DISTRIBUTION, ECOLOGY AND BIOLOGY OF FRESH WATER PRAWNS (*Macrobrachium* spp.) OF NORTH EASTERN REGION

ABSTRACT

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Thesis

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The freshwater prawns belonging to the genus Macrobrachium (Family : Palaemonidae; Sub-family : Palaemoninae) form an important group of edible decapod crustaceans. They are found in a wide variety of habitats in freshwater ecosystems. A notable decline in freshwater prawn populations from their natural environments calls for adequate attention for their culture and mass rearing of their larvae. The practices of paddy-cum-prawn culture or fish-cum-prawn culture offer a bright future prospective to improve socio-economic conditions for the people in rural areas. The former aspect can be more suitable to the low-land areas of hill-states of North-Eastern India wherein paddy-fields comprise an integral part of landscape and rural economy.

As a pre-requisite to any scientific measures for conservations of natural stocks and culture of these organisms, it is essential to acquire knowledge about distribution of different species together with investigation on various aspects of ecology and biology. In view of paucity of such information relating freshwater prawns from North-Eastern region, the present study was undertaken. This dissertation, therefore, deals with composition and distribution of Macrobrachium spp. in this region and observations on some aspects of ecology and biology of two commonly available prawns of Meghalaya state i.e., the hill-stream M. hendersoni hendersoni and a stream-dwelling population of M. lamarrei. The results obtained are presented in three chapters and are briefly summarised below :

Chapter I dealt with thirteen species and four sub-species examined in the collection from various parts of North-Eastern region. The documented taxa are suitably illustrated and their diagnostic features are mentioned in the systematic account. A majority of the reported taxa were known to exhibit exclusively inland aquatic ecosystems while some coastal elements (Vide Tiwari, 1955) were comprised by *M. malcolmsonii*, *M. birmanicum choprae* and *M. rosenbergii*. A notable feature of this study was the occurrence of two endemic taxa *i.e.*, *M. manipurensis* and *M. lamarrei lamarroides*. The former species was apparently confined to Logtak lake in Manipur state; this rare and interesting element was distinguishable from its other Indo-Burmese relatives by the characteristic shape, proportions and colourations of its second pair of paraeiopods. *M. lamarrei lamarroides*, yet another biogeographically prawn occurred in Logtak lake (Manipur) and the tributaries of the streams draining into this lake. This sub-species differed from the nominate *M. lamarrei lamarroides* in the shape, length and dentition of the rostrum.

M. cavernicola and *M. kempi* were obtained from Siju cave in Garo Hills district of Meghalaya state. Of these, the former was the only species known from India which exhibited various cavernicolous adaptations. The occurrence of *M. kempi* in this cave was only accidental as it was originally described from a stream and its distributional range extended from Bangladesh to Mayurbhanj hills in Orissa state.

M. naso represented a new record from North-Eastern region even though it was reported earlier from Burma and recently from Gorakhpur (Uttar Pradesh). The present record might provide a biogeographical link to account for its subsequent distribution in the Gangetic peninsula. The specimens of M. altifrons coincided with the Indo-Nepalese form which was found in the Ganga-Brahmaputra drainage systems. Its present occurrence in a beel in Assam state was of ecological interest as it was earlier collected from stream with clearwater. M. kistnensis, a Malayan element, was collected from Juri river in Tripura state and was of regional distributional importance as it was not earlier known from North-Eastern India.

Amongst the taxa included under hendersoni group, six species and sub-species were included in this study i.e., M. cavernicola, M. hendersoni hendersoni, M. hendersoni platyrostris, M. hendersoni cacharensis, M. assamensis and M. dayanum. These were apparently restricted to Indo-Burmese region; all these prawns except M. dayanum were generally found in hilly regions or in the areas adjacent to their bases. On the otherhand, M. dayanum was reported to be extensively distributed in plains as well as at lower altitudes in hills throughout a large part of India and Pakistan.

M. hendersoni hendersoni occurred at altitudes between 1,500-5,000 feet in Eastern Himalayas, Burma, China and Pachmari in the Mahadeo hills of the Satpura range. M. hendersoni platyrostris exhibited distinct parallel to the altitudes not above 1,500 feet. The present observations confirmed the altitudinal limitations for the distribution of these two sub-species. M. hendersoni cacharensis was so far reported only from Cachar valley of Assam state and its range was now extended to Meghalaya state. This sub-species was presently regarded to be a geographical counterpart of M. siwalikensis which was found at the foots of the Siwalik Hills in the Western Himalayas. M. assamensis assamensis was noticed to occur in the Brahmaputra valley in North-Eastern region.

M. birmanicum included two sub-species - M. birmanicum birmanicum and M. birmanicum choprae. The former was common in the Brahmaputra valley of Assam while the latter was collected from only one locality of this state. M. malcolmsonii, an Indo-Burmese elements comprised a new record from N.E. region and was of regional distributional importance. M. rosenbergii, the largest freshwater species of this genus, was reported only from a riverine system (Fenny river) in Southern Tripura.

This aspect of the present study provided useful and important information about occurrence and distribution of these seventeen taxa (thirteen species). The collections from this region appeared to fairly well diversified when compared with overall Macrobrachium species known from this country. It is believed that further samples from hitherto unexplored areas of this region might add some more rare and interesting taxa or extend the already mentioned distributional ranges.

Chapter 2 included observations on some aspects of water quality, seasonal variations, abundance of biotic communities i.e., benthic organisms, phytoplankton and zooplanktons and seasonal fluctuations in the density, sex-ratios, condition factor, fecundity and length frequency distribution of Macrobrachium hendersoni hendersoni and M. lamarrei. The data for the monthly fluctuations in various physical and chemical parameters of water quality were collected for two annual cycles i.e., period from Janaury, 1983-December, 1984. In Umshing area various climatic factors viz., rainfall, relative humidity, sun-shine, maximum and minimum air temperature fluctuated in the range of 0.0-3.2 cm; 48.0-96.0% (at 8.30 hrs.) and 63.0%-93.0% (at 17.30 hrs), 0.0-11.4 hrs, 3.0$_c$-24^{o}C and 4.0$_c$-17.0^{o}C while in Min-Mintudu (stream) area, they varied in the range of 0.0-3.8 cm; 54.0-94.0% (at 8.30 hrs.) and 64.0%-92.0% (at 17.30 hrs.), 0.0-8.6 hrs, 13.2^{o}C-25.0$_c$ and 4.0-18.0$_c$ respectively.

In Umshing stream, the habitat of M. hendersoni hendersoni the various physico-chemical variables, viz., water temperature, pH, conductivity, dissolved oxygen, free carbon-dioxide, total alkalinity, Calcium, Magnesium, Sodium, Potassium, Phosphate-phosphorus, Ammonia-nitrogen, Silicate and oxidisable organic matters fluctuated in the range of 9.5-18.5^{o}C, 5.3-7.5, 12.0-62.0 umho/cm, 6.2-12.3 mg/l, 1.9-4.7 mg/l, 13.0-48.0 mg/l, 0.5-4.3 mg/l, 0.6-3.5 mg/l, 1.6-4.0 mg/l, 2.4-4.5 mg/l, 0.36-1.30 ug/l, 0.044-0.087 mg/l, 3.81-6.81 mg/l and 1.1-5.0 mg/l while in Min-Mintudu stream these variables fluctuated in the range of 15.8-25.8^{o}C, 5.4-7.7, 34.0-72.0 umho/cm, 6.4-11.8 mg/l, 2.5-5.2 mg/l, 8.0-49.0 mg/l, 1.1-4.4 mg/l, 1.3-4.4 mg/l, 2.0-3.8 mg/l, 1.7-5.0 mg/l, 0.31-1.4 ug/l, 0.041-0.090 mg/l, 2.2-4.41 mg/l and 3.0-8.8 mg/l respectively. The observed temperature variations evidently resulted from altitudinal differences of these two lotic systems. This study indicated the lower temperature range for the occurrence of M. hendersoni hendersoni and M. lamarrei. The pattern of variations in the water temperature was broadly identical in the two streams. Hydrogen-ion concentration showed no definite trend of fluctuations in the various stations. The pattern of fluctuation of dissolved oxygen concentration was more distinct in Min-Mintudu stream in comparison to Umshing stream. Moreover, free carbon-dioxide concentration showed no definite trend at the different sampling stations of these streams. The mode of fluctuations of total alkalinity was relatively more irregular in Umshing stream than Min-Mintudu stream. Calcium and Magnesium concentration was higher in Umshing stream in comparison to the Min-Mintudu stream. Variation of Sodium content in both the stations of Umshing stream was broadly identical. However, in Min-Mintudu stream it indicated different pattern at both the stations. Min-Mintudu stream accounted higher variations in Potassium values than the Umshing stream and fol-lowed identical patterns except for some minor differences. The monthly variations in Ammonia-nitrogen concentrations showed multiple maxima and minima at the different sampling sites. The differences in Silica concentrations in both the streams could be attributed to the litholo-gical differences. High values of oxidisable organic matter during winter and spring was presumably due to reduced precipitation and water-logged conditions.

Umshing stream exhibited varied benthic fauna than Min-Mintudu stream. Insect larvae, Nematoda, Decapoda, Oligochaeta, Gastropoda and miscellaneous group comprised the main benthic components and fluc-tuated in the range of 30.0-50%, 17.0-26.9%, 6.1-19.8%, 3.7-19.4%, 3.8%-15.1% and 1.2-11.7 respectively in Umshing stream while in Min-Mintudu stream these groups fluctuated in the range of 26.1-52.9%, 12-53.0%, 4.0-22.0%, 5.0-21.0%, 3.0-14.0%, 2.0-11.0% respectively. The pattern of monthly variations in quantitative abundance of total benthos did not confirm to any definite trend at various sampling stations. This community registered 87% overall similarity between Umshing and Min-Mintudu stream.

Baed on the composition of different taxa, the total phytoplankton belonged to six different categories, i.e., Bacillariophyceae, Chlorophyceae, Chrysophyceae, Dinophyceae, Myxophyceae and Rhodophyceae. In Umshing stream, the seasonal fluctuations of the stated groups ranged between 16-47.0%, 15.0-31.0%, 11.0-29.0%, 9.1-19.1%, 11.0-18.0%, 3.0-16.0% respectively while in Min-Mintudu stream these fluctuated in the range of 15.0-3.0%, 11.0-24.0%, 9-22.3%, 7.0-23.0%, 11.0-19.0% and 3.0-22.0% respectively. Phytoplankton community of Umshing and Min-Mintudu streams reflected 72.0% similarities. Total phytoplanktons exhibited marked variations in their monthly abundance at different stations. In Umshing and Min-Mintudu stream it varied 100 ind./l - 255 ind./l respectively.

Zooplanktons exhibited a marked variations in their monthly abundance at both the streams and their abundance ranged between 61 ind./l - 203 ind./l in Umshing stream while in Min-Mintudu stream it ranged between 49 ind./l - 140 ind./l. Min-Mintudu stream supported comparatively quite large number of zooplanktons throughout the study period and exhibited seasonal fluctuations. Categorically, the percentage composition of different groups of zooplankton viz., Protozoa, Rotifera, Copepoda and Cladocera varied in the range of 30.0-39.0%, 13.0-30.0%, 10.0-21.0%, 14.0-27.5% in Umshing stream while in Min-Mintudu stream it fluctuated in the range of 28.1-48.0%, 10.0-33.0%, 13.7-24.0%

and 8.0-36.0%. The values for percentage similarities between qualitative occurrence of zooplanktons at different sampling stations ranged between Umshing and Min-Mintudu streams was noticed to be 70%.

The total prawn population exhibited significant positive correlation with pH, dissolved oxygen, free carbon-dioxide, total alkalinity, Calcium while monthly abundance of M. hendersoni hendersoni exhibited positive correlations with water temperature, specific conductivity, dissolved oxygen, free carbon-dioxide, calcium, phosphate-phosphorus, silicate and oxidisable organic matter in Umshing stream. On the other hand, in Min-Mintudu stream total prawns exhibited significant positive correlations with water temperature only while quantitative variations registered significant direct relationships M. lamarrei with water temperature, phosphate-phosphorus and oxidisable organic matter. Amongst biotic factors total benthos, total phytoplankton and total zooplankton exhibited positive correlations and individual groups i.e., Bacillariophyceae, Chlorophyceae, Chrysophyceae, Dinophyceae, Protozoa, Rotifera, Copepoda exhibited positive correlations with M. hendersoni hendersoni in Umshing stream while total prawn exhibited positive correlations with Bacillariophyceae, Chlorophyceae, Chrysophyceae, Dinophyceae, Protozoa, Rotifera and Cladocera in Umshing stream. In addition, total prawns exhibited positive correlations with total phytoplankton, chlorophyceae, Protozoa, Rotifera and Cladocera and M. lamarrei exhibited positive correlations with insecta, oligochaeta, total benthos, bacillariophyceae, chlorophyceae, dinophyceae, mycophyceae, Protozoa and rotifera in Min-Mintudu stream.

The monthly densities of total prawns in Umshing stream ranged between 36-71 ind./m^2 and 48-74 ind./m^2 at stations A and A_1. Quantitative abundance of total prawn populations at stations B and B_1 in Min-Mintudu stream ranged between 37-77 ind./m^2 and 38-76 ind./m^2. In comparison to M. lamarrei, M. hendersoni hendersoni exhibited higher population density throughout the course of the study.

The quantitative abundance of M. hendersoni hendersoni ranged between 22 ind./m^2 - 57 ind./m^2 and 21 ind./m^2 - 51 ind./m^2 at two sampling stations (A and A_1) in Umshing stream while the population density of M. lamarrei ranged between 16 ind./m^2 (December, 1983) - 44 ind./m^2 (October, 1983) at station B and between 16 ind./m^2(December, 1983) - 58 ind./m^2 (September, 1983) at station B_1. In Umshing stream the males of M. hendersoni hendersoni in the first annual cycle ranged between 12 ind./m^2 (December, 1983) - 47 ind./m^2 (August, 1983) and 16 ind./m^2 (February, 1983) - 40 ind./m^2 (September, 1983) at stations A and A_1 respectively. In 1984, the male prawn population exhibited bimodal periodicity and indicated maxima in July (35 ind./m^2) and female population ranged between 2 ind./m^2 (April, 1983) - 17 ind./m^2(July,1984) and 4 ind./m^2 (April, 1983) - 18 ind./m^2 (September, 1984) in stations A and A_1 respectively. On the other hand, in Min-Mintudu stream, the male population of M. lamarrei ranged between 10 ind./m^2 (December, 1983) - 42 ind./m^2 (July, 1984) and 10 ind./m^2 (December, 1983) - 45 ind./m^2 (August, 1984) and female group ranged between 3 ind./m^2 (April,1983) - 17 ind./m^2 (December, 1983) and 4 ind./m^2 (June, 1983) - 18 ind./m^2 at station B and B_1 respectively. The ovigerous females of M. hendersoni hendersoni occurred from April-September in both the two annual cycles and their quantitative abundance ranged between 1-12 ind./m^2 and 2-11 ind./m^2 at stations A and A_1 respectively. Abundance of ovigerous females of *M. lamarrei* ranged between 3 ind./m^2 (August, 1984) - 10 ind./m^2 (July, 1984) in Min-Mintudu streams. The average fecundity in *M. hendersoni hendersoni* ranged between 22 ± 4 eggs./ind - 46 ± 4 egg./ind and 20 ± 5 eggs/ind - 46 ± 6 eggs/ind. at station A and A_1 respectively while production of eggs ranged between 9 ± 13 eggs./ind - 26 ± 4 eggs/ind and 10 ± 1 egg/ind - 29 ± 3 eggs/ind at station B and B_1 in Min-Mintudu stream respectively. The increased fecundity during summer could be related to higher water temperature. The extent of structural and functional dynamicity of the studied palaemonid prawn populations was reflected from length frequency distribution study and was noted to be closely associated with their breeding and growth phases. In all the sampling sites of these studied streams, males predominated the females. On the basis of length measurements, *M. hendersoni hendersoni* and *M. lamarrei* specimens were grouped into six size-classes viz., 20-0 - 30.0 mm; 30.0-40.0 mm; 40.0-50.0 mm; 50.0-60.0 mm; 60.0-70.0 mm and 70.0-80.0 mm. Females of size groups 30.0-40 mm represented the juvinile group; 40.0-60.0 actively breeding group. Ovigerous females of *M. hendersoni hendersoni* and *M. lamarrei* were recorded between April-September and May-October in both the annual cycles. Further, analysis month-wise variation in condition factor ('k') for two categories of prawn populations was based on two size groups (20.0-50.0 mm; 50.1-80.0 mm). The 'k' factor exhibited higher values in case of young populations than the mature individuals. The 'k' values were recorded higher in males than females in both the presently studied palaemonid prawns.

Chapter 3 included the observations on the general food and feeding habits, seasonal variations in different food items and fluctuations in the gastro-somatic indices and larval development of M. hendersoni hendersoni and M. lamarrei. Both these prawns were noticed to be omnivorous in terms of their food habits and their gut contents included a variety of benthic and periphytic elements. The dominant food-items of M. hendersoni hendersoni (in terms of average yearly composition) were found to be diatoms (17.59%), the other groups as mentioned in the decreasing order included : insect larvae (16.27%), detritus (12.57%), sand and silt particles (11.72%), filamentous algae (9.64%), other algae (9.47%), nematodes (9.39%), crustaceans (6.97%), mosses and plant matter (5.57%) and miscellaneous group (0.64%). An average yearly percentage composition of different food items in M. lamarrei was observed and it included insect larvae (14.25%), sand and silt (11.48%), filamentous algae (11.28%), detritus (10.28%), other algae (9.19%), nematodes (8.5%), crustacea (8.39%), mosses and plant matter (6.74%) and a miscellaneous group (0.62%). The miscellaneous group material might be regarded as accidental food owing to the fact this formed a small fraction of the gut contents and occurred without any regularity in the different months of the year. The foregut contents analysis of both M. hendersoni hendersoni and M. lamarrei showed that all the food items available in the matter were also represented in the gut. The present observations indicated a degree of opportunitism and versatility in terms of food preferences of the stated two species. The monthly variations in the food-items in the stated species coincided with their occurrences under natural conditions. Further, it was observed that in M. hendersoni hendersoni and M. lamarrei the food size group II populations (50.1 mm - 80.0 mm) was predominated by detritus, diatoms, insects, sand and silt. This reflected their semi-benthic habit.

The observations in monthly variations in the percentage composition of the different food-items of M. hendersoni hendersoni in size group I reflected that diatoms, insect larvae, detritus, sand and silt particles, filamentous algae, other algae, nematodes, crustaceans, mosses and plant matter and miscellaneous group fluctuated between 14.6 (May) - 21.2 (November), 14.7 (February) - 25.0 (July), 6.8 (February) - 10.6 (July) and 5.4 (February) - 9.3 (October), 8.8 (July) - 13.7 (November), 3.8 (January) - 10.3 (May), 2.7 (February) - 7.8 (September) and 0.2 (Janaury) - 1.0 (August). In size group II these components ranged between 12.6 (May) - 15.8 (November), 13.2 (May)- 22.5 (December), 6.2 (February) - 25.8 (September), 5.6 (May) - 15.7 (December), 8.7 (March) - 13.4 (November), 6.8 (February) - 13.9 (October), 6.4 (April) - 10.7 (October), 6.9 (May) - 10.0 (October), 4.5 (February) - 8.6 (September) and 0.3 (January) - 1.2 (April) respectively. In M. lamarrei (size group I), the monthly variations of insect larvae, diatoms, sand and silt particles, filamentous algae, detritus, other algae, nematodes, crustaceans, mosses and plant matter and miscellaneous group were found to be slightly lower than the size group I of M. hendersoni hendersoni and in size group II and the same ranged between 12.0 (August) - 24.5 (December), 10.5 (March) - 17.7 (July), 9.0 (January) - 15.0 (May), 9.6 (February) - 15.0 (July), 3.4 (April), 15.8 (December), 6.6 (February) - 12.8 (November), 9.0 (Janaury) - 14.0 (April), 2.8 (February) - 24.0 (October), 1.5 (February) - 10.6 (July) and 0.5 (March) - 1.4 (August) in the year 1983 respectively. The observed wide range of components in the food spectrum of these two species did not reflect any specific feeding activity even though some groups seemed to be dominant at times. The variations, however, might be attributed to the routine variations in the occurrence of the different components under natural conditions.

The gastro-somatic index in M. hendersoni hendersoni (size group I : 20.0-50.0 mm) was recorded to be maximum in October, 1983 (1.983), whereas in size group II (50.1-80.0 mm) maximum value of 3.154 was noticed in August, 1984 and minimum (2.032) in February, 1983. In M. lamarrei gastro-somatic index maximum values (3.409) was recorded in March, 1984 in size group I (20.0-50.0 mm) and minimum (2.0535) in December, 1984. The size group II (50.1-80.0 mm) exhibited maximum GSI value (3.509) in August, 1984 and minimum (2.0692) in December, 1983. The increased intensity of feeding in both these prawn populations might be due to recuperative process where the prawn became voracious eaters. The drop in feeding intensity in both the individuals were recorded mostly during winter. This could be attributed to the prevailing low temperatures of the habitat during these months and that lead to reduce general activity of the prawns.

The larval development in M. hendersoni hendersoni and M. lamarrei as observed in the present study was noticed to be abbreviated and was assigned to second category of Sollaud's scheme. M. hendersoni hendersoni showed two larval stages before hatching into post-larva while three larval stages were noticed in stream-dweling population of M. lamarrei. The first larval stage of M. hendersoni hendersoni was characterised by serrated rostrum, short antennal flagellum and settation of antennal scale mostly confined to its distal margin. The distinct appendix interna bearing 2-3 minute hooks on all pleopods except the first and epigastral hump was noticed on carapace and uropod biramous, telson with a terminal tooth with a movable accessory spine on its inner side on outer ramus of the second larval stage of M. hendersoni hendersoni. The newly hatched out larvae of M. hendersoni hendersoni were noticed to be attached to the body of mother for sometimes while the newly emerged larvae of M. lamarrei attached themselves to the walls of the container before becoming free swimming. The first larval stage of M. lamarrei was characterised by sharply pointed antero-lateral spines on antennule, and inner boarder of antenna carrying 10-11 plumose setae, each pleopod with a distinct basal segment. Fifth pair of peraeiopods uniramous, third to fifth pleopods with endopods reaching more than 2/3rd of the exopods. The suppression of exopod in this larvae were noticed to be extended to the fifth pair of peraeiopods. The second larval stage characterised by prominent supraorbital and branchiostegal spines, endopod long and multijointed and third larval stage was characterised by a strong stylocerite, outer flagellum of antennule divided into two distally. The number of larval stages in M. lamarrei agreed with the land locked and riverine population examined earlier from peninsular India. The occurrence of two larval stages in M. hendersoni hendersoni is strickingly contrast to the earlier unpublished report of only one larval stage. The first larval stage corresponded to the second stages of M. hendersodayanum in which this stage evidently appeared to be suppressed. Embryonic development lasted for 10-14 days in *M. lamarrei*. Before emergence, the larvae showed distinct heart-beat and wriggling movements lasted for 7-11 days in *M. hendersoni hendersoni*.

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C E R T I F I C A T E

We certify that the thesis entitled **"Distribution, Ecology and Biology of freshwater prawns (Macrobrachium spp.) of North-Eastern region"** submitted by **Mr. Amrit Lal Paul**, for the **Degree of Doctor of Philosophy** of North-Eastern Hill University, Shillong, embodies the record of original investigation carried out by him under our 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.

Forwarded
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Preface

The prawns comprise an important group of edible crustaceans. They occur in a wide variety of habitats in freshwater, brackishwater and in littoral marine ecosystems. They are locally called as 'Jinga', 'Kolambi', 'Sungata', 'Chameon', 'Shetli', 'Chingri', 'Misa' and 'Konchu' etc. in different regions of India and provide an important natural source of protein. Being highly nutritious and delicious, the prawns have through ages remained one of the most cherished items for the gourmet all over the globe.

These decapod crustaceans are being exported in significant quantities primarily in frozen, canned and dried forms. Interestingly, they comprised between 58.2% - 77.3% of the total marine products export from India during the years 1976-1988 (Dr. M. Sakthivel, Director, MEPDA : Personal communication) thereby contributing 84.93% - 89.55% of the foreign exchange earnings from the total marine export. However, there is no official record of the export of the freshwater prawns in India, though sizeable quantity of *M. rosenbergii* form part of the prawn exports from India along with consignments of penaeid shrimps. However, the importance of the freshwater prawns cannot be underestimated. Some of the larger species of this category i.e., the 'giant freshwater prawn' *Macrobrachium rosenbergii* and *M. malcolmsonii* etc. exhibit potential for good prawn fishery, particularly in certain maritime states while other smaller species can go a long way to meet the local market demands.

Though the technological advancements in fishing methods have been instrumental in the higher exports of the marine prawn from our natural resources, there is concern about the continuously reducing yields in the recent years from the traditional fishing grounds. Hence, there is much emphasis on the culture of the prawns, commonly termed as 'prawn farming'. This is now being practised in certain parts of India and some Asian countries since past few decades. Once again, the attention focussed on the farming of the freshwater prawns is not adequate even to meet our regional home demands. It is worthmentioning that the culture of freshwater prawns and mass rearing of their larvae as seeds provides a thoughtprovoking future prospective. The rotation of paddy crops in rice fields with the rearing of post-larvae of prawns (Mammen et.al; 1978) can be beneficial in the improvement of the socio-economic status of the people in rural areas particularly of North-Eastern India. Culture of prawn species along with the fish culture can be economically viable prospective if provided with sufficient local market demands.

As a pre-requisite to culture of various freshwater prawns, it is essential to know about the occurence of the different species together with the data on various parameters related to their ecology and biology. In view of limited information on the stated aspects of Macrobrachium spp. from North-Eastern region, the present study was undertaken. This dissertation, hence, deals with the distribution of different species of the genus Macrobrachium in the region, while the studies on some aspects of ecology and biology are conducted on two local freshwater prawns from Meghalaya state i.e., the hill stream M. hendersoni hendersoni and a more widely distributed M. lamarrei. It is hoped that the results presented in this study will not merely be of academic value, but shall also prove useful for culture studies of the mentioned local taxa. The information on the biogeography shall be useful to designate target species for different parts of this region, for their eventual mass rearing.

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Lat but not the least, I do express my gratitude to all my family members especially to my parents for patiently enduring the hard moments during this endeavour.

Shillong,

The January, 1991.

(AMRIT LAL PAUL)

Distribution of <u>Macrobrachium</u> spp.

INTRODUCTION

The commercially important prawns mostly belong to the families Penaeidae, Pandalidae, Hippolytidae, Sergestidae and Palaemonidae of the decapod crustaceans. They are commonly divisible into two major groups i.e. Penaeids and non-paenaeids. The former comprises over 50% of the total catch of the marine prawns along the Indian coasts (Kurian & Sebastian, 1982). Amongst the later category, the Palaemonid prawns (Family : Palaemonidae, sub-family : Palaemoninae) have potential economic value in the tropics and have excellent flavour compared with the most palatable paenaeids (Johnson, 1967). Of these, Macrobrachium spp. primarily include freshwater forms which were previously described under the genus Palaemon.

Various species of freshwater prawns belonging to the genus Macrobrachium are reported to show fishery potential in India, both for local as well as for commercial exploitation. M.rosenbergii is stated to show very good fishery in Kerela state but its stocks are reducing recently (Kurian & Sebastian, 1982). The significance of the culture of this species was well emphasized at an International Conference on Freshwater Prawn-farming held at Bangkok (June, 1981). In addition, M.malcolmsonii and M.rude indicate good seasonal fishery in some maritime states of India, while a number of other species have local fishery importance (Kurian & Sebastian,

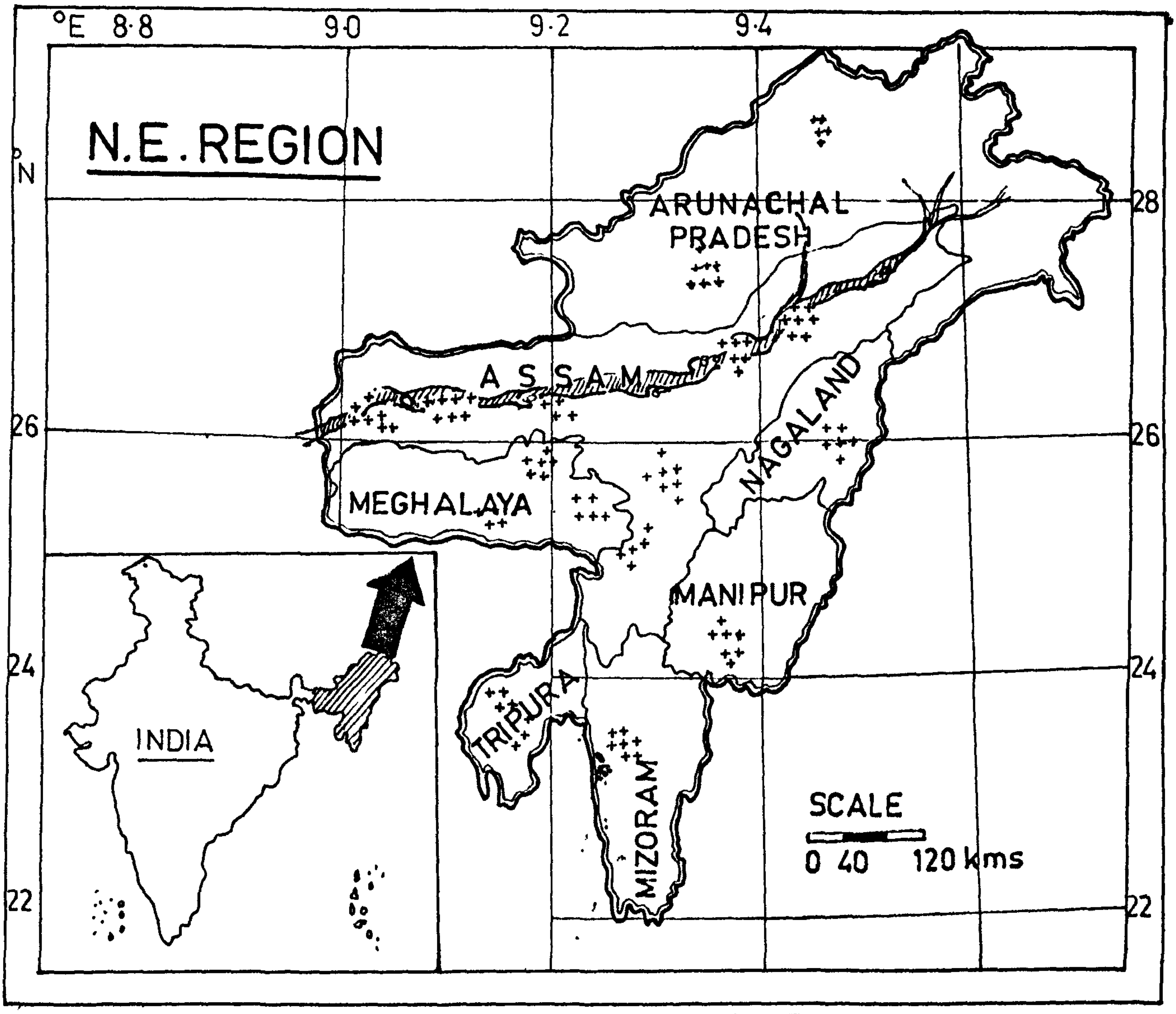


FIG.1. MAP OF NORTH EASTERN INDIA. SHOWING SAMPLING SITES.
(INSET MAP OF INDIA)

Material and Methods

The material for the present study was collected from the different freshwater habitats spread over various localities in the North Eastern region (Fig.1). This material has been indicated in the text as "AP collection". The prawns were collected using a locally fabricated plough net (mesh size; 0.75 x 0.75 cm). The specimens were preserved in 10% formalin. Different samples were screened in the laboratory to separate out specimens belonging to various taxa.

In addition, a number of specimens deposited in the collections of Eastern Regional Station, Zoological Survey of India, Shillong were examined. All such specimens are designated in this account as "ERS/ZSI Collection".

Various species and subspecies are identified on the basis of a number of diagnostic characters indicated in the figures (2.1-2.[illegible]). In addition, works of Tiwari (1947, 1949, 1952, 1955a, 1955b, 1961, 1962), Holthius (1950, 1965, 1978) have been followed to facilitate specific identification of the different taxa. Suitable illustrations are provided for the examined taxa. The measurements are given in millimeters (mm).

Fig. 2.1 : Diagramatic view of a non Penaeid prawn showing taxonomic characters.

Abbreviations :

AB, Abdomen; AF, Antennal flagellum; AM, Arthroidal membrane; AN, Antennule; ANF, Antennular flagellum; AS, Antennal scale; A1-A6, First to sixth abdominal segments; B, Basis, C, Coxa; CE, Cephalothorax; CP, Carpus, D, Dactylus; E, Exopodite; HS, Hepatic spine; I, Ischium; M, Merus; MXP3, Third maxilliped; PL, Pleopods; POS, Postorbital spine; PR, Propodus; PTS, Pterygostomian spine; PL-P5, First to fifth Peraeiopods; R, Rostrum; RS, Rostral spine; T, Telson.

Fig. 2.2 : Side view of the carapace; and Fig. 2.3 : View from above of the carapace, of a non penaeid prawn showing taxonomic characters.

Abbreviations :

1, Rostral tooth; 2, Ventral rostral tooth; 3, adrostral carina; 4, adrostral sulcus; 5, Epigastric spine; 6, Gastrofrontal carina; 7, Gastro frontal sulcus; 8, Postocular sulcus; 9, Orbito-antennal sulcus; 10, Gastroorbital carina; 11, Gastric region; 12, Hepatic spine; 13, Cervical sulcus; 14, Cervical carina; 15, Cardiac region; 16, Longitudinal suture; 17, Pterygostomian sulcus; 18, Orbital or supra-orbital spine; 19, Antennal spine; 20, Postorbital spine; 21, Antinnal carina; 22, Post antennal spine; 23, Branchiostegal spine; 24, Pterygostomian spine; 25, Hepatic carina; 26, Hepatic sulcus; 27, Pterygostomian region; 28, Marginal region; 29, Inferior carina; 30, Inferior sulcus; 31, Branchiocardinal carina; 32, Branchiocardinal sulcus; 33, Transverse suture; 34, Stridulating organ; 35, Postrostral carina; 36, Postrostral or median sulcus.

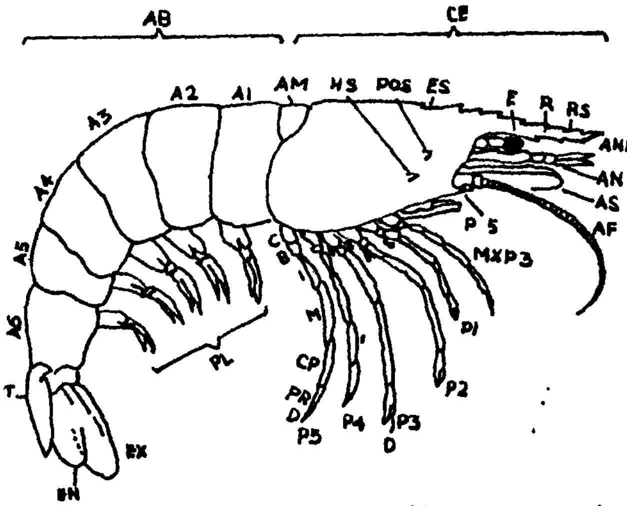
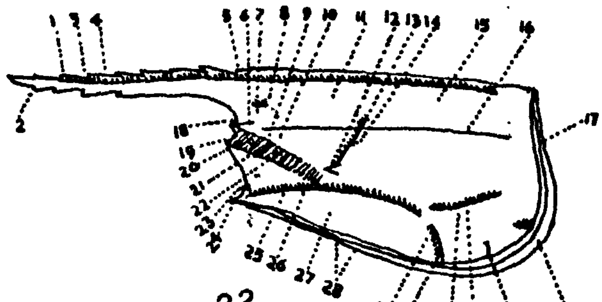
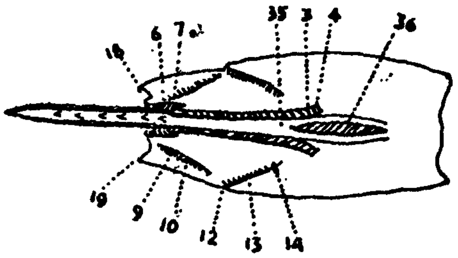


Fig. 2·1 Diagrammatic view of a non penaeid prawn(non) showing taxonomic characters



2·2



2·3

Fig. 2·2 Side view of the carapace; and 2·3 view from above of the carapace, of a non penaeid prawn showing taxonomic characters. (After, Kurian and Sebastian, 1982)

List of the presently examined species and subspecies

1. *Macrobrachium altifrons* (Henderson, 1893)
2. *M. assamensis* (Tiwari, 1952)
3. *M. cavernicola* (Kemp, 1924)
4. *M. birmanicum birmanicum* (Schenkel, 1902)
5. *M. birmanicum choprae* (Tiwari, 1947)
6. *M. dayanum* (Henderson, 1893)
7. *M. hendersoni hendersoni* (De Man, 1908)
8. *M. hendersoni cacharensis* (Tiwari, 1952)
9. *M. hendersoni platyrostris* (Tiwari, 1952)
10. *M. kempi* (Tiwari, 1947)
11. *M. kistnensis* (Tiwari, 1952)
12. *M. lamarrei* (H. Milne Edwards, 1837)
13. *M. lamarrei lamarroides* (Tiwari, 1952)
14. *M. malcolmsonii* (H. Milne Edwards, 1844)
15. *M. manipurensis* (Tiwari, 1952)
16. *M. naso* (Kemp, 1918)
17. *M. rosenbergii* (De Man, 1879)

Systematic Account

Order : Decapoda

Family : Palaemonidae Samouelle, 1819

Sub-Family : Palaemoninae Dana, 1852

Genus : Macrobrachium Bate, 1868

Family : Palaemonidae Samouelle, 1819

Pleurae of second abdominal somite overlapping those of first and third segments; no chela on third pleopods. Gills phyllobranchiate. Carpus of second pair of peraeiopods entire. No epipod or arthrobranchiae. Upper antennular flagellum bifid;mandibles usually with incisorial process.

Sub-Family : Palaemoninae Dana, 1852

With a pleurobranch at the base of the third maxillipede; posterior margin of telson armed with two pairs of spines and two or more pairs of setae. Dactyllus of last three legs uniunguiculate.

Genus : Macrobrachium Bate, 1868

Branchiostegal spine absent; hepatic spine present; dactyli of last three pairs of pereiopods uniunguiculate. Propodus of fifth pereiopod with transverse rows of short satae on its posterior margin;

almost always with a well defined pterygostomial line. Setae on posterior margin of telson slender and never spiniform.

This genus is presently represented by seventeen species and subspecies belonging to thirteen species.

Macrobrachium altifrons (Henderson, 1893) (Fig : 3a,b)

Palaemon altifrons Henderson, 1893; Trans. Linn. Soc. Lond. Zool., Vol.5, p.325, pls. 36-40; Tiwari, 1955; Bull. natl. Inst. Sci. India, Vol.7, p.230-239.

Macrobrachium altifrons (Henderson) Holthius, 1950, Siboga Exped; 39a (10), p 196; Tiwari, 1963, Proc. Zool. Soc. Calcutta, 16 : p. 255-238.

Material examined :

AP Collection : 11♂♂ and 6♀♀; Locality; Dhir beel, Kokrajar district (Assam state); Date of collection; 14 - 10 - 83.

Diagnosis : Rostrum short, extending generally as far as the end of distal segment of antennular peduncle,. sometimes reaching the tip of antennal scale; upper edge of rostrum with a conspicuous convex crest; apex acute and slightly upturned.

Carapace rough; Second pair of peraeiopods strong, subcylindrical and unequal. Merus longer than carpus; carpus thickened distally, chela about two and a half times as long as carpus. Third pair of peraeiopods extending beyond the antennal scale. Fourth and fifth pair of peraeiopods falling short of the apex antennal scale. In young individual spinules on second peraeiopods feeble or absent.

Measurements : Total length: 28-84.0; carapace length: 11.1-14.7; rostral length: 9.3 - 9.8; rostral formula: 8-9/2-4.

Distribution :

N.E. Region : Assam.

India : Uttar Pradesh, Bihar, Delhi and West Pakistan, Eastern and Western Nepal also.

Macrobrachium assamensis (Tiwari, 1952)

(Figs : 4a,b)

Palaemon assamensis Tiwari, 1952; Rec. Indian Mus; Vol.53, p. 297.

Palaemon assamensis assamensis Tiwari, 1952, ibid, vol.53, p. 297.

Material Examined :

AP Collection : 14 ♂♂ and 11 ♀♀; Locality; Mora river, Golaghat district (Assam state); Date of collection : 5-10-84.

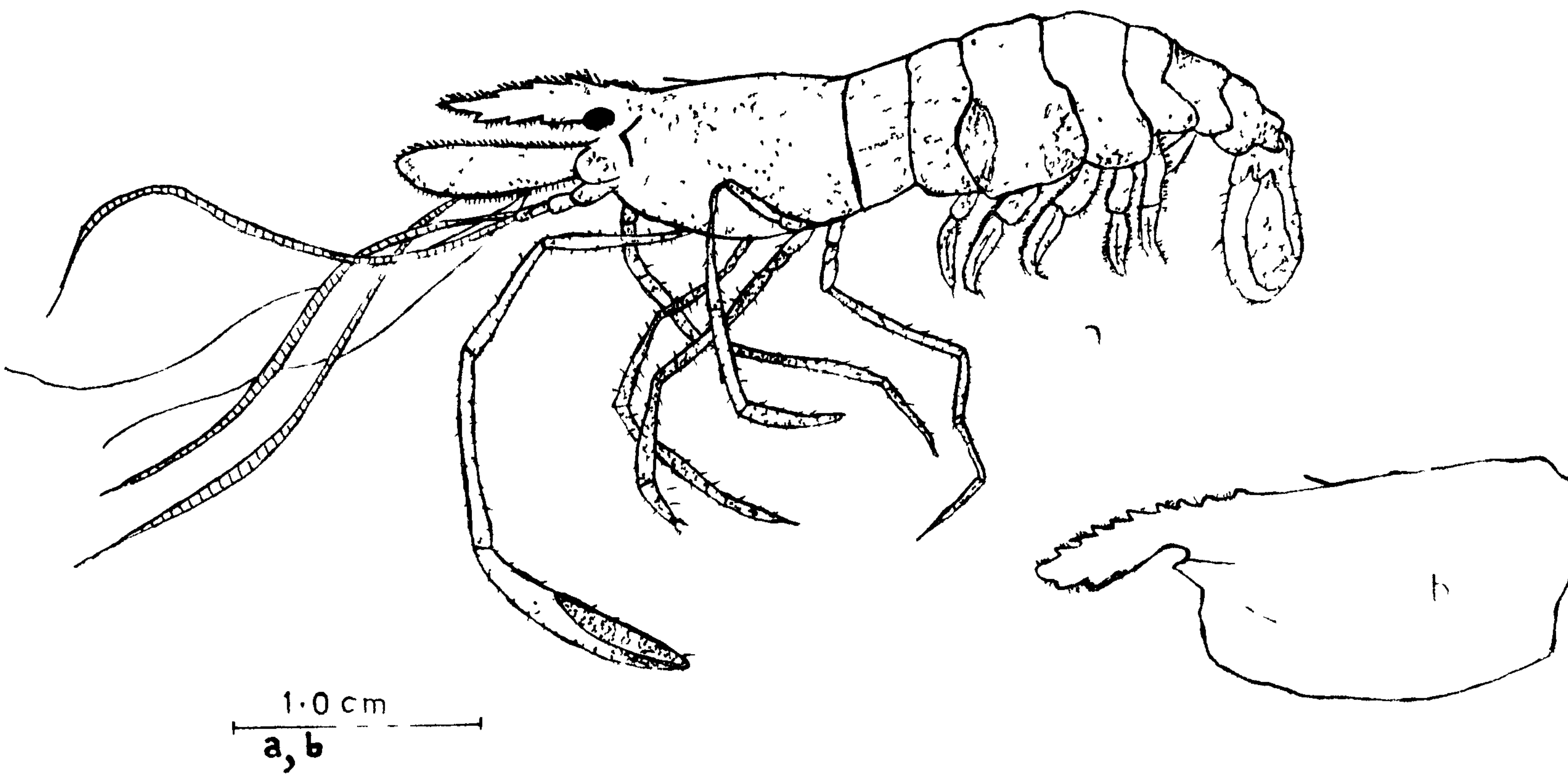


Fig. 3. Macrobrachium altifrons (Henderson):
a. Male (Lateral view); b. Cephalothorax (Lateral view).

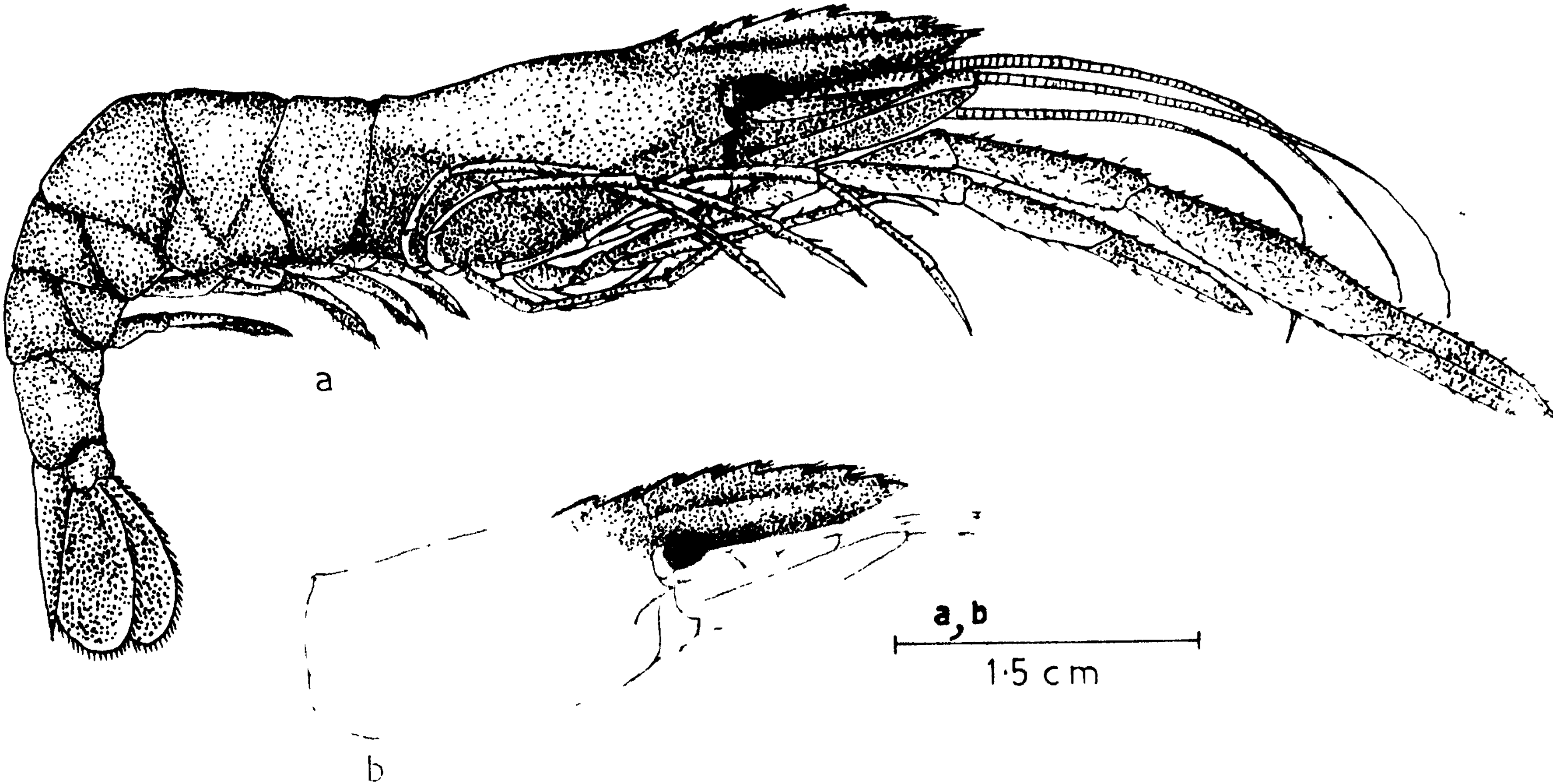


Fig. 4. Macrobrachium assamensis (Tiwari);
a, Male (Lateral view); b, Cephalothorax (Lateral view).

ERS/ZSI Collection : 1 ♂ and 2 ♀♀; Locality : Kopili river, North Cachar (Assam State); Collector : Dr. S.K. Talukdar; Date of Collection : 14-3-70; Regd. No.A1/1623.

Diagnosis : Rostrum extending beyond the apex of antennal scale; with 7-9 teeth on the upper edge and 4-6 teeth on the lower edge. Usually three teeth on the carapace behind the orbital border. Carapace with scattered, minute prickles.

Carpus longer than merus in females and young individuals. Carpus 3.1 - 3.6 as long as its distal thickness; fingers slightly longer than palm; with velvety pubescence arranged along the grooves; female and young males with fluting and pubescence weaker.

Two pairs of hepatic spines, appendix masculina in the second pleopod of male short, not reaching the apex of endopod and with hairy outer margin. Outer margin of the endopod of uropod without any accessory spine near the sub-apical tooth.

Measurements :

AP Collection : Total length: 18.6-74.3; carapace length: 10.0-11.2 Rostral length: 8.1-9.1; Rostral formula : 7-9/4-5.

ERS/ZSI Collection : Total length: 28.6-71.1; Carapace length: 9.6-10.7; rostral length: 8.6-9.2; rostral formula : 7-9/5-6.

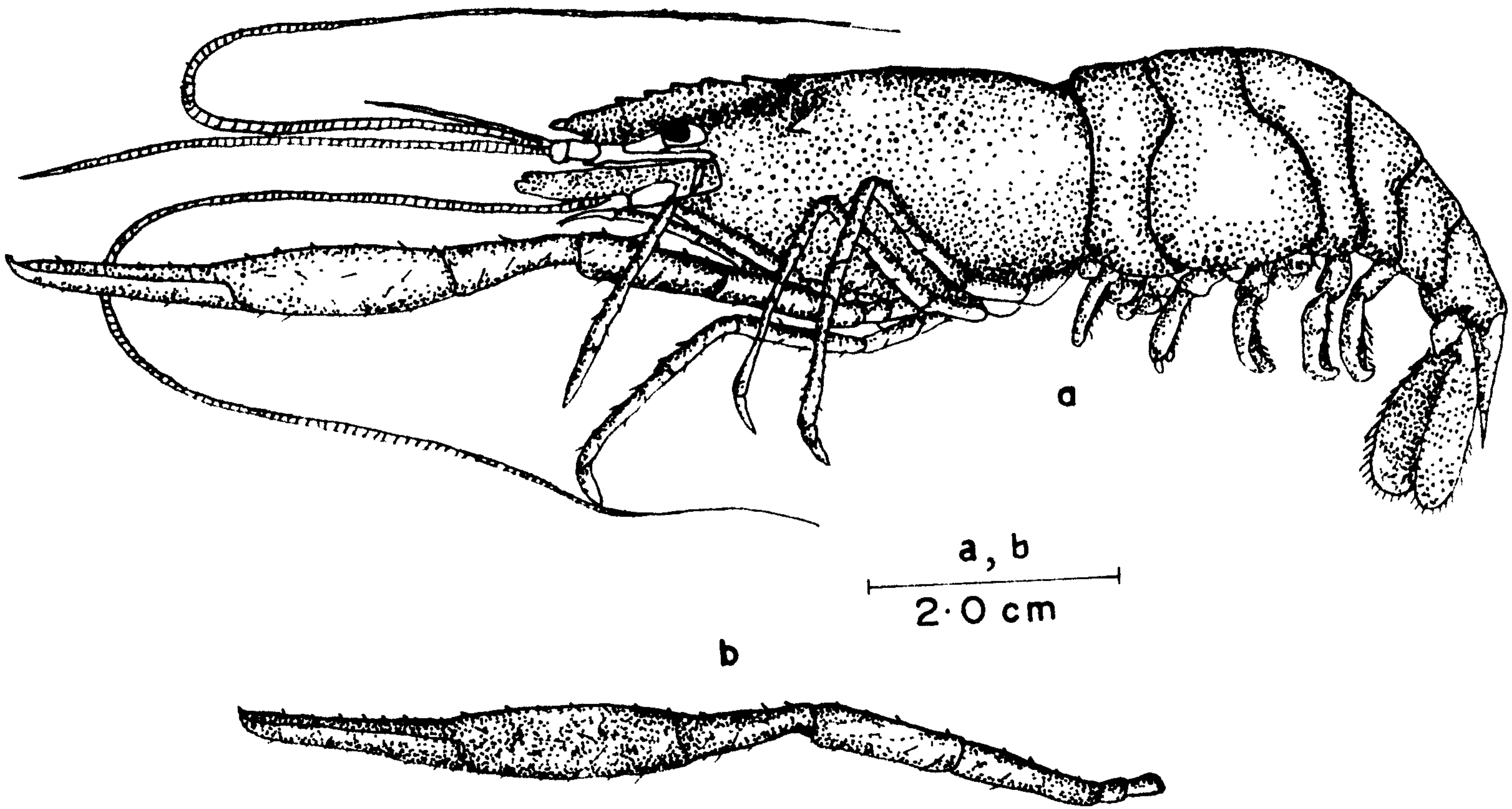


Fig. 5. Macrobrachium cavernicola (Kemp):
a, Female (Lateral view); b, Second cheliped.

Distribution :

N.E. Region : Assam, Arunachal Pradesh and Meghalaya.

India : Bihar, Madhya Pradesh and Northern Burma

Remarks : Pattern of longitudinally grooved fingers of the second pair of pereiopods resembled with *hendersoni* group.

Macrobrachium cavernicola (Kemp, 1924)

(Figs : 5a,b)

Palaemon cavernicola Kemp, 1924, *Rec. Indian Mus.* Vol.26 p.41-48;
Tiwari, 1955, *Bull,natl.Inst.Sci.India*, Vol.7, p.189.

Material examined :

AP Collection : 7 ♂♂ and 5 ♀♀; Locality : Siju Cave, Garo Hill (Meghalaya State) : date of collection : 25-5-83.

ERS/ZSI Collection : 2 ♂♂ and 1 ♀♀; Locality : Siju cave, Garo hills (Meghalaya State); Collector: Prof. R.G. Michael and Dr. J.R.B. Alfred; Date of Collection:25.3.85.Regd No.A1/1853.

Diagnosis : Rostrum variable considerably in length and reaching almost the end of antennullar peduncle. Rostrum straight, its upper border slightly and the lower border strongly convex; dorsally 5 to 9 teeth with plumose setae.

Carapace of male less scabrous. Spine at the distal end of basal segment of antennular peduncle reaching almost to the end of second segment. First leg reaching beyond the antennal scale by the chela. Long hairs on the lower edges of basis and ischium, setose patch at the distal end of carpus and near the base of the chela. Second legs usually equal. In large males ischium,merus,carpus scabrous; covered with minute sharp and pointed tubercles. Dactylus slightly curved.

Telson with tuft of setae in the middle of its dorsal surface near the base and with two pairs of dorsal spines.

Measurements : Total length: 30.1 - 53.8; carapace length: 11.4 - 16.0; rostral length: 10.2 - 11.8; rostral formula : 5-9/2-3.

Distribution :

N.E. Region : Siju Cave, Garo Hills (Meghalaya State)

India : Only in the stated habitat.

Remarks : Eyes are characteristic and exhibit partial adaptation to cavernicular conditions. Shape of carapace, flagella length of the antennule, antenna and oral appendages of *M. cavernicola* are identical with that of *M. hendersoni* (de Man).

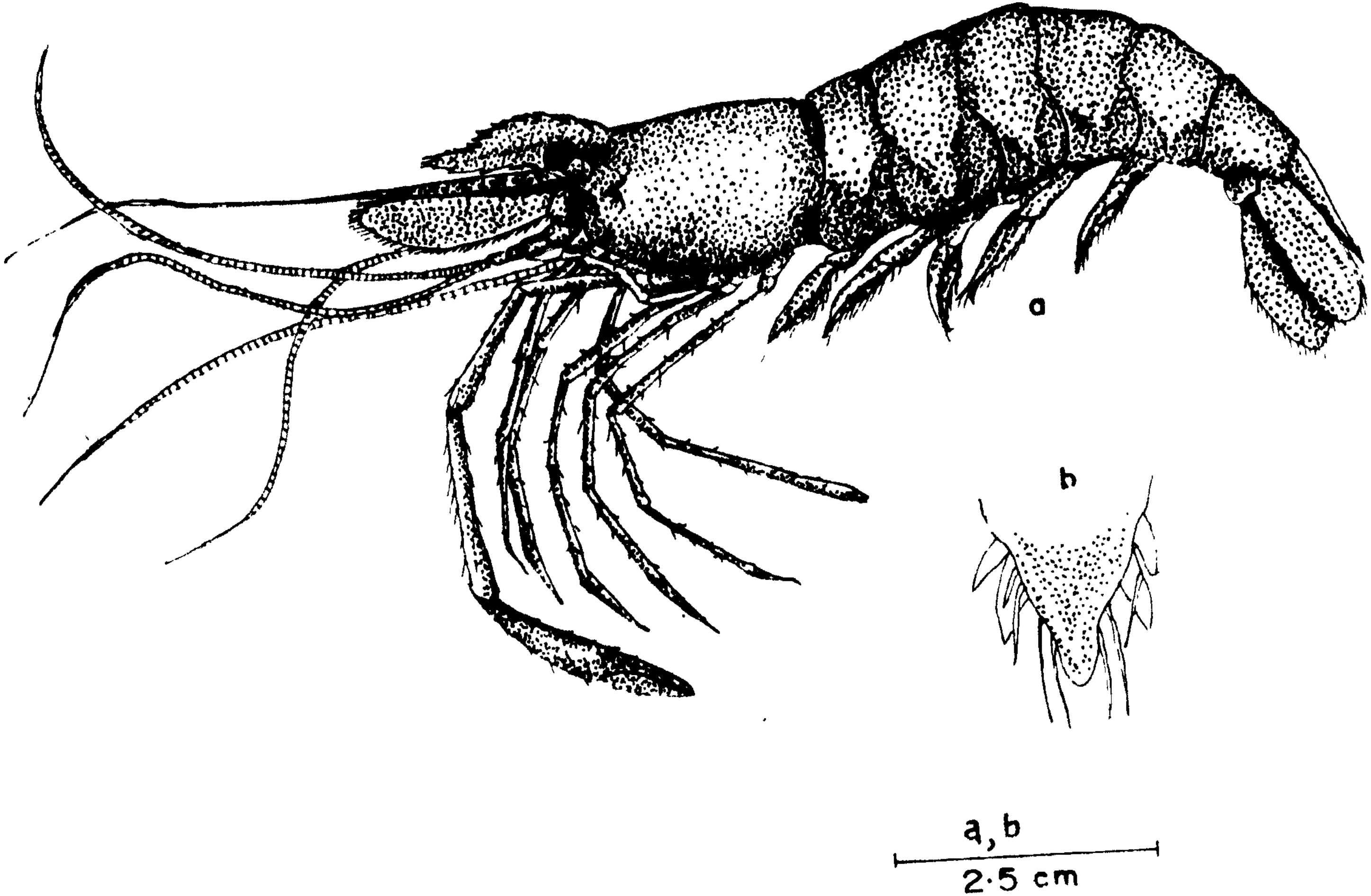


Fig. 6. Macrobrachium birmanicum birmanicum (Tiwari). a. Male (Lateral view); b. Dorsal view of Posterior part of Telson.

Macrobrachium birmanicum birnamicum (Schenkel, 1902)

(Figs : 6a,b)

Palaemon spinipes birmanicus, Schenkel, 1902, *Verh. naturf. Ges. Basel*, vol. 13, p.503, p 1.9 fig.8.

Material examined :

AP Collection : 5 ♂♂ and 8 ♀♀; Locality : Gara Stream, Goalpara district (Assam state); Date of collection : 3-3-83.

Diagnosis : With 8-9 teeth on the dorsal and 3-5 teeth on the ventral surface of the rostrum; generally two teeth behind the orbital border. Hepatic spines present.

Carapace not scabrous. Mandibular palp 2-3 segmented, Carpus of the second pareiopods in adult male slightly longer than half the length of the chela.

Outer margin of the endopod of uropod with accessory spine near the subapical tooth.

Measurements : Total length : 25.0-70.4; carapace length : 9.0-9.7; rostral length : 8.6-9.2; rostral formula : 8-9/3-5.

