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A STUDY OF THE PLANKTONIC
ROTIFERA OF RIVER CANARD
ESSEX COUNTY, ONTARIO

by

Edward A. Hodgkinson Jr.

A Thesis

Submitted to the Faculty of Graduate Studies Through the
Department of Biology in Partial Fulfilment of the
Requirements for the Degree of
Master of Science at the
University of Windsor

Windsor, Ontario, Canada
1970

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ABSTRACT

A study of the planktonic Rotifera of River Canard, Essex County, Ontario was conducted from April 5, 1968 to May 28, 1969. Physical, chemical and biological samples were taken on a weekly basis from a station near the mouth of the river. The parameters studied included air and water temperatures, turbidity, precipitation, concentrations of various chemicals, optical density of chlorophyll a, coliform bacteria concentrations and the abundance of various elements of the phytoplankton and zooplankton.

The Rotifera were the dominant members of the metazoanplankton, with a study average of 362 individuals/liter, compared to 77/liter for the Copepoda and 10/liter for the Cladocera. Seventeen genera of planktonic rotifers, comprising 41 species were identified in the river. The dominant genera were Brachionus, Polyarthra, Synchaeta and Keratella.

Rotifers were most abundant from spring to late fall. Population minima occurred after heavy rainfall. However run-off enrichment from the surrounding farmland enhanced productivity so that within several days the rotifers made a recovery. As a consequence, population maxima tended to follow heavy rainfall by about two weeks. The appearance of resting eggs at the time of some of these maxima is consistent with Gilbert's (1963) hypothesis that the production of mictic females is a density dependent phenomenon.

Chemical analyses indicated that the river was eutrophic. Concentrations of phosphate, total nitrogen, sulfate, iron and chloride were all in excess of the average concentrations for North American

rivers. Chlorophyll a data tended to verify this eutrophic condition.

The planktonic rotifer population reflects this eutrophic nature of the river. The yearly average of 395 rotifers/liter is large compared to other reported annual averages. The maximum number of rotifers, 3641/liter is also considerable. The common occurrence of various species of Brachionus, Keratella, and Synchaeta, as well as Filinia longiseta and Platyras patulus provides evidence for the hypothesis that planktonic rotifers are indicators of the trophic nature of the environment. All of the above have been implicated as indicators of eutrophy, or are at least known to commonly occur under such conditions. Congeneric associations within the genera Brachionus, Keratella and Synchaeta may also be a consequence of the eutrophic state which allows for niche overlap. However the possibility exists that, in some cases at least, size differences between congeners may play a role in niche differentiation.

When available facts are taken into account, it appears that the planktonic rotifer population of River Canard is both quantitatively and qualitatively defined by the agricultural nature of the drainage basin.

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CHAPTER I

INTRODUCTION

The Rotifera "are the most important soft-bodied invertebrates in the fresh-water plankton" (Hutchinson, 1967). This importance is based upon their abundance and their role as intermediates in the aquatic food web. Most rotifers are primary consumers feeding on various-sized phytoplankters. Some, however, feed on detritus and bacteria, while a few are raptorial (Edmondson, 1957). The rotifers in turn are preyed upon by small fish (Prowse, 1966) and predaceous plankters (Edmondson, 1957).

Despite the fact that rotifers make up a substantial portion of the zooplankton, field studies concerning them are few. Consequently, a number of questions relating to their basic ecology still exist. Hutchinson (1967) reviewed the present state of knowledge concerning the planktonic Rotifera. His resumé indicated several areas where more work is necessary.

One such area is the seasonal succession of species. Studies by a number of authors, among them Ahlstrom (1933), Beach (1960), Carlin (1943) and Kofoid (1903,1908) have illustrated that the species of rotifers within the plankton change from one season to another. However, it is also evident that this seasonal succession may follow an irregular pattern (Edmondson, 1957). Species abundant one spring, for example, may be absent the next (Carlin, 1943). The rotifer population may reach a maximum in the summer one year, but may be reduced the following (Beach, 1960). Factors which control this succession remain to be fully elucidated. Temperature is known to

play a significant role, and other factors, principally the quality and quantity of the food supply, have also been implicated. The roles of parasitism, predation and fluctuations in chemical concentrations remain to be established.

