OCCASIONAL PAPER NO. 146

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सत्यमेव जयते

ZOOLOGICAL SURVEY OF INDIA
1992

Published : September, 1992

Price
Indian : Rs. 110.00
Foreign : $ 9.00 £ 6.00

Published by
The Director, Zoological Survey of India, Calcutta

Laser set by Neatpoint Photocomposers, 6A Sudder Street, Calcutta 700 016
and printed by Independent Printers, Calcutta 700 026

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SUMMARY

The family Chironomidae are insects which constitute an obscure group of the Order Diptera. Their larvae are always aquatic and form a major portion of the benthic fauna in most freshwaters. The distribution of Chironomid larvae in the benthos reveal that their biomass production would be an important part of the freshwater system. Moreover, that fish subist on Chironomid larvae in large numbers is a well known fact, and pisciculturists often use them as food, knowing that these larvae form a trophic level capable of converting vegetable detritus and other organic material into a form useful for other consumers. The Chironomid larvae were specially taken up for this study because of their widespread distribution in lakes and rivers of varying quality and their marked habitat preference to exibit a wide range of tolerance to environmental factors and are able to live in "clean" and "polluted" waters. The Family Chironomidae though ubiquitous in nature and a large number of species have been identified, yet very little work has been done on its larval taxonomy or its ecology, and particularly so from N.E. India. Two major study sites were chosen from the State of Meghalaya. In East Khasi Hills around the vicinity of Shillong the lotic systems were chosen, while the lentic systems were in Garo Hills. The two lentic systems were the Tasek Lake and the Chitmareng Lake. At Tasek Lake three stations were chosen, two littoral and one profundal, while only one littoral zone was chosen at Chitmareng, as the lake was much smaller and shallower than the Tasek Lake. Both the lakes were of tectonic origin. The two lotic systems undertaken for the present study were two hill streams – Umkrah and Umshripi, both originating at about an altitude of about 2000 m. They flow down to join the Umiam river which itself is situated at an altitude of 1050 m. In fact these two hill streams are the only important freshwater lotic systems in that area and they are perennial. Both streams flow through reserve forests in its upper reaches and cascades down along urban settlements receiving household and municipal wastes before joining the main river. Five sampling stations were chosen in each lotic system enabling a representative of all habitat types prevalent in these streams.

Population analysis of the larvae were carried out in both the lotic and lentic systems. Simultaneously the physico-chemical parameters were also studied. All larvae collected have been identified upto generic levels and their keys, diagnostic characters and drawings provided. The present investigation revealed maximum densities of 1500 larvae/m^2 in the lentic systems. Six genera being present offered a greater variety of these organisms in these systems of lentic water bodies. In contrast the lotic systems revealed a lesser diversity and a different composition. Freshwaters in these regions of N.E. India tend to be acidic, and harbour not many benthic organisms. In view of the wide tolerance of the Chironomid larvae considerable plasticity in the life cycle was seen, as reflected in the annual overwintering instars during the course of this investigation. Only one or two genera revealed mass occurrences in some localities, and even those which occurred along with them were characterised seasonally. From the present investigation it was observed that though individual genera were useful as index organisms, it was the assemblage of taxa which were of greater value. Subfamilies Tanypodinae and Orthocladiinae represented larger portions of the population at cleaner sites, indicative of higher oxygen and lower carbondioxide and alkalinity levels. On the other hand there were wide divergence of tolerance and the genus **Chironomus** being most conspicuous in that it was available in most of the sites. The analysis of occurrence and abundance data indicated that virtually the same environmental factors which affect one population affects the others, emphasising their potential importance as agents of natural selection. In the present investigation pH, chemical composition of the water and its solute concentrations appeared to be more important in restricting larvae in certain places, while mud sustratum in restricting other larvae and finally oxygen and depth playing a major role in the restriction of larvae belonging to the genus **Chironomus**.

INTRODUCTION

The present investigation was undertaken with a view to identifying the ecological characteristics of some water bodies in the regions of North Eastern India. As work has either been completed or is in progress in the lotic and lentic systems by various workers of the North-Eastern Hill University, Shillong, it was thought best to take up the benthic group of organisms, and in particular the family Chironomidae, to fill in those gaps which were needed for a total understanding of the limnology of the region.

The family Chironomidae are insects which constitute an obscure group of the order Diptera. On account of their small size and inoffensive habits they have largely escaped notice, except when they have been mistaken as mosquitoes, whom they resemble only in their general appearances. In fact, Chironomid adults are referred to as "blind mosquitoes" - an etymological catastrophe since they are neither "blind" nor "mosquitoes" (Beck, 1976). These adults are often seen on moist evenings, flying in dense swarms near the ground, over the sidewalks, under trees or lamp posts by the road side and it is in this brief period of their existence of five to ten days that they are most familiar to the general public. In fact, though any minute fly is referred to as a midge, the adults of this family of Chironomidae are the true midges. Hence, they are also referred to as "midges" or "non-biting midges" forming an exceedingly complex family of more than 3,000 species of worldwide distribution. Their ubiquitous nature of occupying any benthic community is known from the polar regions to the tropics.

The family can be distinguished from others under Diptera, in that, they are delicate gnat-like flies, with the antenna conspicuously plumose in the male and pilose in the female. The head is small and often concealed by the thorax with the ocelli absent. The mouth parts of these adults are poorly developed. The characteristic feature is the elongated forelegs with the anterior wing veins more strongly marked than the posterior. Though they bear a general resemblance to the family Culicidae, they are distinguished mostly by their unscaled wings.

The adults of certain species have become a problem in certain areas. Though they do not seem to bite or carry diseases, at times emerge in tremendous numbers and get attracted to light, congregating at the lighted windows, when many die and pile on ledges giving off a very offensive odour. In fact, there are records where dead midges have been littered on the road or bridges and these highways were temporarily closed as they were too slippery for safe driving (Beck and Beck, 1969). Such emerging adults after mating, lay eggs in all aquatic biotopes throughout the world.

The larvae that hatch out in the aquatic systems form a significant portion of the macro-invertebrate fauna in freshwater habitats. The larvae are referred to as "legless diptera" and "blood-worms". The former is attributed to the presence of vestigeal prolegs and the latter due to the roughly vermiform shape and red colour in particular to the haemoglobin bearing genera. The larvae are always aquatic and usually live in burrows or tubes which they construct, by fastening together the debris or the detritus with the silk secreted from their salivary glands. Very often they make up one fourth to one third of all insect species found especially in lotic systems. They form an important link in the food chain between algae and the macroinvertebrates and that of the larger macroinvertebrates and fish.

The general adaptability of Chironomid larvae to all sorts of aquatic habitats is amazing and unparallelled among the insects. The distribution of Chironomid larvae in the benthic fauna of water bodies reveals that, their biomass production would, be an important part of the examination of most of the freshwater systems. Moreover, that fish subsist on Chironomid larvae in great numbers revealing a direct relationship on their growth rate, exist in various published works. Herein lies the chief interest from the pisciculture point of view, that, as food for fish these form a trophic level capable of converting vegetable detritus and other organic material into a form useful for other consumers.

In addition to their usefulness as such, biologists investigating streams and lakes have found that midge larvae of certain genera and species live with other communities of macroinvertebrates associated with pollution and form an important constituent in freshwater ecosystems receiving organic enrichment (Brundin, 1949; Thienemann, 1954 Gayfin 1958; Hynes, 1960; Curry, 1965; Carr and Hiltunen, 1965; Learner and Edwards, 1966; Davies, 1971; Wilhm, 1975; and Saether, 1979). The Chironomid larvae were specially favoured for study, because of their widespread distribution in lakes and rivers of varying quality and their marked habitat preference to exhibit a wide range of tolerance to environmental factors and live in both 'clean' and 'polluted' waters.

In view of such economic importance of the group, either as indicators of pollution or as fish food, and as in some parts of the world for the control of adults, the need for a thorough study of these organisms cannot be overemphasized. In particular, classification of water bodies seeks to identify the main types of individual, manifold and highly complex biotopes and to characterize these on a casual basis. Since many problems on limnology are directly or indirectly connected in this way, these classifications can be regarded as catalysts, joining and comparing different branches of limnology which, hopefully, will lead to a better definition of problems and throw some light on the problems of the different biotopes. It was for these reasons that Chironomids were particularly chosen as they play a dominant role in both lotic and lentic systems giving information which is not obtainable by other means. The different freshwater systems, list of members of indicative communities, their intricate relationships between themselves and the environment, helps in this evaluation, and the occurrence of certain species in certain quantities, points at normal or abnormal characteristics of that particular biotope. The precondition for improvement of these trophic systems, is to obtain a better ecological knowledge of the members of the different communities as well as detailed work on their taxonomy and zoogeography.

REVIEW OF LITERATURE

The family Chironomidae though ubiquitous in nature and a large number of species have been identified throughout the world, yet very little work has been done in India on either its taxonomy or ecology. Not only are the descriptions of the various species of this family not available, but even a comparative study on the present status does not exist. A need was, therefore, felt to put together a comprehensive review of existing literature in the world so as to form a basis, in addition to the ones available from India.

For the Family Chironomidae, one could go as far back as the works of Meigen (1800, 1803), since Opinion 152 of the International Commission of Zoological Nomenclature gives priority to the names used by Meigen (1800). The most pertinent taxonomical and ecological works for Chironomidae were done by workers of the United States of America, like Johannsen (1905, 1938), Malloch (1915), Muttkowski (1918), Richardson (1921, 1925) and Lindeman (1942). The tribe then known as Tendipedini was worked out in greater detail by Townes (1945) who raised many former subgenera to genus rank. Simultaneously Florida Chrionomidae was worked out extensively by Mitchell and Ensign (1928), Rogers (1933), Cooke (1939), Carr (1940), Hobbs (1942), and Berner (1950). It was Sublette (1955, 1957) who worked in detail North American Chironomidae and provided a list of synonims. The taxa of Freeman (1955, 1956, 1957, 1958, and 1961) have largely been followed by Dendy and Sublette (1959), which culminated in the firm foundation of the systematics of North American Chironomidae by Sublette (1964). Around the same time Beck and Beck (1959), dealing with the habits and habitats of these groups of insects worked out, in detail, nearly all the species for Florida (Beck and Beck, 1966). In the review of Californian Chironomidae by Wirth and Stone (1956), only Clunionae and Tendipedinae (Wirth, 1949) have been extensively studied. In addition to the adequate, treatment of Chironomid species of Northern Mexico by Sublette and Sublette (1965), a detailed study of all type specimens at the National Museum of America and Canada have been described (Sublette, 1960, 1964a, 1964b, 1966a, 1966b, 1967a and 1967b). Mc Alpine (1964) and Oliver (1963, 1964) have done an in depth study of those species found in the Northern Archipelago of Canada. Since then, a number of papers have been published on the occurrence, the record of species and the description of new species all over the United States and Canada. Of these, the works of Hensen and Cooke (1976), and in particular, the complete description of the Coelotanypodinae of the North Eastern U.S.A. with keys by Boesel (1974), stand out as major taxonomic contributions.

The knowledge of Chironomids of the West Indies is rather fragmentary, consisting of the limited reports in papers by Williston (1896), Coquillet (1900), Picado (1913), Gerry (1932, 1933), Johannsen (1938), Miller (1971), Sublette and Wirth (1972) and Harrison and Rankin (1975, 1976b).

As far as the European literature was concerned, the confusion began with the comparison of the original works of Meigen. This necessitated a great revision and hence those of Harnisch (1923), Edwards (1929), Goetghebuer (1937) and Lenz (1941) could be called the earliest European literature available on this Family Chironomidae. Since then, the works of Brundin (1949), stand out as major contributions of this family, who also gave a pioneering idea of the status of this group of insects, especially in Northern Europe. Around the early fifty's, German contributions came from the works of Thienemann (1950a, 1950b, and 1954). It was here that the systematics of the family was given a firmer foundation, as a stress was put on all the three stages of the life history of this family by Thienemann for a total understanding of their taxonomy. In 1956, Brundin clarified the status and position of Orthocladiinae, and a similar analysis of the group Tanypodinae was done in greater detail by Fittkau (1962). Around the same time from Finland, both from forest laplands, (Hirvenoja 1960, 1962a, 1962b, 1962c, 1963 and 1973; Lindeberg 1963, 1967) and the geographical variations in Finnish Chironomids were examined and shown in detail by Wulker (1956), Oliver (1959), Strenzke (1960), Lindeberg (1963, 1967, 1968), Koshkinen (1968), Olander and Palmen (1968). The variation of different characters within Chironomid populations in Europe has been studied in detail by Palmen (1960), Lindeberg (1963, 1967), Reiss (1965), Botnariuc and Albu (1968), Botnariuc *et al.* (1969), Schlee (1968) and Cranston (1974). The lacustrine fauna of European Alps, with a detailed study of Chironomidae on the three life history stages as originated by Thienemann was completed by Reiss (1968) and Fittkau (1968). Since then, European workers have worked out in detail the general status of the genus or the concept of the genus within the family Chironomidae and also the aspect of characterization and delimitation of Chironomid genera (Beck and Beck, 1968; Fittkau, 1968; Saether, 1971 and Lindeberg, 1971). Though many works do exist on Chironomidae in USSR, a review of the Soviet literature on Chironomidae by Konstantinov (1971) is the only one relevant, as most works exist in the Russian language.

The major contribution from South American Chironomidae have been done in detail, though confined only to the Amazonian basin, by Fittkau and Reiss (1973). It is here that for the first time the status of South American Chironomid fauna have been outlined and stress laid on the diversity of species in that area.

Though Kieffer's (1908-1924) could be called the earliest work on African Chironomids, the real foundation was laid by Freeman (1955, 1956, 1957, 1958) as revealed by the monographic series on African Chironomidae. However, a comprehensive bibliography of the Chironomids of Africa and the adjacent islands has been brought out by Davies and Davies (1976, 1978). A considerable data on the geographical distribution of the Chironomidae from the Ethiopian region could be obtained from the report of Dejoux (1976).

In addition to Freeman's earlier work on African Chironomidae the only work from Australia could be traced to Freeman (1961).

In the far east, taxonomic work on this group of insects has been done by Tokunaga (1940). He has also reviewed his own work along modern lines (Tokunaga, 1964). All these materials that have been worked out were based on the collections of Professor T. Esaki's micronesian Expeditions (1936-1940). Of the South Asian Diptera described in Van der Wulp (1896) catalogue with 2889 species, only 18 belong to Chironomidae and three more were subsequently added by Brunetti in 1910.

The collections by Thienemann (1930) and his associates during the German Limnological Sunda Expedition (1928-1929), was worked out by Johannsen (1931, 1932, 1932a), who formulated keys for each sub-family, genus and species. Many of Kieffer's species of the Oriental region have been partly revised and raised to the rank of genus (Kieffer, 1921b).

The Chironomidae fauna of Afghanistan is as yet very little known. Tokunaga (1966) reported twelve species from that territory, describing them on the basis of adults. Hirvenoja (1973) described three species, and Lehmann (1969) one species, while Reiss (1968a, 1969) described some new species from Nepal. Loffler (1969) reported several kinds of Chironomidae on the basis of larvae from Nepal. Further, four new species from Nepal were described by Murray (1976).

Kieffer's (1910-1914) work on Indian Chironomidae were mostly from materials collected from Calcutta, Assam, Darjeeling and Simla hills and described on the basis of colour characteristics of adults (Kieffer, 1911). An extensive manuscript (Kieffer, 1911a) on the species from Assam and Himalayas followed, in addition to the information given in part earlier. While working on Ceylon Chironomidae, Kieffer (1913) added his contributions on further collections from India which included species from North-East, the East and South-West coasts. The type collections in the Museum of the Zoological Survey of India, Calcutta, was finalized by Kieffer in 1914. It was Brunetti (1920) who compiled Kieffer's work in a catalogue on Oriental and South-Asiatic *Nemocera*.

Since then, except for sporadic reports on the occurrence and description of new species, nothing substantial has been added to Indian Chironomidae. Further, many of Kieffer's type species were lost in fire during 1956, when they were at the Hungarian National Museum and the movement between Varanasi and Calcutta during the great floods of West Bengal has destroyed many more. An updating of the work to put Indian Chironomids on the modern taxonomical line is already underway (Alfred and Choudhury, in preparation).

Work on the family Chironomidae by Indian workers have been very meagre and those that exist are mostly during the last decade with one or two papers published earlier. One of the earliest of such taxonomical descriptions was done by Singh (1958, 1968) on a collection from the Western Himalayas. Kaul (1970) recorded two new Diamesinae again from North-West Himalayas. A detailed description on the systematics of adults, pupae and larvae at morphological, cytological and biochemical, along with the larval ecology and feeding habits have been done on five species of Chironomidae from 12 lotic systems in South India (Alfred 1973a, 1974). In addition genetic descriptions of larvae were also given (Alfred, 1973b). Thereafter, Singh and Kulshrestha (1975, 1976, 1977) reported new species from Agra of the sub-family Chironominae.

The only group of Chironomid workers who have done detailed systematics on the family Chironomidae in general and the sub-family *Orthocladiinae* in particular were Choudhury and his students from the University of Burdwan. Of these, on Orthocladiinae both from Burdwan and the collection at the Z.S.I. museum, Calcutta, have been described in detail by Sinharay *et al.* (1978), Choudhury and Nandi (1979) and Choudhury and Ghosh (1980). In addition the same group of workers have given detailed descriptions of the adults of the sub-family *Chironominae* (Guha and Choudhury, 1979; Sinharay and Choudhury, 1979; Choudhury *et al.*, 1981; Guha and Choudhury, 1981a, 1981b and Choudhury and Ghosh, 1981).

In addition to the foregoing literature review on Chironomid taxonomy from different countries, workers on this group of insects have come together and shared ideas in symposium and workshops exclusively on Chironomidae. The latest compilation of such works, entitled "Recent developments in Chironomid Studies" (Diptera, Chironomidae), has been done by Saether (1979), based on a workshop conducted in Winnipeg, Canada.

The foregoing review of literature though is inclusive of the habitats of the different species of Chironomidae, it primarily deals with the taxonomy, systematics, and status of this family of insects. However, the importance of Chironomids as a group, favoured for study, was due to their ecological behaviour, in particular as indicators of pollution in aquatic systems. Moreover, geographically these insects are worldwide in distribution from the high arctic and alpine to subtropical and tropical regions inhabiting all forms of aquatic systems. Further, the adult taxonomy is more established than larval taxonomy. However, as far as this family's ecology is concerned, the work on larvae is more than on the adults.

Hence a review on the larval ecological status is in particular more appropriate for the present investigation. Since time immemorial the larvae of this family have been utilized to classify lakes according to their composition and abundance, in relation to the dissolved oxygen concentration, trophic status and other abiotic factors (Thienemann, 1914, 1915, 1918, 1921, 1922, 1925; Lundbeck, 1926; Valle, 1927; Lenz, 1925, 1928a; Crisp and Gledhill, 1970; Petr, 1970b; Saether, 1980 and Williams, 1980). This work though continued for sometime, yet subsequent authors confined their studies to the distribution of the Chironomid larvae, within particular water bodies (Thienemann, 1954; Bardach, 1955; Curry, 1956; Mundie, 1987; Slack, 1965; Hilsenhoff, 1967; Jonasson, 1971; Laville, 1971; Hunt and Jones, 1972; Morgan, 1972; Maitland *et al.*, 1972; Saether and Mclean, 1972; Saether, 1970, 1973; Petr, 1972, 1974; Charles *et al.*, 1974; Maitland and Hudspith, 1974; Bolt and Allanson, 1975; Cowell and Carrew, 1977; Ali and Mulla, 1979; Moore, 1979; Johannsen, 1970; Hilburn, 1980).

All these led to the confirmation of the work on the relationship of Chironomids with respect to lake typology as identified by Brundin as early as 1949. These works also helped in the identification of concentration zones, which shift with seasons, enabling population density to fluctuate from littoral to profundal zones (Brinkhurst, 1974).

The possible mechanisms and reasons for population density fluctuations were also identified. Some suggest differential mortality in response to seasons and its changes (Borutsky, 1939; Lindeman, 1942; Lellak, 1953a, 1953b; Kajak, 1958; Kajak and Dusoge, 1967). Others, while not negating the above phenomenon, however, were of the opinion that the major cause was larval migrations to better habitats (Hruska, 1961; Barthelmes, 1962a and Kajak, 1964). The latter gained support by studies which showed the hastening of the process of development followed by earlier emergence, as attributes for the movements of populations of Chironomidae (Anderson, 1946; Dugdale, 1955; Flint, 1979). However, temperature has been demonstrated as having no effect on larval distribution (Luferov, 1969). In any case migration of larval Chironomidae is well established by subsequent works causing the fluctuation in their densities both in lakes and rivers (Thut, 1969; Marks and Henderson, 1970; Iovino and Minar, 1970; Aldoori, 1972; Brinkhurst, 1974). This is understandable as the ability of larval Chironomidae to exploit new habitats and enable rapid colonization and succession is a basic nature of this group (Nursall, 1952; Anderson *et al.*, 1964; Aggus, 1971; McLachlan, 1974b, 1974c; Petr, 1975; Bolt, 1975; Ramcharan and Paterson, 1978). Such mechanisms are observed more clearly in running water systems where even a complete recolonization of a stream could be aided by larval migration and by drift of the earlier instars (Harrison, 1966a, 1966b; Thorup, 1970; Mason *et al.*, 1970, 1971, and Hynes, 1975). Population fluctuations are also attributed to the rise and fall of the water level and increase in population have been seen in rising water columns of aquatic habitats where these benthic organisms live (Kajak, 1958a; Hynes, 1961; Thomas, 1966; McLachlan, 1968, 1970c and Whitehouse, 1971).

Human activity interfering with freshwater ecosystems is an established fact. Changes due to such nature effecting the quality of either a lake or a stream can easily be identified with the help of Chironomid larvae. These, by their widespread distributional nature, also possess marked habitat preferences (Paine and Gaufin, 1956; Gaufin and Gaufin, 1966; Hynes, 1970; Oliver, 1971 and Schlott and Reiss, 1975). A clearcut relationship to the pollution and in particular to organic pollutants in lotic ecosystems is well documented by studies on this group of insects (Theinmann, 1954; Gaufin, 1958; Hynes, 1960; Hawkes, 1962, 1963; Learner and Edwards, 1966; Davies, 1971; Hawkes and Davies, 1971; Buckland, 1974 and Tabaru, 1975).

The density of any population and in particular those of the family Chironomidae is primarily determined by the larvae reaching the adult stages. The capability of these adults emerging, mating and laying of eggs is the triggering mechanisms for the newly hatched out larvae to establish itself in a stable equilibrium in relation to the carrying capacity of that ecosystem. Further, their dynamics depends on their sustenance and growth in relation to other species by a maximal utilization of all ecological niches available in that habitat (Hamilton, 1965; Armitage, 1969, 1971; Curry and Curry, 1971; Fittkau, 1971 and Topping, 1971). It was, therefore, that various workers have stressed on adult emergence studies enabling the identification of seasonality in emergence patterns and also whether populations are single or the existence of overlapping generations (Miller, 1941; Brundin, 1949; Remmert, 1955a; Neumann, 1961; Palmen, 1962; Jonasson, 1965; Corbet, 1965; Englemann and Shappirio, 1965; Oliver and Corbet, 1966; Danks and Oliver, 1972; Stahl, 1975; Lavalle, 1976 and Titmus, 1979).

In contrast to all the above, Indian work on benthic fauna in general and family Chironomidae in particular, is rather scanty. Works on benthic fauna have usually been taken up as part of general studies in relation to fish and fisheries, where Chironomids were grouped together as larvae dominating benthos of such studies (Srivastava, 1956a, 1956b; Michael, 1964; Krishnamurthy, 1966; Moitra and Bhowmick, 1968; Mandal and Moitra, 1975). Benthic limnology and its interrelationships of the biota and physico-chemical factors have also been understood very little for Indian aquatic systems (Pruthi, 1933; Sewell, 1934; Ganapati, 1940; George, 1966; Nasar and Munshi, 1974). The only work on detailed aspects on the population dynamics of five species of larvae and their physico-chemical factors as seen in some South Indian ponds, has been done by Alfred (1973). Since then, only two reports exist, one on the biosystematics and ecology of five species of Chironomidae (Alfred and Michael, 1979), and the other on population dynamics of freshwater insects, which includes Chironomid species of Bhagalpur (Roy *et al.* 1980).

BACKGROUND OF THE STUDY REGION

Location

The general study area was the state of Meghalaya located in North East India. This state comprises of three major hill ranges, the Garo, the Khasi and the Jaintia. All these lie as a land-locked territory, sandwiched between the Assam plains on the North and Surma Plains (Bangladesh) on their South.

Meghalaya comprises of a total area of nearly 22,500 sq. km. and lies between latitudes 25°47'N and 26°10'N and 89°45'E and 92°47'E longitudes. The general feature of the territory is marked with high and low rolling hills, on large plateau with a geomorphological landscape of streams, brooks, rivulets, water falls and ponds or lakes. The altitude lies between 600 and 1950 metres with the highest peak, the Shillong peak in the East Khasi Hills district. The capital of Meghalaya is Shillong, situated at the elevation of 1496 m. (Fig. 1).

Physiography

Physiographically Meghalaya represents a remnant of the ancient plateau of Pre-Cambrian peninsular shield uplifted to its present height. It comprises of exposed Archean gneiss and schists covered in the central and eastern parts. The region was formed when the great Himalayan chain were uplifted from the 'Tethy's sea', during Mesozoic and early Tertiary times. The hills are nearly 135 million years old. The Shillong plateau is therefore best regarded as a part of Indian Peninsular cut off therefrom by the intervening spread of the Ganges and Brahmaputra alluvium. The rocks have more in common with the gneissic and Dharwar rocks of Bengal and Bihar than those of the more neighbouring Himalayan sequence.

The drainage pattern of the region has a feature revealing straight course of rivers, rivulets and streams evidently along joints and faults. The magnificient gorges in the southern Khasi and Jaintia Hills are the result of massive headward erosion by antecedent streams along joint and sedimentary rocks. The northern part of the plateau is marked by long incisive valleys due to headward erosion along joints in the gneissic rock and granites. The limestone covered areas of southern Garo, Khasi and Jaintia Hills reveal a typical hurst topography. The present physiographic configuration of the plateau is due to the different geological events from mesozoic to present, indicative of the Polycyclic erosional surfaces at various levels.

Climate

The climate of the region is generally tropical monsoon (Table I). The central and eastern parts due to higher elevations have very little temperature fluctuations while the western parts except during winter, records quite high temperature. The range of temperature is usually from as low as 0°C in Shillong to about 35°C in Garo Hills. The winter months are usually from December to February and the ground is covered by hoar frost every morning but there is no record of snowfall at all.

The important climatic characteristics of these regions is very high rainfall averaging annually 7200 mm. In fact, Mawsynram, situated about 16 km. west of Cherrapunji, which itself is nearly 50 km. from Shillong, records the world's heaviest rainfall, nearly 14,000 mm. This is due to the fact that the south-west monsoon from the Bay of Bengal blowing over Bangladesh gets suddenly cut off by the cliffs with an average elevation of about 1,200 m. resulting in very heavy rainfall.

One can divide Meghalaya into four distinct seasons, the Spring (March to May), Summer or rainy season (June to September), Autumn (October and November) and Winter (December to February). Usually strong winds blow from south-west towards north-east from about the middle of February to about middle of May each year. An interesting feature of the state is that it lies in a highly seismic axis and tremors of small magnitudes are very frequent.

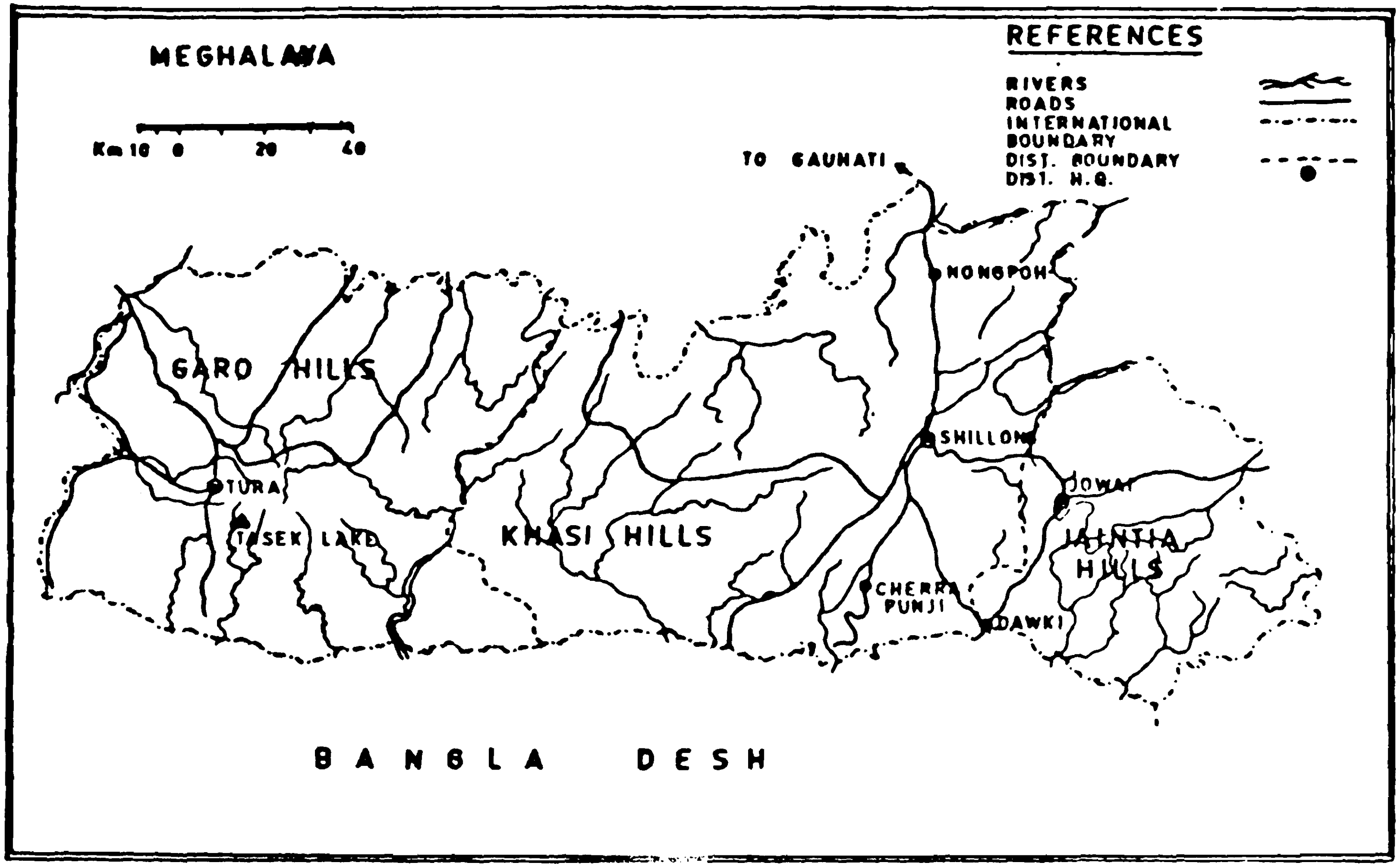


Fig. 1. Map of Meghalaya showing the areas of study. Shillong and Garo Hills.

TABLE I

Meteorological data for the State of Meghalaya

Month	Mean Max. air temp. (°C)	Mean Min. air temp. (°C)	Relative humidity (%)	Rainfall (cm)
February	19.9	7.8	57 – 72	2.3
March	23.4	12.6	51 – 63	44.2
April	21 7	12.7	76 – 82	266.5
May	23.0	16.6	77 – 87	453.4
June	24.2	16.6	85 – 86	310.4
July	24.2	18.1	87 – 88	270.0
August	24.3	17.7	85 – 88	319.8
September	23.0	16.6	76 – 91	279.4
October	20.7	13.2	72 – 90	127.4
November	18.5	12.1	71 – 90	50.3
December	15.1	6.7	60 – 88	25.0
January	13.4	4.5	60 – 88	nil
February	15.2	6.8	52 – 79	17.7
March	21.3	10.3	49 – 52	34.9
April	23.7	13.0	37 – 57	34.4
May	23.1	16.6	79 – 86	228.3
June	22.4	13.6	84 – 88	460.1
July	23.8	13.2	86 – 88	245.2
August	25.0	18.3	82 – 86	193.0
September	23.1	16.6	86 – 91	246.4
October	22.4	15.2	70 – 90	50.6
November	18.5	10.3	64 – 85	20.4
December	17.8	7.4	40 – 84	nil
January	16.2	6.6	50 – 81	1.2
February	17.9	5.1	49 – 70	25.7
March	22.6	10.4	41 – 53	11.7
April	25.5	14.8	54 – 69	136.5
May	26.0	16.7	65 – 70	56.1
June	25.3	14.4	79 – 84	354.5
July	23.3	17.8	88 – 90	512.0
August	24.3	17.7	82 – 87	127.0

Soils

The soil varies all over the Meghalaya plateau both in physical characters and fertility conditions. They are mostly lateritic in origin and vary from sandy loam, red loam to clayloam. The soils in the basins are more fertile than the upland soils since much of the bases and organic matter from the top soil of the latter gets washed away due to high rainfall.

The sediments are mainly sandstones and shales (mud stone), and well defined fossiliferrous limestone. The percentage of organic carbon is nearly 5% to 10% and the pH between 4.5 and 6.5 units.

Vegetation

The state of Meghalaya is endowed with a rich natural vegetation ranging from sub-temperate to tropical. In the upper hills regions and especially the plateau of Khasi Hills coniferous pine (*Pinus kesiya* Royle) dominates. They extend to the Jaintia Hills but in the comparatively dried places are stunted. On the slopes of Shillong peak especially the northern slopes rhododendrons exist along with *Cryptomaria japonica*, resin and *Chinnamonum* species. The trees on the upper reaches are stag-headed and covered with moss and lichens. Canes and Bamboos form rich growths and undergrowths of the lower hills. There are nearly 150 species of ferns, 250 species of orchids and about 150 species of grass. The lower elevations are also occupied by deciduous forests. The common undergrowth which runs like belts on all the hills at all altitudes are *Eupatoriam* sp. and *Lantana camara*.

STUDY SITES AND SAMPLING STATIONS

Two major study sites were chosen from the general area of the State of Meghalaya. In the East Khasi Hills around the vicinity of the capital of Shillong the sites for the lotic ecosystems were chosen, while the Garo Hills was the area of location for the lentic systems.

Lentic Systems

The Lentic systems undertaken for the present investigation were situated in the Garo Hills District of the State of Meghalaya, about 300 kms. from Shillong. The general area of location is called Songsak and lies in deep forested areas inhabited by the local tribal people. The two lentic systems chosen here, were the Tasek lake and the Chitmareng lake. Both these lakes are tectonic in origin, the result of basin subsidence during the great earthquake of 1897; when the epicentre was the Shillong plateau (Oldham, 1899; Karunakaran, 1974). The evidence is still present today in the form of barren stumps of *Shorea robusta* trees submerged in these lakes. The lakes can be classified as tropical (Whipple, 1927) and tectonic (Hutchinson, 1975a). The shape of the lakes are elliptical which is again a general characteristic of tectonic lakes.

The Tasek lake (90°33' 12"E, 25°32' 40"N) comprises an area of nearly 11.7 hectares situated at about 225 m above sea level and surrounded on all the sides by Sal forests (*Shorea robusta*). The lake has two inlets in the form of streams, one on the southern side known as the Innal stream and the other on the western side called after its own name the Tasek stream. On the eastern side there is only one outlet.

The Chitmareng lake is only one tenth of the Tasek lake having an area of nearly 1.9 hectares and is located close to the Tasek lake, on the northern side of the latter. During monsoons both the lakes are inter-connected through the outlet stream by a small channel.

Sampling Stations

At the Tasek lake three stations were chosen, two littoral and the other profundal. The littoral station I was situated near the inlet of the Tasek stream and the littoral station III at the other inlet of the lake. The profundal station II was near the offshore zone situated more or less near the middle of the widest area of the lake. At the Chitmareng lake only one station was chosen as station IV and as the lake was much shallower than Tasek, the station selected was the littoral zone on the far side of Chitmareng away from Tasek (Fig. 2).

Lotic Systems

The lotic ecosystems were two streams, Umkhrah and Umshirpi both originating at an altitude of about 1500-2600 m. on either side of the general township of Shillong (Fig. 3). They flow down before they join the Umiam river situated at an altitude of 1050 m. These two streams are the only important fresh-water lotic systems in the area under consideration. They were also selected because they were perennial and could be sampled throughout the year by simple stream benthos techniques and moreover they were comparatively shallow and short in their entire length enabling a detailed study throughout the entire course of the flow. Further, both the streams were accessible at all the stations during the different seasons and situated sufficiently close to the University laboratories enabling chemical analysis of water samples within hours of collection. The important criteria, however, and specially for the study of Chironomids was the clearcut demarcations of zones present from the source to the mouth identifiable into clean and polluted areas.

