THE INDICATOR VALUE OF THE STONES-IN-CURRENT FAUNA OF THE JUKSKEI-CROCODILE RIVER SYSTEM, TRANSVAAL, SOUTH AFRICA

by

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ABSTRACT

This study is an evaluation of the relationships between the stones-in-current fauna of a river system and variations in water quality influencing it. The value of the biota in indicating short term and subtle changes in water quality when the reactions of whole communities and not just single taxa are examined is shown by the results. These results suggest that misrepresentation of conditions can result from the more rigid methods of biological classification found in many biotic and diversity indices. This is shown by examples of unsuspected contamination of water resulting in misleading faunal associations.

The system derived in this study requires the definition of regionally and locally controlled taxa and their division into dominant and sub-dominant associations. No single taxon has a rigidly defined indicator function.

These results are applicable to this river system only but further studies should show their applicability to other systems.

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INTRODUCTION

A river is a complex ecosystem in which the shape, size and composition of the catchment, the river bed, the water and the riverine biota are interrelated, often in complex and subtle ways. Sioli (1975) indicated this when he stated that streams and rivers are related to and dependant on their terrestrial surroundings because, through rivers, the landscapes eliminate the end products of their whole metabolism, thus acting as the "kidney systems of the landscape". In addition to the natural end products referred to by Sioli one must bear in mind that a river system draining a highly urbanized area also receives the end products of civilization, both industrial and domestic. As a result, the quality of a river's water generally reflects the range of human activities within its catchment area.

Hynes (1975) came to the same conclusion after a lengthy discussion of the influence of "the valley" on "the stream" where he showed the complete dependance of stream water quality on the type of catchment it drains. This leads to the axiomatic statement, "that every stream is likely to be an individual and thus not really very easily classifiable".

There are two basic objectives in the field of water pollution control (Edwards, 1975). The first is to establish quality standards the imposition of which will prevent or at least minimize the harmful effects of chemicals and other waste products released into the system. In addition to this imposing these standards must maximize the potential of such water with regard to its utilization and its aesthetic value. The second objective requires the adoption of technical and regulatory procedures which facilitate the maintenance of these standards. The attainment of these goals requires sound river management procedures based on a complete knowledge of the biotic and abiotic characteristics and relationships within a system.

As both the hydrology and water chemistry of rivers tend to approach steady state conditions i.e. natural conditions, a typical biota may be expected to develop in the system or parts thereof (Curry, 1972). Natural or man-made perturbations of a river may result in changes in the abiotic and thus the biotic characteristics of the system. It is these changes, which may have an adverse effect on the uses of the river system, that make river system management policy necessary. This is particularly pertinent where the river system flows into a large impoundment, the uses of which vary considerably, such as is the case in the river subject to the study reported here.

In order to establish standards the effects of pollutants on the environmental conditions in the river and on the utilization of the water for human activities, must be determined. Edwards (1975) separated the determination of such effects into two broad approaches: "The first relies on simulating pollutant behaviour and its action on resources in experimental systems. The second relies on an examination of pollutant distributions and their pattern of effects on actual resources". Both approaches have their disadvantages but the fact that the experimental simulation cannot include all the factors which can influence pollutant behaviour and action, tends to make this method more useful as a means of confirming field results rather than for the generation of hypotheses. The study of the effects of the environment on any part of the biota is thus better conducted by means of the observational approach, if this is able to include the establishment of a spatial or temporal network of sites with a range or gradient of pollutant levels and effects.

Ideally, a complete river simulation model incorporating all possible interrelationships is needed to implement river management techniques.

However, in practice, the problems involved in obtaining this amount or data and quantifying particularly the non-conservative elements of a system would be virtually insurmountable. Thus in order to obtain adequate theories on the ecological interrelationships within a system which can be developed and tested for policy - making the most practical method seems to be a complete evaluation of the relationships of one part of the ecosystem with as many major influencing factors as possible. This approach, although seldom aimed specifically at water management policy, has in recent years been adopted in a number of fields. Examples are seen in studies of diatoms (Patrick, 1965, Schoeman, 1973), macroinvertebrates Gaufin and Tarzwell, 1956, Chutter, 1963, Dills and Rogers, 1974, Hawkes, 1974), protozoans (Cairns, Kaesler, Kuhn, Plafkin and Yongue, 1976) and many others.

However, most studies of this nature have been conducted in the northern hemisphere where environmental conditions differ from those found in South Africa.

In this study the stones-in-current fauna of a river system is compared with the abiotic factors of the environment, both physical and chemical which may have an important influence on it.

With the results of such an evaluation complete, hypotheses based on these relationships, together with ecological theories based on other aspects of the system can be used to formulate a predictive theory for the purposes of system management.

The interpretation of stream conditions based on the plant and animal populations in the stream has been used for more than 70 years (Wurtz, 1955). This interpretation is based on an analysis of the organisms present, some species being tolerant of specific conditions while others are intolerant.

Early workers in this field tended to base their conclusions on a simple presence/absence theory. Kolkwitz and Marsson (1908, 1909) propounded the well known saprobiensystem which was based on the presence or absence of organisms. This concept was adhered to for many years as is seen in a statement by Campbell (1939), "It is a well established fact that organisms occur in, or are absent from, a given locality in proportion to the extent to which the surroundings are favourable or unfavourable to them". Even current workers still refer to this presence/absence method of classifying water (Resh and Unzicker, 1975) as a viable method.

There have been several useful reviews of the literature on the use of indicator organisms (Gaufin and Tarzwell, 1952, Patrick, 1962, Bartsh and Ingram, 1966) but the most comprehensive recent reviews have been in Chutter (1972), Sladecek (1973) and Alabaster (1977).

However, it is now becoming generally accepted that the mere presence or absence of a species cannot be considered indicative of a particular condition because the presence of moderate or small numbers of a specific species in a population could be due to any of a variety of unpredictable factors other than, for example, organic pollution. Chutter (1972) points out that all indicator organisms, including those associated with the most severely polluted waters, occur in natural waters. Edwards (1975) warns of the danger of adopting the indicator species approach too rigidly when one is concerned in a prospective way with the possible future effects of pollution because there is no guarantee that the chosen indicator species will be particularly sensitive to pollutants with different modes of action.

Thus the more recent trend is to delineate indicator communities, thereby making use of the maximum amount of information that can be derived from the taxa present and their abundance relative to one another i.e. communities not species reflect stream conditions (Richardson, 1929, Wurtz, 1955, Gaufin and Tarzwell, 1956, Brinkhurst, 1966a, 1966b, Chandler, 1970 and Chutter, 1972).

The tendency to base river classifications on the relative abundance of specific taxa led to the formulation of a number of biotic and diversity indices. Reviews of these are extensively covered in Chutter (1972) and Sladecek (1973). Most of these indices are subject to one of two shortcomings. They may be highly technical, requiring specialized studies which result in findings which cannot be expressed in a way that is easily understandable to workers in other disciplines. Such systems of biological classification of water quality are those of Patrick (1950, 1951) and Wurtz (1955). Alternatively there are a number of simple indices in the literature which do consider the whole macroinvertebrate fauna and not just indicator species, but these tend to impose a certain rigidity on the classification. This results in the indices being applicable under limited conditions only or else they are only indicative of a single parameter such as those of Woodiwiss (1964), Cairns, Albaugh, Busey and Charnay (1968) and Chutter (1972).

Although diversity indices are being widely applied in stream pollution research some doubt has recently been cast on the validity of such methods of steam classification (Eberhardt, 1969, Hurlbert, 1971, Godfrey, 1978). Godfrey (1978) concluded that although diversity is not ecologically meaningless, it may not be possible to use diversity indices as a direct measure of pollution's effects on a segment of a natural stream community. Denoncourt and Polk (1975) warn that although diversity and biotic indices are useful tools, they should not be applied too rigidly and must be used in conjunction with a knowledge of the species involved as well as their relative abundance. Hynes (1963) summarizes this when he states that; "to adhere to a rigid system of this kind is to bemuse oneself with the idea that complex ecological changes can be subjected to simple classifications". This rigidity results in a tendency for users of indices to make the assumption that each group of species is a unit in that those species which are grouped together seem to behave in the same way under the effects of pollution, provided the other environmental conditions are comparable. This could lead to a misrepresentation of results as each part of the group is reacting independantly and its variations must be viewed in the light of knowledge of the species.

It must therefore always be borne in mind when working with faunal communities that just as oversimplification can lead to a misrepresentation of results, care must be taken when analysing complex results. As with all continuous variates borderline cases exist and it is still of the utmost importance to recognize environmental influences that have a bearing on community structure but are unrelated to any form of pollution.

In addition to these environmental factors the type of pollution being investigated should also be defined. Brinkhurst (1966a) stated that pollution is a general term covering a wide variety of problems and the term should always be prefixed with a suitable adjective (organic pollution, toxic pollution, thermal pollution etc.).

The value of using the macroinvertebrate fauna as a basic factor in assessing water quality has been extensively debated in the literature (Wurtz, 1955, Hynes, 1958, Brinkhurst, 1966a, Chandler, 1970, Kaesler and Cairns, 1972, Denoncourt and Polk, 1975). Brinkhurst (1966a) felt that while fish are frequently uppermost in the minds of those seeking help with pollution problems, they are not particularly easy to use as pollution indicators. They are relatively difficult to sample and their mobility makes it possible for them to avoid those parts of the environment which become intolerable for short periods. Alternatively the microflora and microfauna can only be identified by specialists and may only reflect temporary or localized conditions owing to the rapidity with which communities of micro-organisms can develop. They can also disappear from the habitat within a matter of hours.

The macrobenthos have a less rapid rate of reproduction than the microbiota and a relative lack of mobility when compared with fish. Ingram (1966) points out that some macroinvertebrates have delicate respiratory mechanisms and may be among the first organisms to respond to the change due to industrial, agricultural or municipal effluents. They are thus readily affected by stress and therefore tend to reflect the general condition of the environment.

Confirming this opinion Kaesler and Cairns (1972) showed that limnological surveys typically include a great deal of redundancy. By means of a Q-mode cluster analysis using several groups of organisms they showed that the information gained from the survey is best shown by the distribution of aquatic insects and, to a lesser extent, diatoms.

The macroinvertebrate fauna of a river can be very complex with biotopes ranging from bare rock, via shingle to sand, mud and beds of water weed. Chandler (1970) found that the "riffle" or stones-in-current biotope, where broken water flows rapidly over a bed of loose stones is the best for pollutional studies, since it is here that the animals most sensitive to pollution are likely to be found. In addition to this important characteristic of the stones-in-current biotope there is also the fact that the faunal communities occupying it are the easiest to analyse, which recommends it. This is intimated by Chutter (1972) when he stated, with reference to formulating biotic indices, that; "data for these other biotopes indicates that this will not be easy, mainly because their faunal communities are rather variable even in clear streams and rivers".

The fact that the fauna of a river system can be determined by both regional and local effects is often neglected when comparisons between rivers are made. These effects on the patterns of species richness have been emphasized in the literature (Levin, 1970, Levins and Culver, 1971, Segel and Jackson, 1972, Horn and MacArthur, 1972, Vandemeer, 1973 and Slatkin, 1974). MacArthur (1960) divides communities subjected to these effects into "equilibrium communities" and "opportunistic communities". The former maintain structure through local factors (population interactions such as competition and predation) which in turn are influenced by prevailing conditions, and the latter through regional factors (migration and population extinction). Stout and Vandermeer (1975) showed, in a study based on the cumulative sampling records of seven mid-latitude and nine tropical streams, that in general mid-latitude streams contain more regionally controlled species while tropical streams have more locally controlled species. Some workers have found that species richness between different latitudinal zones is similar in "ecologically similar" streams

(Patrick, 1964, 1966). Stout and Vandermeer (1975) feel that these results were due to inadequate sampling.

The streams covered in the above studies lie between 6° and 10° latitude (tropical) and 35° and 45° latitude (mid-latitude). The Jukskei-Crocodile River system lies between 25° 45' and 26° 10' latitude and is thus exactly between the zones compared by Stout and Vandermeer (1975).

Apart from a certain amount of incidental information that became available in taxonomic papers little was known about the biology of South African rivers prior to 1950. Most studies in this field had been developed in Europe and North America (Harrison and Elsworth, 1958). As a direct result of the African Regional Scientific Conference held in Johannesburg in 1949 Harrison and Elsworth began a survey of the Great Berg River in the Western Cape. Their ultimate aim was to determine the biological effects and indicators of pollution but they realized that the first essential was to study the biota and conditions of life in an unpolluted South African river in order to provide a standard of reference against which a polluted river could be compared. This basic work was admirable but it was left to others to progress towards the ultimate aim.

Shortly after this a study modelled on that of Harrison and Elsworth (1958) was initiated on the Tugela River system in Natal (Oliff, 1960a). This study included an investigation of one polluted tributary, the Bushmans River, which was however not severely polluted (Oliff, 1960b).

Chutter (1963) followed with a similar study on the Vaal River in the Vereeniging area.

These studies were basically hydrobiological and the fauna of specific river zones, as classified by Harrison and Elsworth (1958), were listed. However, the tendency in these studies was to place the emphasis on a comparison between zones rather than on the variations in relative abundance within characteristic areas. These zones often covered a wide variety of conditions. This was necessary due to the fact that the vast amounts of data covered by these surveys had to be analysed subjectively and specific variability of conditions and its effects would have been difficult to determine.

In a later study on the Vaal Dam catchment area, Chutter (1970) did show the relationships between the relative abundances of the dominant taxa found at different stations. Although the emphasis was principally on comparisons between different zones in the river this study also includes some discussion on the variations of these dominant taxa within a zone. This variation was mainly based on seasonal changes in physical factors such as temperature, nature of the river bed and siltiness which affect the availability of food. There were no apparent relationships between these variations in the fauna and river chemistry or effluent sources due to the fact that there was probably no severe pollution from the mainly agricultural areas of this catchment.

These studies all provided a thorough background on which further South African studies could be based. The Jukskei-Crocodile River system as covered in this study includes both clean water and enriched tributaries. Amongst the latter enrichment by both the conservative mineral elements and the non-conservative plant nutrients (combined nitrogen and phosphates) occur with the possibility of thermal and/or toxic contamination in one tributary. The system thus provides a range of conditions which allows an evaluation of community types for a wide selection of environmental changes.

Prior to this study the system was thoroughly monitored by Allanson (1961) as a study of a polluted river to extend the work of Harrison (1958). Allanson's three basic objectives were:

1. The determination of present chemical and biological conditions of the streams forming the Jukskei-Crocodile River system.
2. The determination of sources of pollution in the system and the effects of these pollutants on the biological conditions of the system.

The present survey was undertaken notwithstanding the existence of this survey for a number of reasons. Firstly, the chemical and biological status of the river and the sources of pollution have changed considerably during the last decade due to extensive industrial and urban expansion and the relocation of sewage treatment plants in the areas drained by this system. More modern sewage treatment processes have also replaced those used at the treatment plants in existence during the Allanson study. With regard to the effect of pollutants on the biological conditions of the system many of the basic principles of Allanson (1961) were, of necessity, indicative of general pollutional conditions only. This does not allow for the understanding of borderline conditions or the effects of specific types of pollution.

With reference to his third objective Allanson concluded that no useful information would be gained by describing indicator species, but that far more valuable information could be obtained using the association of species. This agrees with the literature survey already discussed. However he then found it adequate to divide the species making up the associations into five categories:

1. Polluted
2. Recovery with variable oxygen
3. Recovery with consistent oxygen
4. Clean
5. Ubiquitous.

This is however a very general classification giving no indication of the type of pollution present nor the effects of any other type of pollution. For instance, would the faunal association be affected differently if subjected to mineral enrichment instead of organic pollution? Furthermore no account appears to have been taken of variation in community structure due to causes such as intermittent flooding, periods of adult emergence and other natural factors.

Hynes (1958) criticized the type of approach used by Allanson in the work of Patrick (1951) and Wurtz (1955). Hynes (1963) states that: "it is a great mistake to try and evolve formal methods of classification. In nature little is simple and straightforward and a rigid system can lead only to rigidity of thought and approach". Each river or stream and each effluent is different so the pattern of pollution and its effects varies from place to place. He goes on to say that there is neither need of, nor advantage in, a formal classification into saprobic or pollutional zones, which in any event are not clearly defined. Each river, or even section of river, must be classified on its own in relation to its own type of conditions. This is probably a little severe as general phenomena can be defined but it is correct in that this type of study does not take varying types of pollution into account.

Allanson has justified his approach by stating that Cholnoky (1958) had shown the value of an exactly similar approach during his investigation of the diatom populations of the Jukskei-Crocodile River system. However, this justification has certain shortcomings in that an unpublished study on the diatom populations which ran concurrently with the present one shows that the diatom reaction to conditions is not always similar to that of the macroinvertebrate populations. Also, the taxonomy of the diatom flora in South Africa, without which indicator groups tend to be suspect, is in some confusion as is being shown in a current study by Schoeman and Archibald (1976-).

Cholnoky (1958) also placed more emphasis on the relative abundance of his indicator groups than did Allanson who listed the species characteristic of his broad pollutional zones but did not examine their relation in proportion to each other. His application of relative abundance was based on the number of species present as compared to the total number of individuals rather than the number of individuals of a particular species in relation to that of other species under particular conditions.

A more recent study on the effects of pollution on the flora of this river system (Barlow, 1974) deals only with the upper reaches of the river and due to the relatively superficial data on the chemical and physical parameters of the system it did not reach any conclusions which can be of much predictive value in water management policies.

The use of computers for analysing large quantities of biological data is a reasonably recent innovation. It has become particularly popular in analysing vegetational data (Austin and Greig-Smith, 1968, Grigal and Goldstein, 1971, Swan, 1970, Walker, 1974) but has also been used in a number of other disciplines such as microbiology (Sundman and Gyllenberg, 1967), ecological studies (Williamson, 1961, Goodall, 1970) and marine ecology (Field, 1968, 1969, 1971, Stephenson, 1972). This type of analysis has also been used successfully on data from limnological surveys (Kaesler and Cairns, 1972, Fahy, 1975).

The purpose of the present survey is to attempt an evaluation of the relationships between the stones-in-current fauna of the Jukskei-Crocodile River system and the environmental factors, both natural and man-made, influencing it. These relationships can lead to a correlation between the distribution and relative abundance of "indicator communities" and the characteristics of various water types. Based on these correlations, relatively specific variations in water quality can possibly be determined. The logical extension of these results will be the ability to predict the effects of changing water quality on the fauna. These results will at this stage be applicable to this river system only but further studies should indicate their applicability in other river systems without imposing too much rigidity on the classification.

GENERAL DESCRIPTION OF THE STUDY AREA

The catchment area of the Jukskei-Crocodile River system (Fig. 1) covers approximately 2 500 km² and lies at an altitude of between 1 850 metres in the south and 1 200 metres in the north.

This area lies in the centre of the Transvaal, to the north of the Witwatersrand, a watershed which divides the Vaal River basin in the south from the Limpopo River basin in the north.

The natural vegetation of the area varies from the typical savanna plains of the Highveld to mixed bushveld on the parallel ridges in the north of the survey area. However, most of the northern slope of the Witwatersrand, which forms the southern part of the catchment, is a densely populated urban area. This region is also heavily industrialized but the main concentration of industry falls in the south-eastern region of the catchment. To the north of this urbanized region and most of the eastern part of the catchment are areas of intensive agriculture. The north-western area is relatively undeveloped consisting mainly of small farms, where land is used for grazing and agriculture, and recreational areas such as picnic resorts, "weekend cottages" and small nature reserves.

The geology of the catchment area has been well reviewed by Allanson (1961) so that only a summary of this is necessary here. The Witwatersrand divide is built up of white quartzites, conglomerates, shales and igneous rocks. To the north of the Witwatersrand a denuded granite dome forms undulating country with fairly deep valleys through which the rivers and streams run. The northern edge of the catchment is bounded by a belt of dolomite through which the Crocodile River passes before cutting through the quartzites, shales and diabase of the ridges which form the Pretoria series. The soils

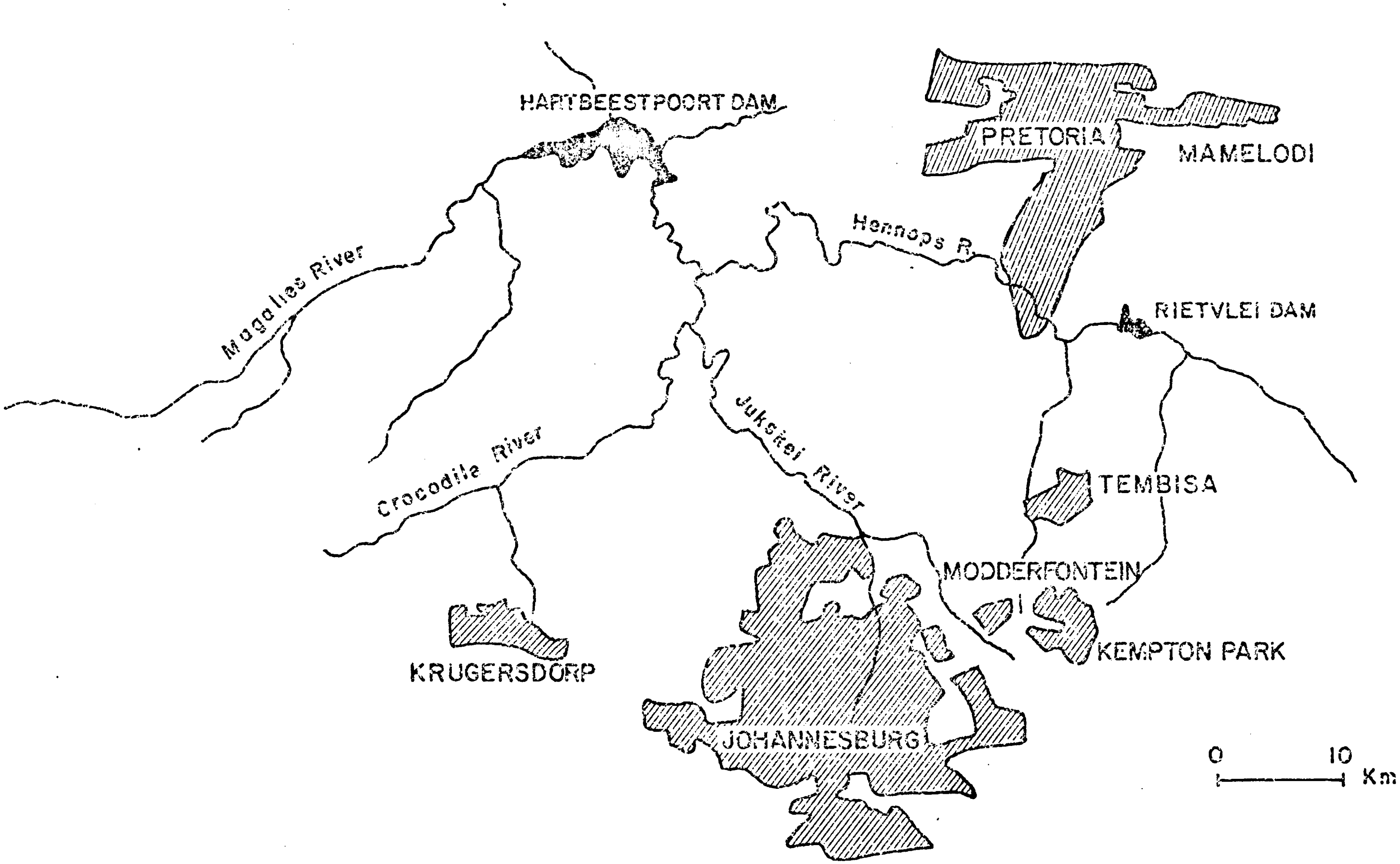


FIGURE 1. The catchment area of the Hartbeespoort Dam

covering the greater part of the catchment are derived from old granite.

The climate in the area can be described as cold and dry during winter and although Allanson (1961) and Barlow (1974) state that it is characterized by occasional snowfalls on the Witwatersrand the last occurrence of snow was experienced in 1964. The summers are warm to hot and rainfall tends to be confined to this period. Rainfall between May and August is negligible but although Allanson (1961) found that 85 to 90 per cent of the rainfall during his study period occurred between November and April, the years covered by the present survey experienced a large proportion of the summer rainfall in the late September/October period. Table 1 summarizes the climatic conditions prevailing during this study period.

Allanson (1961) divided the river into three reaches according to contour lines:

(i) Upper Reach - 5 300 to 4 800 ft (1 600 - 1 450 m) contours from the source of the Jukskei River in Bezuidenhout Valley to just above the confluence of the Modderfontein stream with the Jukskei.

(ii) Middle Reach - 4 800 to 4 300 ft (1 450 - 1 300 m) contours from the above confluence to that of the Jukskei with the Klein Jukskei River. This reach includes the confluence of the Braamfontein and Sandfontein streams with the Jukskei.

(iii) Lower Reach - 4 300 to 3 800 ft (1 300 - 1 150 m) contours from the end of the middle reach to the entry of the river into Hartbeespoort Dam. The confluence of the two main streams of the system, the Crocodile River and the Jukskei River, as well as the confluence of the Hennops River with the Crocodile shortly before the dam, are in this reach.

Table 1: Climatic conditions in the catchment area during the period March 1972 to February 1974.

Month	1972/3		1973/4	
	Mean Temperature (°C)	Rainfall (mm)	Mean Temperature (°C)	Rainfall (mm)
March	16,4	53	18,2	23
April	16,1	72	15,9	67
May	11,3	35	13,3	15
June	9,2	12	10,7	6
July	10,7	4	9,6	0
August	12,7	17	14,8	8
September	15,6	88	16,1	79
October	17,9	250	18,7	175
November	16,2	150	18,2	97
December	19,4	195	19,3	220
January	20,3	172	22,6	182
February	21,2	107	20,4	74

The present study was mainly concerned with the middle and lower reaches of the above division of the system.

At the time this survey was undertaken there were three major point sources of effluent in this section of the river system (Fig. 1) as follows:-

(i) that from a dynamite and chemical factory enters the Modderfontein stream which then passes through three small dams before flowing into the Jukskei River.

(ii) a large sewage treatment plant situated in the lower reach of the river. Effluent from this plant enters the Jukskei River by means of an outfall stream, which passes through a series of maturation ponds, at a point a few miles upstream of the confluence with the Crocodile River. However during peak flow periods excess treated effluent bypassed these ponds by means of a stream which entered the Jukskei River immediately upstream of the confluence with the Klein Jukskei River.

(iii) treated sewage effluent pumped from the above works to a power station for use as cooling water in the cooling towers. The effluent from this power station entered the Modderfontein stream upstream of the point source described in (i) above. The effluent leaving the power station is probably more concentrated due to evaporation in the cooling towers and is also warmer than the river water.

CLASSIFICATION OF THE LOTIC HABITAT

The classification of water type based on substrate composition, steepness of profile and type of flow has been described by Allanson (1961) after the method adopted by Harrison and Elsworth (1958). There are a wide variety of methods of classifying rivers which have been extensively reviewed by Illies and Botosaneanu (1963). They have created a system of nomenclature for the general classification of limnological zones which are typified by a characteristic fauna. According to this system the Jukskei-Crocodile River system would be classified in the rhithron zone. However, as they have omitted all works on polluted waters from their survey, the fauna of this system will not be typical of their rhithron zone.

Pennak (1971) discusses this variety of classification systems and, although he does not take the extreme view of authors who reject all efforts at classification and division as arbitrary and subjective (Badcock, 1953, Armitage, 1961), he feels that many are unreliable. Few have had anything more than local acceptance particularly where they are highly specific.

With the increasing amount of work being done in the world on the ecology of riverine communities a lot of confusion is occurring through inadequate descriptions of the type of habitat involved. Rivers are often simply classified as being eutrophic, oligotrophic, mesotrophic etc. and yet two rivers classified similarly may support entirely different faunas due to any one of a number of other characteristics of the habitat. This makes comparisons between studies of rivers in different parts of the world difficult and Pennak (1971) feels that the most significant system for classifying lotic habitats is one which should be applicable on a world wide basis using chemical, physical and biological features of the environment which give a general picture of the type of stream being dealt with. He suggests a classification system based on thirteen parameters and the criteria for this classification together with the characteristics of the Jukskei-Crocodile River system are given in Table 2. It must be borne in mind that this is a general classification based on the river system as a whole so that it can be compared with systems elsewhere in the world. More detailed descriptions of individual stations or sections of the river will be dealt with in the results of this survey.

Two parameters, turbidity and percentage saturation of dissolved oxygen, were not available so that an indication of turbidity is given by the amount of solids in suspension and the degree of organic pollution is given by the average chemical oxygen demand (COD) values measured.

Table 2 : Criteria for classification of lotic habitats and the classification of the Jukskei-Crocodile River system (categories which are underlined apply to this river system). After Pennak (1971)

Parameters	Categories					
Mean width (m)	<1	1 - 5	5 - 20	20 - 50	50 - 200	> 200
Flow	Temporary	Permanent				
Mean current (km/hr)	<0,5	0,5 - 2,5	2,5 - 5,0	5 - 10	>10	
Dominant substrate	Rubble & boulders	Gravel	Sand	Organic & inorganic silt	Coarse organic debris	
Summer maximum temperature (°C)	>30	20 - 30	10 - 20	5 - 10	<5	
Winter minimum temperature (°C)	>20	10 - 20	5 - 10	<5		
Mean solids in suspension (mg/ℓ)	80 - 100					
Total dissolved inorganic content (mg/ℓ)	very small <30	small 30 - 100	medium 100 - 300	large >300		
Total dissolved organic content (mg/ℓ)	very small <30	small 30 - 100	medium 100 - 300	large >300		
Water hardness (ppm $CaCO_3$)	soft 0 - 10	medium 10 - 40	hard 40 - 100	very hard >100		
Organic pollution (COD in mg/ℓ)	30 - 40					
Maximum rooted aquatic cover	absent or negligible	restricted <10%	moderate 10 - 50%	dense >50%		
Dominant streamside vegetation	absent or negligible	herbs & grasses	brush with some herbs & grasses	woodland		

METHODS AND MATERIALS

SAMPLING PROCEDURE (Data Collection)

Sampling sites and sampling frequencies

Eighteen sampling stations were selected. These were situated in order to obtain the maximum possible information on the sources of contaminated and clean waters so that where a tributary or effluent inflow entered the main stream a sampling station was established on either side of this point and a third one was placed on the tributary itself.

These stations started on the Modderfontein stream in the Edenvale area and on the Jukskei River in the northernmost suburbs of Johannesburg before its confluence with the Modderfontein stream. They ended on the Crocodile River between its confluence with the Hennops River and the Hartbeespoort Dam.

A schematic presentation of the sites of the sampling stations is given in Figure 2 and summarized in Table 3.

Samples were taken at monthly intervals from March 1972 until February 1974.

Determination of chemical status

During the normal monthly sampling trips water samples were taken for chemical analyses. All chemical analyses, done on filtered samples and based on Standard Methods for the Examination of Water and Waste Water (1971), were carried out by the Division of Water Quality and Pollution Criteria of the National Institute for Water Research. Most of these analyses were done by automated procedures.

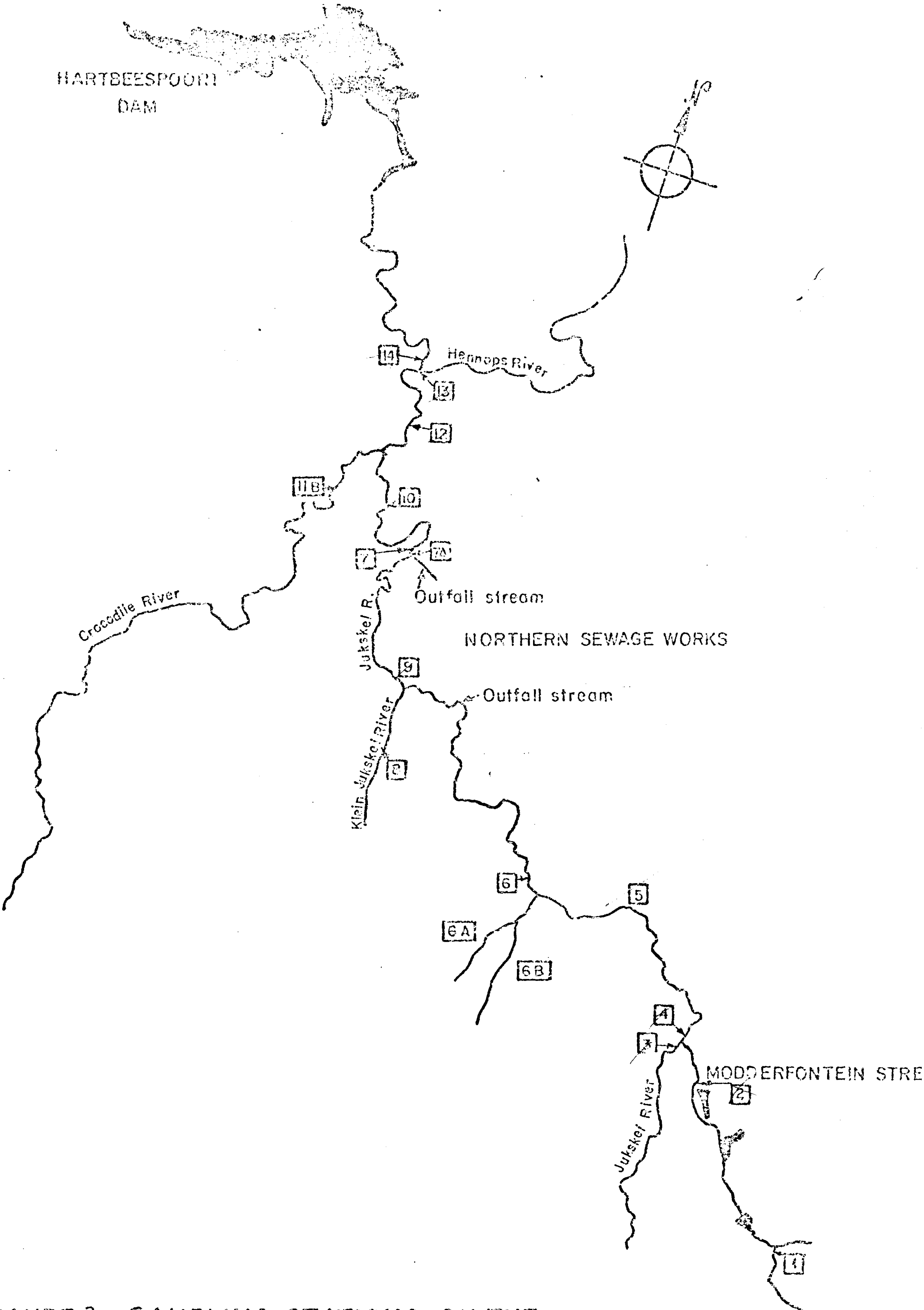


FIGURE 2: *SAMPLING STATIONS ON THE JUKSKEI - CROCODILE RIVER SYSTEMS*

TABLE 3 : Sites of the sampling stations on the main stream of the Jukskei-Crocodile River system and its tributaries

Station number	River on which station is situated	Site of station
1A	Modderfontein stream	Above outflow from Kelvin Power Station at Edenvale
1	Modderfontein stream	Below outflow from Kelvin Power Station
2	Modderfontein stream	Below Modderfontein factory dams
3	Jukskei	Immediately above Modderfontein stream confluence in Buccleugh.
4	Jukskei	A hundred yards downstream of station 3 below Modderfontein stream confluence
5	Jukskei	Weir opposite Kyalami Ranch, Kyalami on the old Johannesburg-Pretoria road
6	Jukskei	Weir A_2M_{42}* below Leeukop Prison, Witkoppen after the confluence with the Braamfontein and Sandfontein streams
6A	Braamfontein stream	On the Witkoppen road above its confluence with the Sandfontein stream
6B	Sandfontein stream	On the Witkoppen road above its confluence with the Braamfontein stream
7	Jukskei	Below the outfall stream from Northern Sewage Works maturation ponds
7A	Northern Sewage Works stream	On the outfall stream below the maturation ponds
8	Klein Jukskei	At the road bridge on the road between Broederstroom and Four Ways approximately 3 km from the confluence with the Jukskei
9	Jukskei	Below the Klein Jukskei confluence at Woodmead school
10	Jukskei	Weir A_2M_{44}* below station 7
11	Crocodile	Approximately 3 km above Jukskei confluence and about 50 metres above Weir A_2M_{45}*.
11A	Crocodile	At Muldersdrift-Krugersdorp-Pretoria crossroads
12	Crocodile	Between Jukskei confluence and Hennops confluence
13	Hennops	Above (100 metres) confluence with the Crocodile.
14	Crocodile	Immediately below Hennops confluence

* Numbers of Department of Water Affairs measuring weirs

The following analyses were performed on the filtered water samples:

total alkalinity (as $CaCO_3$), Kjeldahl nitrogen, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, total phosphorus, orthophosphorus, chemical oxygen demand (COD), methylene blue active substances (MBAS), chloride, sulphate, total inorganic carbon (TIC), total organic carbon (TOC), sodium, potassium, calcium, magnesium and conductivity.

For the purposes of comparing these parameters with the faunal communities the values of three samples over a two month period were averaged so that the fauna were related to prevailing conditions rather than to the values of a "snap" sample taken at the time of sampling. For example, analysis values of samples taken on 20 March, 20 April and 20 May were averaged to be compared with 20 May sample of the fauna.

Determination of other environmental factors

A value for solids in suspension was obtained for each sample by filtering a litre of sample water through a cellulose filter of pore size 25 μ, which was then oven dried and weighed. The difference between this weight and that of the filter is the value given for solids in suspension in mg/litre. This was done as excessive silt and sand can affect the invertebrate fauna (Chutter, 1969).

River flow data were obtained from the Department of Water Affairs for the mainstream and tributaries and from AECI Ltd for the Modderfontein stream. In order to be able to compare variations in flow in the main stream with those of the smaller tributaries these flow figures were standardized. This was done as follows:

$$\frac{x}{y} \times 100 = \text{normalized flow}$$

where x = total flow for a specific month and station

y = total flow for the whole survey period (24 months) at that station.

thus the average flow for a specific station can be given as

$$\frac{1}{24} \times 100 = 4{,}17$$

normalized flows greater than 4,17 indicate high flows conditions while those less than this show that flow was diminished.

Determination of the fauna

The stones-in-current fauna was sampled using a Surber sampler (Surber, 1936) fitted with a 250 micron pore size net.

All samples were immediately preserved in formalin before being returned to the laboratory for analysis.

The macroinvertebrate organisms were identified and counted with the aid of a stereo-microscope mounted on a scanning stand as described by Allanson (1961). Fifty-nine taxa were identified, most of these to the level of genus or species. A few taxa were only classified to family due to small numbers or where apparently similar ecological requirements in a group that were difficult to separate made the effort required for further classification of dubious value. This helped limit the number of taxa sufficiently to be dealt with by the necessarily limited capacity of the computer in the cluster analyses (see below).

The planktonic Cladocera and Copepoda were omitted from this study because most of those found in stones-in-current samples drift into the sampling apparatus and the numbers collected are therefore greatly influenced by current speed and the time taken in sampling (Chutter, 1972).

ANALYTICAL PROCEDURE (Data Reduction)

Numerical techniques are now used extensively in descriptive ecology. According to Austin (1972) they have three main purposes:

(i) Simplification of multivariate data.

(ii) Assistence in hypothesis-generation.

(iii) Domain definition and the probable limits of extrapolation for the experimental results obtained.

He then states that the justification for using numerical techniques is twofold:

(i) Reduction in subjectivity; numerical results are repeatable and internally consistent, while the subjective decisions are explicit rather than implicit.

(ii) Compatibility with computors allows the rapid analysis of very large sets of data.

Biotic index values

A quality index for South African rivers, making use of the stones-in-current invertebrate fauna, was developed by Chutter (1972). It is a measure of the pollution of flowing water by allochthonous, readily oxidizable, organic matter and its breakdown products and summarizes the deviation of the observed community of animals from the community which would be expected where the water is in an unenriched natural state.

The biotic index values range from 0 to 10. An index value of 10 indicates severe organic pollution whereas an index value close to zero indicates a clean river (Table 4).

Biotic Index Values were calculated for every sample in order to analyse the trophic status of all sections of the main stream as well as the tributaries.

The limitations of the index are discussed by Chutter (1972). Chief among these, as far as this study is concerned, is the fact that aquatic communities are not only influenced by organic pollution. Due to the fact that this index is based on biological oxygen demand (BOD), other forms of pollution e.g. toxic, mineral or thermal pollution which may impair water quality and kill some, but not necessarily all, stream animals may thus result in misleading Biotic Index Values.

The limitations of this index made it necessary to carry out further data reduction processes in order to obtain an overall view of all the inter-relationships in the system from which predictive theories can be produced.

Furthermore the considerable instability of flow and of the river beds in the rainy season make some comparison between river flow and its effects on the biota necessary before one is able to ascertain how much of the deviation in an observed community of animals is a result of pollutants.

Cluster analyses

The first stage in any clustering technique involves the choice of a suitable coefficient of similarity. Several such coefficients have been described in the literature (Sneath and Sokal, 1973), but a number of these have been proposed for taxonomical studies and are untenable for an ecological survey.

TABLE 4 : Interpretation of Biotic Index Values - from Chutter (1972)

Value	Interpretation
0-2	Clean, unpolluted water.
2-4	Slightly enriched waters, the slight enrichment may be due either to the natural occurrence of organic matter or to high quality effluents containing a little organic matter or its breakdown products. Chemical changes in the water may be hardly detectable.
4-7	Enriched waters, the higher the Biotic Index Value, the greater the enrichment. Obvious increases in the BOD and nitrogenous compounds in the water and rather wide diurnal fluctuations in the dissolved oxygen are to be expected.
7-10	Polluted waters in which there will be great increases in the chemical parameters associated with organic pollution.

The coefficient of similarity necessary for this study must recognize three criteria. Firstly, it must employ presence-absence or binary data. Allen and Koonce (1974) In: Crossman, Kaesler and Cairns, 1974 have demonstrated the usefulness of presence-absence data in comparisons of ecosystems. In this study the binary data may carry a considerable amount of useful information because it is dealing with the tolerances of organisms to pollutants. This will be particularly pertinent under extreme conditions or in cases where specific animals are susceptible to even the smallest concentrations of a particular pollutant. However, in a case where the pollutant only affects the dominance status of a taxon this will be masked by the binary analysis of the data.

Thus, the second criterion to be considered is that the relative abundance of the taxa in relation to one another must be taken into account. Kaesler and Cairns (1972) stated that consideration of relative abundance in clustering techniques was untenable because methods of sampling different groups of organisms necessarily differed. However, as this study is only concerned with one group of organisms (the stones-in-current benthic fauna) and sampling methods were standard throughout the survey this conclusion does not apply to this study. Notwithstanding the importance of presence-absence data an essential part of the aims of this survey is to ascertain how the relative abundance of a taxon in a community is affected by environmental conditions. This is of the utmost importance because a pollutant that does not have a direct effect on an organism may affect its food supply, biotope or some other part of its environmental niche. This may not result in the eradication of the taxon concerned but will affect its dominance status by making its biotope less suitable.

The third criterion to be considered is whether negative matches should be incorporated. This has occasioned a considerable amount of argument in the literature (Sokal an Sneath, 1963). Kaesler and Cairns (1972) felt that it is essential that negative matches be excluded from this type of study because sampling methods may not produce every species present, so that it is inappropriate for two stations or communities to be considered similar to each other on the basis of the absence of a species from both of them. It has therefore been decided that the coefficient of similarity used should exclude such negative matches.

There are indices of similarity in the literature which simultaneously take account of both the taxa present and their abundance relative to one another (Kemp, Chutter and Coetzee, 1976). However, following the example of these authors this type of index has not been considered because it is not possible to distinguish the role of either the variety of taxa common in a pair of samples, or of the dominant taxa, in the index value.

Comparison of samples with each other has therefore been based on two indices of similarity.

Much confusion exists in the literature regarding the terminology of coefficients of similarity. Kemp *et al.* (1976) discuss these discrepancies in nomenclature and for the purposes of this paper their nomenclature has been followed.

The first index of similarity is the Czeckanowski Index which takes only the presence or absence of taxa into account and their abundance relative to one another is ignored. Rare animals carry as much weight in the calculation of the index value as do common animals.

The Czeckanowski Index measures the similarity between two samples on the basis of taxa present (normal analysis) as follows:

$$\text{Czeckanowski Index} = \frac{2c}{a+b}$$

where a is the number of taxa in sample A

b is the number of taxa in sample B

c is the number of taxa common to samples A and B

When the similarity between the occurrence of two taxa in a number of samples is measured, the same index may be used, but the meanings of a, b and c change so that:

a is the number of samples in which taxon A occurs

b is the number of samples in which taxon B occurs

c is the number of samples in which both taxa A and B occur.

For convenience the Czeckanowski Index values are multiplied by 100 rather than to present them as their absolute values.

The second index of similarity used, in which the abundant animals are of maximum importance, is known as the Bray-Curtis measure of similarity. For the normal analysis the samples were reduced to uniform size by percentage transformation. Thus the formula for Bray-Curtis similarity,

$$I = \frac{2w}{u+v}$$

where u is the sum of the numbers of animals of all taxa found in sample A

v is the sum of the numbers of animals of all taxa found in sample B

w is the sum of the lesser values of those taxa common to both samples A and B is changed to the form

$$I = \frac{2w}{200}$$

and $100 \quad I = w$

or $100 \quad I = \Sigma \min (x_1 , x_2 \ldots\ldots\ldots\ldots x_j)$

where x_1 , x_2 ...... x_j are the percentages of the taxa because u and v have each become equal to 100.

This modified version of the Bray-Curtis similarity is called the Percentage of Similarity (Southwood, 1966).

In the inverse analysis the Bray-Curtis measure of similarity was used in its original form:

$$I = \frac{2w}{u+v} \times 100$$

where u = the sum of the percentages of species A in all the samples being compared

v = the sum of the percentages of species B in all the same samples

w = the sum of the lower percentages represented by species A or B where they occurred in the same sample.

The combination of these two indices of similarity was found by Kemp *et al.* (1976) to be suitable for ecological surveys of this nature.

The second stage in this analysis is the computation of a matrix of similarity coefficients in the Q-mode (the correlation between OTU's as defined by Sokal and Sneath [1963]). The results may be presented as triangular matrices of similarity values, but the information contained in such matrices is not easily discernible, particularly for large sets of data, and requires further reduction (Kemp *et al.*, 1976). A number of clustering strategies are available (Sokal and Sneath, 1963) for sorting information in such matrices into an easily understandable form.

Thus the third stage of a cluster analysis is the clustering itself. Lance and Williams (1967) have analysed the various classificatory programs which they have discussed at length. Their "agglomerative" methods are subdivided into two categories, hierarchical strategies which optimize the routes by which groups are attained and clustering strategies which optimize some property of a group of elements. The strategy used here is a hierarchical strategy known as group-average sorting (Lance and Williams, 1967) and is described by Sneath and Sokal (1973) who call it the unweighted pair group method using arithmetic averages (UPGMA). This method of clustering has been found empirically to produce clusters with less distortion than other commonly used clustering methods (Kaesler and Cairns, 1972). Moreover, Farris (1969) has shown on theoretical grounds why UPGMA should produce less distortion.

The admission of a given parameter into a cluster is based on the average of the similarities of that individual parameter with the members of the cluster. As the cluster grows, and more distantly associated members are considered as prospective members, the value of the average similarity is lowered.

Such a group method is a class of clustering technique suggested by Sokal and Michener (1958) for the analysis of correlation coefficient matrices but can be applied to most methods of similarity coefficient matrices (Sokal and Sneath, 1963).

Sokal and Michener (1958) suggest that when any one prospective member lowers the average similarity value by more than 0,03, this prospective member should not be included. This value of 0,03 was empirically arrived at for correlation coefficient analysis and needs slight adjustment with different similarity coefficients. The size of clusters in this method may vary at any level and the number of parameters joining a new cluster are also variable.

The fourth stage in the cluster analysis is the graphic display of the clusters. Dendrograms are used for this purpose.

The computer program used in this study was compiled by the Natal Regional Laboratory of the National Institute for Water Research for Kemp *et al.* (1976) and modified by the National Research Institute for Mathematical Sciences of the CSIR for use on a IBM 360 computer and to include greater numbers of operational units than was allowed for the original program. This program accepts the raw data sampling point by sampling point, transforms the number of individuals of each taxon in each sample into percentages, computes the indices of similarity, clusters the resulting similarity matrices by group average sorting and plots the resulting dendrograms. The flow diagram for this program is given in Figure 3.

The final stage of the cluster analysis, not included in the computer program, is the assessment of the amount of distortion in the dendrogram. A dendrogram is a two dimensional representation of a multi-dimensional configuration. During the clustering procedure the similarities of the matrix of similarity coefficients are distorted by averaging. This happens because, as with most agglomerative clustering methods, group average sorting forms hyperspheroidal clusters regardless of the actual configura-

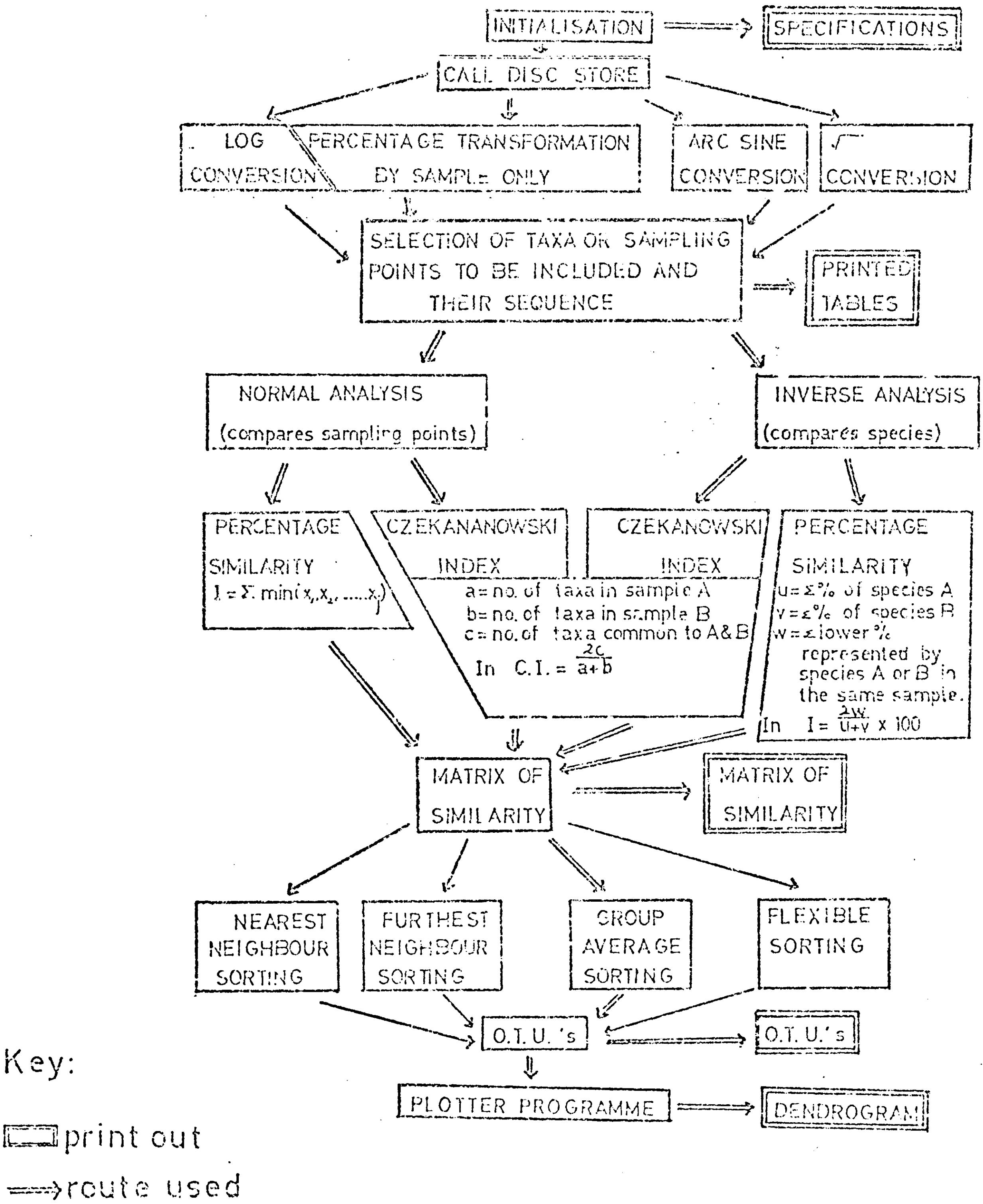


Figure 3: Flow Diagram of the Cluster Analysis Program.

tion of the associations in hyperspace (Sneath and Sokal, 1973). It is imperative that the amount of distortion be measured. This is best done by the use of the cophenetic correlation coefficient (Sokal and Rohlf, 1962). This coefficient, is computed between corresponding elements of the original matrix of similarity coefficients and a matrix of cophenetic values taken from the dendrogram. The nearer the value of the coefficient is to unity, the less the amount of distortion. If the cophenetic correlation coefficients are greater than 0,8 (Kaesler and Cairns, 1972), one can assume that averaging similarities, forcing operational units into a hierarchy and clustering hyperspheroidally have not introduced too great a distortion of the information content of the original matrix of similarity coefficients.

The faunal communities defined by the clustering strategies and changes within them were compared with the environmental conditions under which the community existed, for the proceeding two months (as previously described under Determination of chemical status).

RESULTS

CHEMICAL-PHYSICAL STATUS OF THE SYSTEM

The chemical-physical data obtained from the monthly samples are tabulated as running averages (described earlier) in the appendix (Table A1). These data are summarized in Table 5, showing the mean, minimum, maximum and standard deviation of each parameter, in order to present a general picture of the differences between stations and/or sections of the river system. Table 6 shows the annual mean values for the two years to facilitate recognition of large changes in chemical concentration from one year to another. The annual means include all changes due to seasonal influences so that a marked difference suggests a consistent increase or decrease in a parameter. Such an increase could indicate an overall change in the quantity or quality of a point source effluent.

Mineralization

The Modderfontein stream was the most highly mineralized section of the river system (Table 5). This was reflected by the conductivity, sodium, potassium, calcium, magnesium, chloride, sulphate and alkalinity concentrations.

The degree of mineralization tended to decrease steadily down the mainstream of the system resulting in chemical concentrations of most parameters being considerably less than half at station 14, of what they were in the Modderfontein stream. This was probably mainly due to dilution by the tributaries and to a lesser extent, to plant uptake of mineral elements. The only exception to this trend there was an increase in the concentration of most of the chemical constituents measured between stations 1 and 2,

TABLE 5 : Summarized chemical data for the system showing the mean ($\bar{X}$), maximum (X_{max}), and minimum (X_{min}) and standard deviation (S_x) for all parameters. n = 24 for all stations except stations 6A and 6B where n = 8. (Units are mg/l except conductivity (mS/m) and pH.

Sample		Conductivity	Na	K	Ca	Mg	Cl	SO_4	Tot. alk.	COD	MBAS	Inorg. carbon	Organic carbon	NH_3-N	NO_2-N	NO_3-N	Dissolv. inorg. N	Dissolv. org. N	PO_4-P	Total P	pH
1	$\bar{x}$	160	160,7	30,85	100,9	22,3	130,8	222,8	102,9	43,5	0,78	13,8	14,9	0,4	0,6	50,1	69,61	2,03	3,6	4,35	8,95
	x_{min}	100,0	108,0	18,0	50	1	94	97	29	25	0,22	9,0	11,0	0,1	0,2	5,9	50,2	1,6	0,1	0,1	8,2
	x_{max}	473,4	220,0	40,0	450	37	175	500	554	65	1,10	18,0	18,0	0,7	0,8	90,0	91,15	2,5	5,9	9,5	12,0
	S_x	71,82	28,96	5,07	76,38	9,06	23,07	88,71	104,4	11,87	0,24	2,30	2,42	0,17	0,19	29,10	13,43	0,35	2,66	3,07	1,07
2	$\bar{x}$	193,6	164,9	25,8	111.5	35,9	160,8	399,7	143,3	51,5	0,70	31,5	18,2	36,6	4,8	43,6	84,21	3,85	1,1	1,3	7,7
	x_{min}	130,0	102,0	19,8	87,0	28,0	121,0	300,0	82,0	37,0	0,22	22,0	12,0	23,0	0,1	5,9	55,2	0,6	0,2	0,3	7,3
	x_{max}	237,9	240,0	34,0	200,0	44,0	230,0	540,0	208,0	69,0	0,85	38,0	29,0	48,0	11,0	75,0	102,6	20,0	1,7	3,6	8,3
	S_x	24,78	32,66	3,63	24,43	4.49	27,19	64,95	38,05	11,15	0,03	5,35	5,49	7,62	2,61	19,99	13,37	6,83	0,59	0,74	0,23
3	$\bar{x}$	78,3	54,9	8,4	55,2	23,6	80,4	95,9	150,5	26,0	0,3	33,0	12,0	0,9	0,3	3,3	4,01	0,88	0,2	0,3	8,2
	x_{min}	46,8	17,0	5,0	2,50	11,0	29,0	46,0	92,0	13,0	0,05	17,0	0,0	0,1	0,05	0,5	1,6	0,5	0,1	0,1	7,8
	x_{max}	102,6	98,0	13,0	68,0	35,0	185,0	145,0	219,0	51,0	0,54	46,0	39,0	2,7	0,5	4,7	5,6	1,5	0,3	0,8	8,6
	S_x	18,11	22,57	2,12	11,72	7,45	28,06	24,52	34,02	8,33	0,47	8,99	9,36	0,72	0,24	1,28	1,45	0,29	0,07	0,18	0,24
4	$\bar{x}$	140,0	119,4	18,2	86,8	31,0	127,2	274,1	130,0	38,2	0,5	25,8	14,9	17,6	2,8	27.2	44,57	14,47	0,6	0,9	7,8
	x_{min}	67,6	52,0	7,4	48,0	17,0	56,0	106,0	90,0	22,0	0,10	17,0	9,0	0,1	0,05	6.2	11,3	0,4	0,1	0,1	7,4
	x_{max}	200,5	205,0	23,0	125,0	40,5	187,0	470,0	180,0	64,0	0,87	33,0	26,0	26,5	6,0	57,0	77,0	3,8	1,3	2,2	8,7
	S_x	37,39	29,42	4,73	19,01	7,23	36,03	91,05	32,89	13,03	0,21	6,15	5,63	9,20	1,60	14,72	21,92	1,23	0,39	0,56	0,29
5	$\bar{x}$	139,3	119,8	18,8	86,8	29,7	123,5	278,7	111,0	38,9	0,5	22,5	15,5	13,6	2,3	29,1	42,75	4,08	0,6	0,7	7,8
	x_{min}	44,2	28,0	7,0	34,0	12,0	31,0	60,0	61,0	26,0	0,15	11,0	6,0	0,10	0,05	6,5	10,1	0,6	0,1	0,1	7,6
	x_{max}	219,6	215,0	33,0	130,0	43,0	200,0	476,0	155,0	66,0	0,85	28,0	26,0	29,0	6,0	75,0	76,2	28,4	1,2	1,4	9,2
	S_x	46,68	50,22	5,99	22,38	8,17	48,35	103,01	30,96	12,92	0,21	5,73	5,65	8,66	1,56	18,51	22,93	8,57	0,39	0,53	0,19
6	$\bar{x}$	103,1	85,3	13,5	68,3	24,6	95,3	190,0	91,8	31,8	0,4	19,3	13,3	7,8	1,3	20,9	30,45	1,17	0,3	0,5	7,8
	x_{min}	32,5	22,0	6,0	27,0	8,0	31,0	52,0	62,0	14.0	0,05	11,0	8,0	0,4	0,2	3,9	5,3	0,1	0,05	0,1	7,1
	x_{max}	172,5	170,0	29,0	115,0	40,0	180.0	435,0	116,0	52,0	0,69	26,0	20,0	18,2	3,3	44,0	61,7	3,0	0,8	1,2	8,6
	S_x	38,38	41,37	4,98	20,66	8,54	44,21	89,53	16,41	11,61	0,19	4,20	3,77	5.69	0,96	10,39	16,99	0,84	0,18	0,33	0.23

TABLE 5 : Continued

6A	$\bar{x}$	42,4	28,3	4,4	35,0	12,1	44,5	41,0	94,0	18,0	-	-	-	0,5	0,08	2,0	-	-	0,1	0,2	8,2
	x_{min}	23,3	14,0	3,7	25,0	6,0	15,0	25,0	68,0	12,0	-	-	-	0,1	0,1	0,5	-	-	0,2	0,2	7,7
	x_{max}	60,4	42,0	5,6	48,0	18,0	72,0	57,0	140,0	27,0	-	-	-	1,5	0,2	3,5	-	-	0,2	0,2	8,7
	S_x	12,52	11,16	0,61	9,03	5,29	19,84	10,47	20,95	7,14	-	-	-	0,41	0,03	0,93	-	-	0,0	0,0	0,35
6B	$\bar{x}$	35,2	21,0	5,3	32,6	7,5	28,1	35,9	96,0	25,0	-	-	-	0,4	0,06	0,5	-	-	0,1	0,1	8,0
	x_{min}	19,5	9,0	3,4	22,0	4,0	11,0	26,0	60,0	16 0	-	-	-	0,1	0,1	0,2	-	-	0,1	0,1	7,4
	x_{max}	47,2	35,0	7,6	43,0	11,0	45,0	58,0	134,0	32,0	-	-	-	0,9	0,1	1,5	-	-	0,2	0,4	9,0
	S_x	10,16	25,92	1,56	7,41	3,21	12,45	9,34	26,75	6,76	-	-	-	0,26	0,0	0,42	-	-	0,03	0,07	0,50
7	$\bar{x}$	77,4	75,8	13,7	44,4	15,4	67,9	107,6	104,2	36,8	0,6	20,6	15,2	4,3	1,1	14,7	21,21	1,66	3,4	4,1	7,8
	x_{min}	43,0	27,0	7,1	27,0	9,0	27,0	49,0	75,0	22,0	0,19	13,0	1,0	0,3	0,5	4,6	10,3	0,1	0,1	0,1	7,3
	x_{max}	109,0	110,0	26,0	62,0	22,0	100,0	195,0	158,0	51,0	0,90	26,0	22,0	9,6	2,8	28,7	35,2	5,4	6,5	7,6	8,5
	S_x	19,51	21,13	3,59	9,67	3,67	19,86	31,85	19,46	7,96	0,22	3,69	5,61	3,49	0,52	6,02	9.12	1,40	1,45	1,68	0,26
7A	$\bar{x}$	74,8	77,0	15,3	36,0	11,9	44,9	77,0	133,7	47,8	0,7	24,9	19,9	7,8	1,2	11,1	19,67	1,29	6,8	7,9	8,0
	x_{min}	63,6	67,0	14,0	29,0	10,0	55,0	59,0	103,0	32,0	0,33	17,0	16,0	0,9	0,4	4,3	13,5	0,0	4,0	6,8	7,7
	x_{max}	87,0	87,0	18,8	46,0	16,0	76,0	100,0	182,0	54,0	0,94	34,0	28,0	17,2	1,8	15,8	26,8	3,3	9,9	8,6	8,4
	S_x	6,59	5,86	1,19	5,15	1,54	6,72	14,17	19,49	8,18	0,19	5,73	3,85	4,47	0,51	2,98	5,28	1,11	0,97	0,91	0,20
8	$\bar{x}$	33,6	18,0	3,7	25,8	11,1	17.8	29,7	105,3	19,6	0,3	25,0	9,8	0,4	0,1	0,7	1.08	0,54	0,4	0,7	7,9
	x_{min}	14,7	9,0	2,4	16,0	6,0	9,0	19,0	35,0	8,0	0,05	17,0	5,0	0,1	0,02	0,2	0,75	0,0	0,1	0,1	7,1
	x_{max}	64,9	30,0	5,2	35,0	18,0	34,0	62,0	332,0	32,0	0,65	38,0	14,0	1,3	0,1	2,2	1,51	1,1	1,2	2,4	9,0
	S_x	10,29	6,13	0,83	7,19	3,81	7,23	9,60	31,63	7,53	0,16	6,40	2,71	0,31	0,03	0,48	0,31	0,35	0,29	0,69	0,44
9	$\bar{x}$	78,0	63,9	12,1	46,7	16,7	70,0	114,5	102,4	36,1	0,5	18,9	14,9	6,4	1,0	16,5	22,23	0,98	2,6	2,9	7,6
	x_{min}	27,3	15,0	5,9	23,0	7,0	17,0	30,0	70,0	16,0	0,10	8,0	7,0	0,6	0,2	3,7	4,8	0,1	0,2	0,2	7,2
	x_{max}	146,4	135,0	23,5	83,0	33,0	141,0	300,0	128,0	54,0	0,93	25,0	19,0	15,6	1,7	41,5	54,8	2,1	5,0	5,6	8,05
	S_x	30,00	31,85	4,44	15,35	6,62	31,43	64,07	16.57	10,29	0,24	4,85	3,30	3,97	0,45	9,59	16,88	0,60	1,28	1,50	0,19
10	$\bar{x}$	75,4	68,3	12,6	42,8	15,4	68,9	106,1	93,7	35,4	0,5	17,3	14,8	2,8	1,0	17,1	22,10	1,44	3,2	3,8	7,9
	x_{min}	35,0	26,4	6,5	14,0	8,0	38,0	47,0	70.0	18,0	0,15	13,0	7,0	0,1	0,3	5,8	11,40	0,3	0,2	0,4	7,1
	x_{max}	119,0	110,0	21,5	69,0	26,0	119,0	210,0	131,0	53,0	0,90	21,0	22,0	12,2	2,7	33,5	36,55	2,1	5,7	7,2	8,7
	S_x	20,97	23,18	3,11	13,25	4,43	21,24	26,96	17,72	10,07	0,24	1,17	4,09	2,74	0,59	7,81	9,36	0,57	1,42	1,70	0,35

TABLE 5 : Continued

11	$\bar{X}$	42,6	10,7	1,6	39,8	24,0	18,0	38,4	14,70	11,4	0,2	33,8	5,8	0,3	0,1	2,1	2,58	0,30	0,2	0,4	8,3
	x_{min}	21,4	6,4	0,9	15,0	8,0	8,0	11,0	35,0	1,0	0,05	15,0	1,0	0,05	0,03	0,5	0,95	0,2	0,05	0,05	7,4
	x_{max}	41,5	14,0	5,7	52,0	30,0	27,0	49,0	189,0	18,0	0,4	41,0	15,0	1,0	0,2	3,9	4,03	0,5	0,7	0,8	8,7
	S_x	9,51	1,95	1,03	9,18	5,88	5,10	8,61	37,64	3,92	0,11	7,52	3,41	0,21	0,04	0,83	0,93	0,12	0,18	0,36	0,26
12	$\bar{x}$	68,7	57,3	10,4	44,1	17,9	59,4	92,6	103,2	29,5	0,5	19,3	13,6	1,6	0,6	13,1	15,79	1,24	2,5	2,9	8,1
	x_{min}	25,4	13,0	6,8	20,0	7,0	17,0	40,0	55,0	21,0	0,20	11,0	5,0	0,1	0,1	3,4	54,	0,0	0,1	0,2	7,5
	x_{max}	93,8	100,0	15,5	60,0	25,0	90,0	160,0	148,0	43,0	0,74	26,0	21,0	9,3	1,5	26,2	27,1	1,9	4,0	5,5	8,9
	S_x	17,05	20,59	1,99	10,12	4,45	18,28	30,23	23,29	70,45	0,18	3,64	4,06	2,47	0,36	5,55	7,30	0,54	1,10	1,30	1,00
13	$\bar{x}$	57,8	13,8	1,5	55,4	34,9	26,1	18,8	245,7	11,2	0,2	56,6	9,3	0,3	0,1	1,9	2,62	0,28	0,2	0,4	8,3
	x_{min}	41,6	9,0	0,6	36,0	19,0	21,0	12,0	139,0	5,0	0,05	38,0	3,0	0,1	0,1	0,7	1,1	0,0	0,2	0,2	7,9
	x_{max}	76,7	22,0	3,4	70,0	42,0	55,0	44,0	294,0	19,0	0,41	67,0	30,0	0,8	0,7	2,5	4,15	0,5	0,5	1,0	8,7
	S_x	7,05	3,21	0,67	7,46	5,84	6,84	6,18	41,13	3,04	0,11	7,22	7,24	0,18	0,13	0,77	0,82	0,15	0,12	0,27	0,19
14	$\bar{x}$	65,6	51,6	9,2	45,3	19,7	55,9	77,5	117,5	25,6	0,4	24,3	12,2	1,1	0,5	12,5	12,94	1,23	2,1	2,6	8,1
	x_{min}	41,0	28,0	6,0	33,0	14,0	34,0	25,0	85,0	12,0	0,20	15,0	7,0	0,1	0,1	6,1	8,6	0,3	0,2	0,2	7,6
	x_{max}	87,8	82,0	13,8	56,0	26,0	80,0	130	158,0	38,0	0,65	30,0	21,0	5,3	0,9	23,0	23,93	1,9	3,8	5,2	8,5
	S_x	13,38	15,91	1,94	7,93	4,01	13,59	26,34	20,91	7,40	0,16	3,19	3,71	1,35	0,22	4,67	5,72	0,42	1,06	1,18	0,25

TABLE 6 : Mean concentrations of the chemical constituents of the water at each station for each of the two years of the survey in mg/ℓ (upper value is for 1972/73 and the lower value for 1973/74).

Parameter	Station																		
	1	1A	2	3	4	5	6	6A	6P	7	7A	8	9	10	11	11A	12	13	14
Na	151	-	160	46	110	113	85	-	-	76	79	19	63	69	10	9	60	12	51
	170	42,0	170	64	129	127	86	28	21	68	75	17	65	68	11	-	55	15	52
K	25.9	-	25,9	7,9	17,4	18,0	14,3	-	-	14,6	15,4	3,6	11,5	13,0	1,3	1,9	10,5	1,5	9,2
	31,6	7,4	25,8	8,8	19,0	19,6	12,8	4,4	5,3	12,8	15,3	3,8	12,8	12,1	2,8	-	10,2	1,6	9,2
Ca	117	-	117	52	90	90	74	-	-	49	37	28	49	48	39	17	46	60	40
	85	68,0	106	58	84	84	63	35	33	40	35	24	44	38	38	-	42	51	43
Mg	22	-	22	24	32	30	27	-	-	17	12	12	19	17	26	11	19	38	21
	23	69,0	35	23	30	29	22	12	8	14	11	10	15	14	22	-	17	31	19
Cl	127	-	160	69	119	118	97	-	-	73	65	18	73	73	18	10	60	24	54
	135	96,0	162	93	135	129	94	45	28	63	64	18	67	65	18	-	59	28	58
SO_4	204	-	402	99	264	273	203	-	-	115	77	26	124	116	36	17	92	17	72
	242	102	398	93	284	284	117	41	36	101	77	33	105	96	41	-	93	21	83
NH_3-N	0,3	-	33,1	0,4	12,2	7,6	7,7	-	-	3,9	7,9	0,3	5,1	2,1	0,2	0;3	1,0	0,2	0,5
	0,4	0,8	40,2	1,3	23,0	19,5	7,9	0,5	0,4	4,6	7,7	0,5	7,6	3,4	0,3	-	2,2	0,3	1,6
NO_2-N	0,5	-	5,4	0,2	2,5	2,1	1,3	-	-	1,0	1,1	0,1	0,9	0,9	0,1	0,1	0,5	0,1	0,5
	0,4	0,1	4,2	0,3	3,2	2,5	1,3	0,1	0,1	1,1	1,2	0,1	1,0	1,0	0,1	-	0,6	0,1	0,4
NO_3-N	64,3	-	45,6	3,4	27,6	30,2	20,7	-	-	16,1	12,1	0,7	15,9	18,6	2,4	0,9	13,5	2,1	12,1
	61,3	2,7	41,5	3,2	26,8	28,1	21,0	2,0	0,5	13,2	10,0	0,7	17,0	15,5	2,1	-	12,6	1,7	12,8
Kjeldahl N	2,3	-	35,6	1,3	13,8	11,7	8,8	-	-	5,6	9,1	0,9	6,2	3,6	0,5	0,7	2,2	0,4	1,7
	2,7	1,3	52,5	2,9	28,0	24,7	9,5	1,5	1,5	5,6	8,6	1,4	8,2	4,6	1,0	-	3,4	1,0	2,6
PO_4-P	3,9	-	1,1	0,2	0,5	0,5	0,3	-	-	3,3	6,5	0,2	2,0	2,8	0,2	0,2	2,5	0,2	2,1
	3,4	0,2	1,0	0,2	0,6	0,6	0,3	0,1	0,1	3,5	7,1	0,5	3,1	3,6	0,4	-	2,4	0,2	2,1
Total P	4,4	-	1,1	0,2	0,7	0,6	0,4	-	-	4,0	7,6	0,3	2,3	3,5	0,2	0,2	2,7	0,2	2,2
	4,3	0,4	1,5	0,4	1,0	0,8	0,5	0,2	0,1	4,1	8,2	1,1	3,5	4,1	0,6	-	3,0	0,5	3,0

particularly chloride and sulphate values. The dilution and/or removal of these conservative elements down the course of the mainstream remained relatively consistent as can be seen from Table 7, which shows the relationship between the concentrations of these elements at the beginning and end of the river. Thus an increase in the concentration of, for example, sulphate at station 2 will result in a proportionate increase at station 14.

The summarized chemical data in Table 5 shows that the tributaries were considerably less mineralized than the mainstream of the system (stations 3, 8, 11 and 13).

The Jukskei River above the confluence with the Modderfontein stream was more mineralized than the Klein Jukskei, Crocodile and Hennops Rivers. Thus the section of the river immediately below this confluence was not appreciably diluted and shows high concentrations of all the mineral parameters measured.

The Braamfontein and Sandfontein streams were not heavily mineralized although the mean chloride value of the former (station 6A) was higher than that of the other tributaries. These two streams tended to dilute the mineral concentrations of the main stream at their confluence with it, as is clearly evident from a comparison of the data for stations 5 and 6.

The mineral concentrations in the effluent discharged by the Northern Sewage Works (station 7A) did not differ greatly from that of the Jukskei River at the point where these effluents entered it. Thus little change occurred in the mineral concentrations in this reach of the river.

Table 7: Relationship between the concentrations of conservative minerals in the upper and lower reaches of the system shown by the percentage of the station 2 concentrations found at station 14 . Values are given for the upper, middle and lower ranges of concentrations of each parameter measured at station 2 (mg/ℓ).
(n = the number of samples in a range of concentrations)

Parameter	Concentration Range at station 2	Concentration Range at station 14	n	Mean Percentage
Na	200-240	69-82	5	35,4
	160-200	38-71	7	30,9
	100-160	32-50	9	28,2
K	29-34	8-13	6	34,6
	25-28	8-13	6	37,6
	20-25	6-11	8	36,3
Ca	120-200	33-62	6	35,0
	100-110	36-54	10	45,1
	89-99	33-47	5	41,0
Mg	40-44	15-26	6	49,1
	36-40	17-26	7	58,4
	28-33	10-22	8	59,7
Cl	180-230	54-76	7	34,3
	140-180	37-67	9	32,9
	125-140	34-56	4	33,6
SO_4	410-540	67-130	9	19,0
	350-400	30-100	7	18,9
	300-340	25-100	5	18,9

The Klein Jukskei, Crocodile and Hennops Rivers were not appreciably mineralized and diluted the main stream. This resulted in a progressive improvement in mineral conditions as the main stream approached the Hartbeespoort Dam. The only exception to this were magnesium concentrations which tended to be relatively high in these tributaries, particularly the Hennops River. This explained why a decrease in the magnesium concentrations in the Modderfontein stream was not necessarily accompanied by lower concentration levels at the lower end of the river (Table 8). However the fact that increased magnesium concentrations in the upper reaches lower the station 2:station 14 ratio suggested that these sources (the tributaries) are relatively constant.

