Arkansas Water Resources Center

AN EVALUATION OF THE EFFECTS OF DREDGING WITHIN THE ARKANSAS RIVER NAVIGATION SYSTEM, VOLUME III

The Effects Upon the Zooplankton Associations

by

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Volume III

EFFECTS UPON THE ZOOPLANKTON ASSOCIATIONS

Final Report to the

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INTRODUCTION

The primary purpose of the zooplankton phase of the coordinated study was to attempt to evaluate the effects of dredging operations on the abundance, distribution, composition and complexity of the zooplankton communities within the aquatic system of the Arkansas River. The other phases of investigation include fish, macroinvertebrates, phytoplankton and some physico-chemical parameters. The lack of baseline data, needed for measurement of previous ecological conditions from which to detect past and future changes, proved to be a major impediment to any evaluation. Although the study involved only about 240 miles of the river in Arkansas, it should serve as an adequate baseline for monitoring future changes in the distribution and composition of zooplankton in the river. This report presents both quantitative and qualitative description and evaluation of the zooplankton data taken during four sampling periods in July, October, January, and April, 1974-1975.

Other than scattered investigations, this report includes the first study of the ecology of zooplankton within the Arkansas River. Williams (1964) studied the possible relationships between plankton-diatom species numbers and water quality estimates on the major rivers and Great Lakes of the United States and depicted an overall "trophic index" which includes three stations on the Arkansas River. These stations were located at Pendleton Ferry, Arkansas; Ponca City, Oklahoma; and Coolidge, Kansas. It was found that the Arkansas River at Ponca City, Oklahoma, exhibited the least diversity and the most enrichment with the highest numerical rating of 450. He concluded that the high chlorides at this station appeared to lower the populations of the principal consumer organisms, which were mostly rotifers. The station at Pendleton Ferry, Arkansas, also exhibited a high "trophic index". Williams (1966) made a survey of the dominant planktonic rotifers of the major waterways of the United States which included the same stations noted above. He listed the five most common genera of rotifers with abundance data. Williams also discussed some factors affecting densities of rotifers and explained that repeated observations indicated that small rotifer populations at many stations were probably a result of their intolerance to turbulence and silt. The station at Coolidge, Kansas, on the Arkansas River exhibited extremely low rotifer densities as a result of highly silty conditions, while relatively low densities were observed at Pendleton Ferry, Arkansas.

Kochsiek, Wilhm, and Morrison (1971) reported the diversity of net zooplankton and physico-chemical conditions in Keystone Reservoir, Oklahoma. They listed the species of zooplankton taken from both the Cimarron and Arkansas River arms of the reservoir. Rotifers accounted for 23 taxa, Cladocera 11, and Copepoda 10; and turbidity, alkalinity and zooplankton density were generally higher in the Arkansas arm. Palko (1974) depicted 21 genera of Rotatoria, 2 of Cladocera, and 2 of Copepoda as occurring in Lake Dardanelle on the mainstream of the Arkansas River. He also included a generic list of zooplankton in some surrounding streams. The zooplankton assemblage of Lake Dardanelle differed little from that of the streams.

The seasonal and longitudinal distributions for the total zooplankton populations and for the three major groups (Copepoda, Cladocera and Rotatoria) are described and related graphically. The occurrence and distribution of taxa, which includes an inventory of the zooplankton of the Arkansas River, are presented. The differences in occurrence of taxa by station were tested statistically. Composite ratio indices formulated from the percent frequencies of each taxon at each station proved to be important in determining the dominant species and describing the community complexity. A concept of the relative diversity was taken from the occurrence patterns and ratio indices.

The increased number of flood control, navigational and dual purpose dams constructed on rivers and streams in recent years has resulted in many physical and biological changes within the boundaries of the aquatic systems. The investigation and understanding of changes which occur within these aquatic systems are of considerable interest to the biologist. A comparison of the results of this investigation with other studies on zooplankton of rivers has been included along with the discussion on the effects of dredging. Conclusions and recommendations follow the discussion.

METHODS AND MATERIALS

Thirteen sampling stations were subdivided into a variable number of sites totaling 56. Figure 1 shows the sampling stations both along the river and in profile. The designated stations and sites have previously been described in Volume I. The first zooplankton samples were taken with a Birge closing net in July 1974. It was proposed that sampling dates follow spring, summer, and winter seasons. However, uncontrollable circumstances terminated the summer sampling regime before completion. Nevertheless, data from this sampling period were used for qualitative, relative abundance, comparative and overall analysis.

Some comment on problems associated with conical nets seems appropriate at this time. The various conical nets are considered to be excellent devices for qualitative sampling of zooplankton and upon instances suffice as quantitative instruments. However, introduction of error becomes inevitable if clogging by organisms and detritus occurs as the net is drawn through the water, rendering such samplers useless for quantitative work. Another dissatisfying error occurs if the net drifts a significant distance from the vertical column to be sampled. Swift currents and high turbidity within the Arkansas River were major factors in a decision to re-evaluate the sampling method as heavy

Figure 1. Sampling stations shown both along the study reach and in profile.

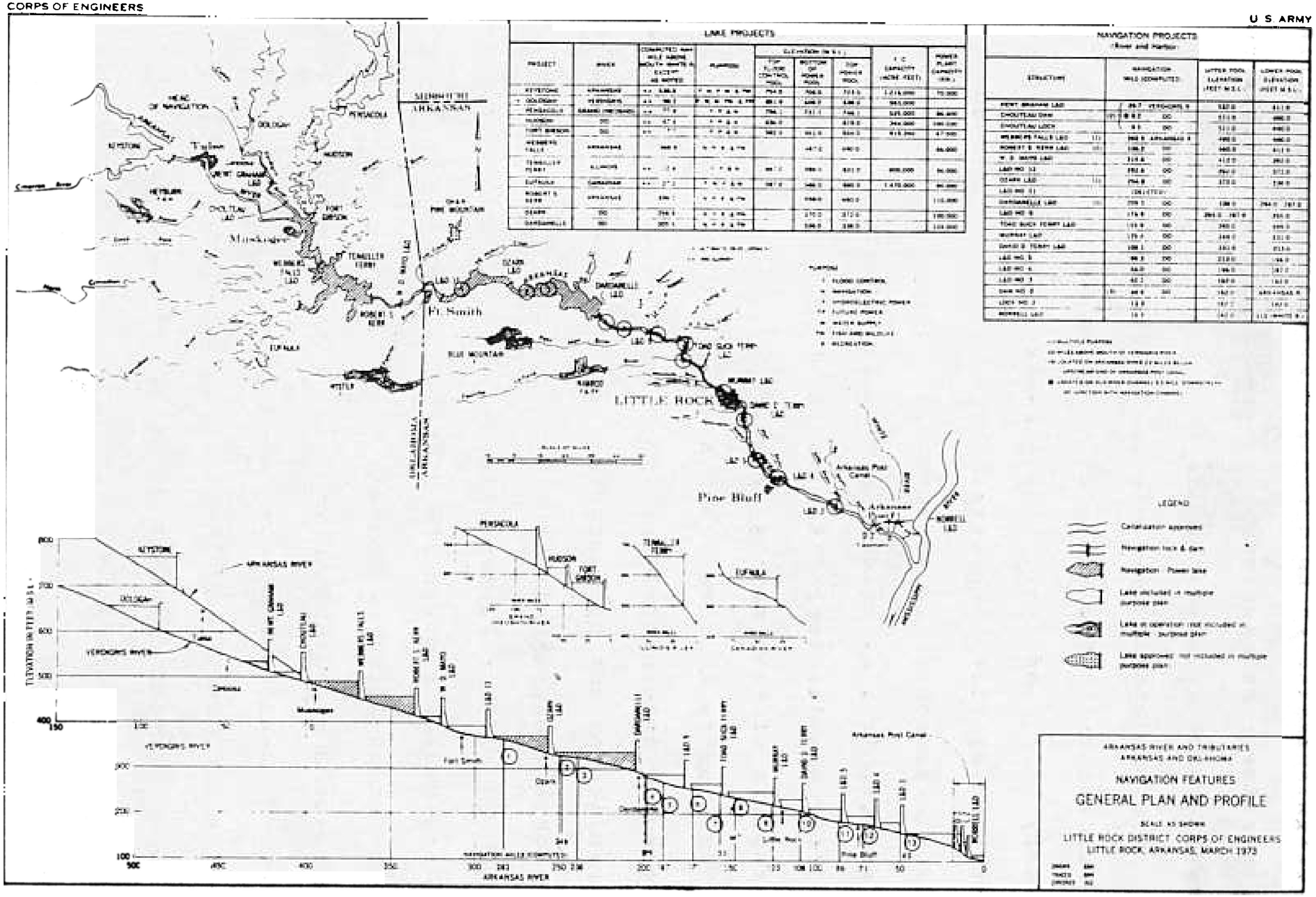

LAKE PROJECTS
NAVIGATION PROJECTS
(River and Harbor)
HEAD OF NAVIGATION
Tulsa
Muskogee
Ft. Smith
LITTLE ROCK
Pine Bluff
OKLAHOMA
ARKANSAS
KEYSTONE
OOLOGAH
PENSACOLA
HUDSON
FORT GIBSON
CHOUTEAU L&D
TENKILLER FERRY
WEBBERS FALLS L&D
ROBERT S. KERR
EUFAULA
OZARK L&D
DARDANELLE L&D
BLUE MOUNTAIN
NIMROD
WISTER
TOAD SUCK FERRY L&D
MURRAY L&D
Arkansas Post Canal
NORRELL L&D
LEGEND
Canalization approved
Navigation lock & dam
Navigation - Power lake
Lake included in multiple purpose plan
Lake in operation (not included in multiple - purpose plan)
Lake approved (not included in multiple purpose plan)
ARKANSAS RIVER
VERDIGRIS RIVER
ELEVATION IN FEET (M.S.L.)
NAVIGATION MILES (COMPUTED)
ARKANSAS RIVER AND TRIBUTARIES
ARKANSAS AND OKLAHOMA
NAVIGATION FEATURES
GENERAL PLAN AND PROFILE
SCALE AS SHOWN
LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, MARCH 1973

PLATE 1

weights failed to hold the net within a proper vertical tow line. An electrical-power-driven, submersible pump was chosen to eleviate the problems.

Zooplankton samples were collected by the Corps of Engineers (Little Rock District) in October 1974, January 1975, and April 1975. Twenty-liter samples obtained by filtering water through a No. 20 net should be large enough to estimate the zooplankton populations present in flowing streams (Weber, 1973). However, 30-liter samples were taken during this study to assure capture of fast moving organisms within the swift current and to increase the chances of taking less frequently encountered species. The 30-liter samples were replicated and concentrated, using a Wisconsin plankton bucket equipped with No. 20 nylon mesh, to a volume of 100 ml in 3% formalin solution. Subsequently, samples were pumped through the plankton bucket into a calibrated 30-liter container, therefore trapping uniformly measured zooplankton samples. Physico-chemical parameters taken by the Corps of Engineers (Little Rock District) during each sampling period included: dissolved oxygen (Winkler Method), specific conductivity, pH, temperature (thermometor, air and water), Secchi disc transparency (standard disc), and alkalinity (Phenolthaline and total). The physico-chemical data is reported in Volume I of this study.

In the laboratory, the 100 ml samples were reconcentrated to 20 ml to expedite subsampling procedures and accuracy. Several subsamples from each sample were examined qualitatively for identification purposes. A Sedgewick-Rafter counting chamber was utilized to directly enumerate the organisms in at least 2 ml of each concentrate at 100X magnification with an Olympus phase contrast compound microscope. All Cladocera and Rotatoria were identified to the lowest taxon possible. Copepoda were identified quantitatively to suborder only because of difficulty in distinguishing characteristics in the counting chamber and because adult copepods occurred in relatively low densities throughout the study. References used for identification purposes included: Voigt (1957), Ward and Whipple (1959), Ahlstrom (1940, 1943), Pennak (1953), Smith (1950), Rylov (1935), and Brooks (1957).

Abundance data shown for the sampling periods of October 1974, January 1975, and April 1975 were converted to organisms per liter (Appendix Tables 1, 2, 3 and Figures 2, 3). The relative abundance data given for the July 1974 sampling period has been derived from the mean number of organisms counted within the two 1 ml subsamples for each site (Figure 4). For purposes of illustrating group importance, abundance data including Copepoda, Cladocera, and Rotatoria were also converted into ratios (%) of the entire zooplankton association. Data was analyzed by the above simple graphical and tabular techniques, and tested statistically with the aid of a Monroe (Model 1930) electronic calculator.

RESULTS

ZOOPLANKTON (General)

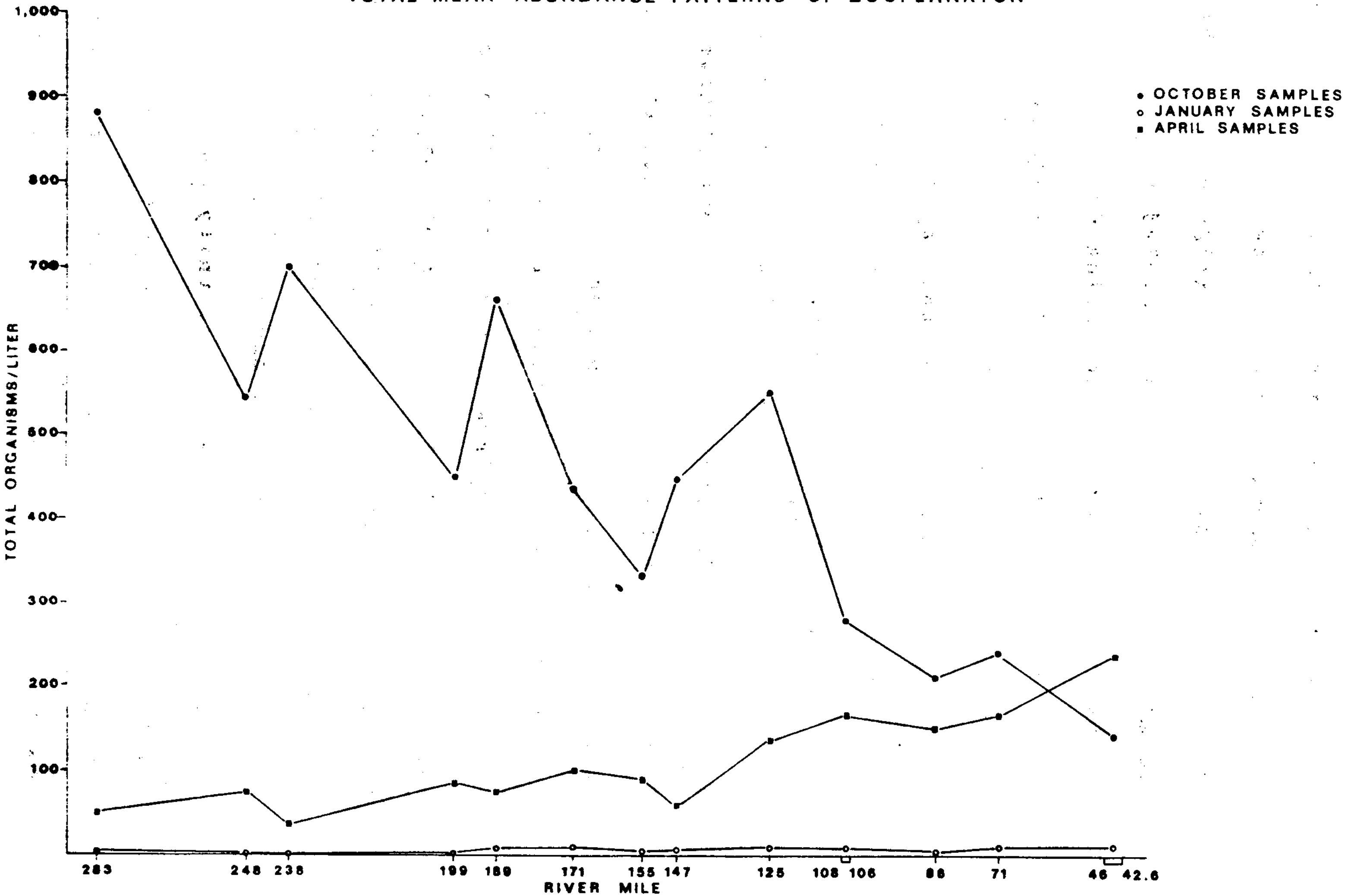
Remarkable changes in zooplankton populations occurred as a function of season and downstream water movement in the Arkansas River during the four sampling intervals in July 1974, October 1974, January 1975, and April 1975.

"Grand means" have been tabulated from zooplankton data taken at all sites within the 13 stations for each sampling period. The "grand mean" for July 1974 was estimated from relative abundance data shown in Figure 4. Caution must be taken in the interpretation of data averaged in this way since all sites were not sampled during each sampling period. Nevertheless, a valid and clear picture of the general trend of seasonal changes in the zooplankton population has been achieved with this technique (Figure 3).

Total longitudinal distribution patterns for the zooplankton taken during the three complete sampling periods (October, January, and April) have been summarized in Figure 2 by river mile and corresponding station. Longitudinal distribution patterns for the Copepoda, Cladocera, and Rotatoria also are presented in Figures 6, 8, and 10 for each station along the Arkansas River Navigational System. Percent frequency (ratios) data for each group (Copepoda, Cladocera, and Rotatoria) are

Figure 2. The total mean abundance patterns of zooplankton during October, January, and April; zooplankton densities expressed in organisms per liter which were calculated from the combined sites.

TOTAL MEAN ABUNDANCE PATTERNS OF ZOOPLANKTON



displayed in graphical form in Figures 7, 9, and 11. Relative abundance data and percent frequency (ratios) data for the incomplete sampling period (July) also are depicted by graphical analysis (Figures 4 and 5). An overall "picture" has been assembled for each segment of the Arkansas River by combining data from each site into a mean value for the respective stations corresponding to navigational miles.

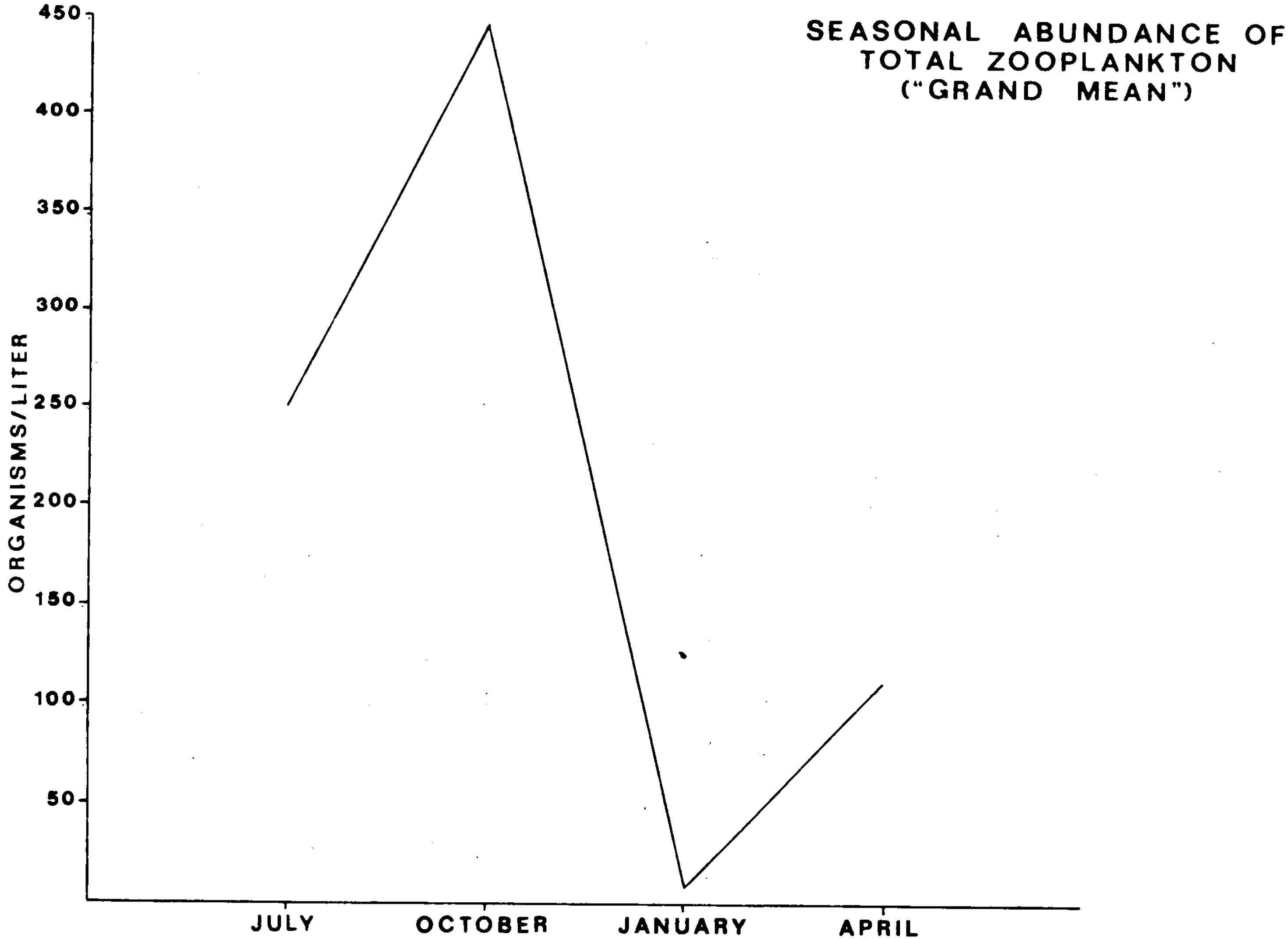
In a study of this type and magnitude, the description and accumulation of qualitative and quantitative data becomes unduly cumbersome. However, detailed raw data has been compiled by computer according to sampling date, river mile (RM) and site. A qualitative list of zooplankton has been composed in tabular form which includes the frequency of appearance of each taxon at each station during the study (Tables 2, 3, 4, and 5). An inventory of zooplankton taxa by families also has been included (Table 1). Results of Chi-squared tests and contingency tables on the differences of occurrence of taxa among the 13 stations for each sampling date are presented in Tables 6 and 7.

