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Title: REPRODUCTIVE RATES OF COPEPODS IN EXPERIMENTAL PONDS IN OREGON

Abstract approved: Redacted for privacy
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Rates of birth, death and population change were calculated for *Cyclops* sp. and *Diaptomus forbesi* in Soap Creek Ponds V-VIII near Corvallis, Oregon during the interval April, 1968 to April, 1969. An egg ratio method was used in calculating these rates. Duration of development of the eggs of both species was determined in the laboratory and found to be highly correlated with water temperature. Even though the ponds are adjacently located and morphometrically very similar, significant differences in birth rates and population densities between ponds were noted. Eggs were collected most frequently in pond VI for *Cyclops* sp. and in ponds VII and VIII for *D. forbesi*. Consequently, populations of each species were most stable in these respective ponds. Predation by small fishes was probably the main cause of zooplankton mortality in all four ponds.

Reproductive Rates of Copepods in Experimental Ponds in Oregon

by

Ronald Lee Lindland

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure | Page

REPRODUCTIVE RATES OF COPEPODS IN EXPERIMENTAL PONDS IN OREGON

INTRODUCTION

The literature on reproductive rates of copepods in freshwater ponds is not extensive. Edmondson (1960) was the first to discuss in detail the egg ratio method of determining reproductive rates in zooplankton. The advantages and disadvantages of this method as applied specifically to copepods were discussed by Edmondson, Comita, and Anderson (1962). Hutchinson (1967) gives a general review of the egg ratio method and its uses.

Previous investigations have shown that temperature and phytoplankton abundance are the two most important factors influencing reproductive rates in zooplankton populations. Ewers (1930) and Coker (1934) showed that temperature is the most influential factor in determining rate of egg development in several species of *Cyclops*. Edmondson *et al.* (1962) found that increases in phytoplankton density tended to be accompanied by, or followed by, increases in birth rates of three species of *Diaptomus*. Wright (1965) found that birth rates of *Daphnia schodleri* were significantly correlated with chlorophyll concentration. Food supply has also been shown to have some effect on number of eggs per egg sac in copepods

(Ewers, 1936) and per brood in Daphnia (Hall, 1964). Hall (1964), however, found that for each temperature condition the food level had no observable effect on reproduction in Daphnia.

Other environmental factors which may have some effect on reproduction in copepods are living space, dissolved oxygen and carbon dioxide content of the water, and bacteria present in the water (Ewers, 1930).

The intent of this study was to investigate reproductive rates of copepods occurring in typical western Oregon farm ponds, and to evaluate the usefulness of zooplankton reproductive rates as indicators of environmental differences between ponds. The Soap Creek Ponds were chosen for this study because they are considered typical and because of their convenient location. Both quantitative and qualitative plankton samples have been taken from these ponds in conjunction with various studies concerning fish production (McIntire, 1960; Goodwin, 1967). In the previous studies, no attempts were made to explain the observed changes in zooplankton populations.

The effects of differences in water temperature, basic water chemistry and primary productivity on copepod reproductive rates were examined. Because fertilization schedules and estimates of fish populations were also known for each of the ponds (Stolte, 1969), an attempt was made to relate these variables to changes and/or differences in copepod reproductive rates.

STUDY AREA

The experimental ponds utilized in this study are located about seven miles north of Corvallis on Oregon State University land near Soap Creek. Four of the eight ponds at the site were constructed in 1958; the other four being constructed in 1962. Only ponds V through VIII (constructed in 1962) were used in this study. The ponds are rectangular in shape with bottoms sloping from west to east. Table 1 lists some morphometric features of each pond. Water for the ponds comes principally from runoff, but supplementary water can be pumped in from Soap Creek during the summer months.

Table 1. Morphometry of Soap Creek Ponds V-VIII (Young, 1964).

Pond	Surface area (hectares)	Average depth (meters)	Water volume (meters^3)
V	0.18	1.07	1890
VI	0.18	1.10	1998
VII	0.21	1.19	2453
VIII	0.24	1.22	2960

Past research on the Soap Creek Ponds has been concerned mainly with fish production as influenced by fertilization and different stocking combinations. Studies on the effectiveness of various herbicides in aquatic weed control and their effects on fishes and invertebrates have been conducted in the ponds (Wilson, 1968). A study on the effect of artificial fertilization on plankton and benthos biomass has also been done (McIntire, 1960). Stolte (1969) conducted a study on the black crappie (*Pomoxis nigromaculatus*) in Oregon farm ponds during the first six months of my sampling.

METHODS

Environmental Variables

Water temperature and dissolved oxygen were measured on each sampling date in each pond throughout the study. Alkalinity, total and calcium hardness, pH, redox potential, and specific conductance were measured in ponds VI and VII on August 2 and August 23, 1968. An estimation of the primary production taking place on these two dates, using the *in situ* carbon-14 technique, was also done. Equipment for these tests was not available throughout the year.

Temperature

Two maximum-minimum thermometers were suspended from a styrofoam float at the deep end of each pond. One thermometer was placed five centimeters under the water surface, with the other 15 centimeters above the pond bottom. A lead weight at the end of each line kept the thermometers in position.

Water Chemistry

Water for dissolved oxygen determinations was taken five centimeters under the surface and 15 centimeters above the bottom. A vacuum bottle and a weighted length of rubber tubing were used to draw water from the desired depth. Samples were taken in the morning between 9 A.M. and 11 A.M. The Alsterberg (azide) modification of the Winkler method was used. Alkalinity, hardness, pH, redox potential, and specific conductance determinations were made from three levels (surface, mid-water, and bottom) in ponds VI and VII on August 2 and August 23, 1968.

Fertilization

As part of his study on the black crappie, Stolte (1969) fertilized the ponds on several occasions during my plankton sampling period. On April 26 and May 3, 1968, 25 pounds per acre of single superphosphate and 16.5 pounds per acre of urea were added to each pond. On June 4, July 10, and August 5, 1968, 50 pounds of single superphosphate and 33 pounds of urea per acre were added to each pond.

Primary Production

Rates of gross primary production were determined by the *in situ* carbon-14 technique (Strickland, 1960). Water for these determinations was collected at the surface, at one meter, and at two meters (near the bottom). A set of light and dark bottles was inoculated with 1 ml of 5 μc/ml of $Na_2{}^{14}CO_3$ each and suspended at each depth. The bottles were then allowed to incubate for four hours (10:20-14:20 in pond VI and 10:50-14:50 in pond VII). After incubation, the bottles were retrieved and the contents of each filtered through separate membrane filters (0.8 μ pore size). The filters were then dried and placed in liquid scintillation counting vials. Knowing the radioactivity of each filter in counts per minute and the amount of carbon-12 in solution, a photosynthetic rate for each depth was calculated.

Plankton Collection

All field data were collected during the interval April 27, 1968 to April 7, 1969. During this time, all four ponds were sampled on 30 different dates. Time between sampling dates ranged from three days to one month. All samples were obtained by taking vertical tows with a plankton tow net 30 cm in diameter, with a No. 20 nylon mesh (0.076 mm aperature). Depth of each tow in meters was recorded so that the total volume of water sampled could be calculated.

I made no attempt to determine the efficiency of my net, so the volumes used in calculating numbers of organisms per cubic meter are not absolute. Some backflushing, due to clogging of the net, undoubtedly occurred. Because of the short towing distance (less than three meters in all cases), I believe that error due to net clogging was minimal.

During the first three months of the study, samples were taken monthly in ponds V and VIII and thrice-monthly in ponds VI and VII from four stations with duplicate hauls being taken at each station.

On July 24, 1968, two stations were sampled with duplicate hauls; on August 2 and 9, 1968, one station with duplicate hauls. The variance of population densities between ponds was found to be much greater than the variance within a pond, and the variance between replicate hauls was insignificant. I therefore decided that one haul per pond per sampling date was adequate for comparative purposes. Finally on August 13, 1968, a twice-weekly sampling schedule was begun with one station in each pond and one haul at each station. This schedule was continued until October 1, 1968. Samples were then taken weekly during October and monthly during November, December, January, and February. Samples were taken twice during March, and the last samples were taken on April 7, 1969.

When four stations were sampled in each pond, two were at the shallow end and two at the deep end. If two stations were sampled, one was taken at each end. When sampling only one station, the tow was made at the deep end of the pond at a point equidistant between the sides of the pond.

Sample Analysis

All samples collected from the Soap Creek Ponds were immediately preserved in three percent formalin. In the laboratory, a Stemple Pipette was used to extract an aliquot from each thoroughly mixed sample. The aliquot was then placed in a counting chamber and the organisms counted under a dissecting scope.

The relationship between aliquot volume and sample volume was determined by weight. By dividing the weight of the aliquot into the weight of the sample and multiplying the quotient times the number of organisms counted, an estimate of the number of organisms in the entire sample could be obtained. This relationship is represented by the following equation:

$$\frac{\text{weight of sample}}{\text{weight of aliquot}} = \frac{\text{organisms per sample}}{\text{organisms per aliquot}}$$

Counts were made in ten categories for each sample: adult *Cyclops* sp., adult *Diaptomus forbesi*, juvenile copepods, *Daphnia pulex*, *Bosmina longirostris*, *Diaphanosoma* sp., *Cyclocypris* sp., *Volvox* sp., *Cyclops* eggs (attached and loose), and *D. forbesi* eggs (attached and loose). The copepods were also separated by sex. Three aliquots were counted for each sample.

Sample means and number of organisms per cubic meter were calculated for all categories. Average number of eggs per female and percent females in the population were calculated for each species of copepod.

Egg Development Time

Duration of development for the eggs of *Cyclops* sp. and *D.*

forbesi was determined in the laboratory at 5, 10, 15, and 22°C. The copepods used in these experiments were collected in early March, 1969 with the same net used for sampling, and placed in one-gallon jars. The copepods were then held at 15°C and were checked twice daily until eggs were visible in the egg sacs. Once eggs were visible, ten egg-bearing females were placed in individual test tubes at each of the above four temperatures. Forty females of each species were used. The eggs were checked three times each day and hatching time in days was recorded for each female. An average development time at each temperature was then calculated by dividing the sum of the individual development times by the number of females used. Females whose eggs did not hatch were not used in computing the average.

Population Growth Rate Calculations

Knowing the average number of eggs per female and the mean duration of development in days (at a given temperature), Edmondson et al. (1962) calculated the finite birth rate of a copepod population in eggs per female per day by the formula:

$$B = \frac{E}{D}$$

Where B = finite birth rate of the population

E = average number of eggs per female

D = mean duration of development in days

The instantaneous birth rate, b, may then be estimated by: $b = \ell n\,(1 + B)$. The derivation of this equation is given by Edmondson (1968).

Hall (1964) estimated an average rate of population change, r, from one sampling date to the next by the formula:

$$r = \frac{\ell n N_t - \ell n N_o}{t}$$

Where r = average rate of population change

N_o = initial population size

N_t = population size at time t

t = time in days

Finally, an estimate of instantaneous death rate, d, can be obtained from: $d = b - r$

Where b and r are as defined above.

All of these population parameters were estimated for _Cyclops_ sp. and _D. forbesi_ in each of the ponds.

RESULTS

Environmental Variables

Temperature

Temperature regimes of the four ponds are shown in Figure 1. Surface temperature differences between ponds were never more than 2°C, while differences in bottom temperatures of up to 4°C between ponds were recorded. Pond VI showed the most pronounced degree of thermal stratification, with a difference of about 4°C between surface and bottom temperatures during July and August, 1968.

Water Chemistry

Dissolved oxygen never fell below 7 mg/l at the surface in any of the ponds (Figures 2-5). Oxygen depletion was evident, however, near the bottom of all the ponds. Pond VI showed the most prolonged depletion with oxygen concentrations of less than 2 mg/l at the bottom in May, 1968 and less than 1 mg/l from June through August, 1968. Pond V reached a low of 3 mg/l in August, 1968, and ponds VII and VIII had concentrations of less than 1 mg/l in June, 1968.

The alkalinity of pond VI was found to be about 1.5 times that of pond VII, for the two dates on which it was measured (Table 2).

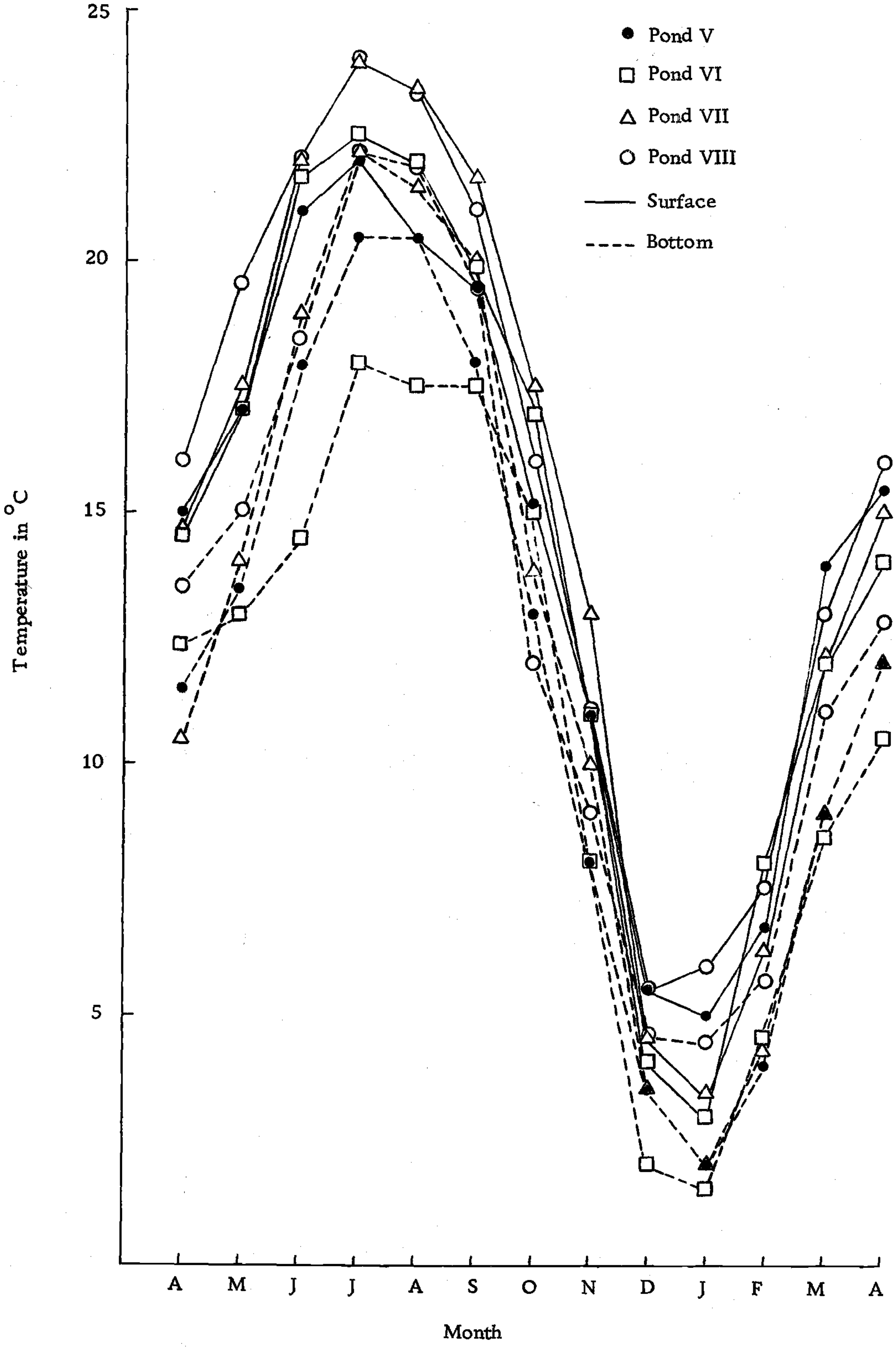

Figure 1. Monthly means of maximum-minimum surface and bottom temperatures for Ponds V-VIII, April, 1968 to April, 1969.