The problem of seasonal succession is closely allied with the niche specificity of planktonic rotifers. As Hutchinson (1967) points out, these organisms probably occupy "fairly discrete niches" within the plankton. These niches are defined by the above factors and perhaps others. Changes in the environment alter the niches available in the planktonic community. Conditions become unsuitable for one species but favourable for another, and succession is initiated. Further research is necessary for a fuller understanding of those factors which delineate these niches. This is especially true for co-occurring congeners.

Another concern is the role of the chemistry of the water in determining the distribution of rotifers. For many species the suitability of a particular habitat is apparently governed by the chemical nature of the environment. Members of the genus Brachionus for example, are restricted to alkaline water (Ahlstrom, 1940). Keratella serrulata on the other hand, becomes abundant only in acidic conditions (Ahlstrom, 1943). But as Hutchinson points out, the nature of these limitations is not fully understood. Pejler (1957a) proposed the idea that such chemical limitations are really of a secondary nature. He suggests that the chemical composition of the water determines the species of rotifers present in a particular habitat through its control of primary productivity. It is the

quantity and quality of the food supply then, that directly determine what species will be present. Pejler further contends that environments of similar trophic conditions tend to possess the same species of planktonic rotifers. Rotifers therefore, may prove to be suitable indicators of the trophic nature of the environment. Pejler's studies (1957a, b) of the planktonic rotifers of central and northern Sweden lend strong support to this hypothesis.

A number of species are thought to be indicative of eutrophic, mixotrophic or dystrophic conditions. However, Hutchinson (1967) sites exceptions in which high concentrations of "typical eutrophic" species occur in oligotrophic situations. Pejler (1957a) is of the opinion that part of this problem may be due to the existence of ecological races within a species, each race being adapted to different environmental conditions. He emphasizes that such exceptions serve as a warning against applying results of one region to another. Apparently further research in a variety of geographical locations and trophic situations is required.

Numerous investigations of zooplankton have been carried out on various lakes and ponds in both North America and Europe. In these lentic situations however, copepods and cladocerans are the dominant metazoan plankters. In the lotic habitat on the other hand, these crustaceans are reduced. Here rotifers are one of the few typical zooplanktonic elements (Coker, 1954; Welch, 1952). In flowing water then, rotifers play a significant role as planktonic organisms. On this account, rotifer studies in lotic habitats would perhaps prove to be of more value for following seasonal trends than similar studies

in lakes or ponds. The rotifers, being the dominant zooplankters, would bear a more noticeable relationship to trends in phytoplankton, bacteria concentrations and so forth, since the effect of zooplankton on these and other factors would be largely controlled by the Rotifera, rather than by the Copepoda or the Cladocera.

Despite this dominance, few papers consider the planktonic rotifers of lotic situations. Beach (1960) made what is perhaps the first North American study dealing specifically with these plankters in flowing water. Sampling at forty-two stations throughout the Ocqueoc River system, Presque Isle County, Michigan, Beach made qualitative and quantitative comparisons among rotifer fauna of the various lentic and lotic habitats.

Other North American papers concerned wholly with the planktonic rotifers of rivers are those of Williams (1966), enumerating the various genera of the dominant planktonic Rotifera of the major waterways of the U.S.A.; and Prins and Davis (1966), considering the fate of planktonic rotifers in a polluted stream.

Several European papers have been devoted entirely to planktonic river-rotifers. Of these, Carlin's (1943) study of the taxonomy and seasonal dynamics of the rotifers of the Motala River in southern Sweden is a classic work. More recently Bogoslovskii (1961) investigated the distribution of rotifers in the river Klyazma, Russia, and Naberezhnyi and Rotar (1965) have examined the rotifer fauna of the Prut River.

Studies of planktonic river-rotifers in other parts of the world are equally sparse. These include works by Green (1960) on the Sokoto

River of North Nigeria and by Novotna-Duorakova Marie (1933) on the River Yamuna near Delhi, India. Hauer (1965) gives a qualitative account of the rotifer fauna of the Amazon region.