Species dominance and community complexity are important parameters within the realm of zooplankton population dynamics. Therefore, a list of numerically dominant species for each station by sampling date is given in Tables 8, 9, 10, and 11. These tables contain only those taxa exhibiting definite numerical dominance for each site within the respective stations and follow in order of decreasing abundance. Only species occurring at densities above the "residual density" were considered as dominant or co-dominant. "Residual density" will be defined here as a low constant numerical level which recessive species or taxa exhibit apart from the dominants. This density was arbitrarily set at 5% of the total organisms per liter during the entire study. Conveniently, the "natural" quantitative breaking point between the dominant and incidental species seemed to fall very close to 5% of the total number of organisms for each major group (Copepoda, Cladocera, and Rotatoria).

SEASONAL DISTRIBUTION

Figure 3 shows that mean zooplankton densities peaked at 448.49 organisms per liter in October 1974 during the 1974-75 study period. Most zooplankton disappeared during the winter; an average of 7.00 organisms per liter was exhibited in January 1975. Many species of zooplankton, particularly rotifers, begin to multiply in early spring and build up to high densities in the summer and the fall. This seems indicative of the zooplankton population found in the Arkansas River, since an increase to 109.25 organisms per liter was observed in mid-April 1975. Estimated densities for July 1974

Figure 3. The seasonal abundance of total zooplankton ("Grand Mean"): "Grand means" have been calculated for each month from the actual densities of zooplankton found at the combined sites and expressed in organisms per liter.


SEASONAL ABUNDANCE OF TOTAL ZOOPLANKTON ("GRAND MEAN")
ORGANISMS/LITER
450
400
350
300
250
200
150
100
50
JULY
OCTOBER
JANUARY
APRIL

(250 organisms/liter) give strong evidence that the zooplankton populations in the Arkansas River continue to reproduce throughout the summer, peaking during the late summer or during the fall. This situation also suggests an unimodal pattern of abundance for standing crops for the entire river. However, many precautions must be taken in predicting a seasonal abundance pattern from three complete and one incomplete sampling period throughout a one-year period. For example, the seasonal abundance pattern could exhibit a variety of productive minima or maxima within any three-month period. Therefore, several weaker peaks may have existed during the summer and fall, while in all probability winter production remained low during the colder months. Moreover, maximum peaks could have occurred during the time between the July and October sampling periods. The fact that 300 plankton are under the influence of many climatic factors such as light, temperature, and rainfall, prevents the immediate conclusion that this seasonal pattern consistantly occurs in the Arkansas River. However, in spite of such uncertainty, the overall seasonal patterns are recognizable and interesting, and may very well represent the "normal situation". Full understanding of the seasonal cycles exhibited by zooplankton in the Arkansas River can be achieved only through a more detailed investigation employing shorter

sampling intervals.

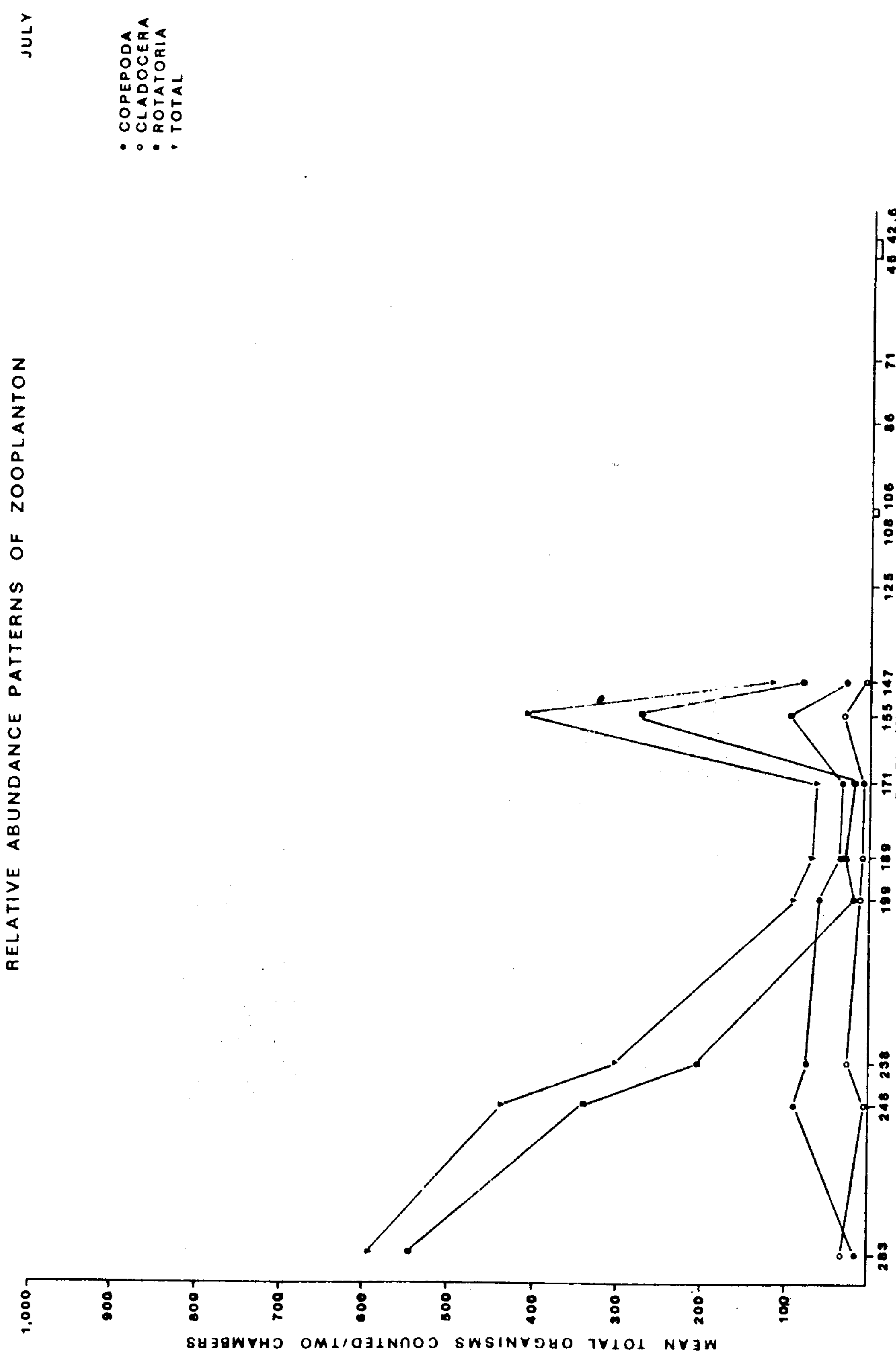
LONGITUDINAL DISTRIBUTION

It seems certain that the longitudinal distribution of plankton along the course of a river from its origin to its mouth depends upon various circumstances; (1) the character, number, and distribution of tributaries; (2) the rate of current; (3) nature, amount, and distribution of back waters; (4) character of the channel; and (5) edaphic conditions (Welch, 1952). This undoubtedly was true of the zooplankton observed in the Arkansas River during the 1974-75 sampling period.

Summer (July)

During the incomplete July 1974 sampling interval the relative abundance patterns of total zooplankton (Fig. 4) exhibited peaks at Station 1 (RM 283) and Station 7 (RM 155). A mean of 593.50 organisms/2 ml subsample was observed at Station 1, while the relative abundance of zooplankton gradually declined down river to a low of 61.10 organisms/2 ml subsample at Station 6. The second peak at Station 7 was an abrupt one, reaching 409.37 organisms/2 ml subsample. Although the July sampling period involved only eight of the upper stations (1-8), an overall decrease in zooplankton density downstream is quite evident. However, respective peaks in abundance downstream from Station 8 may have occurred in

Figure 4. Relative abundance patterns of zooplankton during July; Total abundance Copepoda, Cladocera, and Rotatoria data expressed as organisms per 2-ml chamber.


RELATIVE ABUNDANCE PATTERNS OF ZOOPLANTON
JULY
• COPEPODA
○ CLADOCERA
▪ ROTATORIA
▾ TOTAL
MEAN TOTAL ORGANISMS COUNTED/TWO CHAMBERS
1,000
900
800
700
600
500
400
300
200
100
283
248
238
199
189
171
155
147
125
108
106
86
71
46
42.6
RIVER MILE

accordance with each station's edaphic conditions. It must be kept in mind that these conclusions can only remain speculative without future investigation.

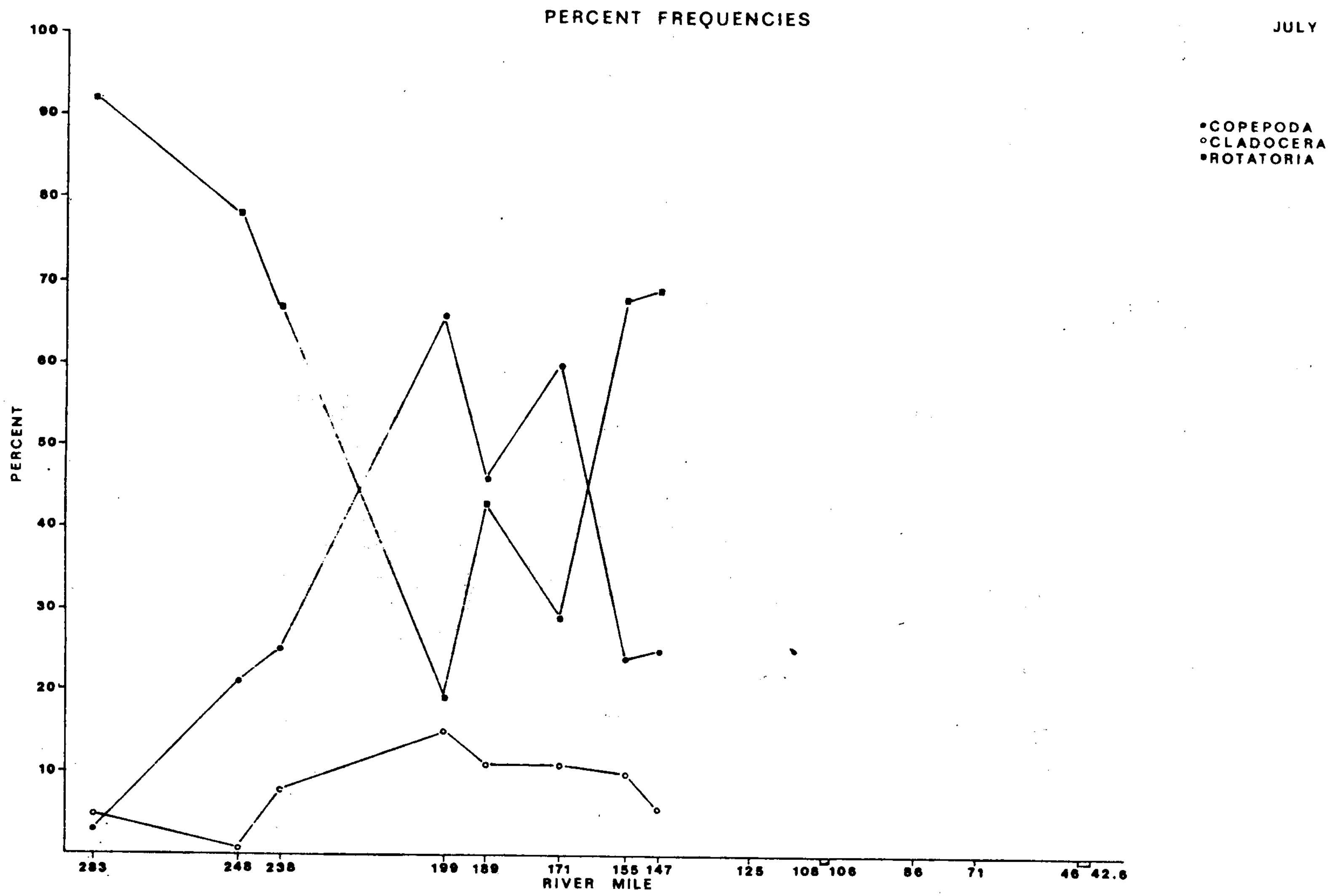
Clearly, the Rotatoria greatly influenced the total longitudinal relative abundance patterns during the July sampling interval. Rotatoria exhibited a peak of 546.00 organisms/2 ml subsample at Station 1 and gradually declined to 18.30 organisms/2 ml subsample at Station 6. The rotatorian populations also exhibited an abrupt peak at Station 7 (273.75/2 ml subsample), coincident with the total zooplankton longitudinal distribution.

The Copepoda proved to be more significant than the Cladocera, but never influenced the total distribution until Station 7 (RM 155), showing a relatively strong peak of 98.00 organisms/2 ml subsample. Another peak of 91.70 organisms/2 ml subsample was observed at Station 2 (RM 248), while the low of 15.50 organisms/2 ml subsample was recorded at Station 1. The longitudinal distribution of the Copepoda zooplankton populations resembles the longitudinal distribution of the total only at Stations 6, 7, and 8.

The cladoceran populations observed during the July sampling interval never reached significant densities, and distinct longitudinal distribution patterns cannot be discerned. However, a relatively weak pulse was exhibited at Station 7 (37.62 organisms/2 ml subsample), while the minimum of 4.9 organisms/2 ml subsample was observed at Station 2. The cladoceran population had an insignificant influence upon the total longitudinal distribution of zooplankton in the Arkansas River during the July 1974 sampling interval.

Indeed, a clear understanding of the relationship of importance among the three groups (Rotatoria, Copepoda, and Cladocera) has been achieved through a numerical ratio of the longitudinal distribution of total zooplankton to the longitudinal distribution of the respective groups (Figure 5). At Station 1 (RM 283), the zooplankton association was composed of: 92.0% Rotatoria, 3.0% Copepoda, and 5.0% Cladocera. The frequency of rotifers decreased to 78.0% at Station 2 (RM 248), and the copepods increased to 21.0% of the total, while cladocerans dropped to 1.0% of the total association. The Rotatoria continued to decrease in frequency, reaching a low of 22.8% at Station 4 (RM 199). On the other hand, Copepoda increased to its maximum longitudinal frequency at Station 4, exhibiting a ratio of 60.0% of the total. Cladocera also reached maximum ratios at Station 4, making up 17.2% of the total zooplankton association. The Rotatoria and Copepoda continued increasing and decreasing in inversely related patterns, showing ratios of: 36.9% and 50.5% (Station 5), 27.2%

Figure 5. The percent frequencies of Copepoda, Cladocera, and Rotatoria of the total zooplankton during July.


PERCENT FREQUENCIES
JULY
•COPEPODA
∘CLADOCERA
▪ROTATORIA
PERCENT
100
90
80
70
60
50
40
30
20
10
283
248
238
199
189
171
155
147
125
108
106
86
71
46
42.6
RIVER MILE

and 62.2% (Station 6), 68.0% and 24.0% (Station 7), and 69.0% and 25.0% (Station 8), respectively. The cladoceran population remained relatively insignificant at the mid-river stations, exhibiting 12.5%, 10.6%, 10.0%, and 6.0% at Stations 5, 6, 7, and 8, respectively.

Autumn (October)

The overall pattern observed at the first 8 stations (RM 283-147) in July 1974 also existed in October 1974 (Figure 6). The mean abundance of total zooplankton was relatively high at Station 1 and gradually decreased in a stair-step pattern to the relatively low densities observed at Stations 11-13 (RM 86-42). A peak of 880.47 organisms per liter at Station 1 was the highest mean density observed throughout the study (1974-1975). The observed maximum and minimum peaks in longitudinal distribution seemed to follow an alternating pattern. For example, the total mean abundance of zooplankton declined from 880.47 organisms per liter at Station 1 to 546.41 organisms per liter at Station 2, but was followed by a peak of 702.75 organisms per liter at Station 3. This phenomenon also occurred at Stations 4 and 5, exhibiting 450.94 and 664.20 organisms per liter, respectively. The mean abundance of zooplankton again decreased at Station 7 to 332.47 organisms per liter but was followed by peaks at Stations 8 (447.48 organisms per liter) and 9 (502.02 organisms per liter).

Relatively low mean densities were observed from Stations 10-13. The minimum longitudinal mean density of zooplankton for October (138.99 organisms per liter) was recorded at Station 13 (RM 46).

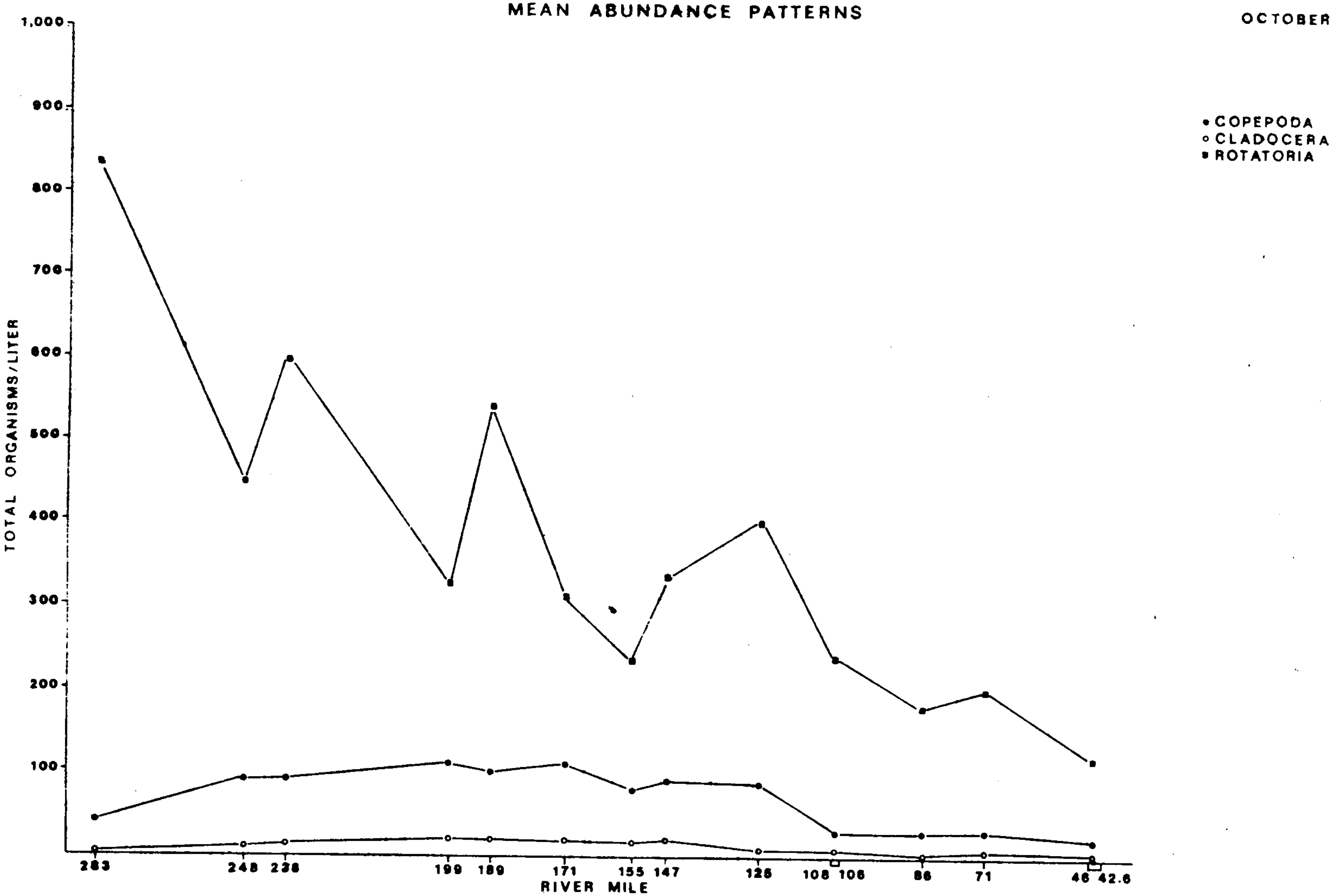
The longitudinal distribution pattern exhibited by the rotatorian population in October was almost identically coincidental with the total zooplankton distribution. Peaks were observed at Stations 1 (RM 283), 3 (RM 238), 5 (RM 189), and 8-9 (RM 147-125); and the lows occurred at Stations 2 (RM 248), 4 (RM 199), and 6-7 (RM 171-155). Undoubtedly, the rotatorian population played a major role in the longitudinal distribution of total zooplankton as shown by Figure 6.

The copepod population reached significant mean densities during the October sampling interval but never greatly influenced the total zooplankton distribution. A relatively low mean density of 38.54 organisms per liter was recorded at Station 1. The mean density increased to 90.57 organisms per liter at Station 2 and remained somewhat constant through Station 6. An overall decrease in abundance of Copepoda was exhibited at Stations 7, 8, and 9 (78.74, 90.10, and 88.07 organisms per liter, respectively). An abrupt decrease in abundance occurred at Stations 10 to 13, as copepod densities were relatively low throughout the lower reaches of the river during the October sampling interval

Figure 6. The mean abundance patterns of Copepoda, Cladocera, and Rotatoria during October; densities expressed in organisms per liter.

MEAN ABUNDANCE PATTERNS

OCTOBER



(28.82, 28.98, 31.84, and 19.75 organisms per liter at Stations 10, 11, 12, and 13, respectively).

The cladoceran population never gained influential status during the October sampling interval in as much as the densities observed ranged from a feeble 2.01 organisms per liter at Station 13 to 20.56 organisms per liter at Station 5. The distribution of Cladocera was relatively uniform from Stations 3 through 10. However, low densities were observed at Station 1 as well as Stations 11 through 13.

The overwhelming dominance of Rotatoria over the Copepoda and Cladocera during October is evident in Figure 7. The ratio of Rotatoria ranged from 72.0% at Station 4 to 95.0% at Station 1. The Copepoda were far more significant than the Cladocera, ranging from 4.0% at Station 1 to 25.0% at Station 6. The cladoceran population never accounted for more than 6.0% (Station 7, RM 155) of the total population during the October sampling interval. Here again, there seems to be an inverse relationship between the abundance of Rotatoria and Copepoda.

