THE INDICATOR VALUE OF THE STONES-IN-CURRENT FAUNAL ASSOCIATION IN A SOUTH AFRICAN RIVER SYSTEM

by

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SYNOPSIS

This is a presentation of the first phase of data reduction of a two year survey of the fauna and influencing environmental characteristics of the Jukskei-Crocodile River system. Relationships within the fauna are discussed and a preliminary analysis of relationships between the fauna and the abiotic results has been done.

OPSOMMING

'n Uiteensetting van die eerste fase van die dataverwerking van 'n opname van die fauna en die kenmerke van die omgewingstoestande wat dit beïnvloed word gegee vir die Jukskei-Krokodilriviersisteem oor 'n periode van twee jaar. Onderlinge verwantskappe in die fauna word bespreek en 'n voorlopige ontleding van die verwantskappe tussen die fauna en die nie-biotiese gegewens is uitgevoer.

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) states that streams and rivers are related to and dependent on their terrestrial surroundings. Through rivers the landscapes eliminate the end-products of their whole metabolism thus acting 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 carries the end-products of civilization, both industrial and domestic.

As rivers tend to approach steady-state conditions (Curry 1972) a 'typical' biota may be expected to develop in the river system or parts thereof. Natural or man-made perturbations of a river may result in changes in the abiotic and thus the biotic characteristics of the system. These changes may have an adverse effect on the uses of the river system. To minimize these adverse effects the river system management must be based on a complete knowledge of the biotic and abiotic relationships in the system.

Ideally, a complete river simulation model incorporating all possible interrelationships is needed to implement river management techniques. However, in practice, the problems in obtaining this amount of data would be virtually insurmountable. Thus in order to obtain ecological theories on the interrelationships within a system, which can be developed and tested for adequate watershed management policies, the most practical system seems to be a complete evaluation of the inter- and intra-relationships of one aspect of the ecosystem with as many major influencing factor as possible. In this study the stones-in-current fauna of a river system is being compared with all the abiotic factors of the environment, both physical and chemical, which are thought to have an important influence on it.

It is now becoming generally accepted that the mere presence or absence of a species cannot be considered indicative of a particular state of pollution. Thus the more recent trend is to delineate indicator communities i.e. populations not species reflect water quality (Richardson 1929, Wurtz 1955, Gaufin and Tarzwell 1956, Brinkhurst 1966, Chandler 1970, Chutter 1972).

The value of using the macroinvertebrate fauna as the basic factor in assessing water quality has been extensively debated (Wurtz 1955, Hynes 1958, Brinkhurst 1966, Chandler 1970, Kaesler and Cairns 1972).

The macroinvertebrate fauna of a river can be very complex, with habitats ranging from bare rock via shingle to sand, mud and beds of water-weed. Chandler (1970) found that the 'riffle' or stones-in-current habitat, where broken water flows rapidly over a bed of loose stones, is the best for pollutional studies. It is here that the animals most sensitive to pollution are likely to be found. In addition to this important facit of the stones-in-current habitat there is also the fact that the faunal communities occupying it are the easiest to analyse which recommends it (Chutter 1972).

The Jukskei-Crocodile River system as covered by this study includes both clean water and polluted tributaries. Amongst the latter both organic and mineral pollution occurs, with the possibility of either thermal or toxic pollution in one tributary. The system should thus provide a range of conditions which will give a complete evaluation of a wide range of community types.

The purpose of this paper is to present the data obtained on the intra-relationships of the stones-in-current fauna of the Jukskei-Crocodile River system as well as a preliminary analysis of their inter-relationships with the abiotic parameters of the system. This is done principally by statistical procedures in order to obtain the utmost objectivity.

METHODS

SAMPLING PROCEDURE (Data collection)

Sampling sites and sampling frequencies

Nineteen sampling stations were selected. These were situated in order to obtain the maximum possible information on the sources of pollution i.e. where a tributary or effluent inflow enters the main stream a station was established on either side of this point and a third one was placed on the tributary itself.

A schematic presentation of the sites of the sampling stations is given in Figure 1.

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

DETERMINATION OF CHEMICAL STATUS

All chemical analyses, based on standard methods, 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.

The following analyses were performed -

> total alkalinity (as $CaCO_3$), Kjeldahl nitrogen; ammonia nitrogen; nitrate nitrogen, nitrite nitrogen; total phosphorus; ortho-phosphorus; chemical oxygen demand; methylene blue active substances; chloride; sulphate; total carbon; organic carbon; sodium; potassium; calcium; magnesium; conductivity.

These results are dealt with in Toerien, Wilkinson and Schoeman (in prep.).

DETERMINATION OF OTHER ENVIRONMENTAL FACTORS

Water temperatures and pH were measured *in situ* with a thermometer and a portable pH meter (Metrohm E444) respectively.

Productivity of the system was measured by doing algal bioassays as described by Steÿn (1974) to give algal growth potentials (AGP).

A value of solids in suspension was determined for each sample as excessive silt and sand can affect the invertebrate fauna (Chutter 1969).

DETERMINATION OF THE FAUNAL ASSOCIATION

The stones-in-current fauna were sampled using a Surber sampler (Surber 1936) with a pore size of 250 micron.

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

All invertebrate 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 were to generic or specific level although 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 further classification unnecessary. This helped limit the number of taxa sufficiently to be dealt with by the necessarily limited capacity of the computer in the statistical analyses.

ANALYTICAL PROCEDURES (Data reduction)

Biotic index values (BIV)

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 organic pollution of flowing water and summarizes the deviation of the observed community from the community which would be expected where the water is in an unenriched natural state. The biotic index ranges from 0 to 10. An index value of 10 indicates heavy organic pollution whereas an index value close to zero indicates a clean river.

BIV's were calculated for every sample in order to analyse the eutrophic state of all sections of the river system. 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 invertebrate communities are not only influenced by organic pollution. Secondly, the considerable instability of flow and river-beds in the rainy season must be taken into account before one is able to determine how much of this observed deviation is a result of pollutants.

Cluster analyses

The first stage in a clustering technique of this sort involves the choice of a coefficient of similarity. Several such coefficients have been described in the literature but a number of these have been proposed for taxonomical studies and are untenable for an ecological survey.

The coefficient of similarity necessary for this study must recognize these criteria. Firstly it must employ presence-absence data. Allen and Koonce (1974) have demonstrated the usefulness of presence-absence data in comparisons of ecosystems.

Secondly relative abundance of the taxa to one another must be considered.

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 and Sneath 1963). It has been decided that for this study negative matches should be excluded.

There are indices of similarity in the literature which simultaneously take account of the taxa present and their relative abundance to one another. However, following the example of Chutter et al (in press) 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.

The first index of similarity is the Czekanowski index which takes only the presence or absence of taxa into account. Their relative abundance is ignored and rare animals carry as much weight in the calculation of the index value as do common animals.

The percentage of similarity index is the second index of similarity used. In its calculation the abundant animals are of maximum importance.

The combination of these two indices of similarity was found by Chutter et al (in press) 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. This was done with the taxa being the OTU's which were compared with each other on the basis of occurrence at all sampling points.

The third stage of this analysis is the clustering itself. The clustering strategy used here to present the data in an easily discernable form 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 methods (Kaesler and Cairns 1972). The graphic display of clusters is by means of dendrograms.

The computer program used is shown in Figure 2.

The final stage of the cluster analysis 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. 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, a product-moment correlation 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 one can assume that averaging similarities, forcing taxa into a hierarchy and clustering hyperspheroidally have not introduced too great a distortion of the information content of the original matrix of similarity coefficients.

Factor analysis

Five groups of the fauna and the BIV were compared by this multivariate analytical procedure with the abiotic characteristics of the system. These were the Oligochaetes, Chironomids, Simuliidae, Tricoptera and *Baetis harrisoni*

The squared multiple correlation coefficients were used as the initial estimates of the communalities. The estimates of communalities and the factor analysis were carried out on an IBM 360 computer using the program BMDX 72 of Dixon (1970). Eight factors were calculated and the varimax rotation was used.

RESULTS AND DISCUSSION

BIOTIC INDEX VALUES

The results obtained for all stations throughout the period of the survey are presented graphically in Figures 3 to 10. Figures 3 to 7 present the BIV for each month at each station while Figures 8 to 10 show the change in BIV down the main stream of the river in flow sequence, and indicate incoming tributaries, for each month.

In this section it will be necessary to assume that the empirical biotic index (Chutter 1972) will give values reasonably indicative of the state of organic pollution. From this one will be able to summarize the most important characteristics of populations under various conditions. The value of these observations will be tested by the subsequent statistical analyses so that populations influenced by factors other than pollutants can be tested for reliability.

The relatively subjective picture drawn from these results can be verified or rejected on the basis of the statistical comparisons between the various taxa composing the population and between them and the abiotic environmental factors.

The results obtained from station 2 are the best to consider as a basic population due to the relatively stable conditions existing at this point. Also the chemical studies, extensively reviewed by Toerien, Wilkinson and Schoeman (in prep.), and diatom studies on the system (Schoeman (pers. comm.)) verify that the BIV is an accurate representation of the status of organic pollution at this point. The BIV is constant at about 7 units which according to Chutter (1972) is a borderline condition between 'enriched water' and 'polluted water'.

The faunal association found under these conditions is summarized in Table 1.

The most notable characteristics of this site are :

(1) A relatively constant flow
(2) High nitrogen concentrations
(3) Low phosphorus concentrations
(4) High mineral concentrations

Under these conditions the faunal association consists almost exclusively of Chironomids, mainly Chironomini and Orthocladinae. The Simuliidae form the only other significant part of the association but the presence of Baetis harrisoni is worth noting as it is relatively constant.

Station 5 showed a constant BIV = 7 during the months July to December in both years of the study.

Once again the association consisted almost exclusively of Chironomids but the Simuliid contribution to the population has dropped and the Oligochaeta (Limnodrilus, Ilyodrilus and Naididae) start increasing. When one considers that the average BIV for station 5 in these months tends to be slightly above 7 while at station 2 it tends to be lower than 7, an interesting point emerges. At station 1A (BIV = 9) and station 6B (BIV = 8) there is a tendency for the Oligochaetes to move into the dominant position in the faunal association while the Chironomids drop off sharply (see Table 2).

This shows the tendency, of which there was an indication at station 5, to move from a Chironomid dominated population to an Oligochaete dominated population with increasing eutrophication. At a BIV of 8 the Nais sp. tended to be the dominant Oligochaetes while increasing eutrophication results in these being replaced by Chaetogaster and Ilyodrilus sp.

Conversely where the organic status moves away from BIV = 7 to lower values the tendency seen at station 2 for Simuliid larvae to increase becomes more marked. There is a simultaneous decrease in the Chironomid population (see Table 3).

Biotic index values of 4 - 5 indicate 'slightly enriched' waters (Chutter 1972). These areas show a tendency for the faunal composition to diversify with more species in each taxon being present.