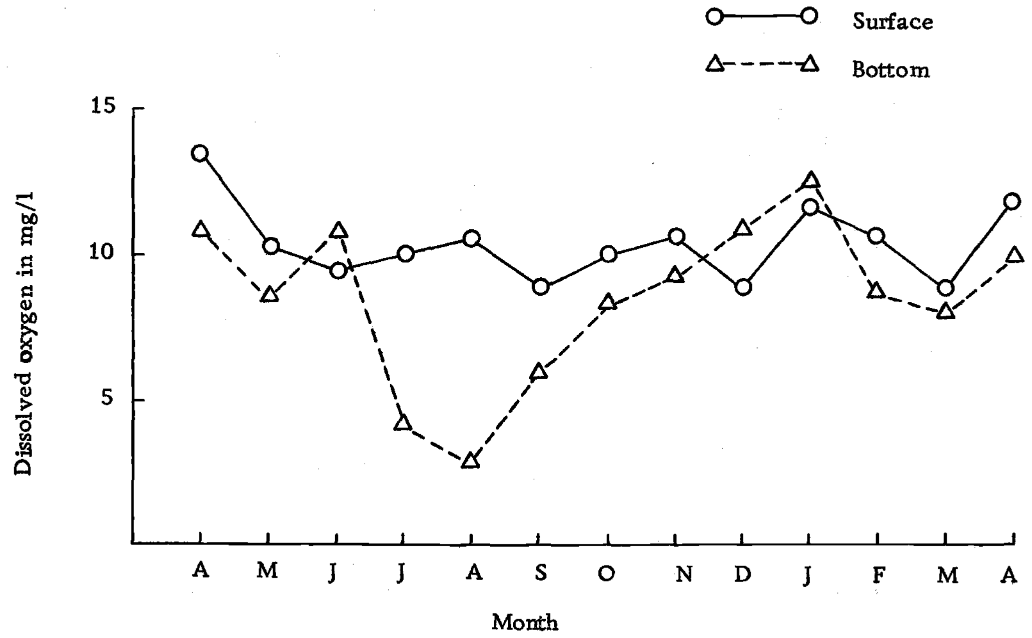

Figure 2. Surface and bottom dissolved oxygen concentrations for Pond V, April, 1968 to April, 1969.

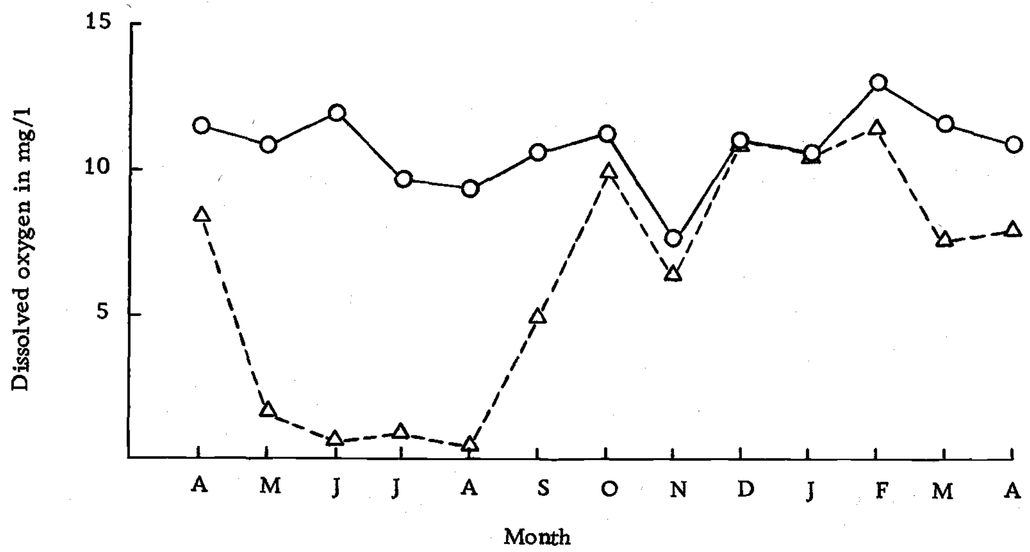

Figure 3. Surface and bottom dissolved oxygen concentrations for Pond VI, April, 1968 to April, 1969.

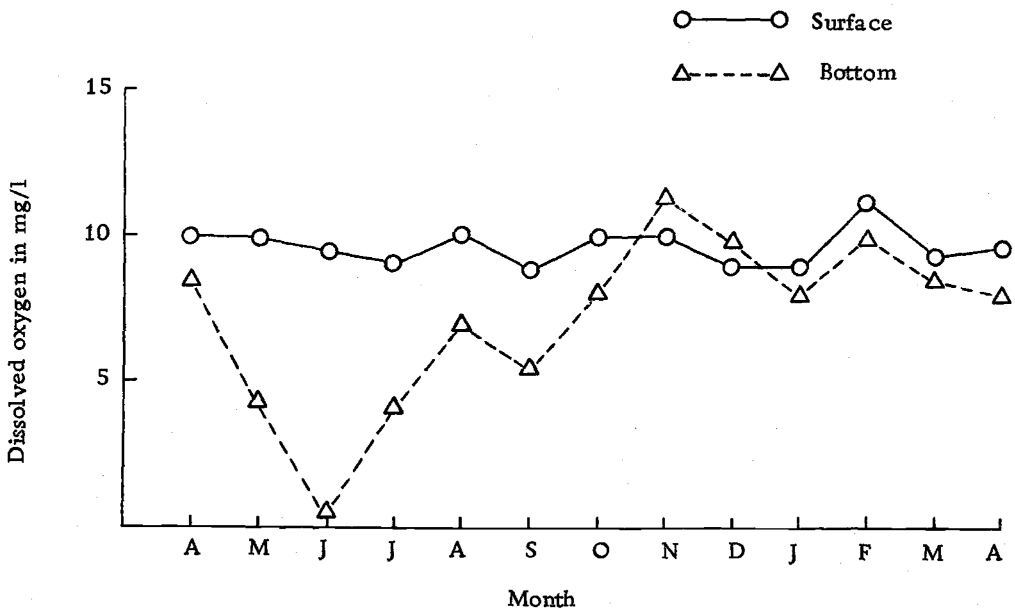

Figure 4. Surface and bottom dissolved oxygen concentrations for Pond VII, April, 1968 to April, 1969.

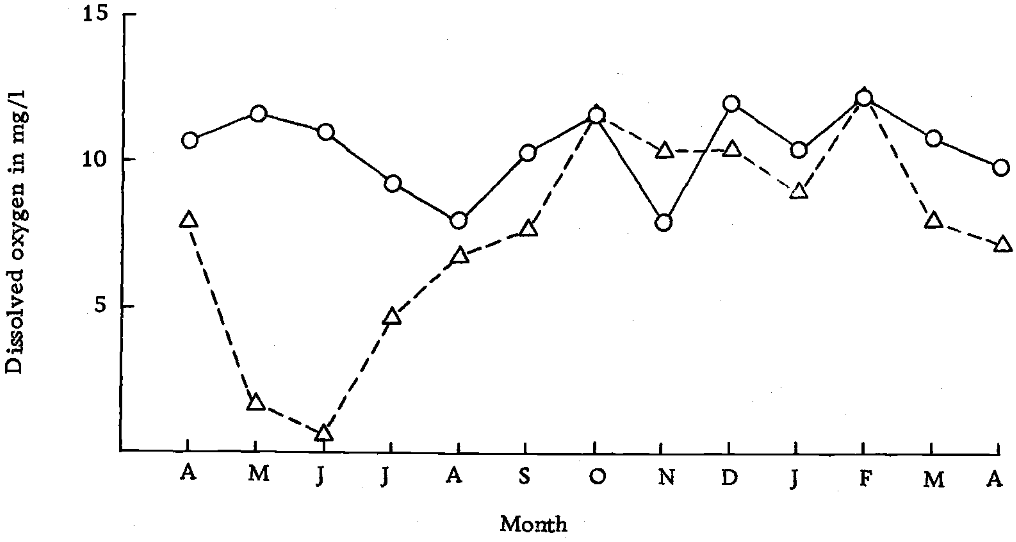

Figure 5. Surface and bottom dissolved oxygen concentrations for Pond VIII, April, 1968 to April, 1969.

Table 2. Alkalinity, hardness, pH, redox, and specific conductance of Soap Creek Ponds VI and VII on August 2 and August 23, 1968.

Date	Pond	Depth (meters)	Alkalinity mg/l $CaCO_3$	Hardness Total mg/l	Hardness Calcium mg/l	pH	Redox Potential	Specific Conductance μ mhos/cm^2
8-2-68	VI	0	74.45	72.00	46.00	8.3	-0.63	1700
		1	74.50	72.20	46.00	8.4	-0.60	1660
		2	78.45	74.20	49.20	7.4	+0.05	1700
	VII	0	46.70	50.00	30.20	7.5	+0.10	1210
		1	46.75	50.00	29.80	7.6	+0.10	1220
		2	46.95	50.40	29.40	7.6	-0.15	1140
8-23-68	VI	0	81.20			8.3		1420
		1	81.30			8.3		1410
		2	81.10			8.3		1410
	VII	0	53.70			7.8		1075
		1	54.00			7.6		1075
		2	54.40			7.6		1080

The greater alkalinity of pond VI is also indicated by a pH of 8.3 as compared to 7.6 for pond VII. In addition, hardness and specific conductance are greater in pond VI.

Primary Production

Primary productivity of the surface water in pond VI was four to five times greater than that of pond VII on both incubation dates (Figure 6). Although no Secchi disc readings were taken, pond VI was observed to be considerably more turbid than pond VII. The higher primary productivity of pond VI at all depths reflects a much greater nutrient content than that of pond VII. This high nutrient content supported a larger phytoplankton population which in turn supplied food for the consistently higher zooplankton populations collected in pond VI.

Fish Populations

All four ponds were stocked with largemouth bass (*Micropterus salmoides*) and black crappie (*Pomoxis nigromaculatus*). In addition, ponds V and VI contained bluegill (*Lepomis macrochirus*). Table 3 shows the estimated fish populations, biomass, and mortality rates from April, 1968 to December, 1968 (Stolte, 1969).

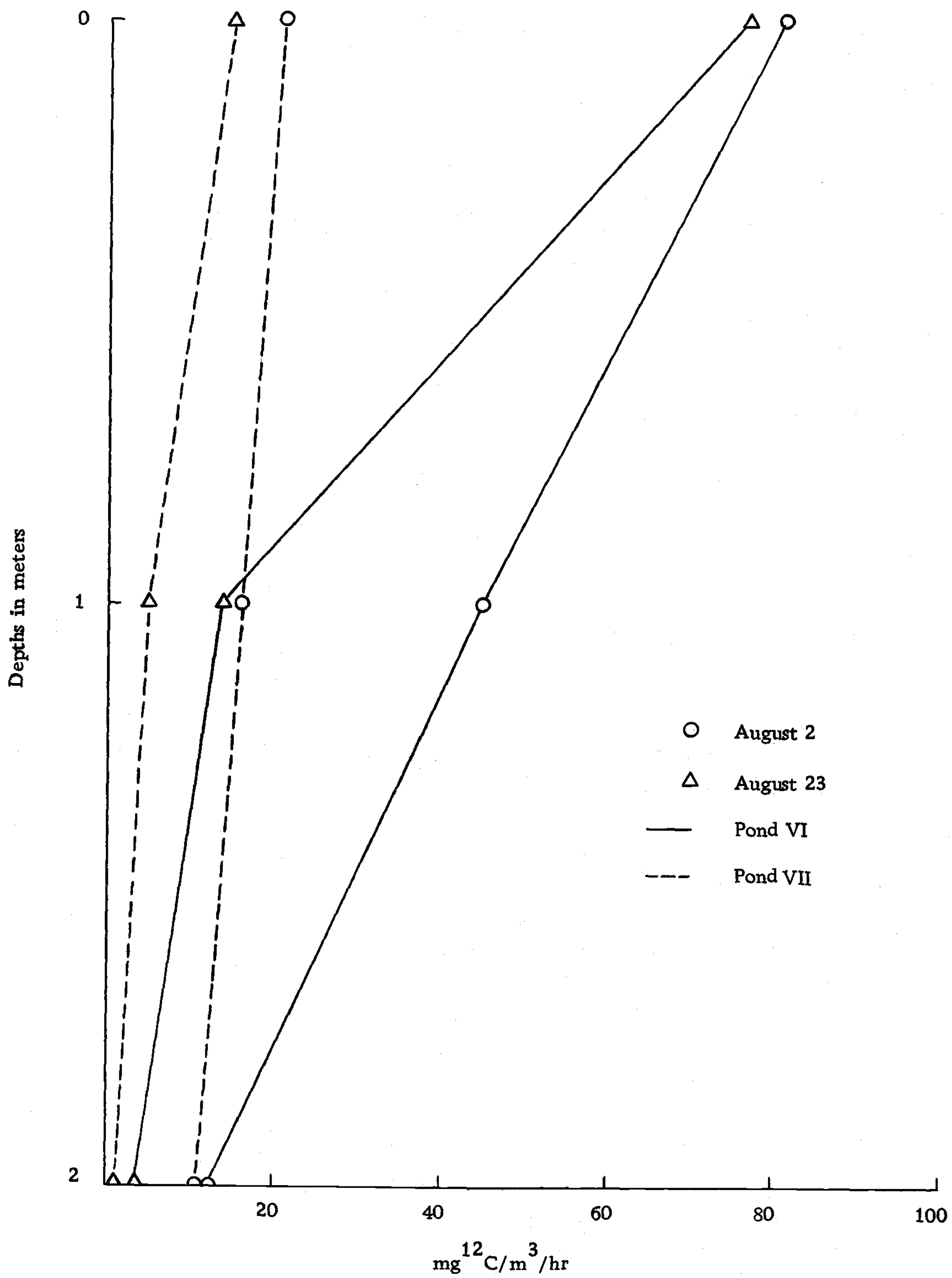

Figure 6. Photosynthetic rate curves for Soap Creek Ponds VI and VII on August 2 and August 23, 1968.

Table 3. Enumeration, biomass, and mortality rates for the experimental fish populations in Soap Creek Ponds for April, 1968 - December, 1968 (Stolte, 1969).

Pond No.	Species	Estimated Fish/Acre April, 1968	Biomass Kg/Acre	Estimated Fish/Acre December, 1968	Biomass Kg/Acre	Mortality Rate Per Mo.
V	LMB	59	16.70	52	13.50	0.005
	BG	543	65.60	487	53.90	0.010
	BC	173	19.80	118	13.40	0.040
	Total		102.10		80.80	
VI	LMB	59	17.90	51	14.00	0.015
	BG	543	34.70	600	55.80	0.000
	BC	173	18.20	106	10.10	0.046
	Total		70.80		79.90	
VII	LMB (adult)	51	23.70	55	24.06	0.000
	LMB (juvenile)	400	8.00	272	17.14	0.040
	BC	165	23.70	131	22.10	0.025
	Total		55.40		63.30	
VIII	LMB (adult)	50	16.50	55	15.09	0.000
	LMB (juvenile)	400	5.70	180	14.11	0.067
	BC	163	25.40	157	34.50	0.003
	Total		47.60		63.70	

Population Dynamics

Population densities for each of the seven genera of zooplankton represented in all four ponds were estimated throughout the year. For the copepods, Cyclops sp. and D. forbesi, rates of population change (r), instantaneous birth rates (b), and instantaneous death rates (d) were also calculated.

