarged and turgid and as a result their walls become thin and intertubular spaces are decreased. However, the maturational changes do not occur simultaneously in all the tubules of testes, as most of the tubules are filled with spermatids and sperms while some others are still at primary or secondary spermatocyte level. This results in the production of sperms in successive waves.

Stage IV (June to September): During this stage, the testes appear opaque and vas deferens is packed with seminal fluid.

Fig. 48: Sections of testes of M. hendersoni hendersoni (de Man)

48.1: Showing seminiferous tubules in May (Stage IV x 90.

48.2: Showing tubules of posterior testis, the germinal area (GA) is reduced x 40.

48.3: Tubules showing primary (PSG) and secondary spermatogonia (SSG), July Specimen x 380.

48.4: Showing dividing spermatogonia (SSG), in January x 600.

48.5: Showing primary spermatocytes at Synezesis Knot (SK) stage x 380 (GA, Germinal zone; L, Lumen; RSG, Residual spermatogonia; S, Sperms; TW, Tubular wall).

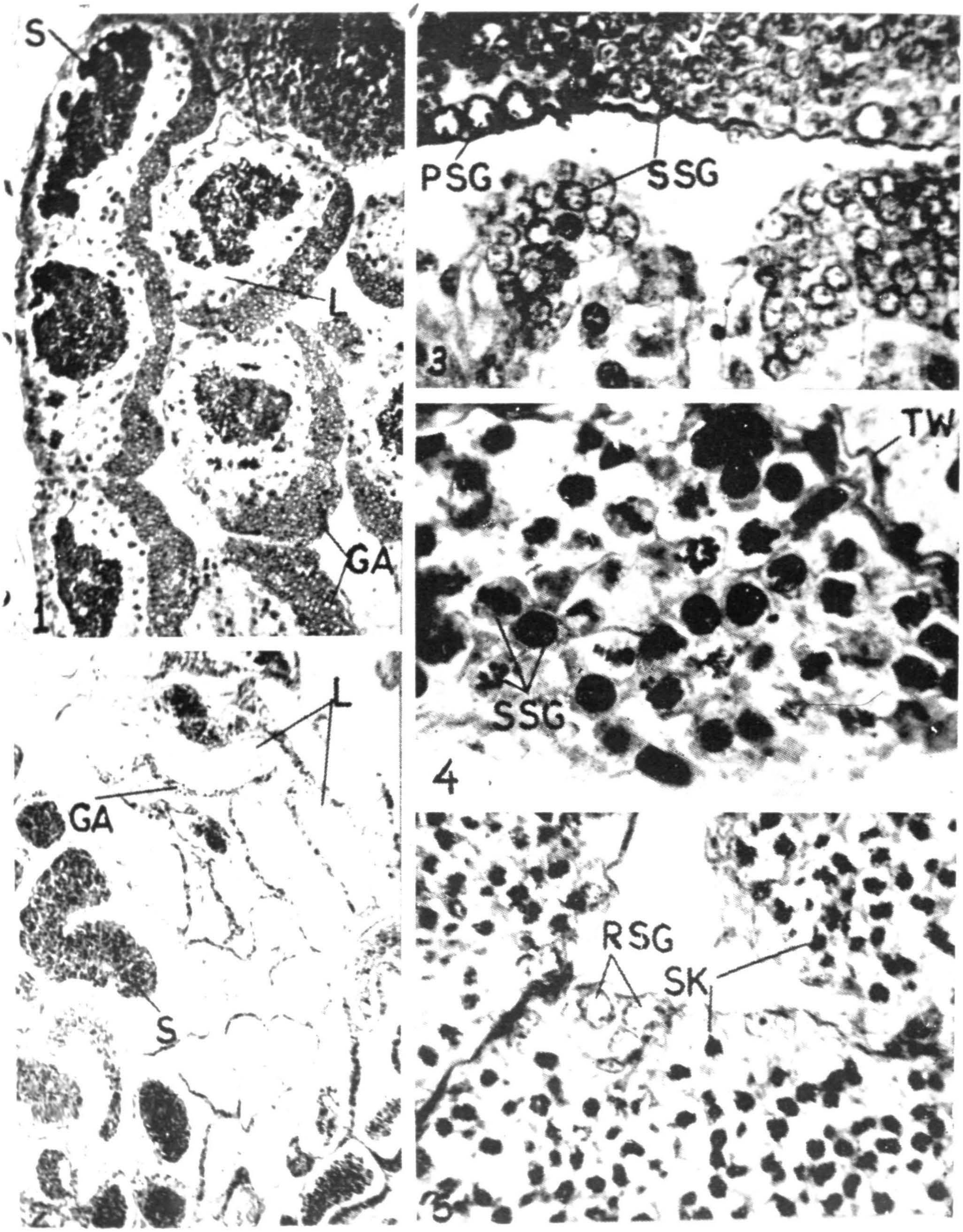


Fig. 48

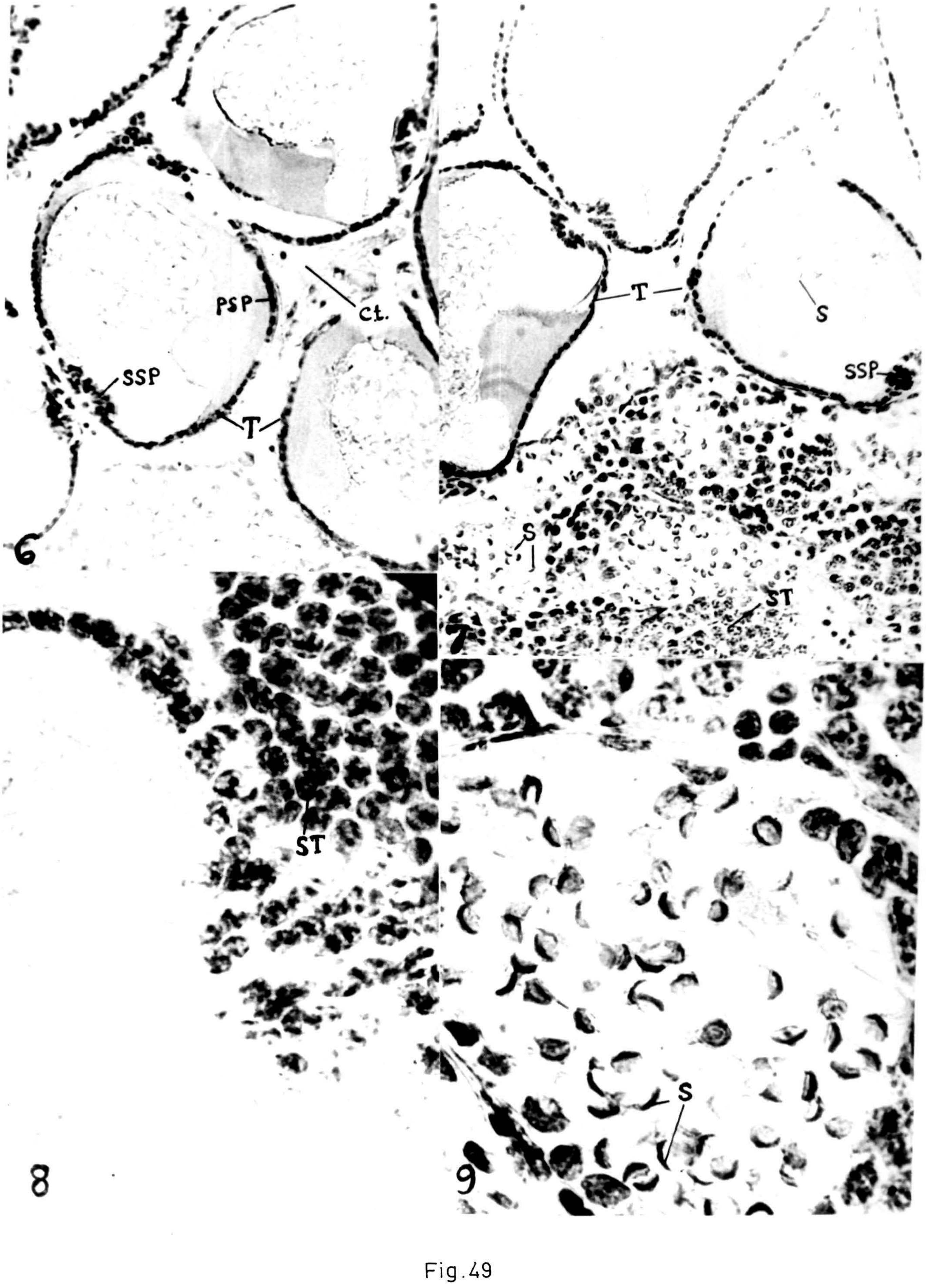


Fig.49

Fig. 50: Sections of testes of M. hendersoni hendersoni (de Man)

50.10: Showing stage I in July x 90.

50.11: Showing tubules filled with spermatogonia in December (Stage I) x 140.

50.12: Showing tubules packed with spermatids (ST) and sperms (S) in May (Stage III) x 90.

(L, lumen; PSP, Primary Spermatocytes; RS, residual sperms; SPG, Spermatogonia; T, tubules).

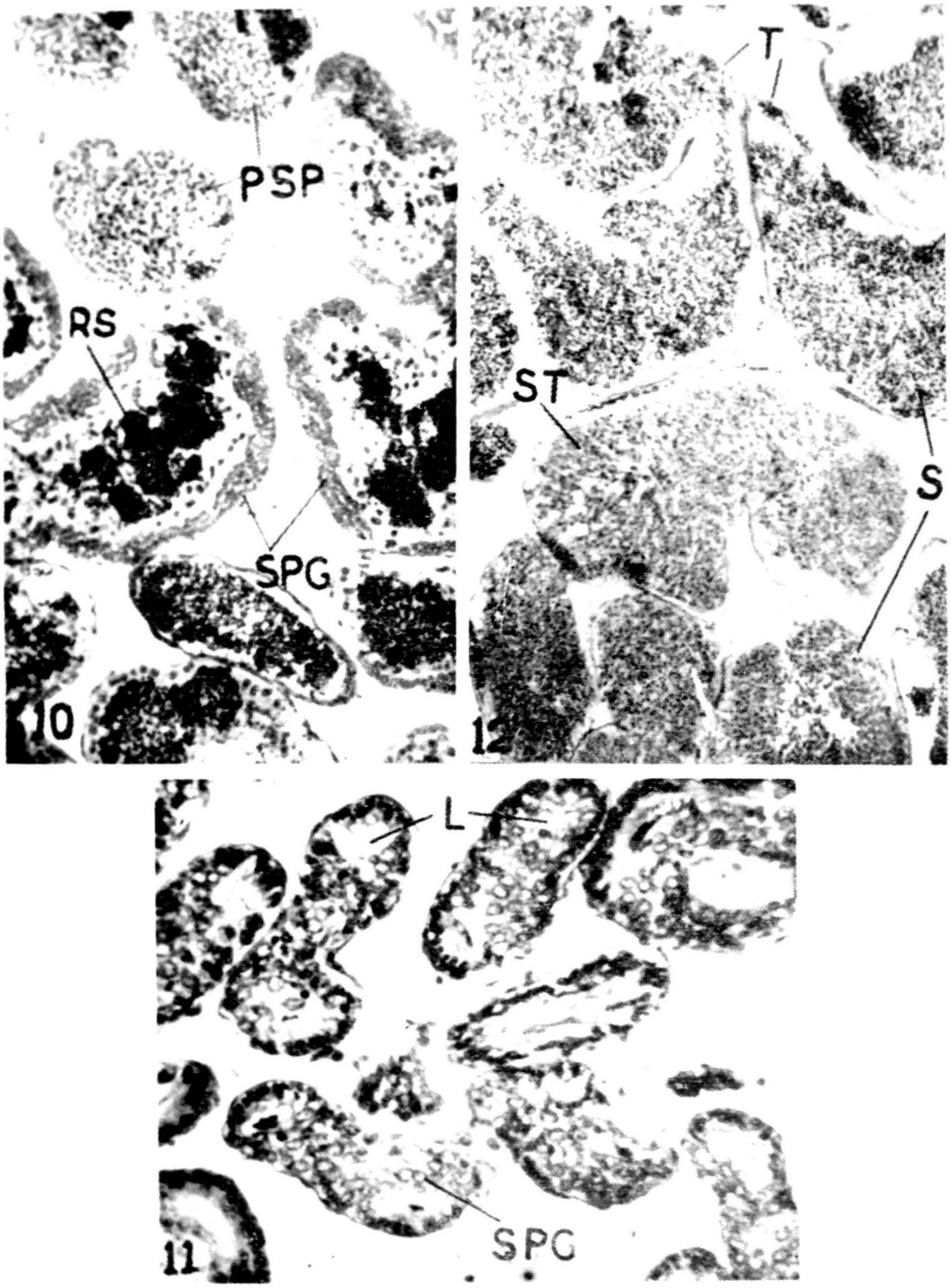


Fig. 50

Both maturing and mature tubules are seen in the same section. Maturing tubules consist of dividing primary or secondary spermatocytes or spermatids and produce sperms a little later. Mature tubules undergo spermination in May to June. Some of the tubules contain primary spermatogonia and residual sperms (Fig. 48.1). This indicates that spermiation has taken place. Almost all the specimens collected during September show spawned conditions in a number of tubules of their testes.

II. Female Gonad (Ovary):

II.a. Morphology:

The ovaries are paired and occupy the same relative position in the body of the female prawn as the testes in the male. The shape and size of the ovaries vary considerably according to the age of the prawn and the season of the year in which it is examined. In a mature female, outside the breeding season, the ovaries appear as compact sickle-shaped structures (Fig. 47D), closely approximating each other at both their anterior and posterior ends and leaving a gap in the middle for the passage of the cardio-pyloric strand. Like the testes, the ovaries extend anteriorly up to the renal sac and posteriorly up to the anterior margin of the first abdominal segment. In breeding season, however, the ovaries may extend into the first abdominal segment as well. Both the oviducts, are shorter in length but broader than the vasa deferentia. Each oviduct originates from the ovary at about the middle of its outer border and presents a large lumen at its commencement.

It then becomes narrow and pursues a vertically downward course, lying between the thoracic wall on the outer side and the flexor muscles of the abdomen on the inner (Fig. 47C). On reaching the ventral side of the body, each oviduct opens to the exterior on the inner side of the coxa of the third walking leg (Fig. 47C).

II.b. Histology:

The ovarian wall is continuous with ovarian stroma and is thicker during post-spawning period but becomes thin at maturing and mature stages of the ovary. Ovarian stroma consists of connective tissue, muscle fibres and blood vessels, and is abundant during post-spawning period but greatly reduced in mature ovaries (Fig. 51.1). A germinal zone is present all along the centre of the ovary (Figs. 51.1, 51.3). During early phase of maturation, the germinal zone consists of oogonia and young oocytes whereas the developing oocytes are displaced tow towards outer region of the ovary (Fig. 51.1). As maturity advances the germinal zones become greatly reduced consisting of a few residual oogonia, the rest of the ovary is filled with maturing oocytes. Ooplasm is heavily impregnated with large yolk globules and yolk vesicles.

II.c. Seasonal changes:

The annual ovarian cycle can be conveniently divided into following four stages on the basis of histomorphological features of ovaries:

i. Spawning and spent stage (May-September): During this period females carry their spawn attached onto their pleopods. Ovaries are small, smooth and cream coloured. Seminal receptacles contain sperms. Ovarian wall becomes thick and the germinal zone consists of numerous oogonia, premeiotic and previtellogenic oocytes. A few primary vitellogenic oocytes also develop at peripheral region of ovary.

ii. Early maturing stage (October-November): Ovaries increase in size and are coloured deep yellow. Externally they appear granular owing to the preponderance of primary and secondary vitellogenic oocytes in them. Germinal zone contains few residual oogonia and previtellogenic oocytes.

iii. Advanced maturing stage (December-February): Ovaries become enlarged, convoluted and orange in colour. Large orange ova bulge out on the surface of ovaries. Tertiary vitellogenic oocytes are commonly present but a few secondary ones also occur. Premeiotic and primary vitellogenic oocytes are rare in the ovaries.

iv. Mature stage (March-April): Ovaries attain a maximum size and deep orange mature ova are visible through the thin ovarian wall. The gonad index also reaches to a maximum value in April and is in conformity with the average ova-diameter (Fig. 54).

Fig. 51: Histology of female gonad of *M. hendersoni hendersoni* (de Man)

51.1: Transverse section of ovary, June specimen x 40.

51.2: Section passing through oviduct (OVD) x 40.

51.3: L.S. of ovary showing germinal zone (GZ) x 140.

51.4: Oogonium (OG) showing mitotic figure (MF), yolk droplets (YD) appear in peripheral ooplasm of primary vitellogenic oocyte (PVO) x 380.

51.5: Showing pre-meiotic oocyte in germinal zone x 380 (DF, discharge follicle; GZ, germinal zone; OG, Oogonia; OS, ovarian stroma; OV, ovary; OVW, ovarian wall; PMO, pre-meiotic oocytes; PO, pre-vitellogenic oocytes; PVO, primary vitellogenic oocytes; SK, Synezesis Knot; SR, Seminal receptacle).

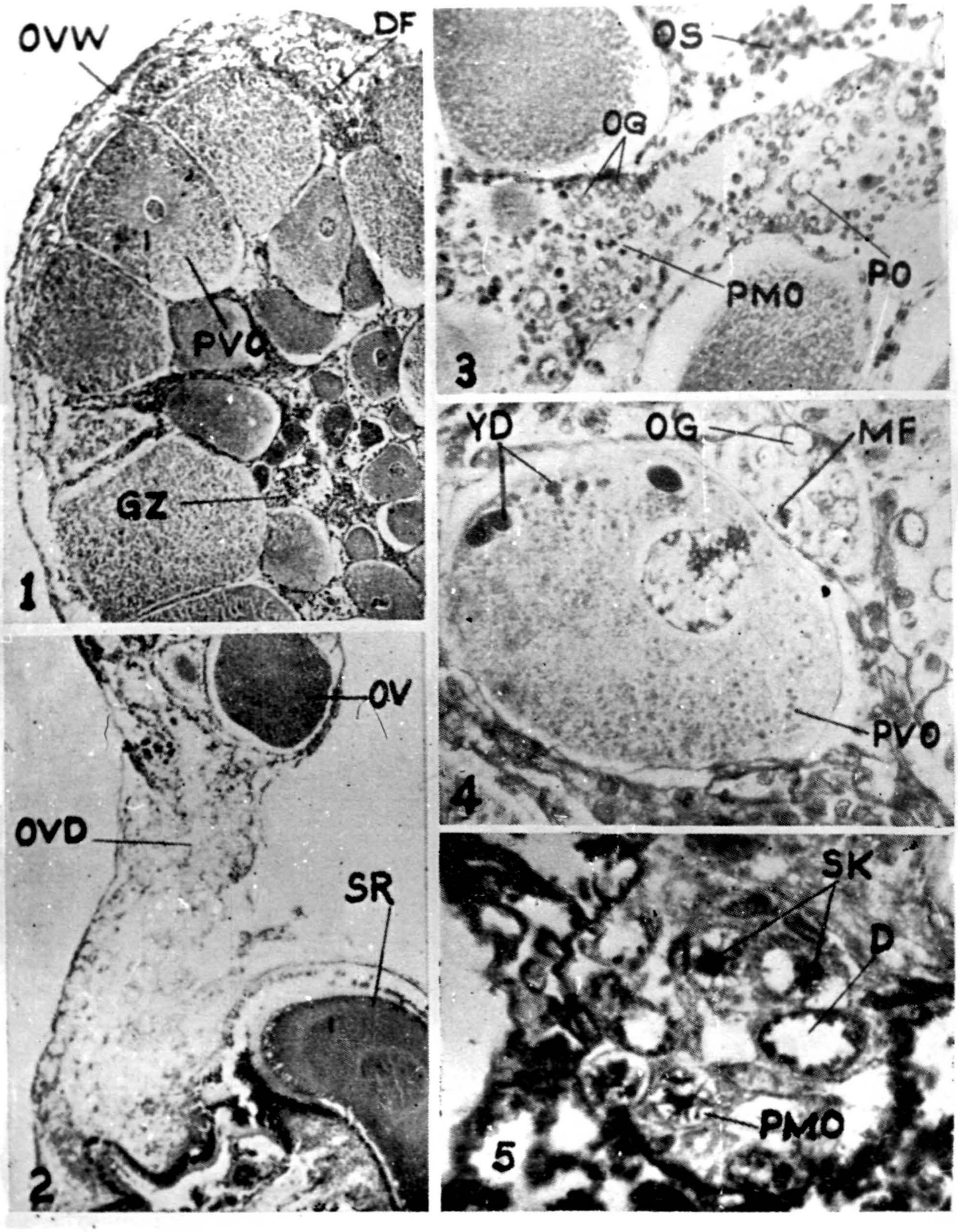


Fig. 51

Fig. 52: Histology of female gonad of M. *hendersoni hendersoni* (de Man)

52.6: Primary vitellogenic oocyte showing yolk droplets (YD) extended towards perinuclear region (PR). Displacement of nucleolus is due to mechanical disturbances during section cutting x 140.

52.7: An enlarged portion of above showing vacuoles (V) inside yolk droplets (YD) x 380.

52.8: Yolk granules (YG) and yolk vesicles (YV) in periphery of secondary vitellogenic oocyte x 70.

52.9: Vacuolation of yolk droplets (YD) to form yolk vesicles (YV) x 380.

52.10: Portion of secondary vitellogenic oocyte showing light yolk grannules (YG), dark yolk droplets (YD) and yolk vesicles (YV) x 380.

(DF, discharged follicle; FL, follicular layer; N, nucleus; VM, vitelline membrane).

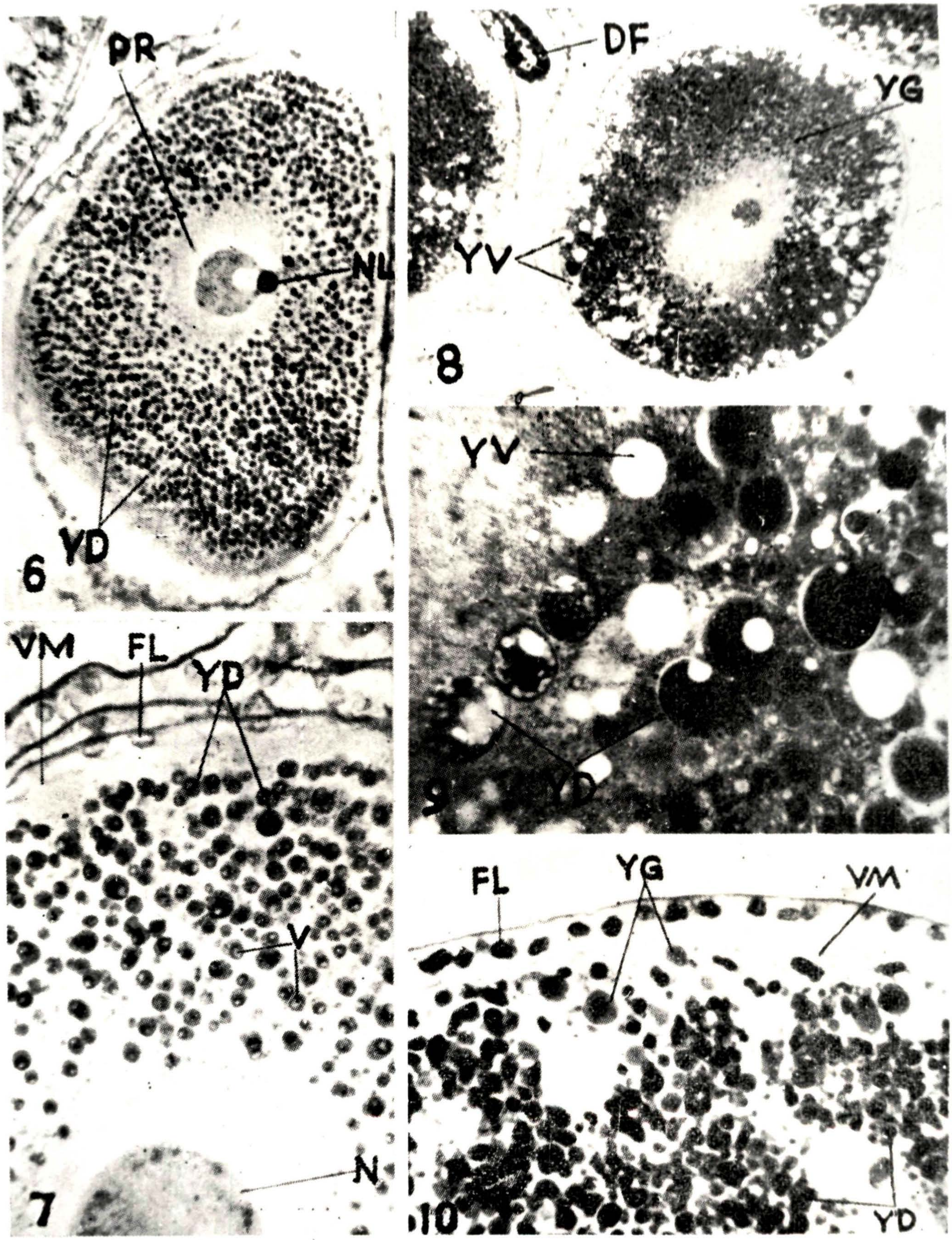


Fig.52

Fig. 53: Histology of the female gonad of M. hendersoni hendersoni (de Man)

53.11: Secondary vitellogenic oocyte showing vacuolation of yolk droplets (arrow). Perinuclear region is yolkless x 40.

53.12: Showing vacuolation (V) and eccentric position of nucleolus (NL) x 380.

53.13: Secondary vitellogenic oocyte showing yolk globules (YGL) and yolk vesicles (YV). Yolk droplets (YD) are in background x 60.

53.14: Tertiary vitellogenic oocyte filled with yolk globules (YGL) and yolk vesicles (YV). Perinuclear region (PR) is occupied by yolk x 60.

53.15: Ripe ovum filled with yolk globules (YGL) and yolk vesicles (YV) x 40.

(FL, follicular layer; NM, nuclear membrane; PR, perinuclear region; YG, yolk granules; YV, yolk vesicles).

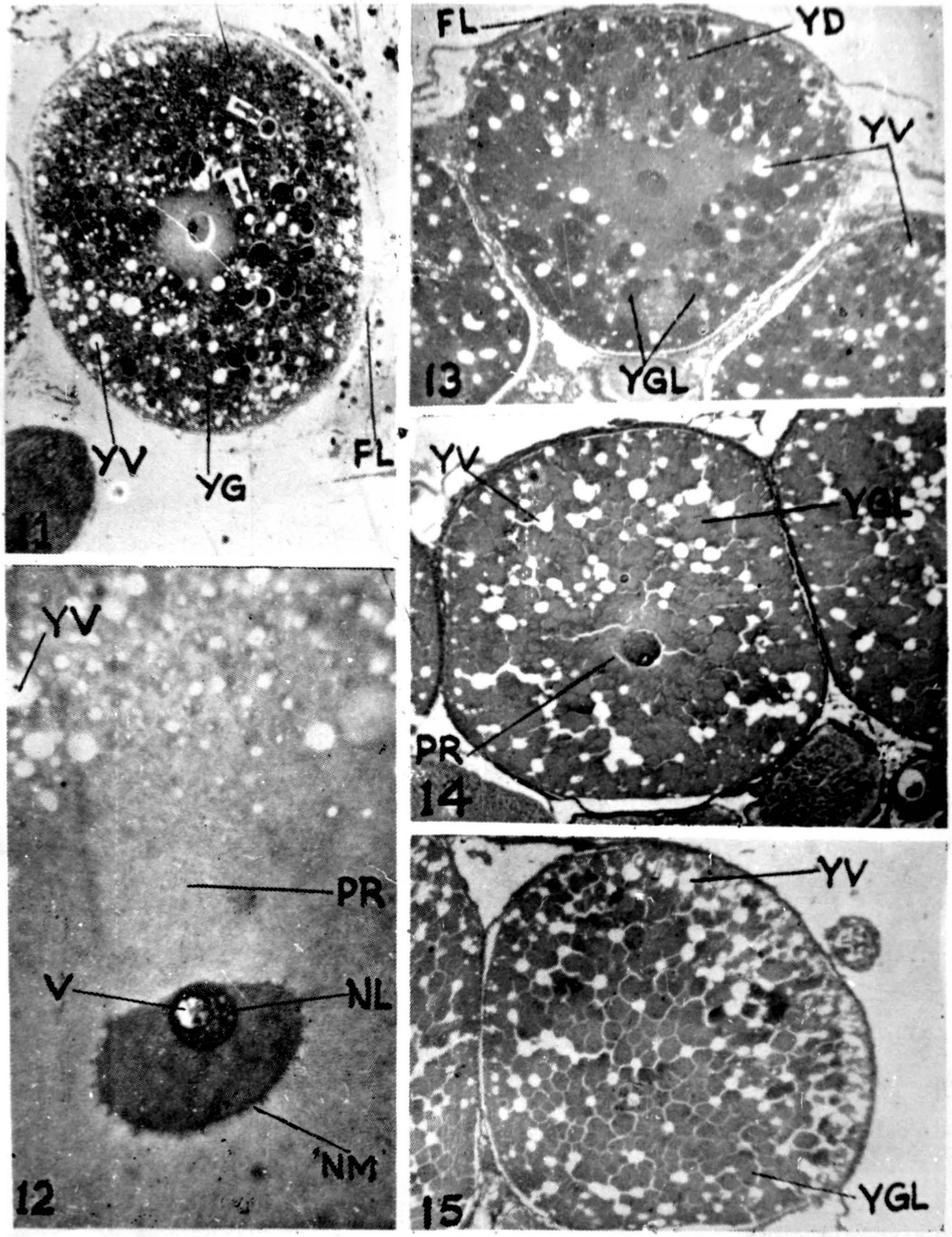


Fig.53

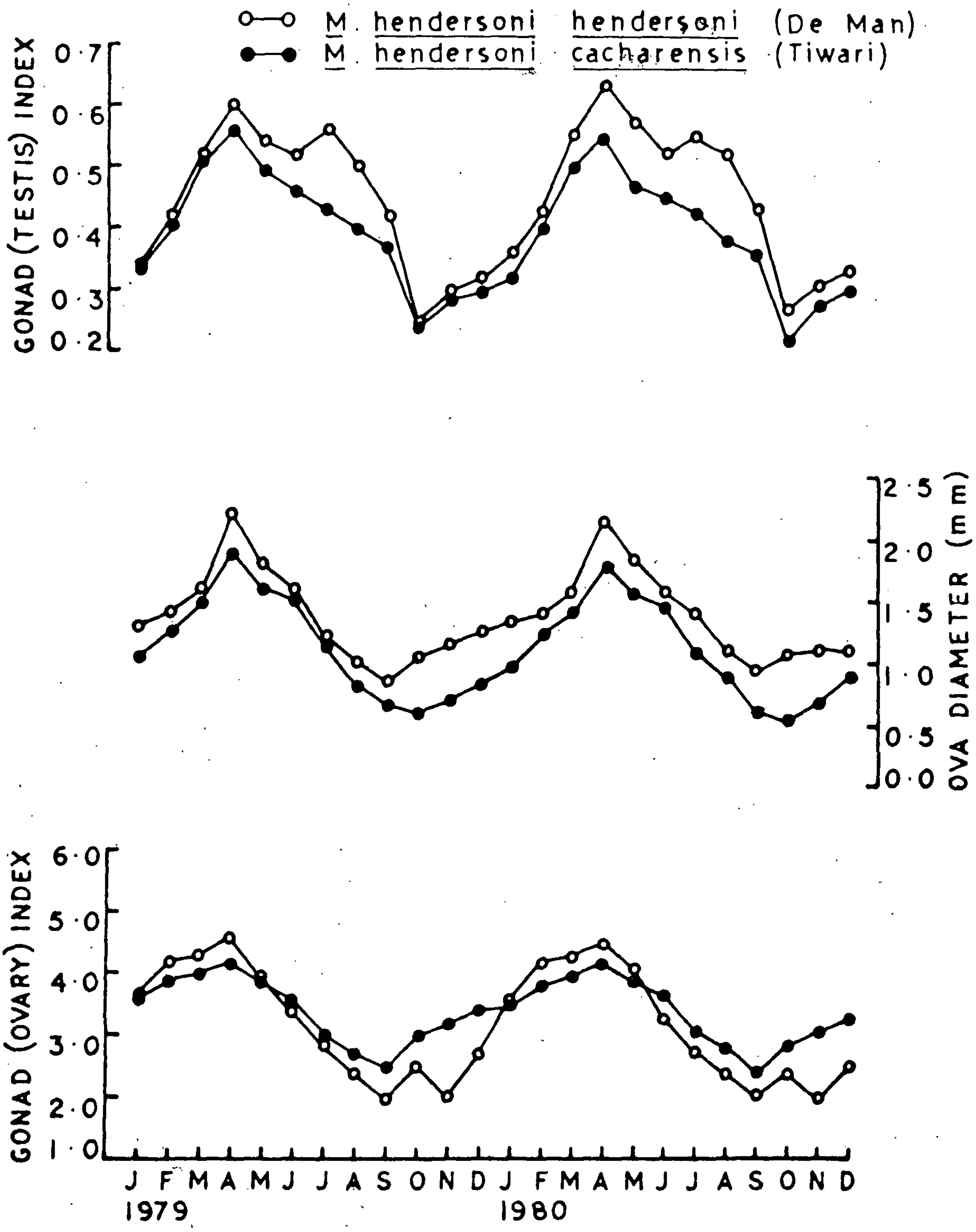


Fig.54 .Monthly fluctuations in the gonad index and ova diameter.

3.2.2. Gonad-Index (GI):

The gonad index which is an indicator of the state of maturity and gonadal development, has been calculated for males and females separately and has been presented in terms of their monthly fluctuations(Fig. 54). Gonad index is minimum in October-December and reaches a peak in April and is in conformity with the histomorphological changes in the gonads.

3.2.3. Size at first maturity:

In both M. hendersoni hendersoni and M. hendersoni cacharensis, maturity first appeared in specimens belonging to length group 35.1-40.0 mm (Table 23). However, male populations are found to encounter faster maturity than the females.

3.2.4. Courtship and mating:

In two instances, the courtship and mating behaviour involving both male and female prawn, M. hendersoni hendersoni in the laboratory aquarium was observed. At 09.30 hours the female moulted and started courtship behaviour at 10-45 hrs. (distinct post-moult swimming movement). Males attracted to females were hard shelled. Mating involved contact between the ventral sides of both male and female at different position.