In addition to these, a number of studies concerned with the lotic plankton in general have considered the Rotifera to some degree. Several papers have dealt with the plankton of the Mississippi River and its major tributaries. Among these is the work of Kofoid (1903, 1908) on the Illinois River, Purdy (1922) on the Ohio River, Galtsoff (1924) and Reinhard (1931) on the upper Mississippi, and Berner (1951) on the lower portion of the Missouri River. Other investigations have been carried out on the plankton of smaller rivers of the Mississippi drainage. These include the work of Eddy (1932) on the Sangamon River, Illinois, and that of Roach (1932) on the Hocking River, Ohio.

Elsewhere in North America, plankton studies by Allen (1920) on the San Joaquin River, California; Chandler (1937, 1939) on the Huron and Cheboygan Rivers of Michigan; and Hooper (1947) on the Yukon and Mackenzie River systems deal in part with the Rotifera, as does the work of Coopey (1953) on the Columbia River, Washington; and that of Parchment (1961) on the Stone's River, Tennessee.

This review of lotic plankton studies, concerned entirely or in part with the Rotifera, includes the major papers published over the past sixty-five years, and serves to emphasize the relatively small number of studies that have been done in this area. In view of this paucity, and bearing in mind the problems mentioned earlier, a study of the planktonic rotifers was undertaken on River Canard, Essex County, Ontario.

A previous study of this river (Winner and Hartt, 1969) indicated that rotifers were the dominant members of the zooplankton and on occasion could be found in rather high concentrations (i.e. in excess of 1000 individuals/L.). Because of this abundance and the variety of rotifers present, this small river seemed to be a good location to investigate the planktonic Rotifera of a lotic situation. A program encompassing qualitative and quantitative plankton sampling, chemical analyses, bacterial counts and chlorophyll extractions was therefore undertaken on the river.

The objectives of the study were (1) to enumerate the species of planktonic rotifers in River Canard, and to establish their patterns of seasonal succession, (2) to attempt to relate the abundance and periodicity of the various rotifers with certain physical, chemical and biological environmental factors and (3) to investigate the role of the Rotifera as indicators of the trophic nature of the environment.

CHAPTER II

DESCRIPTION OF RIVER

River Canard is a small stream draining an area of 465 sq. km. of the west-central portion of Essex County, Ontario (Winner and Hartt, 1969). The major branch of the river arises near a low gravel ridge near the center of the county and flows in a westerly direction. It empties into the Detroit River about 24 km. from its source. The river displays a typical dendritic pattern with the main stream being joined by seven major tributaries (Fig. 1).

River Canard generally does not exceed 6 meters in width for most of its length. Within 6 km. of its mouth it widens to 160 meters. The average depth of the river is 1.2 meters with a maximum depth of 2.4 meters (Winner and Hartt, 1969). The river has a mud bottom covered in places by detrital deposits.

The main channel is lined with large stands of Typha latifolia and T. angustifolia (Fig. 2). Other emergent vegetation includes Pontederia sp, Sagittaria sp, Alisma sp, Lythrum sp and Decodon sp. Nymphia sp and Nuphar sp are prominent floating forms. An isolated Nelumbo lutea colony is also present. Submerged vegetation includes Utricularia vulgaris, Potamogeton sp, Ceratophyllum sp, Myriophyllum sp, Chara sp and Vallisneria sp (Winner and Hartt, 1969). Though present in the upper reaches of the river, submerged vegetation is much reduced in the lower portion due to the high turbidity.