The Umkhrah stream mostly flows through reserve forests along its upper stretches. These forests are pine trees of *Pinus kesiya* Royle with undergrowth of shrubs like *Lantana, Eupatorium* and *Polygonum* spp. The stream in its middle stretch, flows through agricultural and waste pasture lands. The lands used for agriculture are mostly done by hand digging and cowdung manuring methods, without the use of insecticides. Thereafter, the stream flows all along the sides of Urban settlements. Though the houses line the slopes beyond the embankments which are covered with small grasses and shrubs with scattered pine trees, yet the stream receives household wastes. Finally, this stream flows through a pair of hillocks forming a moderately deep gorge before it joins the other stream. The approximate length of the stream is 15 km.

In contrast, the Umshirpi stream has its head waters flowing through the Government Reserve Forest comprising of Pine trees of *Pinus kesyiya*. Thereafter without passing through any agricultural lands it enters an experimental trout farm run by the State Fisheries Department, from where it comes out, to flow through an urban settlement. After traversing for some distance it enters another fish farm and flows through urban areas again. This last patch of stream is lined on either side with houses and received maximal sewage load before it joins the other stream. A few areas of the stretch near the urban locations are lined by grasses and few shrubs of *Eupatorium, Lantana* and *Plygonum* spp. The length of the stream is approximately 12 km.

Sampling stations

Five sampling stations were chosen in each lotic system to enable a representation of all the habitat types prevalent in the systems. The stations were also chosen based on the substrate variation and the quality of the water in relation to its pollution load. Usually station I was very near the headwaters or the source of that stream and station V was the last station of the stream before it joined the other major lotic systems in the area. The other stations were kept more or less equidistant from these two points while at the same time keeping in view the above mentioned criteria for selection of stations.

UMKHRAH STREAM

Station I

This is a small pool, shady and overhung by marginal vegetations. Here the stream flows through two hillocks on either sides and contains swamplands on either banks, formed by the seepage of water upwelling from ground water sources. Current velocity is 35 cm/sec. but considerably slow in the pool, which is strong bottomed with a deposition of sand and silt. The average depth and width are 25.3 cm. and 1.85 m. respectively.

Station II

It is a strong riffle about one km. downstream from station I. At this station there is an uniform, moderately fast flow (40 cm/sec.) on a bed of small fist sized and slightly larger rounded pebbles. The average depth of this station is 12.9 cm. and width 1.9 m.

Station III

This station is almost similar to station I. It is a small pool, with silted sandy bottom, and with scatterings of boulder, gravels and pebbles. Dense vegetation on either side of the station deposits litter. Current velocity (20 cm/sec.) is very low. The average width is 1.5 m and depth 13.2 cm. The station was polluted, as large scale washings of clothes were done here and considered as a bathing place also.

Station IV

In this station the stream flows through hills with reserve forests of *Pinus kesiya* on either sides. The substrate consists of silt, sand, gravel and pebbles. Litter deposition is high. The average width and depth are 2.5 m. and 11.4 cm. respectively. The current velocity is 50 cm/sec.

Station V

This is the sewage effluent station where the stream enters the urban locations. One tributary carrying a heavy load of sewage from urban areas joins the stream at this place. Here the width of the stream also increases (7.5m), the depth is 23.3 cm. The rate of flow is only 5 cm/sec. The substrate at this station consists of sand, silt, pebbles, gravel, miscellaneous articles, and litter. In this station the colour of the water is dirty brown.

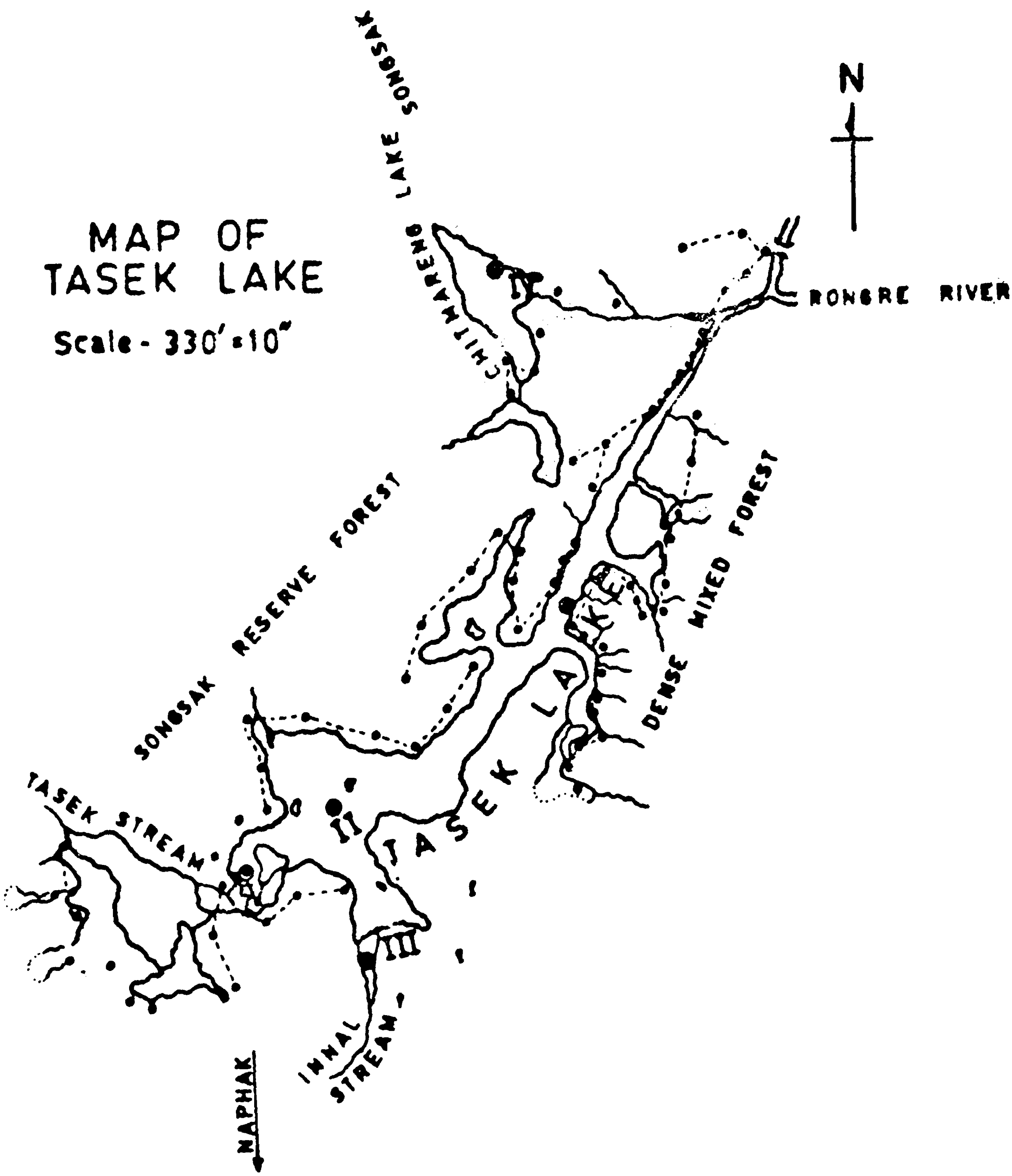


Fig. 2. Map showing the two lentic systems, the Tasek and the Chitmareng lakes. The stations I, II and III in Tasek and station IV in Chitmareng.

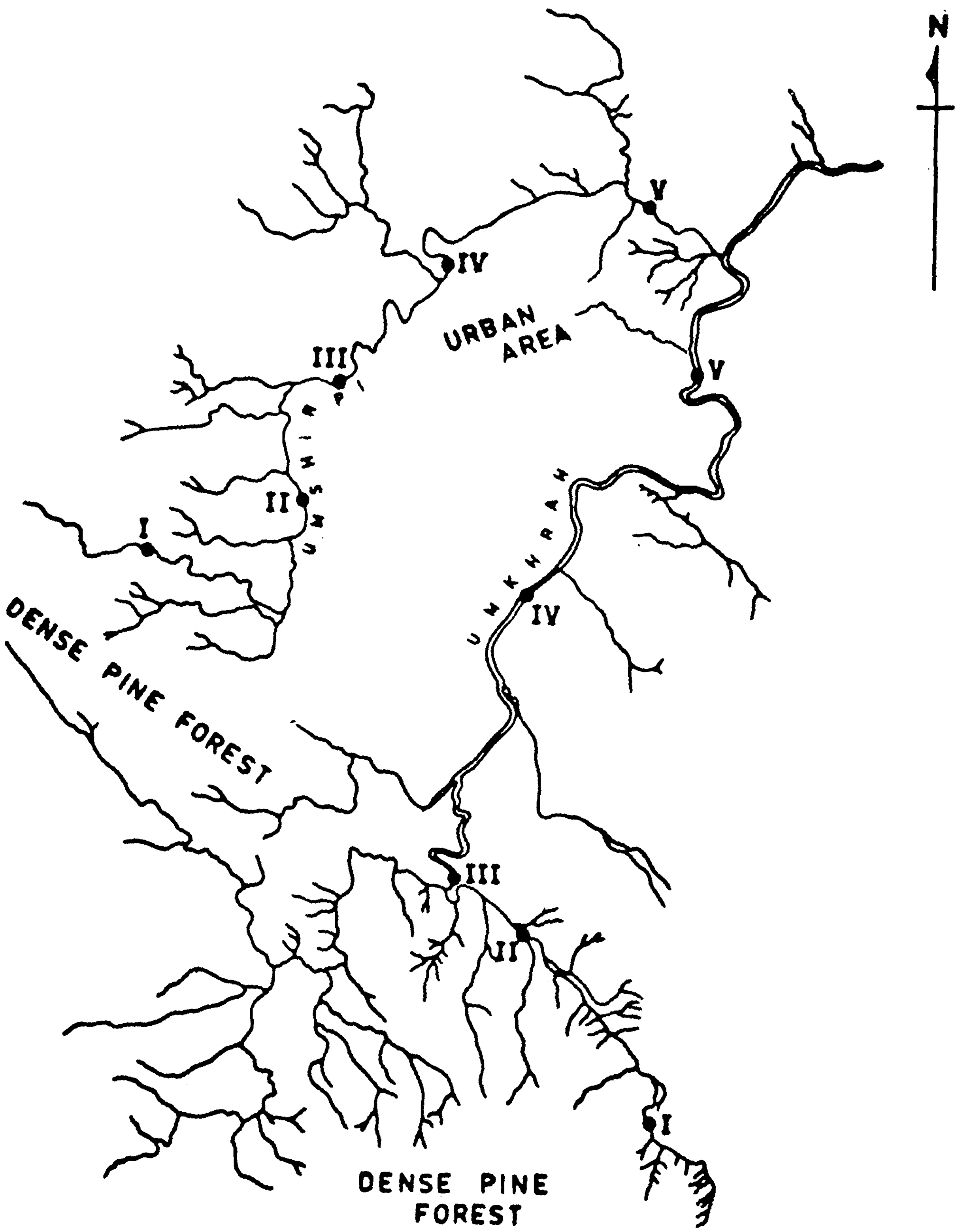


Fig. 3. Map showing the two lotic systems and the sampling stations I to V

UMSHIRPI STREAM

Station I

This station is located at the headwaters of the Umshirpi stream system. The station is almost completely free from human disturbances, before it enters a trout farm erected on the stream. Here the water flows through a reserve forest with dense growth of *Pinus kesiya* which extends upto the margins of the stream. The entire place is shaded and not much sunlight penetrates into the stream particularly in summer and monsoon months. The substratum consists of embedded and loose pebbles, strewn with occasional 3.5 m and a current velocity of 88 cm/sec.

Station II

This station is small, riffle-like (Plate 3b) having dense forests of *Pinus kesiya* on either banks and generally free from any disturbances. The bottom is sandy having large number of small pebbles and rocks covered with silt. The current velocity is 10 cm/sec. on an average. The mean width is 1.9 m and depth is 16.6 cm.

Station III

Here the stream enters a complete urban influenced area having a great amount of sewage and miscellaneous particles. The width of the stream in this station is 5.75 m on average and depth is 23.9 cm. The substratum is composed of silt, sand, gravel, pebbles, litter. The average current velocity is 40 cm/sec.

Station IV

This station is also situated in an area of great human disturbance and can be easily designated a polluted station. Surrounding vegetation comprises of *Pinus kesiya, Eupatorium* spp., *Lantana camara* etc. The bottom consists of silt, sand, pebbles, boulders etc. The average width is 8 m and depth is 22.7 cm. The current velocity on average is 25 cm/sec.

Station V

This station is almost similar to that of station III and IV and is also situated in complete urban areas. Tributaries bringing the waste product from the houses join at this station. Moreover, this is highly disturbed by human interferences. The substratum is composed of boulders, gravel, pebbles and silt. The average depth and breadth are 19.2 cm and 5.6 m. respectively. The flow of water is 50 cm/sec. on average.

MATERIALS AND METHODS

Lentic Systems

The detailed analysis for the population study of the chironomid larvae were first carried out in the stations of the lentic ecosystems of Garo Hills. This was done for a period of about seventeen months beginning February 1977 to June 1978. All collections were done at fortnightly intervals. Sampling time was confined to the morning hours between 0800 and 0900 hrs. Bottom samples were obtained at each station in replicates by the use of an Ekman Dredge. The dredge used, covered an area of 506.25 sq. cm. This bottom substrate was transferred into a 15 litre bucket and washed thoroughly. The larvae were filtered from the bottom mud by using a nylon seive made up of 14 meshes per linear cm. They were then sorted, preserved in 5% formalin and subsequent identification and counting was done. All fortnightly triplicate sampling were brought together as monthly averages for the sake of convenience and the figures represent the seasonal variations monthwise.

At each station, just before the sampling for the larvae, water samples were collected for physico-chemical parameters and the water level also noted. For oxygen analysis the water sample was taken in 125 ml ground glass stoppered bottles and fixed in the field. For the remaining analysis, water was collected in polythene bottles of 500 ml capacity, and was used for pH, conductivity, total alkalinity and free carbondioxide analysis.

Air temperature was measured with the help of an ordinary mercury thermometer at about one metre above the surface of the water at the different stations. The water temperature was taken with a similar thermometer but by placing it inside a polythene bottle securely and the readings taken immediately after the samples were brought up, indicative of the temperature of the water enclosed from that station. Transparency was determined by the use of a Sechi disc.

The physico-chemical factors were all analysed within one hour of collection. pH and conductivity were read off from a Toshniwal pH metre (Model no. CAT CL-43) and Elico conductivity bridge (Model no. Type CL-82) respectively. For dissolved oxygen, the samples which were fixed in the field was analysed with the help of unmodified Winkler's technique (American Public Health Association, 1966). Free carbondioxide and alkalinity was determined after Welch (1948).

In addition to all the above mentioned parameters, some meterological factors like maximum-minimum temperature, relative humidity and rainfall for the whole region under consideration was collected regularly from the local meterological stations.

Lotic Systems

After the seventeen months period of analysis in the lentic systems, the next fourteen months from July 1978 to August 1979 was confined to the work in the lotic systems. Fortnightly samples, confined to the morning hours between 0800 and 1000 hrs. were the time of collections at the different stations. Collections of larvae for relative abundance were made with a hand net fixed to a square frame made of wrought iron with a mesh size of 60μ. It covered an area of 20×25 cm^2 of the substrate bottom. The net was placed on the stream bed with its mouth facing the current and the substratum disturbed thoroughly when the washings got collected in the net. A triplicate number of such samples were done at each station. Samples collected from each station to be a total representative of that station, was based on triplicate collections from the middle, sides and in slower and faster current zones of the stream. This method was found to be the most suitable in shallow stony stream bed than when compared to grabs and shovel or box samplers (Hynes, 1970; Chutter, 1969). For those stations which had very little gravel or stones and which contained thick mud as substrate, larval collections were done by the use of a simple bottom cover, covering an area of 0.019

m^2. All collections were made in triplicate, from all representative parts of the stream in that station also.

In the lotic system for physico-chemical analysis the same method as for the lentic system was followed and the same factors analysed except for the transparency of the water and instead the width of the stream at that station was measured. The former was not measured as the water at most of the stations throughout the period of investigation was more or less transparent enough to see the stream bottom.

For a detailed study of the larval specimens collected, representative specimens were taken and placed in hot 5% KOH for ten minutes, washed in water and transferred to glacial acetic acid for another ten minutes, finally they were left in ethyl alcohol till the different parts were dissected and mounted in DPX. Each mouth part and other important taxonomic characters of the same larvae were mounted on one slide.

For population analysis only the larvae of the genus *Chironomus* was separated into four different stages, representative of the instars, based on the length of the larvae. The other genera were counted as such irrespective of their length groupings. All specimens were, however, finally preserved in 10% formeldehyde.

During the last phase of the work from June 1979 to September 1979 emergence studies were done at one of the tributaries of the Umshirpi stream to obtain a general idea of the number of adults, their sex ratio during the peak monsoon period of emergence. The emergence studies were carried out with the help of light trapping techniques with the use of a fluorescent lamp and confined to the hours just after dusk till about midnight. They were preserved in 80% alcohol.

RESULTS

Larval Taxonomy

The higher categories employed here are those most commonly used by the American authors (Johannsen and Townes, 1952) and which are valid in the light of present knowledge of Chironomidae. The more important character changes at each point are indicated in the keys.

The following sub-family keys are modified from those of Johannsen (1937) and Roback (1957).

Key to the sub-families of larval Chironomidae

1. Antennae retractile into head; basal antennal segment usually elongate. Lingua present .... Tanypodinae
   Antennae non-retractile; lingua absent, labial plate present 2
2. Third antennal segment distinctly annulate .... Diamesinae
   Third antennal segment not annulate 3
3. Premandibles lacking, preanal papillae very long .... Podonominae
   Premandibles lacking 4

4. Para-labials, if present, non-striated, may bear hairs..Orthocladiinae

Para-labial plates striated..Chironominae

During the present investigation the larvae of this family recorded in the lentic and the lotic systems undertaken, come under three sub-families and eleven genera. The taxonomic position and generic names of these genera are :

Family	Chironomidae
Sub-family	Tanypodinae
	Clinotanypus Kieffer
	Tanypus Meigen
	Anatopynia Johannsen
	Pentaneura Phillipi
Sub-family	Orthocladiinae
	Brillia Kieffer
Sub-family	Chironominae
Tribe	Chironomini
	Polypedilum Kieffer
	Harnischia Kieffer
	Dicrotendipes
	Chironomus Meigen
Tribe	Tanytarsini
	Cladotanytarsus Kieffer
	Calopsectra

The taxonomic characters of the above sub-families and their genera for the larvae recorded in the present investigation is detailed below :

Sub-Family TANYPODINAE

General Characters

This is the most primitive of the commoner sub-families. Representatives inhabit both running and standing waters. The larvae are in general, free-living predators. Their food consists chiefly of other Chironomid larvae and minute crustaceans.

Antennae retractile; one-fourth to three-fourths as long as head; eye spots cordate, oval or reniform; epipharynx and premandible rudimentary or wanting; mandibles sickle shaped or hooked; generally with one or two teeth on inner margin; maxillary palpus well developed and slender, maxillary lobe with hair or clavate bristles; hypopharynx consists of suspensoria, superlingua with two or many teeth, and a central toothed lingua; labium soft and colourless; may have paralabial combs on each side; body with scattered hair or lateral line; generally elongate, cylindrical; and papillae moderately to very elongate, with 7-20 hairs, anal gills four or six.

GENERIC CHARACTERS

Genus *Clinotanypus* Kieffer

General Characters

The larvae of the genus *Clinotanypus* is characterized by the head moderately elongate, averaging one and a half times as long as it is broad; the antennae are about three-fourths as long as the head; the mandibles are hook like, paralabial comb absent.

Characters observed

The larvae measure 9 mm in length. The head is 0.42 mm long while the breadth is 0.27 mm. Head capsule pale yellowish brown and is broad behind, tapering anteriorly. Antenna three-fourth as long as the head. The larvae are pinkish white. Superlinguae not scale-like but is pointed and formed into serrations all along the margins of the lingua, lingua with six yellow teeth, the two laterals four times as large as the two central ones. The mandibles are hook like, and have a black apex. Body with very few scattered hairs. The preanal papillae are about four times as long as they are broad. Posterior prolegs well developed and have distinct claws. Four anal gills with pointed apices (Fig. 4).

Genus *Tanypus* Meigen

General Characters

The larvae of *Tanypus* differ from those of related genera in that the head is relatively small, and there are six anal gills, one pair dorsal in position and close to anus, and the others situated on the base of the prolegs. The five teeth of the lingua of the hypopharynx are yellow in colour and are nearly equal in length.

Characters observed

The larvae is about 8 mm long and is greenish with a dark green head. Larval head (0.2 mm) short, and as broad (0.18 mm) as long. Antennae retractile about one-third as long as head, the basal segment more than five times as long as the terminal segments combined. The mandibles are short and broad, with a bristle tooth but otherwise without distinct teeth. The pale labial plate with pale paralabial plates is weakly scelerotized, and have about eight small rounded teeth on each side. The suspensoria of the hypopharynx is blackish brown with pale, closely set, hair like teeth in the pecten. The lingua is yellow and slender, and has five subequal teeth, superlingua pale. Fringe of scattered hairs are present in the body, but tuft of hairs only in the thoracic segment. Anterior prolegs have pale claws, posterior prolegs are yellow. Long preanal papillae. There are six triangular leaf-like anal gills which are about twice as long as they are broad (Fig. 5).

Genus *Anatopynia* Johannsen

General Characters

The larvae bear paralabials and have scattered hair or lateral hair line on the body.

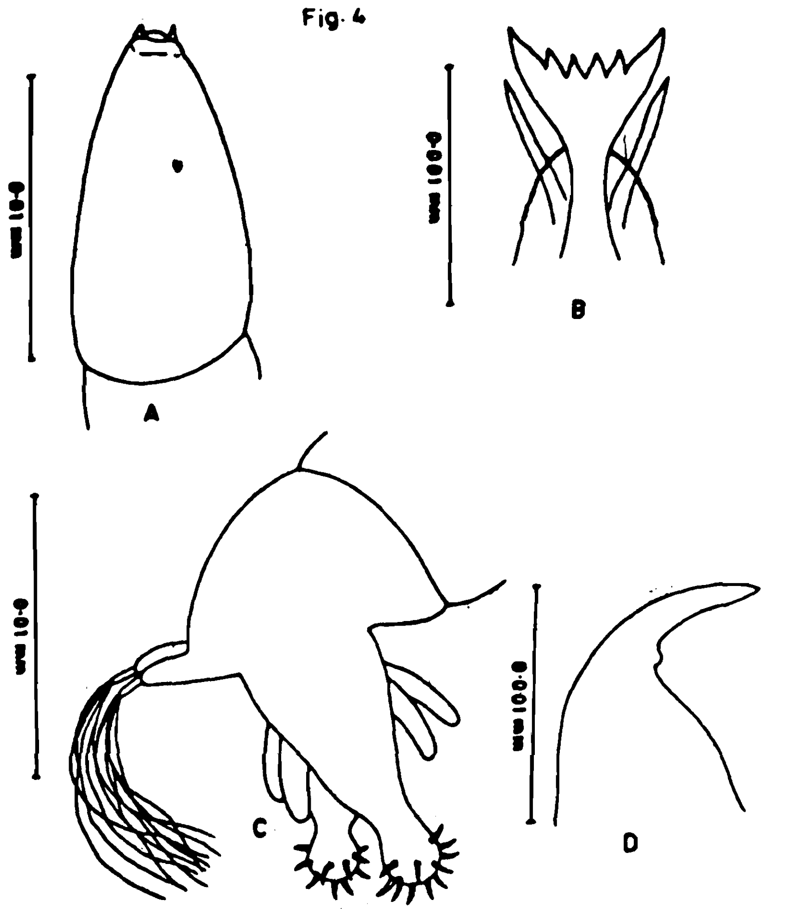


Fig. 4. Larva of genus *Clinotanypus*. A – Head; B – Lingua and superlingua of hypopharynx; C – Posterior end of larva; D – Mandible.

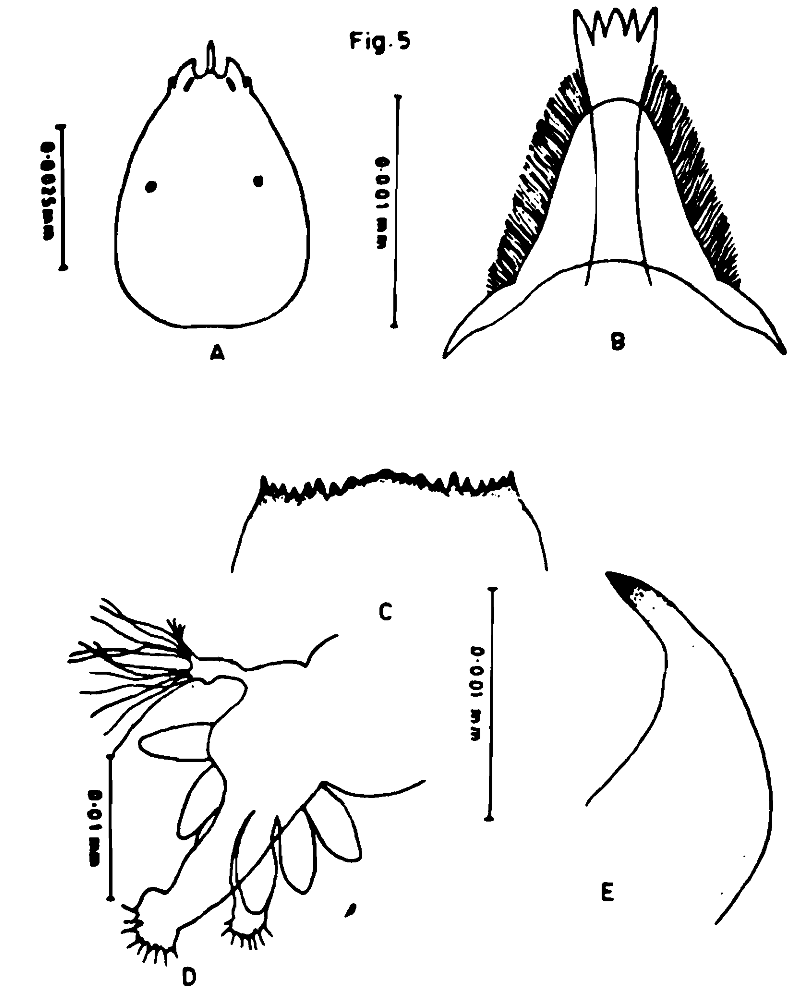


Fig. 5. Larva of genus *Tanypus*. A – Head of the larva; B – Lingua and superlingua of hypopharynx; C – Paralabial plate; D – Posterior end of larva; E – Mandible.

Characters observed

Body colour, green with dark yellow rounded head. The larvae measure 7 mm to 8 mm. Antennae one-third as long as head. Paralabials with five teeth on each side. Lingua of the hypopharynx bears five sub-equal yellow teeth, the laterals unusually large, the middle one small. The superlinguae have pointed teeth. The mandibles are curved. Preanal papillae long with 8 hairs. The four anal gills are sharp and pointed. Scattered hair on the body. The claws of the posterior prolegs yellowish brown (Fig. 6).

Genus *Pentaneura* Phillipi

General Characters

Slender and cylindrical; colour generally yellow or whitish; head one and a half to two times as long as wide, antenae half as long as head; two to three times as long as mandibles; labium with vescicles at sides; body with scattered hairs.

Characters observed

The larvae measure 7 mm to 8 mm. Body is slender and cylindrical and has a slightly enlarged thorax which is especially noticable just before pupation. The head is slender and is one and a half times as long as wide. The colour of the head is yellow with the remaining part of the body whitish. Body with scattered hairs. Anal gills slender and tapering. Paralabial plate absent. The lingua of the hypopharynx have five dark teeth, laterals bigger than the central ones. Anterior prolegs are very slender and tapering. The mandibles have a blackened apex and have distinct inner teeth. The claws of the posterior prolegs are simple (Fig. 7).

Sub-Family ORTHOCLADIINAE

General Characters

The eggs of the members of the sub-family Orthocladiinae, are usually deposited in water in gelatinous strings, or in some cases in irregular clumps within a gelationous mass, or even singly in moist situations as with some species whose larvae are terrestrial.

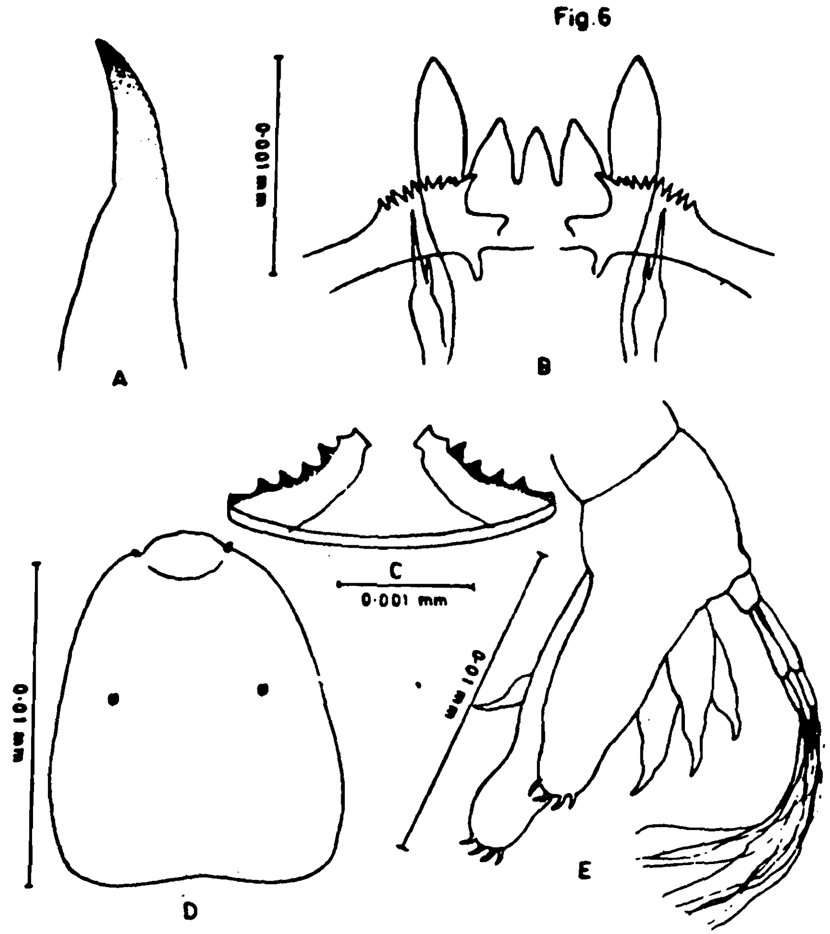
Larvae small to rather large; body colour white, yellowish, greenish or bluish, or more rarely red. Labrum often with two to many prolonged sensory bristles; premandibles have either a single point or several points. the antennae generally five segmented, rarely four or six segmented. Paralabial plates, if present, never movable or radially striate; anal papillae occasionally lacking. The labial plate is provided with nine to nineteen marginal teeth. The anterior prolegs are provided with numerous curved hair like claws,the posterior prolegs if present have simple claws. The anal gills are either four in number and in exceptional cases, two, or completely lacking.

GENERIC CHARACTERS

Genus *Brillia* Kieffer

General Characters

The larvae of this genus are characterized by the curved first antennal segment. they are large, white or amber coloured.



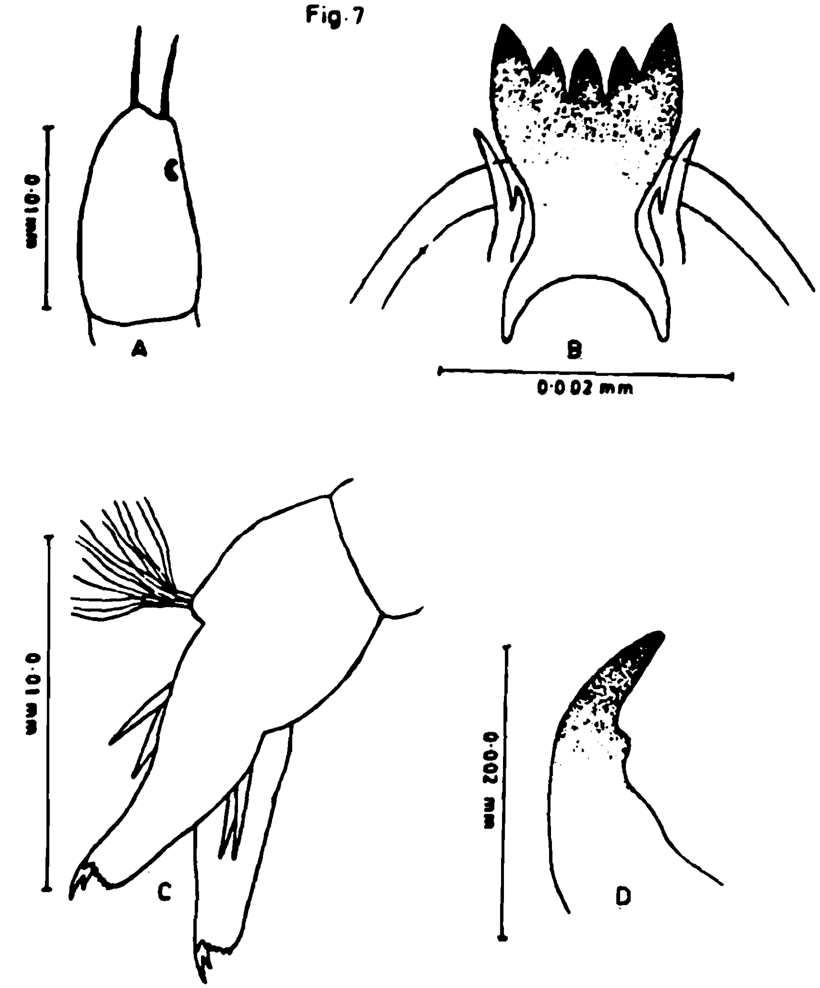


Fig. 6. Larva of the genus *Anatopynia*. A – Mandible; B – Lingua and superlingua of hypopharynx; C – Paralabial plates; D – Head; E – Posterior end of larva.

Fig. 7. Larva of the geus *Pentaneura*. A – Head; B – Lingua of hypopharynx; C – Posterior end of larva; D – Mandible.

Characters observed

The larvae are pale yellow in colour, measure 11 mm in length. The rather short dark brown head is unusually blunt, the apical half of the mandibles, the narrow posterior margin of the head capsule, and the labial plate are darker brown. There is a single eye spot on each side of the head. The antennae slightly curved, is five segmented. The mandible has five prominent teeth. The labial plate is provided with thirteen black teeth with the middle one distinctly smaller than the first laterals; the labial plate is blackened proximally for a distance equal to half its width. The preanal papillae are long. The anal gills are not pointed, but short and oval. The claws of the anterior prolegs are long, slender and those of the posterior prolegs stouter (Fig. 8).

Sub-Family CHIRONOMINAE

General Characters

This is the largest of the sub-families as far as number of species are concerned. The larvae of this sub-family are generally red but other colours are also found. The paralabial plates are well developed and usually striate and the mandible, with few exceptions has a preapical comb of bristles. The antennae are non-retractile. Both the thoracic and the caudal prolegs well developed.

The sub-family is normally divided into two major tribes - Chironomini and Tanytarsini.

Tribe ***Chironomini***

Antennae usually shorter, four to six segmented, the paralabial plates are striated and the mandible, in most cases, has a preapical comb.