3.2.5. Sex ratio and spawning:

The sex ratio of males: females during different periods of the breeding cycle which is arbitrarily divided into the pre-breeding months (January-March). Principal breeding months

Table 23: Matuity percentage at various length groups of the two palaemonid prawns

Size group (mm)	Sex	Immature		Maturing		Mature	
		A*	B**	A*	B**	A*	B**
15.0-20.0	m	100.0	100.0	-	-	-	-
	f	100.0	100.0	-	-	-	-
20.1-25.0	m	100.0	100.0	-	-	-	-
	f	100.0	100.0	-	-	-	-
25.1-30.0	m	85.0	75.0	15.0	25.0	-	-
	f	90.0	79.0	10.0	21.0	-	-
30.1-35.0	m	67.0	60.0	33.0	40.0	-	-
	f	71.6	66.0	28.4	34.0	-	-
35.1-40.0	m	20.0	-	52.0	60.0	28.0	40.0
	f	21.5	-	56.5	63.0	22.0	37.0
40.1-45.0	m	5.0	-	20.0	10.0	75.0	90.0
	f	7.6	-	24.0	12.0	68.4	88.0
45.1-50.0	m	-	-	7.0	-	93.0	100.0
	f	-	-	8.6	3.0	91.4	97.0
50.1-55.0	m	-	-	-	-	100.0	100.0
	f	-	-	-	-	100.0	100.0
55.1-60.0	m	-	-	-	-	100.0	100.0
	f	-	-	-	-	100.0	-
60.1-65.0	m	-	-	-	-	100.0	100.0
	f	-	-	-	-	100.0	100.0
65.1-70.0	m	-	-	-	-	100.0	100.0
	f	-	-	-	-	100.0	100.0
70.1-75.0	m	-	-	-	-	100.0	-
	f	-	-	-	-	100.0	-
75.1-80.0	m	-	-	-	-	100.0	-
	f	-	-	-	-	100.0	-

A* = Macrobrachium hendersoni hendersoni; B** = Macrobrachium hendersoni cacharensis. m = male; f = female.

Table 24: Percentage composition of breeding population of M. hendersoni hendersoni size group 40.0-55.0 mm in different periods of the breeding cycle

Breeding Cycle	Months	Station A_1			Station A_2			Station A_3		
		Frequency	Male (%)	Female (%)	Frequency	Male (%)	Female (%)	Frequency	Male (%)	Female (%)
Pre-Breeding	Jan.'79	4	100.0	00.0	6	83.3	16.7	3	100.0	00.0
	Feb.	12	83.3	16.7	9	77.8	22.2	2	100.0	00.0
	Mar.	14	78.5	21.5	15	80.0	20.0	5	80.0	20.0
Principal Breeding	Apr.	15	73.3	26.5	9	66.7	33.3	7	85.7	14.3
	May	14	57.1	42.9	15	53.3	46.7	7	71.4	28.6
	Jun.	16	62.5	37.5	16	62.5	37.5	6	66.7	33.3
	Jul.	20	70.0	30.0	21	61.9	38.1	9	66.7	33.3
	Aug.	21	71.4	28.6	17	64.7	35.3	10	80.0	20.0
	Sep.	22	72.7	27.3	14	71.4	28.6	13	69.2	30.8
Post Breeding	Oct.	9	77.8	22.2	14	78.6	21.4	9	77.8	22.2
	Nov.	16	81.3	18.7	19	78.9	21.1	3	100.0	00.0
	Dec.	6	100.0	00.0	9	88.9	11.1	4	75.0	25.0
Pre-Breeding	Jan.'80	6	83.3	16.7	8	87.5	12.5	7	85.7	14.3
	Feb.	14	78.6	21.4	10	80.0	20.0	9	77.8	22.2
	Mar.	16	75.0	25.0	14	78.6	21.4	13	76.9	23.1
Principal Breeding	Apr.	17	64.7	35.3	14	64.3	35.7	21	66.7	33.3
	May	15	73.3	26.7	17	70.6	29.4	24	58.3	41.7
	Jun.	17	64.7	35.3	18	50.0	50.0	15	60.0	40.0
	Jul.	25	66.7	33.3	23	43.4	56.6	21	66.7	33.3
	Aug.	22	68.2	31.8	18	61.1	38.9	21	71.4	28.6
	Sep.	25	76.0	24.0	17	64.7	35.3	25	72.0	28.0
Post Breeding	Oct.	12	83.3	16.7	14	71.4	28.6	13	84.6	15.4
	Nov.	16	81.3	18.7	15	80.0	20.0	12	85.9	16.1
	Dec.	9	77.8	22.2	11	81.8	18.2	5	80.0	20.0

Table 25: Percentage composition offbreeding population of <u>M.</u> <u>hendersoni</u> <u>cacharensis</u> size group 40.1-50.0 mm in different periods of the breeding cycle

Breeding Cycle	Months	Station B_1			Station B_2			Station B_3		
		Frequency	Male (%)	Female (%)	Frequency	Male (%)	Female (%)	Frequency	Male (%)	Female (%)
Pre-Breeding	Jan.'79	5	80.0	20.0	7	85.7	14.3	7	85.7	14.3
	Feb.	9	77.8	22.2	14	78.6	21.4	13	84.6	16.4
	Mar.	11	72.7	27.3	18	77.8	22.2	18	83.3	16.7
Principal Breeding	Apr.	14	64.3	35.7	19	73.6	26.4	21	81.0	19.0
	May	13	69.2	30.8	22	72.7	27.3	24	75.0	25.0
	Jun.	18	55.6	44.4	23	65.2	34.8	25	64.0	36.0
	Jul.	12	66.7	33.7	24	70.8	29.2	25	72.0	28.0
	Aug.	14	71.4	28.6	35	71.4	28.6	35	71.4	28.6
	Sep.	17	76.5	23.5	35	71.4	28.6	36	69.4	30.6
Post Breeding	Oct.	7	71.4	28.6	11	72.7	27.3	12	75.0	25.0
	Nov.	10	100.0	00.0	13	77.0	23.0	18.	83.3	16.7
	Dec.	14	85.7	14.3	11	90.9	9.1	14	85.7	14.3
Pre-Breeding	Jan.'80	5	80.0	20.0	7	85.7	14.3	7	100.0	00.0
	Feb.	11	81.8	18.2	14	85.7	14.3	14	78.5	21.5
	Mar.	12	83.3	16.7	17	82.3	17.7	19	89.5	10.5
Principal Breeding	Apr.	11	72.7	27.3	19	78.9	21.1	22	72.7	27.3
	May	16	68.8	31.2	13	69.2	30.8	25	64.0	36.0
	Jun.	18	66.7	33.3	18	61.1	38.9	27	66.7	33.3
	Jul.	12	72.2	27.8	23	69.5	30.5	25	72.0	28.0
	Aug.	14	64.3	35.7	43	76.7	23.3	36	69.4	30.6
	Sep.	18	72.2	27.8	35	71.4	28.6	34	73.5	26.5
Post Breeding	Oct.	7	71.4	28.6	12	75.0	25.0	13	76.9	23.1
	Nov.	10	80.0	20.0	12	83.3	16.7	14	78.6	21.4
	Dec.	15	86.7	13.3	10	90.0	10.0	15	93.3	6.7

(April-September) and post-breeding months (October-December) is given in tables 24 and 25. In general, during the pre-breeding season the ratio of males to females is quite higher in both *M. hendersoni hendersoni* and *M. hendersoni cacharensis*. During the breeding season, the percentage composition of female comparatively increases to certain extent (Tables 24, 25).

The cycle of maturation and seasonal gonad index values provided good indications of the extent of development of ovaries with respect to the time of the year. The presence of ovigerous setae and deep pleura among the females are treated as sign of active spawners. In *M. hendersoni hendersoni*, the spawning period starts from the month of April to September while in *M. hendersoni cacharensis*, it continued from April to October (Tables 24, 25). The factors contibuting to the larger spawning period, is the maturation of continuous batches of ova throughout the season.

3.3. BROOD SIZE AND REPRODUCTIVE EFFORTS:

The maximum brood size recorded for *M. hendersoni hendersoni* and *M. hendersoni cacharensis* was 61 and 74 respectively. The sizes of eggs in the advanced developmental stages are larger than those of the earlier stages. Three such stages of eggs are recognised:

Stage I: Soon after spawning: Eggs dark green in colour. In some, hexagonal markings and oil globules present. Eyes absent.

Stage II: Streaks of pigmented (pitted) eyes noticed in the embryo. Eggs light green in colour.

Stage III: The egg turned yellowish green with developed eyes, Occasional jerky movement of the embryo noticed just before hatching.

The egg sizes of *M. hendersoni hendersoni* are found to be larger than *M. hendersoni cacharensis*. The log of brood size shows significant positive linear correlations with the log of body length, weight, pleuron width, ovigerous setae number, ovipositing setae number and pre-eyed egg volume (Table 26). In *M. hendersoni hendersoni*, log of brood size also exhibited positively significant correlations with the eye pitted egg volume and eyed egg volume but these r-values were found to be **marginal** in *M. hendersoni cacharensis* (Table 26). The observed brood size number against observed body length, body weight, pleuron width, ovigerous and ovipositing setae number, pre-eyed, eye pitted and eyed egg volume are plotted and their parabolic relationship has been obtained (Figs. 55, 56, 57 .

The log of relative brood size exhibited negative correlations with the log of respective body weight, pre-eyed, eye pitted and eyed egg volume (Table 26). The observed values of relative brood size is plotted against respective relative brood weight, pre-eyed, eye pitted and eyed egg volume and their parabolic relationship has been obtained (Figs. 56, 58).

Table 26: Regression equations (Log Y = Log a + b Log X) and their co-efficient correlations (r-values) of certain biological parameters of the berried prawn populations

Parameters	*M. hendersoni hendersoni*	*M. hendersoni cacharensis*
Brood size (Y) Total body length(X)	Log Y=0.3288+0.8237 Log X (r=0.8237)	Log Y=0.2695+0.9436 Log X (r=0.9782)
Brood size (Y) Body weight (X)	Log Y=1.5437+0.8235 Log X (r=0.9892)	Log Y=1.6664+0.9504 Log X (r=0.9803)
Brood size (Y) Pleuron width(X)	Log Y=1.9728+0.9952 Log X (r=0.9884)	Log Y=1.9542+0.8581 Log X (r=0.9517)
Brood size (Y) Ovigerous Setae number (X)	Log Y=0.2551+0.9078 Log X (r=0.9528)	Log Y=0.3077+0.9356 Log X (r=0.9831)
Brood size (Y) Ovipositing setae number (X)	Log Y=-0.0501+0.9590Log X (r=0.9916)	Log Y=0.1795+0.8862 Log X (r=0.9884)
Brood size (Y) Pre eyed egg Volume (X)	Log Y=1.3885+0.3878Log X (r=0.6281)	Log Y=1.6747+0.2631 Log X (r=0.4992)
Brood size (Y) Eye pitted egg volume (X)	Log Y=1.331+0.4121 Log X (r=0.6122)	Log Y=1.6695+0.2317 Log X (r=0.4694)
Brood size (Y) Eyed egg volume(X)	Log Y=1.2189+0.4657 Log X (r=0.6252)	Log Y=1.6568+0.2541 Log X (r=0.4568)
Brood size (Y) Relative brood size(X)	Log Y=7.4248-3.8201 Log X (r=-0.8217)	Log Y=9.6029-4.7957 Log X (r=-0.5277)
Brood size (Y) Relative brood weight(X)	Log Y=-3.0035-3.8105Log X (r=-0.8284)	Log Y=1.8422+0.1552 Log X (r=-0.5209)
Relative brood size(Y) Body weight(X)	Log Y=1.5437-0.1766 Log X (r=-0.8213)	Log Y=1.6664-0.0494 Log X (r=-0.5143)
Relative brood size (Y) Pre-eyed egg Volume(X)	Log Y=1.6081-0.1251 Log X (r=-0.7845)	Log Y=1.6938-0.06231 Log X (r=-0.8467)
Relative brood size (Y) Eye pitted egg volume(X)	Log Y=1.6275-0.1348 Log X (r=-0.7754)	Log Y=1.6995-0.0631 Log X (r=-0.8489)
Relative brood size (Y) eyed egg volume(X)	Log Y=1.6626-0.1500 Log X (r=-0.7799)	Log Y=1.7077-0.0655 Log X (r=-0.8471)

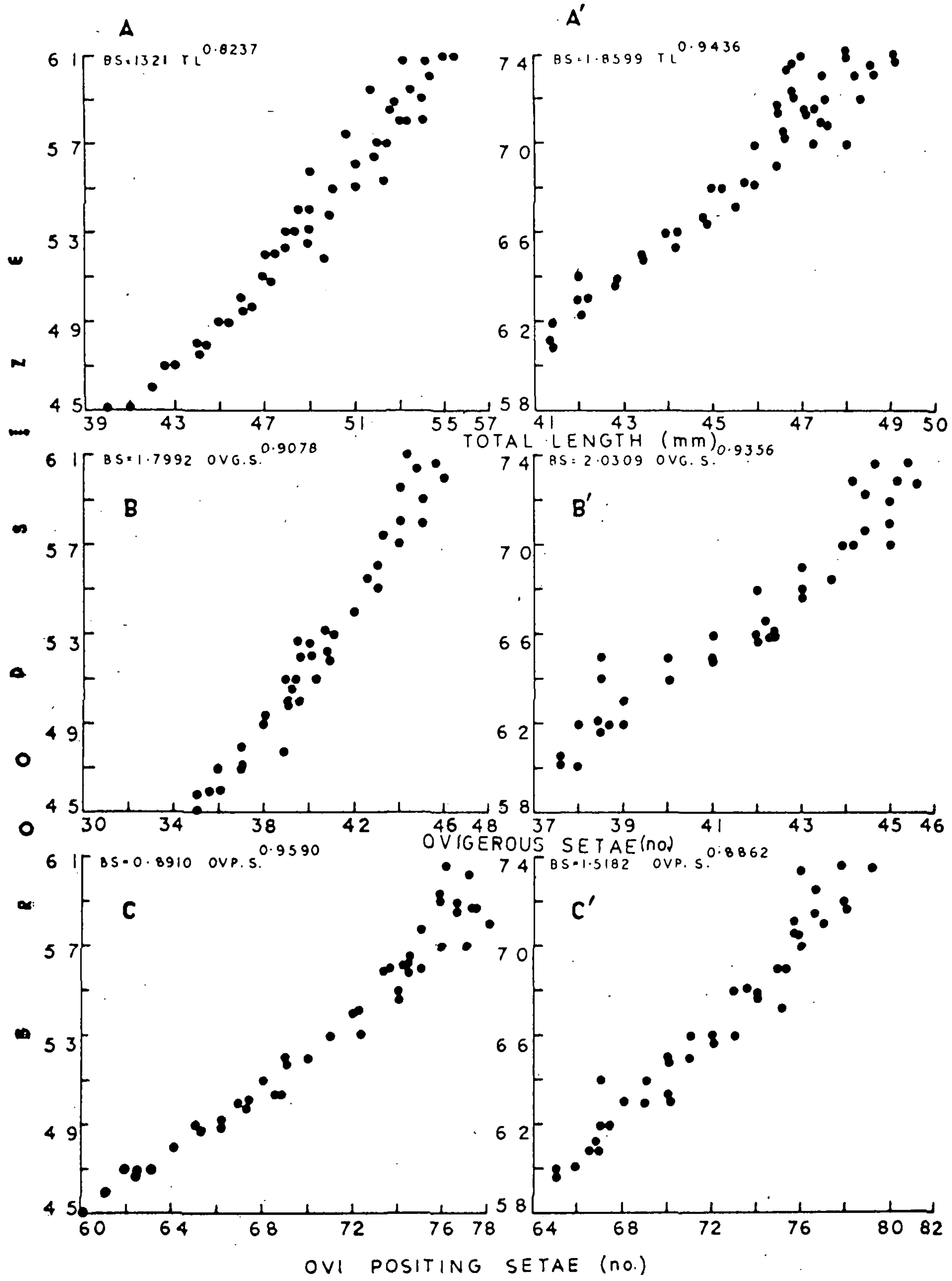


Fig.55 . Relationship of brood size to total length, ovigerous setae and ovipositing setae of *M. hendersoni hendersoni* (A,B,C) and *M. hendersoni cacharensis* (A′, B′, C′).

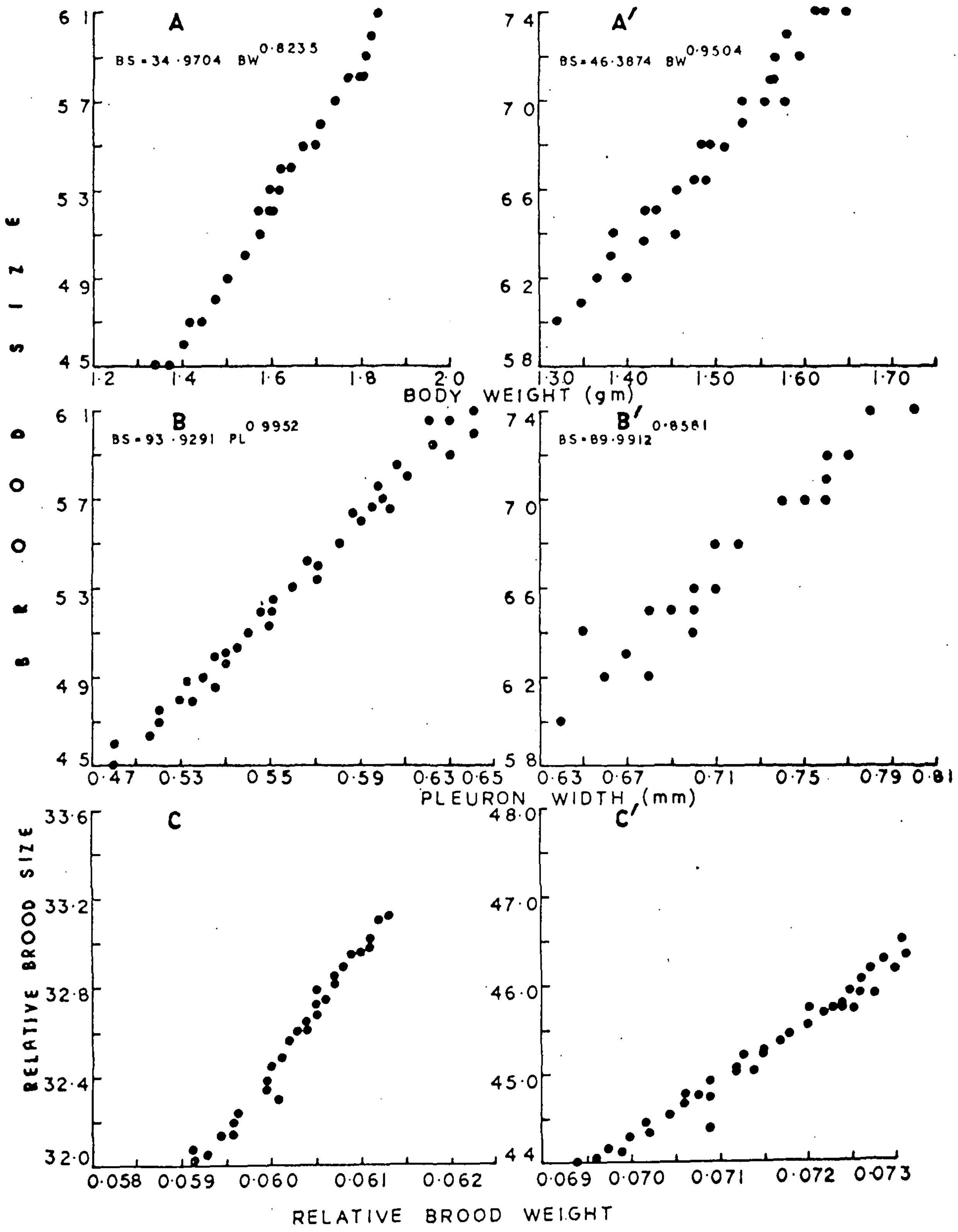


Fig.56. Relationship of brood size to body weight, pleuron width and relative brood size to relative brood weight of M. hendersoni hendersoni (A,B,C) and M. hendersoni cacharensis (A', B', C').

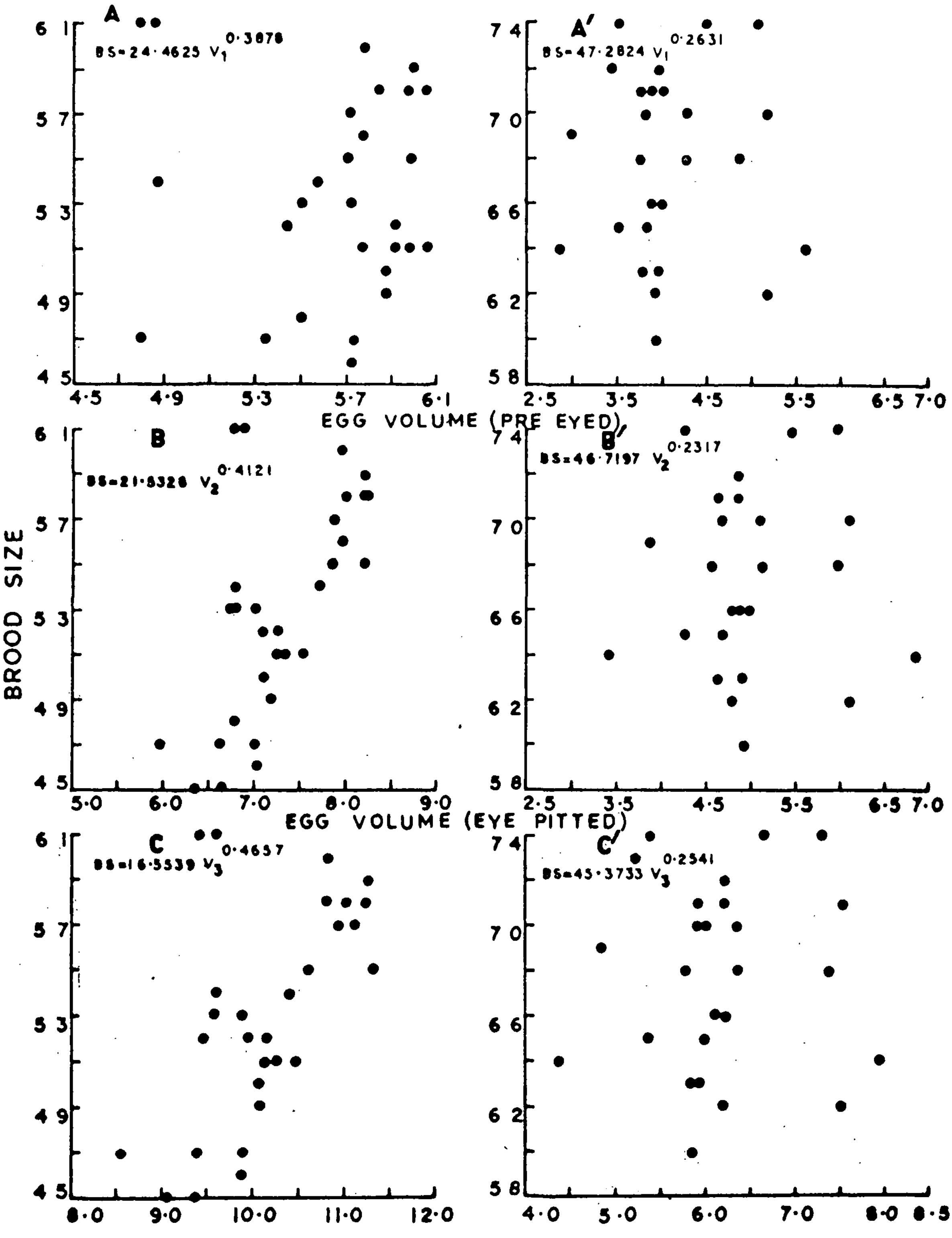


Fig. 57 . Relationship of brood size to pre-eyed, eye-pitted and eyed egg volume of *M. hendersoni hendersoni* (A,B,C) and *M. hendersoni cacharensis* (A′,B′,C′) .

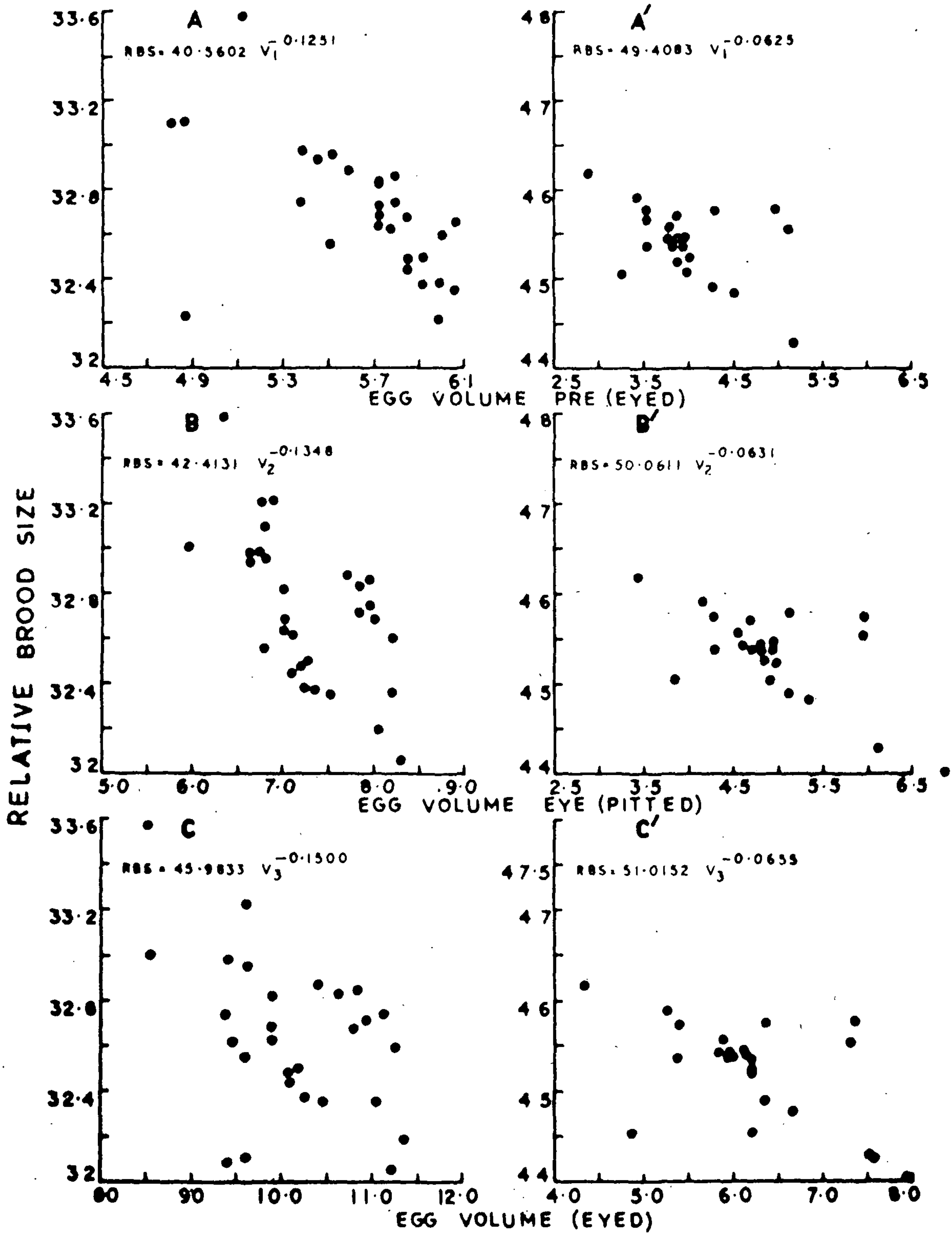


Fig. 58. Relationship of relative brood size to pre-eyed, eye-pitted and eyed egg of *M. hendersoni hendersoni* (A, B, C) and *M. hendersoni cacharensis* (A′, B′, C′).

3.4. LARVAL DEVELOPMENT:

In berried females, the pleopods showed constant movements. Though no records were maintained of the frequency of movements, it appeared that there was an increase in the rate of pleopod movements as the time for hatching came nearer. Feeding of the berried females was necessary. In some cases, where the female were not supplied with food there was no hatching.

3.4.1. Hatching:

Hatching was a very slow and gradual process, only six or seven larvae hatched at a time and about ten to fifteen larvae per day which continued over a period of three to twelve days. Comparatively, M. hendersoni hendersoni took a longer period for hatching than M. hendersoni cacharensis. On emergence through a "tear" in the egg membrane, the larvae were observed to crawl rather than swim unlike the zoeal stages of other caridean prawns. An interesting feature was, the larvae immediately on hatching, were observed to be clinging to the body of the mother on various parts like pleopods, abdomen, carapace, rostrum etc. This tendency of clinging to the mother continued for sometime, after which they were observed to dart away either on their own accord or when disturbed. But, in case of M. hendersoni cacharensis, the situation varied to some extent, some of the larvae passively sank to the bottom of the vessel but within a few minutes they started swimming, sheltering along the sides of the container.

In both the palaemonid prawns, M. hendersoni hendersoni and M. hendersoni cacharensis, it was interesting to observe that like in adults, the chelate legs, particularly the conspicuously large second legs, were used in feeding activities of the larvae. There were some seasonal variations in hatching period. The eggs of berried females of M. hendersoni hendersoni of May 1980 batch took 4 to 6 days to hatch after extrusion but in females that came in berry in late September 1980, the hatching period varied from 3 to 8 days. In case of M. hendersoni cacharensis, the eggs of berried females of May 1980 batch took 5 days to hatch after extrusion but in September 1980 group, the hatching period varied from 3 to 10 days.

3.4.2. Description of larval stages:

In: MACROBRACHIUM HENDERSONI HENDERSONI (de MAN):

I. First larval stage (Fig. 59)

Carapace length = 3.3 mm; Abdominal length = 4.3 mm

Description (Fig. 59): Carapace smooth except for a prominent antennal spine followed posteriorly by a smaller spine which probably represents the future hepatic spine, though situated somewhat like branchiostegeal; Rostrum serrated, reaching almost to the end of antennular peduncle and with fine setae in between the teeth on either margins; Mid-rib prominent and slightly curved. Rostral formula 6/2; No postorbital teeth. Eyes large, stalked, completely free from carapace unlike the sessile eyes of the first stage of other known larvae of the genus, Macrobrachium.

Antennule (Fig.59.d): As in adult, peduncle 3-segmented; both stylocerite and antero-lateral spines prominent, sharply pointed; Basal segment with a ventral spine pointing anteriorly. Statocyst without any statoliths, but its region demarcated by small bristles. Inner flagellum 9 segmented; outer flagellum with 2 basal segments fused and of its 2 branches, the smaller branch 2 segmented and tipped with 2 aesthetascs while the longer branch with 12 segments bearing minute setae. The aesthetascs are peculiarly shaped, like the corn of the millet.

Antenna (Fig.59.e): 3 segmented peduncle; well developed scale and long flagellum (consisting about 40 segments); spine of the bascecerite blunt; antennal peduncle (endopod) carrying plumose setae.

Mandible (Fig.59.f): Incisor and molar processes are well developed; the former with 2-3 blunt teeth, while the latter still a blunt projection unlike the toothed process of the adult. Palp absent.

Maxilla I (Fig. 59.g): Structurally like that of adult, but the coxal and basal endites with 1 and 3 large + 2 small teeth respectively; distinctly bilobed palp, the upper lobe narrow and tubular while the lower broader, bearing a small seta.

Maxilla II (Fig.59.h): Like in adult except for the endites being less setose, coxal with 4 and basal with 7 denticles. Palp with one small marginal seta; scaphognathite fringed with about

42 plumose setae.

All three maxillipeds resemble those of adult but the flagellar portion of exopods still retains long plumose netatory setae.

Maxilliped I (Fig. 59.i): The two endites of portopod large and armed with only a few small tuburoles. Endopod or palp unsegmented, reaching upto scale-like basal portion of exopod. Flageller portion of exopod with 4 long, plumose, terminal setae. Epipod though bilobed, more elongated than in adult.

Maxilliped II (Fig. 59.j): Endopod 5 segmented, incurved, exopod flagellar with 4 netatory setae; Future podobranch represented by gill bud.

Maxilliped III (Fig. 59.k): Endopod less setose than in adult. Exopod with 4 netatory setae, reaching to the tip of the basal segment of endopod. A rudimentary epipod present.

Pereiopods (Figs. 59.l-p): Resemble those of adults; 1st and 2nd pairs chelate, smooth except for presence of a few setae, 1st being much smaller than the 2nd. 2nd cheliped like in adults prominently larger than all the remaining pereiopods. 3rd to 5th pereiopods similar, with a narrow pointed dactylus but the terminal spines being much longer than in adults; also propodal spines of adult yet to develop; rudimentary pleurobranches present one each on all pereiopods.

Abdomen (Fig. 59.a): 6-segmented; 1st to 5th segments smooth, but 5th with 2 delicate hairs postero-laterally; 6th with the dorsolateral spines of adult in addition to 2 characteristic short plumose setae posteriorly.

Pleopods (Fig. 59.r-t): Five pairs of pleopods on 1st to 5th segments; 1st pleopod as in adult with rudimentary endopod, about 1/3 of exopod in length and with only 1-2 setae; 2nd to 5th with endopods reaching more than 2/3 of exopod and bearing 5-8 setae each. A distinct appendix interna bearing 3-4 minute hooks on all pleopods except the 1st; Exopod setae 7-9 on 1st and 10-15 on remaining pleopods.

Telson (Fig. 59.q): Characteristic, almost zoeal, but having a broadly rounded posterior margin with a very faint median notch. Process formula = 10 to 13 + 10 to 13. Uropods are represented only as buds seen through the telson cuticle.

Chromatophores: The larva appears yellowish-brown in colour with numerous orange-red stellate chromatophores densely scattered all over the body. In addition, the larva has the following chromatophores: Orange-red reticulate profusely distributed on the eye stalks and at the base of fingers of 2nd pereiopods; violet-brownish red reticulate forming a dense transverse stripe dorsally in posterior half of 3rd abdominal segment; light-brownish reticulate ventrally between the pleopods of either side and diffused deep violet-brown at the junction of eyes and carapace.

Time for 1st moult: 2 days in observation I (May, 1980) and 2-3 days in observation II (September, 1980).

II. Second larval stage (Post larva):

Carapace length: 3.7 mm; Abdominal length: 4.8 mm.

Description (Fig. 60.a): Rostrum more setose than in 1st stage particularly on lower margin, rostral formula 7/2; Eyes large with cylindrical stalks and completely force from carapace; The density of the chromatophores decreased.

Antennule (Fig. 60.d): With 2 fused basal segments of outer flagellum; statocyst more expanded.

Antenna (Fig. 60.e): External spine of basicerite now more sharp and prominent resembling that of adult. Flagellum with addition of 5-6 segments.

Mandible (Fig. 60.f): With 4 sharp sub-equal teeth on incisor and 2-3 blunt tooth like projections on molar process; palp not yet developed.

Maxillae and maxillipeds (Figs. 60.g-k): Become more setose like in adult.

Pereiopods (Figs. 60.l-p): No appreciable change except for propodus of last 3 legs now bearing more delicate spines on its posterior margin.

Abdomen (Fig. 60.a): 6th segment now with 3 pairs of posterolateral setae. Practically no change in pleopods.

Telson (Fig. 60.q): Still unlike that of adult; long, narrow, rectangular with slightly convex posterior margin. Of the 20-26 processes in previous stage, the first 8 now become spines gradually increasing in size distalwards and shifted on either lateral margin. Posterior margin with 15 plumose setae.

Uropods (Fig. 60.q): Well-developed and functional protopod with a sharp spine. Both rami almost equal reaching to the tip of telson; a terminal tooth with a movable accessory spine on its inner side on outer ramus.

Time for 2nd moult: 2-4 days in observation I (May, 1980) and 3-5 days in observation II (September, 1980).

III. Juvenile stage (Fig. 61):
Carapace length: 4.0 mm; Abdominal length: 5.2 mm.
Description (Fig. 61.a & c): No change in rostrum; the future hepatic spine shifted little upwards towards antennal spine; eyes unchanged.

Antennule (Fig. 61.d): Flageller segments increased in number 13 on the inner; 14 on longer branch of outer. Smaller branch of outer flagellum with 4 aesthetascs arranged.