The Tricopterans consist mainly of Chaematopsyche sp. while the Oligochaetes are principally Nais sp. Ephemeropterans other than

B. harrisoni are rare.

Station 14 has a lower average BIV than the other two stations represented in Table 3 and it shows a tendency towards less Oligochaetes and Planarians and more Tricopterans.

At station 11 the BIV ranges from 1 to 4 and here the diversification is greatly increased with no very obvious dominants. There are however a few notable characteristics of these associations in cleaner-waters. Firstly, a significant contribution is made to the faunal association by Ephemeropterans other than B. harrisoni i.e. Afronurus, Neurocaenis, Caenidae, Charoterpes, Centroptilum and other baetids.

Secondly, the Chironomid population of the clean waters differs from that found at station 2 in that the Tanytarsini and Tanypodinae make a significant contribution while Chironomus tends to be absent.

One taxon that appears to be misplaced in the Biotic index is the Collembola which have been given an index value of 0. They are however present at the more eutrophic stations of the river and are principally associated with faunal associations dominated by Chironomids.

CLUSTER ANALYSIS

Percentage similarity

The dendrograms based on the percentage similarity matrices are given in Figures 11 to 13.

Other than the taxa that show little relationship to the main clusters which are invariably those that occurred rarely and in insignificant numbers these two dimensional representations show all the taxa separated into two main groups.

The first group includes taxa which are associated with (from the BIV and chemical results) a wide range of conditions together with those associated with the more polluted stations. The second group consists of taxa associated with non-eutrophied conditions or the lower range of biotic index values.

The reason for the more ubiquitous species being grouped with the inhabitants of organically polluted waters may be a result of the fact that far more stations were of the enriched to polluted category than the clean water one.

Group 1 : In the dendrogram involving all the data there appear to be two main clusters : The first shows a close association between the most ubiquitous species : Simuliidae; B. harrisoni; Orthocladinae and Chironomini. These are the same species which formed our basic condition at a BIV = 7 in our earlier assumptions. This group is joined by a cluster consisting of Planaria, Chaematopsyche afra and C. thomasseti at an r value of 16,19. At r = 13,65 a cluster consisting of Naididae, Nais sp. and Chaetogaster joins the main cluster. The fact that these three Oligochaete taxa which are found over a wide range of conditions join the main cluster at an r value only slightly higher than that at which the second cluster of this group joins the main cluster suggests that, although closely associated with the more ubiquitous species which apparently indicate the middle range of conditions, increases in their relative abundance could indicate a closer relationship with the members of the second cluster.

This second cluster consists of Collembola, Chironomus, Ilyodrilus, Limnodrilus, Brandchiura and Hirudinea. These are all species which tend to dominate the faunal associations of highly eutrophic water. The position of the Collembola in this group and its close association with Chironomus in all clusters supports the conclusion reached earlier that it is misrepresented in the Biotic index.

Cypridopsis and Hydra show a linkage to the main cluster at r = 7,7 and to the secondary cluster at r = 5,27 which suggests that they are species ubiquitous in the enriched to polluted zones.

During the winter those forms which appear to be representative of the most eutrophied conditions, Chironomus, Collembola and Hirudinea form a separate cluster with the Psychodidae and Eristalis. Hydra is also in this cluster suggesting that its position in the above dendrogram may misrepresent its true affinities.

In summer the relationships are similar to those in the full year's data.

Group 2 : The fact that all the Ephemeropterans other than the ubiquitous B. harrisoni are clustered in this group suggests that these taxa indicate relatively clean water conditions.

The main cluster of this group shows an association between Hydroptila, Charoterpes, Afronurus, Neurocaenis, Caenidae and B. quintus. Linked to this cluster at r = 14,46 is a cluster consisting of Pelesypoda, B. latus, Ceratopogonidae, Centroptilum and the Chironomid, Tanypodinae. Thus all the Ephemeroptera are included here other than B. harrisoni and B. glaucus. This latter shows no affinities to either of the main clusters as a result of the fact that it was rarely encountered in samples.

The rest of the taxa in group 2 do not show marked relationships but are obviously better represented in waters characterized by the above association than in the more eutrophied waters.

Czekanowski similarity

The dendrograms based on the Czekanowski similarity matrices are given in Figures 14 to 16.

The relationships based on the presence or absence of taxa shows the same two groupings composed of the same taxa as was found in the percentage similarity relationships. The interrelationships between them tend to be at much higher r values than described above. This shows that although the correlation between relative abundance of taxa forming an association is not great, these taxa do occur together in most cases and their mutual presence or absence in an association can be indicative of the conditions prevailing in the habitat.

There is so little difference between the summer, winter and combined data that one can safely assume that the stones-in-current fauna show little seasonal variation and that life cycles do not limit them to any particular time of the year. This is shown clearly in the relationship between the larval and adult forms of Stenelmis sp. There appears to be no time when only one or the other occurs.

Cophenetic correlations

The cophenetic correlations for these dendrograms based on the method of Sokal and Rohlf (1962) are all above 0,9 showing that there is little distortion in the representation of the data.

Factor analysis

A factor analysis was carried out to show the relationships between groups of animals and the chemical and physical factors influencing them. The factors and loadings are presented in Table 4. All parameters having factor loadings of 0,3 (absolute value) or higher were used as suggested by Comrey (1973).

Factor 1 : The parameters with the highest factor loadings are all mineral components (or measures thereof i.e. conductivity) and nitrogenous compounds. The high loading on Chironomids in this factor suggests that the distribution and abundance of this group may be determined by either the mineral concentrations or the nitrogen content or both. The loading on MBAS in this factor does suggest that mineral loads and sewage effluents may have similar origins. However, the low loading on ortho-phosphate and total phosphate (a significant factor in sewage effluents) suggests that the Chironomids as a whole are more influenced by mineral pollution than by organic pollution. This may, however, be a characteristic of the Orthocladinae and Chironomini only due to the fact that they constitute a major part of the Chironomid population.

The negative loadings on Simuliidae and Tricoptera are significant but not highly so suggesting that they do form a part of the association under these conditions but tend to be represented by low numbers. This confirms the observations already made which showed that they only form a small part of the faunal association where Chironomids dominate and increase in numbers as the state of enrichment decreases.

The loading on BIV seems to indicate that it is a good general measure of river quality but that although compiled to provide a measure of organic pollution it seems to be representative of mineral conditions as well. However, due to the possible common source of these compounds this is not conclusive.

Factor 2 : This illustrates the CO_2-bicarbonate-carbonate buffer system. This appears to have no influence on the invertebrate fauna.

Factor 3 : The most significant loadings in this factor are on phosphorus. The loading on MBAS suggests that this is principally from sewage sources.

The Oligochaeta have a significant factor loading which suggests that they are the dominant fauna of the sewage effluent. The fact that the loading is not very high may be occasioned by the fact that the Nais sp. form a large part of this group and all previous evidence points to their being of a more ubiquitous nature. This suggests that it might be advantageous to break up this group for a comparison with abiotic parameters.

Factor 4 : This factor suggests a strong relationship between B. harrisoni and temperature. The suggestion in this association that the occurrence of B. harrisoni in the river system is more dependent on a physical parameter than a chemical one concurs with the ubiquitous nature of this organisms. However, the correlation with temperature may be an indirect one because the increased temperatures associated with a decline in the B. harrisoni population are also associated with seasonal changes in the river system. The winter and summer dendrograms do not suggest a period of decrease in numbers due to characteristics of its life cycle so a possible parameter associated with temperature which may affect it is the high degree of flooding in the summer period.

The effect on chironomids appears to be the exact opposite as it has a positive laoding as approved to the negative loading on B. harrisoni. This relationship between these two taxa concurs with the evidence in Section 1.

Factor 5 : pH has a highly significant loading. None of the faunal groups are significantly loaded indicating that pH in the range experienced in this river system has little effect on the fauna.

Factor 6 : This factor indicates that the Tricoptera are important in the determination of the BIV because it had the highest correlation coefficient with BIV of all the invertebrate groups. This may be due to the fact that the Tricoptera are the only group included here which have a fixed biotic index value rather than a sliding scale of values dependent on the association (Chutter 1972).

Factor 7 : Shows no effects on the invertebrate fauna.

Factor 8 : The positive loadings on COD and Oligochaetes indicates that the oxygen availability does not affect this group of invertebrates. Conversely, the negative loading on the Simuliidae suggests that low oxygen concentrations are not suitable for their optimum population growth.

CONCLUSIONS

INTRA-RELATIONSHIPS WITHIN THE FAUNA

All the evidence points towards the faunal associations revolving around a hypothetical population consisting of equal proportions of Orthocladinae, Chironomini, Simuliidae and B. harrisoni. This hypothetical population would ideally indicate conditions exactly midway between perfectly clean water and highly polluted water. As eutrohication increases from this point the Chironomids increase in numbers while the other three taxa decrease until the Chironomids dominate the association completely in enriched waters. At this stage a small percentage of Oligochaetes, principally Nais sp. occur.

With further eutrophication the Chironomids are gradually replaced by Oligochaetes, first Nais sp.and then under highly polluted conditions Chaetogaster, Ilyodrilus, Limnodrilus and Branchiura tend to dominate the association.

Although conditions in the Jukskei-Crocodile River system were never so polluted as to verify it, there seems to be a tendency to show that the Oligochaete dominated association will be replaced by one consisting principally of Chironomus, Psychodidae, Eristalis, Hirudinea and Collembola under extreme conditions of eutrophication.

Conversely, if the hypothetical population shows an increase in B. harrisoni and Simuliidae with the introduction of Chaematopsyche sp. and Planaria and a decrease in the Chironomids the water is of an improved quality and could be termed slightly enriched.

If the Tricoptera increase enough to dominate a diverse population this would be indicative of relatively clean waters.

Very clean water should be indicated by a population consisting of a wide variety of taxa none of which dominate it, where the various Ephemeropterans are well represented.

It must be borne in mind that this refers to the relative abundance of these forms and not to their mere presence. Any of these invertebrates can be found under any of the conditions described.

INTER- RELATIONSHIPS WITH ABIOTIC FACTORS

The Chironomids appear to be at an ecological advantage under conditions of high mineralization and high nitrogen conditions. They do not, however, appear to favour sewage effluents as they show no correlation with sources of phosphorus. This probably does not apply to Chironomus, Tanypodinae and Tanytarsini.

The Oligochaetes, on the other hand, appear to be associated with sewage effluent sources by their significant correlation with phosphates and MBAS.

The Tricopterans and Simuliidae can survive under conditions of slight organic pollution but are at optimum population growth rates where organic pollution is minimal. They also require higher oxygen concentrations whereas the Oligochaetes do not require this.

pH appears to have little effect on the invertebrate fauna of this river system. However, as extremes are not experienced this is inconclusive.

BIV appears to be a good general measure of both organic and mineral pollution.

FURTHER DEVELOPMENT OF DATA

The data obtained in the above analyses provides a number of interesting hypotheses as well as a picture of faunal associations under specific environmental conditions.

At this stage, however, these tend to be inconclusive and further tests suggest themselves particularly with reference to the influence of factors other than pollutants.

