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I hereby recommend that the thesis prepared under my supervision by Elizabeth Burgess Ward
entitled A Seasonal Population Study of Pond Entomostraca
in the Cincinnati Region

be accepted as fulfilling this part of the requirements for the degree of Doctor of Philosophy

Approved by:

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A SEASONAL POPULATION STUDY OF
POND ENTOMOSTRACA
IN
THE CINCINNATI REGION

A dissertation submitted to the
Graduate School
of the University of Cincinnati
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requirements for the degree of

DOCTOR OF PHILOSOPHY

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by

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A Seasonal Population Study of Pond Entomostraca
in the Cincinnati Region

Introduction

The seasonal history of microscopic Crustacea has been traced through entire annual cycles in relatively few parts of the United States. The work of Marsh (1897) on the limnetic Crustacea of Green Lake, Wisconsin, is one of the first important studies of periodic seasonal conditions. Birge (1898) has published a detailed report on the plankton Crustacea of Lake Mendota, Wisconsin, as observed in over two years of consecutive collections. The extensive work of Kofoid (1908) on the plankton of the Illinois River provides an account of the fluctuations of all plankton organisms, including Crustacea, over a five year period. These investigations and others have treated certain areas with great completeness, but there are many parts of the country where the yearly entomostracan populations are quite unknown.

Observations on Cincinnati Entomostraca have been published by several workers. Chambers (1874) has remarked upon the presence of two species of phyllopo-
ods in this general area and has described two species of copepods from northern Kentucky. Hunt (1882) lists nine species of Entomostraca as occurring locally. By far

the most extensive work on local representatives of this group is that of Turner (1892, '93, '94). He lists 31 species with comments on habitat and describes several new species of ostracods from this area. The seasons embraced by the study are not specified but the context implies collection in late spring, summer, and early fall.

The present work was undertaken to analyze the local Entomostraca as to species and numbers at all seasons of the year with the further aim of interpretation from an ecological standpoint. The lack of such seasonal studies in most regions, including Cincinnati, makes a problem of this type worth while both as a contribution to the general field of plankton investigations and as a body of information with intrinsic interest. Virtually all previous serial observations have been lacustrine, and year-round conditions are almost undescribed in such small ponds and pools as were chosen for this work. Although a local species list is provided, its importance is regarded as secondary to the broader problem of seasonal fluctuations and environmental relations. Records of the more important physical and biotic conditions were made with each collection and studied as correlative factors in the annual cycle. Special emphasis on frequent collection at all times of the year was necessary to secure a complete

picture of the entire population. Consequently the chief study has been consecutive observations of a small number of collecting places with the belief that detailed information on a few representative communities throughout the year is of greater value than many scattered investigations without reference to season.

It is a pleasure to thank Dr. William A. Dreyer for his interest and helpful advice during all phases of the work. Dr. William A. Spoor has also given encouragement and counsel on numerous occasions. I greatly appreciate the help given by Dr. Norma C. Furtos in the identification of several ostracods. I am indebted to Lawrence Hobson, Bertrand Kriete, Marguerite Harkness, and several others for frequent assistance on field trips. I appreciate the courtesy of Dr. Charles Goosmann, of C. H. Rouster, and of the authorities of Arlington Memorial Park in allowing weekly collections from ponds on their properties. John A. Eledsoe has kindly given professional help in the making of photographs.

Collecting Sites

The stations from which regular weekly collections were made in 1937-38 were four in number. These stations were visited monthly for six months of the following year also, from October, 1938, to April, 1939. Single collections were made from seventeen other places at

various times from March, 1937, to April, 1939. These spots varied greatly in size, age, and nature, and were visited chiefly for comparison of their fauna with that of the regular stations to ascertain whether or not the weekly collections were of representative character. Two of the four regular spots were visited first in the spring of 1937, while the other two were first sampled in the autumn of the same year. Thus, records for stations 1 and 3 extend over a two year period while those for stations 2 and 4B extend over only eighteen months, and those for station 4A over only a single year.

Station 1. This site consists of a group of small woodland ponds near Goshen, Ohio. (Fig. 1) The pools were dug to provide water for cattle at least 20 years ago and probably somewhat earlier. The surrounding wood, chiefly oak and hickory, is sufficiently dense to provide rather extensive shade for the ponds in summer. The water level and hence the contour of this group of ponds vary considerably with the season. Pond 1C exists only in the spring and summer months. During this time the forest floor is so flooded that ponds A and B are nearly always in communication with each other. While A and B were thus connected samples were taken only from B in the spring of 1938 and from both A and B in the spring of 1939. The following measurements were made on March 3, 1939.

Pond A is the deepest of the three, being 18 inches at the center and sloping gradually to its margins. It is 51 feet long, 25 feet wide, and narrowly oval in shape. It has a very muddy bottom with practically no vegetation and is quite turbid for the greater part of the year. Dead oak leaves are frequently very abundant and make accurate netting difficult. This pond seems to be most visited by cows of any in the woods, which partially explains its high turbidity.

Pond B occupies a greater area than A but is somewhat shallower, measuring 13 inches at the center. The margins, to a distance of about 8 feet, do not exceed 8 inches in depth in most parts of the pond. The shape is roughly rectangular. Many dead branches and fallen leaves occupy this pool. The bottom is similar to that of A, made of soft clay which contributes considerably to the turbidity of the water. This pool has a few pond weeds along one shore in the late spring and summer, but vegetation is never abundant. It measures 47 by 34 feet.

Pond C is a natural temporary pool, first found to contain water in both 1938 and 1939 on February 3. It became dry and refilled several times in the spring and summer of 1938. The height of the water varies considerably, often encroaching on the grassy margins of the pool. The water is very clear, and the bottom, though clay, is so thickly lined with leaves that walking through the pond does not cloud the water. Its greatest depth is

Fig. 1

A--Station 1, pond A, September 28, 1938.
 B--Station 1, Pond B in the foreground; pond
 A in the right background; pond C in the
 left background. February 3, 1939.
 C--Station 1, pond C, a natural temporary
 pool. February 3, 1939.
 D--Station 2, June 29, 1938.

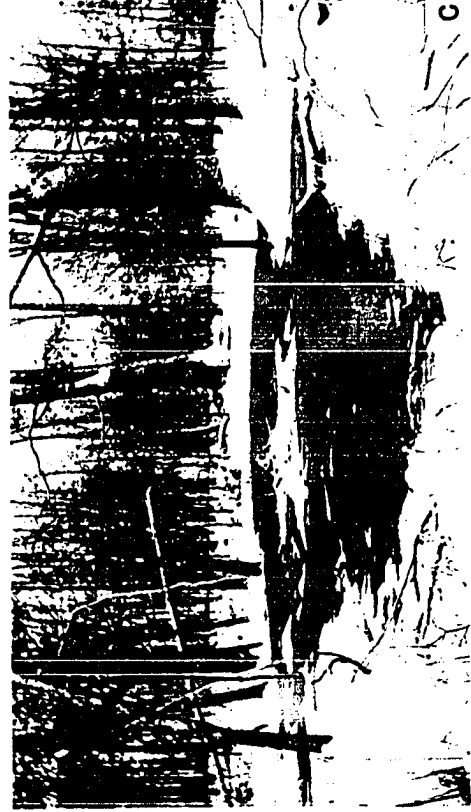
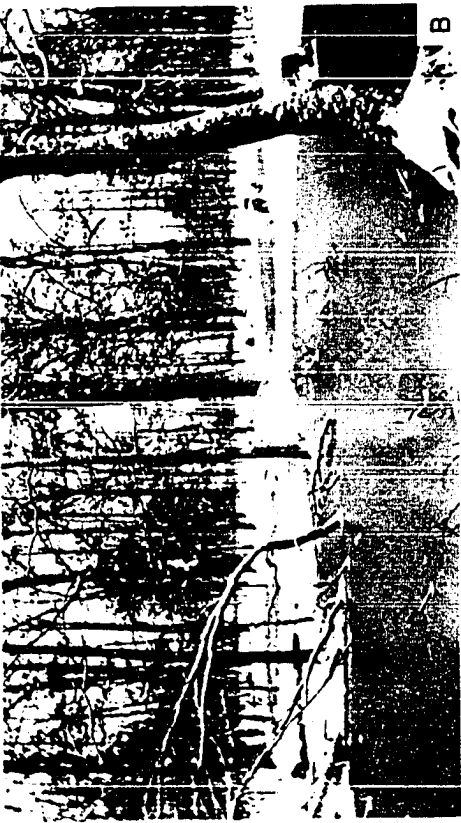


FIG. 1. COLLECTING SITES AT VARIOUS SEASONS

9 inches. The shape is roughly oval, with a length of 38 feet and a width of 23 feet. At times there is so much standing water in the woods that slight communicating channels exist between this pond and 1 B.

These three ponds form a very close group, A and B lying about 15 feet apart, A and C equally far apart, and B and C at the closest point being 8 feet from each other. A larger temporary pond in the same woods but several hundred yards from this group was visited several times but not sampled regularly.

Station 2. This pond was formed about 30 years ago by the damming of a small stream. The main body of water, exclusive of the narrow upper end which is formed by a small trickling brook, measures 89 feet by 276 feet. The width was measured at the bridge (Fig. 1) from which the net hauls were made. The lower end of the pond is bounded by a concrete wall, over which water flows in the spring and in the summer after heavy rain. For most of the year there is little or no flow of water, as the small rivulet at the upper end is often dry. The depth of the water on March 3, 1939, was $4\frac{1}{2}$ feet at the center. There is little slope to the bottom, the depth being attained by a sharp descent from the margin. This station abounds in aquatic vegetation in summer. Cat-tails (Typha) border the sides, pickerel weed (Pontederia) is prominent, Ceratophyllum is thick, and a duck-weed, Lemna minor, blankets the edges.

Station 3.

This was the largest pond regularly visited, measuring roughly 500 feet by 125 feet. The shoreline is irregular and broken in several places by small brooks of more or less temporary character. The most persistent of these lies at the narrow upper end and contributes a slight amount of water which is compensated for by a gentle outflow through a drain at the opposite end. This circulation appears to cease during the later summer and fall but occurs during the greater part of the year. The collections were always made at the same part of the pond, a long inlet on the side least disturbed by the circulating water (Fig. 2). As the summer illustration (2-D).shows, the water in the inlet is so quiet that a dense blanket of duck-weed lies undisturbed on its surface. This plant growth necessitated a shift in collecting position from a point about half way down the inlet (where the figure is visible) to a spot just inside the entrance in the late summer. Manipulation of the net in the shallow water choked it with duck-weed before the haul was completed, and a shift of 50 feet to a spot with less vegetation was imperative.

This pond was formed between 60 and 70 years ago when the embankment raised for a railroad dammed the outflow from a small creek. The present water level is maintained in part by this temporary brook, noted above, and by a number of springs. The depth varies considerably with

Fig. 2

A--Station 4 A. July 2, 1938.
 B--Station 4 B. July 2, 1938.
 C--Station 3. January 16, 1938.
 D--Station 3. June 27, 1938. Note
 the dense blanket of bromweed.



FIG. 2. COLLECTING SITES AT VARIOUS SEASONS

the season in the inlet where collections were made. The greatest depth here is about 4 feet, but netting was usually done near the margin in 15-18 inches of water. The maximum depth of the main body of the pond is about 11 feet.

Vegetation is abundant. At the place of collection and at various seasons were observed Sagittaria, much Ceratophyllum, Spirodela polyrhiza (duck-weed), a few cat-tails (Typha), and many other plants in lesser amount. The collections at many times abound in algae, especially filamentous forms such as Spirogyra and several kinds of small desmids. The bottom is soft brown mud which clouds the water considerably when disturbed but ordinarily remains as a fairly compact floor. Most of the time the water is very clear.

Station 4.

The bodies of water at this station are artificial, having been made for use in raising goldfish. (Fig. 2)

Pond A is a small shallow ditch which was built 8 years ago. It is 63 feet long, 16 feet wide, and about 20 inches deep at the center. It has never been stocked with entomostracans, and during the time of weekly observation was not being used in any phase of the fish culture. It was drained October 1, 1938, and was first found refilled on April 10, 1939. It has a soft mucky bottom, and is choked with vegetation (mostly Elodea) in summer. Also prominent are pond-lilies (Castalia), and

Sagittaria.

Pond B is a small oval pool in a sheep pasture. It is 99 feet long, 50 feet wide, and at the center about 4 feet deep. It was made 4 years ago and stocked once with a net full of Daphnia from another pool on the farm. These ponds have a system of communicating drain-pipes which also probably served to introduce some organisms to the new pool. This station is in a very exposed situation, being sheltered by no vegetation of any sort. In the later summer, the pond develops a few water hyacinths (Eichhornia), some Sagittaria, and an occasional bunch of Cladophora. The bottom is soft clay. The water is usually very turbid and of a pronounced green color due to the presence of a very minute green flagellate in enormous numbers. The normal seasonal picture was somewhat distorted at this pool by the introduction of a number of tropical fish in the early summer. Also, it was dry from October 1, 1938, to November 30, 1938, having been drained. Objections may legitimately be raised to the inclusion of two such recent artificial situations in a study of this kind. They do, however, serve to show the contrast between a natural population and the biota of a semi-controlled environment and since the organisms introduced are common local species, their use seems justified.

Methods

Physical Factors. The following observations were made at each station each week (with 8 exceptions which were

not consecutive) for an entire year, from October, 1937, to October, 1938. From October, 1938, to April, 1939, monthly trips were made to each station. In each case the time of observation of physical factors coincided with that of the collection of material. Similar physical observations were made at the time of some of the collections from localities other than the regular stations.

1. Dissolved oxygen content. This was determined by the Winkler method. Bottles were filled 6--8 inches below the surface of the water.

2. Carbon dioxide. Free CO_2 , bicarbonates, and carbonates were determined by the Seyler method. Bottles were filled 6-8 inches below the surface.

3. Hydrogen ion concentration. The colorimetric method, giving the measurement in terms of pH, was used for this determination. The tubes were filled 6-8 inches below the surface and the readings were made in the field.

4. Temperature. Air and water temperatures were taken with an ordinary Centigrade thermometer. Air temperatures were read at a height of about three feet from the ground and a yard or two from the collecting pond. Water temperatures were taken with the thermometer submerged to a depth of 8-10 inches, which caused it to rest on the bottom of several of the shallower ponds.

5. Turbidity. This was estimated by a modified Secchi disk. A white enamel button 3.5 cm. in diameter

was mounted on a wooden block. A stick marked off in inches was fixed at right angles to the block. For taking a reading the instrument was lowered into the water until the white disk just disappeared and the extent of submersion noted. The reading was checked as the instrument was withdrawn. This gave figures with relative significance but obviously with no absolute value. The amount of light, as affected by sky conditions and time of day, also causes some variation in results.

Also noted as part of the physical environment on each trip were the time of day, the condition of the sky--cloudy or sunny, the falling of rain or snow, the relative amount of water at the station (high, low, or average), and the condition of the winter ice cover.

Prominent biotic features, both plant and animal, were noted and recorded with each collection in addition to observation of the entomostraca present.

Collection. A standard method was evolved for the weekly collections and adhered to throughout the work. The single collections made from other stations were primarily qualitative and consequently material was gathered by many random net sweeps rather than by a constant number. At the regular stations the net was drawn through the water while submerged to a depth of 6-8 inches in a series of two yard sweeps. At the beginning of the quantitative work, twenty such sweeps were taken. On November 20, 1937, when ice appeared for the first time, the number of sweeps was

reduced to ten. Since only a limited amount of water could be exposed for sampling, it was thought that twenty hauls in such a small area would fail to represent the actual number of organisms, due to depletion of the sampled region before the collection was complete. Ten sweeps, equivalent in all to a twenty yard tow, were found to give an adequate picture of the entomostracan population and at the same time to reduce the number of organisms for counting to a workable size. In all subsequent collections ten two yard sweeps were used as standard, and the counts corrected to secure correspondence in all samples.

It is of course realized that such a method of quantitative collection is open to serious criticism. Elaborate equipment was not available for the study, and it is doubtful if any of the more usual devices would have been suited to the small and shallow ponds from which material was drawn. Certainly the plankton pumps and traps designed for lacustrine collecting would have required very extensive modification due to scant depth, muddy bottom, and, at certain times and places, excessive amounts of vegetation. The alternative method, of pouring a measured amount of water through the net, was considered and rejected. If the net used were 50% efficient it would require the use of 42 liters of water to obtain the number of organisms caught by the method used, not counting the inevitable leakage occurring by the volumetric method as well. It would be difficult to draw by hand as representative a

quantity of samples as could be obtained by walking through the water and directing net sweeps to all regions. The movement of the collector through the pond each time doubtless started forms from the bottom which would not have been taken by the volumetric method. In any event, the method adopted unquestionably gives an acceptable picture of relative numbers within each collection. Whether or not the absolute values obtained are of significance can best be seen when results are considered. Small fluctuations due to the human factor in judging length of sweeps were inevitable, but the fact that all but a very few collections were made by one or the other of two people who agreed on their estimates at the outset should minimize them.

The net used was made of fine batiste according to the pattern recommended by Birge (1918) for plankton collecting. The material, as measured under the microscope with a calibrated ocular micrometer, possessed approximately 1700 meshes per sq. cm. The openings in the cloth varied in size in new, washed material from 0.009 sq. mm. to 0.021 sq. mm. In a net which had been used for nine months the openings varied from 0.009 sq. mm. to 0.024 sq. mm., showing a slight increase in dimension. An average of 20 openings in new washed material gave the figure 0.0158 sq. mm., while the average for material after nine months of use was 0.0163 sq. mm. The first net made was used for nine months and replaced in July, 1938, with

an exact counterpart which was used for the remaining period of collection. Whether the slight change in size of openings with use materially affects the amount of the catch has not been determined but it seems unlikely. The important fact is that no adult and few, if any, young Entomostraca are small enough to pass through the net openings, even nauplii being too large for escape. The nets were washed frequently in hot water and soap to prevent clogging and slight rents were promptly repaired. Preliminary collections from the regular stations and others were made in the spring of 1937 using an ordinary gauze dip net.

The nets in regular use were reinforced at the top with several layers of unbleached muslin, which was sewn to the wire frame. This frame had a diameter of 24 cm. and thus encompassed an area of 452.39 sq. cm. The net was conical, 58.5 cm. long and tapering to a lower diameter of 6.5 cm. The lower end was left open and provided with a tape for tying. In practice four to five inches of the end of the net were folded up and tied tightly for collecting. Release of the tape permitted the catch to be washed from the net into the desired volume of water.

It has not been possible to determine the coefficient of the net. Although many methods have been devised for such estimates, none is completely satisfactory and all are too complex for adaptation to this particular work. If the

necessity for standardization becomes apparent later, the net is still available and it is possible that an applicable adaptation of Birge's (1898) tube method can be devised. It is possibly not too much to assume about 40% efficiency for such a net. Birge suggests this figure for his type of silk net (of No. 16 or No. 20 bolting cloth) of form similar to those used here and when towed at about one meter per second, which was approximately the rate adopted here. The somewhat larger openings of the cotton nets would perhaps decrease the resistance enough to make up for lessened intake due to differences in method of use, shallowness of the water, etc. At an efficiency of 40%, the nets used would take the organisms from 33.5 liters of water with each two yard sweep, instead of from the 84 liters which would be filtered by a 100% efficient net. In order to express the number of organisms taken in one net sweep in terms of the number actually present in the volume of water traversed by the net, the catch in a 40% efficient net must be multiplied by 2.5. The net coefficient, since it is unknown for this material, has not been figured into the counts. Numbers are expressed in arbitrary collecting units, a unit representing the catch of a two-yard haul of the net 6-8 inches below the surface and drawn through the water at approximately one yard per second. This catch possibly represents the number of organisms in something between 25 and 35 liters of unfiltered water.

Each collection was washed from the net into a liter of water from the pond from which it was taken. Upon return to the laboratory a portion of each sample was preserved. Each bucket was thoroughly shaken and 200 cc. poured off into a container to which 20 cc. of formalin were added. This gave a 9% solution of formalin, probably considerably stronger than needed, but it ensured perfect preservation even in the presence of much organic matter--plants, etc.--and the quick killing did not cause excessive distortion. From October, 1937, to May, 1938, an additional sample of each collection was preserved after reduction by filtration to a small volume. After May, 1938, these additional samples were prepared only every other week. The 200 cc. samples were used for the differential counts. The remainder of each collection was carefully examined in the fresh condition, and it was from this material in most cases that initial identifications were made.

In all, 320 consecutive collections were made, examined, and counted. Supplementary single samples were taken from 17 other locations and the species identified.

Counting. The 200 cc. samples of each collection were used for differential counts. When 20 net hauls comprised the entire collection, which was concentrated to one liter, the counting sample represented the catch of four net

sweeps or one fifth of the total catch. When the number of net strokes was changed to ten, 200 cc. of the concentrate obviously contained the organisms from only two hauls. Each sample was prepared for counting by draining off the formalin, through cloth identical with the net material, suspending the catch in 50 cc. of water and distributing it evenly (by agitation) in a Petri dish 950 mm. in diameter. Counting all the organisms in one fourth of this area (when the haul was forty yards) or one half of this area (when the haul was twenty yards) represented the actual number of each species taken in an average two-yard sweep.

Counting disks of black background with white lines and the reverse combination were prepared by ruling off sufficient squares, one centimeter on a side, to make up one fourth the area of the dish. This required seventeen 1 cm. squares and one 0.85 cm. square. Each square was divided further into a 2 mm. strip the length of one side and a 2 mm. square, for use when the large catch prevented counting all organisms in the 1 cm. square. When the forty yard hauls were used, counting all organisms in this 17.72 sq. cm. gave the number per single net sweep. With twenty yard hauls, such a count gave the organisms in only a half sweep. In case of very small catches, this contingency was met by counting double the usual area, but in

the vast majority of cases the number of animals was so large that time did not permit counting more than the accustomed area. Hence, in order to permit expression in terms of number per collecting unit, most counts required doubling. Also, in many cases, dilution was imperative before counts could be attempted. This dilution was varied in accordance with the amount of the catch but was always kept as low as possible to prevent distortion of figures. The most extensive amount was 1/20, which was necessary several times particularly on collections from Station 4 B, where the counts frequently ran up to ten or even twenty thousand Entomostraca per net sweep. Dilution several times prevented the appearance in counts of organisms observed in the living material, but no other method was feasible for collections containing considerable numbers.

Counts were made under a Zeiss binocular at a magnification of 10x. In addition to all the organisms within each counting square, those touching two sides were counted, the same two sides always being considered. The magnification was such that one counting square just fit the field. Obviously, many organisms could not be identified under the binocular, although it was sufficient for most forms. In cases where dissection or higher power was required, examination under the compound microscope was always made. This could not be done with every individual,

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but a definite number of those in question was examined and the ratio of the different species recorded. Where several species were involved, twenty were usually examined if available. With a mixture of only two species, the number used was usually twenty, but occasionally only ten could be prepared for determination of the ratio without excessive consumption of time. Thus, the counts probably more nearly represent the true ratios for Cladocera, many of which can readily be distinguished under the binocular, than they do for the Copepoda and Ostracoda, most of which require high power examination.

Counts for each station, with the exception of 1 A, are expressed in two ways. The actual number of each species in each collection and the total Entomostraca are given in tabular form for each station in the Appendix, Part II. Much of the information contained there is not discussed elsewhere in the paper, and analysis of the tables is essential to a full appreciation of results. The total each week and the number of Phyllopoda, Cladocera, Copepoda, and Ostracoda are expressed graphically (except for 1 A) for a one year period from October, 1937 to October, 1938. It is true that combining species into orders or suborders in the expression of their fluctuations often obscures interesting individual species peculiarities in seasonal distribution

and number. These are, however, adequately expressed in the tabular lists, and extreme fluctuations of a single species are pointed out in the text. The grouping used is of value in giving a clear picture of the relative and seasonal importance of the various orders at each station, a condition difficult to visualize from tables alone. The numbers of organisms are expressed per collecting unit and are graphed logarithmically. This logarithmic expression, of course, intensifies small values and minimizes fluctuations when the numbers involved are large. From a practical standpoint such expression was necessary in order to reduce the graphs to workable size, as it is impossible to express with actual values numbers varying from 16 to 41,756, for example, within the limits of an ordinary page. The logarithmic expression does not seem objectionable on theoretical grounds, as increases in number where the total is small are as well shown as changes where the total is large. For instance, on a given day, the number of Ostracoda may increase from 10 to 20 and the number of Cladocera from 2000 to 2500. In an ordinary graph the ostracod increase, although it amounts to a doubling of the number, would be almost imperceptible, while a 25 per cent increase in Cladocera would be far more prominent. From the ecological standpoint, the ostracod increase in such a case is certainly no less interesting or significant than the cladoceran

fluctuation and any form of expression which can present these changes in small groups in such a way that their importance is not overshadowed is desirable. If one adopts the premise that a doubling in number, whether from 10 to 20 or from 10,000 to 20,000, is always equally significant, a logarithmic graph presents results in perfect perspective.

Results

I. Analysis by Stations.

Station 1 A.

Physical factors are presented in tabular form (Appendix, Part I), and only the most salient features need be discussed.

The greatest variable at 1 A, as at all stations, was found to be temperature. In such small bodies of water as these, where thermoclines and overturns did not occur, the water temperature closely paralleled that of the air. This circumstance subjected the contained organisms to great extremes of heat and cold and to rapid fluctuations. Centigrade readings in November, December, and January frequently gave values of 1° and occasionally of 0°C ., while August values ascended to 26°C . A change of 10°C . in water temperature from one week to the next was noted on several occasions. In view of its important influence, the temperature factor will be considered further in the discussion of the seasonal distribution of the Entomostraca.