Winter (January)

The total longitudinal mean abundance patterns in Figure 8 show that zooplankton populations nearly disappeared by January 14, 1975. Total mean zooplankton densities ranged from 3.32 organisms per liter at

Figure 7. The percent frequencies of Copepoda, Cladocera, and Rotatoria of the total zooplankton during October.

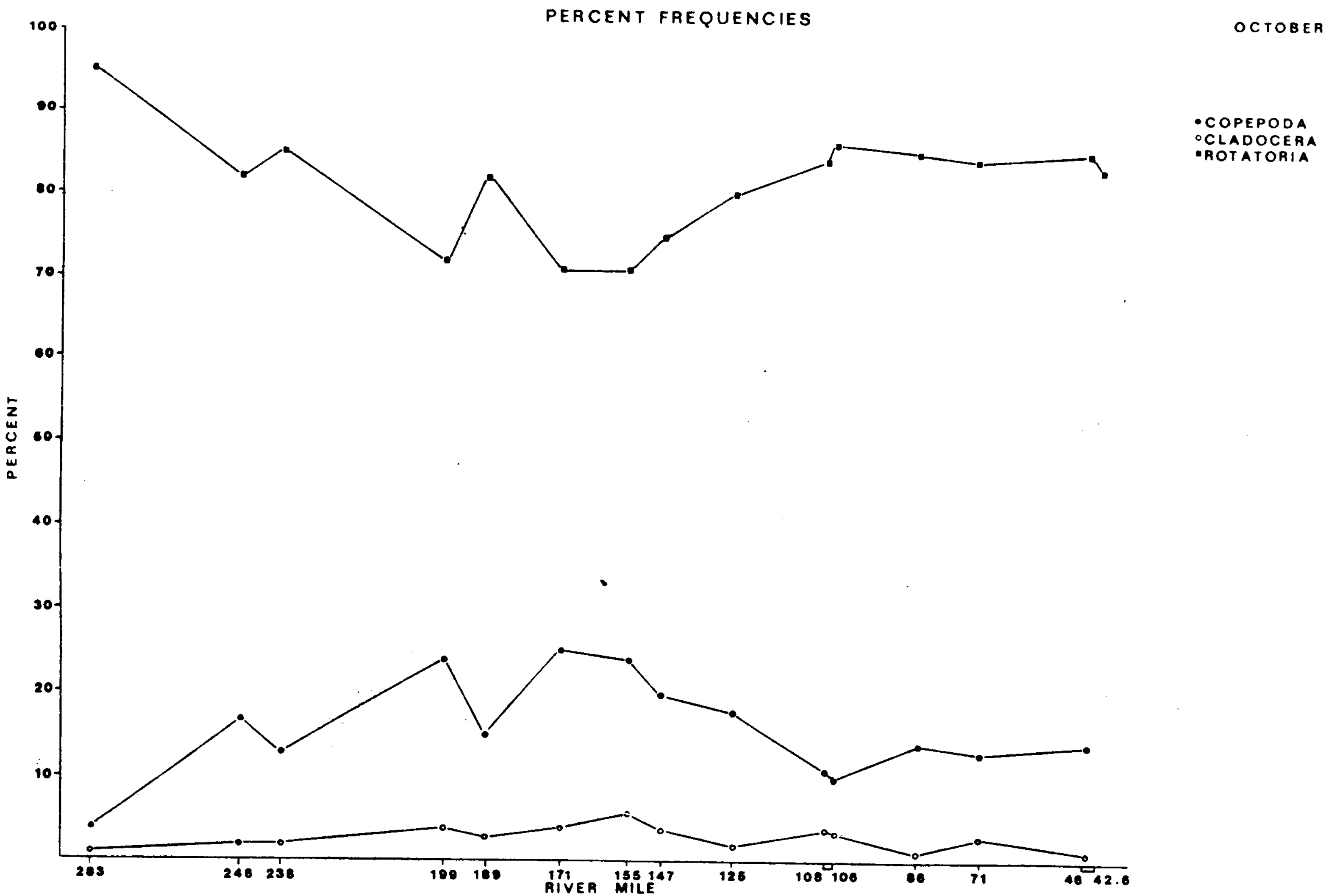
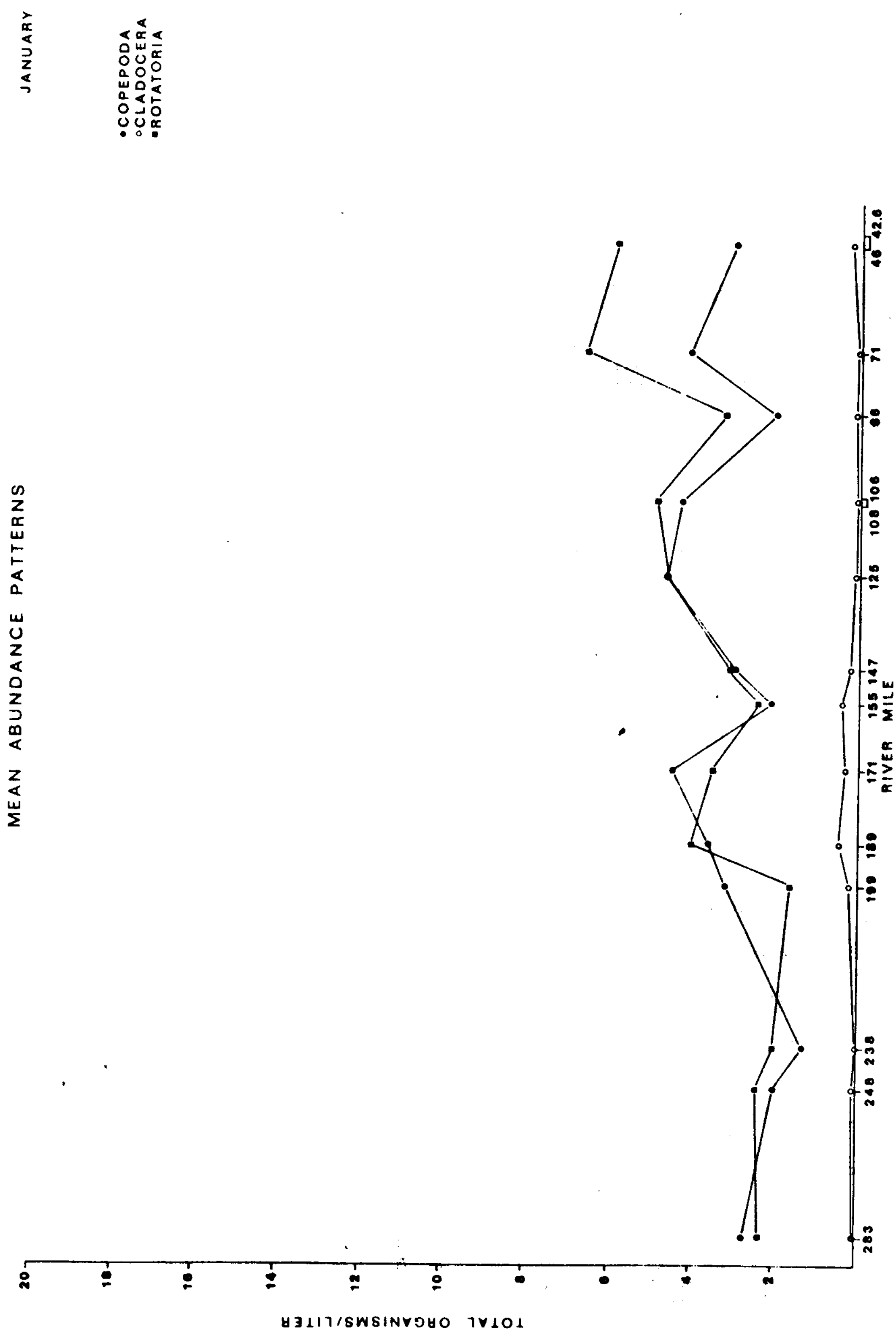

PERCENT FREQUENCIES
OCTOBER
•COPEPODA
○CLADOCERA
▪ROTATORIA
PERCENT
100
90
80
70
60
50
40
30
20
10
283
246
238
199
189
171
155
147
125
108
106
86
71
46
42.6
RIVER MILE

Figure 8. The mean abundance patterns of Copepoda, Cladocera, and Rotatoria during January; densities expressed in organisms per liter.

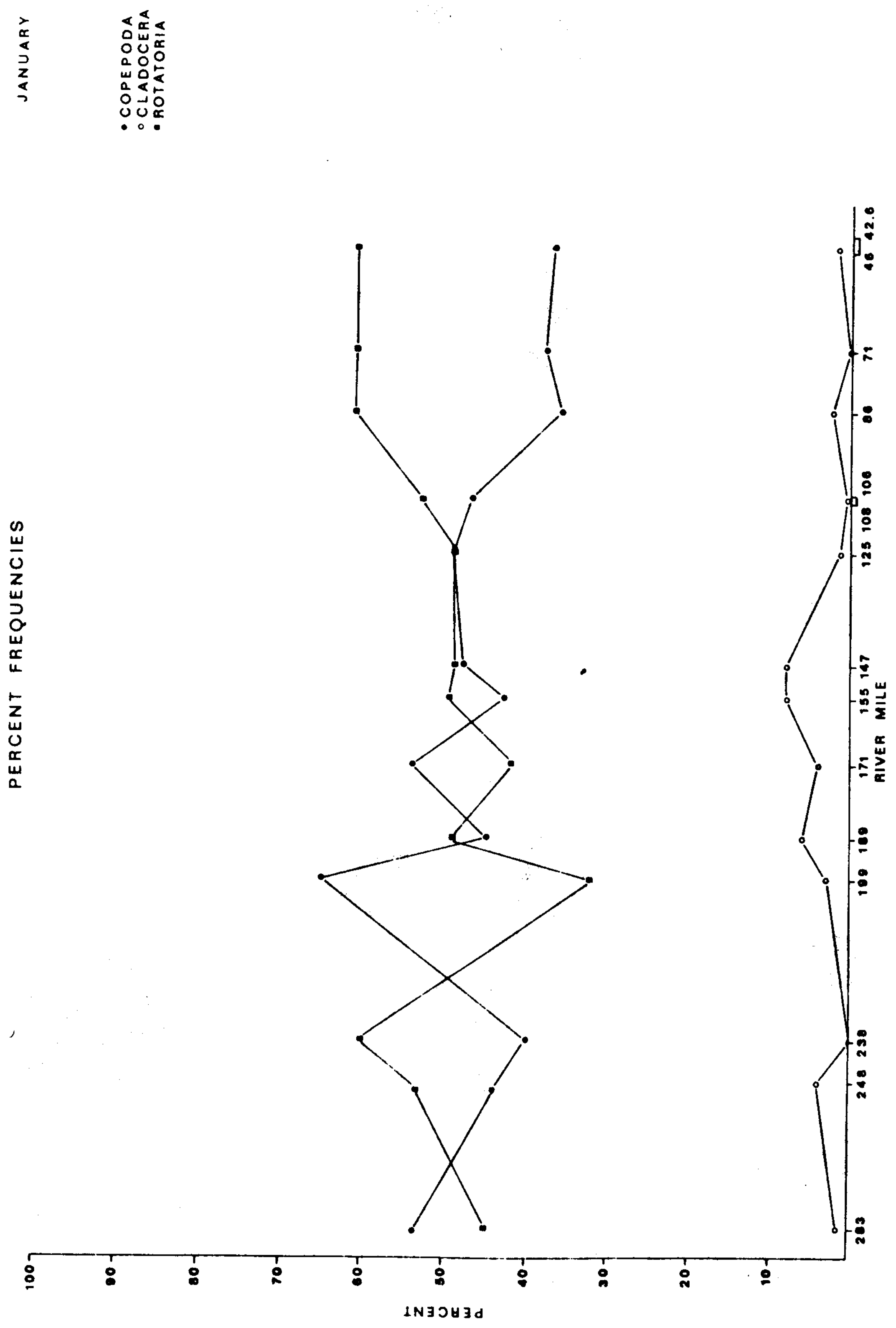

MEAN ABUNDANCE PATTERNS
JANUARY
•COPEPODA
○CLADOCERA
▪ROTATORIA
TOTAL ORGANISMS/LITER
20
18
16
14
12
10
8
6
4
2
283
248
238
199
189
171
155
147
125
108
106
96
71
46
42.6
RIVER MILE

Station 3 to 10.82 organisms per liter at Station 12; no distinct longitudinal distribution patterns could be discerned.

The Rotatoria and Copepoda were observed to be of equal numerical importance during the January sampling interval, while Cladocera again remained insignificant. Rotatoria and Copepoda exhibited peaks of 6.6 (Station 12) organisms per liter and 4.66 (Station 6) organisms per liter, respectively.

Copepoda reached peak frequencies at Stations 1 (53.3%), 4 (65.0%), 6 (54.0%), and 9 (49.4%); and Rotatorians were more frequent at Stations 2 (53.2%), 3 (60.1%), 5 (49.0%), 8 (49.0%), and 11 to 13 (61.5%, 61.5%, and 61.0%, respectively; Figure 9). On the other hand, copepods exhibited low frequencies at Stations 2 (44.1%), 3 (39.9%), 5 (45.0%), 7 (42.7%), and 10 to 13 (46.8%, 36.2%, 38.1%, and 37.0%, respectively); while rotatorians were less frequent at Stations 1 (45.1%), 4 (32.0%), 6 (42.1%), and 9 (49.4%). This type of frequency pattern also adds to the evidence that an inverse relationship exists between rotatorian and copepod populations in the Arkansas River. The cladocerans reached a maximum of 8.0% of the total zooplankton association at Station 8 (RM 147) and were absent from Station 3 during the January 1975 sampling period.

Figure 9. The percent frequencies of Copepoda, Cladocera, and Rotatoria of the total zooplankton during January.


PERCENT FREQUENCIES
JANUARY
• COPEPODA
○ CLADOCERA
■ ROTATORIA
PERCENT
100
90
80
70
60
50
40
30
20
10
283
248
238
199
189
171
155
147
125
108
106
88
71
46
42.6
RIVER MILE

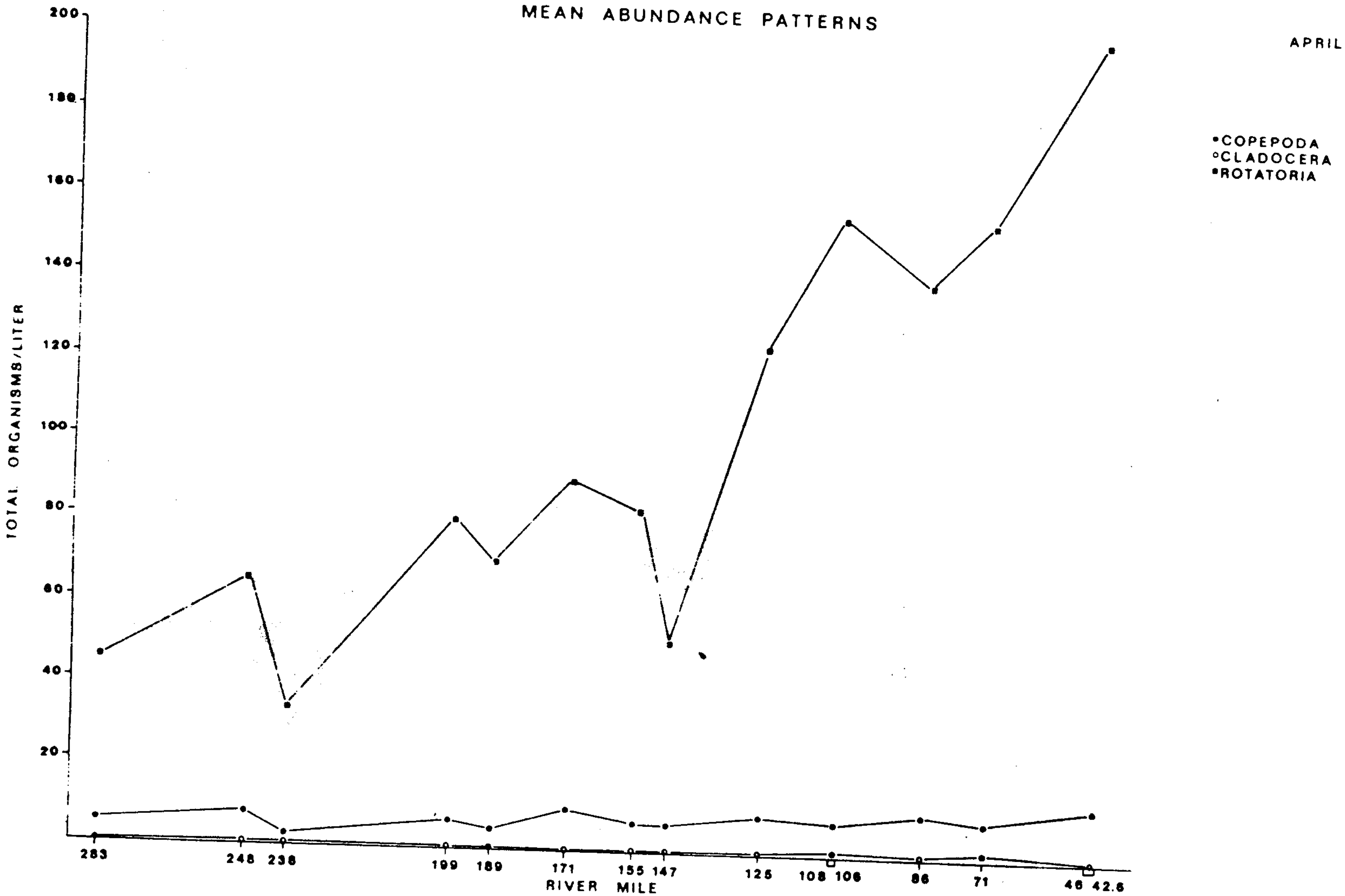
Spring (April)

Zooplankton production began to increase by April 1975. Zooplankters were more abundant in the lower reaches of the Arkansas River (Station 9-13, RM 125-42) during the April sampling interval. The overall trend was a gradual increase of abundance longitudinally from Station 1 to Station 13. Noticeable decreases occurred at Stations 3 (RM 238) and 8 (RM 147), exhibiting 36.72 organisms per liter and 57.04 organisms per liter, respectively. The minimum abundance of zooplankton was recorded at Station 3 (RM 238).

Figure 10 clearly shows the influence of Rotatorian populations upon the total zooplankton distributions in the Arkansas River during the early Spring (April 1975) sampling interval. The abundance of Rotatoria gradually increased going downstream from Station 1 within the upper reaches, with the exception of two abrupt decreases at Stations 3 and 8. On the other hand, the abundance of rotifers increased from 51.76 organisms per liter at Station 8 to 217.95 organisms per liter at Station 13 since a rapid increase was observed within the lower reaches of the river. Again, the general pattern was one of increasing abundance downstream from Station 1 through 13.

The copepod and cladoceran populations did not increase significantly the total longitudinal abundance

Figure 10. The mean abundance patterns of Copepoda, Cladocera, and Rotatoria during April; densities expressed in organisms per liter.


MEAN ABUNDANCE PATTERNS
APRIL
•COPEPODA
°CLADOCERA
•ROTATORIA
TOTAL ORGANISMS/LITER
200
180
160
140
120
100
80
60
40
20
283
248 238
199 189
171
155 147
125
108 106
86
71
46 42.6
RIVER MILE

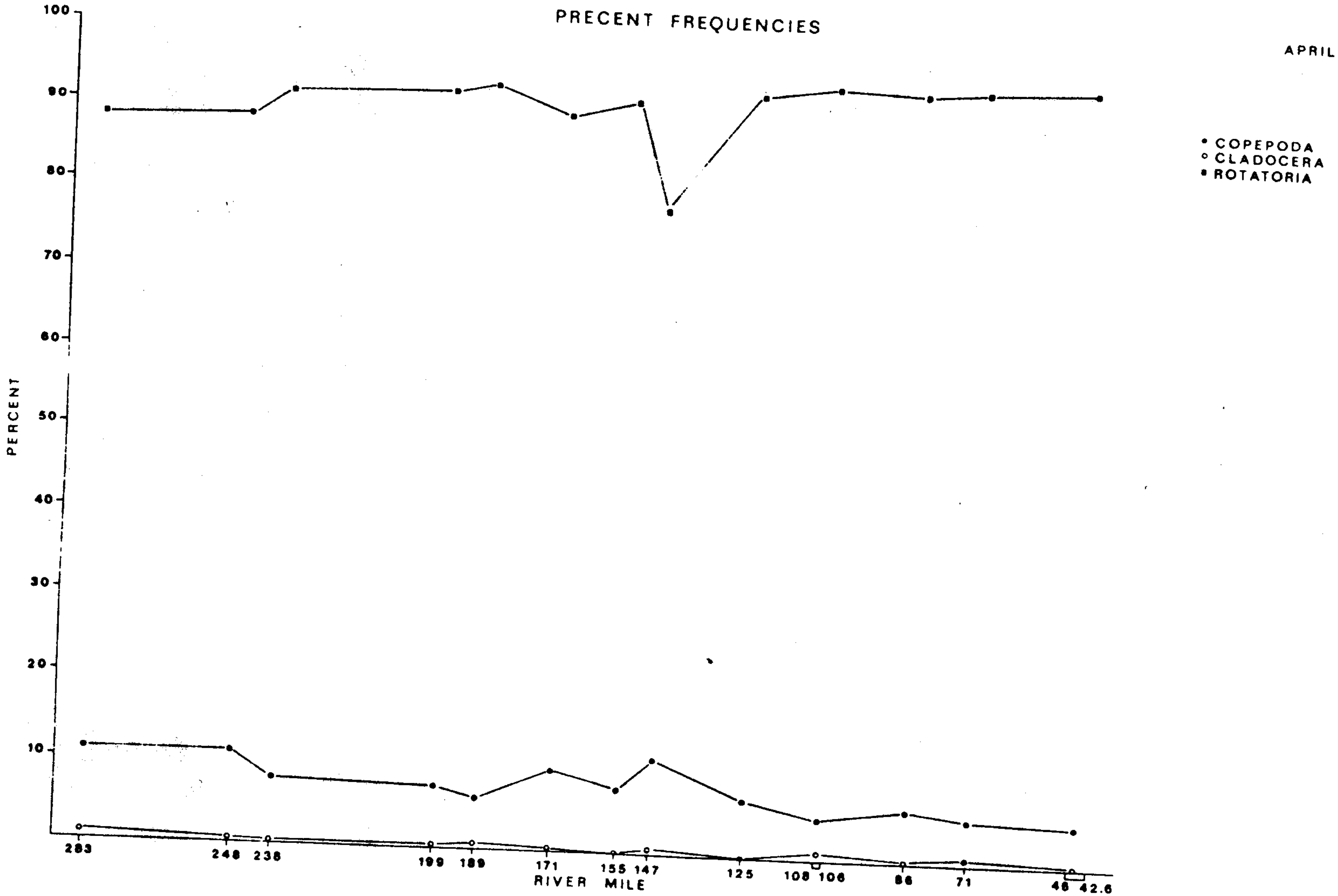
patterns during the April sampling interval. Copepoda reached a maximum of 12.00 organisms per liter at Station 13, and the Cladocera exhibited a very weak maximum of 1.62 organisms per liter at Station 12.

