Population dynamics of rotifers and some factors affecting their populations in Canyon Ferry Reservoir, Montana
by Gerald Lynn Kaiser

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Botany
Montana State University

Abstract:
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Finite birth rates, birth rates, population change, and death rates were calculated for populations of Polyarthra vulgaris, Keratella cochlearis, K. quadrata and Kellicottia longispina. Finite birth rates were strongly correlated with temperature. Birth rates were often correlated with extinction coefficients, temperature and to a lesser extent chlorophyll concentrations, and phytoplankton standing crops. There werq strong correlations between abundance of Daphnia spp. and Diaptomus leptopus and rate of rotifer mortality due to interspecific competition. The correlations between phytoplankton standing crop and rotifer mortality were attributed to Myxophyceaen "blooms". The latter suggests the Myxophyceae have an inhibitory effect on the rotifer community. Correlations with Cyclops bicuspidatus and Asplanchna priodonta versus mortality rates of totifers indicated the predators preferred the illoricate forms; some predation was observed to affect Keratella cochlearis.

It was concluded that mechanisms controlling a rotifer community are primarily temperature, competition, antibiosis, and to a lesser extent predation.

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AFFECTING THEIR POPULATIONS IN
CANYON FERRY RESERVOIR, MONTANA

by

GERALD LYNN KAISER

A thesis submitted to the Graduate Faculty in partial
fulfillment of the requirements for the degree

of

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in

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Approved:

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Chairman, Examining Committee

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ABSTRACT

Zooplankton and phytoplankton collections were taken biweekly and weekly in 1957 and 1958, respectively. A total of 58 samples were taken from one station in Canyon Ferry Reservoir.

In earlier papers, on Canyon Ferry, Dr. J. C. Wright discussed primary production and the population dynamics of *Daphnia schodleri*. However, the rotifer community was not discussed.

Finite birth rates, birth rates, population change, and death rates were calculated for populations of *Polyarthra vulgaris*, *Keratella cochlearis*, *K. quadrata* and *Kellicottia longispina*. Finite birth rates were strongly correlated with temperature. Birth rates were often correlated with extinction coefficients, temperature and to a lesser extent chlorophyll concentrations, and phytoplankton standing crops. There were strong correlations between abundance of *Daphnia* spp. and *Diaptomus leptopus* and rate of rotifer mortality due to interspecific competition. The correlations between phytoplankton standing crop and rotifer mortality were attributed to Myxophyceaen "blooms". The latter suggests the Myxophyceae have an inhibitory effect on the rotifer community. Correlations with *Cyclops bicuspidatus* and *Asplanchna priodonta* versus mortality rates of rotifers indicated the predators preferred the illoricate forms; some predation was observed to affect *Keratella cochlearis*.

It was concluded that mechanisms controlling a rotifer community are primarily temperature, competition, antibiosis, and to a lesser extent predation.

INTRODUCTION

This paper describes a study of rotifer populations and some plausible factors affecting their populations in Canyon Ferry Reservoir, a Missouri River impoundment. Previous limnological studies on Canyon Ferry have been carried out by Wright (1958, 1960, 1961 and 1965). A follow-up study is currently in progress.

Similar studies in Lake Francis Case and Lewis and Clark Lake, two Missouri River impoundments, revealed the occurrence of populations of *Asplanchna priodonta*, *Polyarthra vulgaris*, and *Keratella cochlearis* (Cowell, 1970). Williams (1966) observed that *Polyarthra* spp. and *Keratella* spp. are among the dominant rotifers found in major waterways of the United States.

In Lake Ashtabula reservoir, North Dakota, rotifers were observed to have a bimodal cycle, (Knutson, 1970). Beach (1960) also observed bimodal cycles with pulses occurring in early and late summer.

Edmondson (1960, 1965) observed that reproduction of rotifer populations is strongly influenced by food supply and temperature. Predation on rotifers by the predaceous rotifer *Asplanchna priodonta* has been observed by Edmondson (1946) and Nelson and Edmondson (1955).

Phytoplankton may have inhibitory effects on rotifer populations. Ryther (1954) observed inhibitory effects of phytoplankton on a population of *Daphnia magna*. Phytoplankton present may or may not represent the food of the zooplankton (Hazelwood and Parker, 1963).

Lund (1969) points out that one of the reasons blue-green algae are so often the dominant algae in the plankton is their relative freedom from grazing, compared to smaller green algae.

Rotifer populations may also be suppressed by competition. In an open water system, Brooks and Dodson (1965) found the following relations to prevail.

> "(1) Planktonic herbivores all compete for the fine particulate matter (1 µ to 15 µ in length) of the open waters.
>
> (2) Larger zooplankters compete more efficiently and can also take larger particles.
>
> (3) When predation is of low intensity, the small planktonic herbivores will be competitively eliminated by large forms (dominance of Cladocera and Calanoid copepods)."

The objectives of this study were to determine the mechanisms that influence population control in rotifer communities.