Population Density

Cyclops sp. was present in all four ponds throughout the year, but was much more abundant in ponds V and VI than in VII and VIII

(Figure 7). Definite population pulses occurred in the fall of 1968 and spring of 1969 in pond VI. Only a fall maximum occurred in pond V in 1968, and definite spring pulses were observed in ponds VII and VIII in 1969. In reading the population density graphs for each species, notice that the ordinate scale is not always the same for all ponds.

D. forbesi was most abundant in pond VII with pond VIII also having a good population (Figure 8). Ponds V and VI had smaller populations. *D. forbesi* did not occur in any of the collections during December, January, and February. Spring maxima were observed in ponds V, VI, and VIII on May 31, 1968, but the maximum in pond VII did not occur until July 24, 1968. There were, apparently, no significant increases of this species in any of the ponds during the fall of 1968. Sampling was possibly terminated in 1969 before the spring pulse.

Because the juveniles of the two copepod species could not be distinguished, they were all counted together and their total density is shown in Figure 9. Maximum densities of juveniles occurred during the spring of 1969 in ponds VI, VII, and VIII, and were also quite high during the summer of 1968 in ponds V and VI. The large numbers of juvenile copepods collected in March and April, 1969 in ponds VII and VIII were probably the precursors of a spring population pulse of *D. forbesi* in these ponds.

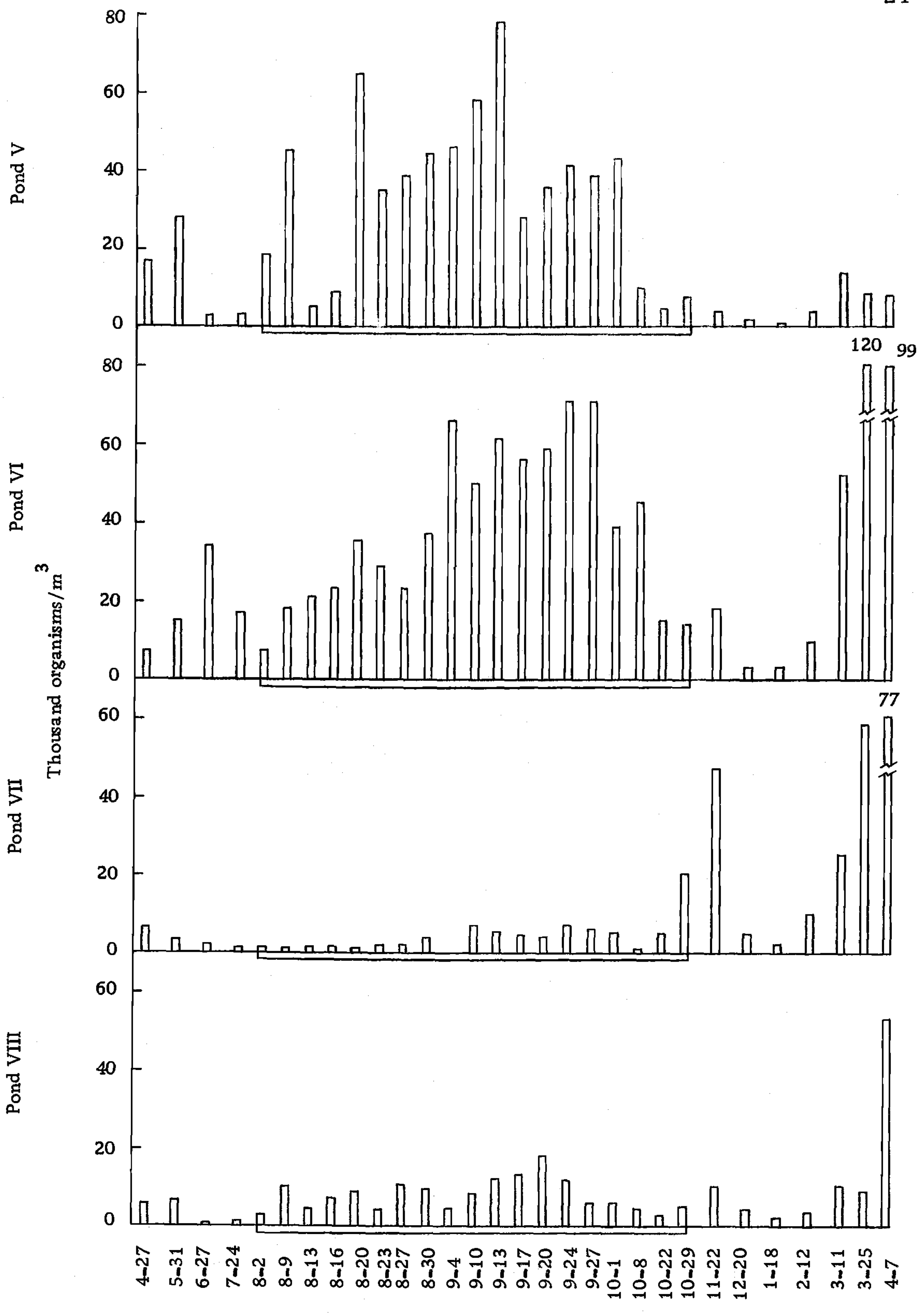

Figure 7. Changes in density of Cyclops sp. in Soap Creek Ponds from April, 1968 to April, 1969.

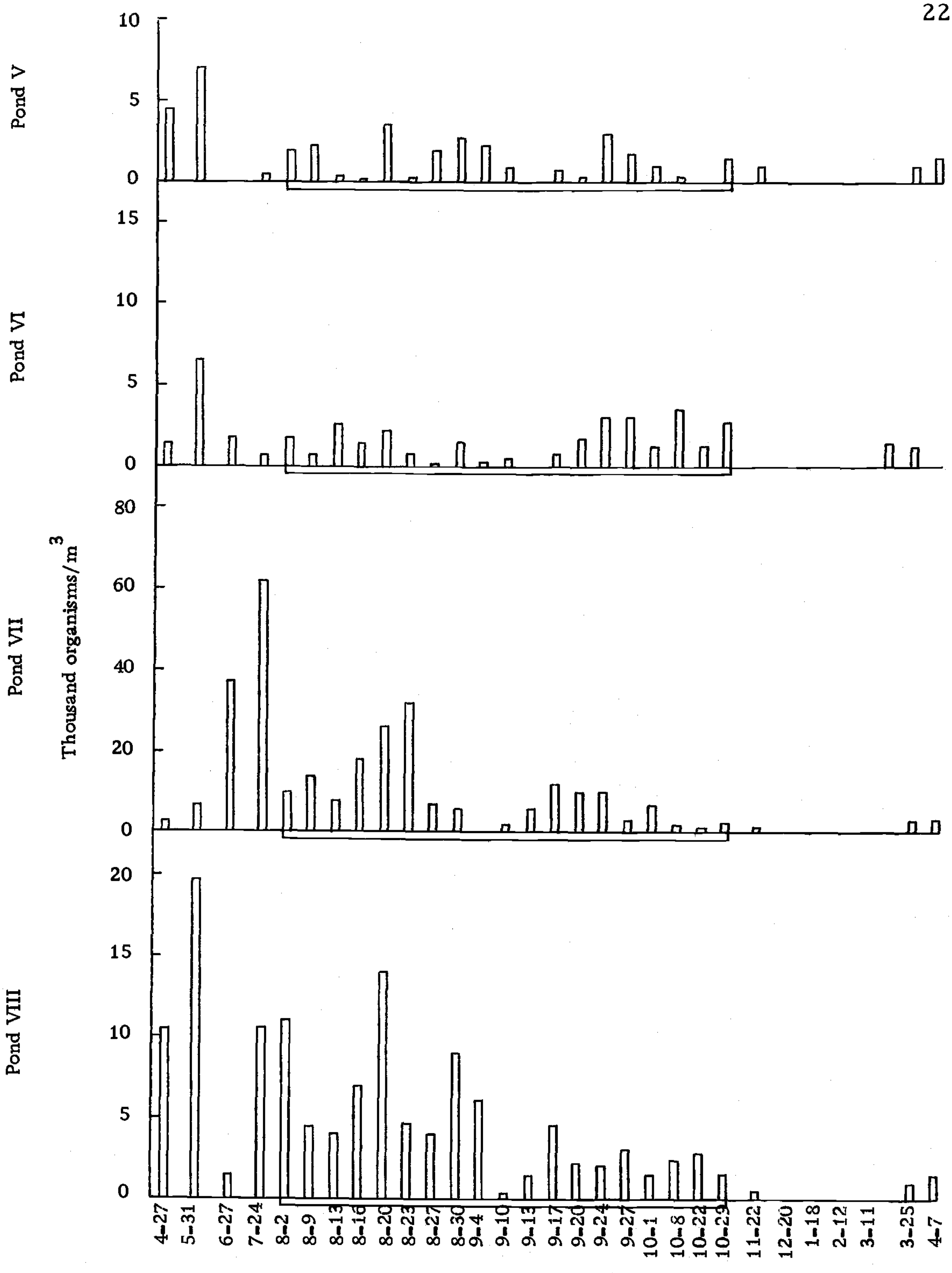

Figure 8. Changes in density of *Diaptomus forbesi* in Soap Creek Ponds from April, 1968 to April, 1969.

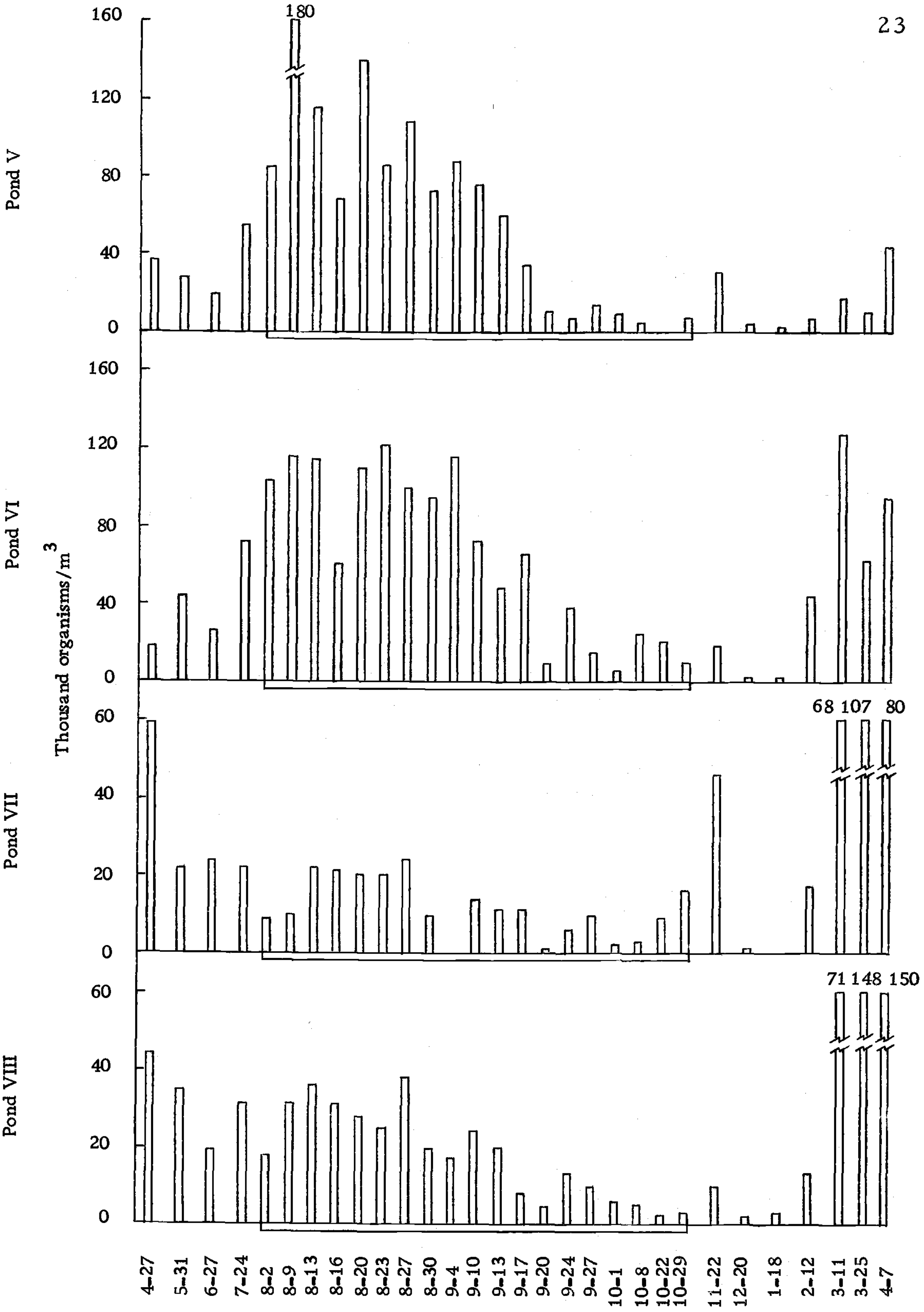

Figure 9. Changes in density of juvenile copepods in Soap Creek Ponds from April, 1968 to April, 1969.

D. pulex was, in general, much more abundant in ponds V and VI than in VII and VIII (Figure 10). Peak numbers for this species were observed during the last week of August, 1968, in all except pond VIII where the peak occurred on May 31, 1968.

Ponds V and VI, again, contained much larger populations of *B. longirostris* than did ponds VII and VIII (Figure 11). Tremendous numbers of this species occurred in pond VI during the middle of August, 1968. Over one million individuals per cubic meter were counted on August 23, 1968.

Three other zooplanktonic genera were periodically important in the ponds. The cladoceran, *Diaphanosoma* sp., was never very abundant in any of the ponds but was most numerous in pond VIII during the latter part of August and early September, 1968. The ostracod, *Cyclocypris* sp., appeared sporadically in all the ponds, but was much more abundant in pond VI. *Volvox* sp. blooms occurred in pond VII on June 27 and August 30, 1968, and in pond VIII on July 24, 1968. This form, however, was never abundant in ponds V and VI.

Egg Development Time

Hatching success of the eggs was high. Of the 40 females of each species used, the eggs of only three *Cyclops* sp. and four *D. forbesi* failed to hatch. These failures all occurred at 22°C.