Antenna (Fig. 61.e): No change except for increase in number of flageller segments to about 46.

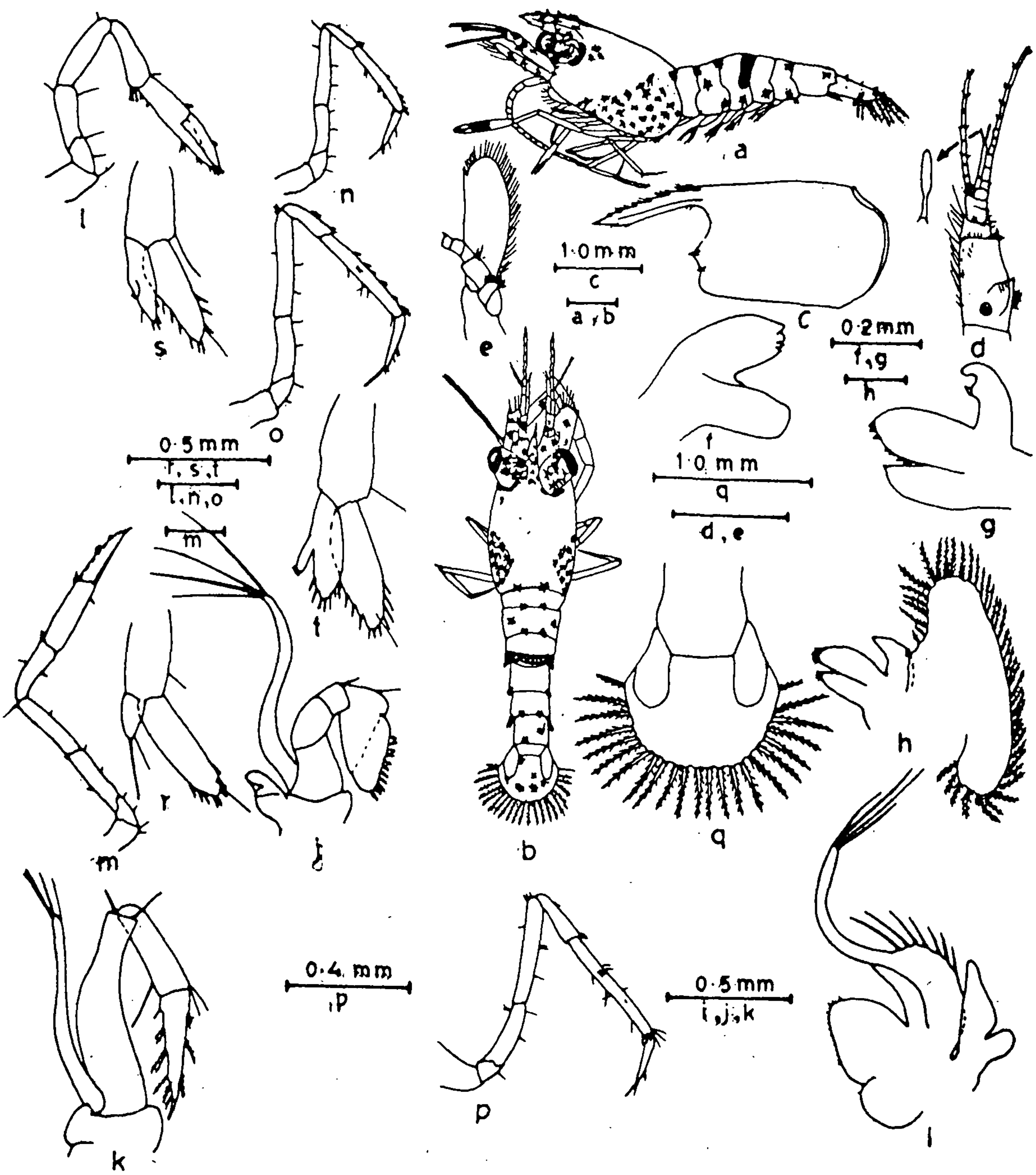


Fig.59 First larval stage of M. hendersoni hendersoni (De Man)

(a, lateral view; b, dorsal view; c, carapace; d, antennule; e, antenna; f, mandible; g, 1st maxilla; h, second maxilla; i, 1st maxilliped; j, second maxilliped; k, third maxilliped; l, m, n, o, p : 1st to fifth pereiopod; q, telson/ telson with uropod; r, s, t : 1st, second and fifth pleopod).

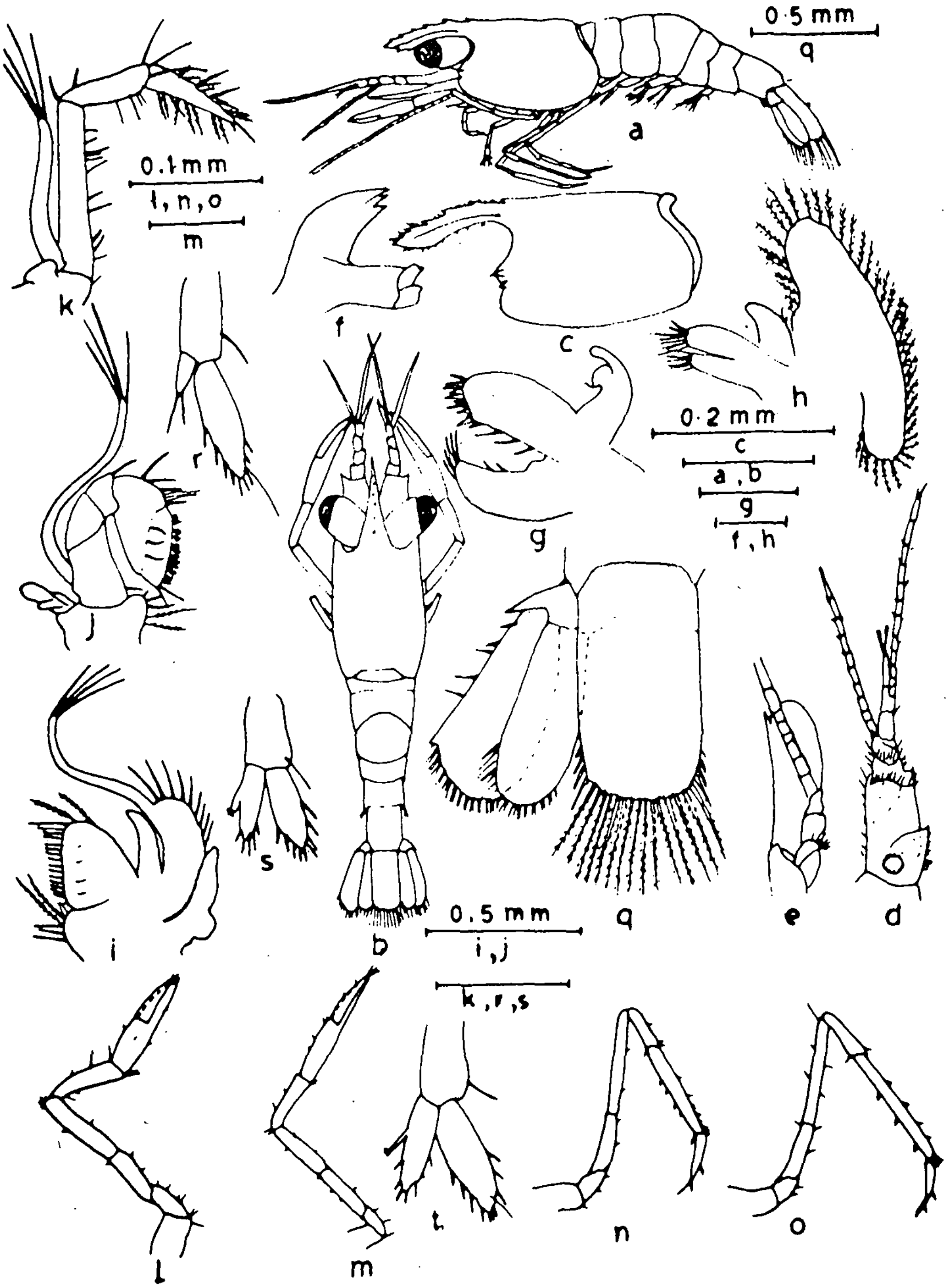


Fig.60 Second larval stage (Post larva) of *M. hendersoni hendersoni* (De Man)

(a, lateral view; b, dorsal view; c, carapace; d, antennule; e, antenna; f, mandible; g, 1st maxilla; h, second maxilla; i, 1st maxilliped; j, second maxilliped; k, third maxilliped; l, m, n, o, p : 1st to fifth pereiopod; q, telson/ telson with uropod; r, s, t : 1st, second and fifth pleopod).

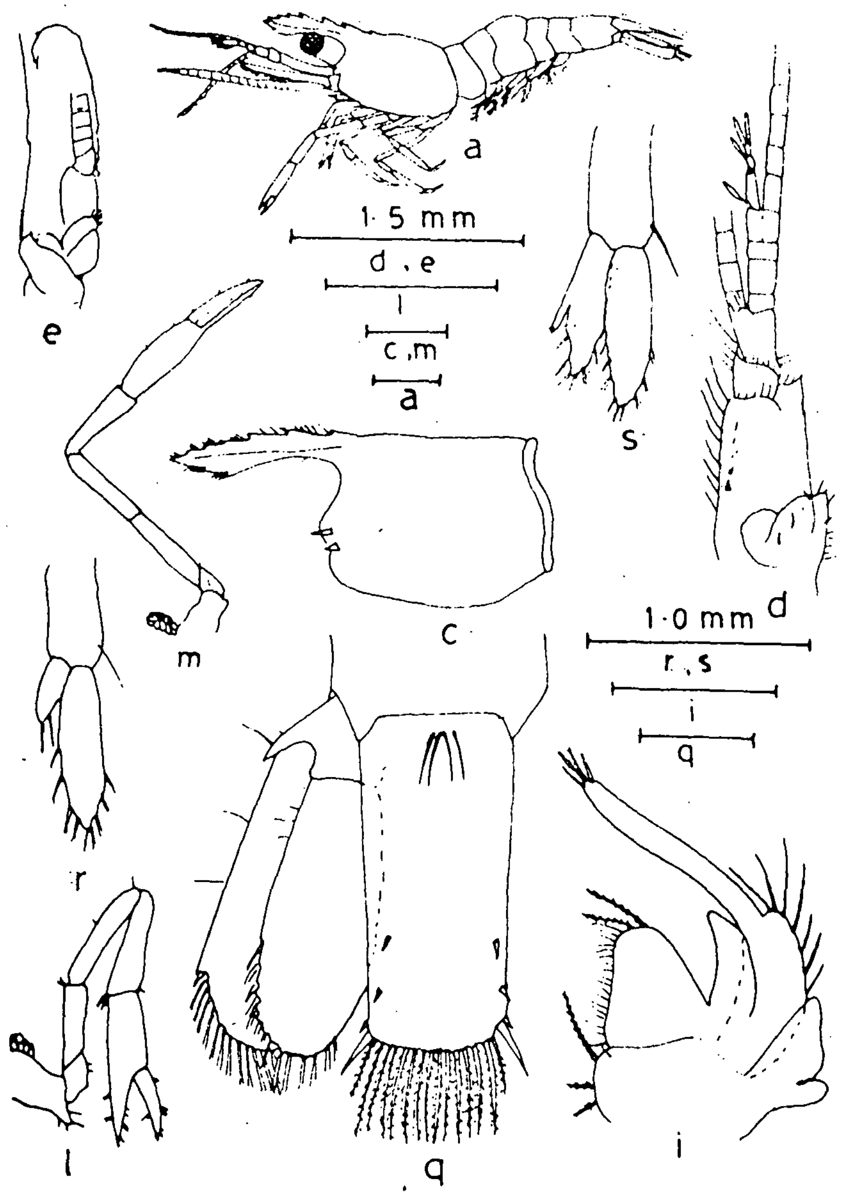


Fig.61 Juvenile stage of *M. hendersoni hendersoni* (De Man)

(a, lateral view; b, dorsal view; c, carapace; d, antennule; e, antenna; f, mandible; g, 1st maxilla; h, second maxilla; i, 1st maxilliped; j, second maxilliped; k, third maxilliped; l, m, n, o, p : 1st to fifth pereiopod; q, telson/ telson with uropod; r, s, t : 1st, second and fifth pleopod).

Mandible (Fig. 61.f): With more molar projections; palp still absent.

Maxillae and maxillipeds: No apprecial change except for increase in number of setae and epipod of 1st maxilliped (Fig. 61.i) broadening slightly, resembling that of adult.

Pereiopods: Only change in pereoiopods is increase in number of setae, especially on 1st pereiopods(Fig. 61.l).

Abdomen and Pleopods (Fig. 61.a, r, s): Almost as in previous stage.

Telson (Fig. 61.q): Longer and narrower than in previous stage but with a group of fairly long setae basally on dorsal side. No change in process formula but, out of the 4 pairs of lateral spines, the proximal 2 pairs now shift inwards and become dorsal in position resembling those of adult. Posterior margin rather straight.

Uropods (Fig. 61.q): Very active; slightly increased in length, over reaching telson as in adult.

ln: MACROBRACHIUM HENDERSONI CACHARENSIS

First larval stage (Fig. 62)

Carapace length : 2.5 mm; Abdominal length : 3.6 mm.

Description (Fig. 62.a & b): Carapace with prominent antennal and branchiostegal spines; rostral formula 6/3; eyes large, stalked; completely free from carapace; chromatophores concentrated mostly near abdominal region; antenna and mouth parts developed; five pairs of pereiopods present; abdomen with six segments and with five pairs of pleopods; telson separated from 6th abdominal segments.

Antennule (Fig. 62.d): Peduncle 3-segmented; outer flagellum with two aesthetes and inner long spine like setae; inner margin of the antennular peduncle with thirteen plumose setae, three of them encircling the terminal segment of peduncle; large number of setae present on all joints on outer margin of peduncle.

Antenna (Fig. 62.e): 3 segmented peduncle; well developed scale and long flagellum (consisting of about 21 segments). The scale provided with 17 plumose setae along its inner margin and a distinct spine at the distal extremity on the outer boarder.

Mandibles (Fig. 62.f): Incisor and molar processes marked from each other; incisor process with one tooth and two denticles and molar process with two denticles.

Maxilla I (Fig. 62.g): Endopod bifid; proximal lacinia with 4 spines and distal with one spine.

Maxilla II (Fig. 62.h): Exopod with 26 plumose setae along its margin, the hindmost seta along and direct backwards, endopods with a single setae at its extremity; endopod carrying three masticatory processes, 1st with four, 2nd with three and 3rd with two setae.

Maxillipeds (Fig. 62.i-k): Three pairs of well-developed biramous maxillipeds with setose expodites; basal segment of 1st maxilliped expanding and carrying short and thick endopodite, a bud-like epipodite also present; maxillipeds II and III almost identical.

Pereiopods (Fig. 62.l-p): Five pairs of pereiopods present; segmentation between its articles not distinct; chelae of pereiopods 1st and 2nd faintly marked; few setae appearing on the segments of 3rd to 5th pereiopods.

Pleopods (Fig. 62.r): Five pairs of biramous pleopods; each pleopod 2 segmented.

Telson (Fig. 62.q): Characteristic, almost zoeal, but having a broadly rounded posterior margin with a very faint median notch; carrying 9 + 9 setose spine.

Chromatophores: Larva semi transparent; distal margin of antennular peduncle with reticulate orange on the anterior and posterior dorsal margins of eye; junction of eye and carapace with diffused violet chromatophore located on a dark background, stellate red chromatophores also on the base of each maxillipeds as well as five pairs of pereiopods; abdominal chromatophores situated on 3rd-4th abdominal segment (on lateral side) and ventrally on 4-5th abdominal segment; an additional dendritic orange red chromatophore also situated at the base of telson.

Time for 1st moult: 2 days in observation I (May, 1980); 1-2 days in observation II (September, 1980).

II. Second Larval stage (Fig. 63)

Carapace length: 2.9 mm; Abdominal length: 4.0 mm.

Description (Fig. 63.a & b): Carapace developed with an epigasteral hump, well developed supra-orbital, branchiostegal and pterygostomian spine; rostrum serrated, reaching almost to the end of antennular peduncle and with fine setae in between the teeth on either margins (Fig. 63.c). Mid-rib prominent and slightly curved; rostral formula 8/4. No post orbital teeth; large stalked eyes completely free from carapace; Orange red chromatophores on eye peduncle and also in the epigastric region of the carapace.

Antennule (Fig. 63.d): Antennular peduncle expanded and 3-segmented; both stylocerite and antero-lateral spines prominent, sharply pointed. Basal segment with a ventral spine pointing anteriorly; statocyst without any statoliths, but its region demarcated by small bristles; Inner flagellum 13 segmented; Outer flagellum with two basal segments fused out of its two branches, the smaller branch 4 segmented and tipped with 2 aesthetcascs which looks like corn of the millet, longer branch with 15 segments bearing minute setae.

Antenna (Fig. 63.e): As in adult with 3-segmented peduncles, well developed scale and long flagellum (consisting of about 40 segments), but the spine of basicerite rather blunt.

Mandible (Fig. 63.f): Well developed incisor and molar processes, the former with 2-4 blunt teeth, while the latter still a blunt projection unlike the toothed process of the adult; pulp absent.

Maxilla I (Fig. 63.g): Structurally like that of adult, but the coxal and basal endites with only 1 and 3 large + 2 small teeth respectively. Palp distinctly bilobed, the upper lobe narrow and tubular while the lower broader, bearing a small seta.

Maxilla II (Fig. 63.h): Almost as in adult except for the two endites being less setose, coxal with 4 and basal with 7 denticles; Palp with one small marginal seta; Scaphognathite fringed with about 45 pulmose setae.

Maxilliped I (Fig. 63.i.): The two endites of protopod large and armed with only a few small tubercles; Endopod or palp unsegmented, reaching up to scale-like basal portion of exopod. Flageller portion of exopod with 4 long, plumose, terminal setae. Epipod though bilobed, more elongated than in adult.

Maxilliped II (Fig. 63.j): Endopod 5-segmented, incurved; exopod flageller with 4 netatory setae. Future podobranch represented by gill bud.

Maxilliped III (Fig. 63.k.): Endopod less setose than in adult. Exopod with 4 netatory setae, reaching to the tip of basal segment of endopod. A rudimentary epipod present.

Pereiopods (Fig. 63.1-p): Resemble those of adults; 1st and 2nd pairs chelate, smooth except for presence of a few setae, 1st being much smaller than the 2nd; Like in adults, 2nd **cheliped** prominently larger than all the remaining pereiopods; 3rd to 5th pereiopods similar, with a narrow pointed dactylus but the terminal spines being much longer than in adult; also propodal spines of adult yet to develop; Pleurobranchs present on all pereiopods, on each as in adults, but rudimentary.

Abdomen (Fig. 63.a): 6-segmented, 1st to 5th segment smooth, but 5th with 2 delicate hairs postero-laterally; 6th with the dorsolateral spines of adults in addition to 2 characteristic short plumose setae posteriorly.

Pleopods (Fig. 63.r & t): 1st pleopod as in adult with rudimentary endopod, about 1/3 exopod in length and with only 2 setae; 2nd to 5th with endopods reaching nore than 2/3 of exopod and bearing 7-9 setae each. A distinct appendix interna bearing 2-3 minute hooks on all pleopods except the 1st; Exopod setae 9 on 1st and 12 on remaining pleopods.

Telson (Fig. 63.q): Developed as post larva; 26 plumose setae at its distal boarder; uropods are represented only as buds seen through the telson cuticle.

Time for 2nd moult: 2 days in observation I (May, 1980) and 2-4 days in observation II (September, 1980).

III. Third larval stage (Post-larva):

Carapace length: 3.3 mm; Abdominal length: 4.2 mm.

Description (Fig. 64a): Rostrum more setose than in 2nd stage particularly on lower margin. Eyes large with cylindrical stalks and completely free from carapace. Cornea unlike in adult not broader than stalk.

Antennule (Fig. 64.d): Statocyst seen at the more expanded base of antennular peduncle, sensorial setae arranged themselves along a circular arc on statocyst; with 2 fused basal segments of outer flagellum.

Antenna (Fig. 64.e): External spine of basicerite now more sharp and prominent resembling that of adult. Flagellum with addition of 2-3 segments.

Mandible (Fig. 64.f): 43 sharp sub-equal teeth on incisor and 2-3 blunt teeth like projections on molar processes; palp not yet developed.

Maxillae (Fig. 64.g. h): and Maxillipeds (Fig, 64.i-k): More setose and developed like adult.

Pereiopods (Fig. 64.l-p): No appreciable change except for propodus of the legs now bearing more delicate spines on its posterior margin.

Abdomen (Fig. 64.a): 6th segment now with 3 pairs of posterolateral setae; no change in pleopods.

Telson (Fig. 64.q): Still unlike that of adult. Now long, narrow, rectangular with slightly convex posterior margin. Out of the 26 processes in previous stage, the first 3 + 3 now become spines gradually increasing in size distalwards and shifted on either lateral margin. Posterior margin with 20 plumose setae.

Unropods (Fig. 64.q): Well developed and functional protopod with a sharp spine. Both rami almost equal reaching to the tip of telson.

Time of 3rd moult: 2-3 days in observation I (May, 1980), and 2-4 days in observation II (September, 1980).

IV. Juvenile stage (Fig. 65):

Carapace length: 3.8 mm; Abdominal length: 4.7 mm.

Description (Fig. 65.a): No change in rostrum; the future hepatic spine (as explained in 1st stage) now shifted little upwards towards antennal spine; Eyes unchanged.

Antennule (Fig. 65.d): Flagellar segments increased in number 11 on the inner; 12 on longer branch of outer; smaller branch of outer flagellum with 3 aesthetascs.

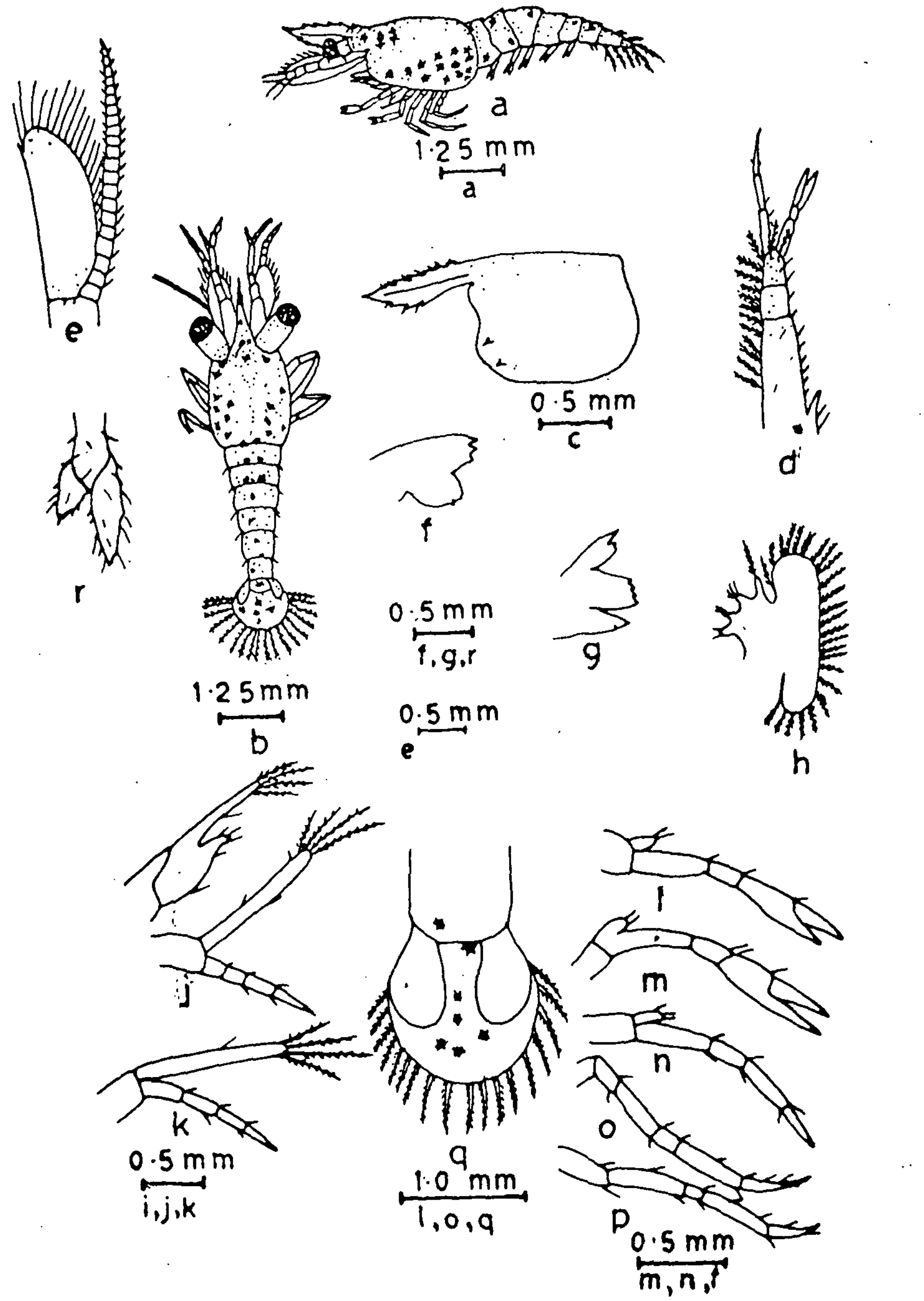


Fig.62. First larval stage of *M. hendersoni cacharensis* (Tiwari)

(a, lateral view; b, dorsal view; c, carapace; d, antennule; e, antenna; f, mandible; g, 1st maxilla; h, second maxilla; i, 1st maxilliped; j, second maxilliped; k, third maxilliped; l, m, n, o, p : 1st to fifth pereiopod; q, telson/ telson with uropod; r, s, t : 1st, second and fifth pleopod).

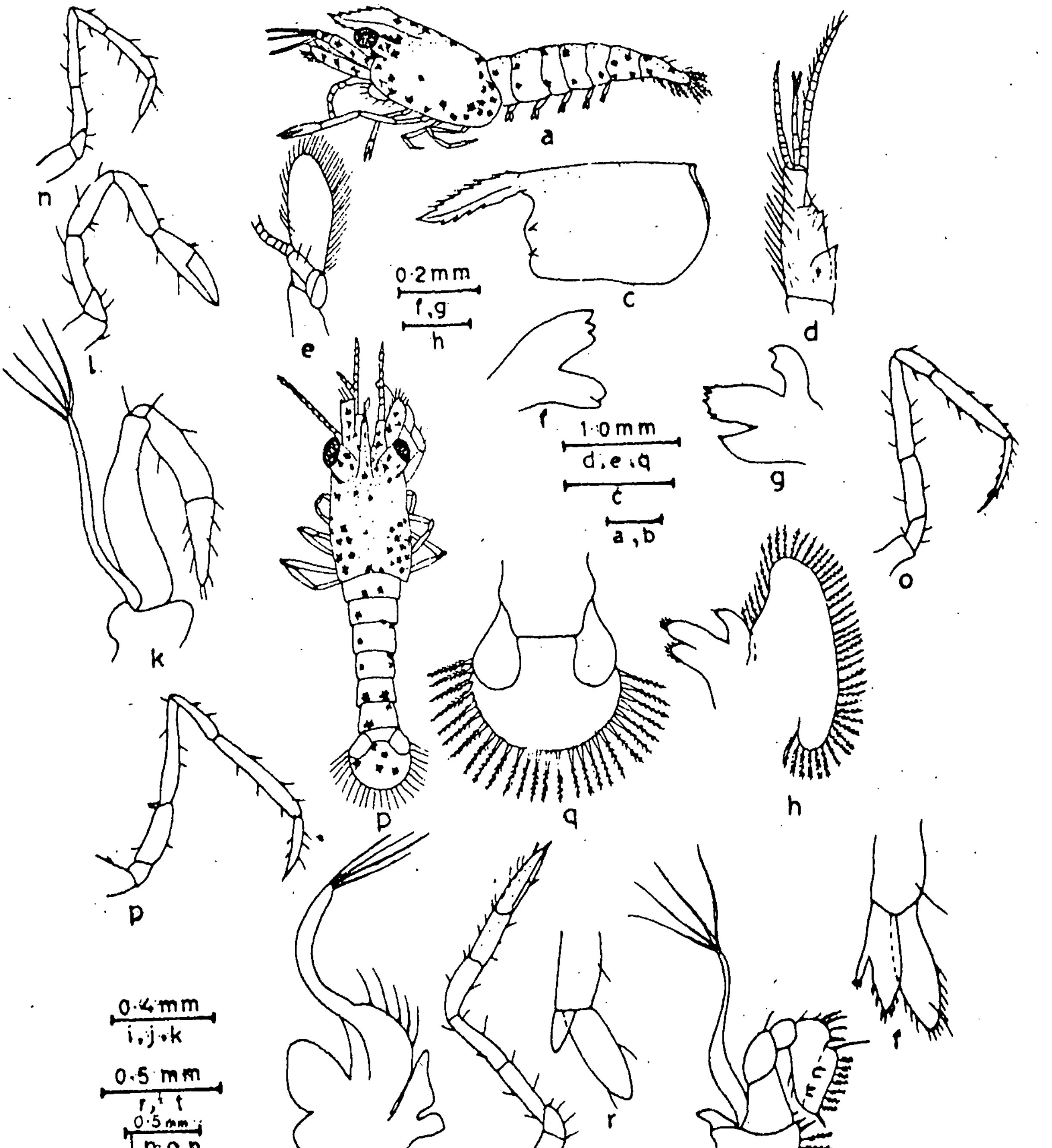


Fig.63. Second larval stage of M. hendersoni cacharensis (Tiwari)

(a, lateral view; b, dorsal view; c, carapace; d, antennule; e, antenna; f, mandible; g, 1st maxilla; h, second maxilla; i, 1st maxilliped; j, second maxilliped; k, third maxilliped; l, m, n, o, p : 1st to fifth pereiopod; q, telson/ telson with uropod; r, s, t : 1st, second and fifth pleopod).

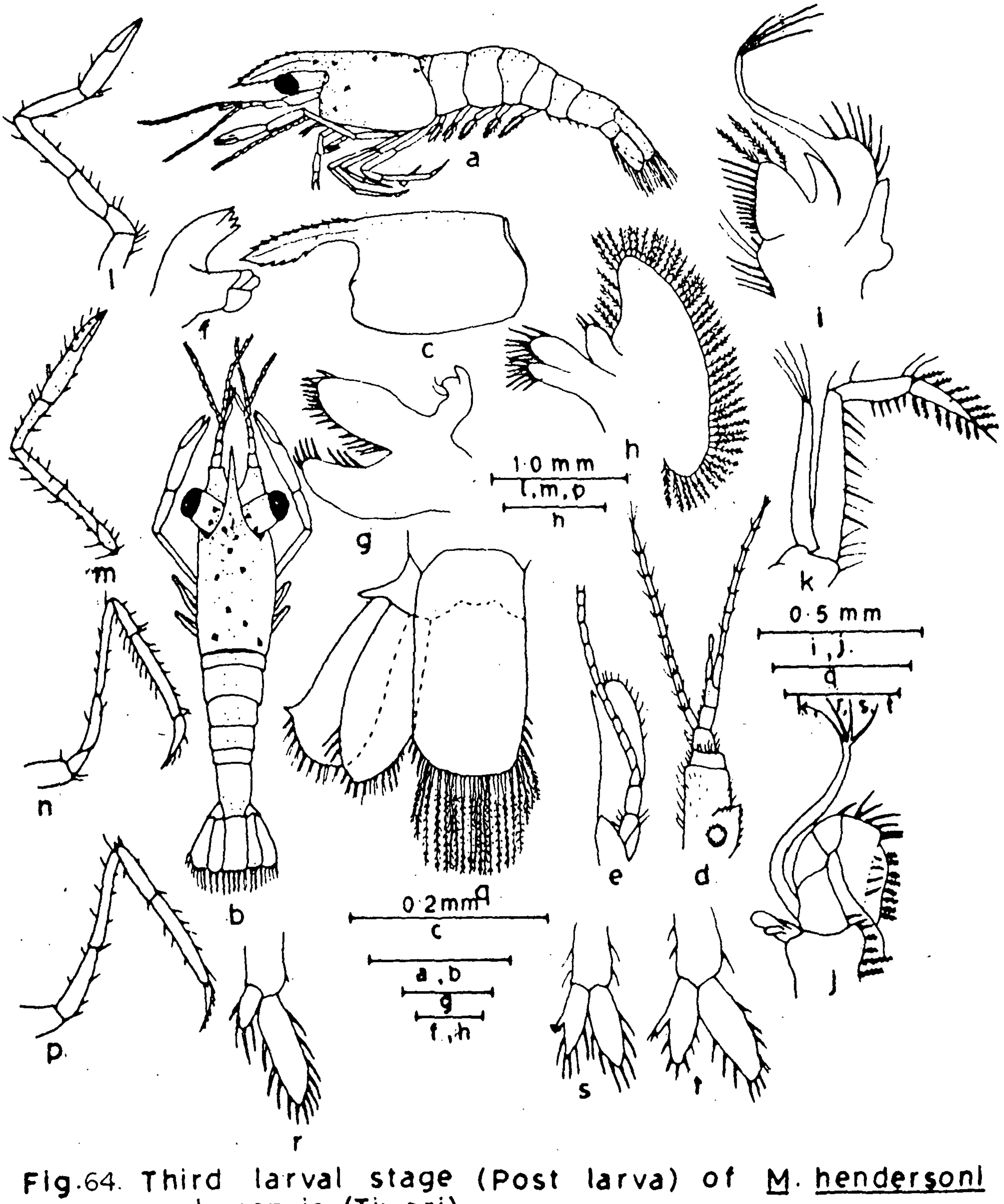


Fig.64. Third larval stage (Post larva) of M. hendersoni cacharensis (Tiwari)

(a, lateral view; b, dorsal view; c, carapace; d, antennule; e, antenna; f, mandible; g, 1st maxilla; h, second maxilla; i, 1st maxilliped; j, second maxilliped; k, third maxilliped; l, m, n, o, p : 1st to fifth pereiopod; q, telson/ telson with uropod; r, s, t : 1st, second and fifth pleopod).