The oxygen content was found to vary considerably and somewhat erratically, the highest values occurring in the winter, which is to be expected, of course, on account of the increased solubility of O_2 at lower temperatures. On November 24, 1937, the time of the first appearance of ice, analysis of the water revealed no oxygen. Although living Entomostraca and dipterous larvae (*Chaoborus* sp.) were present, the former were considerably reduced in number. One week later the oxygen content measured 0.86 cc. per liter, and the number of Entomostraca was nearly quadrupled. On June 15, 1938, although the oxygen content was only 0.68 cc. per liter, over 1400 Entomostraca per collecting unit were taken, this being nearly seven times the number on December 1, when the oxygen content was very similar. These and comparable observations at 1 B suggest that the oxygen level must be extremely low in order to exert a limiting effect upon Entomostraca of certain species. Four species were found when no oxygen was appreciable and five more were added when less than 1 cc. per liter was present. Under ordinary circumstances the oxygen at 1 A appears adequate and no influence, either limiting or augmenting, can be assigned to it.

No particular interest attaches to the carbon dioxide content, except as it records the usual condition of acid, soft water pools, where free CO_2 is high and carbonates are low.

The pH was fairly constant, varying only from 5.6 to 6.8, with the most frequent value lying at or near 6.4. The pools at station 1 all exhibited a lower average pH than any other stations. While it is possible that this fact may be related to the presence of three species at station 1 which were never found elsewhere, it is improbable, in view of the usual entomostracan insensitivity to ordinary pH differences, that it is a causal relation. For instance, this station and station 4 B showed the highest numbers of Daphnia pulex, although the pH at 1 A centers at 6.4 while that at 4 B is most frequently above 9. Such facts do not of course exclude the possibility of pH as a limiting factor to some species, although the present work shows little evidence of such an influence.

The turbidity varied irregularly from the beginning of observation until September, 1938, when it decreased considerably. The importance of turbidity depends chiefly on the nature of the suspended material, which at station 1 was mostly inorganic matter from the clay bottom. While the turbulence here may serve to protect the contained organisms from direct rays of the sun, its importance does not seem great. In summer with the introduction of cows and a horse as frequent visitors to the pond, the turbidity not only increased but began to contain somewhat more organic matter (protozoa, bacteria, etc.). The highest counts of Entomostraca were recorded during this summer

turbulence, which suggests a possible correlation. This is not borne out by all the data, however. For instance, in the autumn and winter of 1937-1938, when the turbidity here was high the entomostracan population was smaller than that of the next season, 1938-1939, when the turbidity was so slight that the bottom was perfectly visible on many occasions.

The biota other than Entomostraca was very rich and can be treated only in a general way. Protozoa occurred in all collections with a spring and summer prominence of stalked ciliates and of flagellates and the presence in winter of shelled rhizopods. Simple plants occurred in small numbers, especially in spring and summer when several species of desmids and other algae as (Pleurotaenium, Zygnema, etc.) were regularly taken. This station was less rich in this respect than 1 B. Chlorohydra viridissima was found in spring and fall in very small numbers, and although they were obviously feeding on Entomostraca, the effects could not have been of great magnitude. Small free-living nematodes were frequent in winter, and in fall and in early winter rotifers were common. Stylaria and Tubifex were common oligochaetes, the latter occurring in enormous numbers in June and July. Odonata nymphs were frequent, larval and adult Coleoptera appeared often, several Hemiptera were regular inhabitants, and larvae of Diptera were very prominent. Of the latter,

Chaoborus was found in great numbers throughout the year, often as many as 200 per collecting unit. That these predacious larvae materially affect the entomostracan fauna can scarcely be doubted from a study of their food. All orders of Entomostraca, but especially Ostracoda were frequently observed in their alimentary canals. In late May and June Chaoborus pupae were common and imagoes began to appear; from then until July the larvae present were nearly all of the young, newly hatched generation. By late July or August many of these were of full larval size, but newly hatched individuals continued to appear until September. Molluscs were never common but an occasional Limnaea or Ancylus was taken.

The amphibian population was the most important spring factor in limiting entomostracan numbers. For several months, beginning in February, all ponds at Station 1 contained numerous Ambystoma larvae, first those of Ambystoma opacum, followed at A and B by those of A. jeffersonianum and A. maculatum. These larvae use Entomostraca as one of their chief foods, and adults were found to be eating some also, especially Ostracoda. Frog tadpoles are prominent at stations A and B except in mid-winter, and these were found to be consuming ostracods to some extent.

The following species of Entomostraca were taken at 1 A during the period of collection:

Cladocera--Alona rectangularis, Chydorus sphaericus, Daphnia pulex, Leydigia quadrangularis, Pleuroxus denticulatus, Pleuroxus hamulatus, Scapholeberis mucronata, and Simocephalus exspinosus; Copepoda--Canthocamptus staphylinoides, Canthocamptus staphylinus, Cyclops albidus, Cyclops prasinus, Cyclops serrulatus, and Cyclops viridis; Ostracoda--Candona crogmaniana, Candona ohioensis, Cypria elegantula, and Cypridopsis vidua. None was exclusively found here although Alona rectangularis and Candona ohioensis were found only at station 1. The seasonal peculiarities of the distribution of each species can be clearly seen from the tabular report (Appendix, Part II), as can their relative numbers each week. Only for 1 A was it found impossible to express the weekly collections graphically, this being due to the spring period of collection only from 1 B (when A and B were continuous). Counts at the two places for the remainder of the year were similar enough in general nature to make graphic representation non-essential, although the relatively greater productivity of the smaller pond, 1 A, is interesting.

Seasonal peculiarities of each species are not discussed for each station separately but will be found assembled in the general results. Only conditions peculiar to one locality are discussed under that heading. Such a set of circumstances is involved in the seasonal history of Simocephalus exspinosus. This large member of the family

Daphnidae is said by Birge (1918) to be "not common; reported from Massachusetts, Wisconsin, and the southern states" and yet it occurred in considerable numbers at various times at station 1. It was also found in an old canal bed near Cincinnati on May 21, 1937. The distribution should certainly be extended to include Ohio, as Roach (1932) has found it also in his studies of the Hocking River, where it was a member of the autumn plankton. It was first found at station 1 on April 9, 1937, and again on May 28, 1937, occurring at both A and B. Early autumn samples of the same year did not reveal it at either pond, its ecological niche apparently being occupied by Daphnia pulex. Daphnia was last found at 1 A on November 3, and the next week showed over 200 Simocephalus exspinosus per unit. Similar observations were made at 1 B, where, however, Daphnia disappeared two weeks earlier, and Simocephalus was first present on October 20. The latter persisted in 1937 until early in December and was not found again until autumn of 1938. Daphnia reappeared in March, 1938 and was the dominant cladoceran at both ponds until September 8, when its place was again abruptly taken by Simocephalus exspinosus at 1 B. This, as in the previous year, was followed by the same behavior at 1 A somewhat later (November 11). During 1937 Simocephalus was found in spring and fall but during 1938 the spring appearance was entirely absent and it was present only in autumn. In the

winter of 1938-1939 it was constantly present, and it was still persistent at the last observation on April 25, 1939. These data suggest the possibility of a biennial cycle for Simocephalus exspinosus somewhat similar to that described by Birge (1898) for Daphniaⁿ pulex pulicaria in Lake Mendota. On the other hand, the cyclic phenomenon may be that of Daphnia, which appeared in spring only in 1938, an appearance which may have prevented the development^{of} Simocephalus at that time. The point cannot be settled, but one argument in favor of Simocephalus exspinosus as possessor of the rhythm is the lack of such a cycle in Daphnia pulex at station 4 B. This also prevents the simple assumption that Daphnia is less tolerant of low temperatures than Simocephalus, as Daphnia was taken in great numbers at 4 B in mid-winter. The similarities in size and general behavior of these two species may make them competitors which cannot exist simultaneously in the same small pond. What circumstances cause the ascendancy of one species at one time and of the other at another cannot be stated with finality on the basis of present records.

The absence of the fairy shrimp, Eubranchipus vernalis, from the records of this station is due to the lack of collection from 1 A during its period of abundance. It occurred in this pond in very small numbers during the time it was confluent with 1 B, from which the samples were then

being drawn, and reference to the counts at B for this period gives the census for the entire body of water.

Quantitative results at this pond were similar in general to those for 1 B and reference to the graph (Fig. 3) of the latter will give the seasonal picture fairly well. The early fall rise was due to Simocephalus exspinosus, and the rather high winter population was mainly Cypria elegantula, with a peak of Canthocamptus staphylinoides on December 22. The reproductive period of Cypria in April and May caused the numbers to rise, due to the many larval ostracods. After a slight reduction in total population with the falling off of Cypria, Daphnia became the dominant form and increased to give the yearly peak at this station on July 20 (total of 14,900 Entomostraca). Summer levels were increased also by another of the Daphnidae, Scapholeberis mucronata. Beginning in August, totals fell gradually until mid-September and then dropped abruptly to the autumn level. This was not so low as in autumn of 1937 due to the somewhat later persistence of Daphnia pulex. Winter and spring levels would not be very different if it were not for the earlier onset of reproduction in Cypria in 1938-1939, which brought somewhat higher totals the second year. Copepods were never responsible for pulsations in the population at this station, occupying a position of medium importance, except for occasional fluctuations throughout

the year. Canthocamptids swelled the winter and early spring numbers, while young Cyclops were important in March and again in July. Ostracods other than Cypria elegantula had virtually no effect on total counts, occurring only in small numbers. Further discussion of quantitative data will be found in the general results.

Station 1 B

Physical factors are presented in tabular form (Appendix, Part I), and much of the discussion under 1 A applies also to this station.

Temperature variations at this station were almost identical with those at 1 A, since the ponds lie only a few yards apart. The water temperature reached extremes of 0° C. and 28° C., the latter slightly higher than at A, due to its less depth. The general discussion of seasonal occurrence of each species, at the end of this section, is essentially a discussion of the effects of temperature, which will not be further considered here.

The oxygen content at B was similar in general to that of A, although it never reached the heights recorded at A in the winter. The conditions attending the absence of appreciable oxygen on November 24 have already been discussed. On normal occasions the oxygen concentration here seemed adequate to entomostracan requirements.

Carbon dioxide, carbonates, and pH were similar in amount or value to the conditions at A.

Turbidity values were roughly similar until August, 1938, when the water at B became very clear. One week after the bottom became visible, the total entomostracan population dropped very abruptly, coincident with the disappearance of *Daphnia pulex*. While the water was still clear, (as it was from then until the end of the observations), *Simocephalus exspinosus* appeared in considerable numbers. If the disappearance of turbidity were correlated with a reduction in food supply, it might partially explain the disappearance of *Daphnia*, except that it seems improbable that an organism with the excellent feeding mechanism of *Daphnia* should have to give way to another form (*Simocephalus*) whose methods of ingestion are certainly not superior.

Biotic features here were very similar to those at A. In addition to the forms mentioned there, a bryozoan, *Plumatella princeps*, was very common in summer and fall and *Gyrinus* was often seen. The same algae, such as *Stauroneis*, *Pleurotaenium*, *Netrium*, *Closterium*, *Spirogyra*, and *Zygnema*, were found at both ponds, but the supply was more plentiful at B. If algae are the chief food of Entomostraca, it seems that B should be more productive of entomostracans than A. However, accurate algal counts might reveal that this difference in plant life between A and B is more apparent than actual. Also, as Birge has shown, various Entomostraca are extremely selective as to algae consumed, and

it may be that the more numerous types at B are not an important source of food. The Crustacea of these ponds may be feeding on fine organic matter in suspension to the exclusion of algae, as examination of stomach contents failed to reveal recognizable plant remains. This is not incompatible with the work of Huff (1923) who found that destruction of algae in Vadnais Lake on several occasions did not materially affect the number of Entomostraca and who states that the decay of higher seed plants, etc. of a lake or pond contributes more largely to the food of Crustacea than do the algae.

The following Entomostraca were taken at station 1 B sometime during the period of observation:

Phyllopora--Eubbranchipus vernalis;

Cladocera--Alona costata, Alona rectangula, Chydorus sphaericus, Daphnia pulex, Leydigia quadrangularis, Pleuroxus denticulatus, Scapholeberis mucronata, and Simocephalus ex-spinosus; Copepoda--Canthocamptus staphylinoides, Canthocamptus staphylinus, Cyclops albidus, Cyclops bicuspidatus, Cyclops fuscus, Cyclops prasinus, Cyclops serrulatus, and Cyclops viridis; Ostracoda--Candona crogmaniana, Candona ohioensis, Cypria elegantula, Cypridopsis vidua, and the larvae of a species of Eucypris.

Several of these forms were never found at A. Alona costata is a common species everywhere, actually much commoner in this series of stations than Alona rectangula, which was found only at station 1; hence its presence is

not extraordinary, although it is rather odd that it was not taken at A. Cyclops bicuspidatus may be assumed to have occurred at A, as well as at B, as it was taken from B during the time it was confluent with A, and the same is true of Cyclops fuscus. Probably it is only because A was not sampled during the time of prevalence of these forms that they do not appear in the records there.

Eubbranchipus vernalis and the young Eucypris sp. fall into the same category and almost certainly occurred in both ponds, although the infrequent spring records of 1937 and 1939 do not reveal them. The changes in water level of A and B probably give them a sufficiently temporary character to allow development of the fairy shrimp eggs. Although migration of the animals, after hatching, from the temporary pond C to B, where they were found, was possible through several small channels, the shrimps at B probably hatched at that pond. This is suggested by the fact that they attained maturity considerably earlier than those in C, were consequently larger and more advanced in development at any given week and were always quite different in coloration.

Seasonal distribution and numbers of all the species at this pond may be found in the Appendix, Part II. The features peculiar to these ponds in this respect are discussed under 1 A, and the general consideration at the end of this section will reveal seasonal relations in their

more general aspects.

Graphic presentation of the numbers of Entomostraca by major groups for a one year period is made in Fig. 3. A rather low level existed in October and November, with Simocephalus exspinosus determining the general shape of the curves, and with small October rises in Cypria and in Cyclops serrulatus. With the disappearance of Simocephalus, the totals for several succeeding months were chiefly determined by the numbers of Cypria elegantula. Four peaks, in Dec., Feb., Mar., and Apr. were formed chiefly of Cypria with Canthocamptus staphylinoides making definite contributions. The spring maximum, on May 4, of 2240 was composed chiefly of young Cypria, with some contribution by Daphnia pulex, while the copepods were unimportant. With the high temperatures of late May, Cypria, being predominantly a cool water form, lost its position and finally ceased to appear in late June. In the meantime Daphnia was on the increase and determined the totals for June, July and August. Some influence on the general level was exerted by young forms of Cyclops, probably chiefly albidus and viridis. The yearly maximum fell on July 13 (for the 1937-1938 period) with a total of 6456 Entomostraca per unit, of which 6408 were Daphnia pulex, nearly all young individuals. A second pulse of 4592, again due to Daphnia, was observed on August 9.

Fig. 3



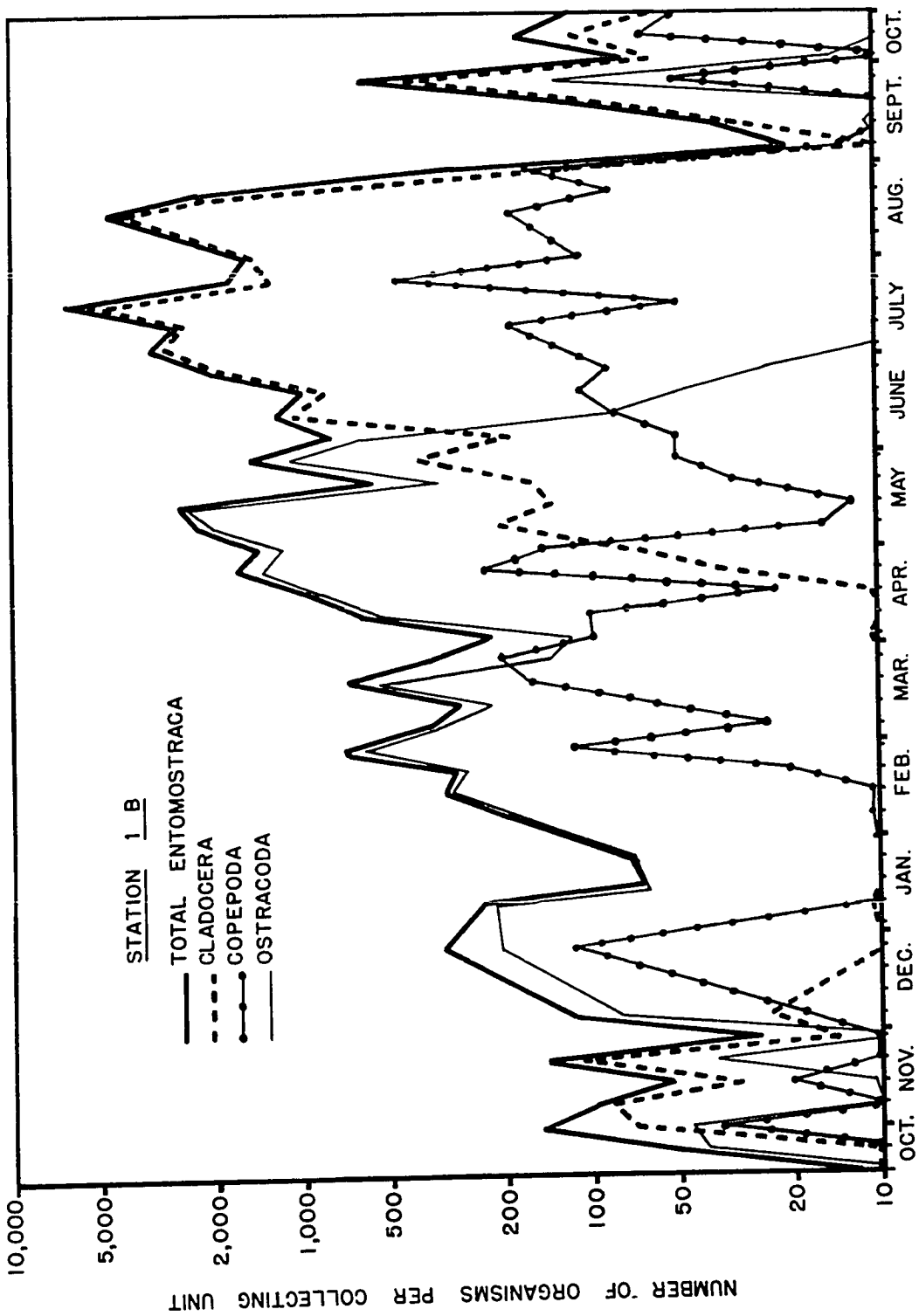


FIG. 3. STATION 1 B. SEASONAL CENSUS OF ENTOMOSTRACA BY MAJOR GROUPS, OCT., 1937 - OCT., 1938

The fall in numbers, occurring in late August when temperatures were still high, involved all groups. This was followed by a rise induced chiefly by Simocephalus exspinosus, with contributions by Cypria and by Cyclops, a general picture somewhat similar to that occurring the previous year a few weeks later. The situation in the following year, while not graphed and observed only at monthly intervals, revealed numbers of the same general level, as the table shows. Several counts are strikingly similar, for instance the total of 54 on November 10, 1937, and that of 52 on November 11, 1938, with the composing species being practically identical. In most cases, however, the correlation is far from close. This is due in part to the erratic behavior of Cypria elegantula and in part to the persistence of Simocephalus exspinosus in the winter of 1938, which was discussed above. Quite a different seasonal picture would certainly exist at this station if the dominant ostracod were not Cypria elegantula. Otherwise the winter numbers would have been extremely few, as these small ponds with their extremes of temperature appear able to support only very cold-hardy forms in any considerable number in winter. The fact that this condition of ostracod dominance is unusual will be more evident after consideration of the populations of the other stations.

Station 1 C

For details of physical conditions the table in the appendix (Part I) should be consulted.

The most important physical feature of this pond was its intermittent character. This limited its fauna to forms which could survive a period of drying and also allowed the appearance of such types as the fairy shrimp, which apparently requires desiccation at one phase of its life history.

Temperature showed less extremes than at A and B, because the pond existed only in spring and summer. The range was from 1° to 24° C.

Oxygen content was always low, but never fell to 0. It seems not to have been an important limiting factor in the amounts in which it was present. Even when the oxygen was as low as 0.86 cc. per liter, Entomostraca were numerous, the fifth largest count of the entire study at 1 C being recorded on that date (August 9, 1938).

CO₂ values were not of particular interest. Free CO₂ occurred in relatively large amounts, paralleling the high acidity which is often characteristic of such temporary pools.

The pH varied from 5.5 to 6.4 but centered around 6.

Turbidity was never measurable, as the bottom of the pond was clearly visible at every observation. This further corroborates the idea that high turbidity is not essential to an adequate food supply, as the high counts

recorded at this station on several occasions certainly indicate an abundance of nutriment in spite of the clarity of the water.

The general biotic picture here is typical of natural temporary woodland pools and will be presented with great brevity. Some of the algae observed at A and B were found in late spring and summer in small amounts, as was also Oedogonium. Protozoa were present at all times, several species of flatworms were common, leeches were abundant, Chaoborus larvae were few, the larvae and pupae of Culex were present in enormous numbers as summer approached, the isopod Asellus communis was prominent, and the small clam Sphaerium was often taken. From the first appearance of water in February, numerous larvae of Ambystoma opacum were present and feeding on the Entomostraca.

The following species were taken at 1 C during the period of study:

Phyllopoda--Eubbranchipus vernalis; Cladocera--Alona costata, Chydorus sphaericus, Daphnia pulex, Scapholeberis mucronata, and Simocephalus exspinosus; Copepoda--Canthocamptus northumbrius, Canthocamptus staphylinoides, Canthocamptus staphylinus, Cyclops bicuspidatus, Cyclops prasinus, Cyclops ater, Cyclops phaleratus, Cyclops serrulatus, Cyclops viridis, Diaptomus sanguineus, and Osphranticum labronectum; and Ostracoda--Candona crogmaniana, Cypria elegantula, Eucypris fuscata, and two Eucypris species of

which descriptions have not yet been published. Dr. Furtos (personal communication) has taken the one listed in the table, a small green form, from ponds near Cleveland in April and has described it but not in publication. A form quite similar to Eucypris fuscata but differing in color and some other features was found in small numbers in association with E. fuscata. This is a species somewhat similar to a new form observed by Furtos in the same type of environment near Cleveland, but is not identical.

Canthocamptus northumbricus, Diaptomus sanguineus, Osphranticum labronectum, and the three eucyprids were peculiar to this pond. Larval Eucypris was observed at several other spots in spring, but only at C did they mature and occur in sufficient numbers to figure in the counts. With the exception of the canthocamptis^d the presence of the exclusives is almost certainly due to the fact that only at C is found the period of drying essential to completion of their life histories. Canthocamptus northumbricus is not described as peculiar to temporary ponds, and it is possible that its absence from other stations is an accident of distribution rather than a significant condition. On the other hand the data on life histories of these forms is rather scanty, and the fact that C. northumbricus is a temporary pond inhabitant may have escaped previous observation or publication. In

addition to the exclusives at C, several species of rare occurrence in this study were also taken. Canthocamptus staphylinus, never common, was found here twice in some numbers. Cyclops ater was so rare as never to figure in the counts and was taken at C only once, in February, during the period of weekly observations. It was found there again in spring, 1939, and was recorded there for April, 1937. Station 3 was the only other place of its occurrence, and it was found there only on November 30, 1938. This autumn appearance agrees with the observations of Roach (1932) as to its seasonal distribution in the Hocking River. The fact that Turner (1892) took it shows that it also occurs in this area in the warmer parts of the year, as his collecting appears to have been confined to late spring, summer, and very early fall. Cyclops phaleratus, likewise exceedingly uncommon, was found in very small numbers in April, 1938, at C. So few were present that none was ever included in the counting samples but the fresh material revealed them. This appearance was not repeated in 1939, but it was observed on one occasion, November 3, 1938, at station 3.