There were no apparent significant differences in any of the mineral parameters measured between the two years of study (Table 6). Thus although monthly or seasonal variations occurred there was no marked change in the addition of mineral elements to the system during the survey.

Trophic status

Concentrations of the various nitrogen forms have been extracted from the raw data to show the summer and winter means for the mainstream stations (Table 9).

The Modderfontein stream showed the highest concentrations of all the nitrogen forms in the river system. There was a massive increase in the total dissolved nitrogen concentration between station 1A and station 1 due to nitrate nitrogen only. This was due to the power station effluent which entered the stream at this point. The total dissolved nitrogen concentrations increased by about half as much again between stations 1 and 2 but in this case the increase was mostly due to ammonia and nitrite nitrogen

TABLE 8 : Magnesium concentrations in the Modderfontein stream at station 2 and the lower reach of the system at station 14, showing that concentration entering Hartbeespoort Dam are not entirely dependant on those in the upper reach of the system. (mg/l).

Month	Station			
	2		14	
	1972/73	1973/74	1972/73	1973/74
March	-	28	22	14
April	37	28	22	-
May	37	31	23	22
June	40	33	26	21
July	39	33	26	22
August	44	37	23	22
September	40	32	24	18
October	38	38	17	21
November	36	41	22	15
December	33	40	10	16
January	30	42	17	17
February	30	38	16	-

TABLE 9 : Mean concentrations (mg/ℓ) of the various forms of nitrogen for the summer and winter periods at all the mainstream stations in downstream order.

Station	Total dissolved nitrogen		NH_3-N		NO_3-N		NO_2-N	
	s	w	s	w	s	w	s	w
1A	5,20	2,26	0,94	0,40	3,68	1,06	0,12	0,06
1	43,65	63,88	0,33	0,38	40,61	60,90	0,42	0,47
2	76,5	88,77	32,33	38,4	30,80	45,43	5,79	3,38
4	38,73	58,69	15,66	19,81	18,08	32,7	3,08	2,23
5	35,67	56,07	11,20	17,64	17,23	37,13	2,66	1,91
6	19,22	40,88	4,64	11,07	8,17	24,58	1,28	1,27
9	14,18	31,62	4,14	8,74	8,58	20,91	0,85	1,02
7	13,58	25,43	2,27	6,27	10,29	16,83	1,12	0,99
10	16,07	25,51	1,38	4,27	12,39	19,09	0,98	0,91
12	13,68	17,88	1,03	2,05	10,61	14,44	0,53	0,55
14	11,28	17,03	0,79	1,41	9,05	14,29	0,41	0,36

from an industrial effluent. Thus the total nitrogen concentration rose from between 2 and 6 mg/ℓ at station 1A to between 70 and 90 mg/ℓ at station 2.

The influence of this addition of nitrogenous compounds to the system carried on into the Jukskei River and the total dissolved nitrogen concentration remained very high as far as station 5 in the summer. Thereafter the diluting effect of the tributaries became noticeable. In winter when there was naturally less dilution this decrease in concentration was not as marked. The total nitrogen concentrations at station 14 were between two and ten times greater than they were in the "natural" tributaries or prior to the addition of nitrogen rich effluents. Thus, notwithstanding the dilution factor, the high concentrations in the upper reaches result in "above normal" concentrations of nitrogenous compounds in the whole main stream. This is shown by the fact that the total nitrogen concentrations at station 14 were between two and ten times greater than they were in the "natural" tributaries or prior to the addition of nitrogen rich effluents.

It appears that the NH_3 and NO_2 nitrogen compounds were nitrified and mineralized down the Jukskei River as nitrate concentrations were higher at station 5 than at station 4.

Between stations 6 and 10 there was an increase in the concentration of some of the nitrogenous compounds, particularly nitrates, in the river. This shows that the sewage effluent, entering the river system immediately above station 7, was nitrogen rich. The concentration in this effluent was very much lower than that in the Modderfontein stream. The fact that this increased concentration was very much greater in summer and that during this season it became apparent at station 9 suggests that the sewage bypass stream, which joined the river immediately above this station, was operational during peak flow periods. This effluent also appeared to be richer in nitrogenous compounds than that of the main sewage outfall at station 7.

The other streams in the system i.e. the Jukskei River above the Modderfontein stream, the Sandfontein and Braamfontein streams, the Klein Jukskei River, the Crocodile River above its confluence with the Jukskei River and the Hennops River, were relatively unpolluted by nitrogenous compounds.

The basic patterns of nitrogen enrichment remained similar in both years of the survey with one exception. The ammonia concentrations in the upper reaches of the system (stations 2, 4 and 5) apparently increased considerably during 1973/74 as can be seen in the NH_3-N and Kjeldahl nitrogen data in Table 6. Table 9 shows that this apparent increase was due to unnaturally low concentrations (particularly at stations 4 and 5) between September 1972 and February 1973 which lowered the 1972/73 annual mean. The immediate inference is that dilution by floodwaters was far greater during this period. However Table 16 shows that flow exceeded the normal at these stations to a far greater degree in the second year of the survey. This plus the fact that stations further downstream did not show such dilution makes flow an unlikely cause of this change in conditions. The high concentrations at station 2 relative to the other two stations during this period (Table 10) indicate that this condition was not caused by a decrease in the addition of ammonia rich effluent. The reason for this exception to the normal nitrogenous pattern is thus not obvious from the available data.

TABLE 10 : Ammonia concentrations at stations 2, 4 and 5 over the whole study period showing the average concentration for each year in mg/ℓ.

Month	Station		
	2	4	5
March 1972	N/D	19,0	6,0
April	38,5	17,2	11,2
May	36,0	15,0	15,0
June	29,6	15,2	12,5
July	N/D	N/D	N/D
August	N/D	26,0	N/D
September	43,5	0,1	0,1
October	42,0	2,5	2,5
November	31,0	21,0	17,2
December	25,0	4,1	1,2
January 1973	23,0	8,1	4,1
February	26,6	6,0	6,0
Mean	33,1	12,2	7,6
March	30,0	8,8	16,0
April	37,0	21,5	16,6
May	35,0	20,6	18,4
June	30,0	27,5	29,0
July	46,0	33,0	32,0
August	N/D	N/D	N/D
September	45,0	22,0	24,0
October	40,0	19,9	9,8
November	48,0	31,0	20,0
December	36,0	21,0	17,0
January 1974	25,0	26,5	12,6
February	29,0	20,0	18,4
Mean	40,2	23,0	19,5

There were three point sources of phosphate rich effluent in the system, although all ultimately derived from the sewage treatment plant. Firstly, there was a marked increase in PO_4-P and total phosphorus concentrations between station 1A and station 1 showing the power station effluent, which was basically treated sewage effluent used in the cooling towers, to be rich in phosphates. This was however largely removed from the system in the dams between stations 1 and 2 as can be seen in Tables 5 and 6. However, at station 2 which was immediately below these dams the phosphate concentration was still higher than it was prior to the addition of this effluent. Biological purification and dilution reduced this concentration to levels similar to those of station 1A further downstream. Thus before the addition of the next source of phosphate rich effluent, concentrations were once again in the region of 0,3 mg/ℓ.

The second source of phosphate in this system occurred between stations 6 and 9 where the sewage works bypass stream entered the Jukskei River. The concentrations for this station show that use of this bypass was not constant and peak flows from it appearred to occur in the summer months (Table 11).

The main outfall stream from the sewage works entered just above station 7. Thus peak phosphate concentrations in the main stream were at station 7. The highest values recorded occurred in the outfall stream itself at station 7A. The main stream from this point to the Hartbeespoort Dam showed the influence of this source of phosphorus. Thus, although dilution and biological removal of phosphates reduced the concentration by approximately half, the concentrations of phosphorus entering the dam were considerably higher than the "natural concentrations" of the tributaries.

TABLE 11 : Phosphorus concentrations at stations 6 and 9 to show the varying influence of the bypass stream from the sewage works on the Jukskei River. (mg/l)

Month	1972/73		1973/74	
	Station 6	Station 9	Station 6	Station 9
March	0,1	1,0	0,2	3,7
April	0,1	4,1	0,4	1,0
May	0,5	2,6	0,2	3,1
June	0,4	2,2	0,5	4,3
July	0,5	3,0	1,2	4,6
August	0,4	2,3	1,1	5,5
September	0,9	3,9	0,8	5,6
October	1,0	0,4	0,5	1,7
November	0,2	3,1	0,1	4,4
December	0,1	0,2	0,3	2,3
January	0,2	2,7	0,2	4,1
February	0,2	1,5	0,4	2,2

None of the tributaries contributed significant concentrations of phosphorus to the system.

In general the Modderfontein stream and the effluent outfall stream at station 7A were the most eutrophied regions in the system. Their influence was seen in the mainstream below their points of confluence with it.

Organic status

The degree of organic pollution was indicated by the amount of readily oxidizable material present in the stream. The COD value is related to organic pollution but is also affected by inorganic oxygen demand (van Steenderen, 1975). However van Steenderen (1975) showed that the total organic carbon values, taken in conjunction with COD, indicates the degree of pollution due to organic material.

Table 12 gives the COD and TOC values for all stations in the system while the average values for each station can be seen in Table 5.

The fact that stations 3, 8, 11 and 13 were characterized by consistently low TOC values (an average of 9,2 mg/ℓ), in conjunction with relatively low COD values when compared with the mainstream stations which showed mean TOC values of between 12 and 20 mg/ℓ suggested that the mainstream was subject to some organic pollution.

The highest values for both COD and TOC were apparently associated with effluents entering the system between stations 1A and 2 and at station 7A.

The COD values at station 2 however fluctuated considerably although both TOC and TIC remained relatively stable (Fig. 4). Van Steenderen (pers.

Table 12: Total Organic Carbon (TOC) and Chemical Oxygen Demand (COD) values (mg/dm^3) for all stations from March 1972 to February 1974.

Station	Parameter	Month																							
		Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	COD	29	30	32	31	65	-	25	46	48	64	44	40	39	35	56	-	47	60	53	36	58	36	36	47
	TOC	12	12	17	-	15	15	16	18	11	17	16	-	14	12	19	-	16	24	18	12	20	14	12	17
2	COD	-	37	42	42	69	-	48	58	56	62	43	50	48	41	41	-	54	71	68	64	49	37	37	65
	TOC	-	12	15	29	27	19	18	20	13	15	14	-	16	24	23	-	19	24	26	28	17	18	18	22
3*	COD	13	17	17	20	29	-	51	30	29	31	18	21	38	21	23	-	24	34	32	27	23	18	20	28
	TOC	6	0	11	39	16	9	12	12	9	8	10	10	18	9	11	-	11	16	16	12	14	7	9	13
4	COD	22	27	25	27	60	-	29	31	50	37	30	29	37	31	34	-	46	63	64	59	43	30	32	59
	TOC	9	12	15	26	23	12	20	13	12	9	13	-	15	13	20	-	19	26	25	16	18	12	15	24
5	COD	28	26	26	27	62	-	48	30	51	31	31	33	40	29	35	-	47	58	66	34	43	27	28	57
	TOC	6	10	15	26	23	15	19	16	12	13	15	-	16	11	14	-	21	22	28	13	17	11	11	15
6	COD	29	20	22	14	48	-	42	36	42	32	28	25	22	22	26	-	33	51	50	29	37	21	20	52
	TOC	8	8	13	20	17	11	16	16	12	11	14	-	9	10	12	-	20	21	30	12	15	8	8	16
6A*	COD	-	-	-	-	-	-	-	-	-	-	-	-	-	17	12	-	19	21	25	25	19	22	15	27
	TOC	-	-	-	-	-	-	-	-	-	-	-	-	-	15	15	-	16	10	21	20	20	17	17	13
6B*	COD	-	-	-	-	-	-	-	-	-	-	-	-	-	24	17	-	19	31	32	28	22	37	17	25
	TOC	-	-	-	-	-	-	-	-	-	-	-	-	-	10	10	-	8	15	16	17	8	15	10	11
8*	COD	8	13	13	29	18	-	22	24	21	32	15	16	14	18	8	-	16	18	25	26	20	16	15	30
	TOC	7	8	8	14	9	5	12	11	10	11	13	-	7	10	13	-	7	9	11	12	9	10	7	16
9	COD	16	31	36	33	49	-	42	32	43	30	52	23	36	24	32	47	39	49	54	36	34	26	22	45
	TOC	7	16	16	19	15	15	19	16	14	12	15	-	15	10	13	20	18	19	25	18	18	10	8	18
7	COD	-	-	28	33	49	-	45	39	43	33	36	32	36	32	32	-	38	48	51	32	33	26	22	45
	TOC	-	-	16	22	18	15	19	17	14	13	17	-	16	14	12	-	17	21	24	14	14	11	10	20
7A*	COD	-	-	32	40	50	-	47	-	51	-	35	36	-	-	40	-	44	54	54	-	45	35	29	50
	TOC	-	-	18	28	20	16	20	-	19	-	18	-	-	-	19	-	22	26	25	-	20	17	14	24

-/ Table 12 cont.

Table 12 continued:

Station	Parameter	Month																							
		Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb
10	COD	21	25	26	18	47	-	43	37	41	38	47	28	28	29	34	47	41	53	49	34	38	25	23	44
	TOC	7	14	16	22	14	17	18	16	12	15	18	9	11	12	14	19	19	22	20	14	12	10	9	18
11*	COD	7	8	7	17	8	-	13	8	11	16	8	7	8	22	8	8	10	12	13	12	10	14	10	10
	TOC	1	7	6	15	4	5	6	7	4	5	7	3	2	10	6	7	7	8	8	7	6	8	8	7
12	COD	-	25	21	23	41	-	37	30	37	28	25	22	26	24	30	37	32	37	43	38	25	22	20	31
	TOC	-	5	13	21	14	15	17	14	12	10	16	13	12	10	12	15	13	18	20	20	10	9	8	13
13*	COD	5	6	7	9	10	-	11	8	11	11	7	9	8	14	8	8	10	14	14	13	10	11	10	[illegible]
	TOC	4	12	7	30	7	3	9	11	8	3	6	12	7	11	6	10	8	8	10	15	8	9	9	[illegible]
14	COD	12	16	18	21	33	-	33	32	31	30	21	19	22	-	32	34	32	20	38	29	22	19	18	[illegible]
	TOC	7	9	13	21	11	15	14	14	9	10	13	10	10	-	15	15	18	9	10	14	10	9	8	[illegible]

* = Stations situated on tributaries.

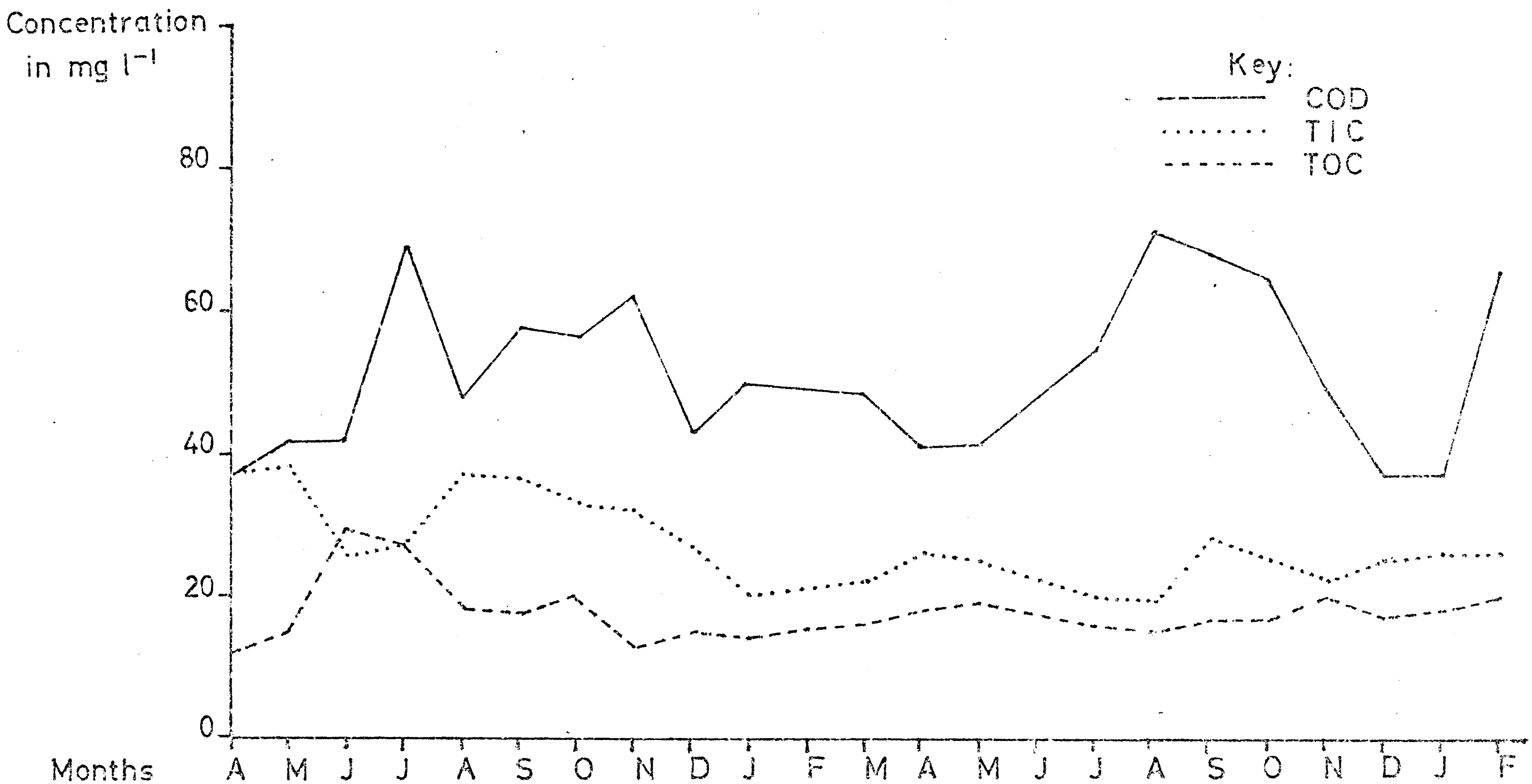


Fig. 4: A comparison of COD, TIC and TOC concentrations from April 1972 to February 1974 at station 2.

comm.) suggested that this was probably due to some substance such as halides, plastics, heavy metals etc. which had no effect on either TIC or TOC but affected COD analysis values.

Table 12 suggests that there was a considerable deterioration in water quality due to organic matter at all stations in the main stream during the winter months. The fact that the tributaries did not show this winter increase in organic pollution to the same degree indicated that the effluents entering the main stream were probably more responsible for this state than were natural factors.

The mean COD and TOC values in the mainstream tended to be very consistent (except at the effluent point sources mentioned above) so there was no apparent improvement in the state of organic pollution down the length of the river.

In general the COD values did not suggest excessive organic pollution anywhere in the system. This impression is gained from the fact that the highest values for the system were approximately 50 mg/ℓ as compared with values of between 10 and 20 mg/ℓ in the tributaries (Fig. 5). However, the fact that the TOC in the tributaries was very much lower than in the mainstream (Table 5) and that the TOC sometimes exceeded the COD values indicated a considerable amount of readily oxidizable matter in the system. This suggested that the state of organic pollution, although not severe, was worse than is suggested by the COD values.

pH status

The mean pH values are based on the mean hydrogen ion concentration and normally varied between 7,5 and 8,5 units with the highest values measured in the upper region of the Modderfontein stream. No acid pollution occurred in this system during the study period. The $CO_2-HCO_3^{-}-CO_3^{=}$ buffer system operated in this river system as indicated by pH, alkalinity and calcium values.

The pH values for the system are shown in Table 13.

Water temperature

Table 14 reflects the mean day-time temperatures for the summer and winter periods.

The seasonal variation in temperature was not great relative to that seen in north-temparate zones where extremes are experienced nor was it constantly extreme such as in the tropical or sub-arctic zones. Influences on the environment caused by temperature changes such as increased viscosity at low temperatures and increased pollutional effects at high temperatures (Hynes, 1970), were minimal in this system. This is particularly pertinent where, as in the case here, temperature changes occur slowly. Sudden changes in temperature are far more detrimental to the biota.

An exception to these conditions occurred at station 1 where a heated effluent raised the mean temperature by about 3 °C in both summer and winter (Table 14). However Table 15 shows that the differences in temperature between stations 1 and 2 varied considerably suggesting that the temperature of the effluent was variable. Thus there was sometimes little difference in temperature and sometimes as much as 10 °C difference. It is therefore likely that the Modderfontein stream at station 1 was subjected to sudden and large fluctuations in temperature.

TABLE 13 : Mean pH (based on mean $[H^+]$) at the different sampling stations in the system

Station	Mean pH	
	1972/73	1973/74
1	9,1	8,5
2	7,8	7,6
3	8,1	8,3
4	7,8	7,7
5	7,8	7,9
6	7,9	7,7
6A	-	8,2
6B	-	8,0
7	8,0	7,8
7A	7,9	8,0
8	8,2	7,7
9	7,7	7,5
10	8,0	7,7
11	8,3	8,0
12	8,3	7,9
13	8,4	8,3
14	8,2	8,0

TABLE 14 : Mean summer and winter temperatures (°C) for all stations during the study period, based on day-time readings taken on each sampling date.

Station	Mean summer	Mean winter
1	23,4	16,3
1A	20,4	13,4
2	21,3	12,5
3	19,5	10,4
4	19,8	11,4
5	19,1	10,6
6	20,3	12,3
6A	19,8	11,1
6B	19,6	9,7
7	21,5	13,2
7A	21,9	14,7
8	21,5	12,2
9	20,8	13,0
10	21,0	12,9
11	21,0	11,7
11A	20,7	10,7
12	21,2	12,7
13	20,1	11,7
14	21,2	12,6

TABLE 15 : Differences in water temperatures between stations 1 and 2 for March 1974 to February 1975, as an example of the influence of heated effluent.

Month	Temperature (°C)		
	Station 1	Station 2	Difference
March 1974	26,9	22,8	+ 4,1
April	23,8	17,9	+ 5,9
May	21,9	14,3	+ 7,6
June	20,8	10,2	+10,6
July	21,2	10,9	+10,3
August	19,1	11,7	+ 7,4
September	24,0	19,4	+ 4,6
October	24,7	19,9	+ 4,8
November	27,4	21,6	+ 5,8
December	25,2	24,2	+ 1,0
January 1975	23,7	22,3	+ 1,4
February	24,0	21,8	+ 2,2

River flow

The flow contribution of the various tributaries is given in Table 16. The normalized flow data (see methods) for each station, for which flow figures were available, are presented in Table 17. The data in this table allow the deviations of the flow at each station away from the mean (4,17 - see Methods p. 25) to be compared in a standard manner.

Although flows in the whole system were below average between June and September of both years, at no time did flow cease resulting in a break in flow and subsequent recolonization which would temporarily change the faunal composition (Hynes, 1958, Harrison, 1966).

Above average flows were recorded in most of the system during the summer months, particularly from October to February, although March 1972 was also a high flow period. Flows in the second summer of the study (October 1973 to February 1974) were very much greater than in the first.

Station 13 on the Hennops River appeared to be more subject to flood conditions than any other section of the river as this was the only station where the deviation from the normal frequently exceeded 10 units.

The greatest single increase in flow above normal was recorded at station 4 in December 1973.

Slightly above normal flow is unlikely to impose stress conditions on a biological community. Those parts of the river which normally carried the greatest quantity of water e.g. stations 10 and 14, seldom experienced excessive deviations from the normal. Alternatively the smaller tributaries were far more subject to flooding. This is shown by the fact that all values above eight units occurred in the upper reach of the mainstream or in the tributaries.

TABLE 16 : Flow contribution (10^9 ℓ/yr) to the Jukskei-Crocodile River system by various rivers (bottom value represents the percentage contribution to the total flow in the river system)

Period	Total flow	Jukskei River above Modderfontein	Modderfontein Spruit	Braamfontein and Sandfontein streams*	Klein Jukskei River	Northern Sewage Works**	Crocodile River	Hennops River	Unaccounted sources
1972/73	66,632 plus flow of Hennops River	8,539	6,402	8,609	6,486	23,46	13,672	ND	
1973/74	94,265	11,921 (12,6)	8,451 (9,0)	11,272 (12,0)	7,114 (7,5)	27,83 (29,5)	14,995 (15,9)	12,62 (13,4)	0,06 (0,1)

* Difference in flow between stations 6 and 5. These streams are the main tributaries in this area.

** Estimated by the flow at station 10 minus the flows at stations 8 and 6.

TABLE 17 : Normalized flow data for the Jukskei-Crocodile River system. (Upper figure represents 1972/73 and lower figure 1973/74)

Month	Station									
	1	2	4	6	9	7A	10	11	13	14
March	5,31	-	5,78	8,01	7,01	6,18	6,69	7,17	14,00	7,28
	3,15	4,04	3,17	4,48	5,55	4,98	5,49	4,57	14,14	6,33
April	4,23	2,75	2,61	2,96	2,80	4,52	3,23	3,48	6,40	3,79
	4,13	4,76	4,09	5,93	6,29	7,65	6,48	7,73	11,08	-
May	4,12	2,95	1,84	2,18	2,07	5,20	2,75	2,91	5,37	3,11
	3,38	6,21	1,51	1,46	1,81	4,36	2,60	3,35	3,19	2,48
June	4,04	3,03	1,95	1,84	1,92	5,00	2,47	5,00	3,55	2,81
	4,09	3,73	1,46	1,43	1,80	3,91	2,47	3,31	2,73	2,41
July	2,43	2,95	1,94	2,02	1,89	4,48	2,55	5,03	3,42	2,83
	4,22	3,31	2,03	1,70	1,99	1,69	2,41	3,68	-	2,45
August	3,58	3,13	1,96	1,98	2,00	4,09	2,40	4,07	2,58	2,53
	3,58	2,95	2,18	2,54	2,43	2,50	2,60	3,10	-	2,47
September	3,46	5,75	1,51	1,39	1,50	3,15	1,95	2,46	2,61	1,91
	4,26	3,18	2,90	3,09	4,19	6,94	3,35	2,08	-	3,05
October	4,22	4,91	2,87	3,86	3,42	-	3,64	2,58	5,13	3,34
	8,53	9,92	5,57	6,39	5,85	-	5,26	3,70	-	5,13
November	-	-	5,02	5,97	5,99	4,81	5,80	3,35	10,08	5,46
	6,03	5,84	7,42	8,75	7,30	2,37	5,99	2,82	-	5,13
December	-	-	5,24	4,72	7,26	-	5,85	1,34	5,92	3,40
	8,23	9,78	18,52	7,83	6,86	2,65	6,35	6,86	-	6,59
January	4,22	4,87	3,88	3,28	3,14	4,18	3,48	2,34	5,08	2,93
	6,81	4,90	8,89	6,66	6,23	2,98	5,50	8,59	-	6,03
February	3,24	3,01	2,97	4,24	3,47	3,97	3,45	2,08	4,52	2,90
	4,77	4,72	4,68	7,27	7,35	3,08	7,23	8,40	-	6,81

The flow in the lower regions of the Modderfontein stream (station 2) and the outfall stream at station 7A was normally relatively constant due to stabilization by maturation dams on these streams. The normalized flow figures at these two stations never dropped below 2 units and seldom rose above 6 units i.e. an approximate variation of 2 units from the normal. However exceptions to the above average flows, particularly at station 2 suggest that under extreme flood conditions complete flow control by these dams was not possible. Thus under these conditions the retention times of these ponds must have been decreased.

Solids in suspension

Chutter (1968) showed that sand and silt can have a great influence on the invertebrate fauna as they tend to smother biotopes.

The maximum, minimum and mean values for the solids in suspension are given in Table 18. From this data it is apparent that the mainstream stations below station 6 are subject to the highest loads while the tributaries, particularly the Hennops and Crocodile rivers tended to be very clear. In general the quantities of solids in suspension were greater in the 1973/74 year, particularly in the tributaries. This correlates with the fact that flows exceeded average levels to a greater degree in this year (Table 17).

The effects of the increased flows were most obvious in the tributaries. This correlation agrees with the personally observed fact that only during flood periods was the river excessively turbid.

The mainstream stations in the middle and lower reaches of the river show an apparent anomaly as the values were higher in the first year. However

TABLE 18 : Solids in suspension (mg/ℓ) data for the Jukskei-Crocodile River system. (1973/74 data in brackets)

Station	Average	Minimum	Maximum
1	77,5 (182,6)	18,0 (24,6)	132,0 (451,8)
2	51,9 (40,3)	11,0 (6,0)	148,0 (102,5)
3	66,1 (23,1)	1,0 (2,1)	231,0 (109,5)
4	69,2 (29,3)	6,0 (1,6)	330,0 (89,3)
5	122,2 (66,1)	6,0 (3,2)	537,0 (188,9)
6	98,9 (57,8)	19,0 (3,0)	380,0 (194,7)
6A	- (11,0)	- (0,9)	- (57,1)
6B	- (39,3)	- (3,0)	- (107,1)
7	170,9 (260,3)	36,0 (13,3)	1051,0 (1408,1)
7A	37,6 (282,9)	25,0 (5,5)	49,0 (1515,7)
8	46,1 (111,3)	1,0 (8,7)	117,0 (411,7)
9	179,6 (125,9)	41,0 (21,3)	674,0 (365,1)
10	153,4 (106,9)	18,0 (5,3)	1031,0 (285,9)
11	18,4 (100,1)	5,0 (0,6)	82,0 (555,0)
12	179,5 (107,2)	25,0 (3,0)	1206,0 (259,7)
13	17,6 (37,8)	0,0 (1,7)	41,0 (112,0)
14	110,8 (69,7)	15,0 (12,1)	621,0 (186,5)

Table 19 shows the monthly values for these stations which indicate that these high values were due to a single reading in December 1972. The averages for these stations without this figure were very much lower than those for the 1973/74 period which thus agrees with the observations made in the tributaries.

These high values for solids in suspension in December 1972 were first seen at station 9 and reached a peak at station 7 further downstream. This does not appear, from the flow data, to coincide with a flood period. The fact that this increase was not evident at stations 7A or 8 suggests that neither the sewage treatment plant nor the Klein Jukskei River brought this load into the river.

On the other hand, in September 1973 there was a similar massive increase in the load of solids in suspension at stations 7 and 7A. This coincided with the highest flow recorded on this outfall stream i.e. well above normal flow. This was a period when no other part of the system exhibited flood conditions (Table 17). It may be inferred from this that the normal practice of the sewage works management to stabilize flows through the maturation dams failed for some or other reason. Exclusion of this figure from the mean gives an average value of 36,4 mg/ℓ for station 7A in 1973/74 which was similar to the average of 37,6 mg/ℓ the previous year. The chemical constituents associated with sewage effluent and the fauna present at this time will be examined under station 7A the section on the faunal associations of individual stations (p. 184).

CHEMICAL CHARACTERIZATION OF STATIONS

Each of the parameters measured have been divided into five categories as follows:

TABLE 19 : Monthly solids in suspension values (mg/ℓ) for the main stream stations of the middle and lower reaches of the system.

Month	Station					
	6	9	7	10	12	14
March 1972	N/D	N/D	N/D	N/D	N/D	N/D
April	N/D	N/D	N/D		N/D	N/D
May	21	48	52	34	50	36
June	33	41	39	27	26	15
July	31	60	34	43	25	25
August	24	109	46	70	52	38
September	19	44	54	39	35	N/D
October	207	391	162	107	212	40
November	62	93	36	91	50	35
December	380	674	1051	1031	1206	621
January 1973	90	156	59	74	99	130
February	122	180	64	18	40	57
March	88	156	153	158	124	100
April	133	172	177	194	204	N/D
May	7	73	43	29	20	49
June	3	36	14	10	3	16
July	6	27	18	14	12	26
August	10	22	29	6	19	12
September	8	57	1408	41	N/D	53
October	195	365	299	286	260	116
November	72	229	203	226	216	187
December	N/D	N/D	N/D	N/D	N/D	N/D
January 1974	N/D	N/D	N/D	N/D	N/D	N/D
February	N/D	N/D	N/D	N/D	N/D	N/D

A - very high for the system

B - high

C - average for the system

D - low

E. - very low

This has been done to avoid placing too much significance on small changes in a parameter. For instance, using sodium as an example, if a value appeared to be excessively high compared to other values at the same station, undue importance may be placed on this value even if it is low compared to other stations in the system. The values indicated by the symbol for each parameter are given in Table 20. Note must be taken of maxima and minima for the system because a value that is low for this system may be high when compared with another river.

The categorization of environmental parameters facilitates the classification of each station by showing immediately which stations were subjected to high concentrations of specific pollutants. For example, station 1A showed a very high degree of mineral enrichment with low nitrogen and phosphorus concentrations as opposed to station 2 which showed a high degree of enrichment by both mineral substances and nitrogenous compounds but relatively low phosphorus concentrations.

The characterization of all stations on this basis is given in Table 21. This table is based on the running averages for these stations (see p. 24) but note has been taken of the maxima and minima in table 5 so that the occurrence of extreme conditions was not neglected.

TABLE 20 : Concentrations of chemical constituents representative of categories A to E for the characterization of stations. (mg/ℓ) except for conductivity and pH)

Parameter	Category				
	A	B	C	D	E
pH	9,1+	8,1-9,0	7,5-8,0	7,3-7,5	7,0-7,2
Conductivity (mSm^{-1})	1881-2300	1461-1880	1041-1460	621-1040	200-620
Na	177-220	133-176	89-132	45-88	0-44
K	24,1-30,0	18,1-24,0	12,1-18,0	6,1-12,0	0-6,0
Ca	108,1-135,0	81,1-108,0	54,1-81,0	27,1-54,0	0-27,0
Mg	34,1-40,1	27,1-34,0	20,1-27,0	13,1-20,0	6,0-13,0
Cl	165-205	124-164	83-123	42-82	0,41
SO_4	401-500	301-400	201-300	101-200	0-100
Alkalinity	173-200	145-172	117-144	89-116	60-88
MBAS	0,81-1,00	0,61-0,80	0,41-0,60	0,21-0,40	0-0,2
COD	56,1-70,0	42,1-56,0	28,1-42,0	14,1-28,0	0-14
Inorganic carbon	56,1-70,0	42,1-56,0	28,1-42,0	14,1-28,0	0-14
Organic carbon	32,1-40,0	24,1-32,0	16,1-24,0	8,1-16,0	0-8,0
NH_3-N	40,1-50,0	30,1-40,0	20,1-30,0	10,1-20,0	0-10,0
NO_3-N	48,1-61,0	36,1-48,0	24,1-36,0	12,1-24,0	0-12,0
NO_2-N	8,1-10,0	6,1-8,0	4,1-6,0	2,1-4,0	0-2,0
Dissolved inorganic N	80,1-100,0	60,1-80,0	40,1-60,0	20,1-40,0	0-20
Dissolved organic N	10,1-12,5	7,6-10,0	5,1-7,5	2,6-5,0	0-2,5
PO_4-P	8,1-10,0	6,1-8,0	4,1-6,0	2,1-4,0	0-2,0
Total P	8,1-10,0	6,1-8,0	4,1-6,0	2,1-4,0	0-2,0

BIOTIC INDEX

Biotic Index Values (BIV) for all stations throughout the period of the survey are presented graphically in the Appendix (Figures A1 - A8). Figures A1 to A 5 show the montnly change in BIV for each station and Figures A 6 to A 8 show the change in BIV down the mainstream of the river, and indicate incoming tributaries, for each month.

Tables showing the percentage composition of the fauna at each station are also presented in the Appendix (Tables A1 - A17).

A general picture of conditions at the different sampling points on the basis of BIV is shown by the average values for each station presented in Table 22. The average values for each month for the whole river system showing seasonal BIV variation, are presented in Table 23.

Based on the assumption that the empirical biotic index reflects the biological oxygen demand (BOD) of a sampling site (Chutter, 1972), these results suggest a clearly defined picture of contamination by organic material in the system. The Crocodile River was very slightly enriched, probably as a result of the natural occurrences of organic matter while the Klein Jukskei and Hennops rivers were, as indicated by Table 22, more enriched but not to a significant degree. The fact that the average TOC values (see chemical analysis) also indicated that there is far less readily oxidizable material in the Crocodile River than in the Hennops or Klein Jukskei rivers confirms the degree of difference in these "clean water" tributaries.

Reference to Table 11 shows that these three rivers were all subjected to occasional anamolous increases in the TOC values although these never

TABLE 21 : Characterization of stations according to the categories shown in Table 20.

Parameter	Station																	
	1A	2	3	4	5	6	6A	6B	7	7A	8	9	10	11	11A	12	13	14
Conductivity	C	AB	D	A–D	A–D	CD	E	E	DE	D	E	CDE	DE	E	E	DE	DE	DE
pH	CD	BC	BC	C	C	C	B	B	BC	BC	BC	C	C	B	CD	BC	B	BC
Na	DE	AB	D	BC	A–D	CD	E	E	DE	D	E	CDE	DE	E	E	CDE	E	DE
K	D	AB	D	A–D	A–D	CD	E	E	CDE	C	E	CDE	CD	E	E	CD	E	CD
Ca	C	AB	CD	BC	BC	CD	DE	DE	DE	D	DE	CD	CDE	DE	E	CDE	CD	CD
Mg	A+	AB	BCD	ABC	A–D	BCD	DE	E	DE	DE	DE	CDE	DE	BCD	E	CDE	ABC	CDE
Cl	CD	AB	BCD	AB	A–D	BCD	DE	E	D	D	E	CDE	CE	E	E	CDE	DE	DE
SO_4	DE	AB	DE	BC	A–D	CD	E	E	DE	E	E	CDE	DE	E	E	DE	E	DE
Alkalinity	A+	BCD	A–D	BC	B–E	DE	CD	CDE	D	BCD	CDE	DE	DE	A–E	DE	CDE	ABC	BCD
COD	CD	ABC	CD	BC	BCD	CD	D	D	BC	BC	DE	CD	BCD	E	DE	CD	E	CD
MBAS	–	ABC	DE	BC	BCD	BCD	–	–	BC	AB	DE	BCD	BCD	DE	DE	BCD	BCD	CD
Inorganic carbon	–	CD	CD	CD	D	D	–	–	D	D	CDE	D	D	C	DE	DE	DE	CDE
Organic carbon	–	CD	CDE	CD	DE	D	–	–	BC	C	DE	C	CDE	DE	DE	DE	DE	CDE
NH_3-N	E	ABC	E	CDE	CDE	DE	E	E	E	E	E	E	E	E	E	E	E	E
NO_3	E	A–E	E	ABC	BCD	CDE	E	E	DE	DE	E	E	CDE	E	E	DE	E	DE
NO_2-N	E	CDE	CDE	DE	DE	DE	E	E	E	E	E	CDE	E	E	E	E	E	E
Total dissolved inorganic N	E	A–E	E	CD	CD	CD	E	E	DE	DE	E	CDE	DE	E	E	E	E	DE
Total dissolved organic N	E	CDE	E	E	A–E	E	E	E	DE	DE	E	E	E	E	E	E	E	E
PO_4-P	E	E	E	E	E	E	E	E	CD	BC	E	CDE	CDE	E	E	DE	E	DE
Total F	E	DE	CDE	DE	E	E	E	E	BCD	AB	E	CDE	BCD	E	E	CDE	E	DE

TABLE 22: The average Biotic Index Values for each station in downstream order

Station	Average BIV 1972/73	Average BIV 1973/74
1A	-	8,73
2	6,91	6,94
3*	5,73	5,54
4	5,13	5,81
5	5,89	6,31
6A*	-	6,08
6B*	-	6,84
6	5,53	5,66
8*	2,71	4,33
9	5,32	6,35
7	5,56	5,93
7A*	5,77	5,11
10	5,11	5,97
11B*	1,60	2,64
12	4,60	4,53
13*	3,88	4,54
14	3,75	4,84

* Tributaries of main stream

TABLE 23: Monthly average Biotic Index Values, calculated from the values of all stations sampled

Month	Average BIV 1972/73	Average BIV 1973/74
March	4,97	3,82
April	4,90	-
May	4,50	5,86
June	5,25	5,71
July	5,56	6,05
August	6,64	6,08
September	5,85	6,00
October	5,61	-
November	5,79	4,76
December	-	5,28
January	5,42	4,48
February	5,41	4,54

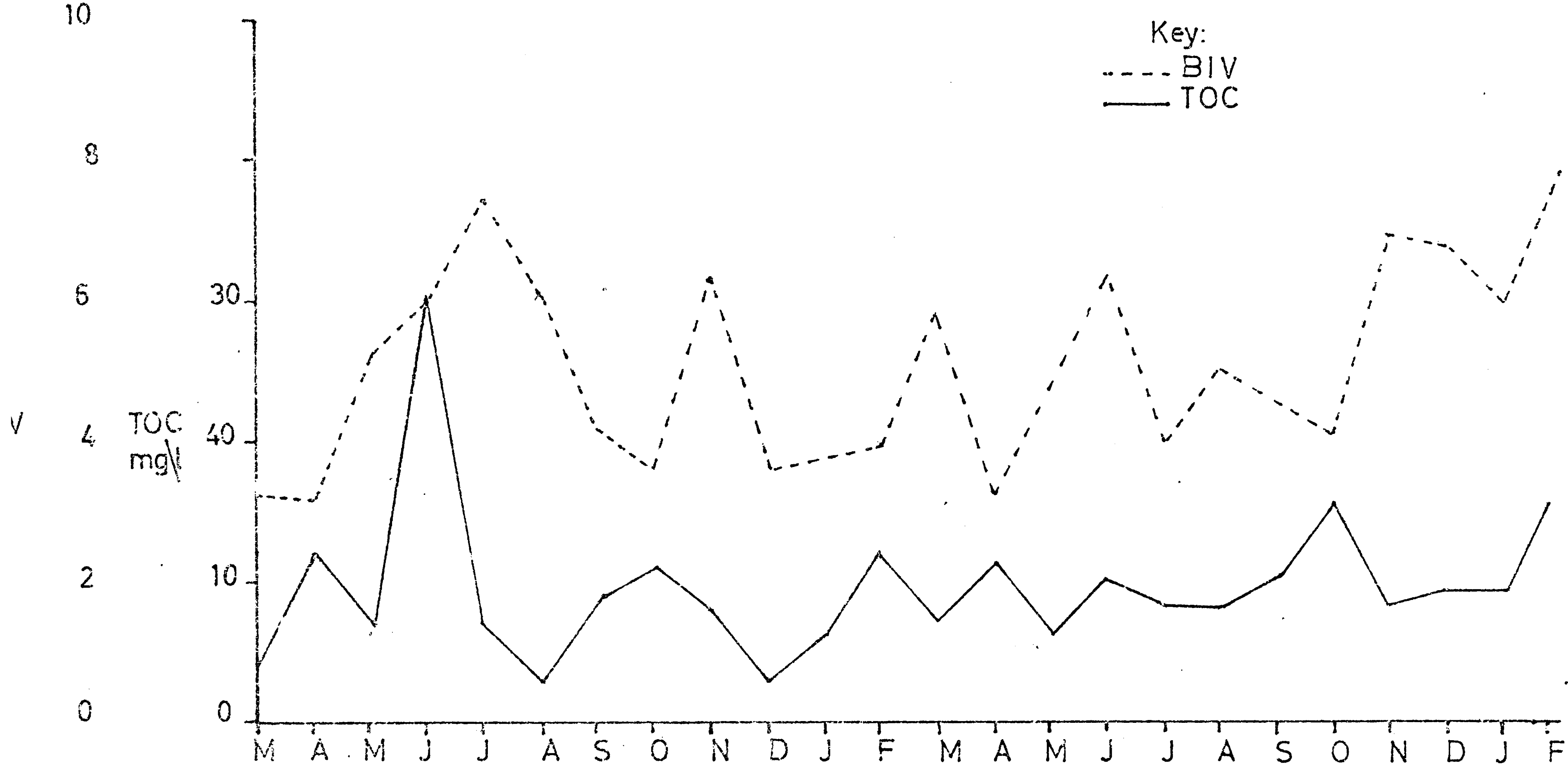


Fig. 5: A comparison between TOC as an indicator of organic status and BIV as an indicator of faunal variation from March 1972 to February 1974 at station 13.

reached the extreme values seen in the main stream. For instance in June 1972 the COD and TOC values in the Klein Jukskei River showed a marked increase in relation to the May and July values. This is shown in Figure A11 by a sudden peak in BIV values caused by a marked change from an Ephemeropteran dominated community to one dominated by the Simuliidae (see fanual composition in the Appendix). From August onwards this station showed steadily increasing BIV's from an average prior to this of 1,5 units to one of approximately 4 units. This too was the result of a decline in numbers and variety of the Ephemeropteran species which were usually replaced by the Simuliidae although increased numbers of Chironomidae and Oligochaetes occurred at times. This coincided with a slight increase in the COD and TOC values and thus suggests more significant enrichment than in the early months of this survey when both the chemical results and the BIV were similar to those in the upper Crocodile River.

The upper Crocodile River showed a fluctuation in index values (Appendix Fig. A17) which is not reflected by the apparent relatively constant state of organic pollution in this river. However, the fact that this fluctuation occurred mainly below 4 units agrees with the low COD and TOC values.

The BIV for the Hennops River (station 13) fluctuated between 2,5 and 6,2 units. Peak values were mainly due to increasing percentages of Chironomidae and Simuliidae at the expense of *Baetis harrisoni* and the Trichoptera. Figure 5 shows the influence of organic material (as TOC values) on the fauna. Sudden increases in the organic carbon coincided with peaks in the BIV graph for this station but it is interesting to note that increase in the BIV tended to follow a deterioration in the organic status of the river rather than to occur simultaneously.

The Braamfontein and Sandfontein streams, the Jukskei River above its confluence with the Modderfontein stream and the effluent outfall stream at station 7A were more enriched than the other tributaries. At times, particularly during low flow periods, all these streams showed a BIV indicating very enriched or polluted waters (above 7 units). In general the fauna of these tributaries indicated more enriched conditions than in the Hennops, Crocodile and Klein Jukskei rivers. This indication of more severe nutrient enrichment is a result of the fact that the Ephemeroptera were represented only by *Baetis harrisoni* while the Chironomidae and Oligochaeta tended to form dominant parts of the communities.

The Simuliidae were considerably less significant than in the "clean" tributaries and the Trichoptera were virtually absent. The amount of organic material in these streams was apparently greater than in the Crocodile, Hennops and Klein Jukskei rivers, although they were all less enriched than the main stream (Table 11).

In these enriched tributaries the TOC values were highest in the effluent outfall at station 7A, but biotic index values were much higher in the upper reaches of the system. Station 7A COD and TOC values suggest quantities of readily oxidizable matter comparable with those in the upper reach of the main stream which was shown by the BIV to be the most enriched region in the river.

In most cases sudden increases in BIV at any of these stations were associated with chemical evidence of increased oxidizable organic material. However in September 1972 station 3 showed an increased BIV of almost 4 units which was associated with an increased COD but low TOC values indicating that the COD change was caused by inorganic matter. Similarly at station 7A an increase in BIV over the September-November 1972 period was also characterized by increased COD values without an increase in TOC.

Finally, with regard to the mainstream of this study, the BIV data indicated a steady improvement in condition from station 1A to station 14. The river is "polluted" (according to Chutter, 1972) in the upper reaches of the system and only just qualified as "enriched" when it reached the Hartbeespoort Dam. This general trend did not agree with the chemical evidence of the amount of organic matter in this river. The COD and TOC concentrations indicated very little change in the organic content of the river down the main stream.

The monthly average BIV (Table 23) indicated that overall, the system can be considered to be enriched but not severely so, and there is a definite suggestion that nutrients reached a peak in concentration in August while the March-April period was characterized by the cleanest waters.

No BIV could be calculated for station 1 which was characterized by a complete lack of permanent fauna at any stage during the study period. Although some isolated individual animals were occasionally found, their occurrence was probably incidental and could have been the result of drift from further upstream.

There was an apparent anomaly in the biotic classification when reference is made to the chemical results of station 1A and 2. According to the BIV station 1A was very much more severely enriched than station 2 even though their mineral content was similar and station 2 showed very much higher concentrations of all forms of nitrogen. Phosphate concentrations were low at both stations and the relationship between COD and TOC indicates more organic material at station 2 than at station 1A.

This difference in the type of water quality indicated by the biotic index and the chemical data respectively is due to the abnormally restricted fauna present at station 2. The fauna at station 2 consisted of a limited number of insect larva and nymphs only, whereas the degree of enrichment indicated by the chemical data would lead one to expect the predominance of Oligochaete worms usually associated with polluted conditions. This situation clearly demonstrates one of the limitations of this index. Chutter (1972) has stated in his discussion of the index that, "Aquatic biocoenoses are not only influenced by organic pollution, but also by poisons such as pesticides, heavy metals and phenols."

The unexpected faunal community at station 2 suggests some such influence. It has been shown that insecticides kill insects and crustacea but not worms and snails whereas metals will eliminate the worms and snails but not affect the insects (Hynes, 1963, Brinkhurst and Jamieson, 1971). Thus the complete absence of Oligochaete worms at station 2 (see appendix) (no snails were found either) indicates that pollution by heavy metals is a possibility in this part of the river. Wittman and Förstner (1976) showed that the sediments of the maturation dams immediately above station 2 contained extremely high quantities, in relation to the rest of the system (Table 24), of a variety of heavy metals.

The marked fluctuation in COD values at this station in relation to relatively stable TIC and TOC values also suggests the possibility of heavy metal contamination which is one of the few causes of such a relationship (see section on organic status).

The fact that the insect fauna found at station 2 was almost entirely limited to the Chironomidae while the more sensitive insect groups such as the Ephemeroptera other than *B. harrisoni* and the Trichoptera, were

TABLE 24: Metal concentrations in the sediments of the dams on the Modderfontein stream - from Wittman and Förstner (1976). (Concentrations in mg/kg; Fe in %)

Metal	Station number (Wittman & Förstner, 1976)		
	2	3	4
Cr	880	360	244
Ni	550	428	530
Co	96	196	416
Fe	6,60%	3,60	7,28
Cu	904	1 880	4 040
Mn	1 400	1 340	1 000
Hg	2,87	10,8	6,71
Pb	282	1 538	1 921
Cd	1,99	4,90	4,58
Zn	1 904	6,902	9 700

completely absent indicates that the dissolved oxygen levels were at times too low for these sensitive taxa. Therefore it is very probable that if the Oligochaeta were not absent, the BIV for station 2 would have shown a greater degree of pollution than would station 1A.

The second major limitation of this index according to Chutter (1972) is the fact that seasonal instability of flows and river beds causes a deviation of the observed fauna from that which would normally occur. Although Table 23 does show a seasonal effect on the BIV, this could be as much due to natural life cycle occurrences in the fauna or their response to increased nutrient concentrations as to flow instability. It appears that flow instability does have some effect on the fauna of the smaller tributaries of this system when excessive floods shown in Table 16 are compared with the BIV for these months. In general the BIV on these occassions indicated a deterioration in water quality due to the fact that those taxa most sensitive to pollution appear to be less able to withstand flood conditions. This is indicated by the fact that the Ephemeropteran percentage tended to be reduced on these occasions (for example: station 13 in November 1972). However apart from these extreme cases in the smaller tributaries flows were relatively stable through most of this system (Table 16).

Hynes (1970) sites a number of studies which have shown that the disruptive effect of floods on the fauna of a river is least obvious in the stony biotope except under extreme conditions. This is shown here by the fact that the BIV after a flood period did not usually differ greatly from that observed prior to the flood. Thus although the number of individuals were sometimes reduced after a flood the composition of the community was not usually affected as can be seen by the relatively constant BIV at most of the stations in this system during the September-December 1973 period during which time two floods occurred.

This empirical biotic index clearly indicates the general pollutional pattern in a river but care must be taken, particularly in a river receiving a number of types of effluent, that the true situation is not masked by pollutants not associated with organic matter. A comparison must be made between the BIV and the known environmental conditions so that spurious results can be checked for the cause of anomalous effects.

Although the index neglects planktonic Copepoda and Cladocera only (Chutter, 1972) it was decided to ignore the occurrence of Collembola in samples as well because strictly speaking, none of the Collembola are aquatic. The few species associated with water remain suspended on the surface film and submerge only accidentally (Pennak, 1953). It is however interesting to note that Collembolan occurrence was strongly linked with that of indicators of very enriched conditions.

CLUSTER ANALYSIS

Cophenetic correlations

All dendrograms based on large quantities of data such as those representing all the data, or all the data for one season have cophenetic correlation values close to unity (0,951-0,998) showing that there is virtually no distortion caused by the clustering strategy. The dendrograms based on the data for single stations show slightly more distortion as the values are as low as 0,785. This is however not so great as to introduce any significant distortion in the two-dimensional presentation of the data (Kaesler and Cairns, 1972) and all the dendrograms presented here are thus representative of the data matrices.

The cophenetic correlation coefficient (ccc) value is shown with each dendrogram.

Interpretation of cluster analyses

In defining the associations of specific taxa, relationships unrelated to the chemical environment i.e. the water quality, may have occurred due to the natural seasonal variation in the fauna which may be related to such parameters as temperature and flow instability. The life cycles of the various taxa may also result in seasonal changes in communities.

The "months" or samples were clustered to see if they grouped into seasons based on the taxa present in each sample.

Thereafter, before the actual seasonal faunal composition could be analysed, it was deemed desirable to eliminate some species from the computation of associations. This will prevent the indiscriminate inclusion of these taxa from the interpretation. This was done by a single clustering of all the data from all seasons and stations. Those taxa which showed a very poor relationship to all other taxa both on the basis of their presence and their relative abundance could then be excluded from further analyses.

Once the seasonal variation in the faunal communities had been established the interpretation of changes at and between stations was attempted. From these results the influence of physical factors and seasonality of life cycles could be defined enabling the recognition of variations due to changes in the chemical environment.

Following the example of Stephenson, Williams and Cook (1972) the terms "association" and "community" are used in this paper as synonyms. Mills (1969) definition of a community as "a group of organisms occurring in a particular environment" is accepted with slight modification. For the purposes of this discussion the definition of a community is: "a community is a group of organisms occurring simultaneously in a particular environment".

(a) <u>Composition of seasons based of faunal variation</u>

A normal analysis of the monthly data for four stations was used to establish whether there was a seasonal variation in the faunal communities in the system. This resulted in the clustering of individual samples, each of which represents a month of the two year sampling period. The four stations chosen i.e. stations 3, 10, 11 and 14 are representative of the various water quality types in the system, based on the chemical and biotic index results. The Modderfontein stream and the Jukskei River immediately below it were excluded from consideration because of the unnatural and extremely limited fauna. Thus trends of seasonal variation evident at stations 3, 10, 11 and 14 are probably representative of trends throughout the river system.

The data was analysed by both the Czeckanowski technique based on the mutual presence of taxa only and by the Percentage Similarity technique which is based on the relative abundance of individual taxa in the association.

These analyses showed which samples were most closely related and grouped them into classes which could be plotted as dendrograms. This suggested the relationship between samples, i.e. months, and thus indicated whether there was a seasonal grouping of months based on the variation in the faunal communities.

For this purpose the Czeckanowski technique was unsatisfactory because the presence of a single individual of a taxon is weighted equally with a dominant taxon. The result would be that a station with a constant population composition but variable abundances of particular species at different times of the year would show all the months to be very closely related. Similarly, in a less extreme case, two months with a similar faunal composition but completely different dominance patterns would be closely associated by the Czeckanowski similarity index. An example of this is shown in the dendrogram of Czeckanowski similarity for station 3 (Fig. 6). In this dendrogram the July 1973 and August 1973 samples are closely linked at a percentage similarity coefficient value r = 88, yet when the relative abundances of the taxa forming the association are taken into account (Fig. 7) these two samples do not show a close relationship (r = 22). With two exceptions exactly the same taxa occurred in both samples. However, in July four taxa (*B. harrisoni*, Orthocladinae, *Nais* sp. and *Chaetogaster*) shared dominance status on a percentage basis whereas in August *Nais* sp. completely dominated the association. Thus in the Percentage similarity dendrogram the August sample tended to cluster with other samples showing a complete dominance by *Nais* sp. as would be expected.

Thus the definition of the survey period into specific seasons is based on the Percentage Similarity dendrograms rather than on the Czeckanowski Similarity dendrograms.

It can be expected that the less polluted regions of the river will show a more clearly defined division of the samples into seasons. As water quality deteriorates so the influence of the chemical environment will tend to dominate natural seasonal variation in faunal communities. Stations 11 and 14 are representative of the "cleaner" tributaries and lower reach of the system while station 3 represents a relatively enriched tributary and station 10 the highly enriched mainstream (according to the chemical and biotic index results). These latter results showed the upper reaches of the mainstream (stations 2 and 4) to be representative of the poorest water quality

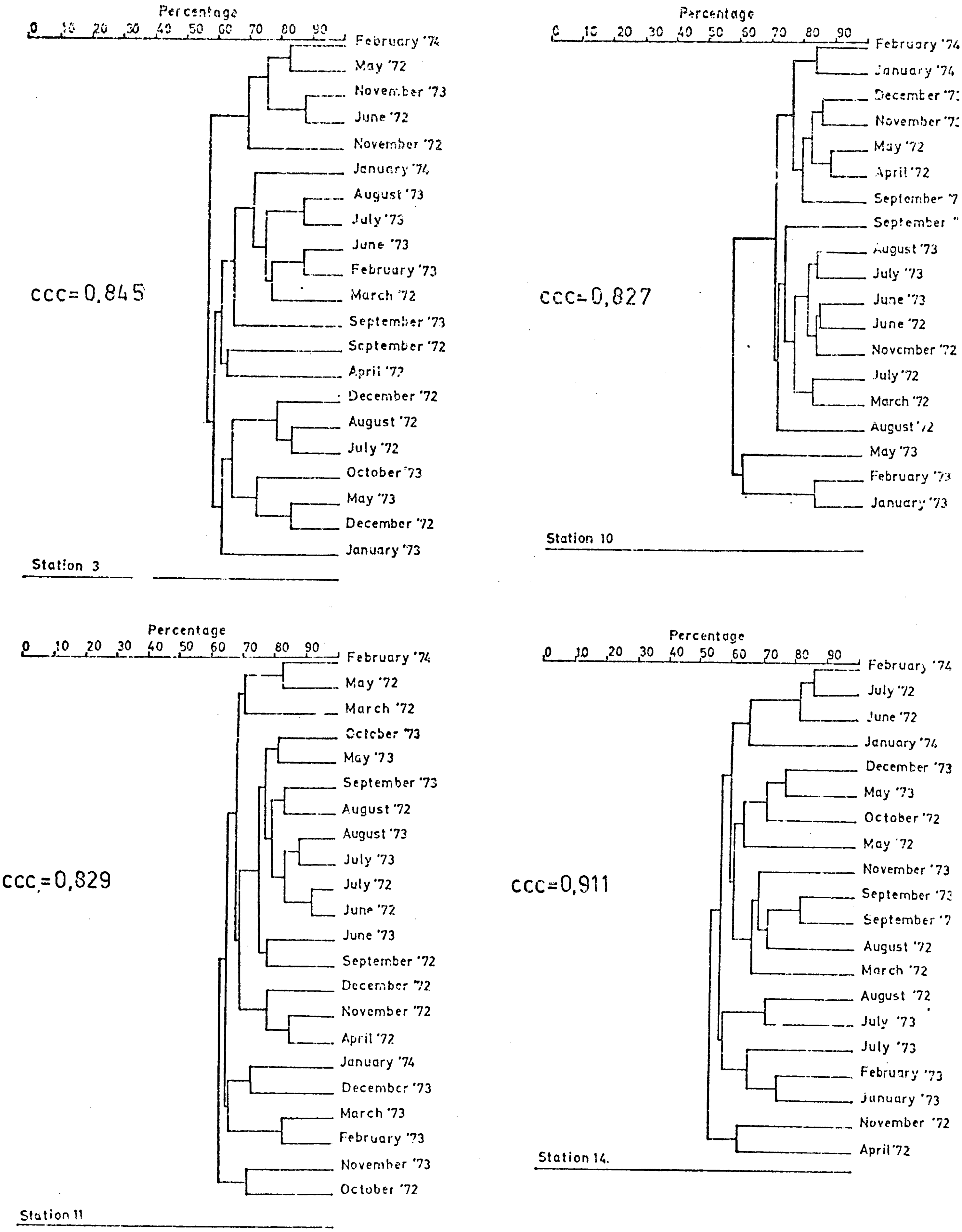


FIGURE 6: Dendrograms of Czechanowski Similarity for Stations 3,10,11 and 14.

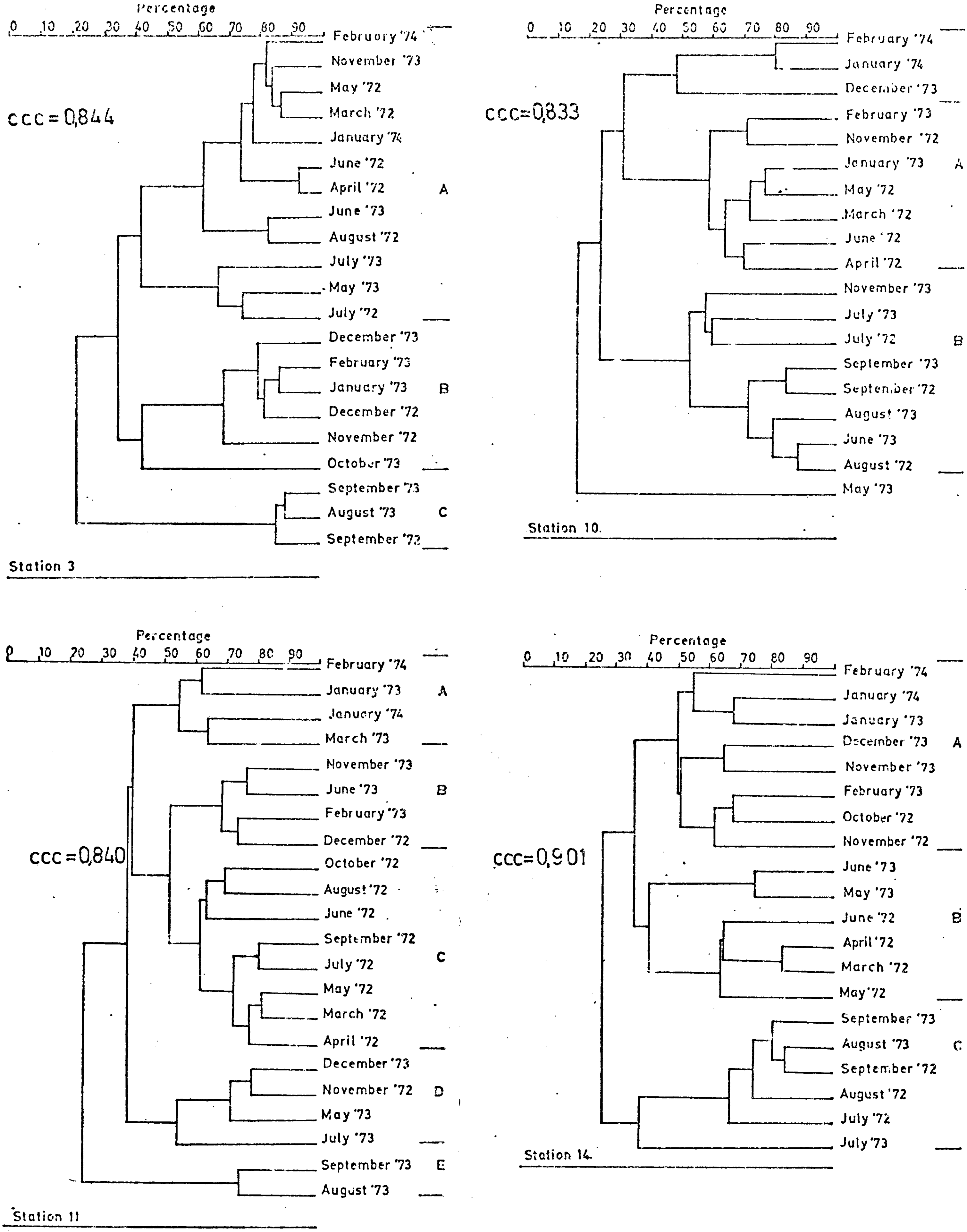


FIGURE 7: Dendrograms of % Similarity between Samples for Stations 3,10,11 and 14.

but these stations were ignored in the analysis of seasons as chemical influence was so great as to make such an analysis useless.

The dendrogram of percentage similarity for station 14 shows the clearest definition of samples into seasons due to the variation in the faunal community (Fig. 7). This dendrogram is divided into three clusters which include all the samples taken over the two year period. Cluster A comprises all samples taken from October to February in both years, cluster B is composed of all the March to June samples while cluster C represents the period July to September. Although May and June 1973 and July 1973 are less closely associated with clusters B and C respectively than are the other samples within these clusters, these samples are still more closely related to their expected groupings than to any other cluster. Figure 8 shows the variation in the dominant taxa underlying this definition of seasons. During the summer period the faunal association was dominated by the Orthocladinae and *Cheumatopsyche thomasseti*, the late summer/early winter period was dominated by *B. harrisoni* and the Simuliidae and the winter/spring period showed *Nais* sp. domination.

Thus this station shows three seasonal periods based on variation in the faunal composition and defines the extent of these seasons.

It would be expected that the dendrogram of percentage similarity between species for station 11 on the Crocodile River (Fig. 7) should show a similar clear definition of natural seasonal variation as this river has been shown to be the cleanest tributary. However the clear definition into seasonal groups seen at station 14 has been masked in this dendrogram by the fact that the two years of this study seem to

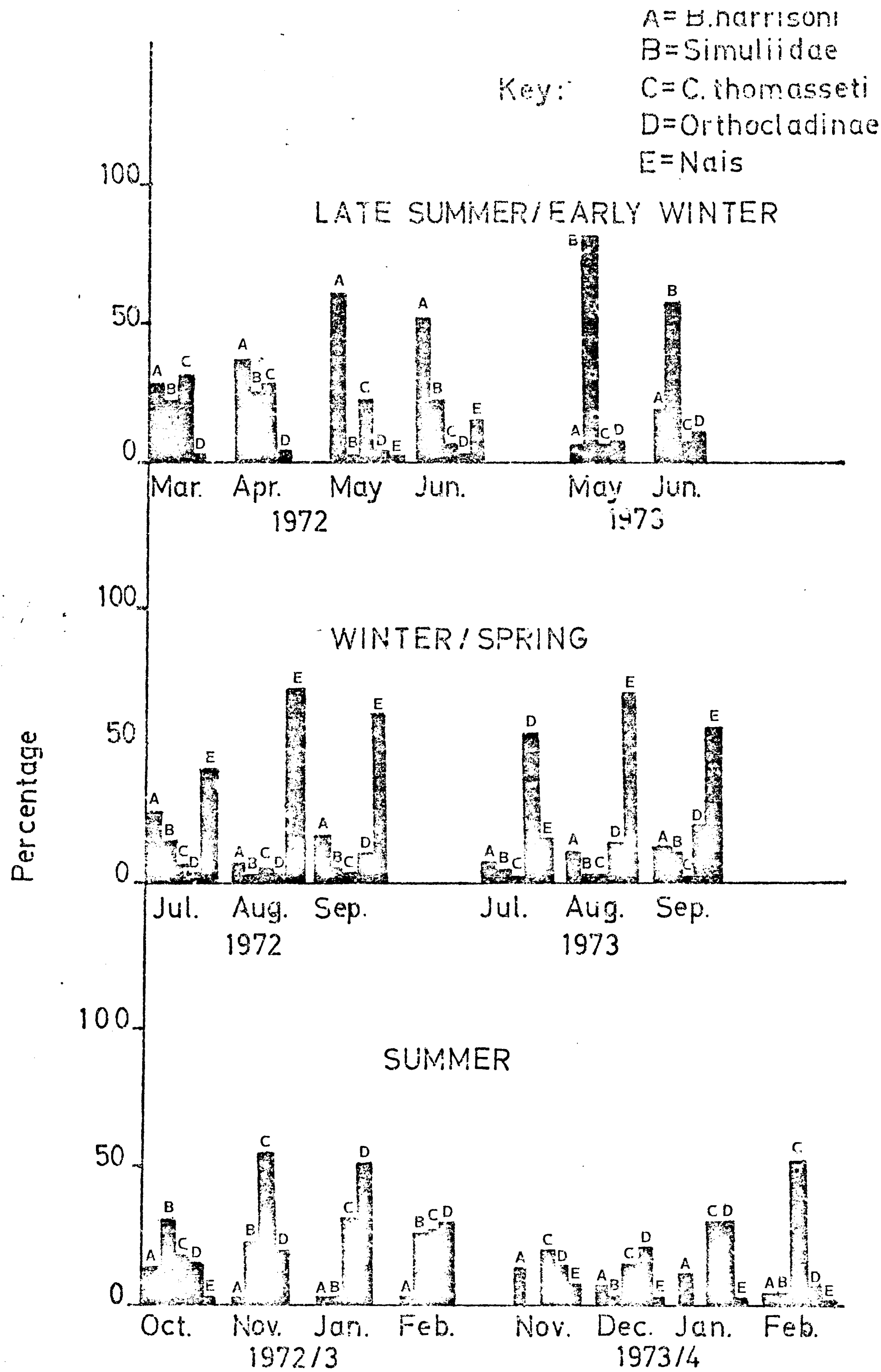


Fig. 8: Percentage contribution of the dominant taxa to the populations at station 14 for the three seasonal periods.

have differed markedly. This station shows the first eight month's samples i.e. March 1972 until October 1972, all grouped together in cluster C. Thus the effect of the change in the fauna late in the first year of the study tended to mask the possible seasonal effects. Due to the fact that this clustering of the first eight months samples is not seen in the dendrogram of Czeckanowski similarity (Fig. 6), this change does not appear to have been caused by a variation in the taxa present, but rather in the relative dominance of the taxa. However clusters A and B (Fig. 7) do show a tendency to group the summer months because it was mainly the winter period cluster which was split by the occurrence of cluster C. Cluster D shows no seasonal affinities while cluster E consists of two samples from the late winter/spring period of the second year. Thus there is some confirmation of the seasonal variation in the fauna suggested at station 14 in this dendrogram.

The change after October 1972 will be further referred to in the discussion of the characteristics of this station where the cause for this change is considered.

The dendrogram of percentage similarity between species at station 3 (Fig. 7) shows the influence of the water quality more than at stations 11 and 14. This was particularly noticeable in winter and late summer (cluster A) because although there is a tendency for samples to group as seen previously, most clusters contain one or more unexpected members. In summer the tendency for the October to February samples to cluster is greater as there are no unexpected relationships in cluster B although some of its expected members are outside this cluster. The spring period shows a highly correlated group in cluster C but this tends to be centred around the September samples as both July samples and one August sample occur in other clusters.

The tendency seen in this dendrogram indicates the effect of water quality as opposed to natural seasonal variation on the fauna because the winter months were characterized by the poorest quality water.

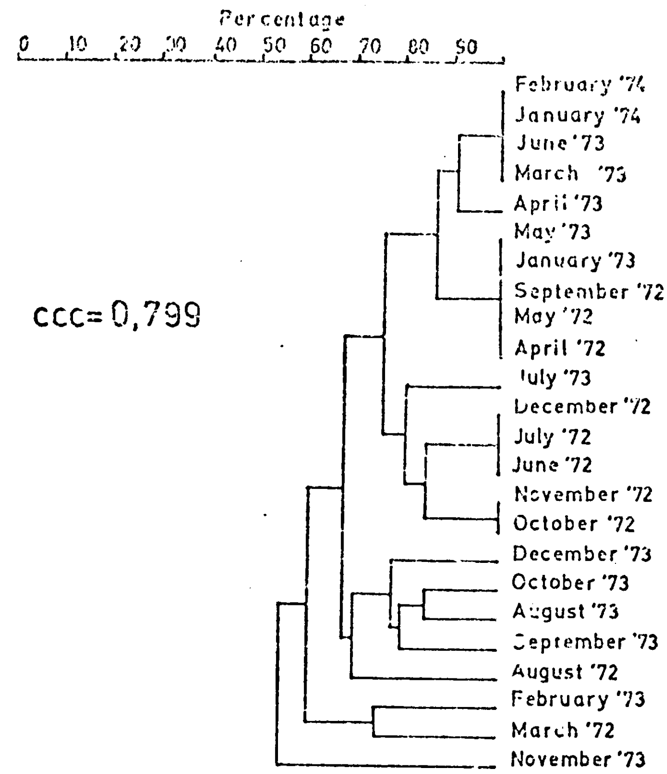
The analysis of data for station 10 also shows some confusion which was probably due to the effects of water quality or the fauna (Fig. 7). However three well defined clusters are shown in this dendrogram. Cluster A1 consists of some of the mid-summer samples and cluster A2 which links to it consists of a mixture of summer and late summer/early winter samples. With the exception of November 1973, cluster B groups the winter/spring samples. There is however a tendency to separate the three cluster B months into separate sub-clusters which suggests a defined pattern of environmental influence during these dry months. The fact that the fauna of this station was divided into summer and winter associations only, rather than two winter and a summer community may have been due to water quality effects or it may be explained by the fact that one April sample and both October samples, all intermediate period samples, were missing from the data. Thus the September samples linked to the winter months while the April and May samples either joined the summer cluster or in the case of May 1973 did not join either group. Thus this station still suggests a difference in the summer and winter compositions of the fauna but a split into two winter periods may be masked by the fact that some samples were missing.

The expectation that natural seasonal variation in communities will be more clearly defined where poor water quality is not exerting an influence appears to be correct. Thus based on the cleaner water stations but with some confirmation in the rest of the system, three seasonal periods have been established on the basis of faunal variation.

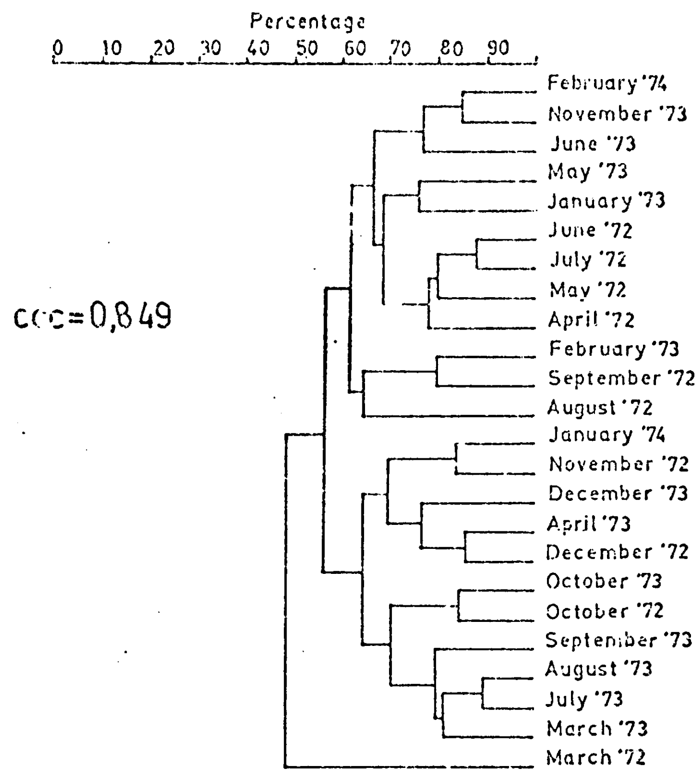
A second point that can be ascertained from these analyses is any significant difference in the faunal populations between the first and second years of the survey. Firstly, the possibility exists that one or more taxa occurring at a particular station may have been totally absent in one year due to a change in the environmental conditions. Secondly, the relative abundance of a taxon might have changed so that, for instance, a species which dominated a population in one year may have lost its dominance status in favour of one or more of the subdominant taxa in the following year because conditions may have become less favourable for it.

In order to see if such a change in conditions did occur the data for stations 2 and 4 in the upper reaches were also subjected to the analyses done above. Even though the fauna was limited these stations were still subject to changes in the environmental conditions of the system.