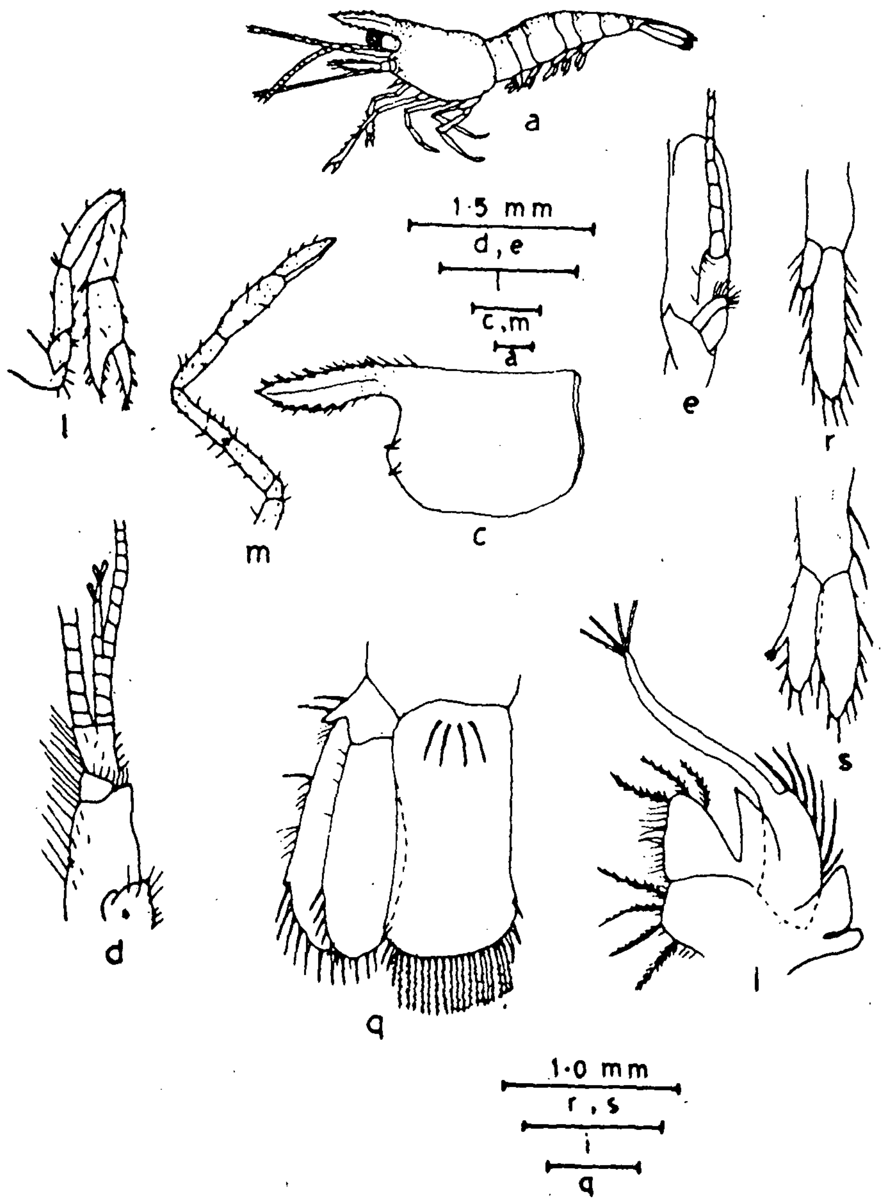


Fig.65. Juvenile stage of *M. hendersoni cacharensis* (Tiwari)

(a, lateral view; b, dorsal view; c, carapace; d, antennule; e, antenna; f, mandible; g, 1st maxilla; h, second maxilla; i, 1st maxilliped; j, second maxilliped; k, third maxilliped; l, m, n, o, p : 1st to fifth pereiopod; q, telson/ telson with uropod; r, s, t : 1st, second and fifth pleopod).

Antenna (Fig. 65.e): No change except for increase in number of flagellar segments to about 53.

Mandible (Fig. 65.f): Only more molar projections; palp absent.

Maxillae and maxillipeds: No appreciable change except for increase in number of setae and epipod of 1st maxilliped (Fig. 65.i) broadening slightly, resembling that of adult.

Pereiopods: Only change is increase in number of setae, especially on 1st and 2nd pereiopods (Fig. 65.l,m).

Abdomen and Pleopods: Almost as in previous stage.

Telson (Fig. 65.q): Longer and narrower than in previous stage but with a group of fairly long setae basally on dorsal side. No change in process formula but, out of the 3 pairs of lateral spines, the proximal one pair now shift inwards and become dorsal in position resembling those of adult. Posterior margin rather straight.

Unropods (Fig. 65.q): Slightly increased in length, over reaching telson as in adult.

3.5. FOOD AND FEEDING HABITS:

Both M. hendersoni hendersoni and M. hendersoni cacharensis are omniverous in terms of their food habits. The chelate legs pick up the food and take it to the mouth, the second and third pairs of maxillipedes held the food in position for the mandibles to cut the food into small pieces by their incisor processes; then food is transferred to the mouth. In the mouth cavity the molar processes of mandibles crush the food which goes to the cardiac stomach through the oesophagus.

The observation on the monthly fluctuations in feeding intensity of both M. hendersoni hendersoni and M. hendersoni cacharensis were based on their Gastro Somatic Index (G.S.I.) values, and are illustrated in the figure 67. The fluctuations of G.S.I. values in different size groups of the prawns, have also been presented in Table 27.

The foregut contents of the prawn have been grouped into eleven broad categories, i.e. i) diatoms, ii) filamentous algae, iii) other algae, iv) mosses and plant matter, v) detritus, vi) nematodes, vii) oligochaetes, viii) crustaceans, ix) insects, x) sand and silt particles and xi) miscellaneous. The miscellaneous groups include the gastropod remains and also other unidentified matter.

3.5.a. In: M. HENDERSONI HENDERSONI (de MAN)

3.5.a. 1. Composition of foregut contents:

Percentage composition of different food items in the foregut is illustrated in Fig. 66. From the two annual cycle data, the most relatively dominant items was found to be Insects (13.13%) and rest in their descending order were: diatoms

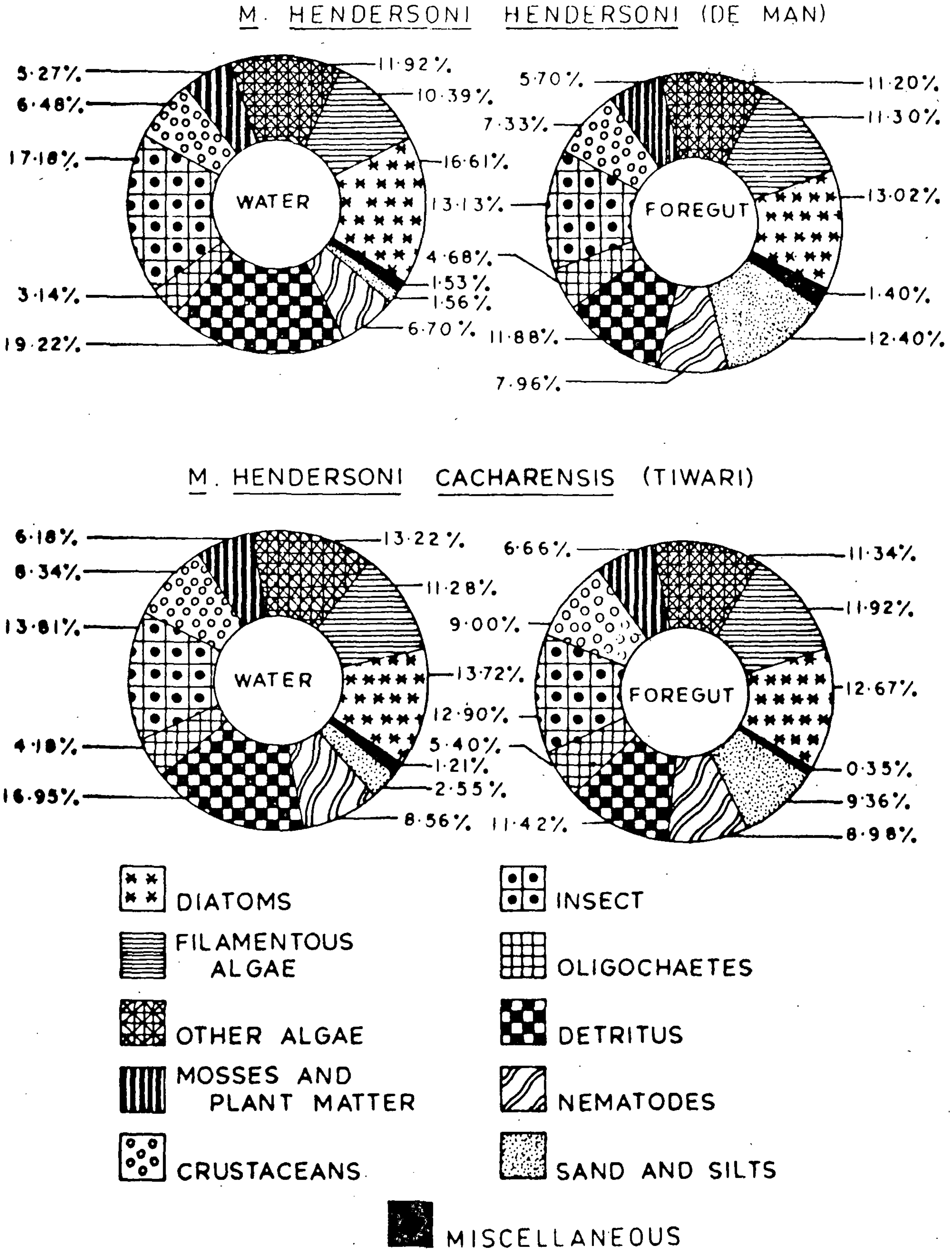


Fig.66. Percentage composition of different food iteams.

(13.02%), sand and silt particles (12.4%), detritus (11.88%), filamentous algae (11.3%), other algae (11.20%), nematodes (7.96%), crustaceans (7.33%), mosses and plant matter (5.70%), oligochaetes (4.68%) and miscellaneous group (1.40%).

Regarding the identification of the different food items, it was found sometimes very difficult to determine the species or even the genus to which the different food items belonged, as they were already subjected to strong action of mastication. The following list of identifiable organisms, recovered from the foregut of the prawn would indicate the diverse nature of its food.

Diatoms:

Melosira spp., *Achnanthes* spp., *Cymbella* spp., *Amphora* sp., *Navicula* sp., *Frustulia* sp., *Nitzschia* sp., *Gomphonema* sp., *Fragillaria* sp.

Filamentous algae:

Lyngbya sp., *Oscillatoria* sp., *Anabaena* sp., *Nostoc* sp., *Spirogyra* sp., *Cladophora* sp.

Other algae:

Ankistrodesmus sp., *Closterium* sp., *Cosmarium* sp., *Coelastrum* sp., *Pediastrum* sp., *Micrasterias* sp., *Staurstrum* sp., *Nitrum* sp., *Ochromonas* sp., *Chlorobotrys* sp., *Mallomonas* sp.

Mosses and plant matter:

Colistella sp., *Dichelyma* sp., *Frontinalis* sp., *Micromitrium* sp., *Hydrilla* sp., *Lemna* sp., *Ceretophyllum* sp., also some unidentified plant leaves.

Nematodes:

Lebronema sp., *Diplogasters* sp., *Chronogaster* sp., also some more unidentified Diplogasterid type.

Oligochaetes:

Chaetogaster sp., *Branchiodrilus* sp., *Limnodrilus* sp., *Pheretima* sp., also few more unidentified forms.

Crustaceans:

Branchionus sp., *Keratella* sp., *Polyarthra* sp., *Cypris* sp., *Cyclops* sp., *Moina* sp., *Daphnia* sp.

Insects:

Baetis spp., *Caenis* sp., *Microgomphus* sp., *Rhynocypha* sp., *Amphinemoura* sp., *Hydrometra* sp., *Limnometra* sp., *Metrocoris* spp., *Micronecta* sp., *Ramphocorixa* sp., *Leptocella* sp., *Oecetis* sp., *Chironommus* sp., *Simulium* sp.

3.5.a. 2. Monthly fluctuations in the foregut contents:

The percentage composition of different food items in the foregut and in the water sample fluctuated considerably and in certain months the percentage composition of certain food

Table 27: Monthly fluctuations in the average gastro-somatic index (G.S.I.)

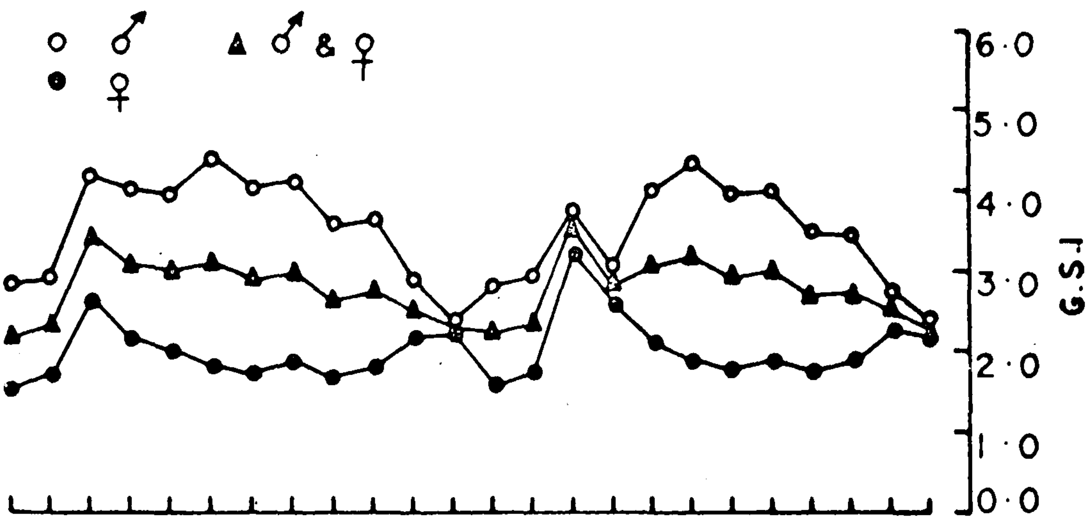
Months	*M. hendersoni hendersoni* Size groups (mm)			*M. hendersoni cacharensis* Size groups (mm)		
	20.0-40.0	40.1-55.0	55.1-80.0	20.0-40.0	40.1-50.0	50.1-70.0
Jan.'79	1.9467	2.4456	2.1762	2.6742	2.5842	2.6424
Feb.	2.0874	2.6672	2.2674	2.9456	2.6236	2.8646
Mar.	2.8468	2.9866	2.6406	3.4562	3.5872	3.4896
Apr.	3.4267	3.8424	3.1245	3.9884	4.0564	3.8842
May	2.9424	3.0514	3.0866	3.0452	3.2463	3.6426
Jun.	3.0467	2.9426	3.4267	3.1674	3.6741	3.7234
Jul.	2.8027	3.0011	2.9041	2.8946	3.7242	3.6825
Aug.	2.9674	2.9824	3.0244	3.0855	3.6072	3.8423
Sep.	2.7468	2.5467	2.6445	2.8466	3.0567	2.9544
Oct.	2.8092	2.9524	2.4898	2.9622	2.9856	3.4425
Nov.	2.9426	2.3064	2.3864	3.0524	3.0674	2.9724
Dec.	2.0456	2.4016	2.4142	2.8641	3.1498	2.8968
Jan.'80	2.0456	2.4592	2.1966	2.5933	2.6023	2.7196
Feb.	2.1427	2.6478	2.2734	2.8642	2.6436	2.9122
Mar.	2.8643	3.0674	2.6523	3.4365	3.6696	3.3426
Apr.	3.4679	3.9226	3.1496	3.8642	4.1102	3.7798
May	2.9672	3.1423	3.1042	3.0522	3.3233	3.6802
Jun.	3.0742	2.9327	3.4867	3.1987	3.7024	3.5402
Jul.	2.8264	3.0247	2.8564	2.9646	3.5422	3.7106
Aug.	2.8742	2.9959	3.0082	3.1162	3.8192	3.8808
Sep.	2.7526	2.5267	2.7462	2.7869	3.2239	3.0824
Oct.	2.8342	2.9424	2.4147	2.9432	2.9498	3.3472
Nov.	2.9267	2.3166	2.3627	3.0734	3.0749	2.9844
Dec.	2.0844	2.4134	2.4006	2.9404	3.1197	2.9064

items exhibited higher values in the gut than in the water samples (Figs. 68, 69).

Diatoms were encountered in the guts throughout the year. The fluctuations in the percentage composition ranged from 10.0 (August, 1980) to 25.0 (December, 1979) and from 9.5 (May, 1979) to 22.0 (December, 1979) in the water sample and foregut of the individual prawn respectively (Fig. 68). Filamentous algae occurred throughout the year and varied in its percentage composition from 5.9 (January, 1979) to 17.2 (May, 1979) and from 6.0 (February, 1979) to 19.0 (May, 1979) in the water sample and foregut respectively (Fig. 68).

The percentage composition of other algae ranged from 7.0 (January, 1979) to 16.5 (May, 1979) and from 18.6 (November, 1979) to 16.2 (May, 1980) in the water sample and in the foregut of the individual prawn respectively. Mosses and plant matter made up from 1.6% (January, 1979) to a maximum of 10.4% (May, 1980) and from 3.6% (February, 1979) to 7.8% (June, 1980) in the water sample and in the foregut of the individual prawn respectively (Fig. 68). The percentage composition of detritus varied from 7.5 (June, 1979) to 27.0 (September, 1980) and from 6.0 (May, 1979) to 16.5 (January, 1980) in the water sample and the foregut of the individual prawn respectively (Fig. 69). The Oligochaetes group was not available during the month of December-March, in both the annual cycle studied. Oligochaetes made up from 2.0% (April, 1980) to 10.0% (June, 1980) and from 4.5% (May, 1979) to 10.2% (July, 1980) in the water sample and

M. hendersoni hendersoni



M. hendersoni cacharensis

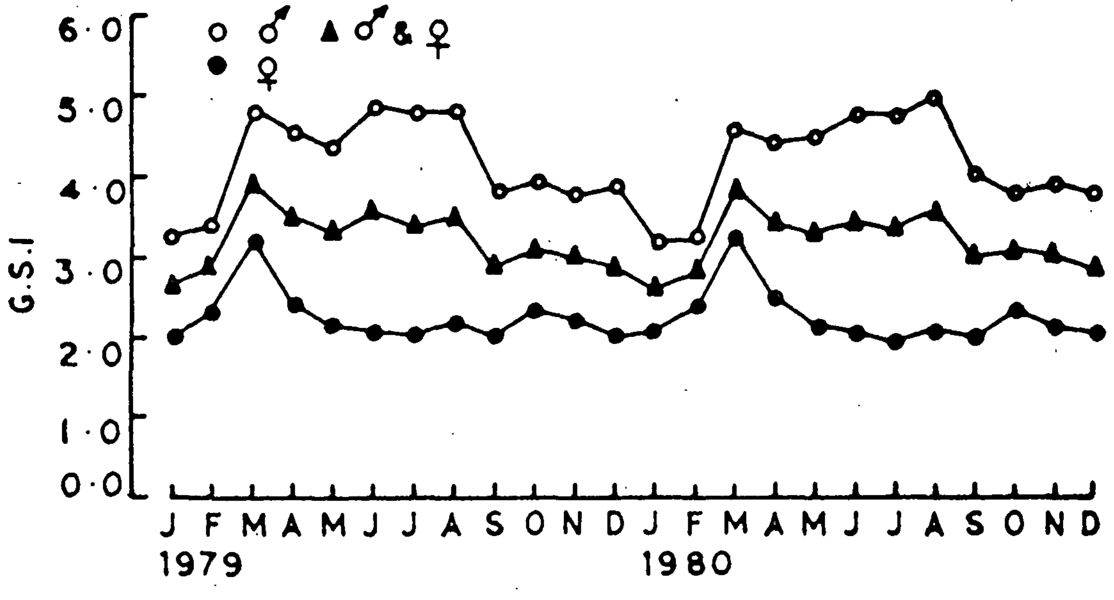


Fig.67. Monthly fluctuations in the gastro-somatic index. (G.S.I)

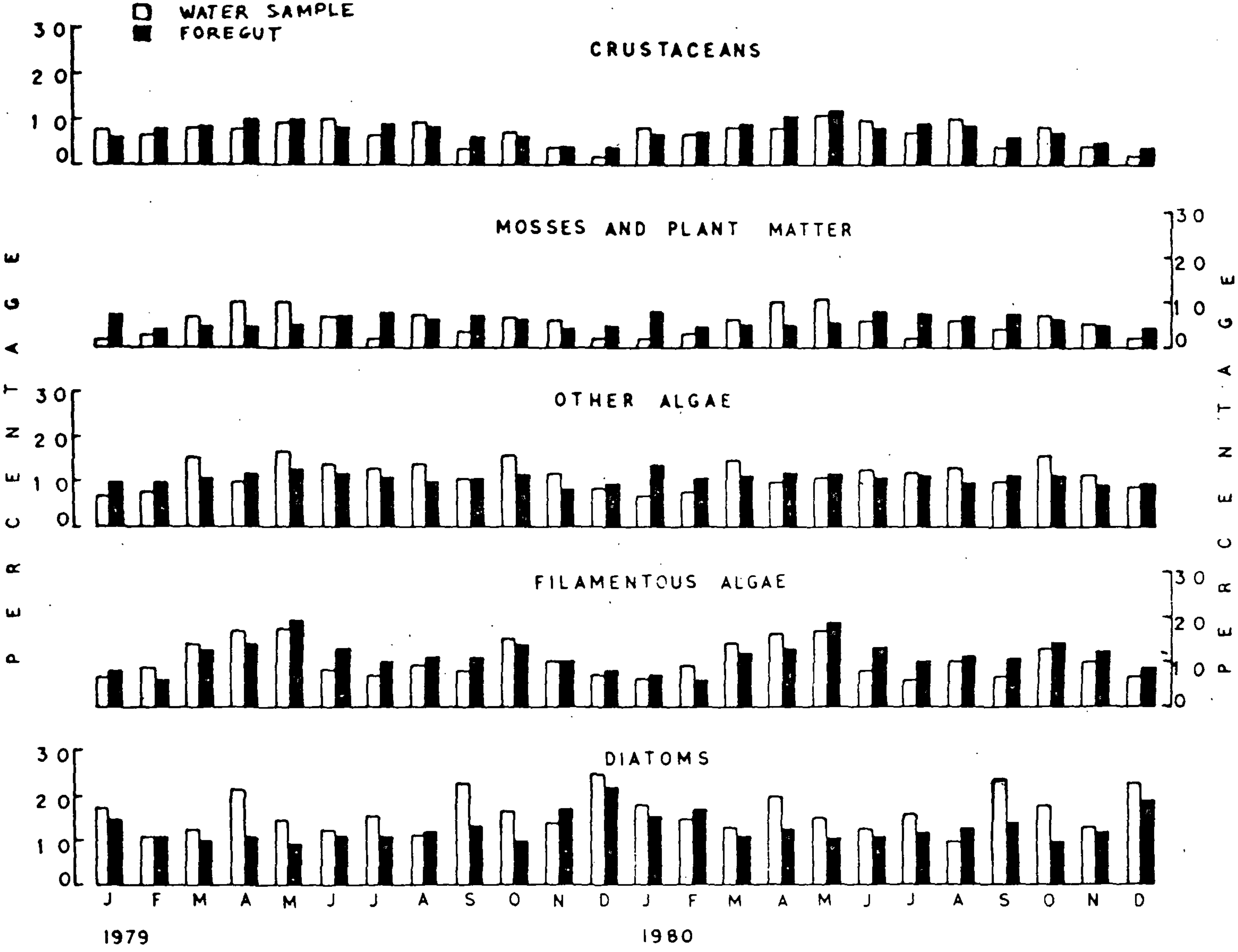


Fig. 68. Monthly fluctuations of the food items in the water sample and in the foregut of M. hendersoni hendersoni (De Man)

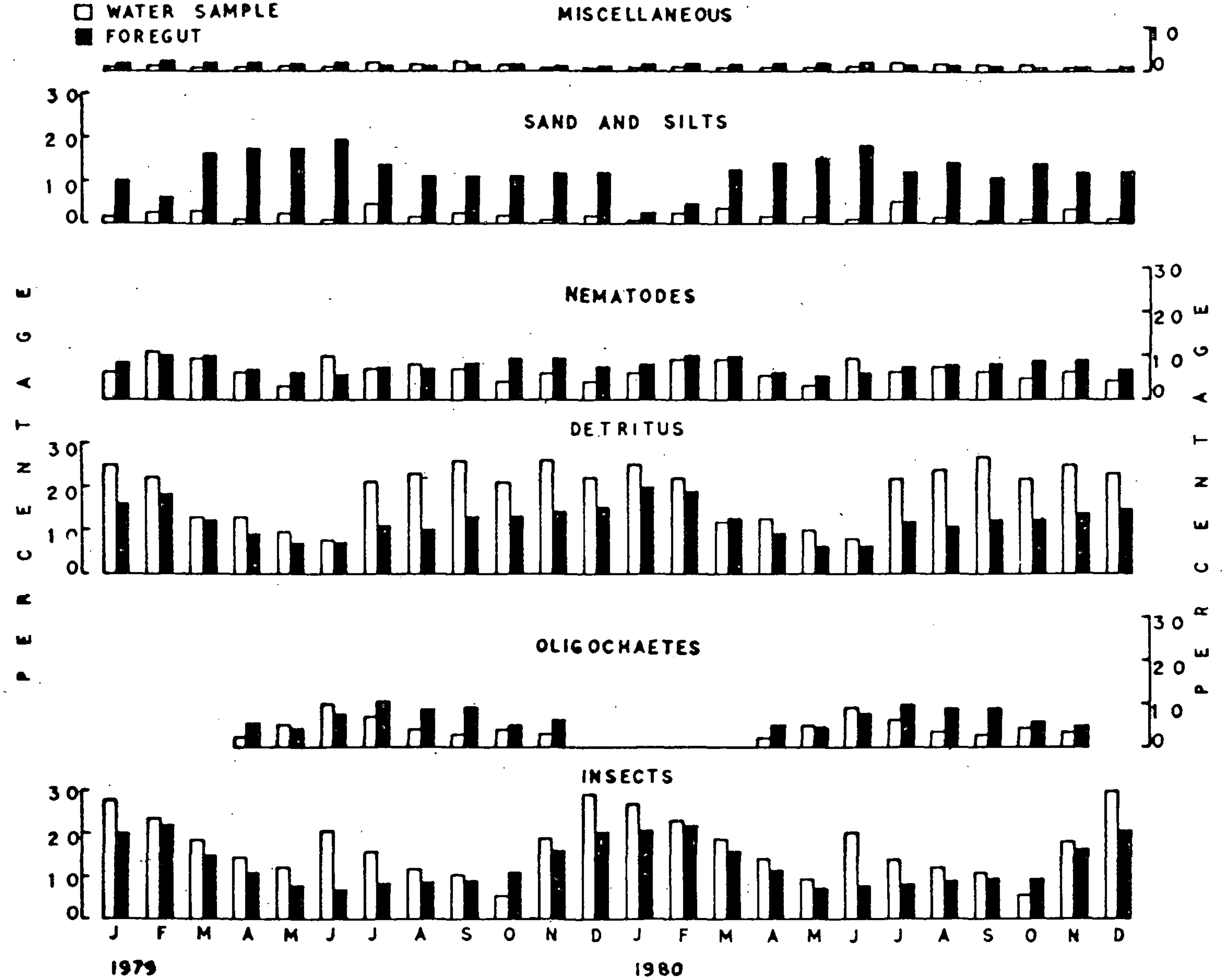


Fig.69, Monthly fluctuations of the food items in the water sample and in the foregut of M. hendersoni hendersoni (De Man) foregut respectively. The percentage composition of namatodes fluctuated from 3.0 (May, 1979) to 10.8 (February, 1980) and from 5.8 (May, 1980) to 10.4 (February, 1980) while the crustacean fluctuated from 1.8% (December, 1979) to 10.6 (May, 1980) and from 3.5% (December, 1980) to 10.9% (May, 1980) in the water sample and the foregut of the individual prawn respectively. The insect group made up from 9.8% (May, 1980) to a maximum of 30.0% (December, 1980) and from 7.0% (June, 1979) to a maximum of 22.4% (February, 1980) in the water sample and foregut respectively (Fig. 69). The percentage composition of sand and silt particles fluctuated in the range of 0.2 (November, 1979) to 5.0 (July, 1980) and from 2.2 (January, 1980) to 19.3 (June, 1979) while the miscellaneous group fluctuated in the range of 0.3 (March, 1979) and 2.2 (September, 1979) and 0.4 (October, 1980) to 2.1 (June, 1980) in the water sample and the gut of the individual prawn respectively (Fig. 69).

3.5.a. 3. Monthly fluctuations of the food composition in three different size groups:

The relative importance of different food items among the individuals of three different size groups (Total length: 20.0-40.0 mm, 40.1-55.0 mm and 55.1-80.0 mm) in terms of their percentage composition, have been presented in Table 28. Salient features of the observations for one annual cycle (January-December, 1979) is described below:

Size group I (20.0-40.0 mm): The percentage composition of different food items i.e. diatoms, filamentous algae, other algae, mosses and plant matter, detritus, nematodes, oligochaetes, crustaceans, insects, sand and silt particles, and the miscellaneous group fluctuated in the range of 15.0 (June) to 25.0 (December), 4.2 (February) to 9.6 (October), 5.0 (February) to 9.6 (March), 1.8 (February) to 4.0 (September), 13.8 (May) to 30.0 (January), 4.2 (April) to 6.8 (July), 6.4 (May) to 11.0 (February), 2.4 (December) to 6.4 (May), 0.4 (May) to 7.0 (February), 15.0 (January) to 33.0 (July) and 0.1 (March) to 0.7 (September) in the foregut of the individual prawn respectively. The most relatively dominant item calculated was the sand and silt particles (25.63%) and the rest in terms of their descending order were: detritus (18.61%), diatoms (18.26%), namatodes (8.40%), other algae (8.24%), filamentous algae (7.98%), crustacean (3.83%), oligochaetes (3.80%) mosses and plant matter (2.85%), insects (2.09%), miscellaneous group (0.79%).

Size group II (40.1-55.0 mm): The percentage composition of diatoms, filamentous algae, other algae, mosses and plant matter, detritus, nematodes, oligochaetes, crustaceans, insects, sand and silt particles and the miscellaneous group fluctuated in the respective range of 9.6 (July) to 20.8 (December), 5.2 (February) to 18.6 (May), 7.8 (February) to 12.9 (October), 4.0 (November) to 7.6 (September), 8.1 (July) to 17.2 (February), 6.6 (April) to 10.2 (February), 4.4 (May) to 7.8 (September), 4.0 (December) to

11.0 (April), 7.2 (June) to 21.0 (February), 4.0 (November) to 20.4 (June) and 0.4 (January) to 1.2 (September) in the foregut of the individual prawn (Table 28). The most relatively dominant food item calculated was the sand and silt particles (14.0%) and the rest in terms of their descending order were: idatoms (13.88%), detritus (12.56%), filamentous algae (12.40%), other algae (11.39%), insects (8.78%), nematodes (8.22%), crustaceans (7.54%), mosses and plant matter (6.00%), oligochaetes (4.54%) and miscellaneous group (0.67%).

Size group III (55.1-80.0 mm): The percentage composition of diatoms, filamentous algae, other algae, mosses and plant matter, detritus, nematodes, oligochaetes, crustaceans, insects, sand and silt particles and the miscellaneous group fluctuated in the range of 9.0 (July) to 21.8 (December), 6.4 (February) to 19.8 (May), 8.0 (January) to 16.2 (May), 4.2 (November) to 9.0 (January), 4.0 (December) to 9.2 (April), 7.6 (June) to 25.0 (February), 4.2 (May) to 8.6 (September), 6.0 (May) to 16.5 (February), 6.3 (May) to 9.6 (May), 4.0 (February) to 16.5 (June) and 0.5 (January) to 1.2 (July) in the foregut of the individual prawn respectively. The most relatively dominant item calculated was the insects (13.85%) and the rest in terms of their descending order were: filamentous algae (12.85%), other algae (12.62%), diatoms (12.60%), detritus (12.03%), sand and silt particles (9.72%), nematodes (7.59%), crustaceans (7.24%), mosses and plant matter (6.33%), oligochaetes (4.36%) and miscellaneous group (0.79%).

Table 28: Monthly fluctuations in the percentage composition of different food items in three size groups of *M. hendersoni hendersoni* (de Man).

Months 1979	Size group	Food Items (%)										
		Diatoms	Filamentous algae	Other algae	Mosses & plant matter	Detritus	Nematodes	Oligochaetes	Crustaceans	Insects	Sand & Silts	Miscellaneous
Jan.	1	19.0	7.6	8.6	2.5	30.0	8.5	-	2.5	6.0	15.0	0.3
	2	16.4	8.4	8.2	7.4	16.0	8.8	-	6.5	17.5	10.4	0.4
	3	15.2	7.0	8.0	9.0	13.0	7.0	-	6.9	24.0	9.2	0.5
Feb.	1	24.0	4.2	5.0	1.8	27.0	11.0	-	3.4	7.0	16.0	0.4
	2	18.0	5.2	7.8	4.2	17.2	10.2	-	6.8	21.0	10.0	0.6
	3	16.3	6.4	11.0	4.5	16.5	9.4	-	7.4	25.0	4.0	0.7
Mar.	1	16.0	7.6	7.0	2.2	18.2	10.2	-	4.0	2.7	32.0	0.1
	2	12.0	11.8	10.8	4.6	13.6	10.0	-	8.6	10.2	18.0	0.4
	3	10.0	13.5	13.4	4.8	12.4	9.6	-	8.4	16.0	11.2	0.7
Apr.	1	17.4	7.8	8.1	2.4	15.2	7.0	4.2	5.2	0.5	32.0	0.2
	2	12.4	12.0	11.4	4.8	10.4	6.6	5.6	11.0	9.0	16.0	0.6
	3	11.0	14.2	14.2	5.0	9.2	6.4	5.0	9.2	11.0	14.0	0.8
May	1	15.8	9.0	9.6	3.0	13.8	6.4	4.3	6.4	0.4	30.0	0.4
	2	10.8	18.6	12.7	5.2	9.7	7.0	4.4	9.4	8.6	13.0	0.6
	3	9.8	19.8	16.2	5.1	6.0	6.3	4.2	8.8	10.2	16.0	0.9
Jun.	1	15.0	8.0	8.7	3.5	14.0	7.6	5.2	4.0	0.6	33.0	0.4
	2	9.8	13.4	12.0	7.0	8.1	7.2	6.6	7.6	7.2	20.4	0.7
	3	9.2	14.3	14.6	7.6	7.2	6.8	7.8	8.0	7.6	16.5	0.7
Jul.	1	15.2	7.8	8.4	3.5	15.8	8.4	6.8	4.5	0.7	29.0	0.3
	2	9.6	12.4	11.2	6.8	9.6	7.4	7.6	7.8	7.6	19.0	1.0
	3	9.0	13.6	13.6	7.8	9.3	7.2	8.4	8.2	8.2	13.5	1.2
Aug.	1	16.8	8.9	8.5	3.6	14.6	8.2	6.2	4.0	0.9	28.0	0.3
	2	10.3	13.0	11.6	7.0	9.4	7.2	7.4	7.4	8.0	18.0	0.7
	3	10.5	14.2	13.8	8.0	9.0	7.0	8.0	7.8	8.8	12.0	0.9
Sept.	1	17.8	8.7	9.0	4.0	16.0	8.4	6.4	3.0	1.0	25.0	0.7
	2	11.4	12.4	12.0	7.6	11.0	7.6	7.8	7.0	8.2	14.0	1.2
	3	11.6	13.0	14.0	8.2	11.0	7.8	8.6	7.3	9.4	8.0	1.1
Oct.	1	15.4	9.6	9.5	3.5	18.4	8.6	6.0	3.6	1.5	23.4	0.3
	2	10.8	13.6	12.9	7.0	12.6	8.0	6.8	7.4	9.6	10.5	0.5
	3	11.0	15.0	14.6	8.4	13.2	8.2	6.0	7.5	11.0	7.5	0.6
Nov.	1	21.0	9.0	8.1	2.0	19.2	9.2	6.4	2.8	3.0	19.0	0.3
	2	18.9	12.8	11.4	4.0	13.4	8.8	6.6	4.2	15.4	4.0	0.5
	3	17.6	13.2	10.2	4.2	13.6	9.4	5.0	4.4	16.8	5.0	0.6
Dec.	1	25.0	7.2	8.0	2.1	20.4	7.0	-	2.4	3.5	24.0	0.4
	2	20.8	10.6	10.4	4.2	15.0	6.8	-	4.0	18.4	9.2	0.6
	3	21.8	11.8	9.6	4.5	15.4	6.9	-	4.0	21.2	4.4	0.7

1 = Size group, 20-40.0 mm; 2 = Size group = 40.1-55.0 mm;
3 = Size group, 55.1-80.0 mm.