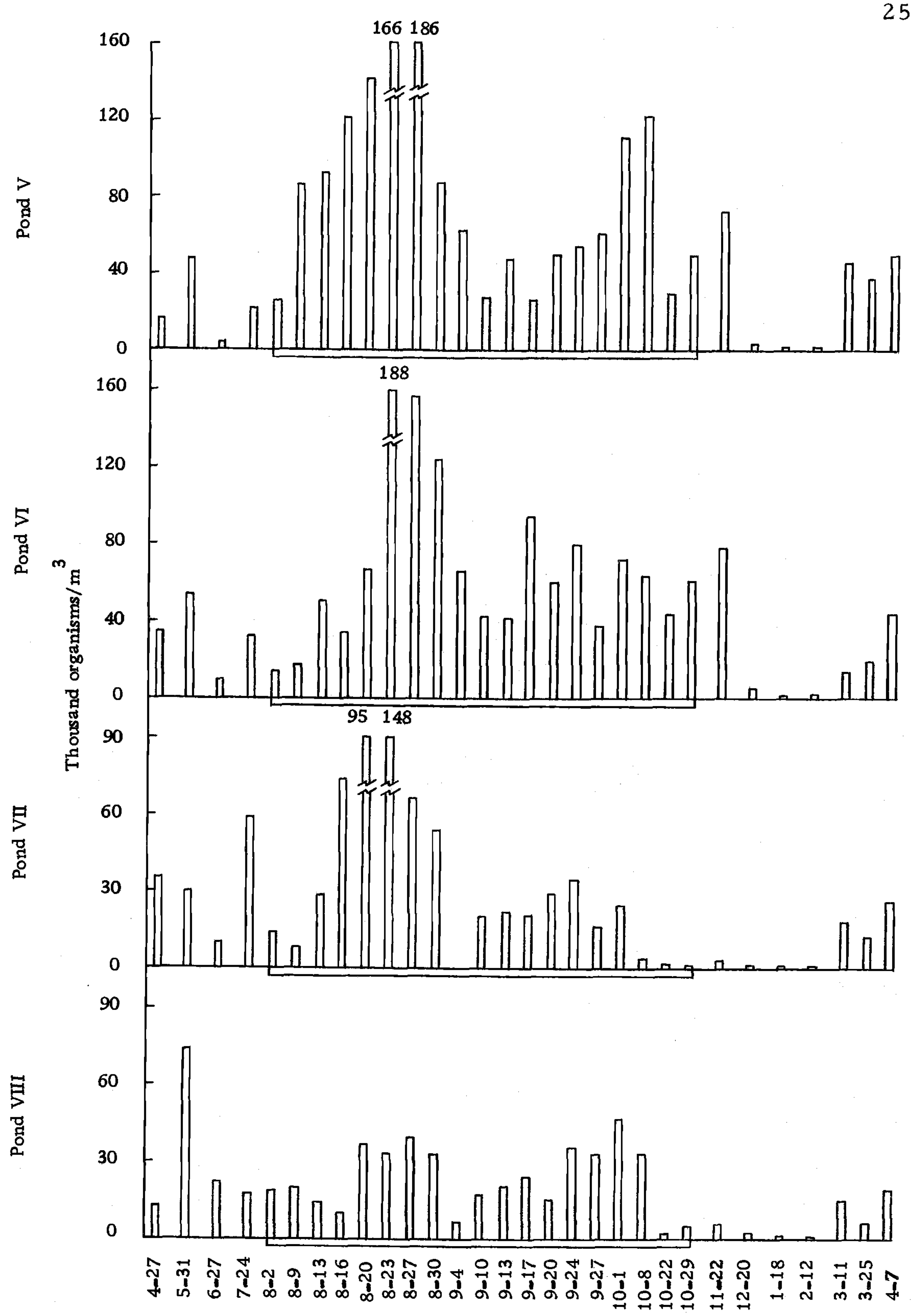

Figure 10. Changes in density of Daphnia pulex in Soap Creek Ponds from April, 1968 to April, 1969.

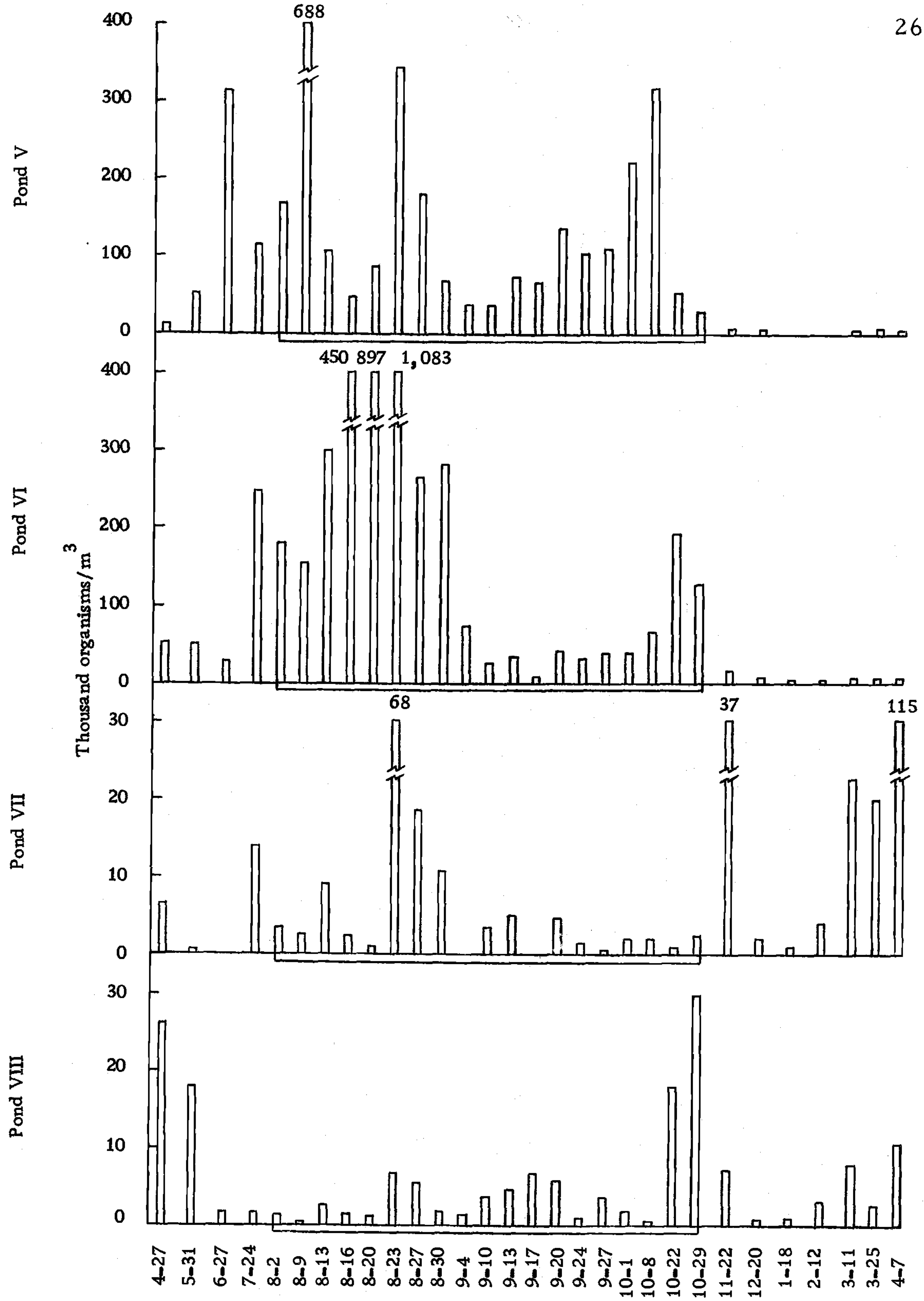

Figure 11. Changes in density of Bosmina longirostris in Soap Creek Ponds from April, 1968 to April, 1969.

Rates of egg development over a range of 5°C to 22°C are shown in Figure 12 for Cyclops sp. and in Figure 13 for D. forbesi. For convenience in machine computation, the values plotted are the reciprocals of the duration of development in days. As can be seen by inspection of these figures, the correlation between rate of egg development and temperature is quite high. The rate of development for D. forbesi at each temperature was quite similar to the findings of Edmondson et al. (1962). In my Cyclops sp., however, the duration of development at 10 and 15°C was considerably shorter than that found by Lenarz (1966) for Cyclops scutifer in Iliamna Lake, Alaska. The ranges in hatching time for each species at each temperature are given in Table 4. Variation in hatching time is greatest at 5°C for both species. At 10, 15, and 22°C variation is less than one day in all instances.

Table 4. Average duration of development and range of development times at 5, 10, 15 and 22°C for Cyclops sp. and Diaptomus forbesi.

Species	Temperature °C	Average duration of development (days)	Range of development times (days)
Cyclops sp.	5	20.0	17.6-21.0
	10	7.2	6.6-7.6
	15	3.8	3.6-4.0
	22	2.5	2.0-3.0
D. forbesi	5	12.5	10.6-15.0
	10	6.7	6.0-7.3
	15	4.0	3.6-4.3
	22	3.0	2.6-3.3

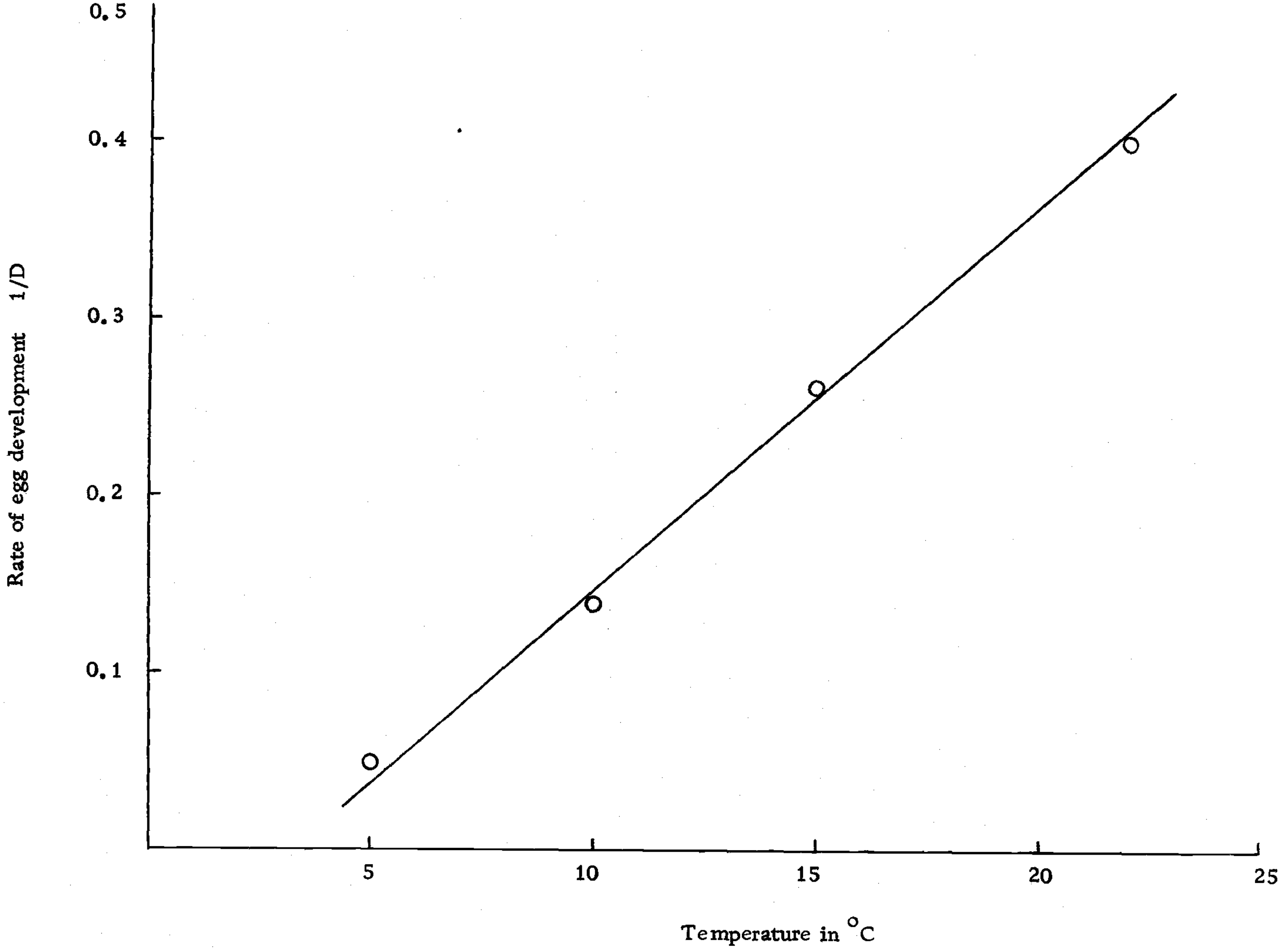

Figure 12. Rate of egg development in relation to temperature for Cyclops sp. collected from Soap Creek Ponds in March, 1969.

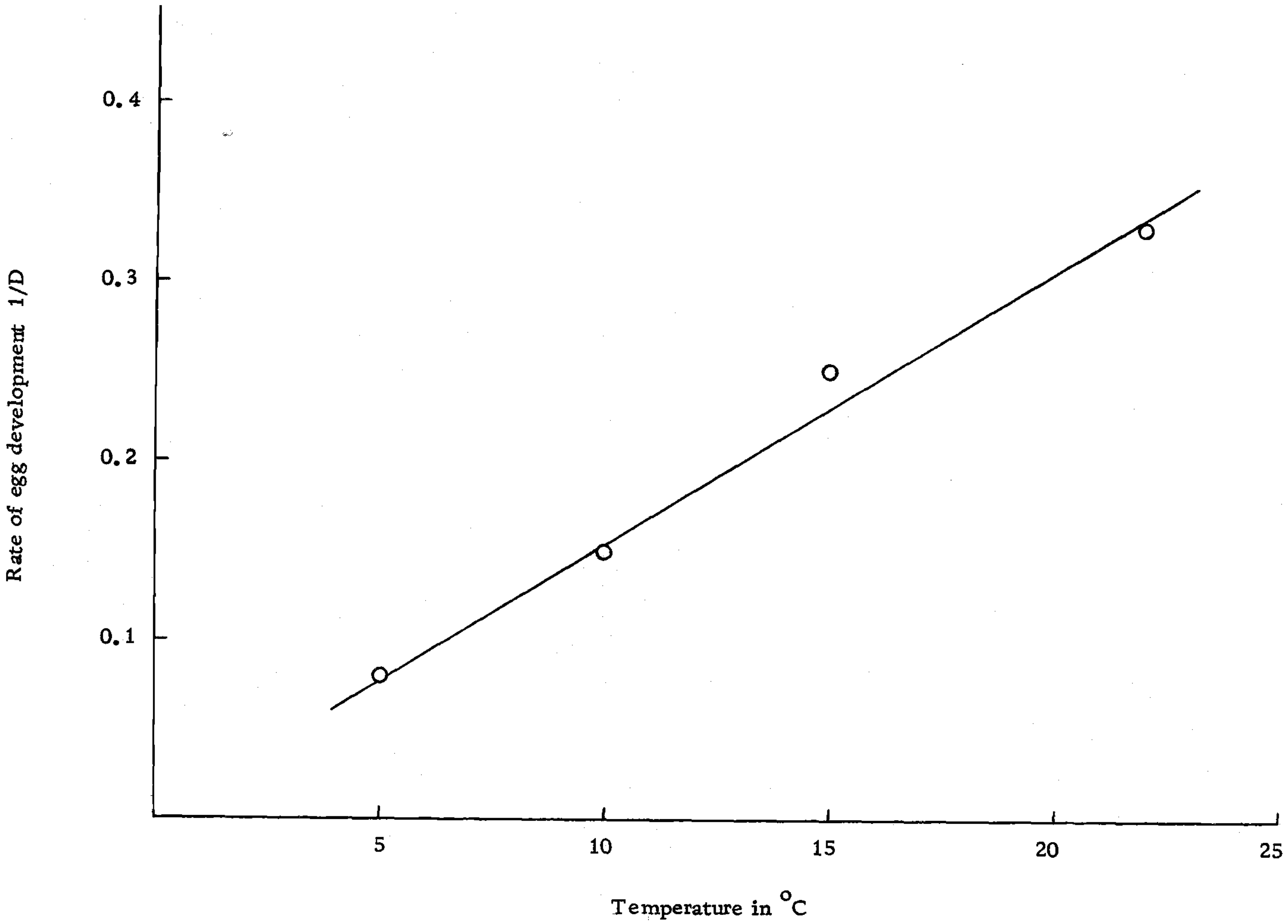

Figure 13. Rate of egg development in relation to temperature for *Diaptomus forbesi* collected from Soap Creek Ponds in March, 1969.

Population Growth Rate

Based on observed average rates of population change (r), the *Cyclops* sp. population in pond VI appears to be more stable than those in the other three ponds (Figures 14-17). Eggs of this species were observed more frequently in pond VI than in any other pond. Apparently, reproduction (expressed as instantaneous birth rate, b) occurred only during the spring in ponds VII and VIII. In all except three instances, population rate of increase based on b alone is higher than the observed rate of increase (r).

Ponds VII and VIII had more stable populations of *D. forbesi* than did ponds V and VI (Figures 18-21). Egg laying was observed in ponds V and VI only during the spring of 1968, while it also occurred periodically throughout the summer and fall in ponds VII and VIII. For this species, values of b were greater than values of r in all except one instance.