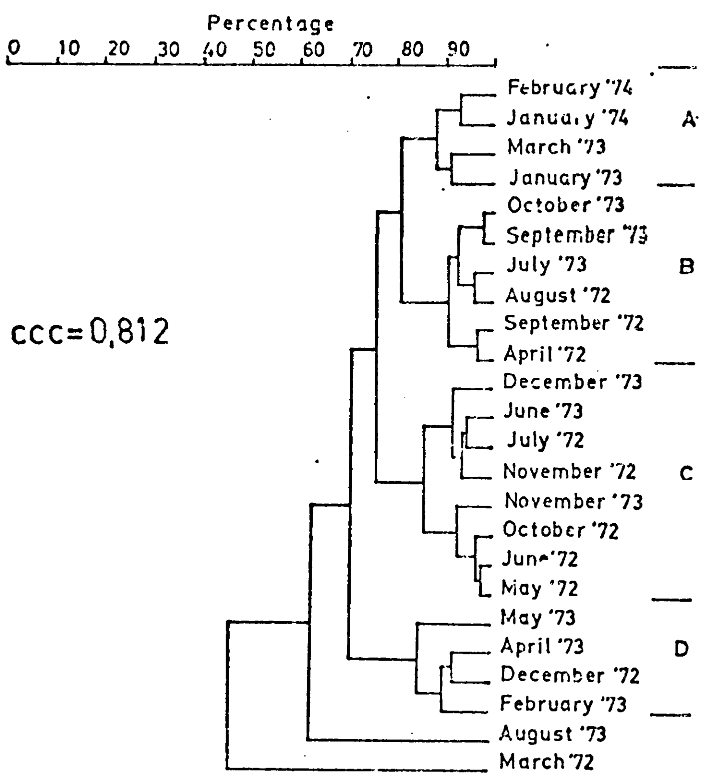
With regard to the presence or absence of taxa, the dendrograms of Czeckanowski similarity for all six representative stations (Figs 6 and 9) show no significant clustering of samples taken in one particular year. In cases where two or three consecutive months are joined to form a small cluster they are invariably joined at significantly high r values by months from the same seasonal period in the other year of the survey. All these dendrograms indicate a remarkable degree of community homogeneity in that all samples are linked at r values above 50 per cent. However it is



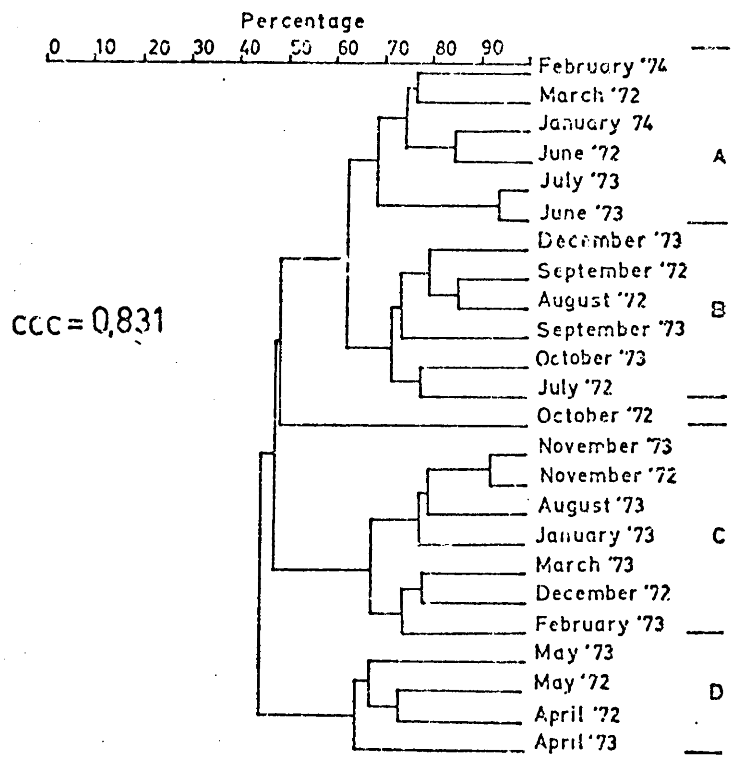
Dendrogram of Czeckanowski Similarity for Station 2



Dendrogram of Czeckanowski Similarity for Station 4



Dendrogram of % Similarity between Samples for Station 2



Dendrogram of % Similarity between Samples for Station 4

FIGURE 9: Dendrograms of Similarity between Samples for Stations 2 and 4.

relavant that station 10 and station 2 show the greatest homogeneity indicating that deteriorating water quality tends to suppress seasonal variation in the fauna.

Other than station 11, which has already been shown to separate the first eight months' data from the rest on the basis of the relative abundance of taxa forming the population, the dendrograms of percentage similarity for these six stations (Figs 7 & 9) also show no significant differences between the two years. Here too one can see in the dendrogram for station 2 (Fig. 9) that water quality restricts population diversity. The remarkable correlation between all samples suggests that even variations in dominance patterns which occur seasonally were restricted by environmental conditions.

(b) <u>The analysis of the fauna of the whole system for the identification of rare species and the most common associations</u>

By subjecting the fauna of the system as a whole to a clustering analysis the rare species in this catchment area can be identified and removed from further analyses. The smaller quantities of data used in ascertaining the similarity index between species at a particular station could result in misleading conclusions. For instance, a taxon rare in the system will be given the same weight as a taxon common in the system but rare at this particular station. Whereas the former occurrence is probably of no significance the latter is an important observation.

The dendrograms of Bray-Curtis similarity between samples and of Czeckanowski similarity between samples for all stations from March 1972 until February 1974 are shown in Figures 10 and 11 respectively.

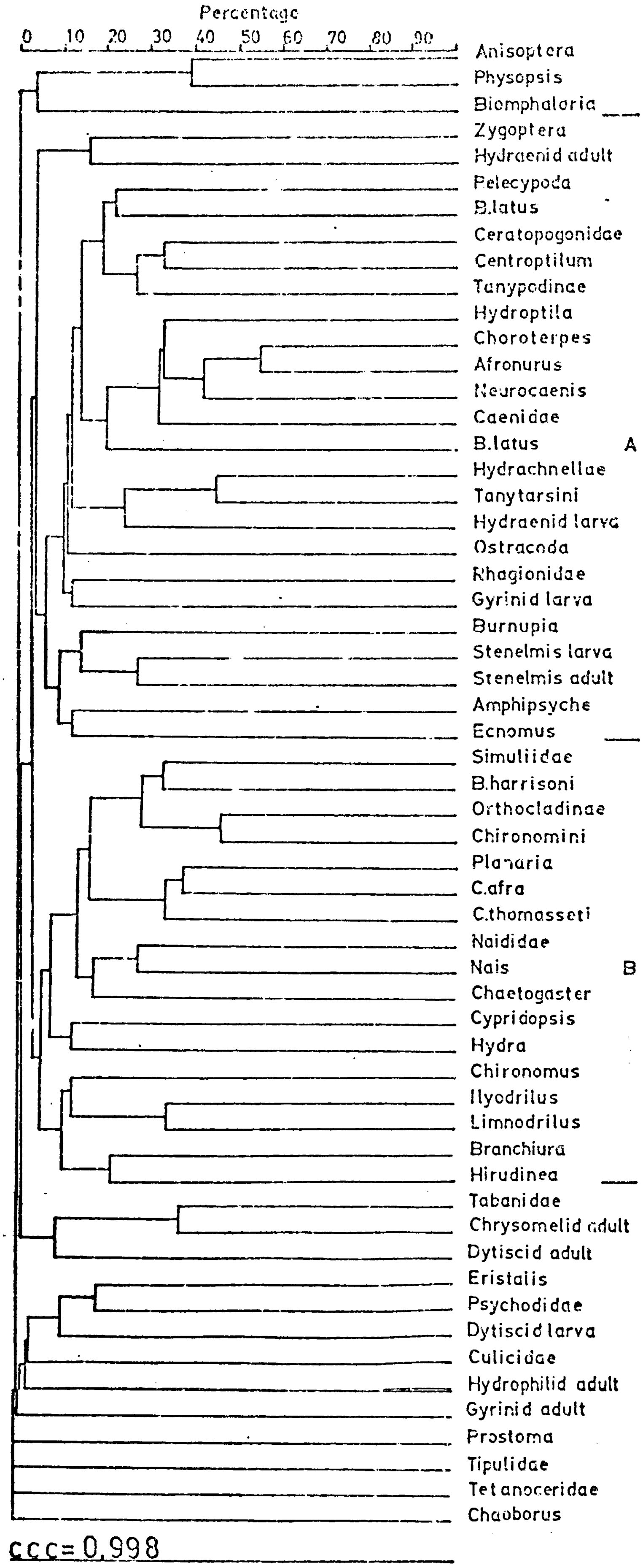


Figure 10: Dendrogram of Bray-Curtis Similarity between Taxa for March 1972-February 1974, from all data for all sampling points.

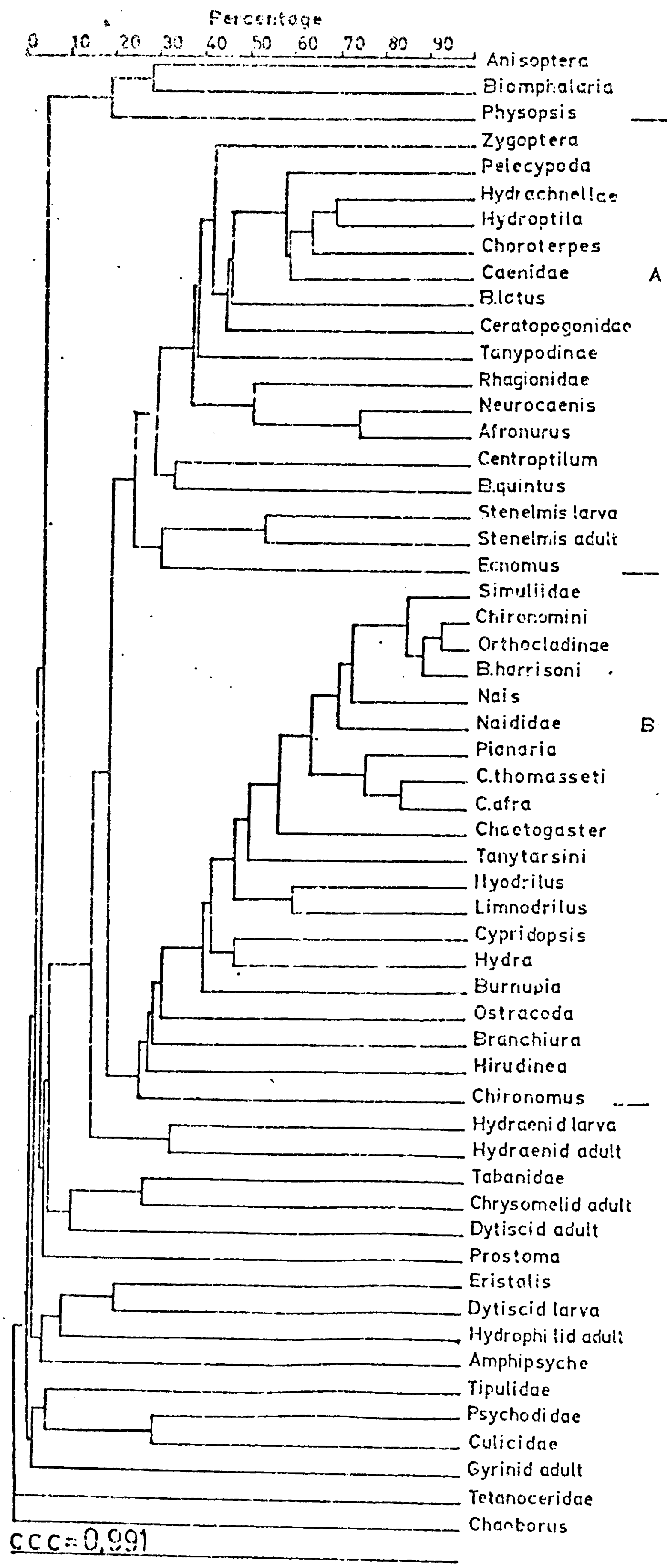


Figure 11: Dendrogram of Czeckanowski Similarity between Taxa for March 1972-February 1974, for all data from all sampling points.

These dendrograms arise from an inverse analysis of the data resulting in clusters of taxa based on their joint occurrence in individual samples. For the purposes of defining species rare in this system as a whole it was unnecessary to extract the sampling points with unusual fauna (stations 2, 4 and 5) because all the Oligochaeta, the taxon not recorded at these sampling points were common at stations elsewhere in the system.

Both dendrograms include two clearly defined clusters. Cluster B in Figure 11 based on frequency of occurrence (presence-absence analysis), had a nucleus of ten closely associated taxa. These were Simuliidae, Orthocladinae, Chironomini, *B. harrisoni*, *Nais* sp., Naididae, Planaria, *Cheumatopsyche afra*, *Cheumatopsyche thomasseti*, and *Chaetogaster*.

Part of cluster B in Figure 10 shows that this group was similarly related although at lower r values, as is to be expected, when compared on the basis of their abundance relative to each other in associations. The high degree of similarity of occurrence and abundance between these taxa suggested that they were the most common in the system and that their presence was probably not dependant on local conditions. This is confirmed in Table 25 which shows that they occurred, usually in large percentages, at all stations. These are what Stout and Vandermeer (1975) call regional controlled species.

On both dendrograms there were seven taxa forming the remainder of cluster B and common to both clustering strategies. These were *Limnodrilus* sp., *Ilyodrilus templetoni*, *Cypridopsis*, Hydra, *Branchiura* sp., Hirudinea and *Chironomus* sp. Three other taxa (Tarytarsini,

TABLE 25: The mean percentage contribution of each of the taxa shown in figures 10 and 11 to be the most common in the system for all stations plus the average percentage contribution of the whole group to the populations

Station	Taxon										Average % contribution
	Simuliidae	Ortho-cladinae	Chironomini	*Baetis harrisoni*	*Nais* sp.	Other naididae	Planaria	*C. Afra*	*C. thomas-seti*	*Chaeto-caster*	
1A	0	18,0	7,7	0	0,5	4,3	1,0	0	0	46,2	77,7
2	7,6	54,6	34,0	0,5	0	0	0	0	0	0	96,7
3	0,7	27,5	3,3	30,6	22,5	4,4	0	0	0	6,8	95,8
4	6,0	37,7	27,1	18,0	1,3	2,7	0	0	0	1,3	94,1
5	0	42,1	24,1	27,1	1,2	1,1	0	0,1	0	0,5	96,2
6	8,5	27,2	11,5	25,8	4,1	9,2	0,4	0,4	0,4	4,7	95,8
6A	3,6	25,0	2,0	20,4	8,3	31,7	0,8	0,7	0,3	2,2	95,0
6B	0,2	23,1	0,7	11,9	50,4	5,6	0,1				
7	10,7	12,6	11,9	8,9	12,7	12,5	1,7	1,3	8,7	2,1	83,1
7A	17,5	10,2	13,8	19,8	0,7	12,1	0,0	0,8	0,9	0,3	76,1
8	43,2	9,0	5,0	6,6	6,6	1,7	5,8	3,9	6,1	0,6	88,5
9	4,1	19,0	14,4	9,7	18,6	9,7	1,3	7,1	1,3	6,4	91,6
10	17,9	7,8	4,4	11,8	24,7	5,9	3,6	1,6	9,5	7,0	94,2
11	24,3	13,2	2,1	17,1	9,6	0,6	1,8	2,8	9,4	0,6	81,5
12	17,3	11,2	5,1	10,8	12,6	7,1	7,4	4,6	12,3	0,8	89,2
13	21,3	24,5	6,8	9,8	5,5	3,0	3,1	0,5	9,3	0,7	84,5
14	15,8	14,5	5,4	15,9	15,9	1,9	1,0	2,9	17,4	0,8	75,6

Ostracoda other then *Cypridopsis* and *Burnupia*) were shown to be an intergral part of this association on the basis of presence-absence data (Fig. 11) but were more closely associated with cluster A when their relative abundance was taken into consideration (Fig. 10). This means that they commonly occurred in association with the cluster B taxa but only occurred in significant numbers with the members of the cluster A association.

Figure 11 shows that, purely on the basis of presence or absence in the association, cluster A had a core of five taxa - Hydrachnellae, *Hydroptila*, *Choroterpes*, Caenidae and Pelecypoda. Linked to this core were *B. latus*, Ceratopogonidae, Zygoptera and Tanypodinae followed by three sub-clusters:

(a) Rhagionidae, *Afronurus* and *Neurocaenis*.

(b) *Centroptilum* and *B. quintus*.

(c) *Stenelmis* larvae and adults and *Ecnomus*.

All these taxa (with the exception of Zygoptera) are also found in cluster A of the dendrogram of Bray-Curtis similarity (Fig. 10) showing that they are similarly related on the basis of their relative abundance in associations. In addition to this there are five taxa which are related to this group on the basis of their percentage contribution to specific communities but are not related on a presence-absence basis. This suggests that these taxa are not often present in such associations but that when they do occur in large numbers it is in association with the members of cluster A rather than with those of cluster B. Three of these taxa (Tanytarsini, Ostracoda and *Burnupia*) are discussed above while the remaining two, the

Hydraenid larvae and *Amphipsyche* sp. showed little relationship on a presence-absence basis with either association. These two species did not therefore, occur commonly in the system but when they did it was in association with a cluster A type community.

The remaining taxa in these dendrograms form a few small groups of two or three members at r values which are as significant as many of the associations in the two major clusters. Nevertheless the majority show very poor relationships to any of the other taxa and were mostly rare occurrences in the system. There are three of these small clusters which are grouped on the basis of both presence-absence data and relative abundance data. This suggests that their groupings are of some significance even though they may be linked at relatively low r values to the rest of the associations. These groups are firstly, *Physopsis*, *Biomphalaria* and Anisoptera, secondly Dytiscid adults, Chrysomelid adults and Tabanidae and thirdly *Eristalis*, Psychodidae, Culicidae, Dytiscid larvae, Hydrophilid adults and Gyrinid adults. This last group forms one cluster on the basis of their relative abundance in associations (Fig. 10). However, on the basis of their occurrence only they showed interrelationships with some but not all members of this group. The most significant part of this group with regard to their linkage appear to be the first three.

It must be borne in mind that these dendrograms present an overall picture of all stations over all seasons so these clusters only give a broad summary which can serve as a point of reference for the analysis of individual stations and periods.

Two conclusions can be drawn from this analysis. Firstly those associations characteristic of the system as a whole are defined and secondly those taxa which show no pertinent relationships to these associations and are possibly rare occurrences may be isolated.

Two large well defined clusters of taxa in both analyses (Bray-Curtis and Czeckanowski) suggest that the river system as a whole is characterized by two basic types of communities. From earlier works on South African river ecology (Allanson, 1961, Chutter, 1970, 1971, 1972) and reference to the taxa which were members of these associations the system may be divided into regions of poor water quality and regions of "clean" water. Cluster A is composed of taxa representative of "clean water" while the taxa in cluster B are more common in the regions of poor water quality. It is interesting that those taxa which showed the greatest similarity of occurrence over the whole river system (Simuliidae, Chironomini, Orthocladinae, *Cheumatopsyche* and the three *Naid* species) are more closely associated with cluster B. This suggests that the region of poor water quality is greater than that characterized by clean water or else that these taxa, although common throughout the system (see species composition in the appendix), tended to dominance in poor quality water only.

Psychodidae, *Eristalis* and *Culicidae*, which are taxa most commonly found in badly polluted water do not necessarily form a well defined cluster nor are they closely related to the two characteristic associations described above. This is probably because the stones-in-current biotope is only subjected to the very low dissolved oxygen levels, of which these taxa are typically indicative, under conditions of extremely severe pollution, due to the physical aeration of this biotope (Chandler, 1970). However the association of these taxa albeit at low r values, in these analyses indicates the possibility of one or more occurrences of such conditions during this survey.

Taxa which were poorly related to either of these characteristic communities and were thus rare occurences in the system are arbitrarily defined as those which show a linkage to any other taxon or cluster at a lower r-value than that at which clusters A and B are linked in both dendrograms (Figs 10 and 11). These are the following:

Prostoma, Hydrophilid adults, Gyrinid adults, Tipulidae, Tetanoceridae, Chaoborus and *Baetis glaucus*.

The species composition tables in the appendix confirm the rarity of these taxa and these taxa are omitted from further consideration.

(c) Seasonal variation in the faunal associations

An inverse analysis of the data for each of the three seasons (as defined by the normal analysis in section (a) above) shows which taxa in the two broadly defined associations discussed in (b) above are affected by seasonal changes. This leads to the identification of associations for specific seasons and indicates taxa whose presence or absence in the association was related to season. In addition taxa rare in the system for one or more seasons which were not identified in the previous section could be identified here.

In this section the analyses of each seasons data is discussed followed by a summary of variations in the most common association and the identification of rare taxa which must be excluded from further analyses.

Dendrograms compiled from the data for autumn (March to June) only, showed that the basic associations described in the previous section have been divided into smaller, more clearly defined clusters.

Cluster C1 of the Czeckanowski similarity dendrogram (Fig. 12) and cluster F of the Bray-Curtis similarity dendrogram (Fig. 13) comprise the taxa shown in the previous section to be the most common in the system over the whole period. Subdivision within these clusters shows that this dominant association was divided into three main groups so that although all of these taxa were common throughout the three associations suggested, they tended to dominate separately. These three groups are:

(a) Simuliidae, *B. harrisoni*, Orthocladinae and Chironomini

(b) Planaria, *C. afra* and *thomasseti*

(c) *Nais* sp., *Chaetogaster* and the other Naididae.

The rest of cluster C in Figure 12 consists of taxa which were apparently common in the system (Table 24) during this period but were widely separated in their occurrence as is shown by the fact that they occur in different clusters when linked on the basis of their relative abundance (Fig. 13).

These two dendrograms show that during the autumn season an association is defined which tends to be intermediate between the most ubiquitous species and the clean water association (cluster D in both dendrograms is composed of taxa shown in the previous section to be characteristic of clean water). This intermediate association is shown as cluster B

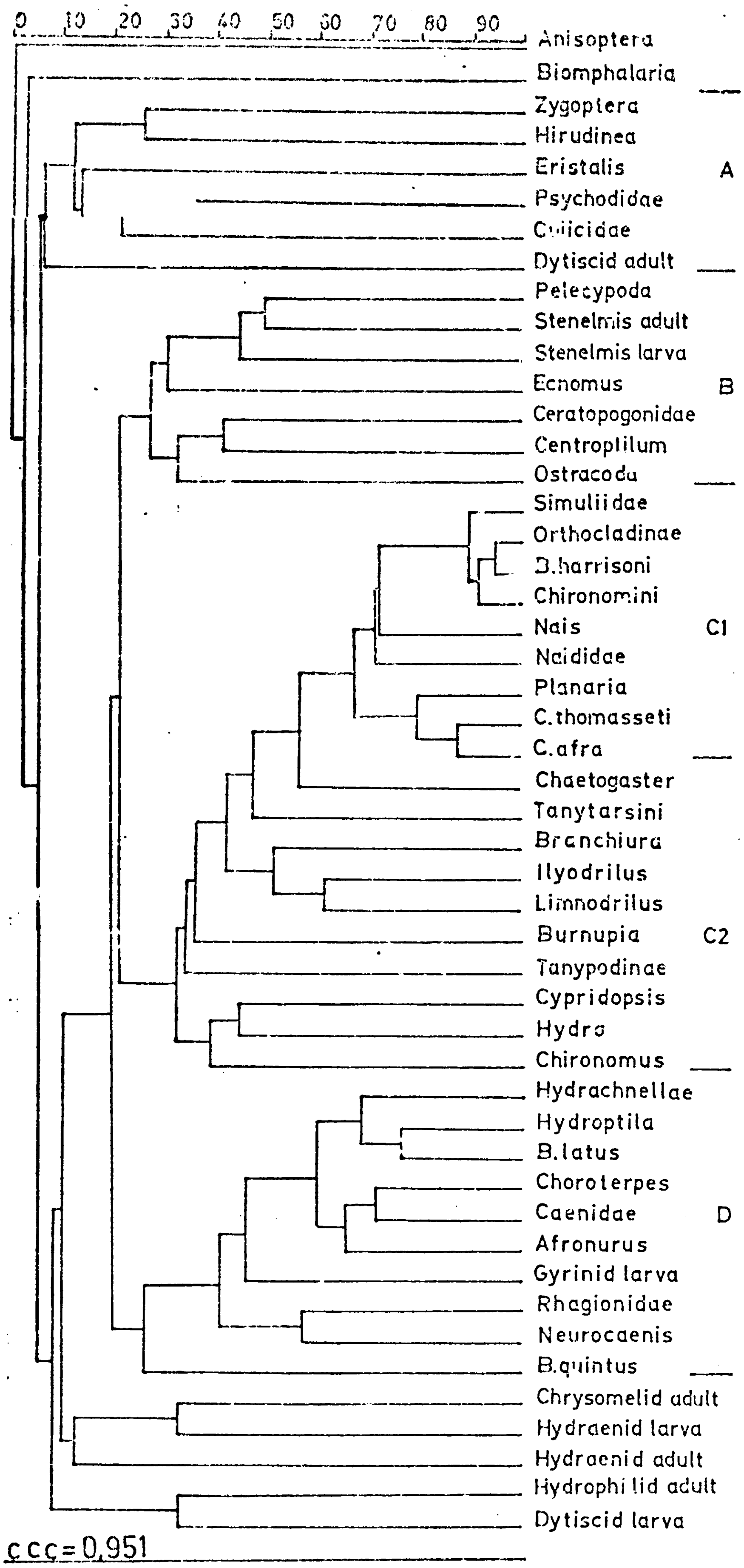


Figure 12 : Dendrogram of Czeckanowski Similarity between Taxa for March-June at all sampling points.

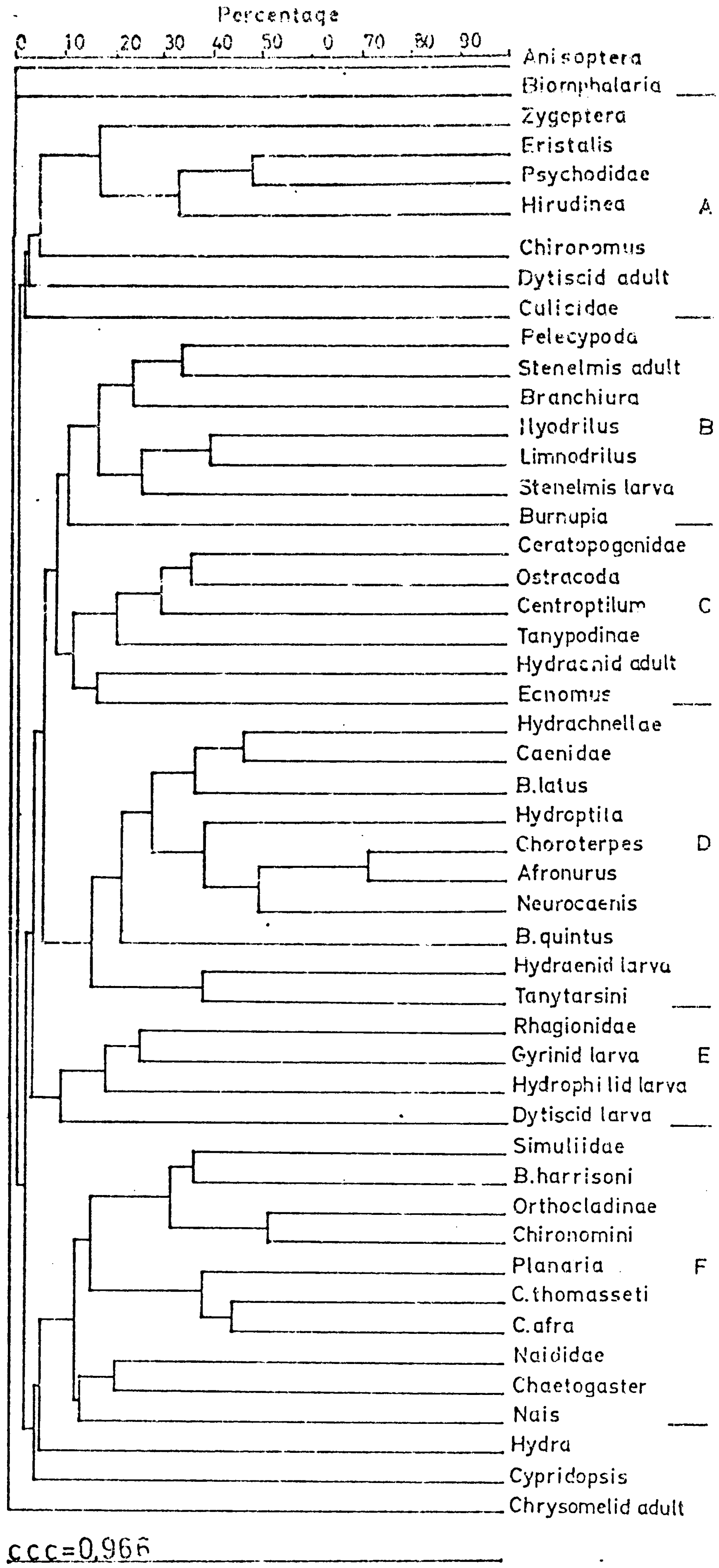


Figure 13: Dendrogram of Bray-Curtis Similarity between Taxa for March-June for all sampling points.

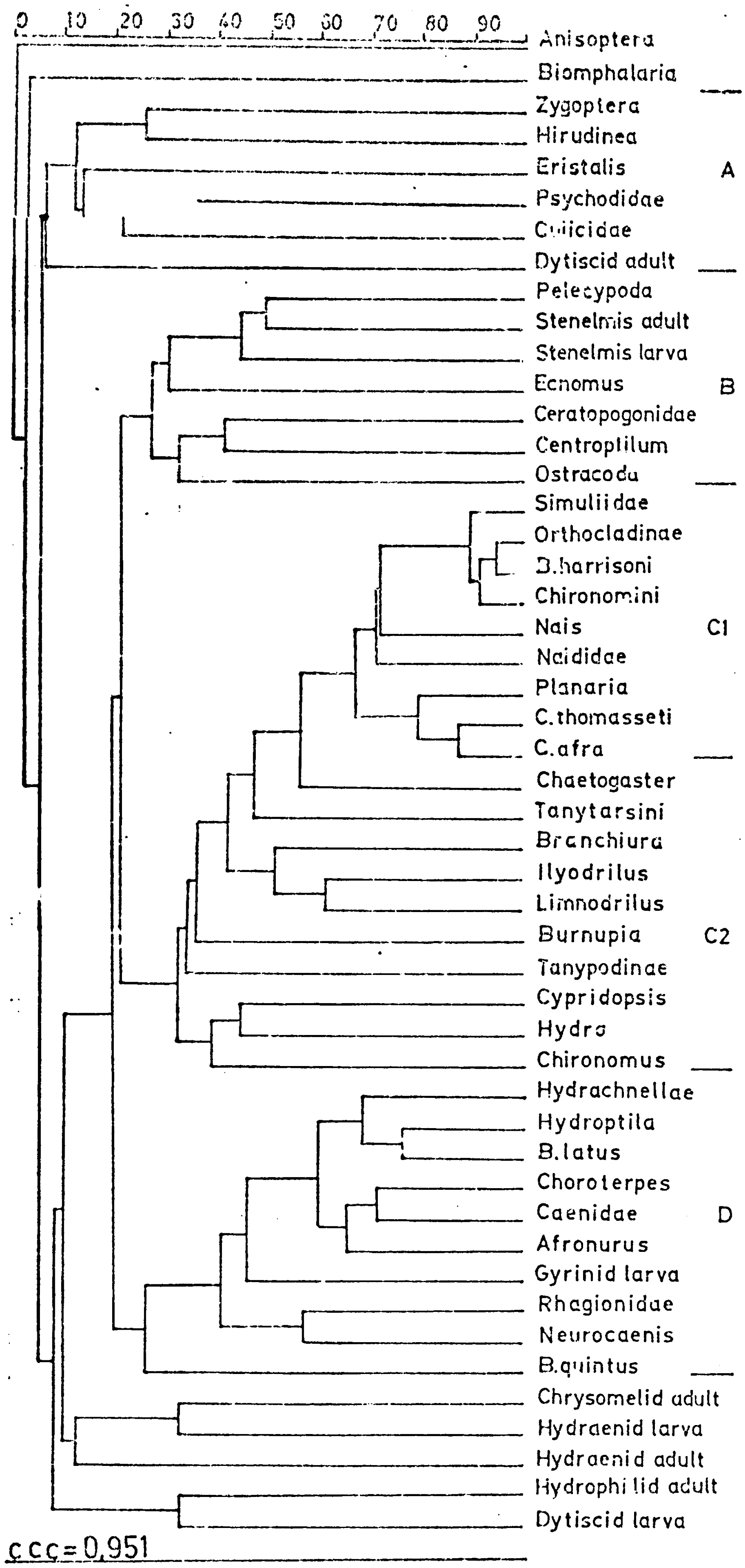


Figure 12 : Dendrogram of Czeckanowski Similarity between Taxa for March-June at all sampling points.

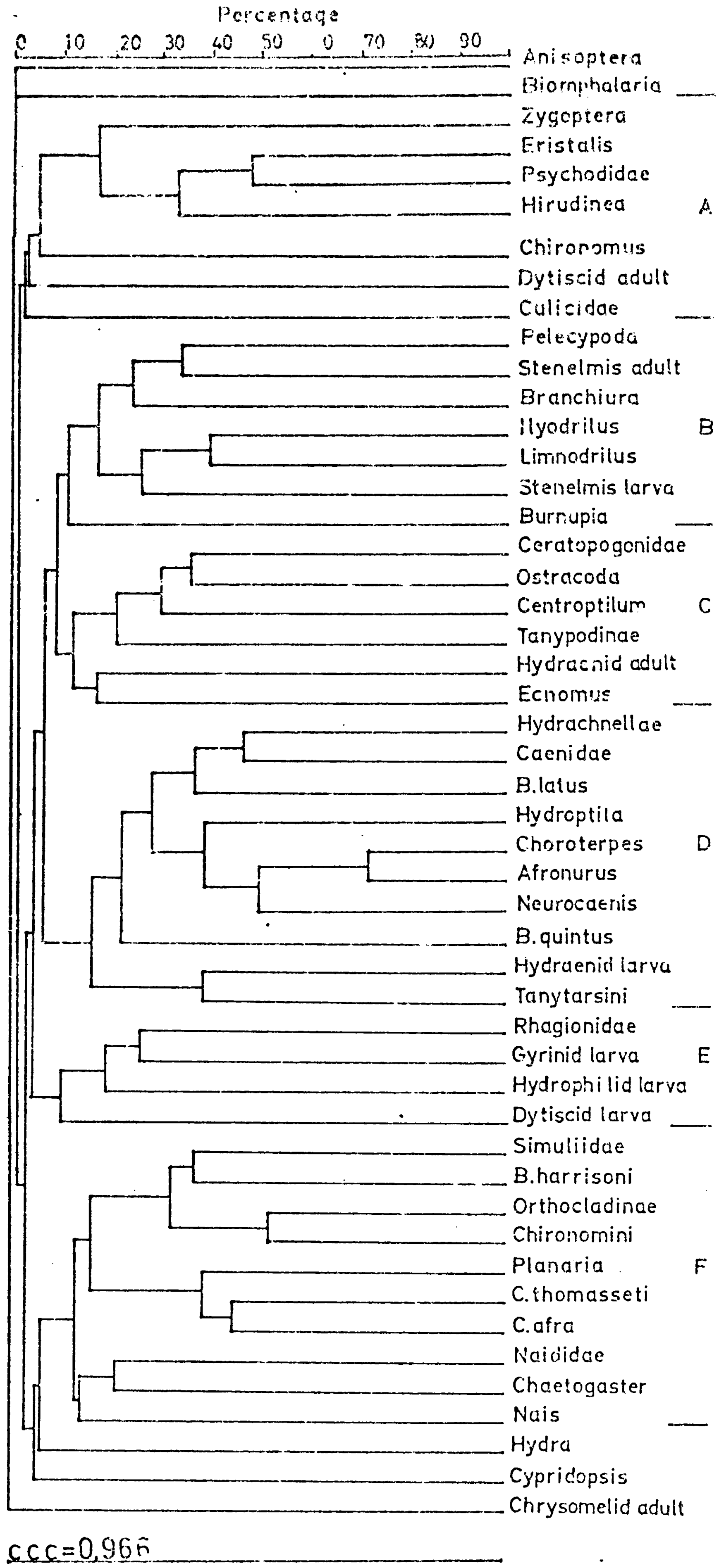


Figure 13: Dendrogram of Bray-Curtis Similarity between Taxa for March-June for all sampling points.

in the dendrogram of Czeckanowski similarity and cluster C in the dendrogram of Bray-Curtis similarity. Both these clusters, although entities in their own right, are linked to associations which include Oligochaetes, *Limnodrilus* sp., *Ilyodrilus templetoni* and *Branchiura* sp. before the Ephemeropteran dominated association joins the cluster.

Cluster A on both figures is composed of taxa indicative of organically polluted water. The presence of Zygoptera in this cluster is possibly anomolous as it is not a true stones-in-current inhabitant. It is included here due to what is probably a coincidental relationship with the Hirudinea, as reference to the species composition for this period (see appendix) shows that the Zygoptera only occurred three times in the autumn period in negligible numbers and two of these occurrences were together with similarly negligible numbers of Hirudinea although these latter occurred more frequently.

The low r-value at which this group is linked to the associations discussed above suggests that extreme organic pollution of a magnitude which results in almost total deoxygenation of the water is not a characteristic of this system during the autumn period. Table 16 shows that this period was characterized by above average flows during both 1972 and 1973 without the more extreme floods usually experienced earlier in the summer. This confirms the above conclusion because dilution will be more effective under these conditions than during the low flow periods but the increased quantities of organic material usually associated with the scouring action of early floods would be missing. The relatively poor interrelationships between individual members of this cluster shows that it is unlikely that they ever dominated any association.

Chironomus sp. were apparently present throughout the system during autumn as they are closely correlated to cluster C in Figure 12 where linkage is on the basis of presence-absence. However this occurrence was limited to small proportions of the total communities because when clustered with respect to their relative abundance (Fig. 13) they formed part of cluster A and showed little correlation to the most ubiquitous taxa. Table 26 shows that this was true for the upper and middle reaches of the system whereas the lower reach showed a lack of *Chironomus* sp. in this period. This coincides with a similar absence of the other cluster A taxa in this reach.

The clean water association shown in cluster D in both dendrograms indicate that the *Hydroptila* and the water mites, Hydrachnellae, are closely associated with the Ephemeropteran fauna. This association was also seen by Chutter (1968).

The dendrograms of Czeckanowski similarity and Bray-Curtis similarity for the July to September period (spring) are given in Figures 14 and 15 respectively. This is the dry weather period when river flow tends to remain constant and thus the effects of effluents entering the system will be most apparent.

On the basis of the mutual presence or absence of taxa there are two basic clusters (Fig. 14) which are similar in structure to those in the dendrograms (Figs 10 and 11) which incorporated all the data for this study. This similarity at a time when river flow conditions were at their most stable and the effects of poor quality effluents were chemically most apparent is a clearer illustration of the earlier conclusion that the areas of the system affected by effluents in this

TABLE 26: The mean percentage contribution of *Chironomus* sp. to the populations at all stations for both autumn periods

Year	Station															
	2	3	4	5	6	6A	6B	7	7A	8	9	10	11	12	13	14
1972	0,50	0,15	1,00	2,50	0,15	-	-	0,15	0,50	0	0,25	0	0	0	0	0
1973	6,25	0,25	0,75	0	0,50	0	0,75	0,50	0	0	0,50	0	0	0	0	0

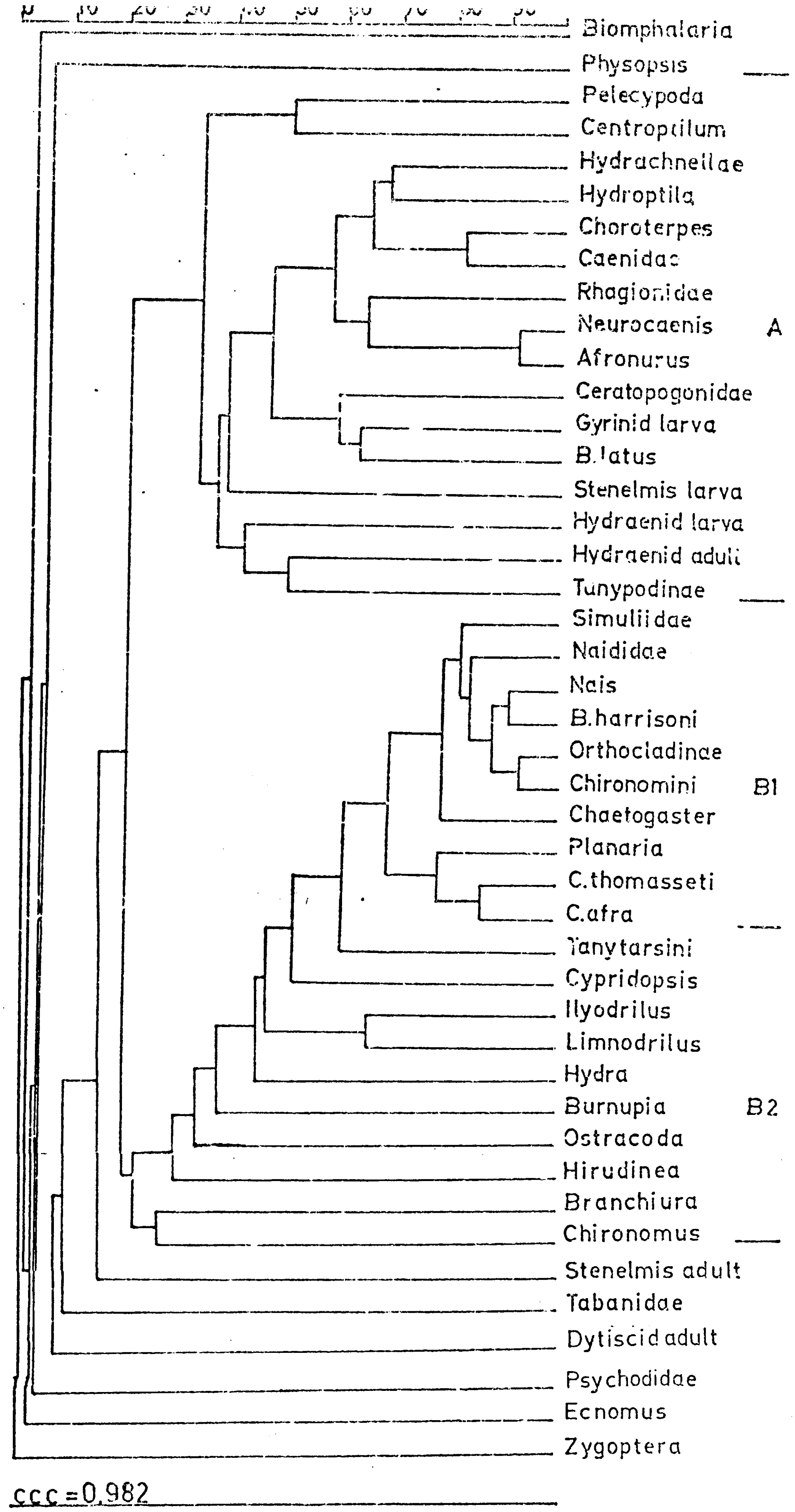


Figure 14: Dendrogram of Czeckonowski Similarity between Taxa for July-September at all sampling points.

study was greater than that characterized by "clean" water. Based on the chemical analyses (Table 5) one can see that the "clean" water occurs in some tributaries while the mainstream, on which most stations are situated, is characterized by poorer quality water. This shows that the dry weather variation in faunal associations between different parts of the system was largely controlled by the chemical quality of the environment.

The percentages of the taxa in relation to each other (Fig. 15) shows that the Oligochaetes formed an integral group with the most commonly occurring species (cluster C) with the Naididae more closely related to the *B. harrisoni* - Simuliidae - Chironomidae group, that is the most common taxa, while the Tubificids appeared to be more closely related in terms of their relative abundance to the *Cheumatopsyche* sp. - Planaria group. This suggests that this latter group and the Tubificids tended to form subdominant associations although not necessarily at the same time. Table 26 confirms this latter deduction in that both these groups tended to be a part of all populations in this season but never increased to a level where they dominated the more ubiquitous species grouped separately in cluster C which are those shown in Table 27 to be the most common.

Cluster A (Fig. 15) which includes all the clean water indicators is subdivided into three clusters (A1, A2 and A3) which might indicate degrees of good quality water or alternatively slight pollution by different factors. Based on the autumn results, cluster A1 indicates very slight pollution while groups A2 and A3 indicate very clean water. The distinction between these latter two groups is at this stage not apparent.

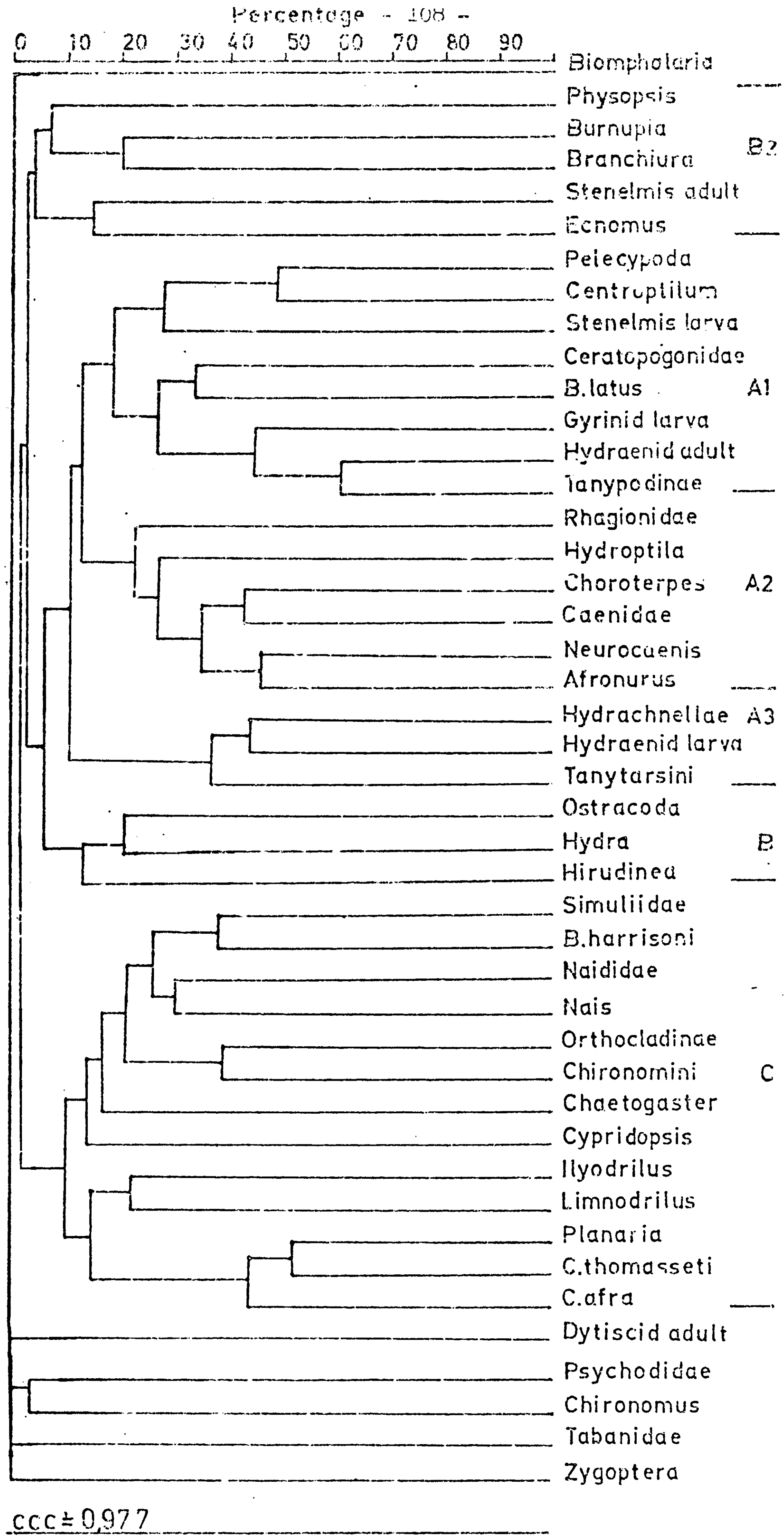


Figure 15 : Dendrogram of Bray-Curtis Similarity between Taxa for July-September at all sampling points.

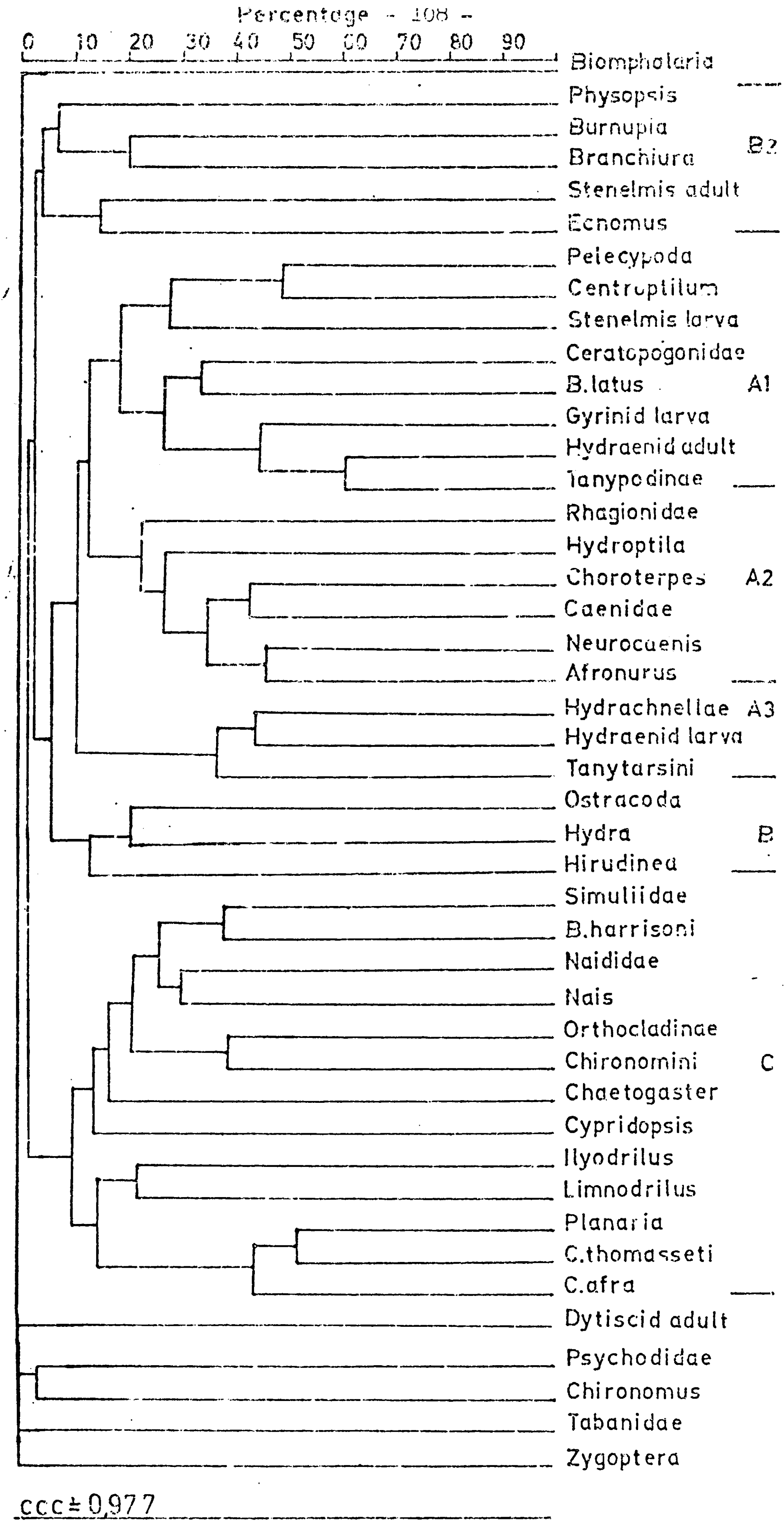


Figure 15 : Dendrogram of Bray-Curtis Similarity between Taxa for July-September. at all sampling points.

Table 27: Average monthly percentage composition of the *Limnodrilus* sp. - *Ilyodrilus templetoni* and *Cheumatopsyche* - Planaria groups for the July to September periods at all stations

Station	Group	
	Limnodrilus - *Ilyodrilus*	Planaria - *Cheumatopsyche*
2	0	0
3	0,25	1,1
4	0,9	0
5	2,25	0,15
6	0,5	2 35
6A	0,25	0,3
6B	0,65	0,4
7	1,5	8,8
7A	3,15	1,0
8	0	16,4
9	0,35	7,5
10	0,65	4,9
11	0,15	4,5
12	2,8	12,0
13	0,15	3,0
14	0,25	3,65

An interesting feature of the dendrograms for this season was that the association related to severe pollution as indicated earlier i.e. taxa such as Psychodidae, Culicidae, *Chironomus* sp., *Eristalis* etc. were either totally absent or poorly interrelated suggesting no clear occurrence of this association during this period. Due to the fact that rainfall and thus flow were low one would expect poorer conditions in this season than in any other. However the absence of these taxa may be related to a period of spring emergence of the adult stages of Dipteran larvae.

Cluster B1 and B2 (Fig. 15) are linked in the dendrogram between clusters A and C. As these clusters contain taxa which have been shown previously to be associated with known indicators of poor quality water (Hirudinea, *Branchiura* sp.) it is possible that these groups are indicative of conditions intermediate between average and very polluted.

The dendrogram of Czeckanowski similarity for the summer period (October to February) is presented in Figure 16 and shows the two groupings of taxa, shown in the previous section to be characteristic of the whole system, with cluster A representing the clean water associations and cluster B showing a closely correlated group of the most ubiquitous taxa linked to taxa representing indicators of poor quality water. Cluster C, although poorly related to the rest of the fauna, does show the existence of the association characteristic of severe pollution during this season.

The dendrogram of Bray-Curtis similarity for this period (Fig. 17) shows both the above major groupings divided into smaller, clearly defined subgroups. The cleaner water association (cluster A) is divided into two associations (A1 and A2) which appear to represent the communities indicative of slight pollution and clean water respectively. However, during this period these two associations were closely correlated and show an equal linkage at a very low r-value to other clusters in the dendrogram. This was different to the other seasons where the group representing slight pollution showed a chain type linkage to the clean water association and then to the cluster indicative of polluted conditions. Thus although this group is separate here its intermediate position is not apparent.

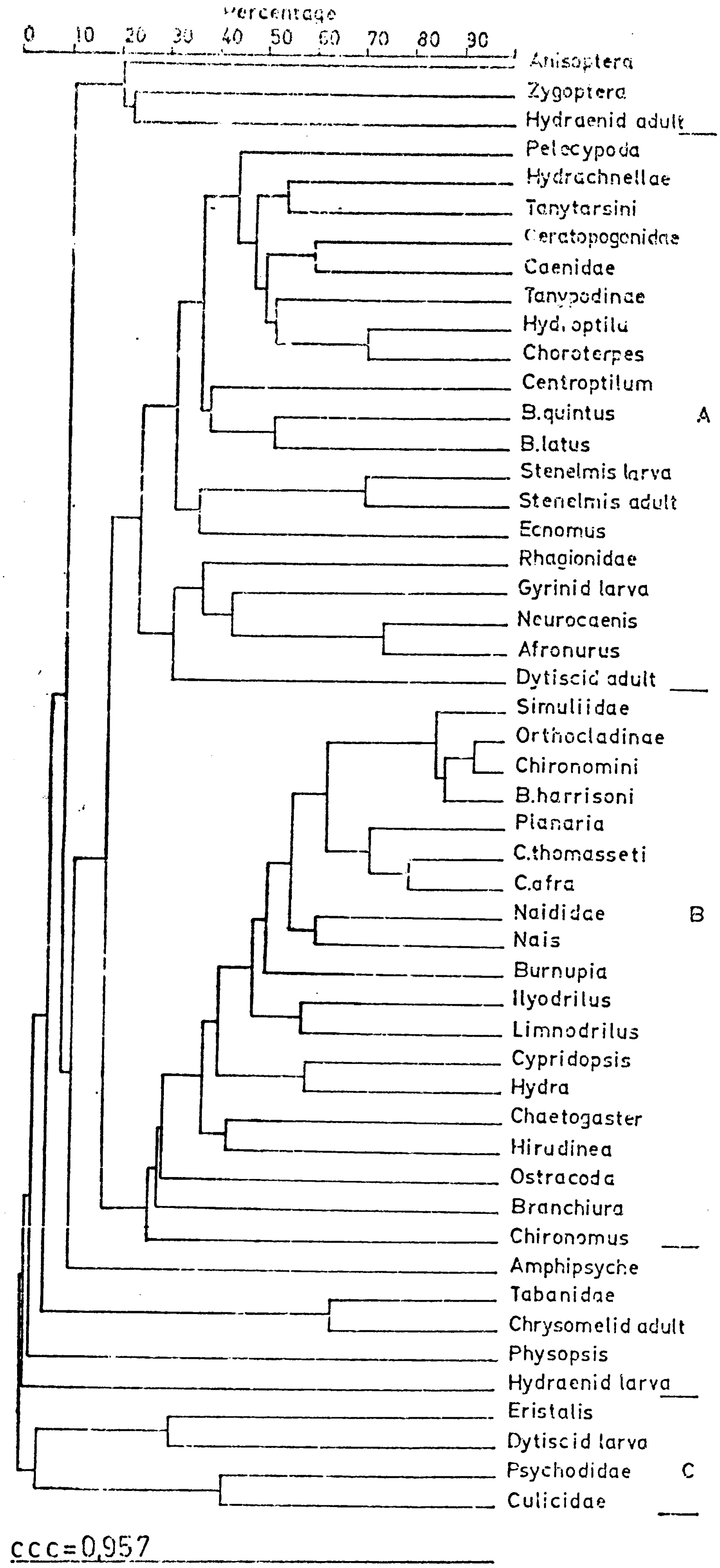


Figure 16: Dendrogram of Czeckanowski Similarity between Taxa for October-February at all sampling points.

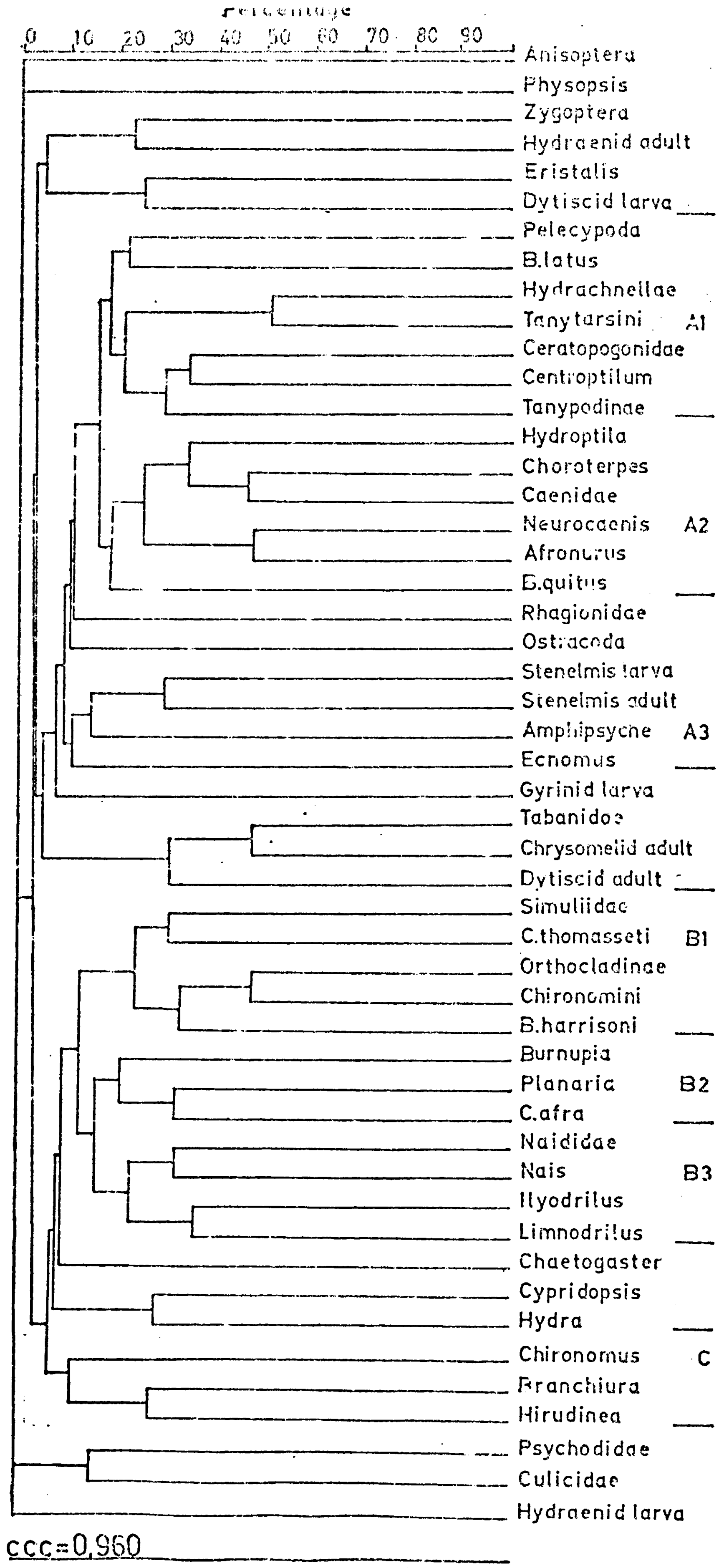


Figure 17 : Dendrogram of Bray-Curtis Similarity between Taxa for October-February at all sampling points.

A third group (A3) links the *Stenelmis* larvae and adults with the Trichopterans, *Amphipsyche* sp. and *Ecnomus* sp., but due to the relatively infrequent occurrence of the latter there is no clear indication of significance in this at this stage.

Cluster B shows three sub-clusters. Firstly, cluster B1 which is the basic grouping of the most ubiquitous species. An interesting point to note is that the *C. thomasseti* is a member of this group instead of occurring in the B2 cluster with *C. afra* and Planaria as occurred in the other seasons. The closer link between clusters B2 and B3 suggests that *C. thomasseti* do not have the same affinities with the Oligochaetes as do the other members of cluster B2. The presence of *Burnupia* in cluster B2 also suggests this link because in the autumn period it was significantly linked to the Tubificids, although the spring period showed them to be relatively rare. However the significance of this split in the *Cheumatopsyche* into connections with the dominant taxa of the river system and the Oligochaetes respectively may be fortuitous in this because on the basis of mutual presence-absence the *Cheumatopsyche* are still closely linked. Thus the possibility of such a split will be considered further as more specific situations are analysed.

Chironomus, *Branchiura* sp. and Hirudinea formed a small group (cluster C) which was linked to cluster B before the whole group linked to the rest of the fauna. This group, by virtue of its inclusion into the main cluster when compared on the basis of mutual presence-absence (Fig. 16) and the fact that its members are sometimes included with the indicators of severe pollution (Figs 13 and 15), suggests that they form an indicator community intermediate between the ubiquitous Oligochaetes/associated taxa and the community representative of extreme pollution as was concluded in the winter/ spring period as well.

Based on these dendrograms, taxa which are linked at similarity values below that at which the two main clusters of each dendrogram join are classified as rare occurrences for the season concerned. This applies only to taxa thus classified in both Czeckanowski and Bray-Curtis similarity indices for a particular season. In addition, any taxon which was completely absent during a particular season (see species composition tables in appendix) are included in the list of rare occurrences for that season. Table 28 lists all taxa which are thus classified as rare occurrences in one, two or all three seasons and includes those shown earlier to be rare in the system as a whole for all seasons. Thus the twelve taxa shown in this table to be rare and negligible in all seasons are removed from further analyses as being of no significance. However taxa which were rare in one or two seasons only are included in the other analyses as they are important in some seasons but note is taken not to place any significance on their presence in associations during seasons for which they are rare.

The Psychodidae, Culicidae and *Eristalis*, which are the indicators of severe pollution were only present in significant numbers in the autumn period. However their clearly defined grouping in the dendrograms of other periods and the whole study period suggests that even when present in relatively small numbers these taxa do occur together so that the likelihood of the influence being purely seasonal is not great.

TABLE 28: Showing taxa which occur rarely or are absent in one season only, in two seasons or in all three seasons based on their poor linkage to the characteristic fauna of the river system in the dendrograms

All seasons	Two seasons	One season
Dytiscid adults	*Amphipsyche*	*B. quintus*
Chrysomelid adults	*Eristalis*	*Ecnomus*
Prostoma	Culicidae	
Chaoborus	Psychodidae	
Tipulidae	*Physopsis*	
Tabanidae		
Biomphalaria		
Anisoptera		
Dytiscid larvae		
Gyrinid adults		
Hydrophilid adults		
Tetanoceridae		

Amphipsyche sp. were not recorded from the system during the spring and autumn. Their significance in the summer was based on their frequency of occurrence rather than on high numbers.

Physopsis occurred in spring only and is shown on a presence-absence basis to be of no significance. This is due to the fact that it was limited to three occurrences. Thus its significance by the above definition was numerical and it is not therefore seasonally controlled. Its occurrence must be due to favourable environmental conditions on these occasions.

Baetis quintus and *Ecnomus* sp. were rare or absent in spring only. This suggests a period of emergence of the adult stage.

As was seen in the analysis of the system as a whole, all three seasons showed two basic groups of taxa. The first comprises those taxa which are dominant throughout the system e.g. *Baetis harrisoni*, Orthocladinae, Chironomini, Simuliidae, *Nais* sp. Naididae etc., (the ubiquitous taxa) which are closely linked with indicators of more enriched conditions e.g. the Tubificidae. This association is composed of 22 taxa of which only four (Hirudinea, Ostracoda, Tanytarsini and Tanypodinae) do not occur in this cluster in all seasons.

These four taxa are all members of what could be termed intermediate associations. These are shown in the dendrograms to vacillate between the above association of dominant species and the groups indicating more extreme conditions, when they do not form a cluster on their own. One of these taxa, Hirudinea appears to belong to the association indicating conditions between "polluted" and "severely polluted", while the other three taxa, Ostracoda, Tanytarsini and Tanypodinae are members of an association which could be defined as indicating "slightly polluted" conditions.

The other major group i.e. the one that appears to be composed of taxa which are indicative of clean water conditions, consists of ten taxa which occur in this cluster in all three seasons and six taxa which either form part of the same cluster or form a closely linked intermediate group.

The Chironomids, Tanytarsini and Tanypodinae, did not always form a part of this "clean water association". These two taxa alternate between the groups of ubiquitous taxa described above and this "clean water" association. This could indicate an intermediate position.

Based on the Bray-Curtis similarity index the cluster of ubiquitous taxa plus pollution indicators show eleven taxa common to this group in all three seasons. The remaining taxa occur as a sub-cluster of this association or a completely separate cluster. This suggests an intermediate position between the association of ubiquitous taxa and severe pollution indicators.

The March-June season particularly is characterized by definition into separate associations with the cluster of ubiquitous taxa and pollution indicators separated as discussed earlier and the severe pollution indicators forming a separate cluster i.e. the *Eristalis*, Psychodidae, *Hirudinea* and *Chironomus* sp. Also the "clean water association" is split into an association characterized by most of the Ephemeropteran taxa and another characterized by the following taxa: *Centroptilum*, Ceratopogonidae, Ostracoda, Tanytarsini, Tanypodinae, Hydrachnellae, *Ecnomus* and Pelecypoda.

Thus the general indication from the seasonal data is that there are five basic associations in the river system other than the taxa which dominate the entire system. These latter taxa do tend to be more closely associated with relatively polluted conditions than with the clean water associations. This is possibly due to the fact that far more of the sampling sites in the river system represented some degree of pollution than clean water. These associations are given in Table 29 based on the degrees of pollution they appear to represent. Thus the indication is that any association dominated (80-90% of the total fauna) by one of these groups together with the taxa shown to be dominant throughout the system is indicative of one of these degrees of pollution. The greater the proportion of this group in relation to the system dominants the more clearly defined this state is, particularly in the case of polluted conditions.

At this stage these indicator associations are general and are based only on the mode of clustering of these taxa. Indication of more specific types of pollution and the limits of these categories remain to be defined by more specific analysis of the data. However, an advantage of these suggested associations is that they are based on the objective grouping of taxa without placing any emphasis on a particular taxon within the association thus evading the rigidity of thought which so often arises from single species evaluation.

It is interesting to note that in general the division of the component members of these associations agrees with the biotic index valuation placed on each by Chutter (1972). Also the ubiquitous taxa in the above analysis are mostly those which this biotic index places on a sliding scale dependant on which taxa comprise the balance of the association. The only difference lies in the fact that in the biotic index these values are dependant on the Baetid Ephemeroptera representation while in the above analysis these are not as all-important resulting in less rigidity.

TABLE 29: Pollutional categories and their indicator associations

Categories				
Clean	Slight	Moderate	Considerable	Severe
B. latus (0)	*Centroptilum* (0)	*Ilyodrilus* (8 - 10)	*Chironomus* (10)	Psychodiae (10)
B. quintus (0)	Ceratopogonidae (0)	*Limnodrilus* (8 - 10)		*Eristalis* (10)
Caenidae (1)	Tanytarsini (0)	*Burnupia* (4)	*Branchiura* (8 - 10)	Culicidae (10)
Choroterpes (1)	Tanypodinae (0)	Hydra (6)	Hirundinea (7)	
Afronurus (0)	Ostracoda (0)	*Cypridopsis* (1 - 7)		
Neurocaenis (0)	*Ecnomus* (0)			
Hydroptila (2)	Pelecypoda (0)			
Hydrachnellae (0)				
Rhagionidae (0)				

(x) = the biotic index value given to these taxa by Chutter (1972).

(d) Faunal associations of individual stations

The fauna characteristic of conditions at each station are used to show either the typical association throughout the study or the type of variation within the fauna. In the latter case these variations could be linked to seasonal changes in the fauna shown above or to changes in the chemical or physical characteristics of the station during this period.

The stations which have been defined as being characteristic of clean water in the earlier sections are discussed first in order to ascertain what can be termed the characteristic fauna in most nearly natural conditions. Thereafter by progressing to increasingly abnormal conditions the changes in the faunal associations can be compared with the chemical characteristics of eutrophied water. Thus the value of these communities as indicators of water quality may be shown.

(i) The tributaries

The Klein Jukskei, Crocodile and Hennops rivers (stations 8, 11 and 13) are chemically the "cleanest" water in the system and can therefore be considered to most nearly represent natural conditions.

The Braamfontein Stream, the Sandfontein Stream and the upper Jukskei River (stations 6A, 6B and 3) show signs of enrichment but still dilute the mainstream at their confluences.

Station 8: The Klein Jukskei River enters the main stream immediately above station 9. According to the chemical analyses the water in this tributary was the "cleanest" in the system i.e. all nutrients showed the lowest values of category E concentrations experienced in the system (Table 21). Only alkalinity and carbon concentrations tended to reach category D levels although these two parameters showed a significant increase to C category levels during the winter months.

The dendrogram of Czeckanowski similarity (Fig. 18) is characterized by one cluster of twenty-one taxa which show a significant degree of similarity (cluster A where r = >50%) and a number of smaller clusters. The taxa which represent these smaller clusters are shown in Table 30 to be negligible in terms of their frequency of occurrence. This table also shows that with the exception of *Baetis quintus* and *Afronurus* these taxa are present in insignificant numbers when they do occur. Thus the most frequently occurring taxa at this station are those grouped in cluster A.

The taxa in cluster C of the dendrogram of Bray-Curtis similarity (Fig. 19), which all occurred significantly (r = >50%) in the presence-absence analysis, are shown in Table 31 to completely dominate the fauna of this station. This cluster is divided into three separate associations, of which cluster C1 (the Simuliidae) dominated at all times except the winter of 1972. The taxa reprecented in cluster C3 usually formed a sub-dominant association but dominated

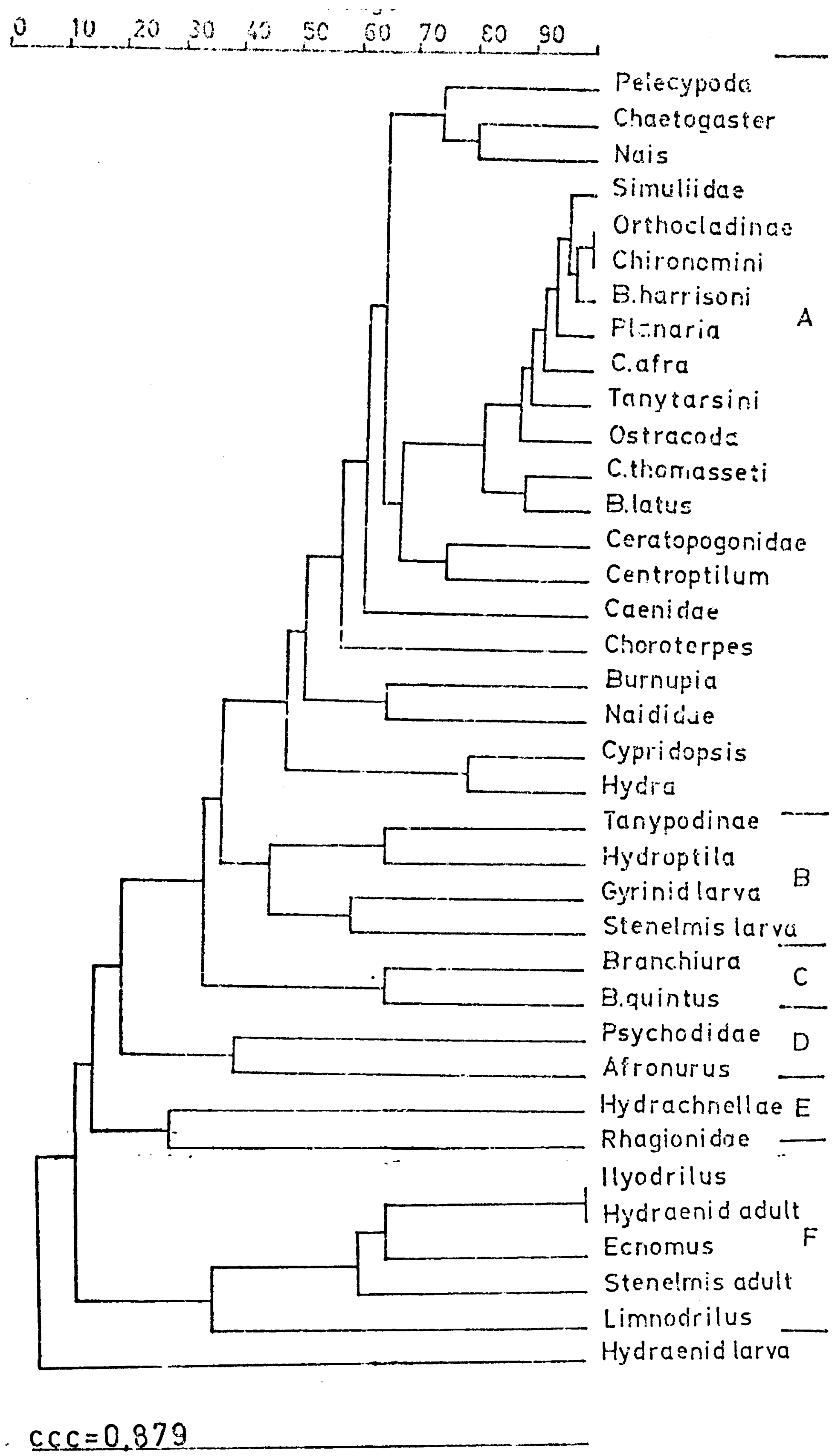


Figure 18: Dendrogram of Czeckanowski Similarity between Taxa for Station 8.