3.5.b. In: M. HENDERSONI CACHARENSIS

3.5.b. 1. Composition of foregut contents:

Percentage composition of different food items in the foregut is illustrated in figure 66. The most relatively dominant item calculated was the insects (12.90%) and the rests in terms of their descending order were: diatoms (12.67%), filamentous algae (11.92%), detritus (11.42%), other algae (11.34%), sand and silt particles (9.36%), crustaceans (9.0%), nematodes (8.98%), mosses and plant matters (6.66%), oligochaetes (5.40%) and miscellaneous group (0.35%).

Regarding the identification of the different food items, it was found sometime very difficult to determine the species or even the genus to which the different food items belonged, as they were already subjected to strong action of mastication. The following list of identifiable organisms, recovered from the foregut of the prawn, M. hendersoni caoharensis would indicate the diverse nature of its food:

Diatoms:

Melosira spp., Achnanthes spp., Amphora sp., Cymbella spp., Navicula spp., Pinularia sp., Frustulia sp., Nitzschia sp., Gomphonema sp., Surirella sp., Fragillaria sp., Synedra sp., Neidium sp., and Tabellaria sp.

Filamentous algae:

Anabaena sp., Nostoc sp., Lyngbya sp., Oscillatoria sp., Schizothrix sp., Calothrix sp., Ulothrix sp., Cladophora sp., *Oedogonium* sp., *Spirogyra* sp. and *Zygnema* sp.

Other algae:

Ankistrodesmus sp., *Scendesmus* sp., *Cosmarium* spp., *Closterium* spp., *Micrasterias* sp., *Staurastrum* sp., *Gymnodium* sp., *Ochromonas* spp., *Dinobryon* sp., *Mallamonas* spp.

Mosses and plant matter:

Colistella sp., *Chiloscyphus* sp., *Fissidens* sp., *Frontalis* sp., *Hypophila* sp., *Micromitrium* sp., *Cladopodiella* sp., *Hydrilla* sp., *Lemna* sp., *Myriophyllum* sp., *Wolffia* sp., *Glochidion* sp., *Quercus* sp., also some unidentified plant leaves.

Nematodes:

Lebronema sp., *Aphelenchoides* sp., *Diplogaster* sp., *Chronogaster* sp., also some more unidentified Diplogasteried type.

Oligochaetes:

Chaetogaster sp., *Stylaria* sp., *Limnodrilus* sp., *Pheretima* sp., also few more unidentified forms.

Crustaceans:

Branchionus sp., *Keratella* sp., *Asplanchna* sp., *Polyarthra* sp., *Testudinella* sp., *Cypris* spp., *Cyclops* spp., *Moina* sp., *Daphnia* sp. and *Semocephalus* sp.

Insects:

Baetis sp., *Pseudocloen* sp., *Caenis* sp., *Neoperla* sp., *Hydrometra* sp., *Limnometra* sp., *Micronecta* sp., *Chrimarra* sp., *Ramphocorixa* sp., *Leptocella* sp., *Oecetis* sp., *Psephenus* sp., *Enochrus* sp., *Chironomus* sp., *Simulium* sp., *Limonia* sp. and *Hexatoma* sp.

3.5.b. 2. Monthly fluctuations in the foregut contents:

The percentage composition of different food items in the foregut and in the water sample fluctuated considerably and in certain months the percentage composition of certain food items exhibited their higher values in the gut than in the water samples (Figs. 70, 71).

The fluctuations in the percentage composition of diatoms ranged from 7.5 (June, 1980) to 20.6 (December, 1980) and from 10.2 (June, 1979) to 16.0 (December, 1980) in the water sample and foregut of the individual prawn respectively. The filamentous algae made up in the range of 5.0% (January, 1980) to 17.0 (May, 1979) and 8.0 (December, 1980) to 17.78% (May, 1979) while other algae occurred in the range of 8.2% (December, 1980) to 16.2% (April, 1979) and 8.33% (July, 1979) to 15.56% (May, 1979) in the water sample and foregut of the individual prawn respectively (Fig. 70).

The percentage composition of the mosses and other plant matter fluctuated from 2.0 (July, 1980) to the maximum of 11.0 (May, 1980) and from 1.8 (March, 1979) to the maximum of

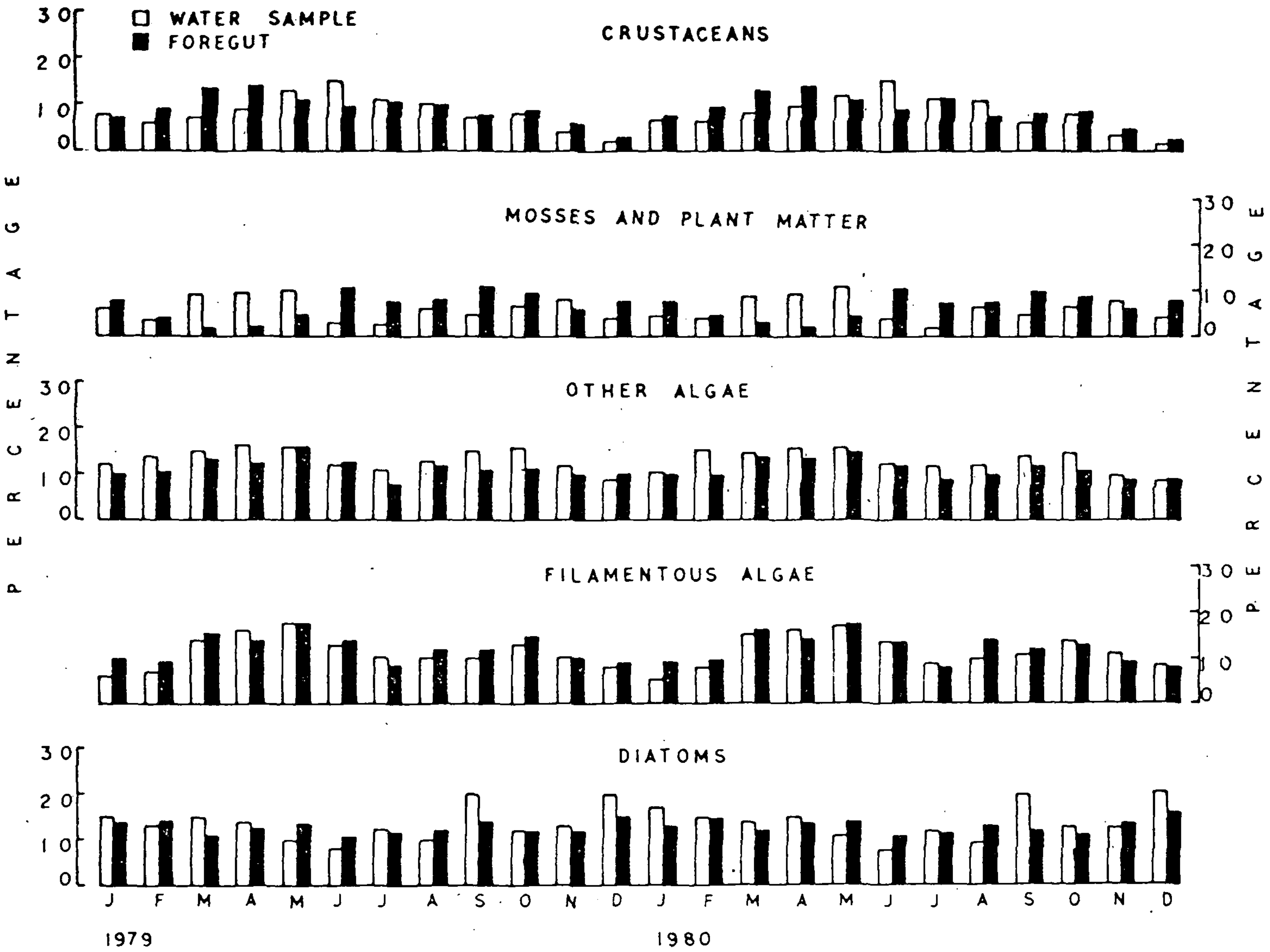


Fig.70. Monthly fluctuations of the food items in the water sample and in the fore gut of *M. hendersoni cacharensis* (Tiwari)

11.11 (September, 1979) while the detritus fluctuated in the range of 6.8 (May, 1980) to 25.0 (December, 1979) and 5.9 (May, 1979) to 17.5 (December, 1979) in the water sample and foregut of the individual prawn respectively. The namatodes made up from 4.0% (October, 1979) to 15.0% (February, 1979) and from 5.2% (August, 1980) to the 13.0% (December, 1980) while the oligochaetes contributed in range of 2.8% (September, 1980) to 12.4% (July, 1980) and 4.44% (May, 1979) to 10.42% (July, 1979) in the water sample and the foregut of the individual prawn respectively. Oligochaetes were not available during the month of December to March in both the annual cycle (Fig. 71).

The fluctuations in the percentage composition of crustaceans ranged from 1.50 (December, 1980) to 15.6 (June, 1980) and from 2.0 (December, 1980) to 14.0 (April, 1980) while the insects ranged from 7.8 (July, 1980) to 25.0 (December, 1979) and from 7.2 (August, 1980) to 18.75 (December, 1979) in the water sample and the foregut of the individual prawn respectively. The sand and silt particles fluctuated in the range of 0.2% (October, 1980) to 5.6% (July, 1979) and 5.3% (November, 1980) to 17.6% (August, 1980) while the miscellaneous group fluctuated in the range of 0.6% (January, 1980) to 2.4% (August, 1979) and 0.3% (March, 1979) to 1.1% (August, 1980) in the water sample and foregut of the individual prawn respectively.

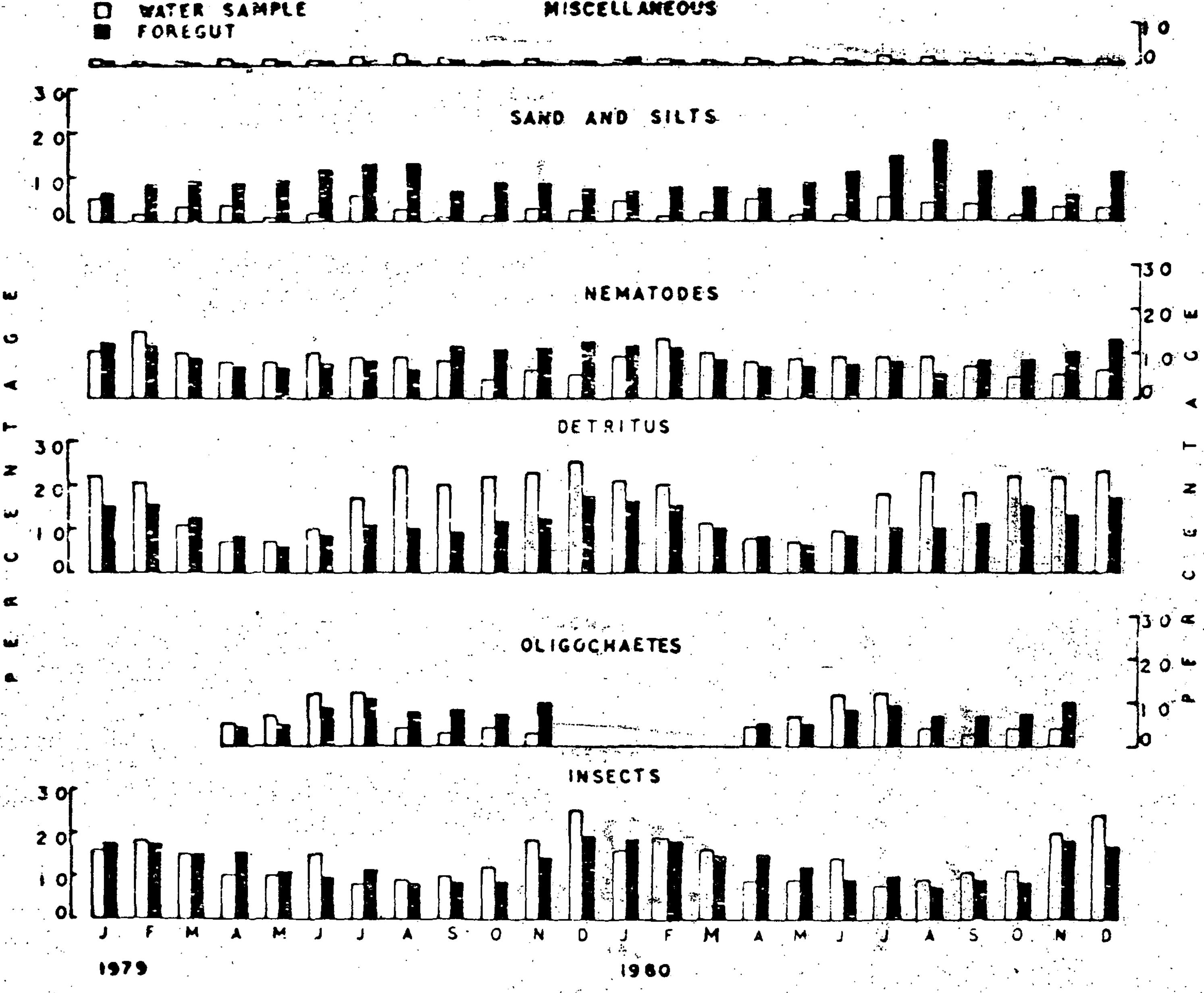


Fig.71. Monthly fluctuations of the food items in the water sample and in the fore gut of M. hendersoni cacharensis (Tiwari)

3.5b. 3. Monthly fluctuations of the food composition in three different size groups of *M. hendersoni cacharensis*.

The relative importance of different food items among the individuals of three different size groups (Total length: 20.0-40.0 mm, 40.1-50.0 mm and 50.1-80.0 mm) in terms of their percentage composition, have been presented in the Table 29. Salient features of the observations for one annual cycle (January-December, 1979) is described below:

Size group I (20.0-40.0 mm): The percentage composition of different food items i.e. diatoms, filamentous algae, other algae, mosses and plant matter, detritus, nematodes, oligochaetes, crustaceans, insects, sand and silt particles, and the miscellaneous group fluctuated in the range of 11.8 (April) to 21.0 (December), 8.3 (February) to 13.5 (August), 8.6 (November) to 12.0 (May), 0.2 (March) to 7.6 (September), 14.0 (May) to 27.6 (October), 6.5 (May) to 13.8 (December), 0.0 (December-March) to 9.2 (July), 2.4 (December) to 9.4 (April), 2.4 (July) to 4.2 (December), 4.6 (October) to 24.3 (June) and 0.1 (January) to 1.4 (April) in the foregut of the individual prawn respectively. The most relatively dominant food item calculated out the detritus (20.16%) and the rest in terms of their descending order were: Sand and silt particles (15.7%), diatoms (14.03%), other algae (9.12%), filamentous algae (9.07%), nematodes (7.95%), crustaceans (5.58%), oligochaetes (4.97%), mosses and plant matter (3.62%), insects (3.15%) and miscellaneous group (0.36%).

Size group II (40.1-50.0 mm): The percentage composition of diatoms, filamentous algae, other algae, mosses and plant matter, detritus, nematodes, oligochaetes, crustaceans, insects, sand and silt particles, and the miscellaneous group fluctuated in the range of 10.8 (July) to 17.9 (February), 8.8 (February) to 14.8 (May), 9.0 (July) to 16.0 (May), 2.9 (March) to 10.6 (July), 6.5 (May) to 16.8 (December), 6.0 (April) to 13.2 (December), 0.0 (December-March) to 8.6 (July), 3.0 (December) to 13.6 (March), 7.2 (August) to 18.4 (December), 2.9 (March) to 16.0 (August) and 0.2 (March) to 1.0 (August) in the fore-gut of the individual prawn respectively. The most relatively dominant food item calculated out was the diatoms (13.49%) and the rest in terms of their descending order were: detritus (12.5%), insects (12.48%), filamentous algae (11.97%), other algae (11.43%), nematodes (9.18%), crustaceans (8.93%), mosses and plant matter (7.30%), sand and silt particles (6.90%) and miscellaneous group (0.55%).

Size group III (50.1-70.0 mm): The percentage composition of diatoms, filamentous algae, other algae mosses and plant matter, detritus, nematodes, oligochaetes, crustaceans, insects, sand and silt particles and the miscellaneous group fluctuated in the range of 10.5 (June) to 16.6 (December), 9.0 (February) to 15.0 (May), 9.6 (July) to 15.6 (May), 3.0 (March) to 11.2 (July), 6.6 (May) to 17.1 (October), 6.5 (April) to 12.8 (December), 0.0 (December-March) to 9.0 (July), 3.2 (December) to 14.0

Table 29 : Monthly fluctuations in the percentage composition of different food items in three size groups of *M. hendersoni cacharensis* (Tiwari).

Months 1979	Size group	Food Items (%)										
		Diatoms	Filamentous algae	Other algae	Mosses & plant matter	Detritus	Nematodes	Oligochaetes	Crustaceans	Insects	Sand & Silts	Miscellaneous
Jan.	1	15.0	9.0	9.2	3.2	27.0	8.0	-	3.4	4.0	21.0	0.1
	2	17.7	9.4	9.8	7.6	16.0	10.8	-	7.8	12.0	8.4	0.5
	3	12.7	9.6	10.0	7.4	15.8	11.0	-	7.5	18.4	7.0	0.3
Feb.	1	16.0	8.3	8.8	2.0	27.4	9.0	-	6.0	3.8	18.4	0.6
	2	17.9	8.8	9.2	6.4	16.5	11.2	-	8.8	12.4	8.2	0.5
	3	13.0	9.0	10.5	7.0	16.2	11.6	-	9.0	18.5	4.6	0.6
Mar.	1	12.8	9.6	9.8	0.2	22.0	7.2	4.6	8.5	3.5	21.7	0.3
	2	11.6	13.0	12.4	2.9	12.0	10.2	5.2	13.6	16.0	2.9	0.2
	3	11.2	13.2	12.8	3.0	11.6	10.7	5.0	14.0	15.8	2.7	0.5
Apr.	1	11.8	9.0	9.6	1.5	18.5	6.6	4.8	9.4	3.4	24.0	1.4
	2	12.0	13.4	12.0	4.2	8.0	6.0	5.8	12.0	16.6	5.4	0.4
	3	11.2	14.0	13.2	5.0	8.4	6.5	6.0	13.0	17.0	5.7	0.5
May	1	16.6	11.0	12.0	3.0	14.0	6.5	4.9	8.0	3.2	20.0	0.6
	2	14.3	14.8	16.0	5.8	6.5	8.4	5.6	10.8	12.2	5.0	0.6
	3	13.4	15.0	15.6	6.4	6.6	8.6	5.4	11.0	12.6	5.0	0.4
Jun.	1	12.4	9.4	10.5	4.0	16.0	6.8	7.6	6.7	2.4	24.3	0.2
	2	10.8	14.2	14.5	9.6	7.6	8.6	8.0	9.2	9.7	7.0	0.8
	3	10.5	14.6	15.0	10.6	7.8	8.8	8.2	9.4	9.8	4.8	0.5
Jul.	1	13.6	8.5	8.7	2.8	17.2	8.5	9.2	7.0	3.0	21.0	0.5
	2	11.8	10.6	9.0	10.6	9.8	7.8	8.6	11.0	10.3	10.0	0.5
	3	11.6	9.6	9.6	11.2	9.6	7.5	9.0	11.4	10.6	9.2	0.7
Aug.	1	14.5	13.5	9.0	4.6	16.8	8.6	7.5	5.8	2.5	17.0	0.2
	2	13.0	14.0	10.5	6.4	11.2	7.9	7.3	6.5	7.2	16.0	1.0
	3	12.8	14.2	11.0	7.2	12.0	8.0	7.0	7.0	7.4	12.0	1.4
Sept.	1	16.0	10.5	10.5	7.6	19.8	8.8	7.6	5.4	3.6	10.0	0.2
	2	12.0	12.4	11.6	10.4	14.0	8.0	7.4	8.6	8.4	7.4	0.6
	3	12.4	12.1	12.0	10.8	14.2	8.2	7.4	9.0	9.6	3.5	0.8
Oct.	1	14.0	11.0	11.0	6.8	27.6	8.4	8.6	5.5	3.2	4.6	0.3
	2	11.2	14.0	12.0	8.5	16.4	7.8	7.6	8.8	8.8	4.2	0.7
	3	11.0	14.2	12.0	8.0	17.1	8.1	7.8	8.6	10.0	2.8	0.4
Nov.	1	16.0	8.4	8.6	4.0	24.5	9.6	8.8	3.6	3.4	13.0	0.2
	2	12.8	9.7	9.8	7.2	14.5	10.0	8.0	6.8	17.4	3.0	0.8
	3	12.4	10.2	10.4	7.4	14.0	9.4	8.2	7.2	18.2	2.0	0.6
Dec.	1	21.0	7.8	9.0	6.8	27.2	13.8	-	2.4	4.2	7.6	0.2
	2	16.4	9.0	10.0	7.8	16.8	13.2	-	3.0	18.4	5.0	0.4
	3	16.6	9.5	10.8	8.0	13.8	12.8	-	3.2	19.8	2.2	1.0

1 = Size group, 20.0-40.0 mm; 2 = Size group, 40.1-50.0 mm; 3 = Size group, 50.1-70.0 mm.

(March), 7.4 (August) to 19.8 (December), 2.0 (November) to 12.0 (August) and 0.3 (January) to 1.4 (August) in the foregut of the individual prawn respectively. The most relatively dominant food item calculated out was the insects (14.05%) and the rest in terms of their descending magnitude were: diatoms (12.47%), filamentous algae (12.14%), other algae (11.98%), detritus (11.97%), nematodes (9.32%), crustaceans (9.23%), mosses and plant materials (7.70%), oligochaetes (5.36%), sand and silt particles (5.12%) and miscellaneous group (0.62%).

3.6. DIGESTIVE PHYSIOLOGY*:

3.6.1. pH measurement: The various enzymes function optimally at different hydrogen ion concentrations. The medium is weakly acidic in mouth, oesophagus and pyloric stomach while it is distinctly acidic in the hepatopancreas and cardiac stomach. The medium was found to be alkaline in the intestine and rectum. A few prawns were starved for about four days by keeping them in filtered water and slight increase in the concentration of acidity and alkalinity were observed (Table 30a, b). In another experiment, a few starved prawns were fed on some selective diet and the pH of the different parts of the digestive tract was measured. It was found to be almost similar to that of normal fed ones.

3.6.2. Qualitative estimation of enzymes: The incubated solutions were tested for the different enzymes after different

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Table 30a: pH in various regions of the alimentary canal of normal feeding prawn, M. *hendersoni hendersoni* (de Man)

Sl. No.	Mouth	Oesophagus	Cardiac stomach	Pyloric stomach	Intestine	Rectum	Hepato-pancreas
1.	6.2	6.1	4.5	6.6	7.4	8.4	5.8
2.	6.5	6.4	4.4	6.7	7.5	8.5	5.9
3.	6.3	6.3	4.2	6.4	7.4	8.4	5.9
4.	6.3	6.2	4.2	6.5	7.3	8.5	5.8
5.	6.4	6.3	4.4	6.6	7.4	8.5	5.9
Average pH	6.34	6.26	4.34	6.56	7.40	8.46	5.86

Table 30b: pH in various regions of the alimentary canal of M. *hendersoni hendersoni* (de Man) after starvation

Sl. No.	Mouth	Oesophagus	Cardiac stomach	Pyloric stomach	Intestine	Rectum	Hepato-pancreas
1.	6.1	6.0	4.3	6.3	7.1	8.1	5.2
2.	6.1	6.1	4.2	6.3	7.1	8.1	5.2
3.	6.0	6.0	4.3	6.4	7.2	8.2	5.1
4.	6.2	5.9	4.1	6.3	7.3	8.2	5.1
5.	6.1	6.0	4.2	6.2	7.2	8.2	5.3
Average pH	6.10	6.00	4.22	6.30	7.18	8.16	5.18

Table 31: Qualitative estimation of digestive enzymes present in the hepatopancreas of *M. hendersoni hendersoni* (de Man)

Sl. No.	Substrate	Duration of reaction and extent of digestion			Control experiment	
		after 24 hrs	after 48 hrs	after 96 hrs	after 48 hrs	after 96 hrs
1	1% starch solution	+	+	+	-	-
2	5% Sucrose solution	-	+	++	-	-
3	2% Maltose solution	-	-	-	-	-
4	2% Lactose solution	-	-	-	-	-
5	1% Raffinose solution	-	+	+	-	-
6	1% Inulin solution	-	+	+	-	-
7	1% Salicin solution	-	-	-	-	-
8	Saturated Glycogen solution	+	+	+	-	-
9	10% Gelatin solution	-	-	-	-	-
10	Condensed milk	-	-	-	-	-

Table 32: Qualitative estimation of digestive enzymes present in the oesophagus of *M. hendersoni hendersoni* (de Man)

Sl. No.	Substrate	Duration of reaction and extent of digestion			Control experiment	
		after 24 hrs	after 48 hrs	after 96 hrs	after 48 hrs	after 96 hrs
1	1% starch solution	±	±	±	-	-
2	5% Sucrose solution	-	+	+	-	-
3	2% Maltose solution	-	+	+	-	-
4.	2% Lactose solution	±	±	±	-	-
5	1% Raffinose solution	±	±	±	-	-
6	1% Inulin solution	-	-	-	-	-
7	1% Salicin solution	+	+	+	-	-
8	Saturated Glycogen solution	+	+	+	-	-
9	10% Gelatin solution	-	-	-	-	-
10	Condensed milk	-	-	-	-	-

++, an intensive reaction; +, definite positive reaction; ± only a trace of reaction; -, no reaction.

Table 33: Qualitative estimation of digestive enzymes present in the stomach of *M. hendersoni hendersoni* (de Man)

Sl. No.	Substrate	Duration of reaction and extent of digestion			Control experiment	
		after 24 hrs	after 48 hrs	after 96 hrs	after 48 hrs	after 96 hrs
1	1% starch solution	-	+	+	-	-
2	5% Sucrose solution	-	+	+	-	-
3	2% Maltose solution	-	-	-	-	-
4	2% Lactose solution	-	-	-	-	-
5	1% Raffinose solution	±	±	+	-	-
6	1% Inulin solution	-	-	-	-	-
7	1% Salicin solution	-	-	-	-	-
8	Saturated Glycogen solution	+	+	+	-	-
9	10% Gelatin solution	+	+	+	-	-
10	Condensed milk	Colour changes to yellow			No change	

Table 34: Qualitative estimation of digestive enzymes present in the intestine of *M. hendersoni hendersoni* (de Man)

Sl. No.	Substrate	Duration of reaction and extent of digestion			Control experiment	
		after 24 hrs	after 48 hrs	after 96 hrs	after 48 hrs	after 96 hrs
1	1% starch solution	-	-	-	-	-
2	5% Sucrose solution	-	±	+	-	-
3	2% Maltose solution	-	-	-	-	-
4	2% Lactose solution	-	-	-	-	-
5	1% Raffinose solution	-	-	-	-	-
6	1% Inulin solution	-	+	+	-	-
7	1% Salican solution	-	-	-	-	-
8	Saturated Glycogen solution	+	+	+	-	-
9	10% Gelatin solution	+	+	+	-	-
10	Condensed milk	No change in colour			No change	

++, an intensive reaction; +, definite positive reaction; ± only a trace of reaction; -, no reaction.

intervals and the results are depicted in the tables 31, 32, 33, and 34 respectively. Table 31 shows that most of the carbohydrates were digested by the enzymes secreted by the hepatopancreas. The inulinase and raffinase are less active and takes more time for complete hydrolysis. The fat digesting enzymes are lacking in the hepatopancreas of M. hendersoni hendersoni (de Man).

Experiments with the digestive juice of the oesophagus revealed that amaylase, invertase, raffinase and glycogenase are the only enzymes present in this part of the gut (Table 32).

Table 33 indicates that the presence of fat and protein digesting enzymes is the characteristic of the somach. However, other enzymes are also represented.

Table 34 shows that very few enzymes like inulinase, glycogenase and also some proteases are present in the intestine of M. hendersoni hendersoni (de Man). Similar experiments were conducted with the extracts of rectum and it was observed that no enzyme is present here.

3.7. NEURO-ENDOCRINE REGULATION OF BLOOD CHLORIDE*:

The blood chloride content in the normal animals (2.55 ± 0.21 mg/ml) decreased significantly (P 0.01) by 54.0% (1.35 ± 0.32 mg/ml) within 24 hr. after eye stalk ablation. The chloride content increased gradually on injection of eye stalk extracts and reached that of almost normal level (2.22 ± 0.08 mg/ml) after about 24 hr. (Fig. 72).

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* In: Indian J. Phy. Nat. Sci., 1983 (in press).

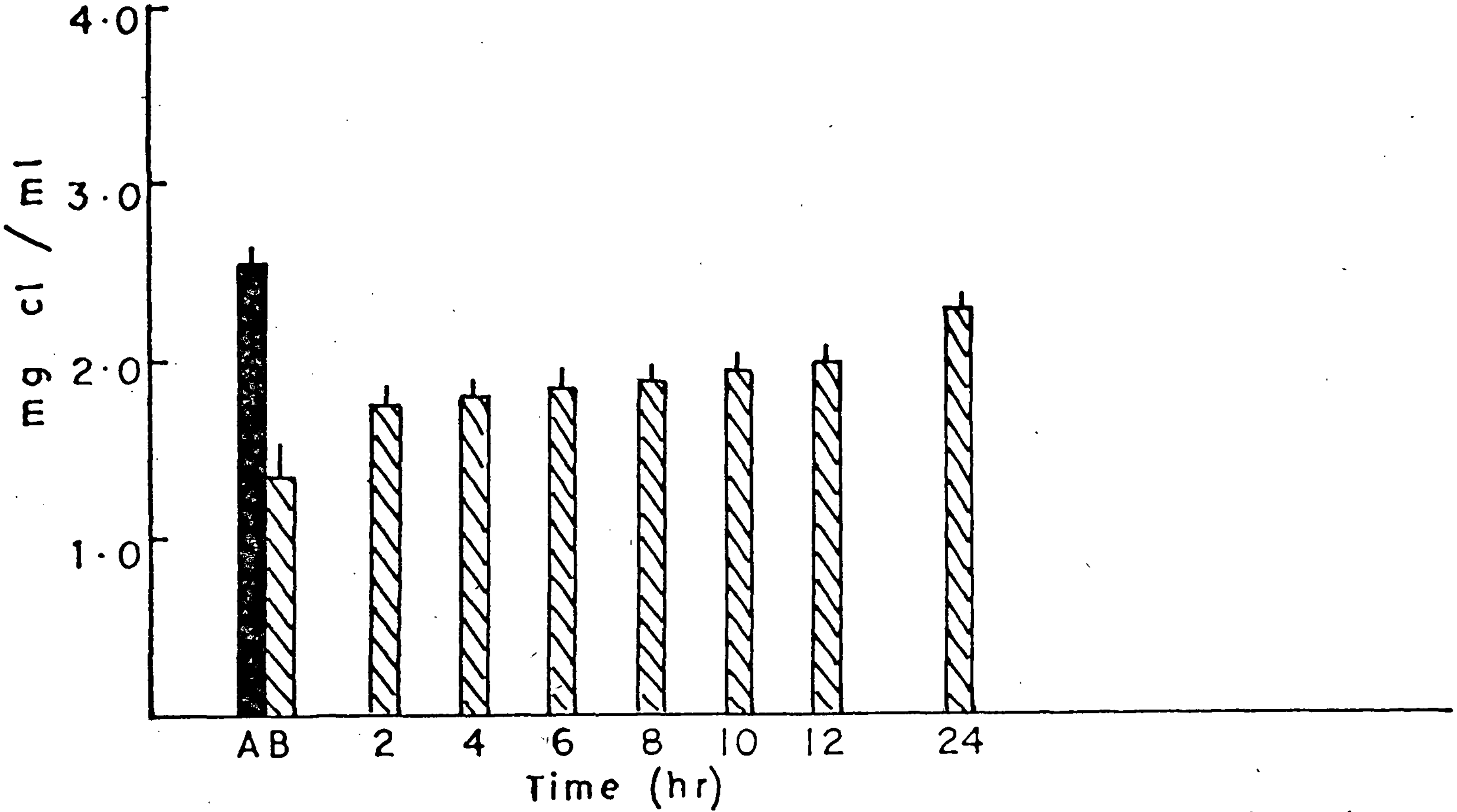

Fig.72. Blood chloride content in normal prawns with intact eye stalks (A), on eye stalk ablation (B) and at different intervals after injection of eye stalk extract into the eye stalkless prawn, M. *hendersoni hendersoni* (De Man).

4. DISCUSSION

4.1. Sexual dimorphism:

In Malacostraca, the first post-embryonic stages can not be sexed by internal or external morphology (Nagamine and Knight, 1980). In the present study a similar situation also exists. The sexual dimorphism in terms of growth size was reported in a riverine prawn, Macrobrachium ohione (Smith) by Truesdale and Mermilliod (1979). Data from the present study reveal that in both M. hendersoni hendersoni (de Man) and M. hendersoni cacharensis also a similar trend exists (Fig. 43). The sexual dimophism (Fig. 44) in terms of the allometric growth in the pleuron width could be an aid to form larger brood chamber as Nagamine and Knight (1980) has also studied in M. rosenbergii (de Man).

The sexually dimorphic endopods of the first pair of pleopods of both M. hendersoni hendersoni and M. hendersoni cacharensis are very similar in morphology to the same endopods of other species of Macrobrachium, e.g., M. rosenbergii (Nagamine and Knight, 1980) and M. malcolmsonii (Patwardhan, 1937) and other Plaemonidae, e.g., Palaemon serratus (Huguet, 1967), P. elegans (Hoglund, 1943) and Palaemonetes varians (Antheunisse et al., 1968). Bauer (1976) demonstrated that the specialized first and second endopods of the males of the hippolytid shrimp, Heptacarpus pictus (Simpson) aid in transferring, spermatophores to the female during copulation. A similar function for the specialized endopods of male palaemonids probably exists. In female Palaemonids, it has been demonstrated that the specialized first parir of endopods propel the newly laid eggs into the brood chamber (Hoglund, 1943; Burkenroad, 1947).

In both M. hendersoni hendersoni and M. hendersoni cacharensis the mature male chelipeds develop by a positive allometric growth of their five distal articles. Although other investigators have reported similar conclusions for other species (Henderson and Matthai, 1910; Cowles, 1914; Nagamine and Knight, 1980) both Misra (1959) and Koshy (1973) have reported that a similar growth pattern did not exist. Thus different growth patterns for the chelipeds exist in the genus. Observations in our laboratory and elsewhere (John, 1957; Rao, 1965) have demonstrated that mature male chelipeds are used for intra- and interspecific aggression. In both M. hendersoni hendersoni and M. hendersoni cacharensis males are territorial. Mature females, soon after the preparturial moult, are extremely active, and it is probable that this activity aids the female in seeking out a suitable mate. Thus, if a male and a female that have completed her prepaturial moult, are placed on opposite sides of an aquarium divided by a screen partition, the male is usually inactive, whereas the female continuously swims and crawls around the edges of the aquarium. After the partition is removed, the female's apparently random movements bring her into contact with the male. It is only after this contact that the male becomes active and mating ensues. After mating, the female, still remains soft and thus susceptible to predation and conspecific aggregation, and usually remains in the territory of the male and retreats to him if threatened. Similar behaviour was reported for *M. australiense* (Ruello *et al.*, 1973). Natural selection for larger male chelipeds probably occurs since males with the largest chelipeds are presumably most effective in fending off competing males, aggressive conspecifics, and predators, and thus are probably able to mate with more female and produce more progeny.