DESCRIPTION OF THE STUDY AREA

Canyon Ferry Dam is located 24 km east of Helena, Montana (Fig. 1). Canyon Ferry Reservoir was formed by the closure of Canyon Ferry Dam in 1953. It was constructed by the Bureau of Reclamation and is the uppermost impoundment on the Missouri River. Canyon Ferry attained operating levels in 1955. The reservoir is approximately 40 km long with a mean width of 1.3 km. At maximum operating pool level (1155 meters m.s.l.) the reservoir has a capacity of $25.3 \times 10^8 m^3$, a surface area of $14.1 \times 10^7 m^2$, with a maximum depth of 49.5 m and a mean depth of 18.1 m.

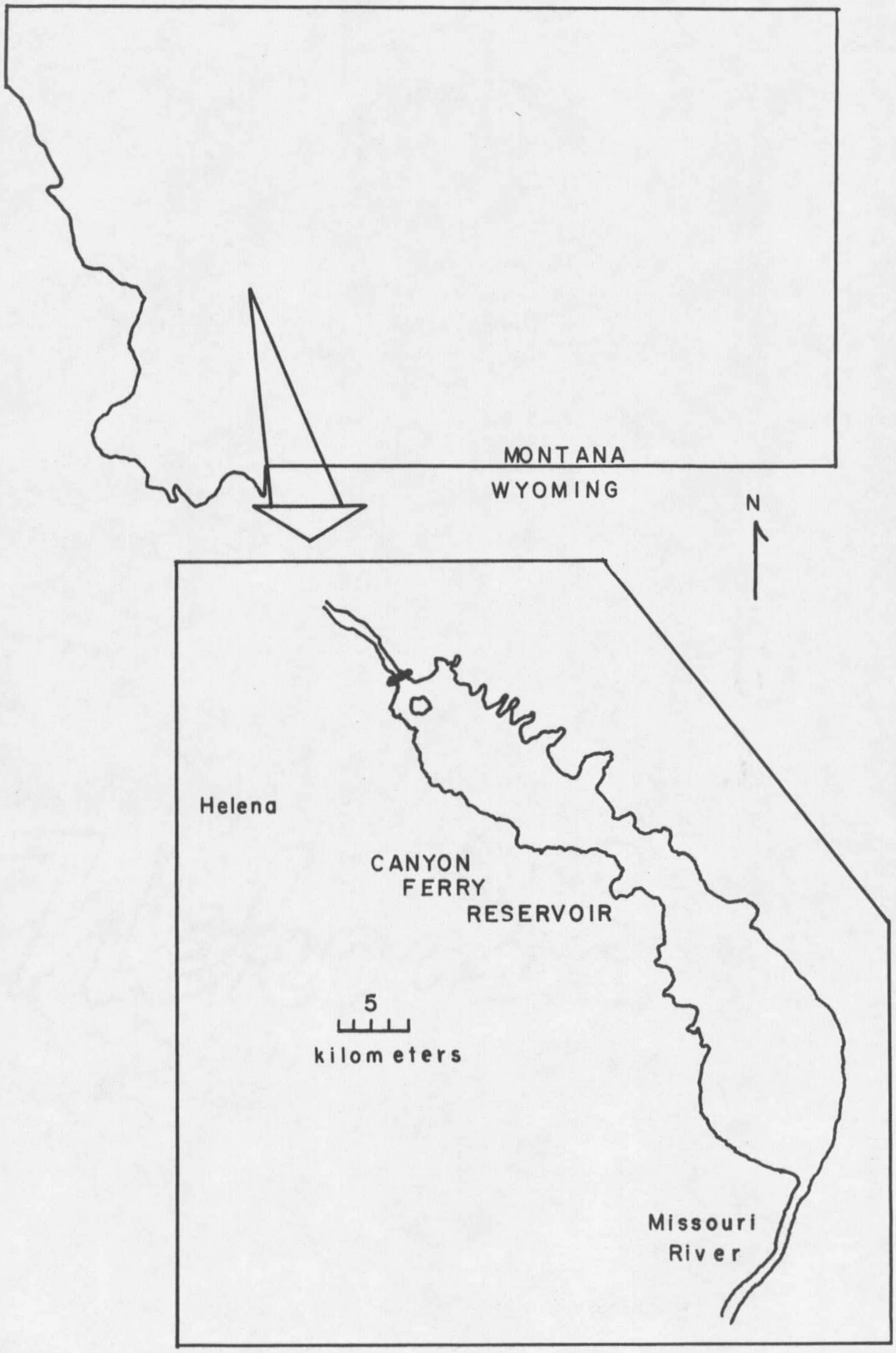

Fig. 1. Map of the study area, Canyon Ferry Reservoir, Montana.

MATERIALS AND METHODS

Zooplankton samples were collected by Dr. J. C. Wright in 1958 and 1959. Oblique tows were made with a Clarke-Bumpus plankton sampler using a No. 10 net. On each sampling date a tow was made through the euphotic zone to the surface and from the bottom (43 m) to the surface. All tows were made in the center of the reservoir at a station near the dam (Wright, 1965).