GENERIC CHARACTERS

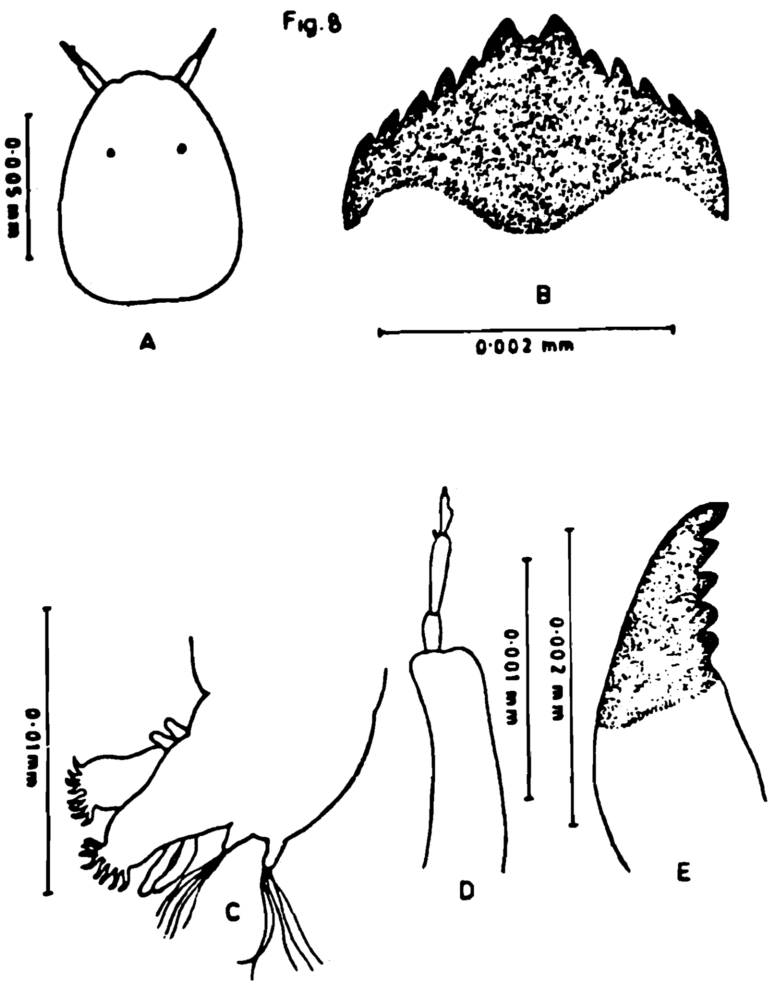
Genus *Polypedilum* Kieffer

General Characters

The larvae of this genus generally red. The labial plate generally has 16 teeth, but some have 12 or 14 teeth. Usually at least the median pair of teeth are elongate and in most cases the second laterals are also elongate. The anal gills taper to a point and many have one or more constrictions. Paralabials widely separated in the median line.

Characters observed

The larvae, brown in colour with comparatively small head. Anterior and posterior ends of the body darker. The larvae measures 6 to 7 mm in length. The head is short, and is pale brown in colour. The mandibles have dark teeth. The labial plate has 14 teeth, the median pair almost equal to the second lateral, labial plate light brown in colour. The paralabials are widely separated. The anal gills are constricted beyond the middle (Fig. 9).



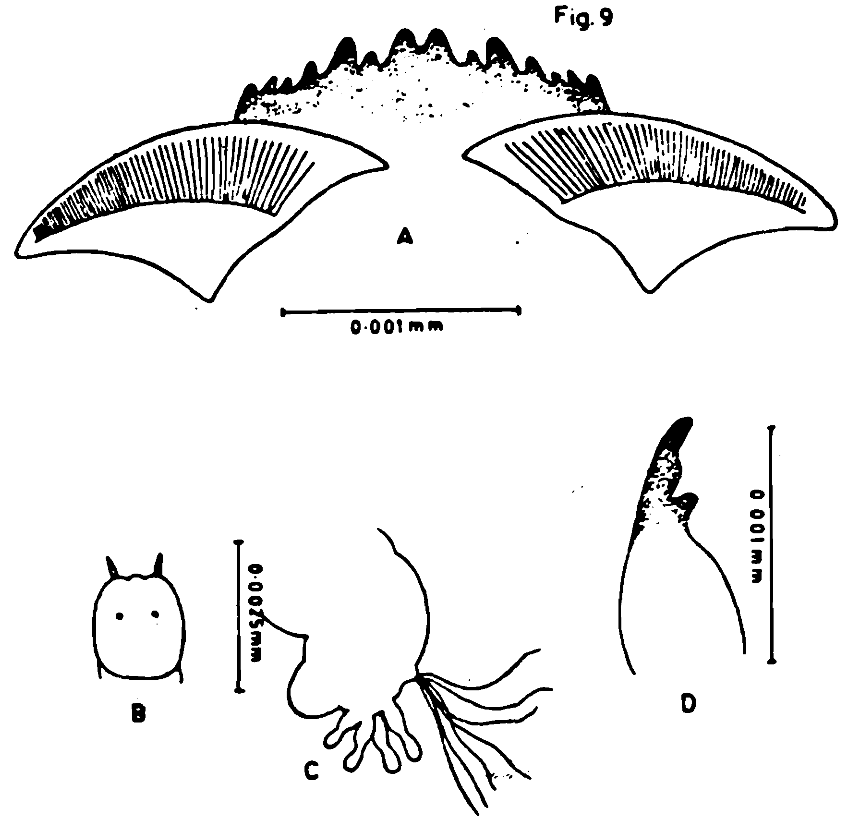


Fig. 8. Larva of the genus *Brillia*. A – Head; B – Labial plate; C – Posterior end of larva; D – Antenna; E – Mandible.

Fig. 9. Larva of the genus *Polypedilum*. A – Labial and paralabial plates; B – Head; C – Posterior end of larva; D – Mandible.

Genus *Harnischia* Kieffer

General Characters

The outermost teeth of the labial plate project forward in most species and the premandibles, though generally bifid, show a tendency to an increase in the number of blades. The antennal blade is generally at the base of the 2nd antennal segment.

Characters observed

The larvae measure 4-5 mm in length. Small slender larvae with distinct body segments. Body colour yellow having darker gular and thoracic region. Two distinct eye spots. Labial plate with odd number of teeth with middle one trifid, with six laterals, 4th & 6th lateral small, 5th one a large tooth. Mandibles with two flat lateral teeth and a moderately long apical tooth. Anal papillae short. Anal gills very small (Fig. 10).

Genus *Dicrotendipes*

General. Characters

The labial plate has 11 to 13 teeth; the middle tooth may appear simple in mature larvae, but is notched midway of its length in early instars. The lateral teeth of the mandible are more rounded.

Characters observed

Body of the larva light green, head yellowish. Eye spots double and clear. The length of the body 6 - 7 mm. Labial plate with 11 teeth, with the middle ones lighter than laterals. Mandible with dark teeth, all are different in size and shape, no blood gills on 11th segment. Five segmented antenna (Fig. 11).

Genus *Chironomus* Meigen

General Characters

The eggs, are enclosed in a gelatious string which in turn is enveloped in a gelatinous mass. The larvae are slender and worm like, with a yellowish brown or darker brown oval head; the body in most cases is blood-red. The front is elongate, acute at the posterior end, and is provided with a few regularly arranged marginal bristles. the antennae may have either five or six segments. the mandibles are stout with an acute apex and have two or three usually dark marginal teeth, on the ventromesal side; proximal of the basal tooth is the pale accessory tooth. The labial plate has dark teeth, in most cases vary in size and in number with the species. Paralabial plates with few exceptions distinctly striated. The anterior prolegs have a pair of lobes with numerous curved bristles, the posterior prolegs with number of sharp claws. On the dorsal side at the caudal and of the twelfth segment there is a pair of small papillae. There are four short anal gills and in some species that live in oxygen deficient waters, there are also two pairs of elongate ventrolateral gills.

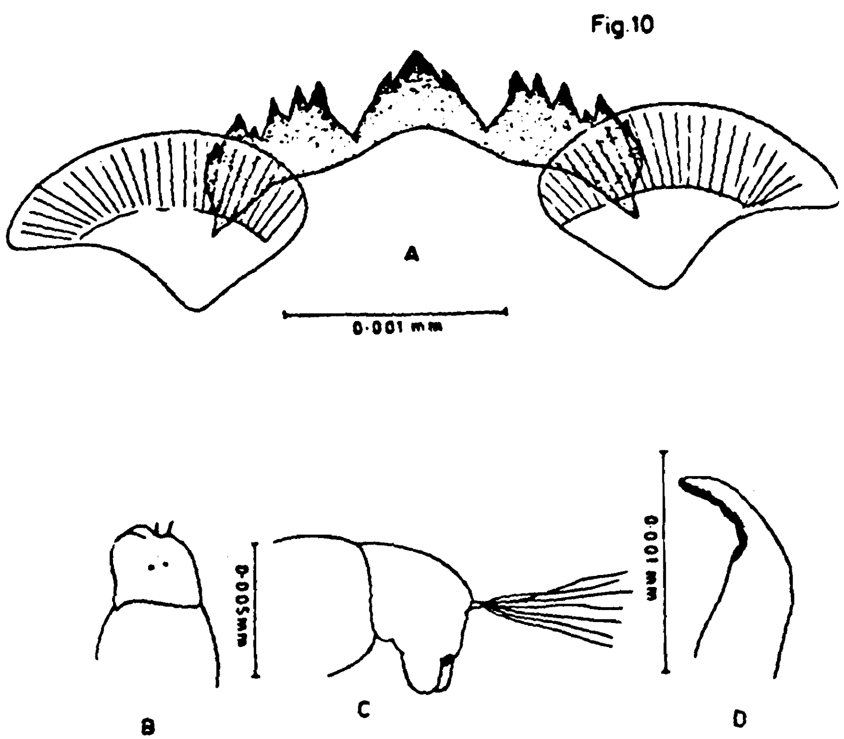


Fig. 10. Larva of the genus *Harnischia*. A – Labial and paralabial plates; B – Head; C – Posterior end of larva; D – Mandible.

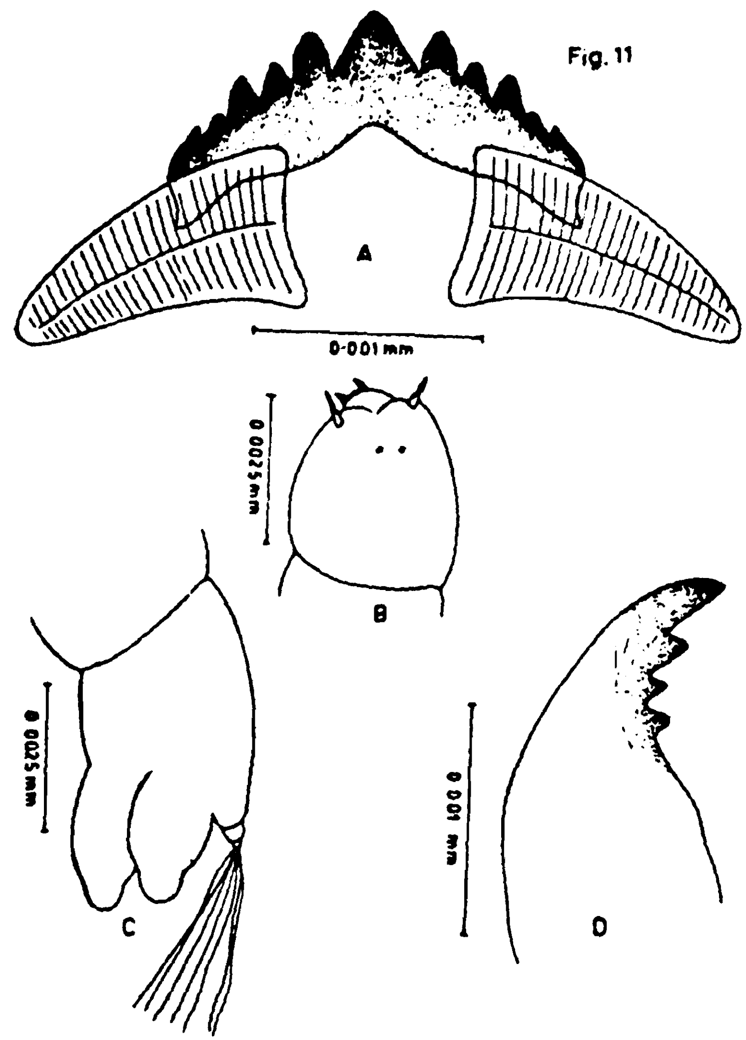


Fig. 11. Larva of the genus *Dicrotendipes*. A – Labial and Paralabial plates; B – Head; C – Posterior end of larva; D – Mandible.

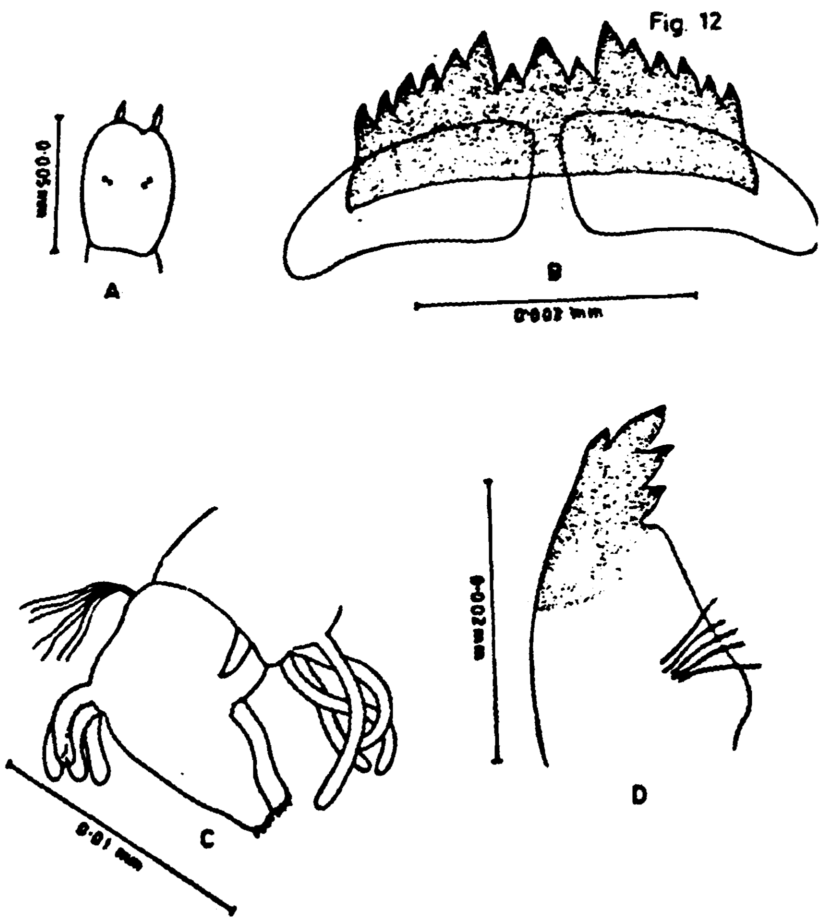


Fig. 12. Larva of the genus *Chironomus*. A – Head; B – Labial and paralabial plates; C – Posterior end of larva; D – Mandible.

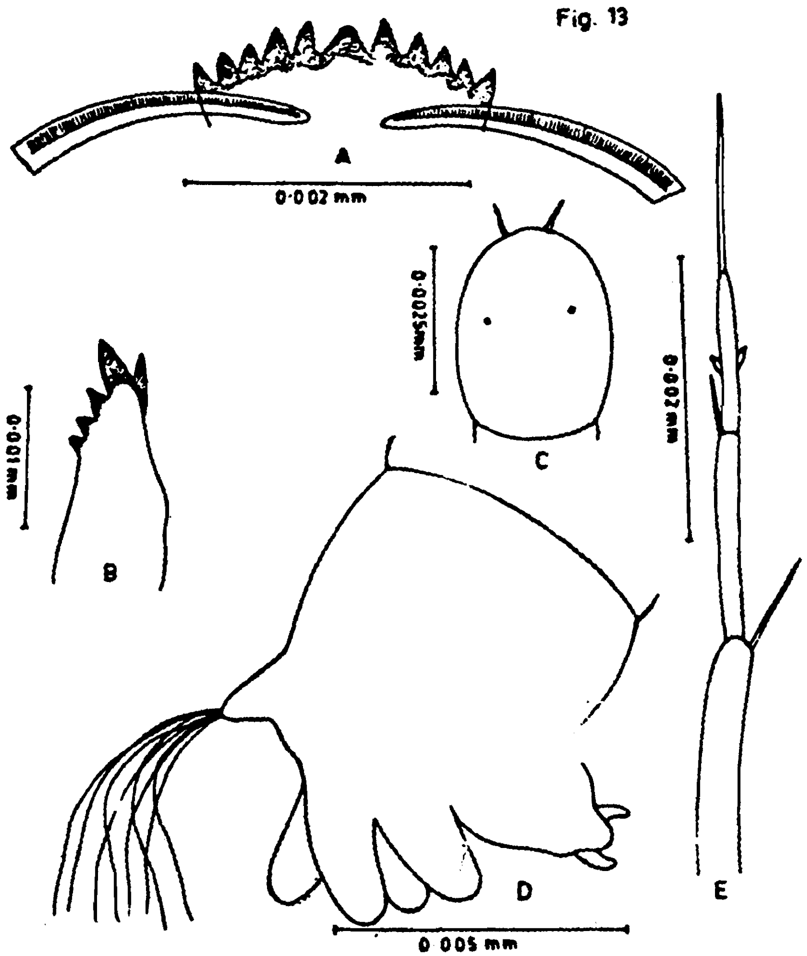


Fig. 13. Larva of the genus *Cladotanytarsus*. A – Labial plates; B – Mandible; C – Head; D – Posterior end of larva; E – Antenna.

Characters observed

Larvae red blood in colour about 14 mm long, labial plate typical of genus with thirteen teeth. The first laterals are longer than their neighbours and closely adjacent to the second laterals. Abdominal segment ten with two short caudolateral gills and segment eleven with four long gills. Posterior claws brown and nearly horse-shoe shaped. Mandible with three long, dark, apical laterals and light dorsomesal tooth. Brush of the mandibles with four main stalks. Anal gills four in number, sausage-shaped, shorter than posterior prolegs. Head capsules dark brown. Paralabial plates well developed (Fig. 12).

Tribe ***Tanytarsini***

The larvae are characterized by a rather long, five segmented antennae mounted on a prominent tubercle or prominence. The basal segment is somewhat curved, nearly twice as long as the remaining segments combined and with a conspicuous lateral bristle. The paralabial plates are narrow and nearly contiguous on the median line.

Genus *Cladotanytarsus* Kieffer

General Characters

This genus is distinguished in the larvae by the large lauterborn organs placed on short petioles.

Characters observed

Small, larvae measure about 3-4 mm. Light yellow coloured body. The head is darker with rather long five semented antennae with the basal segment somewhat curved, and mounted on tubercle, paralabial plates are elongated and not widely separated. Labial plate with 11 light brown teeth with middle one still lighter. Middle one barely notched on each side. Mandible with dark apical, lateral and dorsomesal tooth. No spurs on the antennal tubercle. Lauterborn organ large with short petiole. 4 anal rounded lobes (Fig. 13).

Genus *Calopsectra*

General Characters

Lauterborn organs sessile on tip of second segment, tubercle without spur.

Characters observed

Body length 4 mm to 5 mm. Antenna long and 1st segment curved and longer than the rest of the antennal segments. Paralabial plates close at center, blunt at inner spaces. Lauterborn organs sessile. 4 anal gills. Labial plate with 11 teeth. Second antennal segment about one-quarter as long as first. Median labial tooth uniformly dark and simple (Fig. 14).

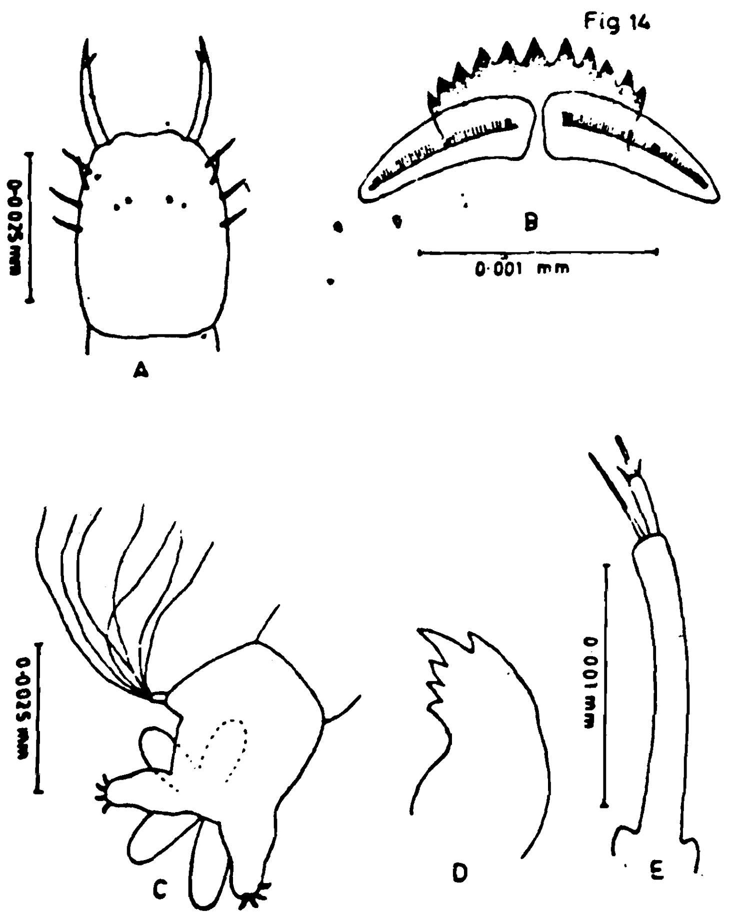


Fig. 14. Larva of the genus *Calopsectra*. A – Head; B – Labial and paralabial plates; C – Posterior end of larva; D – Mandible; E – Antenna.

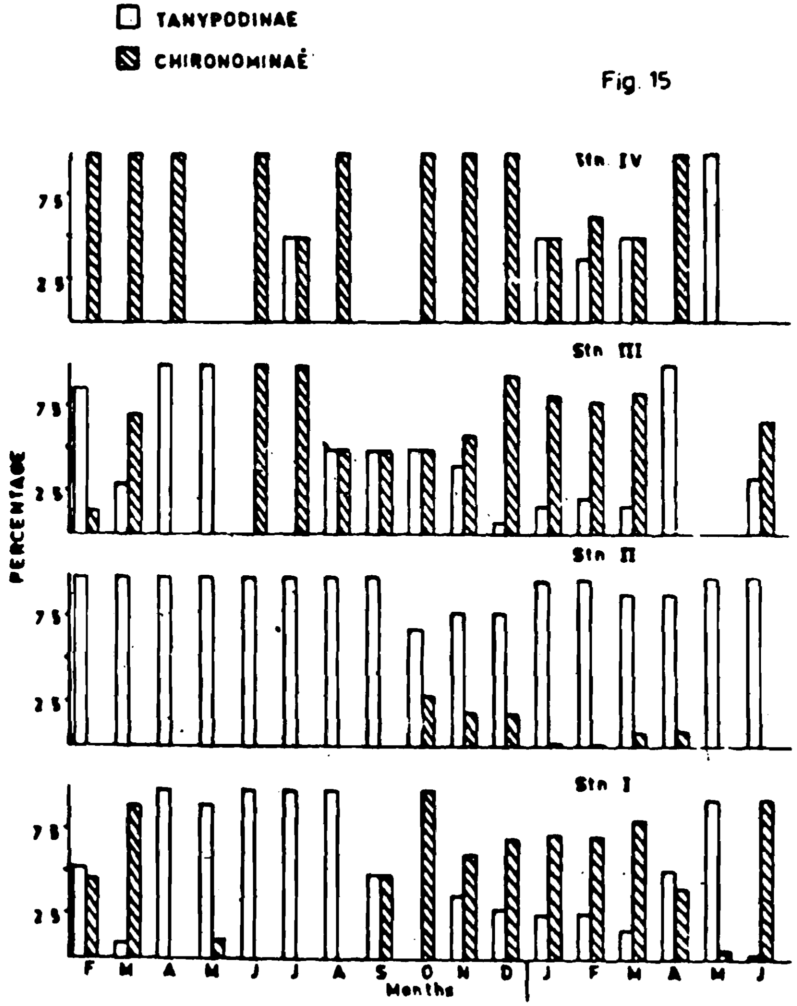


Fig. 15. A percentage occurrence of the two sub-families Tanypodinae and Chironominae seasonally in the two lentic systems.

Population Dynamics.

As the taxonomical differentiation upto the species level for Indian larvae was very difficult, the present work was confined to the identification of these larvae upto the generic levels only. Our work, in the systems studied, fall into three major sub-families, Tanypodinae, Orthocladiinae and Chironominae. Under the Chironominae sub-family both the tribes Chironomini and Tanytarsini were present. However, the lentic habitats possessed only two sub-families, viz. Tanypodinae and Chironominae.

Lentic Systems

Station I

An analysis of the seasonal observation at this station for the two sub-families present, Tanypodinae and Chironominae, seemed to be antagonistic to each other. Except during the months, February and September, during the first annual cycle and in April during the second. where they were more or less equal in numbers, all the other months revealed one to be drastically more than the other. Chironominae dominated in the month of March occurring upto 90.2% which was taken over by Tanypodinae from April onwards when it recorded nearly 100% with a total absence of Chrironominae till August of the first annual cycle. The trend got reversed again after October when Chronominae registered 60-100% till March of the next cycle. The month of May showed a trend in the reverse with Tanypodinae about 93%, while in June again Chronominae took over in very large numbers (Fig. 15).

At this station five genera were present, representative of both the sub-families. They were *Clinotanypus, Tanypus, Harnischia, Dicrotendipes,* and *Cladotanytarsus.*

The genus *Clinotanypus* at this station was recorded in the first two months of the study period, where the second month was nearly half of the first (160/m^2 and 80/m^2). They disappeared from the system subsequently to reappear in very low numbers (20/m^2) in the month of September and disappeared again in October. From November onwards, a significant increase in numbers were seen till they reached a peak in January recording 400/m^2. The next three months a decline was observed and they disappeared from the system during the last two months (May and June). (Table II).

The next genus *Tanypus* of the sub-family Tanypodinae, appeared in the system only from the third month of the study period in April recording 700/m^2 and with a subsequent steady increase revealed a peak in July with 1560/m^2. Thereafter, the numbers showed a decrease and then totally disappeared from the month of October. It reappeared only in May when the numbers were 780/m^2. However, this fell drastically to 20/m^2 in the following months. The general trend of fluctuation was more obvious in the first year of study as the genus was present in larger numbers and that too for many more months than in the next cycle (Table II).

Harnischia, at this station was present in the first two months of the study period, February and March, with the latter showing a maximum occurrence of 740/m^2. It, thereafter, was absent from the system till October with the exception of a record with low numbers once in May and the other in September. From November onwards it reappeared and steadily increased till a peak was obtained in

TABLE II

Seasonal distribution of the different genera of Chironomidae larvae Stations I to IV of the lentic systems

Stn.	Genus	First cycle											Second cycle					
		Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
I	*Clinotanypus*	160	80	—	—	—	—	—	20	—	100	340	400	220	120	180	—	—
	Tanypus	—	—	700	760	1240	1560	1180	40	—	—	—	—	—	—	—	780	20
	Harnischia	200	740	—	80	—	—	—	60	—	180	540	700	260	560	160	60	440
	Dicrotendipes	200	—	—	—	—	—	—	—	20	40	320	—	320	—	—	—	—
	Cladotanytarsus	—	—	—	—	—	—	—	—	—	—	—	400	—	—	—	—	20
II	*Clinotanypus*	—	20	—	—	—	—	20	—	40	60	60	140	40	60	40	20	—
	Tanypus	2040	1360	1040	920	920	1760	540	340	140	500	300	700	980	140	700	960	420
	Harnischia	—	—	—	—	—	—	—	—	—	80	80	20	20	20	80	—	—
	Dicrotendipes	—	—	—	—	—	—	—	—	80	—	—	—	—	—	—	—	—
III	*Clinotanypus*	20	40	—	—	—	—	—	20	—	20	—	20	40	—	—	—	—
	Tanypus	240	—	20	20	—	—	20	—	40	80	20	60	60	40	960	—	20
	Polypedilum	—	—	—	—	—	—	—	—	—	—	20	—	—	—	—	—	—
	Harnishia	40	60	—	—	—	—	—	20	40	—	280	320	320	200	—	—	—
	Dicrotendipes	—	20	—	—	40	40	20	—	—	120	—	—	40	—	—	—	40
	Cladotanytarsus	—	20	—	—	—	—	—	—	—	20	—	60	—	—	—	—	—
IV	*Clinotanypus*	—	—	—	—	—	20	—	—	—	—	—	20	—	—	—	—	—
	Tanypus	—	—	—	—	—	—	—	—	—	—	—	—	20	20	—	20	—
	Polypedilum	20	180	20	—	20	20	20	—	260	900	160	20	20	20	240	—	—
	Harnischia	80	100	—	—	—	—	—	—	—	140	—	—	40	—	—	—	—
	Cladotanytarsus	—	—	—	—	—	—	—	—	—	—	20	—	—	—	—	—	—

Stn. — Station

the month of January with 700/m^2. This fell drastically in the subsequent months but again a trend towards the increase was seen in March. The numbers again fell till May, which thereafter increased to small peak of abundance in the last month of investigation. This genus in its general seasonality was observed to possess a spring and winter maxima (Table II).

The genus *Dicrotendipes* in the first month of the study period recorded 200/m^2. It then disappeared totally from the system to reappear only in October. From then onwards, it rose steadily till it reached a peak of 320/m^2 in the month of December. In the subsequent months it recorded nil. Thereafter, in the month of February, it showed a maximum number (320/m^2) and disappeared from the system for the remaining period. This genus appears to be a winter occurring one in its seasonality of abundance (Table II).

The last genus *Cladotanytarsus* was present only in the last month, January, of the first annual cycle when its numbers recorded were as high as 400/m^2. It reappeared in the system again only in June of the second cycle recording only a minimum of 20/m^2. In all the other months it was not available in the collections (Table II).

Station II

At this station when the seasonal trend of fluctuation was observed as a percentage among the two sub-families Tanypodinae and Chironominae, it was seen that the former sub-family dominated the station. Tanypodinae in addition to its maximal relative abundance which was nearly 100% during most of the months and never below 70% (October, November and December), occurred throughout the period of investigation. In contrast, the sub-family Chironominae appeared at this station only in the month of October and that too in comparatively less numbers with a percentage of nearly 30%. It was present in this station only till April during which it declined to a very low value of nearly 2% during the months of January and February to rise only till 10% in the next two months, and subsequently disappeared from the system (Fig. 15).

Here the two sub-families of Chironomidae were represented by only four genera. They were *Clinotanyous*, *Tanypus*, *Harnischia* and *Dicrotendipes*. Of these four genera, only *Tanypus* occurred throughout the study period while *Dicrotendipes*, occurred only once in the month of October. The other two genera *Clinotanypus* and *Harnischia* with sporadic occurrences of the former were mostly present in the system at this station during the later half of the investigation period (Table II).

The genus *Clinotanypus* occurred in very low numbers (20/m^2) in March and August without being recorded during the period from February to September. Thereafter, it reappeared in the system in the month of October with a number of 40/m^2. Since then it steadily increased to reach a peak of 140/m^2 to steadily fall till May and recording nil in June (Table II).

The next genus *Tanypus* (Table II) appeared in the system with very large numbers, as seen in the month of February, recording 2040/m^2. It steadily decreased thereafter till June to rise again in July though not to a level as in February, with a subsequent fall till October. From November onwards a rise and fall alternated till the remaining study period. The genus seemed to definitely possess a winter maxima with only a slight increase in summer.

The genus *Harnischia* occurred only from November to April, with the maximum record of 80/m^2 in the first two months, November and December and the last month of April during their period of occurrence. The other three months in between had a constant record of 20/m^2 (Table II).

Station III

The two sub-families Tanypodinae and Chironominae at this station revealed a diverse fluctuation in the first few months of the study period with some significance thereafter (Fig.15). This phenomenon is seen in the first two months of February and March, when Tanypodinae dominated with nearly 86% in the former month and Chironominae dominated with nearly 70%, in the latter. Again, in the months of April and May the record of 100% of Tanypodinae was observed, with an absence of Chironominae, followed by a similar occurrence of Chironominae and absence of Tanypodinae in June and July. Thereafter in the next four months the abundance were nearly 50% each. From December onwards Chironominae dominated in the system upto March oscillating around 82 - 90% with very low abundances of Tanypodinae. In April there was a sudden increase of Tanypodinae with the total absence of Chironominae as was seen in April of the first annual cycle. The last month June recorded the usual Chironominae abundance. Station III was represented by six genera. They were *Clinotanypus, Tanypus, Polypedilum, Harnischia, Dicrotendipes* and *Cladotanytarsus.*

All the genera were consistent in that, none of them occurred continuously throughout the investigation period. Of these *Clinotanypus, Polypedilum, Dicrotendipes* and *Cladotanytarsus* occurred six times, once, seven times and three times respectively without any idea of a trend of seasonal fluctuation, as their occurrences were sporadic. *Tanypus* recorded a significant number in the month of February as 240/m^2 but subsequently either disappeared or recorded in very low numbers upto September. From October onwards till April there was a rise and fall, when in the month of April of the second cycle, they reached the maximum of nearly 960/m^2 (Table II).

The genus *Harnischia* during the first ten months of the investigation period occurred not only in very low numbers but also only four times. From December onwards they were suddenly seen to be abundant at this station with a number of 280/m^2, which rose to a peak of 320/m^2 in the subsequent two months. In March, though there was a fall it was not very significant as the numbers recorded were 200/m^2. After that they disappeared from the system (Table II).

Station IV

The sub-families Tanypodinae and Chironominae at this station revealed a definite dominance of the latter. In fact Tanypodinae occurred only during five months of the entire investigation period and was only 50% in most cases except in the month of May during the second cycle, in which, it was the only sub-family which occurred forming 100%. Chironominae on the other hand was present nearly throughout the study period and was absent at this station, whenever the other sub-family was also absent except only once. This non-occurrence of the Chironominae was recorded only four times and whenever it occurred, it was never below 50%. In most of the months it recorded a presence of 100% (Fig.15). This station was represented by five genera.

Clinotanypus, *Tanypus*, and *Cladotanytarsus* occurred sporadically at this station (Table II) and in very low numbers (20/m^2).

The genus *Polypedilum* was present more or less throughout the study period except in May and September during the first annual cycle and during May and June of the second annual cycle. During the first eight months whenever they occurred, they were in very low numbers recording only 20/m^2, with the month of March showing a peak of 180/m^2. November showed the largest peak of 900/m^2, which subsequently fell drastically in the following four months to rise only to about 40/m^2 in the month of April before they disappeared from the system (Table II).

Harnischia in the system occurred only four times throughout the study period of investigation, during February, March, November and March again. A peak was seen in November with 140/m^2 and a small increase was seen in the month of March of the first annual cycle (Table II).

Lotic Systems

The Chironomid larval population in the lotic systems undertaken were seen to possess one extra sub-family in addition to the two as seen in the lentic systems. Hence both the lotic systems were representative of three sub-families Tanypodinae, Orthocladiinae and Chironominae.

UMKHRAH STREAM

Station I

In this lotic system Umkhrah, there was a definite pattern of the occurrence of the three sub-families from the headwaters to the mouth. Station I showed a negligible occurrence of the sub-family Tanypodinae throughout the period of investigation with percentages of 10 and above in only two months, of the five months that they occurred. Orthocladiinae and Chironominae at this station, formed mirror images of each other in that when one occurred maximum the other was very less. Orthocladiinae during the first cycle occurred maximum between July to September ranging between 70 - 80% and again from 80 – 90% during the second cycle from June to August. Similarly November, December, February, March and April were the maximum abundances of the sub-family Chironominae. A clear summer maximal occurrence for Orthocladiinae and a similar winter period for Chironominae was seen in this station as the general trend of fluctuation seasonally (Fig. 16).

At this station the representative genera were four, *Anatopynia*, *Pentaneura*, *Brillia* and *Chironomus*. Of these *Anatopynia* and *Pentaneura* occurred only for two and three months respectively with insignificant numbers except as 320/m^2 for *Pentaneura* in a single month of August. *Brillia* recorded a maximum in July at the beginning of the investigation but fell steadily till November to thereafter rise again and form a much smaller peak (780/m^2) in January. It again fell subsequently till May. A sudden increase in June to very large numbers and in fact the highest recorded for the period of investigation of this genus *Brillia* in this station I, of nearly 2000/m^2 was observed. The subsequent two months of July and August though the numbers fell but were on the higher side and very near to the maximum record.