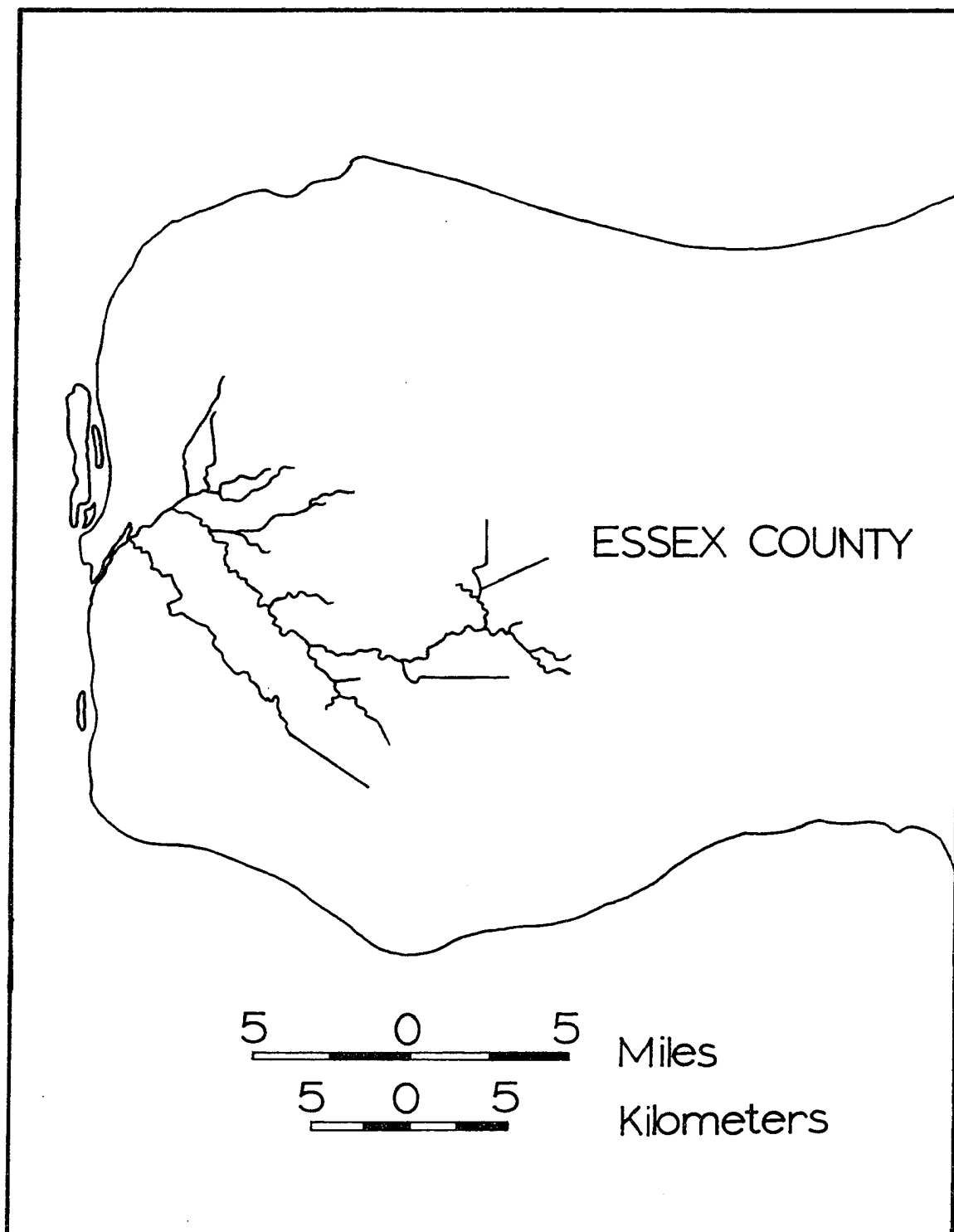


Fig. 1. Map of River Canard
(Vandall, 1965)



Fig. 2. View of River Canard looking upstream from the sampling site.

Note the extensive growth of Typha and the floating colonies of Nymphaea and Nuphar.

The drainage basin of River Canard is part of the Essex Clay Plain, a region of lacustro-morainic deposits overlying a bedrock of Devonian limestone (Richards, Caldwell and Morwick, 1949). Glaciation and subsequent submersion by glacial lakes have resulted in a region of faint relief (Richards et al., 1949). As a consequence, River Canard is a sluggish stream. The flow rate is approximately 295 cu. ft. per second (Winner and Hartt, 1969). The faint relief also creates poor drainage conditions. Consequently, surrounding land is extensively ditched and tiled (Chapman and Putnam, 1966) to facilitate run-off to the river.