Thampy and John (1973) have noted a correlation between size of the androgenic gland and "hypertrophy" of male chelipeds and appendices masculinae during the breeding season of *M. idae* (Heller). The stimulus to develop mature male chelipeds and appendices masculinae is due to the androgenic gland hormone (Nagamine and Knight, 1977). From observations on the attachment of eggs and spermatophores, and on one occasion, of spawning, we concluded that the functions of the various setal groups are the same as for *Palaemon elegans* with one exception, the setae on the posterior sternum of the cephalothorax (Hoglund's Group V). In *P. elegans* this setal group is the site of attachment of spermatophores. Hoglund (1943) was of the opinion that that the setae aided in fertilization of the eggs by acting as a sperm laden "drapery" which the eggs must contact in their passage to the brood chamber. In both *M. hendersoni hendersoni* and *M. hendersoni cacharensis*, spermatophores are attached to the exoskeleton between the third periopods and are not associated with these setae in any way. Thus, in the present study, this setal group probably has no function in the fertilization process and may simply aid in guiding the eggs into the brood chamber as Nagamine and Knight

(1980) also reported in M. rosenbergii (de Man).

4.2. Maturity and Spawning:

In the testes of crustaceans studied so far, the spermatogonic cells are confined in descrete bodies which are variously described as cysts, cluster, seminiferous tabules or lobules each containing germ cells at different stages of spermatogenesis (Binford, 1913; Fasten, 1926; Baker and Rosof, 1927; Ryan, 1967; Gupta and Chatterjee, 1976) or at the same stage of maturation (Iyer, 1933; Wolfe, 1971; Wielgus, 1976). In Callinectes sapidus (Cronin, 1947), Portunus sanguinolentus (Ryan, 1967), Paratelphusa masoniana (Vasisht and Relan, 1971) and Scylla serata (Gupta and Chatterjee, 1976) testes have several lobes and their seminiforerous lobules open into a branched (Cronin, 1947) or unbranched seminiferous duct (Ryan, 1967). This duct continues posteriorly as vas deferens. In Macrobrachium hendersoni hendersoni, the testes are not lobulated and contain numerous seminiferous tubules having germ cell at various stages of spermatogenesis. The tubules become narrower towards posterior side of the testis, where their germ cell area is reduced or absent. These tubules appear to open directly into the vas deferens. Binford (1913) and Gupta and Chatterjee (1976) observed the presence of both spermatocytes and spermatids in the same tubule. Cronin (1947) and Gupta and Chatterjee (1976) found that all the spermatocytes of a tubule occur at the same stage of differentiation. In M. hendersoni hendersoni the meiotic division occurs more or less synchronously, as the individual maturing tubule contains either spermatids or only one type of spermatocytes which occur at approximately the same stage of differentiation.

The decapod sperm is bicentrosomal or tricentrosomal and aflagellated consisting of a head or nucleus and a vesicle variously described as primary vesicle (Fasten, 1926), mitochondrial vesicle (Nath, 1932; Dhillon, 1966) or acrosomal vesicle (Brown, 1966; Langreth, 1969). In M. hendersoni hendersoni also the sperm is aflagellate consisting of a head and a mitochondrial vesicle which encloses an axial filament and distal centrosome.

There is a paucity of information regarding the origin of new crop of germ cells in crustacean testes. A few primary spermatogonial cells (Binford, 1913) or residual spermatogonia (Aoto, 1952) which remained undifferentiated till the spermatogenesis is over, undergo divisions shortly after spermiation so as to produce a new batch of secondary spermatogonia.

In M. hendersoni hendersoni also some undifferentiated or resting spermatogonia are found throughout the year. It appears that after spermiation the new crop of germ cells is supplied by the division of such existing germ cells.

The testes of M. hendersoni hendersoni undergo seasonal histomorphological changes associated with change in testicular weight. The measurement of male gonad index revealed two types of spawning patterns among decapoda. In continuous breeders like *Penaeus indicus* (Subrahmanyam, 1963) and *Portunus pelagicus* (Rahman, 1967), the male gonad index was found constant throughout the year whereas in *Charybdis variegata* (Chandran, 1968) and *Barytelphusa cunicularis* (Diwan and Nagabhushanam, 1974) which breed discontinuously, definite peaks in gonad index were observed. Histological studies revealed the presence of both continuous (Baker and Rosof, 1927; Spalding, 1942; Black, 1966; Ryan, 1967; Haley, 1973) and discontinuous spermatogenetic cycle (Black, 1966; Chiba and Honma, 1972; Wielgus, 1976) in crustaceans. Such variation in the testicular activity may be due to the genetic differences and the local ecological conditions (Joshi and Khanna, 1982). *M. hendersoni hendersoni* shows discontinuous spermatogenetic cycle. Spermatogenesis begins during January-February, progresses slowly through March, reaching a peak in April or May. However, all the tubules do not mature at the same time, as both maturing and mature tubules become filled with sperms whereas maturing tubules consist of dividing spermatocytes or spermatids which produce sperms a little later during the prolonged breeding season (April-September). Thus, results in the production of sperms in successive waves and spermiation start before all the tubules are fully packed with sperms. The mature tubules undergo spermiations in May or June. Tubules soon after evacuation of sperms undergo spermatogonial proliferation. In other tubules of the same section of testis, meiosis is still continued. The production of sperms in successive waves during season indicates that one male prawn attempts to copulate more than once in a single breeding season. This seems to be advantageous since the fertilization is internal in *M. hendersoni hendersoni*. Diwan and Nagabhushanam (1974) reported long resting phase in the reproductive cycle of *Barytelphusa cunicularis*. In *M. hendersoni hendersoni* the spermatogenesis slows down gradually from July onwards and almost ceases by November. The testes enter a brief period of rest during December. In *Pachygrapsus crassipus* also spermatogenesis continues for a longer period during post spawning period as a result the recovery phase takes place gradually (Chiba and Honma, 1972).

The females reproductive organs of *M. hendersoni hendersoni* are built on same general plan as observed in other decapods by Hartnoll (1968), Vasisht and Relan (1971) and Chiba and Honma (1971). Several decapods possess a germinal zone in the centre of ovary (Kessel, 1968; Hinach and Cone, 1969; Rouquette, 1970; Laulier and Demeusy, 1974; Rao *et al.*, 1981) whereas in others the germinal zone is peripheral (Cronin, 1942; King, 1948) or is in the form of nests of germ cells distributed throughout the ovary (Weitzman, 1966), In *M. hendersoni hendersoni* the germinal zone occurs at the centre of ovary.

Little is known about the origin of new crop of germ cell in adult decapods. It is generally agreed that the new crop of germ cells arises by division of existing oogonia. In *Gecarcinus lateralis* (Weitzman, 1966) and *Pachygrapsus mormoratus* (Rouquette, 1970) oogonial mitosis occurs throughout the year. In M. hendersoni hendersoni, the resting oogonia or residual oogonia occur throughout the year but they divide shortly after ovulation and produce a new drop of oogonia cells for further growth of ovaries, as observed by Aoto (1952) and Laulier and Demeusy (1974) in other decapods.

The process of yolk formation varies considerably in different decapods. The yolk vesicles and yolk globules in the oocyte of M. hendersoni hendersoni correspond with fatty yolk vacuoles and proteinous yolk bodies of Carcinus maenas (Harvey, 1929), Macrobrachium lamarrei and Paratelphusa spinigera (Bhatia and Nath, 1931) and P. hydrodromous (Vasisht and Relan, 1971). Bhatia and Nath (1931) observed that the fatty yolk vacuoles appear initially at the peripheral ooplasm while the protein yolk bodies near perinuclear region. In the shrimp, Chirocephalus bundyi (Linder, 1959) the fatty yolk droplets and proteinous yolk granules first appear in the central region of ooplasm. In M. hendersoni hendersoni both yolk vesicles and yolk granules first appear at peripheral ooplasm and then extend progressively towards perinuclear region as has also been observed by Harvey (1929) in Carcinus maenas. The source of yolk material differs in various species of crustaceans according to several authors. Generally the yolk is formed from both extra occyte sources (Perinuclear endoplasmic reticulum and Golgi bodies) in collaboration with nucleolar extrusions (Kessel, 1968; Hinsch and Cone, 1969; Hinsch, 1970; Dhainaut and Leersynder, 1976) and extra oocyte sources (yolk precursors are incorporated from haemolymph into ooplasm) by diffusion through follicular cell layer (Linder, 1959; Beams and Kessell, 1963) or by micropinocytosis at oocyte surface (Hinsch and Cone, 1969; Dhainaut and Leersunder, 1976). The nucleolus during vitellogenesis undergoes progressive increase in size and show vacuolation (Harvey, 1929; Hinsch, 1970; Dhainaut and Leersynder, 1976). The nucleolar extrusions of granules which pass into ooplasm are belived to take part in yolk formation (endogenous yolk) in crabs (Harvey, 1929; Bhatia and Nath, 1931; Hinsch, 1970). In M. hendersoni hendersoni, neither the nucleolar granules were seen nor the nucleolus was found moved into the ooplasm. Although the increase in the size of nucleolus, its eccentric position and progressive vacualation, nothing can be said about its functions in the absence of direct evidence.

Seasonal gonad index studies revealed that the breeding cycle in prawns and other decapods varies widely, even in species having close taxonomic relationships or similar ecological niches, i.e., 1) continuous breeder around the year (Boolootian et al.,1959; Knudsen,1964; Rahman,1967; Badawi,1975), ii) seasonal breeders having one spawning season

(Boolootian *et al.*, 1959; Hartnoll, 1963; Otsu, 1963; Knudsen, 1964; Diwan and Nagabhushanam, 1974; Bomirski and Klek, 1974; Badawi, 1975) or two distinct spawning seasons (Knudsen, 1964; Chandran, 1968; Adiyodi, 1968; Goldstein and Lauria, 1975). The palaemonid prawn, *M. hendersoni hendersoni* is a seasonal breeder, as all the oocytes in the ovaries become fully mature at the onset of breeding season. Observation on the maturity studies indicated that the maximum ripe individuals of both *M. hendersoni hendersoni* and *M. hendersoni cacharensis* were available in April which were also reflected in gonad index and thereafter the gonad index declined indicating the onset of breeding season. The size at first maturity (Table 23) is smaller in *M. hendersoni hendersoni* than *M. hendersoni cacharensis* and this could atttibuted to the temperature differences of the two habitats (Sharma and Tiwari, 1978). Data on the sex ratio reveals the increase of the percentage composition of female in correspondence to the males during the breeding season and a similar situation was also reported by Rajyalakshmi (1980a) in *M. malcolmsonii* from Godavari river.

4.3. Brood size and Reproductive efforts:

It is evident from the observation that there is an increasingly linear relationship between the total length of female and the brood size (Table 26) in both *Macrobrachium hendersoni hendersoni* and *M. hendersoni cacharensis*. A similar relationship was observed in *M. lamarrei* (Katre, 1976). However, within the same size groups of both prawn populations, there appears to be variations in the brood size of the individual female (Figs. 55-57). In the present study for both the populations the log-log relationship between brood size and body weight found to be linear. Such linear relationship between fecundity and fish body weight has already been reported by several workers (Sarojini, 1957; Pillay, 1958; Kandler, 1959; Baxter, 1959; Bridger, 1961; Gupta, 1968; Varghese, 1961, 1973, 1976).

The positively significant correlations between the brood sizes and the ovigerous as well as ovipositing setae (Fig. 55) in the present study support the functions put forward by Nagamine and Knight (1980) for these breeding structures in M. rosenbergii (de Man). Antheunisse et al.(1968) while describing the breeding dresses of Palaemonetes varians in agreement with Hoglund (1943), also referred that it is just at the moment of egg laying that all of special breeding setae perform their real function. That is, they help in forming the closed incubation chamber for the short period before the cement has hardened. This is probably their principal purpose and not that of egg protection (as thought by Solloud, 1923). For, Hoglund very properly noted that in the characteristic spawning postion the pleopods without breeding setae should not fit closely enough to form an egg tight chamber. There are, in fact several gaps through which eggs could pass. It is by closing up these gaps that the breeding setae perform their function. The largest gap is between the fith pereiopod and the first pleopod. The female's second pleura begin to widen at the maturing stage and provides an extra space for the brood chamber, thereafter, accomodating large number of eggs. This situation is also reflected in our present findings (Fig. 56). The brood chamber is a permanent structure, if once it is formed (Nagamine and Knight, 1980).

Cody (1966) wrote of the "Principle of Allocation" as follows: "It is possible to think of organisms as having a certain limited amount of time or energy available for expenditure, and of natural selection as that force which operates in the allocations of this time or energy in a way which maximizes the contribution of a genotype to following generations. This manner of treatment of problems concerning the adaptation of phenotypes is called the Principle of Allocation, and one of its applications might be the formulation of a general theory to account for clutch size in birds". It is apparent that it does not mean the simple relationship among the amounts of time or energy allocated for different requirements, but rather the recognition of the realization of one pattern of allocation as a strategy for successful reproduction. If the amount of energy or substance which can be allocated by a female to the next generation in the form of reproductive matter, that is eggs produced, can not exceed a certain level, a larger relative brood size can only be attained by reducing egg size. This situation was more prevalent in _M. hendersoni cacharensis_ than _M. hendersoni hendersoni_ (Fig. 58). The mean egg volumes are also found to be inversely proportional to the relative brood size. However, the brood size exhibited significantly positive correlations with the egg volumes of three different stages. This suggests the high reproductive efficiencies exhibited by the two prawn populations in relation to their lotic habitat (Nishino, 1980). The intraspecific differences in egg size has been little noticed for freshwater shrimps and Kamita (1961) denied its occurrence for Palaemon paucidens. Kubo (1942) recognizes two groups of species of the genus Leander (= Palaemon) in Japan and adjacent areas in terms of egg size. The large egg group includes Palaemon paucidens, P. miyadii and P. modestus, all freshwater species, and all the small egg group comprises marine and brackish species. The intraspecific variations in the egg volume (Figs. 57 & 58) in both M. hendersoni hendersoni and M. hendersoni cacharensis, is in conformity with findings of Nishino (1980) in Palaemon paucidens from Japan. The pattern of intraspecific variation in egg size in P. paucidens appears to be characteristic. Egg size remains constant within any population except that from Lake Ohnuma, and displays great variation among the population. In fish, both cases are known, where egg size varies with body size, as in rainbow trout (Kato, 1975) and cat fish (Davis, 1977), or remains constant, as in some species of cichlids (Fryer and Ides,1972), within a population. In the case of rainbow trout (Kato, 1975), egg sizes are relatively similar only within a year class. Azuma (1973) reported the variation in egg size between the population of the ayu-fish, Plecoglossus altivelis, but in this case egg size varies with body size within a population. By comparison of three local populations of a goby, Tridentiger obscuIus, Kishi (1978) concludes that egg size of each population remains almost constant regardless of female body size, but the egg size and body size of the female in the lake population are decisively smaller than those from the river and estaury populations.

Barnes and Barnes (1965) reported that the egg of boreo-arctic species are remarkable for their large size compared with all other species, and for Balanus balanoides that eggs are larger in populations from the areas where winters are severe and summers relatively cold. A similar situation also exists for M. hendersoni hendersoni and consequently the egg size were also larger and this could be referred further as an adaptation to low temperature condition (Nishino, 1980).

In M. hendersoni cacharensis, the larger brood sizes are attained in spite of small body size (Figs. 55 & 58), resulting in exceptionally high relative brood size. Being associated with this, an apparent decrease in egg size has also occurred. The high relative brood size achieved through diminishing the egg size in M. hendersoni cacharensis may thus be regarded as an adaptive strategy of allocation as Nishino (1980) pointed out for Palaemon paucidens.

4.4. Larval development:

As regards the larval development, the genus Macrobrachium exhibits three different patterns:

i) Prolonged type: With large number of small sized eggs and larval history having a large number of free swimming larval stages (8-16 zoeal stages), e.g., *M. rosenbergii*(Ling and Merican, 1961; Ling, 1969; Uno and Kwon, 1969), *M. carcinus*, (Lewis, 1961; Lewis and Ward, 1965; Chaudhury, 1971), *M. nipponense*, (Kwon and Uno, 1969), *M. acanthurus*, (Kwon and Uno, 1969), *M. acanthurus*, (Chaudhary, 1970), *M. malcolmsonii*, (Kewalramani *et al.*, 1970), *M. formosense*,(Shokita, 1970), *M. niloticum* and *M. intermedium*, (Williamson, 1972), *M. idella*, (Pillai and Mohamed, 1973), *M. amazonicum*, (Clell Guest, 1979).

ii) Abbreviated type : With comparatively larger sized and lesser number of eggs than in the first type and also with lesser number of free swimming larval stages, e.g., *M. lamarrei*, (Rajyalakshmi, 1961; Sharma and Tiwari, 1978), *M. australiense*, (Fielder, 1970).

iii) Totally abbreviated type : With eggs generally larger than in the second type and lesser in number, larval stages minimum, the larvae on hatching without functional legs, and resemble post larva or adult, e.g., *M. potuina*, (Sollaud, 1923), *M. shokitai*, (Shokita, 1973) and *M. hendersodayanum*, (Jalihal and Shankolli, 1975).

The larval development of both *M. hendersoni hendersoni* and *M. hendersoni cacharensis* fits into the third category. In *M. shokitai*, the life history comprises 3 larval (2 zoeal + 1 megalopa stages as per Shokita, 1973) stages, whereas in *M. hendersodayanum* (Jalihal and Sankolli, 1975) the abbreviation was extreme, with only one larval stage before the post larva. A similar pattern of larval development was noted in the present study for *M. hendersoni hendersoni*. On the other hand, *M. hendersoni cacharensis* exhibited two larval stages and took comparatively longer duration before the post larva. However, the 1st stage larva of *M. hendersoni cacharensis* shows distinct advancement over that of *M. shokitai* (Shokita, 1973) in possessing such advanced features right from rostrum to pleopods, so that even the 2nd stage larva of *M. hendersoni cacharensis* fairly compares well with the 3rd and 4th (post larval) stages of *M. shokitai*.

The larvae of Palemoninae were described by Sollaud (1923) under two groups. To the first group belonged the "normal zoea" and the second group larvae were termed as "hypomysis". The larva which hatch out in *M. hendersoni hendersoni* and *M. hendersoni cacharensis* were similar to Sollaud's second group. The suppressed development of all buccal organisms in these larvae can be correlated with the presence of sufficient amount of reserve food material due to which the larvae do not have to depend upon the external food supply. On the other hand, the differentiated scaphognathite of maxilla II helps to produce a respiratory current in the branchial chamber right from the time of hatching.

The genus *Macrobrachium*, though supposed to have marine origin, has several of its species penetrated into fresh water environments, for the success of which the developmental phase appears to have contributed significantly. This is also supported from the present findings on the life histories of both M. hendersoni hendersoni and M. hendersoni cacharensis. Tiwari (1955) while discussing the trends in evolution of the Indo-Burmese species of Palaemon(=Macrobrachium) suggests that hendersoni group to which the present prawns M. hendersoni hendersoni and M. hendersoni cacharensis belongs, is one of the pioneering groups which started migrating towards freshwater and by now has fully established in freshwater environment. Tiwari's (1955) observations were, however, mainly based on adults and their geographical distribution, lacking direct evidence on larval development. The present study lends further support to Tiwari's above hypothesis. It has been suggested by Gurney (1942) that land-locked populations tend to favour abbreviated development and the amount of yolk in the eggs have great influence on the course of development. The large size and less number of eggs with extremely abbreviated development with no free swimming larval stages considered to be the features of purely freshwater animal (Gurney, 1942). Observation on the present study in M. hendersoni hendersoni reveals that the adaptation of this species to freshwater habitat is completed, Also, the occurrence of the population at Umshing stream at an altitude of 1514 meter further proves the successful establishment of the species to the freshwater environment. On the other hand, M. hendersoni cacharensis collected from Pongtung stream at an altitude of 690 meter and occurrence of two larval stages suggest that this population is still in the process of invasion further towards the inland conditions.

4.5. Food and Feeding habits:

Prawns inhabit the benthic region and feed on living animals and plant matters available nearby as well as sand and silt particles, and dead organic matters. In both *M. hendersoni hendersoni* and *M. hendersoni cacharensis*, food is grabbed by the chelae of the thoracic appendages and taken into the mouth where the maxillipeds help in further cutting and driving it towards the mandibles which macerate the food into finer particles fit for swallowing. A similar feeding habits were also reported for *M. malcolmsonii* by Patwardthan (1937).

Nikolsky (1963) classified the food of fishes into three main categories, i.e. (i) basic food, (ii) secondary food and (iii) incidental food. Nikolsky (1963) further noted that the fishes were either (i) euryphagic (feeding on a variety of food) or (ii) stenophagic (feeding on a few different types of food) or (iii) monophagic (feeding on only a single type of food. Accordingly, the basic food of *Macrobrachium hendersoni hendersoni* and *M. hendersoni cacharensis* as observed in the present study may be considered as insects, diatoms, filamentous algae, other algae and detritus which collectively comprise 60-75% of the total foregut contents. Sand and silt particles, nematodes, mosses and plant matters and crustaceans may be considered as the secondary food of *M. hendersoni hendersoni* and *M. hendersoni cacharensis*. The remaining items i.e., oligochaetes and miscellaneous groups found in the foregut may be regarded as the accidental food due to the fact that they form a very small fraction of the gut contents and occur without any regularity in different months.

Patwartdhan (1937) has mentioned that the food of *M. malcolmsonii* consists of algae, moss, sea weeds and small insects. According to Chopra (1939) the prawns eat all types of food living or dead that comes in the way. Subramayam (1963) studied the stomach contents of *Metapenaeus affinis*. The diet appeared to be predominantly made up of animals from the bottom such as nematodes, foraminiferans and molluscs. Gastropods and bivalves formed about 11 to 90% of food and in several prawns stomachs were gorged with shells of molluscs. Nematodes, copepods and amphipods formed lesser in proportion to molluscs. Diatoms and algal filaments were found in a few prawns. Debris and sand particles were observed along with other items of food. Dall (1968) who studied the stomach contents of Australian commercial penaeid shrimps, *Penaeus esculentes*, *P. merguiensis*, *P. plebejus*, *Metapenaeus bennettae* and *M. macleayi*, found remains of small animals and a large amount of unrecognizable material like chitin fragments, annelid jaws, setae and also sand. According to William (1955) the presence of unrecognizable debris is suggestive of the major role of soft parts in the diet. The mud contains bacterial colonies and filamentous algae in which protozoans, copepods and nematods and other fauna are abundant.

In a densely populated shrimp ground large food masses may be insufficient to support a healthy population, and this deficiency is likely to be made by feeding on the epifauna and epiflora (Dall, 1968). A similar situation also noted for both *M. hendersoni hendersoni* and *M. hendersoni cacharensis* (Goswami *et al.*,1982,1983c).It was observed that few insects viz. *Ramphocorixa* sp. and *Micronecta* sp. deposit the eggs either on the cephalothorax or on the ventral surface of the prawn and once the eggs hatch into new insects, may serve as supplemented food for the prawns.

Kuttayamma (1974) made a study of the feeding habits of *Metapenaeus dobsoni*, *M. affinis*, *M. monoceros*, *Penaeus monodon* and *P. indicus* in the Cochin area. The food, in general, consisted of varying amounts of organic matter mixed with sand and mud. In prawns cought from estauries the food contents comprised polychaetes, amphipods, bivalves, gastropods, foraminiferans, nematodes, sand and mud, thus exhibiting marked benthic feeding. In specimens obtained from paddy fields stomach showed a large amount of plant matter, indicating the the adjustibility of such prawns to environmental conditions. In both the prawns, *M. hendersoni hendersoni* and *M. hendersoni cacharensis* also a similar type of feeding diversity was recorded but comparatively the percentage composition of molluscs in the gut content was almost negligible or rather insignificant and thus, included under miscellaneous group.

The foregut contents analysis of both M. hendersoni hendersoni and M. hendersoni cacharensis have shown that all the items of food organism available in the water are also represented in the gut (Fig. 66). This may indicate a great degree of opportunitism and versatility in terms of food preference. However, it is clear from our data that when all types of food item are available in the water both the prawn populations preferred certain food items, i.e., sand and silts, filamentous algae, mosses and plant matters, crustaceans, oligochaetes and nematodes.

It has been observed from the results that there exists monthly variations of different food items in the foregut contents of M. hendersoni hendersoni and M. hendersoni cacharensis (Figs. 68-71). Similar results have also been observed by various workers in different shrimps (Panikkar, 1952; William, 1955, 1958; Eldred et al., 1961; Hall, 1962; Subramanyam, 1963; Dall, 1967, 1968; Warren and Sheldon, 1967; Hughes, 1968; George, 1972; Rodriguez and Naylor, 1972; Thomas, 1972; Kuttyamma, 1974; New, 1976; Marte, 1980, 1982). The present results support the view of Nikolsky (1969) that the fish fauna of high latitudes are usually adapted for eating various types of food, on account of the high variability of the available food. The range of food organisms may vary greatly from area to area, even as regards to basic food, specially in freshwater conditions. Suyehiro (1942) attributed the omnivorous feeding habit of the freshwater fishes to the limited supply of food in the habitat. The stress is more severed on lotic and brackish water animals since they have to get physiologically adapted to the widely fluctuating ecological factors. The wider choice with the inclusion of animal foods subsequent to the onset of maturity may be to augment the protein intake as well (Nair and Sobhana, 1980). In the present study, a similar situation was also noted for both *M. hendersoni hendersoni* and *M. hendersoni cacharensis*.

The monthly fluctuations of the gastro-somatic index of *M. hendersoni hendersoni* and *M. hendersoni cacharensis* reflects the extent of feeding by them. The major peak in the month of March may be due to prolonged period of metabolic activity to build up the body for the spawning as this period is just prior to spawning season. The other two minor peaks of increased intensity of feeding are in August and October. It is possible that after spawning as a recuperative process the prawn becomes voracious eater which in turn, is reflected with high rate of feeding intensity. The drop in feeding intensity in December to February is likely to be due to the prevailing low temperature of the habitat during the winter months and reduced activity of the prawn (Goswami and Majhi, 1981). The fall in the feeding intensity (Fig. 67) in the month of July might be due to some physiological changes during the breeding season.

During the months when the feeding index is high, crustaceans and algal matter constituted relatively greater proportion of the food. Mosses and plant matter, sand and silts, oligochaetes and miscellaneous group contributed larger fractions of food, in summer and autumn seasons. Insects, nematodes and detritus contributed major part of the food material in autumn and winter season. These variations in feeding habit reflect changes in dietary requirements which may be related to different body metabolism viz. gonad development, moulting etc. (Marte, 1980, 1982). A seasonal fluctuations in fat content was noted in Penaeus indicus (Gopalakrishnan, 1953). In this prawn, a higher percentage of fat is present during the months when non-crustaceans form the bulk of the food. The relatively small amounts of organic detritus, silt and sand, recovered from our specimens indicate that the adult is less of a scavenger and more of a predator on slow moving benthic macroinvertebrates, mainly small insect eggs, larvae and adults, Marte (1980) also reported a similar finding for Penaeus monodon from Makato river. Males of both M. hendersoni hendersoni and M. hendersoni cacharensis seem to feed more actively (Fig. 67) than the females as seen from the higher gastrosomatic index. The poor feeding by the female during the breeding season may be attributed to the development of gonads which occupy the major space of the abdominal cavity. Desai (1970) and Pathak (1975) have recorded similar observations in different fishes.

Panikkar (1952) has stated that food of young penaeids consists of algae, minute organisms and organic detritus. In Macrobrachium hendersoni hendersoni and M. hendersoni cacharensis, the food of juveniles and actively breeding populations (size groups I & II) are dominated by sand and silt particles, detritus and diatoms (Tables 28 & 29). This reflects their semibenthic habits. Gopalkrishnan (1952) has made an analysis of the stomach contents of a large number of Penaeus indicus caught from the inshore waters of Madras coast. Gopalkrishnan (1952) reported that the chief contents of the food in the juvenile group were: digested matter and detritus, vegetable matter, crustacean matter and non-crustacean animal matter. Vegetable matter constituted fragments of different kinds of algae and also cuttings of sea weeds and other green matter. Sand particles were also present.

Prawns kept in laboratory aquarium consumed algae, planktonic organisms and oligochaetes preferring small pieces which could be held in the chelate legs. When the pieces were big, more than one chelate were used. When prawns of different sizes were kept together the bigger ones did not attack the smaller ones inside the aquarium. When one was dead or became weak other attacked and made a meal of it. It is likely that in nature, prawns are partly predatory chasing smaller ones of suitable size that may be caught within their chelae.

The insects, filamentous algae, detritus, diatoms and other algae constitute the major fraction of the food in the post-breeding populations (size group III) of M. hendersoni hendersoni and M. hendersoni cacharensis. The gradual changes of preference from sand and silt, diatoms, detritus and crustaceans to higher aquatic plants, mosses and insects may be to avoid effectively the direct competition for food between the younger group. Such differences in the diet are of survival value reducing the likelihood of intraspecific competition and making it easier for prawn of different sizes to occupy the same habitat.

The distinct preference to benthic flora and fauna by the post breeding prawn populations is probably a reflection of the behaviour of the groups which spend most of the time in benthic zone of the stream because the material in the foregut faithfully reflects the relative environmental densities of food items falling within the ingestible size range. The comparatively lesser amount of detritus and sand particles present in the foregut of the largest size group represents either the gut contents of the prey of materials swept into the mouth during capture of the prey. Such materials may be of nutritional value to the prawns. Although the detritus and algae as the gut contents of the prey have a reduced caloric per gram (Nair and Sobhana, 1980) value such material is mechanically disrupted partially digested, prepacked food supply which may well be assimilated with considerable efficiency. In fact the early instars of benthic insects before they have begun any significant fat deposition, contain large, fully packed digestive tracts which serve as an excellent source of food (Gupta, 1980). A dominance of insects in the diet of older size groups is therefore significant, since they are feeding on the digestive tracts of the prey which serve as convenient instruments of collecting and packaging food.

4.6. Digestive physiology:

The alimentary canal of Macrobrachium hendersoni hendersoni consists of appendages (three pairs of maxillipedes, a pair of maxillae, maxillulae and mandibles), compactly built cardiac stomach, small pyloric stomach, long narrow intestine and a very well marked rectum. The stomach is covered with disc like hepatopancreas which is responsible for the secretion of enzymes and for storing the digested food. Yonge (1937) has reported that there is a definite correlation between the food and the nature as well as the relative strength of digestive enzymes of Nephrops norvegicus. Agarwal (1964, 1965) has reported that the medium in the gut of Orchestia gemmarella and Grammarus pulex is throughout acidic. In the intestine and rectum of M. hendersoni hendersoni (de Man) the medium was found to be alkaline whereas in other parts it has been shown considerably acidic in nature. This can be due to the omnivorous feeding habits of the prawns. It is also found that starvation of the animal alters the pH by increasing the concentration of the media. However, selective feeding seems to have not much effect on the pH of the gut.

The hepatopancreas appears to be the main seat for the secretion of enzymes. However, most of the enzymes are also present in the stomach. It can be correlated with the fact that the enzymes secreted by the cells of the hapatopancreas are carried to the pyloric stomach through the ducts. Nicholls (1931) and Agarwal (1964) have reported the role of central caeca of Ligia and Orchestia in food digestion. But in M. hendersoni hendersoni, it has been observed that the digestion takes place inside the pyloric stomach.

The qualitative estimation of enzymes reveals that all the enzymes are present in some or other parts of the gut. However, the hepatopancreas is specialized in digesting the carbohydrate whereas the stomach for digestion of all types of diet.

In the foregut of Orchestia, Agarwal (1964) has detected only amylase, glycogenase and invertase whereas in the oesophagus of M. hendersoni hendersoni, as found in the present study, raffinase is also present in addition to those of Orchestia.

4.7. Neuroendocrine-regulation of blood chloride:

Most crustacea living in water of low salinity maintain their blood hyperosmotic to the medium by actively transporting salts into the body (Robertson, 1960). The rate at which they have to do this, and consequently the amount of work that has to be done in regulating the blood concentration, depend on the rate at which ions are lost from the body, in the urine and across the surface. The rate of loss depends on the permeability of the body surface to ions and water and on the gradient maintained between the blood and the medium (Gross, 1957; Robertson, 1960). It reveals from the observations that the eye stalks possess a blood chloride regulating factor and it acts in elevating the chloride content. Hence its loss through eye stalk ablation results in a drop in quantity and its replenishment through the extract injection elevate the same to the normal level. The factor might increase the chloride uptake from the medium or may influence the absorption of ions in the excretary organ or may even mobilise the ions from other tissues. It was reported in *Procambarus clarkii* (Kamemoto *et al.*, 1966) that eye stalk removal decreases the blood ion contents and eye stalk injections prevents the decrease (Kamemoto and Ono, 1969). The blood chloride increasing factor have been reported to be present in brain (Kamemoto and Ono, 1969) and thoracic nerve cord (Kamemoto and Tullis, 1972) of these animals. A similar substance is present in other freshwater forms such as *Potamon dehaani* and *Sesarma hematocheir* (Kamemoto, 1974). On the other hand, the marine forms, *Spirontocaris marmoratus*, *Metopograpsus messor* and *Thalamita crenata* seem to possess a blood chloride decreasing factor (Kamemoto and Tullis, 1972).

It was also observed by Kamemoto and Tullis (1966) that the injection of thoracic ganglionic extracts increases the blood chloride level in the freshwater crabs maintained in tap water while in the marine crabs kept in dilute media a similar treatment decrease the blood chloride content. Thus the blood chloride concentration is regulated by the neuroendocine principle in crustaceans and it does so by elevating the level of ions in hyperosmotically regulating freshwater forms and by decreasing the same in hyposmatically regulated marine forms. The prawn, *M. hendersoni hendersoni* being a freshwater animal, has to regulate hyperosmotically and keep the chloride at a higher level. Hence the eye stalk factor increasing the blood chloride concentration, seems to play a significant role in the hyperosmotic regulation of the animal when it is in freshwater.

SUMMARY

There is a paucity of information on the ecology and biology of indigenous prawns in the highlands of the North Eastern Hill Regions of our country. Such a knowledge, is of utmost importance not only from the academic view point, but also in its utility in ever-increasing technological efficiencies of the fishery entrepreneurs for evolving judicious management measures. Meghalaya with its swift flowing streams and rivers offer an excellent scope for studies on available prawn species. The traditional practice of shifting cultivation termed "Jhum" which promotes denudation and soil erosion is part of the stresses to which fauna of this region are usually subjected. The present thesis highlights certain aspects of ecology and biology of two palaemonid prawns, Macrobrachium hendersoni hendersoni (de Man) and M. hendersoni cacharensis (Tiwari).