Rotatoria ranged from 87.7% of the total zooplankton at Station 8 to 94.5% at Station 13 (Figure 11). Again, the Copepoda seemed to be inversely proportional to the Rotatoria, ranging from 5.2% of the total population at Station 13 to 11.6% of the total at Station 8. The cladoceran population approached a maximum of 1.0% of the total zooplankton population at Stations 10 and 12 during the April 1975 sampling interval. The spring reproduction of Copepoda and Cladocera presumably had not made itself apparent by mid-April.

OCCURRENCE AND DISTRIBUTION OF TAXA

A total of 128 taxa of zooplankton and miscellaneous organisms were identified from the Arkansas River during this study. The organisms were distributed in groups as follows (Table 1). Copepoda (nauplii, copepodids, orders and suborders), 5; Bosminidae, 2; Daphnidae, 15; Sididae, 3; Holopedidae, 2; Chydoridae, 1; Brachionidae, 31; Synchaetidae, 13; Trichocercidae, 8; Asplanchnidae, 2; Gastropidae, 6; Notommatidae, 3; Collecidae, 1; Conochilidae, 5; Testudinellidae, 5; Hexarthridae, 1; Lecanidae, 6; Flosculariidae, 2; Philodinidae, 2;

Figure 11. The percent frequencies of Copepoda, Cladocera, and Rotatoria of the total zooplankton during April.


PRECENT FREQUENCIES
APRIL
COPEPODA
CLADOCERA
ROTATORIA
PERCENT
100
90
80
70
60
50
40
30
20
10
283
248
238
199
189
171
155
147
125
108
106
86
71
46
42.6
RIVER MILE

Habrotrochidae, 1; Dicranophoridae, 1; unidentified Rotatoria, 1; and miscellaneous taxa, 12. Qualitatively, the rotatorian families Brachionidae, Synchaetidae, and Trichocercidae, and the cladoceran family Daphnidae were the most commonly represented taxa.

The following taxa were recovered at least once from all 13 (8 in July) stations during the study, irrespective of time and number of individuals (Tables 2, 3, 4, and 5): nauplii, copepodids, Cyclopoida, Calanoida, *Bosmina longirostris*, *Ceriodaphnia lacustris*, *Diaphanosoma leuchtenbergianum*, *Brachionus angularis*, *B. calyciflorus*, *B. dimidiatus*, *B. urceolaris*, *Keratella cochlearis*, *K. earlinae*, *K. valga*, *Kellicottia bostoniensis*, *Polyarthra vulgaris*, *Asplanchna priodonta*, *Gastropus minor*, *Collotheca* sp., *Conochiloides coenobasis*, *Conochilus unicornis*, *Filinia longiseta*, and *Hexarthra mira*. The most frequently represented genera by station, in this case, were *Brachionus* and *Keratella*. It is also interesting to note that all but 7 of these taxa are Rotatoria.

Other taxa which appeared in samples from at least two-thirds (approximately) of the stations during at least one of the sampling intervals include: Copepodid, Cyclopoida, Calanoida, *Daphnia parvula*, *Bosmina longirostris*, *Ceriodaphnia lacustris*, *Brachionus calyciflorus*, *B. caudatus*, *B. dimidiatus*, *Keratella americana*,

Table 1. Inventory of zooplankton taken from the Arkansas River during the 1974-75 study.

Inventory of Zooplankton from the Arkansas River

Copepoda (order and suborder)
- Nauplius
- Copepodid
- Cyclopoida
- Calanoida
- Harpacticoida

Cladocera
- Bosminidae
  - *Bosmina longirostris*
  - *B. coregoni*
- Daphnidae
  - *Daphnia parvula*
  - *D. similis*
  - *D. magna*
  - *D. middendorffiana*
  - *D. ambigua*
  - *D. galeata*
  - *D. rosea*
  - *Daphnia* sp.
  - *Ceriodaphnia lacustris*
  - *C. quadrangula*
  - *C. reticulata*
  - *C. pulchella*
  - *M. micrura*
  - *M. brachiata*
  - *Moina* sp.
- Holopedidae
  - *Holopedium amazonicum*
  - *H. gibberum*
- Sididae
  - *Diaphansoma brachyurum*
  - *D. leuchtenbergianum*
  - *Sida* sp.
- Chydoridae
  - *Chydorus sphaericus*

O. Ploima (Class Monogononta)
- Brachionidae
  - *Brachionus angularis*
  - *B. bidentata*
  - *B. budapestinensis*
  - *B. calyciflorus*

B. caudatus
B. dimidiatus
B. havanaensis
B. nilsoni
B. quadridentatus
B. urceolaris
B. variabilis
Colurella sp.
Diplois daviesiae
Eiphanes senta
Eiphanes sp.
Euchlanis sp.
Kellicottia bostoniensis
Keratella americana
K. earlinae
K. cochlearis
K. serrulata
K. quadrata
K. valga
Lophocharis sp.
Notholca acuminata
N. labia
Notholca sp.
Platyias patulus
Trichotria truncata
T. tetractis
Trichotria sp.

Synchaetidae

Ploesoma hudsoni
P. lenticulare
P. triacanthum
P. truncatum
Polyarthra euryptera
P. vulgaris
Polyarthra sp.
Synchaeta johnsoni
S. oblonga
S. pectinata
S. stylata
S. tremula
Synchaeta sp.

Trichocercidae

Trichocerca brachyura
T. dixon-nuttali
T. multicrinis
T. porcellus
T. rattus
T. similis
T. stylata

Trichocerca sp.
Asplanchnidae
Asplanchna priodonta
A. sieboldi
Gastropidae
Ascomorpha saltans
Ascomorpha sp.
Gastropus hyptopus
G. minor
G. stylifer
Gastropus sp.
Notommatidae
Cephalodella mucronata
C. gibba
Cephalodella sp.
Collecidae
Collotheca sp.
Conochilidae
Conochiloides coenobasis
C. dossuarius
C. natans
Conochilus unicornis
C. hippocrepis
Testudinellidae
Filinia longiseta
F. terminalis
Pompholyx sulcata
Pompholyx sp.
Testudinella patina
Hexarthridae
Hexarthra mira
Lecanidae
Lecane tomata
L. luna
L. salpina
Lecane sp.
Monostyla hornemanni
M. scutata
Flosculariidae
Ptygura libera
Ptygura sp.
Philodinidae
Philodina tridentata
Rotaria neptunia
Habrotrochidae
Habrotrocha sp.
Dicranophoridae
Pedipartia sp.

Unidentified Rotatoria
Misc. taxa
- *Arcella* sp.
- *Ceratium hirundinella*
- Chironomidae
- *Codonella* sp.
- *Cordylophora lacustris*
- *Dasydytes* sp.
- *Hydra* sp.
- Oligochaeta
- Ostracoda-nauplius
- Peritricha
- *Phacus* sp.
- Tardigrada

Table 2. The occurrence and distribution of zooplankton in the Arkansas River during July 1974.

Table 2

Occurrence and Distribution of Zooplankton
in the Arkansas River During July 1974

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Nauplius	X	X	X	X	X	X	X	X						8
Copepodid														
Cyclopoida	X	X	X	X	X	X	X	X						8
Calanoida	X	X	X	X	X	X	X	X						8
Harpacticoida							X							1
Bosmina longirostris	X	X	X	X	X	X	X	X						8
B. coregoni														
Daphnia parvula	X		X	X	X	X	X	X						7
D. similis														
D. magna														
D. middendorffiana														
D. ambigua														
D. galeata	X													1
D. rosea				X										1
Daphnia sp.	X													1
Ceriodaphnia lacustris	X	X	X	X	X	X	X	X						8
C. quadrangula							X	X						2
C. reticulata								X						1
C. pulchella														
Moina micrura		X		X				X						3
M. brachiata					X		X	X						3
Moina sp.														
Holopedium amazonicum														
H. gibberum														

Table 2--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Diaphansoma brachyurum		X												1
D. leuchtenbergianum	X	X	X	X	X	X	X	X						8
Sida sp.	X													1
Chydorus sphaericus														
Brachionus bidentata	X	X												2
B. angularis	X	X	X	X	X	X	X	X						8
B. budapestinensis														
B. calyciflorus	X	X	X	X		X	X	X						7
B. caudatus	X	X	X		X	X	X	X						7
B. dimidiatus	X	X	X	X	X	X	X	X						8
B. havanaensis					X									1
B. nilsoni														
B. quadridentatus			X											1
B. urceolaris														
B. variabilis														
Colurella sp.														
Diplois daviesiae														
Epiphanes senta														
Epiphanes sp.	X													1
Euchlanis sp.														
Kellicottia bostoniensis	X													1
Keratella americana		X		X	X		X	X						5
K. earlinae					X	X	X	X						4
K. cochlearis	X	X	X	X	X	X	X	X						8
K. serrulata														
K. quadrata														
K. valga					X		X							2
Notholca acuminata														
N. labia														

Table 2--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Gastropus hyptopus	X													1
G. minor														
G. stylifer	X							X						2
Gastropus sp.	X													1
Cephalodella mucronata														
C. gibba		X												1
Cephalodella sp.														
Collotheca sp.	X	X	X	X	X	X	X	X						8
Conochiloides coenobasis	X	X	X	X	X	X	X	X						8
C. dossuarius														
C. natans														
Conochilus unicornis	X	X	X				X	X						5
C. hippocrepis	X	X						X						3
Filinia longiseta	X	X	X	X	X	X	X	X						8
F. terminalis														
Pompholyx sulcata														
Pompholyx sp.														
Testudinella patina														
Hexarthra mira	X	X	X	X	X		X	X						7
Lecane tomata														
L. luna	X													1
L. salpina														
Lecane sp.														
Monostyla hornemanni														
Ptygura libera														
Ptygura sp.		X	X											2
Rotaria neptunia														
Habrotrocha sp.														
Pedipartia sp.														
Lophocharis sp.														
Monostyla scutata														

Table 2--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Notholca sp.														
Platyias patulus	X	X			X	X	X	X						6
Trichotria truncata														
T. tetractis														
Trichotria sp.	X													1
Ploesoma hudsoni														
P. lenticulare		X												1
P. tricanthum		X												1
P. truncatum	X	X												2
Polyarthra euryptera														
P. vulgaris	X	X	X	X	X	X	X	X						8
Polyarthra sp.	X	X												2
Synchaeta johnsoni														
S. oblonga	X	X					X							3
S. pectinata		X					X							2
S. stylata	X	X	X	X	X		X							6
S. tremula														
Synchaeta sp.														
Trichocerca brachqura							X							1
T. dixon-nuttali		X												1
T. multicrinis	X	X	X	X		X	X	X						7
T. porcellus							X							1
T. rattus							X	X						2
T. similis	X	X		X	X	X	X	X						7
T. cylindrica		X												1
T. stylata		X					X							2
Trichocerca sp.	X	X												2
Asplanchna priodonta	X	X	X	X			X	X						6
A. sieboldi		X	X	X										3
Ascomorpha saltans														
Ascomorpha sp.														

Table 2--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Monostyla sp.														
Philodina tridentata														
Unidentified Rotatoria														
Dasydytes sp.														
Difflugia	X	X		X	X	X	X	X						7
Hydra sp.														
Peritricha														
Ceratium hirundinella	X	X			X	X	X	X						6
Arcella sp.														
Tardigrada														
Codonella sp.														
Ostracoda-nauplius														
Oligochaeta														
Glochidium														
Chironomidae				X	X	X		X						4
Epistylus sp.														
Hydracarina														
Unidentified Protozoan														
Total	41	42	24	26	27	23	37	34						254

Table 3. The occurrence and distribution of zooplankton in the Arkansas River during October 1974.

Table 3

Occurrence and Distribution of Zooplankton in the Arkansas River During October 1974

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Nauplius	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Copepodid	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Cyclopoida	X	X	X	X	X	X	X	X	X	X		X	X	12
Calanoida	X	X		X	X	X	X	X	X	X		X	X	11
Harpacticoida					X		X					X	X	4
Bosmina longirostris	X	X	X	X	X	X	X	X	X	X	X	X	X	13
B. coregoni														
Daphnia parvula		X	X	X	X	X	X	X	X	X		X		10
D. similis														
D. magna														
D. middendorffiana														
D. ambigua						X								1
D. galeata														
D. rosea														
Daphnia sp.														
Ceriodaphnia lacustris		X	X	X	X	X	X	X	X	X		X	X	11
C. quadrangula														
C. reticulata														
C. pulchella						X								1
Moina micrura	X				X								X	3
M. brachiata														
Moina sp.														
Holopedium amazonicum														
H. gibberum														

Table 3--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Diaphanosoma brachyurum							X							1
D. leuchtenbergianum	X	X		X	X	X	X	X						7
Sida sp.														
Chydorus sphaericus														
Brachionus bidentata														
B. angularis	X	X	X	X	X	X	X	X	X	X	X	X	X	13
B. budapestinensis														
B. calyciflorus	X	X	X	X	X	X	X	X	X	X	X	X	X	13
B. caudatus	X	X	X		X	X	X				X	X	X	9
B. dimidiatus	X	X	X	X	X	X				X		X	X	9
B. havanaensis					X									1
B. nilsoni						X			X		X			3
B. quadridentatus		X					X			X	X	X	X	6
B. urceolaris														
B. variabilis					X									1
Colurella sp.														
Diplois daviesiae														
Epiphanes senta				X	X						X	X	X	5
Epiphanes sp.		X				X	X			X	X	X		6
Euchlanis sp.										X				1
Kellicottia bostoniensis	X	X	X	X	X	X		X	X	X		X	X	11
Keratella americana				X	X	X	X	X	X	X	X	X	X	13
K. earlinae	X	X	X	X	X	X	X	X	X	X	X	X	X	13
K. cochlearis	X	X	X	X	X	X	X	X	X	X	X	X	X	13
K. serrulata														
K. quadrata														
K. valga	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Notholca acuminata														
N. labia														

Table 3--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Gastropus hyptopus														
G. minor	X	X	X	X	X	X	X	X	X	X	X	X	X	13
G. stylifer		X												1
Gastropus sp.						X								1
Cephalodella mucronata														
C. gibba						X	X						X	3
Cephalodella sp.		X				X	X		X	X			X	6
Collotheca sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Conochiloides coenobasis	X	X	X	X	X	X	X	X	X	X	X	X	X	13
C. dossuarius							X						X	2
C. natans														
Conochilus unicornis	X	X	X	X	X	X	X	X	X	X	X	X	X	13
C. hippocrepis	X		X	X	X	X	X	X	X	X	X	X	X	12
Filinia longiseta		X	X		X						X		X	5
F. terminalis														
Pompholyx sulcata	X	X	X	X	X	X	X		X	X	X	X	X	12
Pompholyx sp.										X				1
Testudinella patina														
Hexarthra mira	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Lecane tomata														
L. luna												X		1
L. salpina		X												1
Lecane sp.														
Monostyla hornemanni								X						1
Ptygura libera				X	X						X	X		4
Ptygura sp.	X	X				X	X			X	X	X	X	8
Rotaria neptunia														
Habrotrocha sp.						X	X							2
Pedipartia sp.							X			X				2
Lophocharis sp.														
Monostyla scutata						X	X							2

Table 3 --continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Notholca sp.														
Platyias patulus		X			X	X	X			X	X	X	X	8
Trichotria truncata										X	X			2
T. tetractis													X	1
Trichotria sp.									X					1
Ploesoma hudsoni										X	X			2
P. lenticulare														
P. triacanthum														
P. truncatum	X	X		X	X				X	X		X		7
Polyarthra euryptera				X	X		X							3
P. vulgaris	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Polyarthra sp.														
Synchaeta johnsoni														
S. oblonga	X	X	X	X	X	X		X	X				X	9
S. pectinata	X	X	X	X	X	X	X		X	X	X	X	X	12
S. stylata	X	X	X	X	X	X							X	7
S. tremula														
Synchaeta sp.	X													1
Trichocerca brachqura														
T. dixon-nuttali														
T. multicrinis	X	X	X	X	X	X	X	X	X	X		X	X	12
T. porcellus	X				X									2
T. rattus	X				X								X	3
T. similis				X										1
T. cylindrica														
T. stylata														
Trichocerca sp.					X									1
Asplanchna priodonta	X	X	X	X	X	X	X	X	X	X	X	X	X	13
A. sieboldi	X	X	X		X									4
Ascomorpha saltans											X	X	X	3
Ascomorpha sp.													X	1

Table 3--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Monostyla sp.														
Philodina tridentata														
Unidentified Rotatoria		X			X	X	X	X	X					6
Dasydytes sp.													X	1
Difflugia														
Hydra sp.														
Peritricha														
Ceratium hirundinella														
Arcella sp.						X								1
Tardigrada														
Codonella sp.														
Ostracoda-nauplius														
Oligochaeta														
Glochidium					X									1
Chironomidae						X			X		X	X		4
Epistylus sp.										X			X	2
Hydracarina										X				1
Unidentified Protozoan														
Total	34	39	29	34	46	44	40	27	32	39	32	38	44	478

Table 4. The occurrence and distribution of zooplankton in the Arkansas River during January 1975.

Table 4

Occurrence and Distribution of Zooplankton
in the Arkansas River During January 1975

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Nauplius	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Copepodid		X	X	X	X	X	X	X	X	X	X	X	X	12
Cyclopoida	X	X	X	X	X	X		X	X	X	X	X	X	12
Calanoida	X	X	X	X	X	X	X	X	X	X		X	X	12
Harpacticoida														
Bosmina longirostris	X	X		X	X	X	X	X			X	X	X	10
B. coregoni									X		X			2
Daphnia parvula		X		X		X								3
D. similis														
D. magna														
D. middendorffiana													X	1
D. ambigua														
D. galeata														
D. rosea														
Daphnia sp.														
Ceriodaphnia lacustris						X								1
C. quadrangula														
C. reticulata														
C. pulchella														
Moina micrura														
M. brachiata														
Moina sp.														
Holopedium amazonicum														
H. gibberum														

Table 4--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Diaphansoma brachyurum														
D. leuchtenbergianum														
Sida sp.														
Chydorus sphaericus														
Brachionus bidentata														
B. angularis							X			X				2
B. budapestinensis														
B. calyciflorus				X		X	X	X	X	X		X	X	8
B. caudatus														
B. dimidiatus														
B. havanaensis														
B. nilsoni														
B. quadridentatus														
B. urceolaris														
B. variabilis		X	X			X		X	X			X		6
Colurella sp.					X									1
Diplois daviesiae													X	1
Epiphanes sp.					X				X					2
Euchlanis sp.			X											1
Kellicottia bostoniensis	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Keratella americana							X				X			2
K. earlinae	X	X		X	X	X		X	X	X	X	X	X	11
K. cochlearis		X			X			X		X	X	X	X	7
K. serrulata														
K. quadrata														
K. valga	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Notholca acuminata				X		X	X		X	X		X	X	7
N. labia										X		X	X	3

Table 4--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Notholca sp.				X									X	2
Platyias patulus													X	1
Trichotria truncata														
T. tetractis														
Trichotria sp.														
Ploesoma hudsoni														
P. lenticulare														
P. triacanthum														
P. truncatum														
Polyarthra euryptera												X		1
P. vulgaris	X	X		X	X	X	X	X	X	X		X	X	11
Polyarthra sp.														
Synchaeta johnsoni														
S. oblonga		X							X	X			X	4
S. pectinata	X	X	X	X	X	X	X	X	X	X	X	X	X	13
S. stylata														
S. tremula														
Synchaeta sp.													X	1
Trichocerca brachqura														
T. dixon-nuttali														
T. multicrinis														
T. porcellus														
T. rattus														
T. similis														
T. cylindrica														
T. stylata														
Trichocerca sp.														
Asplanchna priodonta					X				X	X	X	X	X	6
A. sieboldi						X								1
Ascomorpha saltans									X					1
Ascomorpha sp.				X	X	X			X		X	X	X	7

Table 4 --continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Gastropus hyptopus									X		X			2
G. minor									X	X				2
G. stylifer				X	X	X	X	X						5
Gastropus sp.													X	1
Cephalodella mucronata														
C. gibba														
Cephalodella sp.														
Collotheca sp.							X	X		X			X	4
Conochiloides coenobasis														
C. dossuarius														
C. natans														
Conochilus unicornis									X	X				2
C. hippocrepis														
Filinia longiseta						X		X	X		X			4
F. terminalis														
Pompholyx sulcata		X	X					X						3
Pompholyx sp.							X						X	2
Testudinella patina									X					1
Hexarthra mira														
Lecane tomata													X	1
L. luna														
L. salpina														
Lecane sp.														
Monostyla hornemanni														
Ptygura libera														
Ptygura sp.														
Rotaria neptunia											X			1
Habrotrocha sp.														
Pedipartia sp.		X	X	X	X	X	X	X	X	X	X	X	X	12
Lophocharis sp.													X	1
Monostyla scutata														

Table 4--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Monostyla sp.														
Philodina tridentata														
Unidentified Rotatoria	X	X		X	X	X	X	X	X	X	X	X	X	12
Dasydytes sp.														
Difflugia														
Hydra sp.														
Peritricha	X	X				X	X							4
Ceratium hirundinella														
Arcella sp.														
Tardigrada														
Codonella sp.														
Ostracoda-nauplius														
Oligochaeta														
Glochidium														
Chironomidae														
Epistylus sp.														
Hydracarina														
Unidentified Protozoan													X	1
Total	12	19	11	18	18	21	18	19	25	21	18	20	29	249

Table 5. The occurrence and distribution of zooplankton in the Arkansas River during April 1975.