The considerable number of exclusive or uncommon species at C, while chiefly due to its temporary character, may be in part due to its long existence. It appears to be a natural depression which probably has contained water annually for many years. Cyclops ater and

C. phaleratus were found here and at station 3, the pond of greatest known age in the study.

Quantitative results are graphed logarithmically in Fig. 4. The general shape of the curve during the first period when water was present was determined by the Canthocamptids, chiefly Canthocamptus staphylinoides. Eubbranchipus vernalis was present in rather large numbers, but as the size increased, the number per counting unit inevitably fell off. The ostracods, which contributed somewhat to the peak of April, were chiefly larvae of Eucypris, mainly those of E. fuscata. Also contributing considerably to the yearly high on April 21 was Daphnia pulex, which increased gradually in number from February 10 until that time. The May drought was followed by the appearance of organisms in about the same total number as that following the appearance of water on February 3. Here, however, with the warm temperature, Canthocamptus was not the important copepod, the early peak being caused by young Cyclops, chiefly C. viridis and C. serrulatus. This copepod lead was quickly replaced by a cladoceran peak, due to a period of reproduction in Daphnia pulex which produced a second pulse almost as large as the yearly high. The brief periods between droughts in July and August showed a dominance of Cyclops viridis on the earlier date and an ascendancy of Daphnia pulex in August. The

Fig. 4

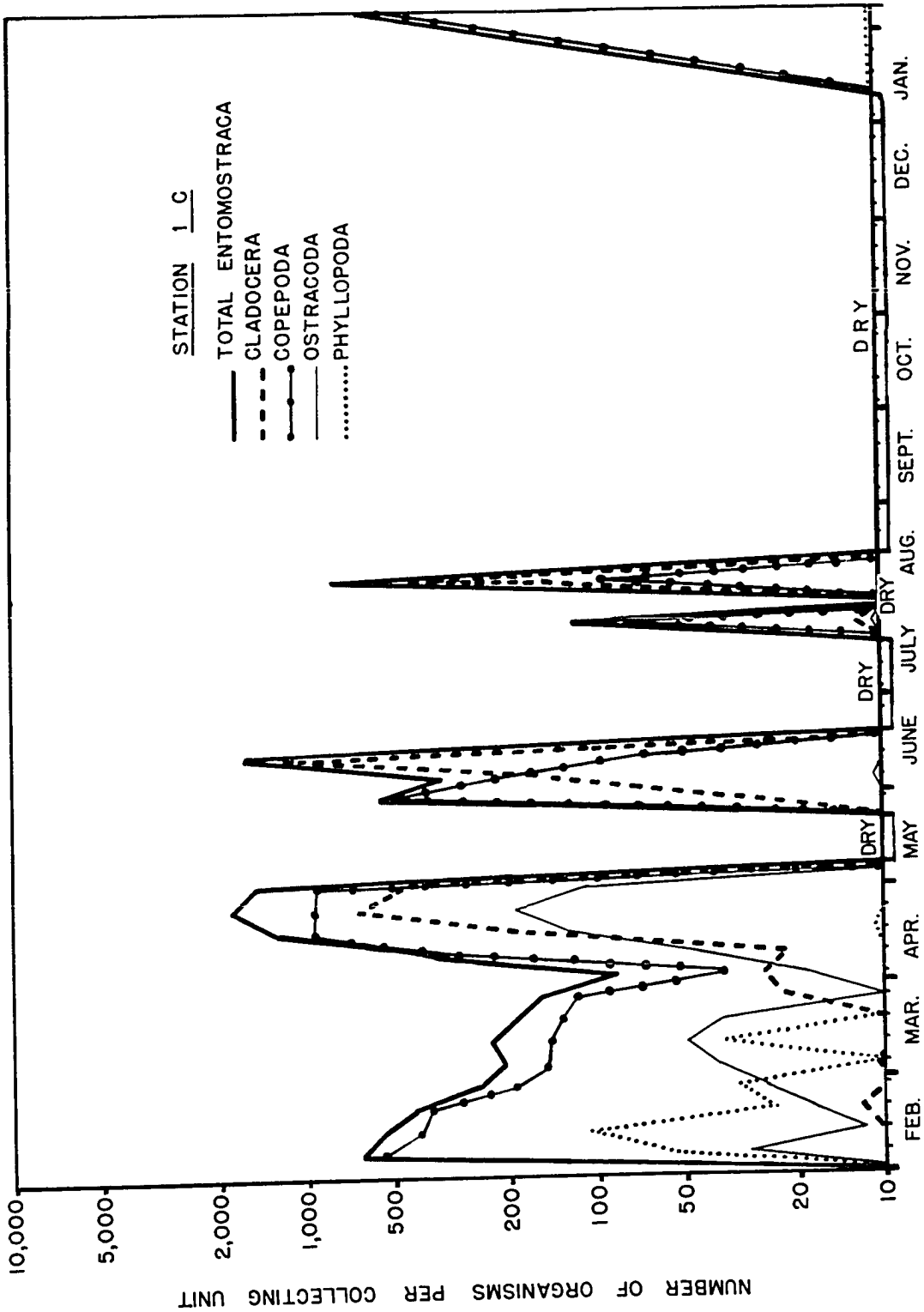


FIG. 4. STATION 1 C. SEASONAL CENSUS OF ENTOMOSTRACA BY MAJOR GROUPS, FEB., 1938 - FEB., 1939

first date, February 3, on which water was found in 1939, after a five-month drought, showed a population very similar to that of the same date the preceding year. Total numbers were much alike (646 and 624) the predominance of canthocamptids was evident, and larval fairy shrimps were present, though fewer than in 1938. This may be due to the much colder weather in 1939, when the pond was covered with ice on that date. Subsequent behavior at this pond is rather similar in 1939 to that in 1938, as the tabular data show. The reduction in number following initial appearance may be referred in part to the influence of predators, such as the Ambystoma larvae. Until the reproductive activities of the inhabitants developing from dried eggs can begin, the population must fall off in proportion to its inability to obtain food and to its consumption by enemies. This diminution in number while the first-hatched forms were growing to reproductive maturity was noticeable both years. The peak of April 21, 1938, while composed of many species, owed its height mainly to the first broods of young which were then developing from the individuals which overwintered in the dry state.

Station 2

Physical factors are given in detail in the appendix, Part I.

Water temperatures varied widely, from 29° to 0° C. All organisms in this pond were not subjected to such extremes, however, as temperatures at the bottom were more moderate. Since thermometer readings were taken less than a foot below the surface (where net hauls were made), the effect of air temperature was always pronounced. In winter the ice cover reduced the water just below it to 1° C or less, while the bottom temperature was usually 3° or 4° C. This condition is quite different from that at the shallow ponds of station 1, where bottom and surface temperatures were nearly identical. Thus, the winter diminution in numbers at this station (2) may in part be actual and in part a result of movement of many Crustacea to the warmer bottom waters where the net did not take them.

Oxygen values varied considerably but in general were fairly high. The largest amounts were found in late February and March, although all the winter readings were also high. The lowest records are those of June 15, 1938 (2.79 cc. per liter) and of September 15, 1938 (0.67 cc. per liter), on both of which dates more than two thousand Entomostraca were found in a collecting unit. These belonged to eight species in the June collection and to six species, of which but one was different, in September. The five highest counts of the entire period of observation occurred when the oxygen content was in each case less than 6 cc. per liter, and the greatest peak (10,378 organisms) fell at a time when the oxygen content was only

3.19 cc. per liter. These data corroborate the previously mentioned suggestion that the critical concentration of oxygen for many Entomostraca is very low.

Carbon dioxide in the free state was usually of medium amount, while carbonates were consistently rather high.

During the greater part of the observation period the pH was remarkably constant, but showed a summer tendency toward alkalinity on three occasions, which extended the range from a low of 6.8 to a high of 8.7. There were frequent periods of several months, however, when pH readings were never more than half a unit apart, with 7.0 the commonest figure. Such constancy naturally throws the burden of responsibility for seasonal changes in the entomostracan population elsewhere.

Turbidity was caused chiefly by the stirring of bottom sediment and the introduction of silt when the small brook at the upper end was flowing and hence was usually highest in spring and after heavy rain in summer. The lack of importance of such turbidity as a controlling factor in entomostracan numbers is easily seen by consultation of the tables in the appendix. For instance, on April 14, 1938, when the pond was so clear that no turbidity was measurable, the total number of Crustacea was 564; while on June 29, with the turbidity at 3 inches, the total number was 680, a negligible increase.

This station contained many algae, especially in fall and spring, and was richest of all stations in diatoms, such as Synedra, Fragilaria, and Stauroneis. Several desmids (Pleurotaenium, Closterium, etc.), the filamentous Zygnema and Viovox were common chlorophyll-bearers. The higher plants, chiefly Ceratophyllum, in addition to supporting diatoms, carried many stalked protozoans, the tubedwelling rotifer Floscularia, and in June and July the bryozoan Plumatella in considerable quantities. Pelmatohydra oligactis was frequently present in spring, in great numbers in May, when it was feeding voraciously on Entomostraca. Small free-swimming rotifers such as Noteus were numerous at times. Chironomid larvae, nymphs of Odonata, Haliplidae, Notonectidae, and several species of Hydra-carina were common arthropods. Only Laevapex and Planorbis among the molluscs were taken and these infrequently. Small fish occurred here, the only species taken being the common sunfish, Eupomotis gibbosus. Frogs were often seen on the margins, although tadpoles were not numerous enough to be taken in collection. The only other vertebrates seen were snakes (species unknown, since none was captured) and a muskrat, which had a dwelling at the upper end of the pond.

The following species of Entomostraca were taken at station 2: Cladocera--Alona costata, Alona guttata, Chydorus globosus, Chydorus spaericus, Leydigia quadrangularis (so few that counting samples never contained them),

Pleuroxus denticulatus, Pleuroxus hamulatus, Scapholeberis mucronata, and Simocephalus serrulatus; Copepoda--Canthocamptus staphylinoides, Canthocamptus staphylinus, Cyclops albidus, Cyclops prasinus, Cyclops serrulatus, and Cyclops viridis; Ostracoda--Cypria elegantula, Cypridopsis vidua, and Physocypria globula. Of these, Physocypria globula was the only form peculiar to this station; this may be due in part to its usual occurrence in slightly larger bodies of water than stations 1 and 4, as it is commonly found in ponds and in small lakes.

This list is composed of one less species than that of 4 A, which is eight years old, while station 2 has been formed for about thirty years. The only station containing fewer species than station 2 is only four years old. It is possible that the fish exerted restraint on the establishment of any species at station 2 which was introduced only in small numbers. The only important predators at station 1 were larval and adult salamanders, which were not year-round occupants and thus would tend to be less destructive of newly introduced species than fish. The pond 4 A, lying but a few yards from each of several other pools of different ages, had a close and abundant supply of Entomostraca ready for introduction at the time of its formation, while such a source was not available at station 2.

Fluctuations in total number of Entomostraca at this station were extremely wide, from 10,378 on July 13, 1938, to 14 on November 11, 1938. For details refer to

the table in Part II of the appendix. Grosser changes can be observed by a study of the graphic representation (Fig. 5). For the first few weeks of collection, the predominant group numerically was that of young Cyclops, probably a mixture of C. albidus, C. prasinus, C. serrulatus, and C. viridis, of which the proportions could not be determined in the larval state. A brief pulse of Chydorus ^Aspæricus and Pleuroxus denticulatus in mid-November produced a cladoceran increase which foreshadowed their winter dominance. This increase in Cladocera was both absolute and relative and very possibly came about partly in response to the copepod behavior. As inspection of the table shows, young Cyclops was an unimportant group in winter, occurring only in small numbers, with occasional sporadic rises of small amount, from December until the latter part of April. The chief Cladocera at station 2 were the small forms Chydorus and Pleuroxus, which are not much bigger than larval copepods, with which they probably compete for food. The continuance of reproduction throughout the winter in these forms, especially Chydorus, initiated the increase, which was probably accentuated by the survival of greater numbers in the absence of their competitors, the young cycloids. During this winter maximum of Cladocera, the ostracod, Cypria elegantula, was present in small numbers but assumed no numerical importance until its reproductive period in

Fig. 5

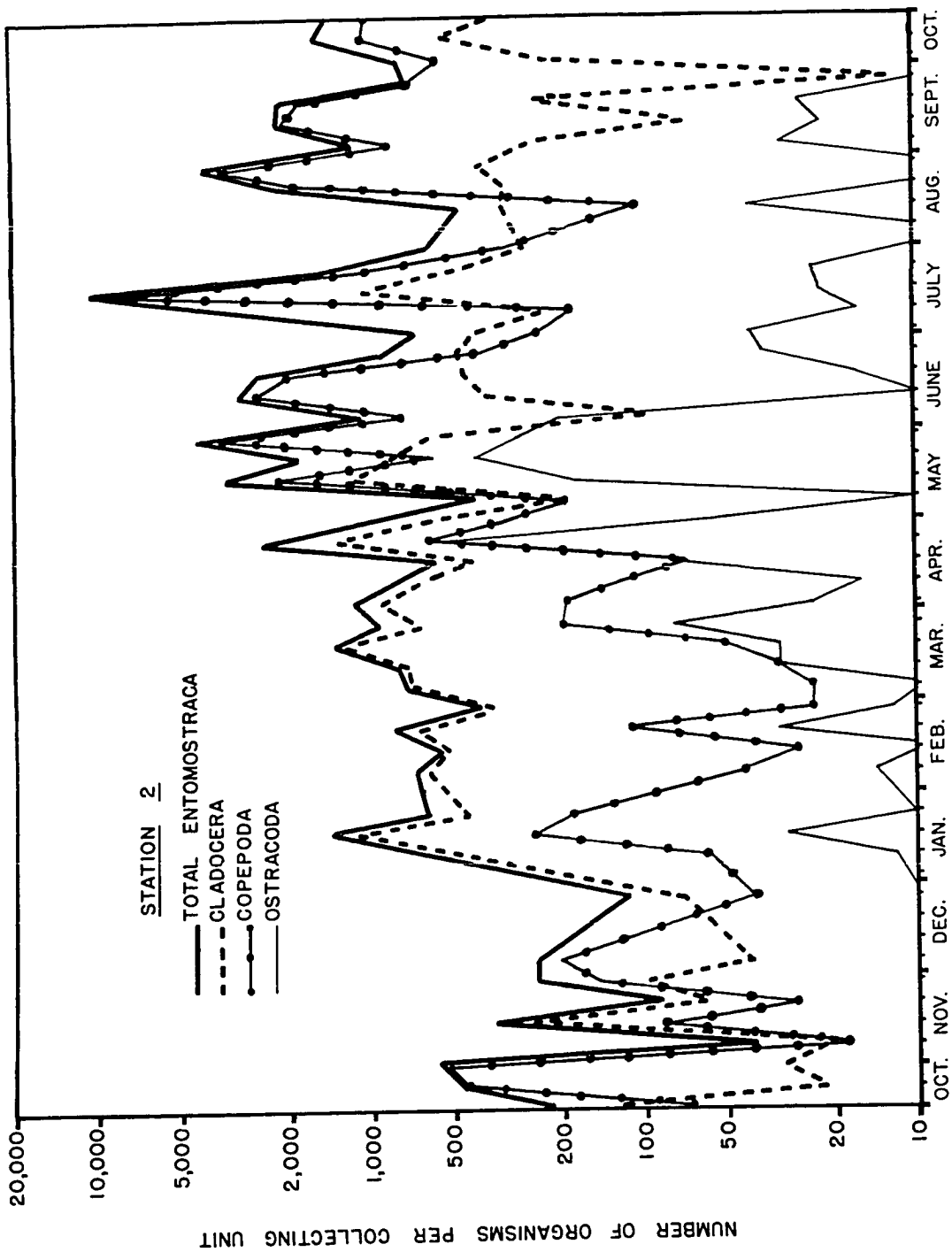


FIG. 5. STATION 2. SEASONAL CENSUS OF ENTOMOSTRACA BY MAJOR GROUPS, OCT., 1937 - OCT., 1938

late April. The greater relative and actual numbers of this species during the winter months at station 1, where it was then the dominant entomostracan, may be due in part to physical differences in the two stations. The chief reason, however, appears to be that station 1 was occupied by Cladocera which did not survive the winter, except for a very few Chydorus, and by copepods whose reproductive activity was suspended by cold weather conditions in these small exposed ponds. Cypria elegantula, a natural cold water form, was thus dominant at station 1 until spring, when other Entomostraca again encroached on its food supply and when it began to be consumed itself by salamanders; while at station 2, with its less rigorous winter conditions and its population of cold-hardy Cladocera, no opportunity for Cypria dominance was afforded.

The general rise in total number in May was due to reproductive activity in all groups, but with a quick assumption of dominance by Cyclops, a dominance which was not lost again until the following winter. Although summer eggs were formed in both Pleuroxus and Chydorus at all times of the year, the number of offspring produced never approached that of Cyclops during its active period. It is important to realize, however, that the cladoceran young were held in the brood chamber during larval stages rather than existing as free swimmers like the copepod nauplii and hence were not counted until after release. Consideration

of adults only shows a year-round dominance of Cladocera, especially Chydorus sphaericus, at station 2.

With the warm waters of late June, Cypria elegantula disappeared, and ostracod numbers for the rest of the period graphed were chiefly those of Cypridopsis vidua, with a very small contribution by Physocypria globula on one occasion. Totals in October, 1938, were considerably above those of October, 1937, but dropped shortly thereafter to a winter level which was much lower, except for a Chydorus pulse on December 10, than that of the preceding year. The winter cessation of reproductive activity in Cyclops was again noted, as was the lack of prominence of Cypria, but data for the second year are not complete enough to trace such conditions in detail.

Station 3.

Reference to the table in the appendix, Part I, is essential for details of physical conditions, which will be treated only in a general way.

The temperature variations here were similar in character to those previously mentioned. The relatively large size of this pond and its depth, as at station 2 to a lesser degree, allowed a moderation of the temperature at the bottom, but readings near the surface ranged from 0° to 28° C. There was little evidence of migration from the surface waters in cold weather, however, as winter numbers were not conspicuously low. However, the fact

that reproduction in Cyclops was not conspicuously reduced during the cold season, as was the case at station 2, argues for some protective effect from low temperatures. Whether this was due to the more moderate temperatures of the deeper levels or to the less abrupt changes in temperature which accompany increase in total volume of water, the graph (Fig. 6) clearly shows little influence of season upon its general trend. Aside from the low initial counts in October and early November and excluding the two high peaks caused by a single species, the general level of numbers at this station is nearly constant in all water temperatures. This material will be discussed further in consideration of the quantitative results at station 3.

Oxygen values never fell so low as at stations 1 and 2, the least amount recorded being 2.72 cc. per liter and the greatest 16.40 cc. per liter. High values were recorded in the winter months of both years, which was to be expected both from the greater solubility of oxygen in cold water and from the abundance of Spirogyra and other green algae. Values above 10 cc. per liter for nine consecutive weeks in the spring of 19 38 are interpretable partly as due to the annual pulse in algae. Although counts of these forms were not made, rough estimates indicated very large amounts of such genera as Spirogyra, Desmidium, Micrasterias, Pleurotaenium, and the green flagellate Volvox. Whether the second period of oxygen

increase in July and August was referable to another algal pulse cannot be determined from the data, although all the above mentioned forms except Spirogyra were present and Cosmarium, Closterium, and Pleodorina were added. The presence in great amounts of Ceratophyllum and Spirodelia during those months probably also contributed to the high oxygen content. It is virtually certain that oxygen at this station was never low enough to impose a limit on the presence of Entomostraca.

In spite of the acidity of the water on most occasions, the free carbon dioxide at station 3 was always rather low. The release of organic acids by the decay of living matter may have been partly responsible for the low pH, as the extensive biota would suggest. Carbonates were high in the autumn of both years and extremely low in the spring and early summer.

The pH varied widely, from 5.5 to 9.5, but the alkaline values were exceptional and occurred chiefly in the summer; 60% of the determinations lay between pH 6 and pH 7. No particular correlation between shifts in pH values and changes in entomostracan populations appeared. To judge from the richness of the crustacean fauna at station 3, considerable variation in pH is not detrimental.

Measurable turbidity at this station was rare, as the water was usually so clear that details of the bottom were plainly visible even in four or five feet of water. Since station 3 produced the greatest variety of Entomostraca and next to the largest single collection, turbidity

does not seem to be an index of productivity.

The biota of this station, in line with its age, was richest of all collecting places. The population of algae and higher plants requires no further mention, while animal forms can receive only the briefest treatment. Protozoa were well represented, especially by colonial flagellates, stalked infusorians, and shelled rhizopods such as Centropyxis and Diffugia. The flatworm Stenostomum was common, as were free swimming rotifers such as Cathypna. The oligochaete Stylaria was frequently taken. Collembolans, Haliphus, Dytiscus, and a number of other aquatic insects were common, as well as a great many larval forms representing the Ephemera, Odonata, Diptera, and Coleoptera. Limnaea was a fairly common mollusc. Fish are common at this station and were several times observed. The bluegill, Lepomis pallidus, and the common sunfish, as well as catfish were present and must exert some influence on the entomostracan numbers. Frog tadpoles were not uncommon. Of their feeding activities, little observation was made; one tadpole examined in the February 5 collection had an intestine filled with Pleurotaenium and Closterium and contained 1 Daphnia longispina, 1 Cypria elegantula, and 2 Chydorus spaeicus, all apparently quite undigested. Observations of frog tadpole intestines on a number of other occasions suggest limited powers of digestion of Entomostraca, as living ostracods

were found several times in the lower gut.

Of all the organisms mentioned the plants probably occupy the position of prime importance to Entomostraca. The living algae serve as a source of oxygen and to some extent as food, while the higher plants are oxygenators while living and, when dead, an extensive source of the decayed organic substances which are important in crustacean nutrition. The vertebrates are limiting factors of significance, but the services of the abundant flora in supplying food, oxygen, and shelter, outweigh their disadvantages, as the productivity of the pond shows.

The following Entomostraca were taken at some time during collection at station 3: Cladocera--Alona affinis, Alona costata, Alona guttata, Alona quadrangularis, Alonella karua, Bosmina longirostris, Camptocercus rectirostris, Ceriodaphnia pulchella, Ceriodaphnia quadrangularis, Pleuroxus denticulatus, Pleuroxus hamulatus, Scapholeberis mucronata, Simocephalus serrulatus, and Simocephalus vetulus; Copepoda--Canthocamptus staphylinoides, Canthocamptus staphylinus, Cyclops albidus, Cyclops ater, Cyclops bicuspidatus, Cyclops fuscus, Cyclops phaleratus, Cyclops prasinus, Cyclops serrulatus, Cyclops viridis, Diaptomus pallidus, and Diaptomus siciloides; Ostracods--Candona crogmaniana, Cypria elegantula, Cypridopsis vidua, and Cyprinotus incongruens. Cyclops ater, Cyclops phaleratus, and Candona crogmaniana were present in such small numbers that they never appeared in counting samples. Ten of these species were found at no other station

of the regular group, these being: Alona affinis, Alona quadrangularis, Alonella karua, Bosmina longirostris, Camptocercus rectirostris, Ceriodaphnia reticulata, Daphnia longispina, Simocephalus vetulus, Diaptomus siciloides, and Cyprinotus incongruens. However, the single collections made from other localities showed six of these species, leaving only the following four as exclusives at station 3: Alona affinis, Alona quadrangularis, Alonella karua, and Ceriodaphnia reticulata.

Although this list of 35 species was much the largest observed at any one place, it is comprised of rather ordinary forms. At any one collection the greatest number of species taken was 16, of which 9 were Cladocera. The preponderance of cladocerans both in the species list and in the quantitative work is very evident. As Shelford (1911) points out, the youngest ponds ecologically have no or few ostracods, few Cladocera, and the most copepods; it is possible that this station is beyond the youngest stage, although only 70 years old. With the gradual introduction of more species of Cladocera competition with the existing copepods for food would inevitably appear. The excellent feeding mechanisms of the cladocerans might conceivably give them sufficient advantage over such forms as Cyclops with their rather inefficient methods (Birge, 1898) to lead to ultimate cladoceran dominance. Probably, however, changes in the physical character and nature of the food

supply which occur as a pond matures are very important in the faunal shifts. Attempts to explain such a succession with the limited data at hand are mere speculations.

The only form apparently unusual for Ohio in the list is Alonella karua, which is described by Birge (1918) as occurring in Louisiana, Texas, and Arkansas, not rarely, and in pools and lakes. However, as Fig. 10 shows, this form occurred here only in the warmest months, which would suggest either a recent introduction with lack of adaptation to cool water as yet, or an inherent lack of cold-hardiness. The Daphnia longispina of station 3, as Fig. 10 shows, appeared sporadically and showed no helmeting or head shape changes at different seasons. This is the expected condition in small bodies of water, as crest formation is characteristic of limnetic crustaceans. Also the D. longispina of station 3 was the type "primitiva" of Woltereck (1932), which is small, with a round head and no helmet, and occurs in small shallow lakes and in ponds, such as the artificial bodies of water in municipal parks. In such localities it usually lives near the surface of the water, where it was taken at station 3.

Quantitative results have been treated briefly in connection with temperature, where the rather uniform character of the graph (Fig. 6) was mentioned. The low values at this station in October and November, 1937, as at several others, may be in part actual and in part an effect of the collecting method. As mentioned previously,

the first five weeks' collections comprised the organisms in 20 two-yard net hauls, while after that time the number of sweeps was reduced to 10. As the area reached by the net was never large, 20 sweeps may possibly have somewhat depleted the stock of Entomostraca even before the collection was complete, with the result that the catch did not represent the actual number of organisms originally present. A reduction of 10 sweeps may have brought about a more accurate correspondence between catch and number of organisms actually present, as each of 10 sweeps could easily be taken at a new spot. If such an explanation is not adequate (and it certainly is not completely so), the low totals of the early fall of 1937 are without obvious cause, as no change in physical factors appears responsible.

The cladoceran preponderance throughout the collecting period was largely caused by a few species, which in order of importance were Bosmina longirostris, Chydorus sphaericus, Ceriodaphnia pulchella (in summer), and Pleuroxus denticulatus. Other species were never present in numbers sufficient to change the totals in a material way. The fall rise was chiefly a rise in Chydorus sphaericus, which continued at a rather high level throughout the winter, except for the latter part of December. The low point on the graph at that time was followed by an enormous increase of Bosmina longirostris (from 12 to 16,618 organisms) in the two weeks from December 18 to December 31.