ECOLOGY

M. hendersoni hendersoni and M. hendersoni cacharensis are commonly available in the lotic as well as semilotic water bodies of Umshing, Barapani (25°41'06"N and 91°51'27"E, altitude, 1050-1514 m) and Pongtung (25°15'00"N and 91°54'15"E, altitude 610-690 m) respectively. The data for the present study were collected for two annual cycles, i.e. January 1979-December, 1980. In Umshing area the various climatic factors viz. rainfall, wind velocity, air temperature - maximum, minimum, humidity at 8.30 hrs and 17-30 hrs, fluctuated in the range of 0.0-512.0 mm, 2.4-8.2 km/hr. 14.7-26°C, 5.1-18.0°C, 41.0-92.0%, and 53.0-92.0% and 53.0-92.0% while in Pongtung area they fluctuated in the range of 0.08-484.2 mm, 2.2-6.6 km/hr, 22.5-34.2°C, 11.2-24.5°C, 48.0-84.0% and 68.0-90.0% respectively.

Physiographically, all these landmasses represents a remnant of an ancient plateau of Pre-cambrian Indian peninsular shield uplifted to its present height. Lithologically, Umshing area is mainly of sandy (arenanceous) and clayey (argillaceous) type while Pongtung area is represented by conglomerates, sand stones and limestones of Jadukata and Mahadek formation. The soil varies all over the study area. It is mostly lateritic type derived largely from granites, schists and the soil in the basins is more fertile than the upland soil.

Both Umshing and Pongtung streams have vegetation cover over the bank sides and included herbs, shrubs, grasses and trees. The coniferous vegetation is the salient feature of the Umshing area while in Pongtung area, the broad leaf vegetation is common. Stream substrates in both the cases are predominantly small boulders with stones, gravels and sand in between. The various emergent vegetation in the shallow areas, mosses and liverwort on the larger rocks and boulders are recorded in both the sites.

From head waters to mouth, the physico-chemical variables within a lotic system present a continuous gradient of physico-chemical condition. This gradient should elicit a series of responses within the constituent populations resulting in a continuum of biotic adjustments and consistent patterns of loading, transport, utilization and storage of organic matter along the length of a lotic body.

In Umshing stream, i.e. the habitat of M. hendersoni hendersoni, the various physico-chemical variables, viz. water temperature, transparency, rate of water flow, specific conductivity, total alkalinity, silicate, phosphate-phosphorous, nitrate-nitrogen, ammonia-nitrogen, calcium, magnesium, chloride, potassium, iron and oxidisable organic matter fluctuated in the range of 10.0-18.8°C, 4.0-33.0 cm, 42.2-94.2 cm^3/sec., 8.5-96.0%, 7.0-13.8 mg/l, 5.7-7.3, 1.8-5.0 mg/l, 31.8-65.2 µmho/cm, 15.0-48.8 mg/l, 3.8-7.6 mg/l, 0.30-1.30 mg/l, 0.14-0.98 mg/l, 0.044-0.094 mg/l, 2.0-3.9 mg/l, 0.51-2.64 mg/l, 0.40-1.35 mg/l, 1.6-4.0 mg/l, 1.6-4.7 mg/l, 0.9-2.7 mg/l and 1.0-5.2 mg/l while in Pongtung stream, these have been fluctuating in the range of 17.0-32.0°C, 10.0-55.0 cm, 38.2-84.5 cm^3/sec., 8.0-80.0%, 6.8-11.2 mg/l, 5.8-7.5 mg/l, 2.4-4.9 mg/l, 17.0-62 µmho/cm, 16.2-48.2 mg/l, 2.10-4.25 mg/l, 0.24-1.10 mg/l, 0.22-0.88 mg/l, 0.05-0.094 mg/l, 2.20-4.50 mg/l, 1.0-2.8 mg/l, 0.35-1.18 mg/l, 1.7-3.92 mg/l, 1.7-4.0 mg/l, 0.50-2.10 mg/l and 2.4-8.4 mg/l respectively.

In comparison to Pongtung stream, the plankton of Umshing stream is limited in mass and productive potential but relatively rich in diversity. Categorically, Myxophyceae, Chlorophyceae, Dinophyceae, Chrysophyceae, Rhodophyceae and Baccillariophyceae contributed in the range of 5.0-20%, 25.0-50%, 0.2-3.5%, 0.5-4.5%, 0.2-2.1% and 35.0-61.9% in the Umshing stream while they contributed 5.0-18.58%, 35.4-65.25%, 0.5-4.3%, 4.0-11.66%, 0.50-3.62% and 16.3-46.0% towards their total phytoplankton composition respectively. In the present study, ten genera of Myxophyceae, twenty-one genera of Chlorophyceae, two genera of Dinophyceae, eight genera of Chrysophyceae, three genera of Rhodophyceae and seventeen genera of Baccillariophyceae were recorded.

In association with the algae, a considerable number of micro-consumers i.e. zooplankton were recorded. In Umshing stream, Protozoa, Rotifera, Ostracoda, Copepoda and 10.0-25.0%, 5.56-24.2%, 4.54-37.0% while in Pongtung stream they contributed in a fluctuating range of 34.0-62.5%, 14.58-30.0%, 2.0-10%, 4.0-28.69% and 2.0-28.0% towards the total zooplankton composition. In the present study, eleven genera of protozoa, nine genera of rotifera, single genus of ostracoda and copepoda and six genera of cladocera were recorded.

Comparatively Pongtung stream supported a quite large number of benthic organisms throughout the annual cycle though there exists seasonal fluctuations too. The benthic fauna of Umshing stream on the other hand is limited in mass and productive potentials but relatively rich in diversity. Categorigally, the percentage composition of different benthic groups, viz. Nematoda, Oligochaeta, Decapoda, Insecta, Gastropoda and miscellaneous groups fluctuated in the range of 5.88-25.0, 2.7-18.0, 16.0-30.24, 21.0-58.82, 2.0-16.13 and 4.0-17.0 while in Pongtung stream in terms of their percentage composition :

these groups fluctuated in the range of 11.11-32.0, 4.0-19.0, 19.0-33.0, 11.8-55.0, 1.0-8.5 and 3.2-17.0 respectively. In the present study, the benthic organism recorded included eleven genera of nematodes, ten genera of Oligochaetes, three genera of decapods, forty three identified and three unidentified genera of Insects, four genera of gastropods and ten genera of miscellaneous group.

In comparison to *M. hendersoni hendersoni*, *M. hendersoni cacharensis* exhibited higher population density throughout the study period. The maximum density recorded was during rainy summer and the minimum in the rainless winter. During the first annual cycle the catches of *M. hendersoni hendersoni* exhibited the maximum density of $67/m^2$ in the month of September and minimum of $14/m^2$ in December while during the next annual cycle again in September the maximum of $70/m^2$ and the minimum of $19/m^2$ in January were recorded. The catches of *M. hendersoni cacharensis* exhibited maximum population density of $104/m^2$ in August and minimum of $18/m^2$ in January during the first annual cycle while the maximum of $102/m^2$ in August and minimum of $18/m^2$ also in January was recorded during the next annual cycle. The extent of structural and functional dynamicity of both the two palaemonid prawn populations were clear from their length frequency distribution study and was noted to be closely associated with their breeding behaviour. Both Umshing and Pongtung stream sites were dominated by male prawns over the female.

Information on the occurrence, characteristics and importance of the accessory habitat reported here, is first of this kind from hill stream condition and unique in many ways. These accessory habitats are found to serve the purpose of breeding. As these breeding depressions are provided in nature by the process of denudation by the running water and active weathering, the presence of accessory habitat becomes an added advantage to the prawn population.

Monthwise averages of condition factor (K) for four categories of prawn population based on the size group have been studied. The 'K' factor exhibited higher values in case of the young population than the actively breeding group and post-breeding group. In all the four categories, the 'K' factor represented its two peaks, one in spring and the other in late summer. Surprisingly, the 'K' values were always higher in males than females of both M. hendersoni hendersoni and M. hendersoni cacharensis.

The total density of M. hendersoni hendersoni exhibited significantly positive correlation with rainfall, water temperature, rate of waterflow, turbidity, dissolved oxygen, phosphate-phosphorous and chloride concentration, while correlation with water transparency, total alkalinity, sodium, potassium and oxidisable organic matter revealed significantly negative. The correlations with total phytoplankton, zooplankton as well as benthic organism resulted significantly positive, and particularly the correlation of the total density of

M. hendersoni hendersoni with chlorophyta, chrysophyta, baccillariophyta, ostracoda, copepoda, cladocera, nematoda, decapoda and Insecta are found to be positively significant. The correlations of the four size groups of M. hendersoni hendersoni with these forty one physico-chemical and biotic parameters (rainfall, water temperature, transparency, turbidity, rate of water flow, dissolved oxygen, pH, carbon dioxide, specific conductivity, total alkalinity, phosphate-phosphorous, nitrate nitrogen, ammonia-nitrogen, silicate, chloride, calcium, magnesium, sodium, potassium, iron, oxidisable organic matter, total phytoplankton, myxophyceae, chlorophyceae, chrysophyceae, dinophyceae, rhodophyceae, baccillariophyceae, total zooplankton, protozoa, rotifera, copepoda, ostracoda, cladocera, total benthic organism, nematoda, oligochaeta, decapoda, insecta, gastropoda and miscellaneous group) were also studied.

The total density of M. hendersoni cacharensis exhibited significantly positive correlations with rainfall, water temperature, turbidity, dissolved oxygen, chloride contents, while the correlations with water transparency, total alkalinity, sodium, potassium, iron and oxidisable organic content resulted in signficantly negative r-values. Total phytoplankton, zooplankton and benthic organisms have shown significantly positive correlations and also categorically, myxophyta, chlorophyta, chrysophyta, baccillariophyta, rotifera, ostracoda, copepoda, nematoda, oligochaeta, decapoda, insecta and gastropoda groups. Probably, these reflect the importance of prawn population in lotic food chain. Correlations of four categories of *M. hendersoni cacharensis* population density with all these forty-one physico-chemical and biotic variables were studied to identify their ecosystem chains.

BIOLOGY

The development, maturation and function of some sexually dimorphic characters of *M. hendersoni hendersoni* and *M. hendersoni cacharensis* were studied. The sexual dimorphism exists among both the prawns populations in terms of the relative growth of the carapace-total length relationship, body weight-total length relationship, pleuron width-total length relationship and exopod-endopod relationship. The growth of the relative length of various distal articles also exhibited sexual dimorphism in both *M. hendersoni hendersoni* and *M. hendersoni cacharensis*. But, the relative growth pattern of carpus and merus length did not show any significant difference. The larger male chelipeds function primarily in reproduction by allowing a male: a) to fend off other males intruding into its territory, and b) to protect females, with which it has mated, from aggressive conspecifics and predators. The brood chamber and reproductive setae of females begin to develop at 37.0 mm total length. This may also occur on several molts before their first spawning. Reproductive setae are divided into ovigerous and ovipositing setae depending upon their function. Ovigerous setae are temporary, others are permanent since they are retained on non-parturial molts.

The paired testes of M. hendersoni hendersoni show histomorphological changes during various stages of maturity. Seminiferous tubules show different stages of spermatogenesis. A few undifferentiated or resting spermatogonia supply a new crop of germ cells for the next breeding season. In a tubule the meiotic divisions occur more or less synchronously in all the primary or secondary spermatocytes. Spermatogentic activity is seasonal spermatogenesis begins in October-February, progress slowly through March, reaching its peak in April-May. However, all the tubules do not mature simultaneously. Spermiation occurs during May-September, the spermatogenesis ceases gradually and by December the testes enter a brief period of rest.

The ovaries of M. hendersoni hendersoni undergo seasonal morphometric and histological changes. A minute oviduct leads into the seminal receptacle which receives sperms during breeding season. Oogonia and young occytes develop in the germinal zone, present in the centre of the ovary. The resting or residual oogonia which occur throughout the year divide shortly after ovulation and supply new crop of germ cells for the next breeding season. The gonad index and ova diameter were minimum in September-November and reached a maximum value in April.

In both M. hendersoni hendersoni and M. hendersoni cacharensis maturity first appeared in the specimens of length group 35.1-40.0 mm. However, male population are found to encounter faster maturity than the females. During the pre-breeding season (January-March), the ratio of male to female is higher in both the palaemonid prawns, However, during the commencement of the breeding season (April-September) the percentage composition of female increases propotionately to some extent. In *M. hendersoni hendersoni*, the spawning period starts from the month of April to September while in *M. hendersoni cacharensis*, it continued from April to October. The factors contributing to the longer spawning period, is the maturation of continuous batches of ova throughout the season.

The egg size of *M. hendersoni hendersoni* are found to be larger than the egg of *M. hendersoni cacharensis*. The log of brood size shows significant positive linear correlations with log of body length, body weight, pleuron width, ovigerous setae number, ovipositing setae number and pre-eyed egg volume. In *M. hendersoni hendersoni*, log of brood size also exhibited positively significant correlations with the eye-pitted egg volume and eyedegg volume but these r-values were found to be insignificant in *M. hendersoni cacharensis* and was discussed. The log of relative brood size exhibited negative correlations with the log of respective body weight, pre-eyed, eye pitted and eyed egg volume and also was discussed,

M. hendersoni hendersoni exhibited a single larval stage before the post larva in the laboratory condition. The development is extremely abbreviated being almost like a post larva on hatching. On the other hand, *M. hendersoni cacharensis* exhibited two larval stage before the post larva in the laboratory condition. All the larval stages and their parts are described in detail and illustrated. It appears that the September brood takes slightly longer time in development than the May brood. The successful penetration of the present prawns, *M. hendersoni hendersoni* and *M. hendersoni cacharensis* into fresh water habitat has been also discussed in light of the larval evidence.

Both *M. hendersoni hendersoni* and *M. hendersoni cacharensis* are omnivorous in terms of their food habits. The most relatively dominant food items of *M. hendersoni hendersoni* was found to be insects (13.13%) and rest in descending orders were: diatoms (13.02%), sand and silt particles (12.4%), detritus (11.88%) filamentous algae (11.3%), other algae (11.2%), nematodes (7.96%), crustaceans (7.33%), mosses and plant matter (5.70%), oligochaetes(4.69%) and miscellaneous group (1.40%) respectively. Nine genera of diatoms, six genera of filamentous alga, eleven genera of other algae, seven genera of namatodes, four genera of oligochaetes, seven genera of crustaceans, fourteen genera of insects were identified from the gut content of *M. hendersoni hendersoni*. The percentage composition of different food items in the fore gut and in the water sample also fluctuated considerably. The food items in order of preference were sand and silts, oligochaetes, nematodes, filamentous algae, crustaceans, mosses and plant matter. However, these prawns pose an opotunistic habit, i.e., if they did not get any preferred food items, they also feed equally on other available food items, i.e. diatoms, other algae, insects, detritus and miscellaneous groups. The relative importance of different food items of both M. hendersoni hendersoni and M. hendersoni cacharensis among the individuals of three different size groups (Total length: 20.0-40.0 mm, 40.1-55.0 mm and 55.1-80.0 mm) have also been studied.

The most relatively dominant food items of M. hendersoni cacharensis was found to be the insects (12.90%) and the rests in terms of their descending order were: diatoms (12.67%), filamentous algae (11.92%) detritus (11.42%), other algae (11.34%), sand and silt particles (9.36%), crustaceans (9.0%), nematodes (8.98%), mosses and plant matter (6.66%), oligochaetes (5.40%) and miscellaneous group (0.35%). Fourteen genera of diatoms, eleven genera of filamentous algae, ten genera of other algae, thirteen genera of mosses and plant matter, four genera of nematodes, four genera of oligochaetes, ten genera of crustaceans, seventeen genera of insects were identified from the gut contents of M. hendersoni cacharensis. The percentage composition of different food items in the foregut and in the water sample also fluctuated considerably. The food items in order of preference were sand and silts, oligochaetes, crustaceans, filamentous algae, mosses and plant matter, nematodes. However, in absence of preferred food items they feed on other available food items.

The alimentary canal of M. hendersoni hendersoni consists of feeding appendages, cardiac and pyloric stomach, long narrow intestine, a distinctly marked rectum and hepatopancreas. The pH is acidic throughout the gut except the intestine and rectum where it is alkanine. The enzymology of the gut indicates that most of the carbohydrate digestion enzymes are secreted by the hepatopancreas. The stomach is also found to consist majority of enzymes and the digestion of food takes place inside the pyloric stomach.

The blood chloride content in the normal prawn, M. hendersoni hendersoni decreased significantly by 54.0% within 24 hrs after eye stalk ablation. The chloride content increased gradually on injection of eye stalk extracts and reached that of normal level after 24 hrs and was discussed.

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APPENDIX

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ON THE DIGESTIVE PHYSIOLOGY OF THE FRESH WATER HILL STREAM PRAWN, *MACROBRACHIUM HENDERSONI HENDERSONI* (DE MAN)

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ABSTRACT

Macrobrachium hendersoni hendersoni (de Man) is an omnivorous in its feeding habit. The alimentary canal consists of the feeding appendages, cardiac and pyloric stomach, long narrow intestine, a distinctly marked rectum and hepatopancreas. The pH is acidic throughout the gut except the intestine and rectum where it is alkaline. The enzymology of the gut indicates that most of the carbohydrate digestion enzymes are secreted by the hepatopancreas. The stomach is also found to consist majority of enzymes and the digestion of food takes place inside the pyloric stomach.

INTRODUCTION

The anatomy of the crustacean alimentary canal has been widely studied (Balss, 1926; Biedermann, 1911; Von Buddenbrock, 1956; Jordan, 1913, 27; Yonge, 1924; Haslar, 1935). Among the best recent descriptions with clear illustrations are those of Patwardhan (1935) and Reddy (1935), who have studied many forms and therefore have been able to consider the evolution of the gastric mill. In Malacostraca the digestive juice is produced almost entirely by the cells of the hepatopancreas and transported from there to the stomach. In lower forms its production presumably takes place in both the hepatopancreas and the midgut, although experimental evidence is lacking on this point. The digestive enzymes of crustacea have been studied most extensively in decapods, particularly, *Astacus* and *Maja squinado* (Mansour-Bek, 1954).

Keeping this in view, we have studied the digestive enzymology and its various roles in the process of digestion in the hill stream prawn, *Macrobrachium hendersoni hendersoni* (de Man).

MATERIALS AND METHODS

Living specimens of *M. hendersoni hendersoni* (de Man) were collected from the Umshing stream near Barapani dam and were reared in the aquarium for about fifteen days with proper aeration. Some of the live prawns were dissected to measure the pH in different regions of the alimentary canal of normal feeding prawns. The different parts of the gut were separated and thoroughly washed to clear them off any food contents. The pH of the gut was measured both by pH indicator paper and pH meter. The pH measurements were also made in the prawns which were starved for about 72 hours and also in those which were first starved and then fed on some selected diets.

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* Previously called A. Sannasi

For qualitative estimation of enzymes, the digestive juices were collected by canula method from different parts of the gut. However, the canula could not be inserted into the intestine, rectum and hepatopancreas. In such cases, these parts were separated and their extracts were prepared according to the method described by Krishna (1955). To investigate the place of secretion, the extracts and digestive juices of different parts of the gut were incubated with different substrates (see the tables II, III, IV and V). The incubated solutions were tested for the different enzymes after different intervals. The amylase and protease activity have been studied and confirmed employing the methods used by Krishna (1955, 58) and Shukla and Upadhyaya (1978) respectively and for lipase, Baldwin and Bell (1955) method as followed by Kumar (1970) was adopted.

OBSERVATIONS

pH measurement: The various enzymes function optimally at different hydrogen ion concentrations. The medium is weakly acidic in mouth, oesophagus and pyloric stomach while it is distinctly acidic in the hepatopancreas and cardiac stomach. The medium was found to be alkaline in the intestine and rectum. A few prawns were starved for about four days by keeping them in filtered water and slight increase in the concentration of acidity and alkalinity were observed (Table I). In another experiment, a few starved prawns were fed on some selective diet and the pH of the different parts of the digestive tract was measured. It was found to be almost similar to that of normal fed ones.

TABLE I: pH in various regions of the alimentary canal of normal feeding and starved prawn, *M. hendersoni hendersoni* (de Man).

Sl.	Mouth		Oesophagus		Cardiac Stomach		Pyloric Stomach		Intestine		Rectum		Hepatopancreas	
No.	N	S	N	S	N	S	N	S	N	S	N	S	N	S
1.	6.2	6.1	6.1	6.0	4.5	4.3	6.6	6.3	7.4	7.1	8.4	8.1	5.8	5.2
2.	6.5	6.1	6.4	6.1	4.4	4.2	6.7	6.3	7.5	7.1	8.5	8.1	5.9	5.2
3.	6.3	6.0	6.3	6.0	4.2	4.3	6.4	6.3	7.4	7.2	8.4	8.2	5.9	5.1
4.	6.3	6.2	6.2	5.9	4.2	4.1	6.5	6.4	7.3	7.2	8.5	8.2	5.8	5.1
5.	6.4	6.1	6.3	6.0	4.4	4.2	6.6	6.2	7.4	7.2	8.5	8.2	5.9	5.3
Average pH	6.34	6.10	6.26	6.00	4.34	4.22	6.56	6.30	7.40	7.18	8.46	8.16	5.86	5.18

N— Normal ; S— Starved

Qualitative estimation of enzymes: The incubated solutions were tested for the different enzymes after different intervals and the results are depicted in the tables II, III, IV, and V respectively. Table II shows that most of the carbohydrates were digested by the enzymes secreted by the hepatopancreas. The inulinase and raffinase are less active and takes more time for complete hydrolysis. The fat digesting enzymes are lacking in the hepatopancreas of *M. hendersoni hendersoni* (de Man).

Table II: Qualitative estimation of disestive enzymes present in the hepatopancreas of *M. hendersoni hendersoni* (de Man).

Sl. No.	Substrate	Duration of reaction and extent of digestion			Control experiments	
		after 24 hrs.	after 48 hrs.	after 96 hrs.	after 48 hrs.	after 96 hrs.
1.	1% Starch solution	+*	+	+	—	—
2.	5% Sucrose solution	—	+	++	—	—
3.	2% Maltose solution	—	—	—	—	—
4.	2% Lactose solution	—	—	—	—	—
5.	1% Raffinose solution	—	+	+	—	—
6.	1% Inulin solution	—	+	+	—	—
7.	1% Salicin solution	—	—	—	—	—
8.	Saturated Glycogen solution	+	+	+	—	—
9.	10% Gelatin solution	—	—	—	—	—
10.	Condensed milk	—	—	—	—	—

* ++, an intensive reaction; +, definite positive reaction; ±, only a trace of reaction; —, no reaction.

Experiments with the digestive juice of the oesophagus revealed that amylase, invertase, raffinase and glycogenase are the only enzymes present in this part of the gut (Table III).

Table IV indicates that the presence of fat and protein digesting enzymes is the characteristic of the stomach. However, other enzymes are also represented.

Table V shows that very few enzymes like inulinase, glycogenase and also some proteases are present in the intestine of *M. hendersoni hendersoni* (de Man).

Similar experiments were conducted with the extracts of rectum and it was observed that no enzyme is present here.

TABLE III: Qualitative estimation of digestive enzymes present in the Oesophagus of *M. hendersoni hendersoni* (de Man)

Sl. No.	Substrate	Duration of reaction and extent of digestion after 24 hrs.	 after 48 hrs.	 after 96 hrs.	Control experiment after 48 hrs.	 after 96 hrs.
1.	1% Starch solution	±•	±	±	—	—
2.	5% Sucrose solution	—	+	+	—	—
3.	2% Maltose solution	—	+	+	—	—
4.	2% Lactose solution	±	±	±	—	—
5.	1% Raffinose solution	±	±	±	—	—
6.	1% Inulin solution	—	—	—	—	—
7.	1% Salicin solution	+	+	+	—	—
8.	Saturated Glycogen solution	+	+	+	—	—
9.	10% Gelatin solution	—	—	—	—	—
10.	Condensed milk	—	—	—	—	—

• ++, an intensive reaction; +, definite positive reaction; ±, only a trace of reaction; —, no reaction.

TABLE IV: Qualitative estimation of digestive enzymes present in the stomach of *M. hendersoni hendersoni* (de Man)

Sl. No.	Substrate	Duration of reaction and extent of digestion after 24 hrs.	 after 48 hrs.	 after 96 hrs	Control experiments after 48 hrs.	 after 96 hrs.
1.	1% Starch solution	—•	+	+	—	—
2.	2% Sucrose solution	—	+	+	—	—
3.	2% Maltose solution	—	—	—	—	—
4.	2% Lactose solution	—	—	—	—	—
5.	1% Raffinose solution	±	±	+	—	—
6.	1% Inulin solution	—	—	—	—	—
7.	1% Salicin solution	—	—	—	—	—
8.	Saturated Glycogen solution	+	+	+	—	—
9.	10% Gelatin solution	+	+	+	—	—
10.	Condensed milk	Colour changes to yellow			No change	

•++, an intensive reaction; +, definite positive reaction; ±, only a trace of reaction; —, no reaction.

TABLE V: Qualitative estimation of digestive enzymes present in the intestine of *M. hendersoni hendersoni* (de Man)

		Duration of reaction and extent of digestion			Control experiments	
Sl. No.	Substrate	after 24 hrs.	after 48 hrs.	after 96 hrs.	after 48 hrs.	after 96 hrs.
1.	1% Starch solution	—*	—	—	—	—
2.	2% Sucrose solution	—	±	+	—	—
3.	2% Maltose solution	—	—	—	—	—
4.	2% Lactose solution	—	—	—	—	—
5.	1% Raffinose solution	—	—	—	—	—
6.	1% Inulin solution	—	+	+	—	—
7.	1% Salicin solution	—	—	—	—	—
8.	Saturated Glycogen solution	+	+	+	—	—
9.	10% Gelatin solution	+	+	+	—	—
10.	Condensed milk	No change in colour			No change	

*++, an intensive reaction; +, definite positive reaction; ±, only a trace of reaction; —, no reaction

DISCUSSION

The freshwater edible prawn, *M. hendersoni hendersoni* (de Man) on which the present study is based, occurs commonly in the streams of North-Eastern region of India. The adult measures from 40 to 75 mm in length and are omnivorous in terms of feeding habit. The alimentary canal consists of the appendages (three pairs of maxillipedes, a pair of maxillae, maxillulae and mandibles), compactly built cardiac stomach, small pyloric stomach, long narrow intestine and a very well marked rectum. The stomach is covered with disc like hepatopancreas which is responsible for the secretion of enzymes and for storing the digested food.

Yonge (1937) has reported that there is a definite correlation between the food and the nature as well as the relative strength of digestive enzymes of *Nephrops norvegicus*. Agarwal (1964, 1965) has reported that the medium in the gut of *Orchestia gemmarella* and *Gammarus pulex* is throughout acidic. In the intestine and rectum of *M. hendersoni hendersoni* (de Man) the medium was found to be alkaline whereas in other parts it has been shown considerably acidic in nature. This can be due to the omnivorous feeding habits of the prawns. It is also found that starvation of the animal alters the pH by increasing the concentration of the media. However, selective feeding seems to have not much effect on the pH of the gut.

The hepatopancreas appears to be the main seat for the secretion of enzymes. However, most of the enzymes are also present in the stomach. It can be correlated with the fact that enzymes secreted by the cells of the hapatopancreas are carried to the pyloric stomach through the ducts. Nicholls (1931) and Agarwal (1964) have reported the role of ventral caeca of *Ligia* and *Orchestia* in food digestion. But in *M. hendersoni hendersoni*, it has been observed that the digestion takes place inside the pyloric stomach.

The qualitative estimation of enzymes reveals that all the enzymes are present in some or other parts of the gut. However, the hepatopancreas is specialized in digesting the carbohydrate whereas the stomach for digestion of all types of diet.

In the fore gut of *Orchestia*, Agarwal (1964) has detected only amylase, glycogenase and invertase whereas in the oesophagus of *M. hendersoni hendersoni*, as found in the present study, raffinase is also present in addition to those of *Orchestia*.

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LOCOMOTION PATTERNS AND RELATED ADAPTATIONS OF THE BUG, *GERRIS* SP. IN RELATION TO AQUATIC HABITAT

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Abstract

The pond skaters, Gerris *sp. which are commonly found in large number on the surface water usually show highly photo-kinesis property. Analysis of their locomotion reveals that they exhibit eight patterns of movement (semi-rowing, clockwise, anti-clockwise, leaping, jumping, usual straight swimming, floating, rowing in a frequent triangular pathway and simple surface running type). The movements of* Gerris *sp. are achieved by the initiation of the fore leg and immediate forceful activity of both middle and hind legs. It was noted that femoro-tibial joint of the middle leg, is a single axis hinge with the effective angle of 180°. Presence of glandular structure on the appendage suggests its secretory nature which may give hydrofuge support to the animal body or may exhibit pheromonal inter-action. Finally, the relative lengthening of the appendage can be the significant contributory factor in its effective achievement of locomotory speed.*

Introduction

Insects are basically terrestrial animals but have successfully invaded the aquatic environment also. From the locomotory point of view, they represent the final stage in a process of appendage reduction, being distinguished by the possession of three pairs of thoracic appendages. Insect movement is characterized not only by rapidity of forward progression but practically by the rate at which the direction can be changed. In addition, among the invertebrates, only the insects and some other groups of Arthropods, are able to lift their body from the substratum which facilitates rapid movement[1].

Among the aquatic insects, the beetles (Coleoptera) and bugs (Heteroptera), are particularly suitable for investigation of the physiology of locomotion in terms of 'biomechanical consideration' viz. the fixed exoskeleton renders their body rigid and firm; their propulsion mechanism, has relatively simple, easily analysed kinematics. Extensive investigations exist so far on the propulsion system of *Acilius sulcatus*, *Gyrinus natator*[2-5] as well as *Dytiscus marginalis*[6] on *Corixa punctata*[3-6] and whirligig beetles, Gyrinidae[15]. Of all the other aquatic insects, generally observations on swimming behaviour and co-ordination are recorded. Aquatic beetles are of special significance because it is possible to make a quantitative analysis of the relationship between their structures (rowing appendages) and the function (propulsion). However, no detailed study has been made on the locomotory behaviour patterns and their related structural adaptations in any one of the Indian aquatic insects.

Keeping this in view we have studied some of the locomotory (swimming) behaviour patterns of the local aquatic bug, *Gerris* sp. and of their related functional-anatomical adaptations.

Materials and Methods

Most of the study deals with field observations. The locally available pond skater, *Gerris* spp (Insecta: Heteroptera) were collected from the pond available in Meghalaya Fisheries Centre and their average body length, weight, appendage length etc. were recorded. The contours of the locomotion patterns were noted immediately after the observations in the natural habitat and have been represented diagrammatically. In order to ensure the locomotion patterns, few experiments were also made with large aquarium in the laboratory itself and placing the animal on the graph paper, various experiments were carried out to study the angle of flexibility or rotative capacity of the appendages. To study the related functional-anatomical adaptation, the whole-mounts of the appendages were prepared. Examinations of the slides were made by the simple and compound microscope and for all of these the camera lucida diagrams were taken carefully.

Observations and Discussion

The pond skater, *Gerris* sp. is very commonly found in large numbers mostly sliding along or occasionally jumping on the surface of the ponds and ditches. It has a thin, flat body with relatively very long legs (Fig. 1).

Behavioural responses:

Survival of an organism depends on its ability to perceive external stimuli and to react suitably. Sensory mechanism and responses vary from simple to extremely complex patterns. Such reactions to environmental stimuli may be physiological, necessitating adjustment in the rate of a metabolic or behavioural process involving changes in the body orientation or simple movement patterns. The bug, *Gerris* sp. starts moving at about 5.30 A.M. in summer which again is dependent on the climatic condition of the day and exhibits a complicated photo kinesis phenomenon. With the increase of the sunlight intensity, they move towards the central part of their respective habitat whereby their frequency of movement also increases and as soon as the intensity of light decreases, they are found near the bank with a reduced frequency of movement. If the bug happens to observe the presence of other individuals nearby, it immediately changes its direction towards them.

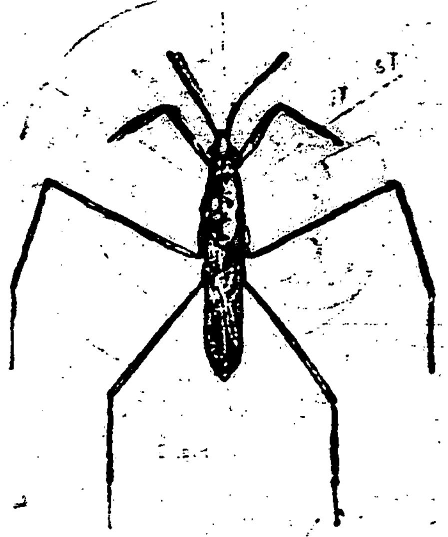

Fig. 1

(For explanation of Fig. 1, please see Page [illegible])

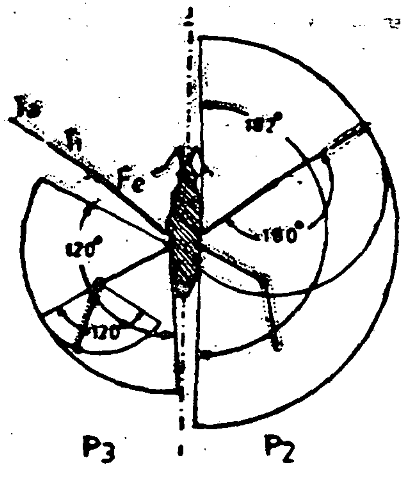

Fig. 2

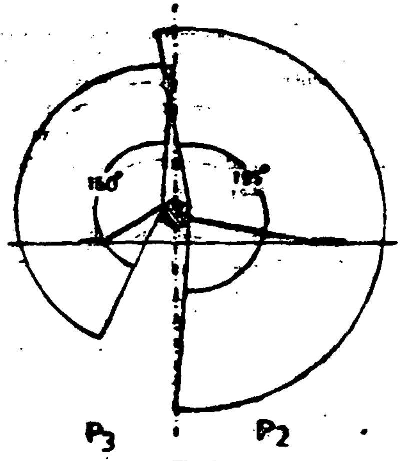

Fig. 3

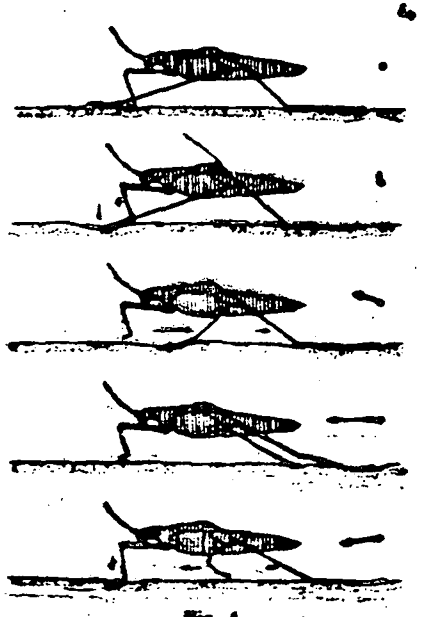

Fig. 4

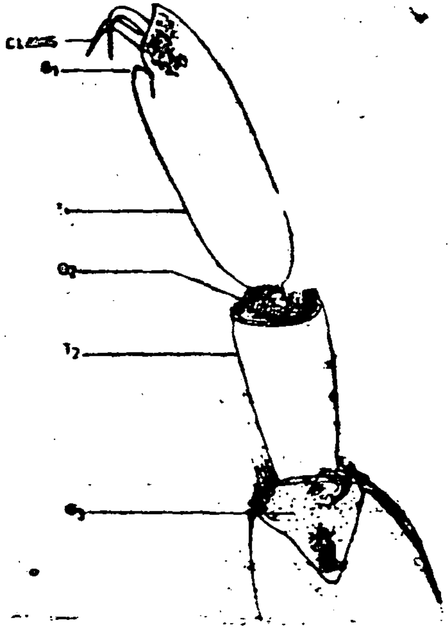

Fig. 5

(For explanation of Figs. 2 to 5, please see page 69)

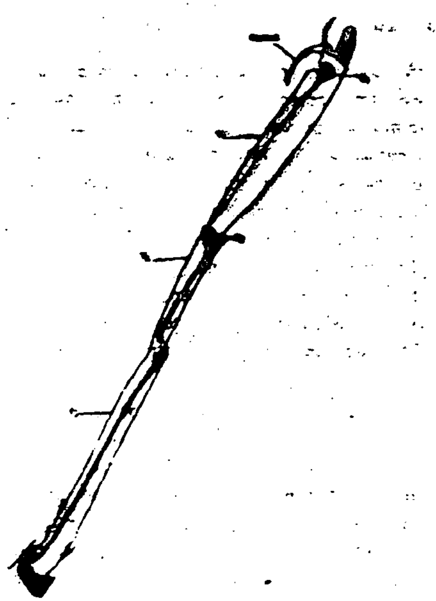

Fig. 6

Locomotion pattern:

As it was observed from the locomotion patterns of the *Gerris* sp., the general patterns of movement, are of eight distinct types. They are as follows: (i) semi-rowing type moving in the clockwise direction, (ii) semi-rowing type moving in the anticlockwise direction, (iii) Leaping but very much similar to jumping from water surface in a straight line, (iv) Jumping-like movement in a straight line, (v) Swimming and rowing type during the slower movement with a continuous change in the direction, (vi) Simple floating movement which is caused due to the movement of water column generated by velocity of wind, (vii) (Rowing in the form of triangular path and (viii) Simple surface running type (Fig. 7, a-h).