The predominant soil type of the basin is Brookston clay, a heavy soil with fairly high organic content in the surface layers (Richards et al., 1949). Two other clay soils, Toledo clay and Caistor clay are also common in the basin. Toledo clay is similar to Brookston clay, both belong to the Dark Grey Gleisolic Great Soil Group. Toledo clay however, has a higher silt content. Caistor clay, a member of the Grey Brown Podsollic Great Soil Group, has a higher shale content. Clay loams, silt loams, and various sands are also found in the basin, though these are restricted to the northern portion (Fig. 3). The land adjacent to the river is, for the most part, bottom land. This land is subject to flooding and becomes covered with alluvial deposits. It has variable physical and chemical characteristics (Richards et al., 1949).

The drainage basin is extensively farmed. According to the Ontario Department of Agriculture (1967), 82% of Essex County is farmland. There is little urbanization in the River Canard area.

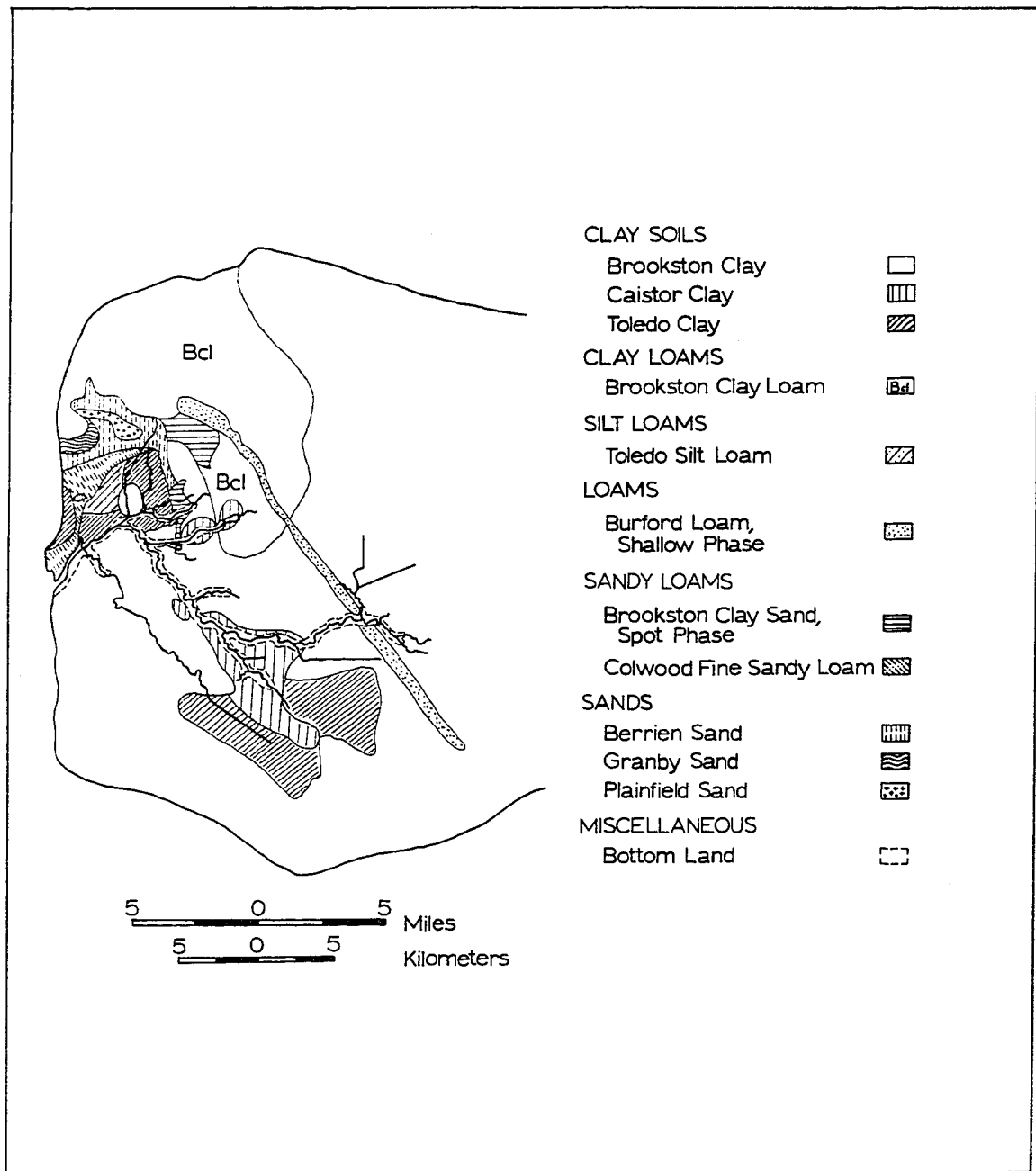


Fig. 3. Soil Map of the River Canard Basin
(after Richards et al., 1949)