A breakdown of the invertebrate groups used in the factor analysis, into component taxa for comparison with environmental factors will clarify the situation further. The inclusion of river flow as an environmental factor will be useful.

The final stage required to make this data useful in other systems would be the determination of the predictive capabilities of the faunal associations, possibly by means of multiple regression coefficients.

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TABLE 1 : The faunal association associated with BIV = 7

Station	Taxa						
	Planarians	Oligochaeta	Tricoptera	B. harrisoni	Chironomids	Simulids	Others
2	2,8	32,7	56,8	7,4		0,3	1,1
5	0,6	29,7	63,0		3,0	1,3	2,0

TABLE 2 : The faunal association associated with BIV = 8 - 9

Station	Taxa						
	Chaetogaster	Limnodrilus	Ilyodrilus	Naididae	Nais	Oligochaetes	Chironomids
1A	64,2	1,2	19,0	1,8	0,7	87,9	11,8
6B	3,5	0,1	0,8	0,5	88,5	93,5	4,8

TABLE 3 : The faunal association associated with BIV = 4 - 5

Station	Taxa						
	Planarians	Oligochaeta	Tricoptera	B. harrisoni	Chironomids	Simulids	Others
10	5,7	21,5	19,5	11,2	18,5	16,7	6,9
12	10,8	24,9	14,4	9,9	19,5	13,4	7,1
14	1,7	14,5	28,8	6,9	26,1	9,9	12,1

TABLE 4 : Rotated factor matrix and factor loadings for the characteristics

Characteristic	No.	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Factor VII	Factor VIII
Na	1	0,92475	0,00769	0,26209	-0,01634	-0,04040	0,02370	0,01956	0,17427
K	2	0,88822	-0,10740	0,31631	0,02740	0,05495	0,02809	0,07757	0,14663
Ca	3	0,85238	0,32587	-0,08221	0,00251	0,25052	0,00418	0,12343	0,03577
Mg	4	0,55849	0,62668	-0,21714	-0,18744	-0,07691	-0,03771	-0,24783	0,04395
Total alkalinity	5	-0,05898	0,96279	-0,14031	-0,06906	0,22962	0,00761	0,38747	-0,11685
NO_2-N	6	0,65771	-0,04108	-0,06085	0,17369	-0,38801	-0,00661	-0,01396	-0,01565
NH_3-N	7	0,70652	0,09004	-0,01102	-0,03388	-0,48605	-0,05495	-0,02226	0,02015
NO_3-N	8	0,90699	-0,06070	0,23044	0,05401	0,15545	-0,01432	-0,03095	0,12266
Total dissolved N	9	0,93703	-0,10381	0,18206	0,06150	-0,00925	-0,00928	-0,06471	0,08941
PO_4-P	10	0,03288	-0,09052	0,91391	0,10836	0,03213	0,10336	-0,03864	0,15099
Total P	11	0,03646	-0,09339	0,93955	0,03416	0,01098	0,07198	-0,02321	0,11114
COD	12	0,64421	-0,14239	0,40211	0,12634	-0,22023	0,03329	0,17427	0,33049
MBAS	13	0,58822	-0,01613	0,59037	0,06470	-0,00203	0,04003	0,11157	0,13822
Cl	14	0,91190	0,02870	0,16504	-0,08997	-0,07044	0,03800	0,01596	0,27010
SO_4	15	0,94383	0,04402	-0,03919	-0,03570	-0,16845	-0,00480	0,01437	0,14758
Total C	16	0,08917	0,95556	-0,00344	-0,10009	-0,09343	-0,01592	-0,11754	-0,05794
Inorganic C	17	-0,11423	0,90302	-0,24557	0,12768	0,01586	-0,02650	-0,21715	-0,14652
Organic C	18	0,40825	0,05691	0,50240	-0,44992	-0,21752	0,01070	0,21053	0,13477
Conductivity	19	0,93326	0,20487	0,08843	-0,07280	0,09685	0,00780	0,07159	0,13811
Temperature	20	-0,11847	-0,15725	0,05320	0,73593	-0,10412	0,12463	0,02972	-0,26006
pH	21	0,00591	0,28557	0,07787	-0,16563	0,88887	0,01717	0,04346	-0,15733
BIV	22	0,53560	-0,04696	0,11080	0,07124	-0,25350	0,83894	0,09423	0,22013
% *B. harrisonii*	23	-0,30949	-0,03340	0,00475	-0,75070	0,08042	-0,2376	-0,04710	0,00341
% Simuliidae	24	-0,34741	0,09282	-0,01004	0,07977	0,02630	0,07519	-0,06185	-0,58166
% Trichoptera	25	-0,38183	0,00146	0,00717	0,14308	0,18576	0,81977	-0,08271	-0,25266
% Oligochaetes	26	-0,23911	-0,08459	0,33371	0,01214	0,14190	-0,04626	-0,09246	0,70411
% Chironomids	27	0,77938	0,02334	-0,26092	-0,33809	-0,26865	-0,26194	0,17234	-0,01022
Solids in suspension	28	-0,11120	-0,34717	-0,17979	0,19917	-0,01112	-0,07095	0,46642	0,12746
AGP	29	0,32443	-0,15625	0,069379	-0,17419	0,16609	-0,13783	0,06264	0,06661

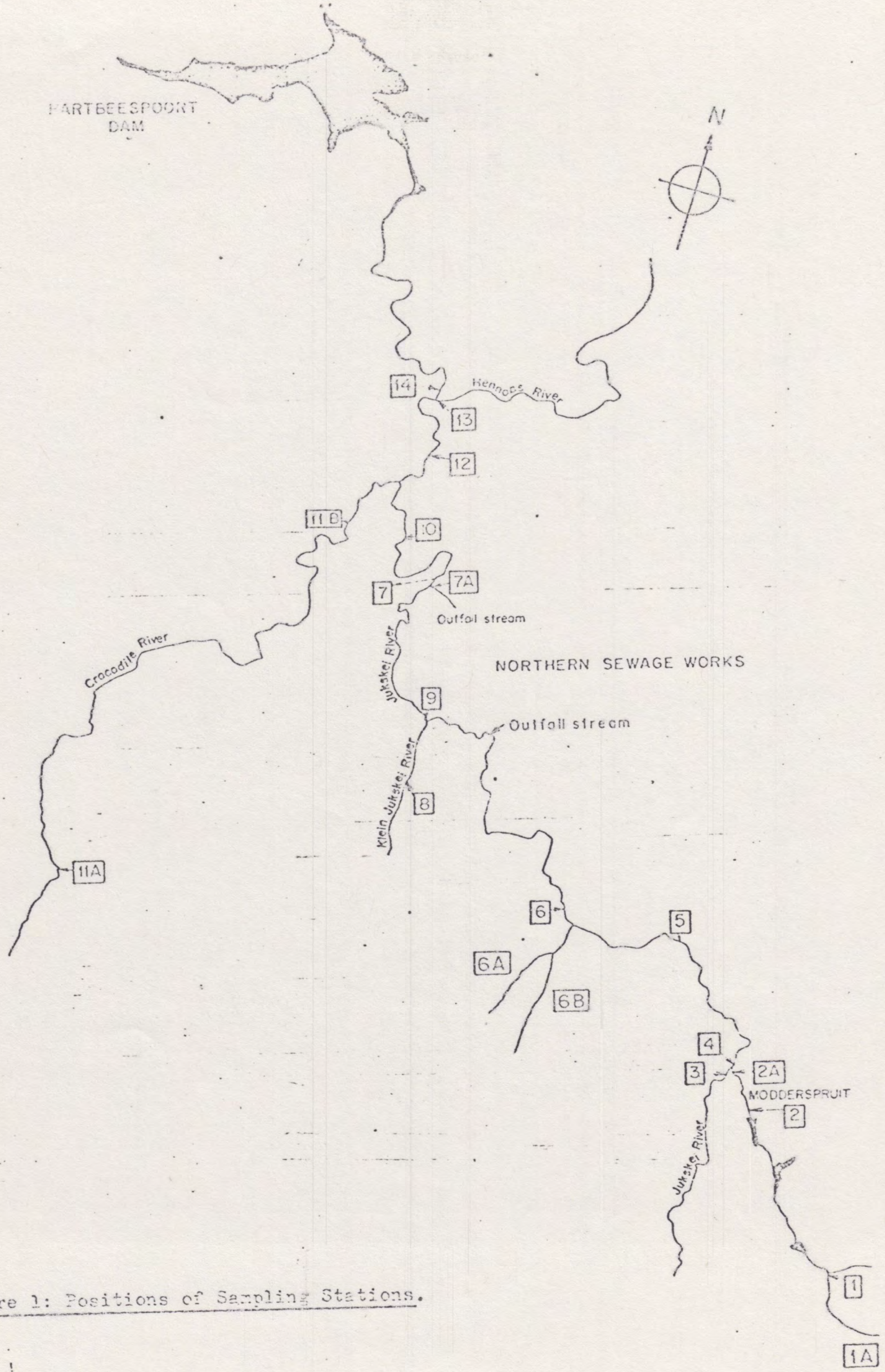

Figure 1: Positions of Sampling Stations.