TABLE III

Seasonal distribution of the difference genera of Chironomidae larvae in the stream Umkhrah

Stn.	Genus	First cycle Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Second cycle Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
I	*Anatopynia*	—	—	—	—	—	—	—	—	—	—	20	—	40	—
	Pentaneura	—	—	—	—	—	—	—	40	40	—	—	—	—	320
	Brillia	1660	1340	640	100	20	60	780	220	380	140	100	2080	1920	1500
	Chironomus	40	640	240	300	560	720	500	980	2520	200	80	180	480	60
II	*Tanypus*	—	—	—	—	—	—	—	52	105	—	—	—	—	—
	Brillia	2368	2684	1631	2631	210	578	210	52	157	263	315	2473	1631	1421
	Chironomus	1157	210	421	736	1263	1473	1473	2631	5420	2999	263	315	1105	1210
III	*Anatopynia*	—	—	—	—	—	—	—	—	157	157	263	—	—	—
	Pentaneura	—	—	—	—	—	—	—	—	105	—	—	—	—	—
	Brillia	—	—	—	—	—	—	—	—	—	—	—	631	—	—
	Chironomus	2105	789	1263	1578	1421	2578	8315	2894	2894	2263	421	3052	1736	1052
IV	*Chironomus*	1736	1526	2430	3420	1263	2052	7526	6368	4736	2263	263	1999	2105	2315
V	*Chironomus*	3526	1789	3894	1584	2052	4210	4894	6368	6315	6315	11947	3420	4105	3894

Stn. — Station

The genus *Chironomus* in this station was seen to rise and fall during the first eight months of the study period with peaks of abundance recorded in August, December and February. This increase in February rose to very high levels in March, recording 2520/m^2 to subsequently fall and rise in the remaining months (Table III).

Station II

The next station in this system when observed for the seasonal fluctuation of the three sub-families they followed a pattern similar to that of station I (Fig.16). Tanypodinae in fact occurred only twice with less than 2%. Orthocladiinae and Chironominae showed the summer and winter maximas respectively and a similar phenomenon of one sub-family occurring less when the other was abundant as in station I was also seen here.

This station was represented only by three genera *Tanypus*, *Brillia* and *Chironomus*. Of these, *Tanypus* occurred only twice during the entire study period. The genus *Brillia* showed significant abundances in their numbers during the first four months, July to October, when they were recorded from 2000 to 2500/m^2. A similar trend was seen during the last three months from June to August. During the other months the numbers were far less and the lowest recorded was in February (52/m^2).

In contrast, *Chironomus* showed a seasonal trend of abundance just opposite to *Brillia*. Though they had increased numbers in July with nearly 1000/m^2 they fell drastically to rise only again in November. Thereafter a steady increase was observed till they reached a peak in March with 5000/m^2. In the next month of April, they fell to 3000/m^2 and in the subsequent two months they recorded very low numbers and rose to their original levels in July and August of the second cycle as in July of the first annual cycle (Table III).

Station III

Of the three sub-families at this station Tanypodinae though occurred only three times from March to May yet the relative percentages were much higher than in the previous two stations. The maximum was seen in the month of May with nearly 40%. The sub-family Orthocladiinae unlike the earlier two stations was recorded only once in the month of June amounting to only 17% at this station III. The sub-family Chironominae was present throughout the period of investigation. They recorded 80 - 100% with the least of about 60% in the month of May (Fig. 16).

This station was represented by four genera, *Anatopynia*, *Pentaneura*, *Brillia* and *Chironomus*.

Of these, *Pentaneura* and *Brillia* occurred only once and *Anatopynia* three times. The genus *Chironomus* which recorded nearly 2000/m^2 in the first month of the investigation period fell and rose in the subsequent months till a peak of more than 8000/m^2 was seen in the month of January. The next three months it fell to levels of about 2000-3000/m^2 and the lowest recorded in the month of May (421/m^2). Again the last three months a sudden increase was seen, with June showing nearly 3000/m^2 and the remaining two months with more than 1000/m^2 (Table III).

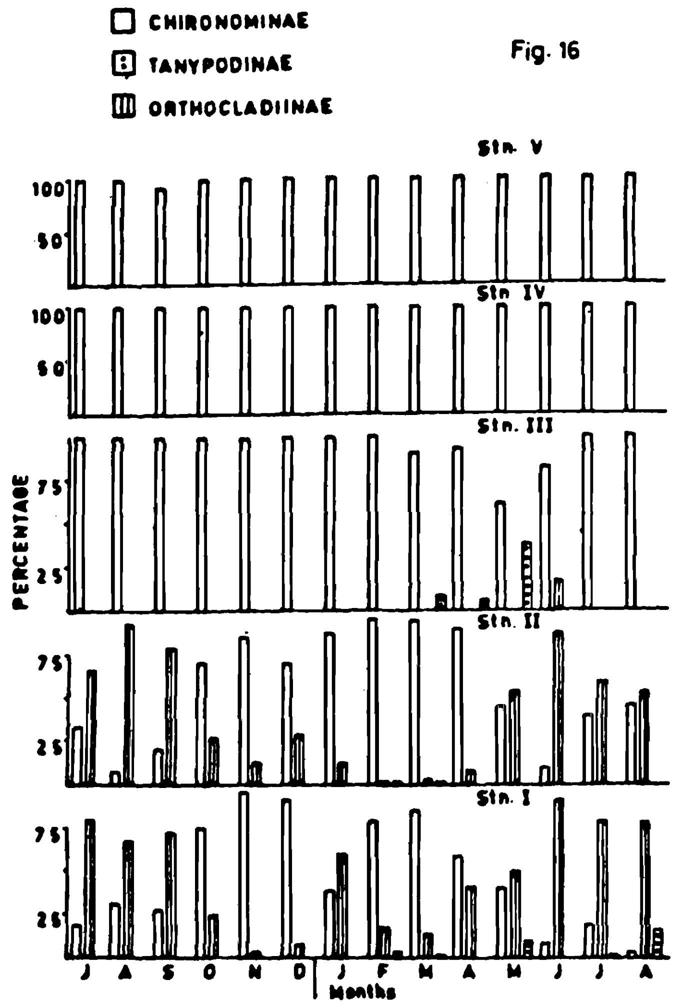


Fig. 16. A percentage occurrence of the three sub-families Tanypodinae, Orthocladiinae and Chironominae seasonally in stations I to V of the stream Umkhrah.

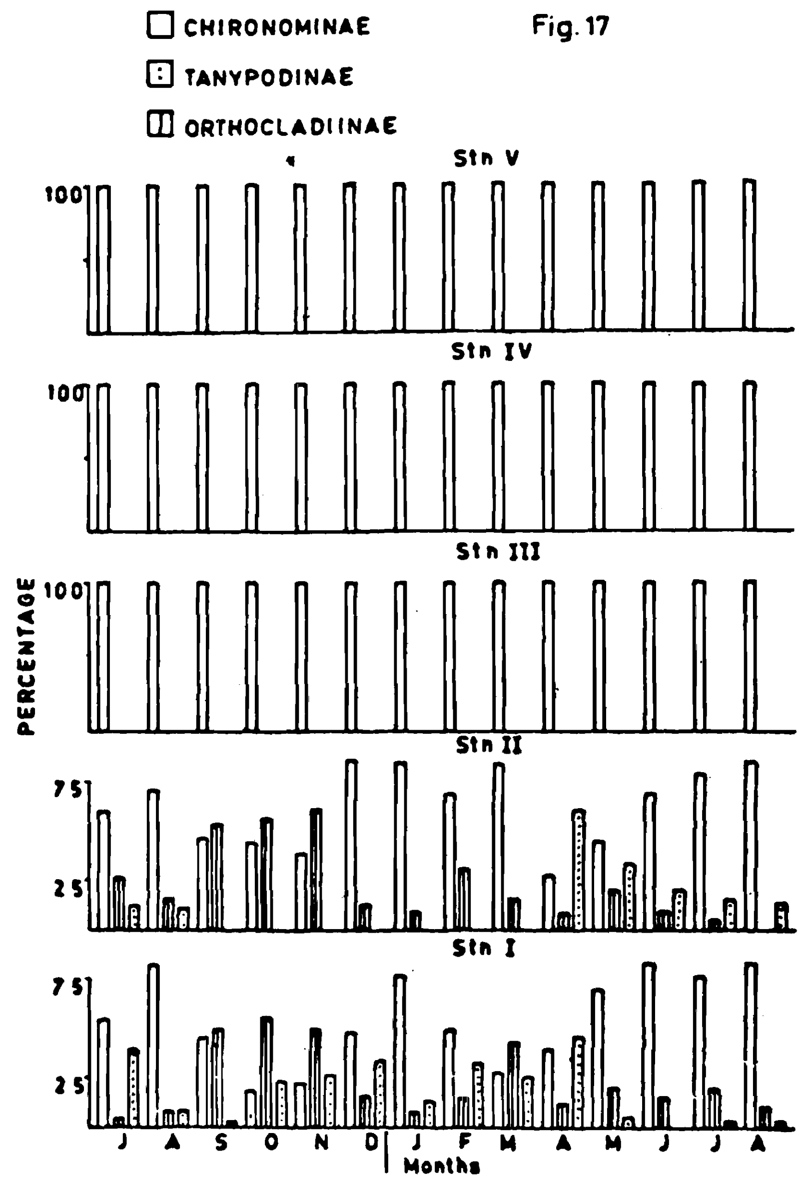


Fig. 17. A percentage occurrence of three sub-families Tanypodinae, Orthocladiinae and Chironominae seasonally in stations I to V in the stream Umshirpi.

Station IV & V

The last two stations IV and V of this lotic system was represented by the sub-family Chironominae only. The other two sub-families Tanypodinae and Orthocladiinae were totally absent in these two stations (Fig. 16).

As is understandable only one genus namely *Chironomus* was represented in these two stations.

In station IV this genus showed a rise and fall in its numbers during the first six months with however the range of abundance between 1000 - 3000/m^2. A final peak of nearly 7500/m^2 was seen in the month of January which steadily fell during the next three months registering a drastic fall in the fourth month with only 263/m^2 in the month of May. The last three months again showed an increase in numbers to nearly 2000/m^2 (Table III).

A similar trend of fluctuation of this genus *Chironomus* was also seen at station V with a peak of nearly same numbers in the month of February. This oscillated for the next two months to rise to drastic levels of 3000 – 4000/m^2. The lowest record was seen however in the month of October though the numbers were pretty high with 1500/m^2 (Table III).

UMSHIRPI STREAM

As in the previous lotic system, so also here the occurrences and abundances of Chironomid larvae had a definite habitat specificity from the headwaters to the lower elevations. Here also, three sub-families Tanypodinae, Orthocladiinae and Chironominae were represented. However, stations I and II of this lotic system had all the three sub-families while the remaining three stations III, IV and V were represented by the sub-family Chironominae only.

Station I

In station I the sub-family Tanypodinae represented much less than the other two sub-families over the seasons. They were nearly 40% in the beginning and fell thereafter to very low levels in September to rise only in December to nearly 35%. Subsequently, they rose and fell till a peak was obtained in April with nil records in June (Fig. 17).

The sub-family Orthocladiinae recorded lowest in the beginning of the period to rise steadily till they reached a peak of more than 50% in October. Subsequently, there was a fall till January which rose thereafter to reach another smaller peak of a little over 40% in the month of March. In the remaining months, however, ups and downs around 20% was observed. The last sub-family, in this system was Chironominae which followed a more or less reverse trend of fluctuation to that of Orthocladiinae. The peak was seen in August, nearly 80% and the lowest recorded in October with the second peak of nearly 75% in January. In last few months of the study period a similar rise and fall was observed in alternate months though the percentage was about 70 – 80% (Fig. 17).

Station I of this system was represented by six genera *Tanypus*, *Anatopynia*, *Pentaneura*, *Brillia*, *Chironomus* and *Calopsectra*.

TABLE IV

Seasonal distribution of the different genera of Chironomidae larvae in the stream Umshirpi

		First cycle						Second cycle							
Stn.	Genus	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
	Tanypus	80	—	—	80	160	180	—	220	—	100	20	—	20	20
	Anatopynia	—	—	—	20	100	40	60	60	100	120	—	—	—	—
	Pentaneura	80	20	20	80	80	80	40	100	140	60	40	—	—	20
I	*Brillia*	20	20	300	420	660	140	60	180	400	80	220	260	140	120
	Chironomus	160	140	120	140	200	220	280	400	100	120	700	1260	460	660
	Calopsectra	60	60	160	220	100	200	260	160	100	120	20	100	60	180
	Anatopynia	—	—	—	—	—	—	—	—	—	240	120	80	20	60
	Pentaneura	40	20	—	—	—	—	—	—	—	160	20	40	40	—
II	*Brillia*	80	60	180	280	420	100	40	220	160	60	100	60	20	—
	Chironomus	160	200	120	140	220	540	300	420	840	200	220	400	260	320
	Calopsectra	20	60	40	80	4	60	40	60	20	—	—	—	20	20
III	*Chironomus*	1936	2420	3157	3999	1473	3420	8315	3999	894	263	578	894	1842	2105
IV	*Chironomus*	1842	1684	2526	2420	3789	5493	7526	7578	4736	842	578	1584	1578	1947
V	*Chironomus*	1789	2315	2894	1526	1999	4210	4894	6368	6315	6420	5052	584	1052	3052

Stn. — Station

The genus *Tanypus* occurred in few numbers and also not present throughout the period of investigation. They began with 80/m^2 as their numbers, and rose steadily to more than 200/m^2 in the month of February, when they formed the maxima peak, and thereafter fell till they reached 20/m^2 (Table IV).

Anatopynia occurred only from October to April, with peaks in November and April recording 100/m^2 and a little more (Table IV).

The next genus *Pentaneura* though occurred for most of the investigation period except for two months, showed rise and fall throughout the period without any definite trend of fluctuation. The peak value of 140/m^2 was seen in March with minimal values in August of both the cycles (20/m^2) (Table IV).

Brillia from the beginning of the investigation period steadily built its population till a peak of 660/m^2 as their numbers were attained in November. The numbers again fell to rise only in March with a smaller peak of 400/m^2, with a trend of rise and fall thereafter. The lowest record of 20/m^2 for this genus at station I was seen in the months of July and August (Table IV).

The genus *Chironomus* similar to *Brillia* rose steadily however with some rise and fall, but attained a peak in February with 400/m^2. However, this peak fell to rise only again in June to reveal a larger peak of 1260/m^2, which fell in July to 460/m^2 and again rose to 660/m^2 in August (Table IV).

The last genus in this station, *Calopsectra*, with minor rises and falls, showed a peak in January with 260/m^2 and a minimum of 60/m^2 in the month of July of the second cycle (Table IV).

Station II

This station was also representative of the three sub-families – Tanypodinae, Orthocladiinae and Chironominae.

The sub-family Tanypodinae was totally absent from the system for seven months, September to March. They showed a peak of abundance in April of a little over 60% to fall in the subsequent month. The sub-family Orthocladiinae with minor variations rose steadily to form a peak of nearly 60% in November and subsequently fell to nil values by the end of investigation period. They, however, had minor ups and downs in their abundances. The sub-family Chironominae at this station began with densities of above 60% but fell in the subsequent months till November. Suddenly in December and in January they recorded nearly 85 - 90%, fell in February to 70% and again rose in March to nearly 85%. In the next month they fell drastically to nearly 25% but rose steadily thereafter till they again attained a peak of 85% in the month of August of the second cycle (Fig. 17).

The station II was represented by five genera, *Anatopynia, Pentaneura, Brillia, Chironomus* and *Calopsectra*.

Of these the genera *Anatopynia* and *Pentaneura* occurred for only 5-6 months and that too not continuously. In both, however, the peaks for maximum values were seen in the month of April (Table IV).

The genus *Brillia* was seen to rise steadily till it reached a peak of about 420/m^2 in the month of November. It thereafter fell and rose till July of the second cycle, recording the least of 20/m^2 and a total disappearance in the subsequent month of August (Table IV).

The next genus *Chironomus* at this station with minor ups and downs, reached peaks of 540/m^2, 840/m^2 and 400/m^2 in the months of December, March and June respectively. The lowest was, however, seen in the month of September with 120/m^2 as their numbers (Table IV).

The last genus *Calopsectra* in the system at this station was present throughout the period of investigation except during April, May and June. They also revealed a picture of ups and downs with their maximal peak of 80/m^2 in the month of October (Table IV).

Station III, IV and V

The remaining three stations of this lotic system Umshirpi was seen to be devoid of the two sub-families – Tanypodinae and Orthocladiinae. Sub-family Chironominae, therefore, formed 100% abundance in all these three stations (Fig. 17).

Only *Chironomus* was represented in these stations. In station III the genus *Chironomus* built a population of nearly 2000/m^2 to reach a small peak of about 4000/m^2 in the month of October. It fell thereafter, to rise and form the largest peak of abundance of more than 8000/m^2 in the month of January. After that they again fell till the lowest was attained in the month of April with only 263 individuals/m^2. Subsequently, the population built upto a steady increase till it attained nearly 2000/m^2 in the month of August (Table IV).

At station IV the population fluctuated at the beginning to rise steadily till it obtained a peak of more than 7500 individuals/m^2 in the month of February. The population fell till it reached its lowest level of little more than 500/m^2 in the month of May. A steady increase till nearly 2000/m^2 in the month of August was observed (Table IV).

In the last station V, (Table IV) the genus *Chironomus*, though increased till April, when it recorded nearly 6400/m^2, yet smaller rises and falls were seen during the same period. Hence, peaks of smaller magnitudes were seen in September and February. After the maximum attainment in April, a fall was seen in the subsequent months till June with 584/m^2 to reach a peak again in August with nearly 3000/m^2.

Physico-Chemical Factors

Lentic Systems

Station I

The air temperature taken at 1 m above the surface of the water at all stations revealed a consistency, in that, the lowest, though recorded in the winter months was seen to be always in the month of January. The present station recorded 11°C as the minimum. The maximum was recorded as 23°C in the month of July. Both these were for the first annual cycle. The second cycle which was not for one year showed a maximum of 24.5°C in the month of April (Fig. 18).

The water temperature at this station ranged between 12.5°C and 23.3°C, the former recorded as minimum in the month of February and the latter maximum in July during the first annual cycle. The trend during the second cycle was more or less same with April recording 24°C as maximum like that of air temperature (Fig. 18).

The water level at this station showed a general increase during summer and a decrease in winter. This was clear in this station where the maximum water level was recorded as 122 cm in the month of June and a minimum of 41 cm in December of the first annual cycle. A similar increasing trend was observed during the second cycle when the month of June recorded maximum with 60 cm (Fig. 18).

The transparency reading as taken with secchi disc was minimum in June and maximum in October during the first cycle recording 40 cm (Fig. 18) and 60 cm respectively. The subsequent cycle though showed an increase in June could not be attributed as maximum as the annual periodicity was not observed (Fig. 18).

The pH of the water remained almost neutral throughout the study period. The range between the minimum and maximum pH recorded was very low being only 1 unit. The minimum was recorded in the months of September and October which was around 6.7 units, while the maximum was in the months of February, May and January each month recording 7.2 units. The next cycle showed an increase in pH values with most of the months recording 7 and above, the maximum being recorded in the month of March as 7.5 units (Fig. 19).

The next factor was conductivity or specific conductance as expressed in µmho/cm. It was seen to be maximum in the month of March (58.99 µmho/cm). Thereafter it fell and rose around this value till the minimum record was 39.34 µmho/cm in the winter month of January. However, during the second cycle the values steadily rose till May which recorded nearly 60 µmho/cm and above and subsequently fell (Fig. 19).

Dissolved oxygen as the next factor analysed, revealed a maximum value in the winter months which was nearly 10 mg/l in December and January. However, the summer months of April and May, recorded only 5.5 mg/l, which was minimum for the first annual cycle. The second cycle revealed values of lesser magnitudes. However, a trend towards lower values was seen during the summer months of April and May (Fig. 19).

The next abiotic factor, Carbondioxide revealed a mirror image of oxygen values. The maximum was recorded as 17 mg/l in May, while the minimum was seen during the winter months of November to January, oscillating around 4.8 mg/l. The next cycle showed an increase in their values and a trend of increase in the summer months with April recording a maximum of 10 mg/l (Fig. 19).

The last abiotic factor analysed was total alkalinity, contributed mainly by bicarbonate ions. This was seen to follow a pattern almost similar to that of free Carbondioxide. The values increased in summer showing a maximum of 45.2 mg/l in the month of June. The minimum values were recorded in the months of August and October with nearly 29 mg/l. The next cycle definitely showed increased values with a maximum of 48 mg/l in the month of May (Fig. 19).

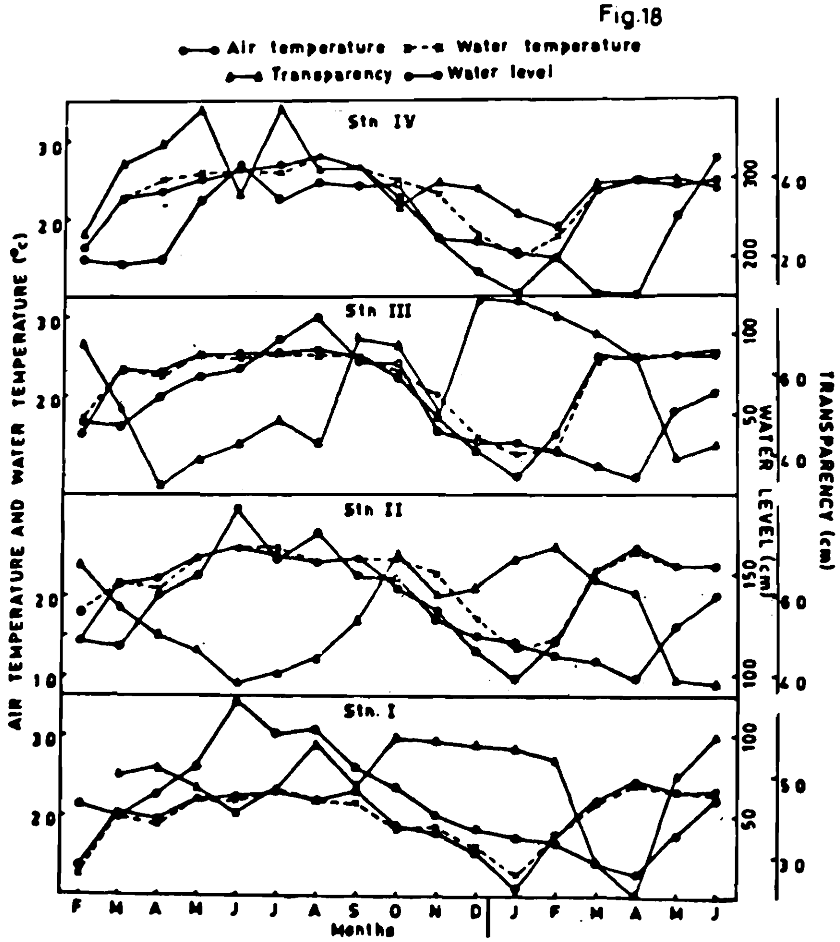


Fig. 18. Showing the seasonal fluctuation of air temperature, water temperature, transparency and the water level in the four stations of the two lentic systems.

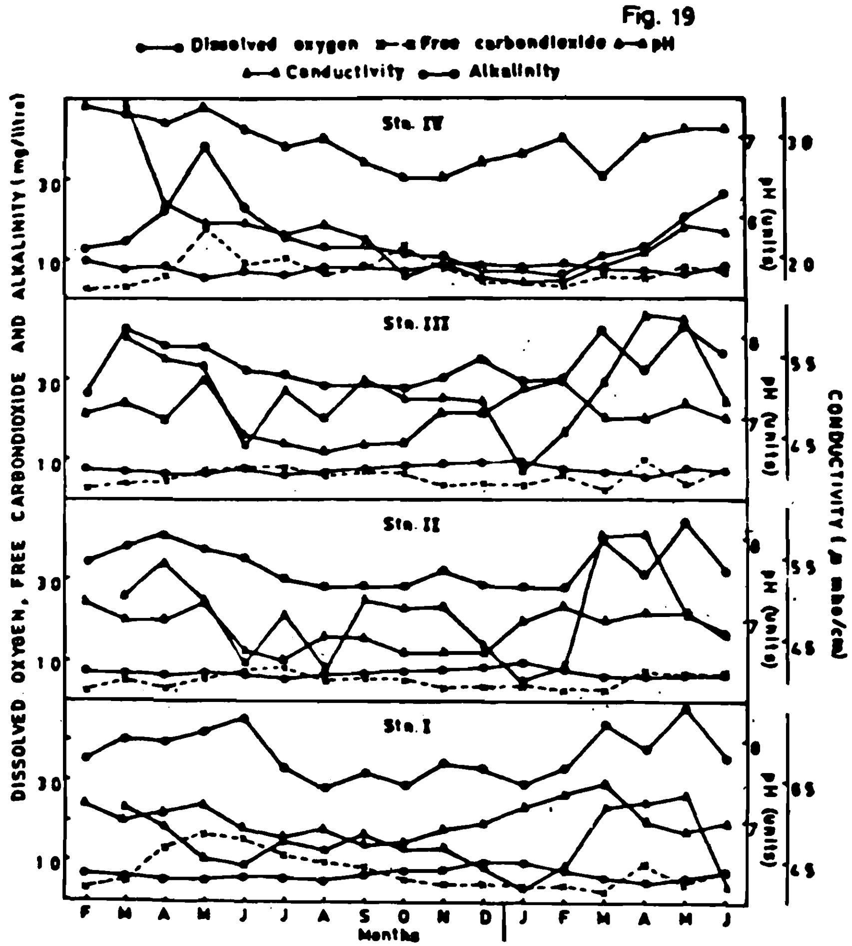


Fig. 19. Showing the seasonal fluctuation of dissolved oxygen, free carbondioxide, pH, conductivity and alkalinity in the four stations of the two lentic systems.

Station

At station II the monthly variations in air temperature revealed a maximum temperature in the month of June (26°C)and minimum in January recording only 9.5°C. There was a steady increase in the water temperature towards the summer months as seen in July with 26.2°C and a fall in winter, in the month of January recording 13.5°C. The second cycle, as is understandable, recorded an increase in the summer months with the maximum in April for both air and water temperatures (Fig. 18).

The water level also followed a similar pattern like temperature fluctuation. The highest value recorded was in June with 183 cm, which thereafter fell gradually to 116 cm. in the month of January in the first annual cycle. The second cycle also followed the same pattern (Fig.18).

Transparency readings were seen to be maximum in the winter months recording the same values as of station I. The minimum values were recorded in June (40 cm.). The second cycle also maintained a similar trend of fluctuation (Fig. 18).

The pH at this station fluctuated from a minimum of 6.5 units to a maximum of 7.2 units during the months of July and February respectively during the first annual cycle. The second cycle revealed higher values, recording the least of 6.8 units (Fig. 19).

Conductivity values did not follow any definite seasonal pattern. The readings oscillated between 39.64 µmho/cm as the minimum during August to a maximum of 55 µmho/cm in March of the first annual cycle. The next cycle revealed maximum values, as recorded in March and April, with nearly 58 µmho/cm (Fig. 19).

The dissolved oxygen values at this station, with increased values of nearly 7.5 mg/l in the month of February, started to fall till they reached a minimum for the first annual cycle in July, recording only 5.6 mg/l. Subsequently, it rose steadily, till it reached a peak in the month of January recording a maximum of 9.8 mg/l. The trend, thereafter, was in the decreasing side as seen in the second cycle. (Fig. 19).

F . carbondioxide content showed an inverse relationship with the dissolved oxygen content. The minimum and maximum values recorded were in the months of February (3 mg/l) and in July (8.2 mg/l) respectively during the first annual cycle. A similar rise in values as 8.0 mg/l April was seen during the next cycle (Fig. 19).

The last abiotic factor considered at this station was total alkalinity which did not follow any definite pattern of fluctuation over the seasons. The range of fluctuation was however between 28 mg/l and 41 mg/l. during the first annual cycle. The months of August, September and October recorded the minimum, while April recorded the maximum. A general summer maxima with winter minima was observed and this trend was also seen for the second cycle (Fig. 19).

Station III

Similar conditions of the physico-chemical factors was observed in this station as in previous stations. The monthly variation in air temperature revealed a gradual increase of temperature in the summer and decrease in winter months. The maximum air temperature was recorded in August (25.6°C) and the minimum in January (9.8°C). Water temperature fluctuations were similar to air temperature. The temperature fluctuated between 12.5°C and 25.2°C. The minimum and maximum were in the same months of January and July respectively. The second cycle in both revealed an increase, as it was the onset of summer (Fig. 18).

A tendency in the increase of water level during summer was observed, recording a maximum value of 100 cm in August. There was a gradual fall in this level in the following months, with the minimum being 35 cm in January. The next cycle revealed a similar pattern. The transparency record did not reveal any definite trend of rise and fall. However, the values ranged from 32 cm in April to 80 cm in December. The maximum value obtained in the next cycle was 70 cm in March (Fig. 18).

The minimum record of pH was seen in the month of August with 6.6 units, while the maximum was in May, 7.5 units. The range of fluctuation was very low, and the next cycle followed similar trend oscillating around 7 units (Fig. 19).

Conductivity, as the next factor, was maximum in March of the first annual cycle. A fall was registered in the subsequent months, which then rose and fell around the value of 50 μmho/cm till the minimum was recorded in January. The next cycle began with a similar fluctuation, with a record of 60 μmho/cm in April (Fig. 19).

Dissolved oxygen values did not show any significant differences in the various months. The value oscillated around 60 mg/l and 9.2 mg/l, the minimum and maximum recorded in the months of July and January respectively. A similar pattern was seen for the next cycle also (Fig. 19).

The range for free carbondioxide present at this station fluctuated between 3 mg/l and 7.8 mg/l during the first annual cycle. The former was recorded as minimum in February and the latter as maximum in June-July. The magnitude of values in the next cycle increased and a record of 10 mg/l was seen in April (Fig. 19).

Total alkalinity also did not show any pattern of fluctuation. The maximum present was in the month of March (41 mg/l) and the minimum in the month of February (26 mg/l). However, the months of August, September and October had the same value, 28 mg/l, very near to minimum. Once again, the next cycle the values were in increased levels (Fig. 19).

Station IV

At this station January recorded the minimum air temperature as 9.7°C and maximum was 28°C recorded in August. Water temperature values fluctuated from 15°C to 28°C, with the usual winter minima and summer maxima (Fig. 18).

The monthly fluctuation of water level showed a maximal rise in June (267 cm) and a crop to 219 cm recorded as minimum in April. No definite seasonal pattern was obtained. A similar trend was seen in the next cycle (Fig. 18).

Transparency readings taken during different months were minimum in February (26 cm) and maximum in May and July (58 cm). There was very little difference in the values during the remaining months, with the values oscillating around 40 cm. This was true also in the next cycle (Fig. 18).

pH of the water during the seasons ranged between 6.5 and 7.4 units. Though there was no definite pattern of fluctuation, lesser values were recorded in the winter period. In the second cycle also the same condition prevailed, with values around the neutral (Fig. 19).

Conductivity was seen to decrease in winter although no significant differences were observed in the different seasons. The maximum was seen in the month of March with a record of 59.91 µmho/cm and minimum in January (14.1 µmho/cm). From the maximum to the minimum value a trend of steady decrease was observed, which continued for the next cycle with a rise only in May (Fig. 19).

Dissolved oxygen ranged between 5.4 mg/l and 9.8 mg/l. These values showed slight increase during winter and spring months. The inverse relationship to temperature was observed for oxygen values (Fig. 19).

Fluctuation of free carbondioxide did not show any significant differences and exhibited no seasonal trends. Only once the free carbon-dioxide rose as high as 18 mg/l in May while the minimum values were seen to be in the months of February and March recording around 3 mg/l. Such low values were also seen during the next cycle (Fig. 19).

The last factor analysed was total alkalinity. The maximum was 38 mg/l in May, and the minimum in December and January (7 mg/l) in the first annual cycle. A trend of increase in the summer months was also observed in the next cycle, when 26 mg/l was recorded in June (Fig. 19).

Lotic Systems

UMKHRAH STREAM

Station I

The monthly variations, in the station I of the Umkhrah stream, for air temperature revealed a maximum in June (24.8°C) and a minimum in January (16.6°C), revealing the usual summer maxima and winter minima. Water temperature also fluctuated between 11.5°C and 22.5°C. The maximum and minimum being recorded in June and January respectively, followed closely that of air temperature (Fig. 20).

The depth readings at this station showed a tendency of gradual decrease from summer months onwards, the lowest being recorded in December and January (12 cm). It then increased to give a maximum value in June (36 cm). The width of the stream also followed a similar pattern. Values ranged from 0.65 m, as recorded in January, to 2.5 m, as in May (Fig. 20).

The pH readings at this station showed no major fluctuations over the seasons. It was seen to be mostly acidic, the values oscillating around 6 units, which was the general minimum as seen in the months of December and January. The maximum occurred in September with 6.6 units (Fig. 21).

The next factor conductivity was seen to be maximum in December (46.2 µmho/cm) while the minimum was recorded in November and February (37.8 µmho/cm). Here also there was hardly any drastic fluctuation (Fig. 21).

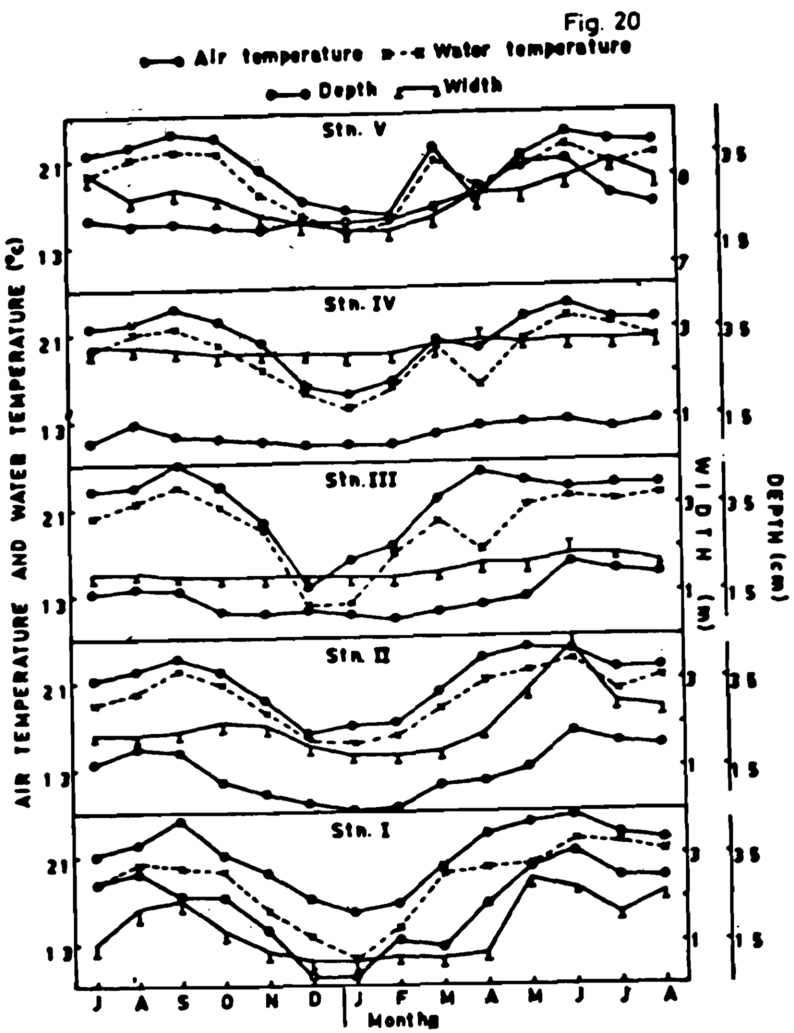


Fig. 20. Showing the seasonal fluctuation of air temperature, water temperature, depth and width in stations I to V in the stream Umkhrah.