The samples from the euphotic zone were used for rotifer counts. The rotifers were identified to genus and species using a 60X binocular microscope and according to Edmondson (1959). Aliquots of 3 ml were placed in a modified rotary counting chamber (Ward, 1955). To attain statistical validity a minimum of 15 ml was counted (Lund, personal communication).

Calculations of the population dynamics follow Edmondson (1960). Rotifer egg duration times are from Edmondson (1965). Finite birth rate (B) was then calculated as follows: $B = E/DN$ where E = number of eggs, D = egg duration, and N = population size. Instantaneous birth rate (b) was then calculated from the following equation: $b = \ln (B + 1)$. Instantaneous rate of increase (r) was obtained from the following: $N_t = N_o e^{rt}$ where N_o = initial population and N_t the population after time t. Therefore, knowing b and r the death rate (d) may be calculated from the following relationship: $r = b - d$.

Statistics reported in this thesis follow standard procedures of Snedecor and Cochran (1967). The multiple linear regression analysis program was provided by Dr. R. E. Lund, Mathematics Department, Montana State University.

RESULTS

In decreasing order of abundance the six most common rotifers in 1957, were: Asplanchna priodonta, Polyarthra vulgaris, Keratella cochlearis, Anuraeopsis sp., Keratella quadrata, and Ascomorpha sp. For 1958, the following six genera were the most abundant: Polyarthra vulgaris, Asplanchna priodonta, Keratella cochlearis, K. quadrata, Ascomorpha sp. and Kellicottia longispina (see appendix, Table XXI).

POLYARTHRA VULGARIS

In 1957, the population was bimodal in appearance. The first peak occurred in mid-June, and the following peak in early July (Fig. 2). The decline in numbers of P. vulgaris at the end of June coincides with the decline of phytoplankton standing crop and phosphate concentrations (see appendix, Table XXII). After the second pulse in July the population declined and never recovered (Fig. 2).

Numbers per liter of P. vulgaris were positively correlated with numbers per liter of other rotifers and negatively correlated with phosphate concentrations (Table I).

Death rate was positively correlated with temperature, phytoplankton standing crop, abundance of Daphnia spp. and copepodids (Table I).

Finite birth rates were positively correlated with temperature and negatively correlated with the abundance of predaceous zooplankton (Table I). Finite birth rate demonstrated a lag phase response to the