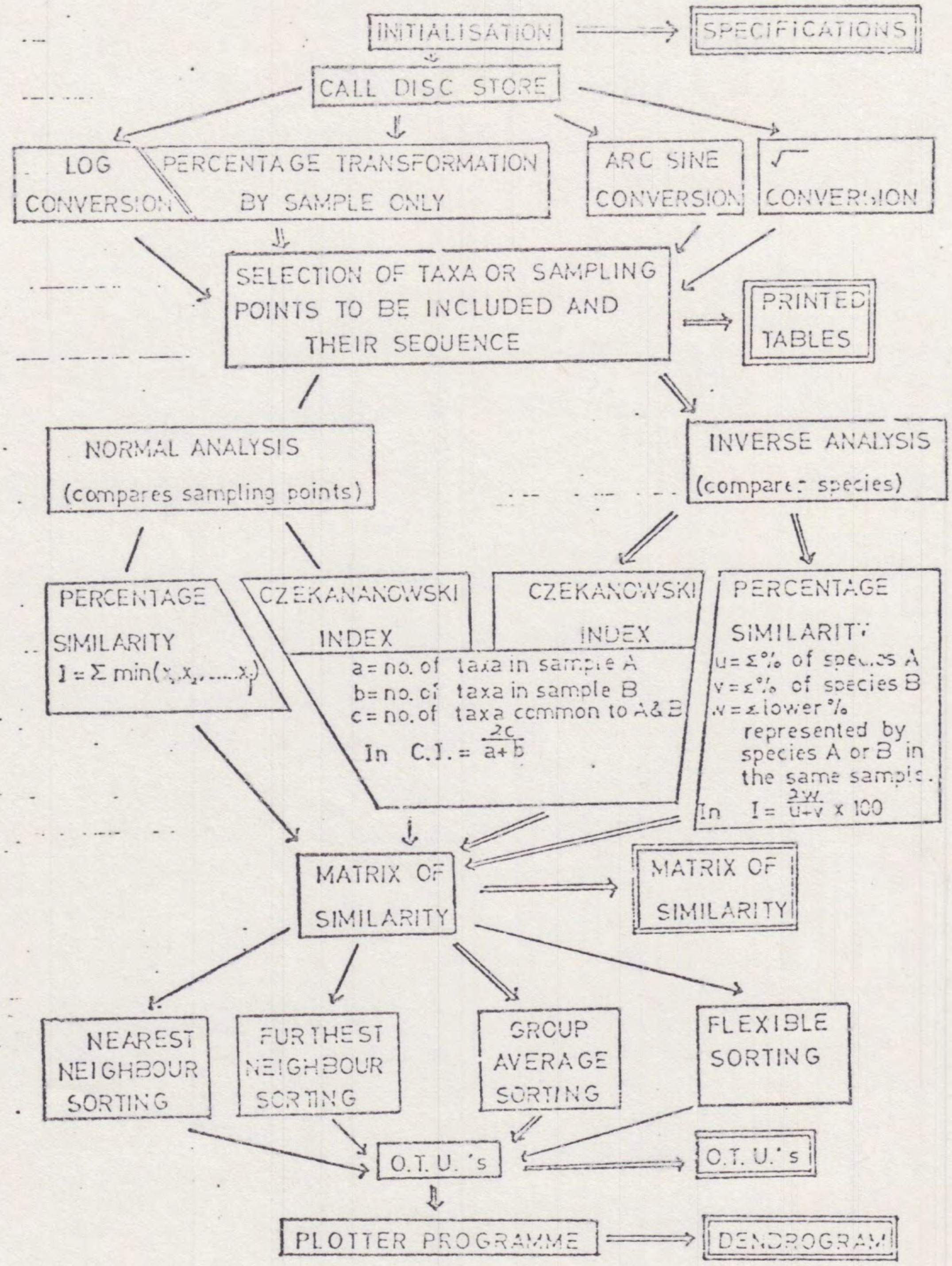

Figure 2: Flow Diagram of the Cluster Analysis Program.

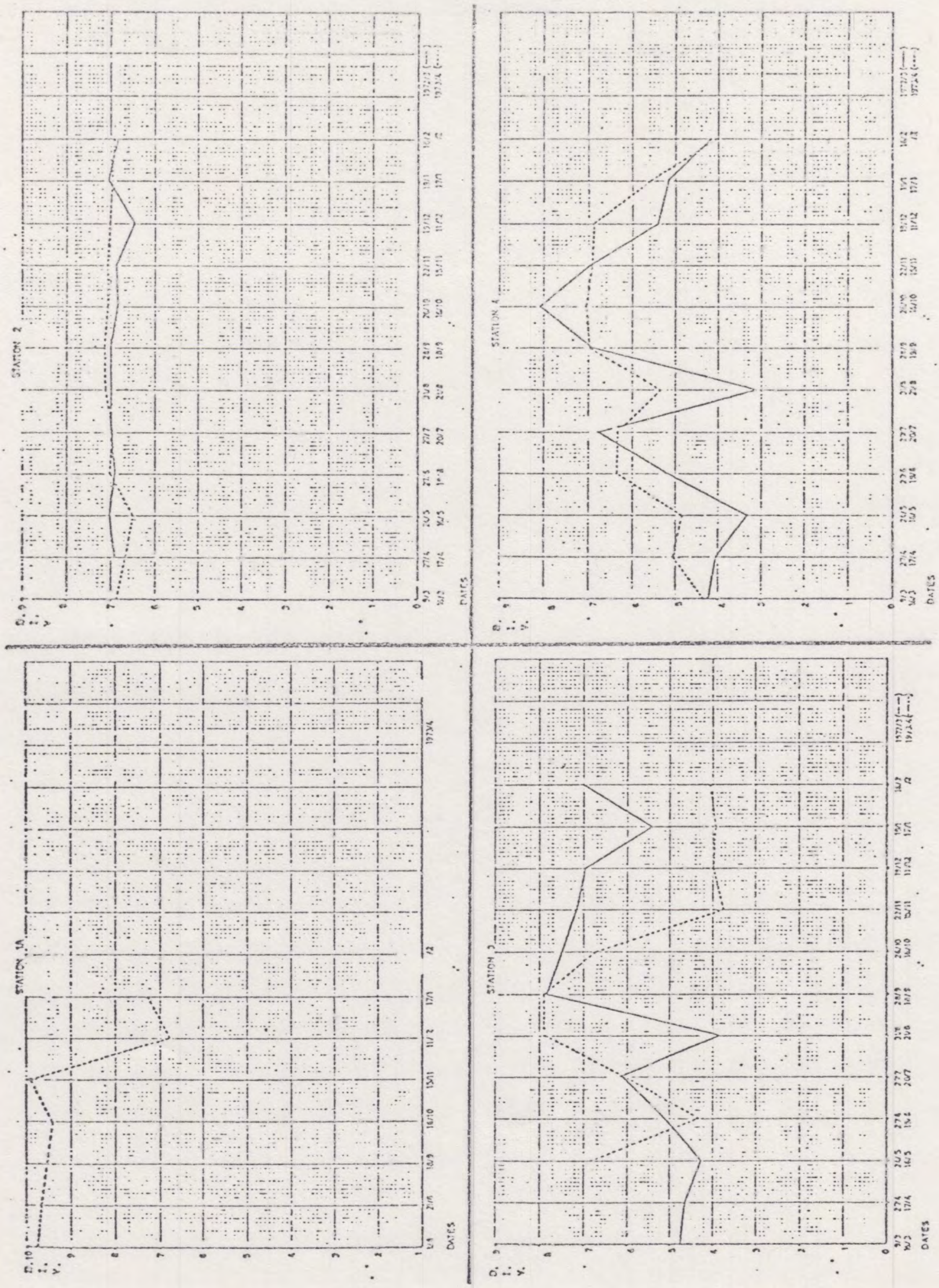

Figure 3: Monthly B.I.V. for Sampling Stations 1A,2,3 and 4.

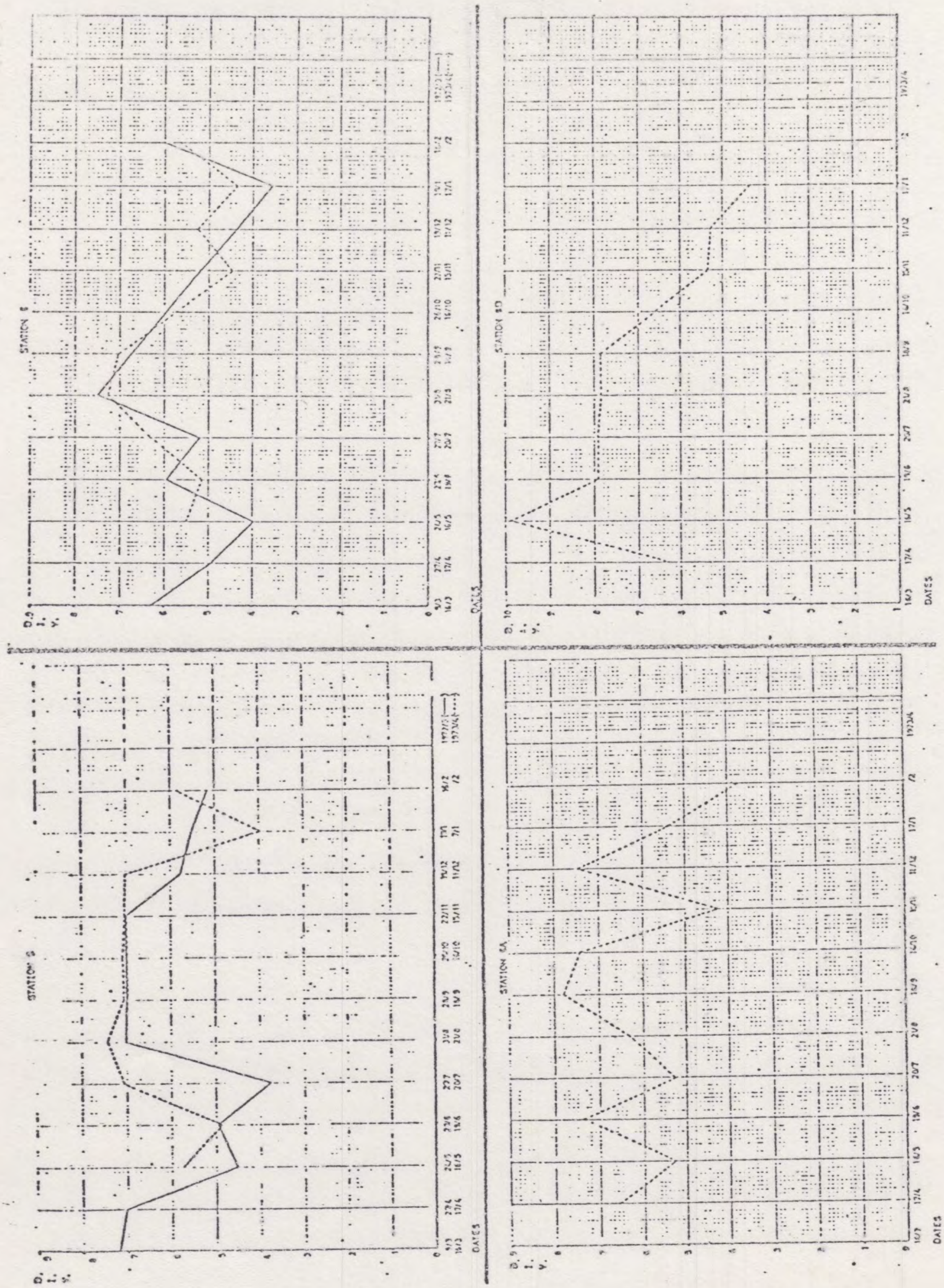

Figure 4: Monthly B.I.V. for Sampling Stations 5,6,6A and 6B.