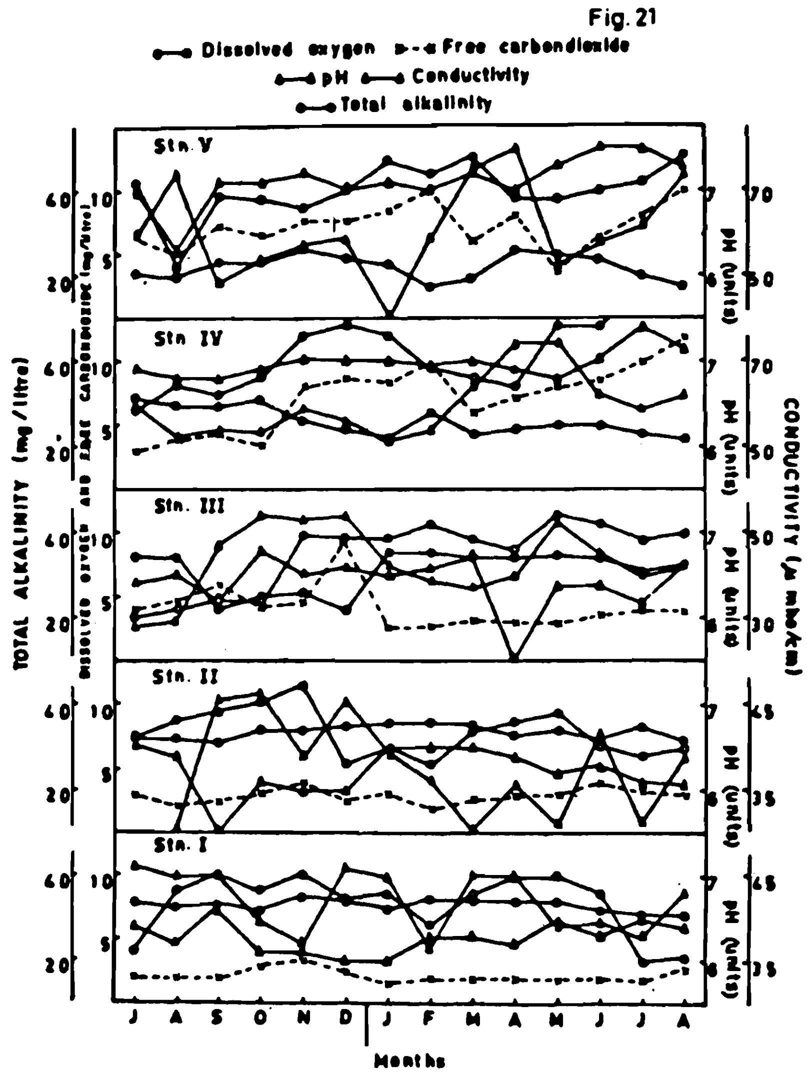


Fig. 21. Showing the seasonal fluctuation of dissolved oxygen, free carbondioxide, pH, conductivity and total alkalinity in Stations I to V in the stream Umkhrah.

Dissolved oxygen revealed maximum values in November, February and March (8.2 mg/l), while October showed a minimum value of 7.2 mg/l. No significant fluctuation pattern was witnessed during the annual cycle, and most values recorded were around 7.5 mg/l. (Fig. 21).

Free Carbondioxide content was quite less in the system at this station ranging from 1.8 mg/l to 3.5 mg/l. These values represented the maximum and minimum as seen in the months of November and January respectively. However, all other values were around 2 mg/l. (Fig. 21).

Total alkalinity was the last factor to be considered which fluctuated between 22 mg/l and 40 mg/l. The values obtained in the different seasons were almost similar. The minimum was obtained during the month of July as 22 mg/l, while the maximum in September, November, April and May in the first annual cycle. Most other readings oscillated around this maximum (Fig. 21).

Station II

The monthly readings of air temperature revealed that the minimum was in December (16.7°C) followed by a steady increase recording a maximum in May (24.5°C). Water temperature similarly fluctuated from 16.5°C to 23°C recorded in the months of January and June respectively. The usual summer maxima and winter minima was observed (Fig. 20).

Depth, like temperature, had the same seasonal pattern with the maximum being recorded in the month of June (23 cm) and minimum in January (4 cm). There was a definite decrease from the summer to winter months and a subsequent rise in the following cycle (Fig. 20).

Width of the station also showed such definite trend of fluctuation, ranging from 1.3 m to 3.8 m. The minimum was seen in January and February, while the maximum in June (Fig. 20).

The pH values were around 5.4 and 6.5 units revealing the acidic nature of the system at this station. The maximum of 6.5 units occurred in July which fell till it reached a minimum of 5.4 units in September. It then steadily oscillated around 6 units, with 6.5 units being recorded in January, February and March (Fig. 21).

Conductivity, as maximum was observed in December (46.25 µmho/cm) while July recorded the minimum with 27.65 µmho/cm. There was a general trend of increase in the autumn months to winter and subsequent fall (Fig. 21).

Dissolved oxygen values were quite high throughout the period of study at this station, fluctuating between 7.2 mg/l and 8.4 mg/l. Generally, these values showed a slight increase during winter and spring months, the range of magnitude was very low (Fig. 21).

Carbondioxide content was not very high in this station and varied from 2 to 4 mg/l. The maximum and minimum were recorded during the months of November and August respectively. All readings oscillated around the value of 3 mg/l (Fig. 21).

Total alkalinity showed an increasing trend from July to November with the latter month recording maximum of 4 mg/l. An immediate fall in the next month revealed the minimum, alongwith February. Thereafter, a steady increase took place till May (Fig. 21).

Station III

Like other stations of this stream Umkhrah, station III also followed a similar pattern for both the air and water temperatures. December recorded the minimum as 13.5°C and 12°C for air and water respectively. September recorded, similarly, the maximum temperature of 25°C and 23°C respectively for air and water (Fig. 20).

The values recorded for depth revealed a considerable decrease from August (16 cm) to February (9.9 cm) followed by a gradual rise upto 22 cm in June. The general trend of a decrease during winter and a subsequent rise in summer was observed. Maximum width at this station was observed to be in the month of June recording 1.85 m, while January and February recorded a minimum of 1.4 m. A similar trend of fluctuation as for depth was seen here (Fig. 20).

pH of the water was always in the acidic range throughout the year, between 5.4 and 6.8 units. There were rise and falls with no significant trend, the maximum recorded in October and minimum in April (Fig. 21).

Conductivity as the next factor revealed its highest value in October and December (54.07 µmho/cm), while July recorded the minimum value of 28 µmho/cm. A trend towards an increase in late autumn and winter was observed for this factor (Fig. 21).

The dissolved oxygen values at this station oscillated around a maximum value of 8 mg/l for most of the months. The maximum, however, was recorded in the months of January and February with 8.4 mg/l. Similarly, the minimum values recorded were during the months of September till December with 4.5 mg/l as the average values. A definite increase in values during winter was observed with minor exceptions (Fig. 21).

In comparison with other stations, free carbondioxide content was quite high in certain months, as in December (9.5 mg/l). However, January and February recorded the lowest values of 2.8 mg/l. Generally, the magnitude of the values were higher than in other stations (Fig. 21).

Total alkalinity was low during the earlier months of the investigation period. A minimum of 20 mg/l as in July, showed a rise in content till October and finally reached a maxima in February (42 mg/l). Thereafter there was a decline in the next two months, with a second maxima in May (44 mg/l) (Fig. 21).

Station IV

The range of air temperature was between 15.5°C and 23.8°C as observed in the months of January and September respectively. Similarly, a gradual fall of temperature in winter, recording a minimum in January of 14°C, which then rose steadily to record a maximum in June (22.5°C) was observed for water temperature (Fig. 20).

A similar pattern was seen for depth, in that, January and February recorded a minimum of 9.2 cm, while June recorded a maximum depth of 14.5 cm. The width of the stream at this station also increased in summer, specially in the rainy season, with the winter months recording the minimum value of 2.5 m (Fig. 20).

The pH values at this station were very near neutral throughout the period of investigation. A maximum record of 7.4 units was seen in July of the next cycle and otherwise no drastic fluctuation was observed (Fig. 21).

Conductivity varied from 52.05 μmho/cm to 74 μmho/cm. No significant pattern of fluctuation was noticed from July to March. However, April and May recorded a maximum of 74 μmho/cm (Fig. 21).

Dissolved oxygen content fluctuated between 4 and 7.2 mg/l. The maximum content was seen to be present in the month of July and minimum in January. A summer maxima with winter minima was seen in the first cycle but the trend reversed in the second (Fig. 21).

Free carbondioxide content of this station was low during the earlier periods of the investigation but a gradual rise was observed from November onwards, showing a maximum record of 10 mg/l in February. This was followed by a decline in the subsequent months. During the next cycle the values rose to 12 mg/l in August (Fig. 21).

Total alkalinity as the last factor measured was only 28 mg/l in July, which thereafter increased upto 48 mg/l in December. The content then fluctuated around 36 mg/l to rise again in May and June with the values around 48 mg/l. A further rise was observed in the next cycle recording the maximum for the entire period, in July - August with 62 and 58 mg/l (Fig. 21).

Station V

The air temperature revealed a consistency in that, the lowest values were recorded in the winter months, in this station, in the month of February with 15.9°C. The maximum air temperature was seen to be in the month of September recording 23.4°C and not in the peak summer months (Fig. 20).

The water temperature, however, revealed the usual winter minima as in January (14.1°C) which recorded the least, and a summer maxima, as in June recording 22°C as highest (Fig. 20).

The range between minimum and maximum depth at this station was seen in January as 20 cm and June as 34 cm respectively. There was a fall in values during the autumn months which steadied in winter and rose subsequently (Fig. 20).

The width readings taken was seen to be minimum in January and February and maximum in July, the former being 7.4 m and the latter 8.1 m. There was hardly any significant fluctuation (Fig. 20).

The range between the minimum and maximum pH recorded was very less at this station. The minimum, however, was seen in the month of August being 6.3 units and maximum was 7.5 units in June and July. All the values oscillated around 7 units (Fig. 21).

The next factor conductivity also did not follow any definite seasonal pattern. It ranged between 38.07 μmho/cm and 8.5 μmho/cm, recorded in the months of January and April respectively (Fig. 21).

Dissolved oxygen values were comparatively low throughout the period of study in comparison with the other stations of the system. It fluctuated between 2.8 mg/l and 5.4 mg/l. February recorded its minimum and November its maximum (Fig. 21).

In contrast to oxygen the next abiotic factor free carbondioxide content revealed a negative relationship. Maximum values were recorded in February as 10 mg/l and minimum in May with 3.5 mg/l, for this factor. There was an increase in winter with summer minima (Fig. 21).

The values recorded for the total alkalinity were seen to increase during the winter months. March recorded the highest content (48 mg/l) and minimum was recorded in August (22 mg/l). There was a slight increasing pattern for this factor from summer to winter (Fig. 21).

UMSHIRPI STREAM

Station I

December recorded minimum temperature for air and water, the values being 11.8°C and 10°C respectively. Air temperature rose upto 23.2°C during September, but 21.5°C was the maximum for water temperature as observed in the month of March (Fig. 22).

The range of depth in different months was from 6.5 to 19 cm. April and November recorded their minimum and maximum depth respectively. A tendency of increase in the late autumn months was observed (Fig. 22).

A minimum width was seen at the beginning of the investigation period which flucutuated around 3.4 m to 3.7 m upto February which then increased in May and June (4.1 m) to reach the maximum of the first annual cycle. It oscillated around these values thereafter (Fig. 22).

The pH was in acidic range fluctuating from 6 to 6.7 units. Unlike other factors, no seasonal patterns of fluctuations was observed. However, the maximum was observed in April and the minimum in September (Fig. 23).

Conductivity as the next factor started with a least value of 21.7 µmho/cm, which increased in the following months recording a maximum in November (38.99 µmho/cm). The values then oscillated around 36 µmho/cm in the subsequent months (Fig. 23).

Dissolved oxygen and free carbondioxide content showed negative correlation. Maximum values for dissolved oxygen was 9.0 mg/l and minimum was 5.2 mg/l, recorded in the months of March and November respectively. Free carbondioxide content was not very high, fluctuating from 1.2 mg/l to 6 mg/l, the least in January and the highest in November (Fig. 23).

Though July recorded minimal value for total alkalinity (18 mg/l), it fluctuated from 20-26 mg/l in most of the months. November recorded 30 mg/l being maximum for this station (Fig. 23).

Station II

The range of air temperature recorded in the different seasons fluctuated between 11.2°C and 23.1°C, observed in January and September respectively. The water temperature was maximum in September (21.6°C) and minimum in January (10°C) (Fig. 22).

Fig. 22

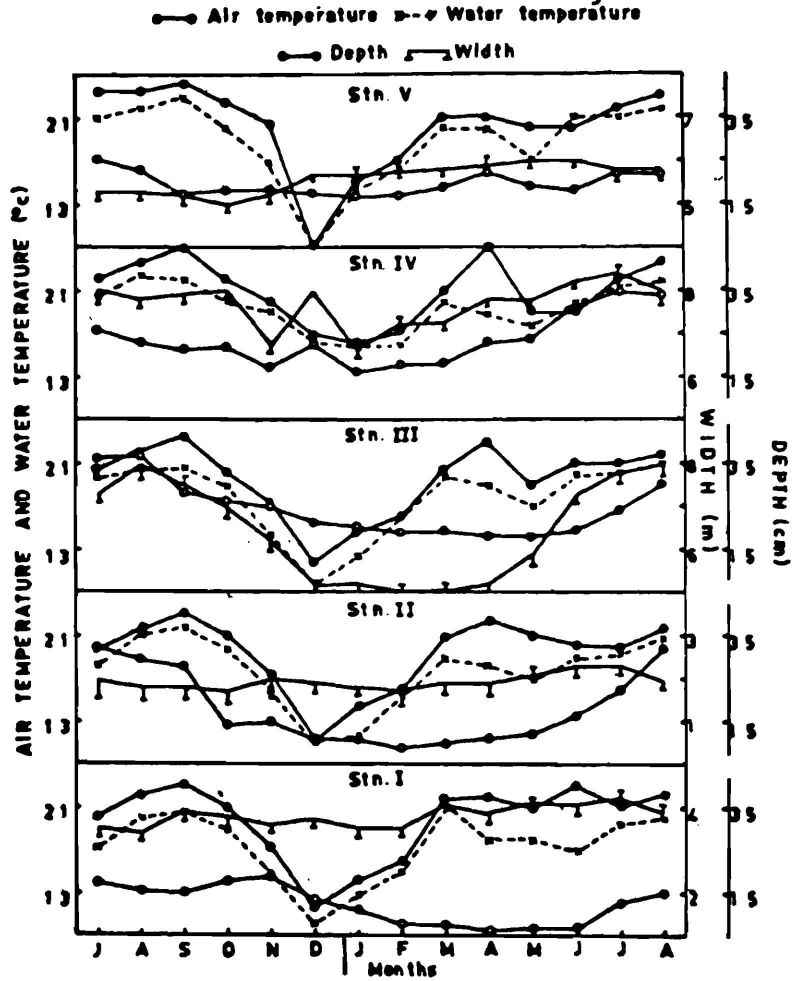


Fig. 22. Showing the seasonal fluctuation of air temperature, water temperature, depth and width in stations I to V in the stream Umshirpi.

Fig. 23

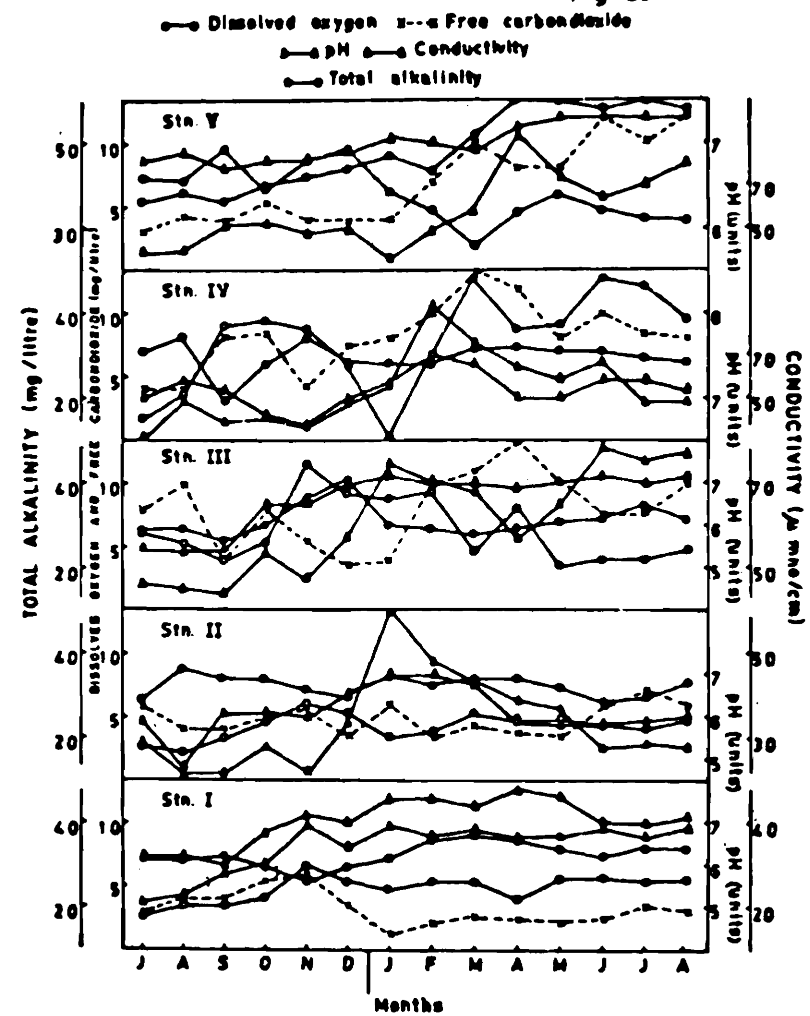


Fig. 23. Showing the seasonal fluctuation of dissolved oxygen, free carbondioxide, pH, conductivity and total alkalinity in stations I to V in the stream Umshirpi.

Both depth and width showed a decreasing during the colder months of the year. February recorded minimum depth (9 cm) and July the maximum (32 cm). Width was maximum in June and July (2.35 m), whereas February and October minimum width (1.7 m) was recorded (Fig. 22).

The pH was in the acidic range fluctuating from a minimum of 4.8 units in August to a maximum of 7 units, the latter reading recorded in January and February. Thereafter, pH declined to 5.8 units in June (Fig. 23).

Conductivity values were also seen to be high in January (68.25 μmho/cm) and minimum in August (22.05 μmho/cm). Except January, no significant difference in the conductivity values were observed in between the different months. There was a winter maxima and summer minima (Fig. 23).

Dissolved oxygen values were moderately high throughout the period of study, although slight increase during winter and spring months was seen. August recorded the peak value (8.8 mg/l), whereas July and June recorded the minimum content (Fig. 23).

The range of free carbondioxide content was from 3.5 mg/l to 7.2 mg/l without exhibiting any seasonal trends. The maximum and minimum content was recorded in the months of July and February respectively (Fig. 23).

August showed a very low content for total alkalinity (16 mg/l), which increased in the subsequent months to touch the maximum, as seen in November (28 mg/l). It thereafter fell in January and February to fluctuate around 22 mg/l to 26 mg/l in the following months (Fig. 23).

Station III

Temperature at this station, for air and water, were seen to follow similar trends of fluctuation. It recorded 23.5°C and 20.5°C for air and water respectively, as maximum, in the month of September, to fall in December, as the minimum, when they recorded 11.5°C and 9.5°C for air and water. It, thereafter, increased steadily till the end of the investigation period (Fig. 22).

The fluctuations of depth revealed, that, in the beginning of the study period values were maximum (36 cm as in August), which steadily fell in the following months recording a minimum in May (18 cm). In the same manner width was also maximum during August (7.95 m), decreased gradually and recorded a low 4.95 m in March (Fig. 22).

From July to November the water was in acidic range. It then increased to touch the alkaline point (7.2 units) in January, to thereafter, remain neutral for the subsequent two months. Except April (6.9 units) the pH values fluctuated between 7.0 and 7.2 units (Fig. 23).

Conductivity on the other hand ranged from 44.1 μmho/cm to 78.75 μmho/cm, as observed in the months of September and June respectively. Although the fluctuation range was quite high, no seasonal pattern was observed (Fig. 23).

Dissolved oxygen content was also moderate except in certain months, where it increased upto 10.2 mg/l as in December. In other months the values ranged from 5.4 mg/l to 8.9 mg/l, the former recorded a minimum in the month of September for this station (Fig. 23).

In contrast, carbondioxide content was moderately high, fluctuating from 4 mg/l to 15 mg/l. The maximum record was observed in April whereas both in September and January the minimum was recorded (Fig. 23).

The last abiotic factor considered was total alkalinity. The content was low in the months of July to October which then rose in November, when it recorded the highest value of 44.6 mg/l. The values then oscillated between 24 and 37 mg/l and suddenly declined in May recording the minimum content of 20 mg/l for that year in this station (Fig. 23).

Station IV

The monthly variation of air temperature revealed that, minimum temperature occurred in January (16.5°C), followed by a steady rise, recording maximum in April (25°C). Water temperature values fluctuated from 16°C to 22.8°C. The months of January, February recorded the minimum, while August the maximum (Fig. 22).

Maximum depth was seen to occur in June recording 32 cm and minimum in January (16.7 cm). No definite fluctuation was observed (Fig. 22).

Width was more in this station ranging from 6.8 m to 8.2 m as seen in November and June, representing the minimum and maximum values (Fig. 22).

pH was in the alkaline range except during October and November when it was 6.9 and 6.8 units respectively. A maximum of 7.5 units was seen in February which then fell down to 7 units in April and May (Fig. 23).

Conductivity also did not follow any particular pattern. In July only 31.22 µmho/cm was seen to occur which increased considerably in the subsequent months to 84 µmho/cm in February. From March, lesser values were obtained fluctuating between 59 and 75 µmho/cm (Fig. 23).

The range of dissolved oxygen obtained from the annual cycle reading revealed that the content was as high as 8 mg/l in certain months, like August and November but the values went down to 3 mg/l in September. No trend was observed seasonally (Fig. 23).

The free carbondioxide content was 4.2 mg/l in the beginning of the study period which went down to 4 mg/l in August but increased upto 8.6 mg/l in October. November again recorded a low content (4.2 mg/l). A maximum of 14 mg/l was seen in March, when it subsequently rose and fell (Fig. 23).

Only 10 mg/l in January recorded as the minimum for the total alkalinity content in this station. But a record of 48 mg/l was seen to occur in March which was the maximum content for this station (Fig. 23).

Station V

Minimum temperature recorded in this station was in the month of December (10°C and 9.5°C) for both air and water temperature respectively. However, the maximum temperature was seen to be 25°C and 23°C as recorded in the months of September for both the factors (Fig. 22).

Depth maintained almost a constant value from September to March (17 cm to 18.5 cm) but a maximum depth was observed in July (25 cm) (Fig. 22).

The range of fluctuation in width was negligible, the minimum being 5 m and maximum 6 m. The former was obtained in the month of October and the latter was in February (Fig. 22).

In July the pH value was only 6.8 when a definite increase of the values were observed during the following months. 7 units recorded in January, maintained in February and again lowered down to 6.9 units in March. 7.3 units the maximum for the entire annual cycle recorded from May onwards upto the end of the investigation period (Fig. 23).

The next factor conductivity was seen to be minimum in the month of January (36.19 μmho/cm). The maximum conductivity value was as high as 84 μmho/cm recorded in April which remained high in the subsequent months. The first few months of the previous cycle had lesser values (Fig. 23).

The dissolved oxygen values fluctuated from 2 mg/l, to 9.6 mg/l. These values were moderately high from 7.2 to 8.6 mg/l in the months of July - November, but a sudden drop in the values till 2 mg/l was observed in March. Thereafter, a slight rise and fall around 4 mg/l was observed (Fig. 23).

In the first eight months of the annual cycle studied, the free carbondioxide content oscillated between 3 and 7 mg/l. The value of 10 mg/l was seen in March which again fell down to 8 mg/l during April and May to reach the maximum in June (12 mg/l) and again in August (Fig. 23).

The last factor total alkalinity ranged between 36 mg/l and 47 mg/l during the earlier months of the investigation period. But from March the values increased upto 60 mg/l as recorded in April and May as maximum. This higher tendency of values continued in the subsequent months (Fig. 23).

Age-Class Distribution

In addition to the general population analysis of the Chironomid larvae at generic levels, it was felt best to analyse genus *Chironomus* in greater detail. This was done by grouping the larvae into four different stages based on their length measurements and some morphological characters. Based on this, a percentage composition of these different stages were seen for their abundance over the seasons in the present investigation.

These length groups are characterized and related to the age of the larvae. Such age-group analysis have also been done by Pleskot (1958) and Macan (1970). Moreover, this has an added advantage since the fourth stage is supposed to be the pre-pupal stage, after which emergence takes place. In the present investigation the four different age groups have been grouped as below :

The first stage were the newly hatched larvae, which were pale grey coloured or whitish with a large head, the length was about 0.8 mm to a little below than 1.5 mm. The body segments were not very distinct and the prolegs short but armed with claws.

The second stage ranged between 1.5 mm and 5 mm. The body was much more proportionate, head with eye-spots and mandibles slightly blackened. Colour of the larvae was pink.

The third stage larvae ranged from 5 to 10 mm. They were bright red in colour and the lateral blood gills well developed.

The last or the fourth stage, were the mature larvae from 10 mm upwards. The characteristic feature were the swelling of the thoracic segments and in particular the first and second thoracic segments. The colour of the larvae was deep to dark red.

UMKHRAH STREAM

Station I

In July, during the first month of the study period the 3rd stage larvae were dominant with 55%, while in August both 3rd and 4th stages were abundant revealing 46.9% and 43.7% respectively. At the same time stage 2 was present with a very low percentage (9.4%). In September, stages 1 and 2 were absent, but stage 4 constituted the major fraction (75%) of the population. October recorded maximum percentage of stage 2 (53.3%) followed by stages 4 and 3. In November and December, all the four stages were present, though with minor population. January again recorded maximum percentage of stage 4 (64%), while stages 2 and 3 were also present but in smaller proportions. Stage 1 present in February and March, was with a very negligible proportion (2% and 3.2%), whereas the other three stages were present in appreciable proportions. In April and May, however, only stages 3 and 4 were available, equally proportional, but in June the density of stage 4 increased to 77.8%, when stage 3 remained at 22.2%. During this month stages 1 and 2 were absent. In July stage 2 reappeared with a considerable percentage, equal to stage 3 (41.7%). The month of August of the next cycle was characterized by an abundance of stage 3 larvae (66.6%), while stage 2 recorded only 33.3% and 1 and 4 were totally absent (Fig. 24).

No definite trend of fluctuation was seen in the stages of 1 and 2. However, an increase in the autumn and summer months was observed in case of stages 3 and 4.

Station II

It revealed, at this station, that, during July there was a dominance of stage 3 followed by stages 2 and 4. In August again stage 3 constituted the larger proportion (75%) and stages 1 and 2 were absent. September was characterised by the presence of all the four stages but still stage 3 populations were larger (50%). Stages 1 and 2 were once again absent in October, while 64.3% was recorded for stage 3 larvae. In November, stage 1 was abundant, forming 50% of the total population followed by stage 2 (29.2%), while in December stage 3 showed a definite increase over the other stages (50%). A rise in percentage was seen from stages 1 to 4 in January, with the following months of February and March having a dominance of stage 3 (44% and 60.2%). During April and May stage 4 were more recording 45.6% and 60% respectively. In June and July stage 3 continued to be the important group with 66.7% and 52.4% respectively. Stage 1 was totally absent at this station for three months May, June and July, while stage 2 was absent in May, June and August. The last month of the study period, August was characterized by the dominance of stage 4(65.2%). A similar trend of fluctuation as in station I was also observed here, in general for all the stages (Fig. 24).

Station III

This station revealed that in July and August, stage 4 larvae were dominant with 52.5% and 60% respectively, while the other stages though present, were in lesser proportions. But in September a reverse condition was observed, in that stage 1 and 2 were more (45.8%). October exhibited an abundance of stage 3 larvae (53.3%), whereas in November and December it was characterized by the dominance of stage 2 (51.8%) and 1 (40.8%). In January and February stages 3 and 4 were more, but in May and April stages 2 and 4 were almost equal in their percentages. Stage 1 larvae were not recorded in April and May. Stage 3 larvae were observed during May and June to be maximum with 50% and 37.9% respectively, followed by the dominance of stage 4 (57.6% and 40%) in the last two months. These months, though, had other stages, were not very significant. A similar summer-autumn maximum for the 3rd and 4th stages were observed here (Fig. 24).

Station IV

The stage group analysis for *Chironomus* at this station showed that in July a preponderance of stage 4 larvae (45.5%) followed by stage 3 (39.4%) was observed. In August and September stages 1 and 2 were more, although other groups were present, while in October stage 2 was dominant (47.7%). In November, stage 3 dominated the other groups but stage 1 represented more in the following months of December, when stages 3 and 4 were almost equal in percentage occurrence. In January it was stage 1 (32.9%) and in February stage 4 (44.6%), which were in higher densities. March and April recorded again higher percentages for stage 4 larvae, but stages 2 and 3 were also present with moderately high percentages. An increase in the stage 3 larvae was seen in the next month recording 40% while the other populations were with only 20% each. This was followed by an increase in stage 4 larvae in June. July and August were characterized as maximum percentages for stage 2 (35%) and stage 1 (40%) respectively. At this station there seemed to be a definite rise in the stages 1 and 2 during the autumn months, and stages 3 and 4 were much less than in other stations (Fig. 24).

Station V

July and August at this station showed stages 4 and 2 as major fractions of the populations respectively. Larvae belonging to stage group 3 were dominant in both the months of September and October, followed by stage 4. In November, stage 1 recorded 33.3% and in December stage 2 had 33.7% which were dominant. In January and February all the stages constituted moderately high population percentages, though stage 2 (39.8%) and stage 4 (46.7%) represented more. Stage 4 remained maximum in the next two months also, while in May the percentage of stage 2 larvae (39.2%) was high. June and July were characterized by the population density (47.7% and 51.3%) of stage 3 larvae. June was marked for the absence of stage 1 larvae. In August, stage 1 larvae not only reappeared but revealed a maximum of 50%, followed by stage 2 (39.2%), which constituted the major fraction of the population. No general trend of fluctuation was observed at this station (Fig. 24).

UMSHIRPI STREAM

Station I

At this station the stage 1 larvae which was the maximum in the month of July (75%) at the beginning of the investigation period fell subsequently in the next month (57.1%), but still comprising the maximum portion. Stage 4 were absent during both the months. 50% of the total population belonged to stage 3 larvae in September. In October stage 4 (42.8.%) was maximum. In November a steady increase of the stage 3 population (56.4%), while in December and January by stage 4 recording 56.4% and 64.31%. February was marked not only for the dominance of stage 4 (55%) but also the minimum percentage of 5% for stage 2 was observed. Stage 1 larvae were absent for three months from February to April. March showed a dominance of stage 3 recording a high percentage of 50%, of the total population. Stage 2 dominated in April, May and June, the percentages being 66.7%, 40% and 58.7% respectively. June did not record any larvae of stage 1 but in July a peak population of 60.9% of stage 1 was seen. This was followed in the next month of August by stage 2 recording 42.4%. Stage 4 in both the months of July and August of the next cycle were minimum. A trend of winter maxima for stages 3 and 4 were observed with a summer-rainy maxima for 1 and 2 stages (Fig. 25).

Station II

This station was marked by the major dominance of stage 1 larvae in the first two months of the annual cycle. Like station 1, stage 4 was absent in July and present only with 10% in August. Absence of stage 1 was seen in September and October, while it formed a maximum in November (36.4%). Stages 3 and 4 were, however, dominant in September and October with 50% and 57.1% respectively. In December the percentage of all the four stages were between 18.5% and 29.6%. A considerable increase of population of stage 4 (73.3%) was seen in January, which formed the maximum in February also, though the percentage reduced to 57.1%. 54.8% and 30.9% of stages 2 and 3 respectively were present in March followed by the dominance of only stage 3 (80%) in the next month. No stage 1 larvae were seen in April. A considerable increase of percentage of stage 4 (54.5% and 85%) was again noticed in May and June and stages 1 and 2 were not recorded in June. Again in July and August a complete dominance of stage 1 larvae was seen recording 57.1% and 43.8% respectively. A similar summer maxima for 1 and 2 stages were observed here (Fig. 25).

Station III

The stage group analysis for the genus *Chironomus* at this station followed the same pattern like the first two stations. A dominance of stage 1 followed by stage 2 group was seen as 42.4% and 45.7% in July and August respectively. This was succeeded by stages 3 and 4 in the next two months. During November and December it was stage 3 again with 39.7% and 30.8% in the respective months, which showed the maximum of the total although other stages were also present with considerable percentages. In January, stage 3 dominated the other stages (38.7%) and those belonging to stage 4 also were reasonably high (34.8%). Stage 4 increased steadily in the next month upto 42.1% but in March, dominance was seen by stages 2 and 4, 29.4% in both cases. In April 80% of the population was of stage 3 larvae, whereas stages 2 and 4 were absent from the system. It was stage 3 which again dominated in May (45.4%). In June stages 2 and 3 had high densities of 41.2% and 35.3% respectively, followed by a gradual fall in percentage in the subsequent months. July and August were dominated by Stage 1 (60%) and stage 2 (42.5%) respectively, whereas larvae belonging to stage 4 were minimum in those two months. No definite trend was observed (Fig. 25).

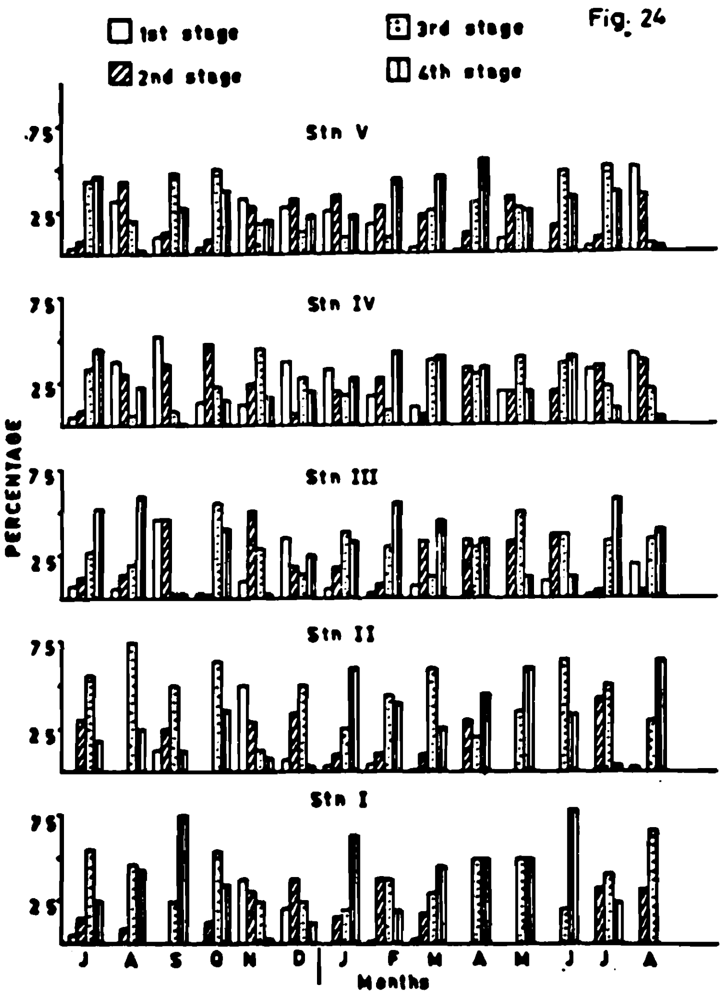


Fig. 24. Showing the percentage occurrence of the four larval stages of the genus *Chironomous* seasonally in stations I to V in the stream Umkhrah.

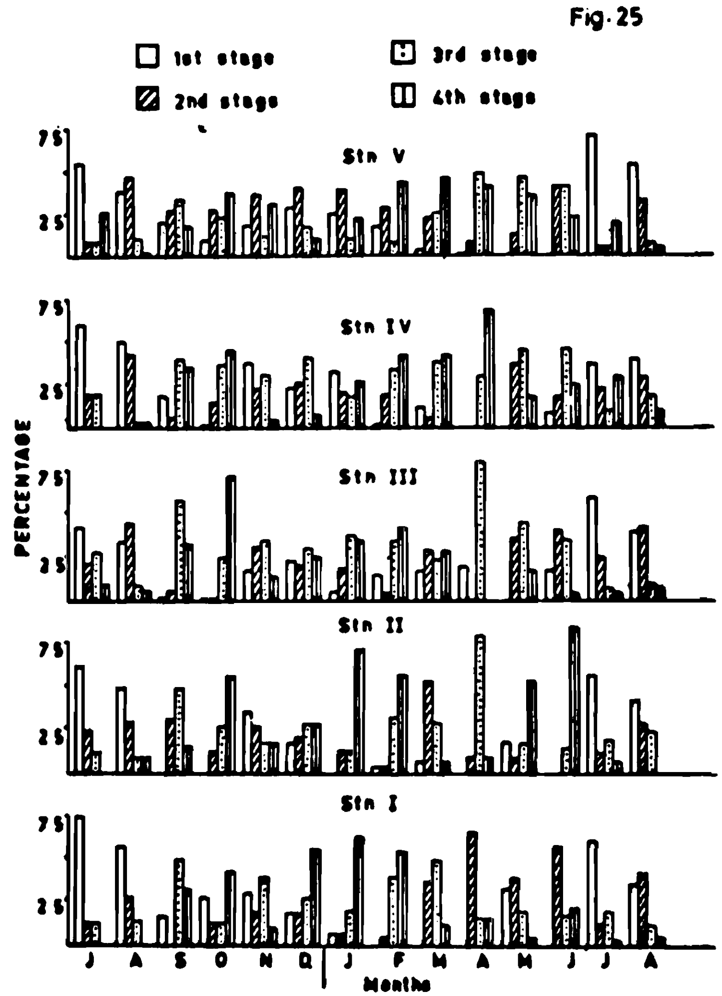


Fig. 25. Showing the percentage occurrence of the four larval stages of the genus *Chironomus* seasonally in stations I to V in the stream Umshirpi.