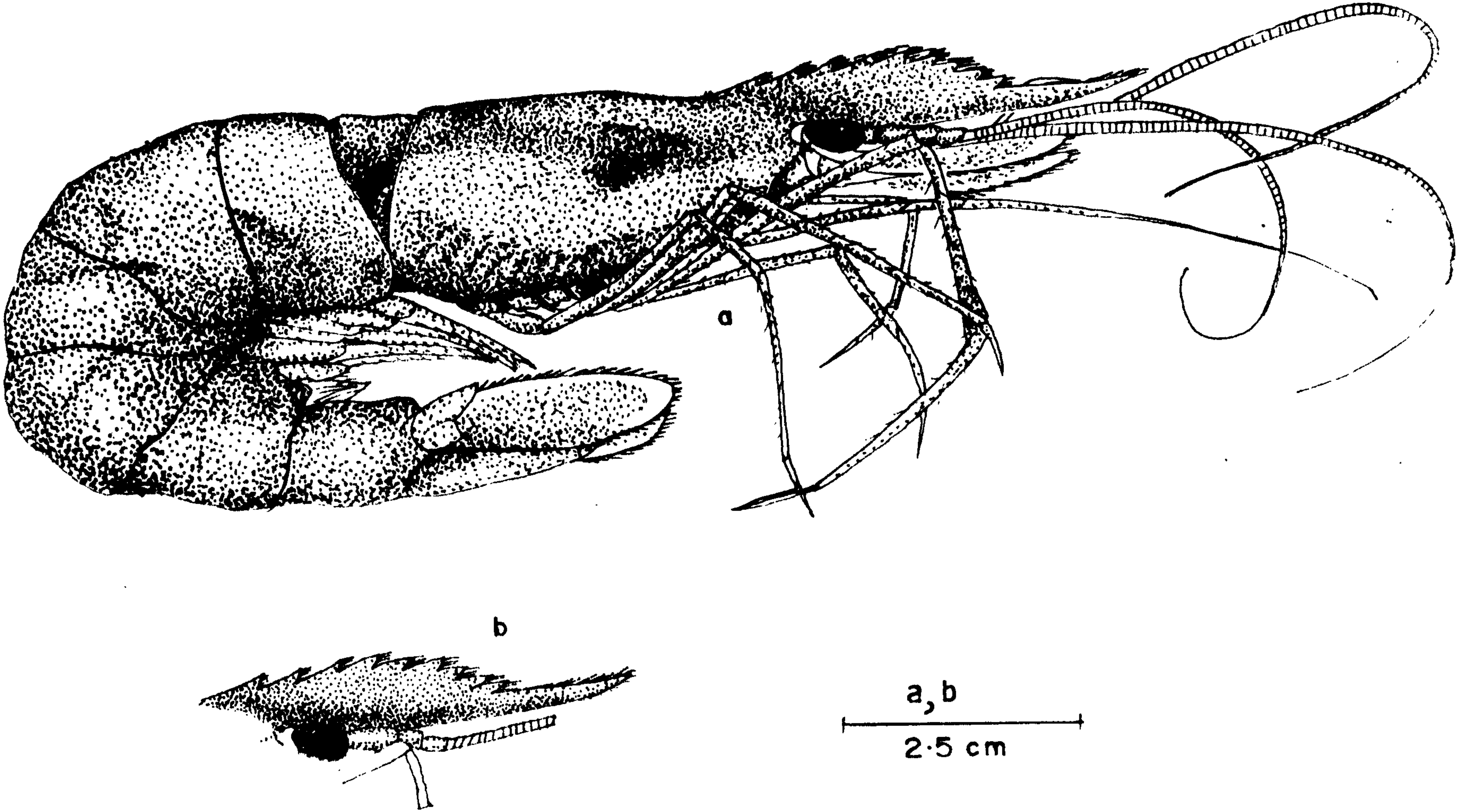


Fig. 7. Macrobrachium birmanicum choprai (Tiwari):
a. Male (Lateral view); b. Rostrum.

Distribution :

N.E. Region : Assam

India : Indo-gangetic region, Irrawady river

Macrobrachium birmanicus choprae (Tiwari, 1947)

(Figs : 7a,b)

Palaemon choprai Tiwari, 1947, Rec. Indian Mus; vol.45 p.333-340, Text fig 1-2.

Palaemon birmanicum choprae Tiwari, 1955. Bull.natl.Inst.Sci.India vol. 7 p.230-239.

Macrobrachium birmanicum choprae Prakash and Agarwal, 1985, Ind.J.Fish, Vol.32 (1), p.139-144.

Material examined :

AP Collection : 18 ♂♂ and 10 ♀♀; Locality : Barpathar pond, district Golaghat (Assam State); Date of collection : 3-6-84.

Diagnosis : Rostrum tipslightly curved; 9-10 teeth on the dorsal and 3-5 teeth on the ventral surface of the rostrum; two teeth behind the orbital border. Hepatic spines present.

Carapace smooth and with dark spot on carapace.

First pair of peraeiopods slender, carpus 1/3 of the entire leg. Second pair of peraeiopods like first pair and about half as

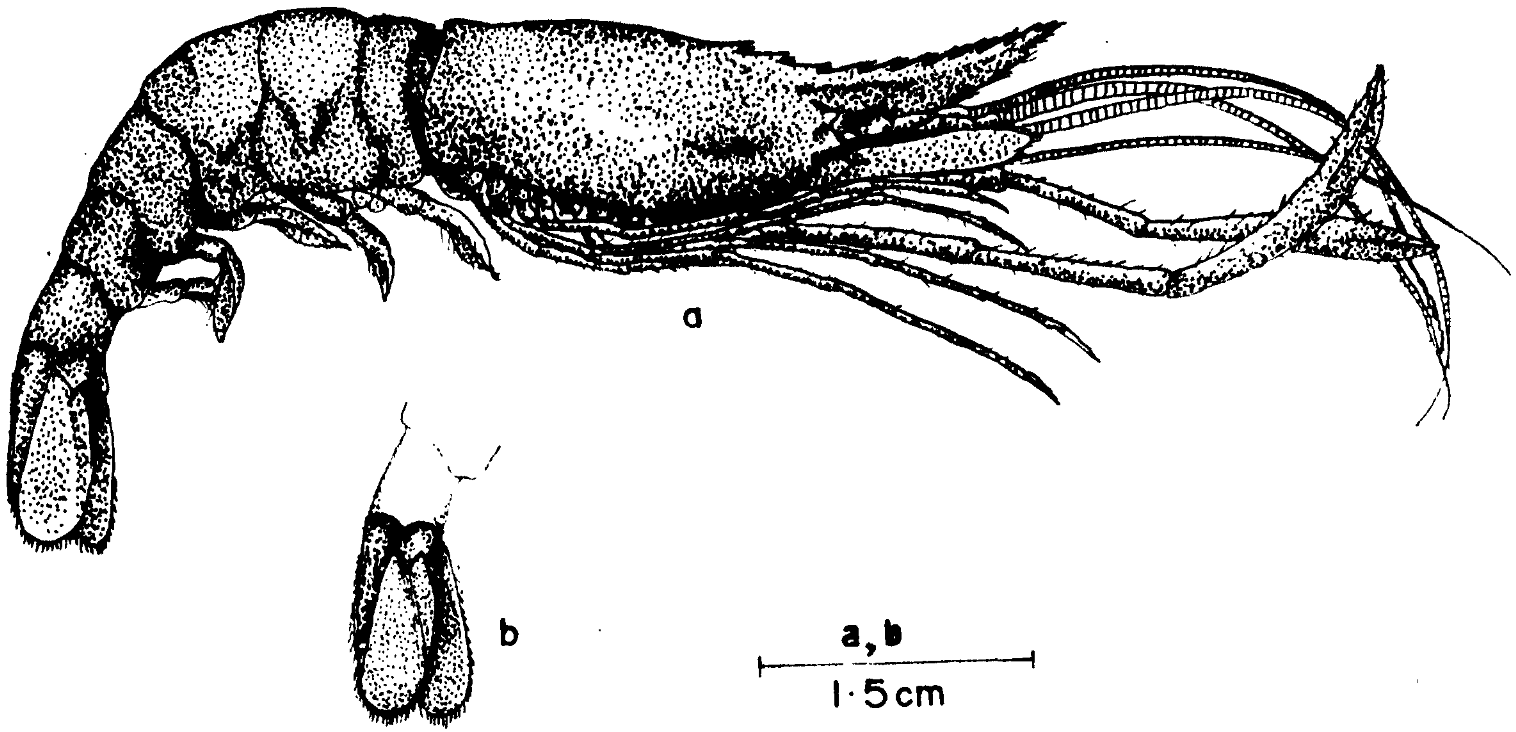


Fig. 8. Macrobrachium dayanum (Henderson):
a, Male (Lateral view); b, Uropod.

long as the body. Appendix masculinaia in the second pleopod of male short, not reaching the apex of the endopod. Outer margin of endopod of uropod without accessory spine near the subapical tooth.

Measurements : Total length : 29.6-71.6; Carapace length : 9.1-9.9; rostral length : 8.9-9.3; rostral formula : 9-10/3-5.

Distribution :

N.E. Region : Assam.

India : Uttar Pradesh, Bihar, Irrawary delta also reported from Burma.

Macrobrachium dayanum (Henderson, 1893)

(Figs: 8a,b)

Palaemon Dayanus Henderson, 1893, Trans.Linn.Soc.Lond.Zool.Ser. 2 Vol.5, p.443, pl.40.

Palaemon dayanus Chopra and Tiwari, 1949, Rec.Indian Mus.Vol.45, p.215, fig.1.

Macrobrachium naso (Kemp) : Shukla et.al 1981, Ind.J.Fish. Vol.28, p.287.

Macrobrachium dayanum (Henderson) : Shukla et.al., 1981, Ind.J.Fish, Vol.28 (1 & 2) : 287-289; Koshy, 1975, Neswl.Zool.Surv.India Vol.1 (1-4), pp.70-71.

Material examined :

AP Collection : 7 ♂♂ and 4 ♀♀ Locality : Difloo river, near Kaziranga (Assam state); Date of collection: 14-8-83.

ERS/ZSI Collection : 5 ♂♂ and 6 ♀♀ Locality : Pangin Beel, Siang district (Arunachal Pradesh); Date of collection : 9-2-73; Collector Dr. R.S. Pillai, Regd.No.A/1590.

Diagnosis : Rostrum almost equal to the antennal scale and 7-8 teeth on the dorsal side and 6-7 teeth on the ventral side of the rostrum. The first two or three teeth widely separated and situated on the carapace behind the orbital border.

Carapace smooth and with small hepatic spines. Chela short and less than half the length of the carpus. Merus cylindrical, fingers either equal or slightly longer than ischium covered with tufts of setae. Second cheliped stout, scabrous, equal or sub-equal and half the length of the body.

Two pairs of dorsal spinules on the posterior half of the telson.

Measurements :

AP Collection : Total length : 36.0-56.1; Carapace length; 10.6-11.67; rostral length : 9.2-10.00; rostral formula 7-8/6-7.

ERS/ZSI Collection : Total length : 40.0-59.8; carapace length; 10.2-11.8; rostral length : 9.8-9.9; rostral formula : 7-8/6-7.

Distribution :

N.E. Region : Assam, Meghalaya and Arunachal Pradesh.

India : Punjab, West Bengal, Orissa, Madhya Pradesh, Maharashtra and northern part of Andhra Pradesh except extreme south India.

Remarks : Females larger compared to male. This species resembles very much to *M. hendersodayanus* but differs in rostral formula. Its second peraeiopods are less prominent and stout than those of *M. naso*.

Macrobrachium hendersoni (De Man, 1906)

Palaemon (*Parapalaemon* ?) *Hendersoni* De Man, 1906, *Ann.nat.Hist,Ser.*7 vol.17, p.405.

Palaemon (*Parapalaemon* ?) *hendersoni* De Man, 1907, *Trans.Linn.Soc.Zool.*, Ser.2 vol.9, p.446. pl.33 figs. 66-68.

Bithynis (*Parapalaemon*) *hendersoni* Rathbun, 1910, *Bull.Mus.Comp.Zool.*, vol.52, p.316, pl.5. fig.3.

Palaemon *hendersoni* Kemp, 1913, *Rec.Indian Mus.*, Vol.8,p.303,pl.19 figs.19-23; Kemp and Chopra,1924, *Rec. Indian Mus.* vol.26, pp.89, 140,fig; Chappuis 1927, *Tierw.unterird.*,Gewasser,p.88.

Diagnosis : Rostrum slightly longer than the antennular peduncle but occassionally extending as far as the apex of the antennal scale and with acute apex. 8-9 teeth on the dorsal and 5-6 teeth on the ventral surface of rostrum; usually three teeth behind the orbital border.

Carapace with scattered minute prickles.First pair of paraeiopods with chela slightly longer than half the carpus. Large number of setae on both the peraeiopods. Second pair of peraeiopods sub-cylindrical, sub-equal and much thicker than first peraeiopods.Merus usually longer than carpus. Carpus thickened distally.

Exopod of the 3rd maxilliped with 4-5 setae reaching to the tip of basal segment of endopod. Two endites of protopod large and armed with few small tubercles. Fingers of the large chela of the male bearing typical longitudinal hairy grooves. Between the pleopods of either side light brown in colour, violet brown at the junction of eyes and carapace.

Telson longer and narrower with a group of large setae basally on dorsal side; lateral spines present.

This species is represented by the following subspecies

i) Macrobrachium hendersoni cacharensis (Tiwari, 1952)

ii) M. hendersoni hendersoni (De Man, 1908)

iii) M. hendersoni platyrostris (Tiwari, 1952)

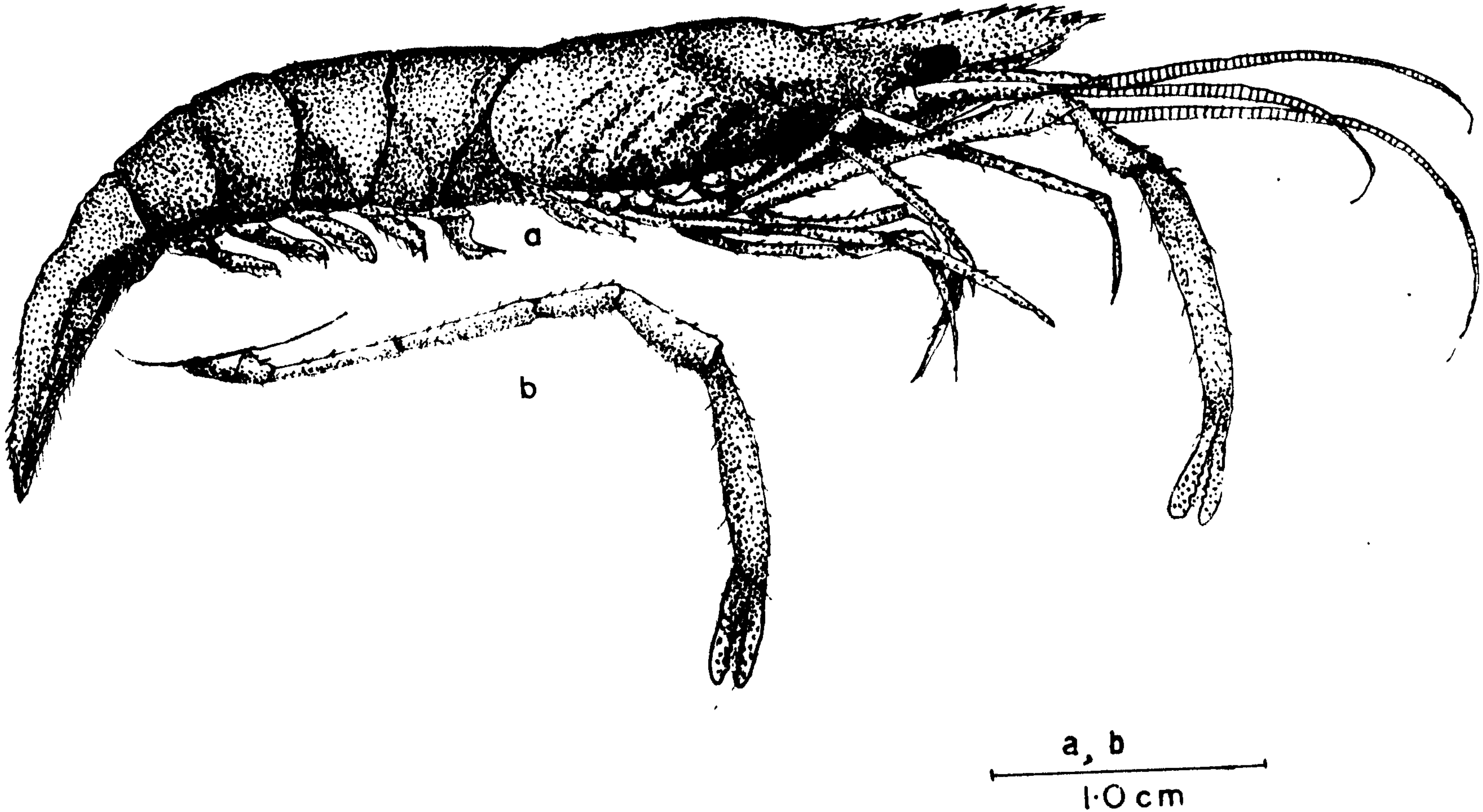


Fig. 9 . Macrobrachium hendersoni cacharensis (Tiwari).
a. Male (Lateral view); b. Second cheliped.

Macrobrachium hendersoni cacharensis (Tiwari, 1952)

(Fig. 9a,b)

Palaemon hendersoni cacharensis Tiwari, 1952, Ann.Mag.nat.Hist;Ser. 12,Vol.V.pp.27-32; Tiwari 1955,Bull.Natl.Inst.Sci, Vol.7 p.230.

Material examined :

AP Collection : 17 ♂♂ and 19 ♀♀ Locality : Pongtung stream (Meghalaya State); Date of collection : 4-11-83.

Diagnosis : Rostrum extending as far as the apex of the antennular peduncle; with 8-11 teeth on the dorsal surface and 2-3 teeth on the ventral side.

Carapace with epigastral hump; supra-orbital, branchiostegal and pterygostomian spines present. Inner flagellum of antennule thirteen segmented; outer flagellum with two basal segments, the smaller branch four segmented and tipped with two aesthetcases, longer branch fifteen-segmented and bearing minute setae.

Carpus of the second pair of cheliped conical and shorter than palm. Pleurobranches present on all peraeiopods but rudimentary. 3rd to 5th peraeiopods with a narrow pointed dactylus. Pubescence only in the basal half or two third of the fingers and distal part smooth and bald.

Three pairs of postero-lateral setae on the 6th segment of abdomen. 40-42 plumose setae on the posterior part of telson.

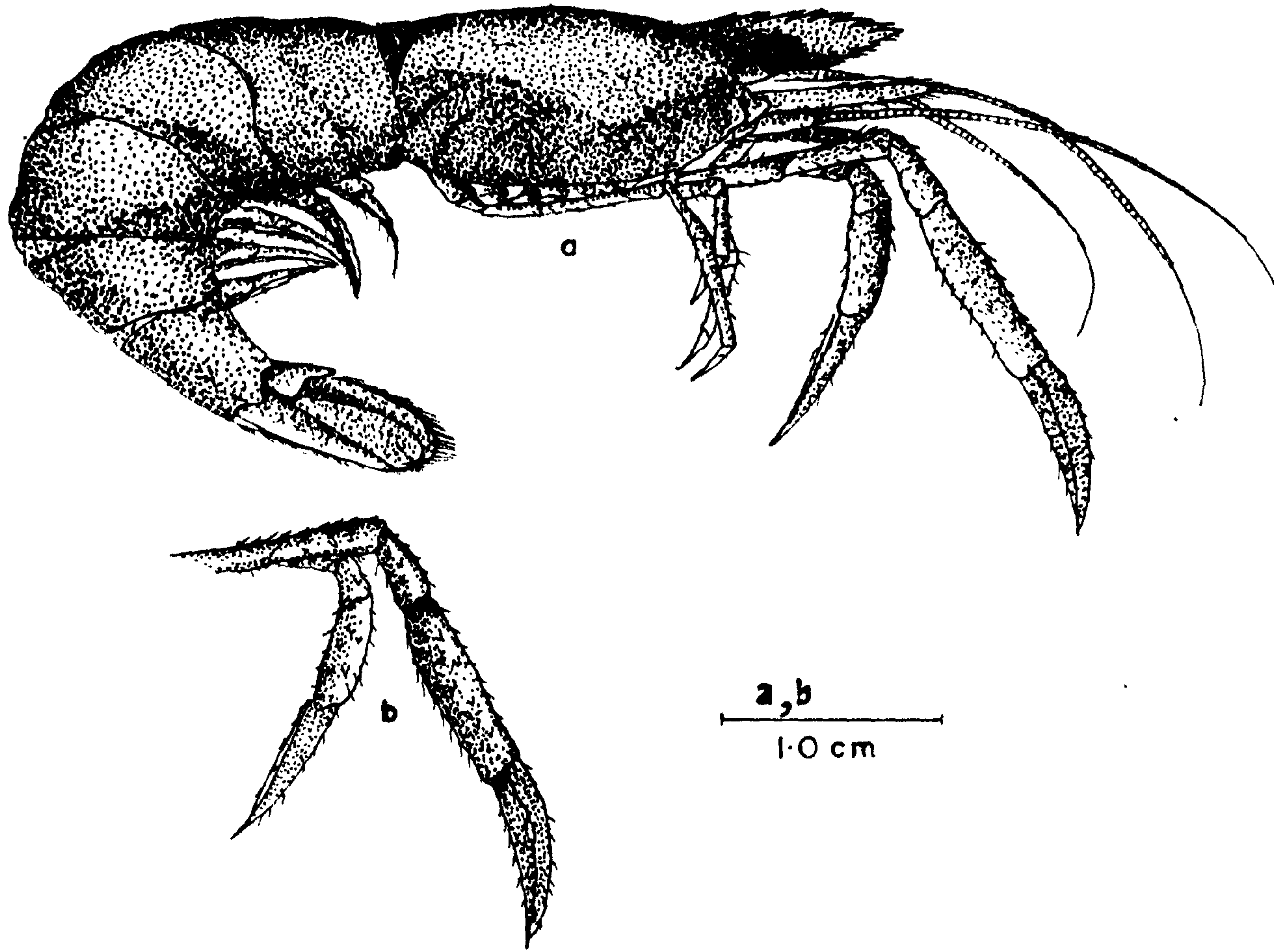


Fig.10. Macrobrachium hendersoni hendersoni(DeMan):
a. Male (Lateral view); b. Second cheliped.

Measurements : Total length : 29.0 - 77.5; carapace length: 14.2 - 16.8; rostral length : 9.6-10.1; rostral formula : 8-11/2-3.

Distribution :

N.E. Region : Cachar district of Assam as reported by Tiwari (1952) and Pontung stream of Meghalaya as reported in the present study.

India : Only in the stated habitat.

Macrobrachium hendersoni hendersoni (De Man, 1908)

(Fig :10a,b)

Palaemon hendersoni hendersoni De Man, 1908; Rec.India Mus; Vol.II, pp.211-231; Tiwari, 1955; Bull.nation.Inst.Sci.India,Vol. 7 : 189-197.

Material examined :

AP Collection : 35 ♂♂ and 21 ♀♀; Locality : Umshing stream (Meghalaya state); Date of collection : 7-2-84.

ERS/ZSI Collection : 1 ♂; Locality : Tirap, Sinjo river bed (Arunachal Pradesh); Date of collection: 3-1-62; Collector : C.B.Srivastava; Regd. No.A/1526 5 0 and 2 00; Locality: Siju cave, Garo hill Meghalaya state; Date of collection : 22-2-71; Collector : Dr. G.M. Yazdani; Regd.No.A.1/5784.

Diagnosis : Rostrum extending upto the end of basal or middle segment of the antennular peduncle. 5-8 teeth on the dorsal surface and 3-4 teeth on the ventral surface of the rostrum. Hepatic spines often missing on one or both sides. No post orbital teeth.

Carapace smooth except for a prominent antennal spine followed posteriorly by a smaller spine.

Antennular peduncle three-segmented, both stylocerite and anterolateral spines sharply pointed. Antennal peduncle three-segmented and with plomose setae, flagellum consists of about 42 segments.

Mandibular palp absent. Endopod of maxilliped II 5-segmented and incurved; exopod flagellum with netatory setae.

Abdomen six segmented. A district appendix interna. bearing 3-4 minute hooks on all pleopods except the first.

Uropod biramous. Telson longer, broader at the distal end and bearing two minute bristles.

Measurements :

AP Collection : Total length : 200-81.0; carapace length : 13.2-15.1; rostral length; 9.2-10.9; rostral formula 5-8/3-4.

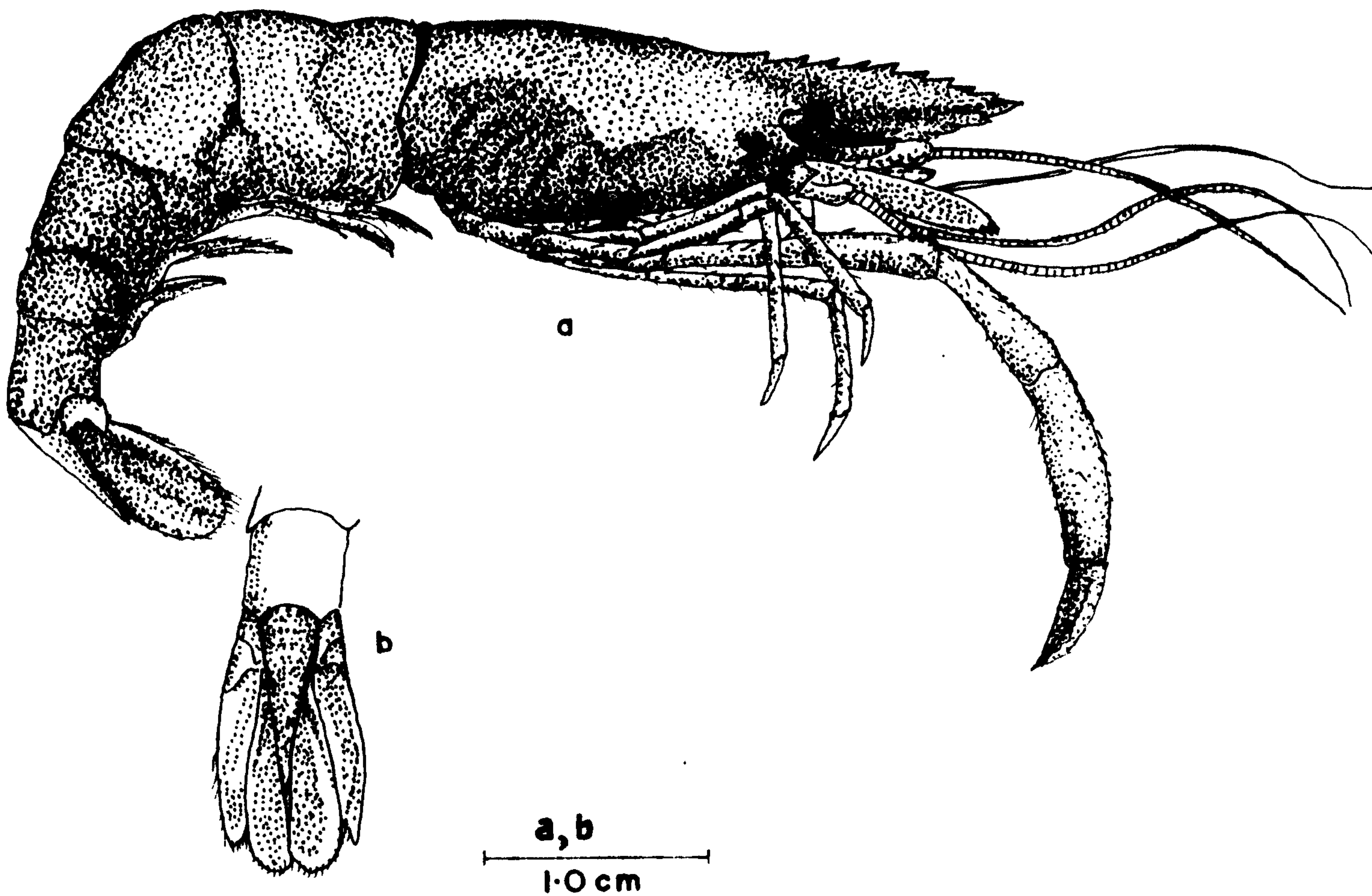


Fig. 11. *Macrobrachium hendersoni platyrostris* (Tiwari).
a. Male (Lateral view); b. Uropod (Lateral view)

ERS/ZSI Collection : Total length : 26.1; carapace length: 15.3-15.6;rostral length 9.0-10.6; rostral formula 5-8/3-5.

Distribution :

N.E. Region : Arunachal Pradesh, Meghalaya, Assam and Manipur.

India : Indo-gangetic plain.

Remarks : Antennal spine followed posteriorly by a smaller spine that probably represents the future hepatic spine. Future podobranch represented by gill - bud.

Macrobrachium hendersoni platyrostris (Tiwari, 1952)

(Fig : 11a,b)

Palaemon hendersoni platyrostris Tiwari, 1952, Ann.Mag.Nat.Hist., Ser. 12.Vol.V.p.27-32.

Material examined :

AP Collection : 5 ♂♂ and 7 ♀♀ : Locality : Logtak Lake (Manipur state); Date of collection 2.4.84.

ERZ/ZSI Collection : 2 ♂♂ and 3 ♀♀ : Locality : Imphal stream (Manipur state); Date of collection : 31-12-61; Collector : C.B. Srivastava; Regd.No. A1/6152.

Diagnosis : Rostrum extending upto the end of the antennular peduncle. The number of teeth on the upper edge ranges from 7 to 9 and only three on the lower edge of the rostrum, with generally two or three teeth on carapace.

Antenna with long and multi-segmented flagellum, antennal peduncle with plumose setae.

Carpus conical and shorter than palm. Second pair of peraeiopods sub-equal, sub-cylindrical and merus longer than carpus. Fingers with velvety pubescence arranged along the grooves.

Appendix masculina in the second pleopod of male short and not reaching the apex of the endopod.

Each uropod biramous, longer, broader at the posterior end and bearing 2-3 minute bristles.

Measurements :

AP Collection : Total length : 18.0-75.4; Carapace length: 13.6-14.1; rostral length : 9.1-9.6; rostral formula 7-9/3-4.

Distribution :

N.E. Region : Manipur and Assam.

India : Only in the stated habitat.

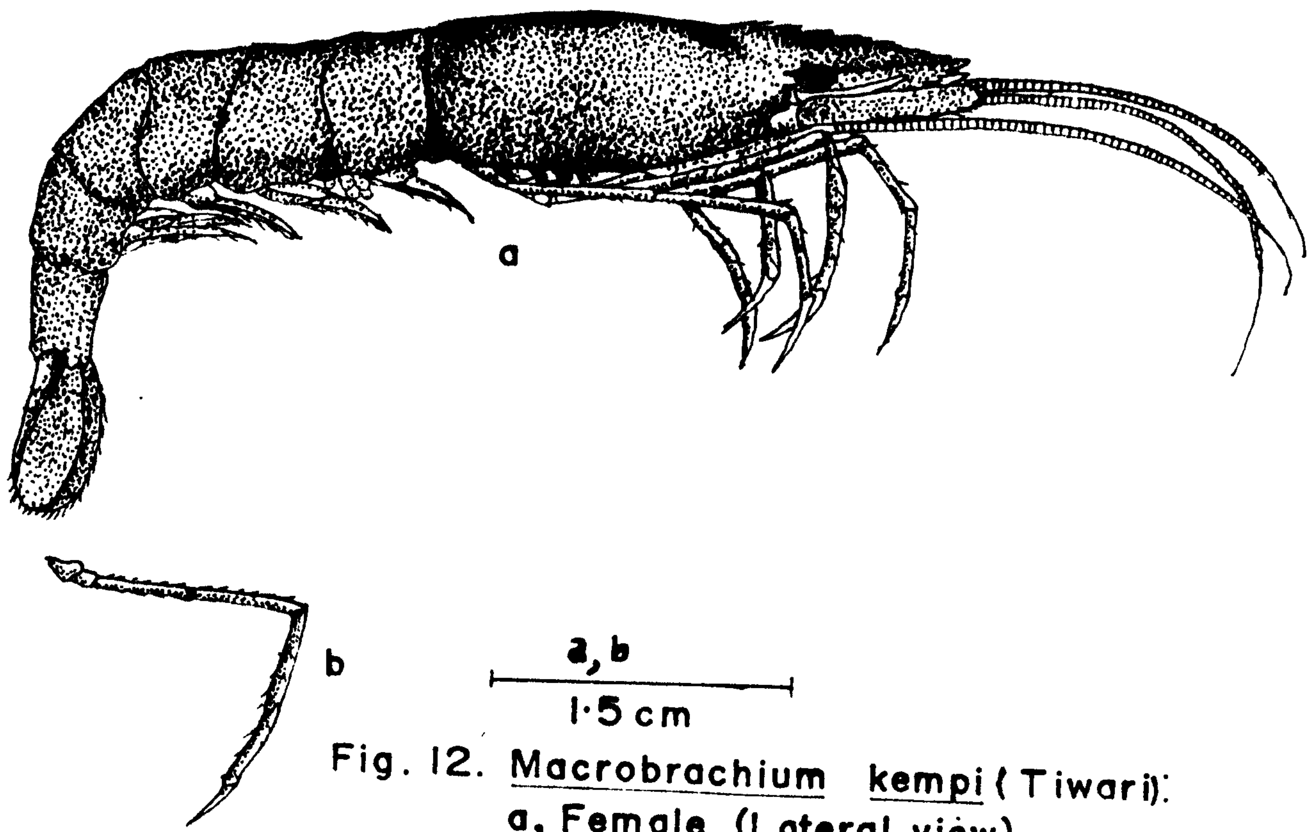


Fig. 12. Macrobrachium kempi (Tiwari):
a, Female (Lateral view);
b, Second chelipod.

Macrobrachium kempi (Tiwari, 1947)

(Fig : 12a,b)

Palaemon kempi Tiwari, 1947, Rec.Indian Mus, Vol.XLV, pp.329-331.

Material examined :

AP Collection : 8 ♂♂ and 5 ♀♀ : Locality : Siju cave, Garo Hill (Meghalaya State); Date of collection 22.7.83.

Diagnosis : Rostrum tapering and extending beyond the antennular peduncle. 7-9 teeth on the upper and 2-3 teeth on the lower margin of the rostrum. Distance between successive teeth diminishes as they approach the tip. Carapace rough.

The first peraeiopods exceeding the antennal scale by almost the entire chela. The second peraeiopods stout and more than half as long as the body. Carpus shorter than merus, palm and fingers and its distal end thickened. Palm slightly thicker than the distal end of the carpus. Fingers equal and pubescent.

Telson with a group of large setae basally on dorsal side; lateral spines present.

Measurement : Total length : 42.0-58.4; Carapace length : 11.6-12.3; rostral length : 8.1-8.4; rostral formula 7-9/2-3.

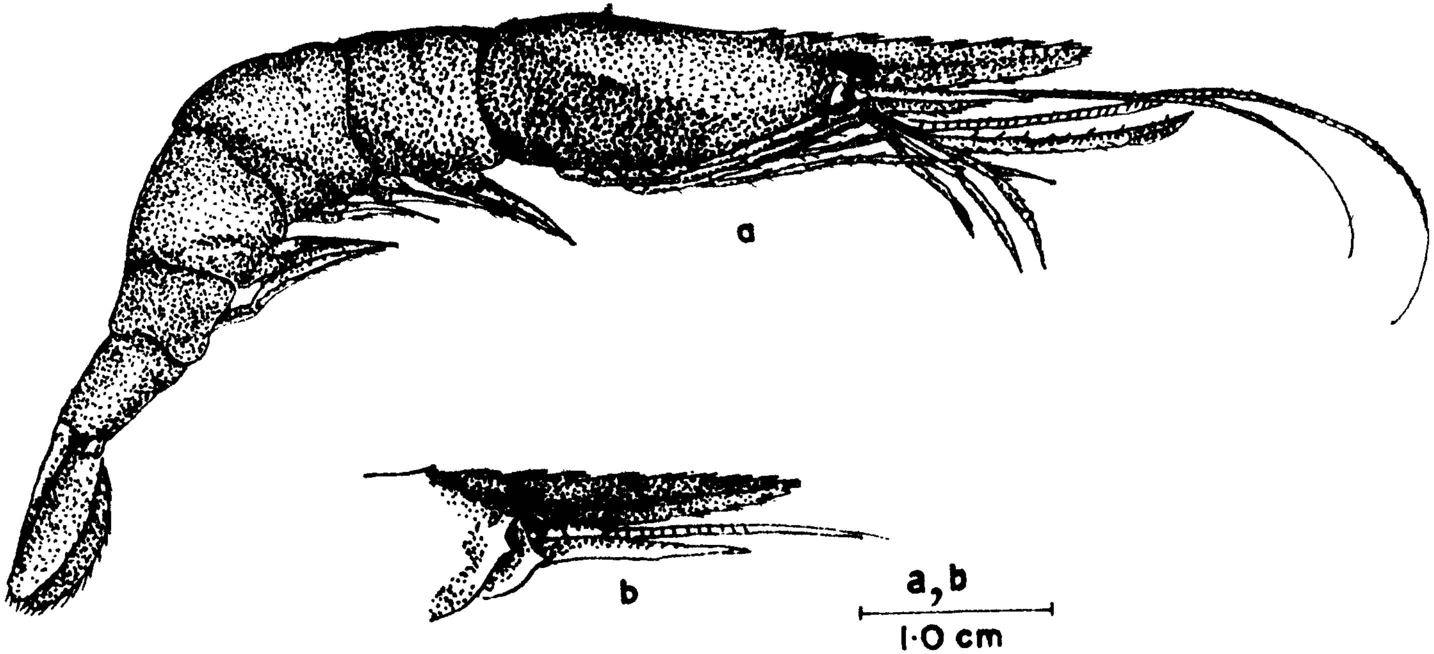


Fig. 13. Macrobrachium kistnensis (Tiwari):
a. Male (Lateral view); b. Cephalothorax (Lateral view)

Distribution :

N.E. Region : Siju cave, Garo Hills (Meghalaya state).

India : Orissa, Bihar & Chittagong district of Bangladesh.

Remarks : This species resembles to M. hendersoni (De Man) and can be distinguished from it in the absence of fluting and pubescence on the fingers; and presence of dense felt hairs on the inner border of palm.

Macrobrachium kistnensis (Tiwari, 1952)

(Fig : 13a,b)

Palaemon kistnensis Tiwari, 1952, Ann.Mag.Nat.Hist.Ser. 12.Vol.V, p.27-32.

Material examined :

AP Collection : 12 ♂♂ and 6 ♀♀; Locality : Juri river, Dharmanagar (Tripura state); Date of Collection: 28-8-'84.

Diagnosis : Rostrum extending as far as the antennal scale and more or less straight. 7-8 teeth on the dorsal surface of the rostrum and 3-5 teeth on the ventral surface of the rostrum. With usually two teeth on carapace behind the orbital border.

First peraeiopods slender and about 1/3 of the total length. Second peraeiopods longer, stouter than the first pair but never more than 2/3 of the total length carpus about 7-8 times as long as its

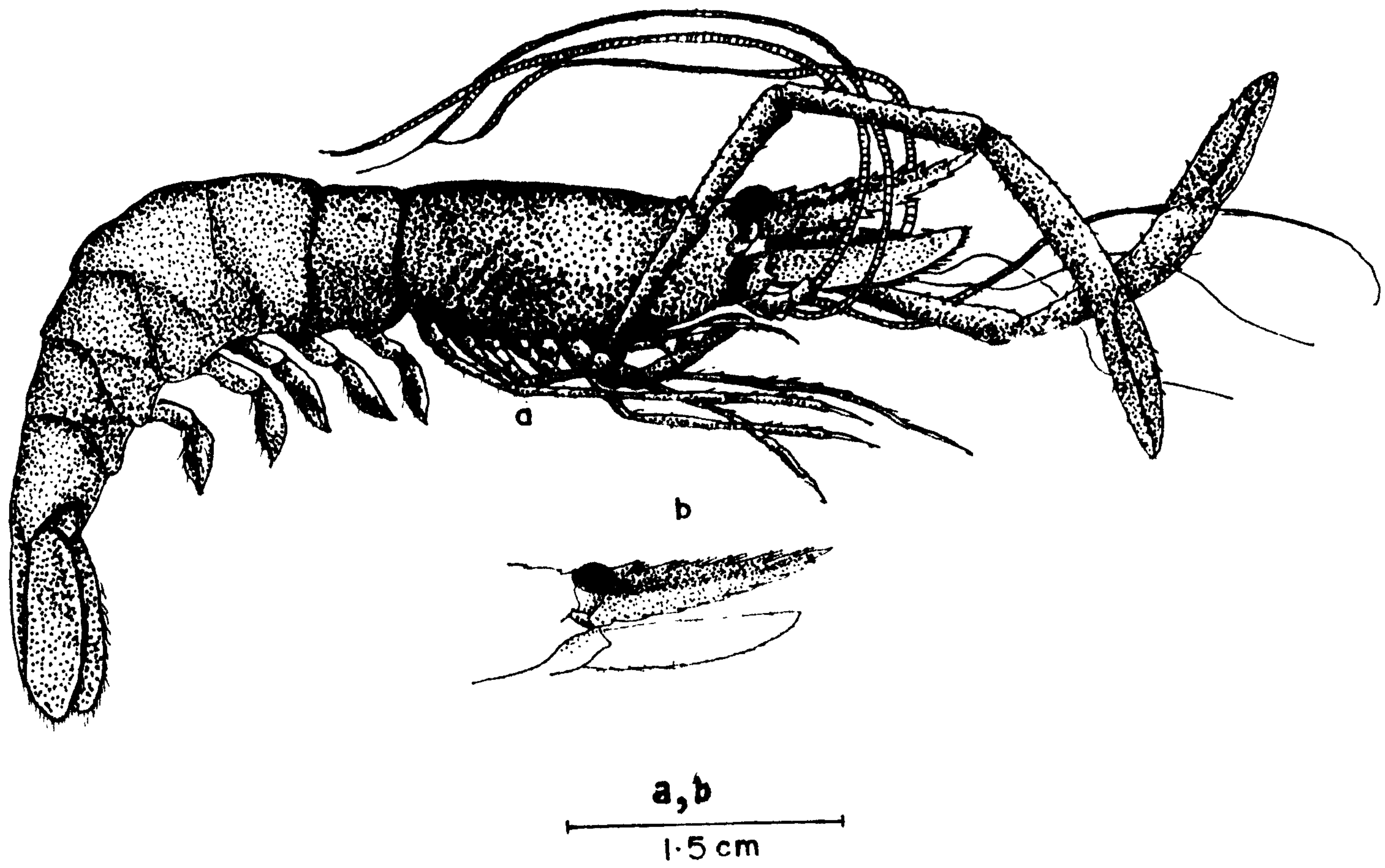


Fig. 14. *Macrobrachium lamarrei* (H. Milne-Edw.):
a. Male (Lateral view); b. Cephalothorax (Lateral view).

distal diameter. Palm often more than half as long as carpus, usually shorter than merus, fingers more than half the length of the palm, smooth, non-pubescent and entire cheliped smooth. Males shorter than females.

Measurements : Total length : 21.0-60.1; Carapace length : 10.2-10.8; rostral length : 12.1-12.8; rostral formula 7-8/3-5.

Distribution :

N.E. Region : Tripura state.

India : Bihar, Uttar Pradesh and Western Ghats.

Macrobrachium lamarrei (H. Milne Edwards, 1837)

(Fig : 14a,b)

Palaemon lamarrei H.Milne Edwards, 1837 Hist.nat.Crust., vol.2 p.397.

Palaemon lamerrei, De Man, 1897, Zool.Jb.Syst.Vol.9, p.767; Henderson& Matthai, 1910, Rec.Indian Mus, Vol.5, p.301; Kemp, 1915, Mem.Indian Mus.Vol.5,p.265;Balss,1930, Ergebn Biol.,vol.6, p.318; Hora, 1933, Curr.Sci; Vol.1, p.4,5,Chopra 1939,Journ. Bombay nat.Hist.Soc.,Vol.41,p.223,pl.1 fig.6; Chopra and Tiwari,1949, Rec.Indian Mus.,vol.45,p.214.

ERS/ZSI Collection : 8 ♂♂ and 4 ♀♀ ; Locality : Karmi beel, aziranga site (Assam state); Date of collection 24-2-72. Collector : Dr. G.M. Yazdani. Regd.No.Al/1596 and 7 OO 3 OO ; Locality : Phulubari river bed, Garo Hills (Meghalaya state); Date of collection : 21-2-1965. Collector : Dr. A.S. Rajgopal; Regd.No.A1/1621.

Diagnosis : Rostrum extending forwards considerably beyond the apex of the antennal scale; its upper margin with a slight convexity over the eyes, a concavity in front of the orbit and an upward reflection at the tip. 5-6 teeth on the upper and 6-7 teeth on the lower margin of the rostrum. Two plumose setae under the 5th rostral tooth and one under the 3rd tooth.

Antennular peduncle three-segmented. Outer flagellum also three-segmented. A number of setae project on all the joints and outer margin of the peduncle.

Carapace armed with a pair of sub-orbital spines in addition to branchiostegal spines.

Orange red anterior and posterior-dorsal margin of the eye and red on the base of each maxilliped and five pairs of peraeiopods.

Basis of maxilliped I with twenty short setae and two plumose setae. Endopodite of third pair of maxilliped also five segmented and profusely setose.

Biramous pleopods present, each with a clearly formed basal segment and two distinct rami.

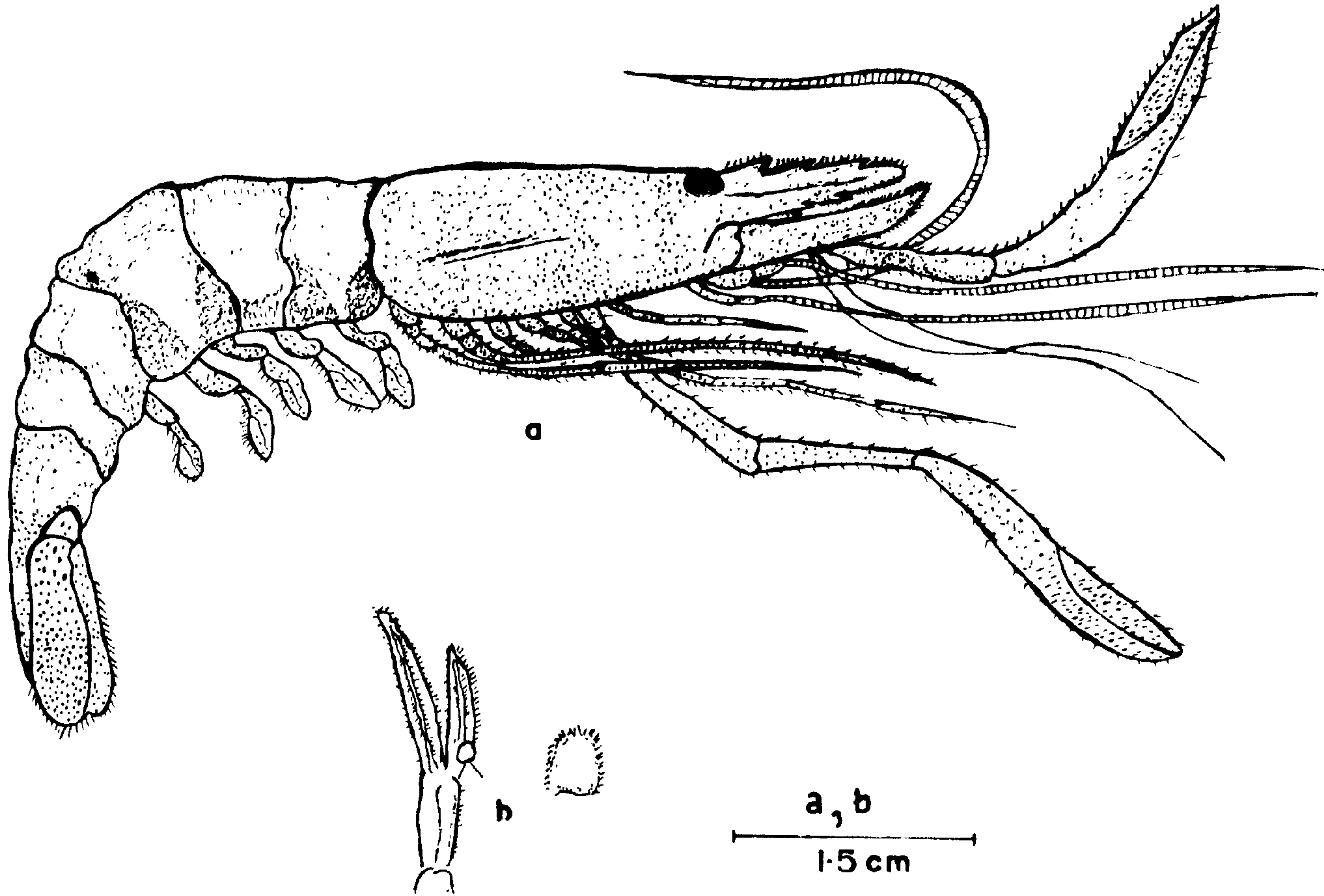


Fig. 15. Macrobrachium lamarrei lamarroides (Tiwari):
a. Male (Lateral view); b. Second pleopod.

Telson expanded, plate like, flat at its posterior end and carries 7+7 spines, 3rd to sixth spines of each lobe sub-equal. No spine on uropod.

Measurements :

AP Collection : Total length; 28.0-69.5; Carapace length 14.6-15.7; rostral length : 10.5-10.8; rostral formula : 5-6/6-7.

ERS/ZSI Collection : Total length : 31.0-71.8; Carapace length : 13.9-15.0; rostral length; 10.6-10.9; rpstral formula 6-6/6-7.

Distribution :

N.E. Region : Assam, Meghalaya.

India : Bihar, Bengal coasts, North West Bengal, lower Bengal, Chilka lake, Ganjam, Madras, and Lahore.

Remarks : M. lamarrei differs from all the other species with respect to lack of spine on uropod.

Macrobrachium lamarrei lamarroides (Tiwari, 1952)

(Fig. 15a,b)

Palaemon lamarrei lamarroides Tiwari, 1952, Ann.Mag.Nat.Hist., Ser. 12, vol..V, p.27-32.

Material examined :

AP Collection : 5 ♂♂ and 3 ♀♀; Locality; Logtak Lake (Manipur state); Date of collection : 12-12-84.

ERS/ZSI Collection : 2 ♂♂; Locality; Logtak; Date of collection : 3-7-72; collector : Dr. R.S. Pillai Regd.No.Nil.

Diagnosis : Rostrum extending upto the apex of antennal scale, slender, distal half upturned and upper edge somewhat sloping. 5-6 teeth on the upper edge of rostrum and 6-7 teeth on the lower edge of the rostrum; lower edge with sub-equal teeth; the gap between the proximal series and the distal tooth generally unarmed.

Basis of maxilliped I with 22-24 short setae and two plumose setae. Endopodite of third maxilliped five segmented and profusely setose.

Measurements :

AP Collection : Total length : 19.6-58.6; Carapace length; 13.3-14.6 rostral length : 10.1-1.6 rostral formula 5-6/6-7.

ERS/ZSI Collection : Total length : 19.3-59.3; Carapace length; 12.9-14.3; rostral length : 10.0-10.8; rostral formula 5-6/6-7.

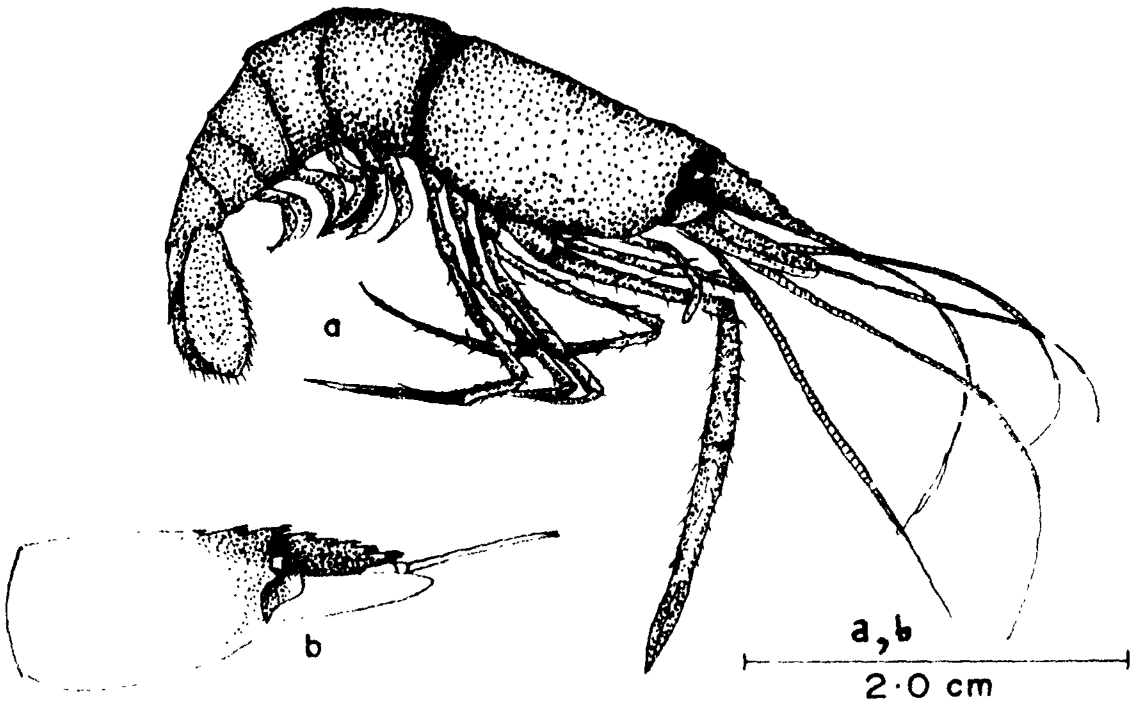


Fig. 16. Macrobrachium malcolmosnii (H. Milne-Edw.):
a. Male (Latera view); b. Cephalothorax (Lateral view)

Distribution :

N.E. Region : Logtak Lake (Manipur state).

India : Only in the stated habitat.

Macrobrachium malcolmsonii (H. Milne Edwards, 1844)
(Fig. 16a,b)

Palaemon malcolmsonii H. Milne Edwards, 1844, Vol.Inde Jacquemont, vol pt.2,p.8,atlas,vol.2,pl.21.

Palaemon malcolmsonii Henderson and Matthai, 1910. Rec.Indian Mus. vol.5,p.283,pl.15 fig.2; Balss, 1930, Ergebn.Biol, vol.6, p.318; Patwardhan, 1937, Indian Zool.Mem, Vol.6,p.1, figs.1-65. Chopra,1939, Journ.Bombay nat.Hist.Soc.,vol.41,p.223, pl.2 fig.3.Chopra and Tiwari, 1949, Rec.Indian Mus, vol. 45, p.214.

Palaemon malcolmsonii Kemp, 1915, Mem.Indian Mus, Vol.5, p.266.

Material examined :

AP Collection : 14 ♂♂ and 8 ♀♀; Mora river, Golaghat District (Assam state) : Date of collection : 7-8/-83.

Diagnosis : Rostrum projecting beyond the antennular stalk about one fifth of its length; its upper margin highly convex. 9-10 teeth on dorsal side and 5-7 teeth on the ventral side of the rostrum.

Anterior surface of the carapace scabrous. Incisor part of the mandibles of both sides with one sharp tooth and one or two denticles. The endopod of maxilla II with a single plumose setae at its extremity and two smaller setae on its basal endites. Scaphognathite quite large.

Postero-ventral regions of the first five abdominal epimera, anterior regions of the second abdominal epimeron, first, fifth and sixth abdominal terga, upper surface of telson scabrous.

Large chelipedes sub-equal in length and with less strongly developed spinules.A groove traverses both the upper and lower surfaces of the palm and carpus.

Telson acutely pointed. Inner sub-terminal spinule on each side projecting backwards beyond the outer one, but nearly reaching the telson tip.

Measurements : Total length : 30-121.3; carapace length : 15.8-16.1; rostral length; 10.8-11.2; rostral formula 9-11/5-7.

Distribution :

N.E. Region : Assam.

India : Southern India, Collair and Chilka lake.

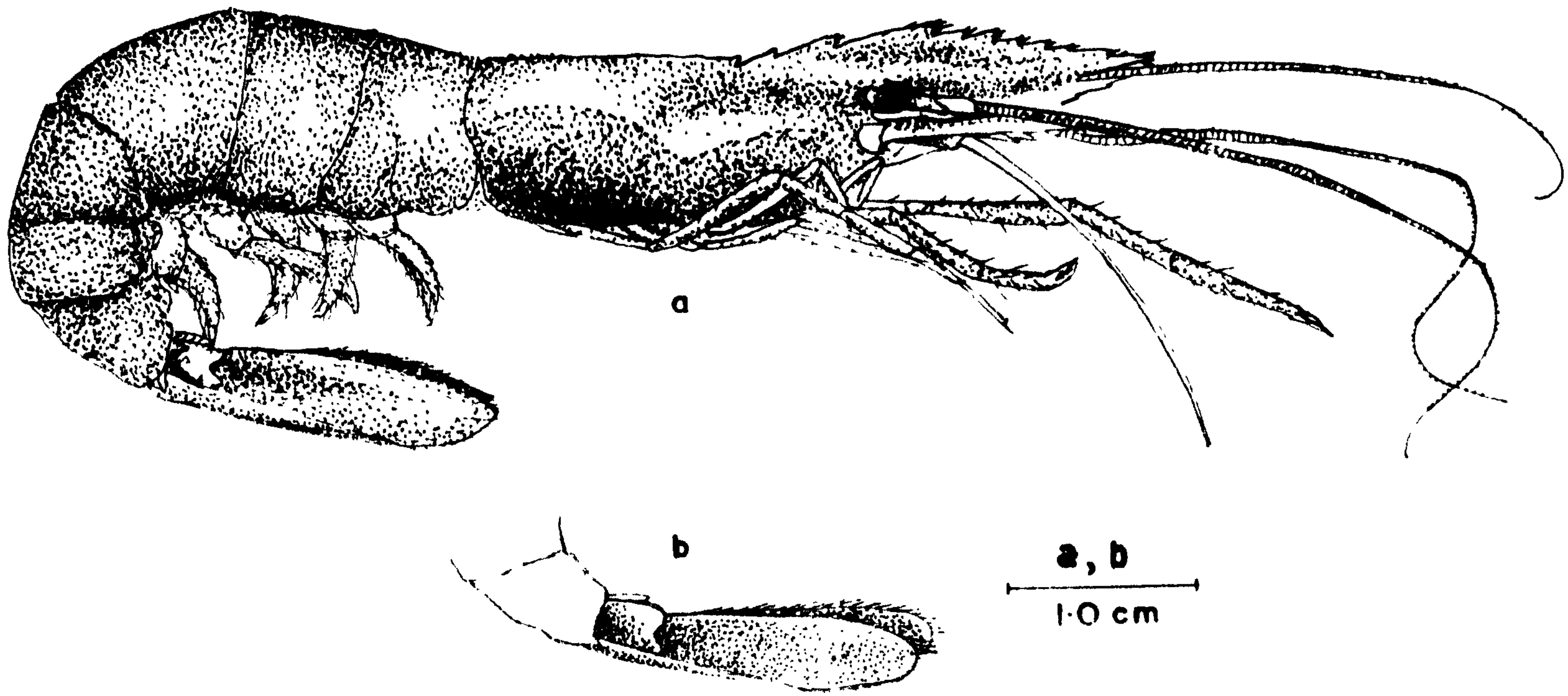


Fig.17. *Macrobrachium manipurensis*(Tiwari):
a. Male (Lateral view); b. Uropod (Lateral view)

Macrobrachium manipurensis (Tiwari, 1952)

(Fig : 17a,b)

Palaemon manipurensis Tiwari, 1952, Ann.Mag.nat.Hist. Ser.12.vol.V, p.27-32.

Material examined :

AP Collection : 3 ♂♂ and 2 ♀♀ ; Locality : Brahmaputra river, Goalpara District. Date of collection : 4-7-84.

ERS/ZSI Collection : 1 ♂; Locality : River Brahmaputra, Chalkbazar, Goalpara (Assam state) Date of collection : 17.1.72. Collector : Dr. R.S. Pillai Regd.No.A1/1414.

Diagnosis : Rostrum extending beyond the second segment of antennular peduncle but not exceeding the end of third segment. 11-12 teeth on the dorsal side of the rostrum and 2-3 teeth on the ventral side of the rostrum. Two pairs of hepatic spines present.

Carapace covered with dense minute prickles except in branchial region.