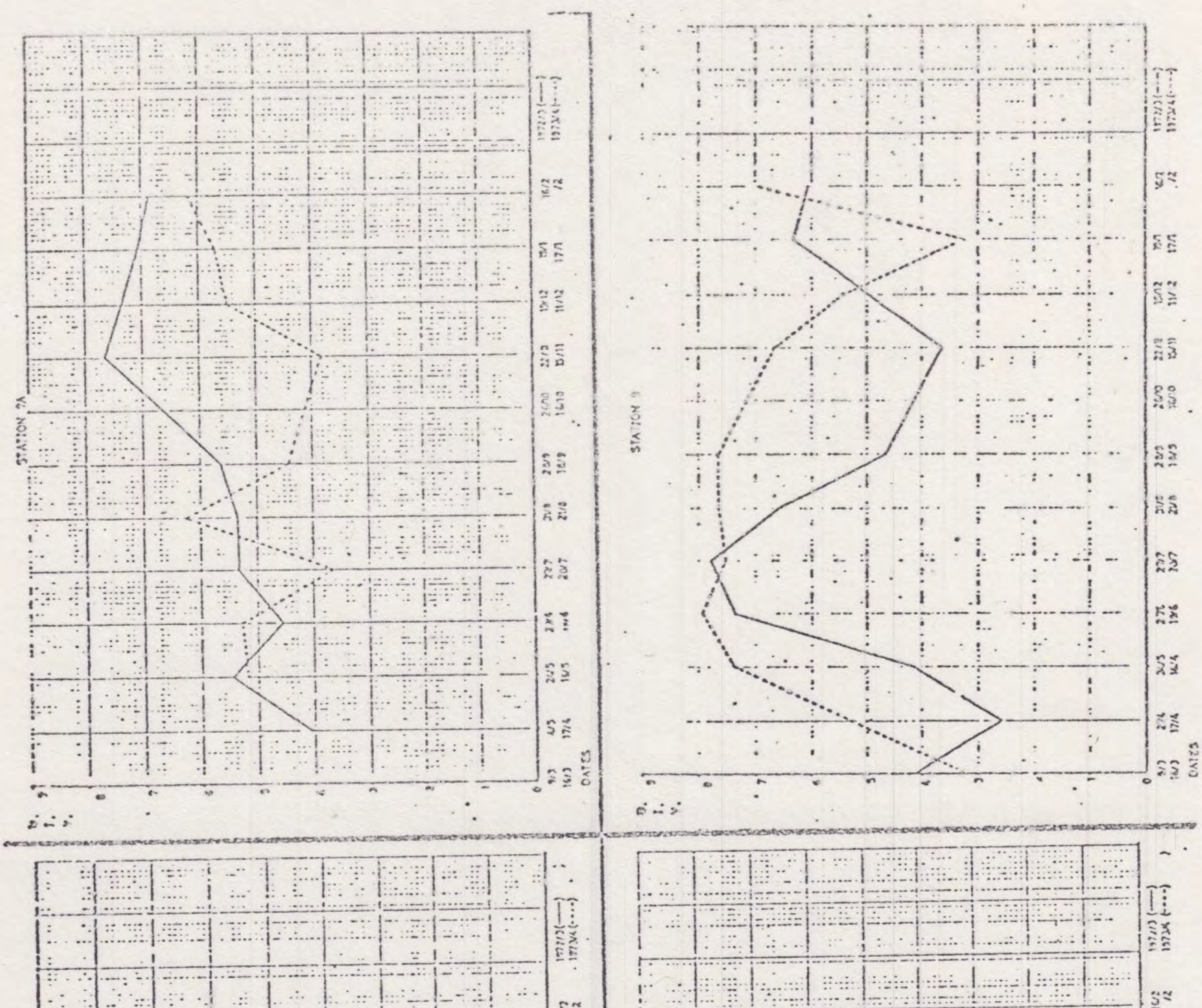

Figure 5: Monthly B.I.V. for Sampling Stations 7,7A,8 and 9

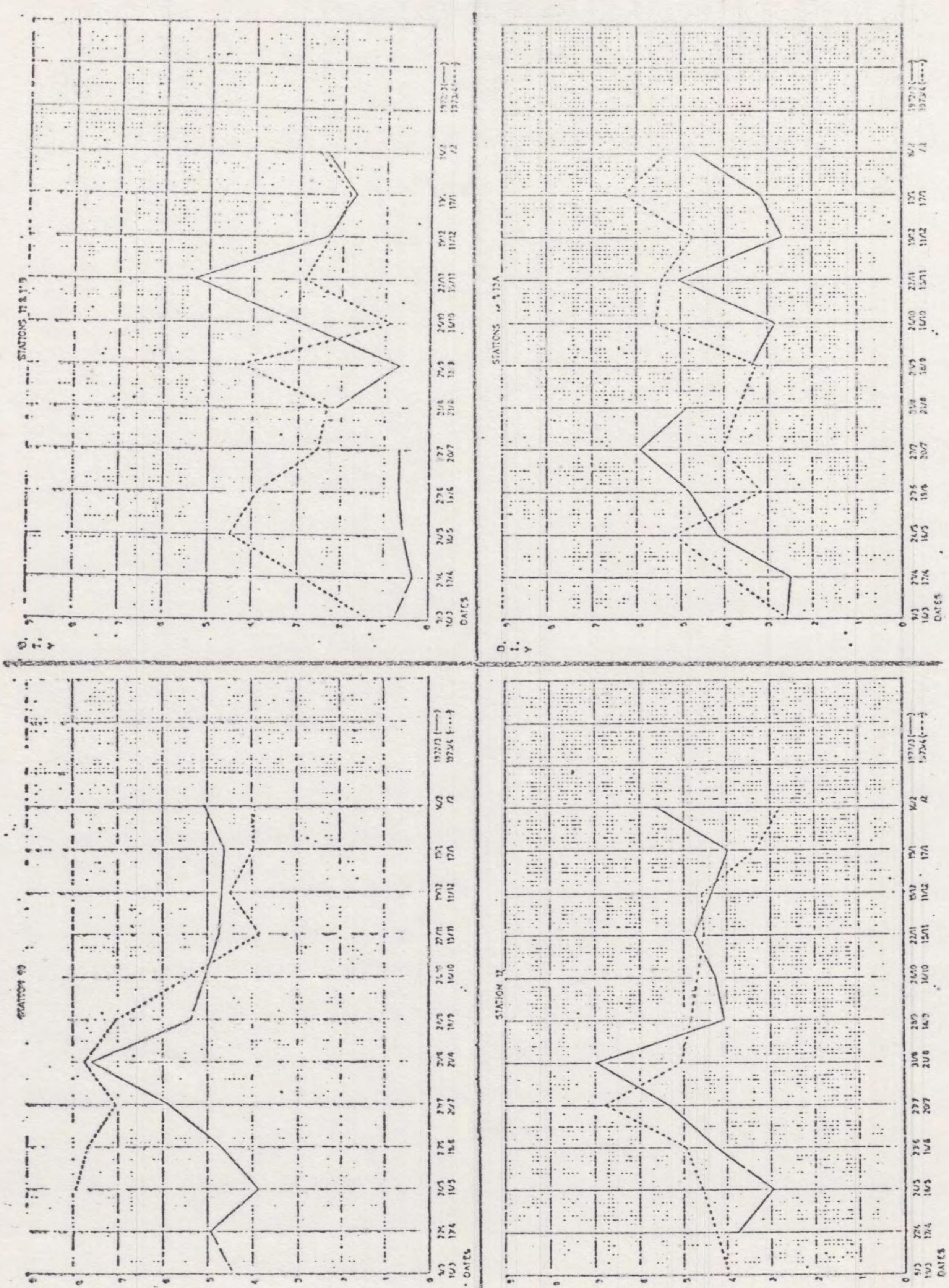

Figure 6: Monthly B.I.V. for Sampling Stations 10,11,12 and 13.

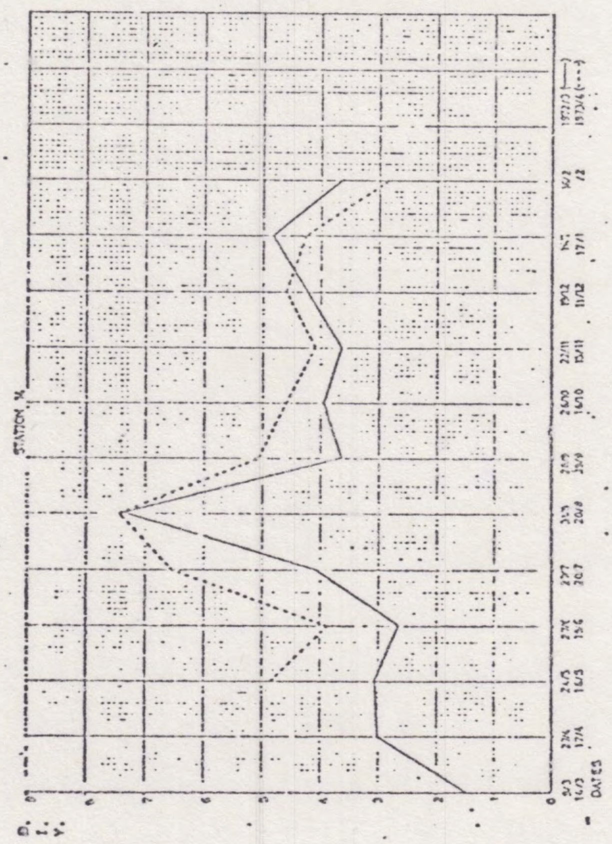

Figure 7: Monthly B.I.V. for Sampling Station 14.

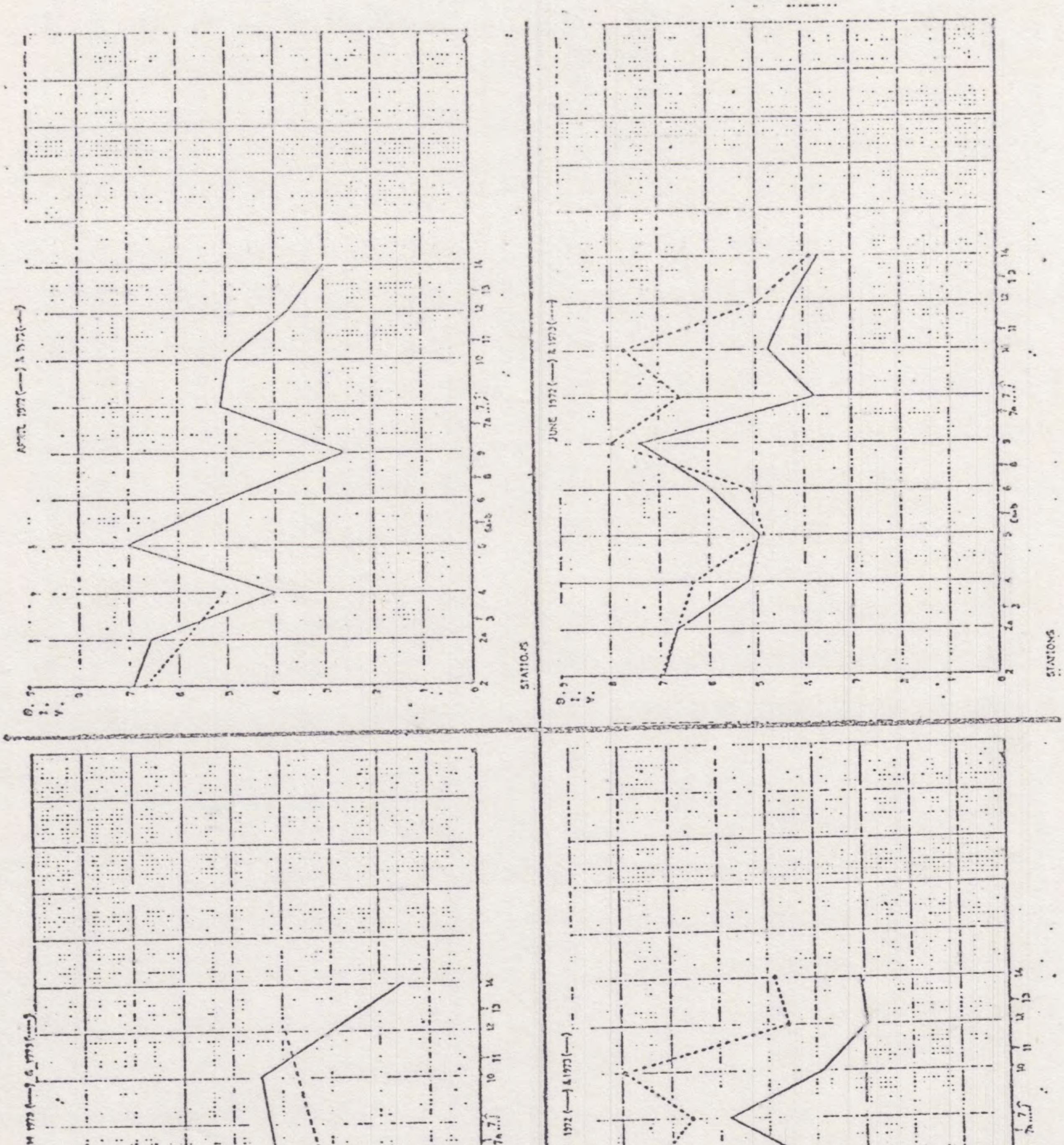

Figure 8: B.I.V. for March to June 1972 and 1973.