Fig. 6

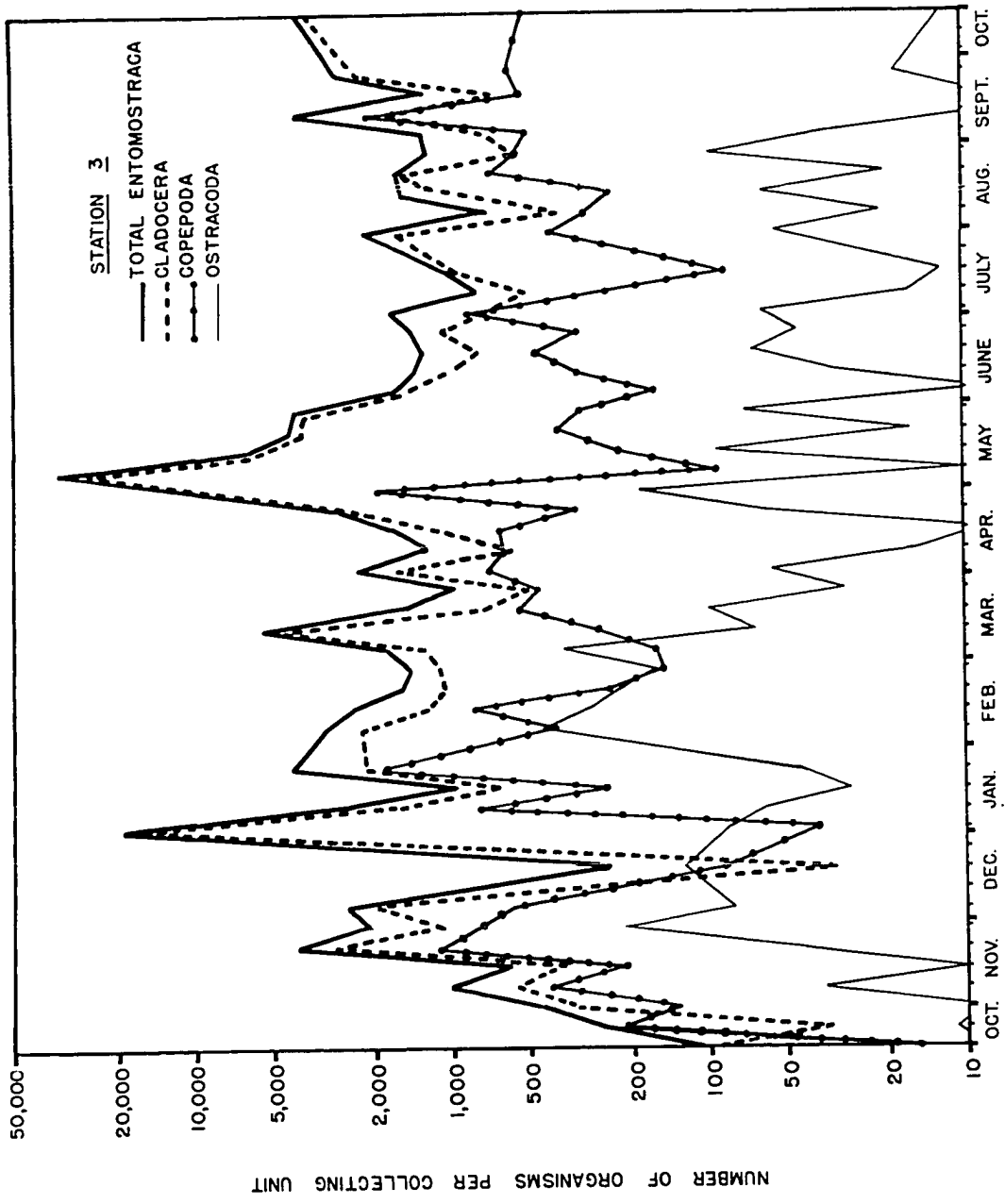


FIG. 6. STATION 3. SEASONAL CENSUS OF ENTOMOSTRACA BY MAJOR GROUPS, OCT., 1937 - OCT., 1938

This corroborates the finding of Kofoed (1908), who states that Bosmina is capable of extremely rapid multiplication, which may be due primarily to increased food supply. That this may be the case here is suggested by the figures of the collection previous to the peak. The low total of 244 organisms on that date, of which only 32 were cladocerans, certainly reduced the consumption of food, which would increase its availability for any form not suffering from the cold. The bulk of the organisms (120) of that date were ostracods, principally bottom feeders, which would not tend to check the stock of food accessible to Bosmina in the upper waters. It is possible that this circumstance, plus the inherent capability of Bosmina for rapid multiplication, caused the sudden increase.

Of the copepods at station 3, the totals were determined by the number of young Cyclops, with little influence by any adult form except Diaptomus pallidus in the warmer months and until the early winter of 1938. Slightly higher numbers of young cyclopids, added to the cold weather numbers of Canthocamptus and to slight increases in the numbers of adult Cyclops viridis and C. serrulatus, raised the Copepoda to a slight plateau in the first four months of 1938. The coincidence of this condition with the maximum cladoceran numbers (exclusive of the two Bosmina peaks) for the year produced a high general level for the first six months of 1938, when the total only once fell below

1000. Narrowing the annual pulse to a particular week or even to a month is difficult at this station. The greatest general increase in all species occurred on the week preceding the high of year, which occurred on May 7. This rise was chiefly, as usual, Bosmina, but definite pulses of Ceriodaphnia pulchella, Chydorus sphaericus, Pleuroxus denticulatus, Simocephalus serrulatus, Simocephalus serrulatus, young Cyclops, Diaptomus pallidus, and Cypria elegantula occurred to bring the total on that date (April 30) to 13,050. The cause for the second Bosmina increase which led to the highest total of the observation period (32,250) the following week is not easily discovered. It was apparently not a food supply fluctuation, as the slight fall in numbers of Bosmina's chief cladoceran competitors in the preceding collection (April 23) was only slight. Kofoid (1908) reports a maximum, very large, for Bosmina in the Illinois River in June. Such a pulse may have occurred here somewhat earlier, although if it is a temperature effect, the reason is not app^arent, as even the June temperatures of station 3 were slightly less than those of Kofoid for the same month.

Ostracods were never important in the totals of station 3. The dominant species, as everywhere, was Cypria elegantula, which was replaced in importance by the other two species, Cypridopsis vidua and Cyprinotus incongruens, in late summer and early fall. As was pointed out previously, numerical dominance of Cypria seems to occur only under

special circumstances, such as obtain at station 1, where other Entomostraca fail to survive the winter. At a station with great numbers of copepods and cladocerans, Cypria does not possess the capacity to assume an important numerical position even in its season of greatest activity.

Data for the second year were obtained at intervals too great to build a complete picture, especially with a rapidly fluctuating organism like Bosmina in a dominant position. Noteworthy are the later persistence of Diaptomus pallidus, the presence of Camptocercus rectirostris, and the larger numbers of Bosmina longirostris in the autumn of 1938 as contrasted to that of 1937. Further points of interest and details of all quantitative information are available in the appendix, Part II.

Station 4 A

Reference should be made to the appendix, Part I, for details of physical factors. Three of these,--water temperature, oxygen content, and pH are also presented graphically in Fig. 8.

This station was visited each time on the same day as were stations 3 and 4 B, and water temperatures were not very different at the three places, so that the temperature curve corresponds almost equally well to conditions at 4 A and 4 B and is roughly correct for station 3. A

Fig. 8

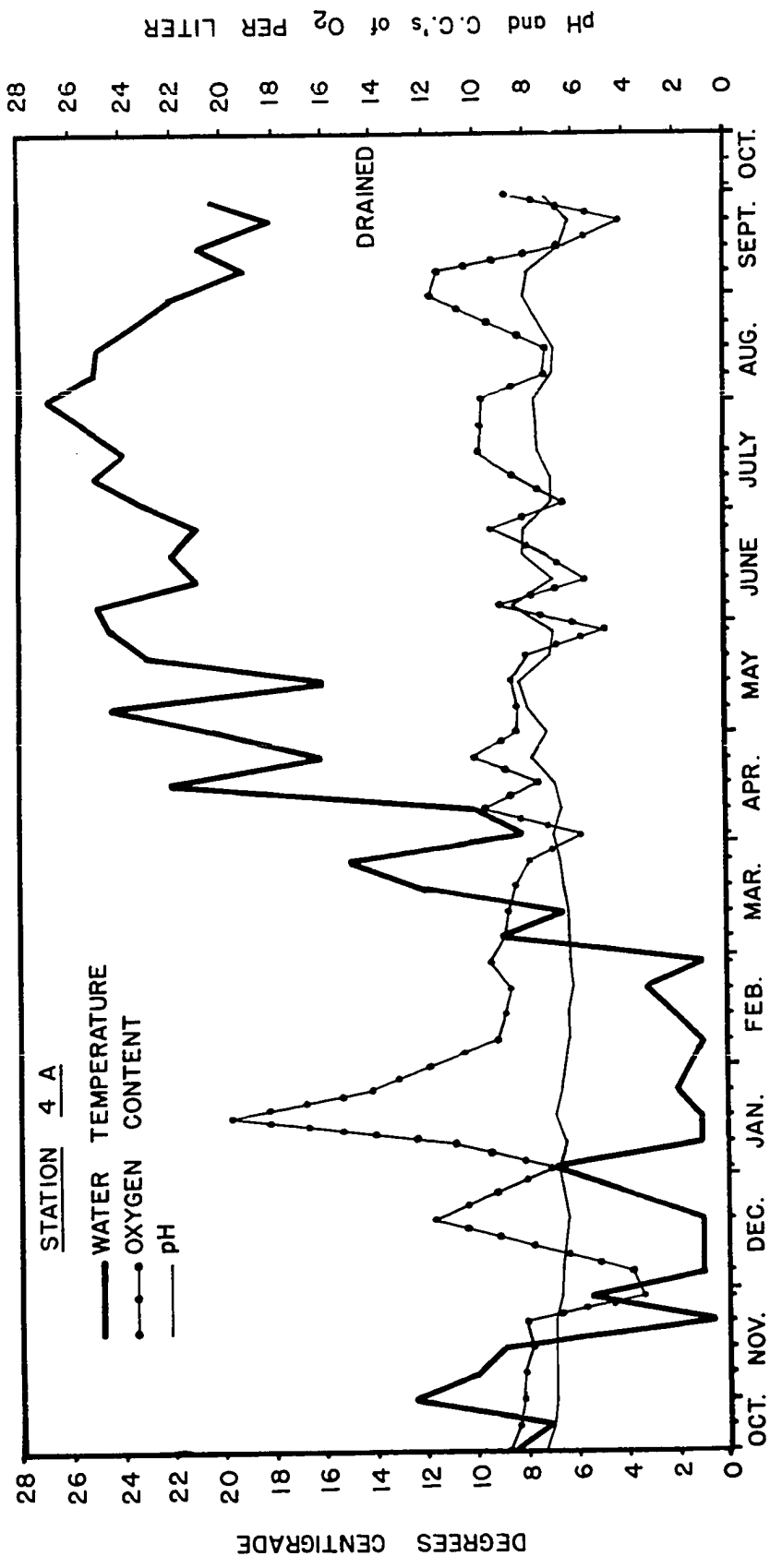


FIG. 8. STATION 4 A. SOME PHYSICAL FACTORS, OCT., 1937 - OCT., 1938

remarkably close correspondence between total Entomostraca and temperature occurred at this station, which, it will be recalled, is a very small and shallow drainage ditch. Winter conditions were severe throughout the entire body of water, the bottom usually showing temperatures between 1° and 0° C. when ice was present, with no deeper regions of greater moderation. Here, as at station 1, where conditions of temperature were somewhat similar, the only consistent winter inhabitant in addition to Cypria elegantula was Chydorus sphaericus. If Cypria had been present except as very few individuals in the fall, a winter curve similar to that at 1 B might have been expected, but the ostracods here were so few that a winter pulse was impossible. To judge from available data on Cypria reproduction, cold weather pulses are due rather to a higher rate of survival of individuals hatched in summer than to an actual period of propagation in early winter. At 4 A, where the greatest number of Cypria ever taken at one time was 4, such a condition could never swell the winter numbers. Further discussion of temperature influences falls more logically with a discussion of the quantitative results.

Oxygen was usually neither strikingly high nor low, although one very high value, of 19.7 cc. per liter, was obtained. This is rather readily explained as due to the

combination of low temperature with the activity of several species of algae which were then especially abundant. The rise in late August and early September was referable to the choking growth of Elodea which then crowded the entire ditch. No values low enough to serve as a check to the Entomostraca appeared. The graph shows the winter increase in oxygen content with the lowering of the temperature very clearly.

Carbon dioxide relationships present no special interest, with free CO₂ usually of medium amount and carbonates especially high in the fall.

The pH varied from 6.1 to 8.4 with remarkably constant values from October, 1937 to March, 1938, and small fluctuations from then until termination of the observations by draining of the ditch.

Turbidity variations were wide but apparently insignificant, as the greatest number of organisms (5,142) and the smallest number (12) occurred when the turbidity was 16 inches and 15 inches, respectively.

The biota here was surprisingly varied, considering the recent origin of the station; but as mentioned above, the ready source of organisms from other ponds a few yards distant was probably responsible. Except in midsummer such algae as Cosmarium, Closterium, Spirogyra, and Ulothrix were common, while the same was true of the green flagellates Euglena and Volvox. Higher plants,

chiefly Elodea and Castalia (see Fig. 2-A), were very abundant in the summer. Hydra americana (Hydra vulgaris) was common at times, occurring in very large numbers in April and feeding extensively on the entomostracan inhabitants. Several species of rotifers and the flatworm Rhynchomesostoma rostratum were common in summer collections. The small oligochaete Chaetogaster accounted for the destruction of many Entomostraca during its period of abundance in May; two typical examples contained respectively 3 Chydorus, 1 Diaptomus, and 1 nauplius, and 4 Chydorus, 3 Cyclops, and 1 Pleuroxus. The leech, Glossiphonia, was abundant in spring. The insect population was very large, the following orders being represented by larvae, nymphs, or adults: Hemiptera, Ephemera, Coleoptera, Odonata, Diptera, and Collembola. Although certain insect nymphs are said to consume Entomostraca, the only group found to do so by the scanty investigations pursued in this study were not nymphs but the dipterous larva Chaoborus. Water mites and the amphipod Hyaella were other common arthropods at 4 A. Physa and Viviparusⁱ were common snails. A few goldfish were put in the ditch in summer to discourage the development of mosquitoes and may have been partly responsible for the midsummer slump in numbers of Crustacea. Frog tadpoles abounded, and adults of Acris gryllus and Rana pipiens were frequently observed.

The following species of Entomostraca occurred at station 4 A during the time of its study: Cladocera--Alona costata, Ceriodaphnia pulchella, Ceriodaphnia quadrangula, Chydorus globosus, Chydorus sp^haericus, Daphnia pulex, Graptoleberis testudinaria, Pleuroxus denticulatus, Scapholeberis aurita, Scapholeberis mucronata, and Simocephalus serrulatus; Copepoda--Cyclops albidus, Cyclops fuscus, Cyclops prasinus, Cyclops serrulatus, Cyclops viridis, and Diaptomus pallidus; Ostracoda--Cypria elegantula and Cypridopsis vidua. One species, Graptoleberis testudinaria, was exclusively found at this station, never being taken even at the scattered collections from localities other than the regular stations, although the numbers at 4 A were often very large (up to 1140). Although a numerical preponderance of copepods was often observed, a greater number of the species taken was Cladocera. This should not be the case if Shelford's (1911) premise is correct that copepods first populate a newly formed body of water. The presence of the near-by ponds of older establishment probably is responsible for this condition.

Chief interest in the quantitative results centers in the pronounced correlation between temperature and numbers described above. The curve of totals takes its shape, except in midsummer, from the copepod population, which experienced a reproductive spurt in February to produce the only prominent increase in numbers before the water began to warm (Fig. 7). While the copepods of numerical importance

Fig. 7

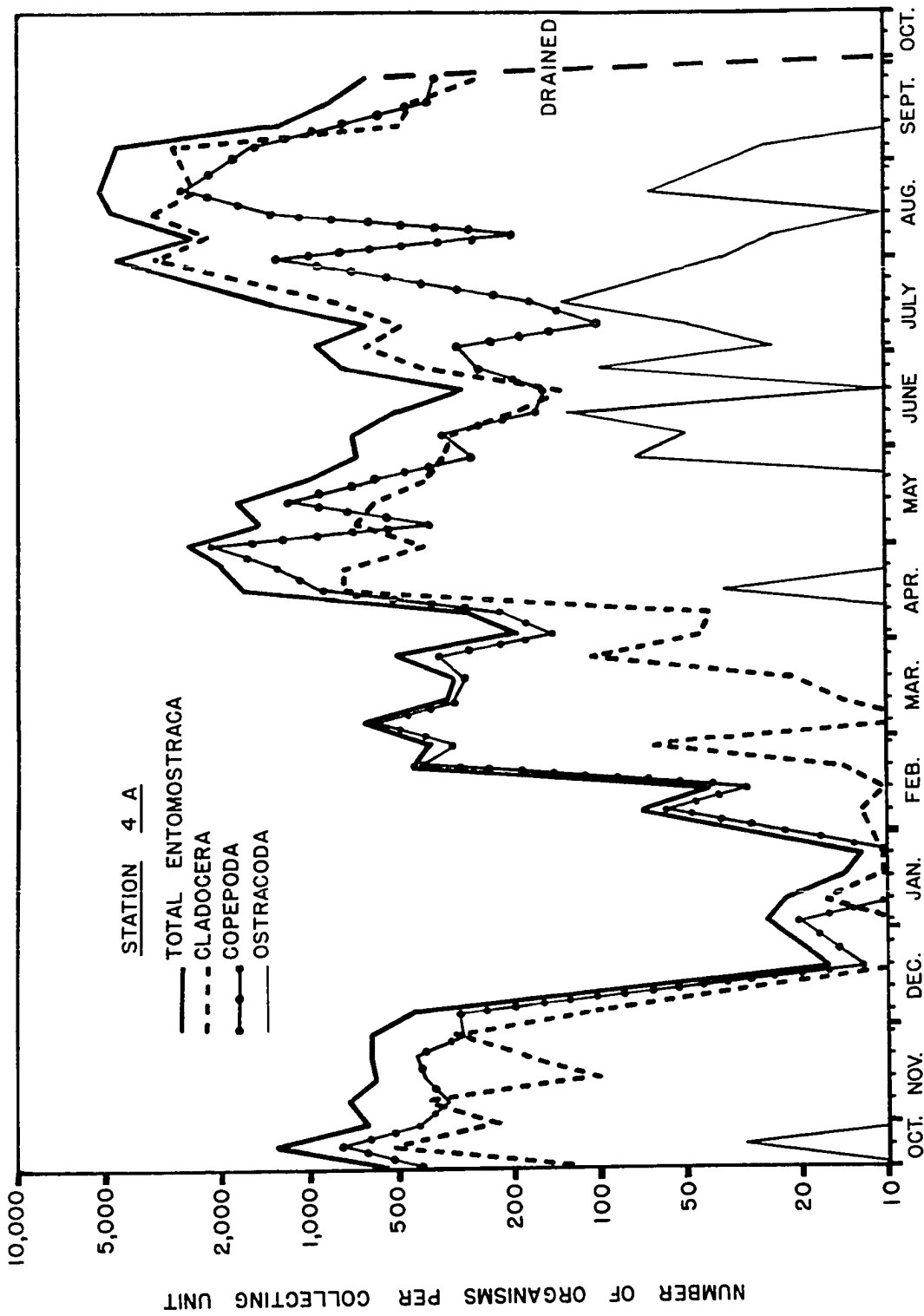


FIG. 7. STATION 4 A. SEASONAL CENSUS OF ENTOMOSTRACA BY MAJOR GROUPS, OCT., 1937 - OCT., 1938

were chiefly young Cyclops, other groups were occasionally much larger. Thus the higher numbers from October, 1937, to the end of November were almost entirely due to Diaptomus pallidus. The Cladocera at this time were mainly Chydorus sphaericus and Pleuroxus denticulatus, with some contribution by Simocephalus serrulatus. The ostracod peak was due exclusively to Cypridopsis vidua. Adult Cyclops viridis paralleled the increase in young cyclopids which followed the general reduction in winter numbers, but at a lower level, while Diaptomus pallidus was also important from early April to mid-May. This rapid recovery from the effects of cold put the copepods in a lead which was not overcome by Cladocera until July, when Chydorus, Pleuroxus, Simocephalus, and, shortly, Graptoleberis pulses brought them to a high level. Daphnia pulex was briefly important in the spring, while except in the winter Chydorus and Pleuroxus vied for prominence, which was attained by Pleuroxus in the late summer coincident with development of Graptoleberis. Simocephalus was important only in the warmer months. The copepod level was increased again in July, August, and early September by the advent of young Cyclops. Cypridopsis vidua was responsible for the ostracod increases of summer, but these totals were relatively very small, as would be expected of ostracods in a pond of recent origin. All groups had fallen off at the last collection before drainage, which occurred two weeks before

the yearly cycle was completed, so that the last collection was made at this station after its refilling in spring, 1939, which makes data insufficient for analysis of second year conditions. The table in the appendix, Part II, gives details of quantitative data.

Station 4 B

Physical factors are listed in the appendix, Part I. The wide fluctuations shown by several of these attest the recent origin of this pond (4 years at the time of study), as it had not yet reached equilibrium.

Temperatures were sufficiently like those of 4 A so that Fig. 8 gives a curve which may be compared with the graph of numbers in Fig. 9. While the temperature effect was less pronounced here (it is both deeper and larger than 4 A), there is a perceptible drop in winter totals. As the effects involved are especially those produced on particular species, the discussion will be deferred until after the qualitative information has been presented. Bottom temperatures never were so low in winter as surface readings; which probably afforded some refuge which was not present at 4 A. On the other hand, on four occasions, the summer temperature reached 28° C., 1 degree higher than at A, a condition probably due to the situation of B where it was partially protected from the wind by hills.

Oxygen content is of special interest at this pond because of the very large amounts usually present. This varied in concentration from 3.08 cc. per liter to the very high figure of 25.00 cc. per liter. Inaccuracy in determination would be suspected here except for the close correspondence between high oxygen values and the presence of myriads of small green flagellates, apparently Cryptoglana. These were so numerous that collecting bottles filled with water from the pond were dull grass green. In the two times of greatest oxygen concentration, November, 1937, and July, 1938, the effect of the flagellate was augmented by the presence of many Scenedesmus, which was frequently present at other times in small numbers. The fact that Shelford (1918) reports a maximum concentration of oxygen in natural fish waters of 24.00 cc. per liter together with the reports by various investigators of super-saturations amounting to 200-300% under special conditions indicate that the values obtained here are within the realm of possibility. This high amount of oxygen immediately suggests itself as responsible in part for the fact that the greatest numbers of Entomostraca were found at this station, but comparison of the table for oxygen with the pulses dispels the idea of direct correlation. During five of the six weeks between April 30 and June 4 the number of Entomostraca was greater than 20,000 per collecting unit; yet only twice during that time was the oxygen

content above 10, while on May 7 it reached the all-time low for station 4 B, when the number of Entomostraca was 22,140. It is certainly true, however, that very low oxygen values would have been a much more serious check here where totals were so large than in a poorly populated pond. To the extent that the high oxygen was essential for survival of the large numbers of Crustacea developing it was a factor in the great productivity of 4 B, but it cannot be regarded as a causal factor in the entomostracan increase.

Free carbon dioxide was seldom found here, although it is supposedly essential to high biological productivity; its rapid consumption by the chlorophyll-bearers was probably partly responsible. This is corroborated by the fact that highest oxygen values roughly correspond with periods of greatest alkalinity, when the flagellates and desmids were most prevalent. Fixed carbonates ran high, as expected in the absence of free CO_2 , while bicarbonates were frequently small in amount.

The very high pH values recorded here on many occasions are unusual. On six observations it was above the highest available indicator--above 9.6. Fluctuations were irregular but often fairly extensive, carrying the pH at one reading down to 7.0. Responsibility for this alkalinity could not be fixed; carbonates alone appeared insufficiently high, and chemical analysis would be interesting. The fact that the dominant cladoceran here, as at

station 1, was Daphnia pulex, is an argument against the sensitivity of this form, at least, to pH. It occurred in numbers at station 1, where the pH is often close to 6, as well as here where the pH was often 9.6 or over.

Turbidity was often high but underwent considerable fluctuation which could not be correlated with population changes.

Biota other than Entomostraca was not extensive. In addition to the chlorophyll-bearers mentioned, Euglena, Pleurotaenium, and Cladophora were occasionally observed, the latter in considerable quantity in September. The flatworm Stenostomum and several rotifers were occasionally taken. Haliphus, Chaoborus (few), chironomid larvae, ephemerid nymphs, Notonectidae, and Gyrinidae were present among the insects. Physa was numerous in May, and many frogs appeared in spring and summer.

The following species of Entomostraca were taken: Alona costata, Chydorus sphaericus, Daphnia pulex, Moina affinis, Simocephalus serrulatus, Cyclops serrulatus, Cyclops viridis americanus, Diaptomus pallidus, and Cypridopsis vidua. Of these only Daphnia, Cyclops viridis, and Moina occurred in numbers sufficiently large to determine the totals. The paucity of species is of course referable to the recent origin of the pond. Inspection of the table of numbers shows that three of these species

occurred only in the fall of 1938, and nearly the entire population at all times was composed of the three forms mentioned above.