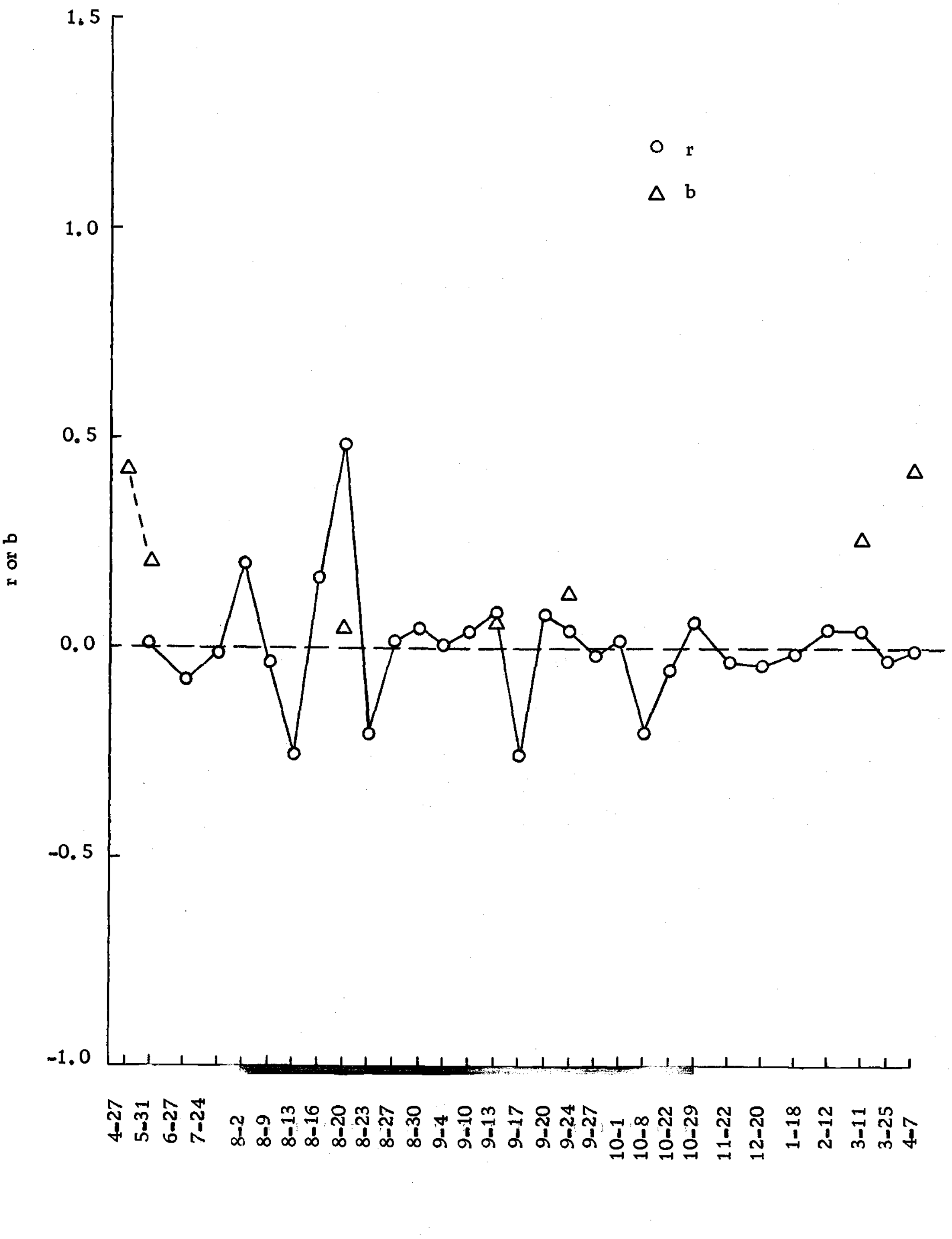

Figure 14. Average rates of population change (r) and instantaneous birth rates (b) of Cyclops sp. in Pond V, April, 1968 to April, 1969.

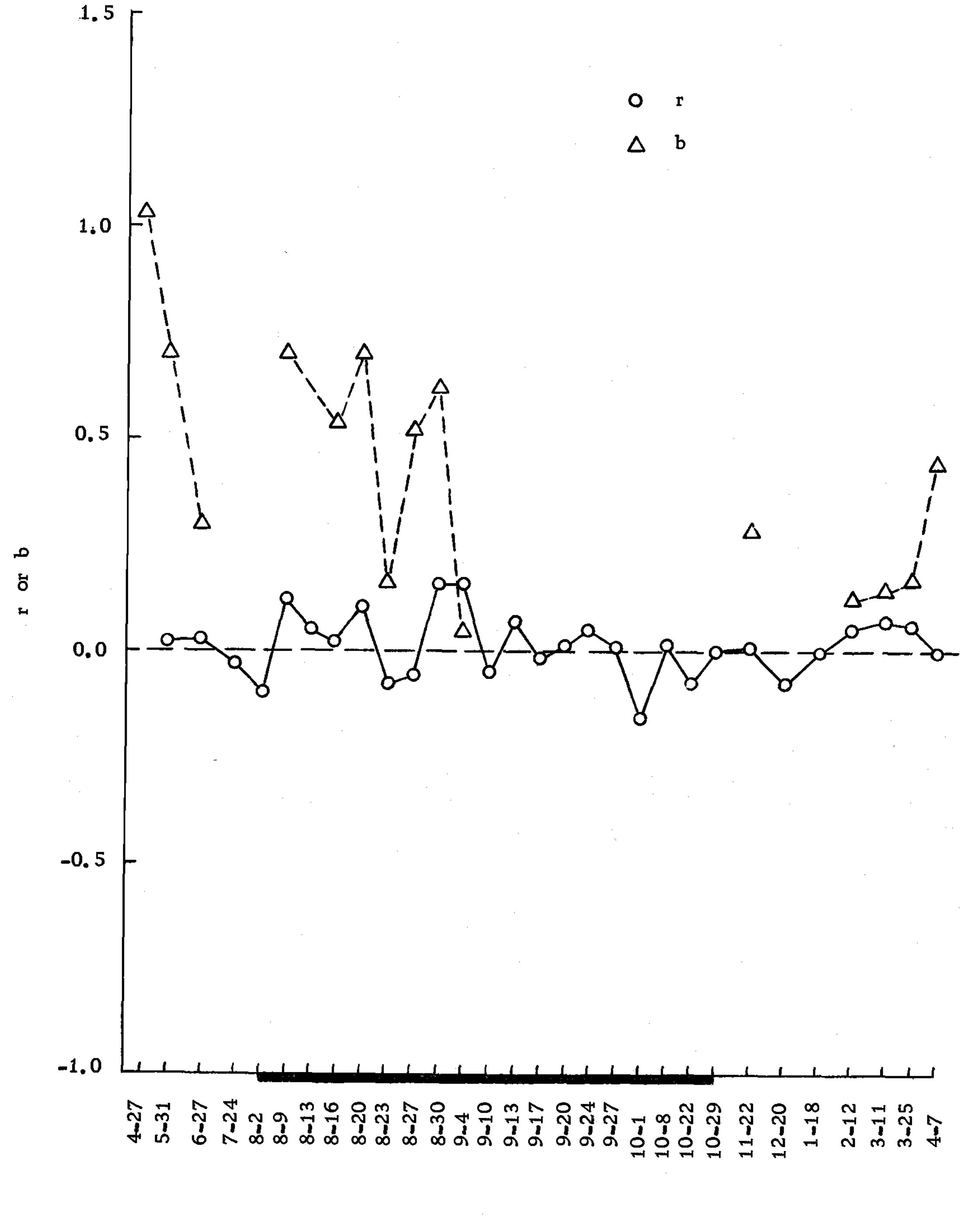

Figure 15. Average rates of population change (r) and instantaneous birth rates (b) of Cyclops sp. in Pond VI, April, 1968 to April, 1969.

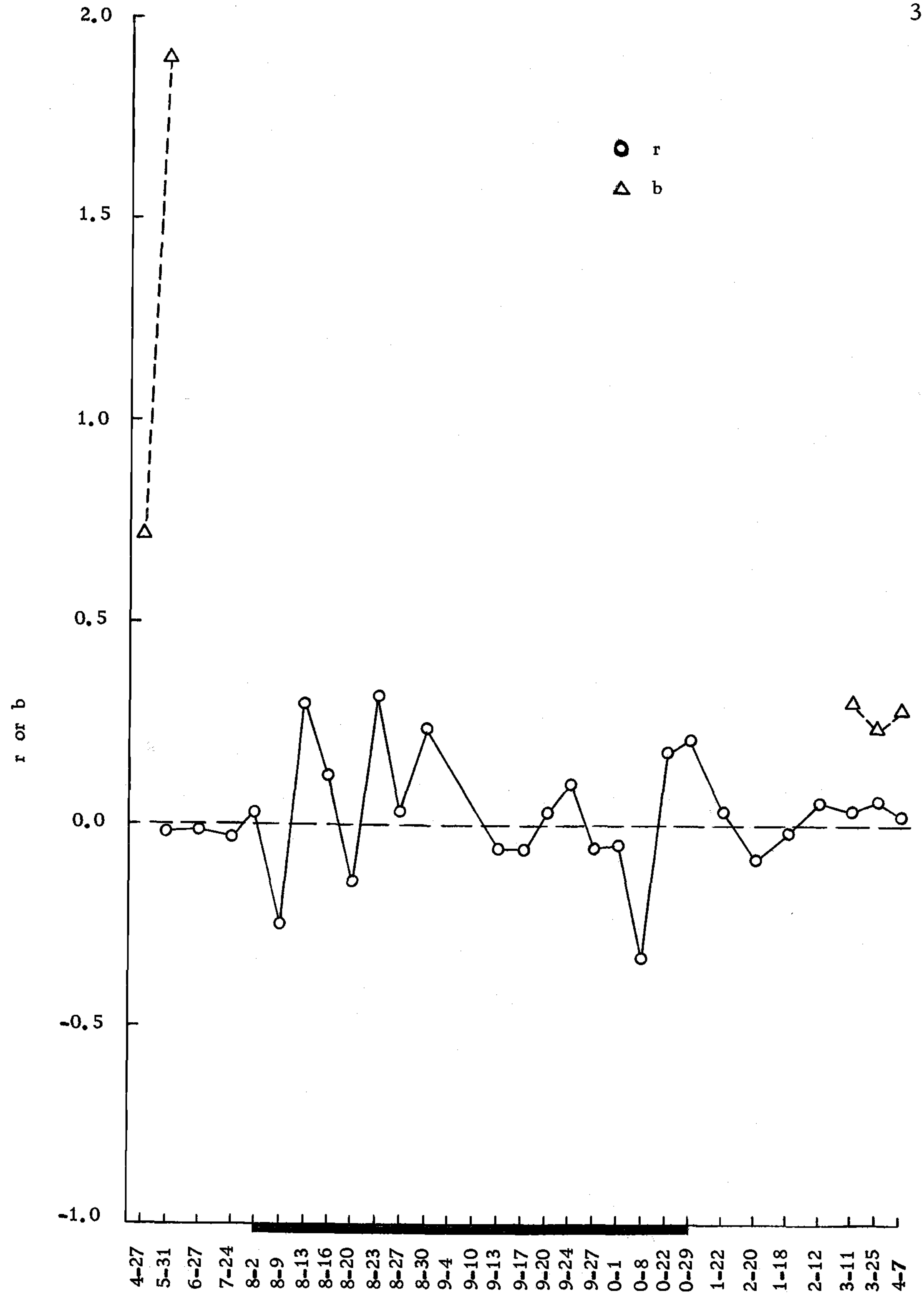

Figure 16. Average rates of population change (r) and instantaneous birth rates (b) of Cyclops sp. in Pond VII, April, 1968 to April, 1969.

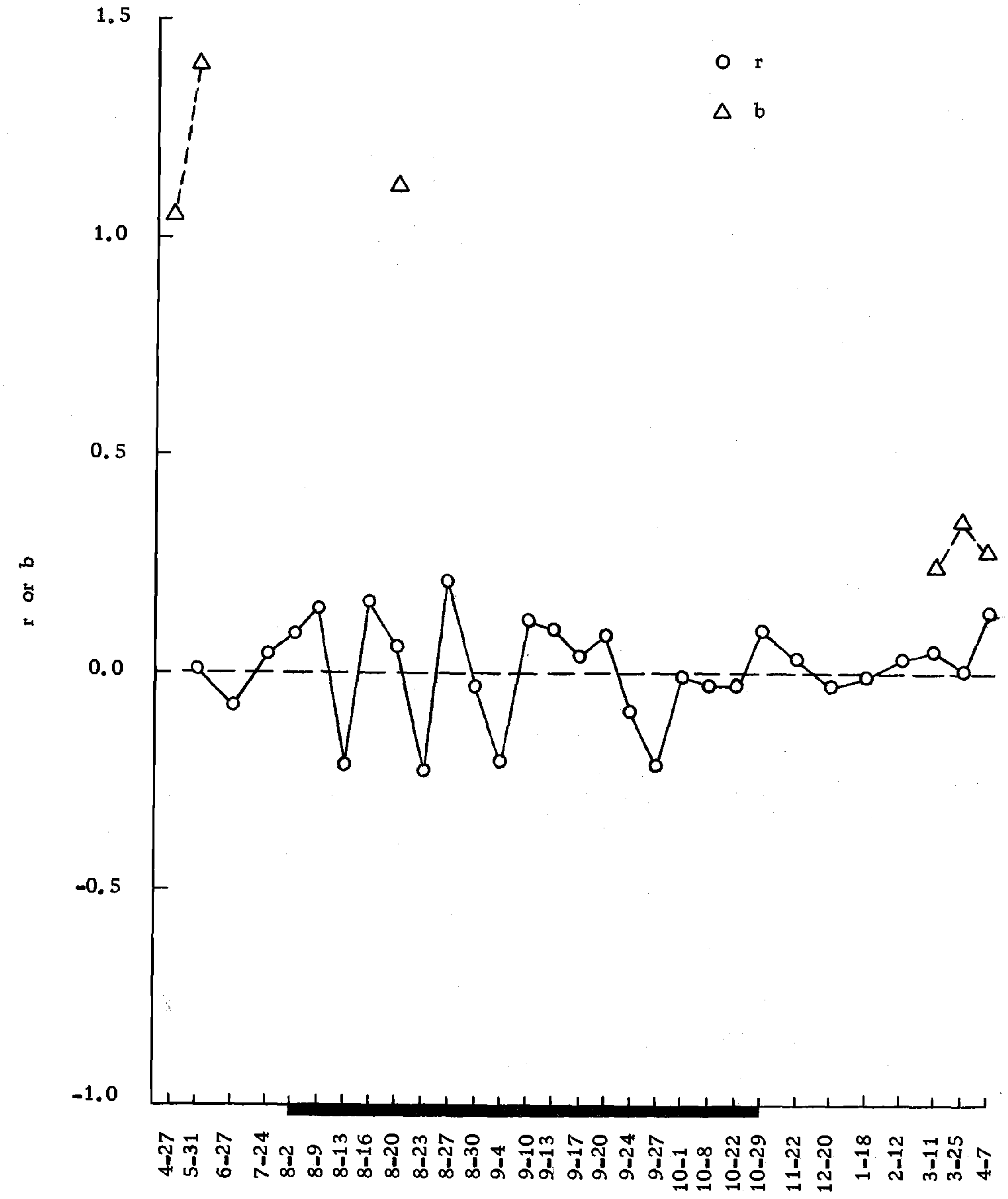

Figure 17. Average rates of population change (r) and instantaneous birth rates (b) of *Cyclops* sp. in Pond VIII, April, 1968 to April, 1969.