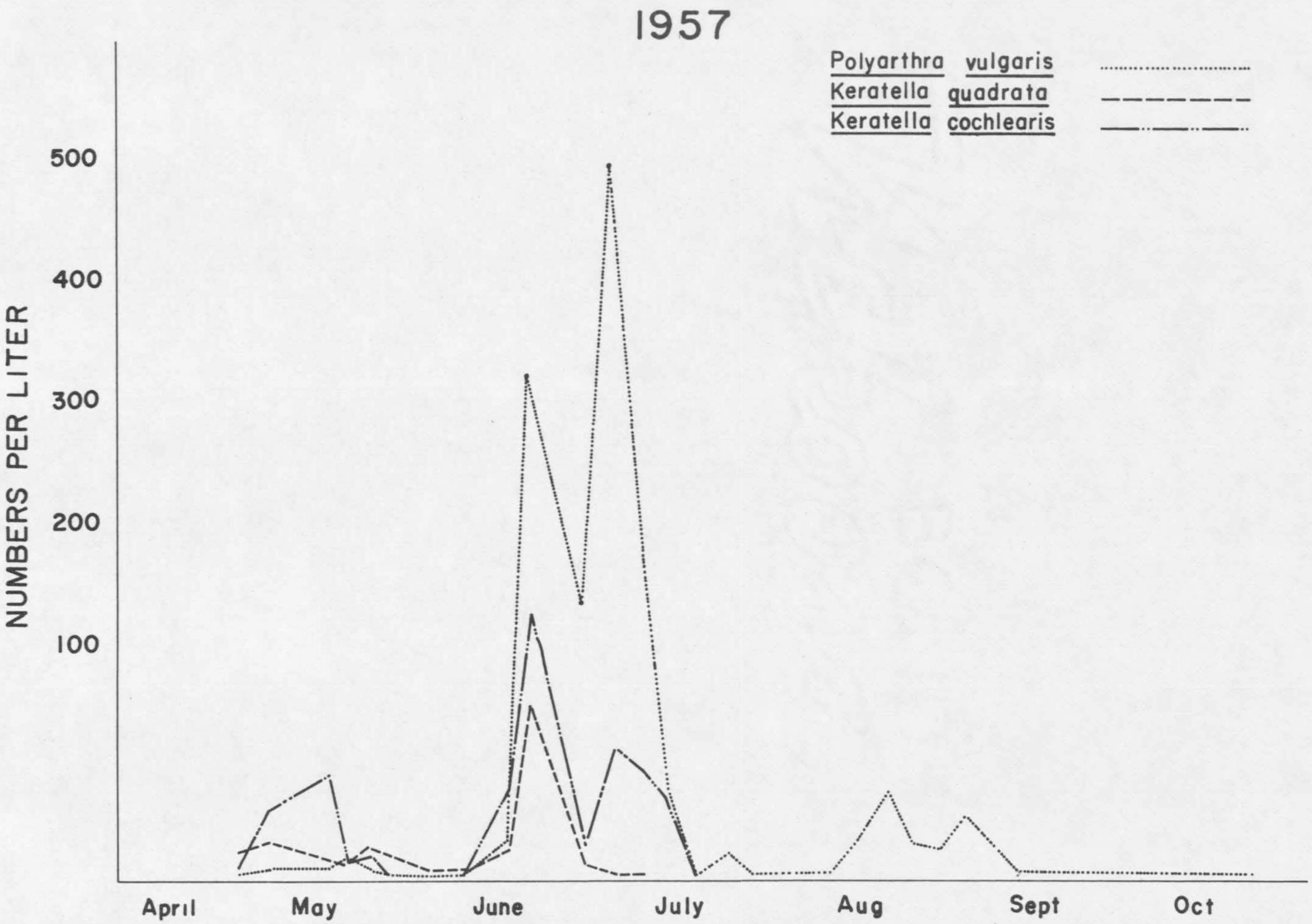

Fig. 2. Fluctuations of rotifer populations for the sampling period of 1957.

Table I. Correlation coefficients (r) for *Polyarthra vulgaris*, 1957.

Independent Variables	Dependent Variables				
	Numbers/Liter	b	r	d	B
Phosphate mg/l	-.2934*	.3133**	.2957	-.2427	-.1243
Extinction coefficient m^{-1}	-.1030	-.2092	-.2139	.1599	-.0841
Temperature C	.1095	.0084	-.2697	.3163*	.3049*
Chlorophyll mg/m^3	.1298	.0920	-.1437	.2028	.1739
Phytoplankton standing crop mm^3/l.	.0905	-.2049	-.3403*	.3377*	-.0979
Rhodomonas sp. mm^3/l	.0325	-.1595	-.1516	.1201	-.0525
Cryptomonas sp. mm^3/l	.1458	.0422	.0206	.0006	.0190
Rhodomonas sp. + *Cryptomonas* sp. mm^3/l	.1467	.0362	.0149	.0051	.0209
Daphnia galeata + *D. schodleri* #/l	.1272	.0177	-.2664	.3068*	.0260
Diaptomus leptopus #/l	-.2448	.1266	-.0795	.1249	.0383
Daphnia spp. + *Diaptomus l.* #/l	.0950	.0370	-.2867*	.3351*	.0325
Nauplii #/l	-.0032	.0157	-.1082	.1275	-.4656***

Table I. (Cont'd)

Independent Variables	Dependent Variables				
	Numbers/Liter	b	r	d	B
Copepodids #/1	-.0912	.0923	-.2625	.3175*	-.1860
Adult *Cyclops* #/1	-.0079	.1324	-.0819	.1291	-.0694
Copepodids + Adult *Cyclops* #/1	-.0865	.1113	-.1320	.1800	-.3654**
Asplanchna priodonta #/1	-.1468	.1585	-.1173	.1754	-.1108
Copepodids + Adult *Cyclops* + *Asplanchna*	-.0996	.1220	-.1303	.1807	-.3781**
Keratella cochlearis #/1	.7137***	-.3354*	-.0881	.0245	-.1108
Keratella quadrata #/1	.4483***	-.0721	-.0154	.0084	-.1550

* Significance level 10%

** Significance level 5%

*** Significance level 1%

Degrees of Freedom N-2 = 33

abundance of Cryptomonas sp. (Fig. 3).

In 1958, numbers per liter of P. vulgaris were correlated with phytoplankton standing crop and the abundance of Keratella cochlearis and Kellicottia longispina (Table II).

Birth rates were negatively correlated with phosphate concentration and the abundance of Keratella cochlearis. Birth rates were also positively correlated with the abundance of Rhodomonas sp., Cryptomonas sp., and numbers per liter of predaceous zooplankton (Table II).

Death rates were negatively correlated with food abundance, and positively correlated with the abundance of predaceous zooplankton and Keratella quadrata (Table II). In other words, as food declined and as the number of predators increased a corresponding increase in the death rate of P. vulgaris occurred.

In 1958, no significant correlations were observed for the finite birth of P. vulgaris (Table II).

Simple correlation coefficients obtained by combining all data indicated that predaceous zooplankton, Daphnia spp., and food scarcity enhanced the death rate of P. vulgaris (see appendix, Table XI).

Multiple linear regression analysis of the variables affecting death rate, birth rate and finite birth rate of P. vulgaris are not presented because of low R^2 values.