Table 5

Occurrence and Distribution of Zooplankton
in the Arkansas River During April 1975

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Nauplius	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Copepodid	X	X		X	X	X	X	X	X	X	X	X	X	12
Cyclopoida	X	X		X	X	X	X	X	X	X	X	X	X	12
Calanoida	X	X		X	X	X	X	X	X	X	X	X	X	12
Harpacticoida														
Bosmina longirostris	X	X		X	X	X	X	X	X	X		X	X	11
B. coregoni														
Daphnia parvula	X			X		X		X			X	X		6
D. similis												X	X	2
D. magna														
D. middendorffiana														
D. ambigua														
D. galeata														
D. rosea														
Daphnia sp.														
Ceriodaphnia lacustris														
C. quadrangula														
C. reticulata														
C. pulchella														
Moina micrura														
M. brachiata														
Moina sp.														
Holopedium amazonicum						X				X	X	X	X	5
H. gibberum									X	X				2

Table 5--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Diaphansoma brachyurum														
D. leuchtenbergianum														
Sida sp.														
Chydorus sphaericus				X						X				2
Brachionus bidentata							X							1
B. angularis	X	X	X	X	X	X	X	X	X	X	X	X	X	13
B. budapestinensis					X		X							2
B. calyciflorus	X	X	X	X	X	X	X	X	X	X	X	X	X	13
B. caudatus														
B. dimidiatus														
B. havanaensis														
B. nilsoni														
B. quadridentatus														
B. urceolaris	X	X	X	X	X	X	X	X	X	X	X	X	X	13
B. variabilis	X	X	X	X	X					X			X	7
Colurella sp.	X													1
Diplois daviesiae														
Epiphanes senta	X													1
Epiphanes sp.		X											X	2
Euchlanis sp.														
Kellicottia bostoniensis	X	X		X	X	X	X	X	X	X	X	X	X	12
Keratella americana														
K. earlinae	X	X	X	X	X	X	X	X	X	X	X	X	X	13
K. cochlearis	X	X	X	X	X	X	X	X	X	X	X	X	X	13
K. serrulata														
K. quadrata		X								X		X	X	4
K. valga	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Notholca acuminata														
N. labia			X											1

Table 5--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Notholca sp.	X													1
Platyias patulus														
Trichotria truncata														
T. tetractis						X		X	X	X				4
Trichotria sp.														
Ploesoma hudsoni										X	X	X	X	4
P. lenticulare														
P. triacanthum														
P. truncatum														
Polyarthra euryptera														
P. vulgaris	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Polyarthra sp.														
Synchaeta johnsoni						X								1
S. oblonga	X	X		X	X	X	X	X	X	X	X	X	X	12
S. pectinata	X	X	X	X	X	X	X	X	X	X	X	X	X	13
S. stylata				X	X	X	X	X	X	X	X	X	X	10
S. tremula	X			X	X	X	X	X	X	X	X	X	X	11
Synchaeta sp.										X				1
Trichocerca brachqura														
T. dixon-nuttali														
T. multicrinis														
T. porcellus														
T. rattus														
T. similis														
T. cylindrica														
T. stylata														
Trichocerca sp.					X						X			2
Asplanchna priodonta	X			X	X	X	X		X	X		X	X	9
A. sieboldi														
Ascomorpha saltans														
Ascomorpha sp.	X				X			X						3

Table 5--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Gastropus hyptopus														
G. minor														
G. stylifer	X			X			X	X	X	X				6
Gastropus sp.														
Cephalodella mucronata														
C. gibba						X								1
Cephalodella sp.														
Collotheca sp.			X	X	X		X	X	X	X	X	X	X	10
Conochiloides coenobasis		X												1
C. dossuarius				X	X									2
C. natans						X	X	X	X	X	X	X	X	8
Conochilus unicornis			X	X					X	X	X	X	X	7
C. hippocrepis														
Filinia longiseta	X	X		X	X	X	X	X	X	X	X	X	X	12
F. terminalis		X	X	X	X	X	X	X	X	X	X	X	X	12
Pompholyx sulcata														
Pompholyx sp.	X	X		X					X	X				5
Testudinella patina									X					1
Hexarthra mira														
Lecane tomata														
L. luna														
L. salpina														
Lecane sp.								X						1
Monostyla hornemanni														
Ptygura libera														
Ptygura sp.														
Rotaria neptunia					X									1
Habrotrocha sp.														
Pedipartia sp.	X	X		X	X	X	X	X	X	X	X	X	X	12
Lophocharis sp.														
Monostyla scutata														

Table 5--continued

	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Monostyla sp.														
Philodina tridentata		X												1
Unidentified Rotatoria	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Dasydytes sp.														
Difflugia														
Hydra sp.														
Peritricha														
Ceratium hirundinella														
Arcella sp.														
Tardigrada													X	1
Codonella sp.				X										1
Ostracoda-nauplius														
Oligochaeta														
Glochidium														
Chironomidae														
Epistylus sp.														
Hydracarina														
Unidentified Protozoan														
Total	28	26	15	32	29	27	27	29	31	36	28	30	33	372

K. earlinae, Kellicottia bostoniensis, Platyias patulus, Notholca acuminata, Polyarthra vulgaris, Synchaeta stylata, S. oblonga, S. pectinata, S. tremula, Trichocerca multicrinis, T. similis, Asplanchna priodonta, Collotheca sp., *Conochilus unicornis, C. hippocrepis, Conochiloides natans, Filinia longiseta, F. terminalis, Hexarthra mira, Pompholyx sulcata, Ptygura* sp., *Pedipartia* sp., *Ceratium hirundinella,* and *Difflugia* sp. The genus *Brachionus* was again the most frequently represented, along with *Synchaeta,* and all but eight taxa were Rotatoria. However, Copepoda (nauplii) constituted the only taxon taken at least once from all the stations during July, October, January, and April. In other words, nauplii probably could be found at every station throughout the year.

On the other hand, 19 taxa were recovered from at least one station during every sampling interval. In this regard, the following taxa could probably be classified as perennial in the Arkansas River: nauplii, Cyclopoida, Calanoida, *Bosmina longirostris, Daphnia parvula, Brachionus angularis, B. calyciflorus, Kellicottia bostoniensis, K. earlinae, K. cochlearis, K. valga, Polyarthra vulgaris, Synchaeta oblonga, S. pectinata, Asplanchna pridonta, Gastropus stylifer, Collotheca* sp., *Conochilus unicornis,* and *Filinia longiseta.* Only 5 of the 19 taxa are distributed between the

Copepoda and Cladocera, since the qualitative dominance of the Rotatoria is quite evident.

Chi-squared Test

Variation was observed in the number of taxa recovered from the 13 stations during each sampling date. The totals of longitudinal and seasonal occurrences of major taxa are recorded at the bottom of Tables 8, 9, 10, and 11. Application of the X^2 test on the differences in the number of taxa found at each station during the study are given in Tables 6 and 7. An important question is whether differences in the number of taxa happened by chance, or whether it was a significant difference that could be linked with the location of the station. Thus, the null hypothesis for each test is that no differences existed between the number of taxa found at the 13 stations (8 stations in July). In other words, were there differences among the 13 stations for each particular sampling interval?

Summer (July)

In July 1974 (data incomplete) the number of taxa taken from each station ranged from 23 at Station 6 to 42 at Station 2. Thirty-two of the 42 taxa recovered at Station 2 were Rotatoria. However, only 13 rotatorian taxa were observed at Station 6. The mean number of taxa captured from the 8 stations in July was 31.8.

Table 6. The application of the chi-squared test to the observed and expected numbers of zooplankton taxa taken during July and October, 1974. The calculated chi-squared = X^2.

Table 6

Observed and Expected Numbers of Zooplankton Taxa
Taken at Stations 1-8, Arkansas River, Arkansas

July 1974 Stations

	1	2	3	4	5	6	7	8	Total
Observed numbers	41.0	42.0	24.0	27.0	27.0	23.0	37.0	34.0	255
Expected numbers	32.0	32.0	32.0	32.0	32.0	32.0	32.0	32.0	256
Deviation (O-E)	81	100	64	25	25	81	25	4	
	9	10	-8	-5	-5	-9	5	2	
$(O-E)^2$	81	100	46	25	25	81	25	4	
$(O-E)^2/E$	2.53	3.12	2.00	0.78	0.78	2.53	0.78	0.12	$12.64 = X^2$

Observed and Expected Numbers of Zooplankton Taxa
Taken at Stations 1-13, Arkansas River, Arkansas

October 1974 Stations

	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Observed numbers	34.0	39.0	29.0	34.0	46.0	44.0	40.0	27.0	32.0	39.0	32.0	38.0	44.0	478
Expected numbers	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	481
Deviation (O-E)	-3	2	-8	-3	9	7	3	-10	-5	2	-5	1	7	
$(O-E)^2$	9	4	64	9	81	49	9	100	25	4	25	1	49	
$(O-E)^2/E$	0.24	0.11	1.73	0.24	2.19	1.32	0.24	2.70	0.67	0.11	0.67	0.03	1.32	$11.57 = X^2$

Table 7. The application of the chi-squared test to the observed and expected numbers of zooplankton taxa taken during January and April, 1975. The calculated chi-squared = X^2.

Table 7

Observed and Expected Numbers of Zooplankton Taxa
Taken at Stations 1-13, Arkansas River, Arkansas

	January 1975 Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Observed numbers	12.0	19.0	11.0	18.0	18.0	21.0	18.0	19.0	25.0	21.0	18.0	20.0	29.0	249
Expected numbers	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	247
Deviation (O-E)	-7	0	-8	-1	-1	2	-1	0	6	2	-1	1	10	
$(O-E)^2$	49	0	64	1	1	4	1	0	36	4	1	1	100	
$(O-E)^2/E$	2.58	0	3.37	0.05	0.05	0.21	0.05	0	1.89	0.21	0.05	0.05	5.26	$13.82 = X^2$

Observed and Expected Numbers of Zooplankton Taxa
Taken at Stations 1-13, Arkansas River, Arkansas

	April 1975 Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Observed numbers	28.0	26.0	15.0	32.0	29.0	27.0	27.0	29.0	31.0	36.0	28.0	30.0	33.0	371
Expected numbers	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5	371
Deviation (O-E)	-0.5	-2.5	-13.5	3.5	0.5	-1.5	-1.5	0.5	2.5	7.5	-0.5	1.5	4.5	
$(O-E)^2$	0.25	6.25	182.25	12.25	0.25	2.25	2.25	0.25	6.25	56.25	0.25	2.25	20.25	
$(O-E)^2/E$	0.009	0.219	6.395	0.429	0.009	0.079	0.079	0.009	0.219	1.974	0.009	0.079	0.710	$10.22 = X^2$

The results of the Chi-squared test in Table 6 (contingency tables) show that there is a 90.0 to 95.0% chance that differences in the number of taxa found are significant. Therefore, the null hypothesis that no differences existed between the stations must be rejected. Inspection of the table shows that the greatest contribution to X^2 or deviation came from Stations 1, 2, 3, and 6. The number of taxa observed at these stations was 41, 42, 24, and 23, respectively. This means that a significantly higher number of taxa was taken at Stations 1 and 2, while a significantly lower number was taken at Stations 3 and 6 (Table 2).

Autumn (October)

During October 1974 the range in number of taxa taken from the 13 stations was 27 to 46 at Stations 8 and 5, respectively. Four Copepoda, 4 Cladocera, and 19 Rotatoria were observed at Station 8, while 5 Copepoda, 5 Cladocera, and 35 Rotatoria were recovered from Station 5. The mean number of taxa recovered from the 13 stations during October was 36.7. Again, the null hypothesis is that no differences existed between stations. The results of the Chi-squared test do not give strong evidence against the null hypothesis. However, there is a 51.9% chance that the differences found between stations was significant. In other words, there is a 48.1% chance that one would expect deviations as large as those found between the stations during the October sampling interval. Nevertheless, Stations 3, 5, and 8 showed more variation in the number of taxa and contributed heavily to the X^2 deviation. Twenty-nine zooplankton taxa were recovered from Station 3, while 46 and 27 were taken from Stations 5 and 8, respectively. Omitting the variation contributed by the above stations (3, 5, and 8) would lead to the acceptance of the null hypothesis (null hypothesis = no differences). On the other hand, there is insufficient evidence to confirm the null hypothesis without omitting Stations 3, 5, and 8.

Winter (January)

The zooplankton densities decreased by January, as did the number of taxa taken from each station. The mean number of taxa recovered per station was 19.0% from a range of 11 at Station 3 to 29 at Station 13. The taxa at Station 3 consisted of 7 Rotatoria and 4 Copepoda; 2 Cladocerans and 23 Rotatoria were taken from Station 13. The results of the Chi-squared test (Table 7) show that there are no differences in the number of taxa collected depending upon the exclusion of deviations from Stations 1, 3, and 13. The greatest amount of deviation and contribution to X^2 came from Station 13. The inclusion of the above stations results in a 68.8% chance that differences are significant. On this basis, evidence leads to the rejection of the null hypothesis (null hypothesis = no differences). However, deviations of this magnitude may be expected in 31.2% of the instances of capture.

Spring (April)

The number of taxa observed in April ranged from five at Station 3 to 36 at Station 10, which resulted in a mean of 28.5 taxa per station. Fourteen Rotatoria and one Copepoda were taken from Station 3; 28 Rotatoria, 4 Copepoda, and 4 Cladocera were captured from Station 10. The contingency table for April shows that there was only a 40.3% chance that differences were significant among all 13 stations. However, a major portion of the deviation and over 80.0% of the X^2 came from Stations 3 and 10. No differences existed among the other 11 stations (Table 7), if the deviations from the above stations are omitted. Nevertheless, the possibility of obtaining deviations of this magnitude was 59.7% and in favor of the null hypothesis (null hypothesis = no differences in taxa among the 13 stations).

DOMINANCE AND COMMUNITY COMPLEXITY

An idea of richness and variation of the zooplankton fauna of the Arkansas River may be obtained from Tables 2, 3, 4, and 5. A composite ratio (percent) of individual taxa has been included with the total zooplankton density (organisms/liter), total dominant taxa, number of total dominant Copepoda, number of total dominant Cladocera and number of total dominant Rotatoria (Tables 8, 9, 10, and 11). The list of predominant, co-dominant, and subdominant zooplankton for each sampling interval includes those taxa which were ubiquitous and occurred at least once at two-thirds of the stations during the respective sampling dates. It was possible to obtain a maximum composite ratio of 1300%. However, only taxa exhibiting composite ratios above 5% were considered predominant, co-dominant or subdominant. On the other hand, taxa exhibiting composite ratios below 5% must be considered of minor importance to the particular community, but it also must be recognized that with changes in environmental conditions these taxa may become competitive and in some cases, dominant.

Summer (July)

During July 1974 nauplii were the most abundant and widely distributed copepod form exhibiting a composite ratio of 660.0 per cent for the 8 sampling stations (Table 8). Cyclopoid and calanoid adults were the second and third most abundant Copepoda exhibiting ratios of 99.7 and 26.2%, respectively. Copepodid stages were not recorded during July. Nauplii were most frequent at Station 2, comprising 96.3% of the total Copepoda population and

Table 8. The composite ratios for the dominant taxa in the Arkansas River during July 1974.

A = Cyclopoida
B = Calanoida
C = Nauplii
D = *Bosmina longirostris*
E = *Ceriodaphnia lacustris*
F = *C. quadrangula*
G = *Daphnia parvula*
H = *Diaphansoma leuchtenbergianum*
I = *Moina micrura*
J = *M. brachiata*
K = *Brachionus angularis*
L = *B. dimidiatus*
M = *B. caudatus*
N = *Keratella americana*
O = *K. cochlearis*
P = *K. earlinae*
Q = *Polyarthra vulgaris*
R = *Synchaeta stylata*
S = *Collotheca* sp.
T = *Conochiloides coenobasis*
U = *Filinia longiseta*
V = *Hexarthra mira*

Total number of dominant taxa observed = TTO

Total number of dominant Copepoda observed = TCoO

Total number of dominant Cladocera observed = TClO

Total number of dominant Rotatoria = TRO

Mean total organisms/2ml = MT O/2ml

Table 8

Composite Ratios for the Dominant Taxa in the Arkansas River During July 1974

Taxa	Stations 1	2	3	4	5	6	7	8	9	10	11	12	13	Ratio
A	15.4		20.0	11.5	9.3	7.5	19.2	16.8						99.7
B			11.4	8.5			6.3							26.2
C	79.8	96.3	68.6	80.0	88.0	90.2	74.5	82.6						660.0
	2	1	3	3	2	2	3	2						
D	79.3	38.8	51.9	13.1	15.6	59.6	18.9	10.3						287.5
E	8.6	10.2	15.4	34.6	32.8	13.4	28.3	17.9						161.2
F								5.1						5.1
G			19.2		9.4									28.7
H	5.9	30.6	13.5	31.8	34.4	25.0	35.7	53.8						230.7
I		14.3		6.5										20.8
J							13.7	5.1						18.8
	3	4	4	4	4	3	4	5						
K	27.9	13.1	12.8											53.8
L	11.4													11.4
M	19.4	6.0	8.8											34.2
N				18.2										18.2
O		6.1	5.2	25.2	18.5	11.3								66.0
P					9.0	15.8	9.0	8.2						42.0
Q	12.7	24.5	26.3	32.9	43.4	45.9	27.2	34.8						247.7
R		14.2	18.9											33.1
S					6.3									6.3
T							8.9	7.4						16.3
U							7.4	9.0						16.4
V	6.7	6.4	13.5		6.3		17.7	15.1						65.7
	5	6	6	3	5	3	5	5						

Table 8--continued

Taxa	Stations												
	1	2	3	4	5	6	7	8	9	10	11	12	13	Ratio
TTO	41	42	24	27	27	23	37	34						
TCoO	3	3	3	3	3	3	4	3						
TC1O	7	5	4	7	5	4	6	8						
TRO	29	32	17	15	16	13	25	20						
MT 0/2ml	593	437	314	78	64	61	409	118						

least frequent at Station 3, exhibiting a ratio of 68.6%. Cyclopoida were most abundant at Station 3 (20.0%) and absent from Station 2. Calanoida were absent from Stations 1, 2, 5, and 6 but exhibited a maximum ratio of 11.4% at Station 3. *Bosmina longirostris* and *Diaphansoma leuchtenbergianum* were the most abundant and dominant Cladocera, exhibiting composite ratios of 287.5 and 230.7%, respectively. *Ceriodaphnia lacustris* was the third most abundant with a ratio of 161.2%. *Daphnia parvula* (28.6%), *Moina micrura* (20.8%), *M. brachiata* (18.8%), and *Ceriodaphnia quadrangula* (5.1%) occupied the 4th, 5th, 6th, and 7th positions, respectively. *Bosmina longirostris, Diaphansoma leuchtenbergianum,* and *Ceriodaphnia lacustris* were widely distributed while the above species were sporadic and inconsistent.

Polyarthra vulgaris was, by far, the most widely distributed and most abundant rotifer during July 1974, compiling a composite ratio of 247.7%. *Keratella cochlearis, Hexarthra mira, Brachionus angularis,* and *K. earlinae* were the second, third, fourth, and fifth most widely distributed and abundant rotatorians exhibiting composite ratios of: 66.0, 65.7, 53.8, and 42.0%, respectively. The following rotatorians were not widely distributed but exhibited composite ratios of 34.2, 33.1, 18.2, 16.4, 16.3, 11.4, and 6.3%, respectively: *Brachionus caudatus, Synchaeta stylata, Keratella* *americana, Filinia longiseta, Conochiloides coenobasis, Brachionus dimidiatus*, and *Collotheca* sp.. *Polyarthra vulgaris* ranged from 12.7% of the total rotifer population at Station 1 to 45.9% at Station 6 and was present at all Stations (1-8). *Keratella cochlearis* was most abundant at Station 4 (25.2%) and absent from Stations 1, 7, and 8. *Hexarthra mira* was absent from Stations 4 and 6 but reached a maximum ratio of only 17.7% at Station 7. On the other hand, *Brachionus angularis* was present only at Stations 1, 2, and 3 but reached a maximum ratio of 27.9% at Station 1. *Keratella earlinae* reached a maximum percentage of the total at Station 6 (15.8%) and was absent from Stations 1 through 4.

Autumn (October)

Nauplii again constituted the dominant copepod group in October and exhibited a composite ratio of 1117.9% (Table 9). However, copepodid stages replaced adult cyclopoids as the second most abundant and widely distributed Copepoda with a composite ratio of 109.5%. Adult Calanoida were the third (41.6%) most abundant Copepoda, while adult Cyclopoida became insignificant. *Bosmina longirostris* also remained the dominant cladoceran with a composite ratio of 1085.8% and comprised 100% of the population at Station 11. *Daphnia parvula, Moina micrura, Ceriodaphnia lacustris*, and *Diaphansoma leuchtenbergianum* were the second, third, fourth, and fifth

Table 9. The composite ratios for the dominant taxa in the Arkansas River during October 1974.