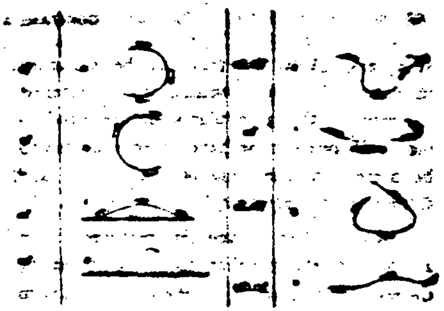

Fig. 7

Adaptations of the locomotory appendages and the process of movements:

The thorax of the bug consists of three segments, each bearing a pair of jointed legs. The principal joint of the legs is constant in number throughout the adult stages of all insects. It has five parts i.e., the coxa, a small stout portion attached to the underside of the thoracic segments, followed by another small joints, the trochanter. Next comes the two longest parts of the leg, the femur and tibia. Attested to the distal end of the tibia, is the tarsus, which is made up of two to three small joints, the last one bearing a pair of claws. They are the rowing appendages, by which the aquatic bug usually moves.

A sucker like structure which appears to be glandular at the base of the claws and in tarsus joining in all the three pairs of the appendages was observed while examining under microscope (Fig. 5, 6 and 8).

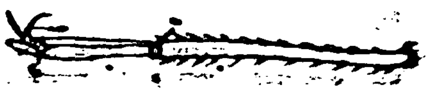

Fig. 8

For explanation of Figs. 6 to 8, please see Page 69)

It is very likely that this may be secretory in nature. In this context, it is of interest to mention that glandular structures producing trial pheromone have been reported to be present in the tibia of the worker ant, *Crematogaster peringueyi*[10].

Analysis of movement pictures drawn arbitrarily shows that the movement of *Gerris* sp. is achieved by the activity of both middle and hind legs in the rowing stroke and not the middle legs alone[11]. It is possible that these insects may have the ability to progress, using a surface tension lowering mechanism as have been studied by Jenkins[12] for *Dianous coerulescens*.

Pro– and mesopods rest on the water for the full length of the tarsae and metapodia for the full length of the tibia and without being being wetted. They are water proof due to the favourable form of extremities, suitable surface structures and hydrophobic secretions[13]. It is probable that the water proof arrangement seems to allow imparted by the glandular structure of the tibia, which live on thr surface of water and also may penetrate the surface layer with certain tarsel parts usually with the claws as in *Aepophilus* and *Velia*[5].

The joint of the meso and metapodia are constructed in such a manner that they allow extremely wide movement in part parallel to the surface of the water (coxo-trochanteral joint and trochantero-tibial joints; denoted by small circle as in Fig. 2) and in part perpendicular to the longitudinal axis (Pleurocoxal joints, denoted by small circles in Fig. 3).

All leg joints except the tarsal joint are well developed hings joints. Pleuro-coxal and coxo-trochanteral joints of the leg act in the manner of a universal joint because its two axis are perpendicular to each other. For this reason, the tip of an otherwise immobile leg can describe a spherical movement around the intersection of the two axis of the joints. Horizontal movements are achieved only by means of the coxo-trochanteral joint, vertical movements by means of the pleuro-coxal joint. In addition, the direction of pull of the corresponding muscles is perpendicular to the axes of the joints[14]. This arrangement allow optimal use of the muscle power.

The femoro-tibial joint of the middle leg of *Gerris* sp. is a single axis hinge with an effective angle of 180°. Short sclerities are inserted in between the tibia and tendon, like apodemes of its flexor and extensor muscles. Flexible at both ends, the sclerites extend the angle of leverage by 120° in the case of the extensor tibia and by 60° in the caseof *flexor tibiae*.

At the beginning of the power stroke, the propodia are lifted off the surface of the water and the mesopodia are very rapidly accelerated backward (Fig. 4). They thereby produce an indentation of the surface of the water which spreads as a wave. The meso-tarsus pushes against the anterior, stees side of that part of the wave which is spreading towards the extreme end, thus further accelerates the animal in the forward direction. This requires that the middle leg is always moved to the rear at the same speed or somewhat faster than the speed with which the wave spreads and swimmering speed also can be determined as in the whirligig beetles, Gyrinidae[15] No backward movement was observed.

Adaptations of the Body:

The chitinous exoskeleton provides a very strong and light support which is most

economical and efficient than endoskeleton of comparable dimension. The permeability to water in aquatic insects is inversely proportional to the degree of development of the epicuticle and the detail structure of the epicuticle varies from one insect to another[16]. In general, there is an inner cuticular layer, then a layer of wax and frequently a layer of cement over this. The wax of the epicuticle consists of long chain hydrocarbon and the ester of fatty acids and alcoholic group The molecules of the monolayer may be very close together and inclined at an angle so that their packing is close as possible and the space between them are extremely small[17] This provides the water proof layer of the cuticle since water is unable to pass between the closely-packed wax molecules. This type of the structures may present which provides their hydrofuge properties to the aquatic bugs, and the cuticle of *Gerris* sp. is hardened by phenolic tanning which suits very well to its aquatic mode of life[18].

It is well known that a fusiform body offers less resistance to the fluid and this is solved by the stream lining of the slender body in the bug, *Gerris* sp. The body weight of the bug varies from 30-40 mg whose mean weight is 35.55 ± 2.30 mg. This gives the co-efficient of variation about 11.5% which implies the relative depression of their body weight. The body length of the bug varies from 0.65-1.7 cm and the mean length is 1.24 ± 0.06. It shows that the co-efficient of variation is about 0.30% which denotes their relative depression of the body size. The mean lengthof the mesopodia 2.58 ± 0.05cm and metapodia is 2.16 ± 0.034 cm. This inoicates the co-efficient of variation is 0.25% and 0.17% respectively. By correlating the body length and mesometapodia it was found that their degree of correlation is quite significant. It indicates that probably with the relative lengthening of their appendages the speed of the locomotion is made more effective.

Acknowledgements

It is a pleasure to record our thanks to Dr. R.G. Michael, *Professor of Zoology*, School of Life Sciences, North-Eastern Hill University, Shillong, for interest in this work. One of us (NG) is grateful to C.S.I.R. for the financial assistance.

Explanation of Figures

Fig. 1. The common water skater, *Gerris* sp. Fig. 2. *Gerris* sp. in resting position(dorsal view) Ta, tarsus; Ti, tibia, Fe, femur; relevant joints are indicated by small circles; the axis of the joints is in the center of the circles and perpendicular to the surface of the paper. P_3, metapodium, P_2 mesopodium Fig. 3. *Gerris* sp in resting position (caudal view). Fig. 4. *Simplified lateral views of Gerris sp.* during a jump straight ahead. The arrows indicate the magnitude and direction of corresponding body velocities (from top to bottom). Fig. 5. Tarsus part of Propodium; G_1, G_2, G_3 are the glandular structures; T_1, T_2, T_3 are the tarsal parts respectively. Fig. 6. Tarsus part of mesopodium; Fig. 8. Tarsus part of metapodium. Fig. 7. Diagramatic representation of eight distinct patterns of locomotion and related angle formed (a) Semi-rowing type moving in clockwise direction (b) semi-rowing type moving in anti-clock wise direction (c) Leaping but very much similar to jumping from water surface in a straight line (d) jumping like movement in a straight line (e) swimming and rowing type during the slower movement with a continuous change in the direction (f) simple floating movement which is caused due to the movement of water (g) rowing in the form of triangular path (h) simple surface running type.

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LEVEL OF GAMMA AMINO BUTYRIC ACID IN THE NERVOUS GANGLIA OF *MACROBRACHIUM HENDERSONI CACHERENSIS* (TIWARI) IN RELATION TO LOW TEMPERATURE ACCLIMATION

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(Received 25 4.81.)

Abstract

Analysis in the level of GABA in the cerebral and thoracic ganglia of the fresh-water prawn, M. **hendersoni cacherensis** *(Tiwari) in cold acclimation reveals a significant decrease and is discussed.*

Introduction

Gamma amino butyric acid (GABA) is generally known as an inhibiting transmitter at a variety of Crust.ceans[1-4] and vertebrate synapses[5-6]. However, changes occurring in the levels of GABA in the different regions of the nervous systems under conditions of thermal stress in Invertebrates, are not known. Hence, it is hoped that this study will throw considerable light on the changes occurring in the level of GABA during thermal acclimation, thus, providing an evidence for one of the molecular mechanisms operating to accomplish cold adaptation involving nervous system.

Materials and Methods

The fresh water prawn, *M. hendersoni cacherensis* (size 1.8 ± 0.3 g) were collected from Pontung stream and the control set were maintained in the laboratory glass aquaria at 23±2°C. The experimental groups kept in bread boxes in tap-water were acclimated to low temperature (9 ± 1°C). The mortality rate of the prawns were minimised (unpublished thesis data, Goswami) by feeding them with earthworm and maintaining the system under continuous water circulation. Prawns were removed from the fridge and both normal and experimental animals were frozen in the freezing jacket of the refrigerator. The cerebral and thoracic ganglia were taken out with sterilized instruments. The tissues pooled from 10 prawns after weighing, were kept in a drop of normal saline at O°C homogenized in 0.2 ml of distilled water. GABA was determined by the paper chromatographic method of Roberts and Frankel as given by Colwick and Kaplan[7] with proper modification on the 3rd, 6th, 9th and 12th day of acclimation using DU-2 Beckmans's Spectrosphotometer at 570 mm. Suitably chosen paper blanks were always included.

Results and Discussion

The significant decrease observed in the level of GABA in both the ganglia (Table 1) indicates the decrease in the production of this amino acid as an inhibitory neurotransmitter during cold acclimation. However, Nayeemunnisa and Leelavathy[8] reported a decrease in the level of GABA in the whole brain of the frog on cold acclimation. Baxter[9] reported that physiological stress causes changes in over all GABA levels and that GABA acts in inhibitory regulation of neuronal activity. Since the altered environmental temperature is essentially a physiological stress, the decrease in the level of GABA suggests a reduced activity of this amino-acid in the inhibitory regulation of neuronal activity. It is therefore, possible that the decrease in the level of GABA observed in the present study may point to higher neuronal activity associated with the cold acclimated state. The decrease in the level of GABA on cold acclimation must have led to decrease in the level of its precursor, Glutamic acid and also an increased utilization of this compound via GABA shunt pathway, indicating augmented oxidative matabolism. A similar explanation has earlier been provided for the possible role of GABA in the homostatic control or brain metabolism in mammals under conditions of hypoxia[6].

TABLE I

Levels of GABA in the cerebral and thoracic ganglionic pools of control (23±2°C) and acclimated (9 ± 1°C) prawns, *Macrobrachium hendersoni cacherensis* (Tiwari)

	Control	Test
Cerebral	41.0 ± 3.00	22.0 ± 3.50
Thoracic	48.0 ± 2.50	24.0 ± 2.55

Values (mean ± SD of 10 observations–pools) are expressed as micromols of GABA/gram wet weight of the tissue. Values are significant at $P > 0.001$.

Table II indicates variation in the decrease of GABA during the course of acclimation. Baslow[10] reported such variations in the levels of GABA and certain other amino acids during cold acclimation in the brain of the gold fish, *Carassins auratus*. According to Baslow during the course of acclimation there is an initial shock effect, a transient oscillatory period and then a stabilized phase. In the light of this, changes occurring between the 3rd and 12th day could be attributed to the oscillatory period in the process of acclimation (Table II). The thoracic ganglia exhibited the lowest level of GABA on the 6th day and probably would have had a high electrial and physiological activity on that day during acclimation. Such a steep variation was not regarded for the cerebral ganglia although it exhibited a significant decrease in GABA on the 6th day (Table II).

TABLE II

Levels of GABA on different days of acclimation in the Cerebral and thoracic ganglionic pools of prawns, *Macrobrachium hendersoni cacherensis* (Tiwari)

	Cerebral	Thoracic
Control	41.0 ± 3.00	38.0 ± 2.50
Days of acclimation	Cerebral	Thoracic
3rd day	28.0 ± 2.50	31.0 ± 3.50
6th day	25.0 ± 1.80	21.0 ± 1.50
9th day	32.0 ± 5.60	31 5 ± 2.50
12th day	22.0 ± 3.50	24.0 ± 2.55

Values (mean ± SD of 10 observations-pools) are expressed as micromoles of GABA/gram wet weight of the tissue. Values significant at $P > 0.001$.

It is possible then that 6th day could be marked as a significant transient period in the course of acclimation. However, it is certain that GABA plays a significant role in the achievement of thermal compensation both as a *neuro-transmitter and as a metabolite.*

Acknowledgement

I express my gratitude to Dr. A Raghu Varman for valuable discussion and interest in this work. Thanks are also due to Prof. M.K. Khare, Head, Department of Zoology, N.E.H.U., for providing the necessary laboratory facilities. Finally, I will like to acknowledge CSIR for the financial support.

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ON THE EPIBIONTS OF *MACROBRACHIUM HENDERSONI HENERSONI* (DE MAN) FROM A HILL STREAM OF MEGHALAYA

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Abstract : Epibionts were noted on adult hill stream prawn, *Macrobrachium hendersoni henersoni* (deMan). Males were the major victims in the form of dense algal growths, covering much of the carapace. The large infested males were sluggish and in some case functionally blind due to the algal covering. Eggs of the water boatman, *Ramphocorixa* sp. were noted on 65.4% of the females (mean size 3.7—6.8 cm) and 6.7% of the males (mean size 4.5—6.6 cm) collected in the month of September, 1980 from the Umshing stream. Egg deposition was limited to the cephalothorax. These insect epibionts appeared to cause no major damage and disappeared shortly after the infected prawns were returned to laboratory aquarium.

Introduction : *Macrobrachium hendersoni hendersoni* (de Man) is commonly available in almost all the lotic water bodies of East Khasi Hills of Meghalaya. The tender young ones of the cultivable prawn require special care and treatment before they are transplanted from the natural conditions to the new habitat of impoundments (Smith *et al.*, 1976; Goswami *et al.*, 1982). The present communication reports on the occurrence and specificity of two epibionts of *M. hendersoni hendersoni*.

Materials and Methods : The hill stream prawn, *M. hendersoni hendersoni* (de Man) were collected from Umshing stream (about 25 Km from Shillong, East Khasi Hills) and the culture were maintained in the laboratory glass aquaria at 24±3°C and the mortality rate of the animals were minimised following the technique of Goswami (1982). The ovigerous animals obtained were maintained seperately in the laboratory hatchery. Spent female from the hatchery were regularly restocked and the hatched post larvae were individually measured, sexed and visually inspected for general condition and presence of parasites, diseases and epibionts. t-tests (Snedecor and Cochran, 1968) were employed to test for statistical significance between mean prawn size of infested and non-infested male and female prawns. The chi-square goodness of fit test (Sokal and Rolf, 1969) was used to examine the possible relationship between deposition of water boatman eggs and reproductive stage of female prawns.

Observations : Dense algal growths on the exoskeleton were observed among 42.0% of the male collected from their natural habitat. No females with epibionts were observed either at this time (July-October, 1980) or later. Algae covered most of the body surfaces including the eyes. Prawns displaying this "moss back" condition were sluggish and appeared to be in poor health. Identification of the algal covering showed that it was comprised primarily (about 90%) of chlorophytes (*Oedogoninm* sp. and *Spirogyra* sp.) with cyanophyte (*Lyngbya* sp.) the secondary dominant. The t-test revealed no difference in mean size of infested and non-infested male prawns. Females harvested, carried eggs of the water boatman, *Ramphocorixa* sp. These eggs supported on pedicels, were usually located on the posterior portions of the cephalothorax although some were also deposited laterally on the first two abdominal segments. Female prawns were grouped separately by reproductive stage and analysed for incidence of egg deposition (Table-I). The chi-square test did not detect any relationship between egg deposition and and reproductive stage. Also, a t-test detected no difference in the mean weight of infested and noninfested female prawns. Thus, the deposition of these aquatic insect eggs appears to have been random with respect to stage in the reproductive cycle and size of prawns. Like the algal infestation observed in the special "brood stock" this epibiont appeared to be sex specific. No detrimental effects associated with the infestation were noted.

Table I

Data on stage in reproductive cycle of female prawn, *Macrobrachium handersoni hendersoni* (de Man) harvested from the brood stock. Incidence of egg deposition by the water boatman, *Ramphocorixa* sp. is shown.

Stage of reproductive cycle	Harvested (no)	Mean Size (cm)	Incidence of intion. (no)	(%)
Ovigerous	31	4.4	24	77.4
Ripe ovaries*	15	3.9	6	40.0
Non ovigerous and without sign of ripe ovaries.	6	4.5	4	66.7
Total female	52	4.2	34	65.4
Total male	32	4.9	2	6.7

*Bright orange ovaries seen through cephalothorax indicative of impending molt followed by deposition of eggs.

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*previously called A. Sannasi

Discussion : The presence of "moss backs" among pond reared *M. rosenbergii* has been noted on some commercial farms (Hall, 1977; Smith *et al.* 1979). Hall (1977) reported maximum infection rate of 0.03% and the responsible organisms were either *Epistylis* sp. or *Zoothamnium* sp. or both. In Hawaii, severe infection of *Epistylis* occurred among prawns reared in ponds having a water hardness in the order of 300 mg/l (Goodwin and Hansen, 1975). In Florida, Hall (1977) reported that adult prawns exhibiting extensive algal growths on the body surfaces also supported the greatest diversity of epibionts. Species composition of the algae was not noted but the other epibionts included : *Cothurina* sp., *Epistylis* sp., *Tokophyra* sp., *Vorticella* sp., *Zoothanium* sp. and *Acineta* sp. Usually these epibionts were observed on the egg masses and some eggs were directly or indirectly killed as a result. However, no mortalities among the adult prawns were noted. The algal growths observed on the male prawns in the carolina brood pond consisted primarily of *Oedogonium crassiusculum* and *Lyngbya* sp. (Smith *et al.*, 1979). In all cases, the infestation was extensive and the prawns demonstrated limited mobility, sluggish reflexes and in some cases functional blindness. In the present study, it was observed that, this functional blindness resulted in death due to bird predation as on occasion heavily infested prawns could be seen in the boarder areas of the stream during day light hours. It is not known whether the poor condition of the prawns enhanced settlement of the algae or was a result of the infection. In spite of this condition one infested male was observed in the laboratory to mate with a sexually ripe female. Further, after placement in indoor tanks, the prawns readily lost the algal growths and their behavoir returned to normal. Smaller prawns (1.5-4.0 cm) grown at the aquarium did not acquire the extensive algal growths on the exoskeleton. In addition, ten small males (2.5-3.8 cm) were accidently stocked in the brood stock aquarium with returned spent females and these males did not support algal growths.

Forbes (1876) first noted a relationship of *Ramphocorixa acuminata* with cray fish. Abbott (1912) provided a full description of the egg deposition by this species on the cray fish, *Cambarus immunis* in Kansas. Hungerford (1919) believed eggs were deposited on those areas of the crayfish most likely to receive aeration by water currents from the gills. This peculiar relationship between the water boatman and the cray fish is believed to be one of the convenience (Klotts, 1966). However, two small adult male prawns (mean size 2.8 cm) of ten accidently stocked into the brood stock aquarium did harbor eggs of *Ramphocorixa* sp. The occurrence of water boatman eggs on prawns does not appear to be a physiological problem. Infested prawns were in good health and responded normally to stimuli. Under stream condition, it is suspected that once the eggs hatch the new insects may serve as a source of supplemented food for the prawns.

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Carbohydrate levels in the hill stream crab *Paratelphusa cunicularis* Westwood in relation to sex, size and nutritional state

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Metabolic picture of crustaceans is a complex one due to phasic nature of various biochemical events in the intermolt cycle. Shedding and renewal of integument are the most prominant morphological events, and the underlying variations in carbohydrate metabolism are far more complex. Information on carbohydrate metabolism and its endocrine control has been reviewed [1-2]. The present communication reports the pattern of quantitative distribution of carbohydrates in relation to size, sex and starvation in the intermolt stage of the hill stream crab, *Paratelphusa cunicularis* Westwood.

P. cunicularis were collected from Pontung stream (72 Km from Shillong) and were cultured in the laboratory aquarium during September 1980. Stage in the intermolt cycle was identified by the criteria of Drach[3] as modified by Kincaid and Scheer [4]. Gravid and injured crabs were not used. Animals were weighed to the nearest 0.1 g before they were sacrificed for chemical analysis (females weighing 5.2 to 32.4 g; mean 14.2 g and males weighing 4.6 to 28.4 g; mean 12.0 g). Haemolymph was drawn with a hypodermic syringe through a puncture in the arthrodial membrane at the base of walking legs. As Dean and Vernberg[5] reported the existence of a diurnal cycle in blood glucose level in *Uca pugilator*, haemolymph and tissue samples were taken mostly in forenoon period. Glucose concentration in whole blood samples was estimated following the standard method[6]. Total carbohydrate in the trichloroacetic acid supernatant of haemolymph was estimated with anthrone reagent[7]. Glycogen from hepatopancreas tissue was extracted with cold trichloroacetic acid, precipitated with 95% ethanol and estimated by anthrone method[8].

Greater individual variations are seen in the blood carbohydrates of freshly collected *P. cunicularis* and these variations are not related to size and sex. The variation is more pronounced in the total sugar level of female crabs. Several factors like handling[9-10], asphyxia[11], temperature[12], stage of reproduction and diurnal cycle[5] are known to cause variations in crustacean blood sugar. As all the crabs used are in intermolt stage and since the determinations are made in the same season, the variations are probably due to differences in the nutritional state of the animals. Crustacean hepatopancreas is well known to be a storage site for glycogen and its quantitative distribution shows great variation. In *P. cunicularis* the individual variation in hepatopancreas glycogen values is less when compared to haemolymph total sugar, the range being 2.22 to 5.86 mg/g wet weight in females and 2.94 to 6.45 mg/g wet weight in males. The difference between the mean values of carbohydrates constituents in females and males is not statistically significant in *P. cunicularis* (Table I). Similar result was reported for haemolymph glucose in blue crab, *Callinectes sapidus*[5-13]. Studies on crustacean blood sugars have been reviewed [12-15]. Glucose is known to be the chief circulating sugar in crustaceans. However, this situation is not universal. In *P. cunicularis* glucose forms less than 15% of total sugar in haemolymph in both the sexes indicating that there are other transport carbohydrates of equal or greater importance. Similar result was reported before in *Hemigrapsus nudus* [16-17], *Cancer magister*[18] and *Callinectes sapidus*[5].

There is a decrease in all the carbohydrates constituents in both males and females after 30 days of starvation. Starvation values are significantly different from those of freshly collected crabs except for haemolymph glucose in males. Individual variations found in these animals are reduced in starved animals. It appears that all the decrease in haemolymph carbohydrates may not be due to their utilization as energy source during starvation, starved haemolymph sugar levels may mostly represent steady state concentrations while the higher and scattered values in freshly collected crabs may be due to differential alimentary glycemia. The significance of the fall in blood glucose as per cent of total sugar in starved females to a low value of 4.6, is not clear while in starved males the glucose-total sugar ratio remains at the normal level.

Crustaceans show great variation in substrates used during starvation metabolism. No change in glycogen and fat was observed after 23 days of fasting

Table I

Concentration of haemolymph and hepatopancreas carbohydrates in normal and 30 day starved *P. cunicularis* Westwood

Nature of the animals	Haemolymph total Carbohydrate (mg/100ml)	Haemolymph glucose (mg/100ml).	Glucose as % of total Carbohydrate	Hepatopancreas glycogen wet wt.
1. Fresh crabs (female)	46.6±15.0*	5.2±2.2	14.4	3.92±0.12
2. Fresh crabs (male)	42.0±6.24	7.6±3.2	16.2	5.25±1.50
3. Starved crabs (female)	24.0±8.40	1.30±0.67	4.6	1.12±0.66
4. Starved crabs (male)	30.2±5.20	4.84±1.21	19.2	2.22±1.60

*mean ± S.D.

Level of significance :

(a) Differences between 1 and 3 : total carbohydrate and glucose at 1% level and hepatopancreas glycogen at 2% level.

(b) Differences between 2 and 4 : total carbohydrate and hepatopancreas glycogen at 1% level and haemolymph glucose not significant.

(c) Difference between 1 and 2 : all values not significant.

in *Hemigrapsus nudus*[19]. Cray fish, *Orconectes virilis* does not utilize glycogen as the main energy source during long term starvation[20]. It was also shown that substrate utilization varies in different tissues[20]. Steeves[21] reported that glycogen is the major metabolic substrate in isopod, *Lirceus brachyurus*. Adiyodi[22] after histochemical examination reported that *P. hydrodromus* after a two month period of starvation accumulates polysaccharides in the storage cells of hepatopancreas and that lipid is used at a rapid state. It is seen in the present investigation that both males and females of *P. cunicularis* utilize hepatopancreas polysaccharides during a 30 day starvation period. Kotiah and Rajabai[23] while studying the effects of starvation stress on temperature acclimation in *P. hydrodromus* showed that glycogen is used as an energy source rapidly in the first two weeks and it becomes secondary to lipid during prolonged period of starvation.

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Oxygen requirement of the hill stream prawn, *Macrobrachium hendersoni cacherensis* (Tiwari) fry

In scientific fish-farming, aimed at maximising production with minimum costs, utmost care is to be observed at every stage, in which nursery rearing of the seed occupies an important position. The tender young ones of the cultivated prawn require special care and treatment before they are transplanted from the natural condition to the new habitat of impoundments. The delicate post-larvae may not readily adjust to the pond conditions and undergo large-scale mortality due to the changed physico-chemical and biotic environment. Oxygen requirements of spawn, fry and fingerlings of major Indian carps have been studied by many workers[1-3]. A precise knowledge of oxygen requirement of the aquatic animal species would be of considerable help in the transport of its seed. Keeping this in view, an attempt has been made to study the oxygen consumption of *Macrobrachium hendersoni cacherensis* fry which are commonly available in the West Khasi Hills of Meghalaya and the results are embodied in the present note.

Fry of *M. hendersoni cacherensis* were collected from Pontung (near Dawki, Meghalaya State) stream and were acclimatised in glass aquaria employing the technique used by Goswami[4]. The oxygen-consumption rate of prawn fry of different size groups and some of the physico-chemical parameters of the water were studied by the method used after Banerjee *et al*[5]. Many sets of experiment were conducted with stream water and the average is reported in Table 1. Oxygen requirement per fry per hr was calculated from the amount of oxygen consumed by 20 fry in 4 hrs. (Table 1). On the basis of the oxygen consumed by the fry, the amount of oxygen required for the respiration of 1000 fry for 12 hr of transport is calculated (Table 2).

The availability of oxygen in water has a great influence on the distribution of aquatic animals[6,7]. It was also investigated that the relation of the oxygen consumption to the oxygen concentration of the habitat and tried to correlate the results to the natural distribution of the animals[8]. In the present study, it was observed that the oxygen-consumption rate of fry (size group 9-19 mm, 19-29 mm and 29-39 mm is 0.02, 0.042 and

TABLE 1: Physico-chemical condition of the water before and after the experiment

		No. of prawn used	Temperature (°C)	pH	Total alkalinity (mg/l)	Conductivity (µmho/cm)	Carbon dioxide (mg/l)	Dissolved oxygen (mg/l)	Oxygen consumed in 4 hrs (mg/l)
Test	Initial	20	15.0	6.80	21.0	42.5	2.00	9.6	1.6
	Final	20	15.0	6.70	20.5	44.0	2.50	8.0	
Control	Initial	Nil	15.0	6.80	21.0	42.5	2.00	9.6	
	Final	Nil	15.0	6.78	21.0	42.8	2.04	9.6	

TABLE 2: Rate of oxygen consumption and an estimation of the amount of oxygen required for respiration of *M. hendersoni cacherensis* fry during transport

Size of the fry (mm)		Weight of the fry (m)		Oxygen consumption per fry/hr (mg)	Oxygen required for 1000 fry for 12 hr (mg)
range	average	range	average		
9-19	14.0	250-380	325	0.02	240
19-29	24.0	370-580	450	0.042	504
29-39	34.0	570-850	575	0.122	1464

0.122 mg/per fry/per hr) varies considerably but it fluctuates maximum in case of the larger fry. The pH of the water from its natural habitat was slightly acidic and after 4 hr of respiration, the pH got slightly more acidic. Similarly, some of the other physico-chemical parameters also fluctuated to some extent (Table 1). This change in the physico-chemical parameters can be attributed to the catabolic activity of the biotic components of the water including the prawn fry. The wide fluctuation in terms of the oxygen consumption of the larger forms suggests that transport of these type is more risky and the fluctuation in general indicates the regulatory habits of this prawn species, i. e. the fry retain their oxygen consumption relatively unchanged in spite of varying oxygen concentration by a compensatory respiratory mechanism[9]. But the oxygen requirement curves of any regulator species have a marked turning point which is called the incipient limiting level or the critical point[10,11]. This was also observed by the present authors in this species while transporting the animals from Pongtung to Shillong under fluctuating environmental conditions and finally resulted in high mortality rate.

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Cellular modification of adrenocortico medullary tissues of immature under ACTH therapy

The adrenal cortex and medulla activate when animals are exposed to various kinds of stressful stimuli[1]. Many attempts have been made to investigate the mechanism of simultaneous release of corticoids and epinephrine from the adrenal under different stresses[2]. ACTH release and corticoids participation as an adaptive response to stimuli or the role of epinephrine in emergency situations have been well documented[3,4]. To our knowledge there has been no work on immature adrenocortical responsiveness of rats under ACTH infusion. So the present investigation is an exploration about the responsiveness of ACTH in the adrenomedullary cells of immature rats.

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A REPORT ON THE TRANSPORTATION OF *MACROBRACHIUM HENDERSONI CACHERENSIS* (TIWARI) SEED UNDER OXYGEN PACKING

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Macrobrachium hendersoni cacherensis (Tiwari) is commonly available in almost all the lotic water bodies of Khasi Hills, Meghalaya. A series of experiments on its seed transport (size group, 9-20 mm) were conducted in uniform transparent polythene bags without any fold at the bottom and having a capacity of 3.0 litre water. Conditioned seeds were packed in various experimental polythene bags with 1 litre of stream water under different artificially created oxygen conditions (Table 1). In one set of experiments, the volume of water and duration of time were kept unchanged, whereas the number of seeds were increased from 25 to 300 subsequently. In other set, duration of transport was increased from 12 to 24 h and the number of seeds and volume of water were kept constant. All the experiments were replicated and the average mortality rate noted. Water samples from the stream were collected and analysed for certain physico-chemical factors employing standard methods (A.P.H.A., 1955) as presented in Table 2.

Data reveal that crowding of the seeds is directly related to their mortality rate and their optimum level is 75 seeds per litre (Table 1). When the seed number was increased to 100, the mortality rate approximately doubled and further increase involved a steady rise in mortality rate. The most optimum dissolved oxygen level was found to be 9.5-10.0 mg/litre.

The availability of oxygen in water has a great influence on the distribution of aquatic animals (Berg, 1952; Eriksen, 1964; Konstantinov, 1971). They also investigated the relation of oxygen consumption to the oxygen concentration of the habitat and tried to correlate the results to the natural distribution of the animals. Goswami et al. (1983) reported oxygen requirement of *M. hendersoni cacherensis* (size group 9.0-19.0 mm) as 0.02 mg/h per fry; and accordingly it was calculated that they require 36 mg per 75 fry and 48 mg per 100 fry for 24 h of survival. But, it is noted from the present study that the maximum dissolved oxygen as recorded was 10.0 mg/l, and thereby the mortality rate was only 11.4% and 24%, respectively (Table 1). Thus, the prawns fry retain their oxygen consumption relatively unchanged in spite of varying oxygen concentration by a compensatory respiratory mechanism (Prosser & Brown, 1961). However, it was observed that the seeds were more delicate and susceptible to injury at the time of handling. The

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Table 1. Mortality rates of post-larva of *M. hendersoni cacherensis* under various experimental and natural oxygen conditions at different stocking levels.

Seeds/l	Experimental oxygen								Natural water	
	8.5 mg/l		9.0 mg/l		9.5 mg/l		10 mg/l			
	A	B	A	B	A	B	A	B	A	B
25	5.6	8.4	3.6	4.8	2.5	4.1	2.5	4.6	2.2	4.0
50	7.2	10.0	4.9	8.0	4.5	6.0	4.6	7.6	3.8	8.0
75	8.4	12.0	6.5	10.0	6.0	8.4	6.8	11.4	9.0	15.0
100	20.2	28.0	15.2	28.2	12.0	24.0	17.0	24.0	16.0	27.0
150	28.0	30.0	18.9	29.0	16.0	29.2	18.0	28.2	19.0	34.0
200	38.2	56.0	34.0	59.0	32.0	50.1	38.2	59.0	40.0	62.0
300	52.0	67.0	49.0	64.0	48.0	59.0	47.0	54.0	52.0	72.0

Average mortality % at the end of 12 h (A) and 24 h (B).

Table 2. Physico-chemical conditions of the transported water.

Sampling	Temp. (°C)	pH	Total alkal. (mg/l)	Conduct. (µmho/cm)	CO_2 (mg/l)	Diss. O_2 (mg/l)
Initial	19.5	6.80	22.0	42.5	2.15	9.6
After 12 h	16.6	6.70	21.5	44.0	2.20	9.2
After 24 h	19.8	6.65	20.5	46.0	2.28	8.7

other possible reasons for high mortality during transport could be the effect of pollution due to decomposition of dead seed.

The physico-chemical conditions of water fluctuated considerably while transporting the seeds (Table 2). The pH of the water from its natural habitat was slightly acidic and after 24 h of community respiration as a whole resulted in more acidity. Similarly, other physico-chemical parameters also fluctuated to some extent and these fluctuations can be attributed to the metabolic activity of the biotic community of the water including the prawn fry.

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