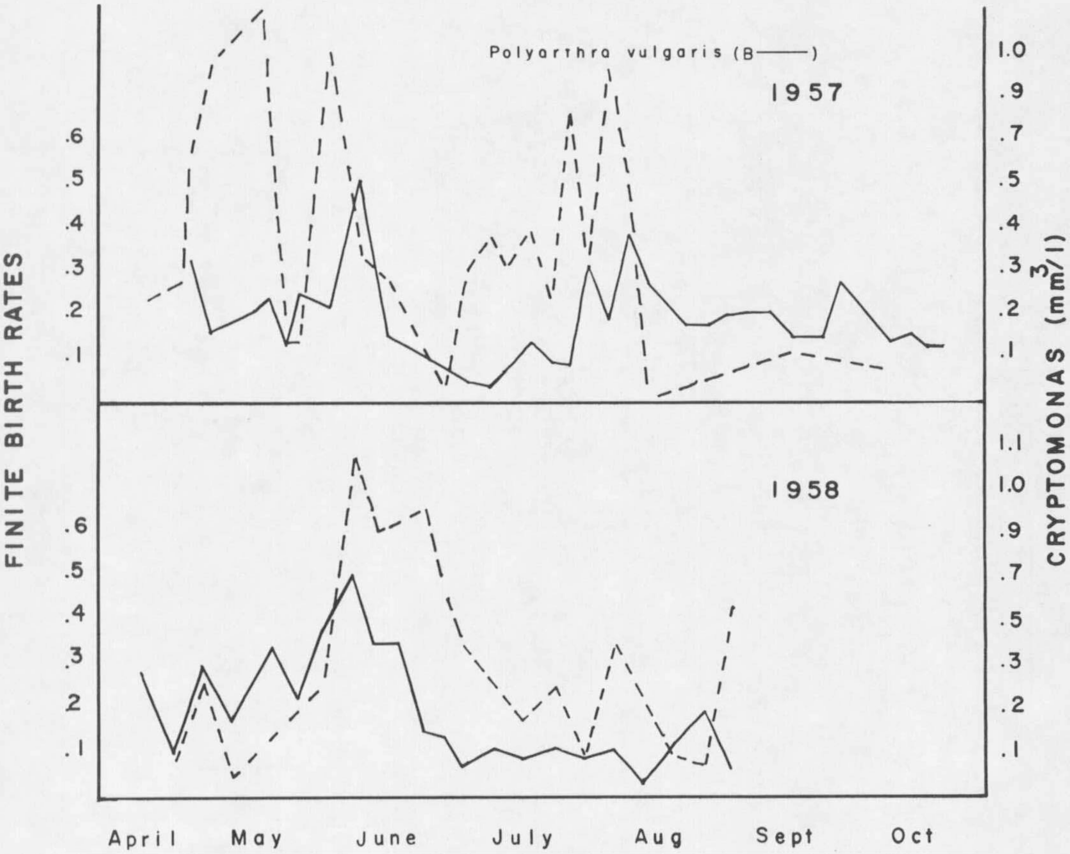

Fig. 3. Finite birth rates of <u>Polyarthra vulgaris</u> versus the abundance of <u>Cryptomonas</u> sp.

Table II. Correlation coefficients (r) for *Polyarthra vulgaris*, 1958.

Independent Variables	Dependent Variables				
	Numbers/Liter	b	r	d	B
Phosphate mg/1	.0592	-.3672*	-.1806	-.0547	.2280
Extinction coefficient m^{-1}	.2177	-.2820	-.7053***	-.0204	.1617
Temperature C	.2856	-.1314	-.0064	.0260	.2821
Chlorophyll mg/m^3	-.2259	.2877	.4567***	-.1638	-.0550
Phytoplankton standing crop $mm^3/1$	.4693**	-.2290	.0127	.1024	-.0004
Rhodomonas sp. $mm^3/1$	.1236	.3503**	.5808***	-.5944***	.0276
Cryptomonas sp. $mm^3/1$	-.0234	.4015*	.5706***	-.4330**	-.0788
Rhodomonas + *Cryptomonas* $mm^3/1$	-.0538	.4315**	.6362***	-.5253***	-.0579
Daphnia galeata + *D. schodleri* #/1	.1863	.2039	.2962	.1574	-.0834
Diaptomus leptopus #/1	-.0956	.0608	-.2110	.2481	-.0023
Daphnia spp. + *Diaptomus l.* #/1	-.0252	.1235	-.0938	.2788	-.0298
Nauplii #/1	-.0790	.3390	.2397	-.0641	.1724

Table II. (Cont'd)

Independent Variables	Dependent Variables Numbers/Liter	b	r	d	B
Copepodids #/1	-.1155	.5234**	-.0157	.3136	-.0109
Adult _Cyclops_ #/1	.1011	.3976*	.2230	.0300	.1627
Copepodids + Adult _Cyclops_ #/1	-.0979	.5309***	.0082	.2969	.0057
Asplanchna priodonta #/1	-.3134	.5508***	-.0553	.2428	.2815
Copepodids + Adult _Cyclops_ + _Asplanchna_ #/1	-.2071	.6666***	-.0149	.3469*	.1166
Keratella cochlearis #/1	.7759***	-.3486*	-.1959	.1843	-.0822
Keratella quadrata #/1	-.0707	.1940	-.1889	.3496*	.0574
Kellicottia longispina #/1	.5202***	-.1353	.2152	.1333	-.3004