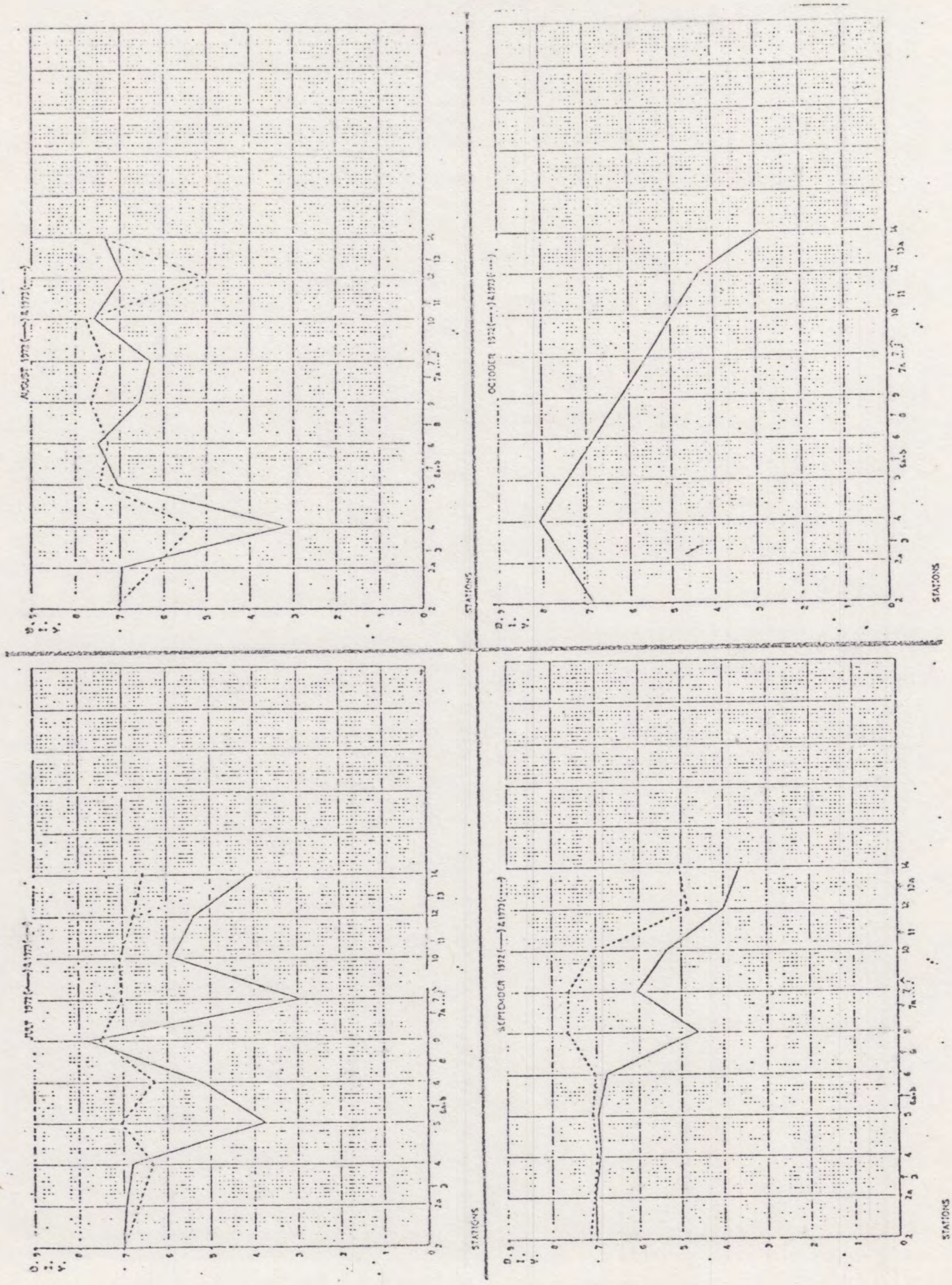

Figure 9: B.I.V. for July to October 1972 and 1973.

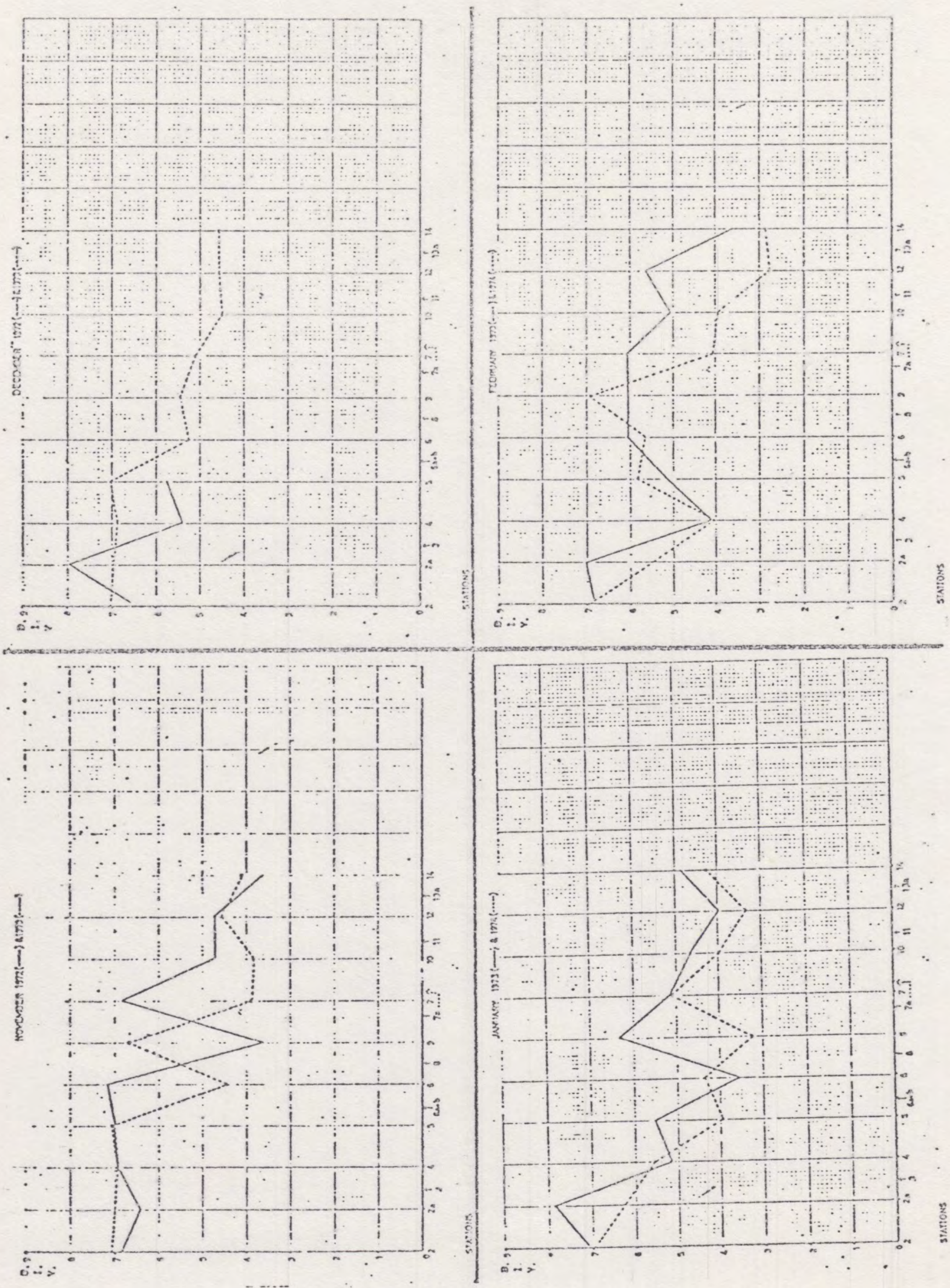

Figure 10: B.I.V. for November and December 1972 and 1973 and January and February 1973 and1974.