Therefore, the percentage of farmland is even greater within the river basin. A 1961 survey (Vandall, 1965) shows that the amount of farmland under crops in the townships through which the river flows ranges from 73% to 81%. Major crops are corn, soyabeans, wheat, oats and tomatoes.

The basin is almost totally deforested. Only about 5% of the basin remains forested with the native northern deciduous hardwoods (Vandall, 1965). Small areas of unimproved land and scrub also occur. As a result of the deforested nature of the basin, the extensive farming and drainage ditches, River Canard is very turbid.

The climate of the region is temperate. The mean annual temperature is 8.3°C (47°F), with a winter mean of -3.3°C (26°F) and a summer mean of 21.1°C (70°F). Consequently the river freezes over for part of the winter, while in the summer water temperatures rise above 25°C. Therefore, River Canard, according to Ricker's (1934) classification of Ontario streams, is a "warm river".

CHAPTER III

MATERIALS AND METHODS

A. The Sampling Station

The sampling station for the study was an old bridge abutment near the Highway 18 bridge over River Canard (Fig. 4, 5). A fallen slab of concrete projecting into the river provided a platform close to the surface of the water. During the winter, collections were made through the ice at a point about 10 meters from the abutment towards the center of the river.

B. Field Procedures

Sampling was carried out on a weekly basis from April 5, 1968 to May 28, 1969. In the field, a quantitative plankton sample was collected with a 2 liter calibrated pitcher and concentrated in a Wisconsin net of #20 nylon bolting cloth. Samples of 20 liters were taken in the summer. These were increased to 50 liters during the winter, a time of low plankton production. Sampling was generally restricted to the surface. However, on several occasions it was carried out at depths of 1.2 meters and 2.4 meters (bottom) using a 2 liter Van Dorn water bottle.

Quantitative nanoplankton samples were also taken using a calibrated pitcher and a nanoplankton net of $28\mu^2$ mesh aperture. Samples of 5 liters were taken in the summer. These were increased to 10 liters during the winter.

Each of the above samples was preserved in the field with 3 ml. of 40% neutral formalin.