Total numbers at this station fluctuated widely. As Fig. 9 shows, copepods were most frequently dominant numerically, the large numbers taken being almost entirely young forms of Cyclops viridis. From October, 1937, until late May, 1938, the cladoceran population was represented by Daphnia pulex, the peaks of these being caused by the presence of great numbers of young. Until the winter temperature drop in December, when the numbers of young Cyclops fell off, the copepods were much more numerous than the cladocerans. From then until February, when, as at 4 A, young cyclopids again appeared, the Daphnia population was numerically dominant. It will be recalled that Daphnia did not survive the winter at station 1; its presence here may be due to the protective effect of the somewhat deeper water, the large quantities of oxygen, or the very abundant food supplied by the green flagellates and Scenedesmus. Food is probably not the least of these in importance. The March decline in both copepods and cladocerans was followed by a second period of rapid Cyclops reproduction which continued with varying intensity until July. After one further pulse the group fell to a level from which active reproduction did not lift it until the following spring. The Daphnia pulse for the year, of

23,670, was attained on May 14, during a temporary decline in Cyclops, which surpassed the cladocerans with the enormous total (highest single count on record in this study) of 41,740 three weeks later. The remarkable decline (from 23,670 to 32 in a single week) is apparently inexplicable except as a result of the introduction of a number of tropical fish. These were placed in the pond sometimes near the first of June to keep down mosquitoes, but the exact date is not known; if it happened before May 21 the Daphnia drop would be explained by the relative ease with which they are captured by fish in comparison to the fast-moving young Cyclops. In any case, the disappearance of Daphnia was followed by the high Cyclops pulse mentioned; whether this was a result of increased availability of food for the copepods or simply the result of attainment of maturity by the cyclopid produced by the reproductive activity in March and April is not clear. Cladocera were very few during this copepod wave, but in late June, a different species appeared and developed rapidly to the high total of 31,600 on July 30. This was Moina affinis, a normal inhabitant of foul and stagnant waters in hot weather. How it escaped the fish, which were still present, is a question, but its glassy transparency may have been a factor in its favor. It had disappeared by mid-September, when the development of Cladophora provided shelter in which appeared Simocephalus

Fig. 9

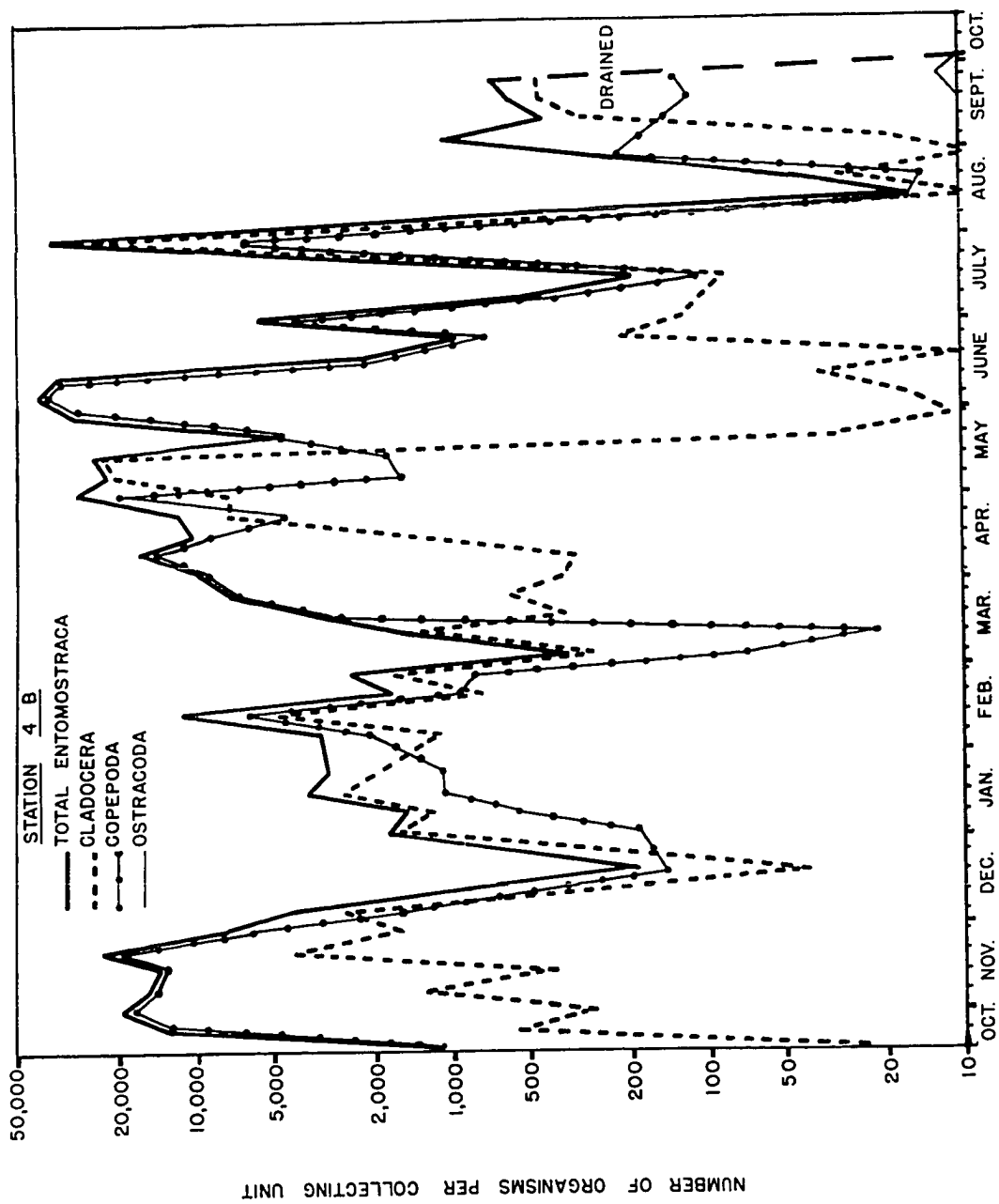


FIG. 9. STATION 4 B. SEASONAL CENSUS OF ENTOMOSTRACA BY MAJOR GROUPS. OCT., 1937 - OCT., 1938

serrulatus and Alona costata for the first time. Drainage of the pond prevented further observation until November. 1939 conditions were somewhat similar, as well as could be judged from the infrequent trips, but Daphnia was much less prominent than in the preceding year. Reference should be made to the seasonal census in the appendix for details.

II. Occurrence of Species

The following species were collected in this work. Due to the somewhat limited nature of the environments from which collections were made, it probably does not include all the Entomostraca which occur in the Cincinnati area.

BRANCHIOPODA

Phyllopoda
Eubbranchipus vernalis
 Cladocera
 *Alona affinis
 *Alona costata
Alona guttata
 *Alona quadrangularis
 *Alona rectangula
 *Alonella karua
Bosmina longirostris
Bosmina longirostris cornuta
Camptocercus rectirostris
 *Ceriodaphnia pulchella
 *Ceriodaphnia quadrangula
 *Ceriodaphnia reticulata
 *Chydorus globosus
Chydorus sphaericus
 *Daphnia longispina
Daphnia pulex
 *Graptoleberis testudinaria
Leydigia quadrangularis
 #*Macrothrix laticornis
 *Moina affinis
 #*Moina brachiata
Pleuroxus denticulatus
Pleuroxus hamulatus
 *Scapholeberis aurita
Scapholeberis mucronata
 *Simocephalus exspinosus
Simocephalus serrulatus
Simocephalus vetulus

COPEPODA¹

*Canthocamptus northumbricus
 *Canthocamptus staphylinoides
 *Canthocamptus staphylinus
Cyclops albidus
Cyclops ater
 *Cyclops bicuspidatus
Cyclops fuscus
Cyclops phaleratus
Cyclops prasinus
Cyclops serrulatus
Cyclops viridis americanus
 *Cyclops viridis ingens
Diaptomus pallidus
 *Diaptomus sanguineus
 *Diaptomus siciloides
 *Osphranticum labronectum

OSTRACODA

*Candona crogmaniana
 *Candona ohioensis
 *Cypria elegantula
Cypridopsis vidua
Eucypris fuscata
Cyprinotus incongruens
 *Physocypria globula
 (*Eucypris n. sp. 1--Furtos)
 (*Eucypris n. sp. 2--Furtos)

*--new record for this area.

#--taken only at some locality other than the regular stations.

1

For several reasons the changes in generic names of the Cyclopidae introduced by Kiefer (1927) were not used in this paper. In accordance with this usage, the following changes would be required: Cyclops albidus to Macrocyclops albidus, Cyclops fuscus to Macrocyclops fuscus, Cyclops phaleratus to Ectocyclops phaleratus, Cyclops prasinus to Eucyclops prasinus, and Cyclops serrulatus to Eucyclops serrulatus.

The species list presented in this study is composed of fifty-two species and three varieties, of which twenty-nine species and one variety are new records for the Cincinnati area. The list contains few species which are unusual or unexpected for this region, in accordance with the recent origin of the collecting sites. Unless particular interest attaches to a species with regard to its unexpected occurrence or other peculiarity, it will not receive special discussion. A number of cases requiring such comment have been considered previously in the description of individual stations when special conditions made such procedure more logical.

The prominence of the genus Alona in the species list suggests a position of importance among the Cladocera which inspection of the numerical tables shows to be unmerited. In spite of the several species taken, the numbers were always small and the appearances scattered. The presence of Alona affinis, A. guttata, and A. quadrangularis only in the larger ponds of the study, with A. costata indifferently distributed in this respect and A. rectangula confined to the small pools of station 1 is an interesting condition. The difficulty in distinguishing certain of these species, which necessitated high power examination, may have caused some inaccuracy in the census tables. The custom in such cases, as has been explained in

the description of methods, was to examine a number of individuals and to express the total number of each species in the proportions in which they occurred among the organisms examined. Whether or not this failed to represent the true ratio in every case, the nature of the distribution described above would not be affected. As these species of Alona are all described by Birge (1918) as common and several are mentioned as very abundant, the small numbers taken here are somewhat unexpected. The possibility of less adequate powers of dispersal than such forms as Chydorus sphaericus or Daphnia pulex affords an explanation on the basis that by the time Alona arrived at these newly formed ponds the cladoceran population was so well established that the new genus has not yet attained prominence. The somewhat limited food supply in these small bodies of water may prevent the simultaneous occurrence in great numbers of two genera such as Alona and Chydorus or Bosmina.

The occurrence of the southern species, Alonella karua, at station 3 has already been mentioned and its prevalence only in the warmest season pointed out, a peculiarity which lends credibility to its presence here.

The only Ceriodaphnia of numerical importance was Ceriodaphnia pulchella, although here, as in the case of Alona, necessity for high power examination to distinguish

C. pulchella and C. quadrangula may have produced slight distortion in the true ratios. In view of the more frequent appearance of C. quadrangula (or its large variety, C. scitula) in species lists, the dominance of C. pulchella observed here is interesting.

Macrothrix laticornis, never found at the regular stations, was taken in very small numbers from a large pond just across the Ohio River from Cincinnati on March 13, 1939. The conspicuous absence of the family Macrothricidae in the usual collections is less strange than it first appears. The group contains many lacustrine members and many of limited distribution of which the latter fact suggests powers of dispersal inadequate for appearance in ponds of recent origin.

Moina brachiata was found only once, in a very foul and muddy old canal bed on May 21, 1937. This appearance was slightly earlier in the year than that of the other species, M. affinis, which populated the regular station 4 B in the summer of 1938. The presence of ehippial eggs possibly attested to the foulness of the water.

Pleuroxus hamulatus is recorded by Birge (1918) as a coastal form from New England and the southern states with no reports from the north central region. Turner's (1892) report of "Pleuroxus hamatus" in the Cincinnati region may have been thought to refer to Birge's old species by that name; although the descriptions given by Turner of the discrepancies between that form and his specimens

seems to point to its being the present P. hamulatus. Its occurrence at three stations studied here, especially frequently at station 2, intensifies this opinion and suggests the necessity of an extension in the recorded distribution.

Scapholeberis aurita is included in the list on the basis of but two observations, on July 9 and August 25, 1938, on each of which dates but a single individual was found at station 4 A. It is regrettable that neither of these specimens was kept, as the preserved material did not disclose their presence. The species would be omitted from the list except that the recorded comments indicate that the identification was quite certain. It is somewhat unexpected but not incredible to find it here, as the species is reported (Birge, 1918) as not common and occurring in weedy pools and lake margins in the northern states.

The pronounced dominance of Canthocamptus staphylinoides over C. staphylinus both in numbers and in season of abundance was a rather unexpected condition observed wherever they appeared together. Quite frequently taken was a type apparently similar in all respects to the ordinary C. staphylinoides except for eight spines rather than six or less on the anal plate. These were large spines, quite different in appearance from the small and numerous ones of C. staphylinus and identical with those

of the usual C. staphylinoides except in number. These individuals were included in the counts under C. staphylinoides without separate designation for the sake of simplicity though it is possible that further study may show the necessity for giving them racial or, doubtfully, varietal value. The presence of C. staphylinus and C. staphylinoides to the exclusion of C. minutus, which Marsh (1918) records as the most common species, found everywhere in the northern continents, is an interesting local condition. C. northumbricus, which he reports as, next to C. minutus, the most widely distributed species of Canthocamptus in North America, was taken only at the small temporary pond 1 C, while the other species of the genus were found at four stations.

The occurrences of Cyclops ater at station 1 C have already been mentioned. It was also found at station 3 on a single occasion in the autumn of 1938 (Nov. 30). Whenever found, this species occurred in such small numbers (usually one or two in the entire collection) that it never appeared in the counting samples but only in the living material. This is not unexpected, as it is said to be, in spite of its wide distribution, a rare form.

Cyclops phaleratus has been mentioned already in connection with the description of station 1 C. It also was found on one occasion at station 3, on November 3, 1938.

It is a commentary on the slow dispersal of these two uncommon forms--i.e., C. ater and C. phaleratus, that they were found only in the oldest (70 years) of the artificial ponds and in a natural temporary pool which has probably contained water annually for a much longer period.

The common variety of Cyclops viridis in this locality is, as might be expected, americanus. Ingens, the large type similar to the European gigas, was taken only at 1 C, where its large size (usually about 2.5 mm.), beautiful reddish coloration, and rather large number made it a conspicuous member of the population of this vernal pool. Since no attempt at varietal distinction was made in counting, the possibility that the records at some stations may include the variety parcus as well as americanus cannot be excluded. But as Chambers (1912) indicates that the two varieties are never found together and as examination of fresh material showed americanus, the chance of such an occurrence is not great.

The rarity of Diaptomus siciloides is somewhat unexpected in view of the comment of Marsh (1918) that it is the species most likely to be found in the Ohio valley, although not the exclusive form. In addition to its infrequent occurrences at station 3, it was taken at a somewhat similar pond about two miles distant from 3 in small numbers on October 1, 1938. The great importance

of D. pallidus in this area is reflected in the notes of Turner (1892) who records it as the only species observed.

The scarcity of ostracods, both in total numbers and in number of species, is probably referable to the recent origin of the ponds studied, in view of Shelford's (1912) comment that ostracods are the last group of Entomostraca to populate a newly formed habitat. Difficulties of identification and the fact that larvae were sometimes taken although adults capable of recognition were absent may have prevented maximum expansion of the list. Two of the forms collected, Candona ohioensis and Physocypria globula, were species first discovered in Ohio and described by Furtos (1932).

Of the entire list, only three species--Chydorus sphaericus, Cyclops serrulatus, and Cyclops viridis were common to all stations. Except for pond 4 B, two more species were universally present--Cyclops prasinus and Cypria elegantula. Found at all but two stations were Daphnia pulex (not at 2 or 3), Pleuroxus denticulatus (not at 1 C or 4 B), and Cyclops albidus (not at 1 C, 4 B). The temporary pond 1 C, while contributing several species peculiar to itself, failed to contain some common species which possibly may be unable to endure drying. At the other extreme from the three ubiquitous species were nine forms which occurred each at a single locality,

these being: Alona affinis (station 3), Alona quadrangula (3), Alonella karua (3), Ceriodaphnia reticulata (3), Scapholeberis aurita (4 A), Canthocamptus northumbicus (1 C), Diaptomus sanguineus (1 C), Osphranticum labronec-tum (1 C), and Physocypria globula (2). Several other species, such as Camptocercus rectirostris and Daphnia longispina, occurred at only one of the regular stations (3) but were taken elsewhere. Study of the lists for each station with their relative ages in mind and reference to the detailed discussion of each place will bring out much information which it is impossible to call to special attention.

Comparison of the species list presented here with other local records brings out many points of similarity and some of difference. Chambers (1874) reported Eubranchippus vernalis (Branchippus vernalis) in a temporary pond near Covington, Kentucky, a few miles from Cincinnati and a single specimen of Estheria of unknown species in a small pool in the same region. The present work confirms the record of the fairy shrimp, but Estheria was never taken. Pearse (1918) stated that no species of the genus Estheria is found east of the Mississippi River. Chambers (1881) described a new species of the Harpacticidae (Copepoda) from saline waters at Big Bone Springs, Kentucky. As he stated that in his opinion the new species, Tachidius (?) fonticola, did not occupy an area of the earth's surface

more than two yards square and that covered with salt water, it is not surprising that it did not occur in the ponds of this study. Chamber's other new species (1881), Diaptomus kentuckyensis from Covington, Kentucky, was recorded fourteen years later by Herrick (1895) as not recognizable, and nothing answering its description occurred in the present collections.

Hunt (1882) listed nine species of Entomostraca for Cincinnati and vicinity, of which five were frequently found in the present collections. The phyllopod, Branchipus stagnalis, of his records has not since been taken here. His record of Camptocercus macouris, which may have been intended for C. macrurus, seems due to a chance in species name since the date of his writing. C. macrurus is now reported (Birge, 1918) as very rare, while C. rectirostris, the species of station 3, is said to be common. The fact that Turner (1893) also listed C. macrurus as occurring locally and the fact that Herrick (1895) recorded C. macrurus as universally distributed and C. rectirostris as not yet recognized in America further indicate a change of the name of the species. Moreover, Herrick's figure labelled C. macrurus has the number of post-abdominal denticles characteristic of C. rectirostris rather than of C. macrurus. It seems probable from this information that both Hunt's and Turner's records of C. macrurus refer to the species now described as

C. rectirostris. Hunt's Cyclops quadricornis is referable to the present C. strenuus, which so far has been found in the United States only in a pond in the Adirondacks (Marsh, 1918); this record is probably in error. Thirteen years after Hunt's report of Diaptomus castor Herrick (1895) wrote that all references to D. castor in America were erroneous, and Marsh (1918) did not list the species.

Turner (1892, '93, '94, '95) reported thirty-one species of Entomostraca as occurring in the Cincinnati area. Twenty of these are identical with or can be related to (see Camptocercus macrurus, above) species taken in the present collections. A partial explanation for the absence from his list of thirty-two species which have now been found to occur locally is his limited period of collection. His admittedly incomplete report was based on three months' study, apparently in the summer months, which prevented the taking of many forms occurring principally at other seasons. Only the species taken by him and not discovered in the present investigation will be discussed.

Turner (1892) reported three species of Alona, of which one species, A. glacialis, was recognized three years later by Herrick (1895) as a variety of A. guttata, with the suggestion that combination with that species was advisable. The variety is not mentioned by Birge (1918) and on the basis of this somewhat negative evidence, A. guttata is not treated in the present species list as a new form

for this area. Turner's report of A. intermedia, a rare species in this country, is not confirmed by this work. A. porrecta, which Turner lists, is of problematical existence and nothing conforming to the descriptions of it was found. Named and described by Birge (1878), the species was nevertheless omitted without comment from his (1891) list of Cladocera from Madison, Wisconsin. It was not included in his account of the Cladocera, Ward and Whipple, (1918); and, as Herrick (1895) said, "we are left in doubt whether the species is abandoned or not."

No particular reason can be assigned to the absence from the present list of Dunhevedia setigera, reported by Turner (1893), except that it is stated to be uncommon. While the species of Moina reported by him was not taken, two other species of Moina were found, and as the genus as a whole is rather widely distributed this condition is not surprising. Turner's (1892, '93) report of Sida crystallina is not corroborated, although the species is common among weeds in ponds and lakes. It may have been found by him in somewhat older ponds than the present series of stations. Cyclops fimbriatus, reported by Turner (1892), is said by Spaeth (1914) to be the rarest Cyclops in the vicinity of Haverford, Pa. As Turner reports it as abundant in all ponds, and as its eight-segmented antennae, a diagnostic character, are also possessed by the young forms of other species of Cyclops, the

possibility suggests itself that his records may have been based not on adult forms of C. fimbriatus but on young forms of some more common species. Eucypris virens (Cypris virens) reported by Turner was not found in the present collections nor was it observed by Furtos (1933), who stated that it was doubtfully present in Ohio. Cypri-notus crenata (Cypris crenata Turner) was not recorded in this study, although its description was written from species taken at Cincinnati. Turner reported it as abundant in a few ponds, which almost certainly were not sampled in connection with this work. Cypria inequivalva, also named and described by Turner (1893) for this area, was not observed. Furtos (1933) reported his description as somewhat confusing and did not find either this or the preceding species in her collections. Chlamydotheca speciosa (described erroneously by Turner as the new species Cypris herricki) was taken by him only in a canal bed which has since been filled and since his record the species has not been reported for Ohio.

In addition to differences in regard to species collected between the present report and those of Turner, there are several discrepancies of varietal rank. His record of Cyclops viridis parvus (then C. parvus) has not been confirmed. The large variety ingens of Cyclops viridis probably was not taken by Turner, as his (1892) record of

Cyclops viridis(unqualified)is more apt to mean the common C. viridis americanus. His record of Bosmina cornuta should be referred to the present Bosmina longirostris cornuta.

Priority is due to Chambers(1874)in recording the local occurrence of Eubbranchipus vernalis, to Hunt(1882) in listing Bosmina longirostris, Camptocercus rectirostris (not certain), Chydorus sphaericus, Cyprinotus incongruens (Cypris fusca), Cypridopsis vidua(Cypris vidua), and Daphnia pulex, and to Turner(1892, '93, '94)for the additional sixteen species and two varieties previously recorded(given without asterisks in the species list).

III. Seasonal Distribution.

Seasonal distribution, one of the chief considerations of this work, has been very little treated in the foregoing account. The graphs(Figs.10 and 11)show the results of this phase of the study sufficiently well for each species so that only general comment is necessary. In examination of these figures it is very important to realize that they do not present any evidence as to the number of each species present at any one time but only indicate that it was observed either in the living material, the counting sample or both on that date at some station. This explains the occasional record of some form in the graph at a time when it does not show in counts.

Forms never taken at the regular stations (Macrothrix laticornis, Moina brachiata) and varietal distinctions were not included in the graphic representation nor were the records of Scapholeberis aurita, which, as described, were based upon only two individuals. With these provisions in mind and with frequent reference to the census tables to detect reductions and increases in number of each species seasonal peculiarities of each form are readily ascertained. Reference to seasonal variations in physical conditions, chiefly temperature, is desirable.

The species recorded here fall, with certain exceptions, into four fairly well defined groups with regard to seasonal occurrence. Species found only once or twice in the entire year of seasonal recording in the graph need no further comment on time of occurrence, and only the rather common inhabitants give sufficient data for adequate interpretation. In other words, a species taken only a few times and in small numbers may indeed have been more prevalent at those seasons but may also have occurred in small numbers on many occasions when it was not taken; hence seasonal analysis on such a basis is unwarranted. The following groupings do not therefore include all the species taken.

A. Forms of constant occurrence.

Cladocera

Chydorus sphaericus
Daphnia pulex
Pleuroxus denticulatus

Copepoda

Cyclops albidus
Cyclops viridis
Cyclops serrulatus

Fig. 10

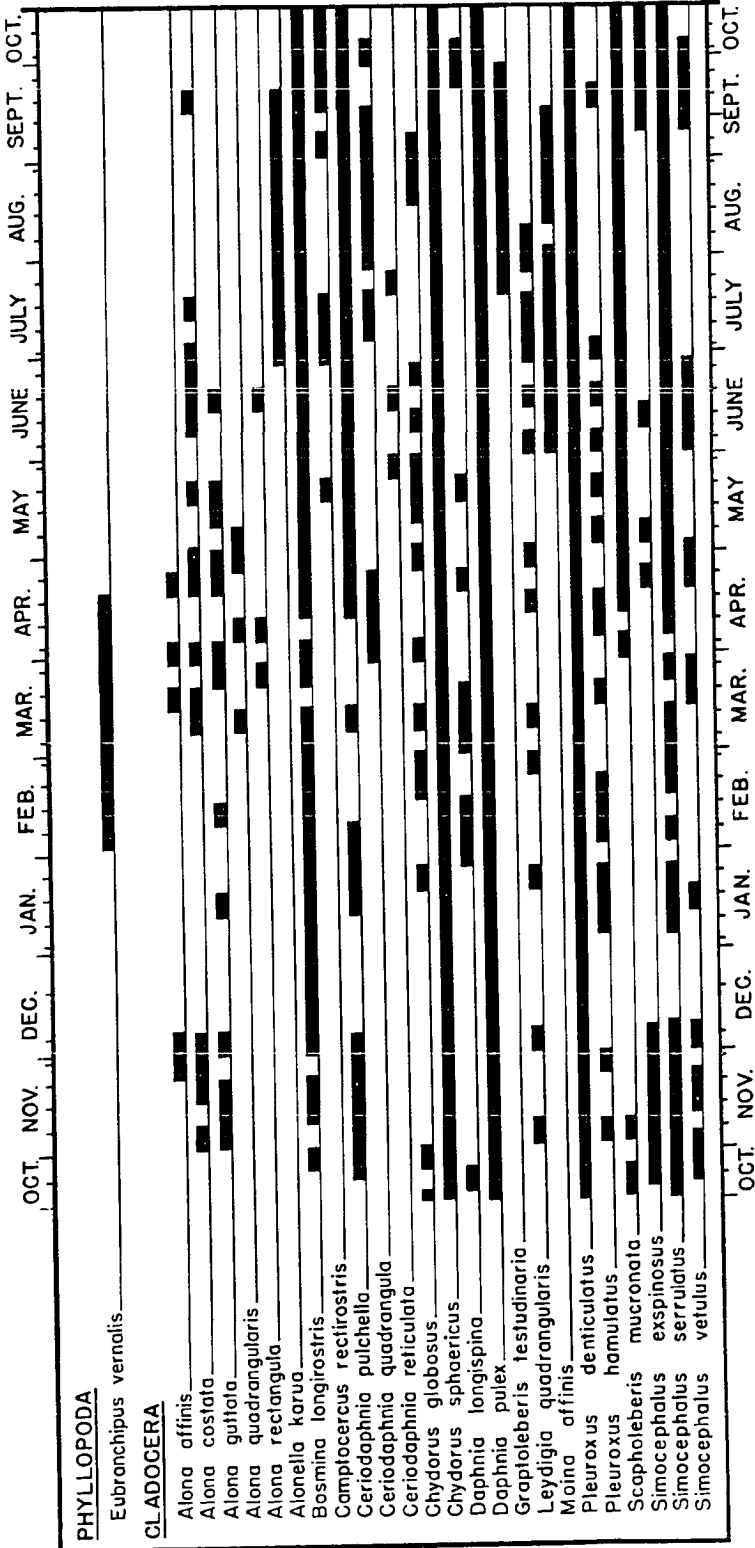


FIG. 10. SEASONAL DISTRIBUTION OF ENTOMOSTRACA BY SPECIES; PHYLLOPODA AND CLADOCERA, OCT., 1937 - OCT., 1938. COMBINED DATA FROM ALL REGULAR STATIONS