A = Calanoida
B = Nauplii
C = Copepodid
D = *Bosmina longirostris*
E = *Ceriodaphnia lacustris*
F = *Daphnia parvula*
G = *Diaphansoma leuchtenbergianum*
H = *Moina micrura*

I = *Keratella cochlearis*
J = *K. earlinae*
K = *Polyarthra vulgaris*
L = *Gastropus minor*
M = *Conochiloides coenobasis*
N = *Conochilus unicornis*
O = *C. hippocrepis*
P = *Hexarthra mira*

Total number of dominant taxa observed = TTO

Total number of dominant Copepoda observed = TCoO

Total number of dominant Cladocera observed = TClO

Total number of dominant Rotatoria = TRO

Mean total organisms per liter = MT O/L

Table 9

Composite Ratios for the Dominant Taxa
in the Arkansas River During October 1974

Taxa	Stations 1	2	3	4	5	6	7	8	9	10	11	12	13	Ratio
A						9.0	10.8	8.6	5.8	7.4				41.6
B	93.5	90.1	79.6	86.0	79.8	82.7	81.4	85.3	86.0	84.8	95.2	89.2	84.3	1117.9
C	6.5	8.2	17.0	12.9	11.5	7.7	7.2	5.3	8.1	7.5		5.5	12.1	109.5
	2	2	2	2	2	3	3	3	3	3	1	2	2	
D	17.5	88.6	93.6	86.6	89.7	83.1	80.0	86.9	91.8	89.4	100	87.9	90.7	1085.8
E								11.9		5.7				17.6
F					6.2	9.8	16.4					7.9		40.3
G	5.4													5.4
H	34.6													34.6
	3	1	1	1	2	2	2	2	1	2	1	2	1	
I	39.7	42.9	42.3	20.3	18.5	20.5	23.2	22.2	19.4	15.7	19.4	22.6	27.9	334.6
J	5.0	10.7	5.8					6.2	5.4	8.5	15.9	10.8	9.9	78.2
K	20.2	16.4	21.6	36.4	32.4	30.1	22.5	24.0	19.1	12.5	22.6	9.8	8.8	276.4
L	10.4	7.4	7.4											25.2
M											5.1			5.1
N	6.8			14.2	17.3	20.5	28.2	29.3	35.1	47.1	25.4	39.3	28.1	284.5
O				6.4	7.9	7.4	8.9	6.6	5.5	5.3				48.0
P				10.3	7.5	6.1								23.9
	4	4	4	5	5	5	4	5	5	5	5	4	4	
TTO	34	39	29	34	46	44	40	27	32	39	32	38	44	
TCoO	4	4	3	4	5	4	5	4	4	4	2	5	5	
TC1O	3	4	3	4	5	6	5	4	3	3	1	3	3	
TRO	27	31	23	26	35	32	30	19	26	30	28	29	34	
MT O/L	880	546	703	451	664	436	332	447	502	279	210	240	139	

most abundant cladocerans, but exhibited sporadic and inconsistent longitudinal patterns during October.

Keratella cochlearis replaced *Polyarthra vulgaris* by October as the predominant rotifer showing a composite ratio of 334.6%. *Conochilus unicornis* and *Polyarthra vulgaris* held second and third positions with indices of 284.5% and 276.4%, respectively. The other significantly important species of rotifers observed during October include: *Keratella earlinae, Hexarthra mira, Gastropus minor, Conochilus hippocrepis,* and *Conochiloides coenobasis*. *Brachionus angularis, Brachionus caudatus, Synchaeta stylata,* and *Keratella americana* were replaced in October by: *Keratella earlinae, Gastropus minor, Conochilus hippocrepis,* and *Conochiloides coenobasis* as the fourth, sixth, seventh, and eighth most important rotifers. *Keratella cochlearis, Polyarthra vulgaris, Keratella earlinae, Hexarthra mira,* and *Conochiloides coenobasis* held co-dominant positions during both July and October sampling intervals.

Winter (January)

The complexity of the zooplankton community was altered by a decrease in productivity in January 1975 (Table 10). Nevertheless, nauplii were the predominant copepod stage with a composite ratio index of 1038.7%. However, both adult Cyclopoida and Calanoida became significantly frequent and exhibited composite ratio indices of 84.1% and

Table 10. The composite ratios for the dominant taxa in the Arkansas River during January 1975.

A = Cyclopoida
B = Calanoida
C = Nauplii
D = Copepodid
E = *Bosmina coregoni*
F = *B. longirostris*
G = *Daphnia parvula*
H = *D. middendorffiana*
I = *Ceriodaphnia* sp.
J = *Brachionus calyciflorus*
K = *Kellicottia bostoniensis*
L = *Keratella earlinae*
M = *K. valga*
N = *Polyarthra vulgaris*
O = *Pedipartia* sp.
P = *Synchaeta pectinata*
Q = *Keratella cochlearis*
R = *Brachionus variabilis*
S = *Pompholyx sulcata*
T = *Euchlanis* sp.
U = *Notholca* sp.
V = *Ascomorpha* sp.
W = *Gastropus stylifer*
X = *Rotaria neptunia*

Total number of dominant taxa observed = TTO

Total number of dominant Copepoda observed = TCoO

Total number of dominant Cladocera observed = TClO

Total number of Rotatoria observed = TRO

Mean total organisms per liter = MT O/L

Table 10

Composite Ratios for the Dominant Taxa
in the Arkansas River During January 1975

Taxa	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Ratio
A	14.9	5.6	12.4	9.0	5.8			11.1			13.0	7.1	5.2	84.1
B		19.9	12.4	5.2	7.0	10.1		11.1	9.8			10.1	3.8	89.4
C	74.6	64.4	62.8	79.3	82.5	85.3	96.0	75.9	84.0	85.9	80.5	80.8	86.7	1038.7
D		11.1	12.4	6.5	4.7				5.4	6.5	6.5			53.1
	2	4	4	4	4	2	1	3	3	2	3	3	3	
E									100		66.7			166.7
F	100	66.7		75.2	100	50.0	100	100		100	33.3	100	90.1	915.3
G		33.3		24.8		37.6								94.9
H													9.9	9.9
I						12.4								12.4
	1	2	0	2	1	3	1	1	1	1	2	1	2	
J								5.4				8.1		13.5
K			8.2	10.8		17.6	8.6	14.5	6.3	8.5		6.9		81.4
L	7.2	19.1		8.1	9.0	11.8		14.5	8.0		12.8	6.9	9.6	107.0
M	5.5	8.7	42.0				6.9	5.4			5.1	20.0		93.6
N	12.8	12.0		18.9	5.0			14.5		5.7				68.9
O		6.9	8.2	8.1	8.0	20.0	22.3	10.9	33.1	38.6	30.8	25.0	41.7	253.6
P	58.1	22.4	8.2	16.2	32.3		13.7		10.8	13.1	9.0	10.0	9.3	203.1
Q		6.9						9.0						15.9
R			17.0					5.4						22.4
S			8.2				8.6							16.8
T			8.2											8.2
U				10.8										10.8
V					17.2	5.9						5.0	10.9	39.0

Table 10-continued

Taxa	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Ratio
W							6.9							6.9
X											9.0			9.0
	4	6	7	6	5	4	6	8	4	4	5	7	4	
TTO	12	19	11	18	18	21	18	19	25	21	18	20	29	
TCoO	3	4	4	4	4	3	3	4	4	4	3	4	4	
TClO	1	2	0	2	1	3	1	1	1	0	2	1	1	
TRO	9	11	7	12	13	14	13	14	20	17	13	15	24	
MT O/L	5.12	4.61	3.32	4.91	8.20	8.45	4.86	6.21	9.50	10.5	5.28	10.8	9.02	

89.4%, respectively, while copepodid stages decreased in importance. Nauplii exhibited a maximum ratio at Station 7 (96.0%) and a minimum of 62.8% at Station 3. On the other hand, adult copepods were absent from Station 7 and most frequent at Stations 2 and 3.

Bosmina longirostris was by far the predominant cladoceran during January, composing 100% of the community at Stations 1, 5, 7, 8, 10, and 12; which resulted in a composite ratio index of 915.3%. *Bosmina coregoni* was the only cladoceran observed at Station 9 and made up two-thirds of the population at Station 11. *Bosmina coregoni*, *Daphnia parvula*, *Ceriodaphnia* sp., and *Daphnia middendorffiana* exhibited inconsistent longitudinal patterns reflecting the relatively low composite ratio indices of 166.7%, 94.9%, 12.4%, and 9.9%, respectively.

The longitudinal distribution of rotatorians was inconsistent during January, and no one taxon was observed at significant levels from all 13 stations. *Pedipartia* sp. was taken from 12 (absent from Station 1) stations and was the predominant rotifer with a composite ratio index of 253.6%. This genus inhabits the psammolittoral but nevertheless will be considered with the other rotatorians. *Synchaeta pectinata* was absent from Stations 6 and 8 but exhibited a composite ratio index of 203.1% and was the second most widely distributed rotifer during January. *Keratella earlinae* comprised 19.1% of the total community at Station 2 but was relatively low at the other stations, resulting in a composite ratio index of 107.0%. *Keratella valga* (the fourth most abundant species) was relatively frequent at Station 3 (42.0%) and 12 (20.0%) but exhibited a composite ratio of only 93.6%. Another species, *Kellicottia bostoniensis*, was taken from 8 stations and exhibited a total composite ratio of 81.4% which places it as the fifth most abundant rotifer in the Arkansas River during January. The following taxa exhibited significant composite ratio indices but were considered subdominant because of inconsistent distribution and abundance patterns: *Polyarthra vulgaris* (sixth), *Ascomorpha* sp. (seventh), *Brachionus variabilis* (eighth), *Pompholyx sulcata* (ninth), *Keratella cochlearis* (tenth), *Brachionus calyciflorus* (eleventh), *Notholca* sp. (twelfth), *Rotaria neptunia* (thirteenth), *Euchlanis* sp. (fourteenth), and *Gastropus stylifer* (fifteenth). The composite ratio indices for these taxa ranged from 6.9 to 68.9%. *Keratella earlinae*, *Polyarthra vulgaris*, and *Keratella cochlearis* were the only rotifer species that held dominant or co-dominant positions during the July, October, and January sampling intervals. The dominant species of October 1974 were replaced by *Pedipartia* sp., *Synchaeta pectinata*, *Keratella earlinae*, *K. valga*, and *Kellicottia bostoniensis* by January 1975.

Spring (April)

The situation in April 1975 resembled that of October 1974 since nauplii and copepodid stages were the most abundant and widely distributed Copepoda compiling indices of 1096.2 and 134.4 per cent, respectively (Table 11). However, both cyclopoid and calanoid adults were significantly frequent with indices of 58.4 and 46.1, respectively. Nauplii were found at every station and comprised 100 percent of the population at Station 3. Copepodids reached a maximum frequency of 21.8 percent at Station 7, while cyclopoid and calanoid adults reached maximums at Stations 12 and 4, respectively.

Bosmina longirostris exhibited its lowest composite ratio index (867.3 per cent) during the April sampling interval. However, this species remained the predominant cladoceran making up 100 percent of the population at Stations 2, 5, 7, and 11 but disappeared from Station 3. *Holopedium amazonicum* became the second most abundant cladoceran being present at Stations 6, 10, 11, 12, and 13, exhibiting ratios of 16.5, 21.3, 73.4, 15.5, and 23.2%, respectively, which resulted in a total of 149.9%. *Daphnia parvula* followed closely with a total of 143.0% but was much more sporadic in distribution. The remaining cladocerans, *Holopedium gibberum*, *Chydorus sphaericus*, and *Daphnia similis* were collected in significant percentages from only one station and exhibited respective

Table 11. The composite ratios for the dominant taxa in the Arkansas River during April 1975.

A = Cyclopoida
B = Calanoida
C = nauplii
D = Copepodid
E = *Bosmina longirostris*
F = *Chydorus sphaericus*
G = *Daphnia parvula*
H = *D. similis*
I = *Holopedium amazonicum*
J = *H. gibberum*
K = *Brachionus angularis*
L = *B. calyciflorus*
M = *B. urceolaris*
N = *Keratella earlinae*
O = *K. cochlearis*
P = *Polyarthra vulgaris*
Q = *Synchaeta oblonga*
R = *S. pectinata*
S = *S. stylata*
T = *Pedipartia* sp.
U = *Brachionus variabilis*

Total number of dominant taxa observed = TTO

Total number of dominant Copepoda observed = TCoO

Total number of dominant Cladocera observed = TClO

Total number of Rotatoria observed = TRO

Mean total organisms per liter = MT O/L

Table 11

Composite Ratios for the Dominant Taxa
in the Arkansas River During April 1975

Taxa	Stations 1	2	3	4	5	6	7	8	9	10	11	12	13	Ratio
A		6.6			11.7				8.4	9.7	6.1	15.9		58.4
B				14.4	8.1		5.8	12.1					5.7	46.1
C	84.7	80.2	100	69.3	71.2	82.0	69.5	79.0	75.1	74.1	87.0	73.4	81.4	1096.2
D	9.6	8.7		12.5	9.0	13.7	21.8	7.3	15.1	12.3	6.1	8.4	9.9	134.4
	2	3	1	3	4	2	3	3	3	3	3	3	3	
E	45.4	100		81.9	100	66.7	100	75.1	100	61.7	6.6	58.9	71.0	867.3
F				9.1										9.1
G	54.6			9.1		16.5		24.9			20.0	17.9		143.0
H												7.7		7.7
I						16.5				21.3	73.4	15.5	23.2	149.9
J										10.7				10.7
	2	1	0	3	1	3	1	2	1	3	3	4	2	
K									5.9	5.1	7.4	5.3	6.7	30.4
L	22.1	21.2	23.7	12.1	18.4	16.8	21.1	14.5	26.6	30.4	30.1	25.7	31.7	294.4
M				5.0	8.1	9.4	12.9	7.8	10.7	9.5	11.9	11.6	10.4	97.3
N	6.4	7.6	6.9	6.3	6.1	6.2	6.8	18.2	16.6	18.0	18.9	26.8	26.1	170.9
O									8.9	6.7	5.4	6.4		27.4
P			6.3											6.3
Q					37.0	33.7	34.2	24.9	11.3	9.0	7.7	5.9	5.2	168.9
R	27.2	43.1	47.8	55.9									5.0	179.0
S					5.9	9.9	8.7	6.9						31.4
T	5.9													5.9
U	7.7													7.7
	5	3	4	4	5	5	5	5	6	6	6	6	6	

Table 11-continued

Taxa	Stations													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Ratio
TTO	28	26	15	32	29	27	27	29	31	36	28	30	33	
TCoO	2	1	0	3	1	3	1	2	2	4	2	4	3	
TClO	4	4	1	4	4	3	4	4	4	4	4	4	4	
TRO	22	21	14	26	24	21	22	23	25	28	22	22	26	
MT O/L	51.1	73.3	36.7	88.0	84.2	98.9	90.3	57.1	134.0	166.0	150.0	166.0	234.0	

total ratios of 10.7% (Station 10), 9.1% (Station 12) and 7.7% (Station 12).

The complexity of rotifer populations during April 1975 tended toward those found during October 1974 since 5 co-dominant and 6 subdominant Rotatoria exhibited significant composite frequency indices. However, the species assemblage was unlike those observed in July, October, or January. *Brachionus calyciflorus*, *Synchaeta pectinata*, *Keratella earlinae*, *Synchaeta oblonga*, and *Brachionus urceolaris* were the 5 most widely distributed and abundant rotatorians, as shown by the respective composite ratio indices of 294.4%, 179.0%, 170.9%, 168.9%, and 97.3%. *Synchaeta stylata*, *Brachionus angularis*, *Keratella cochlearis*, *Brachionus variabilis*, *Polyarthra vulgaris*, and *Pedipartia* sp. compiled significant total ratios ranging from 5.9 to 31.4% and, therefore, were the subdominant rotatorians during April 1975. *Keratella earlinae*, *Keratella cochlearis*, and *Polyarthra vulgaris* were the only dominant rotifers present during all four sampling periods.

A measure of the diversity of zooplankton populations observed in the Arkansas River also can be taken from Tables 8, 9, 10, and 11. The average number of taxa exhibiting ratios above 5% was 10.9 for the 8 stations in July 1974 and 8.5, 9.7, and 9.8 for the 13 stations in October, January, and April, respectively. The average number of Copepoda exhibiting ratios above 5% in July (8 stations), October, January, and April was 2.2, 2.3, 2.9, and 2.8, respectively. The respective mean number of significant Cladocera was 5.7, 3.6, 1.2, and 2.1 for July, October, January, and April; and the mean number of Rotatoria exhibiting ratios above 5% was 4.7 (July), 4.6 (October), 5.4 (January), and 5.1 (April).

The lowest and highest numbers of dominant taxa exhibited during July were 8 and 13 from Stations 3 and 6, respectively. Significant differences did not exist between the other stations since the number of taxa collected ranged from 10 to 12. In October, only 7 dominant taxa were taken from Stations 2, 3, 11, and 13. The maximum number (10) of dominant taxa for October was taken from Stations 1, 6, 8, and 10. Based on these data, there seem to be no significant differences between the number of dominant taxa taken by stations during October. The number of dominant and co-dominant taxa collected from the 13 stations during January ranged from 7 at Stations 1 and 10, to 12 at Stations 2, 4, and 8. However, the lowest number of dominant and co-dominant taxa collected during the study was 5 from Station 3 in April, and only 7 significant taxa occurred at Station 2. The number of taxa taken from the other 11 stations during April ranged from 9 to 13.

Despite the lower production during January, the ratio between the number of species and the number of all individuals in the communities remained relatively high and, therefore, were quite diverse. The overall complexity of the zooplankton communities during July, October, and April were similar although distinct differences existed at selected stations. However, the communities were most diverse during July, based upon the assemblages observed at the 8 stations sampled, and least diverse in October. The production of adult copepods brought about higher diversities among Copepoda during January and April. The cladoceran communities exhibited higher diversities in July, October, and April, respectively, and were least complex during January when most of the co-dominant and subdominant species disappeared. On the other hand, rotifer communities were less diverse during July and October and increased in complexity during January and April. This, undoubtedly, was due to the production of certain predominant rotifer species during July and October.

Nauplii were the predominant copepod stages throughout the study, while copepodids and adults were subdominants. *Bosmina longirostris* was the predominant cladoceran throughout the study, while *Diaphansoma leuchtenbergianum*, *Ceriodaphnia lacustris*, *Daphnia parvula*, and *Holopedium amazonicum* were the most important co-dominant and subdominant species.

The predominant rotifer species were *Polyarthra vulgaris* (July 1974); *Keratella cochlearis, Conochilus unicornis*, and *Polyarthra vulgaris* (October 1974); *Pedipartia* sp. (January 1975); and *Brachionus calycoiflorus* (April 1975). The most important co-dominant and subdominant rotatoria included: *Keratella cochlearis, Hexarthra mira, Brachionus angularis, Keratella earlinae, Synchaeta pectinata, Keratella valga, Kellicottia bostoniensis, Polyarthra vulgaris, Synchaeta oblonga*, and *Brachionus urceolaris*.

DISCUSSION AND HISTORICAL REVIEW

While it may seem appropriate to take up changes in the zooplankton communities due to the construction of the Arkansas River Navigation System, the lack of baseline data needed to measure previous ecological conditions from which to detect changes is a determent to such an evaluation. Nevertheless, some idea of the changes brought about by the construction of the system may be obtained by comparing the results of the present investigation with previous studies of zooplankton within other river systems.

A review of the literature reveals that numerous studies have dealt with the plankton of lentic systems. However, relatively few investigations have dealt primarily with zooplankton of lotic systems. Thus, a thorough understanding of the ecology of zooplankton communities in running waters is lacking. This situation is undoubtedly due, in part, to the difficulty of sampling lotic systems. Moreover, lotic systems also require an extensive sampling program to capture even a rough idea of the on-going ecological events.

It has been suggested that small streams, rivers or tributaries carry a plankton population consisting of predominantly phytoplankton, protozoa, and low densities of Rotatoria. Pennak (1943) studied a typical, small, cascading mountain stream arising from numerous tributaries near the continental divide. He found a scanty zooplankton community which consisted of 1 species of Copepoda, 3 Cladocera, and 6 Rotatoria. The major zooplankton taxa were *Keratella*, *Brachionus*, *Polyarthra*, *Bosmina*, *Daphnia*, nauplii, and *Cyclops*. Total zooplankton numbers varied from 0 to 36.2 organisms per liter. The plankton was dominated by diatoms and *Ulothrix* spp. Lackey, Wattie, Kachmar, and Placak (1943) answered the question, "...Do small streams have a plankton content...?", with a study of plankton relationships in a small, unpolluted stream. They recorded over 250 species of organisms from Four Mile Creek in Ohio which included fungi, algae, and Protozoa. Lackey et al. (1943) believed that the plankton population of this creek represented a "basic" population, i.e., one which might be expected in a small, slightly-alkaline stream that is relatively clear, slow-flowing in some stretches, well oxygenated, of low B. O. D. and not subject to extreme pollution of any sort. Lackey et al. (1943) also felt that the greatest potentially modifying factor in unpolluted streams was the entrance of sewage. Short (1974) has shown that unpolluted streams do carry some plankton other than algae and Protozoa. In a preliminary study of the water quality of the Illinois River, Arkansas, he listed 62 taxa of zooplankton consisting of 3 Copepoda, 15 Cladocera, and 43 Rotatoria.

However, diatoms and other algae dominated the plankton populations, while zooplankton communities remained quantitatively insignificant. Evidently some small streams can and do develop plankton associations independently of any single factor, while others seem to be devoid of such plankton associations. This brief account of unpolluted streams demonstrates the impossibility of labeling a river or stream with the term "normal stream plankton."