Station IV

Abundance patterns of the four different stages in station IV showed that stage 1 formed the maximum portion of the total population in July and August (60% and 50%), which subsequently fell in the next two months, but again dominated the other stages in November (37.5%). Stage 3 larvae were seen to be more in September (39.6%) whereas 45.6% of the density was of stage 4 larvae in October. A steady increase of stage 3 larvae from 31.9% to 41.5% was witnessed in December but the percentage fell in the next month, when again stage 1 took over and was dominant (32%). In February, March and April stage 4 continued to be the dominant group recording 42.4%, 42.2% and 68.8%, in the respective months. Stage 1 disappeared from the system in April and reappeared again in June with only 9.4%, but thereafter rose steadily in the subsequent months forming greater fractions (36.7% and 40.5%) of the total population. Stage 2 was absent in the month of April but constituted a moderate percentage in May (6.4%) where again stage 3 dominated (45.4%), which continued to be the major group in June (46.9%). The last two months were replaced by stage 1 as dominants. Late winter maxima was observed for stage 3 and 4 (Fig. 25).

Station V

It was observed that during the first month of the study period, stage 1 larvae were dominant (55.9%), which steadily decreased in the subsequent months. Stage 2 which was dominant in August (47.7%) maintained almost a good percentage of population in September and October and again formed the maximum (36.8%) in November, December (41.2%) and January (39.8%). October recorded the maximum population of stage 4 (37.9%), which fell in the following months. Stage 3 larvae represented more in September (34.5%), which decreased gradually in the subsequent months upto 9% in February. In February on the other hand stage 4 was dominant (44.6%), which continued to be so in March (46.7%). In April and May stage 3 larvae were preponderant with 48.4% and 46.9% respectively. Both stages 2 and 3 were equally represented in June with 38.5% whereas stage 1 was absent. However, stage 1 larvae reappeared in July with a very high percentage (70%) and still continued to be the major group in August (53.4%) also. The summer-rainy maxima for stage 1 and 2 was observed (Fig. 25).

Emergence Studies

As trapping began, a steady increase in numbers of the total adults captured were seen in the first eight days of June when the population touched 41 individuals. This, thereafter, fluctuated around 30 to reach a peak of 54 on the 22nd day of June, which, thereafter, fell drastically on the 28th day. The next day in the same month 60 individuals were recorded, which incidentally is also the highest catch throughout the emergence period of this investigation. Beginning July, till the end of the period the numbers were far less and in most of the cases were in single digits (Fig. 26).

When a breakup of the males and females of this adult population were seen for their seasonal emergence pattern, a general mirror image of emergence was observed between the males and females, at least during the peak periods of emergence. In most cases the females emerging were much more than the males except probably in the first few days and last few days of June. Peak periods of emergence in females were seen in the first, second and third week of June with a similar pattern in

July recording 26, 36 and 17 respectively. In the month of August, during the third week a peak was observed for these females of 16 individuals, though the magnitude was far less than in the previous months (Fig. 26).

Similar peaks for the males were seen in the first, third and fourth week of June and similarly in July recording 24, 18 and 44 individuals. In the next two months, however, the population densities of these males were less (Fig. 26).

Fig 26

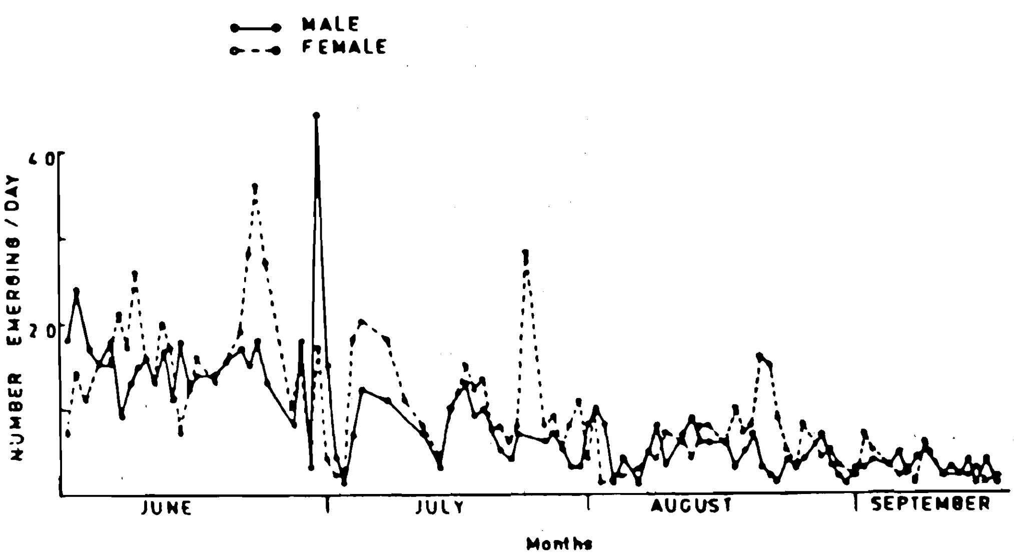


Fig. 26. Showing the number of adults, male and female emerging perday of the genus *Chironomous* during the emergence period, June to September.

DISCUSSION

Lentic Systems

In the present investigation among the two lentic systems it was seen that Chironomid populations, irrespective of the genera had maximum densities of 1500 larvae/m^2. This figure seems to be low for a tropical situation. More so, when compared to some temperate or sub-tropical situations, where densities reported per sq. m are 10,000 or more (Peterson and Fernando, 1970; Jonasson, 1972). Since both the lentic systems were situated at a low altitude, they should have had a greater population density, but without comparative figures for the north-east it is difficult to attribute anything specific other than our own work. The paucity of Chironomid population for Indian conditions, however, have been shown by Michael (1964) and Alfred (1973a), even at latitudes with higher temperatures. The concept that populations which occur in small lakes regardless of latitude are partially related to high temperature also exist (Schindler and Holmgren, 1971; Schindler, 1971). However, as far as the occurrences of the species, it was seen that the present lentic systems offered a greater variety even at generic levels where nearly six genera were recorded in contrast to only five species in South India (Alfred, 1973a). The one notable feature was the total absence of the genus *Chironomus* in all the stations undertaken. However, the genus *Tanypus* was seen to dominate at all the stations except one, the fourth station. Further, among the two genera, *Clinotanypus* and *Tanypus* under Tanypodinae, there was a clear alteration seasonally in their abundances. Even when one occurred throughout, yet the density fluctuations were lower during the occurrences of the other, as in the present investigation at station II (Table II). Such a niche differentiation either for space or food, and possibly controlled by temperature, clearly seen between the two genera *Clinotanypus* and *Tanypus*, of the sub-family Tanypodinae, was not obvious for the genera under the sub-family Chironominae. The four genera *Polypedilum, Harnischia, Dicrotendipes* and *Cladotanytarsus* of the sub-family Chironominae, though did not occur always in all the stations but whenever they occurred it was seen that they always synchronized with the occurrence of *Clinotanypus*. Generally, therefore, from the present investigation it can be seen that *Clinotanypus* and all the genera of Chironominae followed a winter maxima and summer minima, with *Tanypus* showing just the reverse. However, as a relative abundance, it was seen that the sub-family Chironominae, whenever they occurred with Tanypodinae the former were much more. This is very obvious from the present investigation as seen in Fig. 15. Hence, on a broader categorization, Tanypodinae revealed a summer maxima, while Chironominae a winter maxima, their occurrences alternating with each other.

In the present investigation, since the categorization upto species level was not possible, the characterization of habitat of this lentic system has been primarily done on the diagnostic characters of the genus. In certain cases such characterization is enough (Fittkau, 1968), though preferably species differention is more ideal for understanding, ecological differentiation. Even at this level, it was seen that as one traversed from stations I to IV, there was an increasing productivity, indicative of the eutrophic status of the lakes, represented by the low numbers of Tanypodinae, with an increase in Chironominae. The validity of such Chironomid communities as indicators of trophic level has been shown by Brundin (1956). This lake typology founded only on Chironomidae is now recognized as a worldwide validity. However, it was seen that larval population densities of the summer generations, and in large the genus *Tanypus*, were much more in density than the overwintering generations of the genera of Chironominae.

This could probably be due to the fact, that density dependence alone cannot only lead to patterns of stable cyclic oscillations but also to irregular fluctuations. As seen in the present investigation they can be identified in the populations which were discrete and non-overlapping, without any delay in the dynamical behaviour of the genera under consideration (May and Oster, 1976). The occurrence of Tanypodinae and Chironominae in discrete niches, as it were, had become pronounced within the lake divisions as stations I to IV, since it is known that spatial and temporal division will be more pronounced and advantageous in a patchy environment and less marked in an uniform habitat. This aspect is very well documented in the present study as there were considerable differences in the generic composition of the Chironomid populations. A greater variety was seen at stations I and III, followed by IV and the least station II. This may be in part due to the availability of food sources influencing the density available at the littoral and profundal areas. However, due to factors like low mortality, sporadic occurrences and increase of populations, synchronized to seasonality, indicate that density independent factors may be responsible for limiting Chironomid population in this lentic system than density dependent effects.

To identify and confirm this aspect, it was seen from the present investigation, that of the nine physico-chemical parameters undertaken, all but one had a more or less summer maxima and winter minima. The reverse was observed only in the case of dissolved oxygen. A simple observation would therefore indicate that the genus *Tanypus* was primarily dependent on all these factors for its density buildup in contrast to *Clinotanypus* which required higher levels of oxygen for its sustenance. However, the genera under Chironominae also preferred higher oxygen values in comparison to other physico-chemical factors probably reflecting the Oligotrophic nature of the system in general. However, the genus *Chironomus*, representative of eutrophication, was totally absent.

This, however, does not refer to water *per se* but to waters in their manifold forms which produce such biotopes. Therefore, the present investigation of the physico-chemical parameters were done to elucidate and identify the resulting patterns of observations which would probably influence the population dynamics of benthic organisms, and in this case, Chironomids. Works on Indian Limnology have made the scene only in the last three decades. Of these, the lacuna is all the more felt for benthos in freshwater biotopes. However, works throughout the world in this field have helped us to a large extent to take cognizance of the priorities even with the handicap of essential facilities. Of the nine physico-chemical factors undertaken the atmospheric temperature was seen to play a direct effect on the surface water temperature in that it usually followed closely behind that of atmospheric temperature with a few exceptions (Fig. 18). The annual range of variation in the surface temperature revealed that genera of chironomidae encountered were subjected to fluctuation ranging between 13.5° C and 28° C at all the four stations. This range, indicative of a lower minimum temperature for tropics, however, maintained the uniformity of thermal conditions with very little drastic fluctuations throughout the year (Fig. 18). This uniformity of temperature variations, though on the higher side, has been pointed out by many earlier workers for tropical water bodies (Michael, 1964; Sumitra, 1969; Bernice, 1970; Royan, 1972; Alfred, 1973a). It may, however, be mentioned that diurnal variations in temperature especially in shallow environments are wide, again documented by these workers. This may probably control the behavioural pattern of Chironomids, when they are known to be confined in their mud tubes at the cool bottom with increase in surface temperatures (Rzoska, 1961; Weir, 1969). Ganapati (1960) has observed that thermal gradations were more stable in tropics from his work on the tropical waters of South India as it co-ordinated with changes in the density of these waters. This may, therefore, be applied also in the present situation where the lentic system possessed a large area with relatively shallow depth.

The depth in this system never reached three metres at any station, indicating the shallowness of the system. The range for stations I to III was between 35 cm and 183 cm, while station IV the deepest station, ranged between 217 cm and 267 cm. Inspite of the shallowness the actual range of variation at the four stations were 85 cm, 69 cm, 65 cm and 50 cm. This indicate in the first three stations, that this range of variation was nearly 50% or more of the maximum depth, indicative of specific ecophysical conditions at these stations. For comparison very little informations is available on these aspects for tropical species. Tropics in general are known to control their water levels primarily on the amount of rainfall. The present system located in a geographical area of high rainfall was indicative of this phenomenon in that the maximum depth was found during the rainy season and the lowest was during winter months. It is known that the water level goes down at lower latitudes due to increase in temperature in the summer months. However, in the present system since the rainfall extends to a larger part of the year, inclusive of summer months, the lowering of the water levels during winter is partially due to the increasing photoperiod. Winter, therefore, are the months, when with cloudless sky, the evaporation that has to take place does so at that time. moreover, the surface runoff after the rains due to the mountainous character of the region aids in larger percolation of water due to seepage observed clearly during the winter. Atkins and Harris (1924) and Ganapati (1962) have reported a direct relationship of depth to various physico-chemical factors as is also obvious from the present investigation. This group of animals, though found at various depths, beginning from the shore margins of the lentic systems, Chironomid beds could be observed even at depths of 10 cm. The reason for such occurrence in marginal shallows are not quite known though reported earlier (Alfred, 1973a) and probably attributed to a positively phototactic nature as for most anostracans (Bernice, 1970) and conchostracans (Royan, 1972).

The next factor transparency which is effected due to silting, microscopic organisms and suspended organic matter (McCombie, 1953; Bamforth, 1958) in this lentic system was seen to range between 26 cm and 80 cm indicative of wide fluctuations. The range of variation at each station was observed to be 20 cm, 42 cm, 48 cm and 32 cm again showing a 50% variation from its minimum or maximum records in transparency also. This factor in the first three stations showed a drop in the summer-rainy seasons and higher values just after the rains and the beginning of winter. Station IV, however, followed a pattern in the reverse and probably explained by the fact that this was the deepest portion, affected only to a lower extent because of rains and probably more due to turnover. In any case, rainfall as a chief source of turbidity in waters is of overriding importance. Moreover, abundance of the plankton composition and detritus also affects transparency particularly in tropical situations (Roy, 1955; Michael, 1964; Krishnamurthy and Viswaswara, 1965; Sumitra, 1969). These factors, though not analyzed in the present investigation, are probably true only in eutrophic conditions, as has been indicated for Chironomid populations and transparency by Alfred (1973a). Therefore, precipitation could have both beneficial and detrimental effects in lake systems, and in particular, on poorly buffered ones as in the present investigation (Dillon *et. al.*, 1978; Thapa, 1982).

pH as the next factor was mostly seen to be on the neutral side. However, the buffering capability in this system, and at all the stations, revealed a very marked nature as the values oscillated around 7 units. The range of variation was between 0.5 unit and 1 unit. Such narrow range of fluctuations have been recorded earlier both in temperate and in tropical water bodies (Jenkins, 1932; Kato, 1941;

Ganapati, 1941; Moore, 1952; Tucker, 1958; Henson *et. al.*, 1961; Michael, 1964; Sreenivasan, 1964b; George, 1966; Alfred, 1973a; Thapa, 1982). The water remaining neutral or slightly acidic indicates oligotrophic nature of the system pointing to a greater variety of species. This is probably true for the density of autotrophs, as when there is an accumulation of carbondioxide there is lowering of pH. Both these trends were evident in the present study. This neutrality of the pH and the slight acidic nature may be attributed to inflow and surface runoff on leaf litter which is mostly acidic. In the present investigation rainfall also seemed to play a role in the increasing nature of pH probably allowing for easier buffering during such seasons than at other times.

Specific conductivity as a factor is usually seen as another indicator for assessing the trophic status of the lake. The present investigation showed the values ranging between 14 and 60 µmho/cm, indicative of very low specific conductance and therefore again of the oligotrophic nature of the system. Comparisons of this factor with other tropical water bodies do show this range, for the present investigation to be indicative of ultra-oligotrophic situations as records indicated that tropical water bodies are always in terms of thousands of µmho/cm (Alfred, 1973a).

Dissolved oxygen in this system was observed to be indicative of well oxygenated conditions, the values ranging between 5 and 10 mg/l approximately. The annual range, however, was around 4.5 mg/l for all the stations. These oxygen levels are much higher when compared to other tropical ponds (Michael, 1964; Sumitra, 1969; Bernice, 1970; Royan, 1972). However, when compared to similar geographical areas, as shown for larger bodies of water or reservoirs (Alfred, 1973a), the possibility of higher values may be due to the open nature of the system exposed to the action of wind, maintaining adequate levels of oxygen. Further, it is common knowledge that abundance of phytoplankton population leads to increase in oxygen content due to photosynthetic activity (Roy, 1955; George, 1961; Michael, 1964; Thapa, 1982), but there is no direct evidence in the present studies to confirm these findings, This one factor having a winter maxima and summer minima is obvious and understandable as the primordial agencies of photosynthesis depends on the light energy and the efficiency of conversion of this energy. The levels further indicate, as seen for other factors, the system as a whole is oligotrophic.

The free carbondioxide in waters form usually carbonic acid resulting a change in pH. The usual summer maxima and winter minima in the present system could probably be attributed to the fact that acidic waters at lower temperature can release this gas faster and simultaneous uptake due to the growth rate of phytoplankton at the surface layers. The range of fluctuation indicated by a minimum of 2.6 mg/l and maximum of 18 mg/l irrespective of the stations clearly indicate a very low value. It is possible that the buffering nature of the pH has helped to a large extent the maintenance of these values which is definitely much lower than in tropical situations as indicated by workers, as shown for other factors.

Alkalinity of Calcium Carbonate precipitate in any lake metabolism studies is important. The accumulation of large quantities of bicarbonate during summer summer indicated by the higher values of alkalinity as recorded in the present investigation was probably due to the liberation of carbondioxide in the process of decomposition of bottom deposits. This results in the conversion of insoluble ion of calcium into soluble bicarbonates. This was very true in the present study as increase

TABLE V

Co-efficient correlation table, showing the relationship of the physico-chemical factors and the two sub-families Tanypodinae and Chironominae in the two lentic systems

Stn.	Sub-family	A. Temp.	W. Temp.	W. Level	Trans.	pH	Cond.	DO_2	FCO_2	T. Alk.
I	Tanypodinae	0.329	0.338	0.585*	(–) 0.123	(–) 0.203	0.152	(–) 0.556*	0.681**	0.291
	Chironominae	(–) 0.329	(–) 0.338	(–) 0.585*	0.123	0.203	(–) 0.152	0.556*	(–) 0.681**	(–) 0.291
II	Tanypodinae	0.240	(–) 0.012	0.171	(–) 0.506*	0.454	(–) 0.170	(–) 0.270	0.196	0.320
	Chironominae	(–) 0.239	0.012	(–) 0.171	0.506*	(–) 0.454	0.175	0.269	(–) 0.196	(–) 0.320
III	Tanypodinae	0.128	0.151	(–) 0.013	(–) 0.225	0.071	(–) 0.152	(–) 0.430	0.170	(–) 0.152
	Chironominae	(–) 0.239	(–) 0.264	0.316	0.345	(–) 0.171	0.005	0.380	(–) 0.090	(–) 0.148
IV	Tanypodinae	(–) 0.129	(–) 0.173	(–) 0.181	(–) 0.029	(–) 0.095	(–) 0.110	(–) 0.289	(–) 0.066	(–) 0.142
	Chironominae	(–) 0.232	(–) 0.181	(–) 0.331	(–) 0.288	(–) 0.124	(–) 0.037	(–) 0.440	(–) 0.363	(–) 0.459

* $p < 0.05$ ** $p < 0.01$

Stn. – Station
W. Temp. – Water Temperature
W. Level – Water Level
Trans. – Transparency
Cond. – Conductivity
DO_2 – Dissolved oxygen
FCO_2 – Free Carbondioxide
T. Alk. – Total Alkalinity

in carbondioxide also increased alkalinity (Ruttner, 1953; Thapa, 1982). This system was, however, in contrast to the usual tropical situation where the normal carbonates are also present (Michael, 1964; Sumitra, 1969; Alfred, 1973a). The values ranging between 25 and 45 mg/l in station I to III and between 7 and 38 mg/l but mostly around 15 mg/l in station IV indicate much lower levels in comparison to systems in the tropics. Once again this confirms that the system is oligotrophic, enabling a larger diversity of organisms rather than the rise and fall of one or two eutrophic species. The present system having low or moderate alkalinity is indicative of a chemical thermodynamic approach for describing any solution phase composition (Davies, 1962; Nancollas, 1966).

On analysis of the results of the physico-chemical factors, it was seen that the sub-family Tanypodinae allowed its two genera *Tanypus* and *Clinotanypus* to utilize the maximum benefit of the whole system as it were. The physico-chemical factors do seem to play a role in not only reflecting the oligotrophic nature of the system but also the buildup of the different genera in their densities, in relation to the turbulence of the sediments, reducing the transparency of the water and thereby possibly hindering light penetration and subsequent prevention of algal growth. Hence, all the genera of Chironominae and *Clinotanypus* abound at situations when the factors are optimum and possibly with increased rate of food availability. By in built reproductive potential they were possibly able to complete their life cycle within a given period to reappear only when conditions were favourable. The genus *Tanypus* having a summer maxima was probably able to thrive at lower oxygen levels but with increased values of other factors which maintain that type of food and in this case prey, as the genus *Tanypus* is generally known to be a carnivore.

On a general analysis to elucidate the effect of the physico-chemical factors on the sub-families Tanypodinae and Chironominae, a correlation coefficient analysis was performed (Table V). There seemed to be no effect directly at all on these two sub-families at stations III and IV. At station II, transparency was negatively significant at 5% level, with Tanypodinae and positive with Chironominae. In station I, however, water level and free carbondioxide were positively significant with Tanypodinae and negative with Chironominae, the former factor at 5% level and the latter at 1% level, while dissolved oxygen was just the reverse but significant at 5% level. This, however, does not give a true picture as the genera were upheld together, not indicative, of which factor plays a control. It does indicate, however, that physico-chemical factors do play some role in regulating the population of Chironomids, but a detailed work on individual factors and species would throw light into the understanding of Chironomid communities. The lentic systems studies, however, seem to be influenced to a large extent by the biotic interactions also and the detailed study of these would help in the complete understanding of those intricate relationships that exist in such oligotrophic systems maintaining dynamic equilibrium.

Lotic Systems

In contrast to the population dynamics of Chironomid larvae in lentic systems and their inter-relationships with the physico-chemical factors indicative of a greater variety and a general oligotrophic nature, the lotic systems undertaken for the present investigation revealed a lesser diversity and a different composition. On a general analysis of the two lotic systems, it can be seen, that for greater length of the Umshirpi Stream, the occurrence of the genus *Chironomus* in larger quantities was obvious than in Umkhrah Stream. This definitely reflects the trophic status of these streams, in that, Umkhrah Stream not only had fewer genera but also the genus *Chironomus* dominated at all the stations except station I, the headwaters, where *Brillia* occurred in larger quantities. Though it was true for Umshirpi Stream also, except that at the station I, in addition to the domination of *Brillia* and *Chironomus*, four other genera were also present in substantial quantities over the seasons. The pollution load in a lotic system is usually indicative of the abundance of the genus *Chironomus* (Thienemann, 1954; Gaufin, 1958; Hynes, 1960; Hawkes, 1962, 1963; Learner and Edwards, 1966; Hawkes and Davies, 1971 and Gover and Buckland, 1978).

As seen in the present investigation, the tendency for the increase in the load of pollution, though primarily from household wastes and probably siltation, is observed from station III onwards till station V. In fact these last three stations in Umshirpi had only the genus *Chironomus* present and in Umkhrah three other genera though present at station III occurred only one to three times with the last two stations IV and V of the same system recording only the genus *Chironomus*. However, the occurrence of four to six genera in both these lotic systems is indicative of the paucity of the Chironomid diversity. One does not have comparative data under similar situations of the tropics and especially for Indian conditions, though it is a fact that temperate waters at similar latitudes and altitudes have a higher species richness (Hynes, 1970; Peter, 1970; Bishop, 1973).

On an individual analysis of the stream systems undertaken it was seen that in Umkhrah system though three to four genera were present in first three stations comprising of *Chironomus*, *Anatopynia*, *Pentaneura* and *Brillia*, except for *Chironomus* in all the stations and *Brillia* in first two stations *Anatopynia*, *Pentaneura* and *Tanypus* in whichever stations they occurred, were recorded only once or twice throughout the study period. The genus *Brillia* revealed a summer maxima with tendencies of decrease in winter at stations I and II, where they occurred throughout the period of study and at station III, even though, they occurred only once they did so in the summer months of June with large numbers. In contrast to this, the genus *Chironomus* had maximal peaks in the winter months with smaller abundances during late spring or early summer. This aspect of a bimodal peak of the genus *Chironomus* could probably be attributed to different species under the same genus *Chironomus*, which for lack of literature, the present work was confined to generic levels. In addition to these observations for the genus *Chironomus*, it was seen, that from stations I to V there was an increasing density with the highest of 11.947 nos/m^2 recorded in the V and the last station (Table III).

In the next lotic system, which was Umshirpi stream, there was definitely a larger variety of the Chironomid larvae at least in the first two stations. Moreover, of the six genera *Calopsectra*, *Tanypus*, *Anatopynia* and *Pentaneura*, unlike the Umkhrah stream occurred for longer periods of the investigation in addition to the occurrence of the genus *Chironomus* and *Brillia* throughout. The fluctuating trend in the population dynamics of these two genera, *Chironomus* and *Brillia*, followed a more or less similar pattern as for the other lotic system. *Brillia*, however, had the peak slightly shifted to early winter while *Chironomus* revealed the bimodal peak, one in winter and the other in summer. Further, the increasing tendency of the abundance of the genus *Chironomus* from station I to V was also seen in the present system though not in quantities as significant as in the Umkhrah stream.

The genus *Calopsectra* occurred throughout the period of investigation at station I and revealed abundances in winter, though smaller peaks were also seen in late autumn. Though this genus did not occur during the late spring and early summer at station II, the trend of fluctuation was similar to that of station I. *Tanypus, Anatopynia* and *Pentaneura* at station I, occurred predominantly during late autumn, throughout winter and early spring, with their peaks of abundances in winter. However, in station II *Tanypus* was totally absent and the other two genera, *Anatopynia* and *Pentaneura* occurred during the late spring and early summer months. As for the other lotic system Umkhrah, the last three stations were also dominated by the genus *Chironomus* (Table IV).

The bimodality in the peaks of occurrences in some genera and the occurrences in some seasons at one station and at other seasons at the next station was again probably indicative of different species abounding not only in the different ecological niches of the habitat considered, but also the result of some species occurring at one station and not in the other. This again could not be identified in the present investigation as the family Chironomidae was treated only till generic levels and the population-dynamics treated as such.

On a higher level, when these genera were clubbed together under different sub-families, it was seen that in both the systems, they fell into three major sub-families - Tanypodinae, Orthocladiinae and Chironominae. The sub-family Tanypodinae in the Umkhrah stream was negligible, while in Umshirpi they made a slight impact by their larger percentage of occurrence during the month of April at stations I and II. Otherwise, this sub-family could be said not to have utilized the ecological niches available or that conditions do not permit their abundances. However, Orthocladiinae and Chironominae sub-families followed a mirror image of each other, in that when one was abundant in the system the other was at its lowest. The general peak of abundances followed their dominant genera. This was particularly true in the first two stations of both the systems when they occurred throughout the investigation period. Their life cycle patterns were probably adapted to their occurrences and primarily to a much clearer and unpolluted water at the stations where sub-family Orthocladiinae was present.

Population studies on aquatic fauna in lotic systems and the interpretation of the data is very often an arduous task. This is in part due to the multiplicity of biotic and abiotic factors which control such populations and the differences in these factors which varies largely and considerably between two lotic systems not only in one region but also separated by geographical distances.

The present lotic system undertaken is different from those occurring from the rest of India as they pass through conifer forests and fields of agriculture as practised by local tribal methods. In addition, the hill streams in this region experience high spates quite frequent during the monsoons which extend for the larger part of the year. This annual feature where the fauna of these streams are subjected to such spates could possibly have eliminated the sensitive species leaving behind the more hardy ones. However, it is also known that the process of recolonization is quite rapid in such tropical and subtropical situations. These aspects had also been shown for a Malayan river by Bishop (1973) and that spates are known to selectively limit the diversity of fauna in streams, and further that certain species are better adapted to such spates than others (Harker, 1953); Ali, 1968a, 1968b, 1969; Hynes, 1970; Hart and Brusven, 1976). All these point out to the possible resultant condition of a less varied community of Chironomids in the streams undertaken for the present investigation which are definitely liable to very frequent spate conditions.

The other reason could probably be associated due to deforestation and flash floods, resulting in increased silting, particularly after a heavy shower, when the otherwise clean streams turn turbid. The elimination of certain genera, therefore, resulting in the observed low diversity could probably be the result of siltation and the filling up of gravel inter spaces by fine particles of sand. Such silting being responsible for a low species diversity even when sand is deposited only at certain times of the year is known worldwide and specially in South African and Russian rivers (Hynes, 1970). The direct harmful effect of sand and stone is also known (Mackay and Kalff, 1969; Luedtke *et.al.*, 1976; Brusven and Prather, 1974), and the loss of vegetational cover itself has been identified in reducing the number of species, having a long-lasting effect (Minshall, 1968). Although it is rather difficult to exactly quantify these above mentioned effects,due either to siltation or loss of vegetational cover for studies as in the present investigation, it may be suggested that such factors could be the plausible causative agents in restricting the number and variety of Chironomids in the present systems. The nearest to such an understanding could only be pointed out to the fact, that substrate, from the first station to the last showing a definite difference in the diversity of the fauna, as the headwaters representative of station I and II strewn with larger boulders among smaller pebbles are usually accompanied by a corresponding increase in the number of genera at both the systems. The lower stations, probably due to the accumulation of silt and slush creating very little space for diverse genera, was seen to be dominated by the only genus *Chironomus*. Substrate instability is known to be an important factor controlling the diversity of benthic macroinvertebrates (Hynes, 1970; Macan, 1976) and is likely that the present streams too were governed by such factors, though not investigated.

It was, therefore, felt best to identify the physico-chemical factors as analysed in the present investigation to be operative for either the diversity or the abundance of the Chironomid larvae in the two lotic systems. The general climatic conditions are definitely unique and different in many respects than that obtained for the plains of India. The domination of the conifer *Pinus kesiya* is itself an aspect to be reckoned with, as the vegetational composition plays a great role in inland waters generally and lotic systems in particular, as they traverse through larger areas having vegetational cover. This is responsible for the portion of allochthonous material input into the streams through leaf fall.

The air temperature recorded for both the systems ranged between an average of 10 and 25° C indicative of a considerable fluctuation though on lower magnitudes, as compared to other lotic systems in India and South East Asia where not only higher values are seen but the range of fluctuation is quite narrow (Venkateswarlu, 1969; Bishop, 1973). The lowering down of temperature is definitely attributed to the altitude of the study area (ca 1500 m) as pointed out by Hynes (1970).

The water temperature followed closely behind that of air temperature and was true at all the stations at both the systems. The difference in the water temperature between stations was very less. Such uniformity of water temperature at the various stations in both the lotic systems undertaken is probably attributed to the fact that these streams continued to receive groundwater sources all along their lengths thereby keeping an uniformity in temperature from the headwaters or source, down to the mouth. Similar findings also exist in Europe (Beck, 1965). However, at some stations the minimum temperatures recorded had values lower than that at other stations for the same months and is probably because of the shaded areas they were at, and not receiving much of direct sunlight. Therefore, wind and shade could have caused these changes in water temperature (Hynes, 1970).

In lotic systems, the major factor effecting the density of larvae is the water level, measured as depth in the present investigation. It is further known that Chironomids and most macro-invertebrates have a depth distribution (Moon, 1935a; Needham, and Usinger, 1956). In the present investigation of both the lotic systems, in the various stations undertaken the range of depth was approximately between 5 and 35 cm. The annual range of depth was seen to be in a decreasing order from stations I to V in both the systems with an exception at stations I and II of the Umshirpi stream. These annual ranges have been seen to be between 23 cm and below 1 m, the former for station I, the head-water and the latter for station V. This is indicative of the fact that there is a wide range of fluctuation for the head water and the depth or water level probably maintained throughout the year in the last stations. Rapid flooding may, therefore, bring about a lesser density of animals collected at fixed place which on lowering of the water level of the same areas or corresponding areas could lead to a concentration of animals. This was clearly observed in the present investigation where the abundances of Chironomid populations irrespective of the genera have been found either before the rains or after. Reports also exist on migration of bottom fauna to shallower waters during summer and deeper waters during winter (Wesenberg-Lund, 1912; Pauly, 1917; Lundbeck, 1926). This last aspect became all the more clearer when the width of the lotic system was also characterized over the seasons as in the present investigation. The only difference between depth and width in the present investigation was that both these factors have reverse effects as far as the stations situated lower in comparison to those at higher altitudes especially the headwaters.

The pH values in these two systems at the various stations undertaken were seen to be mostly on the acidic side. The range of variation was also very low, not only seasonally over the annual cycle but as well, between the stations. Further, there seems to be no regularity in their fluctuations and such conditions are known to be prevalent in many tropical rivers (Hynes, 1970; Bishop, 1973). The Chironomid larvae recorded in the present investigation could therefore be attributed as acidophilous species and probably the genus *Chironomus* also was made up of species which are acidic adapted in contrast to the usual character of this genus prevalent in highly alkaline conditions in the tropics, especially in lower altitudes and latitudes (Alfred, 1973a).

The conductivity values like pH were also very low. However, the values seem to increase between stations with the highest records observed in last few stations of both the lotic systems. This is understandable because the headwaters change their ionic composition by the diluting effects of rain which over the length of the stream gets stabilized and the load of total dissolved solids increases in the last stations of IV and V Such ideas have already been suggested and supported by Slack and Feltz, 1968; Bishop, 1973).

The next factor, dissolved oxygen, as was quite obvious from the results were high for the initial stations I and II and sometimes III for both the systems, with the lowest values and even the lowest record invariably at station V The former aspects of higher oxygen is likely to have been in part to the turbulence maintained, by the water, rushing through rough boulder strewn, bed, near the headwaters. The possibility of a rich periphyton growth, though not investigated in the present study, could be another reason for their higher values at stations III and IV, where the stream was comparatively slow flowing. Comparable views about such oxygen relationships in running water systems are held by many workers, as reviewed by Hynes (1970) and Bishop (1973). The last station V with low oxygen values could be attributed to the urban area refuse entering the station in these systems and a possible rapid turnover of organic materials by aerobic bacteria indicative of a maximum utilization of oxygen and thereby a reduction.

The free carbondioxide in the present investigation revealed a very large variation not only in their seasonality but also between the stations. The phenomenon was however similar for both the systems. Further, there was definitely an increase in the range of variation from the stations at the headwaters to those at lower elevations. Moreover, carbondioxide values were much lower in the former, than in the latter stations. However, the well known inverse relationship expected between oxygen and carbondioxide values were not clearly established at each station, confirming the findings of earlier workers (Hynes, 1970). The irregular variations could only be attributed to the degree of turbulence, the utilization and abundance of planktonic and periphytonic algae and largely to the geology of the stream bed (Hynes, 1970; Goltermann *et al.*, 1978). As indicated for lower oxygen values the higher values for carbondioxide at the stations IV and V and in particular the last station could again be due to the bacterial decomposition process taking place at these stations which contains the largest amount of slush and sludge.

The last factor, alkalinity, observed in the present investigation was also far less than the tropical situation and ranged between 10 and 50 mg/l at both the systems. As alkalinity is related to the carbondioxide levels and as mentioned in the lentic systems, this factor was very similar in its behaviour, quantity and peak values to that of carbondioxide not only within the stations concerned but also between the systems. A similar increasing tendency of its values from the stations at higher elevations to those at lower elevations was also observed and the range of fluctuation increased similarly, with the widest range over the annual cycle recorded at the last station of both the lotic systems.

The last three factors indicate a clear distribution of these Chironomid fauna even at the generic levels. This was obvious as the hardy genus *Chironomus* which can sustain, lower oxygen values was not only found in large numbers but probably the only genus at the last few stations. In contrast the head-waters with a tendency of a reverse pattern with higher oxygen and lower carbondioxide and alkalinity values helped in sustaining oligotrophic genera of the sub-families Orthocladiinae and Tanypodinae.