First pair of paraeiopods about half as long as body in large males; chela longer than half the carpus. Second pair of paraeiopods unequal, strongly built, entire leg covered with strong erect spines and long stiff hairs arranged in definite pattern. In second

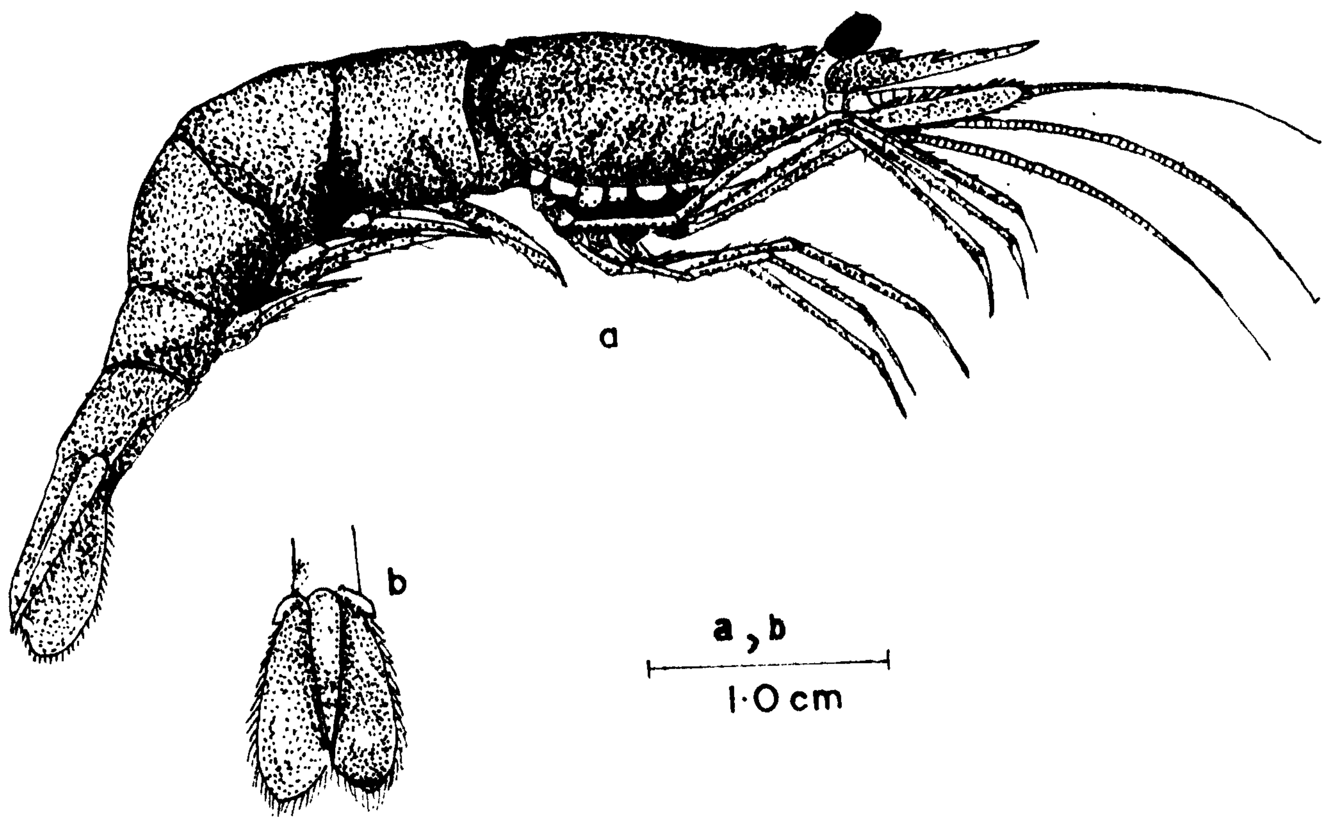


Fig. 18. *Macrobrachium naso* (Kemp): a, Male (Lateral view); b, Uropod.

cheliped, merus slightly longer than carpus but shorter than palm and inflated in the middle region; carpus conical and conspicuously thickened distally; palm compressed,broader than distal part of carpus. Males longer than females. Four hepatic spines.

Measurements :

AP Collection : Total length : 21.0-53.6; carpus length; 9.1-10.4; rostral length : 8.9-9.6; rostral formula 11-12/3-3.

ERS/ZSI Collection : total length : 8.6-9.3; carpus length 10.8; rostral length : 8.6-9.3; rostral formula 10-11/2-3.

Distribution :

N.E. Region : Manipur and Assam.

India : Only in the stated habitats.

Macrobrachium naso (Kemp, 1918)

(Fig. 18a,b)

Palaemon naso Kemp, 1918, Rec.Indian Mus. pp.91,pl.25,fig.1-5.

Macrobrachium naso (Kemp) : Shukla et al, 1981, Ind.J.Fish. Vol.28; p.287, Fig.1.

Material examined :

AP Collection : 14 ♂♂ and 8 ♀♀; Pongtung stream (Meghalaya state); Date of collection : 26-7-84.

Diagnosis : Rostrum curved upwards tapering distally and extending beyond the antennular peduncle. 8-11 teeth on the dorsal surface and 5-9 teeth on the ventral surface of the rostrum.

Second peraeiopods stout and unequal. Fingers about two-third as long as the palm. Palm broader and slightly smaller than carpus in female. Palm of left side longer than carpus but almost equal in right side in males, fingers approximately 2/3rd as long as the palm.

Telson flat at its posterior end and with 7 + 7 spines; 3rd to 5th spines of each lobe sub-equal in length and the spines smallest.

Measurements : Total length : 11.0-59.4; Carapace length : 10.6-11.6; rostral length : 9.0-9.9; rostral formula 8-11/5-9.

Distribution :

N.E. Region : Meghalaya state.

India : Uttar Pradesh.

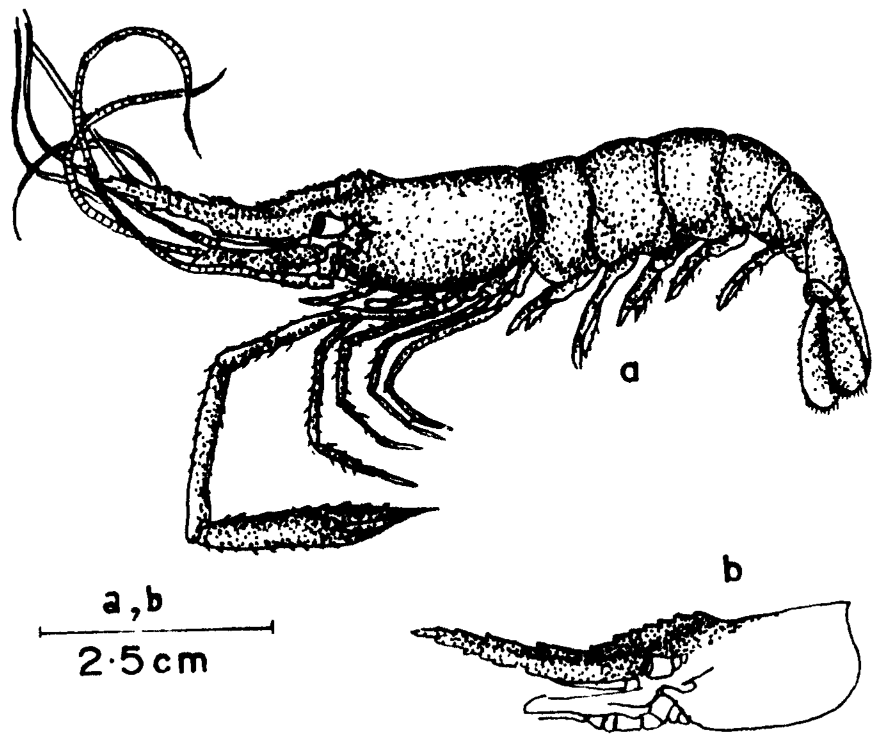


Fig. 19. *Macrobrachium rosenbergii* (De Man):
a, Male (Lateral view); b, Cephalothorax (Lateral view).

Remarks : It can be distinguished from M. dayanum by the shape of rostrum, rostral formula and well developed second peraeiopeds.

Macrobrachium rosenbergii (De Man, 1879)

(Fig. 19a,b)

Locusta marina Rumphius, 1705, Amboin.Rariteikam, ed. I,p.3,pl.1.

Locusta marina Indica Rumphius, 1739, Thesaurus Imag, ed.2,p.1,pl.1. fig.b.

Palaemon carcinus Fabricius, 1798, Suppl.Ent.Syst. 402.Bose, 1801, Hist.nat.Crust., ed.1 vol.2,p.104, Laterille, 1802, Hist.nat. Crust.Ins., vol.6,p.260,pl.54. fig.3; Oliver,1811, Encycl. meth.Hist.nat,vol.8,p.659; Lamarck, 1818,Hist.nat.Anim.S.Vert; ed.1,vol.5,p.207.

Macrobrachium rosenbergii De Man, 1879; Notes Leyden Mus : vol.1,p.116; Lipton, 1980, Curr.Aff.Bull.Indo Pacific fish. Coun, vol.35, p.1-11.

Material examined :

AP Collection : 2 ♂♂ Locality : Fenny river in Sabroom, south District in Tripura;Date of collection : 30-4-84.

Diagnosis : Rostrum extending as far as the apex of antennal scale. 8-10 teeth on the dorsal surface of the rostrum and 8-14 teeth on the ventral surface of the rostrum.

Parallel longitudinal lines on the carapace; rostrum with a distinct elevated basal crest, generally very long or with a distinct naked portion in the distal half of the upper margin.

Carpus of the second peraeiopods in adult male slightly longer than half the length of chela.

Telson tip reaching beyond the tip of the longer posterior spines. Barbel on the setae of pleopod. Setal development in the antennal scale.

Measurements : Total length : 38.0-79.6; Carapace length 10.9-11.8; rostral length : 10.1-10.6; rostral formula 8-10/8-14.

Distribution :

N.E. Region : Tripura.

India : Bengal, Madras, Bombay, Travancore, Trivandrum.

DISCUSSION

The freshwater prawns belonging to the genus Macrobrachium (Palaemonidae : Palaemoninae), previously described under Palaemon, are known to be extensively distributed in tropics and subtropics, They are believed to have originated rather late in geological history in probably littoral (marine) areas and have invaded the freshwater habitats secondarily by migration from sea to land (Tiwari,1955). The process of migration is apparently still incomplete as substantiated by the dependance of some species on brackishwaters for breeding and completion of their larval history (Tiwari, loc.cit; Pannikar, 1967; Jhingran, 1982; Raman et.al., 1986), In fact, the family Palaemonidae as a whole has been considered to be in the process of migrating from marine to freshwaters (Emery & Stevenson, 1957; John Mary, 1957).

Tiwari (1955) divided the known species of the Indo-Burmese prawns of the genus Palaemon (Macrobrachium) into those occuring in inland waters systems and coastal forms. He, further, postulated polyphyletic origin in this genus and commented that these two groups appeared at different times.Thirteen species and four subspecies are examined presently in the collection from various parts of North-Eastern region. A majority of these are noticed to occur exclusively in inland aquatic ecosystems. On the other hand, coastal elements are represented in this study by M. malcolmsonii M. birmanicum choprae and M. rosenbergii. In addition M. lamarrei is widely distributed in freshwater in India and Pakistan and is also reported to occur in brackishwaters i.,e.

in Chilka lake and Gangetic Deltic region (Kurian & Sebastian, 1982). It is also abundant in the Inle' Lake in Burma (Tiwari, personal communication).

Macrobrachium manipurensis (Tiwari) and M.lamarrei lamarroides (Tiwari) are rare and endemic elements. The former was described by Tiwari (1952) from Manipur and is presently observed to be confined to this state only. This interesting species is distinguishable from other Indo-Burmese by the characteristic shape, proportions and colouration of its second pair of peraeipods. It also resembled, in certain respects, with two New world forms - M.spinimanus Edwards and M.olfersii Weigman. M.lamarrei lamarroides is yet another biogeographically significant taxon; it was described (Tiwari, 1955) from Logtak lake, Manipur state. Presently, it is noticed to be confined to the stated lake and the streams draining into it. This subspecies differs from the typical lamarrei specimens in the length and dentition of the rostrum.

The specimens belonging to M.cavernicola and M.kempi collected from Siju cave in Garo Hills district of Meghalaya state (deposited in Eastern Regional station, Zoological Survey of India, Shillong) were examined. Of these, the former species was described (Kemp,1924) from the mentioned locality. The present observations confirm the influence of its cavernicolous environment as manifested in the reduction of cornea of the eye and in the almost complete loss of body pigmentations. The later was described (Tiwari, 1947) from a small stream between Chittagong and Sultan Bagu Bastan (Bangladesh) and its geographical range extends till Mayurbhanj Hills in Orissa state (Tiwari,1955).

M.naso represented a new record from North-Eastern region. This species was previously known to occur around Inle' lake and Myitkina districts of Burma. From India, it has been collected (Shukla et.al., 1981) only from Gorakhpur (Uttar Pradesh). Therefore,its present report from Pongtung stream (Meghalaya state) in this region may provide a biogeographicallink to account for its subsequent distribution in the Gangetic peninsula.

M.altifrons was considered to be widely distributed in Pakistan, northern parts of India and Nepal. Tiwari (1964)critically analysed its various populations thereby recognising the West Pakistani race confined to the Indus drainage system (M.altifrons ranjhai) and the Indo-Nepalese form (M.altifrons altifrons) found in the Ganga-Brahmaputra drainage. The presently examined specimens belong to the second category and are stated to be distributed from Delhi, the Tarai and Duars of Uttar Pradesh, Bihar, Assam to Nepal. Further, the nominate subspecies is reported to occur in streams with clear water (Tiwari, loc.cit.). In this study, it has been collected from Dhir beel in Kokrajar district of Assam state; apparently believed to be introduced in the beel through some of its drainage systems.

The present report of M.kistnensis, a Malayan element, from Juri river near Dharmanagar(Tripura state)is of biogeographical interest as it was not known so far from North-Eastern region. Its distribution range extended from the Tanda falls in Mirzapur district(Uttar Pradesh) Gujarat, Satpuras, the Aravelli hills, Western Ghats to Ceylon. This interesting species is allied to M.lanchesteri (de Man) and indicated certain primitive and advanced characters. The former concern sexual dimorphism, length of second peraeiopods and body size; of the later, it shows a more advanced type of second pair of legs than observed in M.lamarrei, M.lanchesteri and M.naso.

Amongst the taxa included under hendersoni - group by Tiwari (1955), six species and subspecies are represented in this account i.e., M.cavernicola, M.hendersoni hendersoni, M.hendersoni platyrostris, M.hendersoni cacharensis, M.assamensis and M. dayanum. These are apparently restricted to Indo-Burmese region; these, except M.dayanum, are generally found in hill streams or in the areas adjacent to their bases. On the other hand, M.dayanum is reported to be extensively distributed in plains as well as lower altitudes in hills throughout a large part of India and Pakistan. Tiwari (loc.cit;) suggested their origin of hendersoni complex during the pleisto-cene era while the divergence of the existing species from their parental stock (stocks) occured during the mid or late Pleistocene.

Distinct patterns are noticed relating to the distribution of some of the above stated taxa. M.cavernicola (as indicated in this text) is the sole cavernicolous form so far reported from India. M. hendersoni hendersoni occurs, at altitudes between 1500-5000 feet, in Eastern Himalayas, Burma, Yunnan province in China and Pachmarhi in the Mahadeo Hills of the Satpura range. M.hendersoni platyrostris exhibited distribution parallel to the former but is restricted to the altitudes not above 1500 feet.The present observations also confirm to the altitudinal limitations for the occurence of these two subspecies. In addition, M.hendersoni cacharensis was/so far reported only from Cachar Valley of Assam state. However, this study extended its range eastwards to Jaintia Hills district of Meghalaya state. Of the stated subspecies, M.hendersoni cacharensis is presently designated to be a geographical counterpart of M.siwalikensis which is found at the foots of the Siwalik Hills in the Western Himalayas.

M.assamensis, yet another typical Indo-Burmese element, was described by Tiwari (1955) from Someswari river in Garo Hills district of Meghalaya state. Tiwari (loc.lit.) also divided it into two species.The presently examined material refer to typical assamensis species. This nominate subspecies appeared to be confined to lower altitudes in Eastern Himalayas,Burma and extends to Chotanagpur Tract and Kharagpur Hills. M.assamensis assamensis was also noted to occur widely in Brahmaputra Valley in North-Eastern region in the study. It is also abundant in the Northern parts of Irrawady and Burma(Tiwari, Personnel communication).

M.birmanicum includes two subspecies in the examined material i.e. M.birmanichum birmanichum and M.birmanichum choprae.According to Tiwari (1955), the former was distributed in the Ganges and Brahmaputra river systems in Uttar Pradesh, Bihar and Assam while the later occured in the Deltic Bengal and Burma. M.birmanichum choprae as excpected from its previous distributional records, observed to show common occurence in the Brahmaputra Valley of Assam state. On the other hand, M.birmanichum birmanichum rose and has been collected from only one locality (Barapathar) of the mentioned state. M.birmanichum birmanichum occured in Irrawady river and Burma (Tiwari,personnel communication).

M.malcolmsoni, an Indo-Burmese species was reported to occur in India in peninsular rivers draining in the Bay of Bengal and also in the Indus river in Western India (Kurian & Sebastian, 1982. This species is a new record from N.E. region and had been collected from Mora river (near Golaghat) in Assam state. Hence, the present record of M.malcolmsoni is of regional distributional importance.

M.rosenbergii is the largest of all the species of freshwater species of the genus documented in this study. It was widely distributed in the Indo-pacific zone and extends upto Indo-china in the Asian Mainland (Kurian & Sebastian, loc.cit;). The present report of this species is based only on the material collected (Lipton, 1980) from Fenny river in southern Tripura.

This study, though limited in its field survey, presented nteresting information about the distribution of Macrobrachium spp. n North-Eastern India. The difficulties in obtaining extensive collec- ions from all parts of this region were unavoidable because of various easons i.e., transport facilities and time bound tenure of this project. owever, amongst the species reported in this account, a major fraction as comprised by Indo-Pacific elements included. Indo-Malayan and Indo- acific elements included M. kistnensis and M. rosenbergii respectively. urther, a number of species and subspecies could be designated as ypical Eastern Himalayan taxa though they were also reported beyond his range (Tiwari, 1955). M. manipurensis, M. lamarrei lamarroides, . cavernicola indicated much localised occurences while M. hendersoni endersoni M. hendersoni platyrostris & M hendersoni cacharensis also howed restricted biogeographical ranges. Certain other taxa examined rom this region were widely distributed in various regions of India. he importance of Eastern Himalayas in general and Assamese Hills in articular in the distribution of different species of this genus had een adquately exploited previously by Tiwari (loc.cit.). It is believed hat further extensive collections from hitherto unexplored areas of his region may add some more rare and interesting taxa.

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ECOLOGICAL STUDIES

INTRODUCTION

Fresh water ecosystems are inhabited by a diversified groups of organisms which interact through a tropic structure and are influenced by different environmental factors. Investigations on the ecology of biotic communities and their interactions are, therefore, essential to evaluate their role in the functioning and productivity of aquatic environments. Further, some groups are often known to occur under specialized conditions thereby serving as valuable indicators of the tropic status of water quality. The studies on seasonal abundance and population dynamics of natural populations of some economically important groups or species, coupled with relevant ecological data form a pre-requisite for their subsequent exploitation in various aquaculture practices.

Amongst different freshwater habitats, the lotic ecosystems draw special attention as they exhibit a gradient of physical, chemical and biological conditions from head waters to mouth. The physical gradients induce a series of responses within the resident populations leading to a continuous biotic adjustments (Vannote et al; 1980). Variations in the current velocity, water level fluctuations and the quality of substrate greatly influence the composition and colonization of the biocoenosis in lotic habitats (Hynes, 1970; Swanston et al., 1977; Platts, 1979). Drastic changes in physical features are known to invariably eliminate sensitive species while only tolerant ones still thrive. According to Williams and Hynes (1976) insects, worms, crustaceans and molluscs are reported to constantly invade new habitats from surrounding areas under such conditions. Further, substrate effected by current: velocity may act selectively on individual species or on individual life history stages (Leudtke and Brusvon, 1976; Smith and Sandifer, 1976).

An alarming rate of deterioration of water courses because of ever-increasing siltation, poor land utilization patterns, deforestation in the catchment areas and their use as repositories for man's rejectamenta and waste-waters has stimulated research into basic dynamics of running water environments and their biotic communities. Some important investigations on the lotic ecology are those by Ellis (1936), Berg (1943), Allen (1951), Ilies (1952, 1964), Harrison and Elsworth (1958), Oliff (1960), Marglef (1960), Allanson (1961), Macan (1961, 1962), Abraham (1962), Cummins (1966), Ray and Sehgal (1966), Ray et al., (1976), Minshall (1967, 1968), Ulfstrand (1968), Vankateswarlu and Jayanti (1968), Edwards et al., (1972), Hynes (1972), Hynes et al., (1974), Ruggiers and Merchant (1974), Fisher (1977), Crayton and Sommerfield (1979), Hawkes (1979), Pahwa (1979), Pahwa and Mehrotra (1979), Platts (1979), Sharma and Singh (1979, 1980), Paoletti et al., (1980), Dutta and Malhotra (1980), Sharma (1986) and Sunder and Subla (1986).

Of the various economically important groups of decapod crustaceans, the decreasing stocks of freshwater prawns in rivers and streams are of great concern because of their local or regional fishery importance. Therefore, ecological investigations on the natural populations of freshwater prawns in general and that of selected target species in particular provide information for their subsequent mass culture. Some earlier contributions on the ecology of these organisms those by Kubo (1948, 1950a, 1950b), Raman (1966), Johnson (1967), Allen (1967), Hughes (1966), Couture (1967), Baxter and Renfro (1967), Rajyalakshmi (1974), Ling (1969), Truesdale (1970), Truesdale and Mermilloid (1979), and Patel et al., (1984). As indicated, the works related to the Indian species are relatively limited. Further, the ecology of hill-stream prawns remain practically neglected except for the preliminary study dealing with some aspects conducted by Goswami (1983).

This chapter deals with the results of ecological investigation on two species of freshwater prawn i.e., Macrobrachium hendersoni hendersoni (de Man) and M. lamarrei (H. Mine-Edwards). The former is known to be restricted to streams at an altitude between 1,500-5,000 feet and has been reported from Eastern Himalayas, Burma, Yunnan province of China and Pachmarhi in the Mahadeo Hills of the Satpura range. It is also occurred commonly in the streams of East Khasi and Garo Hills districts of Meghalaya state. On the other hand M. lamarrei is widely distributed in freshwaters in India, Pakistan and Inle lake (Burma). It is also reported to occur in brackishwaters i.e. in Chilka lake and Gangetic Deltic region. This palaemonid is represented by both land-locked and running water populations. The present study deals with monthly variations in the water quality at the selected sampling sites; seasonal variations in the abundance of associated biotic communities i.e. phytoplankton, zooplankton and benthic organisms and seasonal fluctuations in the density, sex-ratios, condition factor, fecundity and length frequency distribution of Macrobrachium hendersoni hendersoni and M.lamarrei. All the stated observations are made on stream dwelling populations of the mentioned two species.

MEGHALAYA

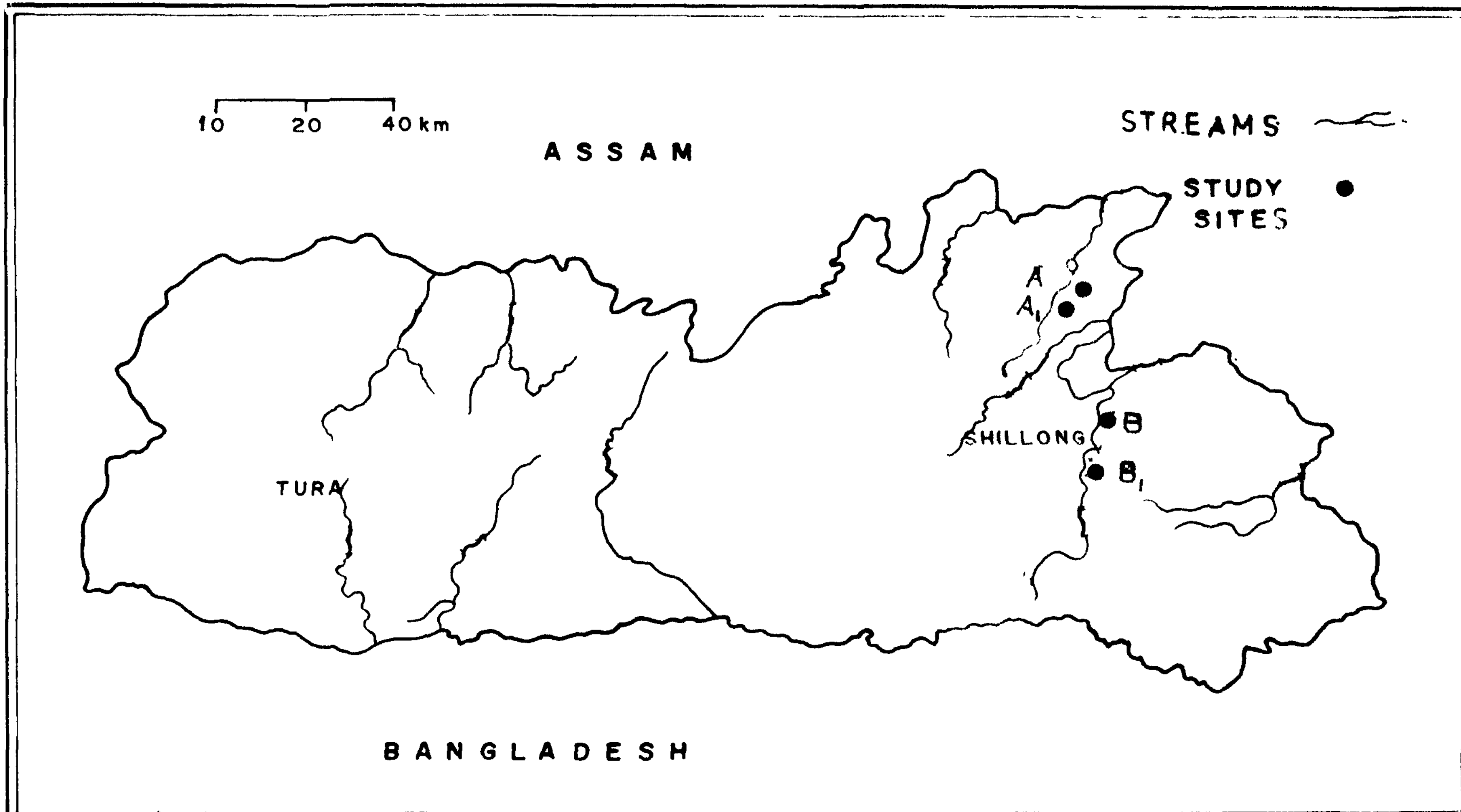


Fig. 20. Map of Meghalaya showing study sites.

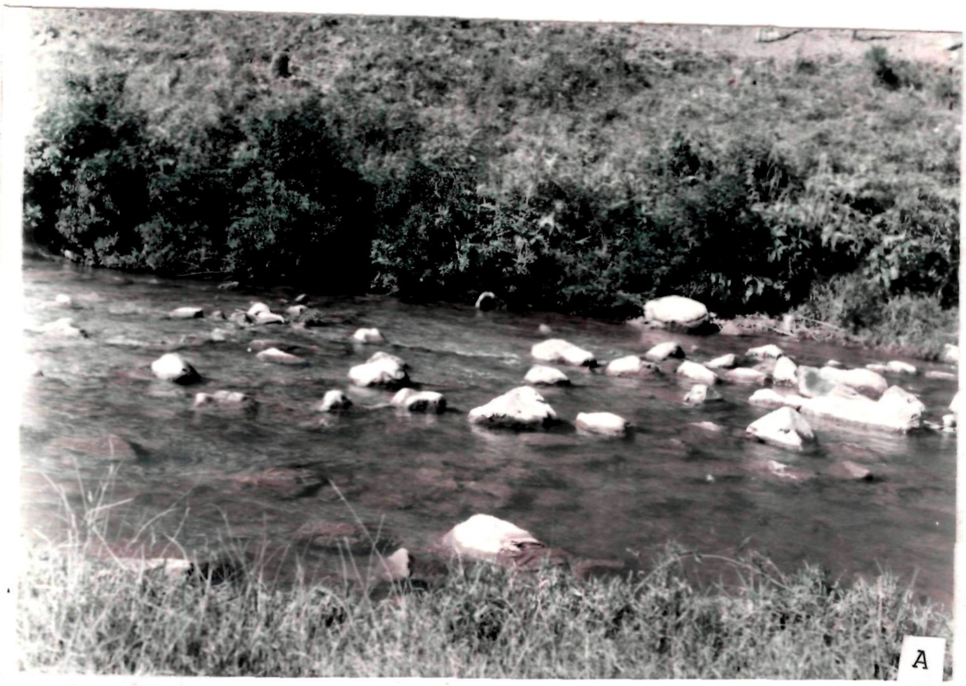


Fig. 21. Photographs showing the sampling stations A and A_1 - Umshing stream during early winter.

MATERIAL AND METHODS

STUDY AREA :(Fig. 20)

The observations on Macrobrachium hendersoni hendersoni (de Man) and various abiotic and biotic factors were conducted in Umshing stream near Barapani (Lat. 25°41' N; Long. 91°52'E) in East Khasi Hills district of Meghalaya State. This study areas was located at a distance of about 25 Km. from Shillong city. Two sampling stations (A and A_1) were selected in this stream (Fig.21). The ecological studies on Macrobrachium lamarrei (H. Milne-Edw.) were undertaken in Min-Mintudu stream near Jowai (Lat. 25°30'N; Long. 92°34'E). This site is located at a distance of about 66 Km. from Shillong city in Jaintia Hills district of Meghalaya. These observations were also restricted to two sampling stations i.e., station B and station B_1 (Fig. 22).

The salient features of the mentioned sampling stations are given below :

Station A : The substrate at this station prominently comprised of small boulders, stones, gravels and sand. The shallow regions of this habitat were infected with some aquatic macrophytes i.e., Lemna and Cerotophyllum while larger boulders indicated the growth of various mosses and liverworts. The marginal vegetation comprised of large bankside trees, shrubs and patches of grasses belonging to Pinus kesiya, Rhododendron, Dendrocalamus, Lantena, Rotella, Cyperus and Eupatorium.

Fig. 22. Photographs showing the sampling stations B and B_1 - Min-Mintudu stream during early summer.

ig. 2

Station A_1 : It was situated downstream to the preceeding station. Its substrate was formed by small boulders together with gravel, sand and stones of variable sizes. It experienced temporary erosion of gravel and sand during rainy season. The marginal vegetation was broadly identical with that indicated for Station A.

Station B : The substrate of this habitat comprised of small boulders of variable dimensions in the midstream and gravels in the marginal areas. The emergent vegetation was much restricted and included Wolffia, Lemna and Rananculus. Various mosses and liverworts were observed to grow on rocky bed and boulders. The extreme upper part of this station had less canopy cover and the marginal vegetation included different trees, shrubs and grasses as indicated in station A.

Station B_1 : It was situated downstream to station B. Its substrate primarily comprised of sand because of out-cropping of gravels and stones; small stones were present only in certain localized fast flowing areas. Its bottom was relatively stable inspite of sand and gravel. The marginal shallow areas indicated some growth of Hydrilla. Filamentous algae (Spirogyra) formed mats in marginal slack waters areas. Diatoms and blue-green algae occurred on the riffle substrates. The bankside vegetation included trees, shrubs while mosses and liverworts were noticed on boulders. Considerable growth in short-tufts of Eladosphora was observed on land substrate in the stream.

Physico-chemical factors :

Water samples were collected from all the sampling stations in Umshing and Min-Mintudu streams at regular monthly intervals between January, 1983 to December, 1984. Data on maximum and minimum air temperature, relative humidity, rainfall and wind velocity of the area were collected from the local meteriological station. Air and water temperatures prevalent at the different sampling stations were measured in the field using a centigrade thermometer. pH was recorded in the field with the help of BDH narrow-range pH paper and thereafter, noted in the laboratory with a pH meter. Conductivity was measured with a conductivity bridge. Dissolved oxygen content of the water was estimated using the modified Winkler's method. The analysis of free carbon-dioxide, total alkalinity, calcium, magnesium,/phosphate and oxidisable organic matter was done following standard methods (APHA, 1985). Sodium and potassium contents were estimated by Flame-photometry; Ammonia-nitrogen by Phenol-disulphonic acid method and silicate by Silico-molybdate method (Mackereth, 1963).

Phyto-and Zooplankton :

Quantitative plankton samples were collected monthly for a period of two years (January 83 - December 84) at each station by filtering a volume of 50 lits. of water through a plankton net of bolting silk (No.25). The samples were preserved in 5% formalin and subsequently each sample was concentrated to 50 ml. The identification of various Phyto- and Zooplanktonic organisms was done with the help of the guideline after Smith (1950), Pennak (1953), Edmondson

(1959) and Needham and Needham (1962). Different planktonic taxa were quantitatively enumerated by counting 1 ml. of the sample in a Sedgwick-Rafter counting cell. 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 Zooplanktons/litre using formula :

$$n = \frac{(a.100)}{l} C$$

Where as : n - number of units/l of original water;

a - average number of planktons in all counts in Sedgwick -Rafter cell; C - volume of original conc. of the sample (in ml.); l - volume of original water expressed in litre.

The densities of total phytoplankton and total zooplankton were expressed as nos./litre. Monthly variations in the different components of the respective planktonic groups were depicted in relative percentage compositions.

Benthos :

Monthly samples of the benthic organisms were collected from each station A, A_1, B, B_1 between January, 1983 and December, 1984, using a quadrate sampler. The collected material was subsequently washed through a set of sieves of different mesh sizes as recommended by Schwoerbel (1970) and Edmondson and Winberg (1971). The contents were later on transfered to the labelled tubes and fixed in 5% formalin for detailed examination. Identification of various benthic organisms was based on the works of Edmondson (1959) and Needham (1962) nisms was based on the works of Edmondson (1959) Needham and Needham (1962) and Pennak (1970). The population densities of total benthic organisms were represented in units/m^2 while their detailed monthly compositions were expressed in relative percentage.

Population study of Prawns :

The monthly collection of the prawns from the different sampling stations were made for the period between January, 1983-December, 1984 following the method adopted by Truesdale and Mermilloid (1979) with certain modification because of the habitat differences. A serine hand net (mesh size 1.0 m x 3.2 mm) 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 and the dislodged prawns were swept into the net. These samples were fixed in 5% formalin and brought to the laboratory to record number/unit area, length, fecundity, size-class composition and sex ratios. The relative abundance of these prawns was expressed as average density/unit area.

Comparisons between ecological similarities of the different biotic communities i.e., phytoplankton, zooplankton and benthic organisms were undertaken between the individual sampling stations and between the two streams. Various similarity indices were calculated vide Sorenson Index :

$$S = \frac{2c}{a + b} \times 100$$

Where as :

S = percentage similarity;

a = number of individuals taxa at one station;

b = number of individual taxa at the second station;

c = number of taxa common to both station.

Condition factor :

Individual variations in length-weight relationships have been studied under the general 'condition' (Le Cren, 1951) the condition factor or Ponderal-index was determined by using the following formula (Hile, 1936) :

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

Where as :

K = condition factor;

W = weight of the prawn;

L = length of the prawn under study;

10^5 = factor to bring the Ponderal-index to near unity (Carlander, 1970).

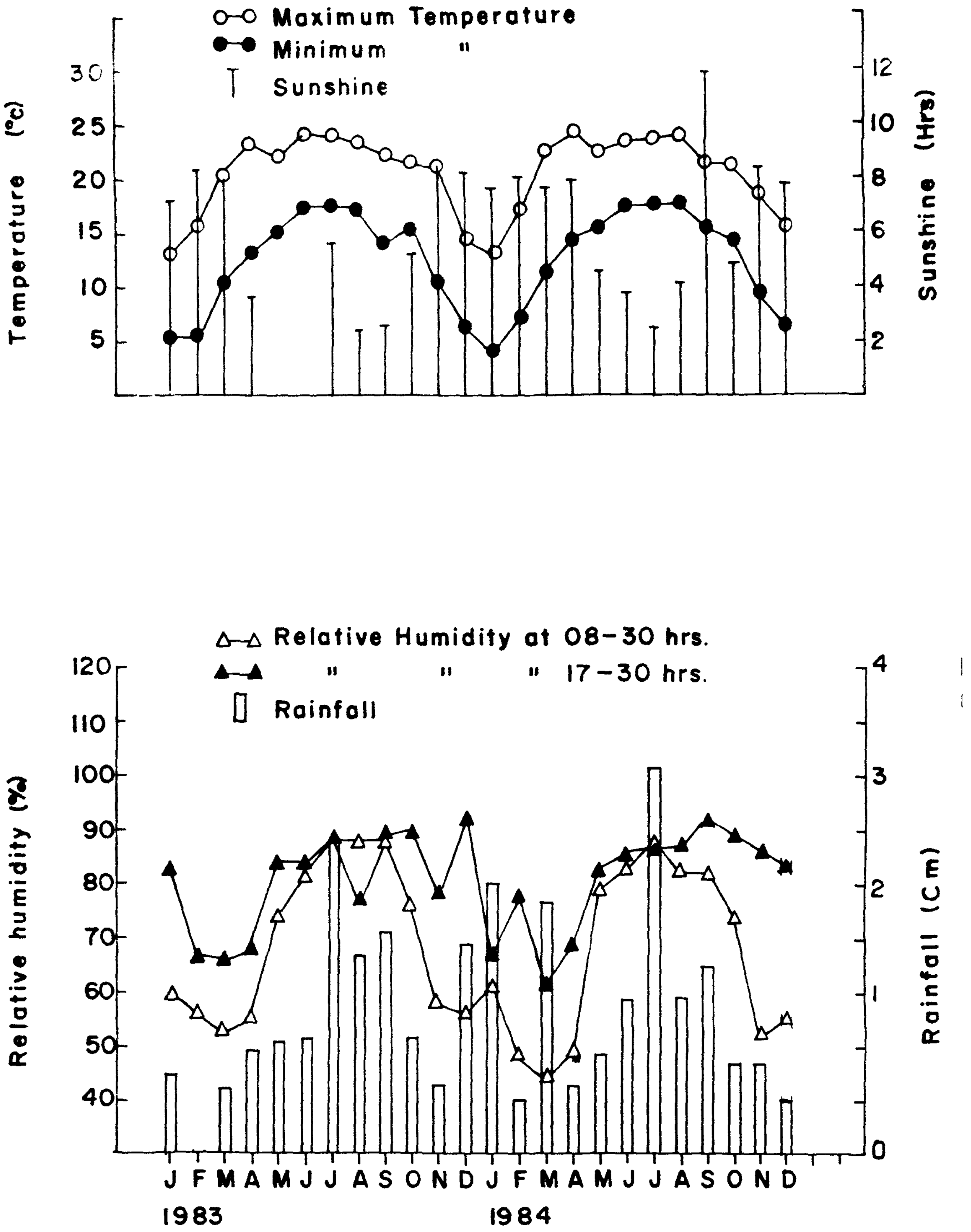
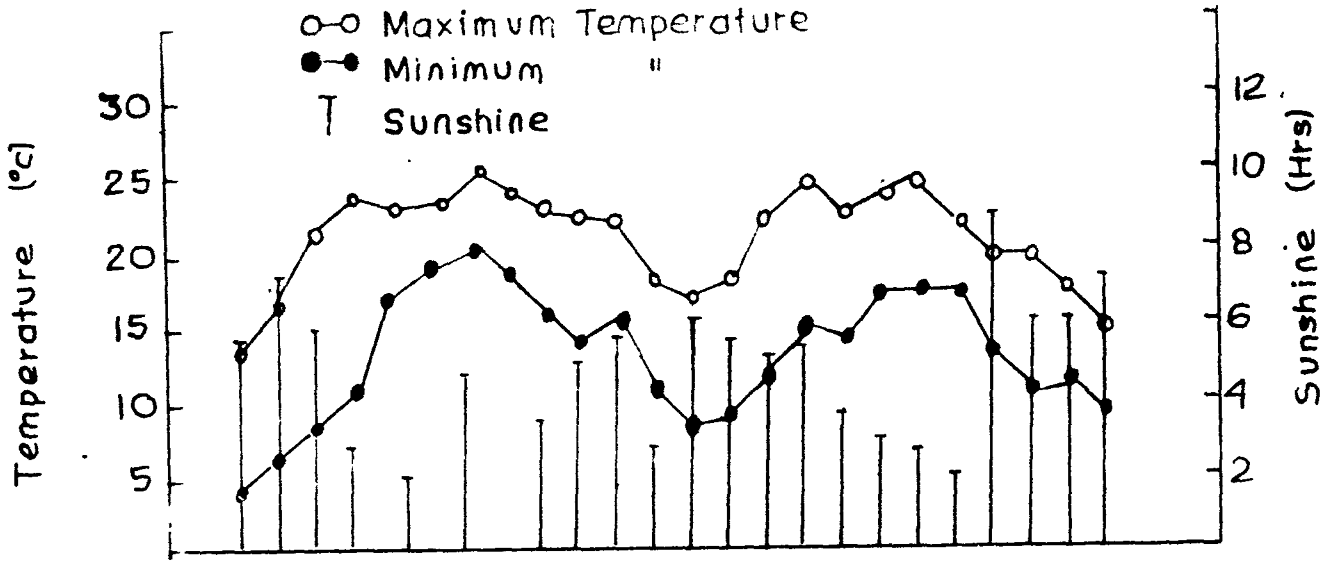


Fig. 23. Monthly changes in local Meteriological conditions : mshing area.



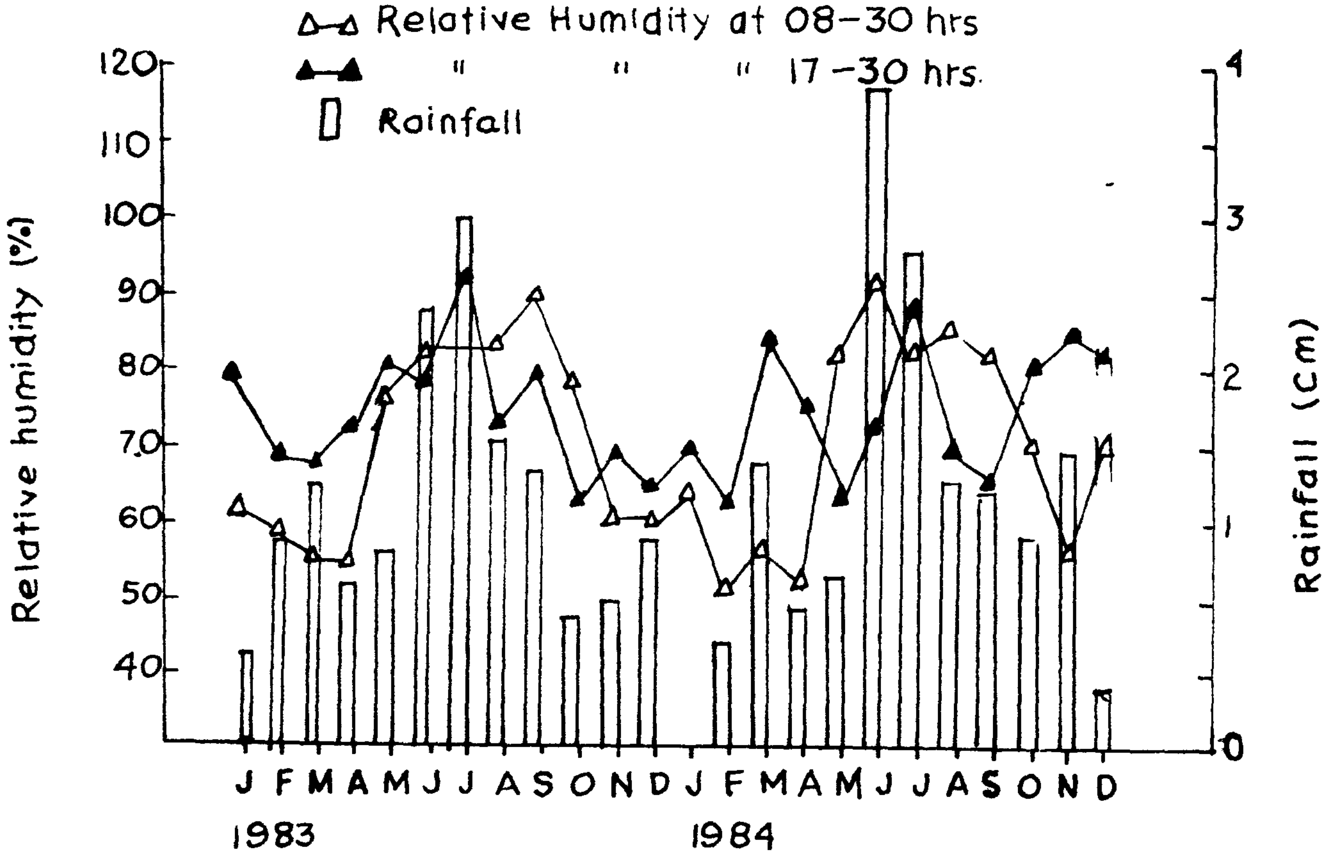


Fig. 24. Monthly variations in local Meteriological conditions in Min-Mintudu area.

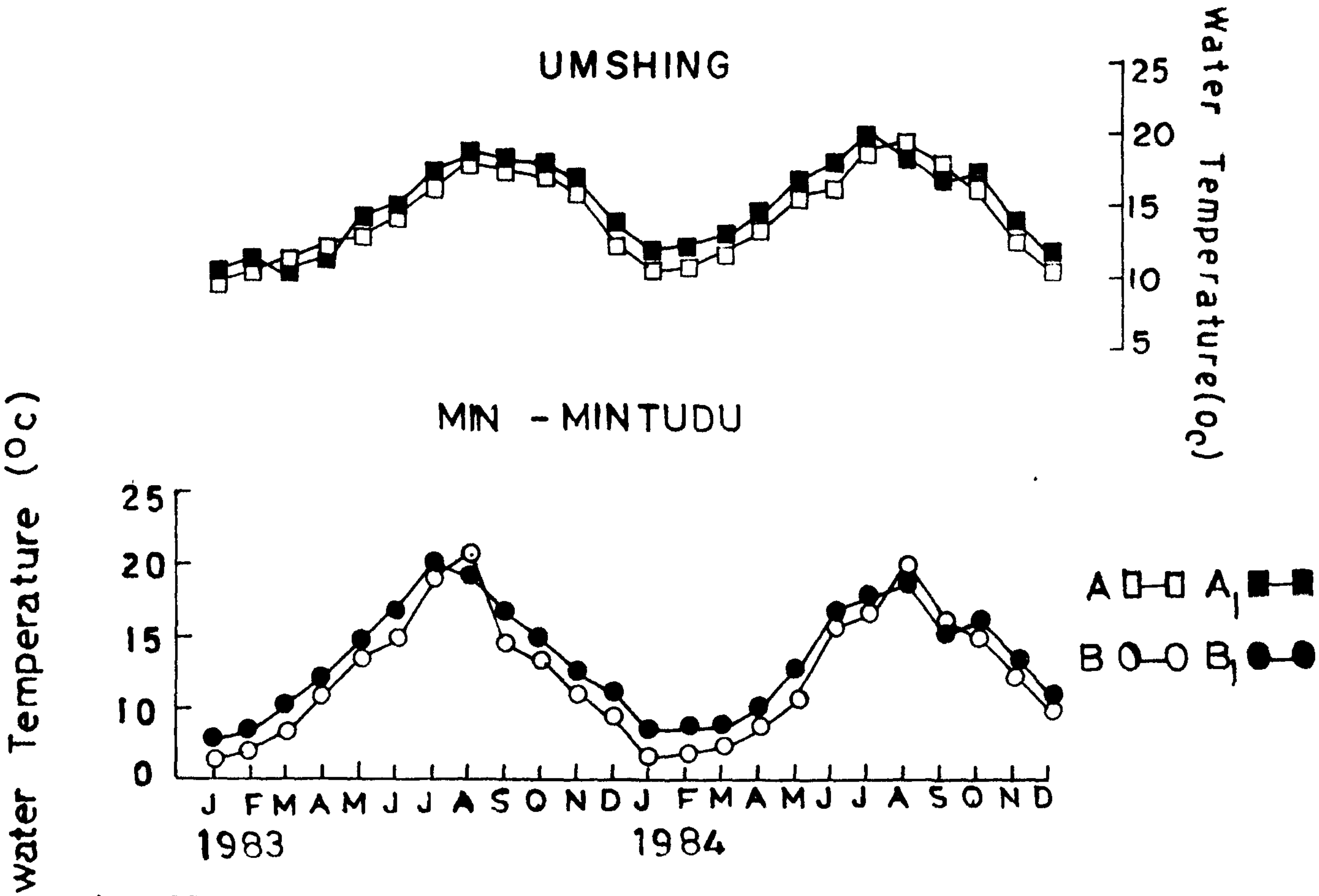


Fig. 25. Monthly variation of water temperature at four different stations.

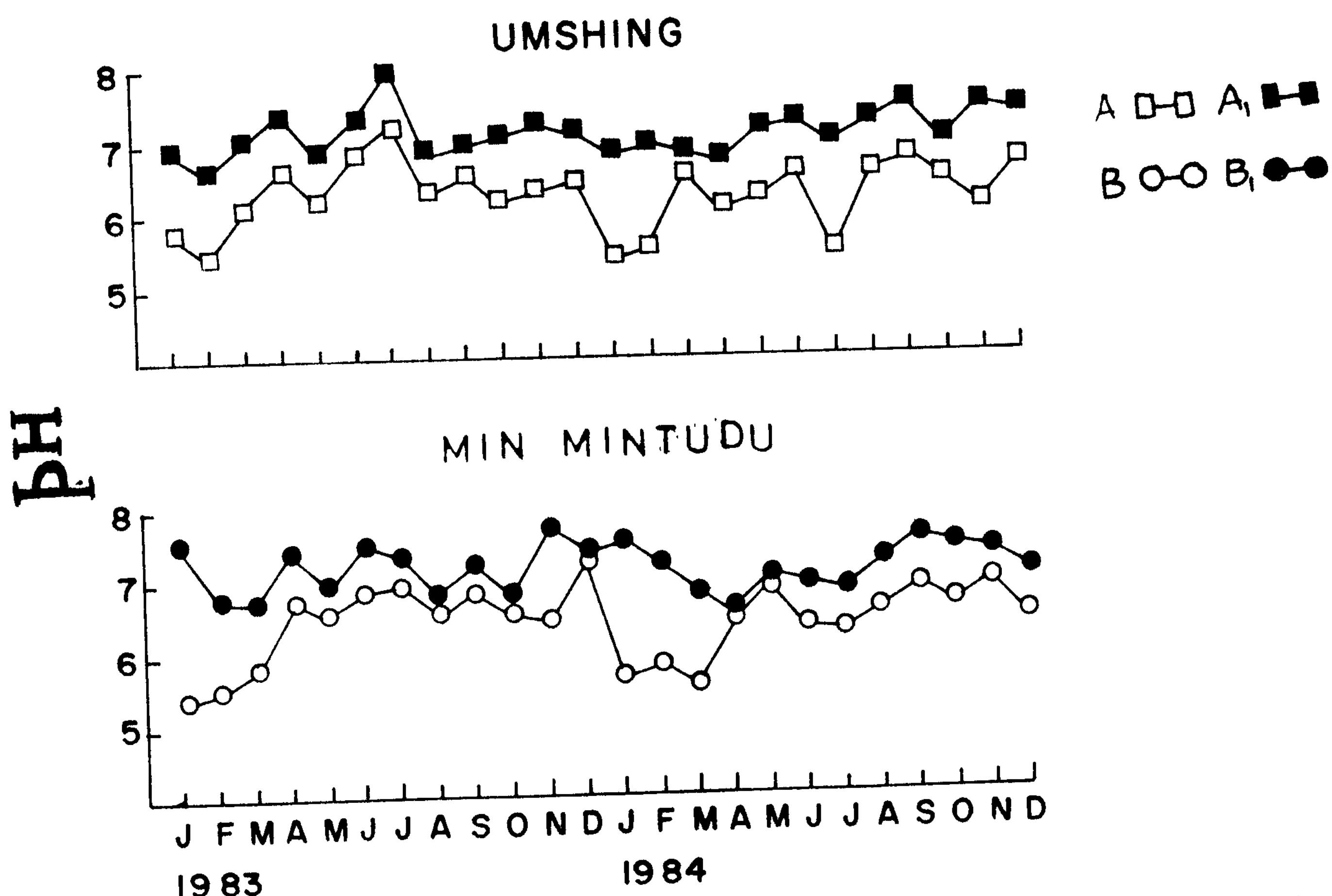


Fig. 26. Monthly fluctuation in pH values at four different stations.

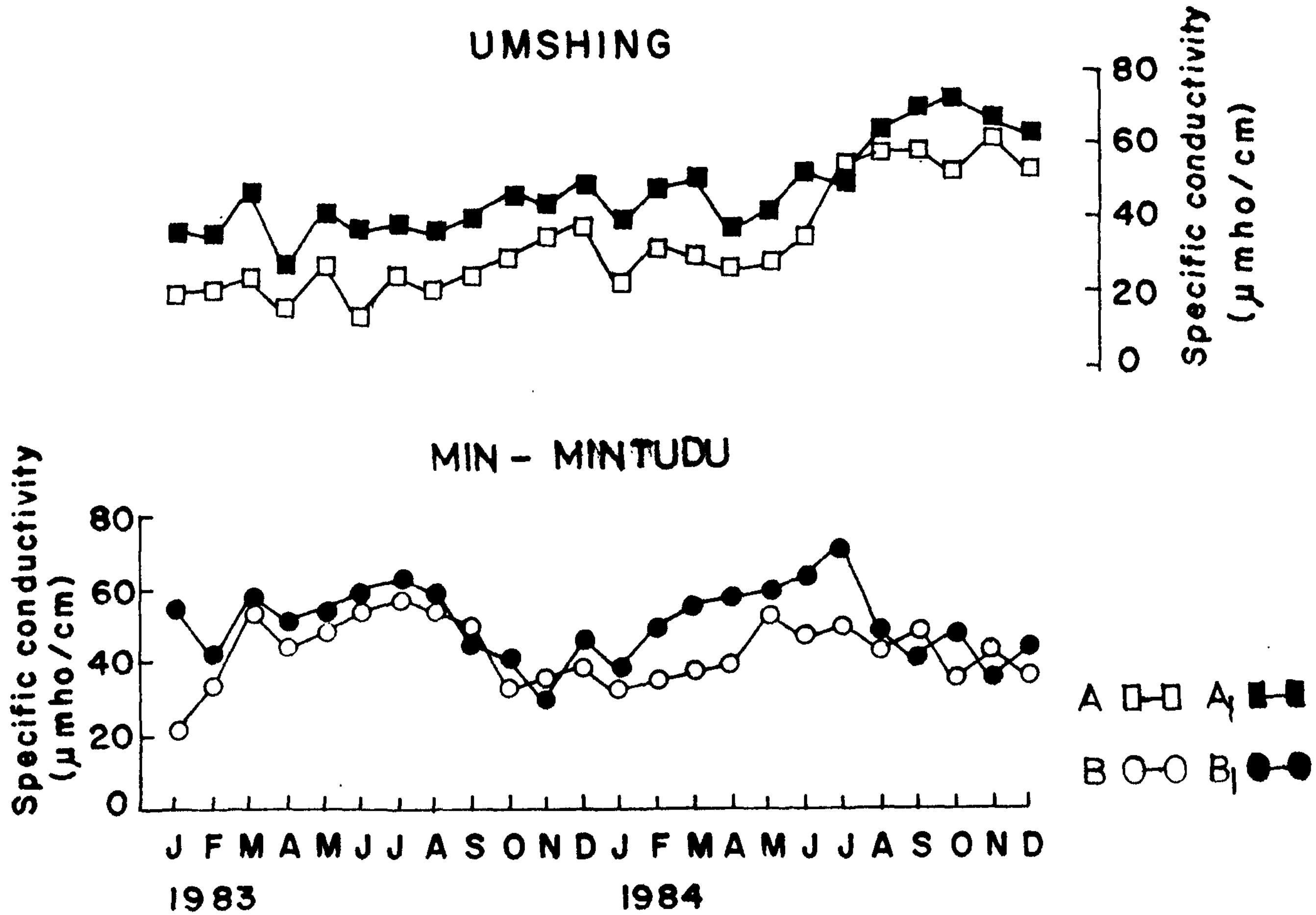


Fig. 27. Conductivity values at four different stations.

OBSERVATIONS

Physico-chemical factors :

The monthly fluctuations in various physical and chemical parameters of water quality as observed at two sampling stations (A, A_1) in Umshing stream and two sampling stations (B, B_1) in Min-Mintudu stream, during the period from January, 1983 - December, 1984, are recorded below :

1. Rainfall : The period of active rainfall (monsoon season) extended from the month of May to October in both the year. The pattern of rainfall observed in these areas is given in Figs. 23, 24. In both the areas, maximum rainfall was recorded in June - July both the years of these observations. The mentioned figures also include trends in variation of some other meteriological factor i.e., maximum and minimum air temperatures, (°C) sunshine (hrs) and relative humidity (%).

2. Water temperature : The water temperature indicated a clear summer maxima and winter minima during the study period. Small temperature differences otherwise observed may be due to local climatic conditions i.e., rain or cloudy weather. The water temperature in sampling stations at Umshing ranged between 9.5°C - 18.5°C and in Min-Mintudu 15.8°C - 25.8°C (Fig.25). The pattern of variations in the water temperatures was broadly indentical in the two streams.

3. pH : The value of hydrogen-ion concentration ranged from 5.4 - 7.5 and 5.3 - 7.4 in Umshing stream and from 5.4 - 7.2 and 6.5-7.7 in Min-Mintudu stream. pH showed notable fluctuations at various

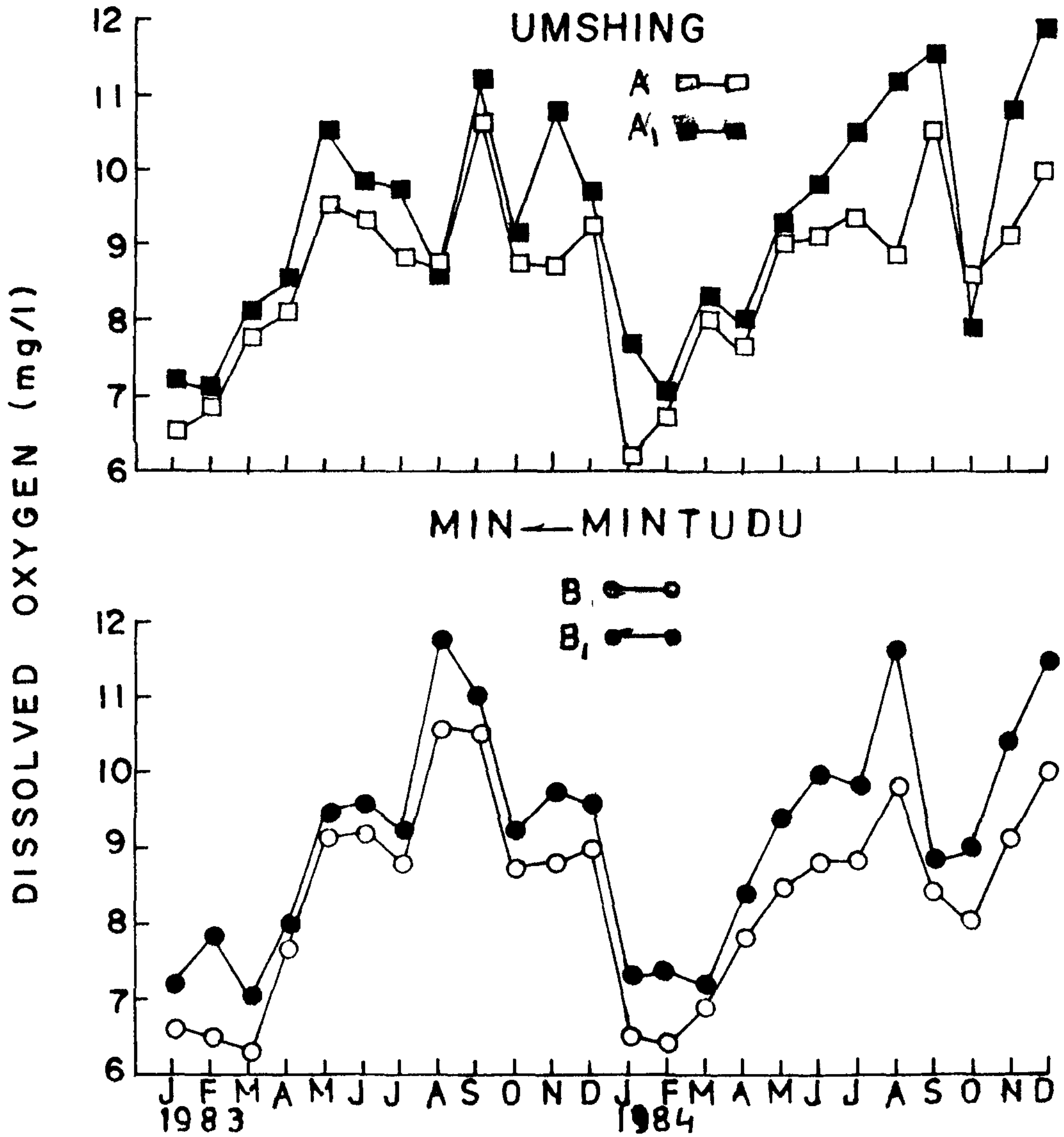


Fig. 28. Monthly variation in dissolved oxygen concentrations at four different stations.