Rivers do exhibit some common limnological characteristics. The first major studies of river plankton in North America were the investigations of Kofoid (1903, 1908) on the Illinois River and its basin. Kofoid (1908) recorded 104 Rotatoria, 26 Cladocera, and 13 Copepoda from the Illinois River and its basin and noted the presence of a summer and a winter assemblage. He also noted a decrease in total plankton progressively downstream. Kofoid listed a total of 529 plankters for the Illinois River, of which 83 were phytoplankters and 446 were zooplankters. The phytoplankton outnumbered the zooplankton 5 to 1, and the Rotatoria were numerically more important than Copepoda or Cladocera. The dominant zooplankton recorded by Kofoid included the genera: *Brachionus*, *Keratella*, *Conochilus*, *Polyarthra*, *Synchaeta*, *Filinia*, and *Hexarthra*, along with such entomostracans as: *Alona*, *Bosmina*, *Ceriodaphnia*, *Daphnia*, *Diaphansoma, Cyclops, Diaptomus,* and copepodan nauplii. Kofoid (1903) computed the total annual production of plankton in the Illinois River to be 67,750 m^3 (67.75 organisms/liter). Kofoid's (1903, 1908) studies formed the basic foundation for plankton ecology of rivers in North America and several of his conclusions have become common knowledge to the limnologist. Many biological and chemical studies have been carried out on the Illinois River since the late 1800's. These include investigations by Calkins (1874), Forbes (1878), Hart (1895), Kofoid (1903, 1908), Baker (1906), Forbes and Richardson (1908, 1913, and 1919), Bartow (1913), Danglade (1914), Malloch (1915), Richardson (1921, 1925, and 1928), Greenfield (1925), Hoskins, Ruchhoft, and Williams (1927), Boruff and Buswell (1929), Purdy (1930). Later investigations have shown that extremely high phytoplankton counts exist in the river due to enrichment and high calcium hardness (Williams, 1964). It was suggested that the plankton of the entire river may be limited by turbidity and the synergistic effects of toxic metals (Starrett, 1971). Williams (1966) studied the rotifers of many rivers in the United States and found that the Illinois River exhibited one of the highest densities of both phytoplankton and rotifers. The Illinois River has become one of the important rivers in America for man and the development of some of his cultural activities (Starrett, 1972). Some of these activities have had adverse effects on the biota of the Illinois River. These include such activities as: sewage treatment, channelization, diversion of water, navigation and dredging. Dredging has been conducted on the Illinois River since 1852 (Barrows, 1910; Starrett, 1972). Through the years, the channel benthic community probably has been affected by dredging (Starrett, 1972). The plankton has been affected by the construction of locks and dams. The changes which have occurred in the fish fauna of the Illinois River also reflect some of the drastic effects modern man has had on the ecology of the river. Thus, within little over a hundred years, recent, modern man has had a tremendous impact on the ecosystem of the river and its flood plain.

Other rivers have received investigations over the past century. Allen (1921) found 396 different plankton taxa in the San Joaquin River, California. Almost all zooplankters were included in three groups; Protozoa, Rotifera, or Entomostraca. Cladocera rarely reached significant numbers, while protozoans and rotifers dominated. The genera included: *Bosmina* sp., *Sida* sp., *Chydorus* sp., *Alona* sp., *Daphnia* sp., *Brachionus* sp., *Keratella* sp., *Filinia* sp., Cyclopoida, Calanoida, and nauplii. Allen noted that temperature, within limits, determined seasonal distribution and that water currents above a very moderate rate were distinctly inimical to plankton development.

Galtsoff (1924) listed 36 phytoplankton taxa and 80 zooplankton from the upper Mississippi River. The important genera recorded by Galtsoff included: *Asplanchna, Brachionus, Keratella, Polyarthra, Gastropus, Synchaeta, Daphnia, Moina* and others. Both Cyclopoida and Calanoida were present, but nauplii were the most important Copepoda. He stated that the plankton of the upper Mississippi was subject to great fluctuations depending on the stage of the water. During the rise of water, the plankton was replaced almost entirely by detritus. The composition of the plankton was described as monotonous, being dominated by Rotatoria, diatoms and blue-green algae. Wiebe (1927) found that no correlation existed between the total number of plankton individuals and the degree of pollution in the upper Mississippi River system, and therefore the abundance of plankton could not be employed as a criterion of the degree of pollution. Only three individual species were considered tolerant fauna that could be employed as rough criteria of pollution. Reinhard (1931) also stated that no definite correlation could be detected between chemical features of the Mississippi River and plankton. Phytoplankton were dominant and Rotatoria dominated the zooplankton communities. The major taxa included: *Diaptomus* sp., *Cyclops* spp., nauplii, *Keratella cochlearis*, *Polyarthra trigla*, *Brachionus angularis*, *Filinia longiseta*, and *Bosmina longirostris*. Reinhard concluded that the age of water, slope of the river and hydrographic stability were all important to plankton production in lotic systems. He claimed that current was the most important physical factor.

Roach (1932) studied the plankton of the Hocking River and cited floods as being most detrimental to river plankton because of current and "wash in acids." Plankton varied in abundance with temperature. The zooplankton included 8 Rotatoria, 3 Cladocera, and 2 Copepoda which consisted of the following taxa: *Keratella* sp., *Notholca* sp., *Polyarthra* sp., *Ploesoma* sp., *Euchlanis* sp., *Brachionus* sp., *Dinocharis* sp., *Rotifera* sp., *Bosmina longirostris*, *Simocephlous expinosus*, *Alonlla* sp., *Cyclops* spp. and nauplii. Several studies have shown an increase in the amount of plankton collected at successive points down a single stream, and some workers considered age of the water to be important in plankton production. Hutchinson (1939) found that a combination of retarded flow, higher temperature, and senescence of the water at a given point increased plankton productivity in the Hocking River. Hutchinson recorded 52 genera of zooplankton in low numbers. The major genera were: *Keratella, Noteus, Polyarthra, Rotifera, Brachionus, Alona, Bosmina, Ceriodaphnia, Chydorus, Daphnia, Pleuroxus, Canthocamptus, Cyclops,* and *Diaptomus*. Stability of hydrographic conditions and high temperature were important factors in determining the monthly and seasonal distribution.

Eddy (1932) reported a decline in the plankton in the lower course of the Sangamon River during the summer of 1929. He also listed *Brachionus, Synchaeta, Polyarthra, Keratella, Moina affinis, Daphnia longirostris, Diaptomus siuloides,* and *Cyclops bicuspidatus* as typical conspicuous forms. Lakes on the course of the river supplied plankton to the lower reaches although selective elimination changed the composition. Eddy (1934) published a monograph based on more than 2,000 collections of plankton from streams, lakes and ponds, mainly of the United States. Some plankton species were found to be conspicuous and abundant, and deserved to be called predominant or prevalent. Several of these were found to be perennial and others, seasonal. He went on to say that rivers and related waters exhibiting some degree of stability usually contain four species of *Brachionus*, two of *Synchaeta, Filinia longiseta,* and *Moina micrura*. The "incidentals" often constituted more than half of the species but were sporadic and seldom abundant. Eddy believed that the most important factors influencing the development of plankton included age of water, temperature and turbidity. In the streams studied, other factors such as light, dissolved oxygen, and hydrogen ion concentration seemed always adequate for plankton production.

It was shown by Ellis (1936) that erosion silt alters aquatic environments, chiefly by screening out light, changing heat radiation, blanketing the stream bottom, and by retaining organic material, as well as other substances which create unfavorable conditions. Erosion silt in river waters acts chiefly as an opaque screen to all wave-lengths of visible light and disrupts the rate of temperature change. In terms of "millionth intensity depth" (the depth at which light is reduced to a millionth of its surface intensity), the results obtained by Ellis show a minimum turbidity or maximum m.i.d. of 53.9 meters for a mountain stream in Mexico, and a minimum m.i.d. of 84 mm for the Missouri River.

Obviously, turbidity must interfere with photosynthesis by blocking out light. Sabaneeff (1956, cited by Hynes 1970) suggests that turbidity and silt also may interfere with the feeding mechanisms of zooplankton. Any river which remains turbid will therefore carry little true plankton during the flood season (Hynes, 1970). Berner (1951) recorded turbidity values over 3000 ppm which affected almost every characteristic of the lower secret to this phenomenon. However, it has become evident that the physical characteristics of the watercourse might be the major underlying factor behind the longitudinal increase or decrease of plankton in a river.

Galtsoff (1924) expressed the importance of lakes, "river lakes", and the hydrographic conditions upon the amount of plankton in the upper parts of the Mississippi River. Galtsoff concluded that, "...obviously the complete cycle of life in the 'river lakes', the plankton pulses, the appearance and disappearance of plankton forms, the seasonal fluctuations in the amount and composition of plankton and even the distribution of plankton and bottom organisms is different from that in lakes ...". He was making reference to the lakes formed by dams on the upper Mississippi and its tributaries.

Eddy (1934) also made observations on the plankton of streams after damming and showed that the impounded water becomes biologically mature. In the many pools on Rock River which were created by power dams, each duplicating the hydrographic conditions of a mature stream, the same species of plankton organisms were found to occur as elsewhere in the river but much more abundantly (Eddy, 1934). An 18-month study of the Huron River has shown that plankton derived from lakes undergoes a quantitative decrease as it flows downstream, Missouri River. The water temperature rose to a high of 82^0F, and the turbidity may have been partially responsible for the mid-summer dissolved oxygen saturation values of less than 50 per cent. Usually, because of the turbidity, the phytoplankters were less common than the zooplankters. Rapid current and high silt content were considered by Hartman and Himes (1961) to be important factors in the decrease of numbers of organisms in the Shenango River. The effects of current and turbidity upon plankton have been noted by a number of workers (Kofoid, 1903, 1908; Allen, 1921; Reinhard, 1931; Eddy, 1934; Berner, 1951; Welch, 1952; Blum, 1956; Hartman and Himes, 1961; Greenburg, 1964; Williams, 1964, 1966; Hynes, 1970 and others).

Plankton also may decrease along the course of a river, but may be influenced by many environmental factors. Certain streams exhibit headwater areas low in plankton, a middle region rich in plankton, followed by a consistent decline in plankton in the lower course (Kofoid, 1903, 1908; Forbes, 1928; Eddy, 1932; Chandler, 1937; Beach, 1960 and others). However, other studies have shown increases of plankton collected at successive points down a single stream (Eddy, 1934; Hutchinson, 1939; Sabaneeff, 1952, cited by Hynes 1970; Greenburg, 1964 and others). Some workers believe that the age of the water in combination with other factors contain the irrespective of season (Chandler, 1937). Chandler's results showed that a quantitative decrease in total net plankton and in certain predominant individual plankters occurred in three lake fed streams of Michigan.

Beach (1960) discussed the importance of lakes and artificial impoundments in a study of the planktonic rotifers of the Ocquec River system in Michigan. Lakes and artificial impoundments of the Ocquec River system were the major locations of plankton development. Lotic systems did not possess a planktonic rotifer fauna distinct from the lakes. However, most of the plankton was derived from lakes but decreased in quantity downstream and eventually disappeared. The length of each continuing stream segment, current, depth of water, turbulence and amount of vegetation or other objects contributed to the plankton decrease. The importance of backwaters and reservoirs in plankton production, particularly zooplankton, in rivers was noted as early as 1903 by Kofoid.

The impact of damming streams was reviewed and studied by Neel (1963) with the purpose of discussing the effects of discharge, turbidity, temperature, water chemistry and biological features. The development of lentic conditions, which eventually follows impoundment where draw down and other practices permit, brings about changes in benthos, nekton, plankton, chemical conditions, etc., within the reservoir area, but usually only the plankton reflects much direct effect beyond the impoundment (Neel, 1963). Reservoir plankters suffer varied fates below dams, and plankton generally will slowly or rapidly decline depending upon stream conditions and volume of reservoir releases. On the other hand, a few workers have shown that plankton does increase downstream in particular rivers (Hutchinson, 1939; Sabaneeff, 1952; Greenburg, 1964). Obviously, the phenomenon depends much on local conditions. Reservoirs often affect turbidity; removing silt, debris and other suspended particles by slowing the current. Temperature changes that normally occur in the spring and autumn are, in general, delayed by the great volume of water held by reservoirs and modifications of water chemistry vary with the age of impoundment (Neel, 1963).

The studies reviewed show that progress has been made into an understanding of plankton ecology of river systems since the early 1900's. Obviously, many gaps remain to be filled in our knowledge of river plankton, and it must be mentioned again that a thorough understanding of ecological events is lacking. Plankton studies of rivers within geographic regions other than North America show that some ecological principles hold true across continents. These investigations include those of Butcher (1932), Symoens (1957), Waser and

Thomas (1944), Wawrik (1962), Shadin (1956), Southern and Gardiner (1938), Rice (1938), Swale (1964), Lauterborn (1902), Bennin (1926), Jürgensen (1935), Vonnegut (1937), Schallgruber (1944), Stundl (1950), Liepolt (1961), Enaceanu (1964), Czernin-Chudenitz (1966), Uherkovich (1965), Sieminska (1956), Behning (1929), Romadina (1959), Monakov (1968), Greze (1953), Pirozhnikov and Shulga (1957), Lakshminarayana (1965), and Lemmerman (1907). Other important investigations outside of North America include those of: Abdin (1948), Brook and Rzoska (1954), Brook and Kufferath (1957), Gay (1956, 1957), Halim, Guergues, and Saleh (1967), Prowse and Talling (1958), Rzoska, Brook, and Prowse (1955, 1957, 1961), Talling and Rzoska (1967), Worral (1958), Mann (1964, 1965, 1972), Liepolt (1967, 1972), Gideiri (1969), Hammerton (1972), Paggi and DePaggi (1974), Kushnikova (1974), and Rai (1974).

The North American studies reviewed by the author but not incorporated into the above discussion include the following: Clark (1960), Cushing (1964), Clifford (1966), Denham (1938), Lackey (1942), Brinley and Katzin (1942), Pierce (1947), Brook and Woodward (1956), Neel (1953), Coopey (1953), Clark and Snyder (1970), Trefethen (1972), Thomann (1972), and several others.

The basic principles known about river plankton have been brought out by the literature review, and it has served to illustrate the "amorphous state" which exists on the subject, although several informative and substantial investigations have been completed. It was necessary to grasp the fundamental knowledge of plankton ecology within lotic systems before an evaluation and recommendations could be attempted. An exhaustive review was considered beyond the scope of this study and the readers are referred to Welch (1952), Blum (1956), Hutchinson (1967), and Hynes (1970) for a more complete overview.

Surprisingly, although it seems that several investigations dealing with plankton of rivers have been completed, the number is relatively small compared to studies upon lake plankton. Investigations concerned primarily with zooplankton within lotic systems are relatively few in number. Moreover, investigations with the intent of describing the effects of physical perturbation, such as dredging, upon zooplankton are practically nonexistent. However, it has been shown by Jeane and Pine (1975), in a study concerned with environmental effects of dredging and spoil disposal in a bay, that dredging can cause changes in the chemical properties of water, especially in the vicinity of the dredge. Dredging also increased the turbidity of the water and caused the death of some fishes. Forshage and Carter (1973) studied the effects of gravel dredging on the

Brazos River, Texas, and found that such perturbation caused increased turbidity several miles below the operations. Dredging also had a detrimental effect upon the fishes and benthic organisms (Forshage and Carter, 1973).

SUMMARY

Summary of the Historical Review

Several conclusions about zooplankton of rivers have been expressed by many authors. The major conclusions are summarized in the following statements:

1. River zooplankton is subject to extreme fluctuations in quality and quantity.

2. River plankton is polymixic, or made up from the mingling of populations within the drainage basin of each particular river system.

3. Backwaters, reservoirs and "river lakes" are very important in the production of zooplankton within a river system. Pools along the course of a river are also important suppliers of plankton.

4. The zooplankton populations are often dominated by planktonic rotifers of the genera: *Keratella*, *Brachionus*, *Polyarthra*, *Synchaeta*, *Trichocerca*, *Asplanchna*, *Filinia*, *Kellicottia*, *Notholca*, *Euchlanis*, and a few others. The entomostracans usually represent the genera: *Cyclops*, *Diaptomus*, *Canthocamptus*, *Bosmina*, *Alona*, *Moina*, *Daphnia*, *Chydorus*, and *Diaphansoma*. Cladocerans usually remain insignificant. Nauplii often dominate the entomostracans population.

5. Species which are conspicuous and abundant make up the predominants and dominants. "Incidentals" may constitute half of the species list but never become

quantitatively significant.

6. Generally, the plankton of rivers is minimal during the winter and maximal during the summer or fall. Winter and summer species assemblages usually occur during these respective seasons.

7. The majority of workers have shown that zooplankton decreases longitudinally downstream. However, a few workers have shown the opposite phenomenon to occur, and it has been suggested that a trophic relationship exists between phytoplankton and rotifers. Reservoirs have a definite effect on the longitudinal distribution of zooplankton in rivers.

8. Many rivers support an abundant and varied zooplankton population. However, the phytoplankton usually greatly exceeds the zooplankton.

9. It is generally agreed that current, turbidity, temperature, and availability of food are the most important factors in the river environment which affect zooplankton populations. Zooplankters may be more susceptible to these forces than phytoplankters.

10. Temperature, light, dissolved oxygen and other physico-chemical factors obviously play an essential part in the development of plankton in rivers, but the depression or amplitude of plankton in rivers is not traceable to any one or a combination of these environmental factors. Thus, correlation between the seasonal

fluctuations of environmental factors and seasonal abundance often remain obscured.

11. Temperature has been shown, within limits, to be a determining factor in seasonal distribution of plankton. Annual production of plankton and fisheries show some correlation from year to year.

12. Human activity has radically changed zooplankton in many rivers, the most important of these being the construction of impoundments and multipurpose dams.

13. Recognized patterns of seasonal zooplankton dynamics and the driving forces which govern such apparently apply over wide geographic areas.

Summary of the Present Study

The results of the present investigation have been summarized as follows:

1. The Arkansas River can be separated biologically and physically into two major longitudinal sections: the section above Dardenelle lock and dam (RM 200 and above) and the section below Dardenelle lock and dam. The upper section contains the main stem lakes, Webbers Falls (Oklahoma), Robert S. Kerr (Oklahoma), Ozark (Arkansas), and Dardenelle (Arkansas). The lower section contains the locks and dams 9 through 1 (RM 201.2 to 10.3).

2. The seasonal abundance patterns indicate that zooplankton densities are minimal during the winter and

maximal during the summer and fall. The mean densities for the Arkansas River show that the overall production of zooplankton is relatively high as compared to other well-known rivers.

3. In general, the overall abundance of zooplankton decreases downstream from the upper reaches to the lower.

4. Clearly, the Rotatoria are the most important zooplankters in terms of numbers and diversity. The Copepoda are the most significant among the Entomostracans.

5. The most important zooplankters observed throughout the study were: nauplii, *Polyarthra vulgaris*, *Keratella cochlearis*, *Conochilus unicornis*, *Pedipartia* sp., *Brachionus calyciflorus*, *Hexarthra mira*, *Brachionus angularis*, *Keratella earlinae*, *Synchaeta pectinata*, *Keratella valga*, *Kellicottia bostoniensis*, *Synchaeta oblonga*, *Brachionus urceolaris*, *Bosmina longirostris*, *Diaphansoma leuchtenbergianum*, *Ceriodaphnia lacustris*, *Daphnia parvula*, and *Holopedium amazonicum*. All of these taxa occur throughout North America and the list is in agreement with other workers except for the genus *Pedipartia*. *Pedipartia* spp. are considered psammolittoral forms, but even so this genus dominated the zooplankton associations during January 1975.

6. The Arkansas River exhibited a diverse

zooplankton fauna during the 1974-75 study period; 5 Copepoda, 23 Cladocera, and 88 Rotatoria were identified.

7. There were significant differences found in the number of taxa recovered at each station during the respective sampling periods. However, these differences cannot be traced to any specific factor based upon the available data.

8. Temperature seems to be a controlling factor affecting the seasonal productivity of zooplankton in the Arkansas River. The production of zooplankton increased sooner in the lower reaches of the Arkansas River as the water began to warm in an upstream direction.

9. The chemical characteristics of the Arkansas River (e.g., dissolved oxygen, hydrogen ion concentration, and alkalinity) seem to be adequate and capable of sustaining a rich plankton population. However, the available physical-chemical data is not adequate to show any specific correlations.

The Effects of the Arkansas River Navigation System and Dredging on the Zooplankton

Comparative analysis of the historical review and the summary of the present study show that the construction of the locks and dams, and subsequently the impoundments, have profoundly affected zooplankton production in the Arkansas River. The "river lakes" (fast turnover impoundments), especially in upper regions, have increased the density and production of zooplankton to a significant degree. The overall seasonal abundance patterns of zooplankton probably have not been affected by the construction of the "river lakes" or a navigation system in the Arkansas River. The longitudinal decrease in abundance of zooplankton is amplified by the decrease in backwater areas, and the increase in water current and silt load within a portion of the lower section of the Arkansas River (RM 201.2-10.3). The qualitative composition of zooplankton has not been affected, but the community structure and diversity have changed as a consequence of increased production of certain dominant species due to changes in the habitat within the river.

Dredging may affect zooplankton via turbidity, stream flow, habitat destruction, mechanical destruction, chemical change, and toxic substances. To measure and monitor such effects many stations must be established above, within, and below the dredging operation areas. This is necessary to gain adequate insight into the longitudinal effects of dredging on water quality and biological conditions. To measure the effects of dredge spoils upon the deposition area, a similar type of monitoring program must be conducted. Such a sampling program was not conducted during this study.

Therefore, it is nearly impossible to evaluate the effects of dredging upon the physical-chemical parameters or zooplankton associations within specific local sites on the Arkansas River.

The overall effect of dredging on zooplankton through such factors mentioned above is a decrease in the abundance or density and diversity of the communities. Local dredging would not have a significant effect on the mean abundance patterns, although the local effects would be inevitable, Dredging on a grand scale; i.e., at many locations from the upper reaches to the lower reaches would have a definite detrimental effect on zooplankton communities. The strategic location of dredging and the placement of dredge materials is very important to the conservation of breeding grounds for zooplankton of the Arkansas River. Thus, it is just as important to preserve the habitats indispensable to the maintenance of breeding grounds as to save a particular population of animals. It is due to these and previous conclusions that such recommendations are made. Again, it was essential that a background on the fundamentals of the ecology of river plankton be brought out by way of an historical review.