Such phenomena also exist in other parts of the world as reviewed by Hynes (1970) on the extensive literature which point out to one or more factors influencing the distribution of stream animals and the association of species. Further, as in the present investigation where the lotic environments with their individual stations can be classified into distinct biotopes and the quantified associations among the genera in such biotopes have been found in literature on systems of similar latitudes (Ulfstrand, 1967; March, 1976). It can, therefore, be said that within a section of stream bed, fauna vary continuously over several independent dimensions. Moreover, a typological view of the habitats studied may be useful in stratification of quantitative sampling for Chironomid larvae, as in the present investigation they seemed to recognise absolute boundaries. However, from the field data it is not possible to separate purely physical from biotic influences.

As for the lentic systems, the lotic systems were also analysed for the correlation coefficient analysis between the various physico-chemical factors analysed and the sub-families as present in the different stations. This analysis was, however, confined only to those stations of both the lotic systems where all the three sub-families occurred. At the Umkhrah stream, of the three sub-families Tanypodinae, Orthocladiinae and Chironominae, only Orthocladiinae and Chironominae showed relationships to some physico-chemical factors. Orthocladiinae was positively significant at 5% levels with air temperature, water temperature and pH and 1% levels with depth and width, while Chironominae revealed the same significant levels but negatively. This was also seen at station II of the same systems Umkhrah where Chironominae was negatively significant to the same factors except pH and Orhocladiinae for only water temperature, depth and width. Station III indicated a negative relationship but highly significant, for the width with the sub-family Tanypodinae, while depth showed a positive significance for Orthocladiinae. In this stream it was very obvious that stations I and II should reveal negative significance for Chironominae as these formed the headwaters of the stream which were clean and highly oxygenated, to be obviously suitable physical factors for the oligotrophic group Orthocladiinae (Table VI).

In contrast in the Umshirpi stream, the only significant levels noted for these three sub-families were at station I, where free carbondioxide was positively significant at 1% levels for Orthocladiinae but negatively significant for the same factor for Chironominae. This can also be attributed to the fact that the carbondioxide levels being not only low at the headwaters but also their range of fluctuation being very low would indicate a positive relationship for Orthocladiinae and negative for Chironominae. (Table VII).

This coefficient correlation at sub-family levels with various physico-chemical factors revealed the importance of abiotic factors but more the physical factors than the chemical, even at such higher levels of sub-families.

In addition to the general population dynamics at both generic and sub-family levels in the two lotic systems undertaken the genus *Chironomus* was analysed in detail. This genus as shown in the material and methods had been divided into four different length groups with the possible reflection of the different instars. There was a clear indication in the seasonality of these different instars, in that the fourth instar larvae was predominantly found in both the lotic systems in abundance, at the various stations during the months of winter, indicative of an overwintering population. The onset of summer indicating emergence, laying of eggs and hatching of the first instar larvae was again seen in the first and second instars and sometimes at the third to form peak values during the summer months. However, the occurrence of the third instars during this time reveals a pattern of overlapping of population with some generations being hatched just before the winter. As this phenomenon was seen only at the generic level, it may not also be due to overlapping generations of the same species, as

TABLE VI

Co-efficient correlation table, showing the relationship between different physico-chemical factors and the three sub-families Tanypodinae, Orthocladiinae and Chironominae in the stream Umkhrah

Stn.	S. – Family	A. Temp.	W. Temp.	Depth	Width	pH	Cont.	DO_2	FCO_2	T. Alk.
	Tanypodinae	0.192	0.271	0.296	0.517	0.385	(–) 0.183	(–) 0.46	0.226	(–) 0.134
I	Orthocladiinae	0.564*	0.543*	0.746**	0.667*	0.543*	0.135	(–) 0.501	(–) 0.374	0.037
	Chironominae	(–) 0.568*	(–) 0.561*	(–) 0.758**	(–) 0.717**	(–) 0.579*	(–) 0.101	0.485	0.323	(–) 0.015
	Tanypodinae	(–) 0.402	(–) 0.397	(–) 0.385	(–) 0.421	0.389	(–) 0.222	0.535*	(–) 0.446	(–) 0.274
II	Orthocladiinae	0.605	0.663**	0.803**	0.633*	(–) 0.441	0.114	(–) 0.477	0.058	0.046
	Chironominae	(–) 0.644*	(–) 0.632*	(–) 0.859**	(–) 0.591*	0.307	0.117	0.565*	(–) 0.066**	(–) 0.004
	Tanypodinae	0.215	0.124	(–) 0.102	(–) 0.794**	(–) 0.070	0.273	0.270	(–) 0.272	0.357
III	Orthocladiinae	0.110	0.229	0.563*	0.368	0.078	0.055	0.166	(–) 0.120	0.256
	Chironominae	(–) 0.251	(–) 0.214	(–) 0.140	0.060	0.034	(–) 0.283	(–) 0.328	0.310	(–) 0.447

* $P < 0.05$ ** $P < 0.01$

Stn. – Station
S. Family – Sub-family
A. Temp. – Air temperature
W. Temp. – Water temperature
Cond. – Conductivity
DO_2 – Dissolved oxygen
FCO_2 – Free carbondioxide
T. Alk. – Total alkalinity

TABLE VII

Co–efficient correlation table, showing the relationship between different physico-chemical factors and the three sub-families Tanypodinae, Orthocladiinae and Chironominae in the stream Umshirpi

Stn.	S. – Family	A. Temp.	W. Temp.	Depth	Width	pH	Cont.	DO_2	FCO_2	T. Alk.
I	Tanypodinae	(–) 0.423	(–) 0.372	(–) 0.036	(–) 0.428	0.241	(–) 0.120	0.039	0.018	(–) 0.190
	Ortholadiinae	0.187	0.294	0.329	0.237	(–) 0.132	0.090	(–) 0.312	0.678**	0.162
	Chironominae	0.142	0.025	(–) 0.229	0.107	(–) 0.060	0.012	0.214	(–) 0.534*	0.004
II	Tanypodinae	0.431	0.181	(–) 0.051	0.332	(–) 0.382	(–) 0.040	(–) 0.052	(–) 0.133	0.033
	Orthocladiinae	0.046	0.105	(–) 0.039	(–) 0.423	0.028	(–) 0.335	0.060	(–) 0.161	0.137
	Chironominae	(–) 0.433	(–) 0.266	0.085	0.117	0.316	0.366	(–) 0.012	0.277	(–) 0.165

* $P < 0.05$ ** $P < 0.01$

Stn. Station
S. Family Sub-family
A. Temp. Air temperature
W. Temp. Water temperature

Cond. Conductivity
DO_2 Dissolved oxygen
FCO_2 - Free carbondioxide
T. Alk. Total alkalinity

different species occupying different ecological niches and adaptable to environmental conditions which may be suitable for one and not for the other, could possibly have taken place.

In any case whatever the species may be, a clear emerging picture was seen in that, either autumn or winter is the turning point in the creation of new generation of populations. The lack of the non-occurrence of the first and second stages at some stations and especially in the lotic system Umshirpi, could possibly be due to the washing away of these instars which are primarily planktonic at this stage. This is further confirmed by the fact that very large densities occur at subsequent stations. Further, the months when they were supposed to occur maximum due to increased temperature would have possibly shortened the time between the first, second and the third stages.

In addition to such variations at instar level for the genus *Chironomus*, at station III of the lotic system Umshirpi was taken up for emergence studies, for a period of four months during the summer-rainy season. The emergence studies is an indicator of whether the larval populations are overwintering, and if so, whether increased temperature and humidity helps in completing the life cycle as revealed in emergence of adults. This aspect could not be done for the whole year for all stations, primarily because these studies were carried out from dusk to dawn and this station was the only one in the vicinity of the campus.

On an analysis of the emergence of adults, both male and female, peak values definitely occurred during two instances, one in the beginning of June and the other in the end of the same month. The largest peak for the females were confined to three times in June and July but only once during the third week of August. In contrast, the males emerged three times in June but only twice in July with the following months showing negligible magnitude. Since much of the emergence was confined to only four months it may be felt to be unreliable. There is some truth in this criticism, but emergence periods especially for this genus *Chironomus* have known to be only during these months, in lotic systems under similar latitudes (Hirvenoja, 1975). Moreover, emergence is a study by itself and depends on several factors, for instance, on voltinism of a species can only be determined by studies on several populations separately. As seen from the present investigation it is difficult to tell whether they are univoltine or bivoltine (Aagaard, 1978).

The male-female emerging of the adults does not also follow any trend in the seasonality nor abundances. This can again be attributed to the fact that different species in the same genera vary to a large extent in their mating behaviour and also the factors which influence this behaviour. Whatever the case may be, the phenomenon of swarming is a common attribute to the Chironomid family in general, though very little work exists on the male-female ratios in such swarms. In fact swarming was known and described by Linnaeus (1745) as quoted by Thienemann (1954) but the actual function of the swarm in relation to mating has been a matter of dispute. In recent years, however, considerable evidence has accumulated in support of the epigamic function of the swarming (Downes, 1958, 1959; Gibson, 1945; Syrjamaki, 1964; 1967), notwithstanding some reports to the contrary (Nielsen and Greve, 1950; Nielsen and Haeger, 1960).

In the lotic systems studied, the population dynamics of the Chironomid larvae, was confirmed by the age-group analysis and emergence studies, to be largely of an overwintering population in the genus *Chironomus*. Detailed aspects and longer duration studies on emergence at species level would help identify the different species colonizing such lotic systems.

GENERAL DISCUSSION

After understanding the population dynamics of Chironomid larvae in lentic and lotic systems from the hill regions of North Eastern India and in particular, Meghalaya, and their relationships with the environment it was felt necessary to identify the causative factors for their abundances in such inland waters. The role of benthic organisms in the economy of natural waters is of great significance as they play an important role in the trophic cycle of many fishes. However, the knowledge, on either the trophic dynamics or the seasonal fluctuation of benthic communities is extremely meagre compared to that of plankton.

Freshwaters, in these regions, tend to be acidic, and harbour not only a poor diversity of benthic organisms, in particular Chironomidae, but also their abundances of such poor representatives are low. These regions are known to be geologically young, and therefore, in such new environments the variety of species (in the present investigation genera), could possibly be in the process of increase, revealing the low diversity, where adaptations or immigrations of new species take a long time to colonize in ecosystems under severe abiotic conditions. Such generalizations, however, must be made cautiously particularly in habitats like that studied here where considerable seasonal inter and intra-habitat differences occur (Danks, 1971), and the results may reflect characteristics of the habitat as much as those of Chironomid biology. Moreover, in view of the tolerance of the Chironomid larvae to a wide range of conditions, considerable plasticity in the life cycle would be expected, as reflected for example in the annual overwintering instars of the present investigation. Inspite of the known diversified composition of Chironomid larvae, only one or two genera show mass occurrences in some localities, and even those which occur along with them are characterized seasonally. In fact, in the present investigation, some genera represent only accessory species in some localities, but in others, they not only make an important part of the total larval population but are also leading species seasonally. Though it is common knowledge that aquatic insects do spread from one habitat to another, the triggering factors which initiate such movements need detailed study, as population dynamics operate at two levels, one as a defence against predators and the other for their own population stability.

From the present investigation it was observed, that, though individual genera of midges could be regarded as useful index organisms by virtue of their conspicuous presence or absence, it was the assemblages of taxa which were of greater value. Surprisingly, as in the present investigation tolerance and sensitivity of taxa was often possible to predict not only at generic levels but even at supergeneric levels. Sub-families Tanypodinae and Orthocladiinae for example, represent comparable portions of the population at the cleanest sites, indicative of higher oxygen values and lower carbondioxide and alkalinity and these animals disappeared when conditions became reversed. On the other hand there were wide divergences of tolerances among single genera of sub-family Chironominae, and in particular and genus *Chironomus* most conspicuous in their wider tolerances levels.

The physical and chemical characteristics of waters also show variations due to rapid turnover of allochthonous materials. As many aquatic organisms have life cycles which extend longer in time than the physico-chemical changes in water receiving artificial effluence, these organisms must be able to cope with these changes and especially in the most detrimental conditions, in order to survive. Therefore, it is the general adaptability and hardiness, rather than specialization which permits Chironomid representation even in the most extreme type of habitats (Brundin, 1966).

The effect of a organically loaded effluent on the benthic community, will vary in the relation to the quality of the effluent, the dilution ratio of effluent to water flow, the flow regime and bed topography of the receiving stream. However, Hynes (1960) points out that organic inflows containing a load of high suspended solids, tend to favour the formation of stereotyped communities as they exert similar effects on both eroding and depositing water reaches, by blanketing out the bed and in filling spaces between large substrate elements. The assemblage of Chironomid species favoured by the imposition of such conditions may be considered to form a tolerant pollutional community. This is very obvious in the present investigation where such areas were dominated or composed of individuals within the genus *Chironomus*.

The analysis of occurrence and abundance data indicates that virtually the same environmental factors which affect one genera also affect the other, thereby emphasizing their potential importance as agents of natural selection. However, while each of these environmental factors may be of potential importance to the genera, not all of them are equally important at all localities where larvae occur. This is true both in lotic and lentic systems of the present investigation where pH, chemical composition and solute concentrations appear to be more important in restricting larvae in certain places; mud substratum in restricting other larvae to certain localities, and oxygen and depth playing a major role in restricting the genus *Chironomus*. In addition, temperature may be important in restricting the downward distribution of the genera in the lotic systems even though it does not appear to be significant. Therefore, one must be certain that larval populations of the family Chironomidae are subjected to selection by the same environmental factors before the evolutionary significance of those environmental factors can be considered. It may, therefore, suffice to state that ecological radiation is naturally possible without any major structural rearrangements. This is particularly true of the family Chironomidae, where the vast majority of its individuals are very conservative.

However, interactions are important. They open doors to the future. We underestimate their significance because, being personal, they are unknown in the aggregate; being unseen, they appear unreal; and, being remote, they tend to be forgotten. Nevertheless, they are there and influential. Moreover, the territories they occupy are of the conceptional nature, hence they can be shared as overlapping networks, strengthening each other through interactions. If these conjectures are correct, the sudden perception of an internal threat to our Biosphere with realization of our dependence on it will strengthen those bonds in the interests of humanity more than a Martian invasion as "no ecosystem is an island"

REFERENCES

Aagaard, K. 1978. The Chironomids of lake Malsjoen. A phenological, diversity and production study. *Norw. J. Ent.* **25** : 21-37.

Aggus, L. R. 1971. Summer benthos in newly flooded areas of Beaver Reservoir during the second and third years of filling 1965-1966. *Spec. Publs. Am. Fish. Soc.* No. **8** : 139-152.

Aldoori, T. Y 1972. The ecology of the Roach (*Rutilus rutilus* L.) in Humbic reservoir. Unpubl. Ph.D. thesis, Univ. Edinb.

Alfred, J. R. B. 1973a. Studies on the biology and ecology of the family Chironomidae from South India. Ph.D. thesis. Madurai Univ. 144 pp.

Alfred, J. R. B. 1973b. Diptera : Tendipedidae (Chironomidae) A guide to the study of freshwater organisms. *J. Mad. Univ.* **1** : 163-185.

Alfred, J. R. B. 1974. On the food of *Chironomus costatus* (Chironomidae : Diptera) from a shallow freshwater pond in South India. *FreshWat. Biol.* **4** : 337-342.

Alfred, J. R. B. & R. G. Michael. 1979. Biosystematics and Ecology of five species of Indian Chironomidae. *Bull. Meghalaya Sci. Soc.* **3** : 5-12.

Ali, S. R. 1968a. Bottom fauna of the streams and rivers of Hazara district after summer rains. *Pak. J. Sci. Ind. Res.* **11** : 208-211.

Ali, S. R. 1968b. Bottom fauna of the streams of Kohat district and Kurram agency after winter rains. *Pak. J. Sci. Ind. Res.* **11** : 449-454.

Ali, S. R. 1969. Effects of rains on the bottom fauna of the streams of Rawalpindi and Wah. *Pak. J. Forest.* **19** : 227-234.

Ali, A. & M. S. Mulla 1979. Diel periodicity of Chironomid larvae and pupal drift in an urban flood control channel system. *Environ. Entomol.* **8**(5) : 902-907.

Anderson, F. S. 1946. East Greenland lakes as habitats for Chironomid larvae : Studies on the systematics and limnology of Chironomidae II. *Medd. Gronland.* **100** : 1-65.

Anderson, L. D., E. C. Bay & A. A. Ingram. 1964. Studies of the Chironomid midge control in water spreading basins near Montebello, *California. California Vector.* Views. **11** : 13-20.

A. P. H. A. 1966. *Standard methods for the examination of water, sewage and industrial wastes.* 10th Edn. New York.

Armitage, P. D. 1969. The ecology of the Chironomid larvae of a shallow woodland lake in South Finland, with some notes on other members of the benthic community. Unpubl. Ph.D. thesis. Univ. of London 132 pp.

Armitage, P. D. 1971. Some aspects of the ecology of *Pagastiella orophila* in the lake Kuusifarvis in the South of Finland. *Can. Entomol.* **103** : 306-310.

Asahina, E. 1942. Bottom fauna of the Lake Beppi of Shumushi island, the Kurites. *Zoo. Meg.* (Tokyo). **54** : 371-372.

Atkins, W. R. G. & G. T. Harris. 1924. Seasonal changes in the water and Heleoplankton of freshwater ponds. *Sc. Proc. Roy. Dub. Soc.* **18** : (1) 1-21.

Bamforth, S. S. 1958. Ecological studies on the planktonic protozoa of a small artificial pond. *Limnol. Oceanogr.* **3** : 398-412.

Bardach, J. E. 1955. Certain biological effects of thermocline shifts. *Hydrobiol.* **7** : 309-324.

Barthelmes, D. 1962a. Uber die horizontale Wanterung der Teichbodenfauna. *Z. Fisch.* **11** : 183-187.

Beck, G. H. 1965. The stream of Florida. *Bull. Fla. State Mus.* **10** : 91-126.

Beck, W. M. Jr. 1976. Biology of larval Chironomids. State of Florida. *Deptt. of Environ. Regulation. Technical Series.* Vol. 2 No. 1. 57 pp.

Beck, E. C. & W. M. Beck, Jr. 1959. A checklist of the Chironomidae (Insecta) of Florida (Diptera : Chironomidae). *Bull. Fla. St. Mus. Biol. Sci.* **4** : 85-96.

Beck, E. C. & W. M. Beck, Jr. 1969. The Chironomidae of Florida. II. The nuisance species. *Fla. Ent.* **52**(1) : 1-11.

Beck, W. M. Jr. & E. C. Beck. 1966. Chironomidae (Diptera) of Florida. 1. Pentaneurini (Tanypodinae). *Bull. Fla. State Mus.* **10**(8) : 305-379.

Beck, W. M. Jr. & E. C. Beck. 1968. The concept of genus in the family Chironomidae. *Ann. Zool. Fenn.* **5** : 14-16.

Berner, L. 1950. The mayflies of Florida. *Univ. Fla. Studies. Biol. Sci. Ser.*, 4(4) : 1-267.

Bernice, S. R. J. 1970. Biology of Anostraca. *Streptocephalus* and *Brachinella*. Ph.D. thesis. Univ. of Madurai.

Bishop, J. E. 1973. *Limnology of a small Malayan river Sungai Gombak.* Dr. W. Junk B. V., Publishers, The Hague, 485 pp.

Boesel, M. W. 1974. Observations on the Coelotanypodinae of the Northern States (USA) with keys to the known stages (Diptera : Chironomidae : Tanypodinae). *J. Kan. Entomol. Soc.* **47**(4) : 417-432.

Boltt, R. E. 1975. The benthos of some southern African lakes. Part V. The recovery of benthic fauna of St. Lucia Lake following a period of excessively high salinity. *Trans. R. Soc. S. Afr.* **41** : 295-323.

Boltt, R. E. & B. R. Allanson 1975. The benthos of some South African Lakes. Part III. The benthic fauna of Lake Nhlange, Kwazulu, South Africa. *Trans. R. Soc. S. Afr.* **41** : 241-262.

Borutsky, E. V. 1939. Dynamics of the total benthic fauna in the profoundal of lake Beloie. *Trudy limnol. Sta. Kossino.* **22** : 196-218.

Botnariuc, N. & P. Albu. 1968. Certain problems concernat l'Etude des populations, Chez les Chironomides. *Ann. Zool. Fenn.* **5** : 22-26.

Botnariuc, N. & P. Albu. & Gh. Ignat. 1969. The variability of a population of *Cricotopus silvestris* F. in the Danube flood plain. *Rev. Roum. Biol. Zool.* **14** : 363-374.

Brinkhurst, R. O. 1974. *The benthos of lakes.* Macmillan Press, London. 190 pp.

Brundin, L. 1949. Chironomiden und andere Bodentiere der sudschewedischen urgebirgssen. *Inst. Freshwater Res. Drottnigholm.* Rep. **30** : 1-914.

Brundin, L. 1956. Zur systematic der Orthocladiinae (Dipt. Chironomidae). *Inst. Freshwater Drottningholm.* Rep. **37** : 5-185.

Brundin, L. 1966. Transarctic relationships and their significance as evidenced by Chironomid midges with a monograph of the sub-families Podonominae and Aphroteniinae and the Austral Heptagyiae. *K. svensk. Vetensk - akad. Handl.* **11** : 7-472.

Brunetti, E. 1910. Review of our knowledge of the oriental Diptera. *Jour. Proc. Asia tec. Soc. Ben.*, **VI**, (3) : 135-140.

Brunetti, E. 1920. Catalogue of Oriental and South Asiatic Nemaecra. *Rec. Ind. Mus.* **XVIII** : 59-79.

Brusven, M. A. & K. V Prather 1974. Influence of stream sediments on distribution of macrobenthos. *J. Entomol. Soc. B. C.* **71** : 25-32.

Buckland, P. J. 1974. A study of the Chironomidae (Diptera) in a stream receiving sewage effluent. Unpubl. M. Phil. Thesis, Wolverhampton Polytechnic.

Carr, A. F. 1940. A contribution to the herpetology of Florida. *Univ. Florida Publ., Biol., Sciesv.* 3(1) : 1-118.

Carr, J. F. & J. K. Hiltunen. 1965. Changes in the bottom fauna of western Lake Erie from 1930 to 1961. *Limnol. Oceanogr.* **10**(4) : 551-569.

Charles, W. N. K. East, D. Brown, M. C. Gray & T. D. Murray. 1974. The production of larval Chironomidae in the mud of Loch Leven, Kinross. *Proc. R. Soc. Edinb.*, **B74** : 241-258.

Choudhury, P. K. & S. K. Nandi. On a new species of genus *Allotrissocladius* Freeman (Diptera, Chironomidae) from India. *J. Bombay Nat. Hist. Soc.* **77** : 292-294.

Choudhury, P. K. & Ghosh M. 1980. The Orthocladiinae (Diptera : Chironomidae) of India. Genus *Cricotopus* van der Wulp. *Aquatic Insects.* **2**(3) : 147-152.

Choudhury, P. K. & Ghosh M. 1981. On the species of *Diamesa* Waltl from India (Diptera, Chironomidae). *Entomologische Berichteu, Deel* **41**, 1. IV 92-94.

Choudhury, P. K. & Guha D. K. & Dasgupta S. K. 1981. Taxonomic studies of Chironomidae (Diptera, Chironomidae) from India. The genus *polypedilum* Kieffer *Tijdschrift voor Entomologie. Deel.* **124**. alf. 4. 11-147.

Chutter, F. M. 1969. The effects of silt and sand on the invertebrate fauna of streams and rivers. *Hydrobiol.* **34** : 57-76.

Cooke, C. W. 1939. Scenery of Florida, interpreted by a geologist. *Fla Geol. Surv. Bull.* **17** : 1-118.

Coquillet, D. W. 1900. Report on a collection of dipterous insects from Puerto Rico. *Proc. U.S. natn. Mus.* **22** : 249-270.

Corbet, P. S. 1965. An insect emergence trap for quantitative studies in shallow ponds. *Can. Ent.* **97** : 845-848.

Cowell, B. C. & W. C. Carrew. 1977. Seasonal and diel periodicity in the drift of aquatic insects in a subtropical Florida stream. *Freshwat. Biol.* 6(6) : 587-594.

Cranston, P. S. 1974. Corrections and additions to the list of British Chironomidae (Diptera). *Entomol. Mon. Mag.* **110** (1319-1321) : 87-95.

Crisp, D. T. & T. Gledhill. 1970. A quantitative description of the recovery of the bottom fauna in a muddy reach of a hill stream in Southern England after draining and dredging. *Arch. Hydrobiol.* **67** : 502-541.

Curry, L. L. 1952. An ecological study of the family Tendipedidae of two freshwater lakes in Isabella country Michigan. Unpubl. Ph.D. thesis. Michigan State College.

Curry, L. L. 1956. Notes on the ecology and taxonomy of the midge *Tendipes (Tendipes) staegeri* (Lundbeck) - *Chironomus staegeri* Lundbeck (Diptera). *Ent. News.* **67a** : 225-236.

Curry, L. L. 1965. A survey of environmental requirements for the midges (Diptera : Tendipedidae). In Biological Problems in Water Pollution, 3rd Seminar, 1962. *U.S. Public Health Service Publication* No. **99-WP-25** : 127-144.

Curry, L. L. & Curry M. C. 1971. The Chironomidae (Diptera) found in the U.S. virgin islands and Anegada, British Virgin Island. *Can. Ent.* **103** : 310-314.

Danks, H. V 1971. Overwintering of some north temperate and arctic Chironomidae. 1. The winter environment. *Can. Ent.* **103** : 589-604.

Danks, H. V. & Oliver D. R. 1972. Seasonal emergence of some high arctic Chironomidae (Diptera). *Can. Ent.* **104**(5) : 661-685.

Davies, C. W. 1962. *Ion Association*. Butterworth and Co., Washington, 190 pp.

Davies, L. J. 1971. Some factors influencing the distribution of macro-invertebrates in the riffles of organically polluted streams. Unpubl. Ph.D. thesis, Univ. of Aston in Birmingham.

Davies, B. R. & T Davies 1978. A bibliography of the Chironomidae (Diptera) of African and adjacent islands - Part **4** : *Institute for Freshwater Studies Publication, Rhodes Univ.* 6 pp.

Davies, T & B. R. Davies. 1976. A bibliography of the Chironomidae (Diptera) of African and adjacent islands : Part **I** : *Institute for Freshwater Studies Publication, Rhodes Univ.* Cyclostyled. 16 pp.

Dejoux, C. 1976. New faunal data on the Chironomids. (Diptera, Nematocera) of the Ethiopian region (Second communication). *Can. Orstom ser hydrobiol.* **10**(**1**) : 19-32.

Dendy, J. S. & J. E. Sublette. 1959. The Chironomidae (Tendipedidae, Diptera) of Alabama with description of six new species. *Ann. Entomol. Soc. Amer.* **52** : 506-519.

Dillon, P. J., D. S. Joffries, W. Synder, R. Reid, N. D. Yaw, D. Evans, J. Moss and W. A. Scheider. 1978. Acidic precipitation in South Central Ontario : recent observations. *J. Fish. Res. Bd. Can.* **35** : 809-815.

Downes, J. A. 1959. Assembly and mating in the biting Nematocera. *Proc. 10th int. Congr. Ent.* vol. **2** : 425-434.

Downes, J. A. 1959. The swarming and mating flight of Diptera. *Ann. Rev. Ent.* **14** : 271-298.

Dugdale, R. C. 1955. Studies on the ecology of benthic Diptera of lake Mendota. Unpubl. Ph.D. thesis, Univ. Wisconsin.

Edwards, F. W. 1929. British non-biting midges. *Trans. entomol. Soc. London.* **77** : 279-430.

Englemann, W. & D. G. Shappirio. 1965. Photoperiodic control of maintenance and termination of larval diapause in *Chironomus tentans. Nature.* **207** (4996) : 548-549.

Fittkau, E. J. 1962. Die Tanypodinae (Diptera, Chironomidae). Die Tribus Anatopynüni Macropelopüni und Pentaneurini. *Abh. Larvalsyst. Insekten.* **6** : 1-453. Akademie - Verlag, Berlin.

Fittkau, E. J. 1968. Die Abgrenzung der Gattung bei Chironomiden. *Ann. Zool. Fenn.* **5** : 33-36.

Fittkau, E. J. 1971. Distribution and ecology of Amazonian Chironomidae (Diptera). *Can. Ent.* **103** : 407-413.

Fittkau, E. J. & F. Reiss. 1973. Amazonian Tanytarsini (Chironomidae, Diptera) : 1. The riopreto group of the genus *Tanytarsus. Stud. Neotrop. Fauna.* **8**(1) 1-16.

Flint, R. W. 1979. Responses of freshwater benthos to open lakes dredged spoils disposal in lake Erie, U.S.A. *J. Great Lakes Res.* **5**(3-4) : 264-275.

Freeman, P. 1955. A study of African Chironomidae. I. *Bull. Br. Mus. nat. Hist.* (*Ent*). **4**(1) : 1-67.

Freeman, P. 1956. A study of African Chironomidae. II. *Bull. Br. Mus. nat. Hist.* (*Ent*). **4**(7) : 285-366.

Freeman, P. 1957. A study of the Chironomidae of Africa South of Sahara. III. *Bull. Br. Mus. nat. Hist.* (*Ent*). **5**(a): 321-426.

Freeman, P. 1958. A study of the Chironomidae of Africa South of Sahara. IV *Bull. Br. Mus. nat. Hist.* (*Ent*). **6**(2) : 161-363.

Freeman, P. 1961. The Chironomidae (Diptera) of Australia. *Aust. J. Zool.* **9** : 611-737.

Ganapati, S. V 1940. The ecology of temple tanks containing a permanent bloom of *Microcystis aeruginosus* (Kutz). Henfr. *J. Bombay Nat. Hist. Soc.* **42** : 65-77.

Ganapati, S. V. 1941. Seasonal changes in the physical and chemical conditions of a garden pond containing abundant aquatic vegetation. *J. Mad. Univ.* **13** : 55-69.

Ganapati, S. V 1960. Ecology of tropical waters. *Proc. Symp. on Algology.* **ICAR** : 204-218.

Ganapati, S. V 1962. "Studies on the sources of the Madras City water supply and on other waters of the Madras State" Thesis approved for the Degree of Doctor of Science of the University of Madras (1956) : 163 pp.

Gaufin, A. R. 1958. The effects of pollution of a midwestern stream. *Ohio j. Sci.* **58** : 197-208.

Gaufin, R. F. & A. R. Gaufin. 1966. Ecological aspects of organic pollution in streams. *Who/Ebl/*66-54.

Gauffin, A. R. & C. M. Tarzwell. 1952. Aquatic invertebrates as indicators of stream pollution. *Public Health Rep., Wash.* **67** : 57-64.

Gauffin, A. R. & C. M. Tarzwell. 1956. Aquatic macroinvertebrates communities as indicators of organic pollution in Lytle Creek. *Sewage Ind. Wastes.* **28** : 906-24.

George, M. C. 1961. Observations on the rotifers from Shallow ponds in Delhi. *Curr. Sci.* **30** : 268-269.

George, M. C. 1966. Comparative plankton ecology of five fish tanks in Delhi, India. *Hydrobiol.* **27** : 81-108.

Gerry, B. I. 1932. A new species of *Chironomus* from Jamaica (Chironomidae). *Psyche. Camb.* **39** : 69-71.

Gerry, B. I. 1933. Four new species of chironomidae from the Grater Antilles. *Psyche. Camb.* **40** : 94-97.

Gibson, N. H. E. 1945. On the mating season of certain Chironomidae (Diptera). *Trans. R. ent. Soc. Lond.* **95** : 263-294.

Goetghebuer, M. 1937. Tendipedidae (Chironomidae); b) Sub-families : Tendipedinae (Chironominae). A die imagines. *In : Iinder, Die Fliegen der palarkischen Region. Bes. S.P.* 1-128.

Goltermann, H. L. R. S. Clyno & M. A. M. Ohustad. 1978. *Methods for physical and chemical analysis of Freshwaters.* IBP Handbook No. 8., Blackwell Scientific Publications, 213 pp.

Gower, A. M. & P. J. Buckland. 1978. Water quality and the occurrence of *Chironomus riparius* Meigen (Diptera : Chironomidae) in a stream receiving sewage effluent. *Freshwat. Biol.* **8** : 153-164.

Guha, D. K. & Choudhury, P. K. 1979. A new species of genus *Cryptochironomus* Kieffer (Chironomidae, Diptera) from West Bengal. *Bull. Zool. Surv. Ind.* **2**(1) : 95-98.

Guha, D. K. & Choudhury, P. K. 1981a. Record of three genera of Chironominae (Chironomidae : Diptera) from India. *Bull. Zool. Surv. India.* 3(3) : 159-165.

Guha, D. K. & Choudhury, P. K. 1981b. *Microchironomus clarilatus* sp. Nov. (Diptera : Chironomidae) from West Bengal, India. *Bull. Zool. Surv. India.* 4(2) : 143-145.

Hamilton, A. L. 1965. An analysis of a freshwater benthic community with special reference to the Chironomidae. Unpubl. Ph.D. thesis. Univ. of British Columbia. 1-93. 1-216 pp.

Harker, J. E. 1953. An investigation of the distribution of the mayfly fauna of a Lancashire stream. *J. Anim. Ecol.* **22** : 1-13.

Harnisch, O. 1923. Metamorphose und system der Gattung *Cryptochironomus* K. K. S. I. Ein.Beitrag zum problem der Differenzierung des Entwicklungs strande der Chironomiden. *Zool. Jb. abt. f. syst.* **47** : 271-308.

Harrison, A. D. 1966a. Recolonization of a Rhodesian stream after drought. *Arch. Hydrobiol.* **62** : 405-421.

Harrison, A. D. 1966b. The effects of Bayluscid on Gastropod snails and other aquatic fauna in Rhodesia. *Hydrobiol.* **28** : 371-384.

Harrison, A. D. & J. J. Rankin. 1975. Forest litter and stream fauna on a tropical island, St. Vincent, West Indies. *Verh. Internat. Verein. Limnol.* **19** : 1736-1745.

Harrison, A. D. & 1976b. Hydrobiological studies of Eastern lesser Antillean islands. II. St. Vincent : Freshwater fauna - its distribution, tropical river zonation and biogeography. *Arch. Hydrobiol. Suppl.* **50** : 275-311.

Hart, D. S. & M. A. Brusven. 1976. Comparison of benthic insect communities in six small Idaho Batholith streams. *Melanderia.* **23** : 1-18.

Hawkes, H. A. 1962. *Biological aspects of river pollution.* I : *River pollution,* 2. *Causes and effects,* 311-432 (L. Klein, Ed.), Butterworths, London.

Hawkes, H. A. 1963. Effects of domestic and industrial discharges on the ecology of riffles in Midland streams. *Int. J. Air. Wat. Poll.* **7** : 565-86.

Hawkes, H. A. & L. J. Davies. 1971. Some effects of organic enrichment on benthic invertebrate communities in stream riffles, 271-293. *In : The scientific management of animal and plant communities for conservation* (E. Duffley and A. S. Watt, Eds.) Symposium of the British ecological society. 11th, Oxford, Blackwell Scientific Publication.

Hensen, D. C. & E. F. Cooke. 1976. The systematics and morphology of the Nearctic species of *Diamesa* Meigen 1835 (Diptera : Chironomidae) *Mem. Am. Entomol. Soc.* **30** : 1-203.

Henson, E. B., A. S. Bradshaw & D. C. Chandler. 1961. The physical limnology of Cayuga lake, New York. *Cornell Univ. Agri. Exp. St. Memoir.* **378** : 3-63.

Hilburn, L. R. 1980. Population genetics of *Chironomus stigmaterus* (Diptera : Chironomidae). Protein variability in population of South Western USA. *Evolution* 34(4) : 696-704.

Hilsenhoff, W. L. 1967. Ecology and population dynamics of *Chironomus plumosus* (Diptera : Chironomidae) in Lake Winnebago, Wisconsin. *Ann. ent. Soc. Am.* **60**(6) : 1183-1194.

Hirvenoja, M. 1960. Massenauuftreten von *Corynocera ambigua* Zett., (Diptera). In See Sompiojarvi, Finnisch-Lappland. *Ann. Ent. Fenn.* **26** : 157-163.

Hirvenoja, M. 1962a. Zur Kenntnis der gattung *Chironomus* (Dipt : Chironomidae). *Ann. Ent. Fenn.* **28** : 85-88.

Hirvenoja, M. 1962b. Zur Kenntnis der Gattung *Polypedilum* Kieff. (Dipt : Chironomidae). *Ann. Ent. Fenn.* **28** : 127-136.

Hirvenoja, M. 1962c. *Cladotanytarsus*-Arten (Dipt., Chironomidae) aus Finnisch Lappland. *Ann. Ent. Fenn.* **28** : 173-181.