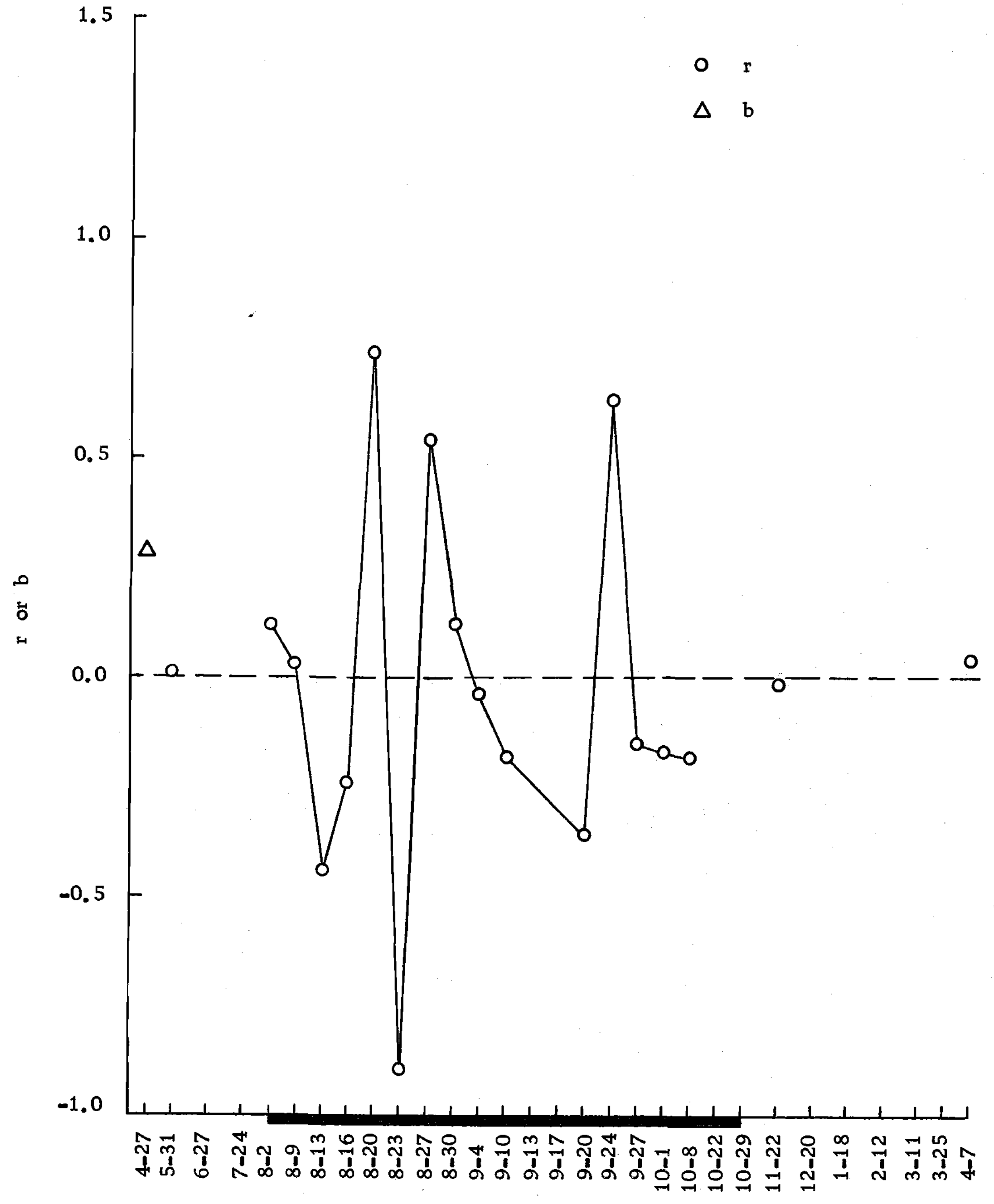

Figure 18. Average rates of population change (r) and instantaneous birth rates (b) of <u>Diaptomus forbesi</u> in Pond V, April, 1968 to April, 1969.

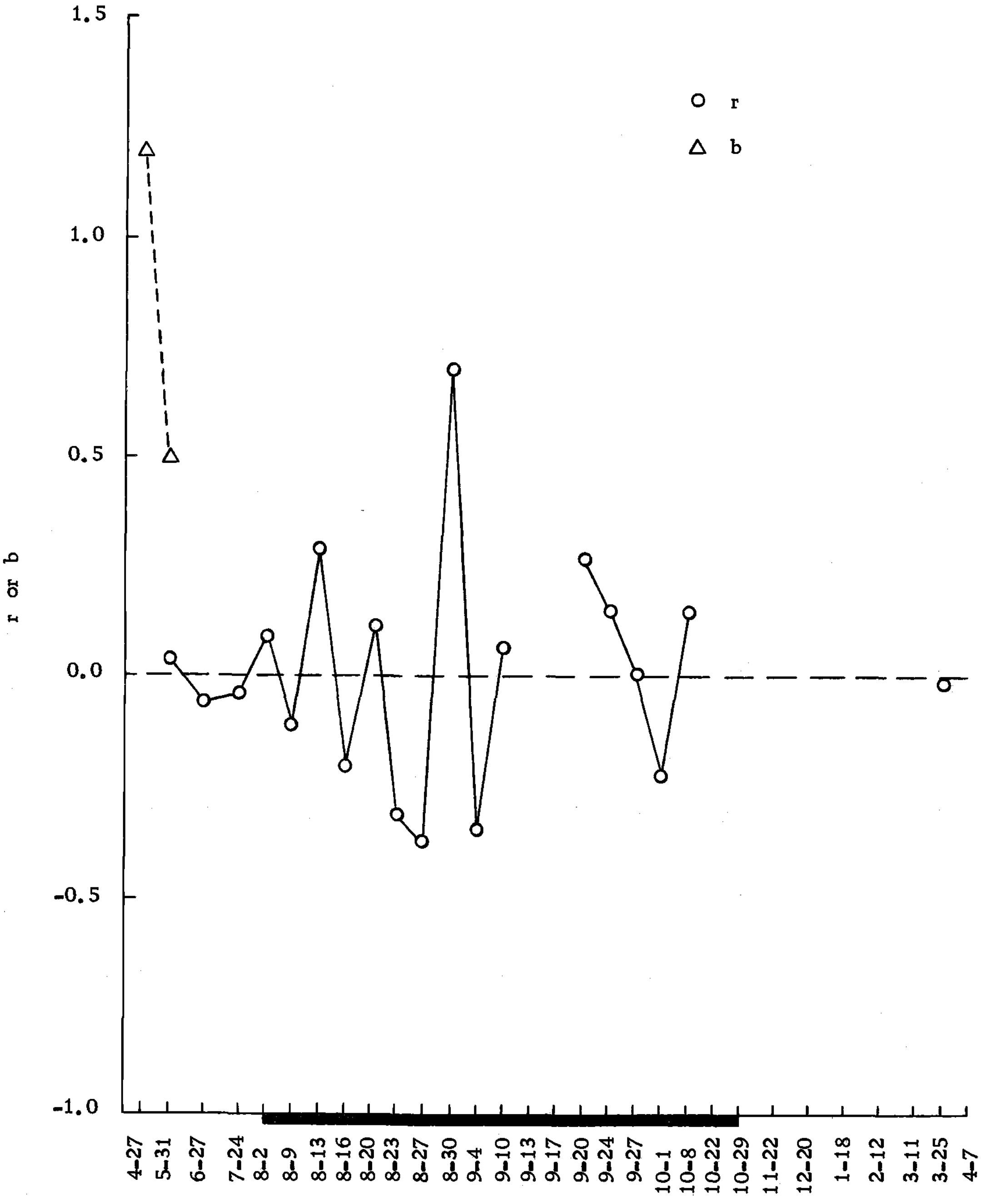

Figure 19. Average rates of population change (r) and instantaneous birth rates (b) of Diaptomus forbesi in Pond VI, April, 1968 to April, 1969.

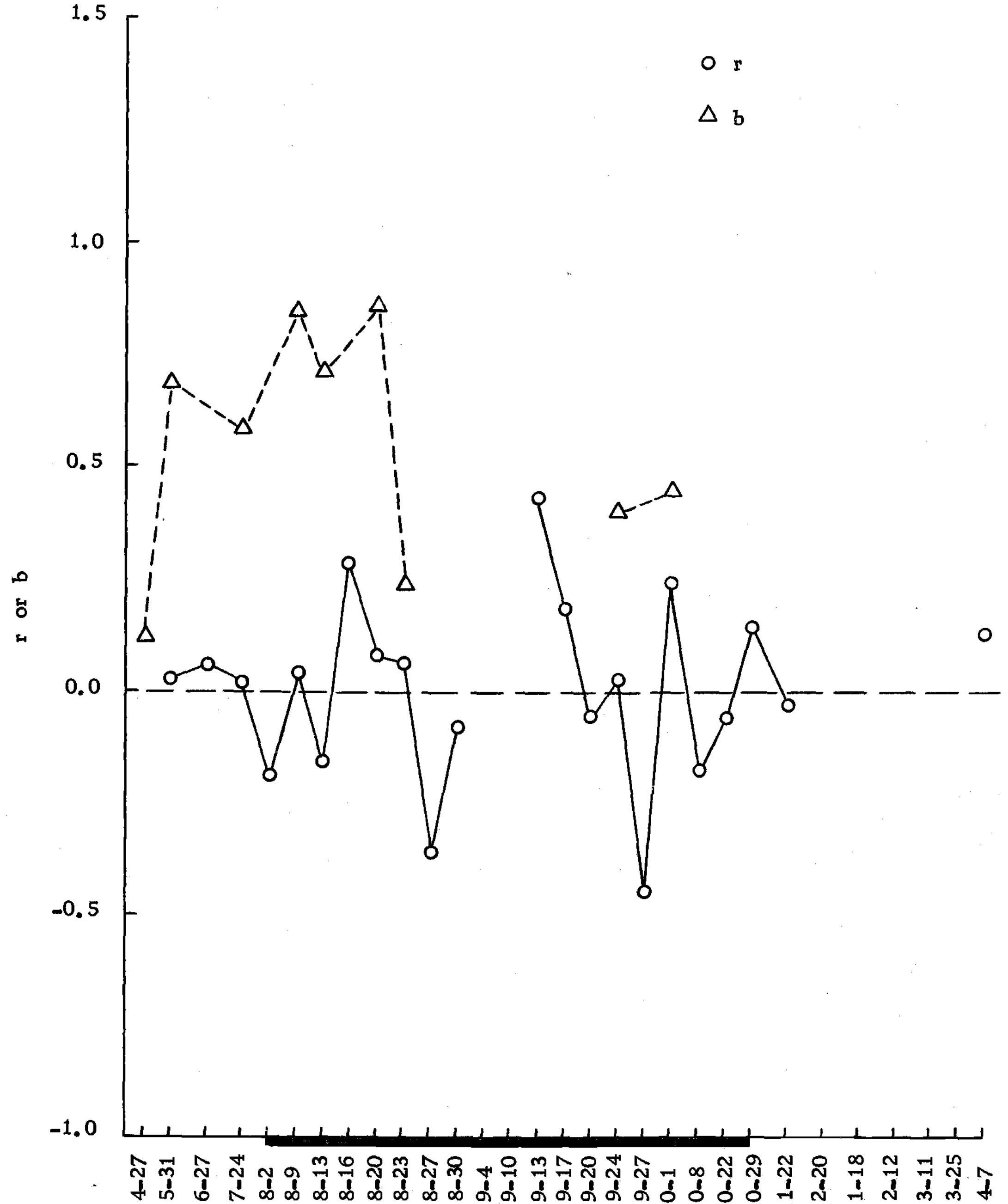

Figure 20. Average rates of population change (r) and instantaneous birth rates (b) of Diaptomus forbesi in Pond VII, April, 1968 to April, 1969.

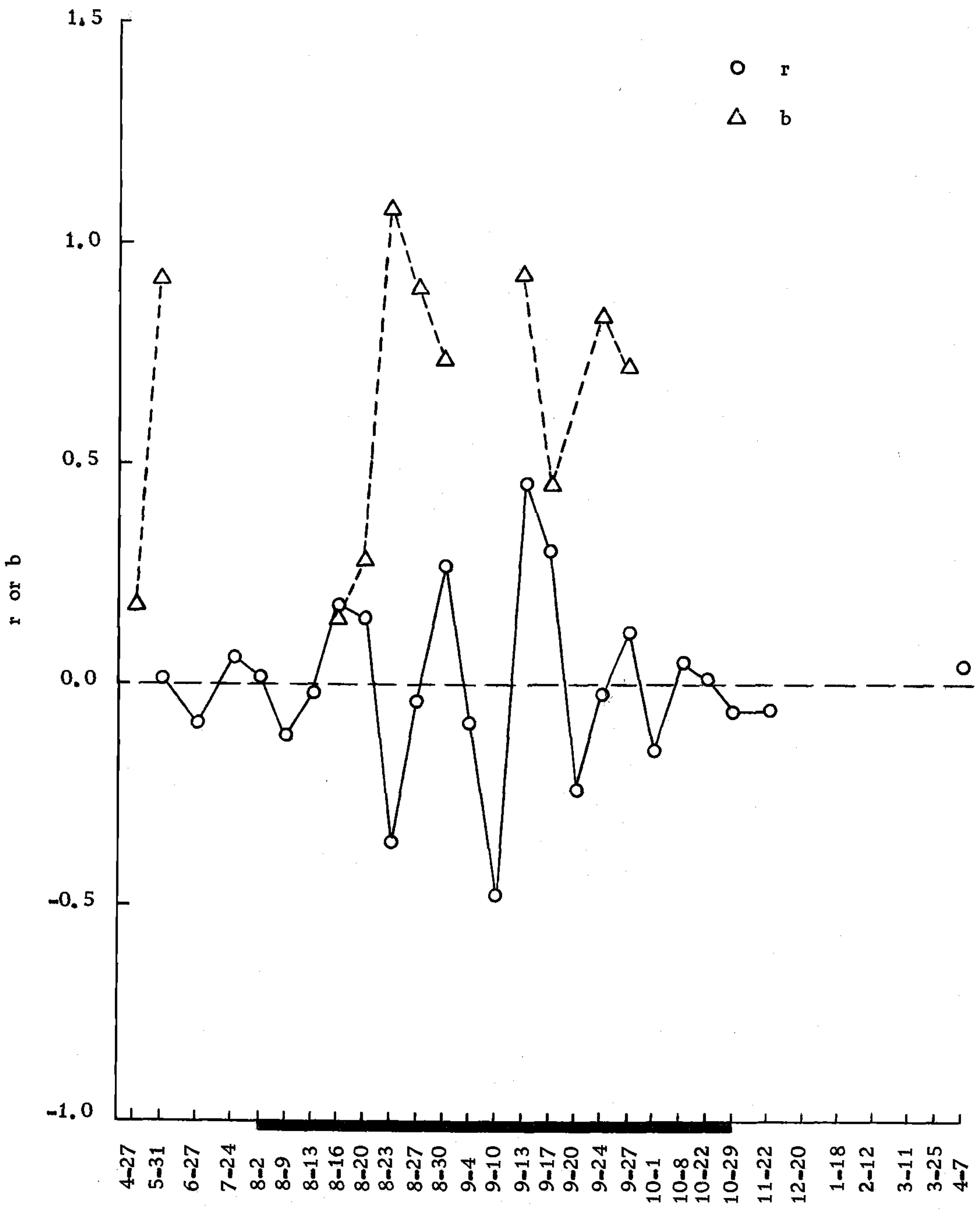

Figure 21. Average rates of population change (r) and instantaneous birth rates (b) of *Diaptomus forbesi* in Pond VIII, April, 1968 to April, 1969.