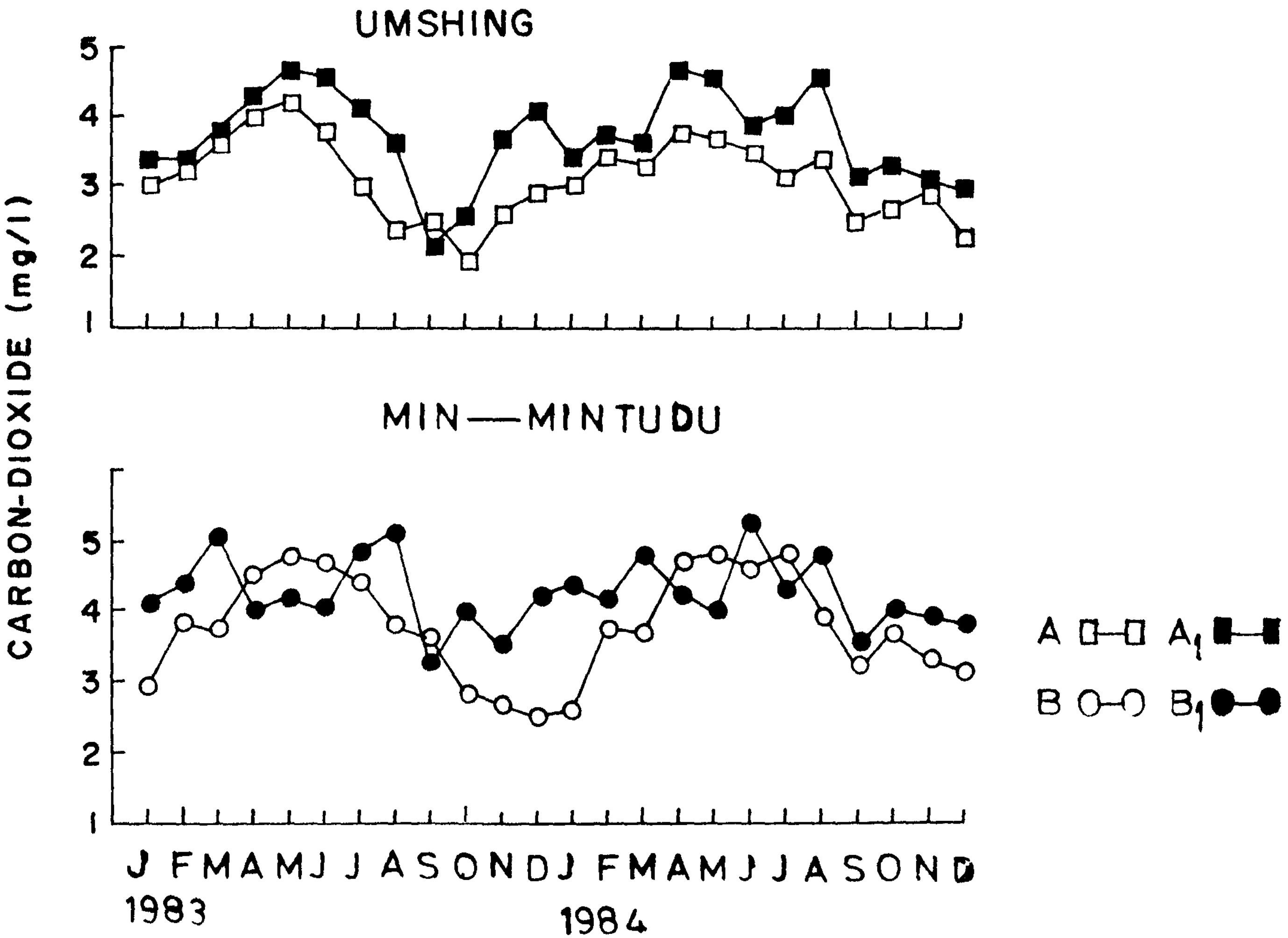


Fig. 29. Monthly variation in free carbon-dioxide values at four different stations.

stations. The values were always higher at station A_1 and B_1 than at stations A and B respectively. Hydrogen-ion concentration did not show any definite trend of fluctuations at various sampling stations (Fig.26).

4. Conductivity : Specific conductivity of water ranged between 12.0-62.0 umho/cm and 34.0-72.2 umho/cm in Umshing and Min-Mintudu stream respectively. The sampling station in the former stream exhibited almost identical pattern of conductivity values; higher values were observed from August, 1984 - December, 1984. The sampling stations in Min-Mintudu stream registered more distinct variations in conductivity values. In this stream the values, however, were noticed to be lower from August - December, 1984 (Fig.27); maximum conductivity was observed in Min-Mintudu stream at sampling station B_1 in July, 1984.

5. Dissolved oxygen : Dissolved oxygen fluctuated in the range of 6.5-11.6 mg/l, 6.2-12.3 mg/l, 6.6-11.8 mg/l, 6.4-11.6 mg/l at the stations A, A_1, B and B_1 respectively (Fig.28). Low concentrations of dissolved oxygen were noticed at all the sampling stations in January and February during both the years. The pattern of fluctuations was more distinct in Min-Mintudu stream, with highest values in August in these years. In addition higher values were also observed at stations A and A_1 in the months of May, 1983 and December, 1984.

6. Free carbon-dioxide : Free carbon-dioxide was detected in water throughout the study period (Fig.29) and its concentration ranged between 1.9 - 4.7 mg/l. The stations A, A_1, B and B_1 registered free

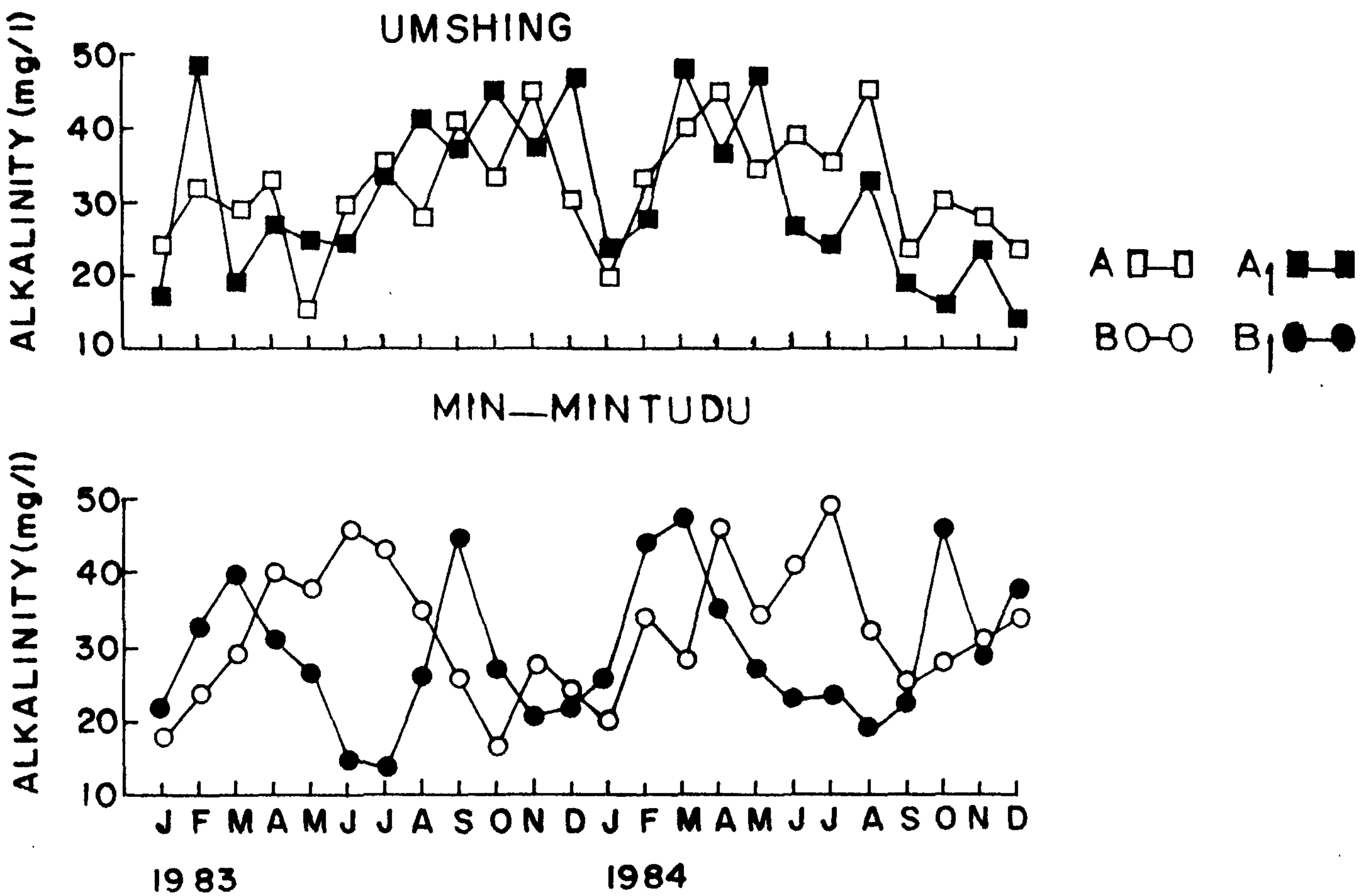


Fig. 30. Monthly fluctuations of alkalinity at four differ·nr stations.

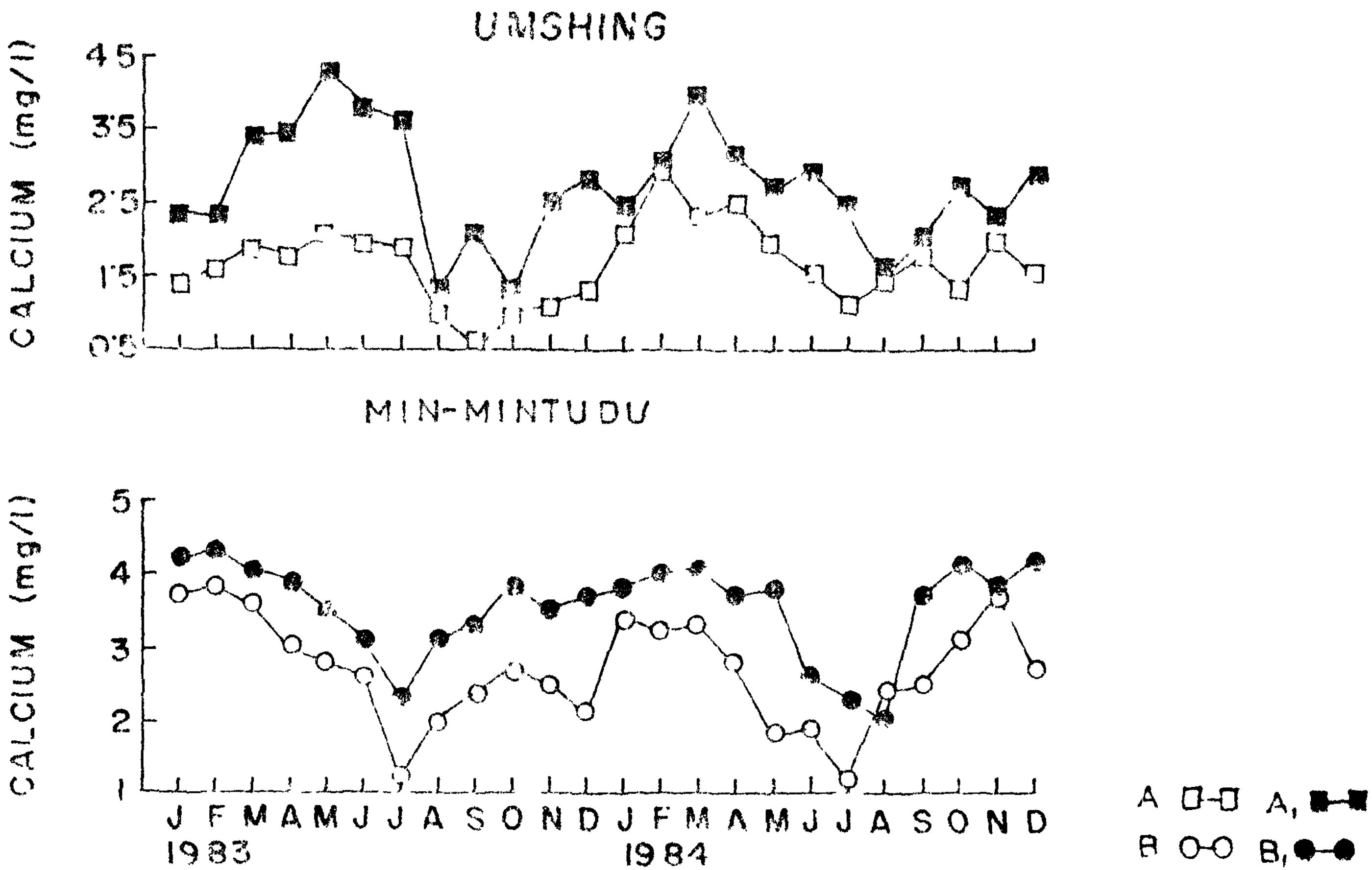


Fig. 31. Monthly variations in Calcium concentrations at four different stations.

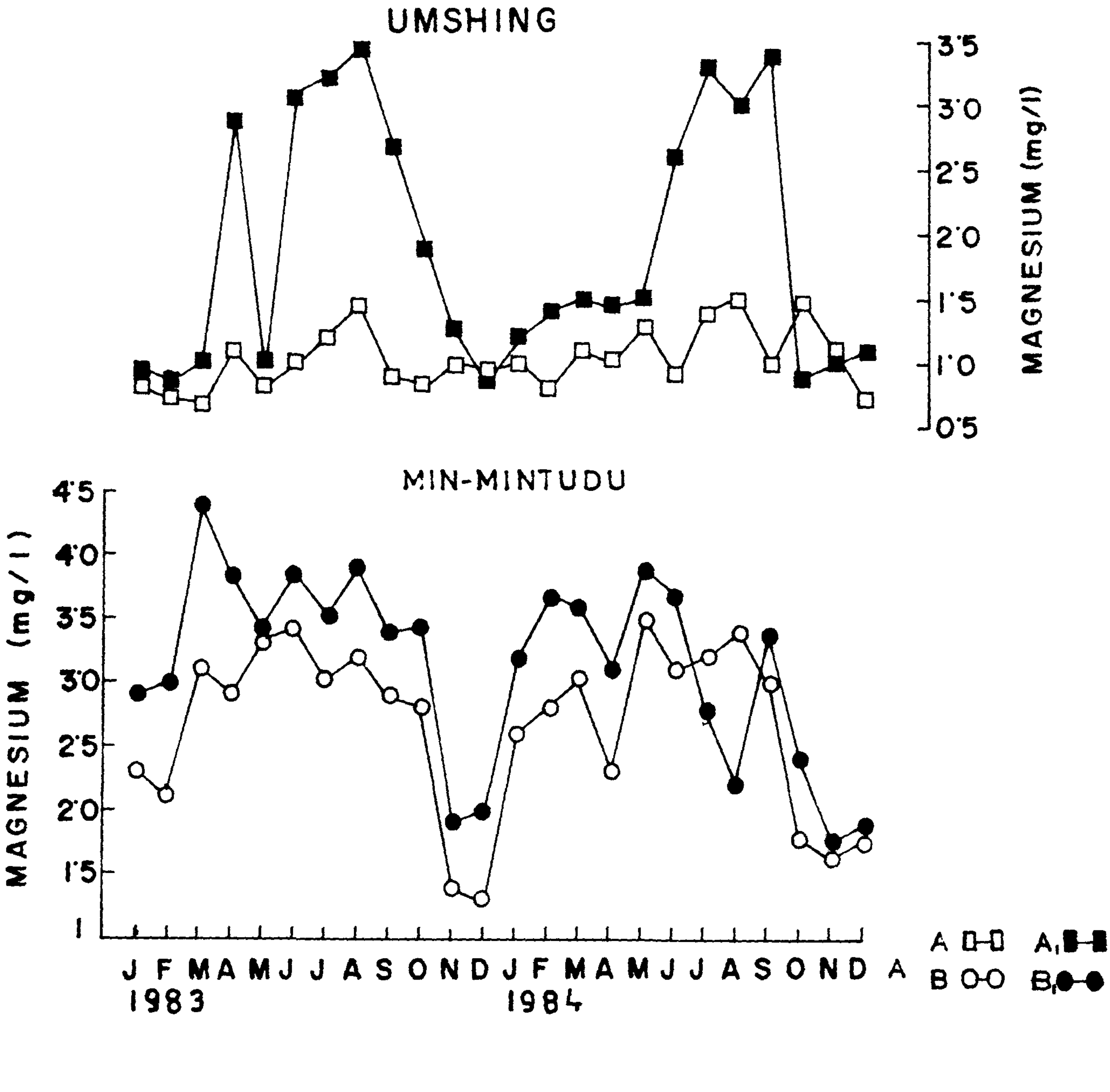


Fig. 32. Monthly variations in Magnesium concentrations at four different stations.

carbon-dioxide in the range of 1.9 - 4.2 mg/ml, 2.1 - 4.7 mg/ml, 2.5 - 4.8 mg/ml, 3.1 - 5.2 mg/ml respectively. No definite trend was noticed in the monthly variations of free carbon-dioxide values at the different sampling stations.

7. Total alkalinity : Total alkalinity fluctuated between 15.0-45.0 mg/l, 13.0-48.0 mg/l, 17.0-49.0 mg/l, 8.0-47.0 mg/l at sampling stations A, A_1, B and B_1 respectively (Fig.30). Total alkalinity represented the values of methylprange alkalinity (due to bicarbonates) during this study period. No definite pattern was noticed in monthly variations of this factor at the various sampling stations. The mode of fluctuations of total alkalinity was relatively more irregular in Umshing stream.

8. Calcium : Calcium concentration ranged between 0.5-3.4 mg/l, 1.3-4.3 mg/l, 1.1-3.7 mg/l, 2.0-4.4 mg/l at all the different sampling stations respectively. The values were relatively higher in Min-Mintudu stream than in Umshing stream (Fig.31). Station B_1 of Min-Mintudu stream recorded higher values (1.2 - 4.3 mg/l) than station B during the first annual cycle. Lower concentration of calcium were noticed in July in both the year at station B in Min-Mintudu while in Umshing the minimum value was noticed at station A in September, 1983.

9. Magnesium : Magnesium concentration registered seasonal fluctuations in the range of 0.7-1.5 mg/l, 0.6-3.4 mg/l, 1.3-3.5 mg/l, 1.8-4.4 mg/l at the stations A, A_1 B, B_1 respectively (Fig.32). Stations

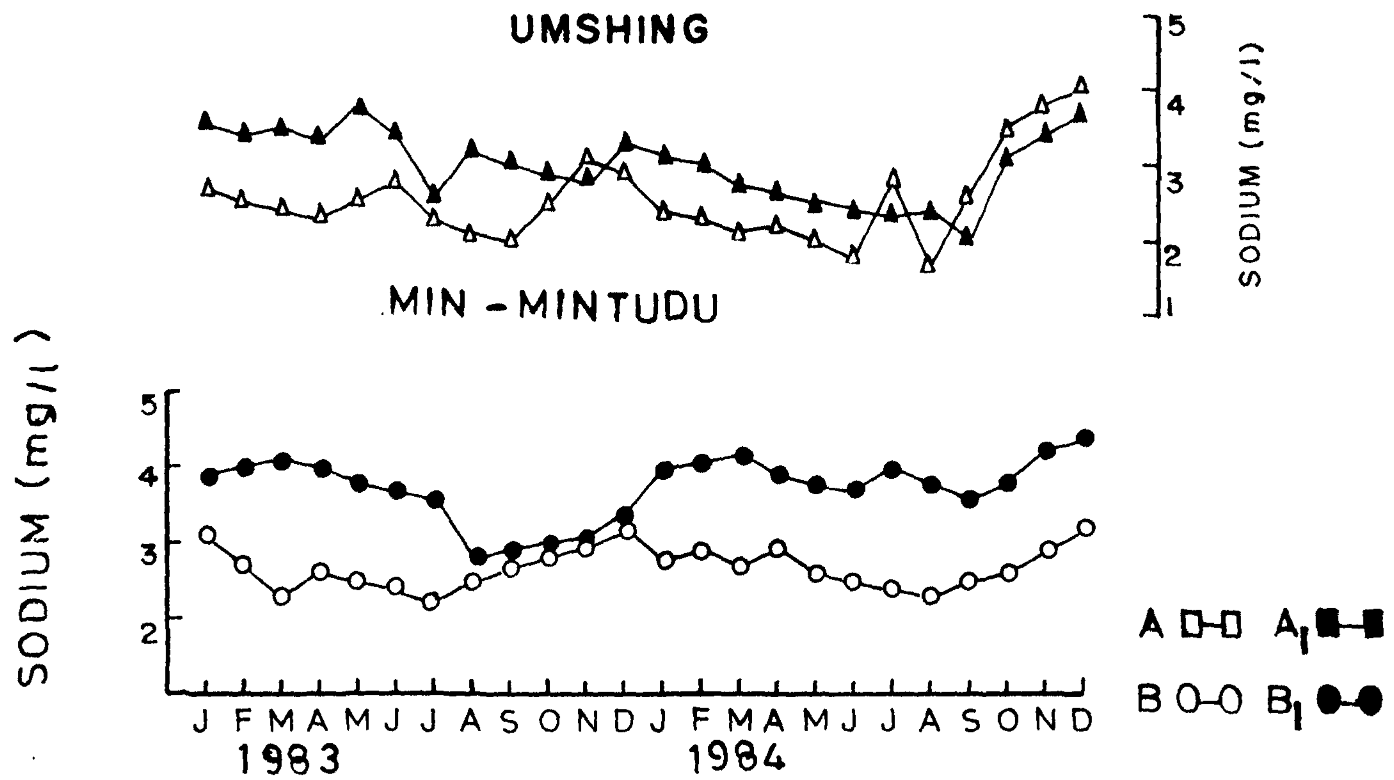


Fig. 33. Monthly fluctuations in Sodium concentrations at four different stations.

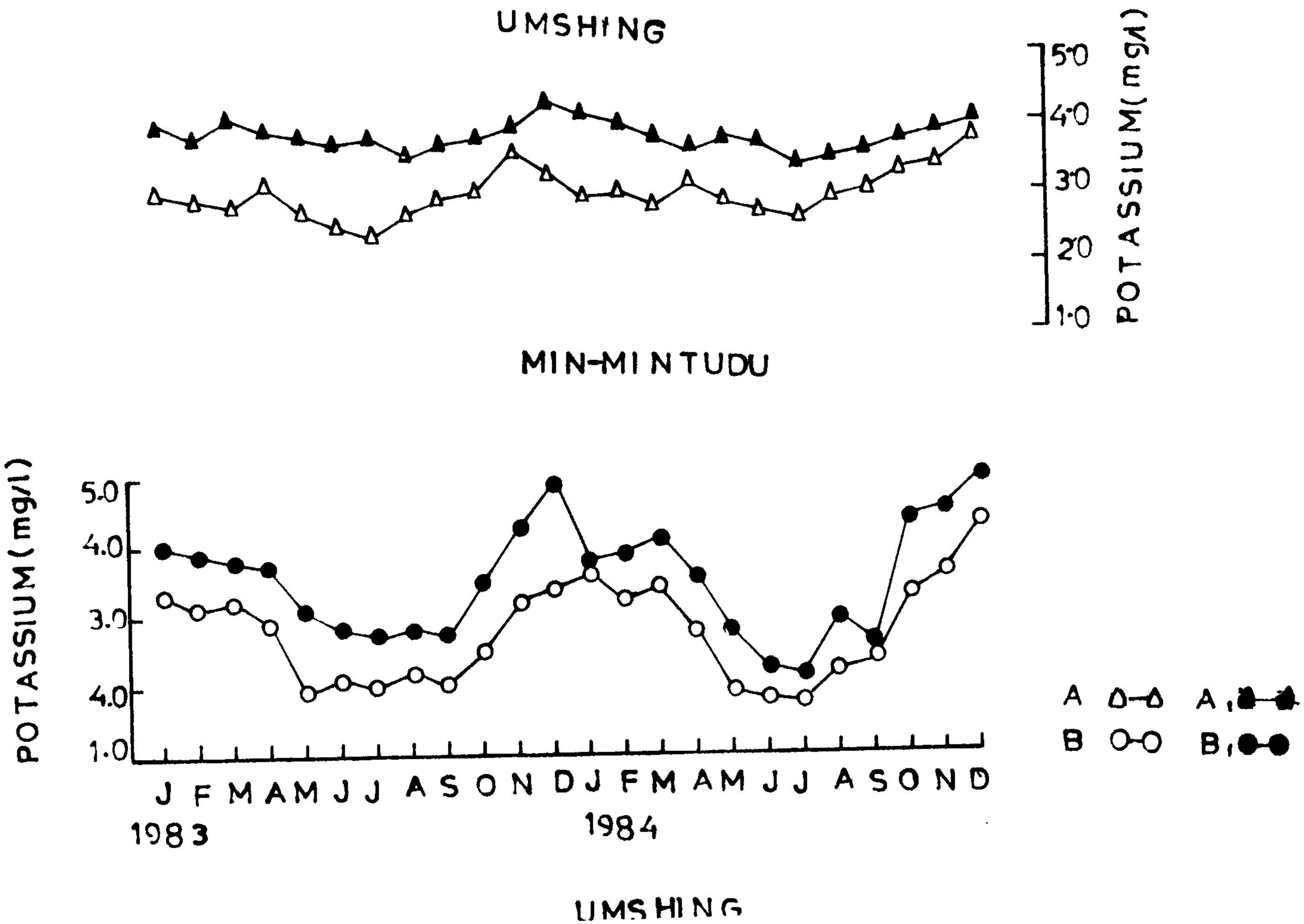


Fig. 34. Monthly variations in Potassium concentrations at four different stations.

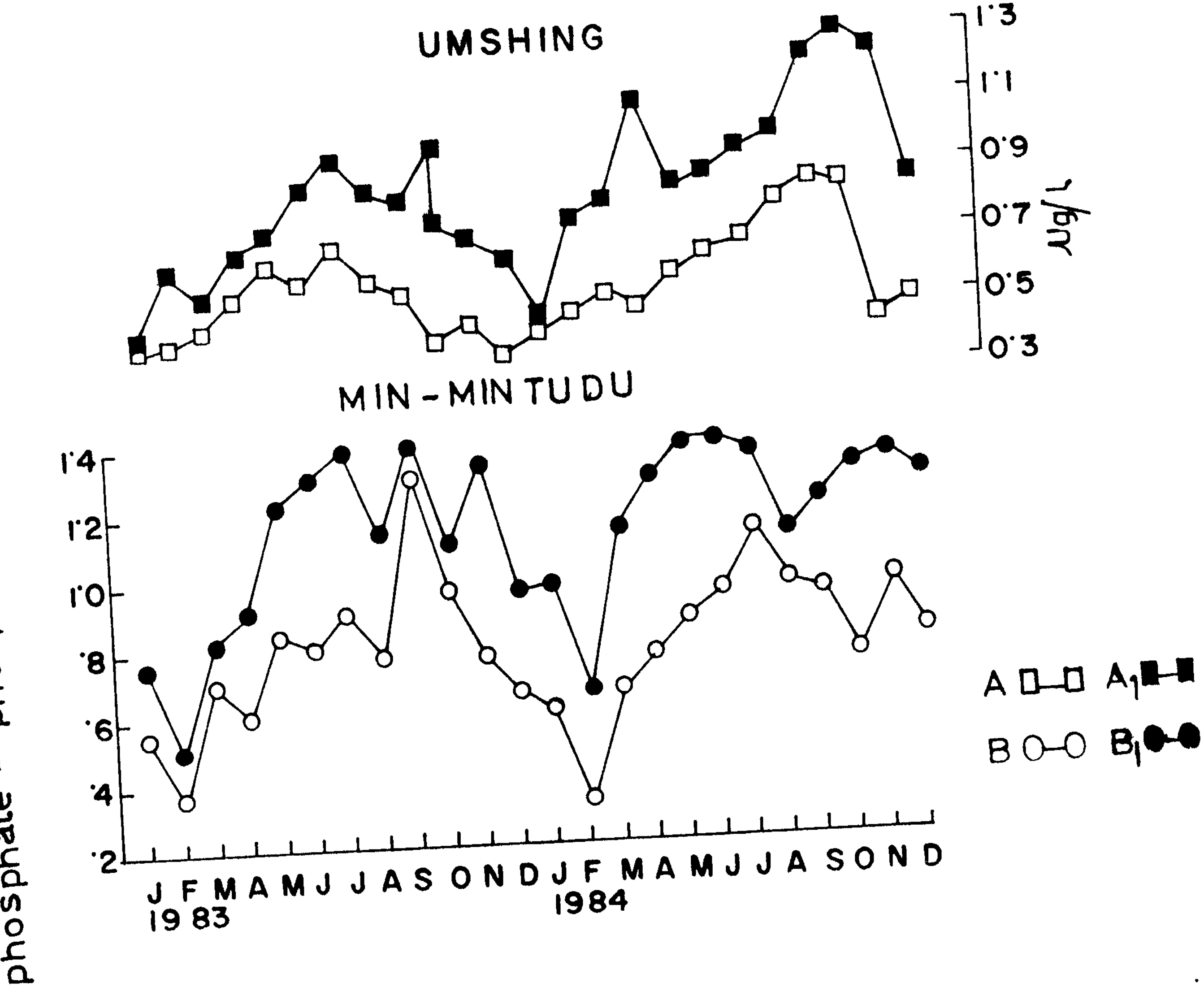


Fig. 35. Monthly variations in Phosphate-Phosphorus concentrations at four different stations.

B and B_1 exhibited higher variations in their Magnesium contents than stations A and A_1. Further, in Umshing stream, station A_1 had distinctly higher magnesium values and indicated notable variations than station A. Both the streams showed lowest magnesium content in December, 1983.

10. Sodium : It fluctuated between 1.6-4.0 mg/l, 2.0-3.8 mg/l, 2.1-3.2 mg/l, 2.8-4.4 mg/l at stations A, A_1, B and B_1 respectively (Fig. 33). The station A registered peak concentration of sodium (4.2 mg/l) in December, 1984. All the stations registered an increase in sodium contents from October-December, 1984. The pattern of monthly variations was broadly identical at stations A and A_1 in Umshing stream. However, in Min-Mintudu it indicated different patterns at stations B and B_1.

11. Potassium : Potassium content ranged from 2.8-3.8 mg/l, 2.4-4.5 mg/l, 1.7-4.3 mg/l, 1.0-5.0 mg/l at the sampling stations A, A_1, B and B_1 respectively. Station B showed maxima (5.0 mg/l) in the month of December, 1983 and B_1 minima (1.8 mg/l) in July, 1984. Stations B and B_1 of Min-Mintudu stream accounted higher variations in Potassium values than the Umshing and followed identical patterns except some minor differences. In Umshing stream, Potassium content varied relatively more widely at station A than at station A_1 (Fig.34).

12. Phosphate-phosphorus : It varied in the range of 0.36-0.87 ug/l, 0.43-1.30 ug/l at station A,A_1 and 0.31-1.28 ug/l, 0.5-1.40 ug/l at station B,B_1 respectively (Fig.35). In Min-Mintudu station B reflected clear pattern with maximum concentrations in September, 1983

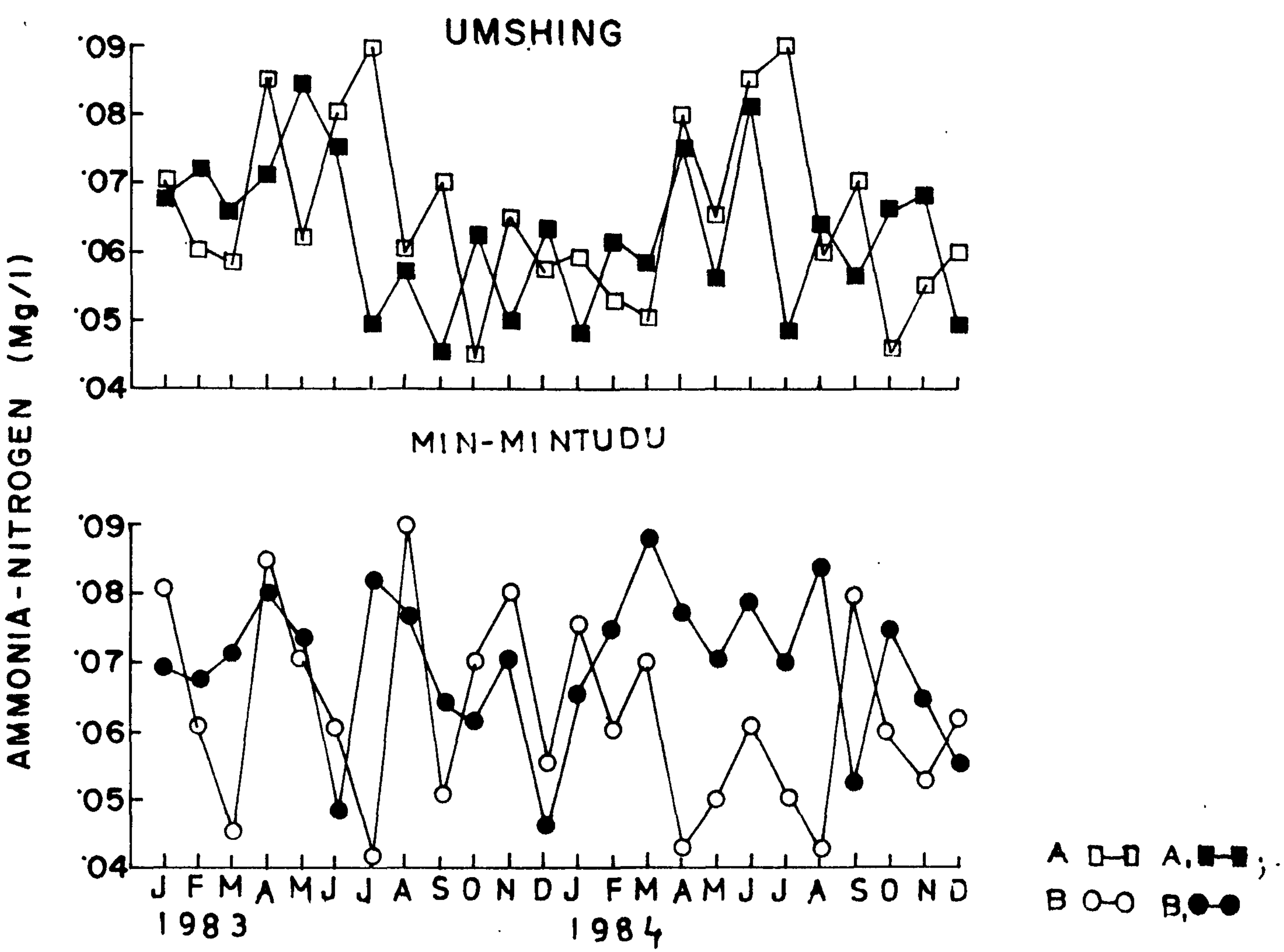


Fig. 36. Monthly fluctuations in Ammonia-nitrogen concentrations at four different stations.

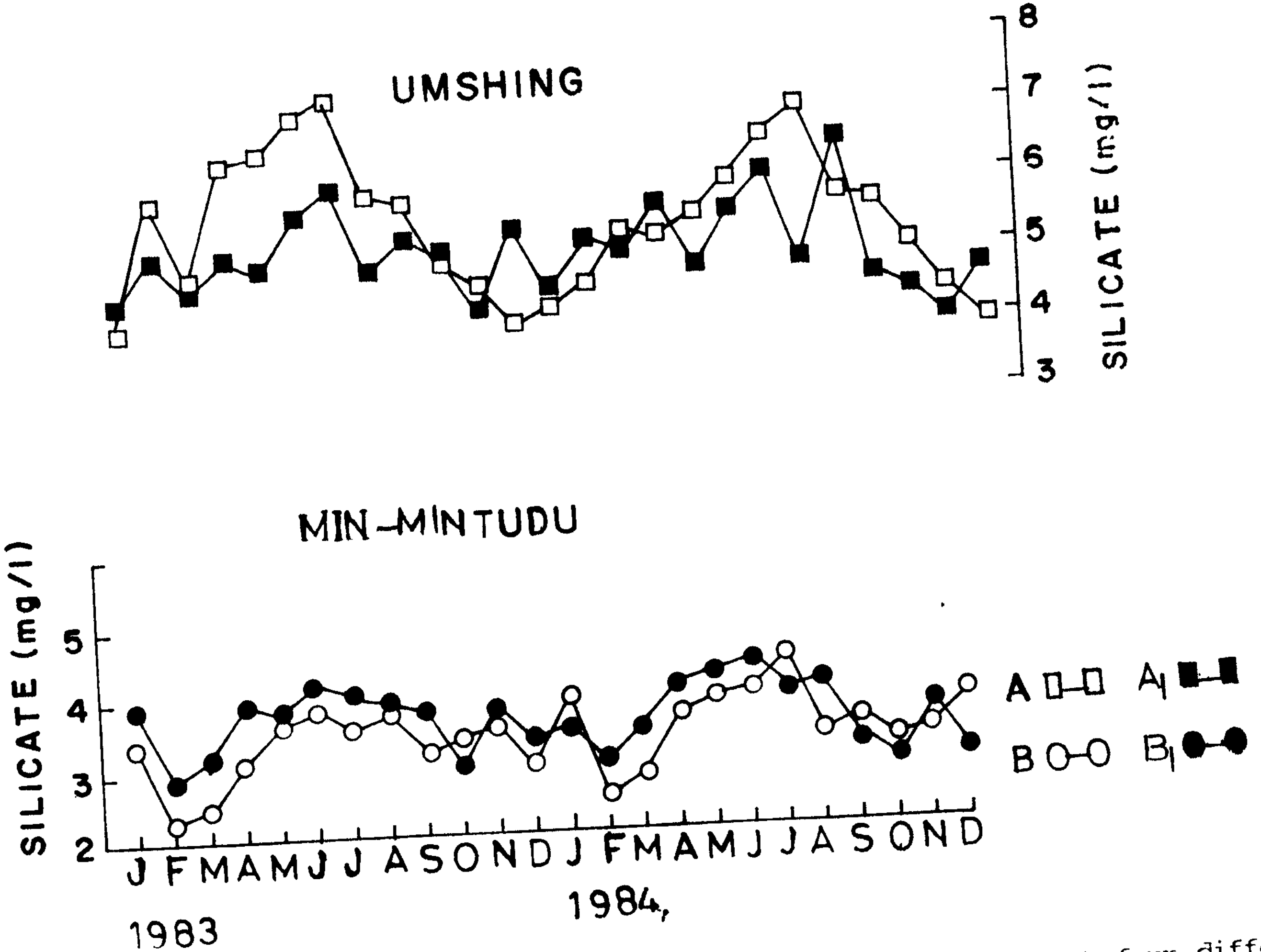


Fig. 37. Monthly variations in Silicate concentrations at four different stations.

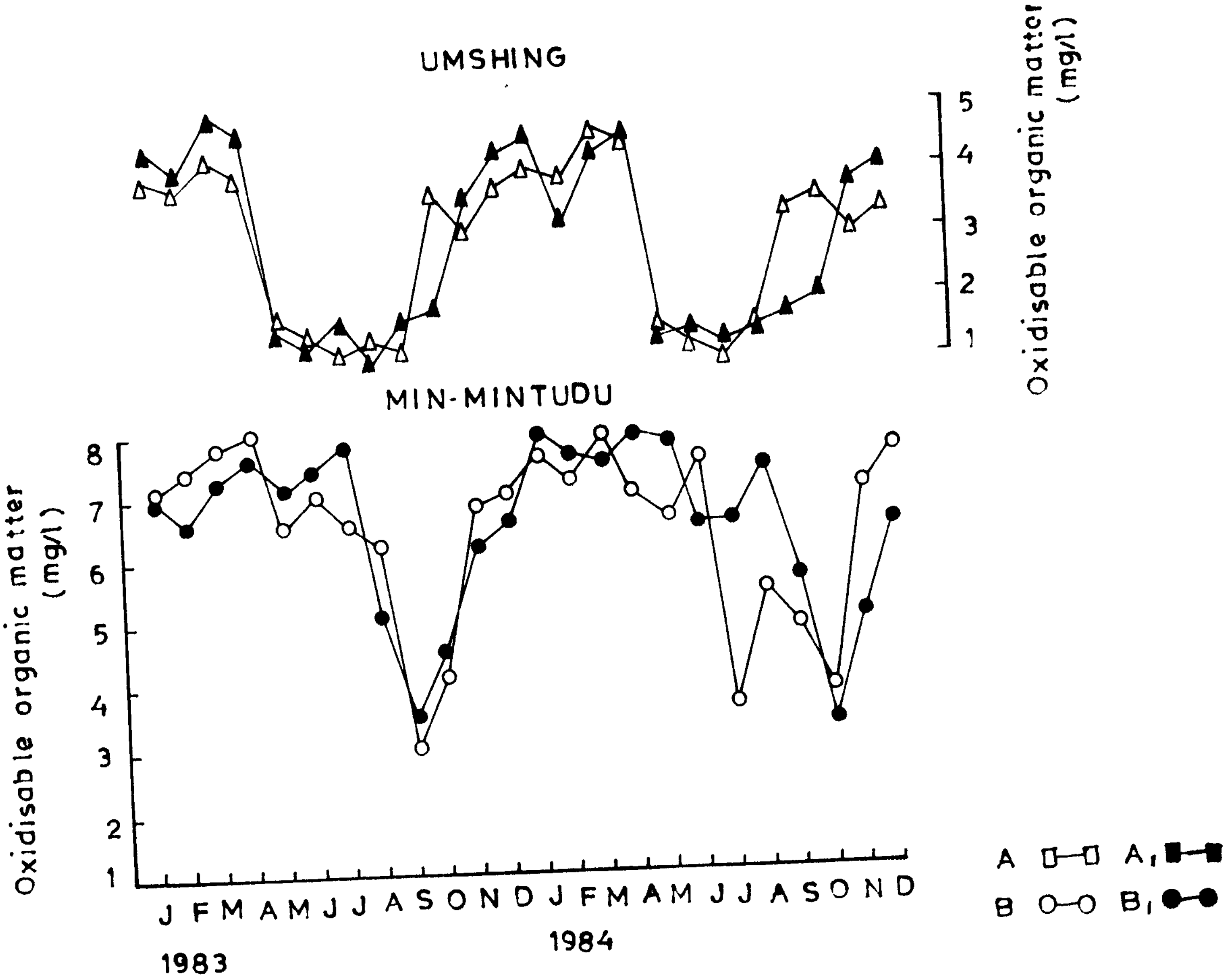


Fig. 38. Monthly fluctuations in Oxidisable organic matter in four different stations.

and July, 1984. The stations A and A_1 showed higher concentration in July, 1983 and October, 1984. In addition station A_1 showed higher concentration concentration in October, 1983 and May, 1984.

13. Ammonia-nitrogen : It exhibited marked seasonal fluctuation at all the sampling stations and ranged between 0.044-0.087 mg/l, 0.045-0.084 mg/l at stations A, A_1 of Umshing stream and between 0.041-0.090 mg/l, 0.046-0.087 at stations B, B_1 respectively (Fig.36). The monthly variations in Ammonia concentrations showed multiple maxima at the different sampling sites and depicted no definite pattern at any of the stations.

14. Silicate : The sampling stations in Umshing stream recorded higher values of silicates than in Min-Mintudu stream and more pronounced variations in the monthly concentration of silicates. It fluctuated between 3.81-7.60 mg/l, 3.98-6.81 mg/l, 2.2-4.41 mg/l and 3.1-4.2 mg/l at the four sampling stations i.e. A,A_1 B and B_1. In Umshing station A_1, reflected high silicate concentration in July, 1983 and August, 1984. The silicate fluctuations followed an identical trend at both the stations in Min-Mintudu(Fig.37).

15. Oxidisable organic matter : Oxidisable organic matter fluctuated in the range of 1.2-5.0 mg/l, 1.1-4.6 mg/l, 3.0-8.8 mg/l, 3.5-8.6 mg/l at the different stations (A,A_1,B,B_1) respectively (Fig.38). Min-Mintudu stream recorded higher load of oxidisable organic matter than Umshing stream. The sampling stations (B,B_1) in the former reflected lower values of oxidisable organic matter in September, 1983

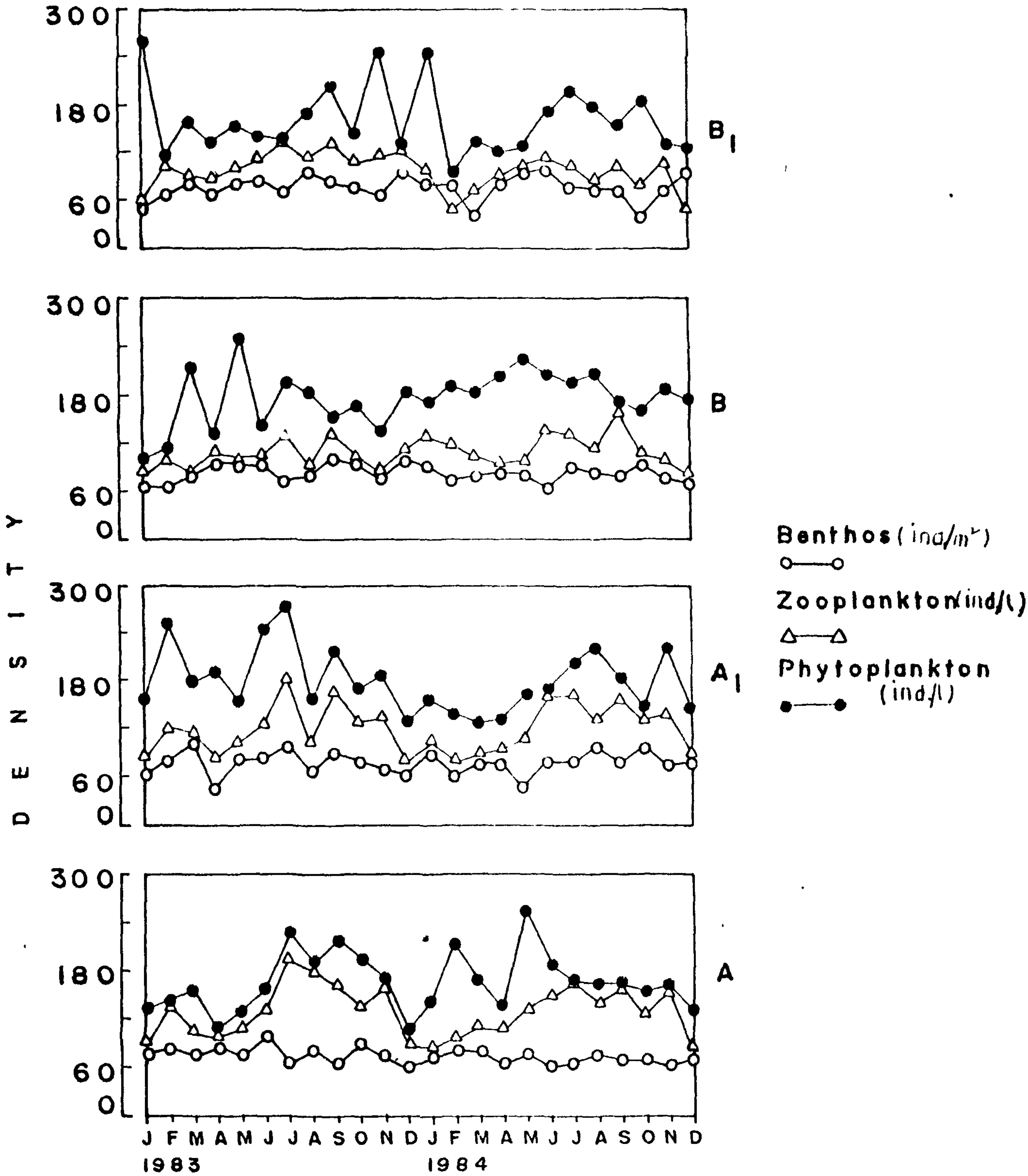


Fig. 39. Monthly variations in the densities of Benthic organism, zooplankton at various sampling stations of Umshing and Min-Mintudu stream.

and October, 1984. On the other hand, in Umshing stream lower values were recorded in May - October, 1983 and May - September, 1984 and both the stations (A, A_1) exhibited a broadly identical pattern in monthly variations of oxidisable organic matter.

Benthic organisms : In this study, the benthic organisms were represented by twenty four genera of insects, six genera of decapods, four genera of nematodes, nine genera of oligochaetes, two genera of gastropodes and a miscellaneous group. The last included one genus each of Bryozoa, Coelenterata and Turbellaria. The relative occurrence of benthic organisms at different sampling stations in two streams is indicated in Table 1. Population density of benthos registered seasonal fluctuations between 62-95 ind./m^2, 43-101 ind./m^2, 47-113 ind./m^2 and 43-100 ind./m^2 at the stations A, A_1, B and B_1 respectively (Fig. 39).

The benthic organisms showed marked variations in their monthly abundance at different stations. Maximum and minimum densities i.e. 95 ind./m^2 and 62 ind./m^2 were noticed at station A in the month of June, 1983 and January, 1984 respectively. The maximum number at station A_1 (101 ind./m^2) was noticed in August, 1984 and minimum number in April, 1983. At station B in Min-Mintudu stream, highest density (113 ind./m^2) was observed in August, 1983 and lowest density (47 ind./m^2) in June, 1984. However, higher densities at station B_1 (100 ind./m^2) were noticed in December, 1983 June, 1984 and December, 1984. The minimum density (43 ind./m^2) was examined at this station

Table I: Relative occurrence of benthic organism at different sampling stations (*, rare; -absent; +, present; ++, common; +++, dominant).

Taxa	Umshing Stream,		Min-Mintudu Stream	
	A	A_1	B	B_1
I. INSECTA:				
Ephemeroptera				
Baetis sp.	+++	+++	++	++
Ephemerella sp.	++	+	+	+
Caenis sp.	+	+	+	+
Odonata				
Rhinocypha sp.	*	+	*	+
Gomphidia sp.	-	*	*	+
Macromia sp.	+	+	*	+
Orthetrum sp.	*	*	-	-
Plecoptera				
Amphinemura sp.	+++	++	+++	+
Neoperla sp.	-	+	++	+
Nemoura sp.	*	+	-	-
Hemipetra				
Limnometra sp.	+	+	+	+
Metrocoris sp.	+	+	*	*
Ranatra sp.	+	+	-	*
Trichoptera				
Ecnomus sp.	+	-	+	++
Oecetis sp.	+	++	+	-
Rhyacophila sp.	+	-	+	+
Leptocella sp.	+	+	-	+
Coleoptera				
Orectochilus sp.	+	*	+	-
Hydrovatus sp.	*	+	-	+
Amphiops sp.	+	-	*	+
Diptera				
Chironomus sp.	+	+	+	*
Limonia sp.	+	*	-	*

Table 1 contd..

Taxa	Umshing Stream		Min-Mintudu Stream	
	A	A_1	B	B_1
Tanytarsus sp.	*	-	*	-
Simulium sp.	++	++	++	+
II. NEMATODA:				
Dorylaimus sp.	*	+	-	+
Diplogaster sp.	+	+	+	+
Anonchus sp.	*	-	-	+
Chronogaster sp.	+	+	+	+
III. DECAPODA:				
Potamon sp.	+	+	-	*
Paratelphusa sp.	+	+	-	+
Macrobrachium kistnensis	+	+	+	*
M. dayanum	+	+	+	+
M. hendersoni hendersoni	+++	+++	+	+
M. lamarrei	-	-	+++	++
IV. OLIGOCHAETA:				
Aulophorus sp.	+	+	-	*
Pristina sp.	-	+	-	+
Pheretima sp.	-	+	-	-
Branchiodrilus sp.	+	+	-	+
Allonais sp.	+	+	+	+
Bothrioneurum sp.	+	-	+	*
Stylaria sp.	-	+	+	+
Limnodrilus sp.	+	-	+	+
Chaetogaster sp.	+	+	+	++
V. GASTROPODA:				
Pila sp.	+	++	+	+
Limnea sp.	+	*	-	+

Table 1 contd..

Taxa	Umshing Stream		Min-Mintudu Stream	
	A	A_1	B	B_1
VI. MISCELLANEOUS:				
Bryozoa:				
Plumatella sp.	+	*	*	*
Coelenterata:				
Hydra sp.	+	-	+	+
Turbellaria:				
Dugesia sp.	+	+	-	+

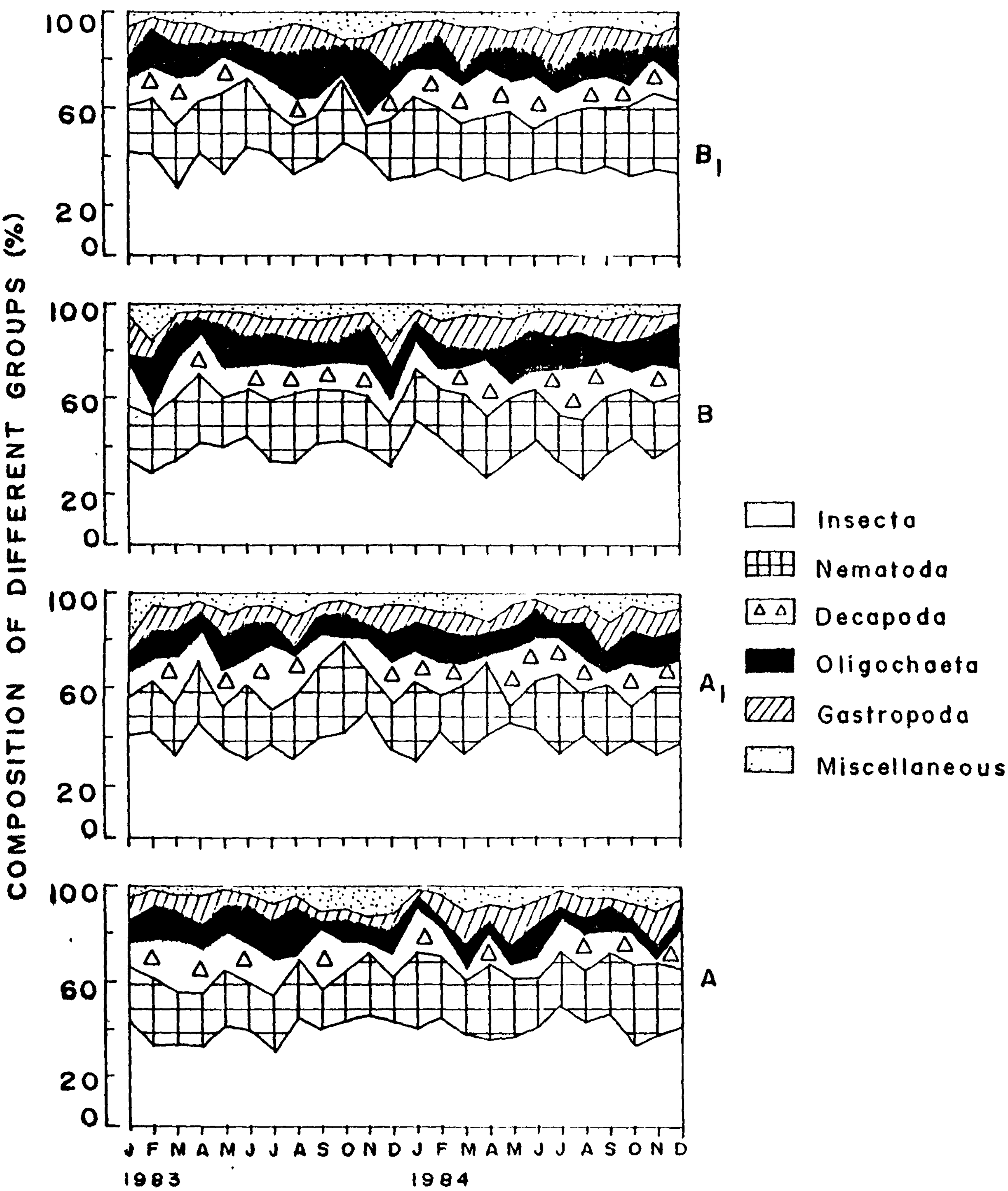


Fig. 40. Monthly fluctuations in the relative percentage compositions of different groups of benthic organism at various sampling stations of Umshing and Min-Mintudu stream.

in October, 1984. The pattern of monthly variations in quantitative abundance of benthos did not confirm to any definite pattern at various sampling stations.

The values for percentage similarities (Table 2) between qualitative occurrence of benthic organisms at different sampling stations ranged between 57.0% - 83.0%. The maximum similarity (80.0%) was reflected between stations A and A_1 in Umshing stream followed by 69.0% similarity between stations A and B_1. However, overall similarity of benthos between Umshing and Min-Mintudu streams was noticed to be 87.0%.

Table 2. Percentage similarities (vide Sorenson Index) between benthic organims at different sampling stations.

STATIONS	A	A_1	B	B_1
A	-	83	59	69
A_1		-	57	56
B			-	64
B_1				-

The variations in percentage compositions of different groups of benthic organisms (Fig.40) are detailed below :

I. <u>Insecta</u> : At the stations A, A_1, B and B_1 insect populations comprised 31.0%-50.0%, 30.0%-49.2%, 28.6%-52.9% and 26.1%-46.0% of total benthos respectively. Ephemeroptera, Trichoptera and Diptera constituted the important component in both the streams. Further, Baetis sp. and Amphinemura sp. were noticed to be dominant taxa at the different sampling stations. Insect populations inhibited all stations throughout the study period. The quantitative abundance of insects varied between 20-45 ind./m^2 at various stations. Station A showed highest abundance (42 ind./m^2) in February and July, 1984 and lowest density (20 ind./m^2) in July, 1983. Station A_1 exhibited irregular pattern of fluctuation, with densities ranging between 21 ind./m^2 (August, 1983) and 42 ind./m^2 in October, 1983 and 28 ind./m^2 (July, 1984) to 41 ind./m^2 in January, 1984. In Min-Mintudu stream, insect populations ranged between 21 ind./m^2 (June, 1984) - 48 ind./m^2 (October, 1984) at station B and between 21 ind./m^2 (May, 1984) - 41 ind./m^2 (in August, 1983) at station B_1.

II. Nematoda : This group exhibited marked seasonal fluctuations in this study and comprised between 17.0%-26.1%, 18.2%-26.9%, 20.0%-53.0% and 12.0%-25.0% of total benthic organisms at stations A, A_1, B and B_1 respectively. Diplogaster and Chronogaster were important nematode taxa (Table 1) observed presently. Min-Mintudu stream reflected relatively higher population of nematodes than Umshing stream; these were mostly observed along the bottom substrates of the forest leaf fall. The quantitative abundance of nematodes varied between 11-37 ind./m^2 at various stations. Station A showed highest abundance (24 ind./m^2) in January, 1983 and lowest density (13 ind./m^2) in June, 1984. Station A_1 exhibited lowest density (11 ind./m^2) in February, 1984 and highest density (24 ind./m^2) in October, 1984. In Min-Mintudu stream, nematode population varied between 10 ind./m^2 (June, 1984) - 29 ind./m^2 (April, 1983) at station B and between 11 ind./m^2 (July, 1983; May and October, 1984) - 26 ind./m^2 in December, 1984 at station B_1.

III. Decapoda : This group occurred at all the sampling stations and comprised 6.1%-19.8%, 6.1%-18.0%, 9.0%-22.0% and 4.0%-22.0% at stations A, A_1, B and B_1 respectively. The decapod crustaceans were represented by prawns and crabs. Of these, the fluctuations in population densities of *Macrobrachium* spp. were dealt with separately. The quantitative abundance of decapodes varied between 3-21 ind./m^2 at various stations during the present investigations. Station A showed highest abundance of decapodes (19 ind./m^2) in March, 1983 and January, 1984 and minimum (5 ind./m^2) in March, 1984. Station A_1 exhibited highest density (18 ind./m^2) in October, 1984 and lowest (5 ind./m^2) in March, 1984. Station A_1 exhibited highest density (18 ind./m^2) in October, 1984 and lowest (5 ind./m^2) in September, 1984. In Min-Mintudu stream, the decapod population varied between 6 ind./m^2 in December, 1984 - 22 ind./m^2 in April, 1984 at station B and between 3 ind./m^2 (October, 1983) - 18 ind./m^2 in September, 1984 at station B_1. Moreover, no definite trend of fluctuation was noticed in any of the stations.