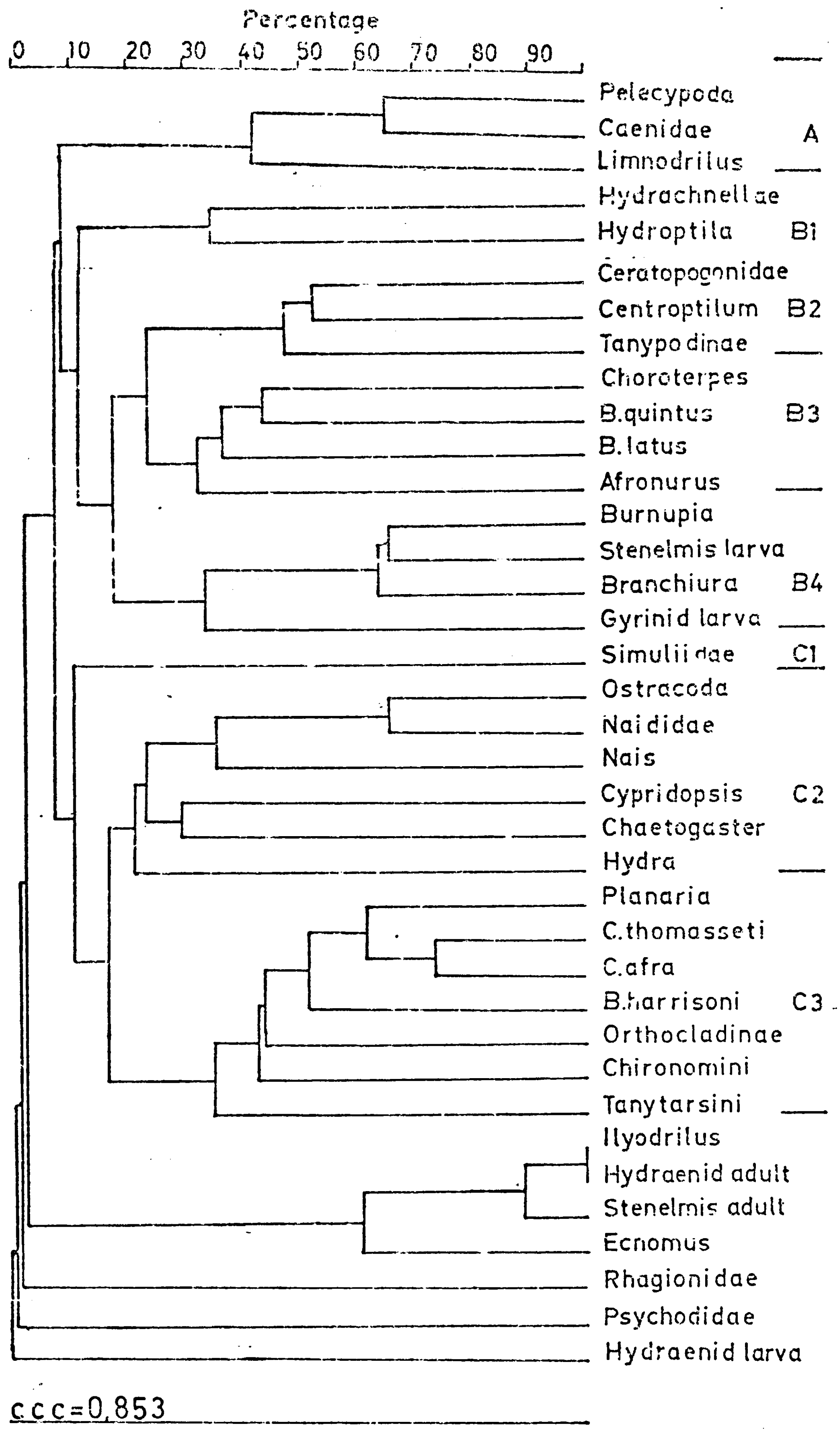


Figure 19 : Dendrogram of Bray-Curtis Similarity between Taxa for Station 8.

TABLE 30: The number of occurrences and the maximum number of individuals per occurrence of taxa recorded at station 8, other than those taxa forming clusters A and B in Figure 18

Taxon	Number of occurrences	Max. number of individuals per occurence
Ilyodrilus	1	1
Hydraenid	1	1
Ecnomus	2	1
Stenelmis a	2	1
Limnodrilus	4	5
Hydrachnellae	2	2
Rhagionidae	1	1
Psychodidae	1	4
Afronurus	4	100
Branchiura	4	8
B. quintus	5	30

in winter 1972 and co-dominated in early winter 1973. Cluster C2 consists of taxa which usually formed 5 and 10 per cent of this association except for the August to October period when they moved into a dominant position.

The only exception to this pattern of events occurred in February 1974 when the whole cluster C association was at its lowest (80,2%) and in this case the C3 taxa dominated and the Simuliidae were totally absent.

The taxa in cluster B, some of which are very significantly related to the common taxa on the basis of frequency of occurrence, generally formed a small but relatively constant part of the faunal population. It was these taxa

TABLE 31: Percentage composition of taxa grouped in cluster C of the dendrogram of Bray-Curtis similarity (Fig. 19) for station 8

Month	C1	C2	C3	Total
March 1972	-	-	-	-
April	36,9	5,1	42,2	84,2
May	3,6	0,4	83,1	87,1
June	56,4	0	40,7	97,1
July	3,9	6,4	86,4	96,7
August	6,0	10,1	77,5	93,6
September	18,6	45,2	32,6	96,4
October	-	-	-	-
November	55,9	9,4	27,6	92,9
December	-	-	-	-
January 1973	77,9	2,6	19,6	100,0
February	73,8	17,0	9,3	100,0
March	25,8	9,6	60,0	95,4
April	-	-	-	-
May	93,9	0,1	5,7	99,7
June	86,3	4,2	9,1	99,6
July	42,7	6,6	43,9	93,2
August	33,1	51,6	14,0	98,7
September	-	-	-	-
October	8,5	75,8	11,0	95,3
November	43,4	6,7	36,4	86,5
December	90,7	0,5	8,3	99,5
January 1974	62,0	0,9	32,6	95,5
February	0	12,0	68,2	80,2

which increased their percentage contribution to the population in the four months (April and May 1972), November 1973 and February 1974) in which the dominant population formed less than 90 per cent of the total population. There are three groups within this cluster and the percentages of each of these for the above four months show that cluster B1 and B2 dominate the increased representation of this association (B) in April and May 1972 (forming approximately 10 per cent of the total population) while cluster B3 dominates it in February 1974. The fact that clusters B1 and B2 include the Ephemeropteran taxa while B3 includes significant numbers of *Branchiura* sp. suggest that these indicate changes in water quality towards and away from clean conditions respectively.

Cluster A of the dendrogram of Bray Curtis similarity is formed by taxa which occurred in small numbers only throughout the survey except in November 1973 when they formed 13,8 per cent of the total population (see appendix, Table 11).

The remaining taxa in this dendrogram were found to occur in no more than three months in numbers of one to six (<0,3% of the total population) and are thus irrelevant in this discussion.

The characteristic population at this station consists of more than twenty taxa normally dominated by the Simuliidae with the Ephemeropteran nymphs and *Cheumatopsyche* species forming important parts of it. Of the Oligochaete taxa only the Naididae form a part of this association and then only during the winter months (Table 31) when the concentrations of most parameters increased slightly and the carbon concentrations (and thus possibly organic matter) increased to C category levels (Table 21). *Cypridopsis*, *Hydra* and the Ostracoda were associated with the period of Naid dominance while the five Ephemeropteran taxa, Tanypodinae and Ceratopogonidae in clusters B1 and B2 (Fig. 19) formed a subdominant association during periods of dominance by *B. harrisoni* and the Simuliidae. These latter were of particular significance in the April to May 1972 period which is characterized by a drop in the already relatively low COD and organic carbon values while all other values were increasing and the biotic index values for this period indicated that BOD was at its lowest.

Station 11: This station was situated on the Crocodile River before its confluence with the Jukskei River, which joins the main stream between stations 10 and 12.

Water quality, with respect to the chemical constituents, at this station was similar to that at station 8, except in three respects. Firstly, magnesium concentrations at station 11 were very much higher and were in fact high in comparison to the rest of the system being in category B or C (Table 21) for most of the year. Secondly, alkalinity levels which were mainly in category D at station 8 but vary at station 11 between categories A and C thus showing some of the highest levels in the system. Thirdly, the inorganic carbon values were higher at station 11 than at station 6 and were approximately average for the system. It must however be noted that although all other parameters fell into category E at both these stations the values in the Crocodile tended to be even lower than they were in the Klein Jukskei River.

The dendrogram of Czeckanowski similarity for this station (Fig. 20) shows the most commonly occurring taxa grouped at an *r*-value greater than 50 per cent (cluster B). There are twenty-five taxa in this group indicating a large degree of diversity. The four taxa grouped in cluster A (Pelecypoda, *Stenelmis* adults, *Centroptilum* and *B. quintus*) are linked due to a short concurrent period of occurrence (Table 32) while the rest of the taxa found at this station occurred rarely, (a maximum of four occurrences) and formed negligible proportions of the populations (Table 33). One exception to this latter is the occurrence of the Ostracoda in August/September 1972 which was significant relative to the rest of these taxa.

The cluster B taxa (Fig. 20) are shown in the dendrogram of Bray-Curtis similarity (Fig. 21) to be divided into two clusters each of which shows a degree of subdivision (clusters A and B). However, the percentage contribution of each of these clusters (Table 34) shows that the association indicated by cluster A only formed between 1 and 3 per cent of the total population in any one sample. The association

TABLE 32: The occurrence of the four taxa grouped in cluster A of the dendrogram of Czeckanowski similarity for station 11 (Fig. 20) and their percentage contribution to the populations

Taxon	Month									
	1972					1973				
	Mar	Apr	Aug	Nov	Dec	Jan	Feb	Mar	Sept	Dec
Pelecypoda	P				P	2			P	
Stenelmis		P		P	P	1			P	
Centroptilum			P		1	1	1			
B. quintus		1			P	2	9	7		2

P = less than 1 per cent.

TABLE 33: Occurrence of taxa which link to the group of most common taxa at station 11 at r = <50% in Figure 20 to show whether they are significant with regard to either frequency of occurrence or relative abundance

Taxon	Number of occurrence	Maximum number of individuals per occurrence	Maximum % contribution to the population
Hydra	3	4	P
Amphipsyche	2	2	1
Ecnomus	4	2	1
Ostracoda	3	45	3
Burnupia	3	2	P
Limnodrilus	3	1	1
Branchiura	3	2	1
Hydrachnellae	2	12	P

P = less than one per cent.

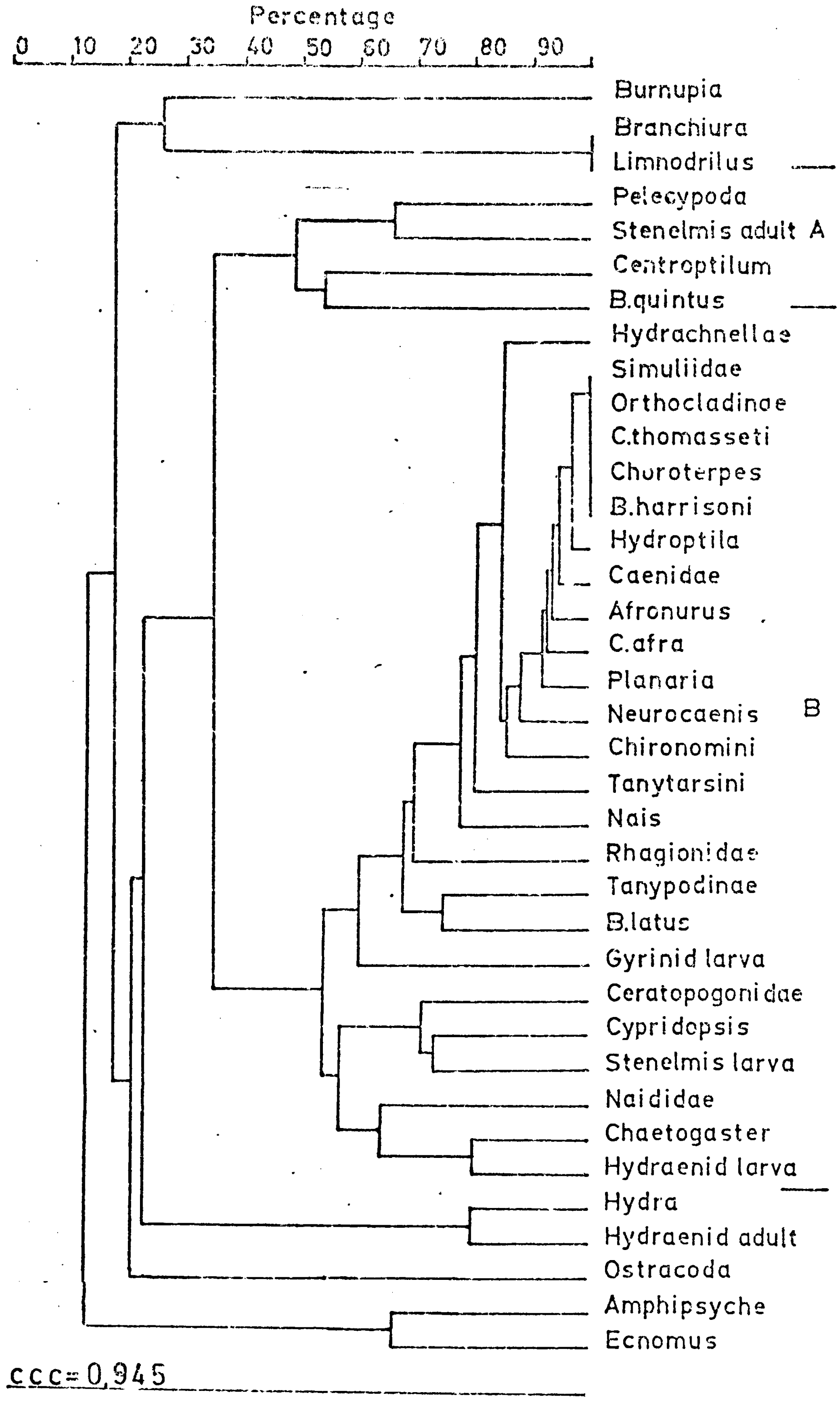


Figure 20: Dendrogram of Czeckanowski Similarity between Taxa for Station 11.

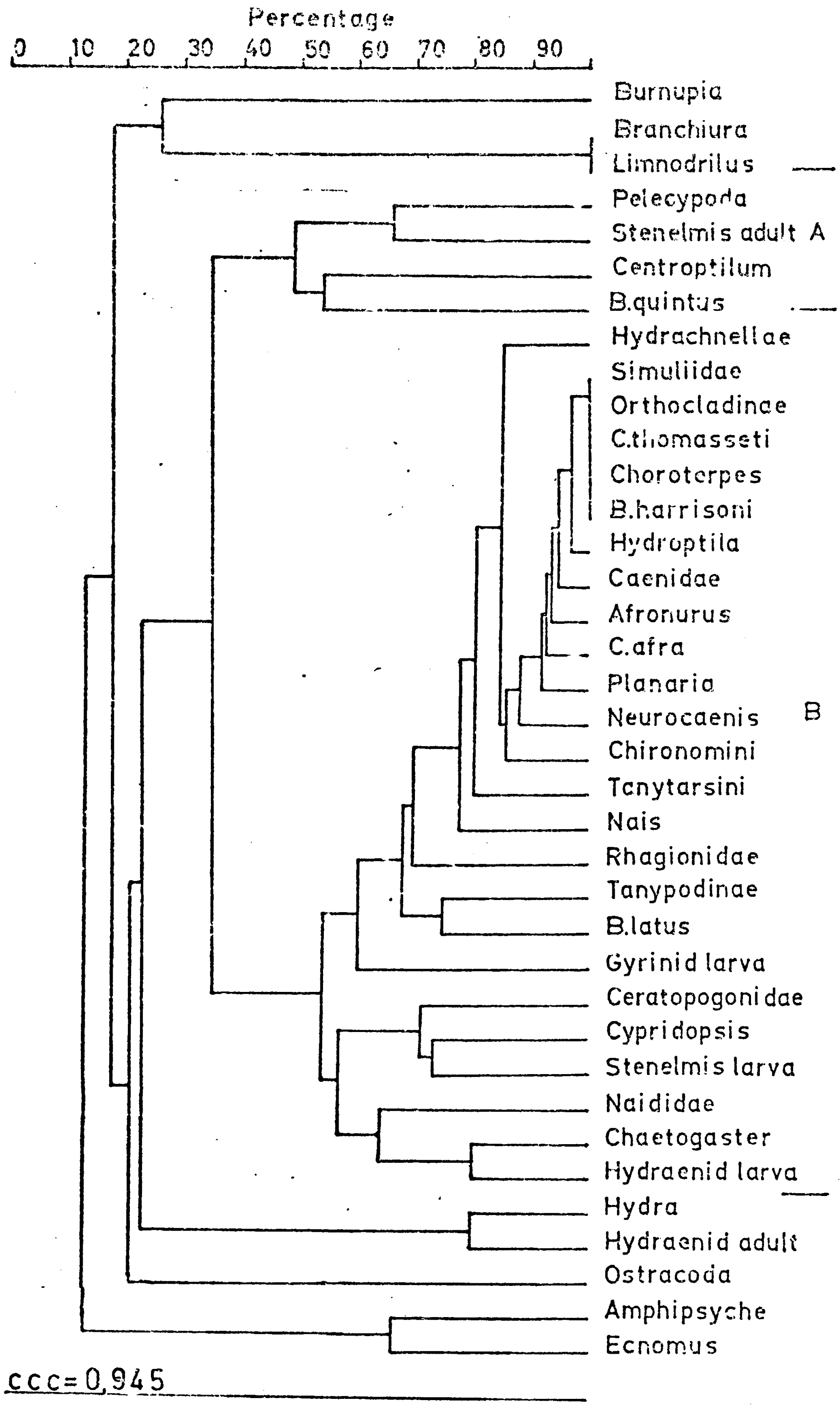


Figure 20: Dendrogram of Czeckanowski Similarity between Taxa for Station 11.

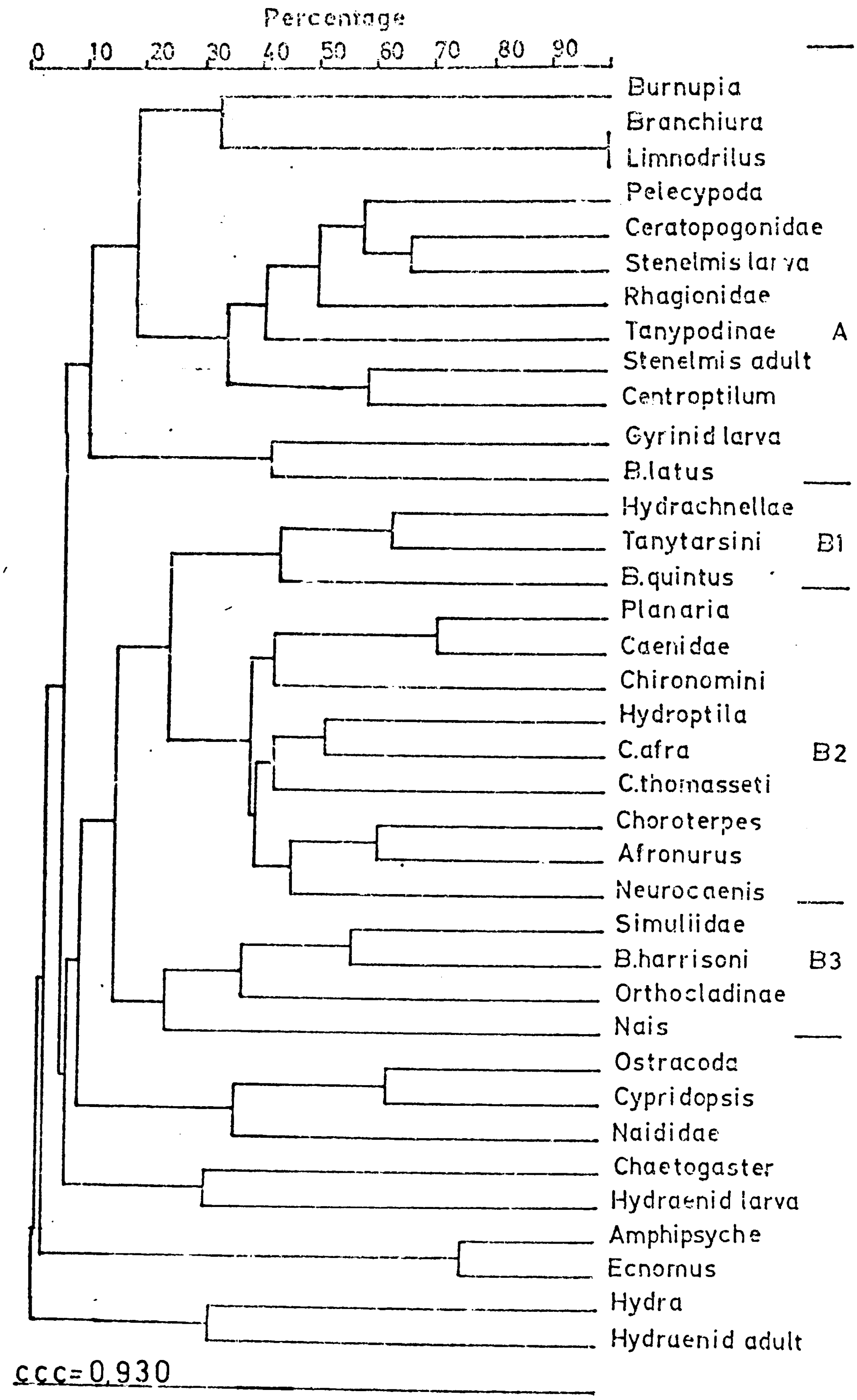


Figure 21 : Dendrogram of Bray-Curtis Similarity between Taxa for Station 11.

TABLE 34: Percentage contribution of taxa in clusters A and B from the dendrogram of Bray-Curtis similarity for station 11 (Fig. 21) to the population

Month	Cluster A	Cluster B			Total B
		B1	B2	B3	
March 1972		0,1	20,7	71,4	92,2
April		3,0	25,2	64,1	92,3
May		0	23,6	74,1	97,7
June		0,9	46,4	49,8	97,2
July		0,2	7,3	91,3	98,8
August		0,6	24,3	62,6	87,5
September		0,8	10,0	86,1	96,9
October		-	-	-	-
November		1,8	30,1	64,6	96,5
December		0,8	22,9	73,9	97,8
January 1973		4,4	65,3	13,6	83,3
February		10,1	24,5	62,5	97,1
March		13,2	59,2	25,9	98,3
April		-	-	-	-
May		0,4	28,8	56,5	85,7
June		0,1	16,3	81,6	97,9
July		0,3	13,6	77,1	91,0
August		0,3	10,2	86,9	97,4
September		0,3	12,7	83,3	96,3
October		1,6	26,4	69,6	97,6
November		0,9	18,2	80,1	99,3
December		7,1	21,4	68,7	97,2
January 1974		0	54,3	44,0	98,3
February		0	74,1	21,4	95,5

represented in cluster B always formed more than 95 per cent of the population (Table 34) so that the fauna of this station can be said to have been completely characterized by this group.

Cluster B is subdivided into three clusters (B1, B2 and B3) with cluster B2 further grouped into three subclusters. Cluster B1 tended to be the least significant in this association as it seldom formed more the 5 per cent of the population. The other two clusters (B2 and B3) both formed important parts of the association (Table 34). The cluster B3 taxa (Simuliidae, Orthocladinae, *B. harrisoni* and *Nais* sp.) tended to dominate throughout the survey except for the last two months (January and February 1974) but the B2 taxa always formed between a third and a half of this association thus being either co-dominant or significantly subdominant.

There were changes in each of these groups (B2 and B3) which may account for the change seen after the first eight months in the seasonal analysis of the data (p. 85).

In the cluster B3 taxa the *Nais* sp. only formed a significant part of the association during the winter months, July to September, while during the rest of the year the association was dominated by the other three taxa. However, there was a change in the dominance status of this group in that the first four months of the survey showed a *B. harrisoni* - Simuliidae dominance which changed after the first winter period to an association dominated by Orthocladinae and Simuliidae. This latter type of association continued to dominate through the summer of 1972/73 and resumed dominance in summer 1973/74 after the decline in *Nais* sp.

The association represented by cluster B2 initially showed an equal spread of dominance amongst its members but with the decline in *B. harrisoni* dominance the Trichopteran taxa dominated other taxa in Cluster B2.

From September 1972 the concentrations of a few parameters, particularly MBAS, both inorganic and organic carbon and total phosphorus, increased (Table 35). There were also slightly increased concentrations of COD and sodium. In view of the fact that the March to September results in Table 35 represented mainly winter data while the rest included two summers, when dilution might be expected, makes this increase even more significant. The effects of these changes on the environment appears to have caused the shift in dominance from *B. harrisoni* to Orthocladinae as co-dominants with the Simuliidae.

TABLE 35: Mean concentrations (mg/ℓ) of those chemical parameters which showed a change after September 1972 and October 1972 to February 1974 at station 11

	Concentrations	
	March 1972-September 1972	October 1972-February 1974
MBAS	0,10	0,20
COD	9,3	11,28
Inorganic carbon	32,2	35,2
Organic carbon	5,75	7,31
Total P	0,09	0,43
Sodium	8,97	11,17

This station showed a degree of faunal diversity on the basis of frequency of occurrence similar to that at station 8. However there was not a total dominance by a single taxon as was evidenced by the Simuliidae at station 8, but rather a shared dominance between the Simuliidae, *B. harrisoni*, Orthocladinae and *Nais* sp. The dominance status of these four taxa varied during the year and as at station 8 the Naididae, together with the Ostracoda and *Cypridopsis*, increased in significance during the dry season.

The association dominated by the Ephemeroptera and Trichoptera formed a far more significant part of the population at this station throughout the year than they did at station 8. However, the Trichoptera (*C. afra, C. thomasseti* and *Hydroptila*) tended to dominate this association after the abovementioned decline in *B. harrisoni* significance. The *B. quintus* - Tanytarsini - Hydrachnellae group of this association made its most significant contribution in the periods February to March 1973 and December 1973.

<u>Station 13</u>: This station, on the Hennops River, was characterized (Table 21) by extremely low values of all forms of nitrogen and phosphorus but MBAS and calcium values were average for the system (category C) and magnesium and alkalinity were very high (categories A and B) with the latter sometimes reaching the highest values recorded in this survey (275 - 294 mg/ℓ, Table 20). The values for the other mineral constituents of the water were low (category E).

There was a change in the chemical characteristics of this station in the second year of the survey in that the COD (Table 12) showed increased values, particularly after the winter of 1973. There was similarly a decrease in the values of the most significant mineral parameters i.e. calcium, magnesium and alkalinity (Table 6) in the second part of the study.

On the basis of the presence or absence of taxa only the dendrogram of Czeckanowski similarity (Fig. 22) shows the commonest taxa to be the twenty-two which are linked in cluster A at a similarity index value of above 50 per cent. The remainder of the taxa found at this station seldom occurred and then only in negligible numbers (Table 36).

TABLE 36: Occurrence of taxa at station 13 shown in the dendrogram of Czeckanowski similarity (Fig. 22) to be of no significance with regard to frequency of occurrence in order to show that they are also numerically insignificant

Taxon	No. of occurences	Mean No of individuals per occurence	Maximum No. of individuals per occurence	Mean % contribution to populations
Chaetogaster	5	12	45	2,8
Hydraenid a	10	5	15	1,1
Limnodrilus	3	2	2	0,7
Stenelmis 1	3	5	13	0,5
Ecnomus	1	1	1	0,5
Psychodidae	2	1	2	0,5
Culicidae	1	1	1	0,5
Centroptilum	5	3	5	0,7
Rhagionidae	1	4	4	0,8
Ilyodrilus	1	2	2	0,4
Stenelmis a	4	1	2	C,3
Cypridopsis	2	5	8	1,9
Amphipsyche	3	1	1	1,0

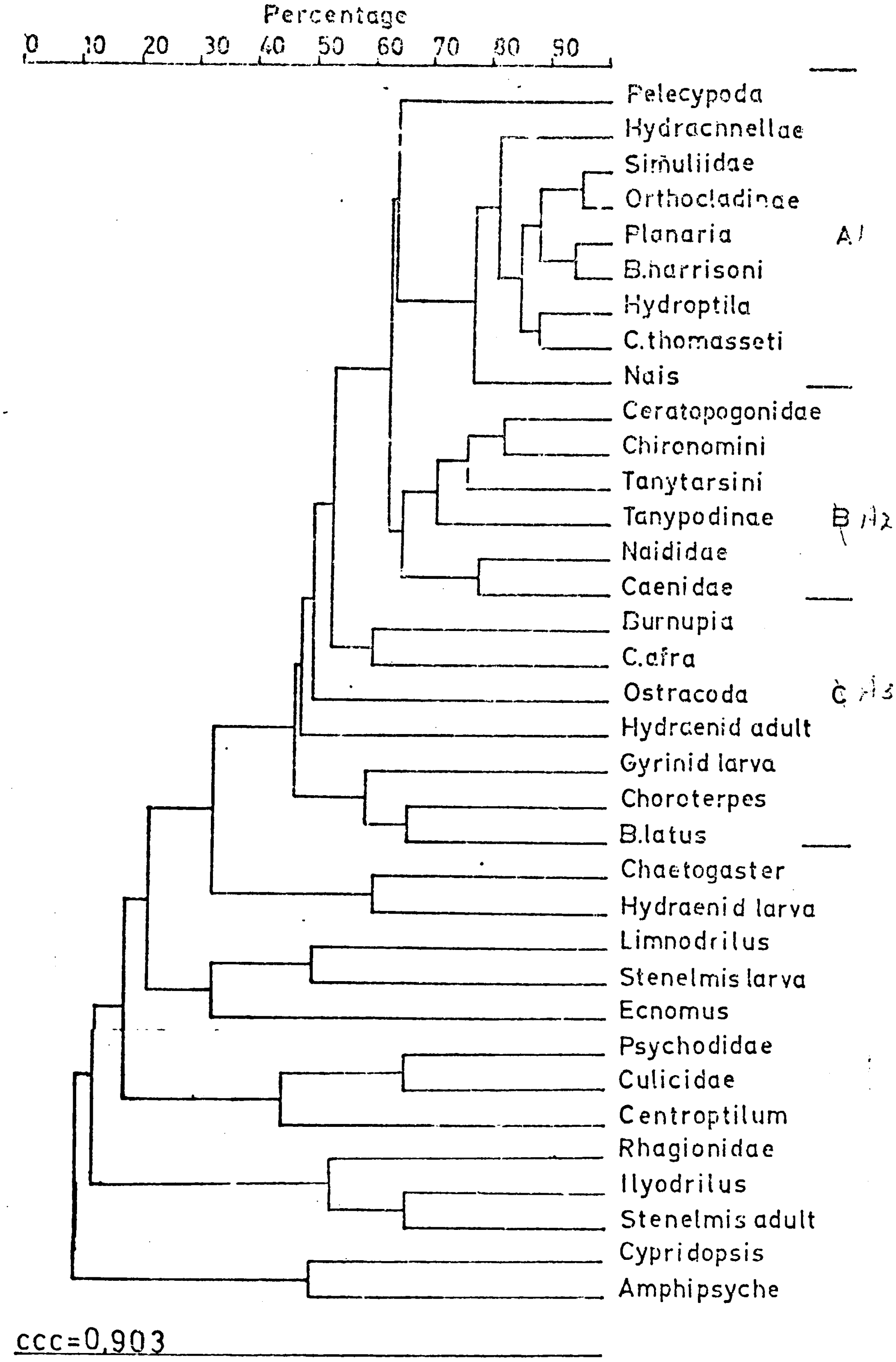


Figure 22: Dendrogram of Czeckanowski Similarity between Taxa for Station 13.

All the significantly occurring taxa i.e. those common at this station are shown by the dendrogram of Bray-Curtis similarity (Fig. 23) to be divided into four clusters (clusters A to D) which join to form a single group before linking to taxa which occur less often. Table 37 shows that these four clusters are comprised of taxa which form between 98 and 100 per cent of the total population at all times thus indicating that the rest of the taxa are of little significance.

The members of cluster D completely dominated the population pf this station until April 1973 usually forming more than 90 per cent of the population. From May 1973 until the end of the survey this association lost its dominance status and only constituted 30 to 60 per cent of the population. The Planaria - *Hydroptila* - *C. afra* part of the cluster D association was comparatively small (usually <10%) but maintained its proportion of the total population after the decline in dominance of this association. It was thus the remainder of this cluster which changed in the second year of the study.

Clusters A, B and C formed a small part of the community (<10%) during the first year of the survey. As from May 1973 cluster C formed between 33 and 60 per cent of the total population, reaching its highest proportion towards the end of the survey, as compared with 1,5 to 2,5 per cent during the first year. It was thus this group which tended to replace the cluster D taxa. However the members of

TABLE 37: Percentage contributions of cluster A, B, C and D in the dendrogram of Bray-Curtis similarity (Fig. 23) to the populations at station 13

Month	Cluster						Total
	A	B	C	D			
				D1	D2	Total	
March 1972	4,3	0	1,5	92,5	1,3	93,8	99,6
April	0,4	0,3	2,1	89,0	6,4	95,4	98,2
May	0,6	0,4	1,5	91,0	4,7	95,7	98,2
June	0,6	0,1	1,4	94,3	2,3	96,6	98,7
July	0,7	0	1,2	96,0	2,1	98,1	100,0
August	3,9	2,3	26,4	62,5	0,3	65,8	98,5
September	0,1	0,6	0,9	95,1	1,9	97,0	98,6
October	0	0,4	2,1	89,9	6,4	96,3	98,8
November	0	3,0	1,5	84,9	9,4	94,3	98,8
December	1,5	4,9	2,9	78,1	12,6	90,7	100,0
January 1973	6,1	3,1	2,2	56,7	19,0	75,5	86,9
February	1,5	1,5	2,9	89,7	4,4	94,1	100,0
March	2,0	0,9	1,5	89,2	6,4	95,6	100,0
April	-	-	-	-	-	-	-
May	6,3	1,4	33,5	54,9	3,6	58,7	99,9
June	40,8	1,0	24,8	32,4	1,0	33,4	100,0
July	11,7	0,6	46,0	38,3	2,5	40,8	99,1
August	-	-	-	-	-	-	-
September	9,4	2,8	36,2	43,5	6,4	49,9	98.3
October	6,8	3,4	41,2	43,2	0,5	43,7	95,1
November	0,2	0,9	45,1	48,7	4,6	53,3	99,5
December	1,0	2,6	55,8	33,6	6,8	40,4	99,8
January 1974	2,6	2,7	58,0	33,9	2,8	36,7	100,0
February	11,6	9,6	40,5	34,6	1,9	36,5	98,2

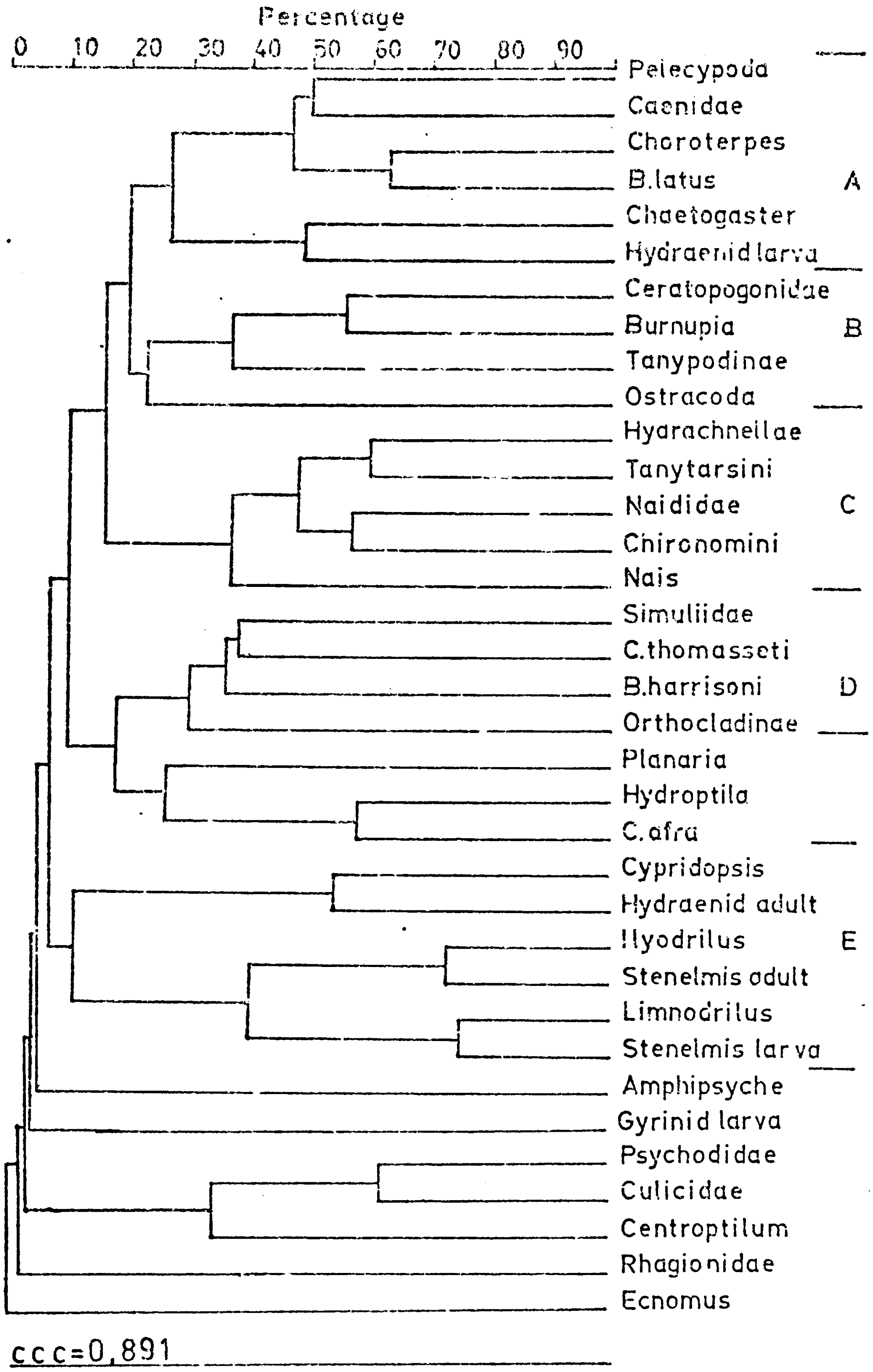


Figure 23: Dendrogram of Bray-Curtis Similarity between Taxa for Station 13.

cluster A were also positively affected by this change in population structure, as prior to April 1973 they usually formed less than 2 per cent of the total population but during the second year of the study their percentage contribution increased to between 6 and 12 per cent, with the exception of June 1973 when they formed 40 per cent of the population thus co-dominating with the clusters C and D taxa.

Cluster B remained a small proportion of the fauna throughout the survey (<5%), not changing in abundance after April 1973, except in February 1974 when it formed 10 per cent of the total population. This relatively significant occurrence of the association of Ceratopogonidae, *Burnupia*, Ostracoda and Tanypodinae in February 1974, with the latter dominating it accompanied an increase in the Ephemeropteran association (cluster A). This occurrence was at the expense of the Hydrachnellae - *Nais* sp. group and was associated with a marked drop in the concentrations of the significant parameters, calcium, magnesium and alkalinity.

The subdominant associations (clusters A and C) show different reactions at the time of this overall change in population structure. Cluster C, like Cluster D, indicated a slight deterioration in conditions which could be a reflection of the small increase in COD. Alternatively, cluster A comprising the Ephemeropteran taxa and Pelecypoda suggested an improvement in conditions coincident with the decrease in mineral concentrations shown in the appendix tables for this station. A similar change was also shown above in February 1974 so that it appears that this cluster A type association may have been indirectly influenced by the effects of the change in mineral status of the water.

In general there was very little variation between the summer and winter populations although small variations occurred, such as the Orthocladinae increasing in significance in the dominant population during winter and all the Trichopteran taxa increasing in summer. Similarly in the subdominant group C *Nais* sp. and the other Naididae tended to dominate the Hydrachnellae and Tanytarsini during winter and vice versa.

A second exception to the above occurred in January 1973 when the association shown to be characteristic of this station only formed 87 per cent of the total population, the remainder of the fauna consisting of taxa shown in cluster E (*Limnodrilus* sp., *Ilyodrilus templetoni*, *Stenelmis*, *Cypridopsis* and the Hydraenids). This indicated a deterioration in water quality as the Tubificidae were not common at any of the clean water stations and were usually associated with deteriorating water quality. The only significant chemical change which coincided with this was an increase in the actual values (not averages) of chloride concentration, MBAS and organic carbon (see Table 38). These three parameters are usually associated with sewage effluent.

TABLE 38: The actual concentrations (mg/ℓ) for chloride, MBAS and organic carbon at station 13 in January and February 1973

Month	Cl	MBAS	TOC
January	20,0	0,05	6,0
February	26,0	0,26	12,0

In general there was a great deal of similarity between the fauna of stations 8, 11 and 13, the three "clean"water stations dealt with above which can thus be considered to be most nearly approaching communities likely to be found in natural streams in this area. All three stations were characterized by a dominant association of over twenty taxa all of which were at times abundant.

It can be seen from Table 39 that in addition to those taxa which have been shown previously to be common throughout the system except in severely polluted conditions, the taxa commonly found in the most nearly natural conditions include a variety of Ephemeropterans, Trichopterans and Coleopteran larvae. There is thus confirmation that station 11 shows the least deviation from natural conditions because it supported the greatest variety of abundant taxa.

Some dominance patterns within this association were common to all three stations. Firstly, the tendency over the whole system for the Oligochaetes to become more prevalent during winter is confined under more natural conditions to *Bais* sp. with *Chaetogaster* and the other Maododae showing a small degree of dominance at the same

TABLE 39: The degree of similarity between stations 8, 11 and 13 with respect to those taxa which were characteristic of these stations on the basis of presence-absence only

	Station 8	Station 11	Station 13
Common at all three stations	*B. harrisoni*	*B. harrisoni*	*B. harrisoni*
	Simuliidae	Simuliidae	Simuliidae
	Orthocladinae	Orthocladinae	Orthocladinae
	Chironomini	Chironomini	Chironomini
	Planaria	Planaria	Planaria
	Nais	*Nais*	*Nais*
	Naididae	Naididae	Naididae
	C. afra	*C. afra*	*C. afra*
	C. thomosseti	*C. thomosseti*	*C. thomosseti*
	Tanytarsini	Tanytarsini	Tanytarsini
	Ceratopogonidae	Ceratopogonidae	Ceratopogonidae
	B. latus	*B. latus*	*B. latus*
	Caenidae	Caenidae	Caenidae
	Choroterpes	*Choroterpes*	*Choroterpes*
Common at two stations	Pelecypoda		Pelecypoda
	Chaetogaster	*Chaetogaster*	
	Ostracoda		Ostracoda
	Cypridopsis	*Cypridopsis*	
		Hydrachnellae	Hydrachnellae
		Hydroptila	*Hydroptila*
		Tanypodinae	Tanypodinae
		Gyrinid larvae	Gyrinid larvae
		Hydraenid larvae	Hydraenid larvae
Only common at one station	*Centroptilum*		
	Hydra		
		Afronurus	
		Neurocaenis	
		Rhagionidae	
		Stenelmis larvae	

time. However the Tubificidae were not part of this association although isolated individuals may occur. The differences in representation by the three Naid taxa at these stations shows that the more natural the conditions (with regard to water quality) the more *Nais* sp. tended to dominate this group leading to the exclusion of the other two taxa. This also resulted in a reduction in the degree to which the dominance status of *Nais* changes between summer and winter periods.

Secondly, the more closely the various Ephemeroptera are related to those taxa shown to be the most common in the system with regard to relative abundance, the cleaner the water.

Thirdly, the whole association is dominated to a greater degree by the Simuliidae and *B. harrisoni* than by the Chironomidae although both groups are part of the dominant association at all these stations. In addition the Chironomini tend to be less closely related to this association than are the Orthocladinae. In general, however, there is a tendency in this type of water for dominance to be split between a variety of taxa with no one taxon ever dominating to the virtual exclusion of others.

Station 3: The abiotic characteristics of this station on the Jukskei River above the confluence with the Modderfontein stream, are not comparable to those of the clean water tributaries. Although most of the chemical parameters show D to E levels of concentration (Table 21) some of the conservative mineral elements (Mg, Cl and Alkalinity particularly) are characterized by high to very high concentrations. Carbon and phosphorus other than ortho-phosphate concentrations were sometimes average for the system (category C).

The dendrogram of Czeckanowski similarity for this station (Fig. 24) shows a cluster of eight taxa which join at r-values greater than 50 per cent (cluster A1). Of the remaining taxa found at this station Table 40 shows that only the association of *Ilyodrilus templetoni* and *Limnodrilus* sp. occurred at all frequently. As these two taxa link to cluster A1 at a little less than 50 per cent, the cluster of taxa whose occurrence is characteristic of this station can

TABLE 40: Frequency of occurrence of taxa at station 3 which are not closely related to cluster A in the dendrogram of Czeckanowski similarity (Fig. 24).

Taxon	Number of occurrences	Maximum number of individuals per occurrence	Average number of individuals per occurrence
Planaria	1	1	1
Tanypodinae	1	9	9
Hirudinea	6	6	2
Chironomus	3	35	15
Psychodidae	3	3	2
Ilyodrilus	8	40	8
Limnodrilus	10	36	7
Rhagionidae	1	22	22
Burnupia	2	4	2
Cypridopsis	1	2	2
Branchiura	1	3	3

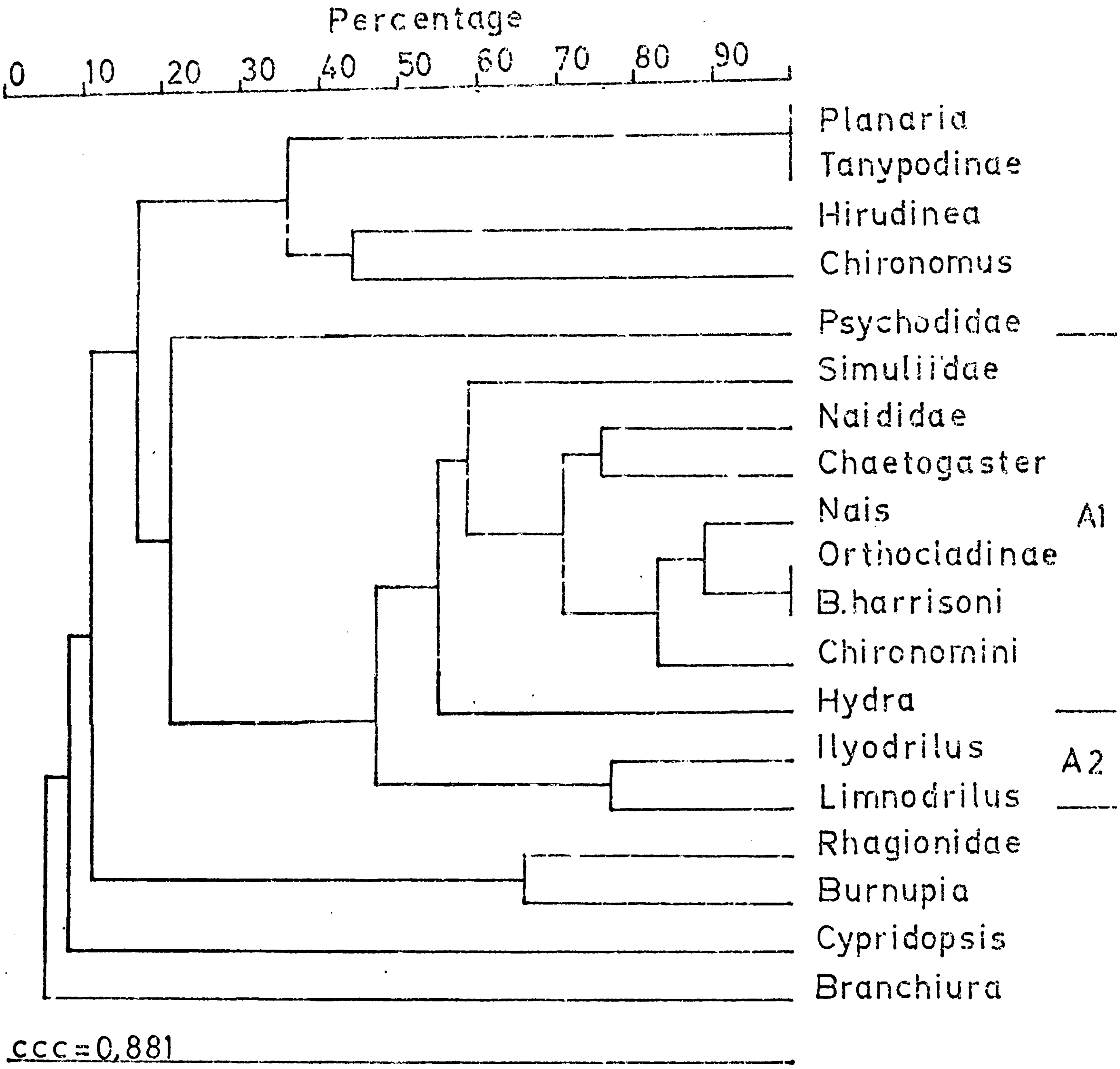


Figure 24: Dendrogram of Czeckanowski Similarity between Taxa for Station 3.

probably be extended to include them. Although the Hirudinea occurred in a quarter of the samples their occurrence was always restricted to less than 2 per cent of the population. It is however worth noting that these occurrences were restricted to the winter months (April to September).

The characteristic taxa of this station (cluster C) show various interrelationships in the dendrogram of Bray-Curtis similarity (Fig. 25). Cluster C of this dendrogram always formed between 80 and 95 per cent of the total population at this station (Table 41) except in October 1973. These taxa thus formed the characteristic fauna of this station. The most closely related taxa within this cluster are the Orthocladinae and *B. harrisoni* which dominated this association except in the winter/spring period when *Nais* sp. dominated (Table 41).

Cluster B formed a small but constant subdominant association which was numerically most significant in the mid-summer months. Thus the low mineral, nitrogen and orthophosphate concentrations and higher (category C) concentrations of total alkalinity, total phosphorus and COD, characteristic of this station in summer are associated with a fauna dominated by *B. harrisoni* and Orthocladinae and two subdominant populations. Firstly one of *Nais* sp. and/or *Chaetogaster* and secondly, an association of Simuliidae, *Hydra* and Chironomini.

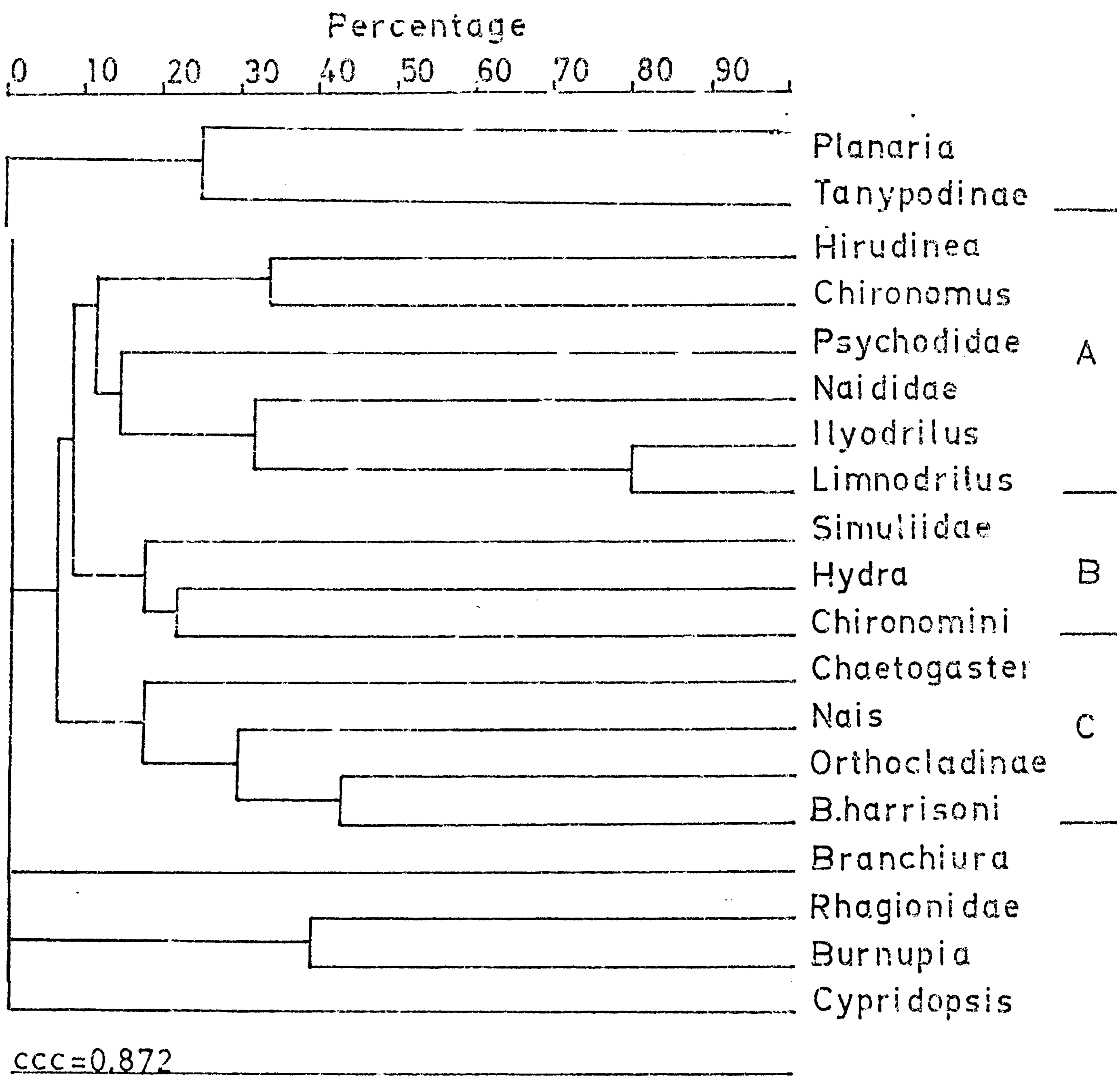


Figure 25: Dendrogram of Bray-Curtis Similarity between Taxa for Station 3.

TABLE 41: Percentage composition showing variation in dominance status between the characteristically occurring taxa at station 3 with the associations based on the dendrogram of Bray-Curtis similarity (Fig. 25)

Month	Cluster						
	A	B	C				
			B. harrisoni	Orthocladinae	*Nais*	*Chaetogaster*	Total
March 1972	2,8	7,8	64,3	19,6	2,6	2,7	89,2
April	1,7	1,7	71,3	8,4	16,2	0	95,9
May	0	2,8	65,5	21,8	9,7	0	97,0
June	7,8	1,0	71,0	5,4	14,8	0	91,2
July	3,9	0	23,1	9,6	18,4	44,7	95,8
August	5,8	0,8	45,2	12,4	32,2	2,3	92,1
September	0,8	2,5	0,6	8,8	86,8	0,1	96,3
October	–	–	–	–	–	–	–
November	11,5	8,3	1,6	58,4	18,4	0	78,4
December	13,2	8,7	8,0	68,1	0,8	0	76,9
January 1973	6,4	0	11,5	73,8	0	6,6	91,9
February	11,3	3,4	9,1	75,0	0	1,1	85,2
March	–	–	–	–	–	–	–
April	–	–	–	–	–	–	–
May	13,4	2,0	13,3	18,4	3,5	47,5	82,7
June	4,9	7,8	34,5	12,5	38,7	1,6	87,3
July	5,4	7,9	13,2	16,5	32,2	24,8	86,7
August	7,6	0,8	3,8	2,9	84,1	0,8	91,6
September	9,0	7,1	0,2	0,8	79,4	3,4	83,4
October	51,7	0	12,1	23,4	11,5	0	47,1
November	0	6,5	54,7	25,9	12,9	0	93,5
December	4,8	0	20,3	65,6	4,7	3,1	93,7
January 1974	0,5	3,3	55,7	38,6	0	1,4	95,7
February	0	18,7	61,0	15,5	4,3	0	80,8

An interesting deviation from the normal pattern of environmental conditions at this station occurred in the period from September to November 1972 when there was relatively little change in the concentrations of COD and Cl and increased concentrations of MBAS while the rest of the chemical concentrations show the characteristic summer decrease (Table 42). These chemical parameters are usually associated with effluent from sewage treatment plants. This period shows a continuation of the typical winter population with a possible deterioration in water quality shown by the fact that the dominanting *Nais* sp. were accompanied by an increased percentage contribution of the association represented by *I. templetoni*, *Limnodrilus* sp. and the other Naididae. After this period the typical summer population reinstated itself. This occurred notwithstanding the fact that flood conditions occurred during these periods which would be expected to scour the river bed of algae and organic detritus usually linked with Oligochaete dominance.

TABLE 42: Concentrations of COD, MBAS and chloride (mg/ℓ) at station 3 for the spring period of 1972 to show how these parameters deviate from the normal pattern of decreasing concentrations characteristic of this period during September to November

Parameter	Concentration						
	July	August	September	October	November	December	January
COD	22,0	26,3	36,7	37,0	36,3	29,7	25,7
MBAS	0,32	0,30	0,29	0,39	0,45	0,41	0,24
Chloride	62,0	69,0	93,0	93,0	95,0	61,0	62,0

The changed chemical environment of this station when compared with the more natural streams in the system has resulted in an obvious deviation from the "normal" with respect to the faunal population. On the basis of mutual presence and frequency of occurrence the characteristic fauna of this station were limited to ten taxa. Other than *Hydra* all these taxa have been shown to be common to the system as a whole. The winter population were characterized by a dominance of *Nais* sp. as was seen in natural waters. However the degree of *Nais* dominance tended to be greater and there was a closer linkage to the other Naididae and the Tubificidae during this period than was seen previously. At no stage did the association of Ephemeropteran and Trichopteran taxa characteristic of natural waters occur here and the Simuliidae only shared dominance with the Orthocladinae and *B. harrisoni* during the mid-summer periods when the water was most diluted.

Stations 6A and 6B: These two stations show conditions on the two streams (Braamfontein stream and Sandfontein stream) which join immediately before their confluence with the main stream between stations 5 and 6. These stations were both characterized by very low concentrations of all parameters measured throughout the survey (category E) except for the alkalinity and calcium concentrations which tended to rise to the category C or D concentration levels in winter. However, there is a possibility that both these stations were subject to some form of pollution by the intermittent addition of domestic or industrial waste (Barlow, 1974; Barlow and Lee, 1974) which could have been missed by monthly sampling.

The taxa characteristic of these two stations on the basis of their frequency of occurrence are very similar (Figs 26 and 27) although their relationships to one another differ. The characteristic associations consist of a group of twelve taxa linked at station 6B at r = 61 per cent and thirteen at station 6A linked at r = 57 per cent. Other clusters linking at above 50 per cent are shown in Table 43 to be irrelevant on the basis of frequency of occurrence.

TABLE 43: Frequency of occurrence of taxa at station 6A and 6B, which are shown in the dendrograms of Czeckanowski similarity to form close relationships, in order to show whether they are significant parts of the faunal populations

Station	Taxon	Number of occurrences	Maximum number of individuals per occurrence
6A	Stenelmis a	1	1
	C. thomasseti	3	2
	C. afra	3	7
6B	*Cypridopsis*	1	73
	Hydraenid 1	2	15
	Chironomus	1	1
	C. thomasseti	1	2

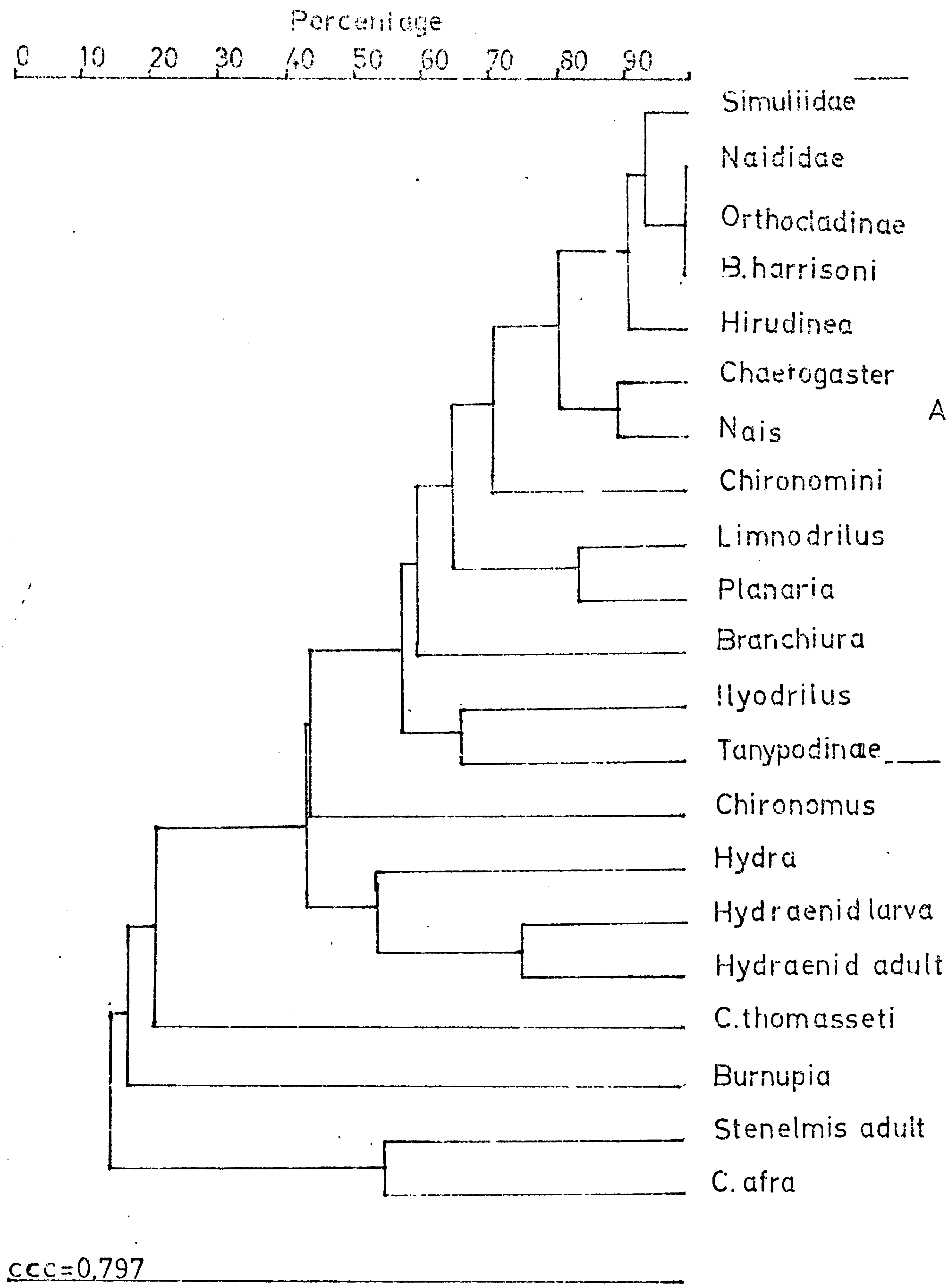


Figure 26: Dendrogram of Czeckanowski Similarity between Taxa for Station 6A.

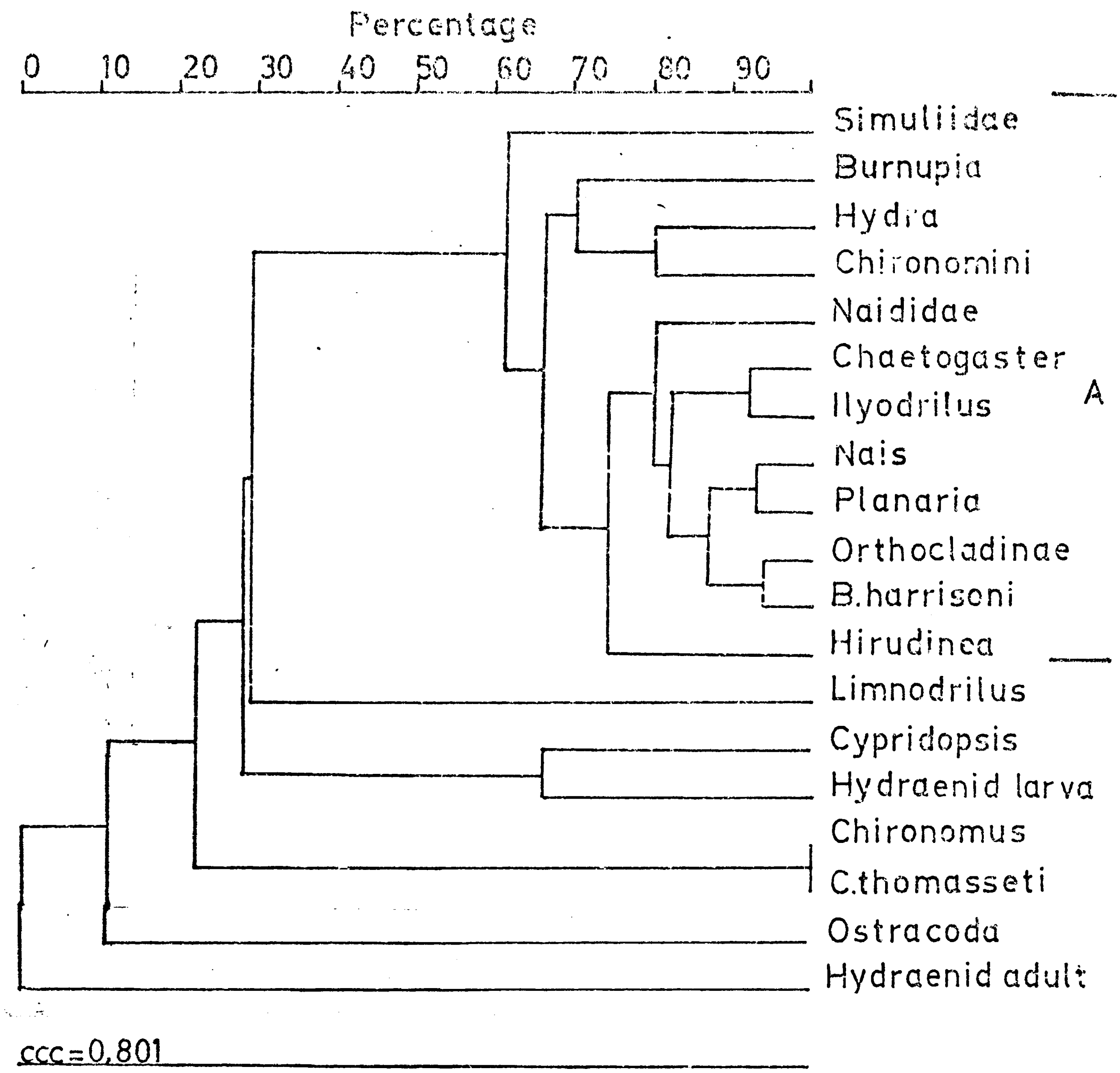


Figure 27: Dendrogram of Czeckanowski Similarity between Taxa for Station 6B.

However the only occurrence of *Cypridopsis* at station 6B might be significant due to the high numbers found at this time although they formed less than 2 per cent of the total population. The association at station 6B on the Sandfontein stream (Fig. 27 cluster A) was very much more clearly defined than on the Braamfontein stream and include some of the Oligochaete taxa with the ubiquitous taxa. The Simuliidae occur least often of this association. Station 6A (Fig. 26) differed from 6B in that the Simuliidae were highly correlated with the most frequently occurring taxa (r = 95,2) while most of the Oligochaete taxa, particularly the Tubificids, were among the least frequently occurring members of this association.

This suggests that the Sandfontein stream was subject to a greater degree of enrichment than the Braamfontein stream. However the total lack of other Ephemeropteran taxa and Trichopteran taxa in the fauna characteristic of these stations showed a marked deviation from the fauna of natural streams which would not be expected from the chemical classification of these stations (Table 21).

The dendrogram of Bray-Curtis similarity for station 6A (Fig. 28) shows the same taxa to be characteristic on the basis of relative abundance as were significant in the Czeckanowski analysis. This fauna is dominated by an association of five taxa, the Simuliidae, *Nais* sp., Naididae, Orthocladinae and *B. harrisoni* (cluster A). This cluster formed more than 80 per cent of the total population of this station in all samples (Table 44). However this table shows that the Naididae, Orthocladinae and *B. harrisoni* tended to dominate this association for most of the year. The former taxon was dominant in late summer and winter while the latter two taxa dominated the summer samples. The Simuliidae and *Nais* sp. formed between 15 and 40 per cent of the population in August to November. *Nais* sp. tended to exceed the Simuliidae contribution when the Naididae dominated the fauna and vice versa when the Orthocladinae and *B. harrisoni* were dominant.

TABLE 44: Percentage contribution of the associations shown in the dendrogram of Bray-curtis similarity (Fig. 28) for station 6A, which comprise the characteristic taxa of this station

Month	Cluster					
	A			B		
	A1	A2	Total	B1	B2	Total
March 1973	-	-	-	-	-	-
April	0	78,0	78,0	20,7	0	20,7
May	2,9	87,7	90,6	6,8	0,8	7,6
June	3,2	93,3	96,5	3,1	0,2	3,3
July	6,6	91,3	97,4	0,6	1,8	2,4
August	32,0	65,4	97,4	1,2	1,2	2,4
September	40,9	53,4	94,3	1,5	0,4	1,9
October	15,4	74,7	90,1	5,5	4,4	9,9
November	20,3	76,3	96,6	1,1	1,4	2,5
December	3,7	77,5	81,2	7,0	12,2	19,2
January 1974	2,9	78,0	80,9	17,6	0	17,6
February	1,5	88,0	89,5	3,1	0	3,1

Cluster B at station 6A (Fig. 28) consisted of two groups whose members appeared regularly in the population (see Table 44) but were usually present in very small numbers. The taxa grouped in cluster B1 tended to decrease in the

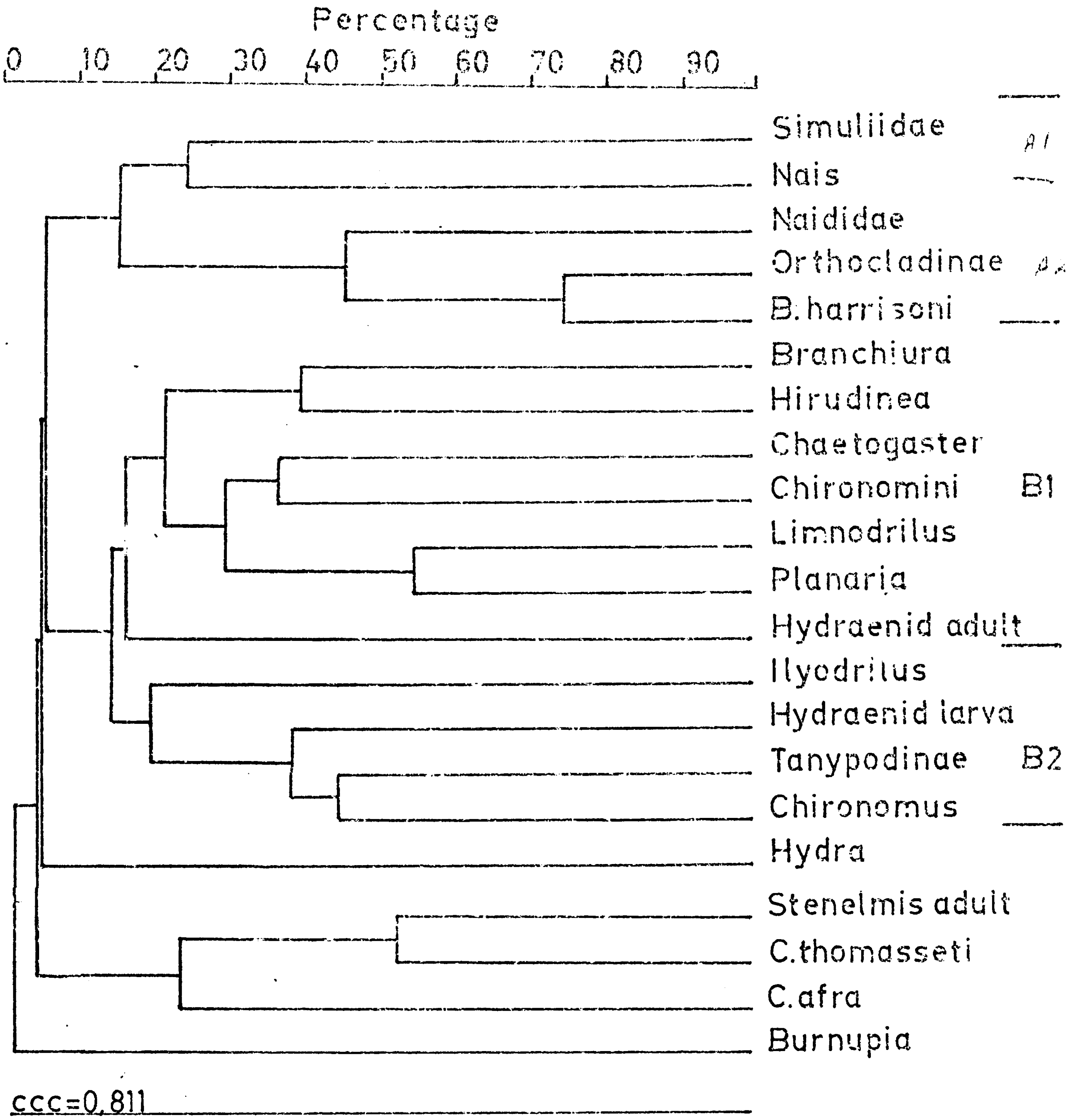


Figure 28: Dendrogram of Bray-Curtis Similarity between Taxa for Station 6A.

winter months (April to September) thus linking them with the decline of the Naididae and the dominance of *B. harrisoni*, Orthocladinae and the Simuliidae. Cluster B2 individuals showed no particular time related significance although *I. templetoni* increased to 11 per cent of the population in December 1973.

The association which dominated the fauna at station 6B is shown in cluster B of the dendrogram of Bray-Curtis similarity (Fig. 29). Table 45 shows that clusters B1 and B2 dominated the association from November to April forming more the 75 per cent of the population. Except for April 1973 when all four members of this group formed a significant proportion of the population with *B. harrisoni* and the Naididae dominating, the tendency was for *B. harrisoni* and the Orthocladinae to dominate the association while the Naididae and *Burnupia* formed less than 5 per cent of the fauna. Cluster B4 completely dominated the association from May to September (more than 90 per cent of the population) with a reduction in the cluster B1 and B2 association to less than 10 per cent of the population.

The members of cluster A at station 6B (Fig. 29), although a constant presence (Fig. 27), seldom exceeded 5 per cent of the population.