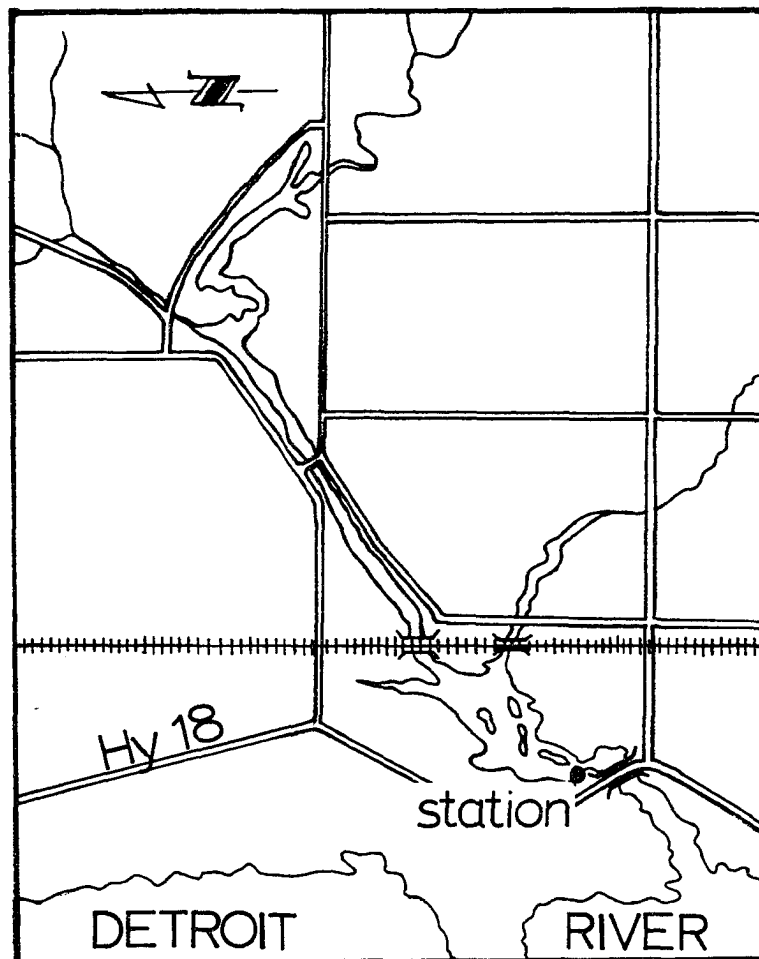


Fig. 4. MAP of RIVER CANARD showing location of sampling station

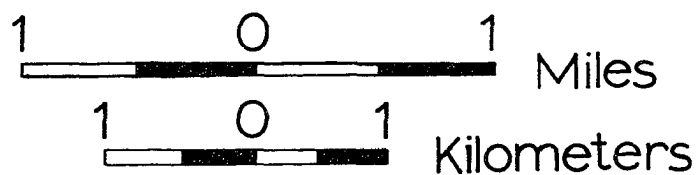




Fig. 5. View of the sampling site looking upstream.

Two net tows were also made. Organisms in one tow sample were kept alive for examination in the laboratory; organisms in the other were preserved with formalin for later reference.

Three water samples were taken at the site. For chemical analyses a 4 liter sample of water was taken and stored in a polyethylene bottle. Commencing June 6, 1968, samples for bacterial analysis and chlorophyll extractions were also obtained. For bacterial analysis, a sterile 50 c.c. flask was filled with water, stoppered and kept cool in an insulated bucket with an "Ice-Pack". For chlorophyll extractions, a one liter sample of water was taken by submerging a polyethylene bottle just below the surface.

At the station measurements of dissolved oxygen, carbon dioxide and pH were carried out using the Hach Chemical Company portable water analysis kit and a two liter Van Dorn water bottle. Air temperature and surface temperatures of the water were taken to the nearest 0.5°C with a mercury thermometer.

C. Laboratory Procedures

In the laboratory, bacterial analysis, chlorophyll extractions, chemical analyses and microscopic examination of the live tow samples were all made the same day as collected, generally within four or five hours after being taken from the river.

The concentration of Coliform bacteria was determined using the membrane filter technique as outlined in Standard Methods (A.P.H.A., 1965).

Chlorophyll extractions using a one liter water sample were made according to the method of Richards and Thompson (1952). The Creitz and Richards (1955) modification of this technique, though more

efficient, was not used because River Canard generally has a high turbidity and consequently the membrane filter employed in this modification was too readily clogged by the suspended clay and detritus. After centrifugation, the sample was dried in a vacuum dessicator for one week then incubated with 5 or 10 ml. of acetone in the dark for 20 hours. The optical densities of chlorophyll a, b, and c were determined with a Bausch and Lomb Spectronic 20 spectrophotometer at wave-lengths of 663, 645 and 630 μ respectively. The concentration of chlorophyll a was determined using the SCOR-UNESCO (1966) equations.

Concentration determinations for chlorine, copper, fluoride, iron, manganese, nitrates, nitrites, phosphates, silica and sulfate were run according to Hach Procedures for Water and Sewage Analysis using the Bausch and Lomb Spectronic 20 colorimeter. Turbidity measurements were also run according to Hach procedures. Alkalinity, chloride and hardness were determined using the titrametric procedures outlined in the manual for the Hach Model DR-EL Portable Water Engineer's Laboratory.

The live tow samples were examined microscopically with an Olympus compound binocular microscope.

Measurements necessary for identification of the rotifers were made with a Wild compound binocular microscope equipped with a Wild ocular micrometer. The micrometer was calibrated using an American Optical Company stage micrometer of 2 mm. divided into units of 0.01 mm.

Drawings of planktonic rotifers were made using the same Wild microscope equipped with a Wild Camera Lucida.

Photographs were made using an Olympus compound microscope and a Pentax Spotmatic 35 mm. camera.