DISCUSSION

Reproductive rates calculated from egg ratios for *Cyclops* sp. and *D. forbesi* were found to vary considerably between ponds. This is in agreement with Armitage and Davis (1967) who found significant differences in the number of eggs per female for copepods occurring in what they considered to be physically and chemically similar ponds. Obviously, the pond in which the ratio of eggs per female (E) was greatest and the duration of egg development (D) was shortest would have the highest reproductive rate. Further, the number of eggs per female has been found to be related to food abundance and the duration of development is influenced mainly by water temperature (Edmondson *et al.*, 1962). Therefore,on any given day, the pond in which food was most abundant and temperature was highest (up to a certain point) would be expected to show the greatest reproductive activity. In my study, pond VI consistently showed (by observation) the greatest density of phytoplankton, and consequently *Cyclops* sp. produced the largest number of eggs per female in this pond. In the case of *D. forbesi*, however, this food dependent relationship is not clear. *D. forbesi* eggs occurred most frequently in the samples taken from ponds VII and VIII which were usually slightly warmer than ponds V and VI, but observed phytoplankton populations were much lower.

The apparent discontinuity of egg laying shown by Cyclops sp. in ponds V, VII, and VIII and by D. forbesi in ponds V and VI is more difficult to explain. Eggs were collected only during the spring in these ponds. This suggests that a lack of certain nutrients or differences in some other environmental factor during the summer and fall limited the production of eggs. Edmondson et al. (1962), in their study of three Washington lakes, found eggs to be present throughout the summer. Hall (1964) suggested that a Daphnia population which has reached the carrying capacity of its environment in terms of food supply will produce very few eggs.

Rate of egg development is definitely correlated with water temperature. The eggs of D. forbesi hatched more rapidly than those of Cyclops sp. at $5^{\circ}C$. At 10, 15, and $22^{\circ}C$, however, there was not more than one-half day difference in the average duration of development for each species. On a given date, temperature differences between ponds were never greater than $4^{\circ}C$ and sometimes as little as $1^{\circ}C$. At temperatures between 5 and $10^{\circ}C$, a difference of $4^{\circ}C$ between ponds would mean a difference of $\pm$ 11 days in egg development time for Cyclops sp. and $\pm$ 5 days for D. forbesi. At higher temperatures (between 15 and $22^{\circ}C$) a $4^{\circ}C$ difference would cause only about $\pm$ 1 day difference in duration of egg development for both species.

The stability of a population depends upon the balance between birth rates (b) and death rates (d). Pond VI had the most stable population of *Cyclops* sp. This relative stability apparently resulted from the greater reproductive activity which occurred in this pond. In the case of *D. forbesi*, birth rates were highest and eggs were observed most frequently in ponds VII and VIII, and, consequently, average rates of population change were more stable in these ponds. Instances in which values of r are greater than values of b may have been caused by rapid changes in the age structure of the population or by sampling error on those dates.

The estimates of instantaneous mortality rate (d) are probably the least reliable of all the population estimates, since they are based on the difference between two other estimates ($d = b - r$). The main cause of zooplankton mortality in the experimental ponds which I studied was probably predation by small fishes. As mentioned above, all ponds had populations of largemouth bass and black crappie, while ponds V and VI also had populations of bluegill. The presence of bluegills in ponds V and VI may explain, in part, the lower numbers of *D. forbesi* occurring in these ponds. The bluegill fry may have fed selectively on *D. forbesi*, and this along with competition from *D. pulex* and *B. longirostris* for filterable food items combined to reduce the *D. forbesi* population. Grygierek, Hillbricht-Ilkowska, and Spodniewska (1966) found that the effect of predation by fishes on zooplankton population numbers was greater in newly established ponds than in older ponds.

Changes in density of each copepod species I studied appear to follow a somewhat different cycle in each pond, and the amplitude of the cycles is also quite variable between ponds. This is in agreement with Armitage and Davis (1967) and Pennak (1946) who found that variations in population size were much greater and occurred more frequently in ponds than in larger lakes. As indicated above, the calculated average rates of population change are directly related to these changes in density. The high primary productivity observed in pond VI as compared to pond VII may explain the consistently greater densities of zooplankton which occurred in pond VI.

Although no quantitative counts were made on phytoplankton species in any of the ponds, large increases in desmids and diatoms were noted after each addition of fertilizer. The response of the zooplankters to these phytoplankton "blooms" was varied. In most instances, *D. pulex* and *B. longirostris* showed pronounced increases about two weeks after fertilization. *Cyclops* sp. showed increases in pond VI after fertilization in June and August. *D. forbesi* increased in pond VII following fertilization in June and July. McIntire (1960) found the responses of zooplankton populations to increases in phytoplankton density quite variable between the ponds which he studied.

Goodwin (1967) found that *Cyclops* sp. populations declined in spring when mid-water temperatures reached 65-70°F, and were completely replaced by *D. forbesi* from late June through early September. This replacement phenomenon was not observed during my study in ponds V and VI, but may have taken place in ponds VII and VIII. In ponds V and VI, *Cyclops* sp. was the dominant copepod throughout the year. *D. forbesi*, however, was dominant in ponds VII and VIII, except during the fall and winter of 1968 and spring of 1969 when *Cyclops* sp. became more abundant. *D. forbesi* did not occur in any of the ponds from December, 1968 through February, 1969.

Pennak (1957) and Timms (1968) found that most small lakes or ponds support two main copepod species and two or three important species of Cladocera. During my study, Soap Creek ponds V-VIII each contained two species of copepod, *Cyclops* sp. and *D. forbesi* and two important species of cladocerans, *D. pulex* and *B. longirostris*. In addition, the cladoceran, *Diaphanosoma* sp. and the ostracod, *Cyclocypris* sp. were collected, but never became very abundant. The effects of competition on the relative abundance of these species populations cannot be explained on the basis of the available data.

The four experimental ponds which I studied are located adjacent to each other and are morphometrically very similar. Here, however, the similarities end. Significant differences between ponds with respect to water chemistry and primary productivity were recorded. These and, no doubt, other environmental differences which were not measured resulted in significant differences in population densities, birth rates, and seasonal species composition.

The rapidity with which significant zooplankton population changes apparently take place, the presence of several genera of potentially-competing zooplankters within a small pond, and the different species combinations of fishes in the ponds combine to make explanation of some of the observed changes difficult. Any future studies along these lines should make an attempt at a more complete analysis of environmental variables within and between ponds. A plankton sampling schedule of one tow per pond per week appears adequate for studies of this type. Studies could also be made on the causes of zooplankton mortality and the effects of interspecific and intraspecific competition of zooplankton populations in small ponds.

In summary, reproductive rates of copepods are quite sensitive to differences in or changes in environmental conditions in small ponds. Population rates can also provide information on the importance of a prey species in the trophic relations of a lake or pond. The rates themselves, however, do not indicate what the existing environmental conditions actually are, and, therefore, cannot be used to characterize a lake or pond. In addition, these population rates do not give one any idea of the density or biomass of the zooplankters in a pond.

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Appendix Table 1. Vertical tows taken in Soap Creek Ponds V-VIII, using a No. 20 mesh, 30-cm diameter net from April, 1968 to April, 1969.

Date	Pond	Cyclops n/m^3	Diaptomus forbesi n/m^3	Copepod juveniles n/m^3	Daphnia pulex n/m^3	Bosmina longirostris n/m^3	Diaphanosoma n/m^3	Cyclocypris n/m^3	Volvox n/m^3
4-27-68	V	16,606	4,452	36,983	16,834	12,080	0	0	200
	VI	7,612	1,635	17,619	35,294	51,029	0	0	55
	VII	6,363	2,777	59,556	36,592	6,570	0	0	0
	VIII	5,977	10,710	48,712	13,380	25,821	0	0	0
5-3-68	VII	11,372	18,137	63,431	33,431	1,274	98	0	0
5-17-68	VII	2,582	9,624	27,934	112,441	1,877	3,286	0	0
5-24-68	VII	3,232	12,334	15,707	91,880	267	0	0	0
5-31-68	V	28,106	7,000	28,062	47,960	49,872	0	0	0
	VI	14,744	6,731	43,269	53,846	48,825	0	427	0
	VII	3,419	6,607	22,288	29,706	637	0	0	1,100
	VIII	6,624	19,765	34,936	74,359	18,056	1,496	0	0
6-14-68	VI	22,644	3,418	76,100	68,120	29,115	0	641	0
	VII	5,098	93,725	85,490	33,333	980	0	0	9,803
6-21-68	VI	27,777	3,632	47,649	90,064	124,145	0	0	0
	VII	12,606	78,632	63,675	62,606	2,350	0	0	31,196
6-27-68	V	3,125	0	19,271	4,036	313,541	0	2,604	94,141
	VI	34,295	1,709	25,854	9,936	27,243	0	12,713	0
	VII	2,030	37,286	23,718	10,363	0	0	0	103,846
	VIII	521	1,693	18,880	22,135	1,823	0	0	83,984
7-3-68	VI	17,370	469	71,596	62,441	142,253	0	151,643	0
	VII	Volvox bloom							
7-18-68	VI	1,995	939	54,108	23,122	85,446	0	10,915	0
	VII	939	75,868	13,896	11,831	3,192	0	0	1,878

Appendix Table 1 Continued.

Date	Pond	Cyclops n/m^3	Diaptomus forbesi n/m^3	Copepod juveniles n/m^3	Daphnia pulex n/m^3	Bosmina longirostris n/m^3	Diaphanosoma n/m^3	Cyclocypris n/m^3	Volvox n/m^3
7-24-68	V	2,934	587	55,164	22,300	113,028	0	0	0
	VI	16,666	704	71,948	32,394	248,004	0	5,399	0
	VII	1,026	61,709	22,222	58,974	14,017	0	0	5,299
	VIII	1,562	10,677	31,510	18,359	1,823	260	260	Many
8-2-68	V	18,403	1,878	85,258	25,540	168,451	0	0	2,253
	VI	7,110	1,878	104,554	17,245	180,000	0	51,216	3,004
	VII	1,314	10,704	9,202	13,896	3,568	0	0	3,755
	VIII	3,756	11,046	18,016	18,900	1,346	1,346	0	Many
8-9-68	V	45,305	2,305	180,202	86,022	688,000	2,934	27,216	2,696
	VI	18,186	833	116,127	17,156	152,261	490	74,144	0
	VII	240	14,384	9,820	8,154	2,570	0	0	0
	VIII	10,270	4,450	31,690	19,640	225	2,582	2,285	0
8-13-68	V	5,432	370	115,061	92,963	105,308	987	864	1,605
	VI	21,092	2,636	115,631	51,130	297,363	1,318	18,926	0
	VII	811	7,747	22,162	29,279	9,009	360	0	1,802
	VIII	4,321	4,074	36,543	14,197	2,345	1,358	0	0
8-16-68	V	9,012	185	68,086	121,173	47,839	1,173	1,111	1,975
	VI	22,794	1,421	60,049	34,559	449,853	1,372	3,382	1,618
	VII	1,127	17,990	21,323	73,725	2,451	147	0	1,519
	VIII	7,042	7,042	31,279	10,387	1,584	763	0	0
8-20-68	V	64,691	3,580	140,000	141,605	85,555	3,210	0	2,716
	VI	35,000	2,255	110,196	67,157	897,157	3,235	5,392	2,059
	VII	659	25,894	20,245	95,386	847	1,506	1,412	1,318
	VIII	8,568	14,084	28,286	36,620	1,173	7,159	0	0

Appendix Table 1 Continued.

Date	Pond	*Cyclops* n/m^3	*Diaptomus forbesi* n/m^3	Copepod juveniles n/m^3	*Daphnia pulex* n/m^3	*Bosmina longirostris* n/m^3	*Diaphanosoma* n/m^3	*Cyclocypris* n/m^3	*Volvox* n/m^3
8-23-68	V	35,211	234	85,915	165,962	340,845	2,230	3,756	1,173
	VI	28,627	882	122,059	187,745	1,083,137	1,470	32,059	686
	VII	1,666	31,765	20,588	147,549	67,549	1,960	392	10,882
	VIII	4,362	4,698	25,615	32,550	6,823	7,159	6,152	447
8-27-68	V	38,615	1,995	108,568	185,681	178,403	3,403	2,817	352
	VI	22,843	196	100,686	156,176	261,765	1,960	13,921	784
	VII	1,892	7,297	23,874	66,486	18,649	1,261	3,333	80,090
	VIII	10,446	3,990	38,380	39,202	5,516	2,230	2,347	3,286
8-30-68	V	44,366	2,817	72,300	87,089	66,197	3,051	6,807	0
	VI	36,666	1,568	94,706	123,921	279,215	0	178,431	42,156
	VII	3,964	5,585	10,270	53,873	10,630	900	0	Many
	VIII	9,624	8,920	19,953	33,098	1,877	6,807	0	43,896
9-4-68	V	46,244	2,347	89,201	62,676	35,446	2,113	10,563	1,408
	VI	66,078	392	115,098	65,686	70,784	980	133,137	392
	VII	No counts							
	VIII	4,225	6,103	17,136	6,572	1,643	3,286	939	64,553
9-10-68	V	58,568	821	76,056	28,756	36,268	1,056	0	0
	VI	49,804	588	72,745	41,765	25,490	882	73,529	0
	VII	6,757	1,622	14,504	19,730	3,693	0	1,261	1,892
	VIII	8,451	352	23,944	17,019	3,756	5,516	0	1,291
9-13-68	V	78,051	0	60,446	48,474	70,775	587	5,047	1,174
	VI	61,176	0	48,431	40,686	32,353	1,078	84,902	0
	VII	5,495	5,766	11,621	22,973	5,225	720	0	2,522
	VIII	11,620	1,408	19,718	20,657	4,695	3,051	0	0

Appendix Table 1 Continued.

Date	Pond	Cyclops n/m^3	Diaptomus forbesi n/m^3	Copepod juveniles n/m^3	Daphnia pulex n/m^3	Bosmina longirostris n/m^3	Diaphanosoma n/m^3	Cyclocypris n/m^3	Volvox n/m^3
9-17-68	V	27,934	704	33,685	26,408	62,676	0	587	0
	VI	56,274	784	66,274	93,627	8,039	1,863	17,254	0
	VII	4,234	11,801	11,621	21,171	0	360	1,802	991
	VIII	13,380	4,577	8,216	23,591	6,572	0	939	0
9-20-68	V	35,680	234	10,094	49,765	134,507	0	3,756	0
	VI	58,627	1.765	9,019	59,803	40,784	1,176	16,470	0
	VII	4,504	9,730	900	28,649	4,865	900	0	0
	VIII	17,840	2,347	5,398	15,258	5,868	469	0	0
9-24-68	V	41,605	2,963	7,531	54,938	101,975	1,481	0	494
	VI	70,784	3,137	38,529	80,294	30,392	490	8,333	0
	VII	7,117	10,450	6,036	34,324	1,441	0	0	0
	VIII	11,854	2,113	13,497	35,328	1,056	352	0	0
9-27-68	V	39,437	1,877	12,910	61,032	107,511	3,051	0	0
	VI	70,980	3,137	14,902	36,862	38,039	784	20,196	0
	VII	5,946	2,703	10,090	15,856	360	0	0	900
	VIII	6,103	3,051	9,389	32,394	3,521	1,643	0	0
10-1-68	V	42,716	987	9,012	111,605	220,617	0	1,358	0
	VI	38,823	1.274	5,784	72,353	38,921	196	8,823	0
	VII	4,865	7,117	2,522	24,234	1,802	0	360	270
	VIII	5,986	1,643	6,455	46,244	1,995	0	0	0
10-8-68	V	10,416	260	5,338	121,744	315,494	0	260	0
	VI	45,194	3,681	25,153	63,088	66,973	716	16,564	0
	VII	450	1,892	3,333	3,693	2,162	0	1,081	0
	VIII	4,460	2,347	5,398	33,803	469	1,643	0	0

Appendix Table 1 Continued.