These two stations showed a great deal of similarity on the basis of relative abundances of taxa. The characteristic taxa at these stations were limited to fifteen taxa which

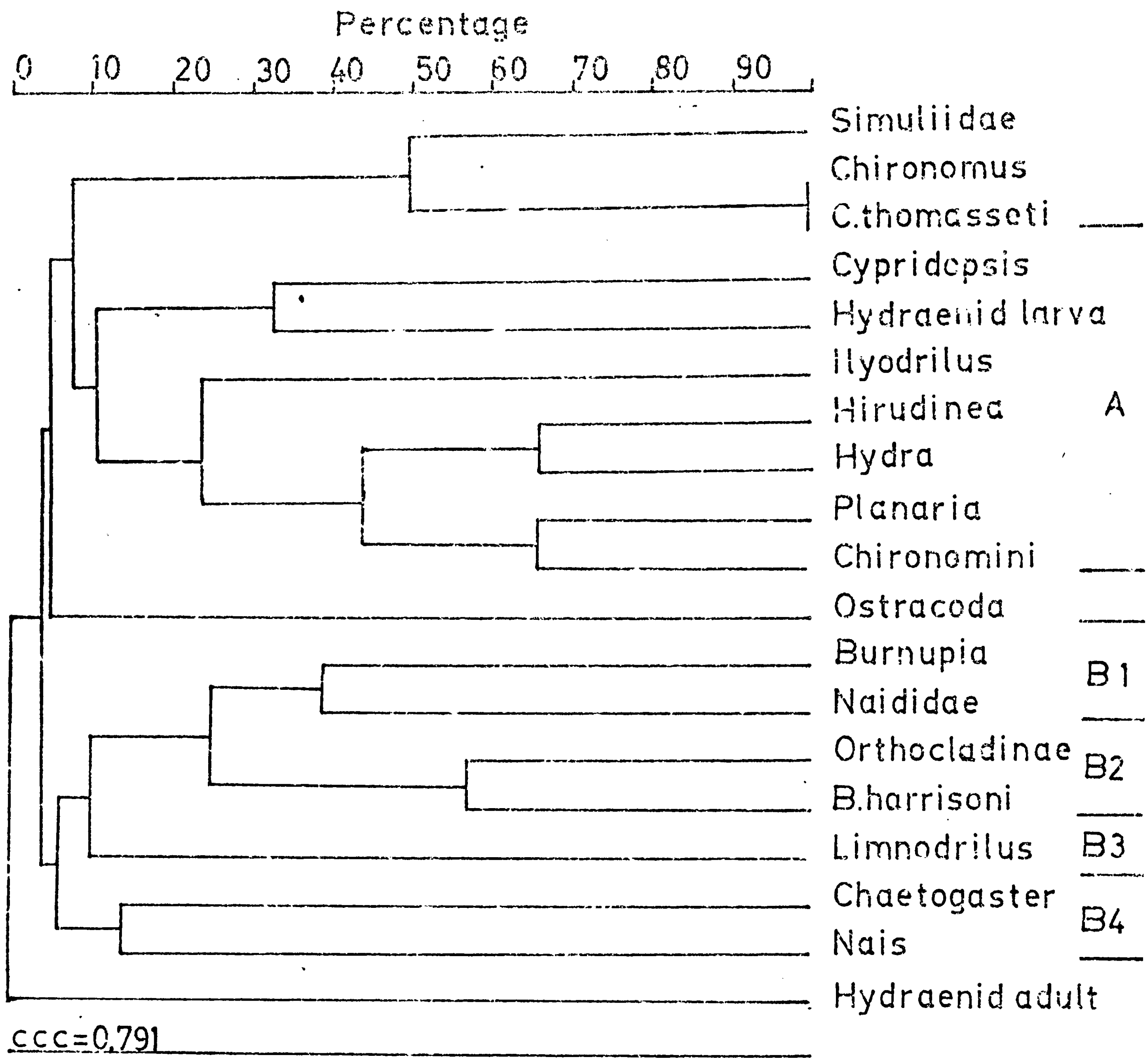


Figure 29: Dendrogram of Bray-Curtis Similarity between Taxa for Station 6B.

TABLE 45: Percentage contributions of the associations shown in the dendrogram of Bray-Curtis similarity for station 6B (Fig. 29) which comprise the characteristic taxa of this station.

Month	Cluster					
	A	B				
		B1	B2	B3	B4	Total
March 1973	-	-	-	-	-	
April	0	53,5	44,1	2,3	0	99,9
May	2,3	2,2	2,0	0	94,2	98,4
June	0,3	0,5	6,3	0	92,7	99,5
July	4,1	0,6	1,4	0,3	93,4	95,7
August	1,0	0	8,7	0	90,1	98,8
September	4,0	1,0	2,9	0	91,8	95,7
October	-	-	-	-	-	-
November	4,3	1,4	73,7	0	19,6	94,7
December	2,0	1,9	92,4	0	3,1	97,4
January 1974	7,2	4,2	83,4	0	5,2	92,8
February	-	-	-	-	-	-

were similar to those characteristic of station 3 but included *Burnupia*, Planaria and Hirudinea. The inclusion of this latter taxon suggests a deterioration in conditions, which is confirmed by a further deviation from the fauna of the natural streams in that the winter population was dominated by the Naididae to a greater degree than by *Nais* sp. In addition the Tubificidae, particularly *I. templetoni* were closely linked to the characteristic association here.

The position of the Simuliidae within the dominant faunal association indicates a difference between these two stations. Its occurrence and abundance was far more significant at station 6A thus showing less deviation from the natural population than at station 6B. The association of Ephemeropteran and Trichopteran taxa typical of clean water associations was lacking at these stations as they were at station 3.

(ii) <u>The main stream</u>

The main stream stations i.e. from station 1A on the Modderfontein stream to station 14 at the entrance to the dam, are dealt with here starting with station 14 which is shown by the chemical analyses and the biotic index (see appendix) to be the cleanest of these stations. By working upstream there is an increasingly greater deviation from the natural tributaries.

<u>Station 14</u>

Due to the influence of the Hennops River (see station 13) this station is characterized by high concentrations of magnesium and alkalinity (Table 21). The other mineral parameters and the various forms of nitrogen and phosphorus all occurred at category D levels so that this water is more enriched than at stations 8, 11 and 13 but according to the biotic index values (see appendix and the chemical results) it is the least enriched of the mainstream stations.

The organic carbon and COD concentrations show that the organic status of the river at this point tended to be average for the system and unexpectedly appeared to be more organically polluted than either station 12 or station 13.

The dendrogram of Czeckanowski similarity (Fig. 31) for this station shows a group of fourteen taxa (cluster A1) linked together at above r = 50 per cent. There are however a number of other small clusters which show similarly close relationships and Table 46 suggests that the taxa linked to these in cluster A2 can be considered with this grouping of common taxa even though they link to cluster A1 below the 50 per cent criterion imposed on the natural stream. However for the purposes of comparison the cluster A1 taxa must be considered the characteristic fauna of this station.

TABLE 46: Frequency of occurrence of taxa at station 14 which appear in the Czeckanowski similarity dendrogram (Fig. 31) but link to cluster A1 at r = <50 per cent

Taxon	Number of occurrences	Maximum number per occurrence	Maximum percentage contribution
Ceratopogonidae	1	1	0,1
Ostracoda	4	6	1,0
Hydraenid a	1	1	0,2
Caenidae	2	2	0,3
Physopsis	6	18	0,3
Cypridopsis	1	4	0,6
Hirudinea	2	4	0,6
Pelecypoda	4	24	3,6
Hydra	6	14	2,1
B. latus	7	172	8,0
Hydroptila	7	5	1,2
Stenelmis a	7	3	1,4
Stenelmis 1	7	9	1,4
Tanypodinae	6	54	2,5
Choroterpes	2	1	0,2
Branchuira	3	3	0,4
Ilyodrilus	3	2	0,3
Chaetogaster	7	24	1,8
Hydraenid 1	2	4	0,6
Centroptilum	2	2	0,5
B. quintus	2	5	1,2
Psychodidae	1	1	0,1
Culicidae	1	1	0,1

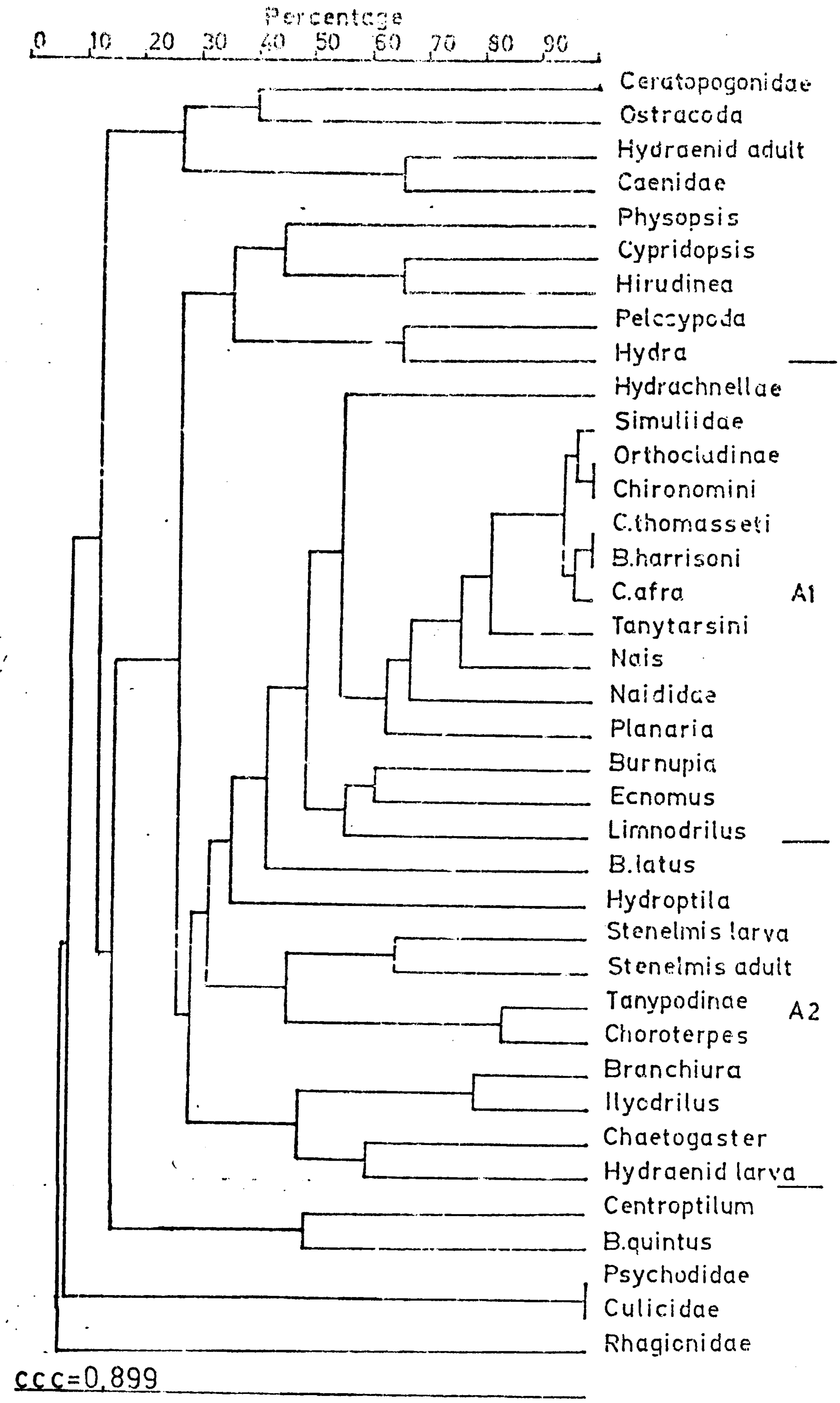


Figure 31: Dedrogram of Czeckanowski Similarity between Taxa for Station 14.

Most of these common taxa are grouped together in the dendrogram of Bray-Curtis similarity (cluster B) showing their relationship to be similar on the basis of relative abundance as well (Fig. 32). Table 47 shows that this association of taxa (cluster B) constituted an average of 98,3 per cent of all faunal samples except for October 1972 (88%) and November 1973 (78%). Thus apart from these two occasions these were the only taxa which formed a relevant part of the fauna at this station.

Within this cluster the *B. harrisoni* - *C. thomasseti* - Simuliidae association totally dominated the fauna in all the summer samples continuing until June 1973 while the Orthocladinae tended to dominate the winter samples in both years. This change to an Orthocladinae dominated association was accompanied by an increase to dominance or co-dominance of the total population by the *Nais* sp. - Naididae association.

During the summer months of 1973/74 the above association decreased its dominance status while the *C. afra* and Chironomini increased in numerical importance to sometimes become a co-dominant group. The increased importance of this group occurred similarly but in smaller proportions in January and February 1973.

The marked increase in the Chironomini - *C. afra* association in the last four months of the survey coincided with a period of increased conductivity and mineral concentrations while the concentrations of the other parameters were decreasing (Table 48).

The subdominant association consisting mostly of *Nais* sp. (Table 47) only replaced the dominant group for two winter months each year showing a similarity to conditions in the clean water tributaries where a lower

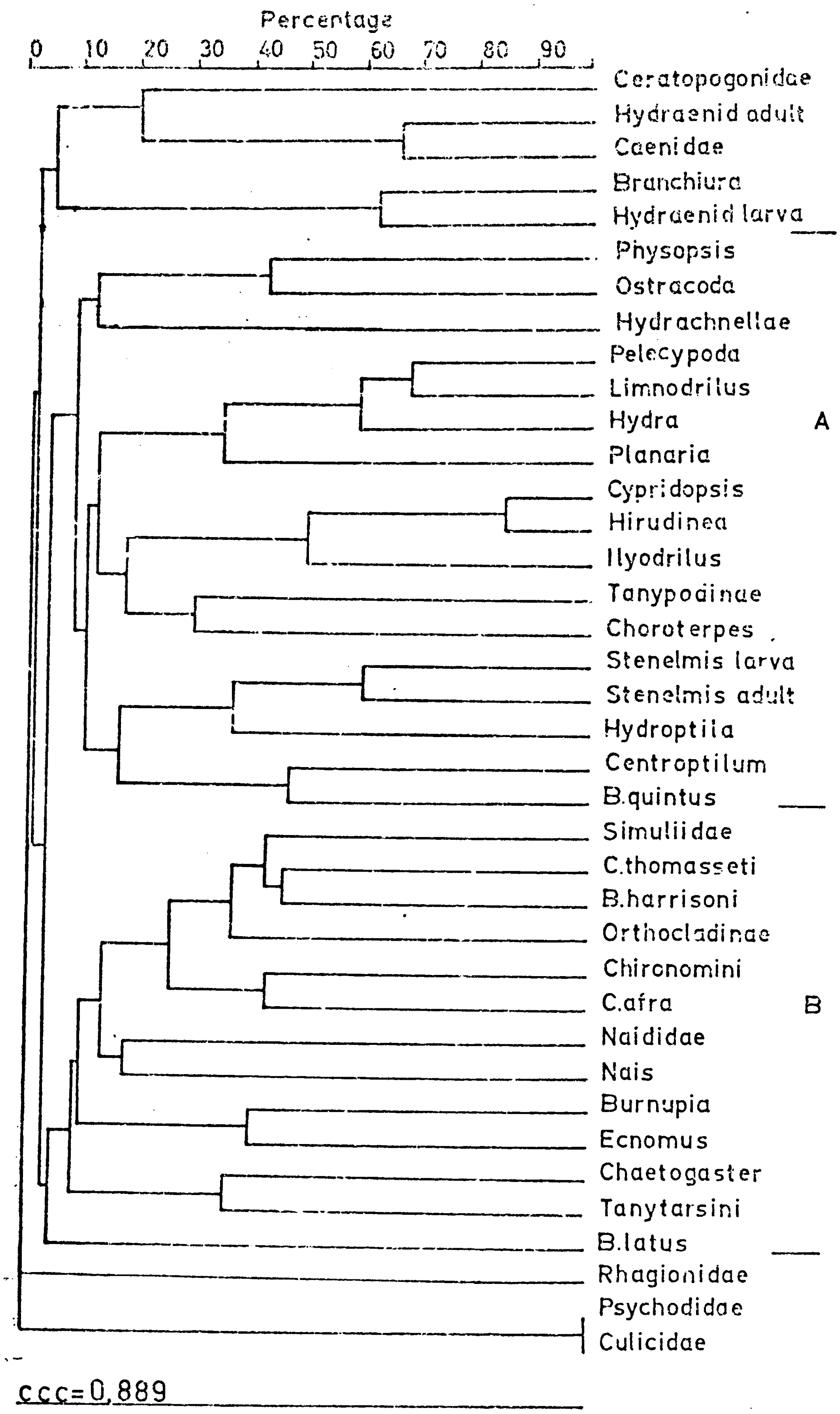


Figure 32: Dendrogram of Bray-Curtis Similarity between Taxa for Station 14.

TABLE 47: Percentage composition of the populations at station 14 based on the associations of commonly occurring taxa as grouped in the dendrogram of Bray-Curtis similarity (Fig. 32)

Month	Association						
	B. harrisoni Simuliidae Orthocladinae *C. thomasseli*	Chironomini *C. afra*	Naididae *Nais*	Burnupia *Ecnomus*	*Chaetogaster* Tarytonimi	*B. latus*	Total %
March 1972	81,3	5,5	0,3	0	1,1	8,0	96,7
April	93,4	4,9	0	0	0	1,0	99,3
May	89,4	2,4	1,3	0,2	0	3,7	97,0
June	80,3	1,8	15,1	0,3	1,8	0,2	99,5
July	48,2	1,6	49,5	0	0,3	0	99,6
August	12,5	1,9	84,5	0	0,3	0,1	99,3
September	32,2	1,2	65,5	0	0,2	0	99,1
October	72,8	11,7	2,7	0,2	0,3	0	87,7
November	94,8	3,9	0	0	0,5	0	99,2
December	-	-	-	-	-	-	-
January 1973	79,9	12,8	0,5	1,0	0,9	0	95,1
February	74,1	21,0	0,2	0	0,7	0	96,0
March	-	-	-	-	-	-	-
April	-	-	-	-	-	-	-
May	97,8	1,0	0	0,4	0,3	0,1	99,6
June	90,4	1,6	0,3	0,2	6,0	0,3	98,8
July	64,7	2,9	17,2	0,2	13,4	0	98,4
August	27,1	2,0	67,2	0,3	2,6	0	99,2
September	43,5	0,5	55,1	0	0,4	0	99,5
October	-	-	-	-	-	-	-
November	42,1	24,2	8,0	2,6	1,1	0	78,0
December	40,4	40,6	2,9	12,9	0,7	0	97,5
January 1974	65,2	15,7	0,5	17,2	0	0	98,6
February	59,7	10,1	0,9	25,7	0,9	0	97,3

dominance status in winter was more clearly defined. However the fact that the other Naididae where closely associated with the *Nais* sp. shows that this station is more subject to enrichment than station 8, 11 and 13 because this was a tendency which became very obvious in the more enriched tributaries.

Of the remaining cluster B taxa, all normally formed a small part of the fauna (<5%) of this station (Table 47) although each showed a single period of increased significance. The *Burnupia* - *Ecnomus* sp. association increased steadily from 2,6 to 25,7 per cent of the total population at the same time as the *C. afra* - Chironomini association became co-dominant thus forming a subdominant association.

TABLE 48: Conductivity (mSm) and mineral concentrations (mg/ℓ) at station 14 for the last five months of the survey to show increasing concentrations from November to February

Parameter	October	November	December	January	February
Conductivity	675	489	579	636	651
Na	48	34	32	40	44
K	8,8	6,0	7,0	8,4	8,9
Ca	52	36	36	44	51
Mg	21	15	16	17	20
Cl^-	65	37	54	43	50
$SO_4^=$	100	55	72	77	83

The association of *Chaetogaster* and Tanytarsini had a brief period of numerical significance during the winter months of 1973 and appeared to be most significant immediately prior to the period of *Nais* sp. dominance in 1973.

Baetis latus only occurred in significant numbers in the first three months of the study and was the only Ephemeropteran taxon (apart from *B. harrisoni*) to occur at all significantly at this station. Its presence however, does show a shift towards more natural conditions when compared with stations 3, 6A and 6B, as does the fact that *Cheumatopsyche* sp. was a member of the dominant association.

The two months (October 1972 and November 1973) shown in Table 46 not to be exclusively dominated by these cluster B taxa were characterized by an increase in the cluster A taxa. Reference to the species composition table for this station in the appendix shows that the Planaria totally dominated this small association on both these occasions. *Physopsis*, Ostracoda and *Limnodrilus* sp. occurred significantly in October 1972 and the Pelecypoda, *Limnodrilus* sp. and *Hydra* did so in November 1973. Of these only *Limnodrilus* sp. was significant on the basis of frequency of occurrence throughout the study (Fig. 31).

This increase in a Planarian dominated association suggests a slight deterioration in water quality due to the close association both here and at stations 3, 6A and 6B of this taxon with the Tubificidae.

The water of this station has been shown earlier to be slightly more enriched than that of the "clean" tributaries and this is confirmed by the composition of the fauna. This population deviates slightly from populations previously shown to be characteristic of more natural conditions in that there was a smaller group of very common taxa. Also the Ephemeropteran taxa were not closely related to these common taxa at this station. However the close relationship of some of the Trichopteran species to the ubiquitous taxa and the significant occurrence of *Baetis latus* showed that this deviation was slight when compared with that of the less natural tributaries (stations 3, 6A and 6B).

The position of *Nais* sp. and its poor association with the Tubificidae also showed that the fauna of this station more closely resembled that of the natural waters. However a closer relationship to *Chaetogaster* and the other Naididae emphasizes the deviation towards poorer water quality type communities. This latter was more apparent in the winter of 1973 than in 1972 when a closer resemblance of this association to a natural population suggested cleaner waters. This agrees with the chemical results which show a change in water quality between the two years (Table 6). Similarly the only significant occurrence of *B. latus* occurred in the first part of the survey which tends to confirm this deterioration later on in the survey. This concurs with the change in the dominant association discussed above where the first summer's association of taxa closely resembled that of the natural streams (*B. harrisoni* - *C. thomasseti* - Simuliidae) which changed to an increased dominance by the Chironomidae.

Thus generally the deviation from natural populations at this station was greater in the second year of the survey.

Station 12

The concentrations of chemical constituents at this station (Table 21) show that it was very similar to stations 10 and 14 although dilution by the Crocodile River (station 11) resulted in slightly lower concentrations of those constituents which were characteristic of station 10. The high concentrations of magnesium and alkalinity in the Hennops River resulted in concentrations of these parameters at station 14 which exceeded those at station 12. Table 21 indicates a drop in concentration of organic carbon at station 12 (category DE) when compared with stations 10 and 14. These latter showed average concentrations for the system at times (categories CDE) although Table 12 shows that this difference was neither large nor constant.

The dendrogram of Czeckanowski similarity (Figure 33) shows considerable diversity in the taxa common to this station (cluster A linked at r = >50). Particularly significant is the fact that six of these nineteen taxa occurred in every sample as shown by their linkage at the 100% similarity level. The remaining thirteen taxa in cluster A formed a constant part of the fauna for most of the year while other clusters all grouped taxa which occurred seldom with no individual taxon ever forming more than 3 per cent of the total population (see appendix). Taxa which occurred in clusters closest to cluster A had a maximum of 6 occurrences while those in clusters furthest from it were recorded once only. While the latter are obviously not significant on the basis of occurrence, the former could be if these occurrences characterized a particular time of the year. Table 49 shows the spread of these occurrences.

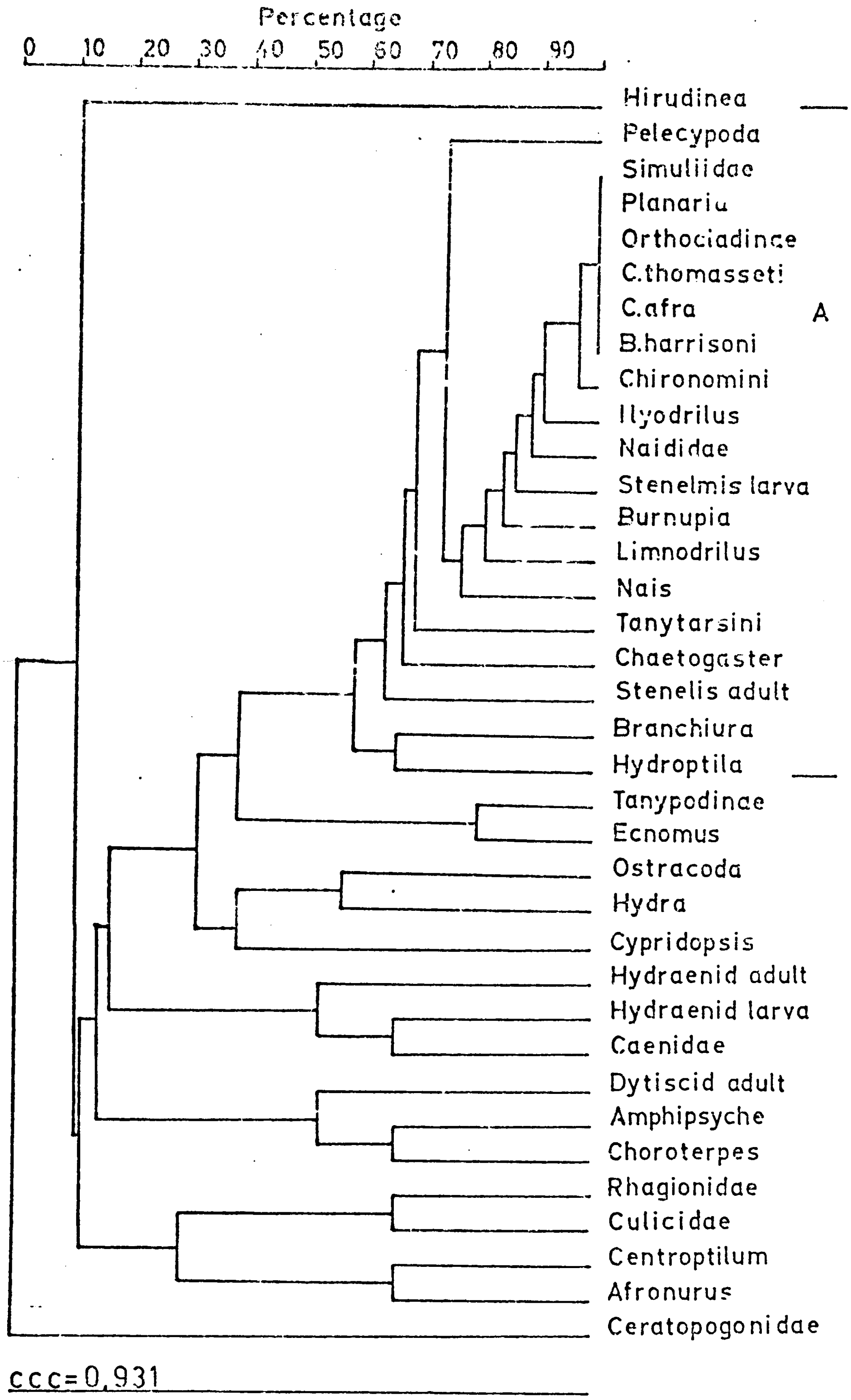


Figure 33: Dendrogram of Czeckanowski Similarity between Taxa for Station 12.

TABLE 49: Occurrence patterns of taxa at station 12 which occurred between two and six times during the survey (March 1972 = 1)

Taxon	Months																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Tanypodinae									X		X	X	X		X									X
Ecnomus		X							X		X	X			X									X
Hydra						X	X	X								X					X			
Hydraenidae										No sample	X		X	No sample						No sample			X	
Choroterpes															X								X	X
Amphipsyche																							X	X
Ostracoda						X		X																

Although the dendrogram of Bray-Curtis similarity (Fig. 34) does not show any of these taxa to be significant on the basis of their relative abundance in the samples, one can conclude from this table that the Tanypodinae and *Ecnomus* did show a period of significant occurrence from November 1972 until May1973. In addition the occurrence of *Hydra* in the spring of 1972 might have been significant, also the association of *Choroterpes* and *Amphipsyche* in January and February 1974.

Of the most frequently occurring taxa, those most closely related are grouped together in cluster A2 of the dendrogram of Bray-Curtis similarity (Fig. 34). All the taxa in cluster A of the presence-absence analysis (Fig. 33) are grouped in cluster A of this dendrogram suggesting that they were just as significant on the basis of relative abundance. These taxa form the dominant part of the association as they always comprise 85 per cent of the total population with only five cases of less than 95 per cent (Table 50).

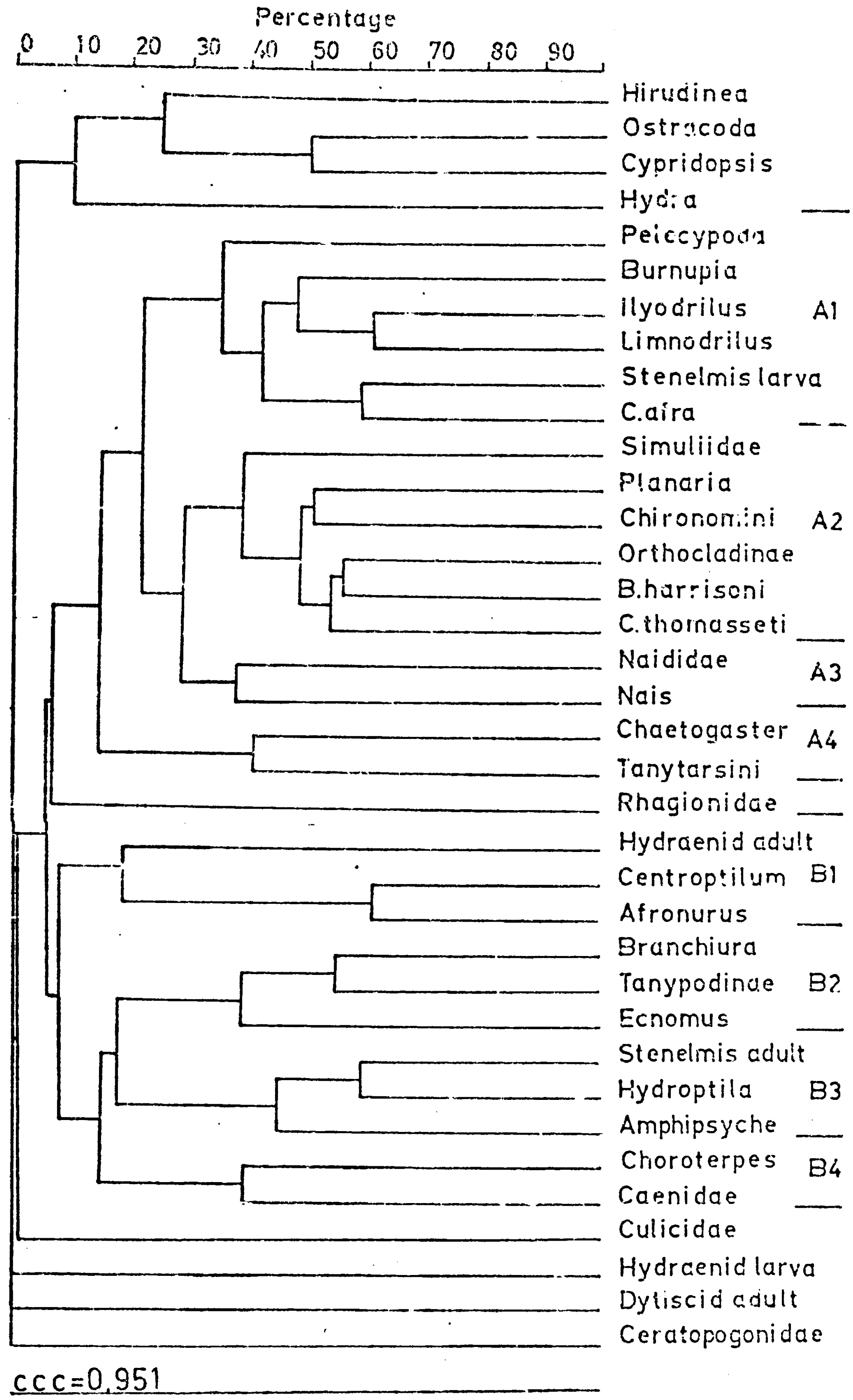


Figure 34: Dendrogram of Bray-Curtis Similarity between Taxa for Station 12.

TABLE 50: Composition of cluster A (Fig. 34) association at station 12 giving percentage contribution of each of sub-clusters A1-A4 for each month to the total community

Month	Sub-cluster				Total
	A1	A2	A3	A4	
March 1972	-	-	-	-	-
April	21,1	64,4	2,4	0	87,9
May	9,4	88,6	0,9	0	98,9
June	19,0	61,4	17,6	1,3	99,3
July	0,9	49,8	30,4	4,3	85,4
August	1,0	17,4	68,4	1,6	88,4
September	4,0	48,0	46,8	0,1	98,9
October	26,3	64,0	7,9	0,3	98,5
November	6,4	85,6	0,5	0,2	92,7
December	-	-	-	-	-
January 1973	19,4	77,0	1,6	0,2	98,2
February	7,9	83,9	4,0	0,8	96,6
March	26,8	66,6	1,6	0	95,0
April	-	-	-	-	-
May	7,9	74,4	3,6	0,4	86,3
June	10,0	72,4	12,5	3,0	97,9
July	2,6	39,6	50,5	5,2	97,9
August	0,5	30,0	65,9	3,1	99,5
September	1,0	52,5	44,5	2,2	100,0
October	-	-	-	-	-
November	4,2	84,2	10,6	0,6	99,6
December	48,8	36,1	13,4	0	98,3
January 1974	9,6	83,6	2,1	0	95,3
February	6,6	78,3	1,3	0	86,2

This table shows a change in the dominance status of the four sub-clusters of cluster A over the survey period. The taxa represented in cluster A2 formed the dominant part of this association throughout the survey except for the July-September periods. All these A2 taxa formed equally significant parts of the population in most samples although a small degree of dominance of one over the others occurred in most samples with the dominant taxon changing in different samples. This appears to be due to natural population fluctuation of these taxa because there is no apparent pattern to these changes.

The members of cluster A1, particularly *Cheumatopsyche afra* which dominates this association, formed the most important subdominant group during all the summer months (between 8 and 30% fo the total population but usually decreased to form a negligible part of the population in the July to September period i.e. between 0,5 per cent and 2 per cent. This coincided with the decline in the cluster A2 taxa contribution to the population.

Together with *C. afra* this subdominant association (cluster A1) at this station was formed by the Pelecypoda, *Burnupia, Stenelmis* larvae, *I. templetoni* and *Limnodrilus* sp. These latter two species are interesting in that they are negligible except when this whole association declined to less than 2 per cent of the total population. At this stage they formed the largest part of this group so they were related more to the winter populations than the summer one discussed above.

During the July to September period when the percentage contribution of the cluster A1 association decreased, the taxa forming cluster A3 increased. This association was co-dominant in July, completely dominated the fauna in August and dropped back to being co-dominant in September. They also formed a significant subdominant group (between 7 and 20%) in the months immediately preceeding and succeeding this winter period but for the rest of the year this group formed less than 1 per cent of the population. *Chaetogaster* and Tanytarsini (cluster A4), shown in Figure 33 to be significant taxa on the basis of frequency of occurrence, increased slightly in percentage contribution during the period of Naid dominance. This was similar to observations at station 14.

Thus this winter rise to dominance of the A3 taxa was accompanied by an increase in the taxa grouped in the A4 cluster so that they form up to 5 per cent of the population whereas these two taxa usually formed less than 0,5 per cent of it.

It is interesting that *Hydra* occurrences were also restricted to the period of Naid dominance.

Cluster B in the dendrogram of Bray-Curtis similarity includes those taxa which form a small but constant percentage of the total population. The only significant occurrence within this association occurred in January and February 1974 when the taxa grouped in cluster B2 and B3 formed an average of 10 per cent of the total population. This was the only period when the general pattern of events at this station changed and was characterized by higher mineral concentrations and lower nitrogen values while the other parameters remained relatively constant (Table 51). The occurrence of the cluster B taxa associated with this period (*Amphipsyche* sp., *Hydroptila*, *Ecnomus* sp., Tanypodinae and *Stenelmis*) together with taxa such as *Choroterpes* which occurred over this period suggested a greater similarity to more natural populations.

TABLE 51: Conductivity (mSm) and nitrogen concentrations (mg/ℓ) at station 14 for the period December 1973 to February 1974 showing increased mineral concentrations and decreased nitrogen concentrations

Parameter	December	January	February
Conductivity	589	732	701
Kjeldahl N	3,3	2,1	1,9
NH_3-N	0,8	0,3	0,2
NO_3-N	15,0	7,0	9,9
NO_2-N	0,6	0,4	0,2

The improved organic status of this station as compared to station 14 (see page 162) appeared from the faunal composition to be more important than was chemically apparent. The fauna at this station shows less deviation from natural populations than did that at station 14 with respect to its greater diversity of common taxa. In addition to this there was a greater spread of dominance between the members of the dominant association so that no one member totally dominated. This is similar to the situation in natural populations and completely unlike that seen in the other tributaries (stations 3, 6A and 6B). In this station 12 showed less deviation from natural populations than did station 14.

In winter the association and dominance status of *Nais* sp., *Chaetogaster* and the other Naididae showed a similar deviation from the "natural situation" to that seen at station 14. However the closer relationship of the Tubificids, *I. templetoni* and *Limnodrilus* sp., to this association, particularly with respect to the presence absence analysis, does indicate a greater deviation from natural communities in winter than at other times.

Within the dominant association (cluster A2 in Fig. 34) station 12 shows one occurrence indicative of a greater deviation from natural communities in the decreased abundance of the Simuliidae and increased significance of the Planaria.

As at station 14 the increased contribution to the populations of the Ephemeropteran taxa other than *B. harrisoni* and Trichopteran taxa other than *Cheumatopsyche*, is limited to short periods in mid-summer.

Station 10

Table 21 shows a change in the chemical condition of the water when compared with the downstream stations already discussed.

The concentrations of some of the mineral parameters, COD, MBAS, organic carbon, nitrates and phosphorus, which are the parameters usually affected by sewage effluent, were average to high for the system. However most of these concentrations dropped during the rainy season to values comparable with the downstream stations.

There are sixteen taxa (clusters A, B and C) which linked at r-values greater than 50 per cent in the dendrogram of Czeckanowski similarity (Fig. 35) forming the common taxa at this station. These were the only significant taxa at this station because the nine most highly correlated taxa in this cluster (r=>85%) all occurred in cluster A of the dendrogram of Bray-Curtis similarity (Fig. 36) which formed more than 95 per cent of the total population in all samples except for December 1973 when this association constituted only half the population and January - February 1974 when it formed between 75 and 80 per cent of it (Table 52). Within this cluster (Fig. 36) there was a clearly defined group (A1) to which the remaining taxa in this cluster are chain linked at progressively lower r values. This group dominates the entire population during the summer months of the first year of the study i.e. March to June 1972 and October 1972 to March 1973. The Oligochaete taxa, particularly *Nais* sp. became dominant during the winter months. From April 1973 the abundance of cluster A1 taxa relative to the rest of the fauna declined and during the summer of the second year of the survey the two *Cheumatopsyche* species (from cluster A2) tended to become progressively more dominant. The winter fauna in 1973 remained similar to that of the previous year although *Chaetogaster* and the Naididae tend to co-dominate with *Nais*.

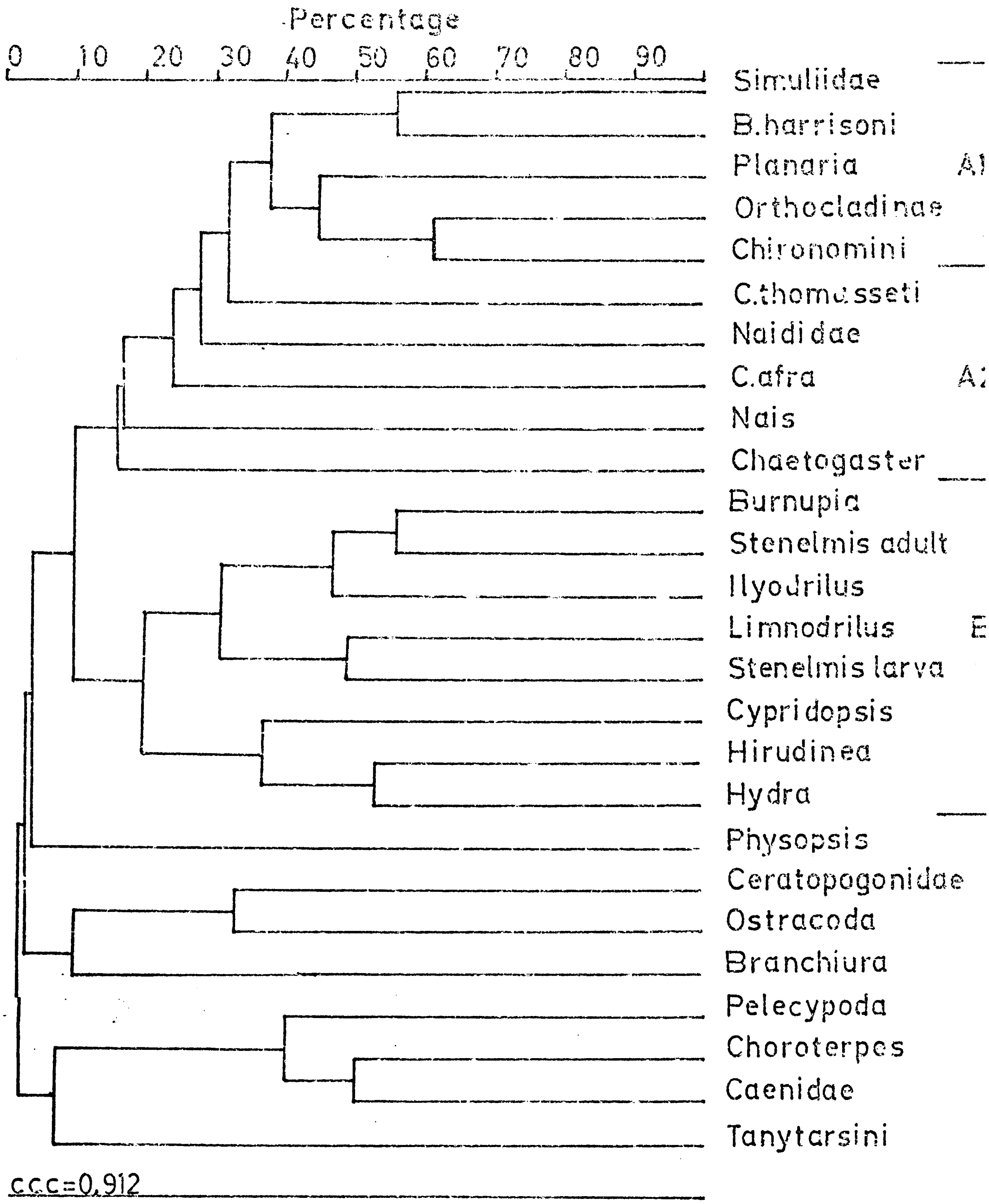


Figure 36: Dendrogram of Bray-Curtis Similarity between Taxa for Station 10.

TABLE 52: Percentage contributions of taxa grouped in clusters A and B of Figure 36 to the total fauna of station 10

Month	Cluster	
	A	B
March 1972	98,9	0,8
April	95,5	4,4
May	99,2	0,8
June	90,2	9,7
July	98,7	1,0
August	99,5	0,4
September	97,2	1,5
October	-	-
November	99,1	0,3
December	-	-
January 1973	98,6	1,4
February	99,9	0
March	-	-
April	-	-
May	99,6	0,2
June	98,9	0,2
July	97,2	0,5
August	99,8	0
September	98,7	0,7
October	-	-
November	94,7	5,2
December	53,8	46,1
January 1974	79,7	19,6
February	76,2	23,6

In the periods during which the cluster A1 taxa dominated the association this was mainly due to the percentage contribution of the *B. harrisoni* and Simuliidae but when the dominance status of this group declined the Planaria - Orthocladinae - Chironomini part of this association tended to increase resulting in the co-dominance of all the taxa within this group. The taxa which have been grouped in cluster B generally formed a small part of the total fauna at this station (<1%, Table 53). This association increases to form a significant part of the population twice. Firstly, in June 1972 it formed almost 10 per cent of the total population mainly due to an increase of *Limnodrilus* sp. and secondly, there was a marked increase in the last four months of the survey of most members of this cluster. This coincided with the decrease in dominance of the cluster A taxa mentioned above. The dominant taxa in this association over this period were the *Limnodrilus* sp. - *Stenelmis* larva group although the rest of the taxa also increased significantly to form up to 10 per cent of the total fauna. This coincided with a significant increase in the mineral concentrations during a period when other parameters showed a decrease in concentration. Although there is insufficient evidence to show that the relationship between mineral concentrations and Oligochaete numbers is a direct one, it was noted at stations in the upper reaches of the system that there was such a relationship. This might be an indirect relationship due to the change in some unmeasured associated parameter, coincident with the measured changes.

The dominant populations at stations 10 and 12 were very similar although at station 12 *C. thomasseti* was more closely associated with the dominant association and *C. afra* formed the largest part of the subdominant association. At station 10 both these species were generally less closely related to the dominant association and their decreased significance confirmed the general improvement in water quality due to the dilution occurring between stations 10 and 12.

TABLE 53: The percentage contribution of the cluster 3 (Fig. 36) taxa to the total populations at station 10 over the study period (1 = March 1972)

Groups	Months																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Burnupia, *Stenelmis a* and *Ilyodrilus*	0,6	1,6	0,5	1,4	0,4	0	0,4	-	0	-	0	0	-	-	0	0,1	0,1	0	0	-	0,7	7,5	6,1	6,0
Limnodrilus and *Stenelmis l*	0,2	2,8	0,3	8,2	0,5	0	0,6	-	0,3	-	1,4	0	-	-	0,2	0	0,4	0	0,4	-	3,6	33,1	13,5	16,7
Cypridopsis, Hirudinea and *Hydra*	0	0	0	0,1	0,1	0,4	0,5	-	0	-	0	0	-	-	0	0,1	0	0	0,3	-	0,9	5,5	0	0
Total	0,8	4,4	0,8	9,7	1,0	0,4	1,5	-	0,3	-	1,4	0	-	-	0,2	0,2	0,5	0	0,7	-	5,2	46,1	19,6	23,6

The association of *Nais* sp., *Chaetogaster* and the other Naididae showed a greater degree of dominance at this station during winter than they did at station 12, particularly in the second year. In addition to this the latter two taxa were more closely related to *Nais* sp. than they were further downstream. This indicates a greater deviation from the more natural populations.

Within the dominant association the overall dominance by the *B. harrisoni* - Simuliidae association is a deviation from the shared dominance seen in more natural populations. However the shift in dominance in the second summer resulting in co-dominance between the whole dominant association (Planaria, Orthocladinae, Chironomini, *B. harrisoni*, Simuliidae and the two *Cheumatopsyche* species) indicates an improvement in water quality because the deviation from the natural populations was reduced. This improvement is only indicated in the chemical analyses by reduced concentrations of the conservative mineral elements. All other measured parameters were similar in both years of the survey (Table 6).

Stations 7 and 7A

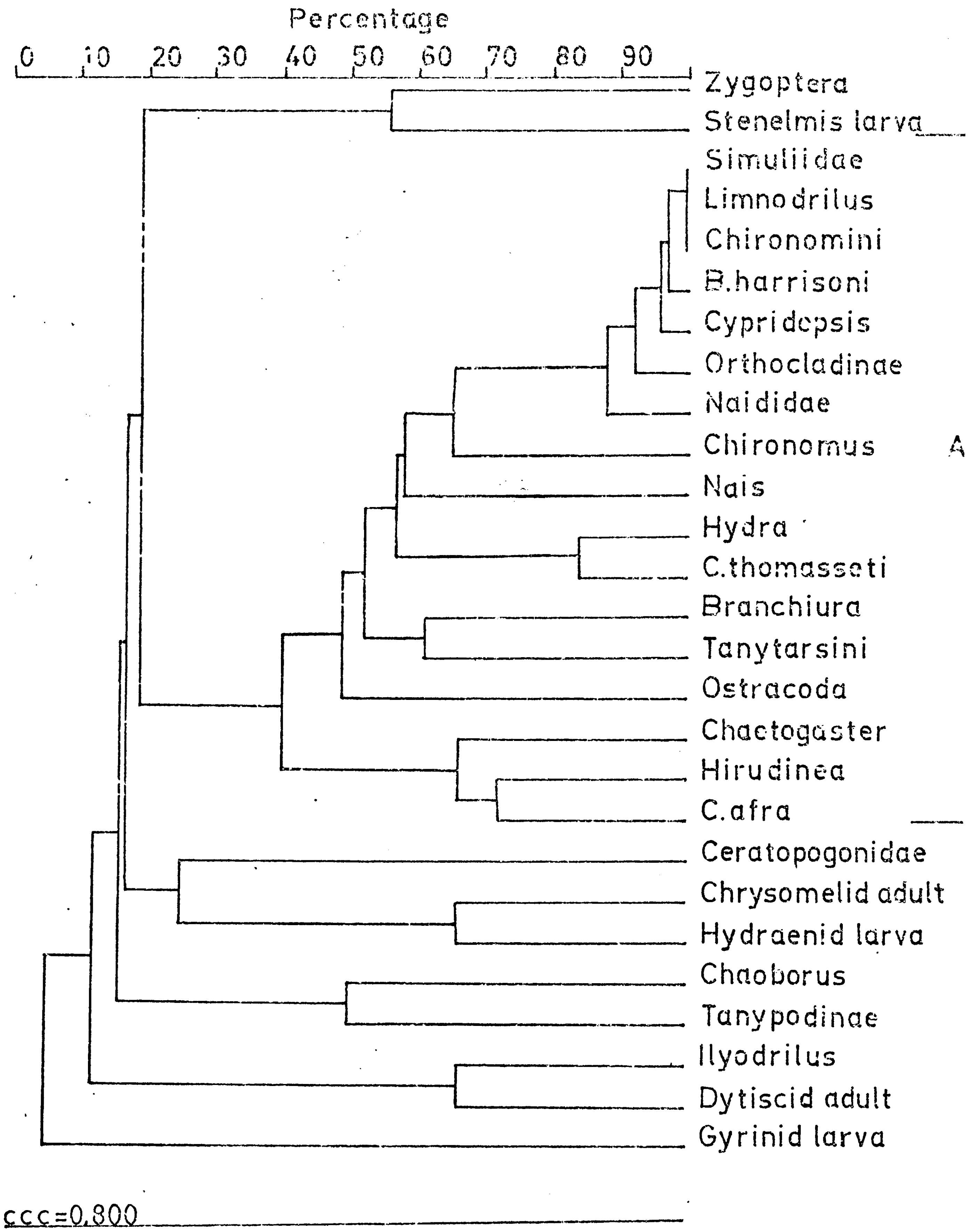
These two stations are dealt with together due to the similarity in faunal populations and the chemical and physical environments as well as the fact that station 7 was markedly influenced by water from station 7A.

The chemical environment at these two stations was characterized by the highest concentrations encountered in the system of COD, MBAS, organic carbon, PO_4-P and total phosphorus. These parameters tended to be in the A and B categories at station 7A and were slightly diluted to category B and C concentrations at station 7. Together with this most of the minerals, the alkalinity, inorganic carbon and all forms of nitrogen occurred in low concentrations compared to the rest of the system. The only high mineral element concentration was that of potassium, particularly at station 7A where it was of the category C order of magnitude. The combination of high COD and organic carbon concentrations suggests that the amount of available organic matter was higher here than at any of the other stations.

The dendrogram of Czeckanowski similarity (Fig. 37) for station 7A shows an association of thirteen taxa which link at r = >50 per cent. However the characteristic association can be extended to include four taxa (Ostracoda, *Chaetogaster*, Hirudinea and *C. afra* which link at r = >40 per cent due to the fact that all the remaining taxa found at this station join this cluster at r = <20 per cent and show no strong interrelationships with each other. This association differs from those seen previously in the "natural" streams and further downstream in that *Limnodrilus* sp. and *Cypridopsis* occurred in nearly every sample and were closely related to the ubiquitous species.

In the Bray-Curtis similarity dendrogram (Fig. 38) this whole association of taxa was divided into two clusters (B and C) each of which shows some subdivision. Table 54 shows that cluster B represents the dominant fauna of this station as it always formed between 85 and 99 per cent of the total population. Its members were also amongst the most highly correlated on the basis of occurrence (Fig. 37).

The three constituent parts of cluster B (Table 54) all formed highly significant parts of the association throughout the survey. There was a tendency however for the *B. harrisoni* - Cypridopsis - Naididae association to dominate during the first year of the survey while the Orthocladinae -



A

Figure 37: Dendrogram of Czeckanowski Similarity between Taxa for Station 7A.

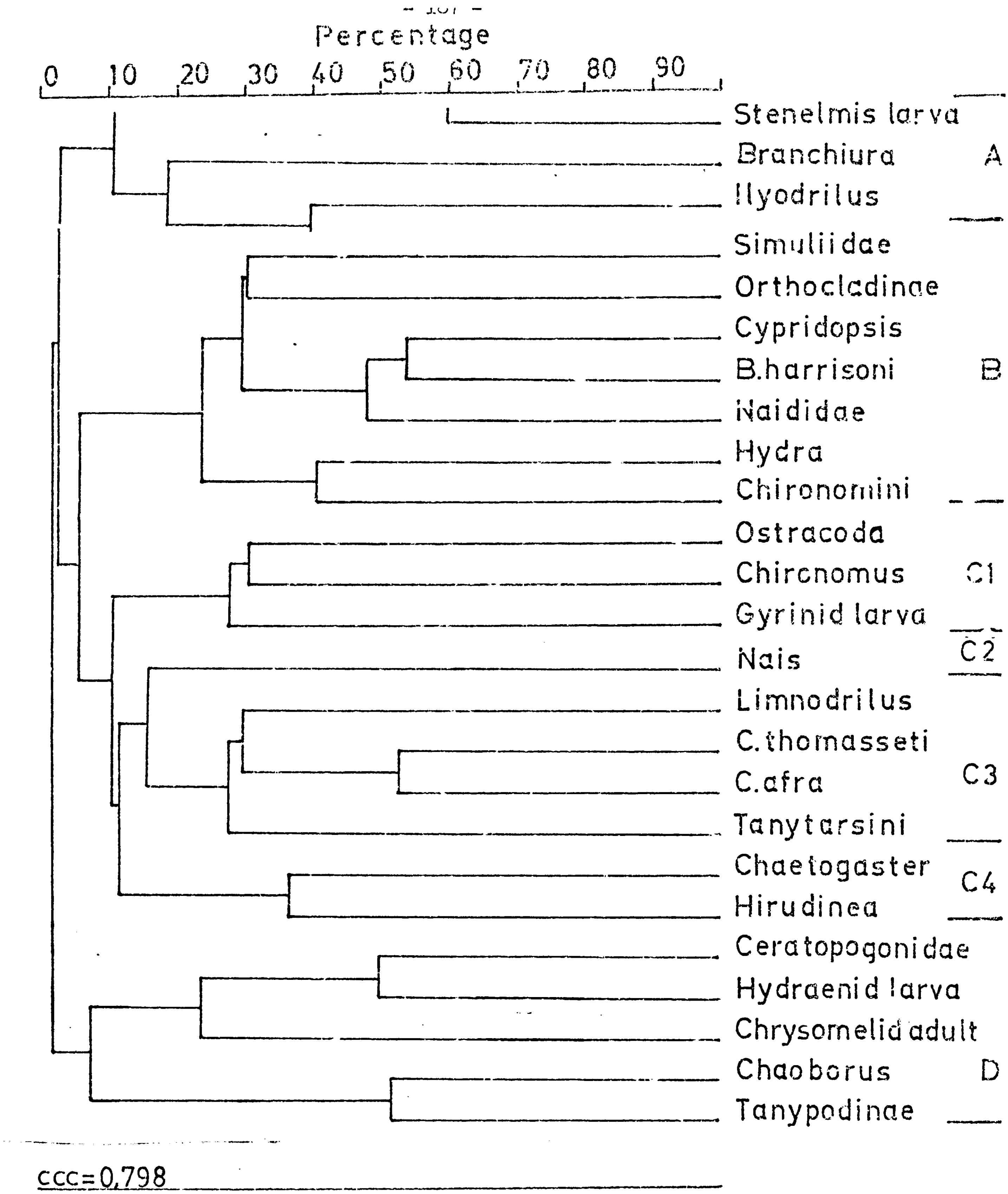


Figure 38: Dendrogram of Bray-Curtis Similarity between Taxa for Station 7A.

TABLE 54: Percentage contribution of significant associations as per the dendrogram of Bray-Curtis similarity (Fig. 38) to the total populations at station 7A

Month	Association								
	Cluster B				Cluster C				
	Simuliidae Orthocladinae	*Cypridopsis* *s. harrisori* Naididae	*Hydra* Chironomini	Total	C1	C2	C3	C4	Total
March 1972	-	-	-	-	-	-	-	-	-
April	20,8	36,1	39,7	96,6	0,1	0,1	2,5	0	2,7
May	4,2	53,6	19,3	77,0	0	1,8	20,9	0	22,7
June	16,7	64,2	13,4	94,3	0,6	0,9	4,0	0,2	5,7
July	1,4	79,9	7,3	88,6	0,3	0,2	10,1	0,8	11,4
August	0,4	83,3	5,7	89,4	0,5	2,0	5,7	2,3	10,5
September	0,5	91,0	7,2	98,7	0,2	0,2	0,7	0,4	1,5
October	-	-	-	-	-	-	-	-	-
November	13,0	35,7	42,8	91,5	1,5	5,9	1,1	0	8,[illegible]
December	-	-	-	-	-	-	-	-	-
January 1973	7,0	53,1	38,7	98,8	0	0,4	0,9	0	1,3
February	45,1	34,5	12,9	92,5	0	0	7,3	0,2	7,5
March	-	-	-	-	-	-	-	-	-
April	-	-	-	-	-	-	-	-	-
May	58,1	12,8	24,2	95,1	1,1	0	0,7	2,1	3,9
June	41,8	50,9	4,0	96,7	0,2	0,6	2,4	0,2	3,4
July	37,3	43,6	15,8	96,7	0,4	0,2	2,5	0	3,1
August	19,1	71,4	6,5	97,0	0	2,1	0,7	0	2,8
September	33,3	49,2	9,6	97,1	0,2	4,6	2,7	0	7,5
October	-	-	-	-	-	-	-	-	-
November	48,8	43,3	4,9	97,0	0,8	0,5	0,8	0	2,1
December	73,3	23,2	0,8	97,3	2,4	0,2	0,6	0	3,2
January 1974	76,4	10,4	8,2	95,0	0	0	4,2	0,3	4,5
February	14,6	10,3	63,6	88,5	1,2	0	10,3	0	11,5

Simuliidae group tended to co-dominate from February 1973 onwards, becoming completely dominant (>70%) towards the end of the survey. The *Hydra* - Chironomini association only dominated in February 1974. There was thus a clear shift in the dominance pattern within this association over the two years. When the chemical environment is considered for this period there was no apparent drastic change which could account for this shift in dominance. The chemical analyses indicated only marginally higher concentrations of all the parameters which were particularly characteristic of this water i.e. PO_4-P and total phosphorus (Table 55). However, it has been shown (see page 65) from a combination of flow figures and concentrations

TABLE 55: A comparison between the mean COD, PO_4-P and total phosphorus concentrations of the two years at station 7A (expressed as mg/ℓ)

Parameter	Year	
	1972/73	1973/74
COD	41,6	54,0
PO_4-P	6,5	7,1
Total P	7,0	8,2

of solids in suspension that a problem with the stabilization of flow by the sewage works maturation ponds occurred during the second year of the survey. Where the first year was characterized by very stable concentrations of solids in suspension, these concentrations varied in the second year from 5,5 to 1515,7 mg/ℓ (Tables 18 and 19). It is interesting that the periods of highest solids in suspension concentrations (September-October 1973) showed no correlation with the concentrations of dissolved nitrogen, dissolved phosphorus or COD in the water. In addition to this the biotic index values decreased significantly, particularly over this period (see appendix).

The dendrogram of Czeckanowski similarity for station 7 (Fig. 39) shows a cluster of fifteen taxa linked at r = >50 per cent (cluster A). Here too *Limnodrilus* sp. and *Cypridopsis* were linked at a high r-value to this cluster. However the fact that the *Cheumatopsyche* species were more closely linked to the ubiquitous species at station 7 and the *Chironomus* sp. and *Branchuira sowerbyii* were included in the characteristic association at station 7A suggests that water quality was poorer at this station (7A). Other taxa found at station 7 which show possibly significant relationships (Fig. 39) are shown in Table 56 to have been negligible on the basis of frequency of occurrence.

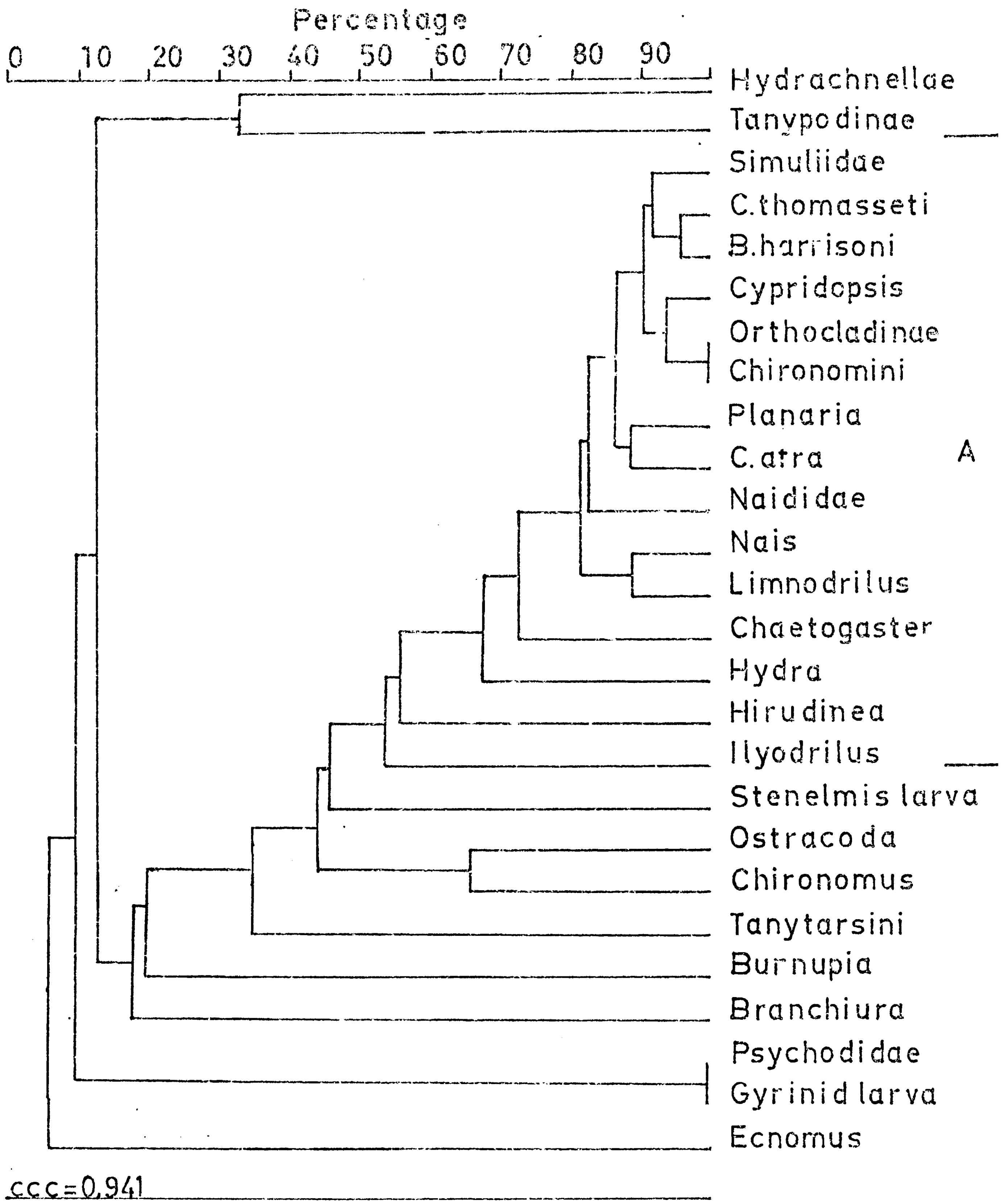


Figure 39: Dendrogram of Czeckanowski Similarity between Taxa for Station 7.

TABLE 56: Frequency of occurrence of taxa found at station 7 which show apparently significant relationships in the dendrogram of Czeckanowski similarity (Fig. 39) other than cluster A

Association	Number of occurrences	Maximum number per occurrence	Maximum percentage contribution
Ostracoda	4	6	0,8
Chironomus	5	26	2,5
Psychodidae	1	2	0,2
Gyrinid 1	1	1	0,1

All these cluster A taxa (with the exception of Hirudinea) are shown in the dendrogram of Bray-Curtis similarity (Fig. 40) to occur in clusters C and D. The ubiquitous species with regard to the whole system occurred in cluster C. Table 57 shows that this cluster formed the dominant association of this station being between 60 and 97 per cent of the total population in all months except May and June 1973 when it formed 18 and 30 per cent of the population respectively. The three sub-groups in cluster C all formed significant parts of the population throughout the study but there was a slight tendency for the Naididae and *Nais* sp. to dominate in the late winter/spring as will be described further upstream. The Simuliidae and *Cheumatopsyche thomasseti* tended to dominate in January and February while the Orthocladinae, Chironomini and *B. harrisoni* formed more than 50 per cent of this association during the remainder of the year.

The close linkage of *Cypridopsis* to this cluster was due to its significant contribution to the population (3 to 11% throughout the year) although it did not show the specific affliation to a particular group within the cluster that was seen at station 7A. This taxon reached its highest proportions in September of both years when water quality was at its poorest and thus comparable with that at station 7A during the time when *Cypridopsis* was one of the dominating taxa. It is possible that these

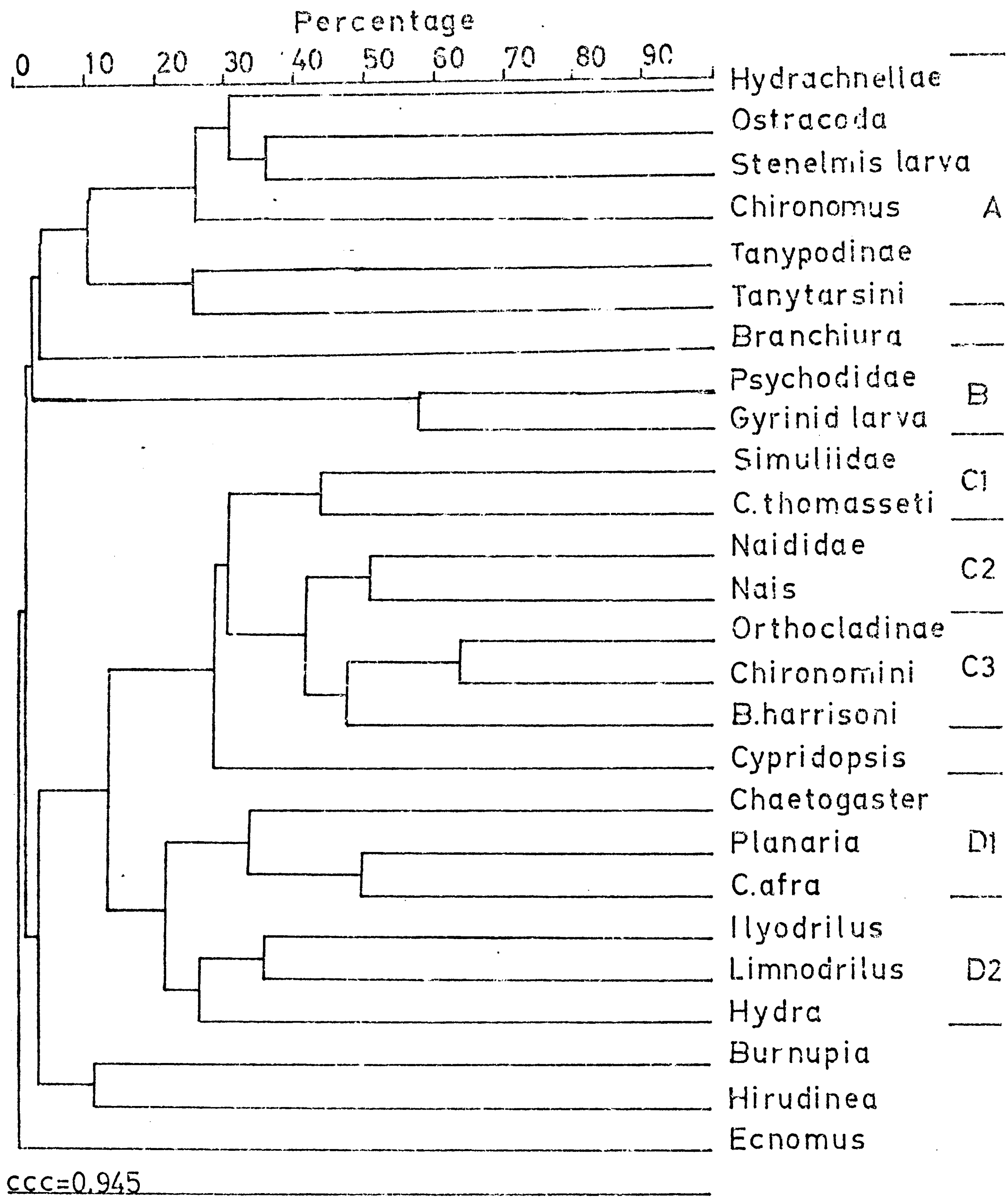


Figure 40: Dendrogram of Bray-Curtis Similarity between Taxa for Station 7.

TABLE 57: Percentage contributions of the associations shown in clusters C and D of the dendrogram of Bray-Curtis similarity for station 7 (Fig. 40) to the total populations.

Month	Cluster								
	C				D			*Cypridopsis*	Total
	C1	C2	C3	Total	D1	D2	Total		
March 1972	-	-	-	-	-	-	-	-	-
April	18,0	8,4	64,1	90,5	1,4	1,2	2,6	6,4	99,5
May	22,6	37,1	28,6	88,3	9,3	0,6	9,9	1,6	99,8
June	5,8	16,0	64,0	85,8	4,9	0	4,9	7,9	98,6
July	3,5	33,1	57,1	93,7	3,9	0,2	4,1	2,0	99,8
August	4,9	48,0	10,8	63,7	27,7	4,4	32,1	3,7	99,5
September	2,6	53,0	33,6	89,2	3,9	0,7	4,6	5,2	99,0
October	0	33,0	50,0	83,0	0	3,3	3,3	10,0	96,3
November	11,5	19,3	50,0	89,8	2,6	12,0	14,6	2,9	98,3
December	-	-	-	-	-	-	-	-	-
January 1973	46,1	5,5	19,8	71,4	3,0	19,6	22,6	5,6	99,6
February	25,2	30,6	19,6	75,4	4,6	15,7	20,3	3,2	98,9
March	-	-	-	-	-	-	-	-	-
April	-	-	-	-	-	-	-	-	-
May	11,2	3,4	3,5	18,0	1,2	2,0	3,2	74,8	96,0
June	21,7	0,7	7,7	30,1	0	0	0	69,9	100,0
July	10,1	58,8	23,6	90,5	4,9	0,8	5,7	2,5	98,7
August	2,0	34,5	28,0	64,5	16,1	1,1	17,2	18,3	100,0
September	0,4	57,7	20,3	78,4	6,1	0,8	6,9	11,3	96,6
October	-	-	-	-	-	-	-	-	-
November	14,2	29,2	52,1	95,5	0,2	0,5	0,7	3,3	99,5
December	55,7	5,1	25,0	85,8	0,2	2,4	2,6	8,4	96,8
January 1974	44,0	0,6	53,2	97,8	1,2	0,1	1,3	0	99,1
February	65,0	1,8	31,4	98,2	0,6	1,2	1,8	0	100,0

Cypridopsis were maturation pond fauna carried into the river which would suggest that their numbers depended upon flow conditions rather than on water quality. However, the fact that they tended to lose their significance with regard to abundance at station 7A during the second year of the survey when apparent failure of the stabilization by maturation ponds occurred tends to contradict this possibility. This lack of stabilization would result in more *Cypridopsis* being carried into the river at times and less at others which was not the case. Thus the indication is that this taxon was a product of the riverine environment.

The abiotic characteristics of this station were very similar to those at station 7A except that the COD, MBAS, organic carbon, PO_4-P and total phosphorus concentrations were not as high. However, Table 58 shows that the concentrations of significant chemical parameters in the effluent did not greatly affect the quality of water downstream of its confluence with the mainstream except that nitrogen values decreased slightly and phosphorus values increased between stations 6 and 10.

The subdominant groups at these two stations showed varying degrees of similarity and it appears as if the dominant and subdominant populations indicated different changes in the water quality of these stations.

At station 7A the subdominant association represented in cluster C of the dendrogram of Bray-Curtis similarity (Fig. 38) formed an appreciable part of the fauna, varying between 1,5 and 22,7 per cent of the total population (Table 54).

TABLE 58: Comparison of the mean values (mgℓ) of all significant chemical parameters between the reaches above and below the point of confluence with the sewage effluent and the effluent itself

Parameter	Station			
	10	9	7A	6
Na	68,3	63,9	77,0	85,3
K	12,9	12,1	15,3	13,5
Ca	42,7	46,6	36,0	68,3
Mg	15,3	16,7	11,8	24,6
Cl^-	68,8	70,0	64,9	95,3
$SO_4^=$	106,0	114,5	77,0	190,0
NH_3	2,8	6,4	7,8	7,8
NO_3	17,8	16,5	11,1	20,9
NO_2	0,9	0,9	1,2	1,3
Total N	20,8	22,8	19,7	31,6
COD	35,4	36,1	47,8	31,8
MBAS	0,52	0,48	0,71	0,40
PO_4-P	2,8	2,5	6,8	0,3
Total P	3,8	2,9	7,6	0,5

This association also showed a change in population composition at the same time as that seen in the dominant taxa at station 7A. Cluster C formed an average of 10 per cent of the total population during the first year of the survey while during the second year it formed an average of 4 per cent of the total in each sample. An exception to this occurred in February 1974 when this association increased again to form 11,5 per cent of the total fauna. The most significant contribution of the cluster C association occurred in May 1972 when it formed 22,7 per cent of the total.

Of the four clusters into which this group is divided (Fig. 38) the cluster C3 (*Limnodrilus* sp., *C. afra, C. thomasseti* and Tanytarsini) tended to dominate (Table 54) with the taxa represented by cluster C2 (*Nais* sp.) forming a significant contribution and actually dominating C3 in November 1972. Cluster C1 and C4 form a very small part of this association (usually <1%). During the first year the two *Cheumatopsyche* species and Tanytarsini dominated during the summer months and *Limnodrilus* sp. with *Nais* sp. tended to dominate in the winter months.

In the second year the decrease in percentage contribution accompanied a shift away from the *Cheumatopsyche* to the other members of cluster C in the dendrogram for this station (Fig. 38) which included *Nais* sp. *Chaetogaster*, Ostracoda and *Chironomus* sp. The shift in this association, unlike that of the dominant association, does suggest a very slight deterioration in water quality which agrees with the marginally higher concentrations in the chemical data for the second year (Table 6). The increased proportions of this association in May 1972 and February 1974 show the same changes in taxa and conditions as seen in the overall shift in dominance. In May 1972 the increase is mainly due to an increase in the *Limnodrilus* sp. relative abundance, indicating a deterioration in conditions while the February 1974 fauna showed a marked increase in the numbers and percentage contribution of the *Cheumatopsyche* species.

The subdominant associations at station 7 are shown in cluster D of Figure 40. This cluster is divided into two sub-clusters, all members of which occurred regularly and formed an average of 8 per cent of the total population (Table 57). The cluster D1 (*Chaetogaster*, Planaria and *C. afra*) was the more abundant association and formed the largest percentage contribution to the population when the dominant taxa (cluster C) declined, particularly in the May-June 1973 period.