* Significance level 10%

** Significance level 5%

*** Significance level 1%

Degrees of Freedom N-2 = 21

KERATELLA COCHLEARIS

Correlation coefficients of *K. cochlearis* given in Tables III and IV show that numbers per liter of *K. cochlearis* were positively correlated with the abundance of *Cryptomonas* sp., chlorophyll, *Daphnia* spp., *Polyarthra vulgaris* and *Keratella quadrata*. Abundance of *K. cochlearis* was negatively correlated with phosphate concentration, extinction coefficient, and *Diaptomus leptopus* abundance (Table III).

The 1957 population peak (123 organisms/liter) of *K. cochlearis* occurred on 19 June (Fig. 2). In 1958, the population peak of 539 organisms per liter occurred on 9 July (Fig. 4). During 1958, the population of *K. cochlearis* did not decline as rapidly as in 1957 (Fig.s 2 and 4). The large numbers of *K. cochlearis* found in 1958 followed a trend similar to that of all the major species, that is, of more rotifers per liter in 1958 than in 1957.

Birth, death, and finite birth rates were positively correlated with temperature in 1957 (Table III). Birth rates were positively correlated with extinction and the abundance of *Diaptomus leptopus*. Negative correlations were observed between birth rate versus the abundance of *K. quadrata*, and finite birth rate versus nauplii abundance.

Table III. Correlation coefficients (r) for *Keratella cochlearis*, 1957.

Independent Variables	Dependent Variables				
	Numbers/Liter	b	r	d	B
Phosphate mg/l	-.2965*	.1666	.1154	-.0391	-.1191
Extinction Coefficient m^{-1}	-.3378*	.4671***	-.0074	.1833	.1390
Temperature C	-.1043	.5474***	-.1087	.3396*	.3521**
Chlorophyll mg/m^3	.2889*	-.1414	-.1962	.1467	.1494
Phytoplankton standing crop mm^3/l	.0649	.0615	-.1129	.1446	-.0801
Rhodomonas sp. mm^3/l	-.1476	.2389	-.1390	.2317	.0819
Cryptomonas sp. mm^3/l	.3328*	-.2742	-.0790	-.0177	-.0081
Rhodomonas + *Cryptomonas* mm^3/l	.3265	-.2647	-.0840	-.0090	-.0050
Daphnia galeata + *D. schodleri* #/l	.3852**	-.2107	-.3253*	.2463	.0040
Diaptomus leptopus #/l	-.3144*	.4824***	-.1772	.3693**	.0787
Daphnia spp. + *Diaptomus l*.#/l	.3510**	-.1461	-.3620**	.3089*	.0158
Nauplii #/l	.2216	-.2289	-.3457**	.2256	-.4822***

Table III. (Cont'd)

Independent Variables	Dependent Variables				
	Numbers/Liter	b	r	d	B
Copepodids #/1	-.0221	-.2236	-.3533**	.2619	-.2069
Adult *Cyclops* #/1	.0642	-.2101	-.0598	-.0163	-.0942
Copepodids + Adult *Cyclops* #/1	.0012	-.2409	-.2829*	.1876	-.1688
Asplanchna priodonta #/1	-.0632	-.1772	-.2824*	.2119	-.2089
Copepodids + Adult *Cyclops* + *Asplanchna* #/1	-.0118	-.2314	-.2869*	.1953	-.1794
Polyarthra vulgaris #/1	.7137***	-.1909	-.0572	-.0119	.0677
Keratella quadrata #/1	.8093***	-.3765**	-.1532	.0086	-.1828

* Significance level 10%

** Significance level 5%

*** Significance level 1%

Degrees of Freedom N-2 = 33

Table IV. Correlation coefficients (r) for Keratella cochlearis, 1958.

Independent Variables	Dependent Variables Numbers/Liter	b	r	d	B
Phosphate mg/l	.2343	.1513	-.2925	.3595*	.2699
Extinction coefficient m^{-1}	.2006	.4849**	-.1865	.3341	.2119
Temperature C	.2823	.4376**	-.2034	.3868*	.3236
Chlorophyll mg/m^3	-.0880	.5666***	.2925	-.1787	-.0452
Phytoplankton standing crop mm^3/l	.6458***	.3545*	.0800	.0735	.0359
Rhodomonas sp. mm^3/l	-.0659	.3024	.3740*	-.3123	.0199
Cryptomonas sp. mm^3/l	-.0119	.7193***	.5828***	-.4067*	-.0732
Rhodomonas sp. + Cryptomonas sp. mm^3/l	-.0283	.6827***	.5890***	-.4253**	-.0554
Daphnia galeata + D. schodleri #/l	.1558	.4035*	.0951	.1152	-.0790
Diaptomus leptopus #/l	-.0907	-.2125	-.4587**	.4500**	-.0170
Daphnia spp. + Diaptomus l. #/l	-.0385	-.0594	-.3868*	.4489**	-.0418
Nauplii #/l	-.0754	-.0776	.3173	-.3473	.1500