IV. Oligochaeta : This group comprised 3.7%-14.5%, 4.7%-19.4%, 5.0%-21.0% and 7.0%-19.0% of total benthos at stations A, A_1, B and B_1 respectively. *Allonais* sp. and *Chaetogaster* sp. were important taxa of oligochaetes in both the streams. Station A showed highest abundance

(9 ind./m^2) in July, 1984 and lowest (3 ind./m^2) in January, 1984; while station A_1 exhibited highest density (18 ind./m^2) in July, 1983 and lowest density (2 ind./m^2) in April, 1983. In Min-Mintudu stream, Oligochaete population varied between 4 ind./m^2 (January, 1984) - 19 ind./m^2 (July, 1984) at station B and between 5 ind./m^2 (November, 1984) - 17 ind./m^2 (September, 1984) at station B_1 during the period of these investigations.

V. Gastropoda : This group was recorded from all the sampling stations throughout the study period and exhibited general peak in summer and minima during winter in both the annual cycles. At stations A, A_1, B and B_1 gastropod populations comprised 3.8%-15.1%, 4.0%-12.5%, 4.0%-12.0% and 30.0%-14.0% respectively of total benthic organisms. Pila and Limnea were noticed to be present frequently. Station A showed highest abundance of gastropod populations (10 ind./m^2) in September, 1983 and lowest (3 ind./m^2) in January,1983 and lowest density (3 ind./m^2) in November, 1984. While in Min-Mintudu stream, this group varied between 4 ind./m^2 (April, 1983) - 12 ind./m^2 (October, 1984) at station B and between 3 ind./m^2 (May, 1983) - 12 ind./m^2 (December, 1983) at station B_1.

VI. Miscellaneous group : This group contributed 1.2%-11.7%, 2.3%-9.1%, 2.0%-7.2% and 3.0%-11.0% of total benthos at stations A, A_1, B and B_1 respectively. Bryozoans, Hydroideans, Turbellarians occurred periodically were categorised into miscellaneous group. The quantitative abundance of this group varied between 1-6 ind./m^2 (December, January, February and July, 1984) - 6 ind./m^2 (October and November,

1984) at station A while at station A_1 the population ranged between 1 ind./m^2 (May and July, 1984) - 6 ind./m^2 (November, 1983). In Min-Min-tudu stream, station B exhibited highest density (5 ind./m^2) in March, 1984 and lowest (1 ind./m^2) in January, 1983. Station B_1 exhibited maxima (5 ind./m^2) in May, 1984 and minima (1 ind./m^2) in October, 1984.

Phytoplanktons : Based on the composition of different taxa, the total phytoplanktons examined in this study belonged to six different categories; Bacillariophyceae, chlorophyceae, chrysophyceae, Dinophyceae, Myxophyceae and Rhodophyceae. The relative occurrences of different taxa at various sampling stations were given in Table 3. The phytoplankton communities were characterised by the dominance of Bacillariophyta, chlorophyta, chrysophyta and Myxophyta in Umshing stream while Dinophyta and Rhodophyta were dominant in the Min-Min-tudu stream. Population density of phytoplanktons registered seasonal fluctuations between 100-267 ind.1, 122-283 ind./1, 69-252 ind./1 and 103-255 ind./1 at stations A, A_1, B and B_1 respectively (Fig.39).

The phytoplanktons exhibited marked variations in their monthly abundance at different stations. Maximum and minimum densities i.e., 267 ind./1 and 100 ind./1 were noticed in station A in May, 1983 and September, 1983 respectively. The maximum number at station A_1 (283 ind./1) was noticed in July, 1984 and minimum (122 ind./1) in September, 1983. At station B in Min-Mintudu stream, highest density was noticed to be 255 ind./1 (May, 1984) and lowest (69 ind./1) in January, 1983. However, higher densities at station B_1

Table 3: Relative occurrence of Phytoplanktons at various sampling stations (*, rare; - absent; +, Present; ++, common; +++, dominant).

Taxa	Umshing Stream		Min-Mintudu Stream	
	A	A_1	B	B_1
I. BACILLARIOPHYCEAE:				
Navicula sp.	++	+++	+	++
Pinularia sp.	++	++	++	+
Melosira sp.	+	+	+	++
Cyclotella sp.	+	++	+	+
Synedra sp.	+	++	*	*
Diatoma sp.	++	+	++	+
Tubellaria sp.	++	++	+	++
Cymbella sp.	+	++	+	++
Amphora sp.	+	++	++	+
Frustulia sp.	++	+	++	+
Nitzschia sp.	+++	++	++	++
Surirella sp.	++	++	*	+
Gomphonema sp.	++	++	+	*
II. CHLOROPHYCEAE:				
Actinastrium sp.	+	-	+	*
Scenedesmus sp.	*	+	-	+
Euderia sp.	+	+	+	-
Gonium sp.	+	+	+	*
Ulothrix sp.	++	+	-	+
Oedogonium sp.	+	+	++	-
Pediastrum sp.	++	+	*	-
Dictyosphaerum sp.	+	+	+	++
Coelastrum sp.	+	+	-	-
Ankistrodismus sp.	+	+	++	+

Table 3 contd..

Taxa	Umshing Stream		Min-Mintudu Stream	
	A	A_1	B	B_1
Actinastrium sp.	++	+	-	-
Tetrastrum sp.	++	+	++	+
Spirogyra sp.	+	+	+	+
Zygnema sp.	+	+	*	*
Cosmarium spp.	+	+	+	+
Closterium sp.	++	+	+	+
Staureastrum sp.	+	+	*	*
Netrium sp.	+	+	-	+
III. CHRYSOPHYCEAE:				
Dinobryon sp.	++	+	++	+
Ochromonas sp.	+	+	-	-
Chlorobotrys sp.	+	++	++	*
Mallomonas sp.	+	+	+	+
Bitrichia sp.	++	-	+	+
Chrysidiastrum sp.	+	++	*	+
IV. DINOPHYCEAE:				
Peridinum sp.	++	-	++	*
Gymnodinium sp.	-	++	++	++
V. MYXOPHYCEAE:				
Oscillatoria sp.	+	+	+	+
Plectonema sp.	++	+	*	-
Lyngbya sp.	+	++	+	+
Nostoc sp.	++	+	-	+
Anabaena sp.	+	+	+	+

Table 3 contd..

Taxa	Umshing Stream		Min-Mintudu Stream	
	A	A_1	B	B_1
Gomphosphaeria sp.	+	+	++	+
VI. RHODOPHYCEAE:				
Lamanea sp.	+	+	+	+
Batrachospermum sp.	-	+	+	+

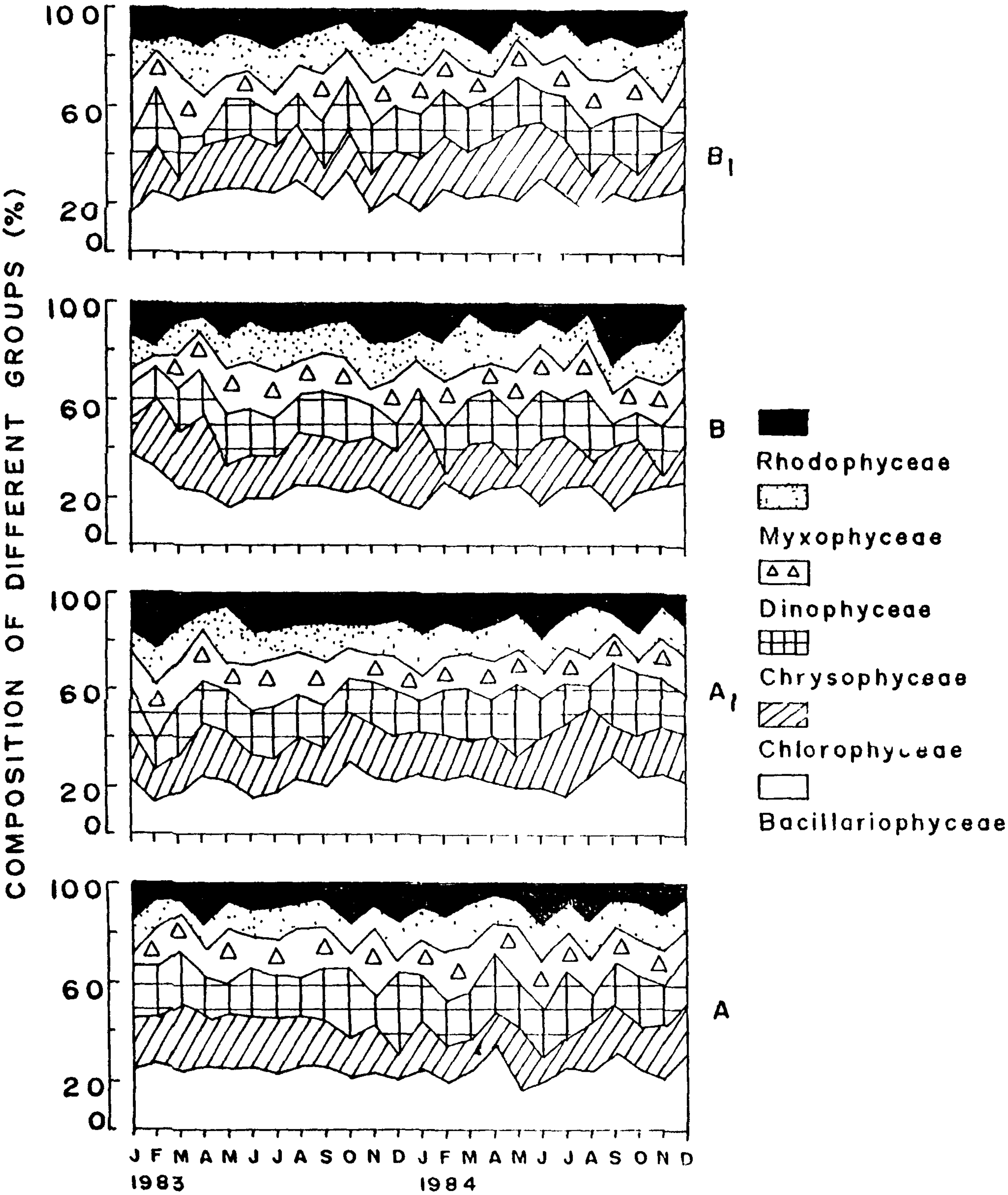


Fig. 41. Monthly variations in the percentage composition of different groups of Phytoplankton at various sampling stations of Umshing and Min-Mintudu stream.

(255 ind./l) were noticed in January, 1984 and minimum density (103 ind./l) was recorded in February, 1983.

The values for percentage similarities (Table 4) between qualitative occurrence of phytoplanktons at various sampling stations ranged between 58.0%-77.0%. The maximum similarity (77.0%) was reflected between stations A and A_1 in Umshing stream followed by 66.0% similarity between stations A_1 and B_1. However, overall similarity of phytoplanktons between Umshing and Min-Mintudu streams was noticed to be 72.0%.

Table 4. Percentage similarities (vide Sorenson Index) between phytoplanktons at different sampling stations.

STATIONS	A	A_1	B	B_1
A	-	77	58	61
A_1		-	62	66
B			-	65
B_1				-

The variation in quantitative abundance of different groups of phytoplanktons were indicated in Fig. 41 and some of the salient features detailed below :

I. Bacillariophyceae : At the stations A, A_1, B and B_1 this group contributed 20.0%-47.0%, 16.0%-34.0%, 15.0%-33.0% and 15.0%-34.0% of total phytoplanktons. The diatoms occurred at all the sampling stations and exhibited summer maxima and winter minima. Out of examined thirteen taxa Navicula, Pinularia, Diatoma and Nitzschia constituted the important component in both the streams. The quantitative abundance of diatoms varied between 23-60 ind./l at various stations during the study period. Station A showed highest abundance (48 ind./l) in April, 1984 and lowest density (20 ind./l) in February, 1984. Station A exhibited maximum diatoms density (41 ind./l) in June 1983 and minimum (16 ind./l) in February, 1983. In Min-Mintudu stream, the abundance of Bacillariophytes varied between 16 ind./l (February, 1983) - 48 ind./l (August, 1983) at station B and between 29 ind./l (February, 1983) - 53 ind./l (August, 1983) at station B_1. No definite trend of fluctuation was observed in any of the stations.

II. Chlorophyceae : This group comprised 19.1%-31.0%, 15.0%-24.0%, 14.0%-22.0% and 11.0%-24.0% of phytoplanktons at stations A, A_1, B and B_1 respectively. The dominant genera of chlorophyta included Closterium, Dictyosphaerum, Cosmarium. Occassionally, Spirogyra developed small mats on muddy banks or sometimes on the boulders and rocky beds. The quantitative abundance of this group varied between 21-60 ind./l in all the sampling stations. Station A exhibited highest abundance of chlorophytes (51 ind./l) in September, 1983 and lowest (21 ind./l) in April, 1983. At station A_1, the number varied between

24 ind./l (December, 1984) - 51 ind./l (November, 1984).In Min-Mintudu stream chlorophytes varied between 12 ind./l (January, 1983) - 47 ind./l (March, 1983) at station B and between 28 ind./l (February, 1984) - 60 ind./l (July, 1984) respectively.

III. Chrysophyceae : This group occurred at all the sampling stations and contributed 11.0%-29.0%, 16.0%-22.0%, 9.0%-18.0% and 13.1%-22.3% at stations A, A_1, B and B_1 respectively. Out of six recorded taxa of chrysophytes *Dinobryon* and *Mallomanas* constituted the important components. In Umshing stream numerical abundance of this group varied between 16 ind./l (April, 1983) - 41 ind./l (February, 1984) at station A, while at station A_1 it ranged between 12 ind./l (January, 1984) - 63 ind./l (July, 1983). Further, in Min-Mintudu stream it varied between 6 ind./l (January, 1983) - 51 ind./l (May, 1983) at station B and between 28 ind./l (February, 1984) - 60 ind./l (July, 1984) at station B_1.

IV. Dinophyceae : At the stations A, A_1, B and B_1, dinophyceae group comprised 14.0%-19.1%, 9.1%-17.0%, 7.0%-19.3% and 9.1%-23.0% of total phytoplanktons. The quantitative abundance of this group varied between 5-60 ind./l. Two genera i.e., *Peridinum* and *Gymnodinium* were recorded from both the streams, the latter being the more abundant than the former. The density of this group fluctuated between 9 ind./l (April, 1984) - 41 ind./l (May, 1984) at station A and between 18 ind./l (October, 1984) - 60 ind./l (February, 1983). In Min-Mintudu stream, the quantitative abundance varied between 5 ind./l (January and February, 1983) - 47 ind./l (May, 1984) at station B and between 11 ind./l (November, 1984) - 58 ind./l (January, 1983) at station B_1. Further, no definite trend of fluctuation was noticed in any of the stations during the present study period.

V. Myxophyceae : This group occurred at all the sampling stations throughout the year with certain seasonal fluctuations in terms of their percentage composition. At various stations (i.e..A, A_1, B and B_1) this group contributed 11.0%-17.1%, 11.2%-18.0%, 11.0%-19.0% and 12.0%-17.0% of total phytoplanktons. Anabaena, Nostoc and Lyngbya formed dominated fraction of myxophyceae in both the streams. In Umshing stream, this group varied between 11 ind./l (February, 1983) - 40 ind./l (February, 1984) at station A and between 16 ind./l (December, 1983) - 42 ind./l (February, 1983). While, in Min-Mintudu stream this group varied between 3 ind./l (February, 1983) - 41 ind./l (May, 1983 and August, 1984) at station B and between 11 ind./l (February, 1984) - 40 ind./l (January, September and November, 1983) at station B_1.

VI. Rhodophyceae : This group contributed 3.0%-16.0%, 7.0%-12.0%, 6.0%-18 0% and 3.0%-22.0% of total phytoplanktons at stations A, A_1, B and B_1 respectively. The quantitative abundance of rhodophytes varied between 3-38 ind./l at various stations. Lamanea was the only dominant type in both the streams. Station A exhibited highest density (29 ind./l) in August, 1984 and lowest density (3 ind./l) in April and September, 1984. Station A_1 exhibited maximum density (38 ind./l) in February, 1983 and minimum (9 ind./l) in November, 1984. In Min-Mintudu stream, at station B the numerical abundance varied between 8 ind./l (June, 1984) - 29 ind./l (September, October, 1984) while the density fluctuated between 4 ind./l (December, 1984) - 38 ind./l (January, 1983) at station B_1.

Zooplanktons : Total zooplanktons in this study were represented by eight genera of Protozoa, seven genera of Rotifera, one genus of Copepoda and five genera of Cladocera. The relative occurrences of zooplanktons at different sampling stations in the two streams were indicated in Table 5. Population density of zooplanktons registered seasonal fluctuations between 73-203 ind./l, 61-180 ind./l, 51-140 ind./l and 49-127 ind./l at the stations A, A_1, B and B_1 respectively (Fig. 39).

The zooplanktons exhibited a marked variations in their monthly abundance at different stations. Maximum (203 ind./l) and minimum (73 ind./l) densities were noticed in station A in July, 1983 and December, 1984 respectively. The maximum number at station A_1 (180 ind./l) was noticed in July, 1983 and minimum (61 ind./l) number in December, 1984. Maximum and minimum densities i.e., 140 ind./l and 51 ind./l were noticed in station B in September, 1983 and in January, 1984 respectively. However, higher densities (127 ind./l) were noticed in July, 1983 at station B_1 and lower densities (49 ind./l) in December, 1984.

Table 5. Relative occurrence of Zooplankton at different sampling stations (*, rare; - absent; +, present; ++, common; +++, dominant).

Taxa	Umshing Stream		Min-Mintudu Stream	
	A	A_1	B	B_1
I. PROTOZOA:				
Vorticella sp.	+	+	++	+
Podophrya sp.	+	-	-	*
Didinium sp.	+	+	-	*
Diffugia sp.	+	+	+	+
Lecythium sp.	+	+	+	-
Euglypha sp.	+	+	+	+
Centropyxis sp.	++	+	+	+
Actinolophus sp.	-	+	++	+
II. ROTIFERA:				
Lecane sp.	*	+	*	+
Brachionus sp.	+	+	+	+
Keratella sp.	+	+	+	+
Polyartha sp.	*	+	+	-
Synchaeta sp.	+	*	-	+
Trichocera sp.	+	-	++	-
Asplanchna sp.	+	+	-	+
III. COPEPODA:				
Cyclops sp.	+	+	++	+
IV. CLADOCERA:				
Daphnia sp.	+	+	+	-
Chydorus sp.	+	++	+	+
Bosmina sp.	+	+	-	-
Alona sp.	+	+	+	+
Alonella sp.	*	+	*	+

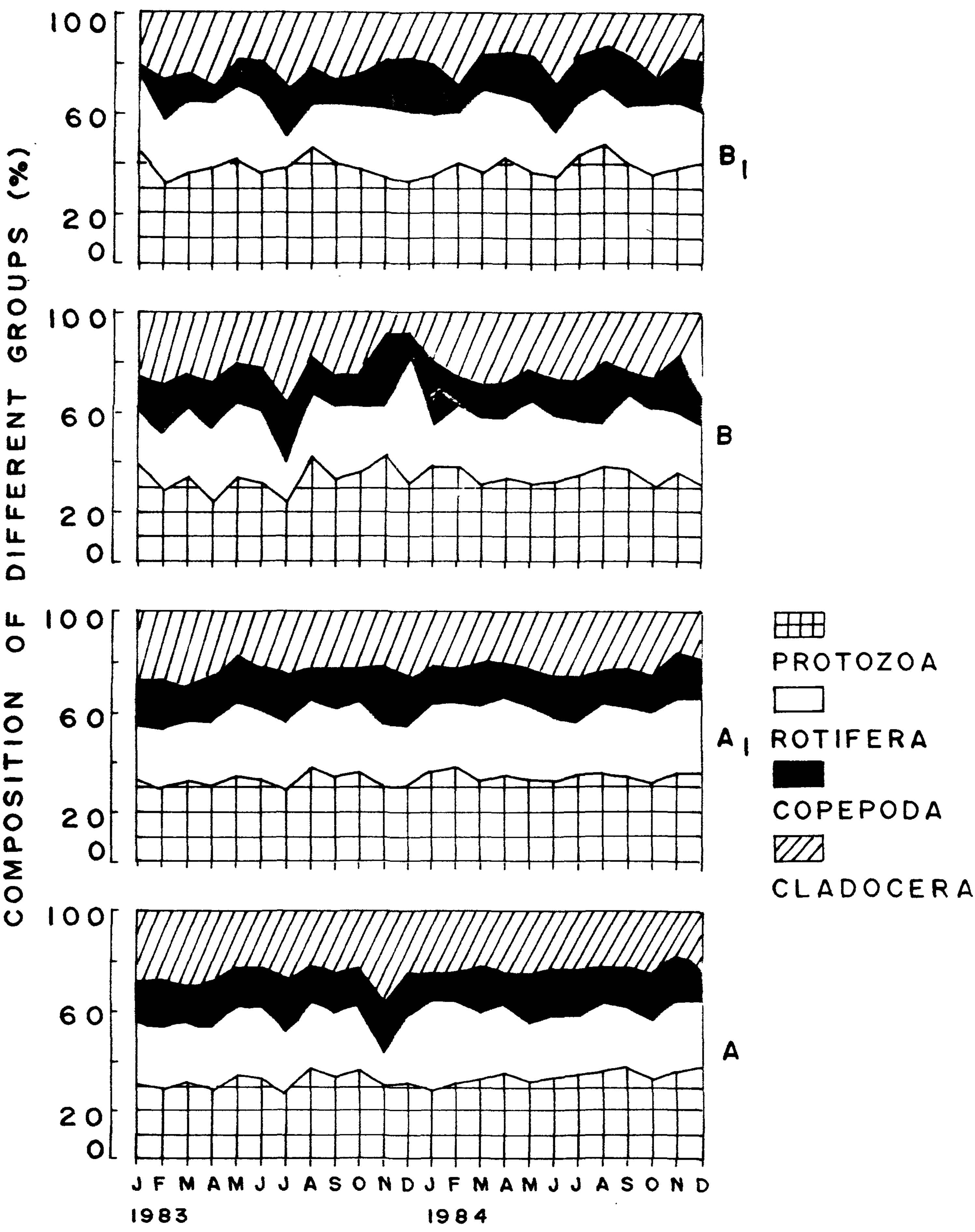


Fig. 42. Monthly fluctuations in the percentage composition of different groups of Zooplankton at various sampling stations of Umshing and Min-Mintudu stream.

The values for percentage similarities (Table 6) between qualitative occurrence of zooplanktons at various sampling stations ranged between 58.0%-91.0%. The maximum similarity (91.0%) was reflected between stations A and B in Umshing and Min-Mintudu streams followed by 81% similarity between A and B_1. However, overall similarity of zooplanktons between Umshing and Min-Mintudu streams was noticed to be 70.0%.

Table 6. Percentage similarities (vide Sorenson Index) between zooplankton at different sampling stations.

STATIONS	A	A_1	B	B_1
A	-	78	91	81
A_1		-	70	58
B			-	64
B_1				-

Variations in percentage composition of different groups of zooplanktons were depicted (Fig.42) and the main features of their monthly abundance were detailed below :

I. Protozoa : At the stations A, A_1, B and B_1 protozoan population comprised 30.0%-38.0%, 30.1%-39.0%, 28.1%-45.0% and 31.6%-48.0% of total zooplanktons. *Lecythium*, *Vorticella*, *Centropyxis* constituted the dominant taxa in both the streams. The quantitative abundance of this group varied between 20-60 ind./l at various stations.Station A exhibited highest population density 60 ind./l (September, 1983 and 1984) and lowest density 26 ind./l (December, 1984) while at station A_1 this group varied between 22 ind./l (December, 1984) - 57 ind./l (September, 1983). In Min-Mintudu stream, the protozoan abundance varied between 20 ind./l (December, 1983 and January, 1984) - 50 ind./l (September, 1984) at station B while at station B_1 it varied between 20 ind./l (December, 1983 and January, December, 1984). No definite pattern of fluctuations was observed in any of the stations during the present study.

II. Rotifera : This group occurred at all the sampling stations and comprised 13.0%-28.0%, 22.0%-30.0%, 12.0%-32.0% and 10.0%-33.0% at stations A, A_1, B and B_1 respectively. Lacane was found to be present only at stations A_1 and B_1. The quantitative abundance of rotifers varied between 10-51 ind./l at various stations. Station A showed highest abundance of this group (51 ind./l) in July, 1983 and lowest density (20 ind./l) in November, 1983 and February, 1984. At station A_1, this group varied between 17 ind./l (January, 1983) - 47 ind./l (July, 1983). In Min-Mintudu stream, the rotifer densities varied between 10 ind./l (February, 1984) - 40 ind./l (September, 1983) while at station B_1, population ranged between 10 ind./l (December, 1984) - 31 ind./l (September, 1983). Station A and A_1 exhibited regular pattern of fluctuation while both the stations of Min-Mintudu exhibited irregular pattern of fluctuation.

III. Copepoda : At the stations A, A_1, B and B_1 copepode population comprised 10.0%-20.0%, 13.1%-21.0%, 13.7%-24.0% and 13.6%-20.0% of total zooplanktons respectively. Cyclop represented the single genus at all the stations during the study period. The quantitative abundance of Copepoda varied between 8-40 ind./l at various sampling stations. Station A showed highest abundance of copepod population (40 ind./l) in July, 1983 and lowest density (15 ind./l) in January, 1983 and at station A_1 it varied between 10 ind./l (January and February, 1984) - 37 ind./l (July, 1983). In Min-Mintudu stream, this group varied between 9 ind./l (August, 1983) - 30 ind./l (July, 1983) at station B and between 8 ind./l (January, 1983) - 24 ind./l (June, 1984) at station B_1.

IV. Cladocera : This group was recorded throughout this study at all the sampling stations i.e., (A, A_1, B and B_1) and contributed 14.0%-20.0%, 16.0%-27.5%, 8.0%-36.0% and 11.0%-30.0% of total zooplankton population. Alona and Chydorus represented represented in all the habitats sampled. The quantitative abundance of Cladocera reflected marked seasonal fluctuations at all the sampling stations and population densities varied between 9-47 ind./l. Station A showed maximum density 47 ind./l (July, 1983) and minimum density 17 ind./l (February and December, 1984) and at station A_1 the density of this group varied between 12 ind./l (December, 1984) - 43 ind./l (July, 1983). In Min-Mintudu stream, at station B it exhibited highest density (40 ind./l) in July, 1983 and lowest density (10 ind./l) in January, 1984. While at station B_1 this group varied between 9 ind./l (December, 1984) - 37 ind./l (July, 1983).

PRAWN POPULATION STUDIES :

TOTAL PRAWN : The prawn populations in Umshing stream were represented by Macrobrachium hendersoni hendersoni, M. kistnensis and M. dayanum (Table 1). Monthly densities of total prawns in this system ranged between 36-71 ind./m^2 and 48-74 ind./1m^2 at stations A and A_1 (Fig. 43) respectively. The pattern of fluctuations indicated variations at the former station (A) during both the years of this study. The density was noticed to be highest in May, 1983 (70 ind./m^2) and relatively higher densities were maintained from July-December, 1983. This station indicated a bimodal pattern in 1984, with a maxima in July, 1983 (69 ind./m^2) and a highest density in October, 1983 (71 ind./m^2). At station A_1, maximum density during the first annual cycle (January, 1983 - December, 1983) was noticed in July, 1983 (70 ind./m^2) while higher numbers were registered again in February, 1983 (64 ind./m^2) June, 1983 (70 ind./m^2) and October, 1983 (69 ind./m^2). During 1984, total prawn populations exhibited more irregular periodicity and indicated peak density (74 ind./m^2) in the months of June, 1984 and August (71 ind./m^2). Both the stations maintained higher abundance in July, 1983, October, 1983 and then again in June, 1984 and October, 1984. Station A indicated higher overall quantitative abundance during the first annual cycle as compared with the succeeding cycle. However, at station A_1, total densities of prawns indicated only marginal differences in the two successive annual cycles.

During this study, the quantitative abundance of total prawn populations at station B and B_1 in Min-Mintudu stream ranged between 37-77 ind./m^2 respectively. This population was represented by Macrobrachium lamarrei, M. dayanum and M. hendersoni hendersoni. The density of total prawns indicated irregular variations at station B during the period from January, 1983 - December, 1983. The peak population was noticed in September (77 ind./m^2) while maxima were observed in the months of April (70 ind./m^2), July (67 ind./m^2) and December, 1983 (68 ind./m^2). These populations registered less quantitative variations during the second annual cycle. During the year 1984, total prawns showed three maxima i.e., January (70 ind./m^2)April (70 ind./m^2) and September (57 ind./m^2). Total abundance gradually decreased from late autumn (October, 1984) to winter (December, 1984). Besides, their maxima in early autumn (September) in both the years, the pattern of fluctuations showed no similarity at this station in the two annual cycles.

The highest density of total prawns at station B_1, during the first annual cycle, was also noticed in September, 1983 (77 ind./m^2). The maxima in May, 1983 (55 ind./m^2) and December (68 ind./m^2) corresponded with the identical observations at station B. During the second annual cycle, total prawns at station B_1 exhibited a broadly bimodal pattern, with peak density in late spring, i.e., May, 1984 (69 ind./m^2) and another maxima in late autumn i.e., October, 1984 (59 ind./m^2) which is followed by a gradual decline till December, 1984. During this year, the total prawn densities

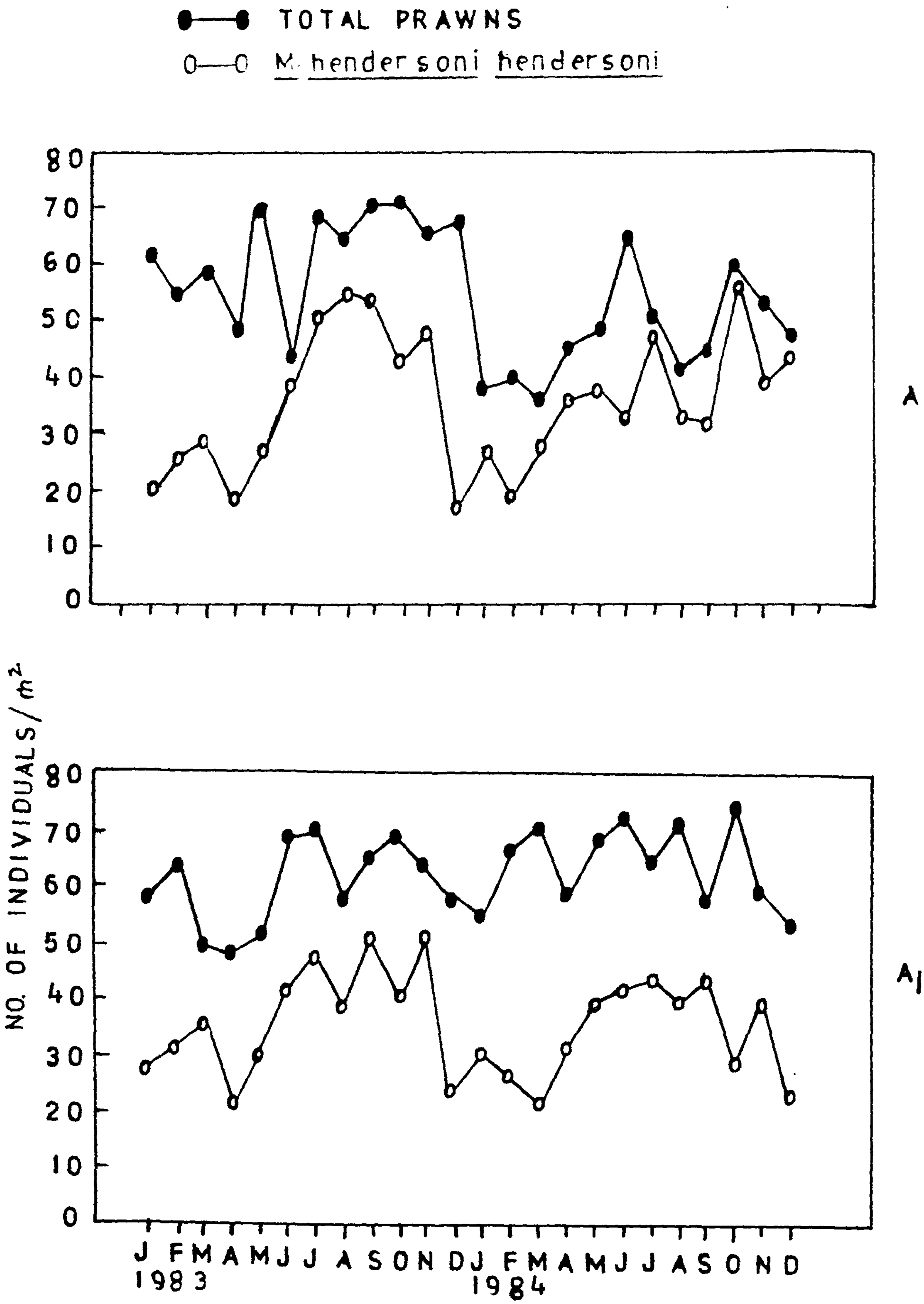


Fig. 43. Monthly fluctuations in the abundance of total prawn [illegible] Macrobrachium hendersoni hendersoni at two stations in Ums[illegible] stream.

were relatively low from mid winter (January, 1984) to early spring (April, 1984).

M. hendersoni hendersoni was prominent at two sampling stations in Umshing stream and *M. lamarrei* was dominant in Min-Mintudu stream. The studies on individual monthly variations and their population structure were, therefore, taken up in Umshing and Min-Mintudu streams respectively. Some salient features of these observations are detailed below :

Population studies on individual species :

Macrobrachium hendersoni hendersoni (De Man) :

TOTAL ABUNDANCE : The quantitative abundance of this prawn ranged between 22 ind./m^2 - 57 ind./m^2 and 21 ind./m^2 - 51 ind./m^2 (Fig. 43) at two sampling stations (A and A_1) in Umshing stream. The pattern of fluctuations indicated differences at both the sampling sites. Maximum density (57 ind./m^2) was noted in October, 1984 and minimum (17 ind./m^2) in December, 1983 at station A. Relatively higher densities were noticed from August, 1983 - November, 1983. On the other hand, in 1984 this station indicated maximum density in October (60 ind./m^2) and a second maxima in July (65 ind./m^2). Station A_1 registered highest densities (51 ind./m^2) in the months of September and November, 1983 during the first annual cycle and lowest density (21 ind./m^2) in April, 1983. Higher densities were again exhibited in July, 1983 (48 ind./m^2). During 1984, this species showed slightly regular trend of periodicity and indicated maxima (43 ind./m^2) in July

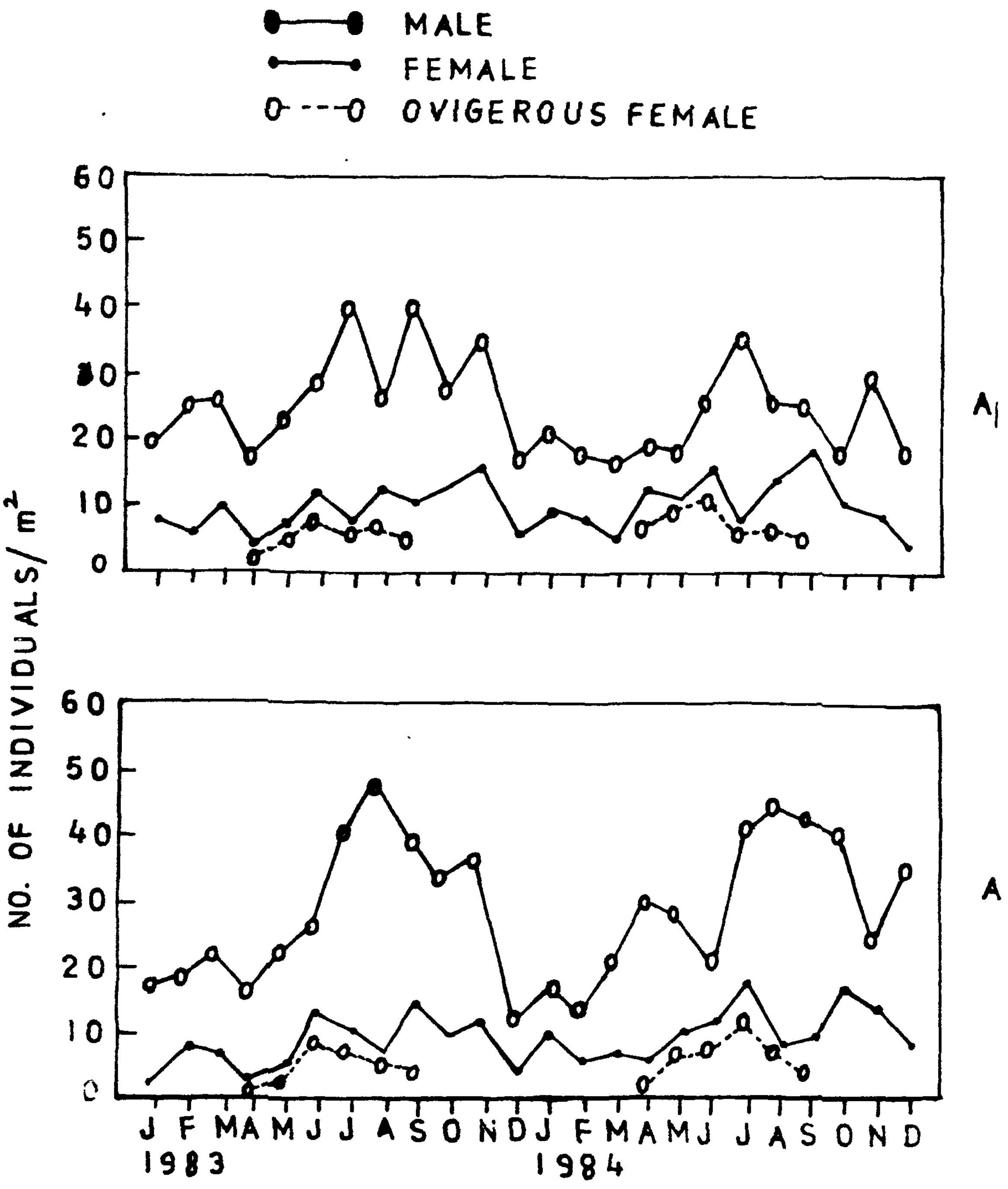


Fig. 44. Monthly variations in the abundance of males, females and ovigerous females of <u>Macrobrachium hendersoni hendersoni</u> at stations A & A_1 in Umshing stream.

and September and again higher abundance in the month of November (39 ind./m^2). However, both the stations maintained higher populations in the first annual cycle. At station A_1, total prawns indicated less population density differences during the period from May, 1984-September, 1984.

MALES : In both the annual cycles at station A and A_1, male populations of M. hendersoni hendersoni showed marked differences in their monthly abundance. Total density of males in this system ranged between 12 ind./m^2 - 47 ind./m^2 and 16 ind./m^2 (Fig.44) at station A and A_1 respectively. Station A indicated broadly a unimodal pattern in 1983 with peak in August, 1983 (47 ind./m^2) and fall in December, 1983 (12 ind./m^2). In 1984, maximum density at all station was registered (45 ind./m^2) in August and minimum density (14 ind./m^2) in February. At station A_1 higher abundance during the first annual cycle was noticed in the months of July and September (40 ind./m^2)while peak density (51 ind./m^2) was recorded in November, 1983. During 1984, the male prawn population exhibited bimodal periodicity and indicated maxima in July (35 ind./m^2) and November (30 ind./m^2) respectively. Station A exhibited marked density variations in the first annual cycle as compared with the succeeding cycle.

FEMALES : The quantitative abundance of female prawns indicated variations between 2-17 ind./m^2 and 4-18 ind./m^2 at station A and A_1 of Umshing stream (Fig.44). During 1983, highest female population at station A was recorded in September (15 ind./m^2) and relatively higher densities were maintained in the months of July (11 ind./m^2) and November (12 ind./m^2). Lowest density (2 ind./m^2) was observed during the first annual cycle at station A in April, 1983. This station indicated a broadly bimodal trend in 1984, with maximum density (15 ind./m^2) in September and another maxima (13 ind./m^2) in June, 1984.At station A_1 highest density during the first annual cycle was noticed in November, 1983 (16 ind./m^2) while another maxima was registered (13 ind./m^2) in June, 1983. The female prawn populations exhibited maxima (18 ind./m^2) in September, 1984 and higher abundance in June, 1984 (15 ind./m^2) in the second annual cycle. Both these stations maintained higher female abundance during June, 1983 - November, 1983. Station A did not exhibit any marked density variations in the first annual cycle as compared with the succeeding cycle.

OVIGEROUS FEMALES : The ovigerous females of *M. hendersoni hendersoni* occurred from April - September in the two annual cycles in both the habitats and their quantitative abundance ranged between 1-12 ind./m^2 and 2-11 ind./m^2 at stations A and A_1 respectively (Fig.46).At station A, maximum density (8 ind./m^2) was recorded in June,1983 followed by a gradual decline till the end of breeding season. Again a unimodal trend was noticed at this station in 1984 with maximum density (12 ind./m^2) in July. The pattern of variations in the density of ovigerous females was almost identical during both the annual cycles at station A except for the shift in higher density to the month of July in the second year of observations. During the second year, maximum density was recorded in June (11 ind./m^2) and minimum density (4 ind./m^2) in September. A unimodal pattern of abundance

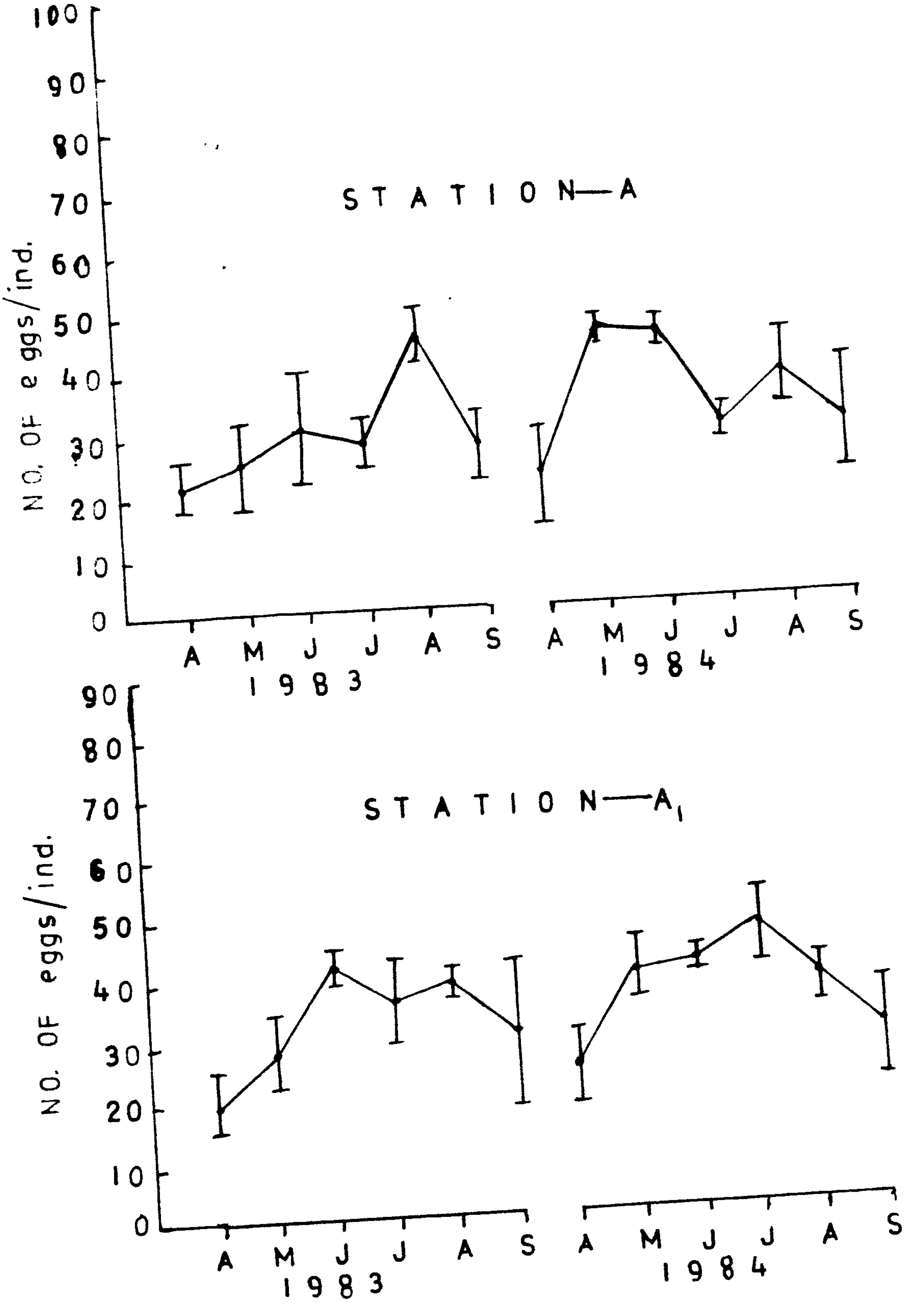


Fig. 45. Monthly variations in average fecundity and range of *Macrobrachium hendersoni hendersoni* at two sampling stations of Umshing stream.

of this group of individuals was evident during each of the annual cycle at station A_1. Maximum density (8 ind./m^2) was recorded in June, 1983 and maximum (12 ind./m^2) was recorded in July, 1984 at this station. The density of ovigerous female prawns indicated only minimal differences in the two successive annual cycles at station A_1.

FECUNDITY : Average fecundity of *M. hendersoni hndersoni* during the course of present investigation ranged between 22 ± 4 eggs/ind - 46 ± 4 eggs/ind and 20 ± 5 eggs/ind - 46 ± 6 egg/ind at station A and A_1 respectively (Fig.45). The overall pattern of egg production was primarily unimodal in the first annual cycle; at station A maximum fecundity (46 ± 6 eggs/ind) was noticed in August, 1983 and minimum (21 ± 8) in April, 1984 while station A_1 recorded maximum (46 ± 6 eggs/ind) in July, 1984 and minimum (20 ± 5 eggs/ind) in April, 1983. The former station showed two maxima during the second annual cycle.

SEX-RATIOS : The male individuals predominated the females of *M. hendersoni hendersoni* throughout the period of these observations at station A and A_1. Sex-ratio (Male : Female) was maximum (8:1) in April, 1983 and minimum (2:1) in the months of February, June and December, 1983. Further, relatively higher sex-ratios were noticed (6:1) in January and August, 1983. During the second annual cycle the higher sex-ratio was noticed in August (6:1) and relatively higher (5:1) in April and September at station A. At station A_1, during the first annual cycle (January, 1983 - December, 1983), the highest

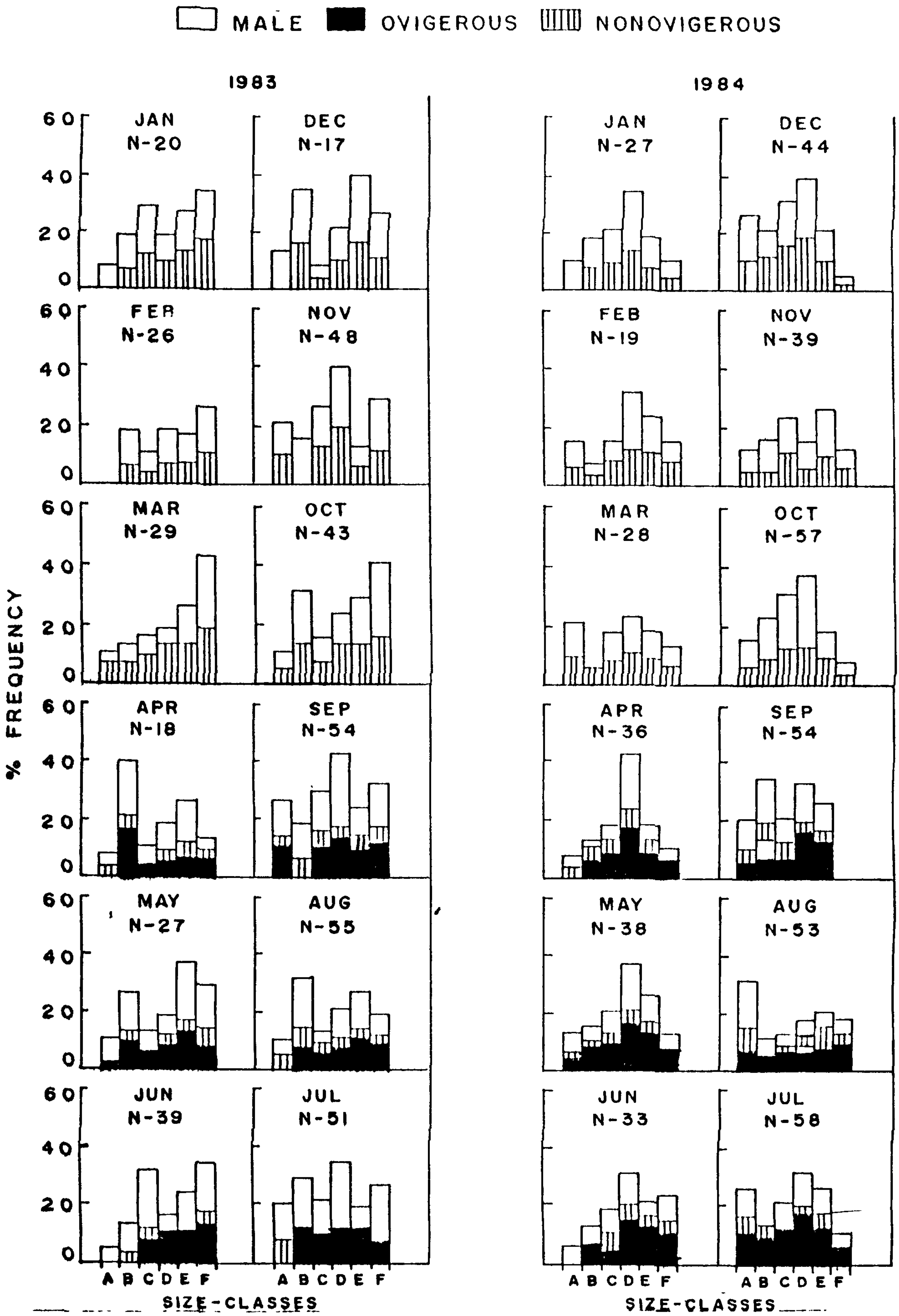


Fig. 46. Monthly variations in percentage frequency of male, ovigerous female and non-ovigerous female individuals of various size-classes in *M. hendersoni hendersoni* at station A of Umshing stream.

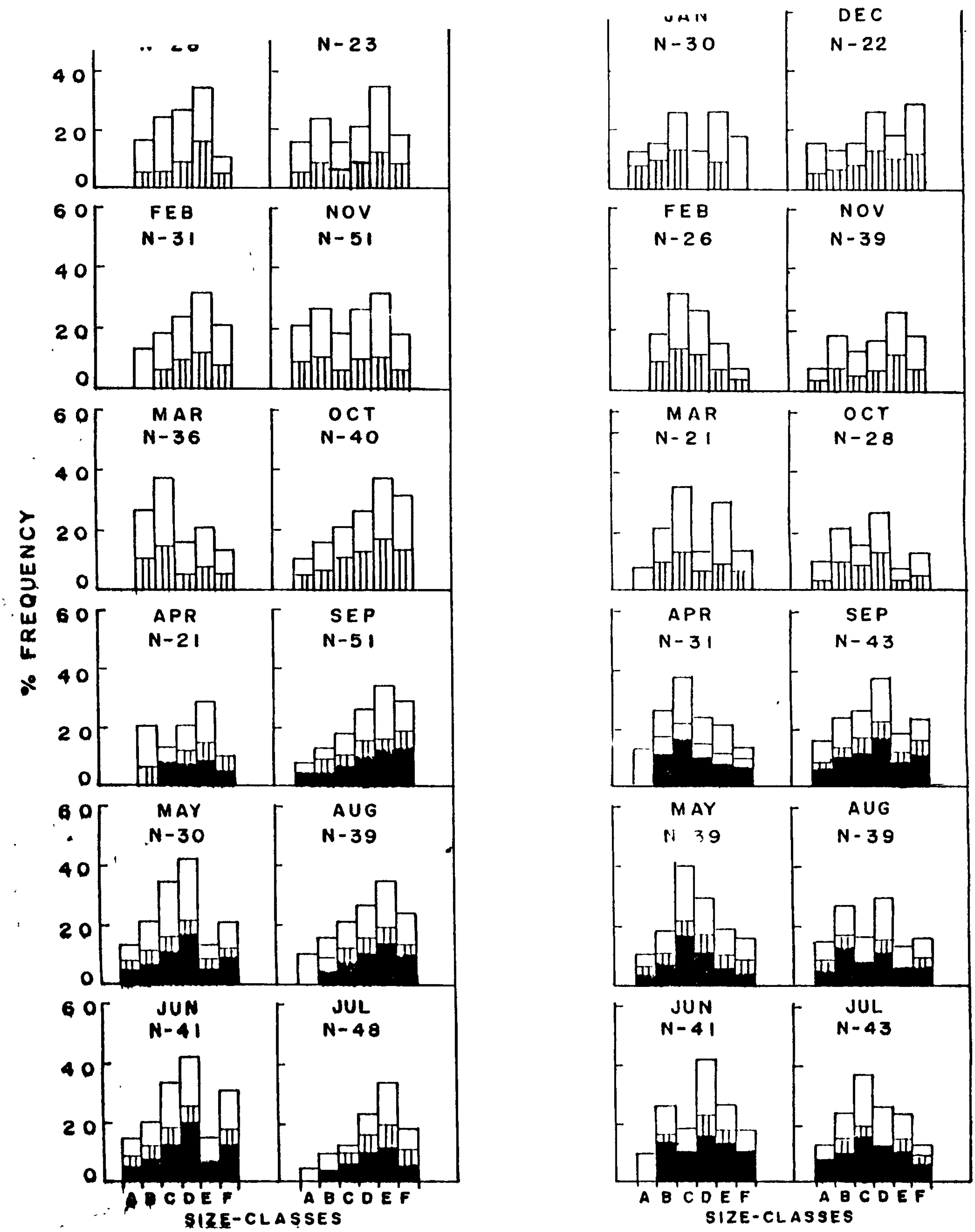


Fig. 47. Monthly variations in percentage frequency of male, ovigerous female and non-ovigerous female individuals of various size-classes in *M. hendersoni hendersoni* at station A_1 of Umshing stream.

(Abbreviations : A= Size-class 20.0 - 30.0 mm; B= Size-class 30.0 - 40.0 mm; C= Size-class 40.0 - 50.0 mm; D= Size-class 50.0 - 60.0 mm; E= Size-class 60.0 - 70.0 mm; F= Size-class 70.0 - 80.0 mm.).

sex-ratio (5:1) was observed in July, 1983 and relatively higher ratios (4:1) in February, April and September, 1983. Again, this habitat registered highest (5:1) sex ratio in July, 1984 and December, 1984 in the second annual cycle and lower sex-ratios (2:1) was exhibited during this annual cycle in the months of January, February, March and October, 1984.

Length-frequency distribution : On the basis of length measurements, M. hendersoni hendersoni specimens were grouped into six size-classes i.e., 20.0-30.0 mm; 30.0-40.0 mm; 40.0-50.0 mm; 50.0-60.0 mm; 60.0-70.0 mm and 70.0-80.0 mm. Females of size group 30.0-40.0 mm represented the juvenile group; 40.0-60.0 mm actively breeding group. Ovigerous females were recorded between April-September at both the stations during this study period. The individuals of size class 20.0-30.0 mm varied between 1 ind./m^2 (April, 1983) - 20 ind./m^2 (July,1983) and these were not recorded in the month of February, 1983. The densities of the specimens of other size-groups ranged between 3 ind./m^2 (January, 1983) - 10 ind./m^2 (July, 1983) under the size-class 30.0-40.0 mm; 1 ind./m^2 (December, 1983) - 8 ind./m^2 (March, 1983) of the size-group 40.0-50.0 mm; 2 ind./m^2 (March, 1983) - 25 ind./m^2 (September, 1983) under the size-class 50.0-60.0 mm; 1 ind./m^2 (March, 1983)- 9 ind./m^2 (Mid August, 1983) under the size group 60.0-70.0 mm; 2 ind./m^2 (April and December, 1983) - 11 ind./m^2 (early March, 1983) respectively at station A. However, during the second annual cycle (January, 1984) at this station the prawn populations of various length frequency groups ranged between 3 ind./m^2 (February) - 33 ind./m^2(August) under the size-class 20.0-30.0 mm; 2 ind./m^2 (February) - 9 ind./m^2 (Ja- (July) under the size-class 30.0-40.0 mm; 3 ind./m^2 (January, February, March and June) - 9 ind./m^2 (July, November) under the size-class 50.0-60.0 mm; 3 ind./m^2 (February) - 17 ind./m^2 (December) under the size-group 60.0-70.0 mm and 2 ind./m^2 (December) - 8 ind./m^2 (July) under the size-class 70.0-80.0 mm. At station A_1 during the first annual cycle (January, 1983 - December, 1983) the prawn population under the size group 20.0-30.0 mm; 30.0-40.0 mm; 40.0-50.0 mm; 50.0-60.0mm; 60.0-70.0 mm and 70.0-80.0 mm varied between 2 ind./m^2 (January) - 19 ind./m^2 (November), 4 ind./m^2 (July) - 11 ind./m^2 (November), 3 ind./m^2 (February, April and May) - 8 ind./m^2 (June, August and September), 2 ind./m^2 (February) - 12 ind./m^2 (June), 3 ind./m^2 (April)-8 ind./m^2 (July) respectively (Fig. 47). During the second annual cycle (January, 1984 - December, 1984) at this station the prawn population marked differences under the size-classes (as stated in the first annual cycle) 2 ind./m^2 (October) - 23 ind./m^2 (July), 4 ind./m^2(March and December) - 9 ind./m^2 (September), 2 ind./m^2 (April) - 10 ind./m^2 (May), 2 ind./m^2 (January and early March) - 8 ind./m^2 (May, June and October), 3 ind./m^2 (October) - 7 ind./m^2 (July, August and September) and 2 ind./m^2 (March) - 9 ind./m^2 (January, April and August) respectively.

CONDITION FACTOR : The condition ('K') factor for two size-classes of male and female prawn population on monthly average basis was calculated and presented in Table 9. This factor showed its higher values for the young populations (1.6403-2.9734) than the mature and post-

Table 9. Monthly fluctuations in condition factor of *M. hendersoni hendersoni* (de Man).

	Month	20.0 - 55.0 mm		55.1 - 80.0 mm	
		Male	Female	Male	Female
Winter	January'83	2.6743	2.5387	1.0931	0.9548
	February	2.6934	2.0197	1.1457	0.9834
Spring	March	2.7874	2.4780	0.9548	0.8739
	April	2.7964	2.6024	0.8714	0.9345
	May	2.8403	2.8761	0.9783	0.9534
Summer	June	2.5875	2.0761	0.9628	0.8796
	July	1.9149	2.1356	0.9186	0.9418
	August	1.6403	2.2984	0.8947	0.9746
	September	2.4909	2.1453	0.9125	0.9068
Autumn	October	2.8997	2.9740	0.9767	0.9566
	November	2.4192	2.4584	0.9371	0.8308
Winter	December	2.0001	2.2956	2.9146	0.8909
	Janaury'84	2.8976	2.4934	0.9499	0.9114
	February	2.9408	2.4036	0.8977	1.5234
Spring	March	2.9042	2.5620	0.8991	2.9698
	April	1.7645	2.6876	0.9548	0.9396
	May	2.8948	2.7589	2.9649	0.8993
Summer	June	2.4605	2.4561	0.8933	0.9912
	July	2.6009	2.2881	0.9103	0.9279
	August	2.8797	2.9091	0.9835	0.9556
	September	2.9734	2.6041	0.9921	0.9121
Autumn	October	2.9374	2.6104	0.9818	0.9126
	November	2.6931	2.4920	0.9455	0.9239
Winter	December	2.6401	2.5380	0.9791	0.9131

mature individuals (0.8714) during the period of these observations. The highest value of condition factor in male population in the size group of 20.0-55.0 mm was noticed (2.8403) in May, 1983 (Spring) and for female group (2.9740) in October, 1983 (early autumn). However, the highest condition factor for male and female individuals in the size class of 55.1-80.0 mm in the first annual cycle noticed to be (1.1457) in February, 1983 (winter) and (0.9834) in February, 1983 respectively. Relatively higher values of condition factor were recorded in January (1.0931) and in October (0.9566). In the second annual cycle (January, 1984 - December, 1984), the highest condition factor was recorded (2.9734) in September (early autumn) for male group and (2.7589) for female group in May (Spring) for the size class 20.0-50.0 mm. In the size group 50.1-80.0 mm the condition factor for male group ranged between 0.8933 (June) - 0.9921 (September) and in females varied between 0.8993 (May) - 1.5234 (February).