During the periods when the Simuliidae and *C. thomasseti* were most abundant in the cluster C association (summer) there was a numerically significant increase in the cluster D1 association. When the concentrations of all parameters were at their maximum in winter (see appendix), particularly potassium which rose to category C and COD, MBAS and total phosphorus which were "very high", the numbers of *I. templetoni* and *Limnodrilus* sp., usually low, tended to increase. This coincided with the dominance of *Nais* sp. and the Naididae.

During May and June 1973 the dominant population at station 7 dropped to 18 and 30 per cent of the total population and the usual summer subdominant association (described above) decreased its significance both numerically and on a percentage basis. This accompanied the total dominance of the population by *Cypridopsis* (74,8 and 69,9%, Table 56). This period was characterized by relatively clean water except for a threefold increase in the ammonia concentration (Table 59) which, although still low compared with the upper reach of the system, was the highest recorded at station 7.

TABLE 59: Ammonia concentrations (mg/ℓ) at station 7 for the period March-July to show increase over the May-June period

March	April	May	June	July
2,2	7,1	4,5	15,2	2,6

The population at station 7 showed similarities to that seen further downstream at station 10 although it tended to deviate from the normal to a greater extent in that dominance of *B. harrisoni* and the Simuliidae in the first summer was not shared with other taxa to the same degree. Also the shift to an Orthocladinae-Chironomini dominated association in the second year was more clearly defined.

The marked contribution of *Cypridopsis* to the population here did not occur downstream so that the dilution or self purification of the water resulted in a continuation of the trend of decreased significance of this taxon seen between stations 7 and 7A. *Cypridopsis* dominance therefore appeared to be associated either directly or indirectly with sewage effluent and their decreased significance between stations 7 and 10 coincided with the fact that the sewage effluent related variables such as phosphates and MBAS were average for the system at station 10 whereas they were high to very high at stations 7 and 7A (Table 21).

A further deviation from the "normal" condition is shown by the increased contributions of *Limnodrilus* sp. to the Oligochaete population which dominated in winter. In addition the Naididae show closer relationships to the most ubiquitous taxa than did *Nais* sp. whereas at station 10 this latter taxon completely dominated the winter population.

Station 9

Station 9 showed slightly higher concentrations of most of the chemical parameters measured than did station 7, except for COD, MBAS, organic carbon, PO_4-P and total P which are the variables associated with sewage works effluent. However, Table 21 shows that concentrations here were generally lower than they were at station 6, upstream of this point, except for these sewage effluent associated variables which were higher as a result of the "bypass stream" from the works which is situated upstream of the main effluent stream.

On the basis of "commonness" or frequency of occurrence the dendrogram of Czeckanowski similarity for this station (Fig. 41) shows a highly significant association of fourteen taxa (r = >66 per cent) in cluster A. All other taxa link to this association at r values of less than 50 per cent. Although this dendrogram shows a number of other apparently significant clusters, Table 60 shows that apart from cluster B the taxa in these clusters occurred infrequently and in very small percentages. Cluster B taxa only occurred five times each but the fact that these occurrences were restricted mostly to the winter months of 1972 does suggest that they should not be overlooked.

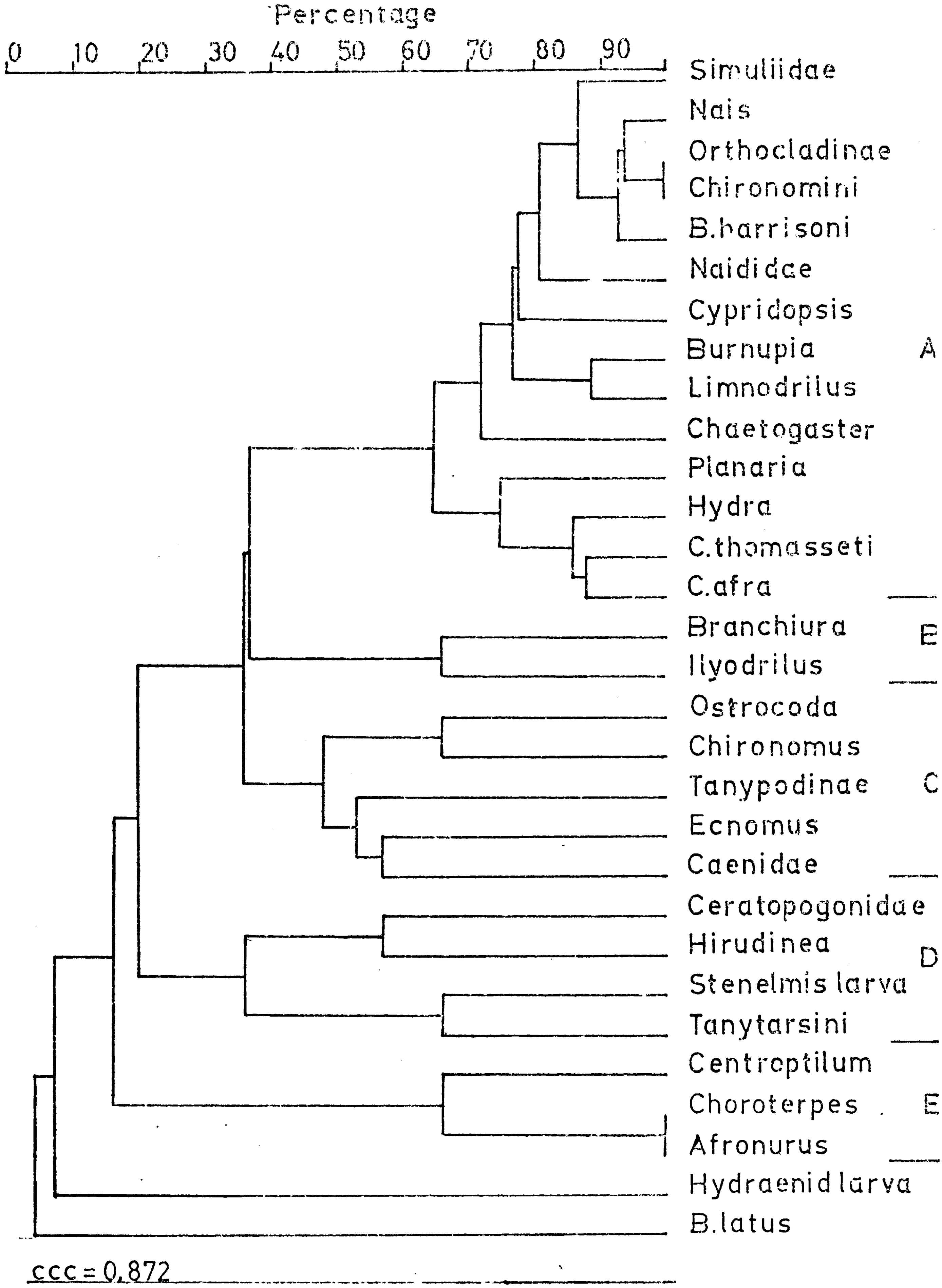


Figure 41: Dendrogram of Czeckanowski Similarity between Taxa for Station 9.

TABLE 60: Frequency of occurrence of taxa at station 9 in clusters B to E of the dendrogram of Czeckanowski similarity (Fig. 41) showing the significance of these associations on the basis of presence-absence analysis

Associations		Number of occurrences	Maximum number per occurrence	Maximum percentage contribution
Branchiura	B	5	1345	7,7
Ilyodrilus		5	50	0,3
Ostracoda	C	7	8	1,2
Chironomus		5	17	2,4
Tanypodinae		5	8	1,2
Ecnomus		3	2	0,2
Caenidae		4	1	0,4
Ceratopogonidae	D	2	1	0,1
Hirudinea		5	9	0,6
Stenelmis		1	1	0,1
Tanytarsini		3	8	0,5
Centroptilum	E	2	1	0,4
Choroterpes		1	1	0,2
Afronurus		3	2	1,4

All the cluster A taxa in the dendrogram of Czeckanowski similarity are linked in cluster A in the dendrogram of Bray-Curtis similarity (Fig. 42). In both dendrograms the ubiquitous taxa occurred in cluster A. Both clusters A and B in the Bray-Curtis dendrogram showed a degree of subdivision into a number of sub-clusters. These cluster A taxa have been divided into five separate groups (A1-A5), all of which are significant on the basis of occurrence. Most of these groups dominated at some time during the survey (Table 61). During both years of the study the taxa represented in cluster A5 (*Nais* sp., *Chaetogaster*, the other Naididae and *Cypridopsis*) completely dominated the association during the winter months (June-August). This period was characterized by low temperatures, low flow and the highest concentrations of the chemical parameters measured.

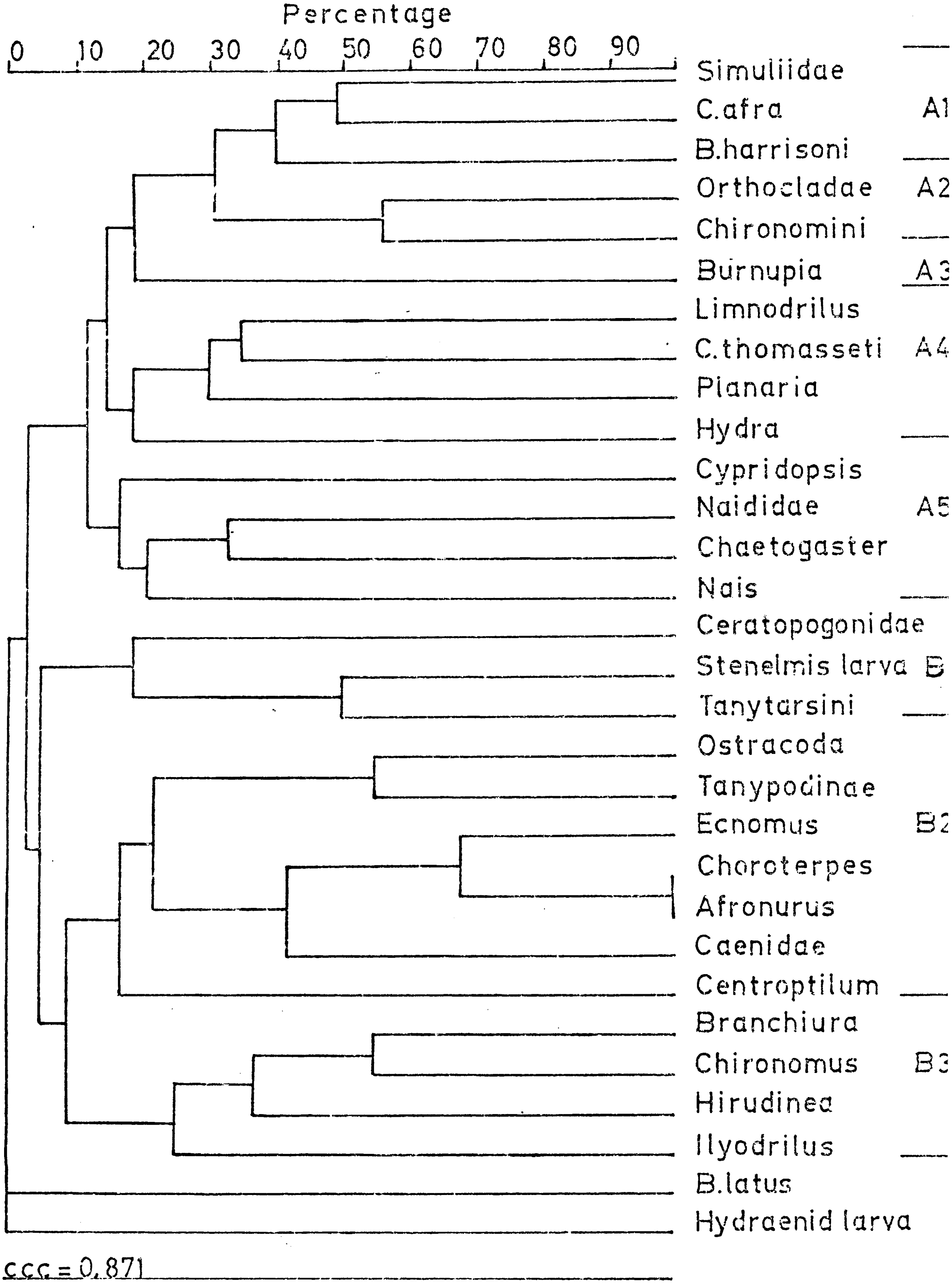


Figure 42: Dendrogram of Bray-Curtis Similarity between Taxa for Station 9.

TABLE 61: Percentage contribution of the associations (A1-A5) in cluster A of the dendrogram of Bray-Curtis similarity for station 9 (Fig. 42)

Month	Association					
	A1	A2	A3	A4	A5	Total
March 1972	54,9	30,9	0	5,8	7,4	99,0
April	64,7	27,5	0,1	4,8	2,5	99,6
May	54,8	32,4	0	3,9	8,9	100,0
June	11,9	3,8	0,1	1,6	82,3	99,7
July	2,5	3,7	0,5	0,8	92,3	99,8
August	13,6	23,5	0,1	6,3	55,7	99,2
September	23,3	61,1	0	0,9	14,4	99,7
October	-	-	-	-	-	-
November	51,0	12,3	2,6	13,8	18,9	98,6
December	-	-	-	-	-	-
January 1973	8,8	63,1	2,2	13,8	0,7	88,6
February	15,6	54,4	1,6	8,0	20,4	100.0
March	24,2	51,9	2,9	1,9	15,1	96,0
April	-	-	-	-	-	-
May	7,9	25,1	1,3	5,3	59,6	99,2
June	0,3	7,8	0,1	0,3	91,5	100,0
July	1,4	35,4	0,4	0,2	62,6	100,0
August	0,1	22,5	0	0	76,7	99,3
September	0	71,3	0	2,2	25,0	98,5
October	-	-	-	-	-	-
November	3,1	51,3	15,2	0,7	29,0	99,3
December	3,0	17,4	58,1	4,0	11,1	93,6
January 1974	51,8	23,8	15,1	2,1	5,8	98,6
February	4,0	86,1	0,7	0	9,7	99,5

For the first year of the study the summer months were dominated by members of cluster A1 with the A2 taxa forming a strongly subdominant group (Table 61). However, although some exceptions occurred, from January 1973 there was a steady decrease in the representation of the cluster A1 taxa until they formed less than 10 per cent of the total population and the Orthocladinae-Chironomini group (A2) tended to dominate with the taxa in clusters A3 and A5 consituting the major subdominant associations. During these summer periods, the first year was characterized by low concentrations of all the chemical constitutents, particularly noticeable in the nitrite nitrogen, PO_4-P and total phosphorus concentrations. The second year differed in that the concentrations of all forms of nitrogen, particularly NH_3-N, and of phosphorus were higher (Table 62). The taxa represented by cluster A4 formed a constant though small part of population (<10%) and the *Burnupia* (cluster A3) only dominated the population in December 1973 (58%). This could be associated with the high flows during this period but other high flow periods did not show this occurrence.

TABLE 62: Comparison of mean nitrogen and phosphorus values at station 9 for the two years showing the higher concentrations in 1973/74 (values expressed as mg/ℓ)

Parameter	Year	
	1972/73	1973/74
NH_3-N	5,2	7,6
NO_2-N	0,8	1,0
NO_3-N	15,9	17,0
Total N	23,9	26,9
PO_4-P	2,0	3,1
Total P	2,3	3,5

Thus the characteristic fauna of this station consisted of all the taxa represented in cluster A. There was a shift in dominance from an association of *B. harrisoni* - *C. afra* - Simuliidae to an Orthocladinae - Chironomini association and both were replaced in the winter months by the three Naid taxa. When the *B. harrisoni* - *C. afra* - Simuliidae part of this association declined there was an increase in the percentage contribution of an association of *Burnupia*, and the three Naid taxa as subdominants. The advent of this association which was usually characteristic of the winter months suggests that these taxa were indicative of a decline in the *B. harrisoni* -*C. afra* - Simuliidae association rather than of water quality. It is thus this decline which indicated a deterioration of water quality rather than the increase in the Naid population. This makes the Naididae an indirect but important indicator of deteriorating water quality which can be especially useful in summer when they were not normally prevalent. The fauna found in winter could however be a result of a natural decline in the populations of *B. harrisoni* and associated taxa. The Naididae would thus be less useful as indicators of water quality changes in winter.

The proportion of the population made up of taxa represented in cluster B seldom exceeded 0,5 per cent of the total population and only twice exceeded one per cent of it. These exceptions occurred in March and December 1973 when the members of cluster B in total formed 4 per cent and 5 per cent of the population respectively. In both cases these percentages are formed by the association consisting of *Branchiura* sp., *Chironomus* sp., Hirudinea and *I. templetoni*. This suggests a deterioration in water quality although their small percentage does indicate that this was not severe or else that the condition was of short duration. There was no indication of this deterioration in the chemical results for these periods so it could have been the result of one or more short term severe increases in effluent into the river between station 6 and this station. The Klein Jukskei River has its confluence with the Jukskei River between these points but it seems unlikely that this was the source of a short term spate of poor quality water as this river did not show a similar faunal effect in this period (see station 8) and there were no measured point sources of effluent on it. However, a small outfall stream from the Northern Sewage Works which acts as a bypass stream during periods of overloading at the works has its confluence above station 9. The fact that the flow figures for these months were considerably higher than was normal for this station suggests that this bypass stream was used resulting in poor quality effluent being added to the river immediately upstream of station 9.

The degree diversity in the association of commonest taxa was similar to that shown in the fauna of stations immediately downstream but more restricted than that seen in the "natural" populations.

Cyridopsis also formed a part of this association here suggesting the effects of sewage works effluents seen at stations 7 and 7A.

The Oligochaete populations characteristic of the winter months showed a slightly greater deviation from "natural" conditions than that seen at stations 7 and 10. Particularly significant is the increased significance of the Tubificids, *I. templetoni* and *Branchiura* sp. during the first winter.

Station 6

The chemical characteristics of this station resembled the upstream stations more closely than those so far described in the increasing concentrations of most forms of nitrogen and the conservative mineral elements and very low PO_4-P and total phosphorus concentrations.

The increased percentages of Oligochaetes at this station (Table 66) suggests that the effects of contamination of the upper reach discussed at stations 2, 4 and 5 can be assumed to be negligible at this station.

The dendrogram of Czeckanowski similarity for this station (Fig. 43) shows a cluster of thirteen taxa linked at R = >50 per cent. The composition of this association consists mostly of taxa which were ubiquitous in the whole system and thus shows a great deal of similarity to the populations which were found in the more polluted tributaries at stations 3, 6A and 6B.

Cypridopsis sp., characteristic of the middle reach of this system, are not included in the association characteristic of this station although Table 63 shows that they did occur six times as very small percentages of the population.

TABLE 63: Frequency of occurrence of taxa grouped in cluster B of the dendrogram of Czeckanowski similarity (Fig. 43) at station 6

Taxa	Number of occurrence	Maximum number per occurrence	Maximum percentage contribution
Burnupia	4	7	4,7
Hirudinea	4	4	1,4
Tanytarsini	1	1	0,4
Cypridopsis	6	15	0,7
Chironomus	4	13	0,6
Branchiura	4	5	1,7

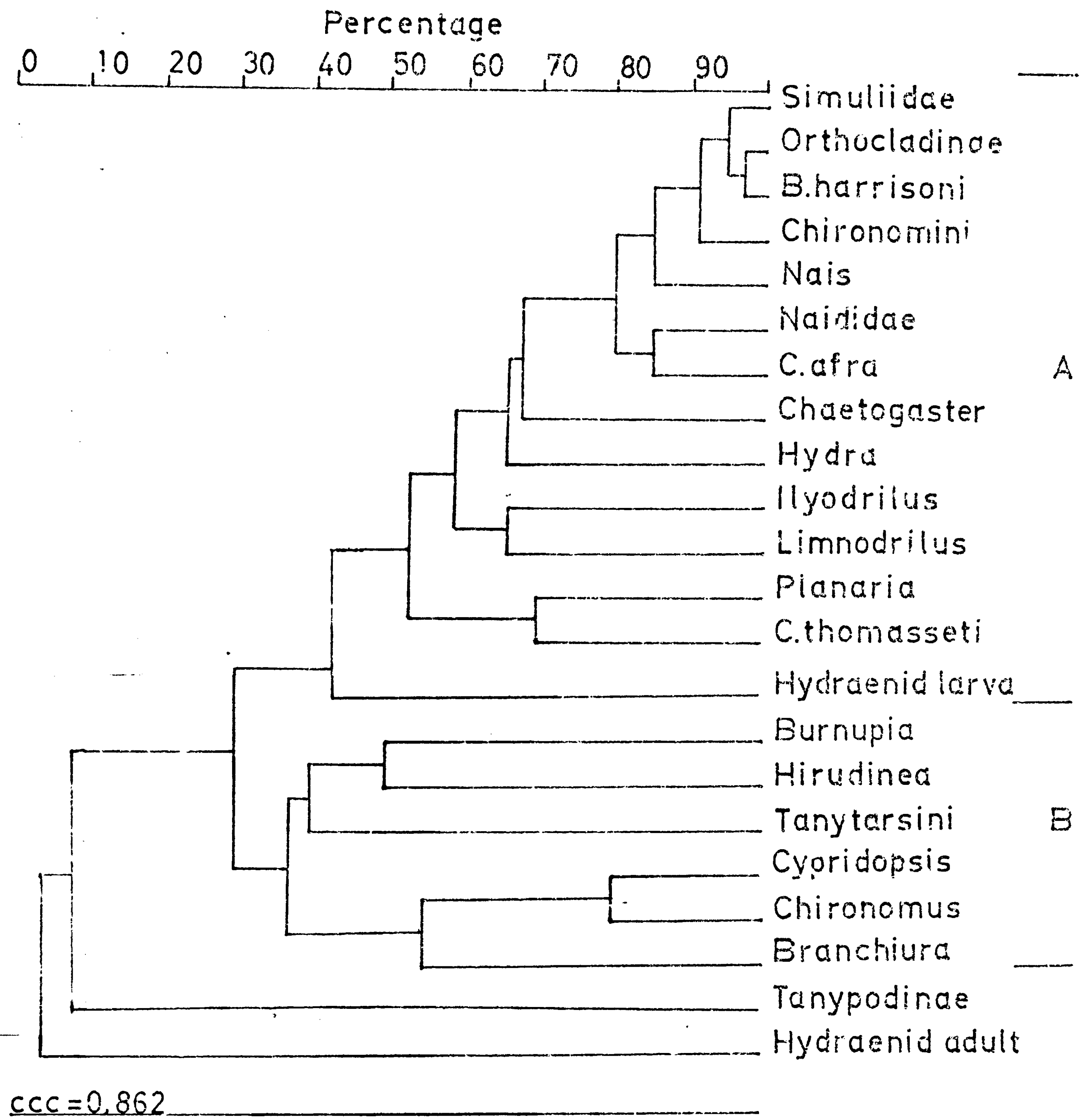


Figure 43: Dendrogram of Czeckanowski Similarity between Taxa for Station 6.

Cypridopsis sp., characteristic of the middle reach of this system, are not included in the association characteristic of this station although Table 63 shows that they did occur six times as very small percentages of the population.

The taxa grouped in cluster B did show some significance on the basis of frequency of occurrence but Table 63 shows that their percentage contribution to the populations was usually negligible. Their occurrences tended to be scattered thus showing no single period of significantly frequent occurrence.

With the exception of the last two taxa to join cluster A of this dendrogram (Planaria and *Cheumatopsyche thomasseti*) all its members are grouped in cluster C of the dendrogram of Bray-Curtis similarity (Fig. 44). Thus the remaining taxa in cluster A of Figure 43 formed the characteristic fauna of this station both on the basis of frequency of occurrence and percentage contribution.

Table 64 shows that cluster C1 of the Bray-Curtis similarity index (Fig. 44) is the dominant association as it formed between 50 and 95 per cent of the total population in all but three of the 24 months.

Cluster C2 and C3 appear to be competing for subdominant position and on two occasions (August-September 1972 and February 1974) actually dominate the whole population. Both groups are present throughout the study as can be seen from Table 63. However, cluster C2 appears to dominate C3 in the June-August period while the C3 taxa dominate from January to April with an even balance occurring between the two groups in May of both years. Thus taxa in cluster C2, *Nais* sp. and the other Naididae dominated the winter

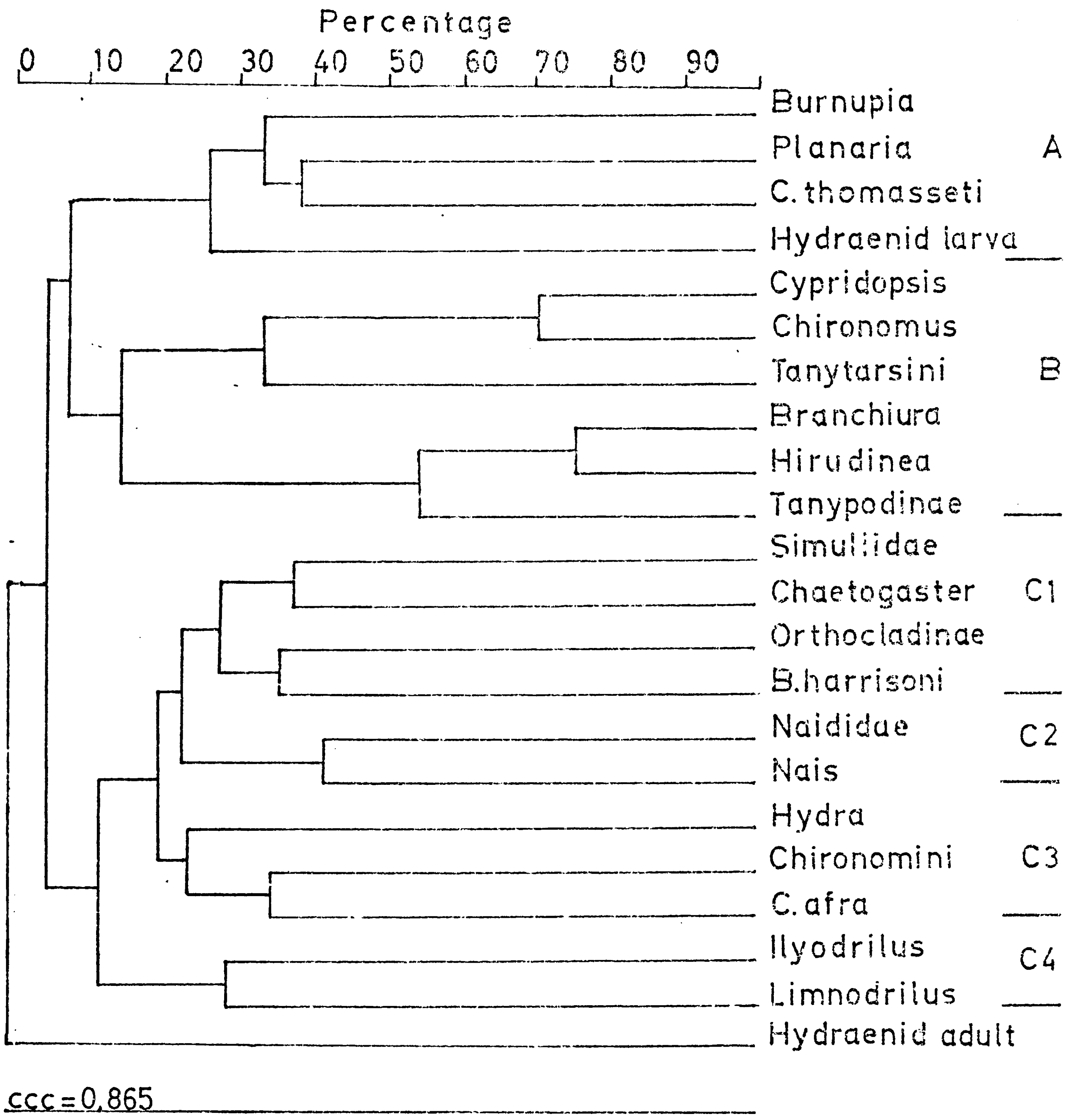


Figure 44: Dendrogram of Bray-Curtis Similarity between Taxa for Station 6.

TABLE 64: Percentage contribution of the associations (C1-C4) in cluster C of the dendrogram of Bray-Curtis similarity (Fig. 44) for station 6.

Month	Association				
	C1	C2	C3	C4	Total
March 1972	65,5	2,2	30,6	0	98,3
April	59,2	12,3	23,2	4,6	99,3
May	68,6	10,7	16,0	0,3	95,6
June	88,9	0,3	4,1	0,1	93,4
July	75,3	18,1	5,6	0,6	99,6
August	14,2	76,4	8,4	0	99,0
September	18,7	0,8	78,7	0,6	98,8
October	-	-	-	-	-
November	64,4	12,5	15,0	7,5	99,4
December	-	-	-	-	-
January 1973	88,8	0,8	9,0	0,8	99,4
February	88,8	0	7,0	0	95,8
March	-	-	-	-	-
April	-	-	-	-	-
May	56,8	29,0	10,1	0	95,9
June	88,0	1,3	2,0	0	91,3
July	75,3	12,8	4,0	0,5	92,6
August	66,4	30,4	2,1	1,1	100,0
September	95,8	1,0	2,5	0	99,3
October	-	-	-	-	-
November	70,0	1,0	22,0	1,0	94,0
December	79,6	2,4	5,6	6,5	94,1
January 1974	71,3	1,0	24,9	0,5	97,7
February	6,4	25,9	67,1	0,2	99,6

months which are, as usual, characterized by the highest concentrations of all nutrients measured while the C3 taxa, Chironomini, *Hydra* and *Cheumatopsyche afra* dominated under improved conditions. This increase in the Oligochaete taxa under conditions of poorer water quality was also associated with the period when the *Chaetogaster* form their greatest contribution to the C1 association. This suggests that the influence of contamination further upstream cannot be completely ignored at this station during the summer months when flow is high.

The normally subdominant groups (C2 and C3) moved into a dominant position on two occasions but there did not appear to be any pattern of preference between the cluster C2 and cluster C3 taxa in this increase. For example, in September 1972 when the C3 taxa dominated the total population (Table 64) there was no apparent seasonal link to the other periods of C3 significance. This suggests that this change in dominant taxa was probably due to conditions adverse to the *B. harrisoni* population. Both these periods, August-September 1972 and February 1974, were characterized by sudden, short term increases in the concentrations of the minerals and/or the nitrogenous compounds, sometimes doubling their previous concentrations as well as a marked increase in temperature up to 9 °C, (Table 65). One member of the C3 association, *Hydra*, showed a marked increase in its proportion of the population in May 1972 and June 1973. Both these months were preceeded by a marked drop in the NH_3-N and SO_4 (see appendix) concentrations during a period when the concentrations of all other parameters were increasing.

Each of the associations within cluster C of Figure 44 exhibits a variation in the dominance status of its member taxa at different times. Cluster C1 was dominated by *B. harrisoni* and the Orthocladinae throughout the survey

TABLE 65: Mineral and nitrogen concentrations (mg/ℓ) and temperature changes (°C) at station 6 for the periods July to September 1972 and December 1973 to February 1974 showing increasing values

Parameter	1972			1973/74		
	July	August	September	December	January	February
Na	119,0	110,0	170,0	34,0	54,0	96,0
K	16,0	16,0	29,0	7,0	9,8	17,4
Ca	84,0	83,0	115,0	41,0	56,0	73,0
Mg	33,0	33,0	40,0	15,0	20,0	29,0
Cl^-	126,0	143,0	174,0	39,0	63,0	92,0
$SO_4^=$	210	270	435,0	97,0	135,0	210,0
NH_3-N	18,2	16,1	15,4	3,1	2,0	8,7
NO_3-N	30,0	35,0	44,0	22,3	17,1	17,1
NO_2-N	0,05	1,08	2,30	0,8	1,2	1,6
Temperature	9,0	14,0	18,5	19,5	26,0	23,2

with the former dominating the latter in the summer months (November-May) and vice versa in winter (June-September). This is associated with the normal difference between summer and winter conditions i.e. flow and temperature changes associated with increased concentrations of nutrients in winter. *Chaetogaster* and the Simuliidae form dominant or subdominant parts of this association in the transitional periods. The *Nais* sp. and other Naididae in cluster C2 showed little dominance by either of its members over the other. There was no apparent connection between either of these taxa with the dominance patterns in the C1 association. In cluster C3 however, there did appear to be a pattern of dominance with the Chironomini dominating this group when Orthocladinae dominated the C1 association and *C. afra* taking the dominant position when *B. harrisoni* was the dominant in cluster C1. In only two instances did *Hydra* dominate this association, as has been described above, and in both cases it coincided with dominance by *Nais* sp. of the C2 association.

The cluster B association of the dendrogram of Bray-Curtis similarity (Table 63) differs from the cluster C association in that they are limited to the early summer months, thus their distinction from the most frequently occurring taxa in the Czeckanowski similarity dendrogram. Within cluster B *Cypridopsis* and *Chironomus* sp. showed their greatest contribution in September which coincided with the highest concentrations of all parameters measured (Table 65). *Branchiura* sp. and Hirudinea showed their highest contribution in December during a peak flow period (Table 17). However, at no stage did any of these taxa exceed 2 per cent of the total population.

The characteristic fauna of this station did not differ greatly from that seen immediately downstream although a change in composition of the Oligochaete association in winter and the more restricted dominant association consisting almost entirely of the ubiquitous taxa showed a further deviation from "natural" conditions. This population showed a close resemblance to that discussed at station 3 apart from the fact that the two *Cheumatopsyche* species were still included on the basis of their frequency of occurrence. This did not occur at station 3 showing that water quality at station 6 is better than in the more enriched tributaries discussed earlier because these two taxa increase their significance in the dominant associations as conditions approach those of the "natural" streams.

However, at this stage (station 6) in the continuing deterioration in water quality the Ephemeropteran taxa other than *B. harrisoni* and the Trichopteran taxa other than *Cheumatopsyche* were never recorded which represents a major deviation from the populations of "natural" streams.

In general the dominant association here resembled that at station 9 in the second year when the *C. afra* and Simuliidae contribution to this association declined resulting in overall domination by an association of *B. harrisoni* - Orthocladinae - *Chaetogaster*.

Stations 2, 4 and 5

These stations are dealt with together because the effect of the contaminant occurring upstream of station 2 (as discussed on page 76) appeared to extend downstream as far as station 5.

The most important characteristic of the faunal population at station 2 was the complete absence of any of the Oligochaete taxa found commonly throughout the rest of the system. The discussion in the biotic index section indicates that the Oligochaeta are absent, notwithstanding the relatively high degree of enrichment indicated by the chemical results (Table 21), due to contamination by a substance toxic to the Oligochaeta.

It is interesting to note from Table 66 that the effect of this contaminant continued into the Jukskei River. The average percentage of Oligochaetes in the total population dropped from 37,7 per cent at station 3, immediately before the Jukskei confluence with the Modderfontein stream to 4,9 per cent and 5,4 per cent at stations 4 and 5 respectively. At station 6 this percentage rose considerably suggesting a return to more natural conditions i.e. the deviation from natural populations was not as great at station 6 as at stations 2, 4 and 5.

TABLE 66: Percentages of communities at stations 3, 4, 5 and 6 which comprise the Oligochaete part of the fauna showing the decrease at stations 4 and 5 (1973/74 data in brackets)

Month	Percentage Oligochaetes			
	Station 3	Station 4	Station 5	Station 6
March	-	-	-	-
	-	-	-	-
April	17,6	2,5	3,3	20,1
	(-)	(16,7)	(-)	(-)
May	9,7	13,0	0,8	11,0
	(61,6)	(21,8)	(2,9)	(36,8)
June	22,6	3,3	1,9	39,5
	(43,8)	(0)	(14,3)	(6,7)
July	67,0	10,6	1,2	27,6
	(62,4)	(2,4)	(14,9)	(19,2)
August	40,3	3,1	1,0	76,5
	(92,4)	(10,1)	(17,4)	(36,0)
September	87,6	0	0	0,8
	(91,1)	(1,1)	(2,0)	(3,3)
October	-	-	-	-
	-	-	-	-
November	29,9	0,2	0	32,5
	(12,9)	(0,9)	(0,8)	(4,0)
December	14,0	4,0	3,0	-
	(11,0)	(3,6)	(1,7)	(10,6)
January	9,8	0,4	27,7	1,6
	(1,9)	(5,6)	(3,1)	(1,5)
February	12,4	0	6,4	2,8
	(4,3)	(1,3)	(0)	(26,7)
Average	37,69	4,91	5,39	19,8

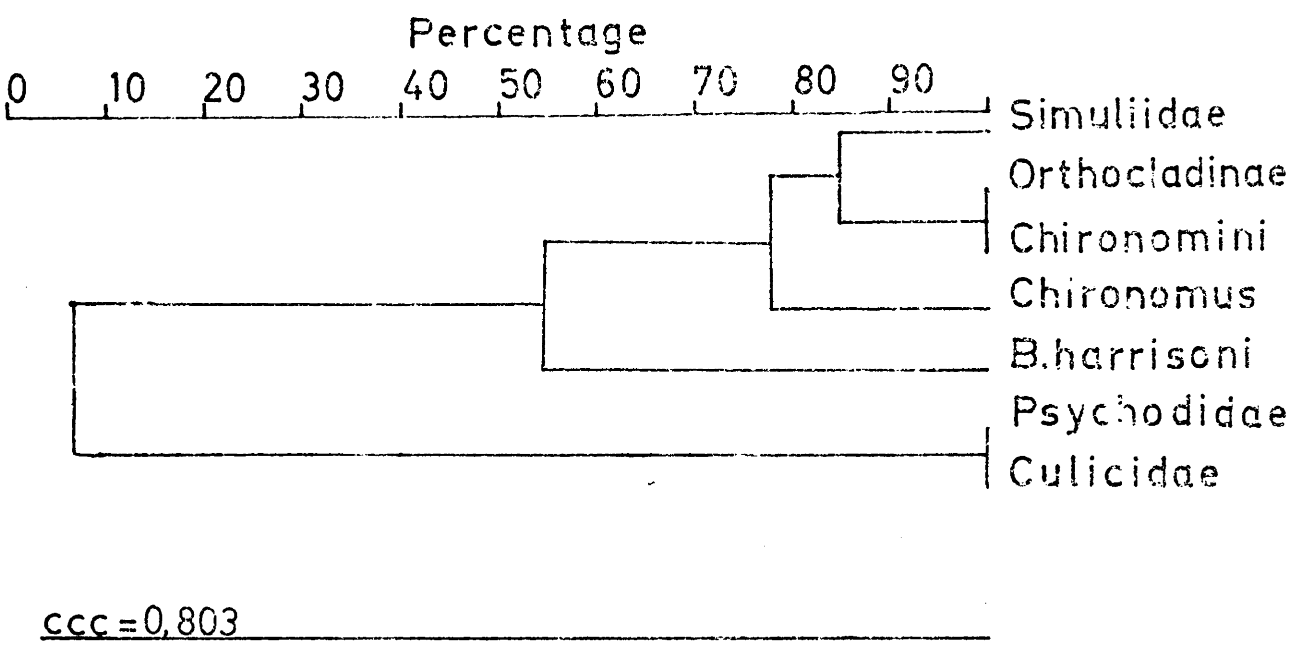


Figure 45: Dendrogram of Czeckanowski Similarity between Taxa for Station 2.

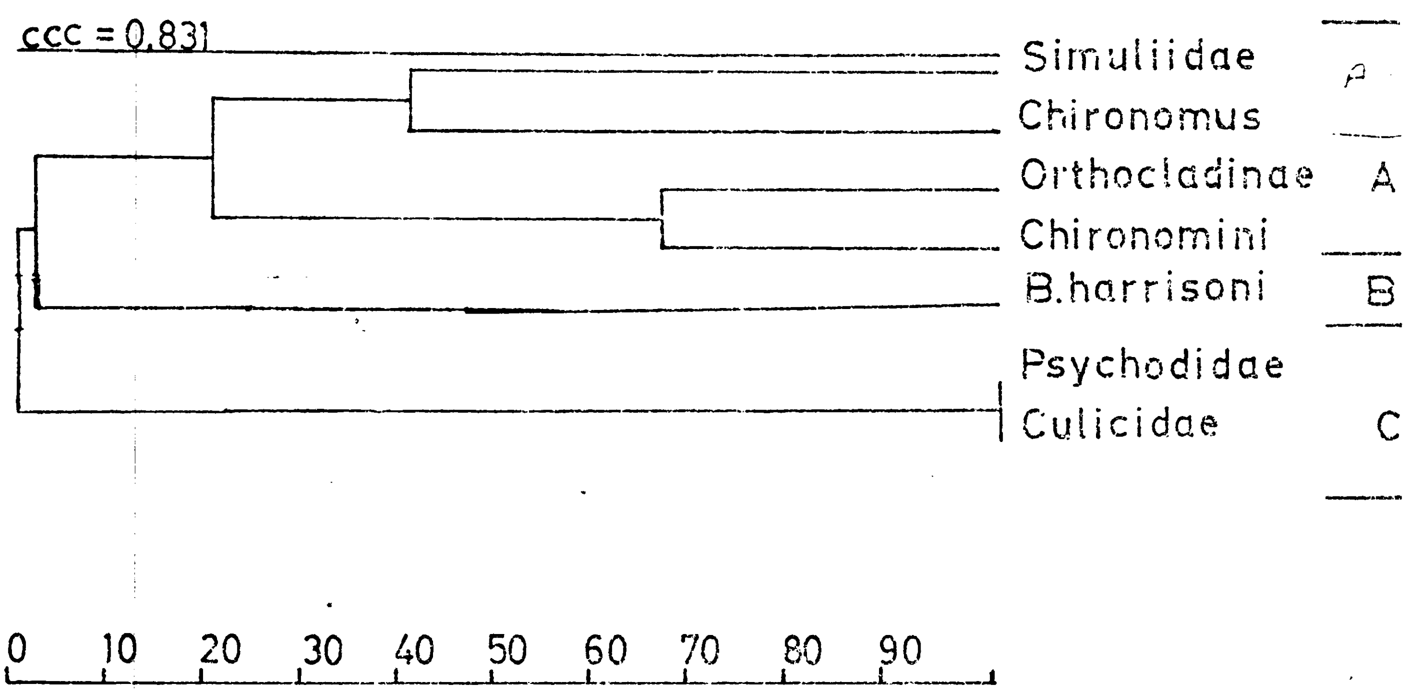


Figure 46: Dendrogram of Bray-Curtis Similarity between Taxa for Station 2.

Table 66 also shows that the disappearance of this influence before station 6 was very much more obvious in the dry winter months. It must be borne in mind that under natural conditions the Oligochaete population declined in summer so that this could have been a natural occurrence. However the extremely low percentages of Oligochaetes at station 6 from September of the second year of study compared to relatively high values at station 3 for the same period suggests that the increased flow resulted in the factor influencing the Oligochaeta being carried further downstream.

Even though the absence of an Oligochaete fauna made comparison between station 2 and other, non-affected stations difficult, the degree of enrichment can be indicated by the composition of the insect fauna and its deviation from that seen in natural populations as well as its variation between seasons.

The dendrogram of Czeckanowski similarity (Fig. 45) shows that five of the seven taxa found at this station formed a cluster at r values above 50 per cent. The remaining two taxa are shown in Table 67 (under cluster C) to have occurred in small numbers once only. Because the Chironomini and Orthocladinae were present in every sample (r = 100%) they were obviously most characteristic of the fauna at this station. On the basis of presence-absence data only the rest of this association consisted of the Simuliidae, *Chironomus* sp. and to a lesser extent *B. harrisoni*.

The dendrogram of Bray-Curtis similarity (Fig. 46) shows a division of all the taxa into four groups. Cluster C consists of the Psychodidae and Culicidae which are shown in Table 67 to have occurred only once in small numbers in November 1973 when the ammonia and nitrate concentrations were the highest recorded at this station (Table 68). This station is shown in Table 21 to have had the highest concentrations of these parameters so that the concentrations shown in Table 68 were the highest measured in this system over the survey period. The one occurrence of the Psychodid-Culicid association at this station was accompanied by a disappearance of Simuliidae and an increase in the *Chironomus* population over the period both preceeding and succeeding this event.

TABLE 67: Percentage contribution of the taxa found at station 2 to the population based on the associations shown in the dendrogram of Bray-Curtis similarity (Fig. 46)

Month	Cluster					
	Cluster A				*B. harrisoni*	Cluster C
	Simuliidae	*Chironomus*	A2	Total		
March	12,2	0,4	83,2	95,8	4,2	0
April	3,2	0,3	96,5	100,0	0	0
May	0,8	0,8	98,4	100,0	0	0
June	2,8	0	97,2	100,0	0	0
July	0,4	0	99,5	100,0	0	0
August	0	0	100,0	100,0	0	0
September	0,3	0,1	99,6	100,0	0	0
October	0,8	0	97,7	98,5	0	0
November	5,6	0	94,1	99,7	0	0
December	25,3	0	74,7	100,0	0	0
January 1973	14,0	11,4	74,6	100,0	0	0
February	23,8	9,8	66,4	100,0	0	0
March	16,0	6,8	76,6	99,4	0,6	0
April	21,4	4,5	73,7	99,6	0,2	0
May	34,1	6,3	59,6	100,0	0	0
June	2,8	2,2	94,8	99,8	0,2	0
July	0,7	0	97,9	98,6	1,4	0
August	0	4,5	94,0	98,5	1,5	0
September	0	4,2	95,8	100,0	0	0
October	0	3,0	97,0	100,0	0	0
November	0	3,0	96,0	99,0	0,3	0,6
December	0	1,3	98,4	99,7	0	0
January 1974	7,9	4,3	87,2	99,4	0,6	0
February	10,9	3,1	84,4	98,4	1,6	0

The only relatively significant occurrence of *B. harrisoni* occurred in March 1972 so that although it occurred frequently enough to form part of the characteristic faunal population of this station it was not normally numerically abundant.

TABLE 68: Ammonia and nitrate concentrations at station 2 for the period August to November 1973 compared to maximum values over the rest of the survey (values expressed in mg/ℓ)

Month	NH_3-N	NO_3-N
August	38,0	39,5
September	45,5	52,8
October	42,5	61,3
November	44,3	70,2
Max over rest of survey	42,7	61,7

The taxa in cluster A (Fig. 46) were the dominant taxa at this station and its members always, with the exception of March 1972, formed between 98 per cent and 100 per cent of the populations. The A2 association (Chironomini and Orthocladinae) dominated this cluster A community throughout the year (Table 66).

The Simuliidae were the next most frequently occurring taxon after the two dominant taxa while *Chironomus* sp. occurred slightly less often (see Czeckanowski similarity, Fig. 45). Table 67 shows that both these taxa made their greatest contribution to the population during the summer months although *Chironomus* sp. only became significant during the second year of the study.

This station was characterized by very high mineral (the highest in the system) and high NH_3-N concentrations with NO_3-N and dissolved inorganic nitrogen values varying from very high to average for the system (categories A to C). The NO_2-N and dissolved organic nitrogen were of the category C-D order of magnitude while carbon and phosphorus concentrations were low. River flow was apparently kept reasonably constant by the dams above this station but flow could vary for very short periods during spells of high rainfall.

The deviation from natural populations reached extreme proportions at this station with the characteristic faunal association restricted to four taxa, the clean water Ephemeropteran taxa absent and even *B. harrisoni* hardly significant, *Chironomus* sp. forming part of the characteristic fauna and complete dominance by the Chironomids only. Thus in addition to the absence of the Oligochaete fauna at this station the insect taxa show great deviation from the expected natural populations indicating the most severe deterioration in water quality in the system.

The difference between this association and that seen at station 7A (the associations typical of the effects of the two main effluent sources in this system) shows that the effects upon the fauna of sewage effluent with its high phosphorus and organic carbon concentrations were not as severe as those of mineral and nitrogenous effluent in the Modderfontein stream. Thus apart from specific variations in the composition of these two "effluent" associations the latter type of enrichment was typified by an association indicating very much more severe pollution than the former.

Due to the effects shown in Table 65 the proportions of Oligochaetes present at stations 4 and 5 cannot be considered as indicative of other forms of pollution. It is thus preferable when discussing changes to consider variation within the Oligochaete fauna and within the rest of the faunal population separately.

On the basis of occurrence only the dendrogram of Czeckanowski similarity for station 4 (Fig. 47) shows an association of nine taxa (cluster A) which are characteristic of this station. All other relationships which appear to be significant in the the clustering occur infrequently and in negligible proportions. Two exceptions shown in Table 69 are the *Chaetogaster* and *Hydra*. The *Chaetogaster* is shown in Table 71 to form part of the dominant fauna on the basis of relative abundance even though it is not constantly present. *Hydra* is only significant with respect to relative abundance in on sample. Cluster B taxa are shown in Table 69 to be limited to occurrences of one or two individuals only (<0,1% of the population) except in December of both years when they formed between 1 and 3 per cent of the total sample. In both years of the survey the increased flow in December (Table 17) was accompanied by a decrease in the concentration of all the parameters except NH_4-N which increased (Table 70). This resulted in the ammonia concentration rising to its high winter level. This makes the condition similar to the condition recorded at station 2 during this period (see above). The relationship between NH_3-N concentration and this faunal association may have been a direct one or the high concentrations of NH_3-N may have been symptomatic of a condition, for example unstabilized organic matter with which this community can be associated.

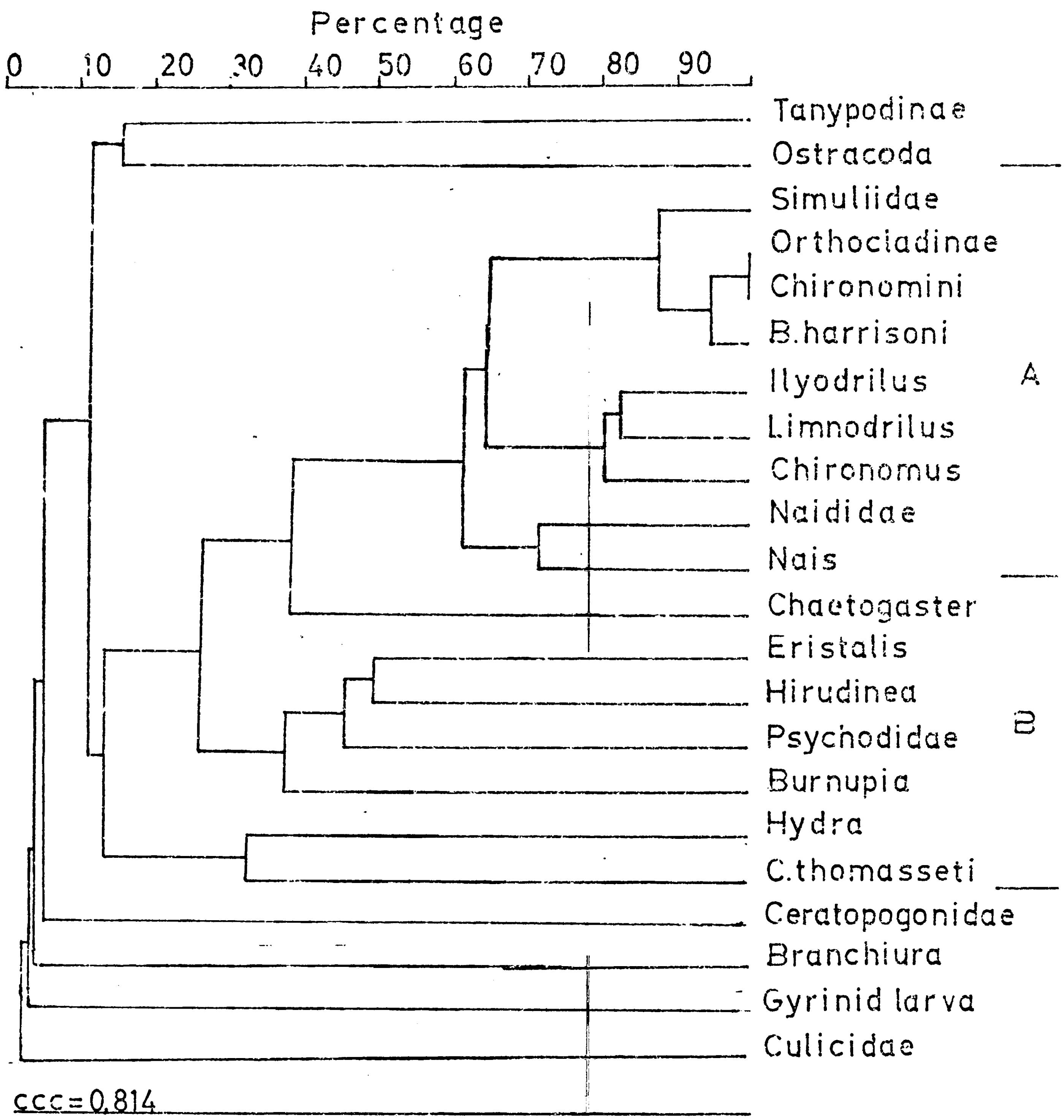


Figure 47: Dendrogram of Czeckanowski Similarity between Taxa for Station 4.

TABLE 69: Frequency of occurrence of taxa found at station 4 which show apparently significant relationships in the dendrogram of Czeckanowski similarity (Fig. 47) other than association A

Taxon	Number of occurrences	Maximum number per occurrence	Maximum percentage contribution
Chaetogaster	7	27	19,0
Eristalis	3	2	0,6
Hirudinea	7	5	1,6
Psychodidae	4	5	3,6
Burnupia	1	1	0,9
Hydra	5	15	16,5
C. thomasseti	1	1	0,1
Branchiura	2	2	0,9
Planaria	1	2	0
Gyrinid 1	1	1	0,5

TABLE 70: A comparison between the July and December chemical concentrations at station 4 showing the high NH_3-N concentrations compared to low concentrations of other parameters in December (values expressed as mg/ℓ except conductivity which is in mSm)

Parameter	Month			
	July		December	
	1972	1973	1972	1973
NH_3-N	26	33	21	31
NO_3-N	57	30	14,8	6,7
COD	60	63	37	30
Conductivity	2005	1875	715	1476

TABLE 71: Percentage contribution of the associations in cluster B of the dendrogram of Bray-Curtis similarity for station 4 (Fig. 48)

Month	association			
	B1	*Chaetogaster*	B2	Total
March 1972	95,9	0	3,7	99,6
April	93,5	0	3,5	97,0
May	86,6	0	2,8	89,4
June	95,6	2,3	1,0	98,9
July	88,3	6,6	4,0	98,9
August	90,5	0,8	2,3	93,1
September	99,1	0	0	99,1
October	-	-	-	-
November	97,4	0	1,4	98,8
December	79,2	0,3	11,6	91,1
January 1973	99,2	0,4	0,4	100,0
February	82,8	0	0	82,8
March	91,9	0	7,3	99,2
April	69,5	0,9	16,7	87,1
May	78,2	19,0	2,8	100,0
June	99,8	0	0	99,8
July	97,5	0	2,4	99,9
August	88,9	0	10,6	99,5
September	97,8	0	2,1	99,9
October	79,4	0	19,7	99,1
November	94,9	0	3,5	98,4
December	85,9	0	8,9	94,8
January 1974	86,8	0	9,9	96,7
February	98,2	0	1,3	99,5

The taxa shown to be characteristic of this station on the basis of occurrence (Fig. 47) are divided into two groups in the dendrogram of Bray-Curtis similarity (Fig. 48). Association B1 dominates this fauna as can be seen in Table 70. The very restricted Oligochaete fauna are clustered in B2.

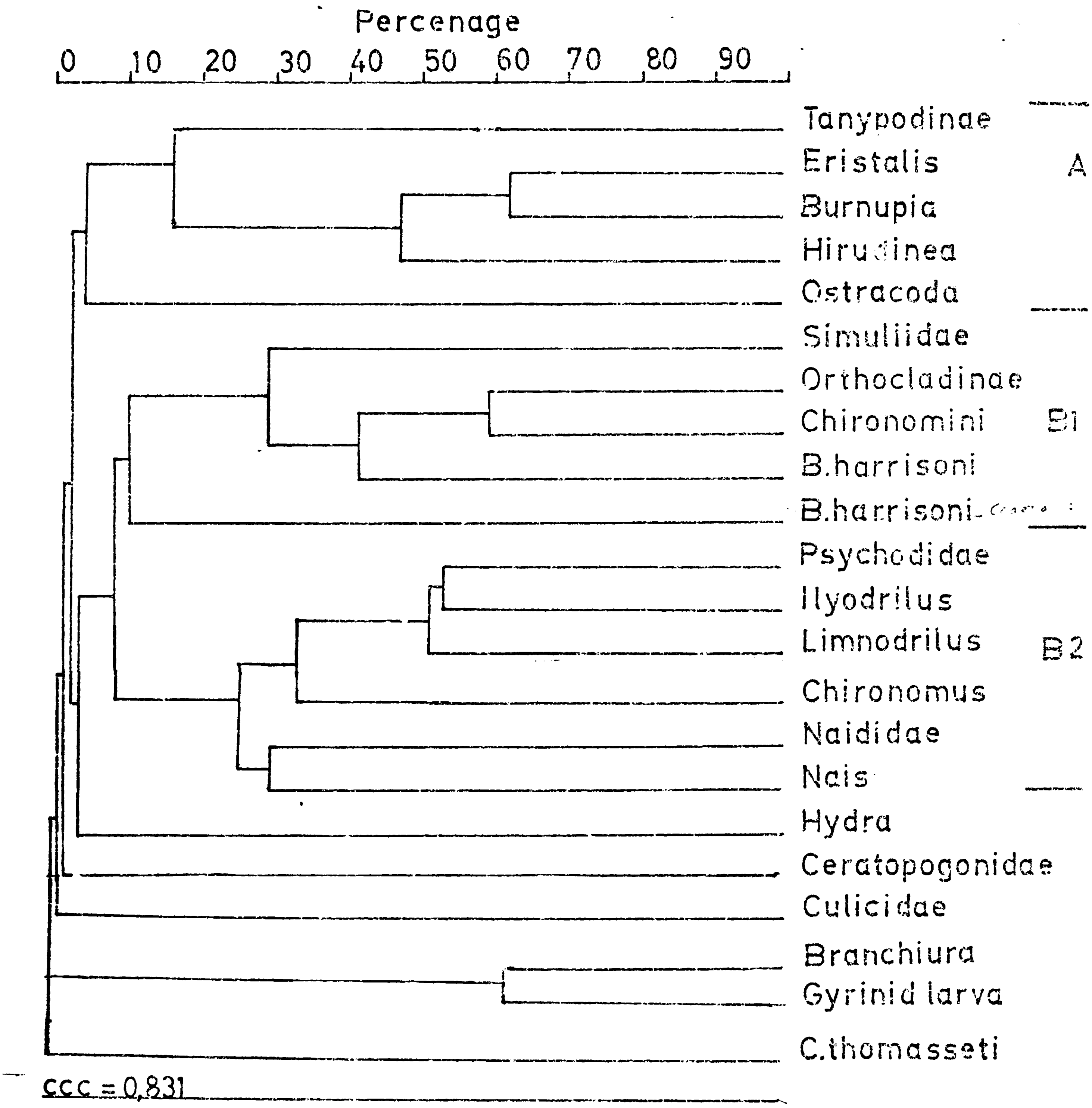


Figure 48: Dendrogram of Bray-Curtis Similarity between Taxa for Station 4.

If the Oligochaete taxa are removed from the characteristic fauna of this station as shown in the dendrograms (Figs 47 and 48) the remaining taxa are identical to those which characterized the population at station 2. This is not surprising as station 4 presents a general picture of high mineral concentrations (although not as high as station 2) and was high in nitrates and low in phosphorus. However the other forms of nitrogen showed comparatively low concentrations (categories C, D and E). Carbon concentrations, pH, COD and MBAS were average for the system (Table 21). Thus although the degree of enrichment is slightly less than that seen at station 2, the chief characteristics of high mineral concentrations, high nitrogen and low phosphorus concentrations and average COD and carbon concentrations are similar at both stations. This difference in degree and the change in the form of the nitrogen enrichment can be seen in the changed proportions of the individual taxa characteristic of this station (Tables 67 and 69). The winter condition at station 4, when flow is considerably decreased, is characterized by particularly significant increases in the concentrations of minerals, ammonia, nitrates and a slight increase in phosphorus. Thus during this period conditions were similar to station 2 (Table 72). This situation is coupled to a fauna completely dominated by the Chironomini and Orthocladinae (Table 69), particularly towards the end of the dry season as occurred at station 2. However during the summer months when the overall picture of enrichment at this station was not as severe as at station 2, those taxa of the characteristic fauna which occurred in small numbers at station 2, increased their proportionate contribution to the population. The Orthocladinae and *B. harrisoni* tend to dominate during these months with the Simuliidae contributing more to the population. It therefore appears that when the degree of enrichment, of the type characteristic at these stations, decreases, the Chironomini are the first to be affected. They tend to decrease in numbers as the other taxa, *B. harrisoni* in this case, increase with improved water quality. This is confirmed by the fact that at station 2 the months that had the lowest Chironomini percentages were those that showed increased percentages of the non-Chironomid taxa (Table 67). However it appears that a deterioration in water quality and an increase in the *Chironomus*-Psychodid association also affects the Chironomini which decrease in numbers. This suggests that the Chironomini are not so much affected by changing water quality but are more susceptible to population pressure than are the Orthocladinae.

TABLE 72: A comparison between winter chemical conditions at station 4 and average conditions at station 2 (values expressed as mg/ℓ except conductivity which is in mSm)

Parameter	Station					
	4					2
	April	May	June	July	August	Average
Conductivity	1252	1344	1361	1872	1807	1936
NO_3-N	19,6	28,9	35,2	34,8	43,5	43,6
NH_3-N	19,4	17,8	21,3	33,0	34,0	36,6
PO_4-P	0,5	0,2	0,8	1,2	0,9	1,1

Although the Oligochaete percentage is considerably less than would be expected due to toxic influences, changes in Oligochaete population variation coincided with that of the non-Oligochaete fauna.

During the winter the percentage contribution of the Oligochaetes increases (Table 69), possibly due to similar processes which resulted in increased NH_3-N in high flow periods (see above) i.e. reduced flow increases the time in which toxic substances can be removed or inactivated. In the index of Czeckanowski similarity (Fig. 47) one can see that the Oligochaetes join the cluster of characteristic non-Oligochaete taxa at a considerably lower r value. This suggests that they tended to occur together but not as frequently as these other taxa i.e. they were restricted to only a part of the year. In the early winter months the first taxa to increase were the *Nais* sp. and the other Naididae. As the winter progresses and water quality deteriorates the Chironomini and Orthocladinae become the dominant taxa and the Oligochaete contribution to the population becomes dominated by *Ilyodrilus templetoni* and *Limnodrilus* sp. Thus, as was indicated downstream, the Tubificidae were indicative of more severe pollution than were the Naididae. However, the indicator value of these Oligochaete taxa appears to differ from that described downstream because during the November-December periods discussed above when conditions deteriorated, the Oligochaetes did not indicate the change. This deterioration in water quality was due to nitrogenous enrichment. This could be due to the fact that increased flow can scour the stones of attached algal material which is an ideal biotope for Oligochaetes.

There appears to have been very little change in the fauna between stations 4 and 5. The basic differences between the characteristics of station 5 and those of station 4 were that there appears to be a greater range of mineral concentrations with winter values very high (categories A and B) and summer values average to low (categories C and D). In addition to this both the inorganic carbon and organic carbon values were lower and associated with a slightly lower COD so one could expect that available organic matter is less than at station 4.

At station 5 the main difference in the faunal association was that the Simuliidae were not closely associated with the taxa which were characteristic at the upstream stations, in either their degree of occurrence (Fig. 49) or their relative abundance (Fig. 50). This taxon as well as those associated with it in cluster A of both dendrograms only occrred in very small numbers in the January to March period (<1% of the population in any one month). The only marked difference in the chemical composition of the water at this station when compared with that of station 4, is that the concentrations of dissolved organic nitrogen were more variable and at times considerably higher at station 5. The above-mentioned period, (January-March) which shows the only advent of Simuliidae in the population, coincides with the period of lowest dissolved organic nitrogen concentrations i.e. when the concentrations of this parameter were most similar to those at station 4.

If the Oligochaete fauna are once again ignored the four taxa shown to be characteristic at stations 2 and 4 are once again clustered as the most frequently occurring at station 5 in the dendrogram of Czeckanowski similarity (Fig. 49). However, the fact that the Orthocladinae, Chironomini and *B. harrisoni* are clustered at r = >90 whereas the *Chironomus* sp. only join this cluster at r = 64 indicates that the *Chironomus* sp. occurred less frequently and this is due to their occurrence being confined to a certain part of the year only (see Appendix).

The taxa shown in the dendrogram of Czeckanowski similarity to be commonest are divided into clusters B and C in the dendrogram of Bray-Curtis similarity. Cluster C taxa usually form between 85 per cent and 100 per cent of the population at this station (Table 73). The dominance status of

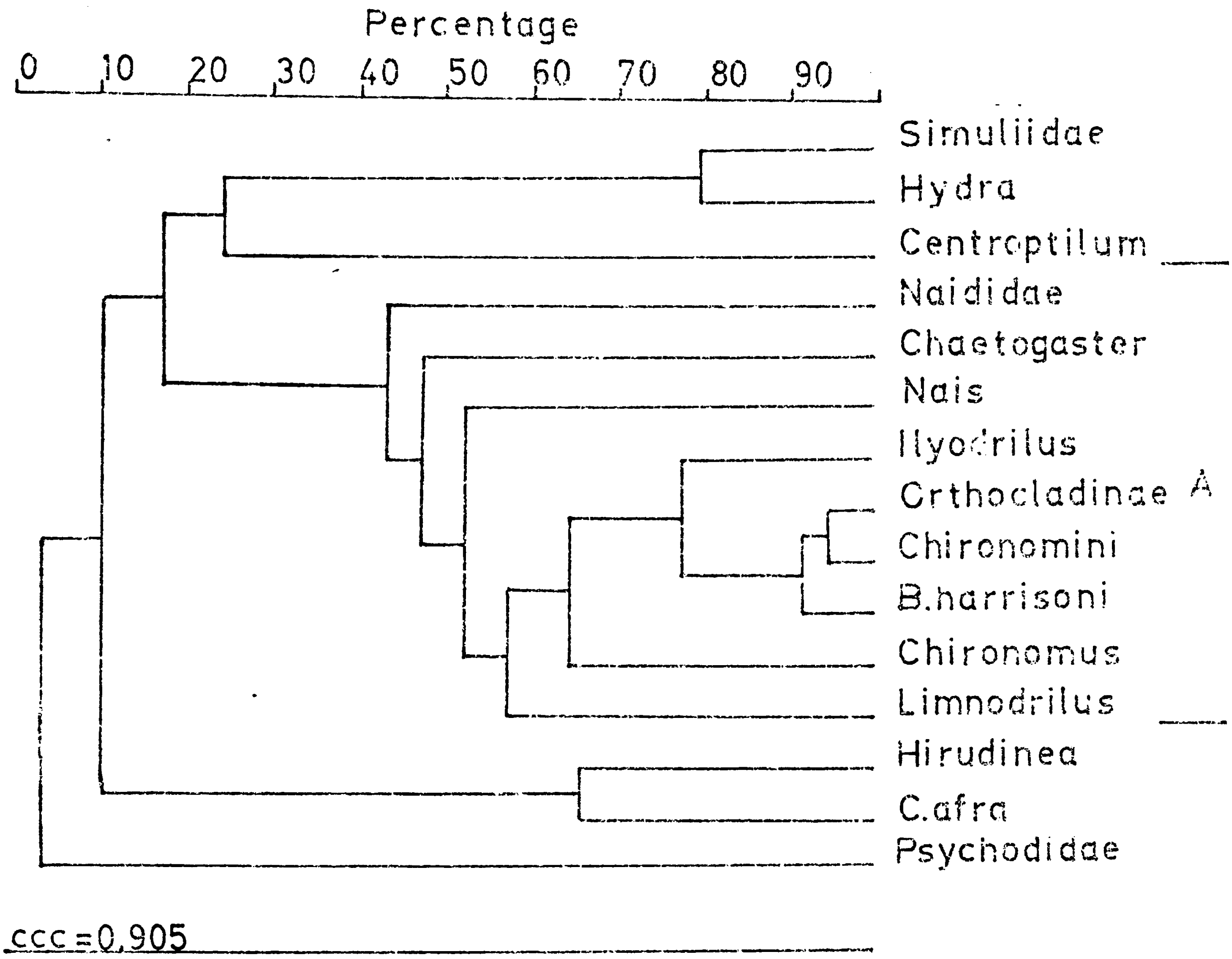


Figure 49: Dendrogram of Czeckanowski Similarity between Taxa for Station 5.

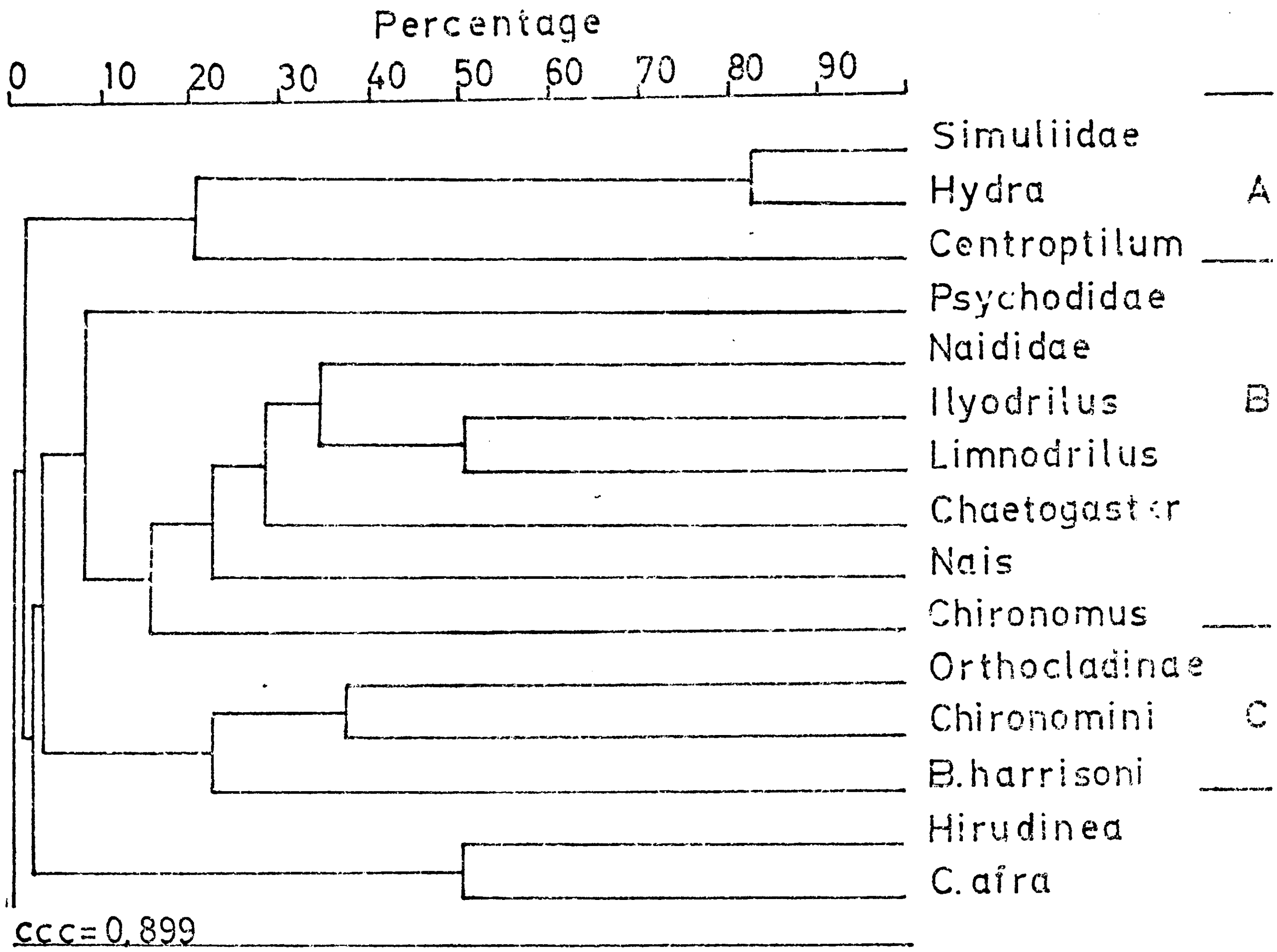


Figure 50: Dendrogram of Bray-Curtis Similarity between Taxa for Station 5.

these three taxa varied throughout the year so that they did not co-dominate but rather had different periods of dominance even though on the basis of occurrence they all occur together at most times. *B. harrisoni* dominated during the May-June and January-February periods of both years and there was a tendency for the Chironomini to decrease in this association when the *B. harrisoni* dominated. The months immediately preceeding and succeeding these two periods show significant numbers of *B. harrisoni* but for the rest of the year this species forms less than 10 percent of this association.

TABLE 73: Percentage contribution of associations shown in the dendrogram of Bray-Curtis similarity (Fig. 50) to the populations at station 5

Month	Association						
	A	B	C				D
			B. harrisoni	Orthocladinae	Chironomini	Total	
March 1972	0,4	11,9	0,5	20,3	67,0	87,8	0
April	0	6,0	8,8	54,9	30,0	93,7	0
May	0	2,3	66,5	19,6	11,5	97,6	0
June	0	1,9	76,3	4,8	17,0	98,1	0
July	0	1,2	23,1	9,3	66,2	98,6	0
August	0	1,5	1,6	16,2	80,5	98,3	0
September	0	0	0,1	8,6	91,1	99,8	0
October	-	-	-	-	-	-	-
November	0	0	0,4	76,6	23,0	100,0	0
December	0	13,8	15,7	52,4	18,1	86,2	0
January 1973	0	27,7	38,8	28,7	3,8	71,3	0
February	2,6	6,4	73,2	10,8	7,0	91,0	0
March	-	-	-	-	-	-	-
April	-	-	-	-	-	-	-
May	0	2,9	90,5	3,8	2,8	97,1	0
June	0	14,3	57,1	24,3	4,3	85,7	0
July	0	14,9	6,7	55,7	21,5	83,9	1,4
August	0	17,4	0	76,9	0	76,9	1,9
September	0	2,4	0	70,1	27,4	97,5	0
October	0	2,8	0	91,3	5,9	97,2	0
November	0	2,0	0,3	78,6	19,0	97,9	0
December	0	2,4	2,4	93,2	1,9	97,5	0
January 1974	0,6	10,0	37,5	27,5	23,8	88,8	0
February	0	0	94,8	3,9	0	98,7	1,3

This increased *B. harrisoni* population which coincided with a drop in the Chironomini contribution occurred at the same time as a marked decrease in the concentrations of the mineral elements in the preceeding months (Table 74) (March-April and November-December) regardless of whether the other chemical parameters were showing an increase or decrease in concentration.

TABLE 74: Concentrations of the mineral elements at station 5 during the March-April and November-December periods showing a drop in concentration (values expressed in mg/ℓ)

Period	Parameter					
	Na	K	Ca	Mg	Cl^-	$SO_4^=$
November 1972	150	20,0	116,0	33,0	149	455
December	28	7,0	34,0	12,0	31	60
March 1973	149	24,0	89	28	138	295
April	89	16,7	66	20	82	220
November	119	17,2	94	33	121	330
December	88	15,0	80	29	90	250

During the rest of the year the Chironomini-Orthocladinae association is dominant with the Chironomini showing a greater percentage contribution in the winter months and the Orthocladinae in the summer months.

Cluster B in Figure 50 which consists mainly of the Oligochaete taxa shows a similar relationship to the dominant fauna to that seen at station 4. It did, however, tend to form a more constant part of the association here (between 2% and 15% in most samples, Table 73). As at station 4 these taxa formed their greatest contribution to the community in the winter months when the concentrations of the nutrient elements of the water were at their highest level. The fact that this association was more constant suggests that either the influence of the contaminant discussed above was considerably reduced at this stage, or that there was a deterioration in one or more specific aspects of the water quality. The close linkage of *Chironomus* sp. and the Psychodidae with the Oligochaete association and the fact that the Tubificidae and *Chironomus* sp. show a very close relationship to the dominant fauna on the basis of occurrence (Fig. 49), suggests that this difference from the station 4 faunal population is at least partially due to a deterioration in water quality.