Table IV. (Cont'd)

Independent Variables	Dependent Variables				
	Numbers/Liter	b	r	d	B
Copepodids #/1	-.1403	-.0303	-.1936	.2474	-.0499
Adult Cyclops #/1	.0187	-.0884	.0091	.0360	.1352
Copepodids + Adult Cyclops #/1	-.1294	-.0374	-.1806	.2357	-.0336
Asplanchna priodonta #/1	-.3455	-.2340	.2124	-.2948	.2394
Copepodids + Adult Cyclops + Asplanchna	-.2464	-.1244	-.0679	.0817	.0666
Polyarthra vulgaris	.7777***	.2032	-.0560	.1812	-.1620
Keratella quadrata	-.0826	-.2179	-.3829*	.3782*	.0351
Kellicottia longispina	.5738**	.5045**	.0661	.0988	-.2404

* Significance level 10%

** Significance level 5%

*** Significance level 1%

Degrees of Freedom N-2 = 21

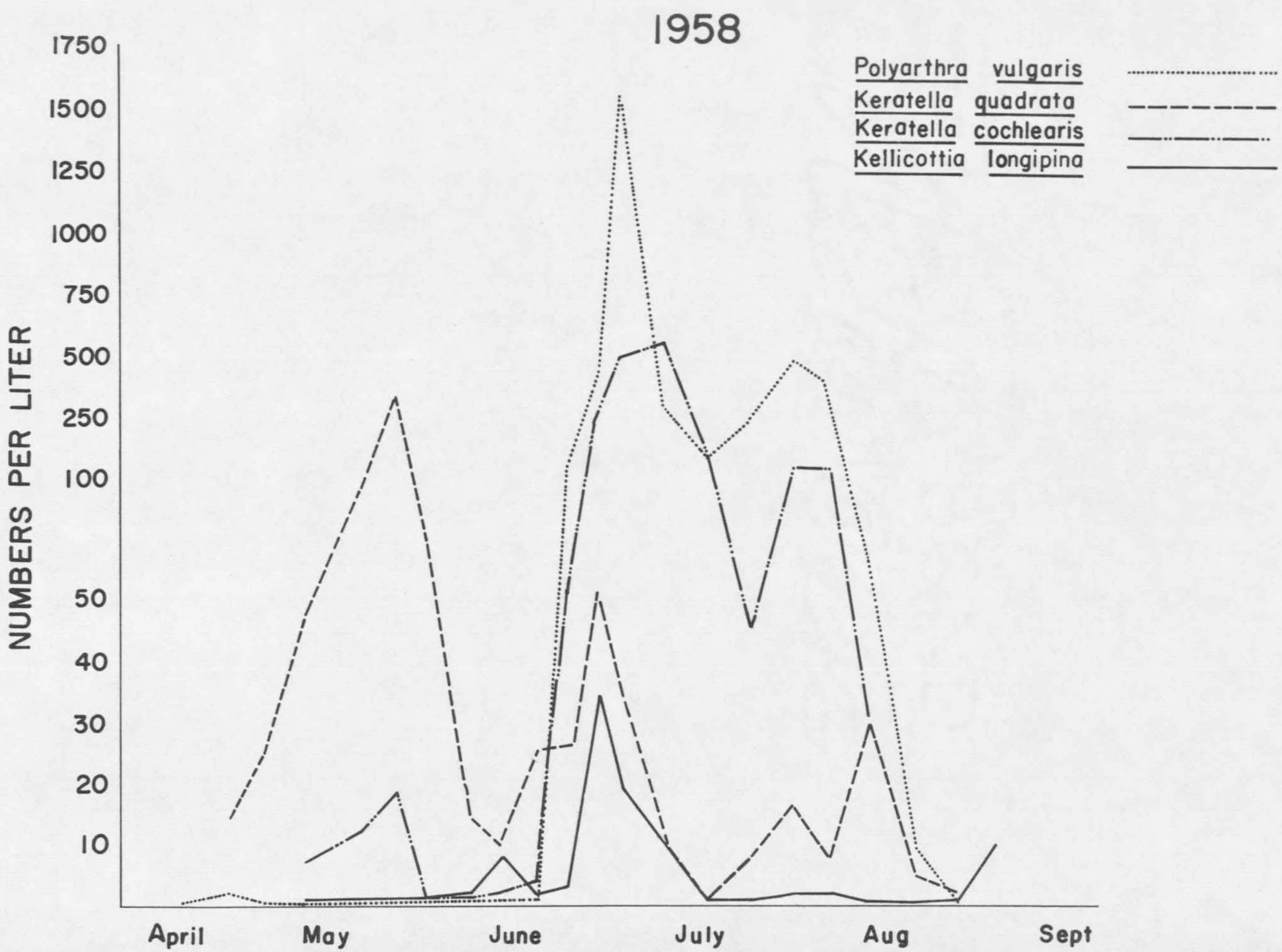

Fig. 4. Fluctuations of rotifer populations for the sampling period of 1958.