Date	Pond	Cyclops n/m^3	Diaptomus forbesi n/m^3	Copepod juveniles n/m^3	Daphnia pulex n/m^3	Bosmina longirostris n/m^3	Diaphanosoma n/m^3	Cyclocypris n/m^3	Volvox n/m^3
10-22-68	V	4,938	0	0	29,876	50,617	2,715	0	0
	VI	14,706	1,372	21,960	44,118	191,372	0	13,725	0
	VII	4,684	900	8,829	900	900	0	0	0
	VIII	2,680	2,680	2,010	1,675	17,755	502	0	0
10-29-68	V	7,654	1,481	7,407	50,123	28,641	0	0	0
	VI	14,509	2,745	10,588	60,980	125,882	0	12,156	0
	VII	20,360	2,342	16,396	360	2,342	0	0	0
	VIII	5,398	1.643	2,817	5,634	30,516	704	0	0
11-22-68	V	3,991	939	31,455	72,535	2,582	1,174	0	0
	VI	18,162	0	17,949	78,632	18,162	0	7,051	0
	VII	47,387	1,081	45,766	3,063	37,297	360	0	0
	VIII	9,390	469	9,390	6,103	7,042	0	0	0
12-20-68	V	1,522	0	4,088	4,120	6,115	0	0	0
	VI	2,840	0	3,143	6,210	7,865	0	2,326	0
	VII	4,250	0	1,924	1,546	2,044	0	0	0
	VIII	4,020	0	2,076	2,642	995	0	0	0
1-18-69	V	1,110	0	3,896	3,124	0	0	0	0
	VI	2,650	0	3,942	1,656	4,143	0	0	0
	VII	2,124	0	0	1,098	1,062	0	0	0
	VIII	2,009	0	2,767	1,147	1,148	0	0	0
2-12-69	V	3,991	0	7,042	2,113	0	0	0	0
	VI	9,608	0	44,902	2,549	1,372	0	0	0
	VII	10,270	0	16,937	1,081	3,964	0	0	0
	VIII	3,632	0	12,607	427	2,991	0	0	0

Appendix Table 1 Continued.

Date	Pond	Cyclops n/m3	Diaptomus forbesi n/m3	Copepod juveniles n/m3	Daphnia pulex n/m3	Bosmina longirostris n/m3	Diaphanosoma n/m3	Cyclocypris n/m3	Volvox n/m3
3-11-69	V	14,084	0	18,310	46,244	2,817	0	0	0
	VI	51,923	1,495	127,350	13,888	7,478	0	6,410	1,068
	VII	25,405	0	67,747	18,558	22,703	0	0	0
	VIII	10,563	0	70,891	14,789	7,981	0	0	0
3-25-69	V	8,685	939	9,624	38,732	7,746	0	4,694	0
	VI	120,085	1,282	62,179	20,299	6,837	0	7,265	0
	VII	58,198	720	107,027	13,333	20,000	0	0	0
	VIII	8,451	939	147,887	6,807	2,582	0	0	0
4-7-69	V	8,451	1,408	43,662	50,000	2,113	0	704	0
	VI	99,259	0	94,074	43,704	5,926	0	9,630	0
	VII	76,760	3,521	79,577	26,760	114,789	1,408	704	0
	VIII	53,125	1,562	150,000	19,531	10,156	0	1,562	0

Appendix Table 2. Population parameters of *Cyclops* sp. collected in Soap Creek Ponds V-VIII from April, 1968 to April, 1969.

Date	Pond	B	E	1/D	r	b	d	%♀
4-27-68	V	.5356	2.3808	.225		.4318		87
	VI	1.8518	8.2305	.225		1.0473		68
	VII	1.0647	5.3236	.200		.7227		78
	VIII	1,8427	7.2263	.255		1.0438		80
5-3	VII	1.2678	4.7844	.265		.8198		80
5-17	VII	3.9477	14.8971	.265		1.5994		55
5-24	VII	5.3439	20.1658	.265		1.8467		83
5-31	V	.2436	.9553	.255	.0152	.2151	.1999	80
	VI	1.0385	4.0728	.255	.0194	.7129	.6935	83
	VII	5.6106	21.1722	.265	-.0183	1.8886	1.9069	90
	VIII	3.0844	9.9497	.310	.0030	1.4061	1.4031	89
6-14	VI	.8632	2.6159	.330		.6206		66
	VII	.0000	.0000					80
6-21	VI	.3441	1.0329	.330		.2927		52
	VII	0	0					66
6-27	V	0	0		-.0810			
	VI	.3514	1.0649	.330	.0313	.3001	.3194	86
	VII	0	0		-.0193			66
	VIII	0	0		-.0942			
7-3	VI	0	0					57
	VII	*Volvox* bloom						
7-18	VI	0	0					66
	VII	0	0					100
7-24	V	0	0		-.0023			
	VI	0	0		-.0267			84
	VII	0	0		-.0261			
	VIII	0	0		.0407			66
8-2	V	0	0		.2040			83
	VI	0	0		-.0964			
	VII	0	0		.0301			
	VIII	0	0		.0975			66
8-9	V	0	0		-.0292			90
	VI	1.0311	2.8252	.365	.1309	.7080	.5771	83
	VII	0	0		-.2429			
	VIII	0	0		.1427			56
8-13	V	0	0		-.2537			
	VI	0	0		.0467			79
	VII	0	0		.3045			
	VIII	0	0		-.2147			

Appendix Table 2 Continued.

Date	Pond	B	E	1/D	r	b	d	%♀
8-16	V	0	0		.1686			67
	VI	.7158	1.9613	.365	.0258	.5423	.5165	75
	VII	0	0		.1096			
	VIII	0	0		.1628			61
8-20	V	.0482	.1286	.375	.4927	.0488	-.4439	89
	VI	.9968	2.7310	.365	.1073	.6931	.5858	72
	VII	0	0		-.1341			
	VIII	2.0905	4.9190	.425	.0490	1.1282	1.0792	66
8-23	V	0	0		-.2027			89
	VI	.1679	.4600	.365	-.0670	.1570	.2240	67
	VII	0	0		.3089			
	VIII	0	0		-.2250			71
8-27	V	0	0		.0230			71
	VI	.6800	1.8632	.365	-.0565	.5188	.5753	85
	VII	0	0		.0319			83
	VIII	0	0		.2184			54
8-30	V	0	0		.0464			83
	VI	.8588	2.3530	.365	.1578	.6206	.4628	60
	VII	0	0		.2465			
	VIII	0	0		-.0274			37
9-4	V	0	0		.0104			78
	VI	.0496	.1504	.330	.1472	.0488	-.0984	71
	VII	0	0					
	VIII	0	0		-.2059			
9-10	V	0	0		.0394			86
	VI	0	0		-.0472			85
	VII	0	0					82
	VIII	0	0		.1155			80
9-13	V	.0648	.1906	.340	.0957	.0583	-.0374	71
	VI	0	0		.0686			77
	VII	0	0		-.0689			89
	VIII	0	0		.1061			75
9-17	V	0	0		-.2569			79
	VI	0	0		-.0209			79
	VII	0	0		-.0652			57
	VIII	0	0		.0353			77
9-20	V	0	0		.0816			73
	VI	0	0		.0137			80
	VII	0	0		.0207			57
	VIII	0	0		.0959			71

Appendix Table 2 Continued.

Date	Pond	B	E	1/D	r	b	d	% ♀
9-24	V	.1424	.4189	.340	.0384	.1310	.0926	68
	VI	0	0		.0471			73
	VII	0	0		.1144			57
	VIII	0	0		-.1023			58
9-27	V	0	0		-.0178			76
	VI	0	0		.0009			68
	VII	0	0		-.0599			
	VIII	1.5423	4.2257	.365	-.2212			
10-1	V	0	0		.0200			73
	VI	0	0		-.1508			71
	VII	0	0		-.0501			73
	VIII	0	0		-.0048			75
10-8	V	0	0		-.2015			69
	VI	0	0		.0151			70
	VII	0	0		-.3401			
	VIII	0	0		-.0420			
10-22	V	0	0		-.0534			
	VI	0	0		-.0769			90
	VII	0	0		.1673			
	VIII	0	0		-.0364			
10-29	V	0	0		.0626			
	VI	0	0		-.0019			72
	VII	0	0		.2099			83
	VIII	0	0		.1000			
11-22	V	0	0		-.0283			
	VI	.3240	2.4001	.135	.0097	.2776	.2679	75
	VII	0	0		.0367			93
	VIII	0	0		.0241			
12-20	V	0	0		-.0344			
	VI	0	0		-.0662			83
	VII	0	0		-.0861			90
	VIII	0	0		-.0303			
1-18	V	0	0		-.0109			
	VI	0	0		-.0024			
	VII	0	0		-.0239			
	VIII	0	0		-.0239			
2-12	V	0	0		.0512			
	VI	.1342	1.9177	.070	.0515	.1222	.0707	
	VII	0	0		.0630			
	VIII	0	0		.0227			

Appendix Table 2 Continued.

Date	Pond	B	E	1/D	r	b	d	%♀
3-11	V	.2896	1.6092	.180	.0467	.2546	.2079	87
	VI	.1475	1.0175	.145	.0625	.1398	.0773	91
	VII	.3364	2.1029	.160	.0335	.2927	.2592	86
	VIII	.2615	1.4530	.180	.0404	.2311	.1907	78
3-25	V	0	0		-.0345			
	VI	.1772	1.1438	.155	.0599	.1655	.1056	84
	VII	.2753	1.7763	.155	.0592	.2390	.1798	80
	VIII	.3937	2.1873	.180	-.0159	.3293	.3452	
4-7	V	.5299	2.2549	.235	-.0021	.4253	.4274	
	VI	.5636	2.9664	.190	-.0146	.4447	.4593	
	VII	.3199	1.4220	.225	.0213	.2776	.2563	
	VIII	.3280	1.3667	.240	.1414	.2852	.1438	

Appendix Table 3. Population parameters of *Diaptomus forbesi* collected in Soap Creek Ponds V-VIII from April, 1968 to April, 1969.

Date	Pond	B	E	1/D	r	b	d	% ♀
4-27	V	0.3424	1.6705	0.205		.2927		33
	VI	2.6273	12.8165	0.205		1.2892		20
	VII	0.1262	0.6645	0.190		.1222		25
	VIII	0.2024	0.8800	0.230		.1823		17
5-3	VII	.0529	.2253	.235		.0488		36
5-17	VII	.1422	.6054	.235		.1310		44
5-24	VII	.4628	1.9695	.235		.3784		41
5-31	V	.0000	.0000		.0133	.0000		
	VI	.6472	2.8140	.230	.0416	.5008	.4592	33
	VII	.9919	4.2212	.235	.0255	.6881	.6626	29
	VIII	1.5106	5.7005	.265	.0180	.9203	.9023	33
6-14	VI	9.5629	34.1533	.280		2.3608		25
	VII	.0233	.0733	.310		.0198		25
6-21	VI	0	0			.0000		20
	VII	0	0			.0000		22
6-27	V	0	0			.0000		
	VI	0	0		-.0508	.0000		33
	VII	0	0		.0641	.0000		45
	VIII	0	0		-.0910	.0000		
7-3	VI	0	0			.0000		
	VII	*Volvox* bloom						
7-18	VI	0	0			.0000		33
	VII	.1699	.4855	.350		.1570		26
7-24	V	0	0					
	VI	0	0		-.0328			
	VII	.8108	2.3167	.350	.0187	.5933	.5746	33
	VIII	0	0		.0682			25
8-2	V	0	0		.1292			
	VI	0	0		.1043			
	VII			.340	-.1947			
	VIII	0	0		.0033			20
8-9	V	0	0		.0226			
	VI	0	0		-.1106			
	VII	1.3416	3.9460	.340	.0434	.8501	.8067	30
	VIII	0	0		-.1293			
8-13	V	0	0		-.4457			
	VI	0	0		.2889			
	VII	1.0448	3.0731	.340	-.1567	.7129	.8696	42

Appendix Table 3 Continued.

Date	Pond	B	E	1/D	r	b	d	% ♀
8-16	V	0	0		-.2310			
	VI	0	0		-.2062			
	VII	0	0		.2809			38
	VIII	.1943	.5553	.350	.1824	.1739	-.0085	45
8-20	V	0	0		.7407			
	VI	0	0		.1156			
	VII	1.3488	3.9673	.340	.0909	.8544	.7635	11
	VIII	.3258	.9309	.350	.1732	.2852	.1120	43
8-23	V	0	0		-.9093			
	VI	0	0		-.3128			
	VII	.2740	.8051	.340	.0682	.2390	.1708	19
	VIII	3.0002	8.5721	.350	-.3659	1.0986	1.4645	40
8-27	V	0	0		.5357			
	VI	0	0		-.3760			
	VII	0	0		-.3677			17
	VIII	1.4415	4.1186	.350	-.0407	.8920	.9327	30
8-30	V	0	0		.1151			
	VI	0	0		.6931			
	VII	0	0		-.0890			
	VIII	1.0883	3.1097	.350	.2681	.7372	.4691	33
9-4	V	0	0		-.0456			
	VI	0	0		-.3465			
	VII	0	0					
	VII	0	0		-.0949			
9-10	V	0	0		-.1751			
	VI	0	0		.0676			
	VII	0	0					
	VIII	0	0		-.4755			
9-13	V	0	0					
	VI	0	0					
	VII	0	0		.4227			27
	VIII	1.5254	5.0014	.305	.4621	.9243	.4622	
9-17	V	0	0					
	VI	0	0					
	VII	0	0		.1790			32
	VIII	.5519	1.8097	.305	.2947	.4382	.1435	17
9-20	V	0	0		-.3672			
	VI	0	0		.2705			
	VII	0	0		-.0643			45
	VIII	0	0		-.2303			

Appendix Table 3 Continued.

Date	Pond	B	E	1/D	r	b	d	% ♀
9-24	V	0	0		.6346			
	VI	0	0		.1438			
	VII	.5038	1.5746	.320	.0178	.4055	.3877	23
	VIII	1.3260	4.3477	.305	-.0205	.8459	.8664	
9-27	V	0	0		-.1521			
	VI	0	0		.0000			
	VII	0	0		-.4508			
	VIII	1.0562	3.4631	.305	.1224	.7227	.6003	
10-1	V	0	0		-.1607			
	VI	0	0		-.2252			
	VII	.5590	2.3789	.235	.2420	.4447	.2027	35
	VIII	0	0		-.1547			
10-8	V	0	0		-.1905			
	VI	0	0		.1516			
	VII	0	0		-.1893			
	VIII	0	0		.0510			
10-22	V	0	0					
	VI	0	0		-.0705			
	VII	0	0		-.0531			
	VIII	0	0		.0095			
10-29	V	0	0					
	VI	0	0		.0991			
	VII	0	0		.1366			
	VIII	0	0		-.0699			
11-22	V	0	0		-.198			
	VI	0	0					
	VII	0	0		-.0336			
	VIII	0	0		-.0545			
12-20	V	0	0					
	VI	0	0					
	VII	0	0					
	VIII	0	0					
1-18	V	0	0					
	VI	0	0					
	VII	0	0					
	VIII	0	0					
2-12	V	0	0					
	VI	0	0					
	VII	0	0					
	VIII	0	0					

Appendix Table 3 Continued.

Date	Pond	B	E	1/D	r	b	d	% ♀
3-11	V	0	0					
	VI	0	0					
	VII	0	0					
	VIII	0	0					
3-25	V	0	0					
	VI	0	0		-.0110			
	VII	0	0					
	VIII	0	0					
4-7	V	0	0		.0311			
	VI	0	0					
	VII	0	0		.1221			
	VIII	0	0		.0391			