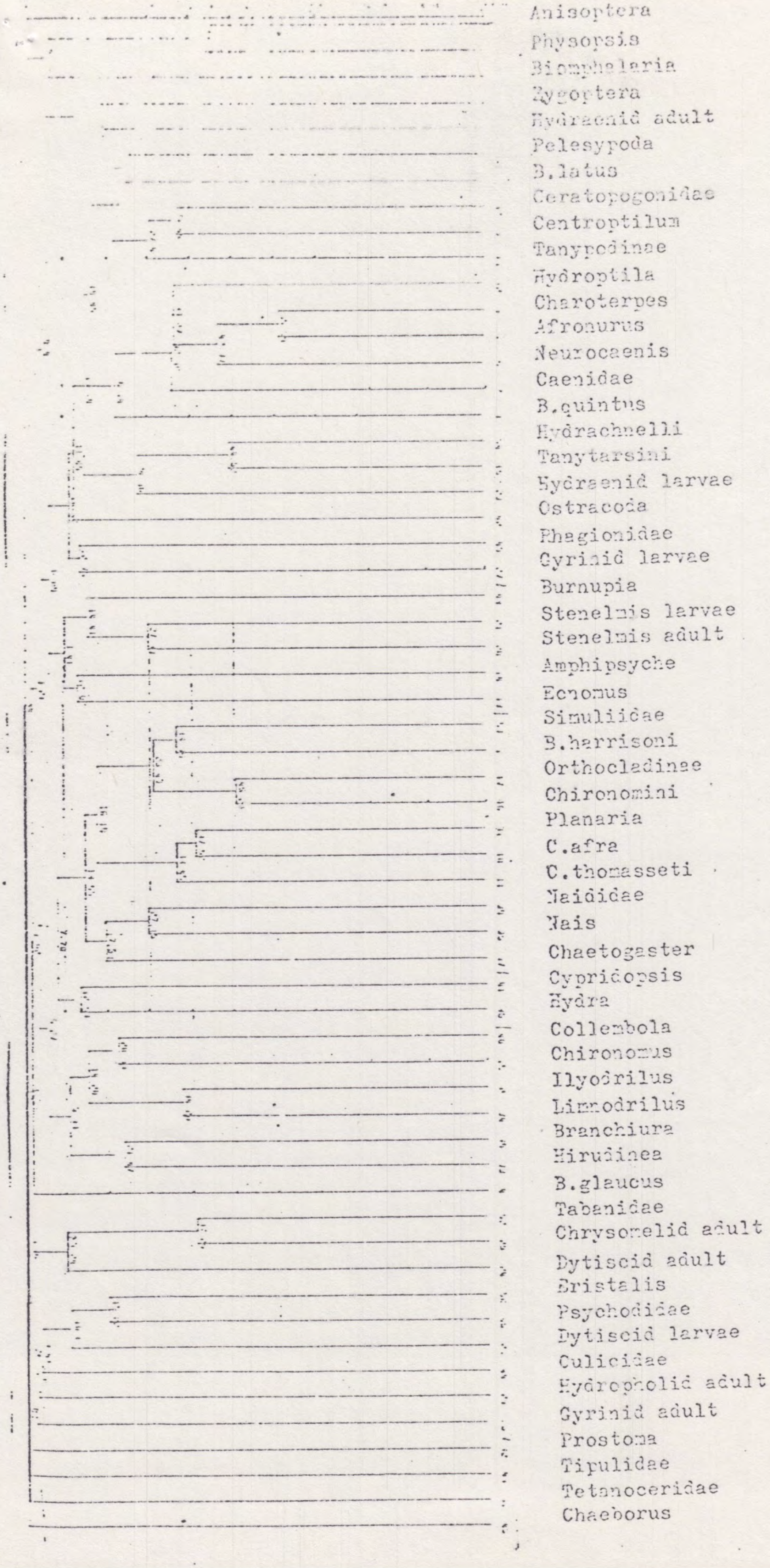

Figure 11: Percentage similarity cluster representing all the data.

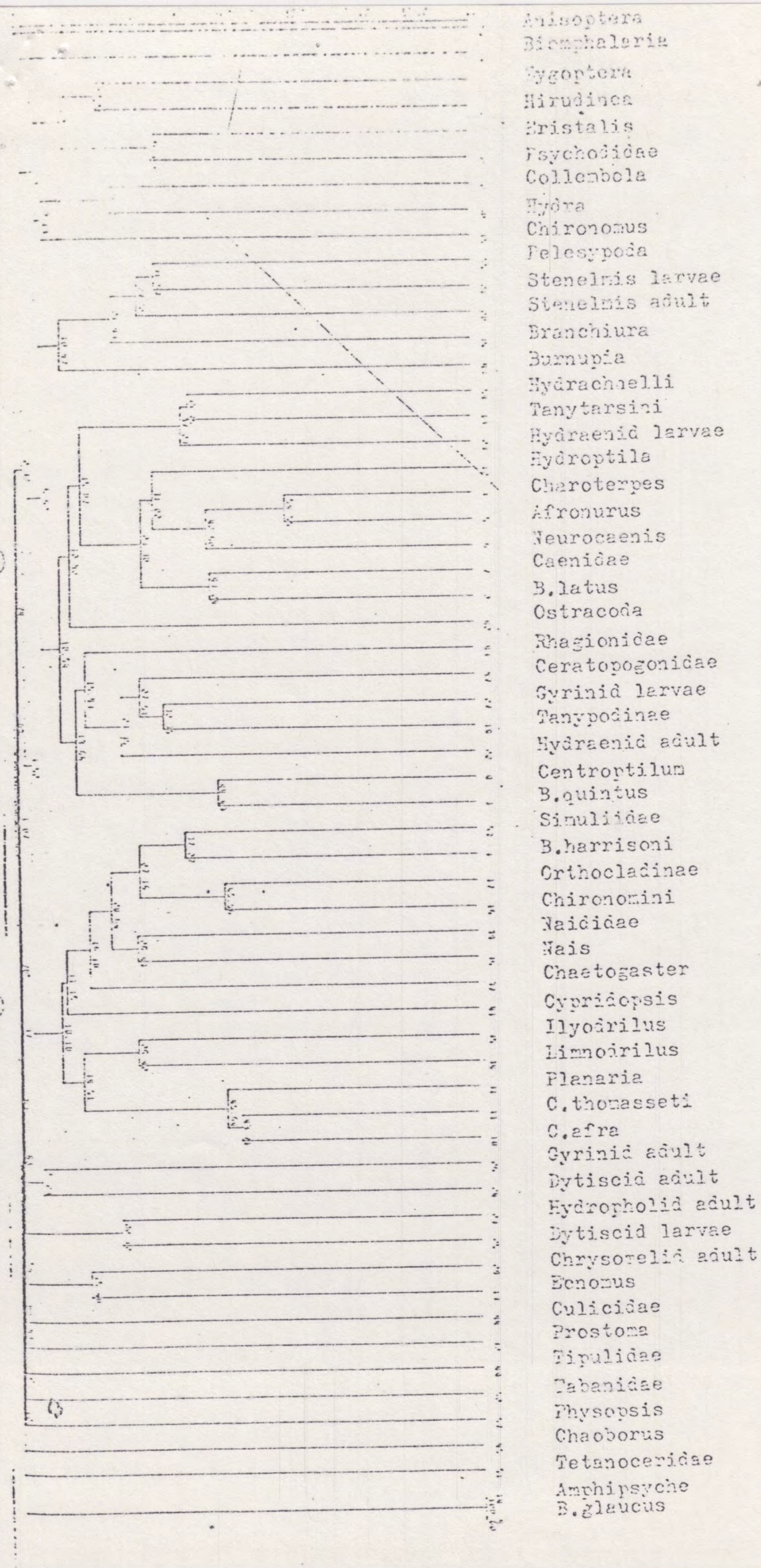

Figure 12: Percentage similarity cluster representing the winter data.

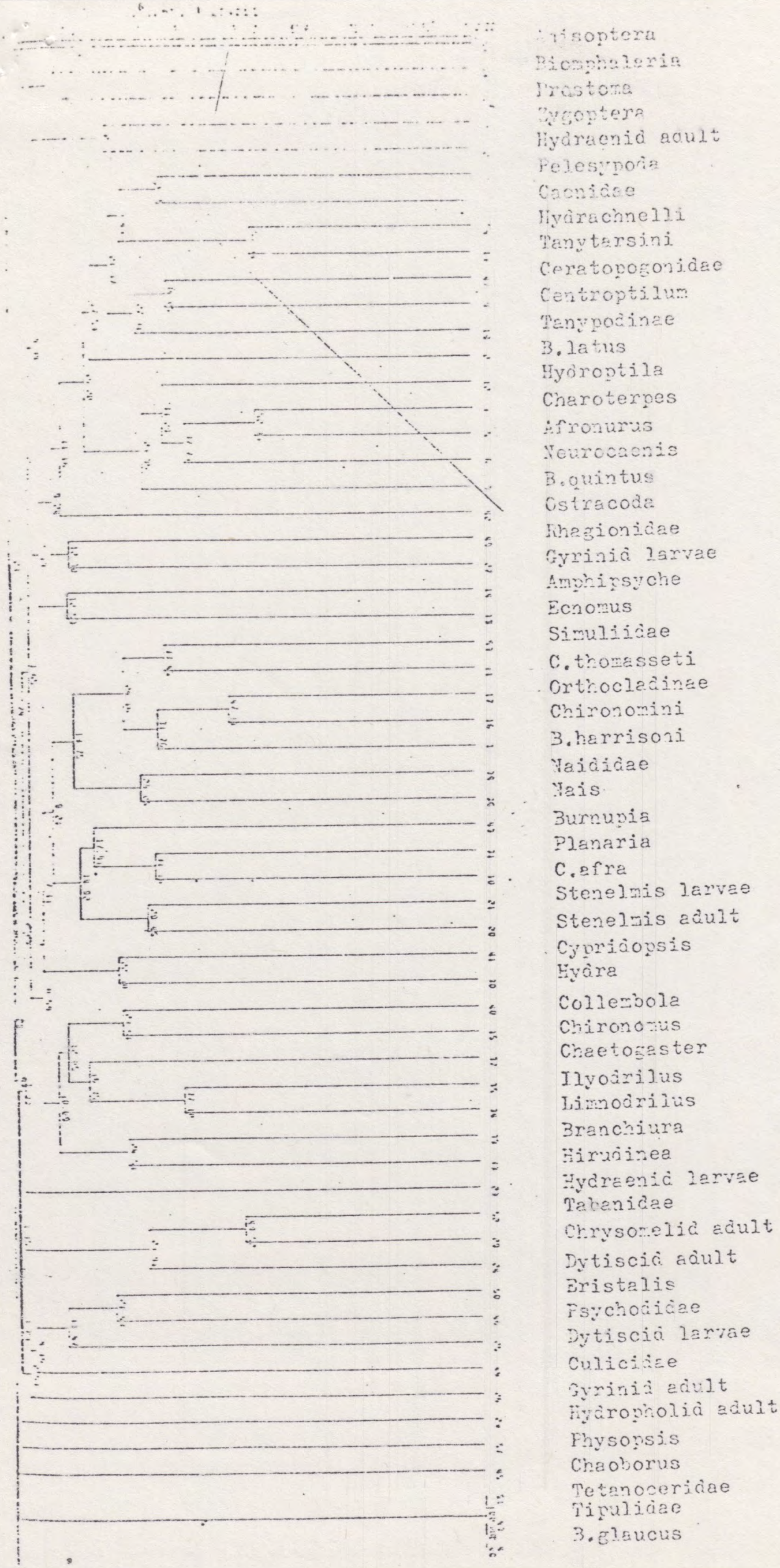

Figure 13: Percentage similarity cluster represnting the summer data.