Recommendations for Decreasing the Effects of Dredging upon Zooplankton of the Arkansas River

1. Limit dredging activities to those necessary

to maintain the navigational system.

2. Minimize grand scale dredging activities; i.e., simultaneous dredging from the upper reaches of the Arkansas River to the lower, if at all possible.

3. Minimize dredging activities in backwater areas, mouths of tributaries, and any slower flowing waters suitable for feeding and breeding grounds for biota. Plankton originates in the tributaries, backwaters, and upper lakes of the river.

4. Passageways from the upper reaches to the lower, and between dredge spoil backwaters should be maintained.

5. The backwater cover (vegetation, brush, etc.) should not be removed from shallow areas or from the banks. These materials provide cover for most aquatic biota and help to prevent erosion and turbidity.

6. Dredged materials should not be placed in backwater habitats since such would obliterate entire assemblages of zooplankton. Place dredged materials in areas in such a way as to minimize the turbidity and mixing factors. The materials should be placed well up on the banks out of the water whenever possible.

7. It is a well-known fact that fish feed upon zooplankton, especially during larval stages. Macroinvertebrates also feed upon plankton and it has been suggested that a trophic relationship exists between

zooplankton and phytoplankton. Therefore, dredging activities, dredged materials deposition, and other activities within the Arkansas River aquatic system must be directed with the "whole" biotic community in mind.

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Inventory of Zooplankton from the Arkansas River with Code Numbers* keyed to Appendix Tables 1-3

Nauplius	1000
Copepodid	1001
Cyclopoida	1002
Calanoida	1003
Harpacticoida	1004
Bosmina longirostris	2000
B. coregoni	2001
Daphnia parvula	2002
D. similis	2003
D. magna	2004
D. middendorffiana	2005
D. ambigua	2006
D. galeata	2007
D. rosea	2008
Daphnia sp.	2009
Ceriodaphnia lacustris	2010
C. quadrangula	2011
C. reticulata	2012
C. pulchella	2013
Moina micrura	2014
M. brachiata	2015
Moina sp.	2016
Holopedium amazonicum	3000

H. gibberum	3001
Diaphansoma brachyurum	3002
D. leuchtenbergianum	3003
Sida sp.	3004
Chydorus sphaericus	3005
Brachionus angularis	4050
B. bidentata	4000
B. budapestinensis	4001
B. calyciflorus	4002
B. caudata	4003
B. dimidiatus	4004
B. havanaensis	4005
B. nilsoni	4006
B. quadridentatus	4007
B. urceolaris	4008
B. variabilis	4009
Colurella sp.	4010
Diplois daviesiae	4011
Epiphanes senta	4012
Epiphanes sp.	4013
Euchlanis sp.	4014
Kellicottia bostoniensis	4015
Keratella americana	4016
K. earlinae	4017

Inventory with Code Numbers (continued)

K. cochlearis	4018
K. serrulata	4019
K. quadrata	4020
K. valga	4021
Lophocharis sp.	5034
Notholca acuminata	4022
N. labia	4023
Notholca sp.	4024
Platyias patulus	4025
Trichotria truncata	4026
T. tetractis	4027
Trichotria sp.	4028
Ploesoma hudsoni	4029
P. lenticulare	4030
P. triacanthum	4031
P. truncatum	4032
Polyarthra euryptera	4033
P. vulgaris	4034
Polyarthra sp.	4035
Synchaeta johnsoni	4036
S. oblonga	4037
S. pectinata	4038
S. stylata	4039
S. tremula	4040
Synchaeta sp.	4041

Trichocerca brachyura	4042
T. dixon-nuttali	4043
T. multicrinis	4044
T. porcellus	4045
T. rattus	4046
T. similis	4047
T. stylata	4048
Trichocerca sp.	4049
Asplanchna priodonta	5000
A. sieboldi	5001
Ascomorpha saltans	5002
Ascomorpha sp.	5003
Gastropus hyptopus	5004
G. minor	5005
G. stylifer	5006
Gastropus sp.	5007
Cephalodella mucronata	5008
C. gibba	5009
Cephalodella sp.	5010
Collotheca sp.	5011
Conochiloides coenobasis	5012
C. dossarius	5013
C. natans	5014
Conochilus unicornis	5015
C. hippocrepis	5016

Inventory with Code Numbers (continued)

Filinia longiseta	5017
F. terminalis	5018
Pompholyx sulcata	5019
Pompholyx sp.	5020
Testudinella patina	5021
Hexarthra mira	5022
Lecane tomata	5023
L. luna	5024
L. salpina	5025
Lecane sp.	5026
Monostyla hornemanni	5027
M. scutata	5035
Ptygura libera	5028
Ptygura sp.	5029
Philodina tridentata	5036
Rotaria neptunia	5030
Habrotrocha sp.	5031
Pedipartia	5032
Unidentified Rotatoria	5033
Dasydytes sp.	6001
Hydra sp.	6002
Peritricha	6003
Ceratium hirundinella	6004
Arcella sp.	6005

Inventory with Code Numbers (continued)

Tardigrada	6006
Codonella sp.	6007
Ostracoda-nauplius	6008
Oligochaeta	6009
Glochidium	6010
Chironomidae	6012

* The code numbers refer to data presented in the Arkansas River data set.

APPENDIX

Table 1. Arkansas River combined zooplankton data, 10-14-74 through 10-23-74.

ARKANSAS RIVER ZOOPLANKTON DATA

OCTOBER 14, 1974 THRU OCTOBER 23, 1974 SURVEY

						DENSITY							
STAT	RIVMI	DEPTH	1000	2000	3000	4000	5000	6000	TOTAL	1+2+3	2+3	2+3+4+5	4+5
1- 1	283.0	5.0	42.29	6.88	2.71	664.58	233.12	0.00	949.58	51.87	9.58	907.29	897.71
1- 2	283.0	4.0	15.00	3.75	0.00	351.25	110.83	0.00	480.83	18.75	3.75	465.83	462.08
1- 3	283.0	5.0	58.33	4.16	0.00	871.00	279.16	0.00	1212.66	62.50	4.16	1154.32	1150.16
2- 1	248.0	2.5	69.99	4.60	0.83	349.79	61.04	0.00	486.26	75.43	5.43	416.27	410.83
2- 2	248.0	2.5	68.54	4.16	0.00	292.09	43.96	0.00	408.76	72.71	4.16	340.21	336.05
2- 3	248.0	2.5	104.58	2.09	0.00	397.92	79.79	0.00	584.38	106.67	2.09	479.79	477.71
2- 4	248.0	2.5	119.17	21.04	0.00	435.20	130.83	0.00	706.25	140.21	21.04	587.08	566.04
3- 1	238.0	2.0	91.62	16.25	0.00	461.75	133.13	0.00	702.75	107.87	16.25	611.13	594.88
4- 1	199.0	2.5	115.88	18.32	0.16	211.96	92.90	0.00	439.23	134.36	18.48	323.35	304.86
4- 2	199.0	2.5	57.94	14.49	0.00	130.55	46.46	0.00	249.44	72.43	14.49	191.50	177.01
4- 3	199.0	2.5	112.06	17.15	1.50	215.80	148.36	0.00	494.87	130.71	18.65	382.81	364.16
4- 4	199.0	2.5	143.69	22.48	0.33	284.22	167.34	0.00	618.07	166.50	22.81	474.38	451.56
5- 1	189.0	2.5	122.89	19.32	1.83	401.26	244.13	0.50	789.94	144.04	21.15	666.55	645.40
5- 2	189.0	2.5	101.41	25.65	0.33	322.03	195.32	0.00	644.75	127.40	25.99	543.34	517.35
5- 3	189.0	2.5	94.75	19.82	0.00	314.02	237.76	0.00	666.35	114.56	19.82	571.60	551.79
5- 4	189.0	2.5	85.25	15.31	0.00	254.91	200.14	0.16	555.78	100.56	15.31	470.37	455.05
6- 1	171.0	2.5	105.61	16.32	0.50	187.38	131.04	0.00	440.85	122.43	16.82	335.24	318.42
6- 2	171.0	2.5	116.05	18.48	0.00	164.20	122.73	0.00	421.46	134.53	18.48	305.41	286.93
6- 3	171.0	2.5	103.08	18.32	0.83	209.38	116.09	0.16	447.87	122.23	19.15	344.62	325.47
6- 4	171.0	3.0	109.94	21.64	1.16	193.15	108.74	0.33	434.98	132.75	22.81	324.71	301.90
7- 1	155.0	3.5	81.62	14.34	0.33	127.77	114.95	0.00	339.01	96.29	14.67	257.39	242.72
7- 2	155.0	3.0	75.60	15.65	0.00	120.43	93.92	0.00	305.61	91.25	15.65	230.01	214.35
7- 3	155.0	3.0	75.46	19.82	0.00	150.21	92.91	0.00	338.40	95.28	19.82	262.94	243.12
7- 4	155.0	3.0	82.29	23.83	0.33	122.93	117.45	0.00	346.85	106.46	24.17	264.55	240.38
8- 1	147.0	2.5	89.25	18.33	0.16	161.14	167.01	0.00	435.90	107.75	18.49	346.65	328.15
8- 2	147.0	2.0	71.27	16.00	0.00	190.05	104.97	0.00	382.30	87.27	16.00	311.03	295.03
8- 3	147.0	2.5	109.77	24.14	0.00	218.14	172.17	0.00	524.24	133.92	24.14	414.46	390.32
9- 1	125.0	3.5	78.49	9.82	0.00	176.52	154.69	0.00	419.53	88.32	9.82	341.03	331.21
9- 2	125.0	2.5	109.65	11.99	0.00	257.85	262.80	0.16	642.46	121.64	11.99	532.64	520.65
9- 3	125.0	2.5	99.99	8.49	0.00	199.23	225.21	0.16	533.10	108.49	8.49	432.94	424.44
9- 4	125.0	2.5	64.16	14.66	0.00	162.14	174.14	0.00	415.11	78.82	14.66	350.95	336.29
10- 1	108.0	2.5	31.65	10.82	0.00	109.65	170.81	2.83	325.78	42.48	10.82	291.29	280.47
10- 2	108.0	2.5	53.32	19.16	0.00	98.80	173.98	0.00	345.26	72.48	19.16	291.94	272.78
10- 3	108.0	2.5	15.15	2.33	0.00	72.32	70.81	0.00	160.62	17.49	2.33	145.47	143.13
10- 4	106.0	2.0	34.99	7.50	0.83	111.81	171.34	0.00	326.48	43.32	8.33	291.49	283.15
10- 5	106.0	2.5	27.49	9.33	0.00	95.65	173.58	0.16	306.22	36.82	9.33	278.56	269.23
10- 6	106.0	2.5	27.33	10.99	0.00	94.97	70.49	0.16	203.95	38.32	10.99	176.46	165.47
11- 1	86.0	2.3	64.13	3.66	0.00	226.02	69.30	0.00	363.12	67.79	3.66	298.99	295.32
11- 2	86.0	2.5	20.66	5.16	0.00	100.79	121.09	0.00	247.70	25.82	5.16	227.04	221.88
11- 3	86.0	2.0	22.32	0.83	0.00	88.47	38.97	0.50	151.09	23.15	0.83	128.27	127.44
11- 4	86.0	2.5	8.82	0.16	0.00	31.47	37.31	0.00	77.77	8.99	0.16	68.95	68.78
12- 1	71.0	2.5	37.82	11.99	0.00	108.96	69.15	0.00	227.94	49.82	11.99	190.11	178.12
12- 2	71.0	2.5	25.15	4.99	0.00	95.71	79.91	0.00	205.77	30.15	4.99	180.62	175.62
12- 3	71.0	2.5	32.64	7.32	0.00	110.47	133.30	0.00	283.74	39.97	7.32	251.10	243.77
12- 4	71.0	2.0	31.82	7.32	0.00	89.62	113.79	0.33	242.89	39.14	7.32	210.74	203.42
13- 1	46.0	2.8	21.15	1.99	0.00	93.97	47.98	0.00	165.10	23.14	1.99	143.94	141.95
13- 2	46.0	2.0	23.82	2.33	0.00	97.63	70.60	0.16	194.55	26.15	2.33	170.56	168.23
13- 3	46.0	4.2	24.16	2.33	0.00	58.80	53.79	0.00	139.09	26.49	2.33	114.93	112.60
13- 4	45.0	2.5	10.83	0.50	0.00	53.80	28.82	0.33	94.28	11.32	0.50	83.12	82.62
13- 5	43.0	2.5	29.32	3.83	0.00	81.14	60.14	0.00	174.44	33.15	3.83	145.12	141.29
13- 6	43.0	2.5	29.15	2.49	0.00	105.45	74.30	0.00	211.40	31.64	2.49	182.25	179.75
13- 7	43.0	1.8	21.48	4.16	0.00	76.45	58.97	0.00	161.06	25.64	4.16	139.58	135.42
13- 8	45.0	2.5	2.83	0.50	0.00	19.81	15.31	0.00	38.45	3.32	0.50	35.62	35.13
13- 9	45.0	2.3	14.99	0.00	0.00	39.47	13.13	0.00	67.60	14.99	0.00	52.60	52.60

ZOO-PLANKTON DATA IN ORGANISMS PER LITER
DEPTH IN FEET
1000 SPECIES CODE INDICATES COPEPODA
2000 INDICATES LIMNETIC CLADOCERA
3000 INDICATES LITTORAL CLADOCERA
4000 INDICATES BRACHIONIDAE ROTATORIA
5000 INDICATES ALL OTHER ROTATORIA FAMILIES
6000 INDICATES MISC.TAXA

Table 3. Arkansas River combined zooplankton data, 4-14-75 through 4-24-75.

ARKANSAS RIVER ZOOPLANKTON DATA

APRIL 14, 1975 THRU APRIL 24, 1975 SURVEY

STAT	RIVMI	DEPTH	1000	2000	3000	DENSITY 4000	5000	6000	TOTAL	1+2+3	2+3	2+3+4+5	4+5
1- 1	283.0	7.0	1.48	0.16	0.00	10.28	6.78	0.00	18.71	1.65	0.16	17.22	17.06
1- 2	283.0	6.0	4.99	0.00	0.00	25.46	9.91	0.00	40.37	4.99	0.00	35.37	35.37
1- 3	283.0	2.5	6.43	0.83	0.00	37.37	12.29	0.00	56.93	7.26	0.83	50.49	49.66
1- 4	283.0	3.0	9.28	0.82	0.00	72.08	6.13	0.00	88.32	10.10	0.82	79.04	78.21
2- 1	248.0	5.0	7.11	0.00	0.00	49.27	2.14	0.00	58.63	7.11	0.00	51.52	51.52
2- 2	248.0	6.0	9.42	0.33	0.00	63.76	2.97	0.00	76.49	9.75	0.33	67.07	66.74
2- 3	248.0	5.0	7.50	0.16	0.00	59.44	1.98	0.00	69.08	7.66	0.16	61.58	61.42
2- 4	248.0	5.0	8.62	0.16	0.00	76.98	3.15	0.00	88.91	8.78	0.16	80.29	80.13
3- 1	238.0	3.0	2.97	0.00	0.00	32.10	1.65	0.00	36.72	2.97	0.00	33.75	33.75
4- 1	199.0	2.5	7.60	0.50	0.00	67.75	3.96	0.00	79.81	8.10	0.50	72.21	71.71
4- 2	199.0	5.0	4.79	0.49	0.16	75.81	4.13	0.00	85.39	5.45	0.66	80.60	79.94
4- 3	199.0	4.0	5.81	0.00	0.00	83.87	9.76	0.16	99.61	5.81	0.00	93.64	93.64
4- 4	199.0	3.0	8.25	0.66	0.00	71.33	6.95	0.00	87.19	8.91	0.66	78.94	78.28
5- 1	189.0	2.0	7.63	1.32	0.00	70.79	3.97	0.00	83.72	8.96	1.32	76.08	74.76
5- 2	189.0	2.5	2.49	0.16	0.00	45.44	6.31	0.00	54.41	2.66	0.16	51.92	51.75
5- 3	189.0	4.0	3.14	0.99	0.00	87.02	14.60	0.00	105.75	4.13	0.99	102.61	101.62
5- 4	189.0	4.0	4.99	0.00	0.00	43.61	4.45	0.00	53.06	4.99	0.00	48.07	48.07
6- 1	171.0	4.0	7.12	0.16	0.33	61.88	4.29	0.00	73.79	7.61	0.49	66.67	66.18
6- 2	171.0	4.0	10.78	0.99	0.00	98.09	7.94	0.00	117.81	11.77	0.99	107.02	106.03
6- 3	171.0	2.0	9.16	0.00	0.00	74.82	3.65	0.00	87.63	9.16	0.00	78.47	78.47
6- 4	171.0	4.0	12.72	0.49	0.16	91.69	11.26	0.00	116.33	13.38	0.66	103.61	102.95
7- 1	155.0	2.0	7.43	0.83	0.00	91.43	2.65	0.00	102.34	8.26	0.83	94.91	94.08
7- 2	155.0	3.5	8.93	0.00	0.00	91.17	6.61	0.00	106.71	8.93	0.00	97.78	97.78
7- 3	155.0	6.0	10.43	0.00	0.00	100.68	7.81	0.00	118.91	10.43	0.00	108.49	108.49
7- 4	155.0	5.0	1.99	0.00	0.00	26.29	5.11	0.00	33.40	1.99	0.00	31.40	31.40
8- 1	147.0	3.0	8.59	0.83	0.00	59.10	7.93	0.00	76.46	9.42	0.83	67.87	67.04
8- 2	147.0	3.0	3.15	0.00	0.00	26.58	1.66	0.00	31.40	3.15	0.00	28.24	28.24
8- 3	147.0	4.0	5.75	0.49	0.00	45.90	11.11	0.00	63.26	6.25	0.49	57.50	57.01
9- 1	125.0	2.5	7.28	0.50	0.00	92.20	10.28	0.00	110.26	7.78	0.50	102.98	102.48
9- 2	125.0	2.5	9.93	0.50	0.00	158.91	19.86	0.00	189.20	10.43	0.50	179.27	178.77
9- 3	125.0	3.5	8.13	0.00	0.33	122.22	17.89	0.00	148.57	8.45	0.33	140.45	140.12
9- 4	125.0	3.5	11.26	0.82	0.00	74.49	1.15	0.00	87.73	12.08	0.82	76.47	75.65
10- 1	108.0	3.0	7.45	1.15	0.00	84.34	8.27	0.00	101.21	8.60	1.15	93.76	92.61
10- 2	108.0	2.5	8.12	2.31	0.00	137.08	19.01	0.00	166.52	10.43	2.31	158.40	156.09
10- 3	108.0	3.0	7.59	0.00	0.82	115.36	10.11	0.00	133.88	8.41	0.82	126.29	125.47
10- 4	108.0	2.5	12.54	0.66	0.49	149.30	21.35	0.00	184.35	13.69	1.15	171.81	170.66
10- 5	108.0	3.5	9.64	0.66	0.00	178.40	17.37	0.00	206.07	10.30	0.66	196.43	195.77
10- 6	108.0	3.0	11.05	0.33	1.32	180.63	17.50	0.00	210.84	12.71	1.65	199.79	198.13
11- 1	86.0	5.0	8.25	0.50	0.16	112.31	6.61	0.00	127.83	8.91	0.66	119.58	118.92
11- 2	86.0	2.5	10.39	0.00	0.16	121.86	9.41	0.00	141.83	10.56	0.16	131.44	131.27
11- 3	86.0	4.0	11.15	0.00	0.50	113.85	5.99	0.00	131.49	11.65	0.50	120.34	119.84
11- 4	86.0	3.5	8.49	0.16	0.99	177.96	11.14	0.00	198.76	9.65	1.16	190.26	189.10
12- 1	71.0	4.0	10.32	1.66	0.00	158.90	6.98	0.00	177.86	11.98	1.66	167.54	165.88
12- 2	71.0	3.5	8.14	0.00	0.00	121.82	4.82	0.00	134.78	8.14	0.00	126.64	126.64
12- 3	71.0	3.5	12.82	1.16	0.16	166.88	6.48	0.00	187.51	14.15	1.33	174.69	173.36
12- 4	71.0	4.0	6.15	2.65	0.83	145.04	10.14	0.00	164.83	9.64	3.48	158.67	155.19
13- 1	45.0	4.0	10.94	0.83	0.50	254.38	9.30	0.00	275.95	12.26	1.32	265.01	263.68
13- 2	45.0	3.0	11.49	0.99	0.50	161.30	15.81	0.00	190.10	12.98	1.49	178.61	177.12
13- 3	45.0	3.0	8.65	0.66	0.50	189.57	8.15	0.00	207.53	9.81	1.15	198.88	197.72
13- 4	45.0	4.0	25.48	0.00	0.00	295.07	12.98	0.00	333.53	25.48	0.00	308.05	308.05
13- 5	45.0	4.0	11.82	0.00	0.00	160.59	5.49	0.00	177.90	11.82	0.00	166.08	166.08
13- 6	45.0	3.5	11.82	0.50	0.00	172.42	7.82	0.00	192.55	12.31	0.50	180.73	180.24
13- 7	45.0	3.0	6.32	1.66	0.00	173.40	4.15	0.16	185.71	7.99	1.66	179.22	177.56
13- 8	45.0	4.5	18.16	0.00	0.00	285.33	6.81	0.00	310.31	18.16	0.00	292.14	292.14
13- 9	45.0	3.5	9.65	0.00	0.00	248.41	7.80	0.00	265.87	9.65	0.00	256.22	256.22
13-10	45.0	10.0	7.48	0.66	0.83	144.92	12.64	0.00	166.54	8.97	1.49	159.05	157.56

ZOO-PLANKTON DATA IN ORGANISMS PER LITER
DEPTH IN FEET
1000 SPECIES CODE INDICATES COPEPODA
2000 INDICATES LIMNETIC CLADOCERA
3000 INDICATES LITTURAL CLADOCERA
4000 INDICATES BRACHIONIDAE ROTATURIA
5000 INDICATES ALL OTHER ROTATORIA FAMILIES
6000 INDICATES MISC. TAXA