Ecological correlations : Various statistical correlations between total abundance of *M. hendersoni hendersoni* at two sampling stations (A and A_1) and different abiotic and biotic factors are given tin Tables 7 and 8.

Macrobrachium lamarrei (H. Milne Edw.) :

TOTAL ABUNDANCE : The population density of *M. lamarrei* ranged between 16 ind./m^2 (December, 1983) - 44 ind./m^2 (October, 1983 and July, 1984) at station B and between 16 ind./m^2 (December, 1983) - 58 ind/m^2 (September, 1983) at station B_1. The pattern of monthly population variations reflected peak during in October, 1983 (44 ind./m^2) and

Table 7. Co-efficient correlations between Total Prawns, Macrobrachium hendersoni hendersoni population densities and various ecological factors at station A, Umshing stream

Parameters	Total Prawn			M. hendersoni hendersoni		
	r	t	p	r	t	p
Insecta	0.398	1.708		0.247	1.099	
Nematoda	0.302	1.325		0.024	0.113	
Decapoda	0.166	0.751		0.1049	0.481	
Oligochaeta	0.139	0.634		0.0107	0.050	
Gastropoda	0.209	0.939		0.005	0.028	
Miscellaneous	0.039	0.182		0.176	0.795	
Total benthic organism	0.280	1.236		0.219	0.980	
Bacillariophyceae	0.454	1.926	0.01	0.720	2.860	0.025
Chlorophyceae	0.518	2.163	0.05	0.721	2.862	0.025
Chrysophyceae	0.454	1.923	0.01	0.683	2.738	0.025
Dinophyceae	0.556	2.299	0.05	0.629	2.557	0.025
Myxophyceae	0.460	1.948	0.01	0.398	1.709	
Rhodophyceae	0.024	0.115		0.283	1.285	
Total phytoplanktons	0.530	2.207	0.01	0.612	2.498	0.05
Protozoa	0.511	2.138	0.05	0.659	2.658	0.025
Rotifera	0.568	2.342	0.05	0.604	2.471	0.025
Copepoda	0.358	1.552		0.553	2.289	0.05
Cladocera	0.579	2.383	0.05	0.468	1.979	0.01
Total zooplankton	0.565	2.332	0.05	0.610	2.492	0.025
Water temperature	0.384	1.652		0.682	2.734	0.025
pH	0.158	0.719		0.324	1.413	
Conductivity	0.147	0.611		0.484	2.035	0.01
Dissolved Oxygen	0.481	2.026	0.01	0.162	0.734	
Free Carbon-dioxide	0.569	2.348	0.05	0.529	2.203	0.05
Total alkalinity	0.265	2.163	0.01	0.289	1.267	
Calcium	0.638	2.584	0.025	-0.351	1.522	
Magnesium	0.347	1.506		-0.021	0.102	
Sodium	0.288	0.577		0.330	1.441	
Potassium	0.017	0.080		0.129	0.592	
Phosphate-phosphorus	0.383	1.652		-0.304	1.333	
Silicate	0.306	1.342		0.436	1.856	0.01
Ammonia-nitrogen	0.501	2.100	0.05	0.293	1.290	
Oxidisable-organic matter	0.086	0.395		0.392	1.685	

Table 8. Co-efficient correlations between total prawns, Macrobrachium hendersoni hendersoni population densities and various ecological factors at station A_1 Umshing stream.

	Total Prawn			M. hendersoni hendersoni		
	r	t	p	r	t	p
Insecta	0.302	1.326		0.235	1.049	
Nematoda	0.023	0.109		0.531	2.207	0.05
Decapoda	0.103	0.471		0.016	0.073	
Oligochaeta	0.184	0.833		-0.107	0.488	
Gastropoda	0.020	0.097		0.132	0.599	
Miscellaneous	0.308	1.351		0.199	0.892	
Total benthic organism	0.197	0.885		0.186	0.837	
Bacillariophyceae	0.415	1.775	0.01	0.646	2.612	0.025
Chlorophyceae	0.579	2.379	0.05	0.499	2.099	0.05
Chrysophyceae	0.601	2.458	0.025	0.490	2.059	0.01
Dinophyceae	0.249	1.106		0.149	0.679	
Myxophyceae	0.048	0.225		0.159	0.721	
Rhodophyceae	0.357	1.547		0.066	0.307	
Total phytoplankton	0.348	1.511		0.520	2.167	0.05
Protozoa	0.346	1.504		0.832	3.209	
Rotifera	0.503	2.107	0.05	0.453	1.921	0.01
Copepoda	0.222	0.990		0.058	0.268	
Cladocera	0.454	1.923	0.01	0.782	3.056	
Total zooplankton	0.477	1.761	0.01	0.821	3.175	
Water temperature	0.375	1.617		0.664	2.673	0.025
pH	0.054	0.251		0.488	2.052	0.01
Conductivity	0.394	1.692		0.069	0.321	
Dissolved Oxygen	0.436	1.857	0.01	0.439	1.867	0.01
Free carbon-dioxide	0.639	2.588	0.025	0.006	0.022	
Total alkalinity	0.193	0.866		0.397	1.704	
Calcium	0.181	0.815		0.622	2.532	0.025
Magnesium	0.042	0.197		0.161	0.728	
Sodium	0.004	0.018		0.242	1.075	
Potassium	0.218	0.975		0.140	0.637	
Phosphate-phosphorus	0.170	0.769		0.297	1.307	
Silicate	0.021	0.097		0.133	0.492	
Ammonia-nitrogen	0.195	0.884		-0.079	0.367	
Oxodisable organic matter	0.286	1.258		0.121	0.555	

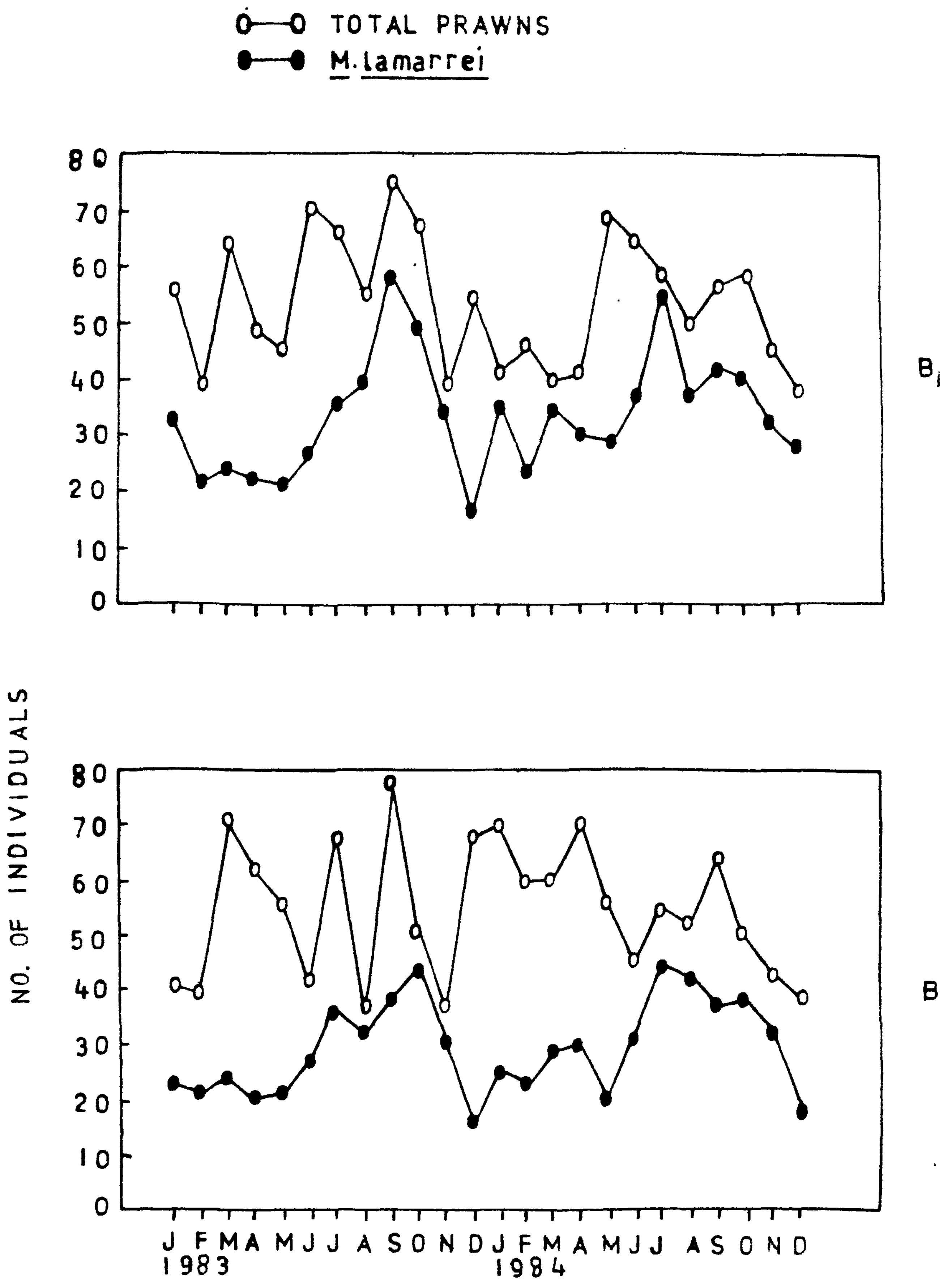


Fig. 2 Monthly fluctuations of Macrobrachium lamarrei with total prawn populations in Min-Mintudu stream.

another maxima is July, 1983 (44 ind./m^2) during the first annual cycle at station B. This station exhibited peak population in July, 1984 (55 ind./m^2) and maxima in October, 1984 (48 ind./m^2) during the suceeding annual cycle. However, during these observations, higher population densities were maintained from mid-summer (July) to autumn (October) and the pattern of fluctuations was broadly identical in both the years at this station.

At station B_1, the population of M. lamarrei indicated a higher initial number in January, 1983 (33 ind./m^2), subsequently followed a unimodal pattern and indicated peak density in September, 1983 (58 ind./m^2) during the first annual cycle. This pattern exhibited variations in the suceeding year and indicated peak population density in July, 1984 (55 ind./m^2). Maxima in this year were also noticed in January, 1984 (35 ind./m^2), May, 1984 (39 ind./m^2) and September, 1984 (38 ind/.m^2).

MALES : The male predominated the female individuals throughout this study period at both the sampling stations of Min-Mintudu stream. The quantitative abundance of males of M. lamarrei varied between 10 ind./m^2 - 42 ind./m^2 and 10 ind./m^2 - 45 ind./m^2 at stations B and B_1 respectively during the present observations.

The males indicated a distinctly unimodal pattern of fluctuations at station B in the first annual cycle. The highest density was noticed in September, 1983 (44 ind./m^2). However, during the second year, this pattern was broadly bimodal, with peak density in July,

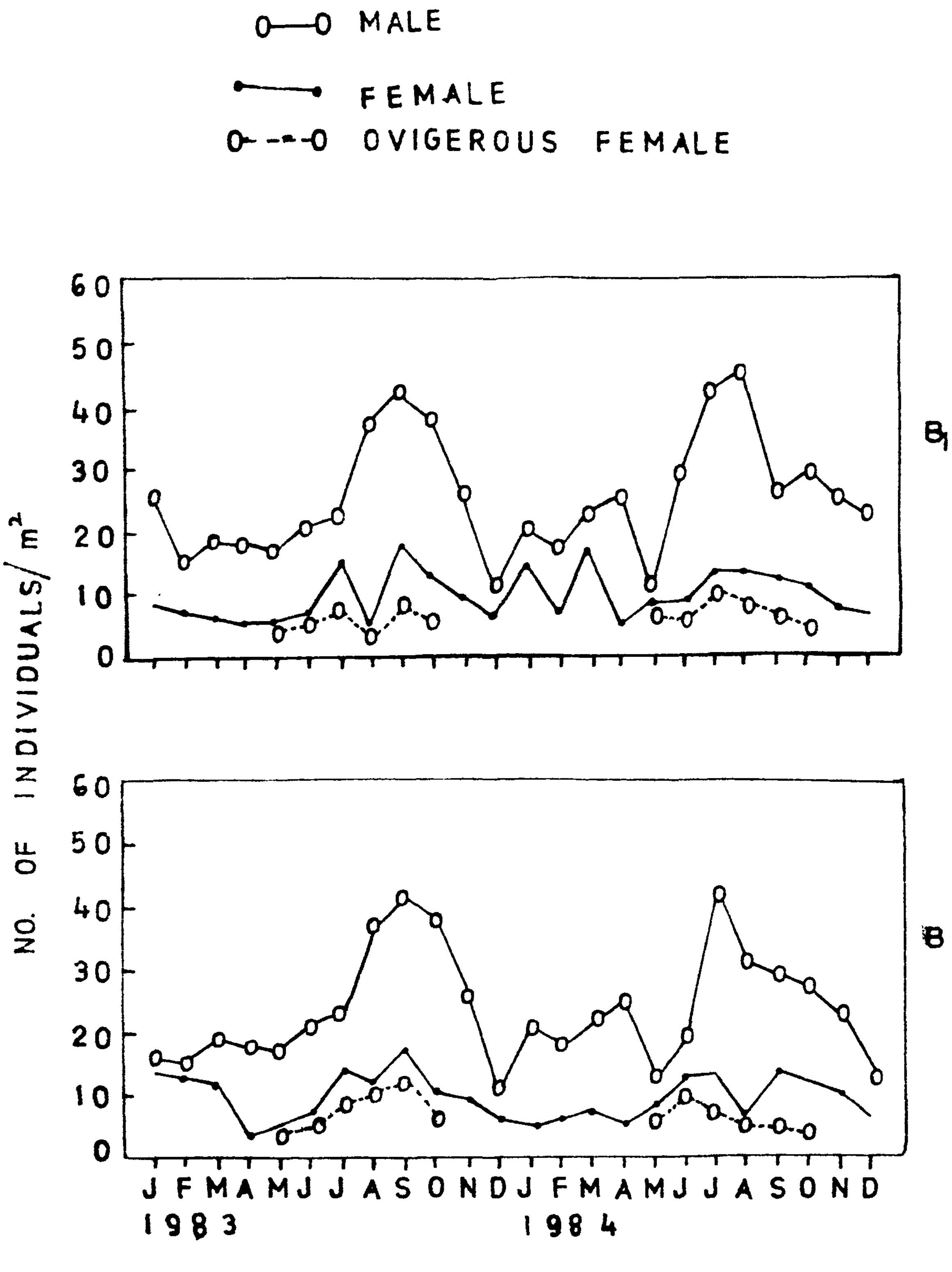


Fig. 49. Monthly variations the density of male, female and ovigerous female of *Macr. achium lamarrei* in Min-Mintudu stream.

1984 (42 ind./m^2) and another maxima in April, 1984 (25 ind./m^2).During both the years, the lowest population densities of prawns were recorded in the months of December, 1983 (10 ind./m^2) and December, 1984 (10 ind./m^2).

The pattern of monthly variations of males was almost identical at station B_1 during the year 1983 except for an initial high abundance in January, 1983 (33 ind./m^2). The peak was recorded at this station in September, 1983 (41 ind./m^2). during the first annual cycle. Again male populations followed an identical trend at station B_1, from January, 1984 - July, 1984; the highest density was observed in August, 1984 (45 ind./m^2) followed by a decline in population till December, 1984. The lowest densities of males at station B_1 were noticed in December, 1983 (10 ind./m^2) and May, 1984 (20 ind./m^2).Both these stations maintained higher population abundance from August - October, during the first annual cycle.

<u>FEMALES</u> : During both the annual cycles at stations B and B_1, the female population of <u>M.</u> <u>lamarrei</u> showed marked monthly variations. The total abundance of female individuals in Min-Mintudu stream ranged between 3 ind./m^2 - 17 ind./m^2 and 4 ind./m^2 - 18 ind./m^2 at station B and B_1 respectively (Fig. 49). Station B indicated primarily a bimodal trend in 1983 with higher initial numbers from January - March, 1983 and then again from July - September, 1983. The peak population of females at this station, during the year 1983, was noticed in September, 1983 (17 ind./m^2) while low densities were noticed in the months of April, 1983 (3 ind./m^2) and December, 1983 (6 ind./m^2). Further, the

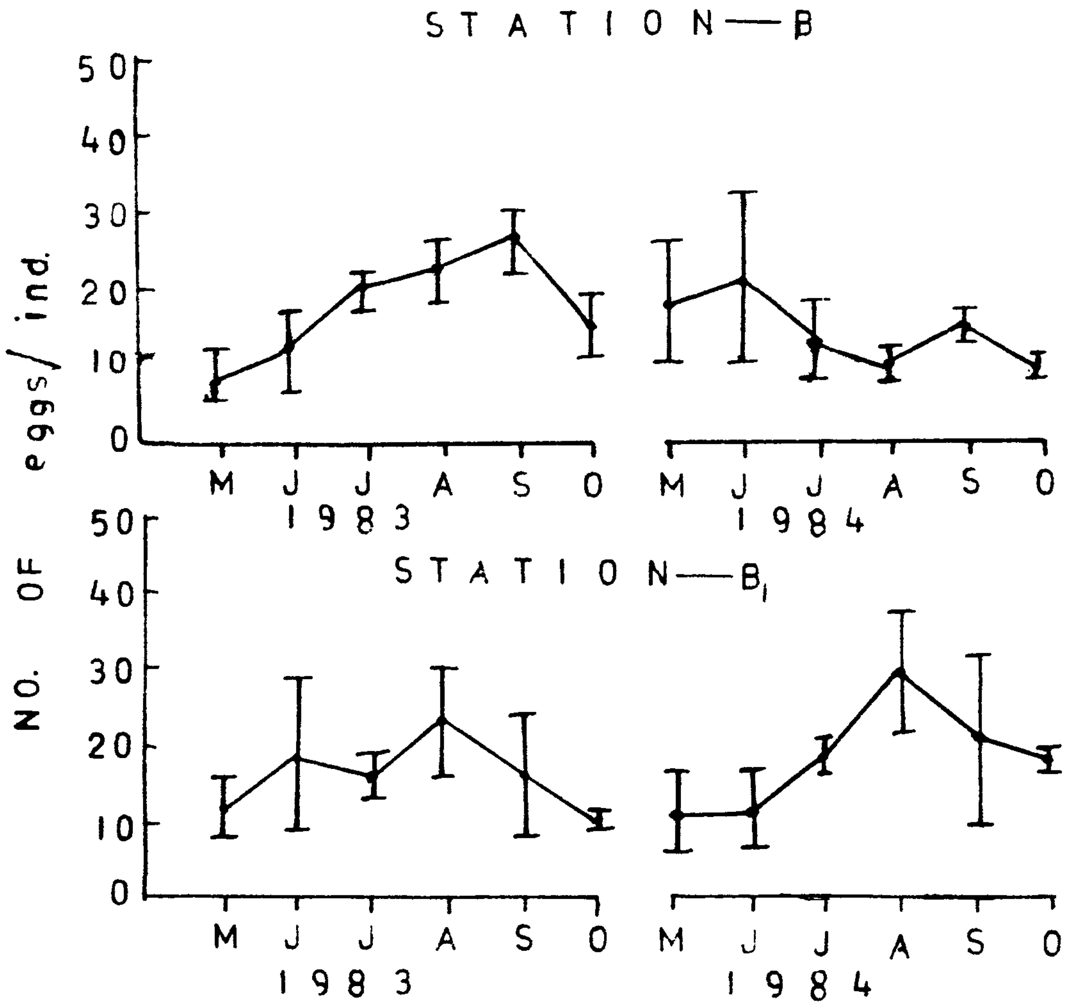


Fig. 50. Monthly variations in average fecundity and range of *Macrobrachium lamarrei* at two sampling stations of Min-Mintudu stream.

density of females at station B_1 indicated very less differences from July-October, 1984 and thereafter gradually declined till December, 1984.

OVIGEROUS FEMALES : The ovigerous females of M. lamarrei occurred from May-October in the two annual cycles at both the sampling stations and their abundance ranged between 3-11 ind./m^2 and 3-10 ind./m^2 at station B and B_1 respectively. Maximum density was observed (11 ind./m^2)in September, 1983 and minimum density (11 ind./m^2) in May, 1983 at station B during the first annual cycle. In the second year, a highest abundance (9 ind./m^2) was recorded in 1984 in June and lowest density (3 ind./m^2) were noticed in October, 1984 at this station. The station B showed a unimodal trend during each of the annual cycles. At station B_1 the peak (8 ind./m^2) was recorded in the month of September, 1983, second maxima in July, 1984 (7 ind./m^2) and fall (3 ind./m^2) in April, 1983 during the first annual cycle. During the period from January, 1984 - December, 1984, the maximum density was noticed (10 ind./m^2) in July and minimum density (4 ind./m^2) in December. This station exhibited bimodal trend of fluctuation in the first annual cycle and a broadly unimodal pattern in the suceeding annual cycle.

FECUNDITY : During both the annual cycles, the average fecundity in M. lamarrei ranged between 9 ± 3 eggs/ind. - 26 ± 4 eggs/ind and 10± 1 egg/ind - 29 ± 3 eggs/ind at station B and B_1 respectively (Fig.50). In 1983, the highest average fecundity was noticed in September (26 ± 4 egg/ind) and the lowest (9 ± 3 eggs/ind) in May and in the suceeding annual cycle the maximum (21 ± 11 egg/ind) fecundity was noticed in

June and minimum (9 ± 1 eggs/ind) in October. At station B_1 the maximum average fecundity (23 ± 7 egg/ind) was observed in August, 1983 and minimum (10 ± 1 egg/ind) in October, 1983 while the maximum(29 ± 3 egg/ind) average fecundity was noticed in August and minimum (11 ± 5 eggs/ind) in June in the suceeding annual cycle at station B_1. The stations B and B_1 indicated almost fecundity pattern during the first year of these.observations but showed variable trends during the second annual cycle. The rate of egg production was relatively low at station B from July - October, 1984.

SEX-RATIOS : The male individuals predominated the females of M.lamarrei at both the stations (i.e. B and B_1) in the present study. During 1883, maximum sex-ratio (6:1) was observed in April and minimum (2:1) in January, February and July at station B. At station B_1, during 1983 highest sex-ratio (9:1) was noted in August and lowest (2:1) in the months of February and June. During the second annual cycle, the maximum sex-ratio peak (5:1) was observed in April and August, 1984 and minimum ratio (2:1) was evident between September - December, 1984 at station B. Relatively identical trend of sex-ratio was indicated at the other station (i.e. B_1) during this cycle, with maximum (5:1) in April, 1984 and minimum sex-ratio (2:1) in September, 1984.

Length-frequency distribution : Based on the length measurements, all the examined specimens of M. lamarrei were categorised into six size-classes i.e., 20-30.0 mm; 30-40.0 mm; 40.0-50.0 mm; 50.0-60.0 mm; 60.0-70.0 mm and 70.0-80.0 mm. Females of size-group 30.0-40.0mm represented the juvenile group; 40.0-60.0 mm actively breeding group.

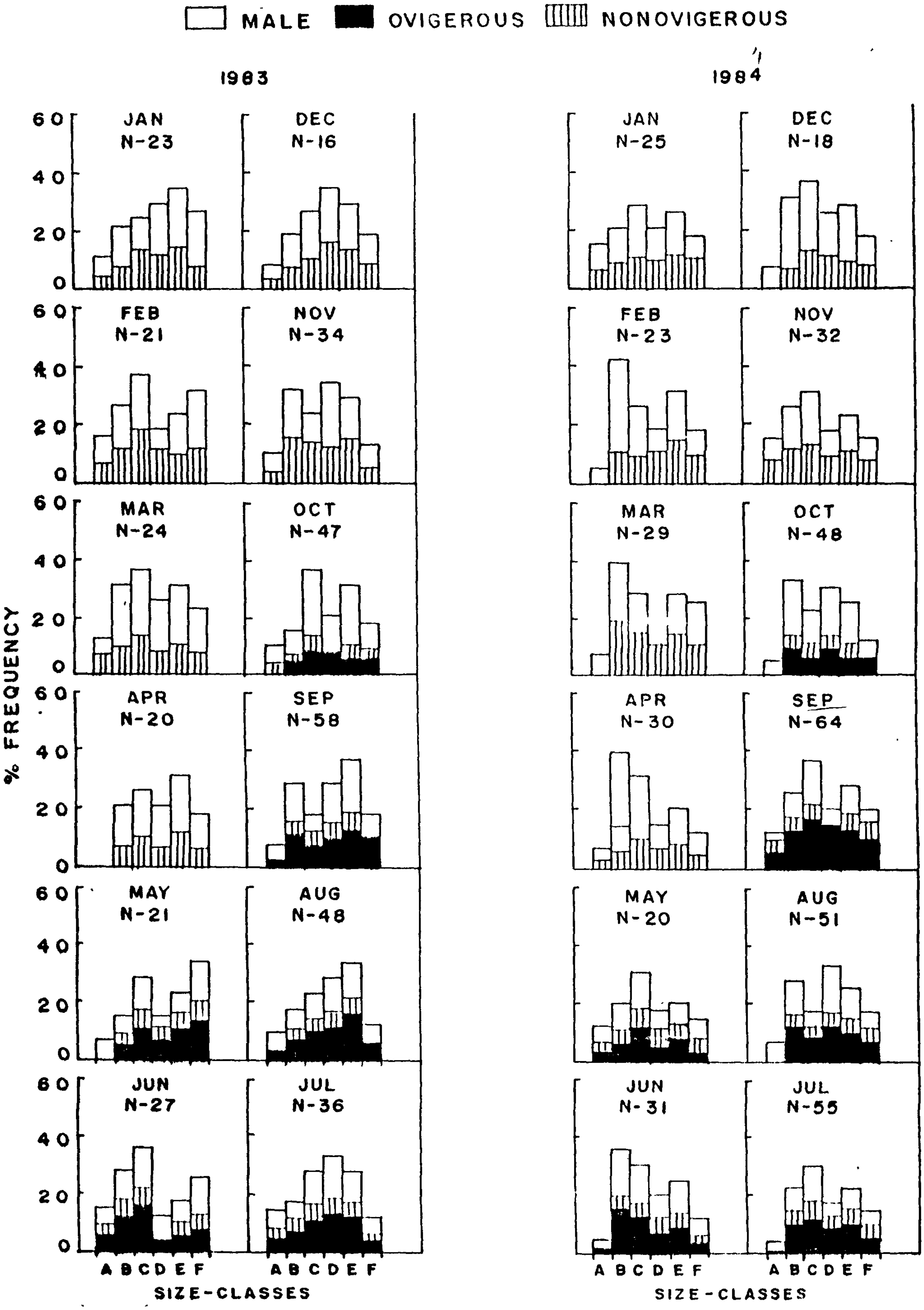


Fig. 51. Monthly variations in percentage frequency of male, ovigerous female and non-ovigerous female individuals of various size-classes in *M. lamarrei* at station II of Min-Mintudu stream.

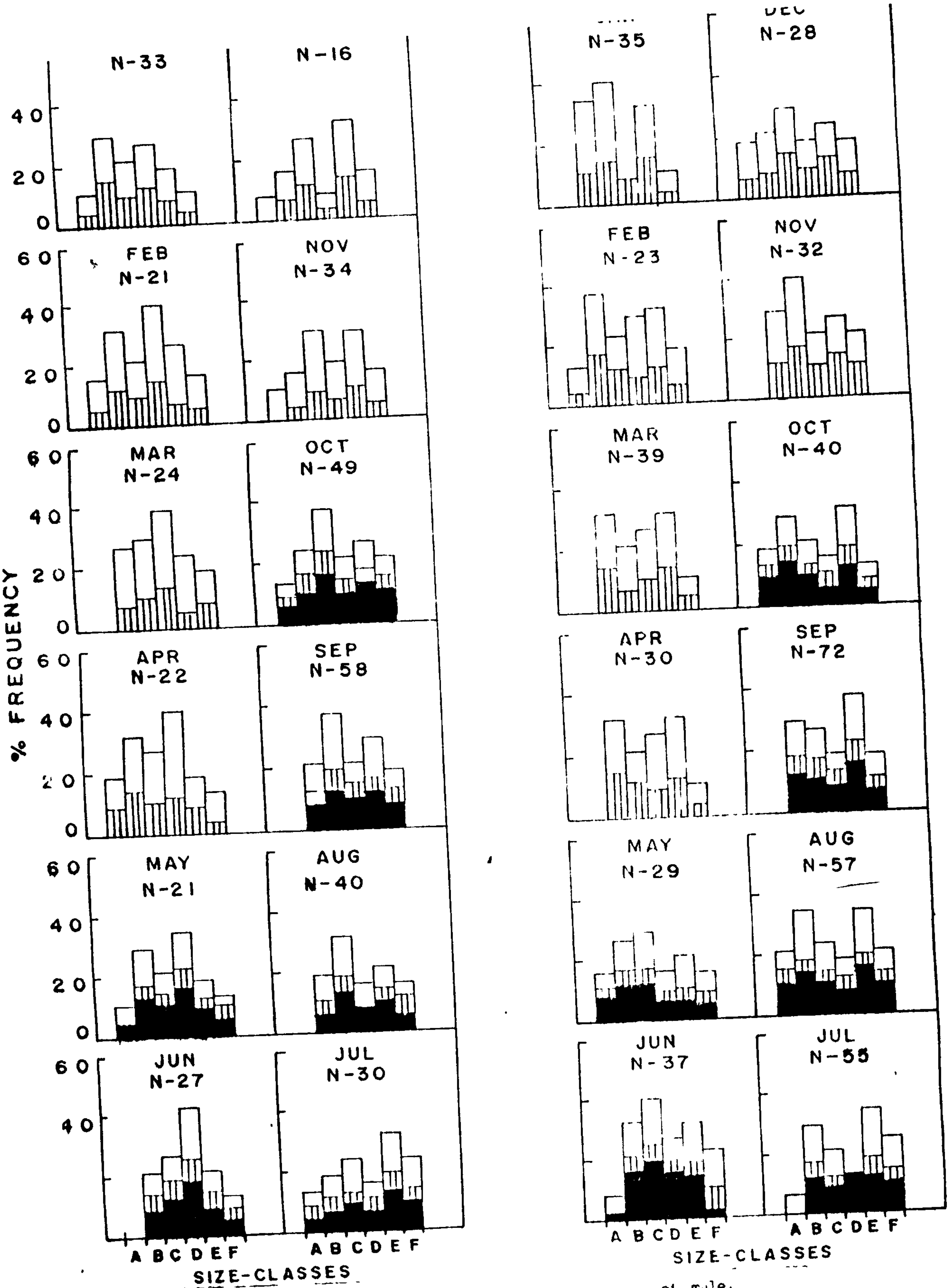


Fig. 52. Monthly variations in percentage frequency of male, ovigerous female and non-ovigerous female individuals of various size-classes in *M. lamarrei* at station I_1 of Min-Mintudu stream.

The ovigerous females were recorded only during early summer to late spring (May-October) at station B and B_1 during both the annual cycles. At station B, the juveniles population of the size-group 20.0-30.0mm recorded their peak (20 ind/m^2) in August, 1984 and lower abundance (1 ind./m^2) in February, 1984 during both the annual cycles and was not detected in the month of April, 1983. The individual size-group 30.0-40.0 mm indicated their maximum density (10 ind./m^2) in August and September, 1984 and minimum density (2 ind./m^2) in the months of April, 1983 and May, 1984. The specimens belonging to size-groups 40.0-50.0 mm and 50.0-60.0 mm were noticed throughout the two annual cycles and exhibited maximum densities (9 ind./m^2) in September, 1984 and (26 ind./m^2) in September, 1983 and a minimum of 31 ind./m^2) in the months of January-February, 1983, January, April and May and (2 ind./m^2) in the months of May and June, 1984. Further at station B_1 the juveniles of size-class 20.0-30.0 mm recorded a distinct peak (9 ind./m^2) in August, 1984 and were absent during June, 1983. The peak (12 ind./m^2) for the size-group 30.0-40.0 mm was recorded in September, 1984 and a decline (2 ind./m^2) in December, 1983. The size-group 40.0-50.0 mm exhibited maxima (10 ind./m^2) in June and September, 1984 and minima (3 ind./m^2)in December both the annual cycles. The size-classes 50.0-60.0 mm and 60.0-70.0 mm showed their peak values (30 ind./m^2) in September, 1984 and (14 ind./m^2) in August and September, 1984 respectively and fall (2 ind./m^2) in December, 1983 and (3 ind./m^2) in February and May,1984. The highest values (10 ind./m^2) was recorded in October, 2983 and lowest value (2 ind./m^2) in December, 1983 and November, 1984 respectively for the size-group 70.0-80.0 mm at station B_1.

CONDITION FACTOR : The condition factor ('k' factors) for two size-classes of male and female prawn populations on monthly average basis was calculated and values were given in Table 12. The 'k' factor exhibited higher values for the young populations (2.0789-3.8739) than the mature and post-mature individuals (1.4590-2.9644). The highest value of condition factor in male population (size-class : 20.0-55.0mm) was noticed (3.8739) in July, 1983 and for female individuals of this size-class 20.0-55.0 mm (3.9103) in February, 1983. Further, the maximum 'k' values for male and female individuals in the size group of 55.1-80.0 mm in the first annual cycle were noticed (2.9644) in September, 1983 and (2.9430) in May, 1983 respectively. During the second annual cycle (January, 1983 - December, 1984), the peak value of 'k' factor in male and female of size group 20.0-50.0 mm were recorded (3.8701) in November, 1984 and (3.1002) in November, 1984 respectively. Relatively lower values were recorded in this size-class during the second annual cycle (2.9431 and 2.9731) in January and November, 1984 for male and female individuals of M. lamarrei.

Ecological correlations : Various ecological correlations between total abundance of M. lamarrei at two sampling stations (B and B_1) and different recorded abiotic and biotic factors are given in Tables 10 and 11.

Table 10. Co-efficient correlations between total prawns Macrobrachium lamarrei population densities and various ecological factors at station B, Min-Mintudu.

Parameters	Total Prawn			M. lamarrei		
	r	t	p	r	t	p
Insecta	0.052	0.239		0.421	1.799	0.01
Nematoda	0.012	0.056		0.233	1.039	
Decapoda	0.007	0.033		0.008	0.038	
Oligochaeta	0.045	0.207		0.422	1.801	0.01
Gastropoda	0.238	1.058		0.302	1.327	
Miscellaneous	0.026	0.109		0.059	0.272	
Total benthic organism	0.058	0.269		0.418	1.788	0.01
Bacillariophyceae	0.296	1.299		0.404	1.729	0.01
Chlorophyceae	0.489	0.054	0.01	0.480	2.020	0.01
Chrysophyceae	0.374	1.615		0.558	2.304	0.05
Dinophyceae	0.152	0.689		0.094	0.341	
Myxophyceae	0.322	1.403		0.403	1.723	0.01
Rhodophyceae	0.163	0.739		0.173	0.783	
Total phytoplankton	0.458	1.938	0.01	0.521	2.174	0.05
Protozoa	0.035	0.166		0.658	2.654	0.025
Rotifera	0.031	0.144		0.509	2.129	0.05
Copepoda	0.117	0.535		0.253	1.124	
Cladocera	0.181	0.816		0.366	1.581	
Total zooplankton	0.087	0.401		0.580	2.385	0.05
Water temperature	0.037	0.174		0.456	1.931	0.01
pH	0.102	0.468		0.268	1.185	
Conductivity	0.074	0.344		0.088	0.405	
Dissolved Oxygen	0.195	0.878		0.364	1.570	
Free Carbon-dioxide	0.113	0.515		0.154	0.699	
Total alkalinity	0.064	0.295		0.246	1.095	
Calcium	0.183	0.824		0.149	0.675	
Magnesium	0.104	0.478		0.321	1.401	
Sodium	0.303	0.189		0.095	0.435	
Potassium	0.283	1.248		0.086	0.394	
Phosphate-phosphorus	0.142	0.646		0.567	2.337	0.05
Silicate	0.108	0.496		-0.105	0.485	
Ammonia-nitrogen	0.094	0.433		-0.119	0.548	
Oxidisable Organic matter	0.194	0.871		0.403	1.729	0.01

Table 11. Co-efficient correlations between total prawns, M. lamarrei population densities and various ecological factors at station B_1, Min-Mintudu stream.

Parameters	Total Prawn			M. lamarrei		
	r	t	p	r	t	p
Insecta	0.148	0.671		0.029	0.139	
Nematoda	0.051	0.234		0.157	0.716	
Decapoda	0.144	0.656		0.031	0.146	
Oligochaeta	0.308	1.351		0.003	0.015	
Gastropoda	0.256	1.134		0.321	1.403	
Miscellaneous	0.003	0.012		0.178	0.803	
Total benthic organism	0.249	1.104		0.123	0.561	
Bacillariophyceae	0.017	0.081		0.552	2.258	0.05
Chlorophyceae	0.201	0.901		0.235	1.047	
Chrysophyceae	0.108	0.495		0.161	0.726	
Dinophyceae	0.103	0.474		0.145	0.659	
Myxophyceae	0.133	0.605		0.233	1.037	
Rhodophyceae	0.101	0.461		0.141	0.642	
Total phytoplankton	0.105	0.481		0.209	0.939	
Protozoa	0.504	2.109	0.05	0.598	2.207	0.05
Rotifera	0.346	1.723	0.01	0.272	1.199	
Copepoda	0.206	0.925		0.322	1.406	
Cladocera	0.614	2.503	0.025	0.339	1.473	
Total zooplankton	0.519	2.167	0.05	0.477	2.009	0.01
Water temperature	0.424	1.811	0.01	0.442	1.878	0.01
pH	0.158	0.715		0.365	1.579	
Conductivity	0.114	0.521		0.193	0.867	
Dissolved Oxygen	0.276	1.217		0.361	0.168	
Free Carbon-dioxide	0.118	0.540		0.278	1.229	
Total alkalinity	0.027	0.125		0.005	0.022	
Calcium	0.218	0.975		0.128	0.584	
Magnesium	0.287	1.265		0.284	1.251	
Sodium	0.338	1.471		0.279	1.231	
Potassium	0.317	1.387		0.038	0.176	
Phosphate-phosphorus	0.294	1.294		0.280	1.236	
Silicate	0.041	1.194		0.241	1.074	
Ammonia-nitrogen	0.182	0.819		0.367	1.586	
Oxidisable Organic matter	0.009	0.041		0.168	0.759	

Table 12. Monthly fluctuations in condition factor of M. lamarrei (H.Milne Edw.)

	Month	20.0 - 55.0 mm		55.1 - 80.0 mm	
		Male	Female	Male	Female
Winter	January'83	3.5712	3.5143	2.0918	1.3627
	February	3.7190	3.9103	2.1673	2.3018
Spring	March	3.1294	3.6734	2.2672	2.4917
	April	2.9670	3.2671	2.6737	2.5471
	May	3.3179	2.5673	2.5671	2.9430
Summer	June	3.6001	2.5991	2.6734	2.5673
	July	3.8739	2.9441	2.6307	2.8710
	August	2.8637	2.1873	2.7341	2.5673
	September	2.9317	2.6731	2.9644	2.6732
Autumn	October	3.1675	2.7991	2.8667	2.9444
	November	3.2678	2.9446	2.9971	2.5673
Winter	December	2.8716	2.7493	2.8767	2.9430
	Janaury'84	2.9042	2.8003	2.9431	1.5234
	February	2.8476	2.4943	1.9473	1.9467
Spring	March	2.6009	2.4561	1.8734	1.4798
	April	3.1072	2.5632	1.9483	1.4590
	May	2.9734	2.9435	2.1673	2.0031
Summer	June	2.6973	2.3417	2.0763	2.9137
	July	2.7964	2.4780	1.7589	1.8736
	August	2.9736	2.0789	2.074	1.9456
	September	2.8734	2.1674	2.1943	2.3471
Autumn	October	2.4176	2.9473	2.0667	2.1744
	November	3.8701	3.1002	2.9471	2.9731
Winter	December	2.9449	2.8876	2.9731	2.8767

DISCUSSION

Various lotic ecosystems exhibit a gradient of physical conditions from headwaters to mouth which might further be influenced by local and regional factors associated with climate, impact of tributaries and geology of the catchment areas. In addition, certain man caused disturbances i.e., fire (Minshall et.at; 1981), silviculture (Molles, 1982), riparian control (Cummins et.al; 1984) tree debris removal (Triska, 1984) and shifting cultivation (Toky and Ramakrishnan, 1984) were known to cause potential changes. All these attributes, in turn, elicit a series of responses within aquatic communities in running-waters and result in a continuum of biotic adjustments (Mcln-tosh, 1967; Mills, 1969, Vannote et.al; 1980). The water quality and biocoenosis of lotic habitats often indicate altitudinal and latitudinal differences depending in the interplay of several of the stated variables which might be unique in every catchment area (Moss, 1988). Moreover, substrate affected by current velocity may act selectively on some species or on individual life history stages of various aquatic organisms (leudtke & Brusvon, 1976; Smith & Sandifer, 1976).

Like other groups of the biota inhabiting streams, the prawn populations were subjected to complex interactions of physical, chemical and biotic factors and the extent of their operation was expected to differ from season to season. The present study, therefore, attempted to analyse some aspects of ecology of hill-stream prawns with special reference to two commonly occurring local taxa i.e., *Macrobrachium hendersoni hendersoni* and *M. lamarrei*. The observation were made on monthly variation in total prawn populations and tat of mentioned individual species and quantitative abundance of males, females, ovigerous females, fecundity, sex-ratios, length-frequency composition and condition factors of these species. The investigations on M. hendersoni hendersoni were restricted to two sampling stations (A, A_1) in Umshing stream in East Khasi Hills District of Meghalaya. Observations were made on stream-dwelling population of M. lamarrei at two sampling stations (B, B_1) in Min-Mintudu stream. Besides, differences in the adjoining vegetation and substrate characteristics, the two streams indicated altitudinal differences. The relationships between various observed ecological (abiotic and biotic) parameters and the monthly variations in the population densities of total prawns and that of M. hendersoni hendersoni and M. lamarrei respectively were highlighted below :

Temperature : It is considered to be the most important factor in an aquatic environment (Welch, 1952). Besides, its direct bearing on physical properties of water, temperature also regulated the occurrence, distribution, growth and reproduction of various organisms in aquatic ecosystems. Temperature tolerance limits varied in different species (Lekmkuhl, 1979) and even in individual taxa, these limits might vary with different sexes or different life-history stages (Lakshmiet.al; 1978; Venkatachari & Ambore, 1979).

The water temperature followed broadly identical pattern of fluctuations at four sampling stations in this study; it ranged between 9.5°C - 18.5°C in Umshing and 15.8°C - 25.8°C in Min-Mintudu stream. These variations evidently resulted from altitudinal differences of the two lotic systems. This study indicated a lower temperature range for the occurrence of M. hendersoni hendersoni as compared to M. lamarrei. This fact was also reflected from the previously commented distributional ranges of these two prawns wherein the former species was noticed to be restricted to altitudes at or above 1500 feet and M. lamarrei indicated common occurrence at lower altitudes of this region and elsewhere in this country. Sharma (personal communication) observed this species to tolerate temperature range of 18°C - 30°C in tropical waterbodies of West-Bengal. The seasonal abundance of M. hendersoni hendersoni indicated significant positive correlation with water temperature at both the stations. M. lamarrei also exhibited direct relationship with water temperature at both the stations in Min-Mintudu stream. At all the sampling stations, the higher densities of total prawns and that of individual species broadly coincided with the periods of high water temperature. However, quantitative abundance of total prawns registered only significant direct relationship with the factor at station B_1 in Min-Mintudu stream.

pH : It referred to the puissans or potential of hydrogen-ion activity and pH of natural waters was governed to large extent by the interaction of H^+ arising from dissociation of H_2CO_3 and from OH^- produced during the hydrolysis of bicarbonates. pH of most natural waters generally ranged between 2 - 12 and provided useful indirect information about alkalinity and photosynthetic activity (Welch, 1952). According to Goldman and Horne (1983), H^+- concentration controlled the chemical state of many nutrients including carbon-dioxide, phosphate, ammonia and trace elements. pH was also known to exert an influence on occurrence, diversity and distribution of aquatic organisms. Moreover, acidic ecosystems oftern supported more density of freshwater communities than alkaline waters within a certain range eventhough adverse effects highly acidic or highly alkaline waters were known to occur.

In this study, pH ranged between 5.4-7.5 and 5.3-7.4 at stations A,A_1 in Umshing stream and between 5.4-7.2 and 6.5-7.7 at stations B and B_1 in Min-Mintudu stream. Further, stations A and B exhibited more variations in pH in the present observations. The waters of the two streams could be classified as "bicarbonate type" following Wetzel (1983) and fluctuation appeared to be regulated by CO_2 - HCO'_3 - CO''_3 buffering system. Ling (1963) reported pH range 7 - 8 to be suitable for M. lamarrei while Truesdale and Mermilloid (1979) reported that M. ohione occurred at pH range between 6 - 8.4. In this study the observed pH ranges for M. hendersoni hendersoni and M. lamarrei were noticed to be 5.3-7.5 and 5.4-7.4 respectively. The present observations showed no significant correlation between the variations in pH and total prawns in the two streams while amongst individual taxa, only M. hendersoni hendersoni exhibited a significant positive correlation with this factor at station A_1 in Umshing stream.

Specific conductivity comprised and important index to measure electrical resistance or ionic condition of natural waters. Seasonal fluctuations in this factor were caused mainly by variations in the ionic precipitation and the diluting effect of rains (Welch, 1952 and Lickens et.al; 1970). The specific conductivity varied in the range of 34.2-68.2 umho/cm. and 31.8-65.2 umho/cm. in the certain hill streams of Meghalaya were recorded earlier by Goswami (1983). In the present study the conductivity values ranged between 12.0-62.0 umho/cm. and 34.0-72.2 umho/cm. in the two streams respectively. This might be attributed to lower ionic inflow from the catchment areas. This factor indicated no significant bearing in the abundance of total prawns in the stated habitats. However, amongst the two individual species only M. hendersoni hendersoni showed a significant direct relationship with specific conductivity at station A of Umshing stream.

Dissolved oxygen as an ecological factor participated in many important chemical and biological interactions. The level of oxygen concentration in aquatic environment depended on temperature, photosynthesis of autothrophs, respiration of the biotic communities and organic loading etc. Dissolved oxygen content ranged between 6.2 mg/l - 12.3 mg/l in the two streams and was found to vary inversely with the free carbon-dioxide. The increase in dissolved oxygen concentration during winter months could be attributed to the low temperature, while the drop during the summer months or early autumn might be due to lower densities of phytoplanktons (Sreenivasan, 1966; Sahai and Sinha, 1969). Total prawns registered significant direct correlation with oxygen content at the two sampling stations of Umshing stream while M. hendersoni hendersoni indicated positive correlation at station A_1. Moreover, total prawns and M. lamarrei showed no definite correlation with this factor at either of the two sampling stations in Min-Mintudu stream.

Carbon-dioxide dissolved in water produced carbonic acid, which dissociated into various fractions (HCO_3 - CO_3^{2}) and interacted with hydrogen-ion concentration. Free carbon-dioxide was detected throughout the period of these observations. This parameter exhibited a summer maxima and winter maxima at all the sampling sites. Carbon-dioxide concentration ranged between 6.2-12.3 mg/l and 6.4-11.8 mg/l in the two streams during the present study. Total prawns exhibited significant positive correlation with free carbon-dioxide at stations A and A_1 of Umshing stream while _M. hendersoni hendersoni_ showed no correlation with this factor. Further, _M. lamarrei_ showed no definite correlation with this factor at either of the two sampling stations.

Total alkalinity was reflected as a sum of carbonate and bicarbonate alkalinity. In this study, bicarbonates were solely/alone responsible for variations of total alkalinity concentrations. Alkalinity values recorded in the present study were seen to be maximum in summer and late autumn and minimum during winter months. The accumulation of larger quantities of bicarbonates during summer may be due to the liberation of carbon-dioxide in the process of decomposition of bottom deposits. Total prawns registered significant direct correlation with alkalinity at station A of Umshing stream while _M. hendersoni hendersoni_ showed no correlation with this factor. However, total prawns and _M. lamarrei_ showed no significant correlation with this factor at any of the stations in Min-Mintudu stream. The node of fluctuation of total alkalinity was relatively more irregular in Umshing stream than Min-Mintudu stream.

The major ions studied presently included Calcium, Magnesium, Sodium and Potassium. They were generally dissolved in quantities of at least $mg l^{-1}$ and in general varied only a little in concentrations during the study period were hence called 'conservative' ions (Wetzel, 1983) and their concentrations were not notably affected by the activities of living organisms. The first two factors undertaken for the detailed analysis were Calcium and Magnesium which constituted the most abundant ions in freshwater systems. Calcium was required as a micro-nutrient for algae though it was known to be a nutrient essential for metabolism of plants (Wetzel, 1983). Magnesium was another conservative ions which formed a major component of the chlorophyll molecule. In the present study, Calcium and Magnesium were seen to be very low in both the streams and they showed no definite pattern of fluctuations in any of the stations. Sources of Calcium for post moult calcification of the exoskeleton in crustacea includes free ionic Calcium available from blood, hepatopancreas (Travis, 1965; Huner et.al; 1978). This factor exhibited positive correlation with total prawns and *M. hendersoni hendersoni* at stations A and A_1 in Umshing stream but no significant correlation was noticed with total prawns and *M. lamarrei* abundance at stations B and B_1 in Min-Mintudu stream.

Among the other major ions, Sodium and Potassium were considered to be important in influencing the productivity of freshwaters

(Moss, 1983). Potassium was requred for all cells principally as enzyme activator and was present in larger quantities inside the cells of the aquatic biota than in the surrounding medium. Most water appeared to possess adequate supply of sodium for plant growth. These factors showed no definite correlation with total prawns and with M. hendersoni hendersoni and M. lamarrei. Monthly variations of sodium content in both the stations of Umshing stream followed identical process, while in Min-Mintudu stream it indicated different pattern. Min-Mintudu stream accounted higher variations in Potassium values than the Umshing stream and followed identical pattern except for some minor differences.

Phosphate-phosphorus was regarded as an essential microelement and was known to act as a limiting factor. Phosphorus was an average, the scarcest element in the earth's crust and was required primarily for algal and higher plant growth (Moss, 1983). It was found that phosphate increased during early summer months and decreased during winter. This factor varied 0.36-1.30 ug/l in Umshing stream and 0.31-1.40 ug/l in Min-Mintudu stream. This important nutrient factor indicated no significant bearing in the abndance of total prawns in either of the stated streams. However, amongst the two individual species only M. lamarrei showed a significant direct relationship with this factor at station B_1.

Silica played an intriguing role in aquatic systems, since it apparently accounted for the success of diatom communities. Silica was normally measured as 'reactive' silicate i.e., the molecule H_2SiO_4 and its short chain polymers. The difference in silica concentration in both the streams could be attributed to the lithological differences (Wang and Evans, 1969). This factor showed a significant positive correlation with M. hendersoni hendersoni and M. lamarrei at stations A and B respectively in the two species but showed no significant correlation with total prawns in any of the stations during the study period.

In aquatic habitat, organisms rely on rapid diffusion of ammonia across the gill membrane of exchange transport of NH_4 + with N_a+ (Cambell, 1974). In the present study ammonia nitrogen content exhibited marked seasonal fluctuations at all the sampling stations of Umshing and Min-Mintudu stream. The monthly concentration of this factor although showed multiple maxima at the different sampling sites but depicted no definite pattern in seasonal fluctuations. Ammonia-nitrogen content exhibited significant positive correlation with total prawns at station A of Umshing stream, while M. hendersoni hendersoni showed no significant correlation in any of the stations. Further M. lamarrei and total prawns exhibited no significant correlations in any of the stations with this factor.

During the present study, high values of oxidisable organic matters were recorded during summer and spring, presumably due to reduced precipitation and water logged condition. Min-Mintudu stream recorded higher load of oxidisable organic matter than Umshing stream. Min-Mintudu stream exhibited irregular whereas the later stream registered a broadly identical pattern in monthly variations of oxidisable organic matter. No significant directed correlation this factor was noticed with total prawns and M. hendersoni hendersoni. Further, M. lamarrei showed direct significant correlations with this factor at station B while total prawn showed no significant correlation in any of the stations of Min-Mintudu stream.

The presently investigated biotic factors were broadly categorised into several groups i.e., Benthos Phytoplankton and Zooplankton. Amongst benthic communities studied at the different stations, insect larvae comprised the predominant component at all the study sites. Decapoda, Nematoda, Oligochaeta came next in their quantitative importance while Gastropoda and miscellaneous group reflected lowest abendance. This study documented twenty four genera of insects, six genera of decapodes, four genera of nematodes, nine genera of oligochaetes, two genera of gastropodes and a miscelaneous group were recorded. The similarity index of benthic organisms between Umshing and Min-Mintudu streams was found to be 87% and higher ecological similarity was noticed between station A and B_1. These associations were attributed to identical substrate characteristics (mostly stony habitats) which were typical for hill streams of this region.

Both M. hendersoni hendersoni and M. lamarrei have been observed to be dependent on insect larvae as also noticed from detailed analyses of the joint contents. The exact reason for their dependency other than food relation (Subramanyam, 1963, Kuttayamma, 1974) was not clear from this study. The main habitat for the Ephemeropteran was comprised by 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 tibia (Jones, 1950). The nymphs of Baetis sp. were facultatively herbivorous grazing on periphyton and collecting detritus from clear stones in currents (Jones, 1950; Hynes, 1961; Champman and Demory, 1963). At all the stations they formed a major component of the insect fauna. Coleopterans, both adults and larvae, were present at all stations. Chironomids were the most abundant group of dipterans collected presently. They occurred in high numbers at all stations during the entire study. Insect larvae indicated no significant bearing on the abundance of total prawns in the stated habitats. However, amongst the two individual species M. lamarrei showed a significant direct relationship with this group at the station B.

Amongst the nematodes, Diplogaster and Chronogaster represented the most abundant component. They occurred in high numbers at all stations during the entire study. Min-Mintudu stream reflected relatively higher population of this group than Umshing stream. Data on the 'y' values revealed that only M. hendersoni hendersoni exhibited significant positive correlation with nematodes while M. lamarrei showed no correlation at any of the stations during the present investigations. Moreover, total prawns showed no significant correlation at any of the stations with this group. Allonias and Chaetogaster were important taxa of oligochaetes in both the streams. No definite trend of fluctuation was observed in any of the stations during the present study. This group indicated no significant bearing on the abundance of total prawns in the stated habitats. However, amongst the two individual species M. lamarrei showed a significant direct relationship with oligochaetes at station B.

Data on 'r' values revealed that M. hendersoni hendersoni and M. lamarrei and total prawns showed no significant direct relationship with decapod group at any of the stations of these streams. Further

in any of the the sampled stations. Potamon and Paratelphusa were recorded in both the streams. M. kistnensis and M. dayanum were also recorded in all the stations during the present investigation.

The gastropod fauna was very poorly reported and might be due to low availability of Calcium and food (Bishop, 1973). This group exhibited no significant relationships with the abundance of total prawns or with the two individual species in the stated habitat. Moreover, no definite trend of gastropod fluctuation was observed in any of the stations. The miscellaneous group exhibited no positive correlation in the total abundance of total prawns and individual two species in any of the stations of the stated habitats. Amongst the members/this group Turbellaria were generally carnivorous (Dittmar, 1955; Macan, 1962) and the probable diet might be nymphs, chironomid larvae. Dugesia was also recorded during the course of present study.

Phytoplankton communities were characterised by dominance of Bacillariophyceae, chlorophyceae, chrysophyceae and Myxophyceae in Umshing stream while Dinophyceae and Rhodophyceae were dominant in Min-Mintudu stream. The similarity index of Phytoplankton composition between Umshing and Min-Mintudu stream was noticed 72.0% and maximum similarity was reflected between station A and A_1 at Umshing stream followed by station A_1 and B_1. This was probably due primarily to the identical habitat nature of the mentioned sampling stations.

Bacillariophyceae indicated direct positive significant bearing in the abundant of total prawns and M. hendersoni hendersoni in the stated habitats. While M. lamarrei showed positive correlation in both the stations of Min-Mintudu streams but no significant correlation was noticed between total prawns with this group in this stream. Steur (1910) advocated the potamoplankton as an ecological group of organisms living and breeding in lotic ecosystems and consisting principally of diatoms like Melosira, Synedra, Fragillaria which were also noted in the present study. The diatom communities exhibited no definite trend of fluctuation at any of the stations.

M. hendersoni hendersoni and M. lamarrei and total prawn population revealed positive significant correlation with chlorophyceae at stations A, A_1 in Umshing stream and B in Min-Mintudu stream. Moreover, green algae reflected no definite pattern of quantitative fluctuations at any of the stations.

The composition of Chrysophyceae of both the streams showed dominance of Dinobryon, Ochromonas followed by Bitrichia and Chrysidiastrum. No definite trend of fluctuation was noticed in the total abundance at any of the stations. This group exhibited significant positive correlation in the abundance of total prawns and M. hendersoni hendersoni in Umshing stream while no significant relation was noticed with total prawn , except with M. lamarrei at station B. Myxophyceae showed direct positive correlation with total prawns at station A but showed no correlation with the individual of prawn population in either of the stations.

Rhodophyceae were represented by Lamnea and Batrachospermum in both the streams and exhibited no significant bearing correlation with total abundance of prawn and individual species in any of the stations. However, no definite trend of fluctuation was observed in any of the stations. This group indicated no significant bearing on total abundance of prawns and individual species in the stated habitats.

Zooplankton comprised of eight genera of Protozoa, seven genera of Rotifera, one genus of Copepoda and five genera of Cladocera. Protozoans did not show any definite pattern of fluctuation in any of the stations. At station A, A_1 the rotifer group exhibited slightly regular pattern of quantitative abundance while B,B_1 stations of Min-Mintudu stream showed irregular pattern of their densities. Copepoda and Cladocera showed no definite pattern of fluctuation; while cladocera showed variations only at station B in Min-Mintudu stream. The similarity index between total zooplankton in two streams was noticed to be 70%. Further the maximum similarity was noticed between station A and B.

Protozoans showed significant correlation with total prawns and individual prawns at station A and B_1, while no significant correlation was seen in the stations A_1 and B of Umshing and Min-Mintudu streams. Lecithium, Vorticella constituted the dominant taxa in both the streams. No definite pattern of fluctuations was observed in any of the stations during the present study period.

The rotifers invariably comprised an important component of zooplankton in freshwater ecosystems. They form an integral link in the aquatic food-chain and contribute significantly to zooplankton dynamics. The rotifers also serve as valuable indicators of trophic conditions of water quality (Sladecak, 1983). Rotifers were known to feed largely by sedimenting seston particles into their mouth orifice cilia (Pourriot, 1965; Hutchinson, 1967). Brachionus, Keratella formed important fraction of this group and occurred at all the stations throughout the study period. This group recorded maximum abundance during summer in Umshing and in Spring in the other stream. Such a pattern was also observed earlier by other Indian workers IVasisht and Dhir, 1970; Sharma, 1978). This group showed a significant correlation with the total prawns and M. hendersoni hendersoni at stations A and A_1 but showed no significant correlation with total prawns while showed positive correlations M. lamarrei with this group at stations B and B_1.

Copepoda indicated no significant bearing on the abundance of total prawns and M. lamarrei in the stated habitats. However, M. hendersoni hendersoni showed a significant direct relationship with this group at station A. The peak exhibited by the Copepodes may be indicative of their active period of reproduction as was suggested by Michael (1968) and Sharma (1978). Cyclop was the single genus recorded from both the streams. Cladocera showed significant positive correlation with the total prawns and M. hendersoni hendersoni in both the stations of Umshing stream while it showed no significant correlation at station B with total prawns and M. lamarrei. Altona and Chydorus represented in all the habitats sampled. The quantitative abundance of cladocera reflected notable seasonal fluctuations at all the study sites.