Fig. 11

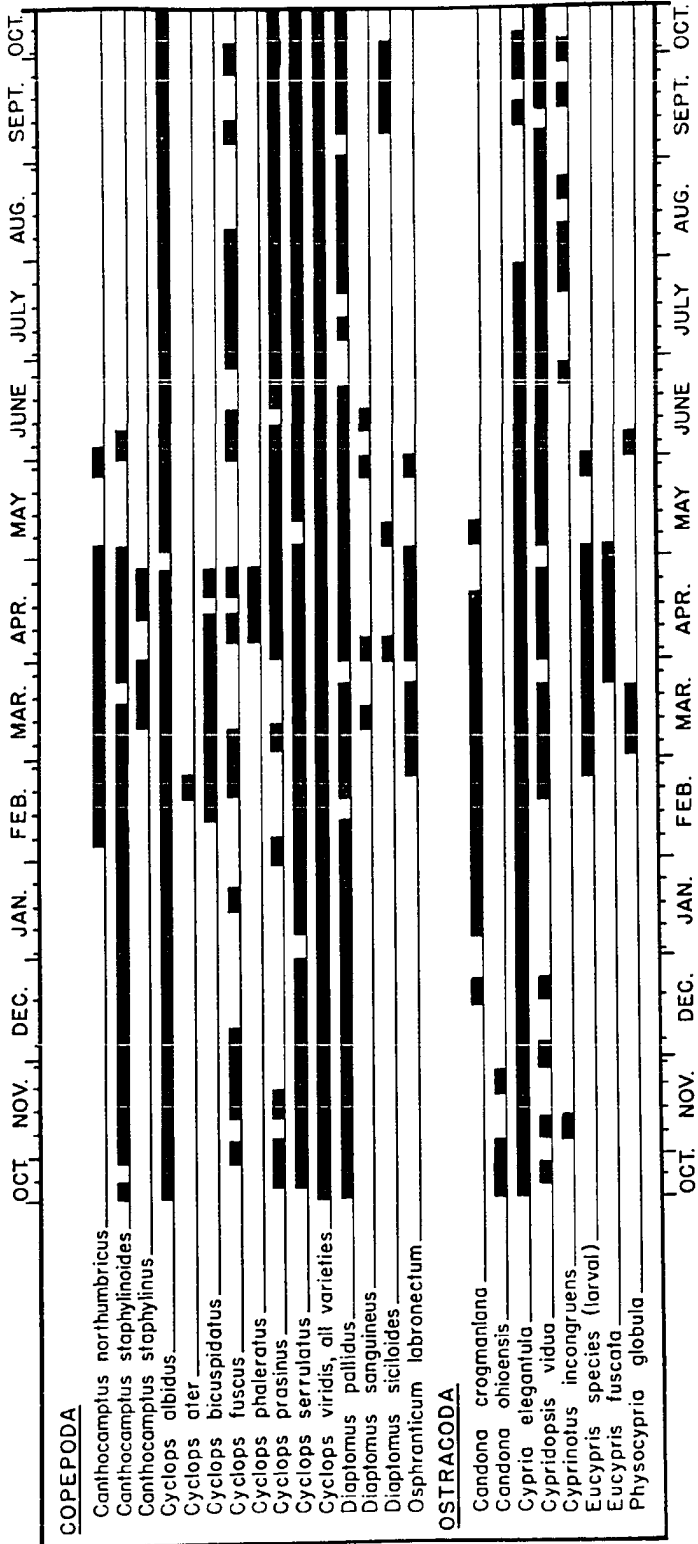


FIG. 11. SAME AS FIG. 10; COPEPODA AND OSTRACODA

The cladocerans showed a tendency toward higher numbers at most stations in the spring, as did young forms of Cyclops viridis, although reference to the results at separate stations will show wide variations in this respect. The behavior of Cyclops albidus is interesting in view of the comments of Elton (1929) who regards it as a predominantly summer species. He grants that it can be found all the year round but cites a pond studied by him where it never occurred in January, February, and March, and suggests that greater numbers always occur in summer even where it may also be taken in the cold months. This species was taken here at some station, often at several, every week of the winter of 1937-'38. The absence of it from the last week's collections in April, the only absence of the year, was apparently mere chance, in view of the rather small numbers in which it usually occurred. It was found in late April, 1939, at 1 A. It is true that at some ponds (1 B, 4 A) the summer numbers of C. albidus were larger than those of winter. At station 2, however, the largest single total of the species (40) was taken on January 12, while it was absent during the summer months. Station 3 gave a similar picture, with the largest total (108) of C. albidus on November 20 and none in late July and August of the following year. The six months from October, 1937, to March, 1938, gave a total of 365 C. albidus, while the last six months of that year, up to October,

1938, totaled only 219. Even excluding the one high count of 108 from the higher number, the results do not suggest a uniformly greater prevalence of C. albidus in the summer. The presence of C. serrulatus was so nearly constant that it should almost certainly go in this first group rather than in the next.

B. Forms not constantly present but occurring without pronounced reference to season.

Cladocera

Bosmina longirostris

Copepoda

Cyclops fuscus
Diaptomus pallidus

This species of Diaptomus is recorded by Kofoid (1908) as not occurring in the Illinois River in February. One of its infrequent absences in this series of collections was also in February, and numbers throughout that month were somewhat reduced, although his report of other seasonal variations in D. pallidus is not borne out.

C. Forms with a tendency toward one period of abundance but not limited to that season.

Organisms	Period of Greatest Abundance
Cladocera	
<u>Alona affinis</u> , <u>A. costata</u> ,	spring and fall
<u>A. guttata</u>	spring and fall
<u>Alona quadrangularis</u>	spring
<u>A. rectangula</u>	spring
<u>Camptocercus rectirostris</u>	summer
<u>Ceriodaphnia</u> (all species)	summer
<u>Chydorus globosus</u>	spring
<u>Daphnia longispina</u>	spring and fall

Leydigia quadrangularis.....summer
Pleuroxus hamulatus.....spring
Simocephalus serrulatus.....summer
Simocephalus exspinosus.....fall
Simocephalus vetulus.....fall

Copepoda

Cyclops prasinus.....summer and fall

Ostracoda

Cypridopsis vidua.....summer and fall

Simocephalus vetulus and S. exspinosus are difficult to place but seem to belong here because of their greater abundance in autumn, although, as mentioned under station 1 A, the seasonal distribution of S. exspinosus was very different the second year of the study. Cyclops prasinus and Cypridopsis vidua were found in some numbers at other seasons than summer and fall but were absent or infrequent in winter. This condition of Cyclops prasinus is at direct variance with the report of Kofoid (1908), who found it only from September to March, when the temperature usually was below 40° F. Here, the warm months showed C. prasinus in far greater abundance, and it was absent in winter. The highest numbers at station 2, for instance, were found on August 17 and August 24, with temperatures above 70° F., and it was absent from that station from November 10 to March 3. Spaeth (1914) reported, in accordance with this record, that few C. prasinus were found in the vicinity of Haverford, Pa., in the winter.

D. Forms with rather sharply limited seasonal distribution. This, like C, is a large group and is divisible into sections depending upon the time at which the periods of frequency fall.

(1) Spring species.

Phyllopoda

Eubbranchipus vernalis

Copepoda

Canthocamptus northumbicus

Cyclops bicuspidatus

Diaptomus sanguineus

Osphranticum labronectum

Ostracoda

Candona crogmaniana

Eucypris (all species)

These forms, except Candona crogmaniana, will be recognized as characteristic of vernal temporary pools. The occurrence of Canthocamptus northumbicus was similar here, although it has not previously been recorded as typical of such situations.

(2) Winter species

Copepoda

Canthocamptus staphylinoides

Canthocamptus staphylinus

Ostracoda

Candona ohioensis

Cyprina elegantula

No species occurred exclusively in the winter but several were characterized by existence only in cool water,

appearing in the fall and disappearing as soon as the water was thoroughly warmed in spring. Candona ohioensis qualified for inclusion here on the basis of its appearance in fall but disappeared before the full onset of winter. Except for the larvae of Cypria elegantula, which prolonged its presence until July, it was typical of cool waters, as the adults rarely appeared after April except in small numbers.

(3) Summer species.

Cladocera

Alonella karua
Moina affinis
Graptoleberis testudinaria
Scapholeberis mucronata

Ostracoda

Cyprinotus incongruens

Such forms often remained through September and into the first weeks of October, but disappeared with the coming of cold weather and did not ^{re-}appear until the water was thoroughly warm in summer. Individual differences in the times of these occurrences were characteristic of the various species, some disappearing a week or more before temperatures dropped, etc., differences which can be seen from the tabular material. Moina (most species) and Scapholeberis mucronata are recorded as typical of warm and stagnant water, but such behavior is not usually reported as characteristic of Graptoleberis testudinaria. The occurrence of Alonella karua only in warm waters has

received previous comment(see station 3). Cyprinotus incongruens, although not constantly present in summer, occurred typically in the warm months.

In general these data on seasonal distribution are in accord with the work of previous investigators. Much more could be said by way of relating the material to the extensive results of Kofoid and others, but only outstanding cases have been selected for comment. Some discrepancies are certainly due to local differences in climate and to peculiarities of the stations involved here. Inasmuch as no extended seasonal records either for this vicinity or for ponds of this type are in existence, further comparisons seem to be unprofitable.

Discussion

Attempts at correlation between the occurrence of organisms and the measurements of oxygen, carbon dioxide, carbonates, pH, and turbidity (see Figs. 3-9 and Appendix, Part II) indicate that these conditions are not limiting factors of the numbers or the distribution of the Entomostraca collected.

Under all ordinary conditions oxygen content appeared to be well in excess of entomostracan requirements. In two cases reduction of measurable oxygen content to zero resulted in some reduction in number of species taken and in perceptible reduction in total numbers of Entomostraca, but when oxygen contents measured only a fraction of a cc. per liter, no such effects were noted. On December 1, 1938, for example, when the oxygen content was 0.86 cc. per liter at station 1 A, 232 Cypria elegantula were taken, while on February 3, 1939, when the oxygen content was 6.95 cc. per liter, a similar number (216) of C. elegantula was counted at the same pond. Evidently if any relationship exists between entomostracan populations and the presence of oxygen, no limitations are imposed until the oxygen content is very near the zero point.

The wide variations occurring between stations in species and numbers of Entomostraca are evidence of the insignificance of pH, which fell within the same general range in most of the ponds. Most widely separated in this respect

were the acid pools of station 1 and the young, alkaline pond 4 B, and yet at times their entomostracan populations were not greatly different. For instance, 2560 Daphnia pulex were counted at pond 1 A on a day when its pH was 6.0, while 2640 D. pulex were counted at 4 B when its pH was 9.3; in both cases the only other entomostracan present was larval Cyclops. Differences in carbon dioxide and carbonates were found to be no more significant than those of pH. This is at variance with the observations of Reed and Klugh (1924), who found pronounced differences between the biota, including Entomostraca, of an acid and that of an alkaline pool.

Turbidity in general appears to depend in significance more directly upon its nature than upon its amount, and in this study no influence, favorable or unfavorable, could be assigned to it.

Temperature was found to be the most influential physical condition observed in controlling entomostracan populations. While it was not the exclusive factor and while its effects were not always directly upon the organisms studied, it played the most important role in inducing the seasonal fluctuations in numbers and in controlling the appearances and disappearances of various species as the yearly cycle progressed. This is in accord with the report of Birge (1898) that temperature determined the reproductive rhythm and was the major factor in determining total numbers of Entomostraca in Lake Mendota. The section on seasonal distribution is, in substance, a description of the reactions of various

Entomostraca to changes in environmental temperature, while the report of quantitative results describes the reactions of the population as a whole to the same factor. An extreme example of dependence upon temperature is afforded by the southern species Alonella karua which has apparently extended its northward range to Cincinnati somewhat recently. This species appeared abruptly and in considerable numbers on July 2, 1938, at station 3, when the temperature was 26° C., a reading first recorded for that year in the observations of the preceding week. It appeared consistently at every collection thereafter until September 24, when the temperature fell below 20° C. for the first time. With this drop to 17° C. the species disappeared completely from collections, although it was several weeks before water temperatures became much further reduced. While it is true that temperature effects are not always so direct as this and often act through influence upon food supply, oxygen content, etc. rather than upon the organisms themselves, its primary role should not be minimized. As Brown (1929) pointed out, temperature alone is sufficient to explain the geographical distribution of a number of common Cladocera. Such effects could not, of course, be noted in a study limited to one locality, but comparison of figures for temperature with the records of seasonal occurrence and of fluctuations in numbers leaves little doubt that here an important role is played by temperature.

There is also a secondary or local relationship between the environmental temperature and the survival of certain Entomostraca occurring in deeper ponds where there is protection from the extreme seasonal variations. Daphnia pulex, for example, survived the winter in great numbers in the relatively deep pond 4 B, while it was absent in winter from the small pool 4 A, where shallowness of the water did not allow the refuge of more moderate bottom temperatures. Likewise, the small cladoceran Chydorus sphaericus suffered little diminution in numbers in the winter in the deeper ponds 2 and 3, but ceased to appear in the uniformly cold waters of the shallow pools of stations 1 and 4 A.

These results on the influence of physical factors are in agreement with those of Petersen (1926), who found that temperature-water level conditions were most important in affecting the general seasonal succession of organisms in a Chara-cattail pond, while pH and oxygen content frequently accompanied rather than caused the changes.

Quantitative results are difficult to correlate at the various stations. Vernal pulses of varying extent and duration are perceptible at all stations but 3, which was also the only station failing to show large summer maxima. As pointed out previously, pulses appear most directly referable to temperature in such situations as these. That this is not the only factor is evident from the differences between stations with similar temperatures. Conditions of

food supply, predators, competitors, certain physical factors, and probably a number of unknown agents are also responsible in varying degrees.

While plants were probably important as food, either directly (algae and bacteria) or as sources of decayed and suspended organic matter, data here are insufficient to evaluate their role in population composition and fluctuations. The fact that the greatest numbers of Entomostraca consistently occurred in the pond (4 B) containing enormous numbers of green flagellates suggests the importance of some, at least, of the simple chlorophyll-bearing organisms as a source of food. In view of the previously cited work of Huff (1923), which tends to minimize the role of algae as entomostracan food, the absence of striking correlation between the algae present and the number of Crustacea is not unexpected.

The role of predators in affecting the numbers of Entomostraca has been considered only incidentally in this study. Positive evidence was obtained for the consumption of small Crustacea by several species of Hydrariae, by the small oligochaete Chaetogaster, by the larvae of the dipteran, Chaoborus, and by the young or adult forms of several amphibians (species of Rana and Ambystoma). How extensively these forms reduce the population of Entomostraca would be difficult to ascertain, but it is certain that definite effects must be exerted at such a station as 1, where all these predators but the oligochaete were present at various times and often

in large numbers. The presence of large spring pulses of Entomostraca at this station in spite of the increased number of amphibian larvae at that time and the occasional occurrence of very large counts even in the constant presence of large numbers of Chaoborus indicate, however, that entomostracan populations are not greatly limited by the predators observed.

In the absence of quantitative evidence on food supply, competitive relationships among various Entomostraca cannot be accurately traced. Evidence that such conditions exist is not strikingly seen in this study, but some indication can be obtained, especially at the smaller ponds with their attendant limitations in food. An inspection of the numbers of two of the Daphnidae, Daphnia pulex and Scapholeberis mucronata, at station 1 A in the summer of 1938 shows that large numbers of both species did not usually occur at the same time. As the numbers of Daphnia began to fall off in June, those of Scapholeberis rapidly rose to a high point of 888 on the day when Daphnia was lowest (70). With the beginning of the July pulse in Daphnia, numbers of Scapholeberis diminished and none was found on July 20, when a Daphnia count of 14,760 set the yearly maximum. As environmental conditions were unusually constant during this period, a state of competition for available food suggests itself as the most logical explanation.

Greatest single and average counts were recorded at 4 B, the youngest station, where the special conditions discussed were probably responsible. Second in this respect was station 3, the oldest pond; thus age alone is no criterion of quantitative production of Entomostraca. Fewest organisms were taken at 1 C, the temporary natural pool, where the short season and the very small area are limiting factors. 4 A was least productive numerically of the permanent stations, a condition referable in part to its small size with attendant limitation of food supply.

The particular species predominating at each station are also of great importance in determining the time and extent of pulses, as inherent tendencies to react in definite and peculiar ways to various alterations in physical and other conditions are common characteristics of Entomostraca. The behavior of Bosmina and its responsibility for the otherwise inexplicable numerical peaks observed at station 3 have already been discussed. The peculiar propensity of Cypria elegantula for dominance only in cold waters from which other Entomostraca are virtually absent is another case in point. The conduct of Moina affinis at station 4 B is a further example of entomostracan peculiarity. This cladoceran appeared in small numbers for the first time on June 4, 1938, one week after Daphnia pulex disappeared from that pond. For six collections thereafter it was taken in small numbers, until, suddenly, following upon a collection of only 84 individuals, 31,600 young Moina appeared in a

collection. This number was reduced to 408 the next week, none appeared at the following collection, and three months after its first appearance there was no sign that Moina affinis had ever populated the pond.

So much conflicting evidence on entomostracan quantitative cycles in large bodies of water, such wide variations in the results even of individual investigators, and the scarcity of such data for small ponds similar to those of this study make correlations between these results and those of other workers extremely difficult. The following brief outline developed by Birge (1898) on the basis of his work at Lake Mendota will be found not inconsistent with the present results if some minor changes in time are granted. A winter minimum from December to April gives way to a spring increase culminating in May, followed by a decline to June or early July. A midsummer maximum occurs in July, with a late summer decrease which is followed by an autumn maximum in September or October. By referring to the quantitative results at each station a fair degree of correspondence is quite frequently evident; 4 B, for example, is described well by such an outline, except for the earlier appearance of changes explicable on the basis of warmer temperatures in this region and for the special conditions existing there in midsummer. 4 A and 3 show somewhat different behavior.

A comparison of the graphic results with Kofoid's (1908) outline also shows some agreement. He ascribes the following behavior to the Illinois River Cladocera: greatest numbers occur between May and September or sporadically in winter (see Bosmina at Station 3). Minimum records occur during minimum temperatures. Numbers increase slightly in March and April and rise steeply at 70° F. and above. Maxima occur in May and June with a midsummer decline except for pulses of Moina (see 4 B) or Diaphanosoma. Autumn pulses may show before a winter minimum appears. For copepods he finds a minimum in December to February with a maximum in late April or early May. Large numbers occur through the summer followed by a late fall decline.

While these general statements show agreement in a number of instances with the results presented here, arduous attempts at generalities on the basis of the present data are unprofitable. Conditions at the various stations find a much readier explanation when considered individually and in view of the special conditions obtaining there. It should suffice to say that the evidence given here indicates a tendency toward lower numbers in winter, the usual occurrence of spring pulses, a yearly maximum in summer, and fall pulses of varying magnitude. Variations upon or omissions of parts of this outline are due to conditions peculiar to the individual stations, in the description of which they have been considered.

Summary

1. Fifty-two species including three varieties of Entomostraca were collected. Twenty-nine species and one variety are new records for this area.

2. Regular weekly collections of Entomostraca and observations of physical and biotic conditions were made at four stations for a one year period, and these data were supplemented by monthly observations in the second year and by occasional trips to other situations.

3. Population counts as to species and numbers were made of weekly collections from four stations for one year and supplemented by monthly counts for the second year.

4. No general correlation between the measurements of oxygen, carbon dioxide, carbonates, pH and turbidity and the entomostracan population was observed.

5. The distribution of species and numbers is related to seasonal temperatures. On the basis of seasonal distribution the species present resolved themselves into four general groups which varied from constant occurrence to presence only within a sharply limited period of the year.

6. Special effects of temperature occur locally in respect to peculiarities of the environment.

7. The number and the variety of the species present is related to the age of the pond within the limits of the environments studied.

8. The importance of predators and the role of vegetation as food are recognized as problems worthy of further study.

9. The composition of the population and peculiarities of individual species are important factors in seasonal fluctuations, both in quality and quantity.

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Appendix, Part I

Physical Factors of the Environment
by Stations

October, 1937--April, 1939

STATION 1 A----PHYSICAL FACTORS

DATE	TEMPERATURE °C.		O cc/L.	CO ₂ cc/L.			pH	TURBIDITY in inches
	AIR	WATER		FREE	BOUND	½BOUND		
5/28/37	20	18	7.62	6.8	38.4	38.4	6.6	8
10/6/37	30	20	9.83	3.8	25.9	25.9	6.4	5
10/13/37	10	11	5.64	6.5	13.9	13.9	6.4	6
10/20/37	15	10	5.65	2.4	17.5	17.5	6.6	6
10/27/37	9.5	9	3.94	3.8	14.1	14.1	6.4	5
11/3/37	11	8	4.07	3.1	14.8	14.8	6.6	5
11/10/37	21	13	2.68	3.6	14.2	14.2	6.4	5
11/17/37	2	3	3.89	3.8	14.6	14.6	6.5	6
11/24/37	9	1-I	0	5.3	17.6	17.6	6.2	5
12/1/37	2	1-I	0.86	4.8	13.6	13.6	6.6	7
12/22/37	5.5	2-I	1.60	5.4	8.9	8.9	6.3	8
1/5/38	8	1-I	8.70	6.1	13.5	13.5	6.6	7
1/12/38	1	0-II	16.50	4.9	9.5	9.5	6.4	6
1/19/38	3	1-II	17.81	5.0	9.5	9.5	6.5	6
#2/3/38	11	3-I	6.22	2.2	7.7	7.7	6.2	10
#2/10/38	5	9	11.00	2.1	9.6	9.6	6.8	6
#2/17/38	3	2	7.83	1.6	6.4	6.4	6.4	5
#2/24/38	2	4	8.80	6.2	9.9	9.9	6.4	6
#3/3/38	2	7	11.71	5.6	5.8	5.8	6.4	6
#3/10/38	17	8	11.50	4.6	10.8	10.8	6.8	4
#3/17/38	8	10	7.52	7.1	7.3	7.3	6.4	8
#3/24/38	12	16	10.21	4.8	6.3	6.3	6.4	7
#3/31/38	17	19	8.22	5.6	6.6	6.6	6.7	6
#4/9/38	1	7.2	8.96	6.0	8.8	8.8	6.6	7
#4/14/38	31.5	19	9.38	5.1	5.1	5.1	6.8	8
#4/21/38	21	19	8.85	7.8	13.1	13.1	6.6	9
#4/28/38	27	20	3.22	13.4	11.6	11.6	6.4	8
5/4/38	27	22	2.70	11.4	14.4	14.4	6.4	8
5/12/38	12.5	13	2.22	13.7	8.3	8.3	6.6	10
#5/19/38	33	22	6.81	4.6	10.6	10.6	6.8	5
#5/26/38	25	26	7.45	6.6	12.6	12.6	6.8	6
#6/1/38	22.5	20	4.37	5.8	12.9	12.9	6.3	5
#6/8/38	23	18.5	2.82	10.5	8.7	8.7	6.3	5
6/15/38	22	18	0.68	21.5	17.2	17.2	6.5	3
6/22/38	28.5	23	7.31	5.6	11.9	11.9	6.7	3
6/29/38	25	22	9.40	5.8	11.7	11.7	6.7	3
7/5/38	27	23	7.36	5.0	16.2	16.2	6.4	3
7/13/38	25	23.5	5.02	8.8	9.8	9.8	6.7	7
7/20/38	28.5	24	6.78	8.0	9.8	9.8	6.7	3
7/28/38	26	23.5	4.35	9.1	12.9	12.9	6.7	12
8/9/38	26	24	3.25	7.6	9.6	9.6	6.5	5
8/17/38	28	26	6.31	8.4	14.7	14.7	6.3	6
8/24/38	24	21	2.76	6.1	21.5	21.5	6.5	12
9/1/38	22	18	3.63	8.6	12.4	12.4	6.4	12
9/8/38	25	21	1.28	5.3	9.0	9.0	6.3	14
9/15/38	18.5	20	3.48	8.1	10.6	10.6	6.4	13
9/22/38	14.5	12	7.24	6.6	8.3	8.3	6.6	12

STATION 1 A----PHYSICAL FACTORS (continued)

9/28/38	22	18	6.88	6.1	13.22	13.22	6.2	11
10/12/38	21	15	5.14	10.1	8.3	8.3	6.5	-*
10/29/38	18	10	3.73	10.6	12.8	12.8	6.8	12
11/11/38	22.5	14.5	6.00	15.2	13.9	13.9	6.7	-
12/10/38	2	4.5	3.12	8.9	10.8	10.8	6.8	-
1/6/39	10.5	6	5.70	6.1	11.8	11.8	5.7	-
2/3/39	-1.5	1	6.95	5.0	12.6	12.6	5.6	12
3/3/39	9	8	5.24	5.6	5.7	5.7	6.0	12
3/30/39	5	4	6.22	5.8	11.2	11.2	6.2	10

I-ice cover

#-observations taken at 1 B which was continuous with 1 A at that time

*-impossible to measure (disk still visible at bottom)