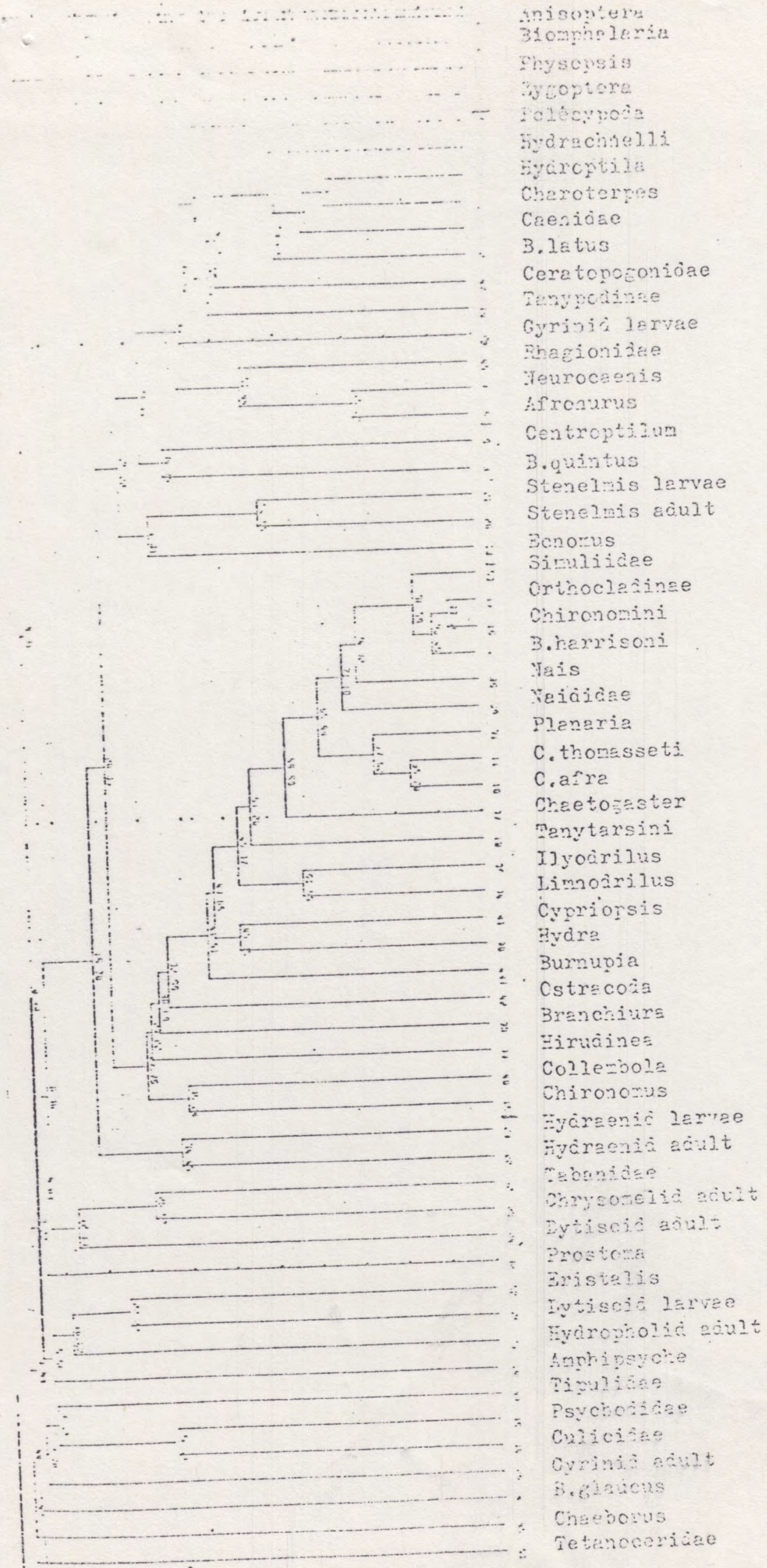

Figure 14: Czekanowski similarity cluster representing all the data.

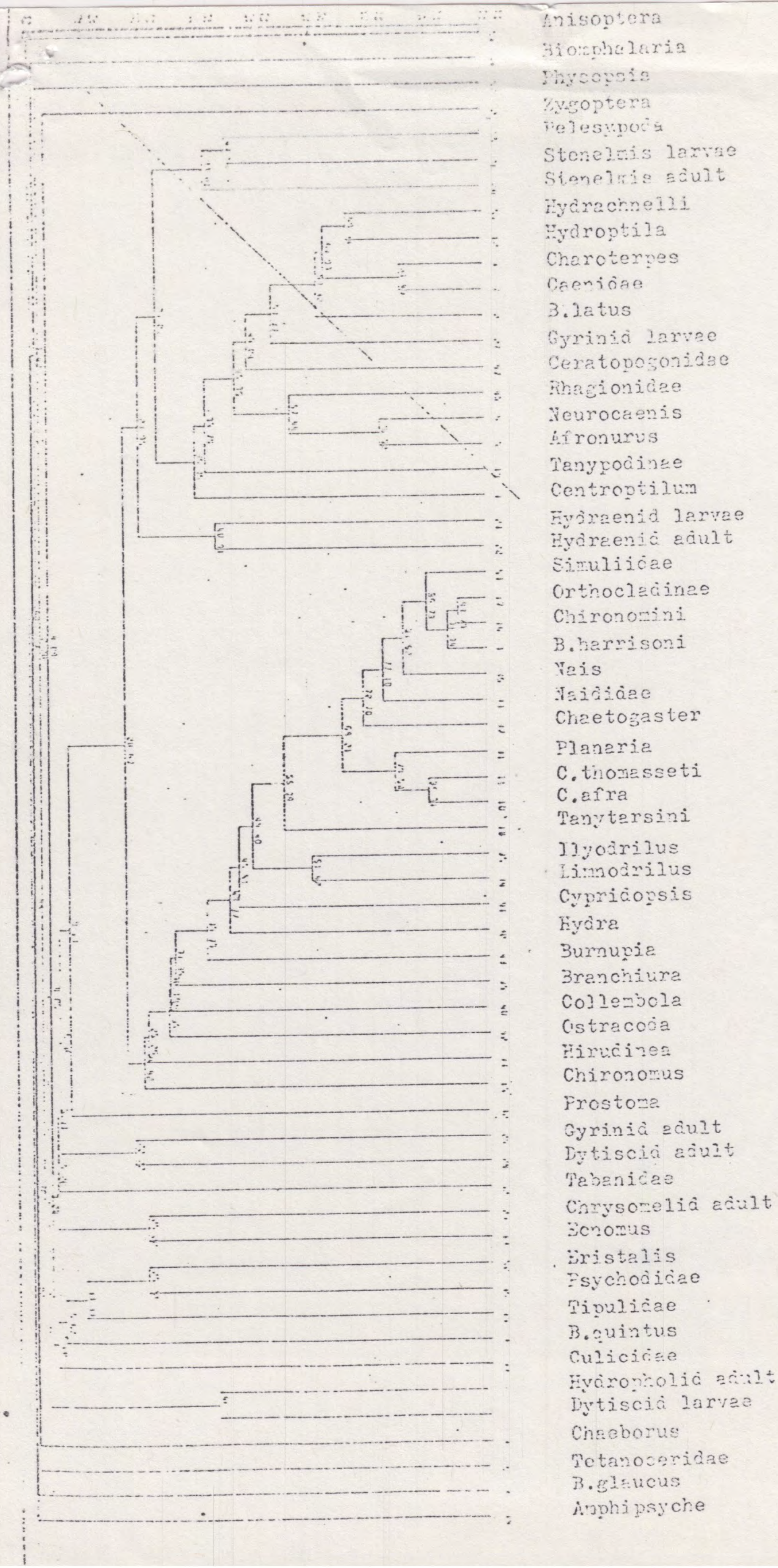

Figure 15: Czekanowski similarity cluster representing the winter data.

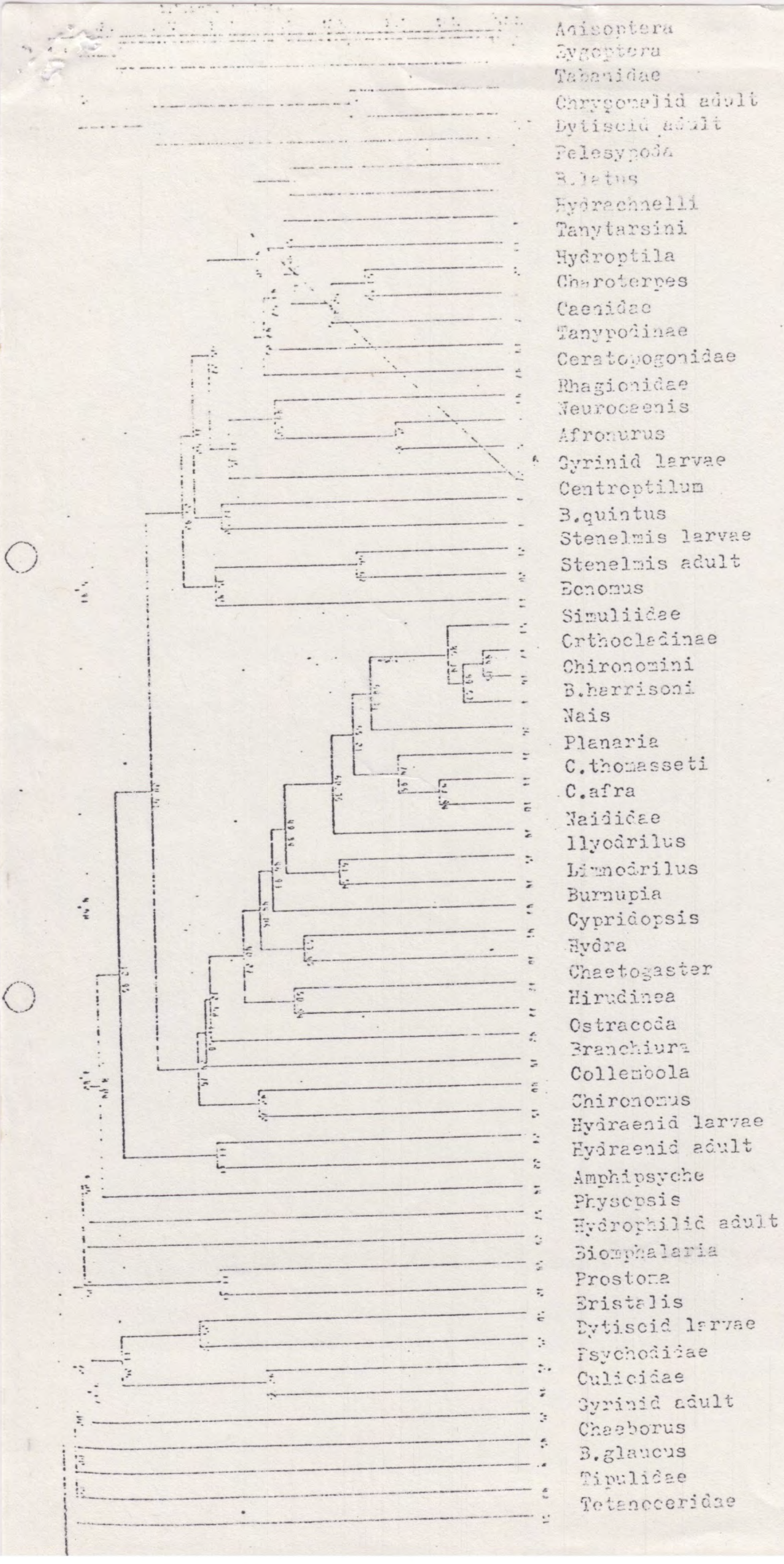

Figure 16: Czekanowski similarity cluster representing the summer data.