Palaemonid freshwater prawns M. hendersoni hendersoni and M. lamarrei were commonly available in the hill streams of Umshing and Min-Mintudu stream respectively. Seasonal fluctuations were noticed in both these two freshwater prawns. During the course of present study, the abundance of M. hendersoni hendersoni was recorded higher in comparison with M. lamarrei. The maximum density recorded during summer and minimum during winter. Monthly densities of total prawns in Umshing stream ranged between 36-71 ind./m^2 and 48-74 ind./m^2 at station A and A_1 respectively. Station A indicated higher overall quantitative abundance during the first annual cycle as compared with the second annual cycle. While in Min-Mintudu stream, the quantitative abundance of total prawns at stations B, B_1 ranged between 37-77 ind./m^2 and 38-76 ind./m^2 respectively. During the first annual cycle , the catches of M. hendersoni hendersoni ranged between 18 ind./m^2 - 55 ind./m^2 in

Umshing stream and M. lamarrei ranged between 19-57 ind./m^2. However, both the stations of Umshing stream maintained higher populations in the first annual cycle and the pattern of fluctuations indicated differences at both the stations. However, both the stations of Min-Mintudu stream exhibited a unimodal pattern of fluctuations. The variations in the density might be attributed to different factors such as food availability, gonadal maturity, abiotic factors, predatation pressure etc. The extent of structural dynamicity of both these two prawn individuals were clear from their length frequency distribution. Both these individuals were grouped into six size classes viz., 20.0-30.0 mm; 30.0-40.0 mm; 40.0-50.0 mm; 50.0-60.0 mm; 60.0-70.0 mm and 70.0-80.0 mm. Under size classes 20.0-30.0 mm and 60.0-70.0 mm, M. hendersoni hendersoni and M. lamarrei varied between 1 ind./m^2 (April, 1982) - 20 ind./m^2 (July, 1983), 2 ind./m^2 (April, 1983) - 1 ind./m^2 (March,1983) and 1 ind./m^2 (February, 1984) - 20 ind./m^2 (August, 1984), 2 ind./m^2 (April, 1983) - 11 ind./m^2 (March, 1983) respectively. However in Umshing stream during second annual cycle at station A the prawn population of various length frequency classes exhibited similar trend of fluctuations. Recruitment of lower size groups might be attributed due to breeding and larger size group due to growth. The main reason for low population densities appeared to be the paucity of aquatic macrophytes. The stream in which Caridina singhalensis was studied contained dense beds of vegetation in many places (Benzie & De Silva, 1988). This generalisation was agreed with the present findings. Breeding season for both the individual prawns appeared to be from June-September during each annual cycle. Among ecological factors affecting breeding in these prawns, temperature appeared to be the most important. Temperature atyids predominantly breed in summer but the breeding season usually extended from Spring-autumn (De Silva and De Silva, 1988). According to Raman and Menon (1961), the prawn catches appeared to follow the pattern of rainfall. Fecundity was found to be higher in summer in both the annual cycles for both the individual prawns. The overall pattern of egg production of *M. hendersoni hendersoni* was primarily unimodal in the first annual cycle at station A, being maximum fecundity (46 ± 6 eggs/ind.) was noticed in August, 1983 and minimum (21 ± 8 eggs/ind.) in April, 1984 while in the other stream it varied between 20 ± 5 egg./ind - 46 ± 6 egg./ind. In *M. hendersoni hendersoni* the highest sex ratio was noticed in August, 1984 (6 :1) at station A and station A_1 registered (5 :1) in July, 1984. *M. lamarrei* accounted highest (6 : 1) in April, 1983 at station B while B_1 exhibited (5 :1), August, 1984. Environmental factors play a great role in the sex ratio and bredding behaviour of the prawns (Rajyalakshmi, 1968).

The studies on the monthly fluctuation of condition ('k') factor in *M. hendersoni hendersoni* and *M. lamarrei* showed higher values for the young populations than the mature and post mature individuals. Higher condition factors other than spawning such as food, abiotic factors effect the relative condition. Le Cren (1951) found that nearly all the differences between seasonal values of relative conditions for mature and immature perch were due to cyclic changes in gonad weight. The seasonal fluctuations might reflect the spawning cycle as the 'k' was influenced by the gonads. 'K' values also revealed that male prawns were having better condition than the female, thereby exhibiting narrow ecological amplitude by females over males.

From the foregoing account it was evident that there were significant direct relationship between total prawns and pH, dissolved oxygen, free carbon-dioxide, total alkalinity, calcium and with individual groups like Bacillariophyceae, chlorophyceae, chrysophyceae, Dinophyceae, protozoa, Rotifera, Copepoda in Umshing stream. Moreover, M. hendersoni hendersoni exhibited direct relationship with water temperature, specific conductivity, dissolved oxygen, free carbon-dioxide, calcium, phosphate-phosphorus, silicate and oxidisable organic matter in Umshing stream. The other parameters did not yield any definite relationships. While in Min-Mintudu stream total prawn exhibited significant positive correlation with water temperature, chlorophyceae, protozoa, rotifera, cladocera. In addition M. lamarrei exhibited significant positive correlation with water temperature, phosphate-phosphorus, oxidisable organic matter, insecta, oligochaeta, Bacilliriophyceae, chrysophyceae, Myxophyceae, protozoa and rotifera. The other parameters did not show any definite relationships. It may, however be accounted that no single factor has been found to have profound influence on the fluctuation. It is likely that production of phyto and zooplankton populations were governed by the cumulative or conjoint action of a set of several physico-chemical factors.

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Some aspects of Biology of *Macrobrachium hendersoni hendersoni* and *M. lamarrei*

INTRODUCTION

Prawn fishery has been receiving considerable attention in India, in the past couple of decades, because of the increasing export of these decapod crustaceans. Over-exploitation of natural stocks of the prawns from their breeding grounds had seriously effected their yield - thereby, indicating the need to focuss more emphasis on the mass culture of selected economically viable species. Most of these attempts primarily involved the rearing of brackish water or marine forms notably Penaeus monodon and various species of the genus Metapenaeus. The culture practices in freshwater prawns, however, deal with Macrobrachium rosenbergii and M.malcolmsonii. There is practically no attempt in India to rear other freshwater species belonging to Macrobrachium, at least to meet local or regional fishery demands.

In order to take up any culture practices, it is desirable to understand different aspects of biology of the selected target species from various parts of this country. A few important parameters, relevant to the success of any subsequent aquaculture operation, involve a knowledge of the food and feeding habits, the nature and amount of the food taken, feeding activity and its duration, optimum utilization of the food given to the organism, the effect of various environmental factors on the feeding behaviour and the relationship between feeding activity and the onset of gonadal maturation (Marte, 1982). Investigations on food-intake, growth and conversion efficiency on Indian species of freshwater decapod crustaceans were completely lacking till the laboratory studies conducted (Katre & Reddy, 1977) on Macrobrachium lamarrei.

Some general information on the food and feeding habits of the prawns was provided in the works of Patwardhan (1937), Chopra (1939), Gopalkrishnan (1952), Panikkar (1952), William (1958), Eldred et.al (1961), Subramanyam (1963), Dall (1968), George (1972), Thomas (1972), Katre et.al (1977), Marte (1980), Rajyalakshmi (1980) and Ponnuchamy et.al (1981). Information related to the prawn species occurring in the streams of sub-tropical India is still much confined (Goswami, 1983). One aspect of the biology of this study, therefore, dealt with the observations on the seasonal changes of the composition of food items and gastro-somatic index of two commonly available prawns i.e., Macrobrachium hendersoni hendersoni and M.lamarrei based on the population collected from the different stream-systems in East Khasi Hills and Jaintia Hills district respectively of Meghalaya State.

Larval development, yet another important aspect of the biology of these organisms (Dobkin, 1969) is poorly investigated with regards to Indian species of freshwater prawns. Amongst about 34 species of the palaemonid prawns of the genus Macrobrachium expected to occur in the inland and estuarine waters in this country(Tiwari, personal communication), the larval history has been worked out so far only in five species. These include M.lamarrei (Das, 1935; Rajyalakshmi, 1961; Sharma & Tiwari, 1978), M.malcolmsonii (Kewalramani et al.1971), M.idella (Pillai & Mohammad, 1973), M.hendersodayanum (Jalihal & Sankolli, 1975) and M.kistensis (Nagabhushanam & Kulkarni, 1979). Some other important studies on the larval stages of fresh-water prawns are those of Ling & Merican (1961), Ling (1969), Lewis & Ward (1965), Uno & Kwon (1969), Kwon & Uno (1969), Fielder (1970), Shokita (1970, 1973), Williamson (1972), Chong and Khoo (1987). This chapter deals with the larval development of common hill stream prawn, Macrobrachium hendersoni hendersoni and also that of a stream dwelling population of the more widely distributed M.lamarrei. The different observed larval stages are described in the present account and their comparison is made with the larval development of various other previously investigated species.

MATERIALS AND METHODS

Food and feeding habits : The specimens of *Macrobrachium hendersoni hendersoni* from Umshing stream and *M. lamarrei* from Min-Mintudu stream collected for the ecological study were used to examine the food and feeding habits. The guts were removed after measuring and weighing each prawn; their weights were also taken and then they were preserved in 10% formalin. A total of 360 and 424 digestive tracts respectively of the above mentioned species were studied. The preserved guts were later uncoiled and cleaned to analyse various food items.

The quantitative analysis of the gut contents was made by following the works of Venkataraman (1970) and Marte (1980). Gut contents were screened microscopically for food organisms and to determine their frequency of occurrence. Identification was primarily based on the different remains. These observations were made on the specimens collected between January, 1983 - December, 1983.

The gastro-somatic index (GSI) was calculated by the following formula (Desai, 1970):

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

The variations in gastro-somatic index of male and female of both *M. hendersoni hendersoni* and *M. lamarrei* were recorded between January, 1983 - December, 1984).

Larval development : Berried females of Macrobrachium lamarrei were collected from Min-Mintudu stream, Jaintia Hill district and that of M.hendersoni hendersoni from Umshing stream, East Khasi Hill district of Meghalaya state. These were kept in aquaria in the laboratory. The aquasystems were maintained under continuous water circulation and aeration. The observations on the larval development of M.lamarrei was made in June, 1983 and September, 1984 and that on M.hendersoni hendersoni in April, 1983 and August, 1983 respectively.

The berried females were fed with cut pieces of earthworm and sometimes with cooked rice. The unconsumed food matter was removed about half an hour after feeding 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. The larvae emerging out following the hatching were removed from the jars.

The rearing of the newly emerged larvae was carried out in glass beakers of 250 ml. capacity; 3-4 larvae were kept in each beaker with about 150 ml. of stream water and covered on top with fine muslin cloth to prevent settling of dust particles. A few specimens of each larval stage were preserved in 5% formalin mixed with glycerine (9:1). Exuviae were also collected and preserved likewise. Morphemetric measurements were made with an ocular-micrometer.

The different larval appendages were dissected and mounted in Polyvinyl alcohol-lectophenol mixture. Appendages dissected from the exuviae also gave good results. All the drawings are made with camera-lucida and measurements recorded in millimeters (mm).

OBSERVATIONS

Food and feeding habits : Macrobrachium hendersoni hendersoni and M. lamarrei are observed to be omnivorous in their feeding habits. The food is picked up by the chelate legs and then taken to the mouth. The second and third pairs of maxillipeds held the food in position for the mandibles to cut the food into small pieces by their incisor process. In the mouth cavity, the molar processes of the mandibles crushed the food which was subsequently passed to the cardiac stomach through the oesophagus.

The examined foregut contents of the two prawn species have been broadly grouped into ten categories. These include : i) filamentous algae (ii) other algae (iii) diatoms (iv) nematodes (v) detritus (vi) sand and silt particles (vii) crustaceans (viii) insect larvae (ix) mosses and plant matter (x) miscellaneous groups comprising gastropod remains and other unidentified matter.

Composition of the food items of M. hendersoni hendersoni (De Man) :

The food of this species included all the above mentioned items. However, some groups were comprised by the following taxa :

Diatoms : Synedra, Navicula, Fragillaria, Amphora, Caloneis.
Insect larvae : Chironmous Simulium, Baetis, Micronecta, Caenis.
Crustacea : Bosmina, Moina, Cyclops.

Filamentous algae : Spirogyra, Nostoc, Oscillatoria.

Other algae : Cosmarium, Netrium, Penium, Pediastrum.

Nematodes : Diplogaster, Chronogaster and also some unidentified diplogasterid.

Mosses and plant matter : Hydrilla, Lemna and also some unidentified leaves.

An average total percentage composition of the different food-items of M. hendersoni hendersoni during the study period, is shown in figure (53). The most dominant food item was comprised by the diatoms (17.59%), the other groups (as mentioned in the decreasing order) included : insect larvae (16.27%), detritus (12.57%), sand and silt particles (11.72%), filamentous algae (9.64%), other algae (9.47%), nematodes (9.39%), crustacea (6.97%), mosses and plant matter (5.57%) and miscellaneous items (0.64%).

Variations in the composition of different food-items :

Variations in the percentage composition of different food-items in M. hendersoni hendersoni (during the period of observations) are analysed in two size-groups i.e., group I (Total length : 20.0mm-50.0 mm) and group II (Total length : 50.1 mm - 80.0 mm). The same are also represented in Fig. 54 and briefly commented below :

Size-group I : The contribution of diatoms, insect larvae, detritus, sand and silt, filamentous algae and other algae fluctuated between 14.6% (May) - 21.2% (November), 14.7% (February)- 25.0% (July), 8.7% (July) 15.9% (December), 2.61% (January) - 18.2% (July) 6.8% (February) - 10.6% (July) and 5.4% (February) - 9.3% (October) respectively.

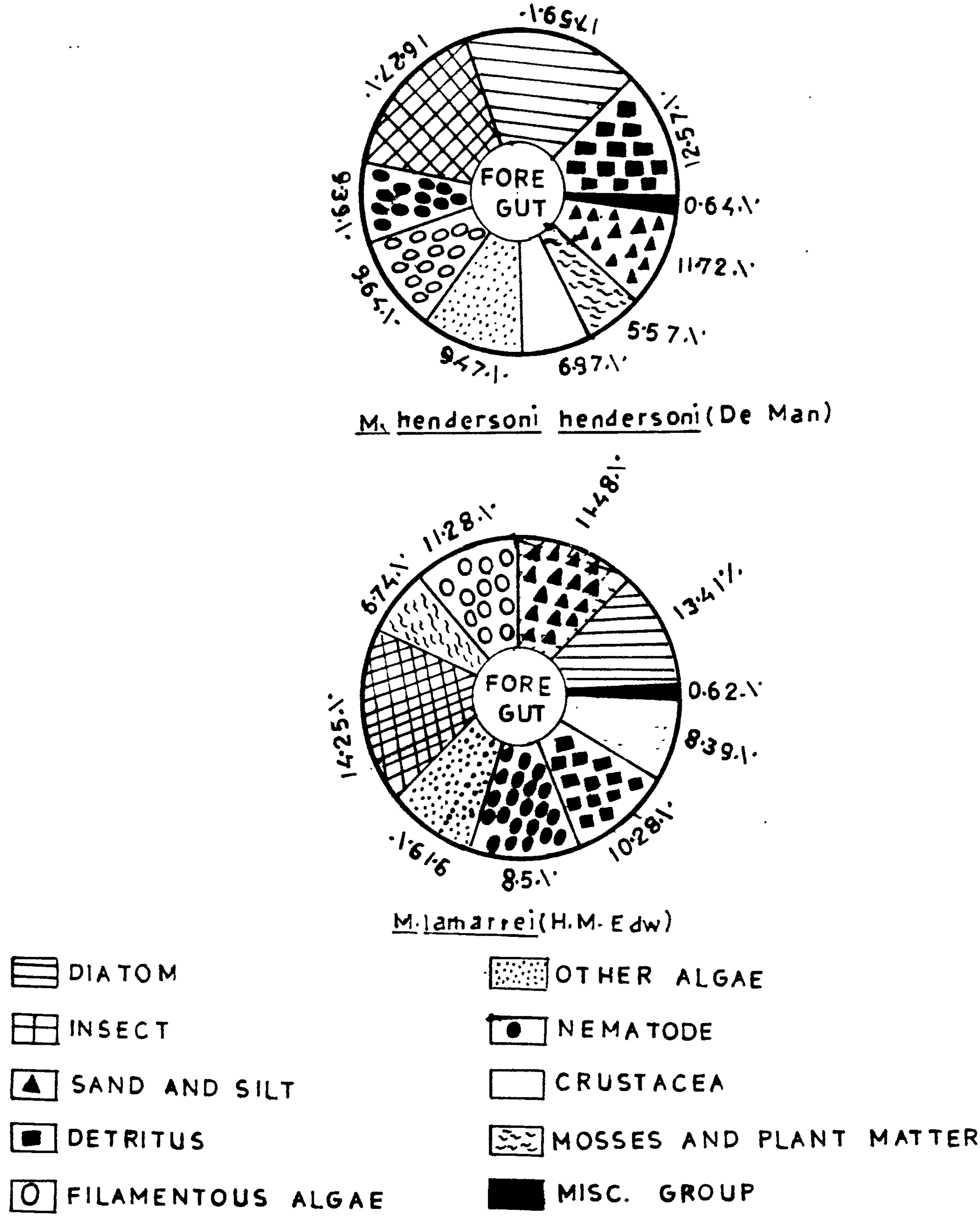

Fig. 53. Average percentage composition of different food items in <u>Macrobrachium hendersoni hendersoni</u> and <u>Macrobrachium lamarrei</u>.

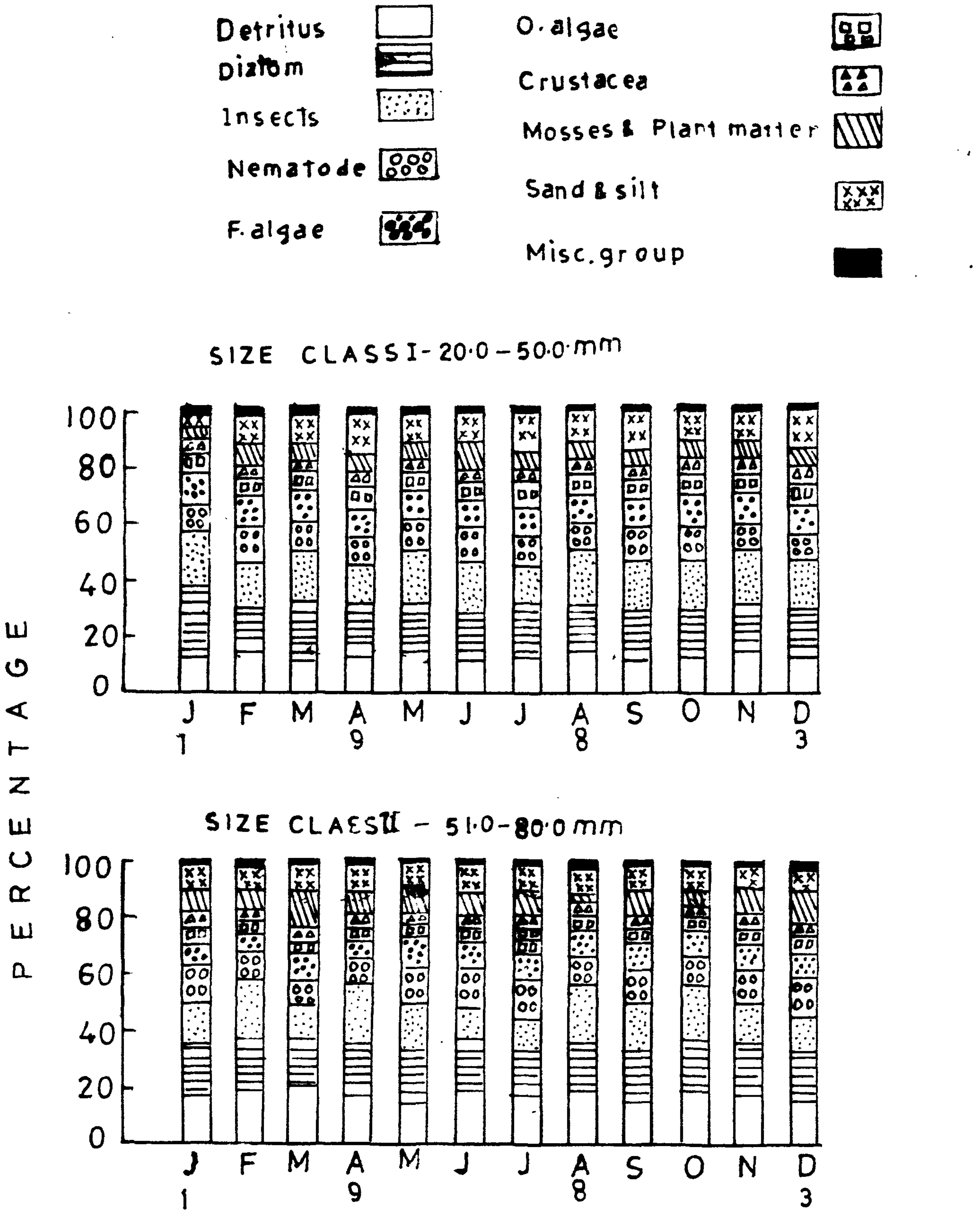

Fig. 54. Monthly fluctuations of the food-items in the foregut of <u>Macrobrachium hendersoni hendersoni</u> (De Man).

Other algae, nematodes, crustaceans, mosses and plant matter and miscellaneous items comprised between 8.8% (July) - 13.7% (November), 3.8% (January) - 10.3% (May), 2.7% (February) - 7.8% (September) and 0.2% (January) - 1.0% (August).

Size group II : The percentage composition of diatoms, insect larvae, detritus, sand and silt particles, filamentous algae, other algae, nematodes, crustaceans, mosses and plant matter and miscellaneous group fluctuated in the individuals of this size class between 12.6 (May) to 15.8 (November), 13.2 (May) to 22.5 (December), 6.2 (February) to 25.8 (September), 05.6 (May) to 15.7 (December), 8.7 (March) to 13.4 (November), 6.8 (February) to 13.9 (October), 6.4 (April) to 10.7 (October), 6.9 (May) to 10.0 (October), 4.5 (February) to 8.6 (September) and 0.3 (January) to 1.2 (April) in 1983 respectively.

From the above data it was noticed that the overall composition of the different food-items in the foregut of M. hendersoni hendersoni fluctuated reasonably. The percentage composition of diatoms ranged from 12.6 (May) 21.2 (November), insect larvae 13.2 (May) to 25.0 (July), detritus 6.2 (February) to 25.8 (August), sand and silt 2.61 (January) to 18.2 (July), filamentous algae 6.8 (February) to 13.4 (November), other algae 5.4 (February) to 13.9 (October), nematodes 6.4 (April) to 13.7 (November), crustaceans 3.8 (January) to 10.3 (May), mosses and plant matter 2.7 (February) to 8.6 (September) and the miscellaneous items varied between 0.2 (January) to 1.2(April) during the present observations.

Composition of the food of *M.lamarrei* (H. Milne-Edw)

The contents of *M. lamarrei* also contained all the categories mentioned earlier but the details of some of these groups were as below :-

Diatoms : *Amphora*, *Navicula*, *Synedra*.

Insect larvae : *Oecetis*, *Limonia*, *Micronecta*, *Caenis*, *Chironomous*, *Hydrometra*.

Filamentous algae : *Spirogyra*, *Zygnema*, *Oscillatoria*, *Calothrix*, *Eodogonium*.

Other algae : *Cosmarium*, *Dinobryon*, *Mallamonas*, *Closterium*.

Crustacea : *Daphnia*, *Moina*, *Cyclops*.

Nematodes : *Diplogaster*, *Lebronema*, *Aphelenchoides*.

Mosses and plant matter : *Hydrilla*, *Quercus*, *Wolffia*.

An average yearly percentage composition of different food-items in the foregut of this species is illustrated in the fig. (53). The insect larvae comprised most dominant items (14.24%), the rest of the items in descending order were constituted by : diatoms (13.4%), sand and silt (11.48%)m filamentous algae (11.28%), detritus (10.28%), other algae (9.19%), nematodes (8.5), crustaceans (8.39%), mosses and plant matter (6.74%) and miscellaneous group (0.62%).

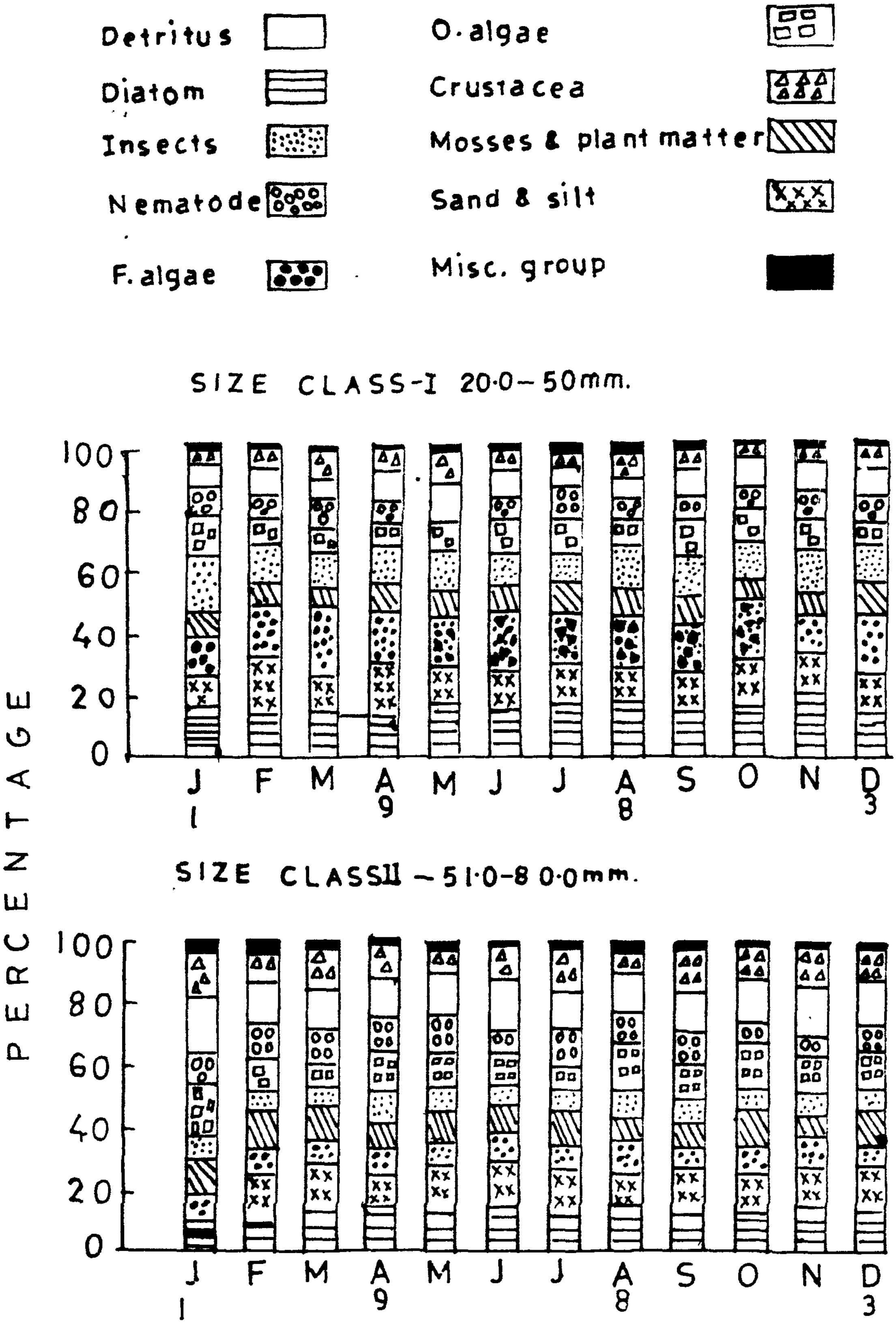

Fig. 55. Monthly fluctuations of the food-items in the foregut of Macrobrachium lamarrei (H. Milne-Edw.).

Monthly fluctuations of the food composition

The monthly variations in the percentage composition of the different food-items among the individuals of two different size groups (Total length : 20.0 mm - 50.0 mm and 50.0 mm - 80.0 mm) of *M. lamarrei* (Fig.55) were briefly indicated below :

Size group I (20.0 mm - 50.0 mm) : The percentage composition of various groups i.e., insect larvae, diatoms, sand and silt, filamentous algae, detritus, other algae, nematodes, crustaceans, mosses and plant matter and miscellaneous groups fluctuated in the range of 8.4 (February) to 17.2 (June), 10.8 (July) to 21.0 (November), 8.5 (June) to 14.0 (October), 8.7 (June) to 12.0 (September), 3.0 (March) to 18.4 (November), 6.5 (February) to 13.8 (November), 7.0 (June) to,9.0 (September), 2.9 (April) to 16.0 (August), 2.9 (April) to 17.2 (June) and 0.2 (April) to 1.0 (August) in the year 1983.

Size group II (50.1 mm - 80.0 mm) : The percentage composition of insect larvae, diatoms, sand and silt, filamentous algae, detritus, other algae, nematodes, crustaceans, mosses and plant matter and miscellaneous group fluctuated in the range of 12.0 (August) to 24.5 (December), 10.5 (March) to 17.7 (July), 9.0 (January) to 15.0 (May), 9.6 (February) to 15.0 (July), 3.4 (April) to 15.8 (December), 6.6 (February) to 12.8 (November), 9.0 (January) to 14.0 (April), 2.8 (February) to 24.0 (October), 1.5 (February) to 10.6 (July) and 0.5 (March) to 1.4 (August) in the year 1983.

From the above findings, it was noticed that the overall percentage composition of the different food-items in the foregut of M. lamarrei exhibited certain fluctuations. The percentage composition of insect larvae ranged from 8.4 (February) to 24.5 (December), diatoms 10.8 (July) to 21.0 (November), sand and silt 8.5 (June) to 14.0 (October), filamentous algae 8.7 (June) to 15.0 (July), detritus 3.0 (March) to 18.4 (November), other algae 6.5 (February) to 13.8 (November), nematodes 7.0 (June) to 14.0 (April), crustaceans 2.8 (February) to 24.0 (October), mosses and plant matter 1.5 (February) to 17.2 (June) and miscellaneous group 0.2 (April) to 1.4 (August) throughout the year.

Gastro-somatic Index :

The monthly fluctuations of gastro-somatic index values in different size groups of M. hendersoni hendersoni and M. lamarrei are indicated in table (13). The pattern of variation in gastro-somatic index in male and female specimens of both the mentioned species are plotted in Fig. 5 6.

G.S.I. value in M. hendersoni hendersoni individuals of size group 20.0 - 50.0 mm was recorded maximum in October, 1983 (3.507) and minimum in February, 1983 (1.983), whereas in size group 50.1-80.0 mm maximum value of 3.154 was noticed in August, 1984 and minimum (2.032) in February, 1983.

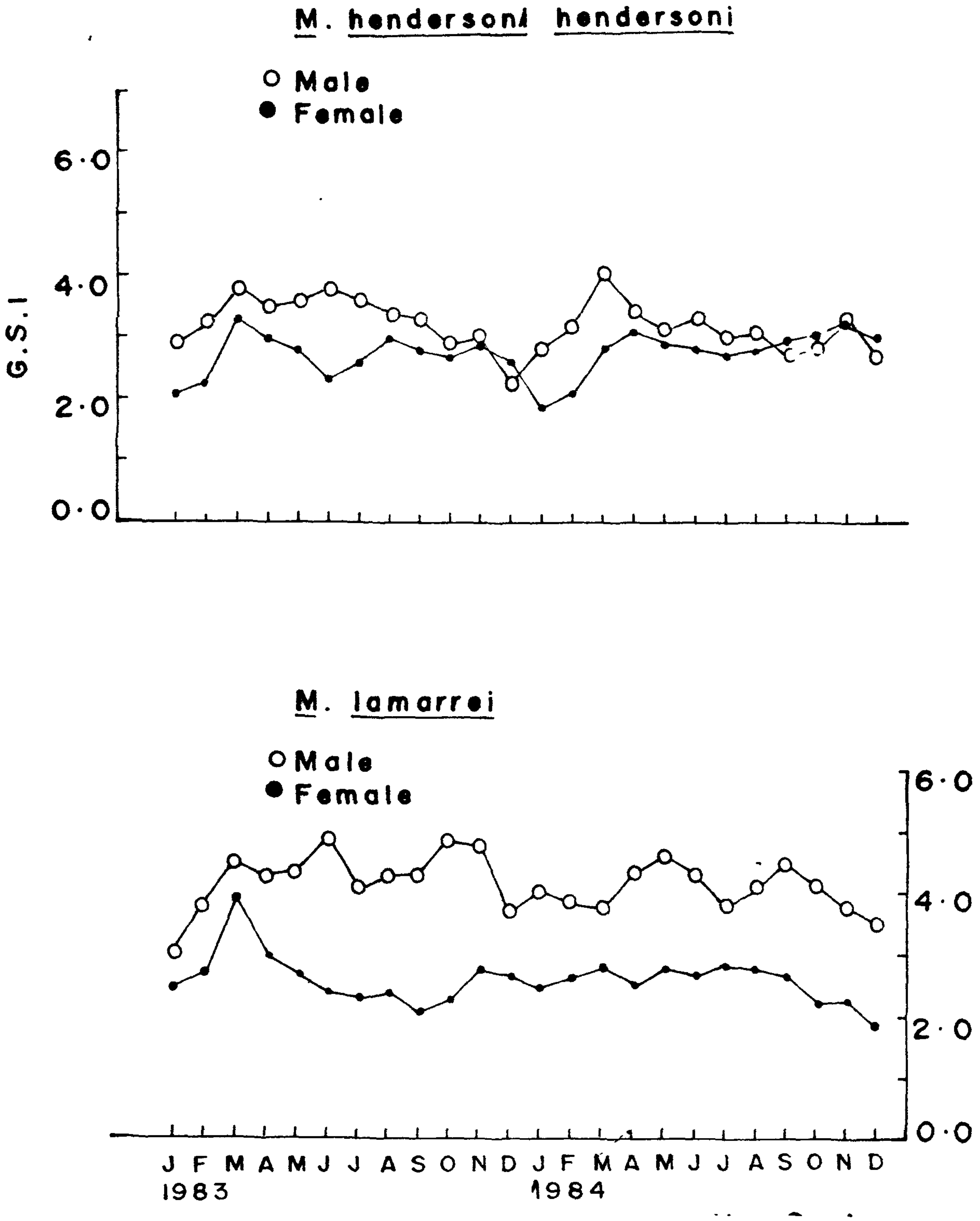

Fig. 56. Monthly fluctuations in the Gastro-Somatic Index of male and females of Macrobrachium hendersoni hendersoni and Macrobrachium lamarrei.

Table : 13

Monthly fluctuations in the average gastrosomatic index (G.S.I.) of M. hendersoni hendersoni and M. lamarrei

Months	M.hendersono hendersoni Size group (mm)		M.lamarrei Size group (mm)	
	20.0 - 50.0	50.1 - 80.0	20.0,- 50.0	51.0 - 80.0
1983				
J	2.510	2.600	2.142	2.150
F	1.983	2.031	2.350	2.309
M	2.087	2.667	2.267	2.845
A	2.400	2.599	2.031	2.500
M	3.150	2.498	2.651	2.192
J	2.840	3.104	3.402	3.316
J	3.105	2.940	2.549	2.569
A	2.405	2.394	2.681	3.108
S	2.145	2.250	2.183	3.059
O	3.507	2.808	2.159	2.563
N	2.152	2.438	3.150	3.049
D	2.510	2.659	2.873	2.069
1984				
J	2.403	2.190	2.430	2.643
F	2.721	2.803	2.413	2.409
M	2.381	2.078	3.409	2.987
A	2.055	2.195	2.530	3.105
M	2.891	2.903	2.400	2.873
J	3.486	2.479	2.362	2.703
J	3.072	2.398	2.414	3.105
A	2.691	3.154	3.050	3.509
S	2.570	3.094	3.104	2.964
O	2.258	2.157	2.651	2.593
N	2.853	2.542	2.275	2.654
D	2.557	2.194	2.053	2.987

In <u>M. lamarrei</u> G.S.I. value maximum (3.409) was recorded in March, 1984 in size group 20.0 - 50.0 mm and minimum (2.0535) in December, 1984. The size group 50.1 - 80.0 mm exhibited maximum GSI value (3.509) in August, 1984 and minimum (2.0692) n December, 1983.

The male of <u>M. hendersoni hendersoni</u> recorded maximum G.S.I. values in March, 1984 and minimum in December, 1983. The female exhibited peak in March '83 and minimum in December '83. The male of <u>M. lamarrei</u> exhibited peak in June'83 and lowest in January'83 while female shows maximum and minimum G.S.I. values in March, 1983 and December, 1984 respectively.

LARVAL DEVELOPMENT IN <u>Macrobrachium lamarrei</u> (H. Milne Edwards)

The eggs of <u>M. lamarrei</u> were yellowish green in the early stages and were broadly oblong in their outline (average size : 0.85 mm x 0.58 mm - 0.95 mm x 0.62 mm). A large amount of yolk was distinctly visible on those eggs on the onset of the cleavage. Various morphological changes involving embryonic development in these eggs were broadly identical with these noticed in <u>M. hendersoni hendersoni</u>. During the later stage of development, the colour of the eggs became yellowish brown. The embryonic development lasted for about 12 days (range : 10-14 days). Before emergence, the larvae showed distinct heart-beat and wriggling movements with the eggs. The larvae emerged through a tearing in the egg membrane and sank passively to the bottom of the vessel (beaker). However, they started swimming within a few movements and aggregated on one side of the container.

This species indicated three larval stages. The detailed description of the same, alongwith the post-larvae are given in the ensuing pages.

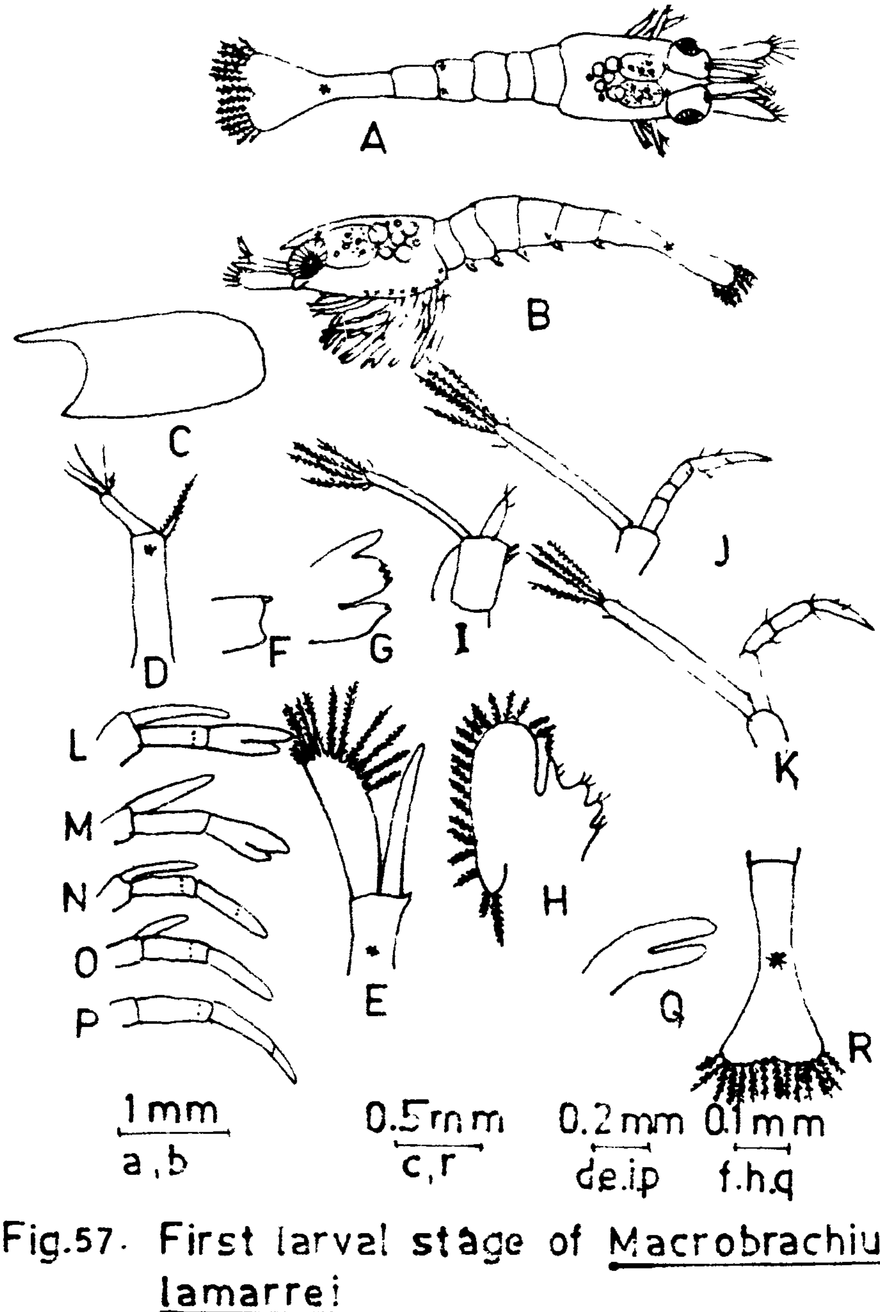

Fig.57. First larval stage of Macrobrachium lamarrei

First larval stage

(Figs. 57)

General characters : (Fig. 57, A,B). Larva transparent; Carapace smooth and with distinct pterygostomian spines at antero-ventral edges. Rostrum unarmed. Eyes sessile. Antennule, antenna and mouth parts developed. Five pairs of peraeiopods present and fifth pair uniramous; first two pairs of peraeiopods chelate and nonfunctional. Abdomen with six segments and with five pairs of pleopods. Telson not separated from 6th abdominal segment. Large amount of yolk granules present under the carapace.

The specific morphological details of the different appendages are as indicated :

Antennule (Fig. 57D) : Both stylocerite and antero-lateral spines prominent and sharply pointed. Antennular peduncle long, slender are unsegmented; carrying two flagella, inner one long, slender and plumose, outer stumpy, bearing four aesthetes and one short spine-like plumose inner seta.

Antenna (Fig. 57E) : Endopod stout (antennal peduncle) unsegmented process reaching beyond the exopod margin. Exopod distict, plate like and its inner margin carrying 10 or 11 plumose setae at the distal extremity of its external border.

Mandible (Fig. 57F) : Large and prominent; no demarcation between the incisor and molar parts; one sharp tooth in the upper incisor region, molar region almost smooth. Palp absent.

Illustration

Fig. 57 : First larval stage of *M.lamarrei* : A - dorsal view; B - lateral view; C - carapace; D - antennule; E - antenna; F - mandible; G - maxilla I; H - maxilla II; I-K. maxillipeds I - III; L - P. peraeiopods; Q - Pleopods; R - telson.

Fig. 58 : Second larval stage of *M.lamarrei* : A - dorsal view; B - lateral view; C - carapace; D - antennule; E - antenna; F - mandible; G - maxilla I; H - maxilla II, I-K. maxillipeds; L-P. peraeiopods; Q - pleopod; R-telson.

Fig. 59 : Third larval stage of *M.lamarrei* : A - dorsal view; B-lateral view; C - carapace; D - antennule; E - antenna; F - mandible; G - maxilla I; H - maxilla II; I-K. maxillipeds; L-P. peraeiopods; Q - pleopod; R - telson and uropod.

Fig. 60 : Post larval stage of *M.lamarrei* : A - dorsal view; B - lateral view; C - carapace; D - antennule; E - antenna; F - mandible; G - maxilla I; H - maxilla II; I-K. maxillipeds; L-P. peraeiopods; Q - pleopod; R - telson with uropod.

Maxilla I (Fig. 573) : Endopod smooth, not bifid. Three distinct lobes; the proximal lacinia carrying two small spines and larger distal lacinia with two large spines on the outer border and two on the inner border.

Maxilla II (Fig. 57 I) : Endopod with 18 plumose setae along its margin; the hind most seta long and directed backwards. Endopod with a single seta at its extremity and two small setae at its base. Exopod carrying three masticatory processes; the first process with three setae, second with two and third with one seta and also carrying an additional seta.

Maxillipeds (Fig. 5 7 I-K) : Three pairs of biramous maxillipeds developed. Basal segment of first maxilliped expanding and carrying short and thick endopodite; a bud like eppodite also present. Maxillipeds II and III almost identical; each with a four segmented endopodite, ending in a stout dactylus. Maxilliped II with also a small epidodial bud.

Peraeiopods (Fig. 57 L-P) : Five pairs of peraeiopeds present; only 5th pair uniramous. Setose exopodites present on only first three pairs of peraeiopods.

Pleopods (Fig. 57Q) : Small and biramous pleopods developed on I-V abdominal segments. Each pleopod with a distinct basal segment. Third to fifth pleopods with endopods reaching more than 2/3rd of the exopods.

Telson (Fig. 57R) : With broadly rounded posterior margin and having a faint median notch; carrying seven setose spines on either side of the notch.

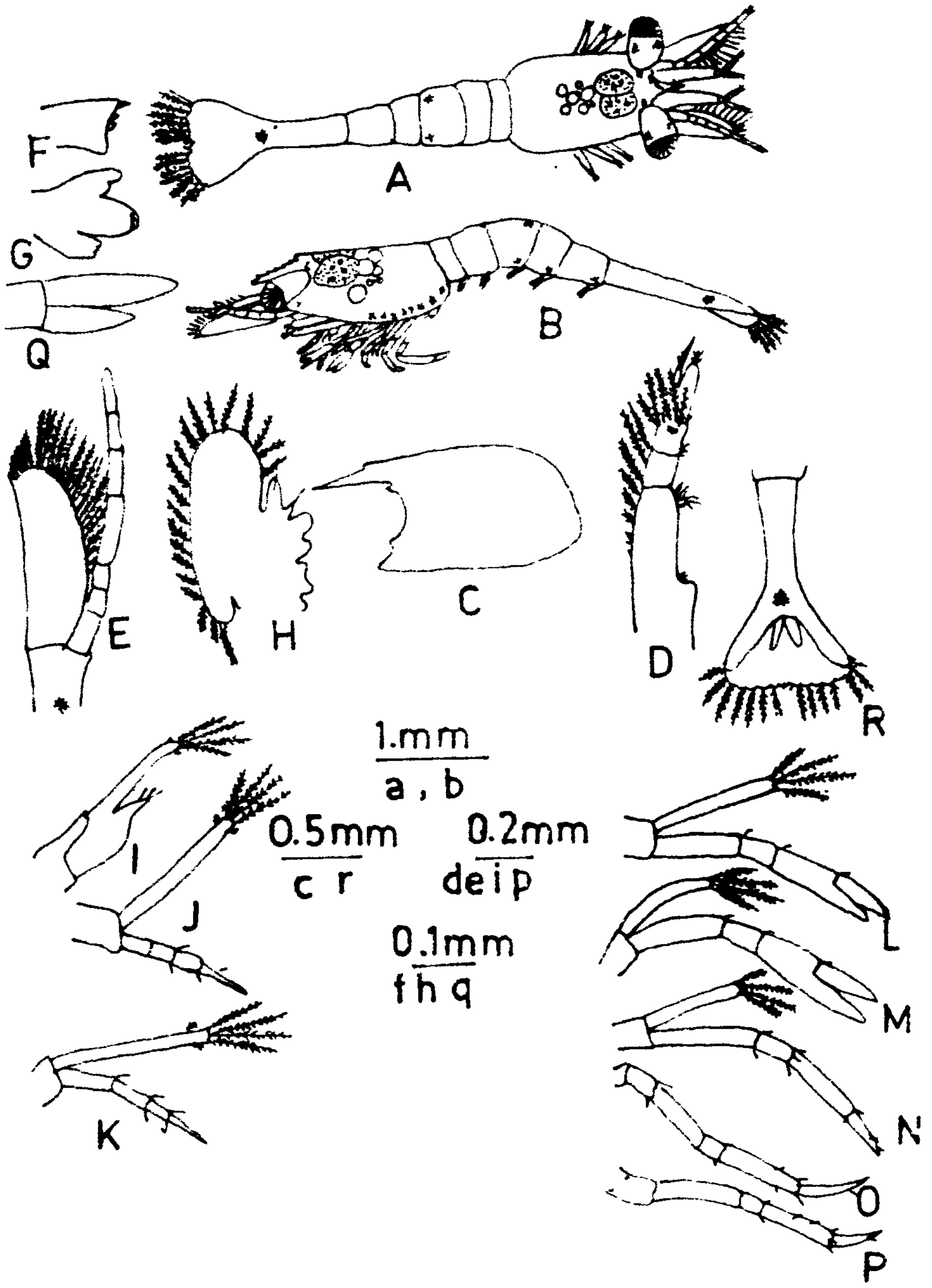

Fig-58. Second larval stage of <u>Macrobrachium lamarrei</u>

Chromatophores : Reticulate orange red chromatophores at the distal margin of antennular peduncle. Anterior and posterior dorsal margins of eye with stellate orange red chromatophores and junction of eye and carapace with diffused violet chromatophores located on a bluish abackground. The base of each maxillipeds and five pairs of peraeiopods with stellate red chromatophores. Abdominal chromatophores situated on 3rd abdominal segment and ventrally on 4th abdominal segment. A dendritic orange red chromatophore situated at the base of telson.

Measurements : Total length : 7.6 mm - 7.9 mm; Carapace length : 2.6mm-3.0 mm.

Time for 1st moult : 1-2 days in observation I (June, 1983) at temperature 21°C - 23°C. 3-4 day in observation II (September, 1984) at temperature 18°C - 20°C.

Second larval stage

(Fig.58)

Description (Fig. 58 A,B) : The larva exhibited considerable morphological changes. Carapace showed prominent supraorbital and branchiostogal spines in addition to pterygostomian spine (Fig. 58 C). Rostral formula 1/0; eyes stalked. Chromatophores at the base of 4th pair of pleopods became prominent. Additional chromatophores developed at the basis of 3rd and 5th pairs of pleopods.

Various appendages indicated the stated morphological features:

Antennule (Fig. 58E) : Showed all the feature characteristics of the adult appendages. Endopod long and multijoined; exopodite with 26 plumose

Antennule (Fig. 58D) : Antennular peduncle three segmented. Outer and inner antennular flagella unsegmented; outer flagellum with four aesthetes and inner long spine-like setae and two aesthetes. Large number of setae present on all joints of the outer margin of peduncle.

Antenna (Fig. 58E) : Showed all the feature characteristics of the adult appendages. Endopod long and multijoined; exopodite with 26 plumose setae along its inner margin and a distinct spine at the distal extremity on the outer border.

Mandibles (Fig. 58F) : Incisor and molar processes not distinct; former carrying 1-3 teeth and later with only one tooth.

Maxilla I and II (Fig. 58 G-H) : Showed an increase in the number of setae and spines. Endopod bibid; proximal and distal lacinae with five small spines. Maxilla II almost retained the same structure. Ist and IInd masticatory processes lacking setae.

Maxillipeds (Fig. 58 I-K) : Epipodial bud of the 1st maxippliped more elongated and reaching beyond the base of exopod, endopodites of maxillipeds II and III 4-segmented; numerous; numerous spines on the segments.

Peraeiopods (Fig. 58 L-P) : Showed some movements but still not functional, segmentation between coxa and basis, ischium and merus not distinct. Peraeiopods 4th and 5th pair unimarous. The pleurobranchiae of the peraeiopods I - V well developed, with a double row of numerous lamellae. Pleurobranch of the peraeiopod I is the smallest and that of the 5th, the largest.

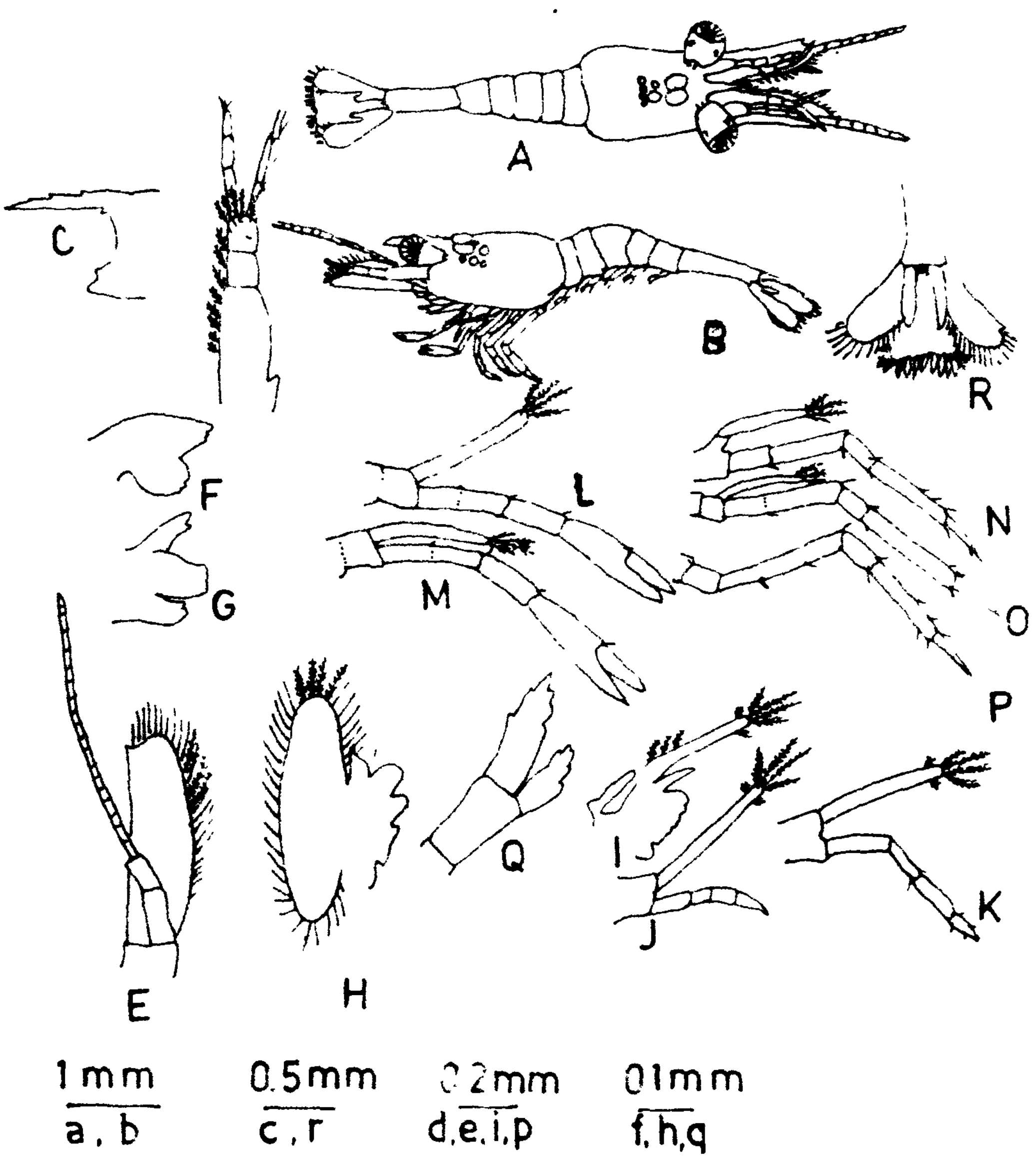

Fig.59. Third larval stage of <u>Macrobrachium lamarrei</u>

Pleopods (Fig. 58Q) : On the abdominal segments five pairs of biramous pleopods present; each pleopod two segmented.

Telson (Fig. 58R) : Fused with the last abdominal segment; carrying 9 + 9 spines; one additional small, non-setose spine developed on inner aspect of each side of telson; outlines of developing uropods distinguishable in larvae which were about to moult to next larval stage.

Measurements : Total length 7.8 mm - 8.3 mm; Carapace length : 2.3 mm -- 2.6 mm.

Third larval stage

(Fig. 59)

Time for second moult : 1-2 days in observation I, at temperature 18.1°C - 20.3°C (September, 1984) and 2 - 3 days in observation II (June, 1983) at temperature 20.5°C - 22.2°C.

Description : Carapace with epogastral hump, well developed supraorbital, branchiostegal and pterygostomian spines. Rostrum about 0.89 mm 8 long (range 0.70 - 0.98 mm) rostral formula, 2+1/0. A pair of lateral spines on 5th abdominal segment; reticulate orange chromatophore appearing at the basal segment of antennular peduncle and at the base of 2nd pair of pleopods.

Antennule (Fig. 59D) : Antennular peduncle expanded; a strong stylocerite present; inner flagellum segmented and elongated, carrying two aesthetes; outer flagellum divided into two distally.

Antenna : (Fig. 59E) : Endopodite very long; multijoined; with large number of setae, 4 setae at the apex of flagellum.

Mandible (Fig. 59F) : Incisor and molar processes marked from each other; incisor process with one tooth and three denticles and molar process with two denticles.

Maxilla I (Fig. 59G) : Endopod deeply notched, proximal lacinia with four spines and distal with five spines.

Maxilla II (Fig. 5 H) : Setae on the scale increased in number and the masticatory processes with setae. Endopod without any setae.

Maxillipeds (Fig. 59 I-K) : Coxa and basis of first pair of maxillipeds flattened, leaf-like, basis bearing a row of projections all along its border; epipodite elongated; basal part of exopodite slightly flattened and carrying three plumose setae.

Peraeiopods (Fig. 59 L-P) : Segmentation clearly visible on the endopodites of all peraeiopods;.Propodus and dactylus clearly demarcated; claws without spines.

Telson and Uropods (Fig. 59R) : Both demarcated from each other in this stage; uropod biramous, exopodite with 20 plumose setae at its distal border; small endopodite not setose; telson separated from last abdominal segment, with 8 + 8 spines at the posterior border.

Measurements : Total length : 7.9 mm - 8.5 mm; Carapace length : 3.7 mm - 4.0 mm.

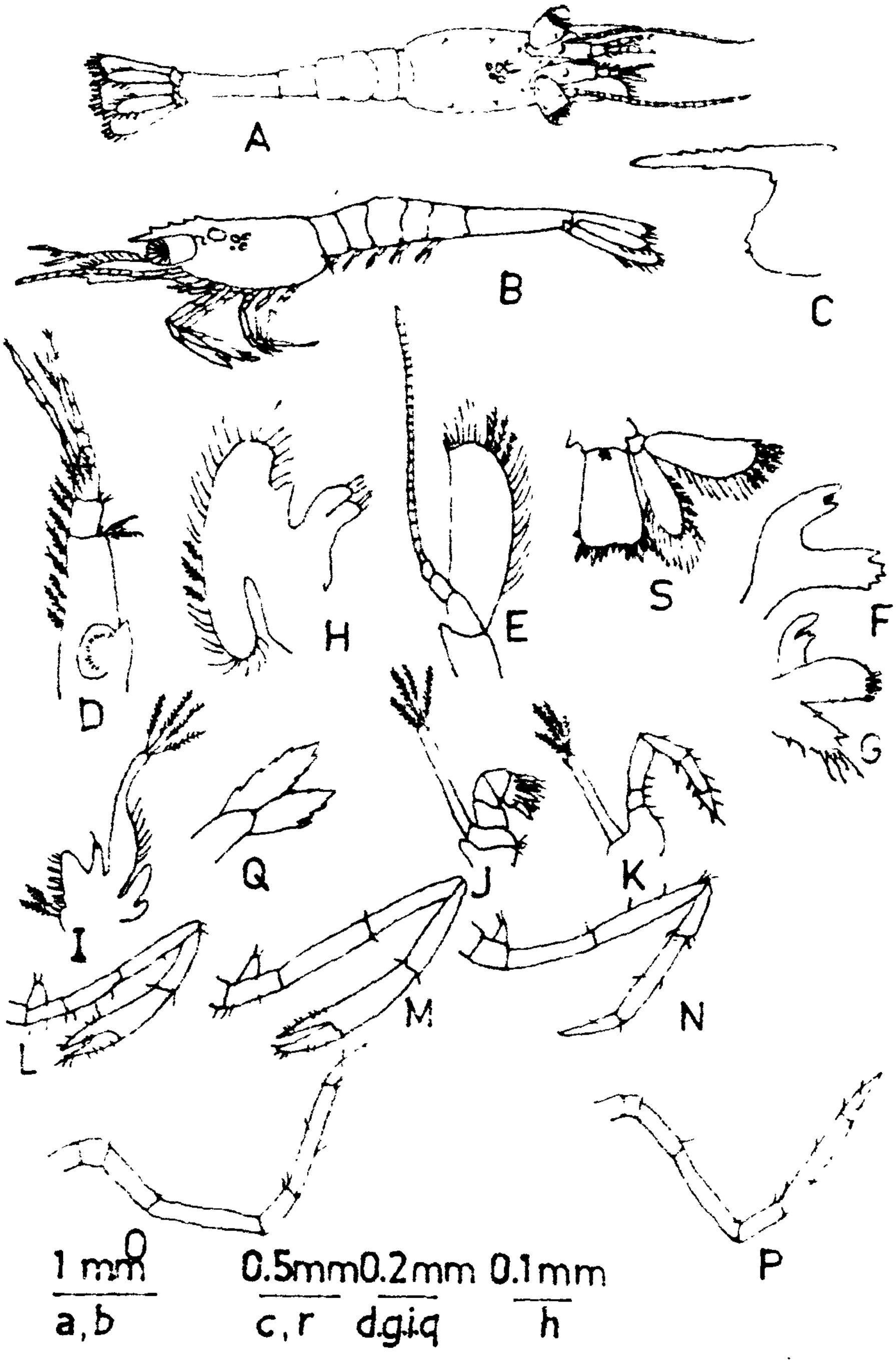

Fig.60. Fourth stage (post larval stage) of
Macrobrachium lamarrei

Fourth Larval stage (Post larva)

(Fig. 60)

Time for 3rd moult : 3 days on observation I (September, 1984) at temperature 18.3°C - 20.0°C 2 days on observation II (June, 1983) at temperature 19.0°C - 21.9°C.