Hirvenoja, M. 1963. *Microtendipes nigeilus* n. sp. (Chironomidae). *Ann. Ent. Fenn.* **29** : 247-249.

Hirvenoja, M. 1973. Revision der guttung *Cricotopus* van der Wulp und ihrer Verwandten (Diptera : Chironomidae). *Ann. Zool Fenn.* **10** : 1-363.

Hirvenoja, M. 1975. Species of the genus *Cricotopus* van der Wulp (Dipt, Chironomidae) and its closest relatives in Eastern Fennoscandia, especially in Finland. *Ann. Ent. Fenn.* **41** : 19-37.

Hobbs, H. H. Jr. 1942. The cray fishes of Florida Univ. *Fla. Publ., Biol. Sci. Ser.* 3(2) : 1-179.

Hruska, V. 1961. An attempt at a direct investigation of the influence of the carp stock on the bottom fauna of two ponds. *Verh. Internat. Verein. theor. angew. Limnol.* **14** : 732-736.

Hunt, P. C. & J. W. Jones. 1972. The profoundal fauna of Llyn Tegid, North Wales. *J. Zool. Lond.* **168** : 9-49.

Hutchinson, G. E. 1975a. *A treatise on Limnology, Geography, Physics and Chemistry.* 2nd Edn. John Wiley and sons. Vol. I. 1015 pp.

Hynes, H. B. N. 1960. *The biology of polluted waters.* Liverpool Univ. Press, Liverpool, 202 pp.

Hynes, H. B. N. 1961. The effect of water level fluctuation on littoral fauna. *Verh. Internat. Verein. theor. angew. Limnol.* **14** : 652-656.

Hynes, H. B. N. 1970. *The ecology of running waters.* Liverpool Univ. Press, 655 pp.

Hynes, J. D. 1975. Annual cycles of macroinvertebrates of a river in Southern Ghana. *Freshwat. Biol.* **5** : 71-83.

Iovino, A. J. & F. D. Miner. 1970. Seasonal abundance and emergence of Chironomidae of Beaver Reservoir. Arkansads (Insects : Diptera). *J. Kansas ent. soc.* **43** : 187-216.

Jenkins, P. M. 1932. Reports on the Percy Sladen expedition to some Rift Valley Lakes in Kenya in 1919. I. Introductory account of the biological survey of the five freshwater and alkaline lakes. *Am. Nat. Hist.* **2** : (10), 535-552.

Johannsen, O. A. 1905. Mayflies and midges of New York. II. Aquatic nematocerous Diptera. *New York State Mus. Bull.* **86** : 76-331.

Johannsen, O. A. 1931. Tanypodinae from the Malayan Subregion of the Dutch East Indes. *Arch. Hydrobiol.* **9** : 493-504.

Johannsen, O. A. 1932. Orthocladiinae from the Malayan subregion of the Dutch East Indes. *Arch. Hydrobiol.* **9** : 715-732.

Johannsen, O. A. 1932a. Chironominae of the Malayan subregion of the Dutch East Indes. *Arch. Hydrobiol.* **11** : 503-553.

Johannsen, O. A. 1937. Aquatic Diptera III and IV *Cornell Univ. agric. Exp. stu.* **205** : 3-84, **210** : 1-52.

Johannsen, O. A. 1938. New species of Nemocera from Puerrto Rico. *J. Agric. Univ. P. Rico.* **22**(2) : 219-226.

Johannsen, O. A. & H. K. Townes. 1952. Tendipedidae (Chironomidae), 3-103. *In : The guide to the insects of Connecticut,* Part 6, Fasc 5; *Conn. State. Geol. Nat. Hist Surv. Bull.* **80**.

Johannsen, O. E. 1980. Energy dynamics of the eutrophic chironomid *Chironomus plumosus* and *C. semireductus,* from the Bay of Quinte, Lake Ontario, Canada. *Can. J. Fish. Aquat. Sci.* **37**(8) : 1254-1265.

Johanson, P. M. 1965. Factors determining population size of *Chironomus anthracinus* Zelt. in lake Esrom. *Mitt. internat. Ver. Limnol.* **13** : 139-162.

Johanson, P. M. 1971. Population studies on *Chironomus anthracinus* 220-232 - *In : Dynamics of populations*, (P. J. den Boer and G. R. Gradwell Eds.), Proc. Adv. Study, Inst. (Oosterbeck, 1970).

Johanson, P. M. 1972. Ecology and production of the profoundal benthos inrelation to phytoplankton in lake Esrom. *Oikos Supplementum.* **14** : 1-148.

Kato, G. 1941. Studies on the freshwater regions in the compound of the palan Tropical Biological station (2) Temperature, O2 - content and pH of the water, Kagaku Nanyo. Sci. of the South Sea. **3** : 29-36.

Kajak, Z. 1958. Character of the numerical dynamics of benthic Tendpedidae in shallow parts of an old branch cut off from the river Vistura. *Bull. Acad. Polanaise Sci. Ser. Sci. Biol.* **6** : 489-493.

Kajak, Z. 1958a. An attempt at interpreting the quantitative dynamics of benthic fauna in a chosen environment in the "Konfederatha" pool (Old river Bed) adjoining Vistula. *Ekol. Pol. A.* **6**(7) : 205-291.

Kajak, Z. 1964. Remarks on conditions influencing the appearance of new generations of Tendipedidae larvae. *Ekol. Pol. A.* **7**(12) : 173-183.

Kajak, Z. & K. Dusoge. 1967. Influence of artificially increased abundance of *Chironomus plumosus* on the benthos. *Bull. Acad. Pol. des. Sci. Ser. biol. Cl. II.* **15**(1) : 27-33.

Karunakaran, C. 1974. Geology and mineral resources of the states of India. part IV. Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. *Geo. Surv. India. Misc. Publ.* No. **30** : 78-79.

Kaul, B. K. 1970. Torrenticole insects of the Himayala. II. Two new Diamesini. (Dipt. Chironomidae) from North-West Himalaya (India). *Orient. Insects.* **4** : 293-297.

Kieffer, J. J. 1908. Description de deux nouveaux Chironomides. *Bull. Acad. Roy. Belg., Cl. Sci.* : 705-707.

Kieffer, J. J. 1909. Diagnoses de nouveaux Chironomides d'Allemagne. *Bull. Sco. Hist. nat. Metz.* **26** : 37-56.

Kieffer, J. J. 1910. Etude sur les chironomides des Indes Orientales aves description de quelques nouvelles especs d'Egypt. *Mem. Ind. Mus.* **2** : 181-242.

Kieffer, J. J. 1911. Description de nouveaux Chironomides de l'Indian Museum de Calcutta. *Rec. Ind. Mus.* **6**(3) 113-117.

Kieffer, J. J. 1911a. Les Chironomides (Tendipedidae) DE" l Himalaya Et D" Assam. *Rec. Mus.* **XX** : 319-352.

Kieffer, J. J. 1912. Nouveaux Chironomides (Tendipedidae) De Ceylon. *Spolia Ceylanica.* **8** : 1-8.

Kieffer, J. J. 1912a. Beschreibung einer neuen bothyphilen Tendipedide des Luganer Sees. *Z. Wiss Insekt. Biol.* **8** : 153-156.

Kieffer, J. J. 1913. Nouvelle Etude sur les Chironomides de l' Indian Museum de Calcutta. *Rec. Ind. Mus.* **9** : 119-197.

Kieffer, J. J. 1913a. Nouveaux Chironomides d' Allemagne. *Bull. Soc. Hist. nat. Metz.* **28** : 7-35.

Kieffer, J. J. 1913b. Nouvelle contribution a la connaissance des Tendipedides d' Allemagne. *Bull. Soc. Hist. nat. Metz.* **28** : 37-44.

Kieffer, J. J. 1913c. *Chironomidae et Cecidomyidae.* Voyage de Ch. Alluaud et R. Jeanneal an Afrique Orientale - 1911-12, Resultats Scientifiques, Diptera. 1 : 1-143. A. Schutz, Paris.

Kieffer, J. J. 1914. Quelques nouveaux Chironomides des Indes. *Rec. Ind. Mus.* **10** : 313-315.

Kieffer, J. J. 1914a. South African Chironomidae. *Ann. S. Afr. Mus.* **10** : 259-270.

Kieffer, J. J. 1914b. A new genus of Chironomid from the Cape. *Ann. Mus.* **1914** : 523-525.

Kieffer, J. J. 1915. Chironomides du lac de Tiberiacdae. *J. As. Soc. Bengal.* **10** : 359-372.

Kieffer, J. J. 1915a. Fauna Faeroensis ... Chironomidae. *Zool. Jb. Abt. f. Syst.* **39** : 103-120.

Kieffer, J. J. 1918. Chironomides d' Afrique et d' Asie conserves au Museum National de Budapest. *Annls hist. - nat. Mus. natn. hung.* **16** : 31-139.

Kieffer, J. J. 1921. Chironomides de l' Afrique Equatoriale. I. *Annls. Soc. ent. Fr.* **90** : 1-56.

Kieffer, J. J. 1921a. Chironomides de Courlande. *Annls. Soc. scient. Brux.* **40** : 275-298.

Kieffer, J. J. 1921b. Chironomides neuveaux on peu Connus la region palearctique. *Bull. Soc. Hist. Nat. Mosselle* - **27**, S. 51-109.

Kieffer, J. J. 1922. Chironomides de la Nouvelle-Zemble. *Rep. scient. Results Norw. Exped. Novav. Zemlya.* **1**(2) : 1-24.

Kieffer, J. J. 1922a. Chironomides de l' Afrique Equatoriale. II. *Annls. Soc. ent. Fr.* **91** : 1-72.

Kieffer, J. J. 1923. Chironomides de l' Afrique Equatoriale. III. *Annls. Soc. ent. Fr.* **92** : 149-203.

Kieffer, J. J. 1923a. Chironomidae de l' Afrique du Sud. *Annls. Soc. scient. Brux.* **42** : 382-388.

Kieffer, J. J. 1924. Si nouveaux Chironomides d' Afrique. *Annls. Soc. scient. Brux.* **43** : 255-261.

Konstantinov, V. K. 1971. Review of the Soviet literature on Chironomids. *Limnologica.* **8**(1) : 225-236.

Koshkinen, R. 1968. Seasonal and diel emergence of *Chironomus salinarius* Kieff (Dipt., Chironomidae) near Bergen : Western Norway. *Ann. Zool. Fenn.* **5** : 65-75.

Krishnamurthy, K. N. 1966. Preliminary studies on the bottom macrofauna of Tungabhadra reservoir. *Proc. Ind. Acad. Sci.* **63** : 96-103.

Krishnamurthy, K. P. & G. Visweswara 1965. Hydrobiological studies with reference to sudden fish mortality. *Hydrobiologica.* **21** : 3/4, 275-303.

Lavallee, W. H. 1976. Emergence and reprodutive behaviour of *Glyptotendipes lobijirous* (Dipt. Chironomidae). *Mosq. News.* **36**(3) : 259-272.

Laville, H. 1971. Rechcches sur les Chironomides (Diptera) lacustres du massif de Neovicille (Hautes-Pyrenees). *Annls. Limnol.* **7** : 335-414.

Learner, M. A. & R. W. Edwards. 1966. The distribution of the midge *Chironomus riparius* in a polluted river system and its environs. *Ints. J. Air Wat. Pollut.* **10** : 757-768.

Lehmann, J. 1969. Die europaischen Arten der Gattung *Rhoeocricotopus* Thien. und Harn. und drei neue Artvertreter dieser Gattung aus der Orientalis (Diptera, Chironomidae). *Arch. Hydrobiol.* **66**(3) : 348-381.

Lellak, J. 1953a. A quantitative study of the Zoobenthos of some stagnant waters in the Central Lake (Elbe) region. *Rozpr. esl. Akad. Ved.* **63**(8) : 1-67.

Lellak, J. 1953b. The Chironomidae and other bottom fauna of some stagnant waters in the Central Lake (Elbe) region. *Rozpr. esl. Akad Ved.* **63**(9) : 69-144.

Lenz, F. 1925. Chironomiden und Seetypenlehre. *Naturwissenschaften.* **13** : 5-10.

Lenz, F. 1928a. Chironomiden aus Norwegischen Hochgebirgseen Zugleich ein Beitrag zur sletypenfrage. *Nytt. Mag. Naturvid.* **66** : 111-192.

Lenz, F. 1941. Die Metamorphose der Chironomiden guttung *Cryptochironomus. Zool. anz.* **133** : 29-41.

Lindeberg, B. 1963. Taxonomy, biology and biometry of *Tanytarsus curticornis* Kieff. and *T. brundini* n. sp., (Dipt. Chironomidae). *Ann. Ent. Fenn.* **29** : 118-130.

Lindeberg, B. 1967. Sibling species delimination in the *Tanytarsus lestagei* aggregate (Dipt., Chironomidae). *Ann. Zool. Fenn.* **4** : 45-86.

Lindeberg, B. 1968. Population difference in *Tanytarsus gracilentus* (Holmgr) (Dipt., Chironomidae). *Ann. Zool. Fenn.* **5** : 88-91.

Lindeberg, B. 1971. The delimination of genera among the Chironomidae (Diptera). *Can. Ent.* **103**(3) : 373-376.

Lindeman, R. L. 1942. Seasonal distribution of midge larvae in a senescent lake. *Amer. Mid. Natur.* **27** : 428-444.

Loffler, H. 1969. High altitude lakes in Mt. Everest region. *Int. ver. Theoret. ang. Limnol.* **17** : 373-385.

Luedke, R. J. M. A. brushven & F. J. Watts. 1976. Benthic insect community changes in relation to instreams alterations of sediment polluted stream. *Melanderia.* : **23** : 21-39.

Luferov, V. P. 1969. The role of light in the distribution of ebiontic Chironomd larvae in the Lake Seven. *Biol. Vnutr. Vod. Inf. Byull. Akad.* 23-27.

Lundbeck, J. 1926. Die Bodentierwelt norddeutscher Seen. *Arch. Hydrobiol. Suppl.* **7** : 1-473.

Macan, T T 1970. *A key to the nymphs of British species of Ephemeroptera with notes on the ecology.* F.B.A. pubs. No. 20.

Macan, T. T. 1976. Relation entre la fauna de quelques rivieres du nord onest de l' Angleterre et les activities humaines. *Bull. Fr. piscic.* **48** : 153-160.

Mackay, R. J. & J. Kalff. 1969. Seasonal variation in standing crops and species diversity of insect communities in a small Quebec stream. *Ecology.* **50** : 101-109.

Maitland, P. S., W. N. Charles, N. C. Morgan, K. East & M. C. Gray. 1972. Preliminary research on the production of Chironomidae in Loch Leven. Scotland, 795-812. *In : Productivity Problems of Freshwaters.* (Kazimierz Dolny Ed.) 1970. Proc. IBP. UNESCO. Symp.

Maitland, P. S., W. N. Charles, N. C. Morgan, K. East & M. C. Gray. & P. M. G. Hudspith 1974. The zoobenthos of Loch Leven, Kinross and estimates of its production in the sandy littoral area during 1970 and 1971. *Proc. R. Soc. Edinb.*, B74 : 219-239.

Malloch, J. R. 1915. The chironomidae, or midges, of Illinois, with particular reference to the species occurring in the Illinois River. *Bull. Ill. State Lab. Nat. Hist.* **10** : 275-543.

Mandal, B. K. & S. K. Moitra 1975. Seasonal variation of benthos and bottom soil edaphic factors in a freshwater fish pond at Burdwan, West Bengal. *Tropical Ecology.* **16**(1) 1. 43-48.

March, B. G. E., 1976. Spatial and temporal patterns in macrobenthic stream diversity. *Jour. Fish. Res. Bd. Can.* **33** 1261-1270.

Marks, R. J. & A. E. Henderson. 1970. An examination, of the larval Chironomidae (Diptera, Nematocera) in Lennymore Bay, Longh Neagh. *Ir. Nat. J.* **16** : 328-334.

Mason, W. T. J. B. Anderson, R. D. Kreis & W. C. Johnson. 1970. Artificial substrate sampling macro-invertebrates in a polluted reach of the Klamath River, Oregon. *J. Wat. Poll. Control. Fed.* **42** : 315-328.

Mason, W. T & P. A. Lweis & J. B. Anderson. 1971. *Macroinvertebrate collections and water quality monitoring in the Ohio River Basin 1963 - 1967.* Environmental Protection Agency, Ohio Basin region and Analytical Quality Control Laboratory water quality Office, Co-operative report, 117 pp. Cincinnati, Ohio.

May, R. M. & D. Oster. 1976. Bifurcations and dynamic complexity in simple ecological models. *Am. Nat.* **110**(974) : 573-599.

McAlpine, J. E. 1964. Arthropods of the bleakest barren lands: Composition and distribution of the arthropod fauna of the North-Western Queen Elizabeth Islands. *Can. Ent.* **96** : 127-129.

McCombie, A. M. 1953. Factors influencing the growth of phytoplankton. *Fish. Res. Bd. Canada.* **10** : 253-282.

Mclachlan, A. J. 1968. A study of the bottom fauna of lake Kariba. Unpubl. Ph.D. thesis, Univ. London. 374 p.

Mclachlan, A. J. 1970c. The effect of aquatic macrophytes on the variety and abundance of benthic fauna in a newly created lake in tropics (lake Kariba). *Arch. Hydrobiol.* **66**(2) : 212-231.

Mclachlan, A. J. 1974b. Recovery of the mud substrate and its associated fauna following a dry phase in a tropical lake. *Limnol. Oceanogr.* **19** : 74-83.

Mclachlan, A. J. 1974c. Development of some lake ecosystems in tropical Africa, with special reference to the invertebrates. *Priol. Rev.* **49** : 365-397.

Meigen, J. G. 1800. *Novelle classification, des mouches a deux ailes (Diptera L.) d' apres un plan tout nonveau.* 40 pp. Paris.

Meigen, J. G. 1803. Versuch einer neuen Gattungseinteilung der europaischen zweiflugeligen. Isekten. *Illigers Mag. fur Insektenkende* **2** : 259-281.

Michael, R. G. 1964. Limnological investigations on pond plankton, Macrofauna and Chemical constituents of water and their bearing on fish production. D.Phil. Thesis. Calcutta Univ.

Miller, A. C. 1971. Observations on the Chironomidae inhabiting the leaf axils of two species of Bromeliaceae on St. John. U.S. Virgin Islands. *Can. Ent.* **103** : 391-396.

Miller, R. B. 1941. A contribution to the ecology of the Chironomidae of Costello lake, Algonquin Park, Ontario. *Publs. Ont. Fish Res. Lab.* **60** : 1-63.

Minshall, G. W. 1968. Community dynamics of the benthic fauna in a wood springbrook. *Hydrobiol.* **32** : 305-339.

Mitchell, A. J. & M. R. Ensign. 1928. The climate of Florida. *Univ. Fla. Agri. Exp. Stat. Bull.* **200** : 95-300.

Moitra, S. K. & M. L. Bhowmick. 1968. Environmental factors affecting the fish food in the fish farm at Kalyani, Wst Bengal. Ph.D. Thesis, Kalyani Univ. India.

Moon, H. P. 1935a. Flood movements of a littoral fauna of Windermere. *J. Anim. Ecol.* **3-4** : 216-228.

Moore, J. W. 1979. Some factors influencing the distribution, seasonal abundance and feeding of subarctic Chironomidae (Diptera). *Hydrobiol.* **85**(3) : 302-325.

Moore, J. W. 1980. Factors influencing the composition, structure and density of a population of benthic invertebrates *Arch. Hydrobiol.* **88**(2) 202-218.

Moore, W. G. 1952. Limnological studies of Louisiana lakes. 2. Lake Chicatn. Proc. Louisian. *Acad. Sci.* **15** : 37-49.

Morgan, N. C. 1972. Productivity studies at Loch Leven (a shallow nutrient rich lowland lake), 183-205. *In* : Productivity Problems of Freshwater (Kazimierz Dolny Ed.) 1970 Proc. IBP. UNESCO Symp.

Mundie, J. H. 1957. The ecology of Chironomidae in storage reservoirs. *Trans. R. ent. soc. Land.* **109** : 149-232.

Murray, D. A. 1976. Four new species of *Conchaphelopia* Fittkau from Nepal, with a discussion of the Phylogeny of the *Nepalicola* group (Dipt. Chironomidae). *Ent. Scand.* **7** : 293-301.

Muttkowski, R. W. 1918. The fauna of lake Mendota, a qualitative and quantitative survey with special reference to the insects. *Trans. Wis. Acad. of Sci., Arts Lett.* **19** : 374-482.

Nancollas, G. H. 1966. *Interactions in Electrolyte solutions*. Elsevier Publishing Co., Amsterdam. 214 pp.

Nasar, S. A. K. & J. D. Munshi. 1974. Seasonal variations in physico-chemical and biological properties of a tropical shallow pond. *Japanese J. Ecol.* **24** : 256-259.

Needham, P. R. & R. L. Ushinger. 1956. Variability in the macrofauna of a single riffle in Prosser Creek, California, as indicated by the surber sampler. *Hilgardia*. **24** : 383-409.

Neumann, D. 1961. Der Einfluss des Eisenangebotes auf die Hamoglobinsynthese und die Entwicklung der *Chironomus* Larvae. *Z. Naturf.* **166** : 820-824.

Nielsen, E. T & H. Greve. 1950. Studies on the swarming habits of mosquitoes and other Nematocera. *Bull. Ent. Res.* **41** : 227-258.

Nielsen, E. T. & J. S. Haeger. 1960. Swarming and mating in mosquitoes. *Misc. Publs. Ent. Soc. Am.* **1** : 71-75.

Nursall, J. R. 1952. The early development of a bottom fauna in a new power Reservoir in the Rocky Mountains of Alberta. *Can. J. Zool.* **30** : 387-409.

Olander, R. & E. Palmer. 1968. Taxonomy, ecology and behaviour of the Northern Baltic *Clunio marinus* Hal. (Dipt. Chironomidae) *Ann. Zool. Fenn.* **5** : 97-110.

Oldham, R. D. 1899. Assam earthquakes of 12th June 1897. *Mem. G. S. I.*, Vol. **29**.

Oliver, D. R. 1959. Some Dimaesini (Chironomidae) from the Nearctic and Palearctic. *Entomol. Tidskr.* **80** : 48-64.

Oliver, D. R. 1963. Entomological studies in the Lake Hazen area, Ellesmdere Island, including lists of species of Arachnida, Collembola and Insecta. *Artic.* **16**(3) : 175-180.

Oliver, D. R. 1964. A limnological investigation of a large arctic lake, Nettilling Lake, Baffin Island. *Artic.* **17**(2) : 68-83.

Oliver, D. R. 1971. A life history of the Chironomidae *A. Rev. ent.* **16** : 211-230.

Oliver, D. R. & P. S. Corbet. 1966. *Operation Hazen : Aquatic habitats in a high arctic locality*. The Hazen Camp study area, Ellesmere Island, N. W. T. Defence Reserch Board Dipt. of Nat. Def. Canada, Ottawa. 1-115.

Paine, G. H. & A. R. Gaufin. 1956. Aquatic Diptera as indicators of pollution in a mid-western Stream. *Ohio. J. Sci.* **56** : 291-304.

Palmen, E. 1960. *Paratanytarsus*-Arten (Dipt.) ans dem B-mesohalinen und Oligohalinen Brackwasser des finnischen Meerbusens. *Ann. Ent. Fenn.* **26** : 280-291.

Palmen, E. 1962. Studies on the ecology and phenology of the Chironomidae (Diptera) of the Northern Baltic. I. *Allochironomus crassiforceps* K. Suom. *Lyont. Aikak.* **28** : 137-168.

Paterson. C. G. & C. H. Fernando. 1970. Benthic fauna of a new reservoir with particular reference to the Chironomidae. *J. Fish. Res. Bd. Can.* **27** : 213-232.

Pauly, M. 1917. Zur Fruhjahrswanderung der Uferfauna in grosseren Uuggelsee. *Z. Fisch.* **19** : 77-212.

Petr, T. 1970. The bottom fauna of the rapids of the Black Volta River in Ghana. *Hydrobiol.* **35**(4) : 399-418.

Petr, T. 1970b. Macroinvertebrates of flooded trees in the man-made Volta lake (Ghana) with special reference to the burrowing mayfly *Povilla adusta* Navás. *Hydrobiol.* **36**(3-4) : 373-398.

Petr, T. 1972. Benthic fauna of a tropical man-made lake (Volta Lake, Ghana, 1965-1968). *Arch. Hydrobiol.* **70**(4) : 484-533.

Petr, T 1974. Dynamics of benthic invertebrates in a tropical man-made lake (Volta lake, 1964-1968), Standing crop and bathymetric distribution *Arch. Hydrobiol.* **73** : 245-265.

Petr, T. 1975. On some factors associated with the initial high fish catches in a new African man-made lakes. *Arch. Hydrobiol.* **75** : 32-49.

Picado, C. 1913. Les Bromeliacees epiphytes conoiderees comme milieau bilogique. *Bull. Scient. Fr. Belg.* 7e. Serie 47.

Pleskot, A. D. 1958. Die periodizitat einiger Ephemerepteran der Schwechat. *Wasser und Abwasser.* 1-32.

Pruthi, H. S. 1933. Studies on the bionomics of freshwaters of India. I. Seasonal changes in the physical and chemical condition of water in the tank in the Indian Museum compound. *Int. Rev. Hydrobiol.* **28** : 46-67.

Ramcharan, V. & C. G. Paterson. 1978. A partial analysis of ecological seggregation in the Chironomid community of a bog lake. *Hydrobiol.* **58**(2) : 129-136.

Reiss, F. 1965. *Microspectra praecox* Meig. und *Microspectra contracta* n. sp. (Diptera, Chironomidae). Chironomidenstudien III. *Arch. Hydrobiol.* **61** : 228-241.

Reiss, F. 1968. Verbreitung lakustrischer Chironomiden (Diptera) des Alpengebietes - *Ann. Zool. Fenn.* **5** : 119-125.

Reiss, F. 1968a. Neue Chironomiden. Arten. (Diptera) aus Nepal. *Khumbu Himal.* 3(1) : 55-73.

Reiss, F. 1969. Tanytarsini - Arten (Chironomidae, Diptera) ans. Nepal mit der neubeschreibung von funf *Micropsectra* und drei *Tanytarsus* Arten. *Khumbu Himal.*, 4(1) : 131-151.

Remmert, H. 1955a. Okologische Untersuchungen uber die Dipteren der Nord - und Ostsee. - *Arch. Hydrobiol.* **51** : 1-53.

Richardson, R. E. 1921. The small bottom and shore fauna of the middle and lower Illinois river. *Bull. Ill State Lab. Nat. Hist. Surv.* **13** : 363-522.

Richardson, R. E. 1925. The bottom fauna of the middle Illinois river, 1913 - 1925. *Bull. Ill. State Lab. Nat. Hist.* **17** : 387-475.

Roback, S. S. 1957. The immature tendipedids of the Philadelphia Area (Diptera : Tendipedidae). *Acad. Nat. Sci. Phila. Monogr.* **9** : 1-152.

Rogers, J. S. 1933. The ecological distribution of the craneflies of northern Florida. *Ecol. Monogr.* 3(1) : 1-74.

Roy, H. K. 1955. Plantation Ecology of the River Hooghly at Palts, West Bengal. *Ecology*. **36** : 169-175.

Roy, S. P., D. N. Rai & U. P. Sharma. 1980. Investigations on the seasonal changes in population of Chinonomid larvae in freshwater shallow tropical pond at Bhagalpur. *Ind. Orient. Insec.* **14**(1) : 1-9.

Royan, J. P. 1972. Biology of Conchostroca, Ph.D. Thesis Madu. Univ. Madurai.

Ruttner, F. 1953. *Fundamentals of Limnology*. 1st. ed. (transt. by D. G. Frey and F. E. J. Fry). Univ. Toronto Press. Toronto. 295 pp.

Rzoska, J. 1961. Observations on tropical rainpools and general remarks on temporary waters. *Hydrobiol.* **17** : 265-286.

Saether, O. A. 1970. A survey of the bottom fauna in lakes of the Okanagan Valley, British Columbia. *Fish. Res. Can. Tech. Rep.* **196** : 17 pp.

Saether, O. A. 1971. Nomenclature and Phylogeny of the genus *Harnischia* (Diptera, Chironomidae). *Can. Ent.* **103**(3) : 347-362.

Saether, O. A. 1973. Taxonomy and ecology of 3 new species of *Monodiamesa* Kieffer with keys to Nearctic and Palearctic species of the genus (Diptera : Chironomidae). *J. Fish. Res. Bd. Can.* **30** : 665-679.

Saether, O. A. 1979. Recent developments in chironomid studies (Diptera : Chironomidae). *Ent. scand., Suppl.* No. **10**. 150 pp.

Saether, O. A. 1979a. Chironomid communities as water quality indicators. *Holarct. Ecol.* **2** : 65-74.

Saether, O. A. 1980. The influence of Eutrophication on Deep lake Benthic Invertebrate Communities. *Prog. wat. Tech.* **12** : 161-180.

Saether, O. A. & M. P. Mclean. 1972. A survey of the bottom fauna in wood, Kalamalka and Skaha lakes in the Okanagan valley, British Columbia. *Fish. Res. Bd. Can. Tech. Rep.* **342** : 1-20.

Schndler, D. W. 1971. Light, temperture and oxygen regimes of selected lakes in the Experimental lakes area, north-western Ontaro. *J. Fish. Res. Bd. Can.* **28** : 157-169.

Schndler, D. W. & S. K. Holmgren. 1971. Primary production and Phytoplankton in the experimental lakes area, north-western Ontario, and other low carbonate waters, and a liquid scintillation method for determining ^{14}C activity in photosynthesis. *J. Fish. Res. Bd. Can.* **28** : 189-201.

Schlee, D. 1968. Vergleichende Merkmalsanayse Zur Morphologie und Phylogenie der *Corynoneura*. Gruppe (Diptera-Chironomidae). *Stuttgarter Beitr. Naturkumde* **180** : 1-150.

Schlott, G. & F. Reiss. 1975. The occurrence of *Tanytarus aculeatas* Brundin (Insecta ; **Dipt.** Chironomidae) in Piburger lake. (Tiral, Austra). *Ber. Natuwiss. Med. Ver.* ***Innsb.*** **62** : 131-137.

Sewell, R. B. S. 1934. Studies on the bionomics of freshwaters in India. II. On the fauna **of the tank** in the Indian Museum Compound and the Seasonal Changes observed. *Int. Rev.* ***Hydrobiol.*** **31** 203-238.

Singh, S. 1958. On a collection of nival Chironomidae (Diptera) from North-West **Himalaya.** ***Proc.*** *nat. Acad. Sc.* (B) **28**(9). 308-314.

Singh, S. 1968. Entomologial Survey of Himalaya. Part 29. On a collection of nival **Chironomidae** (Diptera) from the North-West (Punjab) Himalaya. *Proc. natn. Acad. Sci. India.* **(B)28 (4)** : 308-314.

Singh, S. & Kulshrestha A. K. 1975. Three new species of *Tanytarsus*. *Orient. Ins.* 9(4) : **419-424**.

Singh, S. & Kulshrestha A. K. 1976. *Chironomus bharati* n. sp. and *C. uttarpradeshensis* **n. sp.** from India (Diptera : Chironomidae). *Entomol. Scand.* 7(2) : 155-158.

Singh, S. & Kulshrestha A. K. 1977. *Dicrotendipes rajasthani* n. sp. from India **(Diptera,** Chironomidae). *Entomol. Scand.* 8(3) : 233-235.

Sinharay, D. C. & Chaudhuri, P. K. 1979. Genus *Parametriocnemus Goetghebuer* **from India** (Diptera : Chironomidae). *Ent. Scand. Suppl.* **10** : 119-123.

Sinharay, D. C. & Chaudhuri, P. K. & D. K. Choudhury. 1978. Studies on Orthocladiinae **(Diptera :** Chironomidae) of India. Genus *Eukiefferiella* Thienemann. *Orient. Insec.* **12**(3) : **347-354.**

Slack H. D. 1965. The profoundal fauna of Loch Lomand, Scotland. *Proc. R. Soc. Edinb.* **B. 69** : 272-297.

Slack, K. V & Feltz, H. R. 1968. Tree leaf control on low flow water quality in a small Virginia stream. *Environ. Sci. Technol.* 2 : 126-131.

Sreenivasan, A. 1964a. A hydrobiological study of a tropical impoundment, Bhavanisagar reservoir, Madras State, India, for the year 1956-61. *Hydrobiol.* 24 : 514-539.

Sreenivasan, A. 1964b. Limnological studies and fish yield in the three upland lakes of Madras state India. *Limnol. Oceanog.* 9 : 564-575.

Srivastava, V K. 1956a. Studies on the freshwater bottom fauna of North India. Quantitative fluctuations and qualitative composition of benthic fauna in a lake in Lucknow. *Proc. Nat. Acad. Sci.* (B)**25** (6) : 406-416.

Srivastava, V. K. 1956b. Benthic Organisms in a freshwater tank. *Curr. Sci.* **25** : 158-159.

Stahl, J. B. 1975. Emergence, occurrence and mating behaviour of *Hydrobaenus pilipes* (Malloch) (Dipt. Chironomidae). *Ent. News.* **86** (3&4) : 69-72.

Strenzke, K. 1960. Die systematische und okologische Differenzierung der Gattung ***Chironomus.*** *Ann. Ent. Fenn.* 26(2) : 111-138.

Sublette, J. E. 1955. The Physico-Chemical and Biological features of lake Texoma (Denison Reservoir) Oklahoma and Texas : A preliminary study. *Tex. J. Sci.* 7(2) : 164-182.

Sublette, J. E. 1957. The ecology of macroscopic bottom fauna in lake Texoma (Denison Reservoir) Oklahoma and Texas. *Amer. Midl. Nat.* **57** : 371-402.

Sublette, J. E. 1960. Chironomid midges of California. I. Chironominae, exclusive of Tanytarsini (Calopsectrini). *Proc. U.S. natn. mus.* **112** : 197-226.

Sublette, J. E. 1964. Chironomidae of Louisiana 1. Systematics and immature stages of some lentic Chironomids of West Central Lousiana. *Tulane stud. Zool. Bol.* **11** : 100-150.

Sublette, J. E. 1964a. Chironomidae (Diptera) of Lousiana 1. Systematics and immature stages of some lentic Chironomids of West Central Lousiana. *Tulane stud. Zool.* 11(4) : 109-150.

Sublette, J. E. 1964b. Chironomid midges of California. II. Tanypodinae, Diamesinae and Podonominae. *U.S. natn. Mus.* **115** : 85-135.

Sublette, J. E. 1966a. Type specimens of Chironomidae Diptera in the American Museum of Natural History. *J. Kans. ent. Soc.* 39(1) : 1-32.

Sublette, J. E. 1966b. Type specimens of Chironomidae (Diptera) in the U.S. National Museum). *J. Kans. ent. Soc.* 39(4) : 580-607.

Sublette, J. E. 1967a. Type specimens of Chironomidae (Diptera) in the Canadian National Collections, Ottawa. *J. Kans. ent. Soc.* **40** : 290-331.

Sublette, J. E. 1967b. Type specimens of Chironomidae (Diptera) in the Cornell University collection. *J. Kans. ent. Soc.* **4** : 477-564.

Sublette, J. E. & Sublette M. S. 1965. Family Chironomidae 142-181. *In : A catalog of the Diptera of America north of Mexico* (A. Stone *et al.* Eds). U.S. Dept. of Agriculture Handbook, No. 276, 1696p.

Sublette, J. E. & Sublette M. S. & W. W. Wirth. 1972. New genera and species of West Indian Chironomidae (Diptera). *Fla. Ent.* 55(1) : 1-17.

Sumitra, V. 1969. Limnological studies of some tropical ponds. Ph.D. thesis. Madu. Univ. Madurai.

Syrjamaki, J. 1964. Swarming and mating behaviour of *Allochironomus crassiforceps* Kief. (Dipt. Chironomidae). *Ann. Zool. Fenn.* **1** : 1?5 145.

Syrjamaki, J. 1967. Laboratory studies on the swarming behaviour of *Chironomus strenzkei* Fittkau in litt. (Dipt. Chironomidae). *Ann. Zool. Fenn.* **4** : 19-28.

Tabaru, Y 1975. Outbreak of Chironomid midge in a polluted river and the chemical control of the larvae. *Jpn. J. Sanit Zool.* 26(4) : 247-252.

Thapa, M. P. 1982. Limnological investigations and their ecological significance of a Lacustrine system and selected water bodies in and around Shillong. NEHU unpublished thesis. 237 pp.