Station 1 B----PHYSICAL FACTORS

DATE	TEMPERATURE °C.		O ₂ cc/L.	CO ₂ cc/L.			pH	TURBIDITY in inches
	AIR	WATER		FREE	BOUND	½BOUND		
10/6/37	30	20	9.02	3.8	19.8	19.8	6.6	5
10/13/37	10	10.5	8.72	1.8	16.5	16.5	6.8	6
10/20/37	15	11	6.78	2.3	21.4	21.4	6.6	6
10/27/37	9.5	9	6.83	2.9	16.1	16.1	6.6	8
11/3/37	11	8	5.04	2.5	22.1	22.1	6.8	6
11/10/37	21	14	3.87	3.3	16.6	16.6	6.8	3
11/17/37	2	4.5	5.05	3.4	25.9	25.9	6.8	6.5
11/24/37	9	1-I	0	3.8	24.3	24.3	6.6	6
12/1/37	2	1-I	1.05	7.7	14.4	14.4	6.8	6
12/22/37	5.5	2-I	5.36	4.3	13.9	13.9	6.2	6
1/5/38	8	1-I	9.65	5.5	13.9	13.9	6.4	7
1/12/38	1	0-I	4.52	6.5	12.8	12.8	6.4	6
1/19/38	3	1-I	5.49	8.5	10.3	10.3	6.2	6
2/3/38	11	3-I	6.22	2.2	7.7	7.7	6.2	10
2/10/38	5	9	11.00	2.1	9.6	9.6	6.8	6
2/17/38	3	2	7.83	1.6	6.4	6.4	6.4	6
2/24/38	2	4	8.80	6.2	9.9	9.9	6.4	6
3/3/38	2	7	11.71	5.6	5.8	5.8	6.4	6
3/10/38	17	8	11.50	4.6	10.8	10.8	6.8	4
3/17/38	8	10	7.52	7.1	7.3	7.3	6.4	8
3/24/38	12	12	10.21	4.8	6.3	6.3	6.4	7
3/31/38	17	19	8.22	5.6	6.6	6.6	6.7	6
4/9/38	1	7.5	8.96	6.0	8.8	8.8	6.6	7
4/14/38	31.5	19	9.38	5.1	5.1	5.1	6.8	8
4/21/38	21	19	8.85	7.8	13.1	13.1	6.6	9
4/28/38	27	20	3.22	13.4	11.6	11.6	6.4	8
5/4/38	27	20	4.25	7.3	14.4	14.4	6.3	8

STATION 1 B----PHYSICAL FACTORS (continued)

5/12/38	12.5	12.5	3.45	9.6	9.8	9.8	6.5	7
5/19/38	33	22	6.81	4.6	10.6	10.6	6.8	5
5/26/38	25	26	7.45	6.6	12.6	12.6	6.8	6
6/1/38	22.5	20	4.37	5.8	12.9	12.9	6.3	5
6/8/38	23	18.5	2.82	10.5	8.7	8.7	6.3	5
6/15/38	22	18.5	1.42	10.8	12.4	12.4	6.1	4
6/22/38	28.5	28	6.55	7.1	15.2	15.2	6.7	4
6/29/38	25	24	8.35	4.0	10.8	10.8	6.7	4
7/5/38	27	25	5.40	4.6	8.6	8.6	6.7	4
7/13/38	25	24	2.39	11.1	12.9	12.9	6.5	3
7/20/38	28.5	25	3.28	10.1	11.9	11.9	6.5	7
7/28/38	26	24	2.00	12.4	11.2	11.2	6.3	12
8/9/38	26	24.5	1.63	8.4	12.6	12.6	6.4	16
8/17/38	28	27	4.32	5.8	19.5	19.5	6.6	-*
8/24/38	24	21	6.21	8.8	15.1	15.1	6.5	-
9/1/38	22	19	1.88	8.3	6.3	6.3	6.4	-
9/8/38	25	21.5	1.87	9.0	8.6	8.6	6.5	-
9/15/38	18.5	21	2.76	6.1	13.2	13.2	6.4	-
9/22/38	14.5	12	5.17	6.8	8.6	8.6	6.7	-
9/28/38	22	18.5	8.38	5.8	9.1	9.1	6.7	-
10/12/38	21	15	5.98	8.8	9.4	9.4	6.4	-
10/29/38	18	9	6.28	7.1	9.9	9.9	6.6	-
11/11/38	22.5	12.5	3.13	7.2	11.4	11.4	6.4	-
12/10/38	2	3.5	4.64	6.8	9.8	9.3	6.8	-
1/6/39	10.5	5	5.00	15.7	10.4	10.4	5.6	-
2/3/39	-1.5	1-I	4.88	9.1	5.3	5.3	5.5	-
3/3/39	9	8	5.37	3.8	5.5	5.5	6.1	-
3/30/39	5	4	6.01	9.7	13.2	13.2	6.2	-

I-ice cover. *-impossible to measure (disk visible at bottom)

STATION 1 C----PHYSICAL FACTORS

DATE	TEMPERATURE °C.		O ₂ cc/L.	CO ₂ cc/L.			pH	TURBIDITY in inches
	AIR	WATER		FREE	BOUND	½BOUND		
5/28/37	20	18	1.44	9.4	36.2	36.2	6.4	-*
2/3/38	11	6	3.79	3.3	9.1	9.1	5.5	-
2/10/38	5	10	5.30	4.4	15.0	15.0	5.8	-
2/17/38	3	4	4.86	3.3	10.2	10.2	6.0	-
2/24/38	2	4.5	2.33	16.9	5.8	5.8	6.0	-
3/3/38	2	6	4.33	16.4	11.0	11.0	6.0	-
3/10/38	17	9	5.79	8.7	6.3	6.3	6.2	-
3/17/38	8	9	8.60	12.4	9.4	9.4	6.0	-
3/24/38	12	15	2.27	9.4	7.6	7.6	6.0	-
3/31/38	17	20	5.84	6.3	6.3	6.3	6.2	-
4/9/38	1	7	5.02	9.6	6.8	6.8	6.1	-
4/14/38	31.5	21	4.61	11.6	10.1	10.1	6.4	-
4/21/38	21	18	3.21	12.1	10.1	10.1	6.2	-
4/28/38	27	21	1.79	35.5	13.4	13.4	6.3	-
5/26/38	25	21	2.78	11.3	11.6	11.6	6.2	-

STATION 1 C----PHYSICAL FACTORS (continued)

6/1/38	22.5	19	1.24	14.4	13.7	13.7	6.2	-
6/8/38	23	18	1.79	16.8	9.2	9.2	6.1	-
7/20/38	28.5	23	1.31	10.2	8.7	8.7	5.8	-
8/9/38	26	24	0.85	9.8	10.7	10.7	6.0	-
2/3/39	-1.5	1-I	4.44	7.6	12.1	12.1	5.6	-
3/3/39	9	8	5.37	3.8	5.5	5.5	6.1	-
3/30/39	5	4	2.53	5.4	7.1	7.1	6.0	-

*-impossible to measure (disk still visible at bottom)
I-ice cover

STATION 2----PHYSICAL FACTORS

DATE	TEMPERATURE °C.		O ₂ cc/L.	CO ₂ cc/L.	PH			TURBIDITY in inches
	AIR	WATER			FREE	BOUND	½BOUND	
10/13/37	10	12	11.08	2.7	28.5	28.5	7.2	16
10/20/37	15	11	6.34	3.2	26.1	26.1	7.0	17
10/27/37	10	10	8.46	2.9	28.3	28.3	7.2	15
11/3/37	12	10	8.89	2.4	19.6	19.6	7.2	15
11/10/37	22	10	8.92	1.7	27.0	27.0	7.3	24
11/17/37	1	4	9.73	3.6	16.9	16.9	7.2	-*
11/24/37	7.5	2-I	8.03	2.5	32.1	32.1	7.2	20
12/1/37	1.5	1-I	9.39	2.7	34.2	34.2	7.1	18
12/22/37	5	2-I	10.50	1.9	18.3	18.3	7.0	10
1/5/38	9	2-I	8.18	2.4	23.3	23.3	7.0	9
1/12/38	1	1-I	6.68	3.5	27.8	27.8	6.9	13
1/19/38	3	1-I	9.92	11.8	37.3	37.3	7.0	18
2/3/38	12	4	9.89	1.4	6.8	6.8	6.8	6
2/10/38	4	1-I	9.40	3.3	21.1	21.1	7.0	6
2/17/38	5	3	7.92	3.2	20.7	20.7	7.0	9
2/24/38	2	2	11.73	4.3	15.3	15.3	7.0	8
3/3/38	5	5.5	11.28	3.4	23.0	23.0	7.2	9
3/10/38	16	10	12.15	5.3	16.7	16.7	6.9	3
3/17/38	9	9	8.21	8.8	11.6	11.6	6.8	4
3/24/38	16	17	10.21	3.0	3.3	3.3	7.1	4
3/31/38	23	20	7.94	2.5	7.6	7.6	6.8	5
4/9/38	2	6	10.08	4.8	15.7	15.7	7.0	8
4/14/38	29	20	7.42	8.6	24.7	24.7	7.3	-
4/21/38	22	20	7.05	8.8	31.6	31.6	7.5	9
4/28/38	26	19	5.38	9.6	35.7	35.7	7.5	12
5/4/38	29	24	7.40	8.8	41.1	41.1	7.4	10
5/12/38	15	17	4.65	7.1	23.5	23.5	7.2	12
5/19/38	32	23	7.89	5.2	27.4	27.4	7.6	18
5/26/38	29	21	5.78	3.8	22.8	22.8	7.3	6
6/1/38	22.5	21.5	5.71	5.1	5.1	5.1	7.2	22
6/8/38	31	24	5.63	5.1	27.2	27.2	7.3	12
6/15/38	28	22	2.79	6.8	30.4	30.4	7.1	12
6/22/38	28.5	25	7.91	0	26.4	26.4	8.3	22
6/29/38	26	22	8.26	5.3	8.6	8.6	7.1	3

STATION 2----PHYSICAL FACTORS (continued)

DATE	TEMPERATURE °C.		O ₂ cc/L.	CO ₂ cc/L.			pH	TURBIDITY in inches
	AIR	WATER		FREE	BOUND	$\frac{1}{2}$ BOUND		
7/5/38	26	25	9.70	0	19.9	14.7	8.4	15
7/13/38	23.5	26	3.19	7.4	21.8	21.8	7.1	15
7/20/38	32	24	9.71	0	14.7	8.9	8.7	17
7/28/38	31	26	6.40	3.6	15.9	15.9	7.3	18
8/9/38	30.5	26	3.56	9.6	22.8	22.8	7.0	23
8/17/38	30	29	5.34	6.4	11.8	11.8	7.2	19
8/24/38	25	24	5.42	9.3	15.0	15.0	7.3	19
9/1/38	27	21	7.78	7.9	23.1	23.1	7.2	15
9/8/38	26	23	6.32	6.8	17.3	17.3	7.1	17
9/15/38	19	21	0.67	7.1	17.4	17.4	6.8	13
9/22/38	18	14	3.03	11.9	21.4	21.4	7.0	33
9/28/38	27	20	6.75	3.8	36.4	36.4	7.3	19
10/12/38	26	15	5.28	4.3	15.4	15.4	7.1	20
10/29/38	20	11	8.26	5.6	20.0	20.0	7.2	19
11/11/38	23	10	8.37	5.3	25.3	25.3	7.3	19
12/10/38	2.5	5	5.67	7.6	27.9	27.9	7.0	17
1/6/39	9.5	7	6.47	5.8	8.6	8.6	6.9	6
2/3/39	-3	1-I	11.50	5.0	10.6	10.6	6.9	12
3/3/39	10	7	9.89	6.0	11.1	11.1	7.0	15
3/30/39	5	5	8.42	5.2	11.7	11.7	7.0	9

*-impossible to measure (disk still visible at bottom)
I-ice cover

STATION 3 ---- PHYSICAL FACTORS

DATE	TEMPERATURE (degrees °C.)		O ₂ cc/L.	CO ₂ cc/L.			pH	TURBIDITY in inches
	AIR	WATER		FREE	BOUND	½BOUND		
10/16/37	13	11	4.87	4.3	28.6	28.6	6.8	-*
10/23/37	7	14	2.72	2.8	30.5	30.5	6.8	-
10/30/37	20	13.5	7.11	2.2	21.3	21.3	6.6	-
11/6/37	14.2	9	4.86	2.2	10.2	10.2	7.0	-
11/13/37	18	14	8.76	1.5	13.8	13.8	6.8	-
11/20-37	-6.5	0-I	6.47	5.2	12.1	12.1	6.6	-
11/27/37	11	2-I	4.89	6.6	15.2	15.2	6.5	-
12/4/37	3	2-I	16.40	5.4	19.8	19.8	6.7	-
12/18/37	2	1-I	12.10	2.8	7.1	7.1	6.0	-
12/31/37	9	6	5.59	3.1	8.7	8.7	6.3	-
1/8/38	-6	0-I	6.12	6.0	12.4	12.4	6.4	-
1/16/38	8.5	1-I	12.40	4.4	11.7	11.7	6.6	-
1/22/38	5	1-I	9.03	1.4	14.4	14.4	6.6	-
2/5/38	11	3-I	7.00	2.4	6.4	6.4	6.0	15
2/12/38	8	4	8.40	3.4	3.7	3.7	6.4	-
2/19/38	-1	2	11.80	1.3	4.8	4.8	6.6	15
2/26/38	1.5	1.5	11.71	5.5	8.8	8.8	6.4	-
3/5/38	21	10.5	12.00	3.0	6.4	6.4	6.3	-
3/12/38	20	8	10.23	2.1	5.3	5.3	6.4	-
3/19/38	21	12	13.21	1.3	4.3	4.3	6.6	7.5
3/26/38	13	15	14.20	3.0	4.6	4.6	6.9	-
4/2/38	3	9	10.54	3.6	4.4	4.4	6.8	14
4/10/38	19	13	11.93	3.5	3.5	3.5	6.6	-
4/16/38	28.5	20	12.90	1.2	7.6	7.6	8.4	-
4/23/38	19.5	17.5	8.72	3.1	6.3	6.3	7.1	-
4/30/38	22	20	6.60	6.6	9.0	9.0	6.9	-
5/7/38	25.5	20	8.30	2.0	8.1	8.1	7.4	-
5/14/38	15	15	8.02	4.5	7.6	7.6	7.4	-
5/21/38	19.5	21.5	5.71	5.1	15.4	15.4	6.2	6
5/28/38	26.5	23.4	6.58	2.0	6.3	6.3	7.0	-
6/4/38	25.5	23.0	8.61	4.3	8.8	8.8	6.8	-
6/11/38	22	21	4.26	2.5	7.6	7.6	6.7	-
6/20/38	24.5	21	4.70	5.0	7.3	7.3	6.7	-
6/27/38	24	26	9.10	0	15.2	3.8	8.5	-
7/2/38	27.5	26	6.90	3.5	11.4	11.4	6.9	-
7/9/38	28	26	11.40	0	11.1	2.5	9.1	-
7/15/38	26.5	28	11.10	0	9.4	3.3	9.5	-
7/30/38	34	30	11.70	0	10.2	7.3	8.4	-
8/8/38	29	27	10.20	0	11.6	0.2	8.7	-
8/16/38	27	26	6.00	4.8	23.2	23.2	7.2	-
8/24/38	28	24	8.41	1.5	9.2	9.2	8.6	-
9/1/38	24.5	22	7.05	5.8	11.4	11.4	7.4	-
9/10/38	23	23	6.80	1.3	10.6	10.6	7.3	-
9/17/38	18.5	20	4.20	5.5	13.1	13.1	6.6	-
9/24/38	24.5	17	8.30	3.3	12.6	12.6	7.0	-
10/1/38	17	16	5.90	4.5	13.2	13.2	7.0	-

STATION 3----PHYSICAL FACTORS (continued)

10/20/38	8.5	14	8.10	4.3	11.6	11.6	7.4	-
11/3/38	24.5	14.5	7.80	1.3	8.7	8.7	8.2	-
11/30/38	6	3-I	10.11	2.5	11.4	11.4	6.6	-
12/28/38	-8	0-I	12.00	9.1	18.4	18.4	7.4	-
1/29/38	6	2-I	10.92	9.6	11.4	11.4	5.5	-
2/25/39	-2	3-I	11.00	2.9	6.8	6.8	6.2	-
4/10/39	7.7	11.1	9.83	3.7	8.4	8.4	6.6	-

*-impossible to measure (disk still visible at bottom)

I-ice cover

STATION 4 A----PHYSICAL FACTORS

DATE	TEMPERATURE °C.		O ₂ cc/L.	CO cc/L.	pH		TURBIDITY in inches	
	AIR	WATER			FREE	BOUND		
10/10/37	20	14.4	5.56	0.5	33.4	33.4	7.1	-*
10/16/37	15	8.5	8.75	3.7	30.7	30.7	7.3	-
10/23/37	7	9	8.37	2.7	21.3	21.3	7.1	-
10/30/37	24	12.5	8.13	3.0	22.6	22.6	6.8	-
11/6/37	16	10	8.17	3.0	7.9	7.9	6.8	-
11/13/37	13	8	7.86	2.0	16.6	16.6	6.8	-
11/20/37	-6	0.5-I	8.08	1.1	13.5	13.5	6.8	-
11/27/37	12.5	5.5	3.47	3.6	13.4	13.4	6.6	-
12/4/37	3.5	1-I	3.82	2.4	10.3	10.3	6.6	12
12/18/37	1	1-I	11.70	3.0	3.5	3.5	6.3	-
12/31/37	10	7	6.42	4.2	7.2	7.2	6.4	-
1/8/38	-5.5	1-I	10.92	6.5	7.6	7.6	6.5	14
1/16/38	8.5	1-I	19.70	1.3	11.5	11.5	6.8	15
1/22/38	6	2-I	14.20	2.0	8.0	8.0	6.6	15
2/5/38	12	1-I	9.10	1.3	6.3	6.3	6.3	9
2/12/38	8	2	8.87	1.3	6.4	6.4	6.3	-
2/19/38	-1	2.5	8.61	5.6	4.3	4.3	6.1	3
2/26/28	1.5	1-I	9.31	9.8	7.1	7.1	6.2	7
3/5/38	17.5	9	8.85	7.5	5.8	5.8	6.3	16
3/12/38	16	6.5	8.78	6.7	5.1	5.1	6.4	15
3/19/38	19	12	8.37	4.6	5.6	5.6	6.5	3
3/26/38	13	15	7.82	5.1	5.8	5.8	6.6	6
4/2/38	3.5	8	5.81	4.6	5.1	5.1	6.8	4
4/10/38	15	10	9.69	4.3	5.3	5.3	6.6	3
4/16/38	26	22	7.62	3.8	20.2	20.2	6.8	6
4/23/38	19	16	9.91	2.8	8.4	8.4	7.6	9
4/30/38	20	19	8.40	2.0	8.4	8.4	7.2	16
5/7/38	28.5	24.5	8.31	2.0	16.7	16.7	7.9	-
5/14/38	13	16	8.50	2.8	9.4	9.4	8.2	-
5/21/38	21	23	7.91	2.0	8.1	8.1	7.0	12
5/28/38	27	24.5	4.78	1.9	9.8	9.8	6.8	18
6/4/38	26	25	8.93	0	5.5	3.5	8.4	-
6/11/38	23	21	5.51	2.2	5.8	5.8	6.9	-
6/20/38	24	22	7.21	1.7	7.8	7.8	7.9	-

STATION 4 A----PHYSICAL FACTORS (continued)

6/27/38	23	21	9.20	4.3	12.1	12.1	7.9	16
7/2/38	28.5	23	6.34	3.8	7.6	7.6	6.9	-
7/9/38	28	25	8.39	7.1	4.8	4.8	6.9	13
7/15/38	28	24	9.70	4.05	7.3	7.3	7.3	-
7/30/38	34	27	9.67	5.8	7.3	7.3	7.6	-
8/8/38	31	25	7.10	9.0	8.6	8.6	6.9	-
8/16/38	28.5	25	7.10	7.6	12.8	12.8	6.8	-
8/24/38	29.5	22	11.71	4.8	16.2	16.2	8.0	16
9/1/38	25	19	11.40	5.9	18.0	18.0	7.8	-
9/10/38	22	21	6.28	3.7	5.3	5.3	6.6	11
9/17/38	21	18	4.10	6.0	8.6	8.6	6.2	-
9/24/38	28	21	8.68	4.0	5.6	5.6	7.2	-
10/1/38	--	--	drained	--	--	--	--	--

*-impossible to measure (disk still visible at bottom)
I-ice cover

STATION 4 B----PHYSICAL FACTORS

DATE	TEMPERATURE °C.		O ₂ cc/L.	CO ₂ cc/L.			pH	TURBIDITY in inches
	AIR	WATER		FREE	BOUND	BOUND		
10/10/37	20	15	13.70	1.2	27.6	27.6	8.3	6
10/16/37	15	10.5	16.93	0	52.6	17.2	8.4	6
10/23/37	8	10	11.81	0	26.8	26.0	8.5	6
10/30/37	24	14	13.81	0	19.6	16.4	9.6	7
11/6/37	16	9	19.60	0	42.5	32.8	9.6	5
11/13/37	14	9	22.21	0	18.1	1.5	9.6+	5
11/20/37	-6	0-I	8.08	0	37.0	27.2	9.2	4
11/27/37	12	5	11.86	2.6	10.6	10.6	8.0	6
12/4/37	3.5	1-I	15.36	0	47.4	43.4	9.0	5
12/18/37	0.5	1-I	11.25	1.4	11.1	11.1	7.0	7
12/31/37	10	8	9.18	1.3	18.3	18.3	7.3	8
1/8/38	-6	1-I	20.92	0	9.5	1.8	8.9	7
1/16/38	9	1-I	21.80	0	19.5	11.0	9.3	7
1/22/38	6	1-I	11.91	0	19.5	1.6	9.0	5
2/5/38	12	2-I	16.65	0	10.25	8.8	9.4	5
2/12/38	9	3	8.09	0	16.9	13.2	8.8	6
2/19/38	-1	3	12.27	3.8	11.6	11.6	8.2	5
2/26/38	1.5	1	12.38	6.6	15.4	15.4	7.1	9
3/5/38	18.5	12	13.60	4.6	15.4	15.4	8.0	6
3/12/38	17	7.5	11.98	0	21.0	19.8	8.4	9
3/19/38	17	12	14.23	0	12.9	6.8	9.0	3
3/26/38	13	15	13.97	0	13.9	13.9	9.0	7
4/2/38	3	9.5	7.30	2.2	12.8	12.8	8.0	6
4/10/38	19	9	12.58	3.5	11.8	11.8	7.8	5
4/16/38	25	20	11.20	0	12.6	3.1	9.2	9
4/23/38	19	16	12.20	0	21.7	1.0	9.6+	6

STATION 4 B-----PHYSICAL FACTORS (Continued)

DATE	TEMPERATURE		O ₂		CO ₂		pH	TURB.
	AIR	WATER						
4/30/38	21	20	12.30	0	16.9	1.2	9.4	8
5/7/38	28	22	3.08	5.1	18.7	18.7	7.6	—*
5/14/38	13	16	6.08	5.6	16.8	16.8	7.4	21
5/21/38	21	24	8.98	0	16.4	0.3	9.4	5
5/28/38	28	27	6.90	0	25.8	25.8	9.6	19
6/4/38	26	25	10.72	0	13.6	4.3	9.6	8
6/11/38	23	22	10.20	0	17.6	0.2	9.5	5
6/20/38	26	22.5	13.30	0	18.4	7.8	9.5	4
6/27/37	23	24	14.21	0	40.5	0.1	9.5	5
7/2/38	28.2	23.2	10.81	0	23.5	12.1	9.6+	4
7/9/38	28	27	17.80	0	18.2	5.5	9.6+	4
7/15/38	28	28	22.80	0	20.0	2.0	9.5	—
7/30/38	34	28	25.00	0	21.1	2.7	9.6+	8
8/8/38	31.5	28	14.42	0	27.1	4.2	9.3	12
8/16/38	28.5	28	6.36	0	21.7	17.2	8.8	25
8/24/38	29	27	15.66	0	16.2	6.3	9.6+	19
9/1/38	25	22	7.72	0	18.2	11.7	8.8	22
9/10/38	22	22	6.59	3.0	12.5	12.5	8.1	7
9/17/38	21	20	7.80	0	19.3	10.1	7.1	—
9/24/38	28	20	9.41	0	12.9	12.9	8.4	—
10/1/38	--	--	drained		--	--	--	--
11/30/38	8	3	9.81	2.5	15.1	15.1	7.6	5
12/28/38	-7	1-I	15.80	0	29.8	4.3	9.4	8
1/29/39	6.5	3-I	19.81	0	8.9	3.9	9.6	4.5
2/25/39	-3	3-I	16.20	0	11.1	6.6	9.3	6
4/10/39	8	10	13.23	0	16.3	11.1	9.5	8

*-impossible to measure (disk still visible at bottom)

I-ice cover

Appendix, Part II

Seasonal Census of Entomostraca

by Species

October, 1937--April, 1939

Figures represent the number of organisms per collecting unit--i.e., one two-yard haul of the net propelled at approximately one yard per second six inches below the surface of the water.

STATION 1 A--SEASONAL CENSUS OF ENTOMOSTRACA BY SPECIES

	10/13	10/20	10/27	11/ 3	11/10	11/17	11/24	12/ 1
CLADOCERA								
<i>Alona rectangula</i>				1	2			
<i>Chydorus sphaericus</i>				2			1	
<i>Daphnia pulex</i>	40	44	11					
<i>Leydigia quadrangularis</i>				1	2			
<i>Pleuroxus denticulatus</i>								
<i>Pleuroxus hamulatus</i>								
<i>Scapholeberis mucronata</i>								
<i>Simocephalus exspinosus</i>					205	74	8	18
COPEPODA								
<i>Canthocamptus staphylinoides</i>						1		16
<i>Canthocamptus staphylinus</i>						1	8	
<i>Cyclops albidus</i>								
<i>Cyclops prasinus</i>								
<i>Cyclops serrulatus</i>			1	5	40			3
<i>Cyclops sp. (young)</i>		2	37	9		9	28	11
<i>Cyclops viridis</i>	1				3			
OSTRACODA								
<i>Candona crogmaniana</i>								
<i>Candona ohioensis</i>	4	1	1			2		
<i>Cypridopsis vidua</i>	1	7	2		16	40	28	232
<i>Cypridopsis vidua</i>		1						
TOTAL	46	55	52	18	268	127	73	282

*--chiefly young or larval forms

#--collections made at 1 B, which was then continuous with 1 A.