Description : Carapace with an epigastral hump, well developed supra-orbital, branchiostegal and pterygostomian spines (Fig. 56), rostrum elongated, rostral formula 5/1, 1 or 2 small plumose setae under 5th rostral tooth and one under 3rd tooth; orange red chromatophores on eye peduncle and also in the epigastric region of carapace.

Antennule (Fig. 60 D) : Statocyst seen at the expanded basal joint of the peduncle, sensorial setae are arranged along a circular are of the statocyst. Inner flagellum multijointed outer branch 4 segmented and carrying 3 setae.

Antenna (Fig. 60E) : Endopod carrying more plumose setae; exopod (flage-llum) becomes more elongated and multi-segmented.

Mandible (Fig. 60F) : Three large teeth on the molar and three teeth on the incisor parts. The molar process carries many small denticles.

Maxilla I (Fig. 60G) : Distal lacinia with 8-10 teeth and 2 marginal spines; proximal lacinia with 6-7 teeth and 3 marginal spines.

Maxilla II (Fig.60 H) : Exopod of maxilla II with more plumose setae; endopod bare, basis with endites each terminating into 3 bristle-like setae.

Maxillipeds (Fig. 60 I-K) : Coxa and basis of I maxilliped with a single row of pointed spines on their median edges. The coxa bearing limbed and leaf-like epipodite. The exopodite shows platelike expansion along the proximal half. In the II maxilliped, the coxa is slightly expanded. Noclear joint between the ischium and merus of the endopod. Propodus and dactylus strongly bent. Endopodite of III pair of maxllipeds also five segmented and profusely setose.

Peraeiopods (Fig. 60 L-P) : Segmentation in peraeiopods distinct; exopodite of 1st, 2nd and 3rd pairs of peraeiopods very much reduced, chelipeds I and II showing setae on their segments; chelae with well developed terminal claws.

Pleopods (Fig. 60 Q) : Exopodite and endopodite of all pleopods carry setae; appendix interna bud like; all pairs of pleopods biramous.

Telson and Uropods (Fig. 60 R) : Each uropod biramous, exopod with twelve and endopod with seven plumose setae, telson longer, broader at posterior and bearing five spines and one lateral spine on either side.

Measurements : Total length : 8.1 mm - 8.7 mm; Carapace length : 3.9 mm - 4.3 mm.

LARVAL DEVELOPMENT IN Macrobrachium hendersoni hendersoni (de Man)

The egg of this species were broadly oval in shape and dark green in colour in the initial stage; their average size was observed to be 0.80 mm x 0.50 mm (range : 0.75 mm x 0.48 mm - 0.85 mm x 0.52mm). Each egg filled with yolk, was attached to the pleopods with a thin membrane. After their extrusion, the fertilized eggs underwent a number of morphological changes. The process of cleavage was effected by the shrinking of the yolk slightly to one side of the egg. The embryonic development lasted for an average of 9 days (range : 7-11 days). The cleavage lasted for about two days and terminated with the development of an embryonic streak. Thoracico-abdominal lobe and the rudiments of the appendage buds were observed on 3rd days. These subsequently became more prominent. The antennae, antennules, buds representing maxillae and maxllipeds were seen after 5th day. The optic rudiment, heart and clear abdominal segmentation could be noticed till 7th day. Byt the 9th day, the embryo was clearly visible within the eggs and its various features particularly eyes, heart and various appendages could be clearly observed. The movement of embryoes with the eggs lead to the rupture of inner egg membrane and subsequently the larvae emerged through a tear in the outer egg membrane. The period of emergence lasted for 15-30 minutes. All the larvae did not hatch simultaneously; process of hatching lasted for about one day.

The larvae, immediately after hatching, were observed to be clinging to the various body parts (rostrum, carapace, abdomen and pleopods etc) of the mother for sometimes. Subsequently, they concentrated on one corner of the beaker with their heads hanging downwards. They underwent two moults before being transferred to post larvae. The detailed descriptions of two larval stages and the post-larva of M. hendersoni hendersoni are described hereunder :

Illustration

Fig. 61 : First larval stage of M.hendersoni hendersoni (de Man).
A - lateral view; B - carapace; C - antennule; D - antenna; E - maxillule; F - mandible; G - maxilla I; H - maxilla II; I - peraeiopods (1st to 5th); N - pleopods; J-L. maxillipeds; M - telson with uropod.

Fog. 62 : Second larval stage of M.hendersoni hendersoni (de Man).
A - lateral view; B - carapace; C - antennule; D - antenna; E,F - maxilliped II,III; ,G - mandible; H - peraeiopods; J,K - pleopods; L - maxilla; I - telson with uropod.

Fig. 63 : Juvenile stage of M.hendersoni hendersoni (de Man).
A - lateral view; L - carapace; B - antennule; C - antenna; D,E,F - maxillipeds (first to third); H - maxillule; J,K - pleopods; I - peraeiopods (1-5= first to fifth); G - telson with uropod.

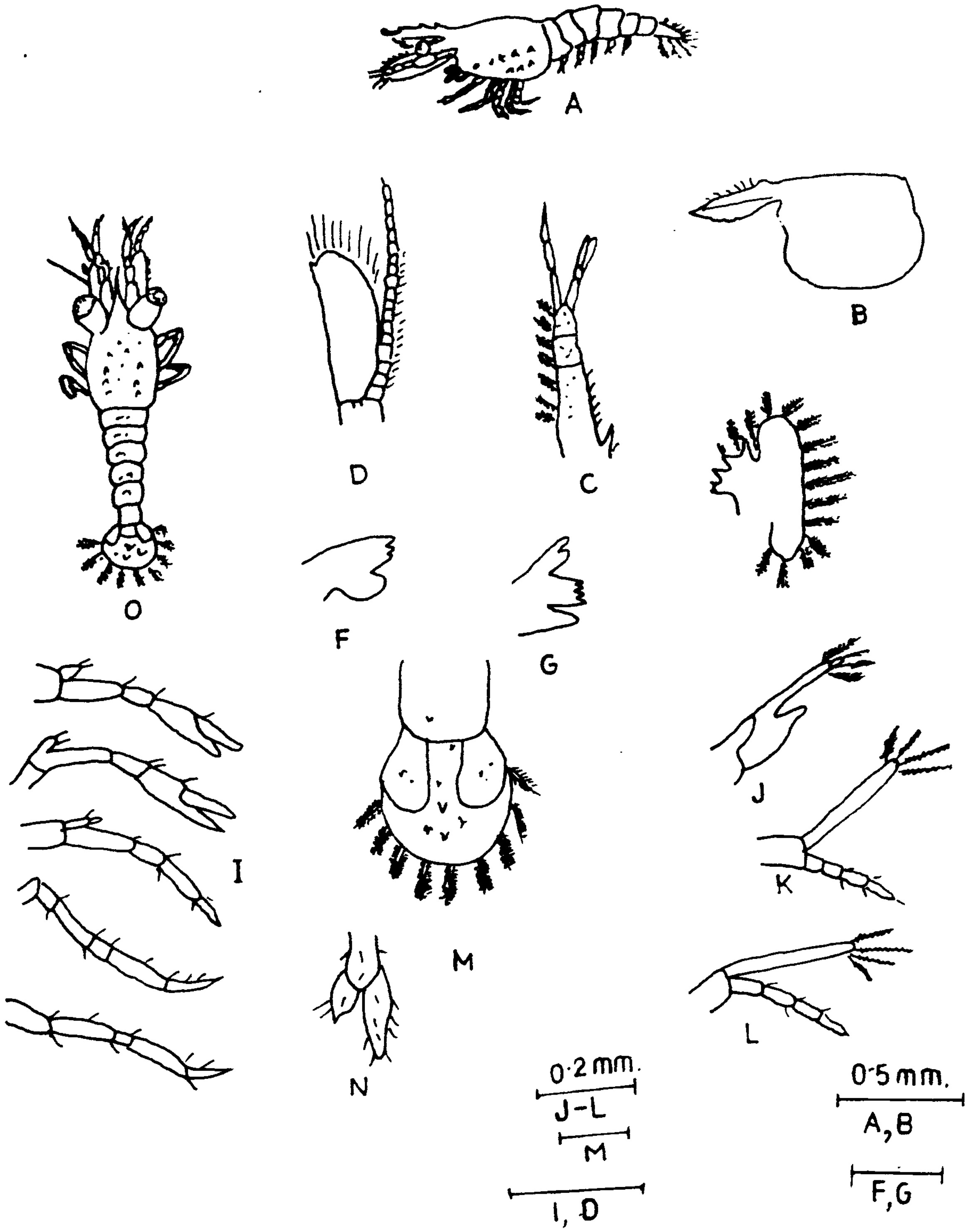

Fig. 61. First larval stage of Macrobrachium hendersoni hendersoni (De Man).

Description of larval stages :

First larval stage : (Fig.61)

Carapace length : 3.1 mm - 3.7 mm; Abdominal length : 4.0 mm-4.8 mm.

Description : Body transparent; Carapace smooth with a distinct antennal spine and another. Rostrum serrated, reaching almost to the end of antennular peduncle and with fine setae in between the teeth on either side. Mid rib prominent and slightly curved. Rostral formula 5-6; No postorbital teeth. Small spine that probably represented future hepatic spine. Telson characteristic, almost 30 cl and separated from the last abdominal segment.

Antennule (Fig.61 C) : Peduncle three segmented, both stylocerite and anterolateral spines promient and sharply pointed; basal segment with a ventral spine pointing anteriorly. Statocyst without any statoliths. Inner flagellum 9-10 segmented; outer flagellum with two basal segments fused and consisted of two branches, the smaller branch two segmented and tipped with two aesthetases while the larger branch with 10-12 segments bearing minute setae.

Antenna (Fig.61 D) : Apex and inner edge of the endopod carrying eleven plumose setae and one small seta on the outer dege. Unlike the zoea the apex had no trace of segmentation. Three segmented peduncle; well developed scale and long flagellum (consisting about 40 segments); spine of the bascecerite blunt. Endopod with plumose setae.

Mandible (Fig. 61F) : Incisor and molar processes well developed; the former with 2-3 blunt teeth, molar processes still a blunt projection. Palp absent. The molar part of the two mandibles unarmed.

Maxilla I (Fig. 61 G) : Coxal and basal endites with one and three large and two small teeth respectively. Palp distinctly bilobed palp, the upper lobe narrow and tubular while the lower broader and bearing a small seta.

Maxilla II (Fig. 61 H) : Structurally like that of adult, except for the endites being less setose, coxal with four and basal with seven denticles. Palp with one small marginal seta. Scaphognathite fringed with about 42 plumose setae.

Maxilliped I (Fig. 61 J) : Three maxillipeds resemble those of adult but the flagellar portion of exopods still retains long plumose setae. The endites of protopod large and armed with only a few tubereles. Endopod unsegmented. Flagellar portion of endopod with four long plumose, terminal-setae. Epipod bilobed.

Maxilliped II (Fig. 61 K) : the endopoidte elongated, clearly five segmented stalk ending terminally in an elongated and bent dactylus. Future podobranch represented by gill bud.

Maxilliped III (Fig. 61L) : Exopod with four netatory setae, reaching to the tip of basal segment of endopod. Rudimentary epipod present.

Peraeiopods (Fig. 61 I) : All the peraeiopods segmented, though this segmentation being faint at some joints. In the first and second paris of peraeiopods (the chelipeds I and II), the endopod terminated in a well formed chela. 3rd-5th peraeiopods similar with a narrow pointed dactylus, rudimentary pleurobranches present on all these peraeiopods.

Pleopods (Fig. 61N) : Five pairs of pleopods developed. First pleopod as in adult with rudimentary endopod, about 1/3 of exopod in length and with only 1-2 setae. Distinct appendix interna bearing 3-4 minute hooks on all pleopods except the first; exopod setae 7-9 on 1st and 10-15 on remaining pleopods.

Telson (Fig. 61M) : Posterior margin broadly rounded and with a faint median notch. Uropods represented only as buds seen through the telson cuticle.

Chromatophores : Larva appeared slightly yellowish brown in colour with numerous orange-red stellate chromatophores densely scattered all over the body. In addition, orange-red reticulate chromatophores profusely distributed on the eye stalks and at the base of fingers of 2nd peraeiopods; light brownish reticulate chromatophores located ventrally between the pleopods of either side and diffused deep violet-brown chromatophores at the junction of eyes and carapace.

Time for 1st moult : Two days in observation I (April, 1983) and 2-3 days in II observation (August,1983). at temperature 18.1^{o}C - 21.1^{o}C and 19.0^{o}C - 20.6^{o}C respectively.

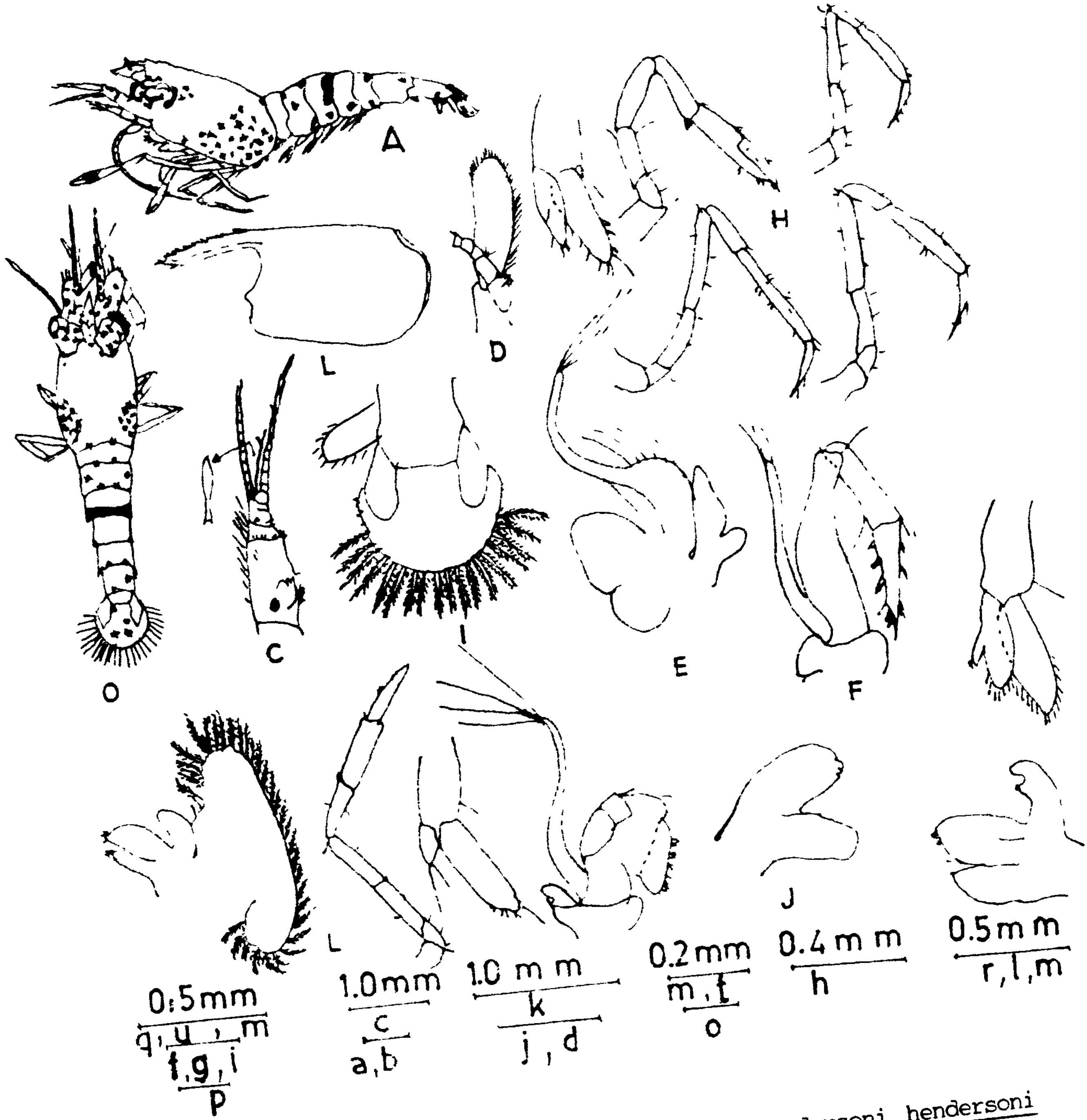

Fig. 62. Second larval stage of Macrobrachium hendersoni hendersoni (De Man).

II. Second Larval Stage :

Carapace length : 3.5 mm; Abdominal length : 4.9 mm.

Description (Fig. 62) Larvae indicarted slight increase in their length. Rostrum at this atage; rostral formula being $\frac{5}{1-2}$; Eyes large and with cylindrical stalks; Density of chromatophores decreased. Carapace is armed with a pair of suborbital spines.

Antennule (Fig. 62 C) : Outer flagellum with two fused basal segments. Statocyst expanded. A number of setae appeared on all the joints and outer margin of peduncle.

Antenna (Fig. 62 D) : External spines of bascecerite sharp and prominent resembling that of adult.

Mandible (Fig. 62 G) : Incisor with four sharp sub-equal teeth and 2-3 blunt tooth like projections on molar process; palp absent.

Maxillae and maxillipeds (Fig. 62 E,F,L) : Becme more setose like in adult.

Peraeiopods (Fig. 62H) : First and second pairs chelate, smooth except for presence of few setae; 2nd cheliped prominently larger than all the remaining peraeiopods. Third to fifth peraeiopods similar; each with a narrow pointed dactylus but the terminal spines being much larger than the adult; propodal spines yet to develop; Pleurobranches present on all peraeiopods.

Pleopods (Fig. 62 J,K) : First pleopod as in adult with rudimentary exopod about 1/3 exopod in length and with only two setae; second to fifth with endopods reaching more than 2/3rd of exopod bearing 7-9 setae each; distinct appendix interna bearing 2-3 minute hooks on all pleopods.

Telson (Fig. 62 I) : Long, narrow with slightly convex posterior margin. Posterior margin with 14-16 plumose setae.

Uropods (Fig. 62 I) : Biramous, both rami and 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 second moult : 2-4 days in observation I (April, 1983) at temperature 21°C - 22.6°C and 3-5 days in observation II (August, 1983) at temperature 19°C - 21.8°C.

III. Post Larval stage (Fig. 63.) :

Carapace length : 4.1 mm; Abdominal length : 5-6 mm.

Description (Fig. 63) : Carapace with supraorbital, branchiostegal spines; no change in rostrum; the future hepatic spines, shifted little upwards towards antennal spines; uropods developed; orange-red chromatophores on eye peduncle and also in the epigastric region of carapace.

Antennule (Fig. 63 B) : Flagellar segments increased in number 15 on the inner; sixteen on longer branch of outer; smaller branch of outer flagellum with four aesthetas arranged.

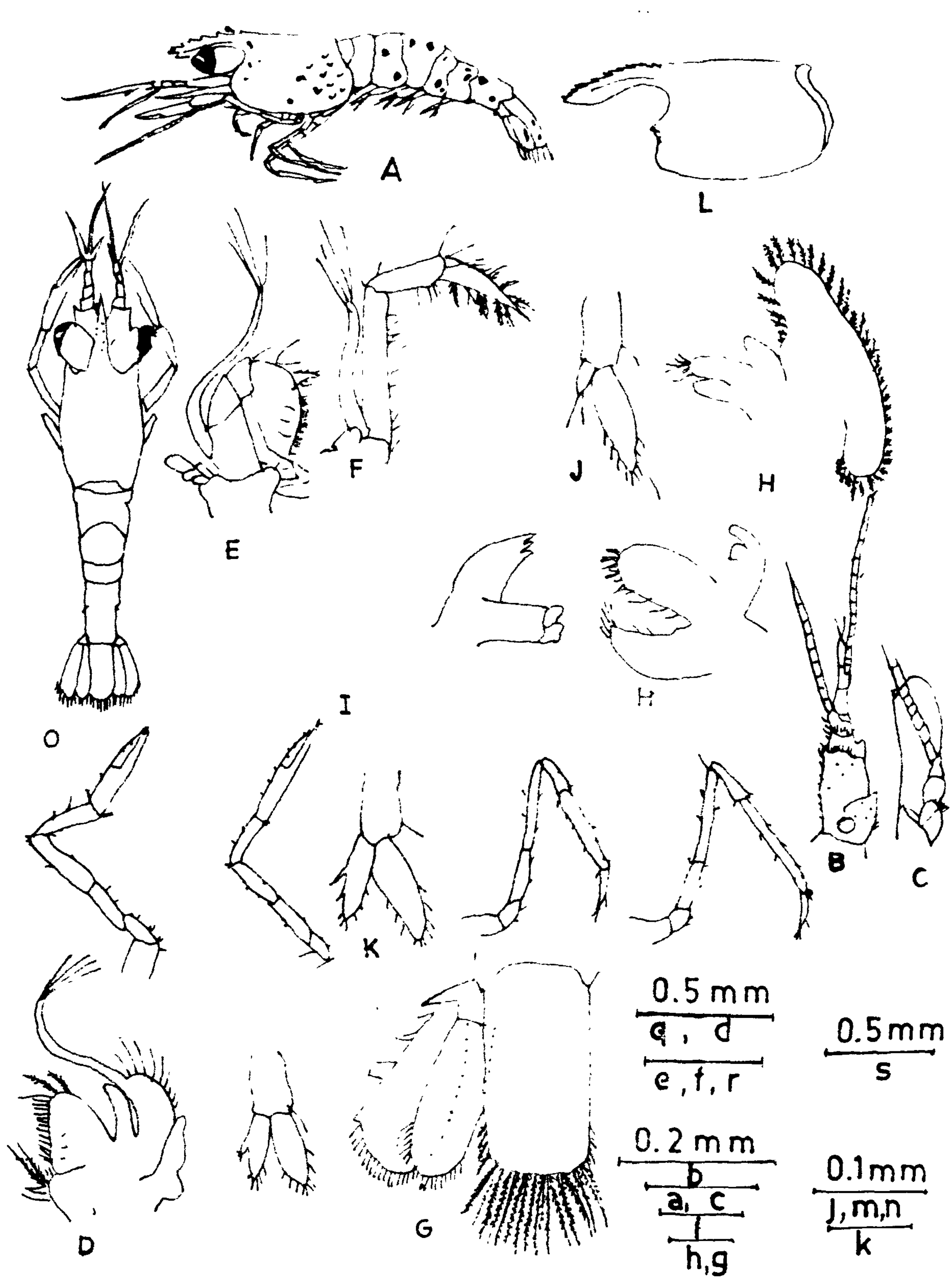

Fig. 63. Post larval stage of Macrobrachium hendersoni hendersoni (De Man).

Antenna (Fig. 63 C) : No change except for increase in number of flagellar segments to about 48.

Mandible : More molar projections; palp still absent.

Maxillae and maxillipeds (Fig. 63 D,E,F,H) : No appreciable change except for increase in number of setae and epipod of 1st maxilliped broadening slightly, resembling that of adult.

Peraeiopods (Fig. 63I) : No appreciable change except for increase of number of setae on peraeiopods, especially on 1st and 2nd peraeiopods.

Abdomen and pleopods (Fig. 63 J,K) : Almost as in previous stage.

Telson (Fig. 63 G) : Longer and narrower than in previous stage; a group of long setae on dorsal side; out of the four pairs of lateral spines, the proximal two pairs now shift inwards; posterior margin straight.

DISCUSSION

Food and feeding :

Investigations on the composition of food-items of the prawns, in their natural environments, are of basic biological importance for their subsequent culture in view of their increasing economic importance. The prawns are primarily adapted to the benthic region for their feeding and, hence, their food includes a wide variety of components depending on the composition of the benthic biocoenosis. A wide range of food-items have been reported in the gut contents of the various studied species of these decapod crustaceans. Patwardhan (1937) observed that the food of *Macrobrachium malcolmsonii* consisted of algae, mosses, sea-weeds and small insects while Chopra (1939) stated that the prawns consumed all types of food (living or dead) that come their way. Williams (1955) suggested the major role of debris in *Penaeus aztecus*; this debris contained bacterial colonies, filamentous algae, protozoans, copepods and nematodes etc. The diet of *Metapenaeus affinis* predominantly comprised of nematodes, molluscs (Subramanyam, 1963). In a number of commercial prawns i.e., *Penaeus esculentes*, *P. merguiensis*, *P. plebejus*, *Metapenaeus bonnettae* and *M. macleayi* the food consisted of remains of small animals and a large amount of materials like chitin fragments, annelid jaws, setae and sand (Dall, 1968). Kuttayamma (1974) observed that in *Metapenaeus dobsoni*, *M. affinis*, *M. monoceros*, *Penaeus monodon* and *P. indicus* the food in general, consisted of varying amounts of organic matter mixed with sand and mud. In prawns caught from estuaries, the food included polychaetes, amphipods, bivalves, gastropods, foraminiferans, nematodes, sand and mud while those from paddy fields showed a large amount of plant matter, indicating the adjustibility of such prawns to environmental conditions. Moriarty (1976) noticed that in Metapenaeus bonnettae, bacteria from ingested sediment contributed significant quantity of organic carbon in the foregut content. According to various observations in Penaeus monodon (Hall, 1962; Thomas, 1972; Marte, 1980, 1982) crustaceans appeared to be 'Staple' food while the occurrence of non-crustaceans food (e.g., molluses and fish) was more variable.

In the present study the basic food material of Macrobrachium hendersoni hendersoni and M. lamarrei comprised of a wide variety of item including benthic and periphytic organisms. Various food-items were noticed to be diatoms, detritus, insect larvae, sand and silt, filamentous algae, other algae, nematodes, crustaceans, mosses and plant matter and miscellaneous group. The last group consisted of Hydra, Dugesia, Helobdella, snails. These fndings indicated the semi-benthic mode of life of both the species. These results suported the view of Nikolsky (1969) regarding fish fauna of high altitude being adapted for eating various types of foods on account of high variability at the avialable food components. However, Suyehiro (1942) attributed such a condition of omnivorous feeding habit to the limited supply of food in the habitat. The importance of such impact cannot be overlooked in the lotic system from where M. hendersoni hendersoni and

M. lamarrei had been collected. The analysis of gut contents in this study indicated that all the food-items available in the natural habitat were also represented in the food.

In M. hendersoni hendersoni the diatoms, insect larvae and detritus (in the stated order) comprised on an average about 46.0% of the total food consumed while in M. lamarrei insect larvae, diatoms, filamentous alage and detritus were dominant food-item. The high amount of sand and silt, noticed in both the species may be attributed to high siltation rate in the lotic habitats where these observations were conducted. On the basis of this study insect larvae, diatoms, detritus, filamentous algae, other algae are believed to be the major food components while miscellaneous group may be regarded as accidental food-item.

Some differences observed in the relative percentage composition of food-items in M. hendersoni hendersoni and M.lamarrei in this study may be due to the variability of same in their natural environments. In these findings diatoms comprised the dominant food of M. hendersoni hendersoni (average 17.59%) as compared to the occurrence of insect group in an unpublished report by Goswami, 1983. The observed wide range of components in the food spectrum of these two species did not reflect any specific feeding activity even though some grouos seemed to be dominant at times. The variations, however, may be attributed to the routine variations in the occurrence of the different conponents under natural conditions. On the other hand,some specimens of these species obtained from paddy-fields showed large amount of plant matter thereby, indicating a great degree of opportunitism in terms of food preferences.

A number of workers (Goswami, 1983; Panikkar, 1952; William, 1955; Eldred et.al., 1961; Hall, 1962; Subramanyam, 1963; Dall, 1968; Warren and Sheldon, 1967; Hughes, 1968; George, 1972; Rodriguez and Naylor, 1972; Thomas, 1972; Kuttayamma, 1974; New, 1976; Marte, 1980, 1982) observed monthly variations in the food-items of various species of prawns and shrimps. The present study also reflected seasonal changes in the nature and percentage composition of food-items in M. hendersoni hendersoni and M. lamarrei. In M. hendersoni hendersoni the percentage composition of diatoms ranged from 12.6 - 21.2 in winter, insect larvae 13.2 - 25.0 in summer, detritus 6.2 - 25.8 from late winter to late summer, sand and silt 2.61 - 18.2 in rainy season, filamentous algae 6.8 - 13.4 in winter, other algae 5.4 - 13.9 in winter, nematodes 6.4 - 13.7 in summer, crustaceans 3.8 - 10.3 in early summer, mosses and plant matter 2.7 - 8.6 in summer and miscellaneous group varied between 0.2 and 1.2 in summer season. While the percentage composition of different food-items in M. lamarrei representing insect larvae, other algae, crustaceans ranged from 8.4 - 24.5, 6.5 - 13.8, 2.8 - 24.0 in winter season respectively. On the other hand, filamentous algae, nematodes, mosses and plant matters and miscellaneous group ranged from 8.7 - 15.0, 7.0 - 14.0, 1.5 - 17.2, 0.2 - 1.4 respectively. Diatoms and sand and silt varied from 10.8 - 21.0 and 8.5 - 14.0 in early winter and detritus ranged from 3.0 - 18.4 in early and late summer.

From the present investigations both the stated freshwater Palaemonid prawns can be considered as euryphagic animals. Basic food-items were observed as insect larvae, diatoms, filamentous algae, detritus, while sand-silt particles, mosses and plant matters and crustaceans may be considered as secondary food and the remaining food-items i.e., oligochaetes and miscellaneous 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 occurred without any regularity in different months during the study period.

Monthly fluctuations of the gastro-somatic index of M. hendersoni hendersoni and M. lamarrei reflected the extent of feeding by them. The major break in March'84 for M. hendersoni hendersoni and June'83 for M. lamarrei may be due to prolonged period of metabolic activity to build up the body for the spawning as these periods were just like prior to spawning season. The other minor peak of increased intensity of feeding may be due to recuperatuve process the prawns become voracious eater. The drop in feeding intensity in M. hendersoni hendersoni was recorded mostly during winter. The drop in feeding intensity from October - January'84 may be due to the prevailing low temperature of the habitat during these months and reduced activity of the prawn. In M. hendersoni hendersoni gastro-somatic index varied from 1.983 - 3.500 and in M. lamarrei from 2.053 - 3.509. The variation in feeding habit reflected changes in in dietary requirements which may be related to different body metabolism viz., gonad development, moulting etc., (Marte, 1982). Males of both the stated prawns seemed to feed more actively than females as seen from the higher gastro-somatic index. The poor feeding by the females during breeding season may be attributed to the development of gonads which occupy the major space of the abdominal cavity. Desai (1970) has recorded similar observations in fishes and Goswami (1983) in some freshwater Palaemonid prawns.

Larval development

Sollaud (1923) recognized three types of larval development in the genus Macrobrachium based on the number and size of their eggs and early life-history. These categories included :

i) Typical type; with large number of small sized eggs and numerous zoeal stages, some of which are free swimming.

ii) Semi-abbreviated type; with slightly fewer, larger sized eggs and fewer zoeal stages, some of which are also free-swimming.

iii) Highly-abbreviated type ; eggs generally larger than in second type and free swimming zoeal stages altogether lacking.

Prolonged larval history had been reported in a number of species i.e., M. rosenbergii (Ling and Merican, 1961; Ling, 1969; Uno and Kwan, 1969), M. carcinus (Lewis and Ward, 1965; Chaudhury, 1971), M. nipponense (Kwon and Uno, 1969); M. acanthurus (Chaudhury, 1970); M. malcolmsonii (Kewalramani, et.al., 1970); M. formosense (Shokita, 1970); M. niloticum & M. intermedium (Williamson, 1972); M. idella (Pillai & Mohamed, 1973). Abbreviated larval history has so far been documented in M. lamarrei (Rajyalakshmi, 1961; Sharma & Tiwari, 1978); M. australiense (Fielder, 1970) and M. kistnensis (Nagabhushanam & Kulkarni, 1979) and M. malayanum (Chong & Khoo, 1987). On the other hand, highly abbreviated larval history had been observed in M. potiuna (Sollaud, 1923); M. shokitai (Shokita, 1973) and M. hendersodayanum (Jatihal & Sankolii, 1975).

The larval development in Macrobrachium hendersoni hendersoni and M. lamarrei, as observed in the present study, can be assigned to second category of Sollaud's scheme, although the eggs produced in these species were smaller in size and relatively larger in number. Such differences in the number and size of the eggs had also been observed in M. australiense (Fielder, 1970) which was allocated to this group (according to larval stages). In the study, M. hendersoni hendersoni showed two larval stages before hatching into post-larva while three larval stages and one post-larva were noticed in sub-tropical population M. lamarrei.

Various parameters of freshwater species of Macrobrachium are summarised in Table 14. The number of larval stages generally varied between two and three with some exceptions i.e., only one larval stage in M. herdersodayanum and four larval stages in M. kistnensis. The presently observed species also fit in the general plan. The size of eggs in M. hendersoni hendersoni corresponded broadly to that of M. kistnensis while the eggs of M. lamarrei of the present stream-dwelling specimens were smaller than those reported by Rajyalakshmi (1961) and Sharma & Tiwari (1978). The number of larval stages in M. lamarrei agreed with the land-locked and riverine populations examined earlier from peninsular India. The exopods were noticed to be suppressed only on 5th pair of peraeiopods as against the suppression on 4th and 5th pair of peraeiopods (Sharma & Tiwari, Loc. Cit.). The occurrence of two larval stages in M. hendersoni hendersoni is strikingly in contrast to the earlier unpublished report of only one larval stage

Table : 14

Some parameters of larval development in *Macrobrachium* spp.

Sl. No.	Species	Egg size(mm)	Time for hatching (days)	Total number of larval stages	Duration of larval development(days)	Source
1.	*Macrobrachium lamarrei* (H. Milne Edw)	1.05 x 0.90	12 - 14	3 + 1	21 - 28	Rajyalakshmi, 1961
2.	*M. lamarrei* (H. Milne Edw)	0.90 x 0.60	10 - 14	3 + 1	21 - 26	Present study
3.	*M. lamarrei* (H. Milne Edw)	0.97 x 0.90	18 - 20	3 + 1	20 - 28	Sharma and Tiwari, 1978
4.	*M. hendersodayanum* (Tiwari)	-	3 - 5	1 + 1	5 - 10	Jalihal & Sankolli, 1975
5.	*M. hendersoni cacharensis* (Tiwari)	0.90 x 0.50	3 - 6	2 + 1	14 - 18	Goswami, 1983.
6.	*M. hendersoni hendersoni* (de Man)	0.80 x 0.50	3 - 8	1 + 1	19 - 22	Goswami, 1983.
7.	*M. hendersoni hendersoni* (de Man)	0.80 x 0.50	5 - 11	2 + 1	18 - 24	Present study.
8.	*M. cavernicola* (Kemp)	1.9-2.1 x 1.4 - 1.7	-	-	-	Kemp, 1924.
9.	*M. kistnensis* (Tiwari)	0.90 x 0.50	2 - 3	4 + 1	7 - 11	Nagabhushanam & Kulkarni, 1979.
10.	*M. australiense* (Holthius)	0.8 x 1.0 - 0.8 x 1.1	6 - 10	3 + 1	14 - 17	Fielder, 1970.
11.	*M. shokitai* (Shokita)	-	-	2 + 1	5 - 10	Shokita, 1970.
12.	*M. malayanum* (Roux)	1.75 x 1.35	-	1 + 1	4 - 10	Chong & Khoo, 1987.
13.	*M. malcolmsonii* (H. Milne Edw)	0.75 x 0.85	-	3 + 1	-	Kewalramani, *et.al*; 1973.
14.	*M. idella* (Hilgendorf)	0.90 x 0.70	8 - 14	3 + 1	5 - 11	Pillai & Mohamed, 1973.

(Goswami, 1983). On both the observations (June'83 and September'84) this species always exhibited two larval stages. the first larval stages corresponded to the second larval stages of M. hendersodayanum (Jalihal and Sankolli, 1975) in which this stage evidently appeared to be suppressed.

The larvae of M. hendersoni hendersoni were broadly identical with zoea and megalopa larvae of M. malayanum (Chong & Khoo, 1987). The first larval stage of the former is characterised by serrated rostrum, short antennal flagellum and settation of antennal scale mostly confined to its distal margin. The larvae in M. lamarrei closely resembled to zoea and megalopa of M. australiense (Fielder, 1970).

The larvae of sub-family Palaemoninae were described by Sollaud (1923) in two groups. The first group included the normal zoea and the second group larvae were further differentiated into 'Subparva' and 'Preparva'. The larvae which hatched out in M.lamarrei and M. hendersoni hendersoni were similar to Sollaud's 'Subparva'. The newly hatched larvae were characterised by five pairs of immobile pleopods folded ventrally. The suppressed development of all buccal organs in the larvae may be correlated to the presence of sufficient amount of reserve food in the form of yolk granules. The scaphognathite of maxilla II helped to produce respiratory current in the branchial chamber right from the time of hatching.

The newly hatched larvae of Macrobrachium hendersoni hendersoni were noticed to be attached to the body of the mother for sometime.

Such an interesting behavioural pattern coincided with the observation of Nagabhushanam & Kulkarni (1979) in M. kistnensis. The newly emerged larvae of M. lamarrei, however, attached to the walls of the container before becoming free-swimming as also observed earlier by Sharma and Tiwari (1978).

Broad (1957b) noticed variability in the number of larval stages in two species of Palaemonetes on account of their diet as they were considered active feeders. Dobkin (1953) commented the lack of such a variability in Palaemonetes paludosus (Gibbes). This also holds true in earlier studied various species of Macrobrachium. M. hendersoni hendersoni exhibited no such variability in their number of larval stages as these larvae were exclusively dependent on their internal food supply (yolk granules) and became active feeders only after the post-larval stage.

Variations had been reported in the durations of embryogenesis and larval development in different Macrobrachium species (referred Table 15). Such differences are also noticed in this study. The embryonic development in M. lamarrei lasted for 10-14 days while larval development took 21-26 days. In M. hendersoni hendersoni, the total duration from the extrusion of the eggs till hatching took 5-11 days and the early larval development was completed in 18-24 days. The above mentioned differences may be due to the temperature differences during these observations. In Sept'89 (temperature range : 18°C - 21°C the entire development process in M. lamarrei took about 3-4 weeks, while in June'83 (temperature 19^{o}C - 22.6^{o}C) it was completed in less than three weeks.

However, a detailed study of the effects of temperature is being attempted.

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SUMMARY

SUMMARY

The freshwater prawns belonging to the genus Macrobrachium (Family : Palaemonidae; Sub-family : Palaemoninae) form an important group of edible decapod crustaceans. They are found in a wide variety of habitats in freshwater ecosystems. A notable decline in freshwater prawn populations from their natural environments calls for adequate attention for their culture and mass rearing of their larvae. The practices of paddy-cum-prawn culture or fish-cum-prawn culture offer a bright future prospective to improve socio-economic conditions for the people in rural areas. The former aspect can be more suitable to the low-land areas of hill-states of North-Eastern India wherein paddy-fields comprise an integral part of landscape and rural economy.

As a pre-requisite to any scientific measures for conservations of natural stocks and culture of these organisms, it is essential to acquire knowledge about distribution of different species together with investigation on various aspects of ecology and biology. In view of paucity of such information relating freshwater prawns from North-Eastern region, the present study was undertaken. This dissertation, therefore, deals with composition and distribution of Macrobrachium spp. in this region and observations on some aspects of ecology and biology of two commonly available prawns of Meghalaya state i.e., the hill-stream M. hendersoni hendersoni and a stream-dwelling population of M. lamarrei. The results obtained are presented in three chapters and are briefly summarised below :

Chapter I dealt with thirteen species and four sub-species examined in the collection from various parts of North-Eastern region. The documented taxa are suitably illustrated and their diagnostic features are mentioned in the systematic account. A majority of the reported taxa were known to exhibit exclusively inland aquatic ecosystems while some coastal elements (Vide Tiwari, 1955) were comprised by M. malcolmsonii, M. birmanicum choprae and M. rosenbergii. A notable feature of this study was the occurrence of two endemic taxa i.e., M. manipurensis and M. lamarrei lamarroides. The former species was apparently confined to Logtak lake in Manipur state; this rare and interesting element was distinguishable from its other Indo-Burmese relatives by the characteristic shape, proportions and colourations of its second pair of paraeiopods. M. lamarrei lamarroides, yet another biogeographically prawn occurred in Logtak lake (Manipur) and the tributaries of the streams draining into this lake. This sub-species differed from the nominate M. lamarrei lamarroides in the shape, length and dentition of the rostrum.

M. cavernicola and M. kempi were obtained from Siju cave in Garo Hills district of Meghalaya state. Of these, the former was the only species known from India which exhibited various caverniculous adaptations. The occurrence of M. kempi in this cave was only accidental as it was originally described from a stream and its distributional range extended from Bangladesh to Mayurbhanj hills in Orissa state.

M. naso represented a new record from North-Eastern region even though it was reported earlier from Burma and recently from Gorakhpur (Uttar Pradesh). The present record might provide a biogeographical link to account for its subsequent distribution in the Gangetic peninsula. The specimens of M. altifrons coincided with the Indo-Nepalese form which was found in the Ganga-Brahmaputra drainage systems. Its present occurrence in a beel in Assam state was of ecological interest as it was earlier collected from stream with clearwater. M. kistnensis, a Malayan element, was collected from Juri river in Tripura state and was of regional distributional importance as it was not earlier known from North-Eastern India.

Amongst the taxa included under hendersoni group, six species and sub-species were included in this study i.e., M. cavernicola, M. hendersoni hendersoni, M. hendersoni platyrostris, M. hendersoni cacharensis, M. assamensis and M. dayanum. These were apparently restricted to Indo-Burmese region; all these prawns except M. dayanum were generally found in hilly regions or in the areas adjacent to their bases. On the otherhand, M. dayanum was reported to be extensively distributed in plains as well as at lower altitudes in hills throughout a large part of India and Pakistan.

M. hendersoni hendersoni occurred at altitudes between 1,500-5,000 feet in Eastern Himalayas, Burma, China and Pachmari in the Mahadeo hills of the Satpura range. M. hendersoni platyrostris exhibited distinct parallel to the altitudes not above 1,500 feet. The present observations confirmed the altitudinal limitations for the distribution of these two sub-species. M. hendersoni cacharensis was so far reported only from Cachar valley of Assam state and its range was now extended to Meghalaya state. This sub-species was presently regarded to be a geographical counterpart of M. siwalikensis which was found at the foots of the Siwalik Hills in the Western Himalayas. M. assamensis assamensis was noticed to occur in the Brahmaputra valley in North-Eastern region.

M. birmanicum included two sub-species - M. birmanicum birmanicum and M. birmanicum choprae. The former was common in the Brahmaputra valley of Assam while the latter was collected from only one locality of this state. M. malcolmsonii, an Indo-Burmese elements comprised a new record from N.E. region and was of regional distributional importance. M. rosenbergii, the largest freshwater species of this genus, was reported only from a riverine system (Fenny river) in Southern Tripura.

This aspect of the present study provided useful and important information about occurrence and distribution of these seventeen taxa (thirteen species). The collections from this region appeared to fairly well diversified when compared with overall Macrobrachium species known from this country. It is believed that further samples from hitherto unexplored areas of this region might add some more rare and interesting taxa or extend the already mentioned distributional ranges.

Chapter 2 included observations on some aspects of water quality, seasonal variations, abundance of biotic communities i.e., benthic organisms, phytoplankton and zooplanktons and seasonal fluctuations in the density, sex-ratios, condition factor, fecundity and length frequency distribution of Macrobrachium hendersoni hendersoni and M. lamarrei. The data for the monthly fluctuations in various physical and chemical parameters of water quality were collected for two annual cycles i.e., period from Janaury, 1983-December, 1984. In Umshing area various climatic factors viz., rainfall, relative humidity, sun-shine, maximum and minimum air temperature fluctuated in the range of 0.0-3.2 cm; 48.0-96.0% (at 8.30 hrs.) and 63.0%-93.0% (at 17.30 hrs), 0.0-11.4 hrs, 3.0_{c}-24^{o}C and 4.0_{c}-17.0^{o}C while in Min-Mintudu (stream) area, they varied in the range of 0.0-3.8 cm; 54.0-94.0% (at 8.30 hrs.) and 64.0%-92.0% (at 17.30 hrs.), 0.0-8.6 hrs, 13.2^{o}C-25.0_{c} and 4.0-18.0_{c} respectively.

In Umshing stream, the habitat of *M. hendersoni hendersoni* the various physico-chemical variables, viz., water temperature, pH, conductivity, dissolved oxygen, free carbon-dioxide, total alkalinity, Calcium, Magnesium, Sodium, Potassium, Phosphate-phosphorus, Ammonia-nitrogen, Silicate and oxidisable organic matters fluctuated in the range of 9.5-18.5^{o}C, 5.3-7.5, 12.0-62.0 umho/cm, 6.2-12.3 mg/l, 1.9-4.7 mg/l, 13.0-48.0 mg/l, 0.5-4.3 mg/l, 0.6-3.5 mg/l, 1.6-4.0 mg/l, 2.4-4.5 mg/l, 0.36-1.30 ug/l, 0.044-0.087 mg/l, 3.81-6.81 mg/l and 1.1-5.0 mg/l while in Min-Mintudu stream these variables fluctuated in the range of 15.8-25.8^{o}C, 5.4-7.7, 34.0-72.0 umho/cm, 6.4-11.8 mg/l, 2.5-5.2 mg/l, 8.0-49.0 mg/l, 1.1-4.4 mg/l, 1.3-4.4 mg/l, 2.0-3.8 mg/l, 1.7-5.0 mg/l, 0.31-1.4 ug/l, 0.041-0.090 mg/l, 2.2-4.41 mg/l and 3.0-8.8 mg/l respectively. The observed temperature variations evidently resulted from altitudinal differences of these two lotic systems. This study indicated the lower temperature range for the occurrence of *M. hendersoni hendersoni* and *M. lamarrei*. The pattern of variations in the water temperature was broadly identical in the two streams. Hydrogen-ion concentration showed no definite trend of fluctuations in the various stations. The pattern of fluctuation of dissolved oxygen concentration was more distinct in Min-Mintudu stream in comparison to Umshing stream. Moreover, free carbon-dioxide concentration showed no definite trend at the different sampling stations of these streams. The mode of fluctuations of total alkalinity was relatively more irregular in Umshing stream than Min-Mintudu stream. Calcium and Magnesium concentration was higher in Umshing stream in comparison to the Min-Mintudu stream. Variation of Sodium content in both the stations of Umshing stream was broadly identical. However, in Min-Mintudu stream it indicated different pattern at both the stations. Min-Mintudu stream accounted higher variations in Potassium values than the Umshing stream and followed identical patterns except for some'minor differences. The monthly variations in Ammonia-nitrogen concentrations showed multiple maxima and minima at the different sampling sites. The differences in Silica concentrations in both the streams could be attributed to the lithological differences. High values of oxidisable organic matter during winter and spring was presumably due to reduced precipitation and water logged conditions.

Umshing stream exhibited varied benthic fauna than Min-Mintudu stream. Insect larvae, Nematoda, Decapoda, Oligochaeta, Gastropoda and miscellaneous group comprised the main benthic components and fluctuated in the range of 30.0-50%, 17.0-26.9%, 6.1-19.8%, 3.7-19.4%, 3.8%-15.1% and 1.2-11.7 respectively in Umshing stream while in Min-Mintudu stream these groups fluctuated in the range of 26.1-52.9%, 12-53.0%, 4.0-22.0%, 5.0-21.0%, 3.0-14.0%, 2.0-11.0% respectively. The pattern of monthly variations in quantitative abundance of total benthos did not confirm to any definite trend at various sampling stations. This community registered 87% overall similarity between Umshing and Min-Mintudu stream.

Baed on the composition of different taxa, the total phytoplankton belonged to six different categories, i.e., Bacillariophyceae, Chlorophyceae, Chrysophyceae, Dinophyceae, Myxophyceae and Rhodophyceae. In Umshing stream, the seasonal fluctuations of the stated groups ranged between 16-47.0%, 15.0-31.0%, 11.0-29.0%, 9.1-19.1%, 11.0-18.0%, 3.0-16.0% respectively while in Min-Mintudu stream these fluctuated in the range of 15.0-3.0%, 11.0-24.0%, 9-22.3%, 7.0-23.0%, 11.0-19.0% and 3.0-22.0% respectively. Phytoplankton community of Umshing and Min-Mintudu streams reflected 72.0% similarities. Total phytoplanktons exhibited marked variations in their monthly abundance at different stations. In Umshing and Min-Mintudu stream it vartied 100 ind./l - 255 ind./l respectively.

Zooplanktons exhibited a marked variations in their monthly abundance at both the streams and their abundance ranged between 61 ind./l - 203 ind./l in Umshing stream while in Min-Mintudu stream it ranged between 49 ind./l - 140 ind./l. Min-Mintudu stream supported comparatively quite large number of zooplanktons throughout the study period and exhibited seasonal fluctuations. Categorically, the percentage composition of different groups of zooplankton viz., Protozoa, Rotifera, Copepoda and Cladocera varied in the range of 30.0-39.0%, 13.0-30.0%, 10.0-21.0%, 14.0-27.5% in Umshing stream while in Min-Mintudu stream it fluctuated in the range of 28.1-48.0%, 10.0-33.0%, 13.7-24.0%

and 8.0-36.0%. The values for percentage similarities between qualitative occurrence of zooplanktons at different sampling stations ranged between Umshing and Min-Mintudu streams was noticed to be 70%.

The total prawn population exhibited significant positive correlation with pH, dissolved oxygen, free carbon-dioxide, total alkalinity, Calcium while monthly abundance of M. hendersoni hendersoni exhibited positive correlations with water temperature, specific conductivity, dissolved oxygen, free carbon-dioxide, calcium, phosphate-phosphorus, silicate and oxidisable organic matter in Umshing stream. On the other hand, in Min-Mintudu stream total prawns exhibited significant positive correlations with water temperature only while quantitative variations registered significant direct relationships M. lamarrei with water temperature, phosphate-phosphorus and oxidisable organic matter. Amongst biotic factors total benthos, total phytoplankton and total zooplankton exhibited positive correlations and individual groups i.e., Bacillariophyceae, Chlorophyceae, Chrysophyceae, Dinophyceae, Protozoa, Rotifera, Copepoda exhibited positive correlations with M. hendersoni hendersoni in Umshing stream while total prawn exhibited positive correlations with Bacillariophyceae, Chlorophyceae, Chrysophyceae, Dinophyceae, Protozoa, Rotifera and Cladocera in Umshing stream. In addition, total prawns exhibited positive correlations with total phytoplankton, chlorophyceae, Protozoa, Rotifera and Cladocera and M. lamarrei exhibited positive correlations with insecta, oligochaeta, total benthos, bacillariophyceae, chlorophyceae, dinophyceae, mycophyceae, Protozoa and rotifera in Min-Mintudu stream.

The monthly densities of total prawns in Umshing stream ranged between 36-71 ind./m^2 and 48-74 ind./m^2 at stations A and A_1. Quantitative abundance of total prawn populations at stations B and B_1 in Min-Mintudu stream ranged between 37-77 ind./m^2 and 38-76 ind./m^2. In comparison to M. lamarrei, M. hendersoni hendersoni exhibited higher population density throughout the course of the study.

The quantitative abundance of M. hendersoni hendersoni ranged between 22 ind./m^2 - 57 ind./m^2 and 21 ind./m^2 - 51 ind./m^2 at two sampling stations (A and A_1) in Umshing stream while the population density of M. lamarrei ranged between 16 ind./m^2 (December, 1983) - 44 ind./m^2 (October, 1983) at station B and between 16 ind./m^2(December, 1983) - 58 ind./m^2 (September, 1983) at station B_1. In Umshing stream the males of M. hendersoni hendersoni in the first annual cycle ranged between 12 ind./m^2 (December, 1983) - 47 ind./m^2 (August, 1983) and 16 ind./m^2 (February, 1983) - 40 ind./m^2 (September, 1983) at stations A and A_1 respectively. In 1984, the male prawn population exhibited bimodal periodicity and indicated maxima in July (35 ind./m^2) and female population ranged between 2 ind./m^2 (April, 1983) - 17 ind./m^2(July,1984) and 4 ind./m^2 (April, 1983) - 18 ind./m^2 (September, 1984) in stations A and A_1 respectively. On the other hand, in Min-Mintudu stream, the male population of M. lamarrei ranged between 10 ind./m^2 (December, 1983) - 42 ind./m^2 (July, 1984) and 10 ind./m^2 (December, 1983) - 45 ind./m^2 (August, 1984) and female group ranged between 3 ind./m^2 (April,1983) - 17 ind./m^2 (December, 1983) and 4 ind./m^2 (June, 1983) - 18 ind./m^2 at station B and B_1 respectively. The ovigerous females of M. hendersoni hendersoni occurred from April-September in both the two annual cycles and their quantitative abundance ranged between 1-12 ind./m^2 and 2-11 ind./m^2 at stations A and A_1 respectively. Abundance of ovigerous females of M. lamarrei ranged between 3 ind./m^2 (August, 1984) - 10 ind./m^2 (July, 1984) in Min-Mintudu streams. The average fecundity in M. hendersoni hendersoni ranged between 22 ± 4 eggs./ind - 46 ± 4 egg./ind and 20 ± 5 eggs/ind - 46 ± 6 eggs/ind. at station A and A_1 respectively while production of eggs ranged between 9 ± 13 eggs./ind - 26 ± 4 eggs/ind and 10 ± 1 egg/ind - 29 ± 3 eggs/ind at station B and B_1 in Min-Mintudu stream respectively. The increased fecundity during summer could be related to higher water temperature. The extent of structural and functional dynamicity of the studied palaemonid prawn populations was reflected from length frequency distribution study and was noted to be closely associated with their breeding and growth phases. In all the sampling sites of these studied streams, males predominated the females. On the basis of length measurements, M. hendersoni hendersoni and M. lamarrei specimens were grouped into six size-classes viz., 20-0 - 30.0 mm; 30.0-40.0 mm; 40.0-50.0 mm; 50.0-60.0 mm; 60.0-70.0 mm and 70.0-80.0 mm. Females of size groups 30.0-40 mm represented the juvinile group; 40.0-60.0 actively breeding group. Ovigerous females of M. hendersoni hendersoni and M. lamarrei were recorded between April-September and May-October in both the annual cycles. Further, analysis month-wise variation in condition factor ('k') for two categories of prawn populations was based on two size groups (20.0-50.0 mm; 50.1-80.0 mm). The 'k' factor exhibited higher values in case of young populations than the mature individuals. The 'k' values were recorded higher in males than females in both the presently studied palaemonid prawns.

Chapter 3 included the observations on the general food and feeding habits, seasonal variations in different food items and fluctuations in the gastro-somatic indices and larval development of M. hendersoni hendersoni and M. lamarrei. Both these prawns were noticed to be omnivorous in terms of their food habits and their gut contents included a variety of benthic and periphytic elements. The dominant food-items of M. hendersoni hendersoni (in terms of average yearly composition) were found to be diatoms (17.59%), the other groups as mentioned in the decreasing order included : insect larvae (16.27%), detritus (12.57%), sand and silt particles (11.72%), filamentous algae (9.64%), other algae (9.47%), nematodes (9.39%), crustaceans (6.97%), mosses and plant matter (5.57%) and miscellaneous group (0.64%). An average yearly percentage composition of different food items in M. lamarrei was observed and it included insect larvae (14.25%), sand and silt (11.48%), filamentous algae (11.28%), detritus (10.28%), other algae (9.19%), nematodes (8.5%), crustacea (8.39%), mosses and plant matter (6.74%) and a miscellaneous group (0.62%). The miscellaneous group material might be regarded as accidental food owing to the fact this formed a small fraction of the gut contents and occurred without any regularity in the different months of the year. The foregut contents analysis of both M. hendersoni hendersoni and M. lamarrei showed that all the food items available in the matter were also represented in the gut. The present observations indicated a degree of opportunitism and versatility in terms of food preferences of the stated two species. The monthly variations in the food-items in the stated species coincided with their occurrences under natural conditions. Further, it was observed that in M. hendersoni hendersoni and M. lamarrei the food size group II populations (50.1 mm - 80.0 mm) was predominated by detritus, diatoms, insects, sand and silt. This reflected their semi-benthic habit.

The observations in monthly variations in the percentage composition of the different food-items of M. hendersoni hendersoni in size group I reflected that diatoms, insect larvae, detritus, sand and silt particles, filamentous algae, other algae, nematodes, crustaceans, mosses and plant matter and miscellaneous group fluctuated between 14.6 (May) - 21.2 (November), 14.7 (February) - 25.0 (July), 6.8 (February) - 10.6 (July) and 5.4 (February) - 9.3 (October), 8.8 (July) - 13.7 (November), 3.8 (January) - 10.3 (May), 2.7 (February) - 7.8 (September) and 0.2 (Janaury) - 1.0 (August). In size group II these components ranged between 12.6 (May) - 15.8 (November), 13.2 (May)- 22.5 (December), 6.2 (February) - 25.8 (September), 5.6 (May) - 15.7 (December), 8.7 (March) - 13.4 (November), 6.8 (February) - 13.9 (October), 6.4 (April) - 10.7 (October), 6.9 (May) - 10.0 (October), 4.5 (February) - 8.6 (September) and 0.3 (January) - 1.2 (April) respectively. In M. lamarrei (size group I), the monthly variations of insect larvae, diatoms, sand and silt particles, filamentous algae, detritus, other algae, nematodes, crustaceans, mosses and plant matter and miscellaneous group were found to be slightly lower than the size group I of M. hendersoni hendersoni and in size group II and the same ranged between 12.0 (August) - 24.5 (December), 10.5 (March) - 17.7 (July), 9.0 (January) - 15.0 (May), 9.6 (February) - 15.0 (July), 3.4 (April), 15.8 (December), 6.6 (February) - 12.8 (November), 9.0 (Janaury) - 14.0 (April), 2.8 (February) - 24.0 (October), 1.5 (February) - 10.6 (July).

and 0.5 (March) - 1.4 (August) in the year 1983 respectively. The observed wide range of components in the food spectrum of these two species did not reflect any specific feeding activity even though some groups seemed to be dominant at times. The variations, however, might be attributed to the routine variations in the occurrence of the different components under natural conditions.

The gastro-somatic index in M. hendersoni hendersoni (size group I : 20.0-50.0 mm) was recorded to be maximum in October, 1983 (1.983), whereas in size group II (50.1-80.0 mm) maximum value of 3.154 was noticed in August, 1984 and minimum (2.032) in February, 1983. In M. lamarrei gastro-somatic index maximum values (3.409) was recorded in March, 1984 in size group I (20.0-50.0 mm) and minimum (2.0535) in December, 1984. The size group II (50.1-80.0 mm) exhibited maximum GSI value (3.509) in August, 1984 and minimum (2.0692) in December, 1983. The increased intensity of feeding in both these prawn populations might be due to recuperative process where the prawn became voracious eaters. The drop in feeding intensity in both the individuals were recorded mostly during winter. This could be attributed to the prevailing low temperatures of the habitat during these months and that lead to reduce general activity of the prawns.

The larval development in M. hendersoni hendersoni and M. lamarrei as observed in the present study was noticed to be abbreviated and was assigned to second category of Sollaud's scheme. M. hendersoni hendersoni showed two larval stages before hatching into post-larva while three larval stages were noticed in stream-dweling population of M. lamarrei. The first larval stage of M. hendersoni hendersoni was characterised by serrated rostrum, short antennal flagellum and settation of antennal scale mostly confined to its distal margin. The distinct appendix interna bearing 2-3 minute hooks on all pleopods except the first and epigastral hump was noticed on carapace and uropod biramous, telson with a terminal tooth with a movable accessory spine on its inner side on outer ramus of the second larval stage of M. hendersoni hendersoni. The newly hatched out larvae of M. hendersoni hendersoni were noticed to be attached to the body of mother for sometimes while the newly emerged larvae of M. lamarrei attached themselves to the walls of the container before becoming free swimming. The first larval stage of M. lamarrei was characterised by sharply pointed antero-lateral spines on antennule, and inner boarder of antenna carrying 10-11 plumose setae, each pleopod with a distinct basal segment. Fifth pair of peraeiopods uniramous, third to fifth pleopods with endopods reaching more than 2/3rd of the exopods. The suppression of exopod in this larvae were noticed to be extended to the fifth pair of peraeiopods. The second larval stage characterised by prominent supraorbital and branchiostegal spines, endopod long and multijointed and third larval stage was characterised by a strong stylocerite, outer flagellum of antennule divided into two distally. The number of larval stages in M. lamarrei agreed with the land locked and riverine population examined earlier from peninsular India. The occurrence of two larval stages in M. hendersoni hendersoni is strickingly contrast to the earlier unpublished report of only one larval stage. The first larval stage corresponded to the second stages of M. hendersodayanum in which this stage evidently appeared to be suppressed. Embryonic development lasted for 10-14 days in M. lamarrei. Before emergence, the larvae showed distinct heart-beat and wriggling movements lasted for 7-11 days in M. hendersoni hendersoni.