A comparison of the three stations considered here suggests that the influence of heavy metal toxicity waned far more rapidly during the low flow season than in the increased flows experienced in the summer. During the summer high flow period there appears to have been a gradual improvement in water quality with respect to nutrient concentrations from station 2 to station 5. However the winter months show very similar conditions at these three stations with the possibility of a slight deterioration in quality at station 5. The implication being that there was an added source of nutrients in this region rather than increased addition higher upstream. This deterioration is indicated by the fauna which appears to be characteristic of the higher concentrations of dissolved organic nitrogen measured at station 5.

All three these stations deviated markedly from the "natural" streams with respect to their faunal populations. Apart from the deviation already discussed which manifested itself in the limited Oligochaete populations, there tended to be a pattern of total dominance by two or three taxa and all the Trichoptera are absent from these stations.

Station 1

This station was characterized by a complete lack of fauna at any stage during the study period. Although some isolated individuals were occasionally found, their occurrence was probably incidental and could be the result of drift from further upstream.

At no stage are the chemical characteristics of this station so different from those in other parts of the river system as to explain the total absence of a fauna. River flow is relatively small and is no more subject to flooding than the rest of the Modderfontein stream. The only two measured parameters which were significantly different from the rest of the system were pH and temperature. It is possible that one or a combination of these brought about the absence of the fauna.

The pH values were, for most of the survey period, between 8 and 9 units which level is not high enough to eliminate all the animals since station 2 which had an average pH above 8 units (Table 13) supported a large if restricted fauna. However, there were six occurrences of pH values between 9 and 12 units at this station and Hynes (1963) states that pH values of below 5 units and above 9 units are definitely harmful to most animals. In addition to this a high pH value has a considerable influence on the toxicity of some potential poisons.

The temperature at this station was normally within the limits of that found in the rest of the river system but there were three occurrences of temperatures between 26 °C (the upper limit for the rest of the system) and 30 °C . This is a result of heated effluent from the power station whose inflow is immediately above this station. There is thus a possibility that there are periodic increases in the temperature of this effluent. This could result in temperatures being suddenly raised to well above the normal as recorded in this survey. The peaks of such increases could well have been missed in the monthly recording if these increases are of a relatively short duration. An increase in temperature, particularly if it is sudden, can adversely effect the fauna even though it is only at temperatures above 40 °C that most normal river fauna will be eliminated (Hynes, 1963, Hynes, 1970). However, Hynes (1963) shows that the addition of heated effluent, even if within the range of temperature tolerance of most animals, to an already polluted stream, does have serious consequences for the fauna. Firstly, it raises the BOD, by killing the bacteria, small plants and animals and thus turning them into dead organic matter as a result of the heat itself or of chlorination intended to prevent growths of sewage fungus in pipes. The heat increases the rate of oxidation of the organic matter and so deepens the oxygen sag. Secondly, an increase in temperature also increases the toxicity of such poisons as may be present, and the greater rate of oxidation results in a higher production of CO_2 which itself raises the lowest oxygen content which most invertebrates can tolerate. Hynes thus shows that the heating of a polluted river, even without the usual increase in BOD and the probable addition of extra poisons, enhances the effect of toxic and organic pollution. The fact that this stream was polluted prior to the addition of heated effluent is shown by the fact that the average biotic index value at station 1A was 8,73 (Table 28) and the concentrations of many of the chemical parameters measured were in the B and C categories as per Table 5. In addition to this the effluent itself (treated sewage effluent from Northern Works concentrated by evaporation in the cooling towers) was polluted as can be seen from the chemical results at station 1. The concentration of ammonia, whose toxic properties are particularly enhanced by both high pH values and high temperatures, was however not particularly high at either of these stations (Table 21).

Confirmation of this condition was seen in a diatom survey which was done concurrently with this study. The diatom flora was often absent from this station and, where present, consisted of species known to be resistant to high pH levels (Schoeman, pers. comm.).

Thus although neither pH nor temperature nor pollutional levels of any sort appear to be of such an extreme nature as to account for the total lack of fauna, the combination of these three effects is probably sufficient to cause it. Alternatively sudden variations in one of these parameters, e.g. periodic increases in temperature, might also be the cause.

DISCUSSION AND CONCLUSIONS

Although the wide range of conditions found in this system should allow the identification of communities characteristic of a variety of water types, the complexity of the system leads to some confusion in the correlation of the fauna and its environment. the clearly defined effects of a single source of pollution and distinct recovery zones seen in many studies (Oliff 1960b; Roback, Cairns and Kaesler 1969; Herricks and Cairns 1974; Nichols 1977) were not apparent. However some of the faunal variation seen in different parts of the system could be characterized by reference to populations in the tributaries or upper reach of the system where there was less mixing from various point sources.

Chemical Conditions

In general there were three types of environment with regard to water quality. Each of these shows varying degrees of mixing with the others and a number of borderline cases common to such continuous variates.

Firstly, there are the tributaries of the middle and lower reaches of the system which were not affected by any known point sources of pollution. These drain mainly agricultural areas. The concentrations of all measured chemical constituents of the water were comparatively low in these streams. This suggests that this water quality type represents the most nearly natural conditions in the system. The only chemical constituents of the water in these streams which occurred in comparatively high concentrations at times were some of the conservative mineral elements, notably magnesium.

The second general water quality type occurred in the Modderfontein stream and the reach immediately below its confluence with the Jukskei River. This was affected by the nitrogenous industrial effluent which enriches this stream. This region was characterized by very high concentrations of all forms of nitrogen with ammonia concentrations particularly high in the Modderfontein stream. Concentrations of all the conservative mineral salts measured were also high in this part of the system. Although individual mineral elements do occur in higher concentrations in other parts of the system on occasions, generally the concentrations in this part of the stream were highest. Enrichment by phosphorus, the other important nutrient in the system, was negligible in this reach because although added to the system in high concentrations in the upper Modderfontein stream, phosphorus was apparently retained in the dams immediately below this point source.

The third water type occurs in the middle to lower reaches of the system as a result of a point source of phosphorus-rich treated sewage effluent. This water still showed relatively high concentrations of the nitrogenous and mineral elements typical of the upper reach but was also characterized by the highest concentrations of phosphorus, particularly orthophosphate.

The organic status of the system has the most effect on the fauna (Allanson 1961; Chutter 1972) and is thus the parameter most obviously comparable to the biota. The organic condition will naturally be affected by the levels of available plant nutrients. Although biological oxygen demand, the most direct measure of organic status, was not measured, a combination of COD and organic carbon concentrations indicate poor water quality throughout the main stream. These results also show some similarity with the degree of nitrogen enrichment as the poorest quality water occurred in the upper reaches followed by a gradual improvement downstream.

The Modderfontein stream is chemically the most complex part of the system to correlate with its faunal population. It is typically as described for the upper reach of the system but is also subject to the influence of one or more contaminants. This severely affects the fauna resulting in completely atypical communities. Futhermore, "thermal pollution" in the upper region of this stream is apparently detrimental to the fauna.

Faunal Communities of the System

The biotic index developed by Chutter (1972) was based on the organic status of rivers. As can be expected from the obvious correlation between organic status and nutrient levels, the index results show a general agreement with observed changes in the chemical environment. That is, the biotic index values tend to decrease down the main stream coinciding with the progressive dilution in concentration of most of the chemical constituents of the water. In addition the biotic index confirmed that the tributaries of the middle and lower reaches were the least polluted.

Due to the fact that a comparison between varying types of nutrient enrichment and organic status is difficult this index does not show whether the variations in faunal communities can be indicative of different types of pollution. The middle reach of the river, subjected to an effluent containing phosphorus (mainly orthophosphate) concentrations of up to 10 mg/ℓ and relatively high concentrations of other sewage related parameters, is an example of how a specific type of enrichment may be masked in a complex system of this kind if only the BOD based index is used. According to a number of studies on the pollutional effects of plant nutrients (Velz 1949; Roback 1962; Hynes 1963) this level of phosphorus enrichment is excessive and thus constitutes a severe degree of pollution. However the biotic index values showed that the water quality at stations 7, 7A, 9 and 10 was considerably better than in the upper reach of the main stream. This was in spite of the fact that this was the most highly polluted region in the system in terms of phosphorus, MBAS, COD and organic carbon concentrations. It thus appears as if the macro-invertebrate communities as ranked in the biotic index and thus the organic status of the water are comparable with the degree of enrichment by nitrogenous compounds. When the nitrogen content was diluted the biotic index showed an improvement in water quality regardless of the high degree of orthophosphate enrichment. The *Cheumatopsyche* sp. are a typical example of the problem with rigidly defined indicator values. This taxon has a low index value and is totally absent, or present in small numbers only, under conditions of severe nitrogenous enrichment. When the concentrations are diluted this taxon increases its contribution to the fauna regardless of increased concentrations of orthophosphate. At station 7A, which has comparitively low ammonia and nitrate nitrogen but the highest phosphorus concentration, *Cheumatopsyche* formed an important part of the association. This group was particularly significant in the summer months when the total phosphorus concentrations varied between 6 and 8 mg/ℓ . It is interesting to note that Roback (1962) gives the maximum tolerance level for *Cheumatopsyche* sp. to orthophosphate as being 1 mg/ℓ .

A limitation of this index discussed by Chutter (1972) is the disruptive effect of toxic substances in a river. This is well shown in the confusing results which occurred in the Modderfontein stream and extended into the Jukskei River. The limited fauna at station 2 was obviously caused by some contaminant in this part of the system. The fact that there were no Oligochaetes here, even though the chemical results would lead to the expectation of a large Oligochaete fauna, suggests, according to the literature (Hynes 1963; Brinkhurst and Jamieson 1971), that this is a typical case of heavy metal contamination. However it must be remembered that the extremely high ammonia concentrations in this stream are unique in river studies. Roback (1962) and Hynes (1963) have shown that ammonia has a serious influence on the macroinvertebrate fauna.

Thus the concurrent effects of various types of pollution result in a certain amount of confusion in interpreting results as complex as those in the Jukskei-Crocodile River system. This confusion tends to be masked by the apparently clearly defined results of the biotic index.

The analysis of changes in faunal communities between and within sampling sites indicates various relationships between faunal associations and changing environmental conditions. However, a number of factors such as geology of the catchment, geographical location, degrees of flooding etc. are common to all stations. Thus such relationships must at this stage be considered applicable to this system only because these constant factors will exert a different influence on the fauna in another catchment. For example, this whole system is characterized by very alkaline waters (pH 7,9 - 9,0 units) so that the dominant fauna of this system is adapted to this and differs from that of neutral or acid waters (Harrison and Agnew 1962). Further studies on other catchments and river systems would be required before any of the indicative features of communities suggested here could be applied generally.

A significant feature of this study has been an apparent division of communities into dominant and sub-dominant associations which differ in their indicator value. Isolated occurrences of small but significant associations also appear to have indicator value.

The dominant associations are composed primarily of taxa shown in the analysis of the system as a whole to be ubiquitous. These are probably the best adapted to regional conditions in this catchment suggesting that their presence is less dependant on pollutional influences and more on the characteristics of the system as a whole. This is confirmed by the fact that many of these taxa formed a significant part of the dominant associations in the most polluted sections of the river as well as in the clean water tributaries. Examples of these taxa are *B. harrisoni*, the Orthocladinae and Chironomini. However, their relationships to one another and to other co-dominant taxa or sub-dominant associations varied with changing conditions.

Each of the water type regions discussed earlier is associated with specific patterns of faunal change as conditions improve or deteriorate.

(i) Upper reach subject to nitrogen enrichment

Baetis harrisoni, the Orthocladinae and the Chironomini dominated all samples in this reach, with the former being least significant where the highest nitrogen and mineral concentrations occurred. As conditions improved the *B. harrisoni* part of this association increased its percentage contribution at the expense of the other two taxa. The Chironomini tended to be the first to decline as nitrogenous concentrations became lower and were almost negligible when *B. harrisoni* completely dominates this association and the Simuliidae join the dominant association.

Although the occurrence of Oligochaetes in this reach is affected by contamination of the water it appears that the *B. harrisoni* and Simuliidae tend to be replaced by the Naididae during the winter months. Although the greater concentrations of nitrogenous compounds during this low flow period may be partially responsible for this change it is more likely that the change is due to seasonal occurrences in the life cycles of these taxa. This succession occurs under a wide variety of conditions even when maximum winter concentrations at one station are not as high as the summer concentrations at another, e.g. stations 4 and 6. It has also been shown (Chutter 1971) in the Vaal catchment that the "spates" characteristic of summer periods tend to wash away *Nais* sp. and the attached algae upon which they feed. In addition the marked drop in *B. harrisoni* dominance over the whole system shown for the July to September period could indicate a period of maximum emergence. It therefore appears that if *Nais* sp. and the Orthocladinae dominate the dominant association in winter, the association is indicative of similar conditions to those indicated by a dominant association of *B. harrisoni*, Simuliidae and Orthocladinae in summer.

Further decreases in the concentration of the mineral and nitrogenous compounds resulted in the addition of *C. thomasseti* to this group. At the same time the proportions of the Simuliidae increase until they dominate the whole association. This change occurs at the expense of both *B. harrisoni* and the Orthocladinae. In such a case the winter population showed an increase in the significance of *Chaetogaster* sp. rather than *Nais* sp.

Under conditions of severe nitrogenous enrichment there was usually no clearly defined sub-dominant association although the possibility of Oligochaetes filling this role if no toxic influence was present must be recognized. There are however indications that a deterioration in conditions resulted in the increased significance of an association of *Chironomus* sp., Psychodidae, *Eristalis* and Culicidae. Further downstream improving conditions resulted in the occurrence of a sub-dominant association consisting of Simuliidae, *C. afra* and *C. thomasseti*. These taxa gradually increased in significance as water quality improved until one or more of its members became part of the dominant association. At this stage *Hydra* and Planaria became part of this sub-dominant association.

In general, with the water quality conditions being considered here the diversity of taxa is comparatively restricted.

(ii) Middle reach subject to phosphorus enrichment

Under these conditions the dominant association was similar to the above except that *B. harrisoni* tended to be less significant. The Simuliidae tended to dominance even when orthophosphate concentrations are at their highest levels. In addition *Cypridopsis* sp. and the Naididae formed a large proportion of the dominant association. These latter two taxa completely dominated this association during the winter months but again this was apparently due to a seasonal decline in the Simuliidae and *B. harrisoni* and flow conditions advantageous to Naid colonization rather than to a change in water quality. As the degree of pollution decreased the Simuliidae and *B. harrisoni* tend to form equal parts of this association and *Cypridopsis* representation declined.

It is possible that the *Cypridopsis* were maturation pond fauna being carried into the river. In this case their numbers would depend on flow conditions rather than water quality. However, the fact that they become less significant in the second year of the survey tends to contradict this possibility. During this year an apparent failure of the stabilization of these ponds would have resulted in more *Cypridopsis* being carried into the river at times and less at others, which was not the case. Thus the indication is that this taxon was a product of the riverine environment.

The stations further downstream of this region are subjected to relatively low degrees of enrichment by both nitrogen and phosphorus due to dilution or biological removal. This condition was characterized by smaller proportions of Simuliidae in the dominant association and increasing proportions of *C. afra*, *C. thomasseti* and Planaria. These taxa co-dominated with smaller proportions of all the other taxa which, under various conditions, dominated the fauna further upstream. There was thus greater diversity within the dominant association here.

There were apparently two sub-dominant associations occurring in this reach of the river system. The first was an association of *C. afra*, *C. thomasseti*, Tanytarsini, *Limnodrilus* sp. and *Nais* sp. The first three of these taxa dominated this sub-dominant association when water quality shows signs of improving while the Oligochaetes dominated the association as water quality deteriorated.

The second sub-dominant association only became numerically significant towards the end of the survey and was composed of *Hydra* and Chironomini. Its relevance appears to be associated positively with variations in the ammonium nitrogen and sulphate concentrations. The relationship between this association and these variables was seen several times in the upper reach of the system as well.

Further downstream, where nitrogen, phosphorus and the conservative mineral elements all occurred in relatively lower concentrations than in the upper and middle reaches, these sub-dominant associations expanded to include more taxa. Total dominance by any one taxon over the others was less evident in the associations at this stage. Thus the sub-dominant association dominated by the *Cheumatopsyche* sp. included three other groups: *Burnupia* and Tanytarsini; Pelesypoda and *Stenelmis* larvae; *Amphipsyche*, Hydroptila and *Ecnomus*. These three groups appear in this order as conditions improve downstream.

(iii) Clean water tributaries subject to negligible enrichment

All the clean water tributaries showed similar dominant associations to those already described for the lower reach of the main stream. Thus the dominant association alone indicates no difference between the clean waters of the tributaries and the slightly enriched water in the lowest reach of the main stream. The distinction between these two water types is indicated by the variation in the sub-dominant associations.

The sub-dominant associations of these tributaries showed an increase in the proportion of the population formed by all the Ephemeropteran taxa (*Choroterpes*, Caenidae, *Baetis quintus*, *B. latus*, *Afronurus* and *Neurocaenis*) as well as *Hydroptila*, Hydrachnellae, *Ecnomus*, Tanypodinae and Ceratopogonidae. As water quality improved further this association tended to co-dominate with the dominant association. This resulted in a very diverse association dominating the total population.

A deterioration in water results in the percentage contribution of the above taxa decreasing and the dominant association increasing in its degree of numerical significance.

Effects of other Environmental Parameters

The effects of these parameters on the fauna are important in order to avoid attributing these influences to changes in water quality.

As the limits of temperature variation within this system did not include extreme conditions, the influence of temperature on the observed variations in the fauna had little significance. The only exception to this was that one station was subjected to heated effluent from a power station which has already been fully discussed in the results. Although the limits of temperature tolerance of all macroinvertebrates were not exceeded, the fact that the whole fauna was destroyed at this station could still be due to this "thermal pollution". There is a lot of evidence in the literature that sudden changes in water temperature can be more harmful than slow increases to much higher levels (Hynes 1963; Tarzwell 1970; Cairns 1976).

Similarly pH effects cannot be determined from this study as the whole system is characterized by similar very high pH values. The few occassions when the pH did drop to near neutral level were isolated occurrences which could not be realistically linked to faunal variations. Thus at this stage the only conclusion that can be reached is that the fauna which dominated this system is probably indicative of very alkaline conditions.

It has been shown by many workers (Hynes 1970) that flow conditions have a very marked effect on the fauna of a river. However, in this system, although it was subjected to severe flooding in October and December of both years, the only effect appeared to be a reduction in the number of individuals. There was little change in the composition of dominant associations at the various stations before and after the flood. This effect of floods on the size of populations is the chief effect of "spates" according to a number of workers (Moffet 1936, Jones 1941, Mikulski 1961, Maitland 1964). These workers did however find that some taxa were more susceptible to flooding so that the dominance status within an association changed. This was not as apparent in this study because the region most affected by flooding, the upper reach of the system, was characterized by a very restricted fauna. The main effect of floods in this system on the fauna appears to have been an indirect one caused by the dilution of the chemical constituents of the water.

Solids in suspension, particularly silt and sand, which Chutter (1969) shows to have a deleterious effect on the macroinvertebrates biotope, do not show an appreciable effect on the fauna in this study. Even in the extreme case at the sewage effluent outflow when an apparent malfunctioning of the control dams occurred there were no obvious effects. This is probably due to a combination of two factors, the very short duration of floods which cause the suspension of such solids and the fact that the stones-in-current biotope is not normally an area of deposition. It is this deposition which Chutter (1969) has shown to cause the smothering of biotopes and thus influence the population composition.

Biotic Analysis of the River System

In view of the fact that the physical variations in this environment have such a limited effect on the fauna, changes in population composition are probably mainly caused by changing water quality. Seasonal variation resulting from life cycle patterns and food availability must also be taken into account when judging the indicator potential of a given community.

This study has shown the value of biologically indicating water quality as opposed to relying solely on chemical analyses. The biota show up short term and subtle changes over a period of time which cannot be seen in a "snap" water sample taken for chemical analysis. The most obvious examples of this shown by this study occurred in the Braamfontein and Sandfontein streams and at the overflow stream from the sewage works. The former site showed that very poor quality water did enter the mainstream from these streams although the chemical results would classify them as very clean water tributaries comparable to the Klein Jukskei and upper Crocodile rivers. Station 9, below the sewage works bypass stream, is shown by the biota to be comparable with the region below the main sewage works outflow over an extended period.

However, the comparison between faunal communities and the chemical environment substantiate the opposition by Hynes (1963) to rigid methods of biological classification. In such systems there tends to be a user assumption that the indicator community is a unit similar to the earlier concept of an indicator species rather than a number of independantly reacting parts. Most numerical systems of analysis impose such rigidity to a greater or lesser extent. This study has shown the applicability of a good biotic index and has also suggested that the variations on which diversity indices are based are not completely erroneous. However the number of exceptions arising in the analysis of such results show that systems devised for use by the non-biologist must lead to a misrepresentation of conditions.

The system used in this study requires the definition of the dominant and sub-dominant associations within a population. This should preferably be done by some form of numerical grouping as only in very simplified communities or with single samples can this be done subjectively. If these are identified for a population in this river system, comparison with the changing populations discussed under sections (i), (ii) and (iii) of this discussion will facilitate the classification of water condition. If a different river system is being studied the definition of regionally and locally controlled taxa should help to develop a similar standard for comparison which could then be applied.

The advantage of examining indicator communities in this way lies in the fact that no taxon has a rigidly defined indicator function. Communities must be intensively examined before water quality can be categorized which allows exceptions due to other influences to be recognized. This precludes an oversimplistic approach by an unqualified worker resulting in a misrepresentation of conditions.

Furthermore although organic pollution is the most easily correlated with faunal populations as is shown by the construction of most indices, this study suggests a definite difference in the effects of various forms of enrichment. Continued investigations on this basis could easily refine this system of specifying the form of enrichment rather than the general organic state.

Comparison with Earlier Studies on this River System

It is necessary to note how the results of this study compare with the general principles of Allanson (1961) notwithstanding the fact that the sources of pollution and quantities of effluent have changed over the decade preceeding this study.

Allanson (1961) also noted a difference between the dominant and sub-dominant associations which he called primary and secondary associations. He defines these as follows: "the most abundant species belong to the primary association while the species which are less abundant, but whose precence could be relied upon in samples, belong to the secondary association". This manner of categorization is convenient but does not show any difference in indicator value between the two associations. Indicator value depends more on the individual taxa in the association notwithstanding the fact that Allanson and a number of other workers (see introduction) had concluded that communities as a whole had to be used as indicators.

The analysis of the data by the more objective computer methods has shown that this definition of the associations seldom holds true. All members of the dominant association are not always equally abundant but achieve their position in this association on the basis of their constant presence in the population as well as their relationship to other members of this association. This relationship tends to be a function of the reaction of all members of the association to environmental changes as well as the basic conditions prevailing in their particular biotope. Similarly the members of the sub-dominant associations could not be relied upon to be constantly present in relatively small numbers. Their proportions of populations often rose to levels of co-dominance or virtually disappeared depending on their reactions to changing conditions. For example the two sub-dominant populations in the upper reach (Simuliidae-*Cheumatopsyche* and Psychodidae-*Eristalis*-*Chironomus*) could both form small sub-dominant associations in these populations if conditions were average for the region but tended to disappear or increase as water quality deteriorated or improved even though the dominant association remained relatively constant. Thus these taxa form part of the "normal" fauna of this biotope if this is defined as the fauna which can be expected when average conditions prevail.

Also, these "secondary association taxa" could not necessarily all be grouped as one association. This study has shown that there are often more than one sub-dominant association present at a particular site at one time, each reacting independantly to different changes in conditions. An example of this occurred in the middle reach of the system where the *Hydra*-Chironomini association was not influenced by the variation in the conditions characteristic of this reach as was the other sub-dominant association present. This *Hydra*-Chironomini group was absent or negligible under all concentration levels of to phosphorus and allied substances but apparently reacted to a more specific environmental change. The evidence suggests that this reaction was to ammonium sulphate concentrations but this could well be an indirect correlation.

As was the case in the dominant associations all members of a particular sub-dominant association do not carry equal weight numerically as their relationship is based on similarity of reaction rather than numbers.

Lastly, a complete change in the dominance status of taxa within any association does not necessarily indicate a similar change in conditions. Seasonal variations in the life cycles of specific taxa can change the structure of an association without altering its basic composition e.g. the *B. harrisoni*-Naid relationship within most dominant associations. Thus an association must be regarded as a whole to be of indicative value.

Allanson (1961) found that the fact that all major sources of pollution were situated in the headwaters of the system caused some confusion. He stated that, "moments of distribution could be related to the overall intensity of pollution, (but) it was realized that the study of the effect of a single polluting discharge upon the invertebrate faunas would be required before a completely satisfactory description of this method of analysis could be made". Although no such simple case exists the distinct spatial separation between sources of nitrogenous and orthophosphate enrichment facilitate more specific effects being recognized.

Whereas Allanson (1961) has classified specific taxa such as *Tubifex* sp., *Limnodrilus* sp and *Psychoda* sp. as typical pollution indicators this study has shown how little value can be placed on specific taxa in such a complex system. For example specific toxic effects can result in the absence of a particular taxon which could lead to the erroneous conclusion that severe pollution is not present. Thus no reliance can be placed on the indicator value of specific taxa and the whole community must be viewed as an independantly reacting unit. The error of categorizing specific taxa is a common one. Learner, Williams, Harcup and Hughes (1971) found that an increased proportion of *Limnodrilus hoffmeisteri* to the other Oligochaetes, an increasing representation of tubificids and a decline in Chironomid numbers were the principle effects of organic enrichment. Due to an unexpected contaminant this study showed the opposite trend in a very enriched stream. Thus in the hands of an unexperienced worker these conclusions would lead to a complete misrepresentation of water quality.

Hellwig, Botha and Marais (1966) found a similar pattern of enrichment in the system to that seen in this study although water quality has deteriorated slightly since then. Based on the invertebrate populations they described river zones after the method of Harrison (1958) but did not attempt to further analyse or classify indicator communities.

A study of the diatom flora and their use as indicator groups (Schoeman 1976) produced results highly comparable with those of this study. This diatom study, carried out on the same river system over the same period indicated similar conditions in the system particularly with respect to nitrogen enrichment. The diatom association did not appear to be as sensitive to very short term "spates" for poor quality water as were the macroinvertebrates.

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APPENDIX

Table A1: Chemical concentrations (mg dm^3) of all parameters measured at all stations given as running averages for the preceeding two months.

Sample	Conductivity	Na	K	Ca	Mg	Cl	SO_4	Total Alkalinity	COD	MBAS	Inorganic carbon	Organic carbon	NH_3-N	NO_2-N	NO_3-N	Dissolved inorganic N	Dissolved organic N	PO_4-P	Total P
Station 2																			
1972 March	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
April	1819	102,0	19,8	109,0	37,0	135	375	155	37,0	0,58	37,0	12,0	38,5	6,0	35,5	80,0	4,0	0,7	1,0
May	1797	121,5	20,9	107,5	37,0	138	373	160	39,5	0,59	37,5	13,5	37,3	5,2	45,3	87,7	4,2	0,9	1,0
June	1965	141,0	22,0	108,3	38,0	154	352	164	40,3	0,66	33,7	18,7	34,7	5,2	48,5	86,6	4,6	1,1	1,3
July	2098	167,0	22,7	113,3	38,7	169	344	169	51,0	0,70	30,3	23,7	32,8	2,2	55,0	78,3	-	1,2	1,4
August	2299	190,3	25,0	129,7	41,0	183	378	165	55,5	0,78	30,0	25,0	-	1,1	61,7	72,3	1,1	1,4	1,4
September	2245	200,3	28,3	129,7	41,0	185	455	165	58,5	0,75	33,3	21,3	38,2	1,9	61,7	78,3	0	1,3	1,4
October	2199	202,7	30,0	132,3	40,7	183	500	149	43,0	0,79	35,3	19,0	42,8	3,9	57,8	90,2	0	1,4	1,5
November	2016	187,7	28,5	123,3	38,0	177	501	136	54,0	0,75	33,7	17,0	38,8	5,2	53,8	97,9	0,3	1,3	1,4
December	1910	167,0	26,8	126,7	35,7	159	455	107	58,7	0,72	30,7	16,0	32,7	7,7	52,3	92,7	7,0	1,0	1,1
1973 January	1744	154,7	25,8	114,3	33,0	155	393	107	53,7	0,51	27,0	14,0	26,3	7,7	53,7	87,7	7,0	0,8	0,9
February	1741	146,7	27,3	104,7	31,0	142	343	98	51,7	0,50	24,5	14,5	24,9	8,7	46,7	80,0	7,0	0,8	0,9
March	1567	149,7	27,0	96,3	29,3	142	337	102	47,0	0,51	28,2	15,0	26,5	6,7	46,3	72,7	0,8	0,9	1,0
April	1585	147,0	27,8	95,7	28,7	133	353	107	46,3	0,58	31,3	18,3	31,2	6,0	40,4	57,6	1,5	1,1	1,3
May	1565	154,0	26,5	94,3	29,0	142	383	106	43,3	0,63	34,1	21,0	34,5	3,3	43,4	36,5	2,4	1,0	1,4
June	1811	165,7	26,3	96,7	30,7	155	368	131	41,0	0,71	35,1	22,3	34,5	2,5	42,1	43,7	2,4	1,1	1,6
July	2018	185,3	27,5	99,0	32,3	170	385	154	47,5	0,75	40,2	20,7	37,5	1,4	44,5	50,0	2,2	1,4	2,2
August	2137	211,0	28,1	100,7	34,3	187	382	182	62,5	0,81	39,1	21,0	38,0	2,7	39,5	72,0	1,7	1,6	2,6
September	2161	213,7	27,7	96,3	34,0	205	403	194	64,3	0,72	35,8	23,0	45,5	4,5	52,8	47,4	1,9	1,6	2,8
October	2158	211,7	28,0	99,7	35,7	207	440	180	67,7	0,76	37,3	26,0	42,5	6,0	61,3	34,9	1,8	1,4	2,2
November	2017	183,7	27,1	99,7	37,0	190	457	185	60,3	0,77	33,2	23,7	44,3	5,6	70,2	10,4	1,9	1,2	1,5
December	1949	161,7	26,5	103,3	39,7	160	437	152	50,0	0,63	26,1	21,0	41,3	4,2	60,1	10,8	3,1	0,9	1,1
1974 January	1785	140,0	22,8	133,3	41,0	139	410	133	41,0	0,60	30,4	17,7	33,0	3,8	46,2	9,4	3,3	0,4	0,6
February	1733	131,3	21,3	129,0	40,0	129	370	108	46.3	0,55	28,2	19,3	30,0	4,0	41,3	10,0	3,1	0,3	0,6
Station 3																			
1972 March	550	38,8	8,8	59,4	23,4	50	108	100	13,0	0,05	34,0	6,0	0,2	0,1	4,3	4,6	1,0	0,1	0,1
April	708	40,0	9,3	64,1	27,3	59	127	133	15,0	0,14	40,0	3,0	0,4	0,2	4,6	5,1	1,3	0,1	0,1
May	722	32,3	7,4	51,1	21,9	57	123	144	15,7	0,19	38,3	5,7	0,4	0,1	4,5	5,1	1,1	0,1	0,1
June	810	34,1	7,0	50,6	25,4	60	125	165	18,0	0,31	34,7	16,7	0,6	0,1	4,6	5,4	1,0	0.1	0,2
July	813	40,3	6,7	50,3	26,0	62	118	174	22,0	0,32	30,0	22,0	0,6	0,1	3,2	5,4	0,9	0,2	0,2
August	837	51,7	8,5	61,3	33,3	69	123	177	26,3	0,30	32,0	21,3	0,7	0,1	4,3	5,1	0,9	0,2	0,2
September	875	67,0	10,3	62,0	33,7	93	112	196	36,7	0,29	39,3	12,3	0,4	0,2	3,1	3,8	1,0	0,2	0,3

Table A1 continued:

Sample	Parameters																	
	Conductivity	Na	K	Ca	Mg	Cl	SO_4	Tot. Alk.	COD	MBAS	TIC	TOC	NH_3-N	NO_2-N	NO_3-N	Diss. inorg. N	Diss. org. N	PO_4-P	Total P
Station 3																			
1972 October	782	61,3	9,0	52,7	27,7	93	96	161	37,0	0,39	34,3	11,0	0,4	0,3	2,7	3,4	0,8	0,2	0,2
November	764	65,0	9,0	52,0	24,3	95	87	152	36,3	0,45	32,3	11,0	0,2	0,3	2,1	2,6	0,8	0,2	0,2
December	612	42,7	6,7	44,7	17,0	61	75	116	29,7	0,41	24,3	9,7	0,3	0,2	3,0	3,5	0,7	0,1	0,1
1973 January	652	44,7	7,6	50,7	20,3	62	78	137	25,7	0,24	30,0	9,0	0,2	0,1	2,4	2,8	0,7	0,1	0,1
February	583	34,3	6,7	45,0	17,0	49	63	127	23,3	0,27	28,3	9,3	0,3	0,1	2,9	3,3	0,8	0,1	0,1
March	619	52,3	7,0	47,0	18,7	78	66	129	25,7	0,19	32,3	12,7	0,4	0,1	2,5	3,0	1,0	0,1	0,2
April	535	45,3	6,6	42,0	15,0	64	64	112	26,7	0,18	35,7	12,3	0,5	0,1	3,1	3,7	1,2	0,1	0,2
May	671	63,0	7,7	51,3	20,3	95	89	130	27,3	0,22	36,6	12,7	0,5	0,1	3,5	4,1	1,5	0,1	0,2
June	808	64,3	8,4	59,0	24,7	95	107	154	22,3	0,23	32,1	10,3	0,8	0,1	4,0	4,9	1,8	0,1	0,3
July	984	79,0	9,3	64,7	28,7	117	112	172	23,3	0,31	28,7	11,0	1,1	0,1	3,5	4,7	2,5	0,2	0,5
August	1003	80,7	9,5	64,0	29,0	117	105	175	27,0	0,29	40,1	12,7	1,3	0,2	2,9	4,4	2,2	0,2	0,6
September	1008	86,3	10,5	61,3	27,3	140	100	172	30,0	0,35	42,2	14,3	1,2	0,2	1,8	3,2	2,4	0,2	0,6
October	869	72,3	9,5	54,7	23,0	121	95	151	31,0	0,41	35,3	14,6	1,6	0,2	1,7	3,5	1,5	0,2	0,5
November	768	58,7	8,4	53,0	20,0	98	88	147	29,0	0,33	36,2	14,0	1,7	0,2	1,6	3,5	1,6	0,2	0,3
December	739	38,7	6,9	52,3	18,3	50	88	135	24,3	0,21	31,1	11,0	1,5	0,2	3,0	4,7	1,9	0,2	0,3
1974 January	874	47,3	8,7	60,7	21,3	57	85	173	22,0	0,27	33,3	10,0	1,2	0,5	3,2	4,9	1,8	0,1	0,3
February	913	53,3	9,7	63,0	23,3	62	83	171	22,0	0,22	28,2	9,7	1,5	0,6	3,5	5,6	1,3	0,1	0,4
Station 4																			
1972 March	1200	94,0	15,8	101,5	40,5	88	360	92	22,0	0,20	18,0	9,0	19,0	4,0	30,0	53,0	1,0	0,1	0,1
April	1264	84,0	15,6	95,8	37,3	94	317	119	24,5	0,27	25,0	10,5	18,1	4,0	25,8	47,9	0,8	0,2	0,2
May	1257	85,3	15,5	91.8	35,8	95	286	131	24,7	0,31	27,3	12,0	17,1	3,5	24,9	45,4	1,4	0,2	0,5
June	1211	90,7	15,2	86,3	35,7	105	233	152	26,3	0,45	28,7	17,7	15,8	2,5	26,9	45,2	2,4	0,4	0,7
July	1436	119,7	17,1	95,3	37,3	127	241	162	37,3	0,50	27,3	21,3	15,1	1,2	33,1	44,3	3,1	0,6	0,9
August	1602	142,0	19,0	100,7	39,7	150	285	153	41,3	0,55	27,7	20,3	18,7	0,8	44,3	58,8	2,5	0,8	1,0
September	1892	173,7	25,0	114,0	39,7	173	375	154	42,0	0,60	30,7	18,3	13,7	1,9	50,2	60,6	2,4	1,0	1,1
October	1449	137,3	20,5	91,0	32,3	142	310	126	32,3	0,60	27,0	15,0	9,5	2,0	39,6	51,1	1,9	0,7	0,8
November	1390	133,0	19,8	97,7	30,0	134	327	120	36,7	0,69	25,7	15,0	7,9	3,6	37,2	48,7	1,8	0,7	0,8
December	984	82,7	12,7	73,7	22,7	92	211	100	39,3	0,59	21,7	11,3	9,2	2,8	24,3	29,5	1,1	0,3	0,4
January	1159	100,7	16,5	85,3	26,3	107	249	117	39,0	0,42	23,7	11,3	11,1	3,4	27,2	41,7	0,7	0,4	0,5
February	1018	79,0	15,0	67,7	22,3	97	157	110	32.0	0,32	21,7	11,7	6,1	2,2	16,4	24,7	0,7	0,3	0,4
March	1059	95,0	15,9	70,7	23,7	120	174	110	32,0	0,20	17,2	14,0	7,6	1,9	16,4	25,9	0,9	0,4	0,5

Table A1 continued:

Sample	Conductivity	Na	K	Ca	Mg	Cl	SO_4	Tot. Alk.	COD	MBAS	TIC	TOC	NH_3-N	NO_2-N	NO_3-N	Diss. inorg. N	Diss. org. N	PO_4-P	Total P
Station 4																			
1973 April	1051	92,3	15,8	67,0	21,7	117	175	102	32,3	0,24	20,6	14,0	12,1	2,2	16,7	31,0	0,8	0,5	0,7
May	1153	111,0	17,1	74,3	25,0	126	235	106	34,0	0,31	24,2	16,0	16,9	1,9	22,3	40.1	0,8	0,4	0.7
June	1426	128,7	19,5	84,0	28,7	137	275	127	35,0	0,52	25,7	17,7	23,2	2,0	28,9	54,1	1,7	0,6	0,9
July	1614	151,7	20,7	90,7	32,0	157	301	149	40,0	0,61	30,3	21,7	27,0	1,0	32,8	60,8	2,1	0,8	1,1
August	1757	169,0	22,1	94,3	33,3	168	313	165	49,7	0,68	31,4	23,3	31,8	1,8	31,3	64,7	3,0	1,1	1,7
September	1820	170,7	22,3	87,7	32,0	179	313	170	57,7	0,55	28,2	22,3	30,0	2,7	24,8	57,5	4,2	1,2	2,0
October	1611	146,0	20,7	80,0	28,7	155	285	149	55,3	0,54	29,1	19,7	25,6	3,4	20,0	46,0	3,7	1,0	1,6
November	1540	129,3	19,8	78,0	29,0	137	297	143	48,7	0,55	27,4	15,3	24,3	3,5	12,1	39,9	5,7	0,8	1,0
December	1415	110,0	17,8	85,3	30,3	109	293	118	37,3	0,43	20,1	15,0	24,0	3,4	17,1	44,5	3,7	0,5	0,6
1974 January	1540	114,0	17,8	92,0	34,3	111	325	146	35,0	0,31	21,2	16,3	26,2	4,2	14,3	44,7	4,2	0,3	0,4
February	1480	108,3	17,2	88,3	33,7	108	292	137	40,3	0,38	19,8	17,0	22,5	4,1	14,5	41,1	2,5	0,2	0,3
Station 5																			
1972 March	800	63,8	11,1	74,8	18,6	69	240	61	28,0	0,20	16,0	6,0	6,0	4,3	19,7	30,0	1,5	0,1	0,3
April	1061	69,9	13,3	83,2	26,2	87	263	91	27,0	0,28	22,0	8,0	8,6	3,2	22,1	34,0	0,8	0,2	0,3
May	1145	79,3	14,5	84,4	28,9	92	254	105	26,7	0,35	24,0	10,3	10,7	2,7	23,7	37,2	1,6	0,2	0,4
June	1233	93,0	16,1	87,8	36,0	109	240	132	25,3	0,45	25,0	17,0	12,9	1,6	32,2	46,6	1,9	0,5	0,6
July	1462	123,3	18,3	96,7	37,7	131	250	143	38,3	0,53	24,0	21,3	12,2	0,8	42,3	52,3	2,3	0,7	0,8
August	1756	155,3	21,3	107,3	40,7	164	318	134	46,3	0,58	23,7	21,3	8,5	0,5	58,3	63,0	1,8	0,9	0,9
September	2092	192,0	27,0	122,3	40,7	188	410	131	53,3	0,64	26,7	19,0	4,4	1,7	62,5	64,2	10,5	1,0	1,0
October	1617	149,0	22,9	98,3	33,0	146	333	121	42,7	0,62	26,3	16,7	2,2	1,8	46,6	49,3	10,2	0,8	0,8
November	1426	134,0	20,9	97,3	29,7	129	338	113	43,0	0,68	25,3	15,7	6,6	3,6	39,2	49,4	10,2	0,7	0,7
December	883	72,0	12,2	65,3	20,3	75	200	97	37,3	0,55	19,7	13,7	7,0	2,3	23,0	32,2	0,9	0,3	0,4
1973 January	1128	97,0	15,3	78,7	24,3	104	248	93	37,7	0,42	17,7	13,3	7,5	2,7	26,6	36,7	0,9	0,3	0,3
February	1101	81,7	15,3	69,0	22,0	87	183	91	31,7	0,31	16,0	14,3	3,8	1,5	16,1	21,3	1,0	0,2	0,3
March	1340	122,0	21,0	87,3	27,3	123	262	87	34,7	0,32	15,2	15,7	8,7	2,2	20,6	31,5	1,5	0,4	0,5
April	1259	114,0	20,2	80,7	24,7	107	258	84	34,0	0,34	18,1	14,0	12,9	2,5	20,2	33,6	1,6	0,5	0,7
May	1227	123,7	20,6	82,3	26,0	118	282	83	34,7	0,28	16,3	13,7	17,0	2,0	25,9	44,9	1,3	0,4	0,6
June	1390	126,3	19,8	83,0	27,7	127	283	116	34,7	0,41	17,0	14,3	21,3	1,7	27,7	50,7	0,6	0,5	0,7
July	1592	151,3	21,6	92,0	31,7	157	314	134	40,7	0,64	22,2	17,7	26,5	0,9	22,0	49.4	1,3	0,8	1,1

Table A1 continued:

Sample	Parameters																	
	Conductivity	Na	K	Ca	Mg	Cl	SO_4	Tot. Alk.	COD	MBAS	TIC	TOC	NH_3-N	NO_2-N	NO_3-N	Diss. inorg. N	Diss. org. N	PO_4-P	Total P
Station 5																			
1973 August	1714	164,7	23,9	94,7	32,7	172	311	151	48,3	0,68	24,2	24,2	29,7	1,9	30,3	61,9	1,2	1,0	1,7
September	1802	175,7	24,7	93,0	31,7	183	338	143	57,0	0,65	24,5	24,5	28,0	2,7	26,2	56,9	7,0	1,1	1,8
October	1492	139,0	19,0	78,7	26,0	147	273	120	52,7	0,70	26,2	26,2	20,6	3,0	18,8	42,4	10,1	0,8	1,3
November	1407	121,0	17,4	76,7	26,0	127	277	114	47,7	0,53	21,0	21,0	17,9	2,9	10,6	31,4	17,5	0,7	0,8
December	1220	87,0	14,4	74,7	25,7	91	233	92	34,7	0,59	18,2	18,2	15,6	2,7	14,3	32,6	16,0	0,3	0,4
January	1410	100,0	16,1	86,3	31,0	101	283	91	32,7	0,60	16,0	16,0	16,5	3,2	13,1	32,8	16,1	0,2	0,3
February	1301	99,0	16,4	82,7	31,3	99	267	84	37,3	0,37	17,3	17,3	16,0	3,1	14,2	33,3	1,5	0,1	0,2
Station 6																			
1972 March	1100	80,0	13,4	90,5	34,5	78	300	76	29,0	0,20	15,0	8,0	11,8	3,3	25,7	40,8	1,0	0,1	0,1
April	1015	66,8	11,9	79,3	30,3	78	238	89	24,5	0,24	19,0	8,0	6,6	2,1	21,6	30,4	1,0	0,1	0,1
May	1004	67,5	12,0	75,8	28,8	78	215	94	23,7	0,29	20,0	9,7	6,5	1,7	22,1	28,3	1,4	0,1	0,2
June	973	70,8	12,2	69,0	29,0	87	170	106	18,7	0,39	20,3	13,7	4,9	0,8	17,8	23,5	1,4	0,1	0,3
July	1150	92,7	14,1	74,3	31,3	103	182	111	28,0	0,47	19,0	16,7	10,4	0,6	22,0	33,0	1,2	0,2	0,5
August	1310	106,3	15,3	79,0	33,7	125	215	113	35,7	0,48	20,3	16,0	13,7	0,6	28,0	42,3	0,7	0,3	0,4
September	1544	133,0	20,3	94,0	35,3	148	305	112	45,0	0,54	22,0	14,7	16,6	1,1	36,3	54,1	0,5	0,5	0,6
October	1353	117,0	19,2	88,0	30,7	130	298	103	41,0	0,57	21,7	14,3	12,9	1,9	32,0	46,8	0,9	0,5	0,8
November	1292	119,0	19,7	90,7	30,0	125	283	94	40,0	0,65	20,3	14,7	9,5	2,3	27,8	39,6	1,0	0,4	0,7
December	825	67,7	12,1	61,3	20,0	75	153	80	36,7	0,52	17,0	13,0	4,6	1,6	14,6	20,8	1,1	0,1	0,4
1973 January	815	66,7	12,5	59,3	21,0	82	132	87	34,0	0,34	17,3	12,3	2,3	1,0	13,8	17,1	1,4	0,1	0,2
February	675	47,3	10,2	48,3	16,0	59	97	89	28,3	0,26	15,7	12,7	0,6	0,5	10,5	11,7	1,5	0,1	0,2
March	724	58,0	11,1	54,7	17,3	69	112	94	25,0	0,19	14,8	11,7	0,8	0,6	11,9	13,3	1,4	0,1	0,2
April	660	51,7	9,7	49,3	14,3	53	107	86	23,0	0,20	15,3	10,3	3,0	0,8	10,7	14,5	0,9	0,2	0,3
May	730	63,0	10,6	54,3	17,3	68	143	83	23,3	0,25	14,2	10,3	8,1	0,7	14,7	23,4	1,1	0,2	0,3
June	1005	86,7	13,0	65,0	22,0	98	173	92	26,0	0,41	15,1	12,7	12,2	1,0	22,0	34,2	0,8	0,2	0,4
July	1221	110,0	14,8	76,0	27,3	127	208	100	29,7	0,47	16,1	16,0	12,9	0,9	26,2	40,0	0,8	0,3	0,6
August	1367	126,0	16,8	81,7	29,0	143	218	101	38,0	0,52	22,3	19,0	10,9	2,0	27,3	40,2	0,8	0,4	0,9
September	1467	141,3	17,6	80,3	28,7	155	265	97	44,7	0,61	31,1	23,7	10,3	2,1	22,2	34,6	1,7	0,5	1,0
October	1161	109,0	14,5	64,3	21,7	120	211	82	43,4	0,53	32,4	21,0	8,1	2,0	15,6	25,7	1,8	0,4	0,8
November	1040	92,0	12,5	59,0	20,3	102	200	83	38,7	0,56	26,8	19,0	8,5	1,2	8,7	18,4	1,4	0,3	0,5
December	741	48,3	8,9	48,0	16,3	55	126	73	29,0	0,42	21,7	11,7	5,6	0,9	7,8	14,3	1,5	0,2	0,3
1974 January	879	59,0	10,1	57,0	20,3	66	154	75	26,0	0,37	19,6	10,3	5,5	1,2	8,9	15,6	1,4	0,1	0,2
February	774	61,3	11,4	56,7	21,3	65	147	72	31,0	0,25	19,9	10,7	4,6	1,2	8,8	14,6	2,0	0,1	0,3

Table A1 continued:

Sample	Conductivity	Na	K	Ca	Mg	Cl	SO_4	Tot. Alk.	COD	MBAS	TIC	TOC	NH_3-N	NO_2-N	NO_3-N	Diss. inorg. N	Diss. org. N	PO_4-P	Total P
Station 6A																			
1973 April	330	18,0	4,4	30,0	9,0	27	39	88	17,0	0,15	14,4	15,0	0,4	0,1	1,4	1,9	0,4	0,1	0,2
May	435	26,4	4,7	37,0	12,0	48	48	100	14,5	0,12	12,2	15,0	0,3	0,1	1,8	2,2	0,9	0,1	0,2
June	489	31,0	4,7	40,3	14,0	56	48	113	14,7	0,36	31,1	15,0	0,3	0,1	2,2	2,6	0,9	0,1	0,1
July	580	37,7	4,8	45,7	17,0	70	53	122	15,3	0,41	24,4	15,3	0,6	0,1	2,5	3,2	1.0	0,1	0,2
August	601	38,3	5,0	47,0	18,0	66	52	124	18,3	0,12	14,3	13,7	0,9	0,1	2,2	3,2	0,7	0,1	0,2
September	578	39,0	5,2	39,7	16,3	65	51	106	21,7	0,17	17,8	15,7	1,0	0,1	1,4	2,5	0,9	0,1	0,2
October	455	29,7	4,9	32,7	12,3	47	44	91	23,7	0,20	20,1	17,0	0,7	0,1	0,9	1,7	0,9	0,1	0,3
November	400	26,0	4,4	29,3	10,3	39	43	88	23,0	0,18	18,7	20,3	0,4	0,1	1,6	2,1	1,3	0,1	0,3
December	334	16,7	4,0	30,7	8,7	28	37	88	22,0	0,17	17,4	19.0	0,4	0,1	1,8	2,3	1,7	0,1	0,3
1974 January	411	20,3	4,4	36,3	11,0	36	38	97	18,7	0,14	14,5	18,0	0,3	0,1	2,0	2,4	1,7	0,1	0,1
February	419	21,7	4,9	38,3	12,3	41	38	98	21,3	0,19	19,8	17,3	0,5	0,1	1,4	2,0	1,3	0,1	0,2
Station 6B																			
1973 April	226	13,0	4,4	29,0	5,0	14	42	67	24,0	0,12	19,4	10,0	0,4	0,1	1,5	2,0	0,4	0,1	0,1
May	340	22,0	5,2	35,0	7,5	27	50	91	20,5	0,14	18,7	10,0	0,3	0,1	0,9	1,3	0,9	0,1	0,1
June	384	25,0	5,4	37,7	8,7	32	47	105	19,7	0,12	20,6	9,7	0,2	0,1	0,6	0,9	1,0	0,1	0,1
July	449	30,3	5,7	39,7	10,3	39	47	119	18,0	0,12	18,2	9,0	0,2	0,1	0,3	0,6	1,1	0,1	0,1
August	448	29,0	6,2	40,3	10,3	37	39	125	22,7	0,10	17,1	10,7	0,2	0,1	0,3	0,6	1,4	0,1	0,2
September	434	30,3	6,4	34,3	9,7	38	35	113	27,3	0,15	19,6	13,0	0,3	0,1	0,3	0,7	1,4	0,1	0,2
October	358	23,7	6,0	30,0	7,7	29	32	97	30,3	0,17	20,4	16,0	0,4	0,1	0,5	1,0	1,2	0,1	0,2
November	306	18,0	4,6	25,3	6,0	23	29	80	27,3	0,14	22,2	13,7	0,5	0,1	0,6	1,2	1,0	0,1	0,1
December	244	9,7	4,1	25,3	4,7	17	29	69	29,0	0,13	18,3	13,3	0,7	0,1	0,9	1,7	1,1	0,1	0,1
1974 January	292	11,7	4,4	29,3	5,3	21	27	74	25,3	0,12	16,1	11,0	0,5	0,1	0,8	1,4	1,1	0,1	0,1
February	296	12,7	5.0	30,3	5,7	21	29	76	26,3	0,13	19,2	12,0	0,4	0,1	0,9	1,4	0,9	0,1	0,1
Station 7																			
1972 April	888	68,8	12,2	42,6	16,4	61	100	115	28,0	0,30	26,0	1,0	0,3	0,7	9,3	10,3	5,4	3,5	3,9
May	824	70,4	12,6	44,3	16,7	65	101	108	28,0	0,40	23,5	8,5	2,2	0,8	11,5	14.4	3,6	3,6	4,2
June	872	76,9	13,2	46,2	17,8	71	107	111	29,7	0,57	21,7	13,0	3,8	0,7	13,4	17,8	2,9	2,8	4,4
July	909	76,3	13,8	50,7	18,7	74	118	112	36,7	0,65	20,3	18,7	6,9	0,7	17,6	25,1	1,1	3,0	4.6
August	1015	85,0	14,5	54,7	20,3	84	139	114	44,0	0,70	21,7	18,3	7,9	0,7	21,4	30,0	0,9	3,3	4,8
September	1035	91,7	18,3	58,0	20,3	90	164	116	48,0	0,63	22,7	17,3	7,3	0,9	25,2	33,4	0,8	4,5	4,9
October	918	89,7	17,5	54,0	19,0	86	149	113	45,0	0,65	22,3	17,0	4,9	1,3	21,6	27,8	1,4	3.9	4,3

Table A1 continued:

Sample	Conductivity	Na	K	Ca	Mg	Cl	SO_4	Tot. Alk.	COD	MBAS	TIC	TOC	NH_3-N	NO_2-N	NO_3-N	Diss. inorg. N	Diss. org. N	PO_4-P	Total P
Station 7																			
1972 November	853	86,3	17,9	55,3	18,0	81	135	109	42,3	0,70	21,0	16,7	3,6	1,5	19,8	24,9	1,7	3,5	4,0
December	665	59,7	12,5	46,7	14,7	59	90	94	38,3	0,58	16,3	14,7	2,6	1,3	12,8	16,7	1,3	2,0	2,2
1973 January	712	66,7	13,5	47,3	15,3	68	97	98	37,3	0,45	17,3	14,7	1,9	1,1	13,8	16,8	1,2	2,5	2,7
February	660	58,7	12,6	39,0	12,7	59	79	98	33,7	0,43	15,3	14,7	1,4	1,0	10,9	13,4	1,1	2,8	3,0
March	656	69,7	13,2	36,7	13,0	64	75	106	34,7	0,52	14,1	16,3	1,4	1,1	11,1	13,5	1,2	4,2	4,4
April	615	62,7	12,6	34,3	11,7	54	76	91	33,3	0,48	17,3	15,3	3,7	1,2	10,7	15,6	0,7	3,4	3,6
May	624	65,7	12,3	37,0	13,0	61	83	96	33,3	0,47	18,7	14,0	4,6	1,0	11,1	16,7	1,0	3,2	3,3
June	755	72,0	13,6	41,3	13,7	69	104	116	33,0	0,48	18,6	13,3	8,9	0,9	12,8	22,6	0,7	3,9	4,4
July	846	84,0	14,6	46,7	15,7	82	114	129	35,0	0,48	19,2	14,3	7,4	0,7	14,4	22,5	0,9	4,8	5,9
August	890	90,0	15,6	48,7	16,7	81	122	123	40,3	0,56	21,1	17,3	7,4	1,3	15,3	24,0	0,5	5,0	6,4
September	906	94,7	16,2	47,3	17,0	86	125	110	45,7	0,69	22,3	20,7	4,5	1,4	15,9	21,8	1,4	4,4	5,6
October	717	71,0	13,3	39,0	13,7	64	96	97	43,7	0,73	24,8	19,7	4,6	1,4	11,5	17,5	1,1	3,3	3,9
November	607	57,3	11,3	33,0	11,0	54	76	93	38,7	0,71	22,7	17,3	3,9	0,8	9,4	14,1	1,5	2,9	3,2
December	576	45,3	9,4	36,7	11,7	41	68	82	30,3	0,78	24,9	13,0	3,3	1,0	9,4	13,7	0,9	2,1	2,3
1974 January	665	54,3	10,7	42,7	13,0	50	77	86	27,0	0,62	25,2	11,7	2,5	1,2	10,1	13,8	1,1	2,8	3,0
February	640	58,0	11,9	41,7	14,7	56	83	87	31,0	0,64	21,8	13,7	2,6	1,2	9,5	13,3	0,7	2,9	3,5
Station 7A																			
1972 May	722	75,0	14,5	36,0	12,0	62	78	117	32,0	0,70	22,0	18,0	6,5	0,4	10,6	17,5	3,3	5,6	7,0
June	796	78,5	14,5	38,0	14,0	66	89	128	36,0	0,80	21,0	23,0	9,1	0,5	11,2	13,8	2,7	4,8	7,7
July	816	81,3	14,3	40,7	14,0	69	89	135	40,7	0,77	23,3	22,0	10,4	0,6	11,8	18,4	1,9	5,7	7,6
August	850	83,7	14,1	42,3	14,3	72	93	146	46,7	0,77	27,3	21,3	11,6	0,7	13,1	21,0	1,0	5,9	7,8
September	803	84,3	15,6	41,0	13,0	72	95	150	49,0	0,71	30,0	18,7	11,1	0,9	14,4	22,0	0,3	7,0	7,9
October	758	82,0	16,6	37,7	12,0	68	85	146	48,3	0,81	29,7	18,3	9,7	1,2	14,4	25,1	0,5	6,9	8,0
November	715	80,3	17,5	36,0	11,3	64	74	142	48,7	0,89	26,7	19,3	8,6	1,5	13,7	23,6	0,5	7,1	8,0
December	688	77,3	16,4	35,0	11,0	61	66	131	48,0	0,88	24,0	19,0	6,6	1,8	12,4	20,3	0,8	7,0	7,6
1973 January	660	74,7	15,9	33,0	11,0	58	62	119	43,7	0,69	20,7	18,7	3,9	1,8	11,7	17,1	1,3	7,0	7,5
February	677	73,3	15,8	31,3	10,7	58	61	113	38,7	0,62	19,0	18,5	2,9	1,8	10,9	15,4	1,4	7,0	7,4
March	720	74,3	15,5	32,0	10,7	62	60	113	36,3	0,82	22,1	-	3,2	1,6	10,3	15,1	-	6,9	7,3
April	763	76,3	15,3	33,7	11,0	67	62	122	37,3	0,67	20,0	-	5,3	1,3	10,0	16,6	-	6,9	7,0
May	720	79,3	15,0	36,0	12,0	72	63	127	38,7	0,71	21,4	-	6,8	1,0	10,2	18,0	1,1	6,6	7,0

Table A1 continued:

Sample	Conductivity	Na	K	Ca	Mg	Cl	SO_4	Tot. Alk.	COD	MBAS	TIC	TOC	NH_3-N	NO_2-N	NO_3-N	Diss. inorg. N	Diss. org. N	PO_4-P	Total P
	Parameters																		
Station 7A																			
1973 June	763	79,0	15,2	39,7	12,3	70	77	148	40,0	0,85	21,7	-	10,8	0,8	10,4	22,0	1,0	7,9	7,7
July	765	78,3	15,2	40,0	12,3	68	78	154	42,0	0,56	21,8	20,0	10,6	0,8	10,7	22,1	1,0	7,3	8,5
August	767	77,7	15,4	39,3	12,0	64	81	156	46.7	0,73	25,6	22,7	10,8	1,1	9,7	21,6	1,0	7,5	9,4
September	768	79,0	15,8	35,7	11,7	67	73	136	50,7	0,68	24,3	25,3	9,1	1,2	9,2	19,4	1,0	7,2	8,9
October	750	78,7	15,7	31,7	11,3	70	82	127	52,7	0.65	20,7	24,0	10,0	1,4	8,2	19,6	1,0	7,1	8,6
November	734	75,3	15,2	30,7	10,7	70	82	120	49,7	0,69	19,9	20,3	9,8	1,4	8,0	19,2	0,5	7,1	8,4
December	687	72,3	14,5	31,3	10,7	63	79	120	43,3	0,71	18,8	18,2	7,3	1,6	9,0	17,9	0,5	6,9	8,1
1974 January	680	69,7	14,7	33,3	11,0	60	69	120	36,3	0,62	22,2	17,1	4,8	1,6	8.3	14,7	0,5	7,1	8,0
February	668	69,0	15,2	32,3	11,0	58	68	119	38,0	0,59	25,1	18,3	3,1	1.3	7,4	11,8	[illegible]	6,7	7,4
Station 3																			
1972 March	250	19,4	3,5	26,3	10,0	17	29	110	18,0	0,10	22,0	7,0	0,2	0,1	0,8	1,1	1,1	0,1	0,1
April	279	15,4	3,5	26,8	10,9	16	25	110	15,5	0,38	23,0	7,5	0,2	0,1	1,1	1,3	0,9	0,1	0,1
May	312	15,7	3,4	27,5	11,6	15	23	111	14,7	0,28	23,3	7,8	0,2	0,1	0,9	1,1	0,7	0,1	0,1
June	356	15,9	3,4	28,7	13,3	17	23	117	18,3	0,35	23,3	10,0	0,3	0	1,0	1,3	0,4	0,1	0,1
July	379	19,7	3,3	29,3	15,0	21	27	124	20,0	0,20	23,7	10,3	0,3	0	1,0	1,3	0,3	0,2	0,2
August	393	23,0	3,2	30,3	16,7	24	30	135	22,3	0,20	28,3	9,3	0,4	0	1,0	1,4	0,4	0,2	0,2
September	399	26,3	3,6	32,0	17,7	26	28	149	20,0	0,20	32,0	8,7	0,2	0	1,0	1,2	0,7	0,2	0,2
October	395	26,3	4,0	31,7	16,7	24	24	150	22,0	0,24	33,7	9,3	0,3	0,1	0,7	1,0	0,6	0,1	0,2
November	356	23,3	4,2	31,0	14,0	19	24	147	22,3	0,32	28,7	11,0	0,2	0,1	0,7	0,9	0,6	0,2	0,2
December	301	18,3	3,4	25,3	10,3	13	25	117	25,7	0,28	23,3	10,7	0,4	0,1	0,5	1,0	0,3	0,3	0,4
1973 January	264	15,3	3,3	23,7	8,0	11	25	102	22,7	0,19	19,0	11,3	0,4	0,1	0,4	0,9	0,5	0,2	0,3
February	252	14,0	3,5	21,0	6,7	11	28	77	21,0	0,17	17,0	12,0	0,6	0,1	0,3	0,9	0,5	0,3	0,4
March	223	12,0	4,1	20,7	6,7	11	27	80	15,0	0,14	20,8	10,0	0,5	0,1	0,4	1,0	0,2	0,3	0,3
April	355	11,0	4,1	18,3	6,7	10	36	62	16,0	0,20	22,4	11,1	0,6	0,1	0,4	1,1	0,1	0,3	0,3
May	363	12,3	3,6	19,5	7,7	11	31	72	13,3	0,21	26,9	10,0	0,4	0,1	0,4	0,8	0,7	0,2	0,5
June	430	16,0	3,0	23,3	9,0	14	31	79	12,0	0,20	24,2	8,7	0,3	0,1	0,5	0,6	0,9	0,3	0,6
July	364	21,0	2,9	29,3	11,7	19	28	113	11,3	0,20	24,7	9,0	0,3	0,1	0,3	0,7	1,0	0,4	1,2
August	402	24,0	3,2	31,3	13,3	23	27	127	14,7	0,20	28,3	10,7	0,4	0,1	0,4	0,8	0,5	0,5	1,7
September	427	26,7	3,7	30,3	14,0	27	28	130	19,7	0,14	33,4	9,0	0,3	0,1	0,3	0,7	0,7	0,3	1,6
October	366	23,0	4,3	27,0	12,0	23	30	115	23,0	0,19	35,1	10,7	0,5	0,1	0,5	1,0	0,9	0,3	1,1

Table A1 continued:

Sample	Conductivity	Na	K	Ca	Mg	Cl	SO_4	Tot. Alk.	COD	MBAS	TIC	TOC	NH_3-N	NO_2-N	NO_3-N	Diss. inorg. N	Diss. org. N	PO_4-P	Total P
Station 8																			
1973 June	430	16,0	3,0	23,3	9,0	14	31	79	12,0	0,20	24,2	8,7	0,27	0,1	0,3	0,6	0,9	0,3	0,6
July	364	21,0	2,9	29,3	11,7	19	28	113	11,3	0,20	24,7	9,0	0,3	0,1	0,3	0,7	1,0	0,4	1,2
August	402	24,0	3,2	31,3	13,3	23	27	127	14,7	0,20	28,3	10,7	0,4	0,1	0,4	0,8	0,5	0,5	1,7
September	427	26,7	3,7	30,3	14,0	27	28	130	19,7	0,14	33,4	9,0	0,3	0,1	0,3	0,7	0,7	0,3	1,6
October	366	23,0	4,3	27,0	12,0	23	30	115	23,0	0,19	35,1	10,7	0,5	0,1	0,5	0,1	0,9	0,3	1,1
November	320	17,7	4,3	22,6	9,7	18	33	92	23,7	0,18	31,2	10,7	0,5	0,1	0,5	1,0	0,8	0,2	0,6
December	275	13,0	4,4	21,3	8,0	20	34	78	20,7	0,18	32.7	10,3	0,6	0,1	0,6	1,3	0,8	0,3	0,8
1974 January	280	11,7	3,9	20,3	7,7	19	30	74	17,0	0,12	33,6	9,7	0,5	0,1	0,5	1,0	1,1	0,6	1,3
February	264	13,7	4,2	21,0	8,0	21	40	80	20,3	0,17	27,7	11,7	0,8	0,1	0,8	1,7	1,3	0,9	1,3
Station 9																			
1972 March	390	31,8	7,9	34,7	12,5	35	78	76	16,0	0,10	15,0	7,0	0,5	1,0	6,5	8,1	1,3	1,0	1,0
April	551	40,3	9,5	37,8	13,5	46	83	97	23,5	0,38	20,0	11,5	4,0	0,8	6,1	13,9	1,2	2,3	2,6
May	622	46,2	10 2	42,5	15,3	50	78	98	27,7	0,42	20,0	14,0	4,3	0,8	10,4	15,5	1,5	2,2	2,6
June	827	63,9	11,9	52,6	21,1	71	99	106	33,3	0,58	20,3	17,0	5,6	0,7	14,6	20,9	1,6	2,5	3.0
July	982	55,0	9,2	48,3	21,0	86	123	101	39,3	0,52	18,7	16,7	7,1	0,6	20,7	28,4	1,4	2,3	2,6
August	1215	78,3	11,3	58,7	25,7	114	191	99	42,3	0,55	19,3	16,3	9,5	0,5	30,2	40,4	0,9	2,3	2,5
September	1294	95,0	14,8	63,7	25,7	125	244	101	45,3	0,58	20,0	16,3	10,6	1,1	34,7	46,3	0,6	2,8	3,1
October	1078	100,7	16,6	68,3	28,6	107	220	103	39,7	0,59	19,3	16,7	6,9	1,2	27,5	35.7	0,9	2,0	2,2
November	899	87,7	15,9	60,0	22,0	88	174	111	39,0	0,70	20,3	16,3	5,5	1,4	20,2	27,1	0,7	2,2	2,5
December	576	47,7	10,0	41,7	14,3	49	84	100	35,0	0,56	17,0	14,0	3,2	0,9	10,6	14,7	0,5	1,1	1,2
1973 January	612	55,0	10,9	41,3	14,0	53	77	99	41,7	0,45	18,0	13,7	3,4	0,9	10,9	15,2	0,7	1,8	2,0
February	510	39,0	8,7	35,3	11,0	40	54	95	35,0	0,29	15,7	13,0	1,6	0,6	6,4	8,6	0,8	1,3	1,5
March	582	52,7	11,1	39,0	12,7	51	69	106	37,0	0,21	11,5	15,0	3,9	0,9	9,3	14,1	0,2	2,5	2,8
April	552	46,3	10,6	37,7	12,0	45	78	93	27,7	0,29	13,0	13,3	5,2	0,8	9,2	15,2	0,3	2,0	2,4
May	637	58,7	11,9	41,7	14,0	57	102	94	30,7	0,41	17,0	12,7	7,1	0,9	12,9	20,9	0,6	2,5	2,9
June	820	70,7	12,7	49,3	16,7	72	126	101	34,3	0,57	16,7	14,3	9,6	0,9	16,7	27,2	1,3	2,6	2,8
July	996	90,7	15,1	57,3	20,0	93	148	120	39,3	0,43	16,3	17,0	9,9	1,0	20,2	30,1	1,2	3,6	4,0
August	1030	95,3	16,2	58,3	20,3	94	152	119	45,0	0,55	20,4	19,0	9,9	1,4	21,2	32,5	0,9	3,8	4,8
September	992	96,0	16,9	52,7	18,7	95	142	118	47,3	0,62	19,8	20,7	8,9	1,4	17,7	28,0	0,2	4,2	5,2
October	790	76,3	14,9	44,0	14,7	71	118	104	46,3	0,81	22,3	21,0	8,6	1.3	13,1	23,0	0,2	3,4	4,3

Table A1 continued:

Sample	Conductivity	Na	K	Ca	Mg	Cl	SO_4	Tot. Alk.	COD	MBAS	TIC	TOC	NH_3-N	NO_2-N	NO_3-N	Diss. inorg. N	Diss. org. N	PO_4-P	Total P
Station 9																			
1973 November	668	62,3	12,9	36,7	12,0	62	91	101	41,3	0,64	18,4	20,7	8,5	0,7	8,8	18,0	0,3	3,3	3,9
December	560	43,7	9,9	35,3	11,0	51	74	92	32,0	0,48	17,9	15,3	6,0	0,6	7,7	14,3	0,3	2,4	2,8
1974 January	613	47,0	10,2	36,0	12,0	56	70	106	27,3	0,33	18,7	12,0	5,7	0,8	8,1	14,6	0,4	3,3	3,6
February	657	45,0	10,2	38,0	13,3	56	74	102	31,0	0,31	15,6	12,0	4,9	0,9	8,0	13,8	0,6	2,7	2,9
Station 10																			
1972 March	490	52,2	9,8	39,4	14,4	50	100	77	21,0	0,20	16,0	7,0	0,3	1,8	31,8	33,9	1,7	2,6	3,1
April	569	39,3	10,3	40,2	14.5	52	94	84	23,0	0,18	17,0	10,5	0,5	0,8	21,9	23,5	1,6	2,6	3,0
May	620	48,2	10,8	41,8	15,3	56	92	88	24,0	0,28	17,0	12,3	0,9	1,0	19.1	21,0	1,6	2,8	3,3
June	779	59,1	12,1	47,0	17,2	67	100	99	23,0	0,52	17,3	17,3	2,5	0,5	14,8	17,8	1,7	2,5	4,2
July	887	69,0	11,5	42,7	15,0	79	114	105	30,3	0,63	18,3	17,3	4,5	0,5	19,2	24,1	1,3	3,0	4,6
August	1043	83,3	12,8	50,7	18,0	98	154	98	36,7	0,67	18,0	17,7	4,5	0,7	25,8	31,3	1,3	2,9	4,5
September	1052	91,7	15,5	54,0	19,7	102	175	96	45,0	0,62	18,3	16,3	3,7	1,0	28,7	33,4	1,4	3,9	4,4
October	908	89,3	16,3	57,0	21,0	88	153	94	41,7	0,63	17,7	17,0	2,0	1,4	23,6	26,9	1,9	3,6	4,3
November	808	84,0	16,2	56,0	19,0	76	129	99	40,3	0,73	18,0	15,3	1,7	1,6	19,3	22,5	1,7	3,6	4.3
December	663	62,0	13,0	48,3	14,7	58	98	94	38,7	0.60	16,3	14,3	2,0	1,4	14,4	17,9	1,1	2,2	2,5
1973 January	739	72,7	13,5	53,3	16,3	67	110	100	42,0	0,54	16,3	15,0	1,5	1,0	15,4	17,9	1.1	1,9	2,0
February	680	61,0	12,2	43,3	13,7	63	88	100	37,7	0,41	16,3	14,0	1,4	0,5	12,1	14,0	1,1	1,7	2,0
March	610	61,7	11,5	37,7	12,3	61	73	103	34,7	0,37	18,2	12,7	0,4	0.3	10,5	11,2	1,0	2,6	2,8
April	534	52,0	10,4	31,3	11,0	51	70	86	28,7	0,24	14,3	10,7	1,7	0,5	9,4	11,7	0,7	2,3	2,4
May	568	58,0	10,9	22,7	12,3	54	81	92	30,3	0,29	15,1	12,0	3,2	0,7	11,6	15,5	0,5	2,8	2,9
June	754	72,0	12,7	30,3	14,3	41	101	104	36,7	0,48	17,5	15,0	7,1	0,9	15,1	23,1	0,6	3,7	4,0
July	912	87,7	14,6	38,0	17,0	87	116	118	40,7	0,52	20,2	17,3	6,5	0,7	18,8	26,0	0,5	5,0	5,5
August	927	91,0	15,3	49,3	17,3	86	121	111	47,0	0,60	21,6	20,0	6,1	1,2	19,5	26,8	0,7	5,4	6,4
September	911	93,7	15,3	45,0	16,7	88	118	106	47,7	0,57	20,7	20,7	3,8	1,3	17,7	22,8	1,3	5,4	6,4
October	728	74,7	12,3	38,7	14,0	68	97	92	45,3	0,72	19,9	18,7	4,1	1,4	12,8	18,3	1,3	4,0	4,9
November	636	63,3	10,6	33,7	12,0	59	78	88	40,3	0,63	17,8	15,3	3,3	1,0	8,9	13,2	1,8	3,4	3,8
December	594	47,3	8,9	38,7	12,3	50	85	73	32.3	0,54	14,2	12,0	2,4	1,1	9,3	12,8	1,5	2,4	2,7
1974 January	701	53,6	10,9	42,3	14,0	57	100	73	28,7	0,21	12,1	10,3	1,6	1,0	9,8	12,4	1,4	3,0	3,5
February	770	57,7	11,6	44,3	15,0	60	105	73	30,7	0,22	15,3	12,3	1,4	0,9	9,8	12,1	1,5	2,9	3,4

Table A1 continued:

Sample	Conductivity	Na	K	Ca	Mg	Cl	SO_4	Tot. Alk.	COD	MBAS	TIC	TOC	NH_3-N	NO_2-N	NO_3-N	Diss. inorg. N	Diss. org. N	PO_4-P	Total P
	Parameter																		
Station 11																			
1972 March	325	8,0	1,2	36,4	23,3	16,0	35,0	155	7,0	0,05	31,0	1,0	0,05	0,05	2,2	2,3	0,5	0,1	0,1
April	378	7,2	1,0	38,3	24,5	15,5	36,0	157	7,5	0,07	31,5	4,0	0,08	0,05	2,1	2,2	0,4	0,1	0,1
May	394	7,8	1,0	39,5	25,3	15,0	35,0	158	7,3	0,08	32,0	4,7	0,08	0,05	2,0	2,1	0,4	0,1	0,1
June	447	8,1	0,9	41 4	27,6	15,7	37,7	160	10,7	0,17	30,0	9,3	0,13	0,05	2,2	2,3	0,3	0,1	0,1
July	455	9,7	1,0	42,7	27,7	17,0	39,7	163	10,7	0,15	30,7	8,3	0,13	0,05	2,8	3,0	0,3	0,1	0,1
August	472	10,3	1,0	43,3	28,0	18,0	41,7	136	11,7	0,13	33,0	8,0	0,17	0,05	3,3	3,5	0,2	0,1	0,1
September	467	11,7	1,4	44,3	27,7	19,7	40,7	176	10,3	0,08	37,3	5,0	0,13	0,05	3,5	3,7	0,3	0,1	0,1
October	462	11,3	1,6	45,0	28,0	19,0	38,7	175	10,3	0,11	39,0	6,0	0,13	0,05	3,1	3,3	0,4	0,1	0,1
November	458	12,3	1,7	47,7	28,3	19,7	41,7	180	10,7	0,22	38,5	5,7	0,10	0,05	3,1	3,2	0,4	0,1	0,1
December	458	12,0	1,3	48,0	28,0	19,3	42,3	172	11,7	0,22	39,3	5,3	0,17	0,05	2,4	2,6	0,3	0,1	0,1
1973 January	469	12,7	1,4	47,7	28,0	22,7	37,7	175	11,7	0,21	39,3	5,3	0,17	0,05	2,0	2,2	0,2	0,1	0,1
February	389	10,7	1,6	35,3	21,0	19,0	25,3	136	10,3	0,19	31,7	5,0	0,27	0,05	1,1	1,5	0,3	0,1	0,1
March	324	9,3	2,0	30,3	18,0	16,3	20,3	118	7,7	0,23	33,2	5,8	0,20	0,05	1,5	1,8	0,5	0,1	0,1
April	238	9,0	3,4	20,3	11,7	11,7	27,7	70	12,3	0,21	31,5	6,7	0,50	0,05	1,5	2,1	0,2	0,2	0,2
May	318	10,0	3,1	30,3	17,7	15,3	38,0	106	12,7	0,19	33,6	6,0	0,40	0,05	1,8	2,3	1,5	0,2	0,4
June	389	11,7	2,7	35,0	20,3	17,7	43,7	128	12,7	0,25	32,1	8,8	0,47	0,05	1,8	2,3	1,0	0,3	0,6
July	474	11,0	1,1	44,7	26,7	19,7	43,7	167	8,7	0,21	33,4	8,3	0,33	0,05	2,2	2,6	0,1	0,2	0,9
August	479	11,3	1,1	44,3	27,0	20,3	42,7	162	10,0	0,26	33,8	8,2	0,47	0,07	2,0	2,5	0,3	0,3	1,0
September	482	11,3	1,1	41,0	25,3	21,0	44,7	143	11,7	0,24	36,3	9,7	0,50	0,07	1,7	2,3	1,0	0,4	1,0
October	479	12,0	1,3	41,7	24,7	21,7	43,7	144	12,3	0,20	38,2	10,5	0,40	0,07	1,3	1,8	0,9	0,4	0,7
November	476	12,0	1,4	42,0	24,0	21,3	42,7	147	11,7	0,15	39,5	9,9	0,27	0,05	1,1	1,4	0,8	0,3	0,4
December	430	11,3	1,9	40,0	22,0	14,7	37,7	140	12,0	0,19	35,1	9,4	0,30	0,05	1,4	1,8	0,5	0,1	0,2
1974 January	438	10,7	1,9	38,0	21,3	14,3	36,0	136	11,3	0,17	31,2	7,4	0,30	0,05	1,4	1,8	0,2	0,3	0,3
February	407	11,3	2,3	36,0	20,3	15,0	39,3	121	14,0	0,14	33,2	6,0	0,33	0,10	1,8	2,2	0,5	0,5	0,6
Station 12																			
1972 March	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
April	733	46,8	9,4	43,8	20,2	47,0	77,0	115	25,0	0,20	26,0	5,0	0,60	0,30	10,1	11,0	0,8	2,0	2,0
May	710	51,9	9,6	45,4	20,1	51,0	88,0	112	23,0	0,35	23,0	8,5	0,60	0,40	11,4	12,4	0,8	2,2	2,3
June	744	55,3	9,5	46,3	20,7	55,3	92,0	115	23,0	0,43	21,0	13,0	1,40	0,40	12,0	13,8	1,1	2,6	2,7
July	769	63,0	9,7	49,3	21,7	63,3	103,0	115	28,3	0,48	19,3	16,0	2,30	0,40	14,9	17,6	1,2	3,1	3,2

Table A1 continued:

Sample	Parameters																		
	Conductivity	Na	K	Ca	Mg	Cl	SO_4	Tot. Alk.	COD	MBAS	TIC	TOC	NH_3-N	NO_2-N	NO_3-N	Diss. inorg. N	Diss. org. N	PO_4-P	Total P
Station 12																			
1972 August	845	71,3	10,1	53,0	23,0	74,0	119,3	109	34,3	0,52	19,3	16,7	2.2	0,3	19,4	21,9	1,4	3,1	3,2
September	887	84,0	12,2	57,0	24,3	82,7	139,3	107	39,0	0,53	20,0	15,3	1,2	0,5	23,7	25,4	1,5	3,3	3,6
October	785	72,0	11,6	52,0	21,7	71,7	122,6	106	35,3	0,55	20,0	15,3	0,3	0,7	20,4	21,3	1,5	2,8	3,1
November	736	71,3	12,4	52,0	20,0	65,7	108,3	111	34,7	0,60	20,0	14.3	0.3	1,0	17,7	19,0	1,6	3,0	3,3
December	508	42,3	9,5	38,7	14,0	41,3	68,3	92	31,7	0,46	17,3	12,0	0,9	0,8	10,1	11,8	0,9	1,7	1,8
1973 January	561	50,7	10,4	40,7	14,3	46,7	68,3	100	30,0	0,43	17,0	12,7	0,8	0,5	10,5	11,8	1,0	1,8	2,0
February	529	41,3	9,4	34,0	12,3	46,0	52,5	94	25,0	0,34	17,3	13,3	0,7	0,2	7,8	8,7	1,0	1,6	1,9
March	597	59,7	11,3	38,7	14,7	56,7	64,7	90	26,3	0,25	22.3	14,0	0,1	0,2	11,1	11,4	1,5	2,5	2,8
April	516	52,3	10,3	32,0	12,3	49,3	69,0	92	25,0	0,22	23,3	12,0	1,0	0,3	10,1	11,4	1,1	2,2	2,4
May	519	54,3	10,0	34,7	14,3	47,3	83,7	85	26,7	0,31	26,7	11,3	1,4	0,5	10,8	12,7	1,3	2,1	2,3
June	624	54,3	9,6	38,7	16,0	53,3	89,7	108	30,3	0,44	30,3	12,3	4,1	0,6	11,0	15,7	0,9	2,5	2,7
July	746	67,3	10,8	48,0	20,3	71,0	103,7	126	33,0	0,49	29,7	13,3	3,7	0,6	10,6	14,2	1,0	3,2	4,0
August	770	70,7	11,2	48,3	20,3	73,3	104,3	121	35,3	0,47	26,3	15,3	3,7	0,7	14,1	18,5	0,4	3,5	4,9
September	780	72,7	11,5	45,0	19,7	74,7	105,0	102	37,3	0,47	23,3	17,0	1,5	0,8	14,4	16,7	0,6	3,4	4,9
October	805	70,0	11,6	46,7	18,7	74,3	116,7	97	39,3	0,52	24,3	19,3	4,1	1,1	14,4	18,6	0,6	2,7	3,7
November	721	60,7	10,5	42,3	16,3	65,7	103,0	91	35,3	0,62	23,3	16,7	3,7	0,9	13,7	18,3	0,8	2,4	2,8
December	650	49,3	9,1	43,7	16,0	60,7	92,0	88	28,3	0,50	20,0	13,0	3,5	0,7	11,9	16,9	1,3	1,5	1,9
1974 January	608	42,7	8,5	39.3	15,3	49,0	70,0	102	22,3	0,50	18,0	13,3	0,5	0,5	12,2	13,2	1,7	2,0	2,2
February	595	34,3	9,0	41,0	17,0	51,3	81,3	124	24,5	0,45	18,0	10,0	0,5	0,4	9,7	10,6	2,0	1,5	2,1
Station 13																			
1[illegible] March	490	15,2	1,4	57,8	37,2	27,0	18,0	294	5,0	0,05	62,0	4,0	0,2	0,1	1,2	1,5	0,4	0,1	0,1
April	554	13,4	1,3	59,5	39,7	25,5	18,0	281	5,5	0,10	59,0	8,0	0,2	0,1	1,3	1,6	0,4	0,1	0,1
May	572	12,3	1,1	61,3	39,7	24,0	17,3	283	6,0	0,10	60,0	7,7	0,2	0,1	1,4	1,7	0,3	0,1	0,1
June	664	11,9	1,1	62,7	41,3	24,3	17,3	276	7,3	0,18	51,7	16,3	0,6	0,1	1,7	2,4	0,2	0,1	0,1
July	649	12,7	1,3	61,3	41,0	25,0	17,3	277	8,7	0,18	50,3	14,7	1,0	0,1	2,2	3,3	0,3	0,1	0,2
August	647	13,3	1,5	58,3	40,3	26,0	18,0	270	10,0	0,18	51,7	13,3	1,1	0,1	2,5	3,7	0,2	0,1	0,2
September	580	13,3	1,8	57,0	37,0	24,3	17,7	276	10,6	0,14	61,3	6,3	0,7	0,1	3,2	4,0	0,3	0,1	0,2
October	576	12,3	1,7	58,7	36,0	22,3	16,7	270	10,0	0,23	64,0	7,7	0,3	0,1	2,8	3,2	0,2	0,1	0,1
November	562	14,0	2,1	63,3	35,3	23,0	16,0	270	10,0	0,26	60,7	9,3	0,1	0,1	2,7	2,9	0,3	0,1	0,1
December	564	13,0	1,7	64,0	37,3	23,3	15,7	261	10,0	0,24	59,0	7,3	0,5	0,1	2,2	2,8	0,3	0,1	0,1
1973 January	570	12,7	1,6	61,0	37,6	23,3	16,3	268	9,7	0,12	59,0	5,7	0,5	0,1	1,9	2,5	0,3	0,2	0,2
February	594	10,7	1,2	56,3	37,6	23,3	16,0	266	9,0	0,14	57,7	7,0	0,6	0,1	1,7	2,4	0,3	0,2	0,2

Table A1 continued:

	Conductivity	Na	K	Ca	Mg	Cl	SO_4	Tot. Alk.	COD	MBAS	TIC	TOC	NH_3-N	NO_2-N	NO_3-N	Diss. inorg. N	Diss. org. N	PO_4-P	Total P
Station 13																			
1973 March	553	11,3	1,3	54,3	37,7	24	17	261	8,0	0,10	57,3	8,3	0,2	0,1	1,7	2,0	0,3	0,1	0,2
April	500	14,3	1,8	48.7	31,3	28	18	216	10,3	0,15	59,7	10,0	0,5	0,1	1,8	2,4	0,4	0,1	0,2
May	474	15,0	1,8	49,3	30,3	26	18	221	10,0	0,10	63,0	8,0	0,9	0,1	1,8	2,8	0,7	0,1	0,3
June	519	14,7	1,5	51,0	35,7	27	17	225	8,7	0,12	54,3	9,0	2,6	0,1	1.5	4,2	0,9	0,2	0,3
July	568	12,0	0,9	58,0	37,3	24	15	263	10,7	0,19	49,0	8,0	2,9	0,1	1,5	4,5	0,8	0,2	0,3
August	573	11,3	1,0	57,0	35,7	24	16	250	12,7	0,23	50,3	8,7	2,6	0,1	1,5	4,2	0,4	0,2	0,5
September	569	10,3	1,1	51,7	31,3	24	19	230	13,7	0,27	62,3	8,7	0,9	0,3	1,3	2,5	0,1	0,2	0,7
October	608	11,7	1,0	47,3	29,7	23	29	204	12,3	0,22	68,0	11,0	1,7	0,3	1,1	3,1	0,3	0,2	0,8
November	601	12,7	1,1	47,0	29,0	24	27	203	11,3	0,19	62,7	11,0	1,5	0,1	0,8	2,4	0,3	0,2	0,5
December	607	15,7	1,4	50,3	32,0	33	24	205	10,3	0,24	60,0	10,7	2,1	0,1	1,1	3,3	1,0	0,1	0,3
1974 January	595	17,3	1,9	55,0	32,0	37	16	224	13,3	0,13	61,1	8,7	0,9	0,1	1,0	2,0	1,1	0,3	0,4
February	624	19,3	2,5	50,0	28,3	39	22	200	13,4	0,12	67,7	11,0	0,9	0,1	1,3	2,3	1,2	0,4	0,6
Station 14																			
1972 March	460	34,7	6,4	43,5	21,7	39	82	130	12,0	0,20	27,0	7,0	0,2	0,5	8,7	9,4	1,0	1,1	1,2
April	536	33,9	6,8	44,0	21,9	40	75	136	14,0	0,26	29,0	8,0	0,2	0,2	8,5	8,9	1,2	1,4	1,7
May	581	38,9	7,3	45,7	22,2	44	70	134	15,0	0,31	28,0	10,0	0,2	0,2	9,3	9,9	1,0	1,6	1,8
June	692	43,3	7,6	49,2	23,7	49	51	143	18,0	0,44	28,0	14,0	0,6	0,3	10,0	10,9	1,1	2,1	2,2
July	761	52,7	8,2	52,3	25,0	56	62	142	24,0	0,43	26,0	15,0	1,1	0,3	12,3	13,4	1.3	2,4	2,6
August	830	62,7	9,1	54,7	25,0	66	85	133	29,0	0,52	24,0	16,0	1,2	0,3	16,3	17,4	1 5	2,8	3,0
September	842	74,0	11,3	54,7	24,3	73	117	132	33,0	0,51	24,0	13,0	0,7	0,4	20,1	20,9	1,5	3,2	3.4
October	749	66,3	11,1	51,0	21,3	66	106	128	33,0	0,56	24,0	14.0	0,3	0,6	18,3	19,1	1,4	2,8	2,9
November	700	63,7	11,2	53,0	21,0	60	87	132	32,0	0,55	25,0	12,0	0,1	0,6	16,0	16,7	1,4	2,6	2,7
December	562	45,6	10,2	46,0	16,3	47	57	114	31,0	0,43	22,0	11,0	0,5	0,6	10,9	9,1	1,0	1,4	1,5
1973 January	582	49,7	10,3	45,0	16,3	47	54	113	27,0	0,36	21,0	11,0	0,5	0,4	10,6	11,5	1,0	1,4	1,6
February	543	39,3	9,3	37,0	14,3	45	46	108	23.0	0,29	20,0	11,0	0,6	0,3	7,9	8,7	1,1	1,2	1,5
March	541	45,0	8,7	37,0	15,7	47	53	103	21,0	0,28	25,0	11,0	0,2	0,2	9,3	9,6	1.3	1,5	2,2
April	541	42,5	8,5	35,0	15,0	48	51	95	22,0	0,31	23,0	11,0	0,6	0,1	10,1	10,3	1,5	1,6	2,4
May	575	51,0	9,2	40,0	18,0	52	72	109	26,0	0,35	28,0	13,0	1,1	0,2	11,5	12,5	1,7	2,8	2,8
June	687	60,5	9,8	47,5	21,5	65	98	137	30,0	0,49	27.0	14,0	2,8	0,4	12,6	15,5	1,7	3,1	3,2
July	731	63,3	10,1	48,7	21,8	67	97	129	33,0	0,48	30,0	16,0	2,9	0,4	14,0	17,3	1,2	3,2	3,7
August	733	65,0	10,2	49,0	21,8	66	95	122	29,0	0,50	25,0	14,0	2,5	0,4	13,5	16.5	0,7	2,3	4,4
September	754	67,7	11,2	45,0	19,0	69	94	105	30,0	0,44	25,0	12,0	0,9	0,4	13,5	14,8	0,6	2,5	4,4
October	734	60,7	10,6	45,3	20,3	67	95	107	29,0	0,51	24,0	11,0	1,7	0,6	11,2	13,6	0,8	2,0	3,3
November	656	51,3	9,3	41,3	18,0	59	85	102	30,0	0,52	23,0	11,0	1,5	0,4	9,6	11,6	0,9	1,1	2,6
December	581	38,0	7,3	41,3	17,3	52	76	104	23,0	0,48	20,0	11,0	2,1	0,5	8,1	10,4	0,7	1,5	1,8
1974 January	568	35,3	7,1	38,7	16,0	45	68	95	20,0	0,39	18,0	9,0	0,9	0,3	7,4	8,6	0,8	1,2	2,1
February	608	37,0	7,5	40,0	16,5	49	75	96	18,0	0,26	18,0	8,0	1,1	0,2	8,1	6,3	0,8	1,5	1,7

	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Febr	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb
Baetis harrisoni	5												1	P		P	1	2			P		1	2
Chironomus	P	P	1				P				11	10	7	5	6	2		5	4	3	3	1	4	3
Chironomini	72	31	53	53	42	22	31	53	39	33	25	23	20	29	27	37	24	6	25	26	56	47	29	23
Orthocladinae	11	65	46	44	57	78	68	44	55	42	50	43	56	45	34	58	74	88	71	71	40	52	59	61
Dytiscid														P										
Collembola								2	P												P	P		
Culicidae																					P			
Psychodidae																					P			
Simuliidae	13	3	1	3	P		P	1	6	25	14	24	16	21	34	3	1						8	11
Total Number in Sample	1176	377	259	345	225	276	1834	129	324	415	229	395	325	471	223	461	144	67	861	163	397	318	484	193

FIG.A1 : Percentage composition of taxa found at station 2 from March 1972 to February 1974.

*P = less than 0,5% present

	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Febr	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb
Baetis harrisoni	64	71	66	71	23	45	1		2	8	12	10			13	35	13	4	P	12	55	20	56	61
Chironomus		P									2					1			1					
Chironomini	5	1	1	1			2		8	9		2			2	2	5	P	4		7		2	18
Orthocladinae	20	8	22	5	10	12	9		58	68	74	75			18	13	17	3	1	23	26	66	39	16
Tanypodinae		1																						
Dytiscid																							1	
Hydra	3	P				1	1										1	P	3					1
Planaria		P																						
Prostoma																			P					
Hirudinea		P					P				2				2			P	P					
Limnodrilus	1								P	1	2	6			4	P		P	P	19				
Ilyodrilus	P									1		1			2	1			P	21		2		
Nais	3	16	10	15	18	32	87		18	1					4	39	32	84	79	12	13	5		4
Chaetogaster	3				45	2	P				7	1			48	2	25	1	3			3	2	
Branchiura	P																							
Naididae	2	1		8	4	6	1		11	11	2	5			5	3	5	7	8	10		2	1	
Collembola			P		P	1	P		2	1	2				1							2		1
Ostracoda (incl.Cypridopsis)																			P					
Burnupia							P		P															
Psychodidae															P					2		2		
Rhagionidae							P																	
Simuliidae		P	2				P		P			1				6	2	P					1	
Zygoptera							P			P					1				P					
Anisoptera		P																	P					
Total Number in Sample	552	1230	464	500	282	516	7765		755	263	61	88			255	512	242	1573	5405	188	139	64	210	187

FIG.A2 : Percentage composition of taxa found at station 3 from March 1972 to February 1974.

*P = less than 0,5% present

	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Febr	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb
Baetis harrisoni	35	57	45	16	9	3			1	17	16	25	32	39	47	5	5	10	1	10	4	4	19	32
Cheumatopsyche thomasseti													P											
Chironomus	3	1						1	1	7	P		2	1			P	1	1	1	3	5	5	
Chironomini	34	9	24	34	45	55	53	18	18	7	1	9	2	7	15	30	36	15	71	51	18	38	26	26
Orthocladinae	27	26	16	35	26	32	46	32	78	55	81	48	54	18	9	27	24	61	24	19	72	43	31	20
Tanypodinae										1														
Dytiscid										P						P								
Gyrinid								1															1	
Hydra	P					3						17	P						P					
Hirudinea									P	2				1		P					P	1	1	1
Limnodrilus	1							4	P	1			P	7	1		P	2	1	3		1		
Ilyodrilus				P				7	P	1			1	2			P	1	P	2		1	5	
Nais		2	10	P	2	2		2					P				1	2	P	8				
Chaetogaster				2	7	1				P	P			1	19									
Branchiura																	P						1	
Naididae		1	3	P	3			28		3			4	7	2		P	6		4	1	1		1
Collembola		2		1	1	4	1	3	1	5		1	P	8						1	2	4	1	
Cypridopsis																						P		
Other Ostracoda	P																			1				
Burnupia														1										
Culicidae		1																						
Ceratopogonidae								1																
Psychodidae								4		1				2						1				
Tipulidae																		1						
Eristalis										1				1								P		
Simuliidae		1	1	10	8		1		P	1	1	1	4	7	9	30	33	3	2		1		10	20
Zygoptera	P									P														
Total Number in Sample	773	635	715	570	197	261	1782	139	607	317	514	91	795	108	142	1662	584	198	405	156	823	284	202	157

TABLE
FIG.A3 : Percentage composition of taxa found at station 4 from March 1972 to February 1974.

* P = less than 0,5% present.

	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Febr	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb
Baetis harrisoni	1	9	67	76	23	2	P		P	16	39	73			90	57	7				P	2	38	95
Centroptilum																							1	
Cheumatopsyche afra																	1							1
Chironomus	5	3	2			1				11									P	3	1	1	7	
Chironomini	67	30	12	17	66	81	91		23	18	4	7			3	4	22		27	6	19	2	24	
Orthocladinae	20	55	20	5	9	16	9		77	32	29	11			4	24	56	77	70	91	79	93	28	4
Dytiscid											1													
Hydra	P											1												
Hirudinea																	1	2						
Limnodrilus	3	P			P	1				3	5						1	6	P			P		
Ilyodrilus	3	1	P	P	P	1					6					3	1		2		1	1	1	
Nais		1														11	8	4			P	P	1	
Chaetogaster				1	P						13	2			2		3					P	2	
Naididae	1	2	P	P							4	5			1		3	8						
Chaoborus		P																						
Psychodidae																		2						
Simuliidae	P																							1
Zygoptera												1												
Nematodes	P																							
Total Number in Sample	1751	703	260	376	225	185	1515		278	166	209	157			105	70	149	52	452	355	896	1235	160	77

FIG. A4 : Percentage composition of taxa found at station 5 from March 1972 to February 1974.

*P = less than 0,5% present

	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Febr	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb
Baetis harrisoni	10	22	44	36	56	4	4		41	-	50	10			32	17	8	2	P		20	69	60	6
Cheumatopsyche afra	7	1		2	2	3	2				4	1			9		2	1			1	1	17	22
Cheumatopsyche thomasseti	1	P	1				P								1	1	1						2	P
Chironomus		P					1												P			P		
Chironomini	15	9	3	2	4	6	77		15		5	4			1	2		1	3		22	4		45
Orthocladinae	56	31	16	3	10	10	13		10		33	44			4	28	50	59	93		46	4	6	
Tanytarsini																						P		
Tanypodinae												1												
Hydracarid				1	P	P	P									3	5							P
Hydra	8	13	13	P		P						1			P	2						1	8	
Planaria	P	P				P	P		1						2	1	1		P					
Prostoma																							1	
Hirudinea												1							P		1	1	1	
Limnodrilus		4	P	P	P				5								1	1				1		
Ilyodrilus		1			P				3		1							P			1	6	1	P
Nais	2	2	10		8	15	P		2						1	1	6	12	1		1	1		11
Chaetogaster		3		34	9				13			1			8	5	6	5	2		2			1
Branchiura		P				P						1										2		
Naididae	1	11	1	6	11	61	P		11		1				28		6	19	P			1	1	15
Collembola			4	P		P											1				1	1	1	
Ostracoda (incl.Cypridopsis)		P				P	1								P				P			1		
Burnupia															1	5					2	1		
Simuliidae	P	3	9	27	P		1		1		7	34			14	38	11	2	P		2	7	5	
Zygoptera																					1			
Total Number in Sample	499	1685	355	1044	450	2231	2025		160	[illegible]	122	71			529	149	203	289	2039		100	290	205	1034

FIG.A5 : Percentage composition of taxa found at station 6 from March 1972 to February 1974.

*P = less than 0,5% present

	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Febr	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb
Baetis harrisoni														20	34	8	20	16	3	4	36	1	35	47
Cheumatopsyche afra															1								2	5
Cheumatopsyche thomasseti														P							1			2
Chironomus														2					P	1		1		
Chironomini														12	3					3	1	1		2
Orthocladinae															31	36	37	9	2	9	39	45	32	35
Tanypodinae															1	P				1				
Stenelmis																								1
Hydraenid														1			2	1	P	1				
Hydra															P			P	4		P			
Planaria														5	P	1	P	1	P			1		
Hirudinea														1	P	P		1		1	P	1	3	1
Limnodrilus														3		P	P		P			3		
Ilyodrilus																P	P			1	1	11		
Nais															1	2	5	31	41	9	1	1		
Chaetogaster														10	4	2	P		1	1	P	1	4	
Branchiura														P		P					P	2	10	
Naididae														46	22	48	34	41	48	62	1	32	10	5
Collembola																					1			
Burnupia																	P							
Simuliidae															2	1	1	1	P	7	20	2	3	2
Total Number in Sample														415	482	823	1311	3014	914	91	445	222	68	133

FIG.A6 : Percentage composition of taxa found at station 6A from March 1972 to February 1974.

*P = less than 0,5% present

	Mar.	Apr.	May	June	July	Aug.	Sept	Okt.	Nov.	Dec.	Jan.	Febr	Mar.	Apr.	May	June	July	Aug.	Sept	Okt.	Nov.	Dec.	Jan.	Feb
Baetis harrisoni														30		P	P	1	1		18	15	42	
Cheumatopsyche thomasseti																					P			
Chironomus																					P			
Chironomini																	P		1		2	1	2	
Orthocladinae														14	2	6	1	8	2		56	77	42	
Hydraenid																	P		P					
Hydra															P		P		P		1		1	
Planaria															P	P	1	P	1		1		2	
Hirudinea															P			P	P		1	1	1	
Limnodrilus														2			P							
Ilyodrilus															1	P	3	P			1	P		
Nais															76	92	88	89	85		17	2	5	
Chaetogaster															18	1	6	1	7		3	1		
Naididae														42	2	1	1		1		1	2		
Ostracoda (incl.Cypridopsis)																		P	2					
Burnupia														12	P		P				1	1	4	
Simuliidae															P		P	P			P			
Total Numbers in Sample														43	554	3034	1658	1147	4090		651	527	96	

TABLE
FIG.A7 : Percentage composition of taxa found at station 6B from March 1972 to February 1974.

*P = less than 0,5% present

	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Febr	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Febr
Baetis harrisoni		18	13	41	23	5	15		1		2	P			P		2	3	1		27	12	3	4
Cheumatopyche afra		1	1	4	3	7	1		1		2	2			P		1	P					1	P
Cheumatopsyche thomasseti		9	4	2	3	5	2		3		18	18			5		7	1			P	P	30	53
Ecnomus												P												
Chironomus				P					P						3				P			P		
Chironomini		24	6	16	18	5	2	40	16		10	7			2	1	7	5	4		23	9	21	11
Orthocladinae		23	10	7	16	1	17	10	33		9	12			2	7	14	21	15		2	4	30	17
Tanytarsini			P	P	P												1							
Tanypodinae				P																		P		
Stenelmis						P						1			P		P					1	P	
Dytiscid						P									P									
Gyrinid															P						P			
Hydra		1				P	1		2		19	3									P	1	P	1
Planaria			8	P	P	13	2		1		P	3			1		P	P	P		P		P	P
Hirudinea						P	P	3	1								P		P		P		1	
Limnodrilus		1	P		P	4	P	3	9		P	8			2		1	1	1		P	1		
Ilyodrilus			P		P	P			1			4			P						P			
Nais		1	5	6	26	26	17	10	5						1		30	26	55		29	4		
Chaetogaster				1	1	9	1		1		1						3	16	6		P	P		
Branchiura																		P	P					
Naididae		8	32	10	7	22	36	23	14		6	31			2	1	26	9	6		P	1	1	2
Collembola						P	1		P						1				P			P		
Ostracoda (incl.Cypridopsis)		6	2	8	2	4	5	10	3		6	3			75	69	3	18	11		3	9		
Burnupia							P														P			
Psychodidae															P									
Tabanidae											P													
Simuliidae		9	18	4	P		P		9		28	8			6	21	3	P	P		14	55	14	12
Hydrachnellae																						P		
Total Number in Sample		418	579	516	969	2466	1631	130	596		603	901			1056	143	1238	630	1039		1547	486	727	1308

FIG.A8 : Percentage composition of taxa found at station 7 from March 1972 to February 1974.

*P = less than 0,5% present

	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Febr	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Febr
Baetis harrisoni		27	25	31	58	40	48				1	1			5	19	22	13	28		25	8	2	4
Cheumatopsyche afra		1	5	2	1	3	P					2												
Cheumatopsyche thomasseti		1	3	1		1					1	2			P								1	6
Chironomus		P		1					1						1	P	P		P		1	1		
Chironomini		39	19	13	7	6	7		34		11	8			24	4	16	7	10		5	1	8	29
Orthocladinae		8	2	1	P	P			10		7	41			8	14	14	18	33		4	6	10	7
Tanytarsini			P	1								2			P				P		P	P		
Tanypodinae				P																				
Stenelmis						P																		
Hydraenid				P		[illegible]											P							
Dytiscid															P									
Gyrinid									1												P			
Chrysomelid				P																				
Hydra		1	P	P			P		9		28	5			P								P	35
Planaria																								
Hirudinea				P		2	P					P				P								
Limnodrilus		P	13	1	10	2	1		1		P	2			P	2	3	1	2		1	P	3	4
Ilyodrilus															P						P			
Nais		P	1	1		1	P		3									1	4		P			
Chaetogaster				P	1	P	P								2								P	
Branchiura			1			23									P				P		P		1	
Naididae		9	24	13	10		30		31		43	33			1	1	1	1	10		P	2	4	4
Collembola			1	P	P	2			3		P					1	P	1	1		P	P		
Ostracoda (incl.Cypridopsis)			5	20	12	21	13		5		10	P			7	31	21	57	12		18	15	5	4
Chaoborus		P																						
Ceratopogonidae																	P		P					
Simuliidae		13	3	16	1	P	1		3		P	4			50	28	23	1	1		45	67	66	8
Zygoptera																					P			
Total Number in Sample		818	471	2128	617	1361	1721		353		545	689			903	505	689	227	658		997	1128	2399	261

FIG.A9 : Percentage composition of taxa found at station 7A from March 1972 to February 1974.

*P = less than 0,5% present

	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.
Baetis harrisoni		8	34	6	21	18	17		1		1		P		P	P	1	1		2	13	1	2	1
Baetis latus		3	5	1	1		1		P			P				P	P				P	P	2	1
Baetis quintus		2	1						P														P	1
Afronurus		4		P		P															P			
Caenidae		2	1		P	1	P													1	6	P	P	
Choroterpes		2			P	1	1		2														P	2
Centroptilum		1	3	P	P	1	P		1				1				P	P		P		P		
Cheumatopsyche afra		6	13	7	9	6	1		P			P	8		P	2	1	1		P		1	5	12
Cheumatopsyche thomasseti		8	21	8	12	12	2		P			P	16			1	1	P			2	1	9	21
Hydroptila			P	P		P			P								P						P	
Ecnomus													P										P	
Chironomini		9	1	2	1	8	6		2		18	6	18		2	1	6	1		P	4	1	1	7
Orthocladinae		7	3	2	22	4	2		16			2	12		3	3	33	6		7	13	5	16	14
Tanytarsini		1	1	7	10	3			1			2	P		P	1	2	1		1	3	1	1	
Tanypodinae		P	1	P		P			1									P						
Stenelmis			P			1	P						1											4
Hydraenid													P			P	P							
Dytiscid					P																			
Gyrinid			P	1	P	1	1																	2
Hydra						1	3		P		2	16	P					2		5				
Planaria		3	10	9	11	27	5		8		1		6		P	1	6	4		1	3	P	P	14
Protosoma																		P			2			
Limnodrilus													P							2	2	P		
Ilyodrilus													P							2				
Nais					4	2	24		4				3			3	6	38		39	1			2
Chaetogaster		1			1	1	1									P	P	4		1	P			
Branchiura		P							P											P				6
Naididae		5				1			4			1	5			1		5		11	3	P	1	5
Collembola			1			1												1						
Ostracoda (incl.Cypridopsis)		1	P		2	5	18		1		1	1	3		P	P		3		19	3	P	P	5
Burnupia									P								P	P		P			1	4
Psychodidae		P																						
Ceratopogonidae			1	P	P		P		1				1		P		P			P				
Rhagionidae					P																			
Tetanoceridae																P								
Simuliidae		37	4	56	4	6	19		56		78	74	26		94	86	43	33		9	43	91	62	
Hydrachnellae						P																		
Pelecypoda		1				1	1		P				P				P	P		1	3			
Biomphalaria																					P			
Total Number in Sample		2629	843	919	483	700	1717		713		276	5095	240		5035	3204	1273	964		308	196	1541	589	126

	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.
Baetis harrisoni	4	35	40	6	1	4	13		6			2	12		4	P	P	P			3	2	48	3
Baetis latus		P																						1
Afronurus													P											
Caenidae									P		P		P								P			
Choroptherpes													P											
Centroptilum													P										1	
Cheumatopsyche afra	32	10	6	5	2	9	9		39		4	11	4		2	P	1							
Cheumatopsyche thomasseti	5	2	P	P	P	1	P		1		6	5	1		1								1	
Ecnomus													P								P			
Chironomus	1								1				P		1							2		
Chironomini	25	3	5	3	1	7	3		8		28	43	37		4	4	4	7	52		26	13	17	31
Orthocladinae	6	20	27	1	2	17	58		5		35	11	15		21	4	31	16	19		25	5	7	55
Tanytarsini						1	P															P		
Tanypodinae											1		1		P	P								
Stenelmis																						P		
Hydraenid						P																		
Hydra	P	3	3	1	P		P		P			1	P		P	P							1	
Planaria			1	P	P	6	P		10		5	P			P									
Prostoma																		1						
Hirudinea						P			1												P	1		
Limnodrilus		P		P	P	P			2		3	2	P		4	P	P		2		1	4		
Ilyodrilus					P										P				P			P		
Nais	4	1	9	80	85	32	13		1				P		6	89	6	13	11		6	4	1	4
Chaetogaster				2	8	17	1						2		17	1		46	3		22	3	2	
Branchiura				P	P								P		P							2		
Naididae	3	2	P	P		6			18		11	19	13		36	1	56	8	6		1	3	2	4
Ostracoda (incl.Cypridopsis)	P	P				1	1		1			1	2		P	P	1	10	6		P	P		1
Burnupia		P		P	1	P			3		2	2	3		1	P	P				15	58	15	1
Ceratopogonidae							P														P			
Simuliidae	20	20	9	1		P	1		6		4	2	9		2	P					1	1	4	1
Nematodes	P												P											
Total Number in Sample	897	711	436	5231	17454	1556	1419		1395		225	377	661		1718	5013	2854	1279	499		1004	706	139	151

Table
FIG.A11 : Percentage composition of taxa found at station 9 from March 1972 to February 1974.

*P = less than 0,5% present

	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.
Baetis harrisoni	10	18	33	29	17	4	10		12		14	15			9	1	5	3	6		21	6	3	9
Caenidae																			P					
Choroterpes																	P		P					
Cheumatopsyche afra	4	4	5	2	3	1	1		2		4	P			1	P	P	P			P	1		
Cheumatopsyche thomasseti	8	16	7	5	4	2	2		5		11	3				P	1	P	P		2	12	50	51
Chironomini	5	6	1	2	2	2	3		11		6	16			1	4	1	P	2		13	6	2	
Orthocladinae		4	4	2	5	3	13		11		14	32			3	5	15	2	14		15	1	1	4
Tanytarsini	P			P	P				P							1	2	P	1					
Stenelmis	1	1	P	P	P		P								P		P		P		2	29	5	10
Hydra					P	P	P										P		P		1	2		
Planaria	P	1	P	1	2	1	2		17							1	1	1	6		8	12	5	2
Hirudinea							P												P			3		
Limnodrilus	P	2	P	8	1		1		P		1								P		2	6	10	10
Ilyodrilus	P	1		1	P		P									P					P	1	1	1
Nais	P	2	1	11	24	72	51		6						P	74	36	90	61		33	3		5
Chaetogaster	P	1	P	1	9	6	3		P						80	1	23	2	3		2			
Branchiura		P		P			P															P	P	
Naididae	P	13	P	5	24	9	11		6		P					10	7	P	6		1	3	12	3
Ostracoda(incl.Cypridopsis)	P			P	P	P									P	P					P	1		
Burnupia		P	P				P														P	5	4	2
Ceratopogonidae					P										6									
Simuliidae	71	32	47	34	9		P		30		49	34				3	8	P	P		1	11	7	3
Pelecypoba																			P		P			
Physopsis							1																	
Total Number in Sample	4059	1335	1391	1836	1724	2446	5207		700		70	228			468	1993	1949	3129	2869		994	527	325	444

FIG.A12 : Percentage composition of taxa found at station 10 from March 1972 to February 1974.

*P = less than 0,5% present

	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.
Baetis harrisoni	23	31	34	32	35	37	31		3	6	3	4	7		2	10	18	17	5	30	21	10	13	3
Baetis latus	2	1	2	P	P					P	P				1	P		P	P			P		1
Baetis quintus		1								P	2	9	7									2		
Afronurus	4	11	4	8	P	2	1			1	1	1	9		11	P	1	3	P	P		1	1	4
Neurocaenis	4	2	6	9	2	1	P		P	3	P	1	3			1	P	P	P			1	1	
Caenidae	2	1	2	2	1	3	P		5	1	6	P			1	1	P	1	2	2		1	1	6
Choroterpes	4	7	2	16	1	8	3		1	1	15	2	12		9	3	4	2	7	2	P	1	3	9
Centroptilum						P				1	1	1												
Cheumatopsyche afra	2	1	2	2	1	1				5	3	7	6		1	4	3	P	1	6	7	1	8	1
Cheumatopsyche thomasseti	5	3	3	3	1	6	1		7	5	25	8	24		8	5	3	1	1	13	8	7	24	46
Hydroptila	4	6	3	2	1		2		2	1	2	1	5		1	1	1	P	P	1	2	5	15	6
Ecnomus										P	P											P	1	
Amphipsyche																						1	1	
Chironomini			1	1		1	3		13	1	3	5	2		5	1	1	1	P	1	1	4		1
Orthocladinae	6	3	2	3	5	5	7		47	2	3	8	2		48	20	30	8	1	7	21	47	6	10
Tanytarsini		1		P	P	1	P		2	1	1	1	3				P	P	P	1	1	3		
Tanypodinae			P	P	P	P				P	3	1	1		2			P	P					1
Stenelmis	1			P		P	P		P	1	1	1			P	P	P	P	P	P				
Hydraenid				P	P	P					2					1	1	1	P	P				
Dytiscid											1	P							P			P		
Gyrinid	P	P	1	P	P				P	P							P		P			P		1
Hydrophilid	1																							
Planaria	1	1	1	4	1	3	1		2	4	10				1	2	1	2		2	P	1	1	2
Hydra						P													P	P				
Limnodrilus	P										P								1					1
Nais			1	4	10	15	16		1	P						P	17	58	73	13	P	1		1
Chaetogaster				1	1	P									P		7	1	P	P				
Branchiura	P										P													1
Naididae	P					5			2		P				P	P	P	P	2	1		1		
Collembola			P			P	P									P								
Ostracoda (incl.Cypridopsis)						5	3			P	P				P			P		P	1			
Burnupia					P	P					P													
Ceratopogonidae						P			P	P	2		1		P		P	P	P	P				
Rhagionidae	P	P		1	P	1	P		P	1	2				P		P		P		P			1
Tabanidae											1						P	P						
Simuliidae	43	30	37	10	42	6	32		14	66	8	50	17		7	52	12	4	4	20	37	11	24	8
Hydrachnellae	1	2		1	P	P	1			P	2		4		P	1	P	P	P	1		3		
Pelecypoda	P									P	2								P					
Zygoptera			P								P													
Total Number in Sample	1440	819	2383	995	2164	1510	1711		277	2100	599	375	[illegible]		246	1424	1074	1318	2802	751	559	300	218	220

FIG.A14 : Percentage composition of taxa found at station 11 from March 1972 to February 1974.

*P = less than 0,5% present

	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.
Baetis harrisoni		10	26	20	20	4	23	6	P		4	P	6		8	14	9	11	12		13	2	17	10
Afronurus			P										P											
Choroterpes															P								P	P
Caenidae									P															
Centroptilum													1			P								
Cheumatopsyche afra		10	9	9	7	2	2	5	3		13	1	9		2	2	P	P	P		3	5	5	3
Cheumatopsyche thomasseti		17	5	19	14	4	3	6	14		17	12	21		13	3	2	1	1		9	7	30	43
Hydroptila		10	1								P	P	1		P	1	P						2	6
Ecnomus		P							P		P	1			P									P
Amphipsyche																							2	3
Chironomini		1		P	1	2	1	5	6		7	16	3		2	2	3	2	1		22	3	16	8
Orthocladinae		12	15	3	6	1	10	11	15		15	30	16		6	8	15	6	10		26	6	9	4
Tanytarsini					P			P	P		P	P			P	2	3	1	2					
Tanypodinae									P		1	1	1		P									1
Stenelmis		4	P	1	P	1	1				6	1	11		2	2	1				P	19	2	7
Hydraenid				7	3						P		P								P	P		
Dytiscid																							P	
Hydra						P	1	P								P					P			
Planaria		8	2	8	4	7	9	29	4		10	1	2		3	3	5	5	5		11	15	10	6
Hirudinea								P									P					P		
Limnodrilus		2		2	4	6	1	5	2		1	3	4		P	3	2	P				6		
Ilyodrilus		1			1	1	P	2	P		P	2	3		1	3	P	P	P		P	9		P
Nais		1	1	7	3	37	30	6	P							1	46	62	43		10			1
Chaetogaster				1	4	2						P			P	1	3	3	P		1			
Branchiura		1	P			P		P				1	1		P	P	1					P		
Naididae		2	P	11	27	31	16	2	P		2	4	2		4	13	5	4	2		P	13	2	1
Collembola							P	1	1															
Ostracoda (incl.Cypridopsis)						P		P									P							
Burnupia		P	1	P		2	P	3	1			1	1		2			P	P		1	4	2	
Culicidae																P	P							
Ceratopogonidae		P																						
Rhagionidae																P								
Simuliidae		18	41	12	5	P	2	7	53		23	25	19		55	42	5	5	24		4	2	P	2
Pelecypoda		4	P	1		P	1	12	P		P				P	P	P		P			6		P
Zygoptera																						P		
Total Number in Sample		2983	739	882	3132	3672	2828	911	911		1343	455	257		1211	1441	1612	1297	3664		1005	1628	[illegible]	382

FIG.A15 : Percentage composition of taxa found at station 12 from March 1972 to February 1974.

*P = less than 0,5% present

	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.
Baetis harrisoni	25	12	10	16	17		77	25	4	2	3	1	5				4		12		P	P	2	
Baetis latus	4	P	1			P	P			P	1	1	1		1	4	1							4
Caenidae		P								P	1	1	1		2	5	1		P	6	P	1	1	2
Choroterpes	P	P	P								3				1	4	P		P					4
Centroptilum		P						P		1							P			2				
Cheumatopsyche afra		P	P		P		P		1		2	2	3				P				P	P		
Chematopsyche thomasseti	3	7	6	5	4		1	36	21	38	30	22	20		1	1	1				2	1	P	
Hydroptila	1	5	3	P	1	P		1		P	1	1	3		4	1	P		P		1	1	1	
Ecnomus																							1	
Amphipsyche																					P			2
Chironomini	1	1	1		P	5			50	2	P	1			6		2		2	2	18	9	31	17
Orthocladinae	4	11	9	9	14	62	7	22		11	20	28	40		42	24	28		30	43	44	32	29	35
Tanytarsini	1	P	1		P	10				P					10	19	5		4	4	6	9	4	
Tanypodinae						2			1	2	1								P	2	1	1	2	10
Stenelmis		P						P		P	1						1		P					
Hydraenid				1	1	5	P		1		7					15	8		9		P	P		
Gyrinid	P	P	P	1		3	1		P								P		P					
Hydropholid		1	1																					
Hydra																								
Planaria	P	1	1	2	1		2	5	8	12	17	2	1				2		6	1	4	5	1	2
Limnodrilus											1								P	1		P		
Ilyodrilus																			P					
Nais				P	P	1	1	1	1			1	1		2		36		22	23	6	7	11	6
Chaetogaster				P											1	10	2			1				
Naididae		1				1			P	P		1	1		9		4			6	3	13	12	14
Collembola										P							P							
Ostracoda (incl.Cypridopsis)			P	P			P	P			4	1			1	1			P		P	1	1	
Burnupia		P					P		1	2	1	1	1							1		1		
Culicidae																				1				
Psychodidae																	P			1				
Ceratopogonidae		P				1			1	1	1	1			1		P		2	1	P	1	1	
Rhagionidae																			1					
Tipulidae																	P		1					
Simuliidae	60	60	66	64	62	P	10	7	10	27	5	39	25		12	8	6		1	1	3	1	2	
Hydrachnellae	1		1	1	1	10	P	1		1	2		1		6	4	P		8	6	12	18	1	4
Pelecypoda	P				P					1	1	1	1		1	3	P		P				1	2
Anisoptera	P					P																P		
Total Number in Sample	2797	1257	1102	1126	1408	333	2473	279	266	531	227	184	221		140	101	2031		501	206	599	519	210	52

FIG.A16 : Percentage composition of taxa found at station 13 from March 1972 to February 1974. *P = less than 0,5% present

	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Febr	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb
Baetis harrisoni	28	36	61	50	25	7	16	12	1		1	1			5	18	6	10	12		11	6	9	3
Baetis latus	8	1	4	P		P									P	P								
Baetis quintis								P				1												
Caenidae	P															P								
Choroterpes											1	1									P			
Centroptilum																	P							
Cheumatopsyche afra	1	2	2	2	1	1	P	3	2		4	2			1	1		P	P		2	16	11	6
Cheumatopsyche thomasetti	31	28	23	7	6	4	3	16	53		29	21			6	7	1	2	1		18	14	28	50
Hydroptila		P	P								1	1				P	P						1	
Ecnomus			P	P							1				P		P					P	1	8
Chironomini	4	3	1	P	P	1	1	9	1		9	19			[illegible]	1	3	2	P		23	25	5	5
Orthocladinae	1	4	4	2	3	1	9	15	19		49	28			7	10	54	14	20		13	18	29	5
Tanytarsini	1				P		P	P	1		1	1			P	6	5	P	P		1	1		
Tanypodinae	3								1		2										P		1	
Stenelmis	P		P	P	P						2	1					P				2			2
Hydraenid				P	P				P							P	P	P						
Dytiscid			P																					
Hydropholid			P																					
Chrysomelid				P																				
Hydra	P					P	P												P		2'	1		
Planaria	P	P	1	P			1	7							P				P		7		1	1
Hirudinea								P													1			
Limnodrilus			P					1							P		P				5	1		
Ilyodrilus																	P	P			P			
Nais	P		1	15	42	68	60	1									15	67	55		7	1	1	1
Chaetogaster				2	P	P											8	3			1			1
Branchiura																	P	P						
Naididae	1				7	16	5	2			1	P				P	2		P		2	2		
Collembola		P							P						P							P		
Ostracoda (incl.Cypridopsis)	P						P	1									P	P			1			
Burnupia											1				P	P	P				3	13	16	17
Culicidae		P																						
Psychodidae		P																						
Ceratopogonidae	P																							
Rhagionidae			P												P									
Simuliidae	22	25	3	23	14	2	4	30	22		1	25			80	57	4	2	11		P	3		3
Hydrachnellae	P		P					P				P			P	1		P			P	P		
Pelecypoda	P		P																P		4			
Zygoptera								P										P	P			P		
Physopsis						P	P	2													P			
Biomphalaria	P																							
Total Number in Sample	2151	1016	459	1317	2661	2777	5721	622	845		218	433			1526	650	830	2698	3006		665	455	388	109

FIG.A17 : Percentage composition of taxa found at station 14 from March 1972 to February 1974.

*P = less than 0,5% present

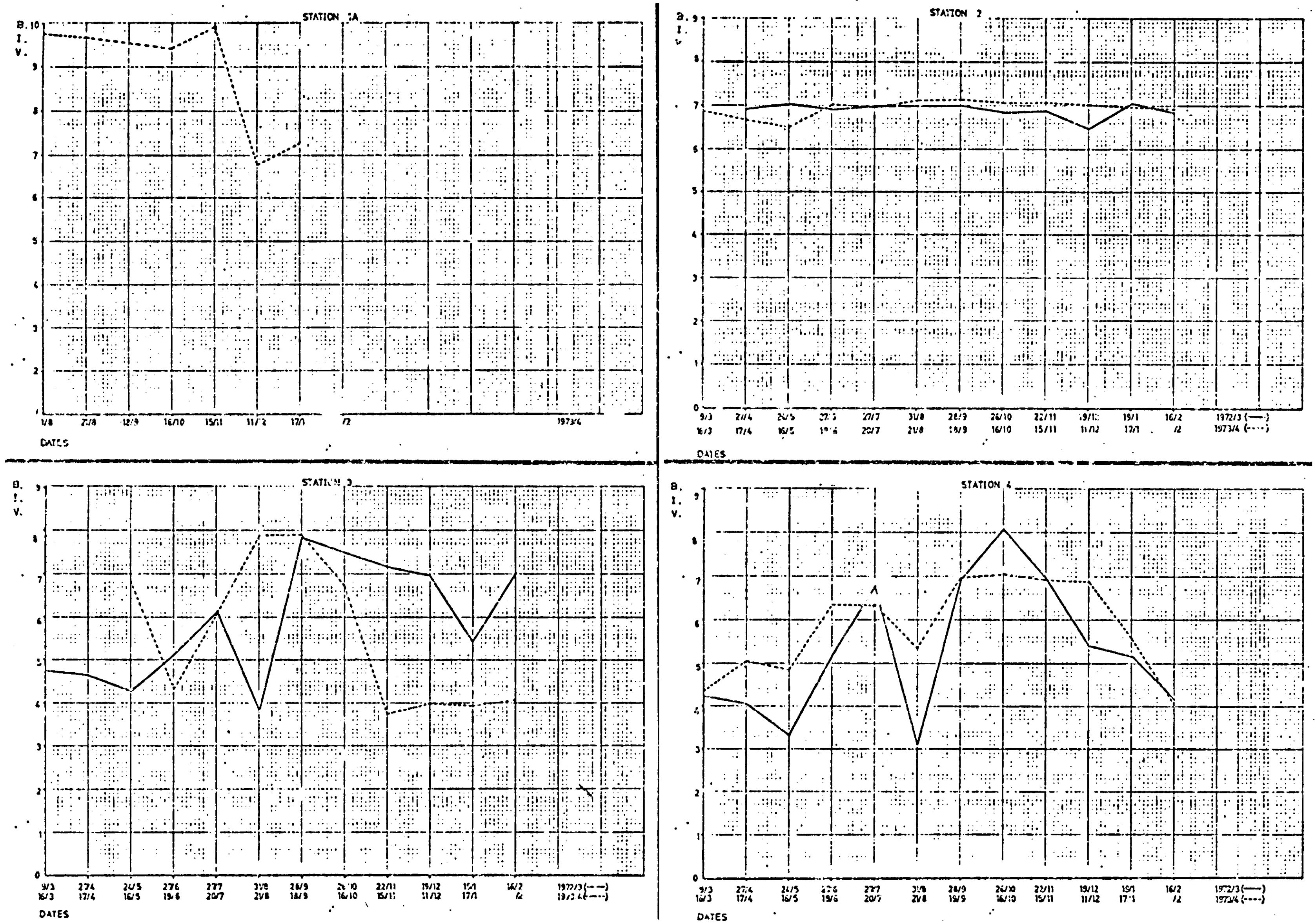

Figure A1: Monthly B.I.V. for sampling stations 1A, 2, 3 and 4.

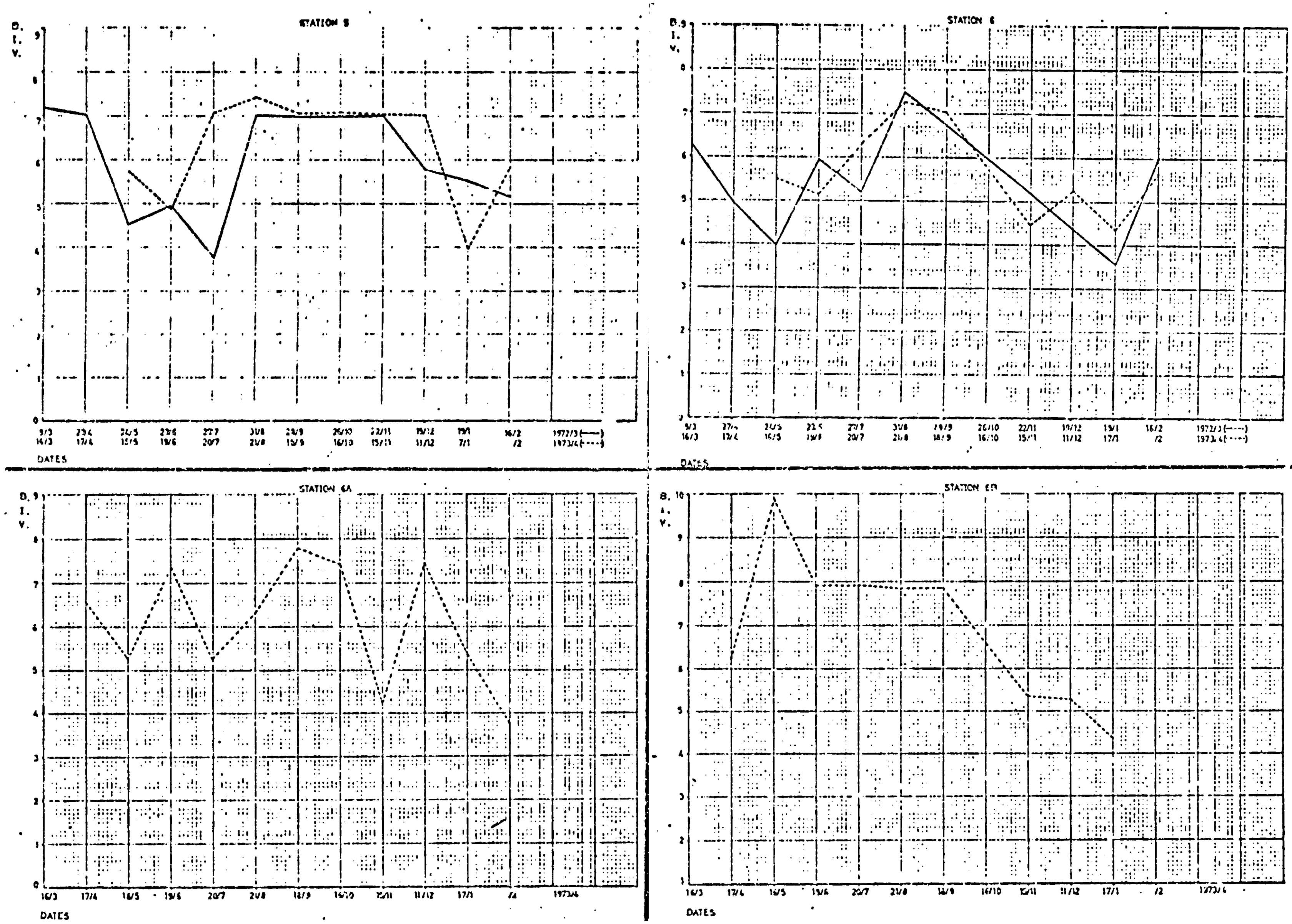

Figure A2: Monthly B.I.V. for sampling stations 5, 6, 6A and 6B.

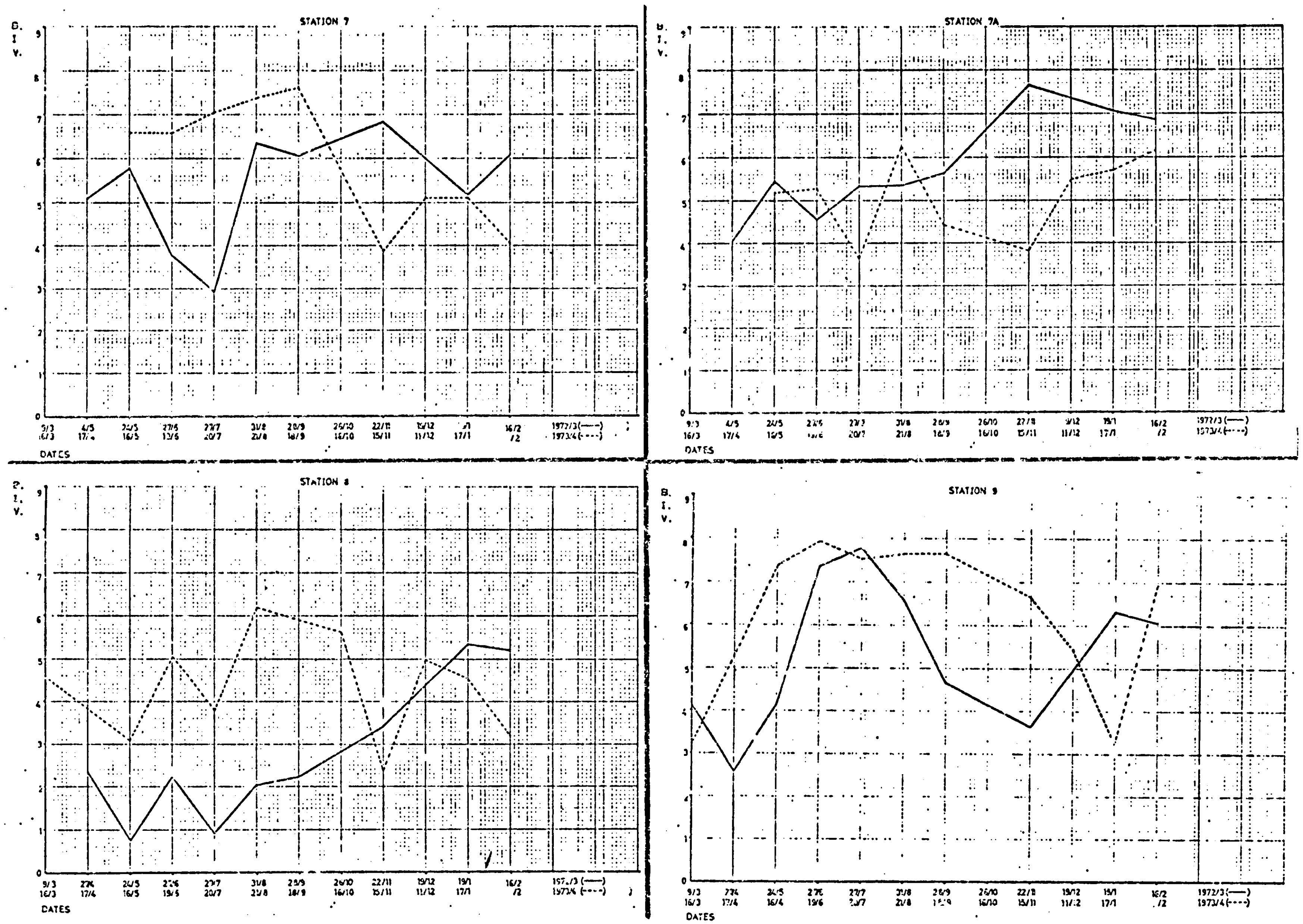

Figure A3: Monthly B.I.V. for sampling stations 7, 7A, 8 and 9.

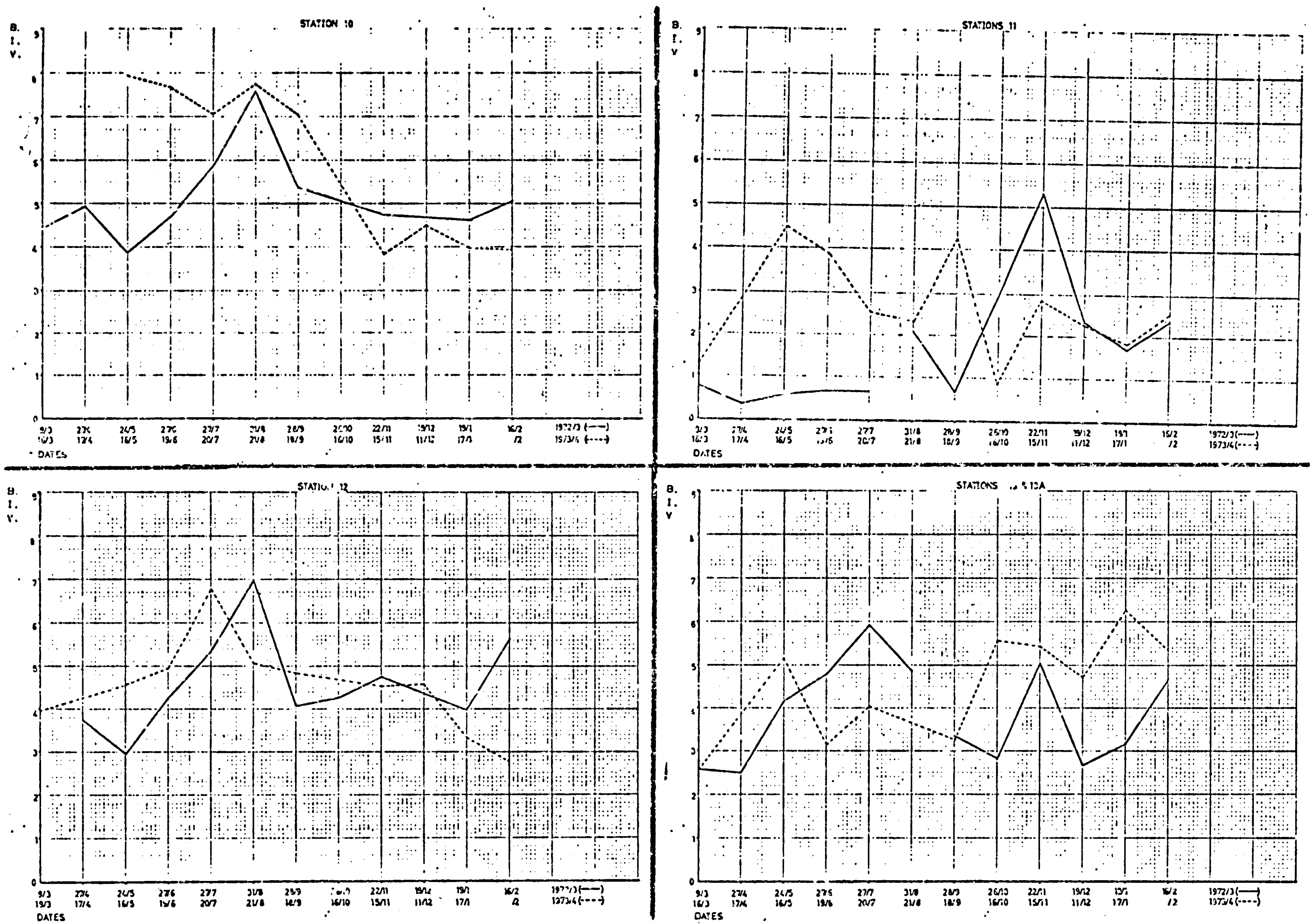

Figure A4: Monthly B.I.V. for sampling stations 10, 11, 12 and 13.

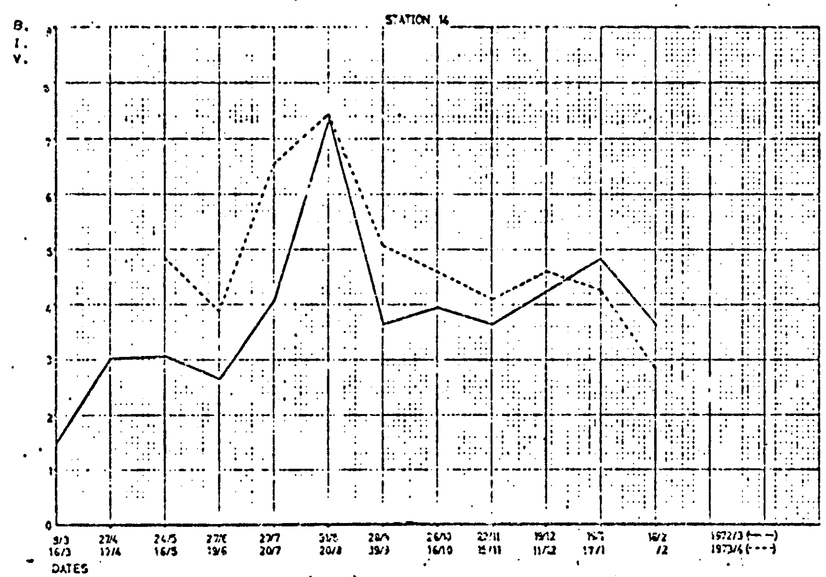

Figure A5: Monthly B.I.V. for sampling station 14.

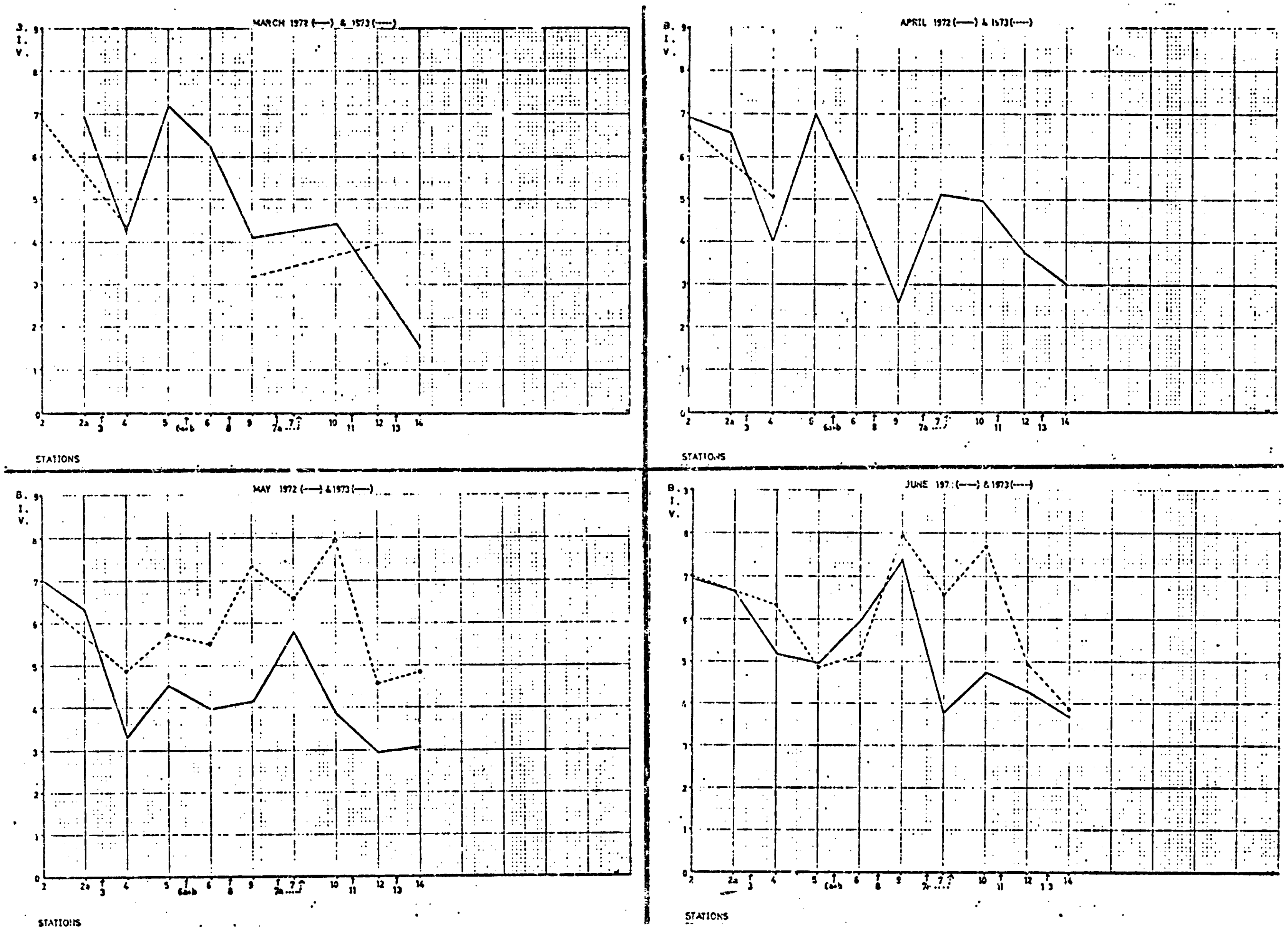

Figure A6: B.I.V. for March to June 1972 and 1973.

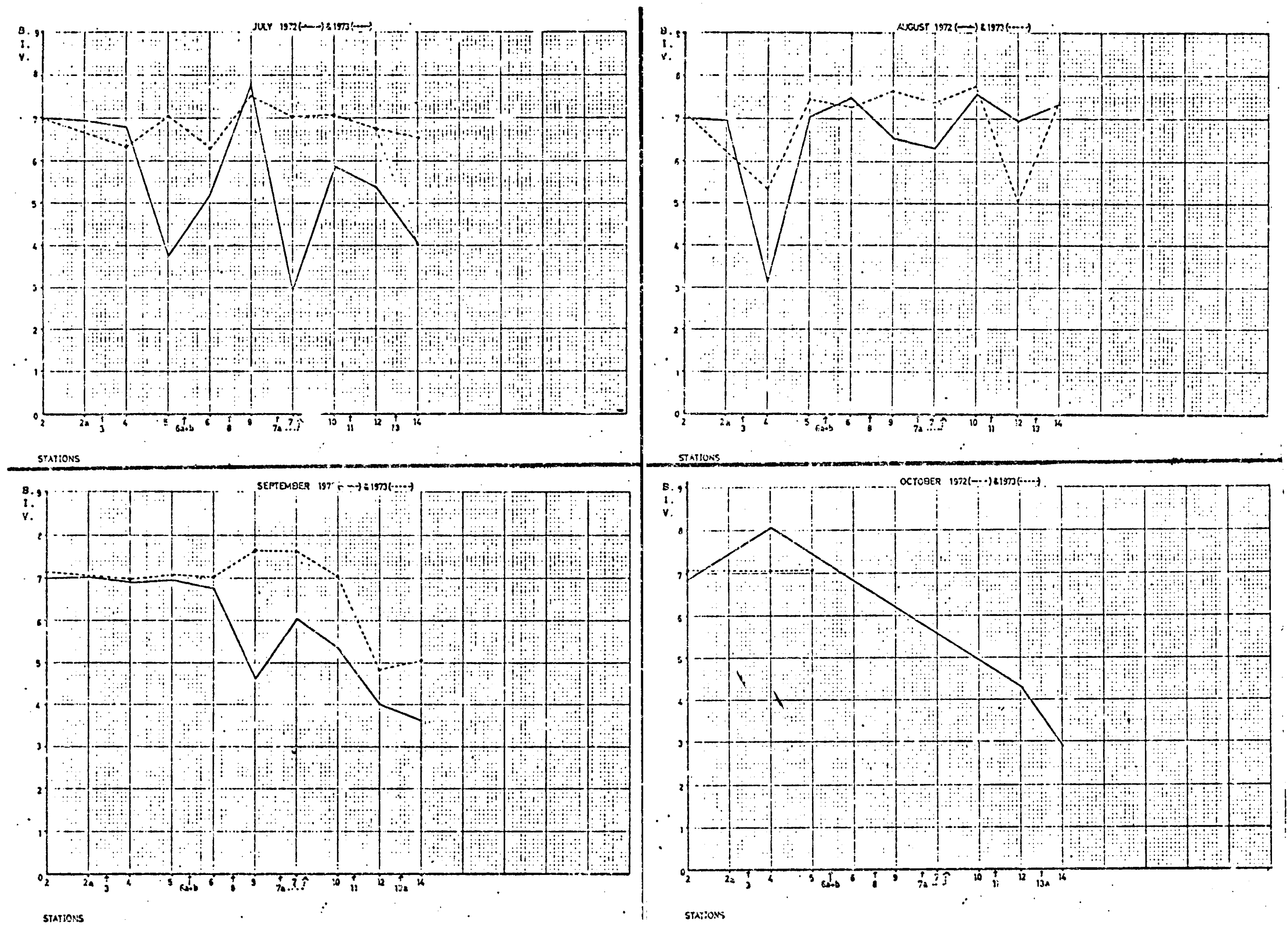

Figure A7: B.I.V. for July to October 1972 and 1973.

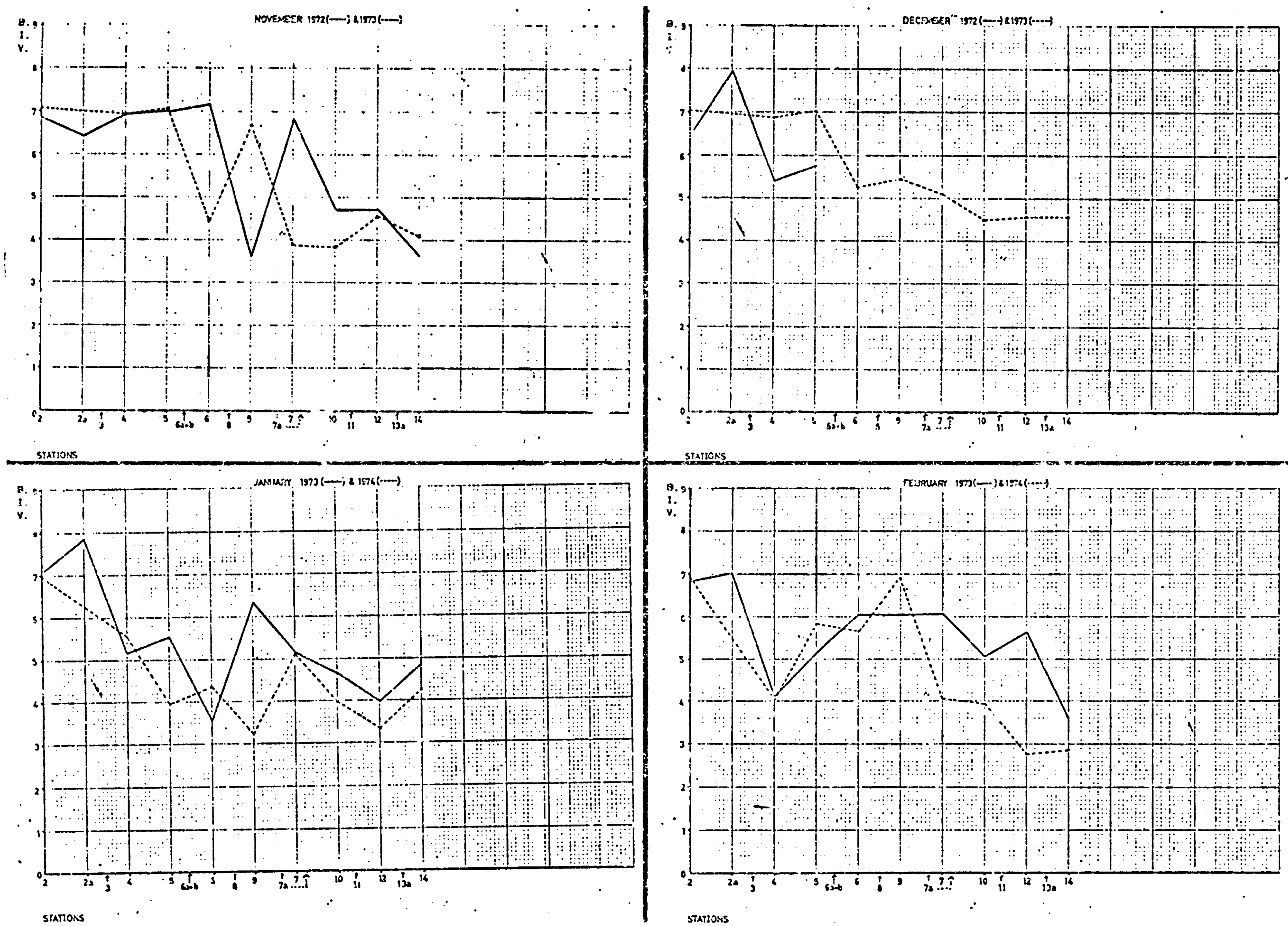

Figure A8: B.I.V. for November and December 1972 and 1973 and January and February 1973 and 1974.