STATION 1 B--SEASONAL CENSUS OF ENTOMOSTRACA BY SPECIES

	10/13	10/20	10/27	11/ 3	11/10	11/17	11/24	12/ 1
PHYLLOPODA								
<i>Eubbranchipus vernalis</i>								
CLADOCERA								
<i>Alona costata</i>								
<i>Alona rectangula</i>								
<i>Chydorus sphaericus</i>				2		1		
<i>Daphnia pulex</i>	8	4						
<i>Leydigia quadrangularis</i>								
<i>Pleuroxus denticulatus</i>				1		1		
<i>Scapholeberis mucronata</i>					1			
<i>Simocephalus exspinosus</i>		4	71	86	30	102	14	16
COPEPODA								
<i>Canthocamptus staphylinoides</i>			9			1		
<i>Canthocamptus staphylinus</i>								
<i>Cyclops albidus</i>							8	
<i>Cyclops bicuspidatus</i>								
<i>Cyclops fuscus</i>								
<i>Cyclops prasinus</i>								
<i>Cyclops serrulatus</i>		13	27	1	5			
<i>Cyclops sp. (young)</i>		11		6	15	4		12
<i>Cyclops viridis</i>	1					2		

1	12/22	1/5	1/12	1/19	2/3 #	2/10 #	2/17 #	2/24 #	3/3 #	3/10 #	3/17 #	3/24 #	3/31 #
	2		2										
18													
16	128	14											
3													
11	6		2										
2													
	2												
2	200	92	18	12									
2	338	106	22	12									

1	12/22	1/5	1/12	1/19	2/3	2/10	2/17	2/24	3/3	3/10	3/17	3/24	3/31
								2	2	4	2	2	2
8	6	8			2	2				6	2	2	
										2	4	2	10
6													
6	106	8		2	8	6		72	24	32	112	12	70
							6				2		4
							6				1		
2	7							32		12	38	179	22
	1	2				4	8	12		10	7	19	

4/9 #	4/14 #	4/21 #	4/28 #	5/4	5/12	5/19 #	5/26 #	6/1 #	6/8 #	6/15	6/22	6/29	7/5	7/13	7/20
										3					
				120	48					939	12 108	70	30 2052	3358	14760
												28	36	6	
										96	564	888	810	168	
				8						46			52	2	2
				37	36					124	132	12	780	178	118
				1470*	*132					*224	24	*98	18		20
				1635	216					1442	840	1102	3778	3712	14900

4/9	4/14	4/21	4/28	5/4	5/12	5/19	5/26	6/1	6/8	6/15	6/22	6/29	7/5	7/13	7/20
									6		8	12			
2									8				8		
4	8	36	72	210	60	112	250	184	754	576	1036	1924	468	6408	1260
									6		8	12			
					60	9	134		264	274	912	1216	2142		12
68	182	128	36												
3	3	7			12			24	16	17		32	4		
1										17	14		14		48
26	34	101	108	15		16	48	24	64	78	70	96	162	48	408
	3					16									

	7/20	7/28	8/9	8/17	8/24	9/1	9/8	9/15	9/22	9/28	10/6	10/12	10/29	11/11	12/10	1/6	
3																	
8	14760	4800	2860	2694	2560	1512	1072	112	432	684	496	102	28		2	16	8
5													4		6		
3		30	40	12											12	8	12
2	2												6	10			
3	118	360	160	146	100	8		8	10		8	4			2	8	
															6		
	20							8	12		18	40	64	80	532		
2	14900	5100	3060	2852	2660	1520	1072	120	450	696	504	124	94	108	112	560	

	7/20	7/28	8/9	8/17	8/24	9/1	9/8	9/15	9/22	9/28	10/6	10/12	10/29	11/11	12/10	1/6
	1260	1440	4408	2182	120	6			38						2	
	12															
							30	106	396	60	112	59	40	28	56	16
														4	16	
								10					6	2	8	
	48															
	408	108	184	84	160	14		10	38		64	50	30	10		

8/9	8/17	8/24	9/1	9/8	9/15	9/22	9/28	10/6	10/12	10/29	11/11	12/10	1/6	2/3	3/3	3/30	
												2	16	8	8	12	16
860	2694	2560	1512	1072	112	432	684	496	102	28							
										4		6					
40	12																
												12	8	12	92	100	124
										6	10				16	136	16
																	8
										16	2		8	24			
											2	8					
160	146	100	8		8	10		8	4		6			24			
											4						
																	2
						8	12		18	40	64	80*532*216	240	26			
6060	2852	2660	1520	1072	120	450	696	504	124	94	108	112	560	380	488	220	

8/9	8/17	8/24	9/1	9/8	9/15	9/22	9/28	10/6	10/12	10/29	11/11	12/10	1/6	2/3	3/3	3/30	
							38					2					8
4408	2182	120	6														
				30	106	396	60	112	59	40	28	56	16	8	64	576	
											4	16					48
						10				6	2	8					4
																	1
											10						
184	84	160	14		10	38		64	50	30							8

STATION 1 B--SEASONAL CENSUS OF ENTOMOSTRACA(continued)

	10/13	10/20	10/27	11/3	11/10	11/17	11/24	12/1
OSTRACODA							1	9
<i>Candona crogmaniana</i>								7
<i>Candona ohioensis</i>			1			1		
<i>Cypria elegantula</i>	3	38	44	1	3	32	4	74
<i>Cypridopsis vidua</i>								
<i>Eucypris</i> sp.(larval)								
TOTAL	12	51	152	97	54	44	26	116

*--chiefly young or larval forms

STATION 1 C--SEASONAL CENSUS OF ENTOMOSTRACA

	10/13	10/20	10/27	11/3	11/10	11/17	11/24	12/1
PHYLLOPODA	x	x	x	x	x	x	x	x
<i>Eubranchipus vernalis</i>								
CLADOCERA								
<i>Alona costata</i>								
<i>Chydorus sphaericus</i>								
<i>Daphnia pulex</i>								
<i>Scapholeberis mucronata</i>								
<i>Simocephalus exspinosus</i>								
COPEPODA								
<i>Canthocamptus northumbrius</i>								
<i>Canthocamptus staphylinoides</i>								
<i>Canthocamptus staphylinus</i>								
<i>Cyclops bicuspidatus</i>								
<i>Cyclops prasinus</i>								
<i>Cyclops serrulatus</i>								
<i>Cyclops</i> sp.(young)								
<i>Cyclops viridis</i>								
<i>Diaptomus sanguineus</i>								
<i>Osphranticum labronectum</i>								
OSTRACODA								
<i>Candona crogmaniana</i>								
<i>Cypria elegantula</i>								
<i>Eucypris fuscata</i>								
<i>Eucypris</i> n.sp.(Furtos)								
<i>Eucypris</i> sp.(larval)								
TOTAL								

x--dry

STATION 2--SEASONAL CENSUS OF ENTOMOSTRACA

	10/13	10/20	10/27	11/3	11/10	11/17	11/24	12/1
CLADOCERA								
<i>Alona costata</i>								
<i>Alona guttata</i>								
<i>Chydorus globosus</i>								
<i>Chydorus sphaericus</i>	74	20	16	14	143	36	82	36
<i>Pleuroxus denticulatus</i>	47	1	10	6	108	14		
<i>Pleuroxus hamulatus</i>					12		4	
<i>Scapholeberis mucronata</i>	3				2			
<i>Simocephalus serrulatus</i>	1		5	1	8	8	12	4

7	12/22	1/5	1/12	1/19	2/3	2/10	2/17	2/24	3/3	3/10	3/17	3/24	3/31	4/9
	1	2		1	2		2		2	14	16	2	8	4
4	205	216	66	69	186	306	272	600	332	208	*502	110	78	*525
								2			12	26	26	
6	326	236	66	72	198	318	294	718	362	288	698	352	220	628

1	12/22	1/5	1/12	1/19	2/3	2/10	2/17	2/24	3/3	3/10	3/17	3/24	3/31	4/9
	x	x	x	x	52	106	24	32	8	36	6	4	4	
						6	12	4	8	4	2	8	22	26
					200	42	88	98	78	65	56	58	4	6
					298	104	110	24	14	23				130
						108	80	9	18	12	17	10	14	1
									1				3	
					66	100	86	33	17	13	15	10	3	164
					6	48	10	24	19	28	42	40	12	5
								2	1	3	2			4
						2		5	4	19		2		4
					24	10	4	3	16	6	4		2	
													6	16
							14	18	18	23	32	8	10	24
					646	526	428	252	202	232	184	154	84	382

1	12/22	1/5	1/12	1/19	2/3	2/10	2/17	2/24	3/3	3/10	3/17	3/24	3/31	4/9
									3/		4			
												12		
36	58	566	874	388	574	490	512	340	680	692	1194	588	888	640
	16	18	170	30	38	32	154	16	40	32	68	56	32	18
		12	20	6	2	3	12				4			2
4			42	10	2					4				

														<u>1 9 3 8</u>		
4/9	4/14	4/21	4/28	5/4	5/12	5/19	5/26	6/1	6/8	6/15	6/22	6/29	7/5			
4	8			5												
*525	*734	*1332	*1170	*2010	*2555	*336	*928	504	82	48	24	8				
							32									
628	964	1604	1386	2240	2699	521	1492	736	1194	960	2064	3298	2790			

4/9	4/14	4/21	4/28	5/4	5/12	5/19	5/26	6/1	6/8	6/15	6/22	6/29	7/5
	6			X	X	X	X	X		X	X	X	X
			18										
2		20	54						16				
26	176	564	360				32	138	*1496				
	16	72	36						32				
6	29	88	126				3						
130	149	264	66										
		86											
1		46											
			35				30						
								23					
164	732	188	490				438	171	54				
5	8	230	177				12	22					
							3		2				
4	12	24	18										
4													
		20	36										
16	46	106	60										
	8	20	10										
24	70	42	2				32						
382	1252	1780	1488				550	364	1600				

*--chiefly young or larval forms

4/9	4/14	4/21	4/28	5/4	5/12	5/19	5/26	6/1	6/8	6/15	6/22	6/29	7/5
			16		72	32			8	16			
640	404	1260	488	150	918	624	368	66	148	144	132	224	18
18	8	50	90	28	90	156	80	4	72	208	252	128	
2	4			8		4		2					
	4			10	72	16	160	24	144	80	84	32	
		10										16	

7/5	7/13	7/20	7/28	8/9	8/17	8/24	9/1	9/8	9/15	9/22	9/28	10/6	10/13
								6	4	114	14		
										14			
2790	6456	1728	1548	4592	2266	280	20	36	120	610	74	176	

7/5	7/13	7/20	7/28	8/9	8/17	8/24	9/1	9/8	9/15	9/22	9/28	10/6	10/13
x	x	x	x		x	x	x	x	x	x	x	x	
		12	2	694									
				92									
		96											
		8											
		116		786									

7/5	7/13	7/20	7/28	8/9	8/17	8/24	9/1	9/8	9/15	9/22	9/28	10/6	10/13
180	252	60	126	130	108	12	72	24	84		110	528	
	564	360	108	136	56	48	40	14	96	12	48	10	
54	204	60	20	56	142	300	120	22	10		44	6	
	24		18	8	14	36	24	8	58		12	6	

9/8	9/15	9/22	9/28	10/6	10/12	10/29	11/11	12/10	1/6	2/3	3/3	3/30
6	4	114 14	14		3	8	6	208	56	8	*144	76
36	120	610	74	176	112	84	52	288	72	16	216	725

9/8	9/15	9/22	9/28	10/6	10/12	10/29	11/11	12/10	1/6	2/3	3/3	3/30
x	x	x	x	x	x	x	x	x	x	8	16	8
												4
										238	18	40
										306	120	4
										24	65	8
										16	68	112
										32	35	56
											8	
											32	32
											48	4
											48	12
										624	410	280

9/8	9/15	9/22	9/28	10/6	10/12	10/29	11/11	12/10	1/6	2/3	3/3	3/30
						6		8				
24	84		110	528	340	184		840	32	16	64	134
14	96	12	48	10	14	32		80				28
								8				
22	10		44	6								
8	58		12	6	16	8		16				

STATION 2--SEASONAL CENSUS OF ENTOMOSTRACA(continued)

	10/13	10/20	10/27	11/3	11/10	11/17	11/24	1 9
GOPEPODA								
Canthocamptus staphylinoides			1	4	1			
Canthocamptus staphylinus								
Cyclops albidus	1		26					
Cyclops prasinus			29		6			
Cyclops serrulatus			53	3	10			26
Cyclops sp.(young)	50	430	378	11	68	28		110
Cyclops viridis	18	18	55					12
OSTRACODA								
Cypria elegantula	1	1	2	1		1		2
Cypridopsis vidua		1						2
Physocypria globula								
TOTAL	225	471	575	40	358	87		250

*--chiefly young or larval forms

STATION 3--SEASONAL CENSUS OF ENTOMOSTRACA

	10/16	10/23	10/30	11/6	11/13	11/20	11/27
CLADOCERA							
Alona affinis						160	22
Alona costata				40	25	40	
Alona guttata							
Alona quadrangularis							
Alonella karua					63	28	
Bosmina longirostris		2					
Camptocercus rectirostris		8		16	4	6	8
Ceriodaphnia pulchella							
Ceriodaphnia quadrangula							
Ceriodaphnia reticulata							
Chydorus globosus	1		1				
Chydorus sphaericus	78	8	287	368	195	2378	960
Daphnia longispina		1					
Leydigia quadrangularis							
Pleuroxus denticulatus	10	1	2	13	44	66	48
Pleuroxus hamulatus				3			
Scapholeberis mucronata	1	3					
Simocephalus serrulatus	1	10	14	112	42	80	32
Simocephalus vetulus		1				32	
COPEPODA							
Canthocamptus staphylinoides	1			16	1		
Canthocamptus staphylinus							
Cyclops albidus	7	34	8	8	7	108	65
Cyclops bicuspidatus						8	5
Cyclops fuscus							
Cyclops prasinus		36					
Cyclops serrulatus			6	8	20	19	70
Cyclops sp.(young)	3	140	118	380	185	973	556
Cyclops viridis	4						
Diaptomus pallidus		2					
Diaptomus siciloides							
OSTRACODA							
Cypria elegantula		7	4	11		44	216
Cypridopsis vidua		4		18			
Cyprinotus incongruens				6			
TOTAL	106	257	440	1009	596	3942	2064

*--chiefly young or larval forms

1 9 3 7												
11/24	12/1	12/22	1/5	1/12	1/19	2/3	2/10	2/17	2/24	3/3	3/10	3/17
				16		8		8				
			4	40	14							6
26		4		20	32			8	4	5		8
110	206	34	38	182	136	24	20	88		5		18
12						10	6	8	10	5	32	
2	2	2	12	30	10	14		32	12		28	24
2												8
250	248	114	650	1404	628	672	551	818	392	740	*4 792	1334
11/27	12/4	12/18	12/31	1/8	1/16	1/22	2/5	2/12	2/19	2/26	3/5	3/12
2	4											
22	16										4	10
	16							10				2
	692	12	16496	1424	284	1696	160	30	60	190	20	2348
8	16			12		16						4
						4		18	20	30		4
960	1120	20	4	136	366	436	1060	1150	990	860	1280	2276
						2	60	10			8	16
										20		8
48	32				2	8					4	28
32	40				6							
	24				8							
	56	64	12	32	34	112	80		60	60		76
65	30		3	6		53	20				6	10
								10				
5	20				6				8	5	6	
						6						
70	20					53	18	10	42	10		30
556	450	22	21	490	198	1377	144	580	120	25	73	130
						159	18	50		20	27	10
		2		184	14	152	100		10			12
216	80	120	82	60	28	45	400	290	210	150	368	64
		4							10	15		1
2064	2616	244	16618	2436	946	4119	3060	2318	1530	1405	1796	5029

/17	3/24	3/31	4/9	4/14	4/21	4/26	5/4	5/12	5/19	5/26	6/1	6/8
		27										
6	14	1	16	3	10		5	95	65	580	30	
8	14	4		3	10					14	12	20
18	172	12	48	3	15	5				501	2864	704
		148	44	59	565	337	190	2042	5	15	30	12
							5	5				16
24	71	24	20	60	*500	*54		*162	*352	*272	*184	
8				16	19		10	18	64	16	32	
	6										2	
334	933	1136	798	564	2439	990	406	3474	1829	4384	1082	3044

/12	3/19	3/26	4/2	4/10	4/16	4/23	4/30	5/7	5/14	5/21	5/28	6/4
			2			2						
10	32					8	4			12		
2		20	14				2					
								2				
348		24			566	1963	10020	30960	4410	208	2304	128
										16		
4			2	4	4	7	60	208	144	3376	716	688
				2	2							
4							60		104		144	
276	736	426	770	506	488	220	450	60	234	32	192	590
16	8					20				16		
8					1							
28	16	20	840	26	4	120	204	60	126	112	168	152
												10
											120	
		2		16	16	40	110	60	18	32	48	22
	8	2				10	40					10
76	14		56	32		10	30					
	16	8										
10		10				3				15	24	32
			17	240	50					15		
30	200	80	13	60			30				24	16
130	322	292	582	300	416	300	1140	79	105	278	192	64
10		60	26		150	17		11	1			16
12					32	10	*720	*800	*110	64	72	32
			4									
64	96	29	54	16	4	60	*180	*10	*72		72	
1									18	16		
029	1448	973	2400	1200	1733	2790	13050	32250	5332	4192	4080	1760

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6/8	6/15	6/22	6/29	7/5	7/13	7/20	7/28	8/9	8/17	8/24	9/1	9/8	9/15
	112	24		7	60	12		4	210	180	30	70	1
20	25		4	21		24		16	20		60		1
2636	1952	384	236	152	9252	984	324	184	1560	3456	756	1994	177
16	7												
		*36	*32										
	16			16	22	24	6	40			32	17	2
			8									5	
3044	2560	912	680	430	10378	1524	602	474	2110	4032	1134	2154	208
6/4	6/11	6/20	6/27	7/2	7/9	7/15	7/30	8/8	8/16	8/24	9/1	9/10	9/15
			16										
		48											
128	14	480	464	76	32	12	102	108	48	20	120	10	4
				356	282	924	1152	216	896	710	82	12	62
				36	24						6		1
688	504	94	192	228	84	38	280	48	144	735	284	564	92
		2					8						
	16		62										
590	400	64	162	96		22	108		16			34	2
152	48								112	110	60	60	8
10													
	20	80	176	22	36							12	1
	16		10	12			16		32	8	20	38	8
			4									8	2
32			32	12	10						14	10	1
				12	10								12
				12									2
16		2	64	12	30			31	30		14		
64	240	260	224	780	192	76	180	125	146	240	532	422	175
16		96		24	10	8							
32	80	112			12		230	144	64	440		69	13
												7	
	32	*50	32	*60	*10								
		16	12			12	38	5	60		96		
							16	17		20			
1760	1370	1304	1450	1726	762	1092	2134	694	1548	1603	1228	1246	388

9/15	9/22	9/28	10/6	10/12/	10/29	11/11	12/10	1/6	1 9 3 9		3/30
									273	373	
18	84	65	198	46	16 312		8				
18	14	13	2	20	64	14	40				4
1776	622	474	810	934	640		216	8			18 6
											10
26							6				
2086	732	766	1560	1370	1282	14	1322	40	16	64	200
9/17	9/24	10/1	10/20	11/3	11/30	12/28	1/29	2/25	4/10		
				8		2	6 2	8	4		
40											
620	208	1416	3420	7224	64	34	144		142		
16	10	22	24								
920	312	238	120	4							
20	8				104	58	24 144	704	16 490		
	22	338			72	40					
80	26	82	10		8		16		4 12		
18	6	8									
84	68	58	12	4		24	8		12		
22	12	6									
								6			
18	13	20	10					15			
120	65	20							110		
24	39	20	10		24	12		15	54		
1758	331	310	174	12	544	48	32	44			
			10		8						
132	88	192	312	228	144	56	672	8	24		
8		8									
								32	18		
		18	12								
3880	1208	2756	4114	7492	976	234	1198	832	886		

STATION 4 A--SEASONAL CENSUS OF ENTOMOSTRACA

	10/16	10/23	10/30	11/6	<u>1 9 3 7</u> 11/13
CLADOCERA					
Alona costata					
Ceriodaphnia pulchella					
Ceriodaphnia quadrangula					
Chydorus globosus					
Chydorus sphaericus	31	174	98	268	88
Daphnia pulex			2		
Graptoleberis testudinaria					
Pleuroxus denticulatus	21	272	107	98	100
Scapholeberis mucronata	37	9			
Simocephalus serrulatus	38	70	15	24	
COPEPODA					
Cyclops albidus	1	9	7	1	
Cyclops fuscus					
Cyclops prasinus					
Cyclops serrulatus	2	13	1		3
Cyclops sp.(young)		8	66	30	37
Cyclops viridis					
Diaptomus pallidus	410	741	342	305	356
OSTRACODA					
Cypria elegantula					4
Cypridopsis vidua		31			
TOTAL	540	1297	638	726	588

*--chiefly young or larval forms

STATION 4--B--SEASONAL CENSUS OF ENTOMOSTRACA

	10/16	10/23	10/30	11/6	11/13
CLADOCERA					
Alona costata					
Chydorus sphaericus					
Daphnia pulex	28	523	276	1236	390
Moina affinis					
Simocephalus serrulatus					
COPEPODA					
Cyclops serrulatus					
Cyclops viridis	*1100	*12020	*18920	*14056	*13392
Diaptomus pallidus	16				
OSTRACODA					
Cypridopsis vidua					
TOTAL	1144	12543	19196	15292	13782

*--chiefly young or larval forms

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1/13	11/20	11/27	12/4	12/18	12/31	1/8	1/16	1/22	2/5	2/12	2/19	2/26
		4										
88	42	202	92	2	4	16	6	10	12	8	14	32
100	122	60	8							2		16
	18	50	8									16
	12	26	4	4	3		6					
		6										
3									8		18	8
37	26	78	16	4	17	4			40		320	168
			4	2				2	4	30	82	140
556	392	188	280	2					6			
4			4	2		2	2					
588	612	614	416	16	26	22	14	12	70	40	434	380
1/13	11/20	11/27	12/4	12/18	12/31	1/8	1/16	1/22	2/5	2/12	2/19	2/26
390	*4136	1584	2596	40	1584	1196	2640	1920	1100	*4900	*760	1696
392	*19272	*6144	*1560	146	184	542	*1008	*1100	*2180	*6160	*938	*776
						12						24
782	23408	7728	4156	186	1768	1750	3648	3020	3280	11060	1700	2496

	2/26	3/5	3/12	3/19	3/26	4/2	4/10	4/16	4/23	4/30	5/7	5/14	5/21	5/28
	32		4	14	44	36	24	12	180 20	120 120	150 270	126 216	160 80	168
	16		10	8	60	8	12	606	400	60	120	90	64	24
	16						4	99	120	90	150	162	85	144
								42						8
	8					1		42	10			30	16	8
	168	620	300	200	210	63	168	677	1180	522	127	1004	544	240
	140	8	14	88	140	8	64	85	10	18	8	10	32	8
						72	8	24	10	*1590	240	90		
							4	36						*72
	380	628	328	310	494	188	284	1623	1930	2520	1045	1728	981	672
	2/26	3/5	3/12	3/19	3/26	4/2	4/10	4/16	4/23	4/30	5/7	5/14	5/21	5/28
		2												
	1696	280	*1304	352	*596	360	328	*1312	*7340	*7380	*20580	*23670	32	12
		6											6	
	*776	60	24	*3130	*6670	*9290	*16640	*8888	*4430	*20250	*1560	1740	*4570	*28320*
	24	2		4										
	2496	350	1328	3486	7266	9650	16968	10200	11770	27630	22140	25410	4608	28332

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5/28	6/4	6/11	6/20	6/27	7/2	7/9	7/15	7/30	8/8	8/16	8/24	9/1	9/10	9/17
						12	36	1980	1200	1240	64	44	20	
							12		24	40		4		
168	168	128	96	14	80	180	360	468	198	108	140	112	256	60
	24	24				24						48		
24		26	16	80	36	24	204	468	264	1140	1120	880	38	20
144	120	16	16			36		576	396	400	1062	1536	380	44
				192	372	36	12	16	154	18		94	18	18
8				24				36	48	360		80	20	280
										10	52	68	21	12
8	40	48			10			32	82	30	51	140	63	
240	256	104	150	24			12		10		153		21	12
8	40	8		208	290	72	156	1228	100	1250	2400	1344	634	356
						24					16		21	
*72	48	*128	10	*96	24	48	132	36	24	10	64	32		
672	696	484	288	718	936	612	1032	4570	2410	4638	5142	4478	1236	802

5/28	6/4	6/11	6/20	6/27	7/2	7/9	7/15	7/30	8/8	8/16	8/24	9/1	9/10	9/17
		16												8
12														
	16	20	8	216	120	102	84	*31600	408		32	4	16	282
*28320	*41740	*34560	*2248	*728	*5328	438	108	*6140	696	*16	14	*240	*1024	*140
28332	41756	34596	2256	944	5448	540	192	37740	1104	16	46	244	1044	430

	9/1	9/10	9/17	9/24	11/30	12/28	1/29	
4								1939 2/25 4/10
4	44 4	20						
8								
2	256		60	74				30
0	880	38	20	18				16
2	1536 94 80	380 18 20	44 18 280	58 8 98				8
2	68	21	12	11				
1	140	63						
3		21	12	11				32
0	1344	634 21	356	330				108 44
6				14				
4	32							
2	4478	1236	802	622				238

	9/1	9/10	9/17	9/24	11/30	12/28	1/29	
4								2/25 4/10
			8		4			
						2	8	60 48
2	4	16						
			282	448	4			
					44			
4	*240	*1024	*140	*130	*700	*2600	*8700	*11020 2090
				12				
6	244	1044	430	690	752	2602	8708	11080 2138