In 1958, the abundance of *K. cochlearis* was positively correlated with phytoplankton standing crop and the abundance of *Polyarthra vulgaris* and *Kellicottia longispina* (Table IV).

Birth rates were positively correlated with extinction, temperature, phytoplankton standing crop, chlorophyll, abundance of *Cryptomonas* sp., *Daphnia* spp., and *Kellicottia longispina* (Table IV).

Death rates were positively correlated with phosphate concentration, temperature, abundance of *Diaptomus leptopus* and *Keretella cochlearis*. A negative correlation was obtained with death rates versus the abundance of *Cryptomonas* sp. (Table IV).

No significant correlations were found with finite birth rate.

Simple correlation values for both years showed that the most significant correlations were the effect of temperature and the abundance of *Daphnia* spp., plus *Diaptomus leptopus* on death rates of *K. cochlearis*.

The multiple linear regression equation best explaining the observed variation in birth rates of *K. cochlearis* is as follows:

$$b = -0.072 + 0.008T + .424k + 0.003C \qquad R^2 = 0.52 \qquad (1)$$

Where T = temperature (C)
k = extinction coefficient (m^{-1})
C = chlorophyll (mg/m^3)

The R^2 value of 0.52 for 1958 was the best value obtained for either year and using all combinations of independent variables. Factors in decreasing order of significance were: chlorophyll (r = 0.57; P = .01), extinction coefficient (r = 0.48; P = .01) and temperature (r = 0.44; P = .05). The R^2 values for death rate and finite birth rate were not significant.

KERATELLA QUADRATA

On 19 June 1957, K. quadrata reached a maximum of 72 organisms per liter (Fig. 2). This maximum occurred after the decline of Cyclops bicuspidatus (see appendix, Table XIX). Numbers per liter of K. quadrata were positively correlated with the abundance of Cryptomonas sp., Daphnia spp., and the other major species of rotifers (Table V).

A negative correlation between the birth rate of K. quadrata and Rhodomonas sp. and Cryptomonas sp. was observed. A negative correlation also existed between the birth rate of K. quadrata and the abundance of Keratella cochlearis (Table V).

Death rate was negatively correlated with phosphate concentration, and positively correlated with Diaptomus leptopus (Table V).

Finite birth rate was positively correlated with temperature, and negatively correlated with the abundance of nauplii (Table V). These two correlations were also noted for P. vulgaris in 1957.

K. quadrata attained a maximum of 327 organisms per liter in 1958. Numbers per liter were positively correlated with herbivorous and predaceous zooplankton (Table VI). A negative correlation was

Table V. Correlation coefficients (r) for *Keratella quadrata*, 1957.

Independent Variables	Dependent Variables: Numbers/Liter	b	r	d	B
Phosphate mg/1	-.2360	.2885*	.5201***	-.2988*	-.1049
Extinction coefficient m^{-1}	-.4450***	.5508***	-.0515	.3644**	.1582
Temperature C	-.1712	.4209**	-.1021	.3511**	.3463***
Chlorophyll mg/m^3	.2317	.0208	-.0578	.0752	.1700
Phytoplankton standing crop $mm^3/1$	-.0065	.2906*	-.0215	.2012	-.0517
Rhodomonas sp. $mm^3/1$	-.1386	-.0434	-.2427	.1986	.0535
Cryptomonas sp. $mm^3/1$	.4858***	-.2862*	-.1159	-.0575	-.0172
Rhodomonas sp. + *Cryptomonas* sp. $mm^3/1$	.4794***	-.2871*	-.1247	-.0500	-.0150
Daphnia galeata + *D. schodleri* #/1	.4761***	-.2702	-.1902	.0205	-.0069
Diaptomus leptopus #/1	-.2689	.4363**	-.0832	.3399**	.0843
Daphnia spp. + *Diaptomus l.* #/1	.4516***	-.2142	-.2086	.0715	.0053
Nauplii #/1	.0872	-.1729	.0177	-.1110	-.4752***

Table V. (Cont'd)

Independent Variables	Numbers/Liter	b	r	d	B
	Dependent Variables				
Copepodids #/1	.1664	-.2140	-.0308	-.0957	-.2111
Adult *Cyclops* #/1	.1457	-.1562	.0700	-.1542	-.0929
Asplanchna priodonta #/1	.0381	.1228	.2413	-.1461	-.0608
Copepodids + Adult *Cyclops* + *Asplanchna*	.1436	-.1357	.0641	-.1362	-.1450
Polyarthra vulgaris #/1	.4483***	-.2193	-.1126	-.0236	.0627
Keratella cochlearis #/1	.8093***	-.3072*	-.1274	-.0613	-.1266

* Significance level 10%

** Significance level 5%

*** Significance level 1%

Degrees of Freedom N-2 = 33