Examination of live rotifers aided in the identification of species, especially of those forms which contract on being preserved. Both the live and preserved tow samples were used to maintain a qualitative check on the quantitative samples.

In identifying the rotifers, use was made of monographs by Ahlstrom (1940, 1943) for the genera Brachionus and Keratella, Rousselet (1902) for the genus Synchaeta, and Bartos (1948) for the genus Hexarthra (= Pedalia). In addition, the trophi drawings of Ahlstrom (1938) for the genus Conochiloides were referred to. Other identifications were made with the aid of Ward and Whipple's Fresh Water Biology (Edmondson, 1959).

Quantitative counts of the rotifers and other zooplankters were made with a 1 c.c. Sedgwick-Rafter cell using a modification of the technique outlined in Welch (1948). The same cell was used throughout the study. The concentrate was poured into a dropper bottle. To insure complete transfer of planktonic organisms, the sample jar was rinsed with distilled water at least five times. After each rinse, the water was swirled in the jar and poured into the dropper bottle. The volume of the concentrate in the dropper bottle was brought up to 100 c.c. The bottle was then inverted 10 times to insure thorough mixing and the Sedgwick-Rafter cell was filled by means of a wide-mouthed dropper. All the zooplankters in the entire cell were counted. Five cells were counted for each sample. The plankton concentration was then calculated and expressed as number of organisms per liter according to Welch (1948).

Because of the thickness of the Sedgwick-Rafter cell an objective no larger than 10 X could be used. At this magnification certain

morphological features necessary for species determination could not be observed. This was especially true for the genus Polyarthra. Consequently, some rotifers in the quantitative counts could only be identified to genus. At times typically littoral forms occurred in the plankton. These too were identified only to genus.

Quantitative nanoplankton counts were made according to the procedure of Welch (1948) using a Sedgwick-Rafter cell and a Wetzlar compound microscope equipped with a Whipple ocular micrometer. The phytoplankton in ten fields were counted. The average of these ten counts was used to calculate the number of phytoplankters per liter.

CHAPTER IV

RESULTS

A. Physical Results

Physical factors are summarized in Table 1. Graphs of these factors appear in Fig. 6.

Water temperature closely followed the air temperature and ranged from 0°C in winter to a high in summer of 26.5°C. The river was frozen over from December 11, 1968 to March 12, 1969. Open water occurred during a thaw in late February and early March.

Water levels fluctuated during the study from a minimum in winter of about 1.5 meters to a high in spring of about 3 meters.

There was unusually heavy rainfall during much of the sampling period. In winter, snowfall was light. According to the records of the University of Windsor weather station, located 9.5 miles from the sampling station, the maximum rainfall between successive samples was 4.38 inches and occurred during the period of June 19 to 26. Extensive rainfall also occurred on several other occasions during the spring and summer of 1968. These heavy rains produced conditions of high water with increased current and turbidity. Each of these factors had important consequences with regard to the plankton in general and the rotifers in particular.

Turbidity ranged from a high in spring of 670 Jackson Units (J.U.) to a low in winter of 30 J.U., averaging 200 J.U. for the duration of the study. In general, the highest turbidities were recorded in the spring and summer after thaws or rains. Lowest turbidities were

TABLE 1. SUMMARY OF PHYSICAL FACTORS

	1968			1969			Study Average
	Spring	Summer	Autumn	Winter	Spring	Summer	
*Precipitation (inches)	High	3.37	4.38	2.70	2.38	2.68	0.74
	Low	0.03	0	0	0	0	
	Mean	0.78	1.02	0.51	0.53	0.86	
Temperature Air (°C)	High	27.5	29.5	21.0	12.5	22.5	10.5
	Low	3.0	15.5	-4.0	-11.5	-2.5	
	Mean	17.5	17.5	6.5	0.5	11.0	
Temperature (Water (°C))	High	25.5	26.5	22.5	7.0	18.0	11.0
	Low	9.0	17.0	0.5	0	2.0	
	Mean	15.5	18.0	8.0	1.5	11.0	
Turbidity (J.U.)	High	640	670	295	395	670	200
	Low	120	99	64	30	184	
	Mean	227	201	116	135	324	

*based on total precipitation between consecutive samples

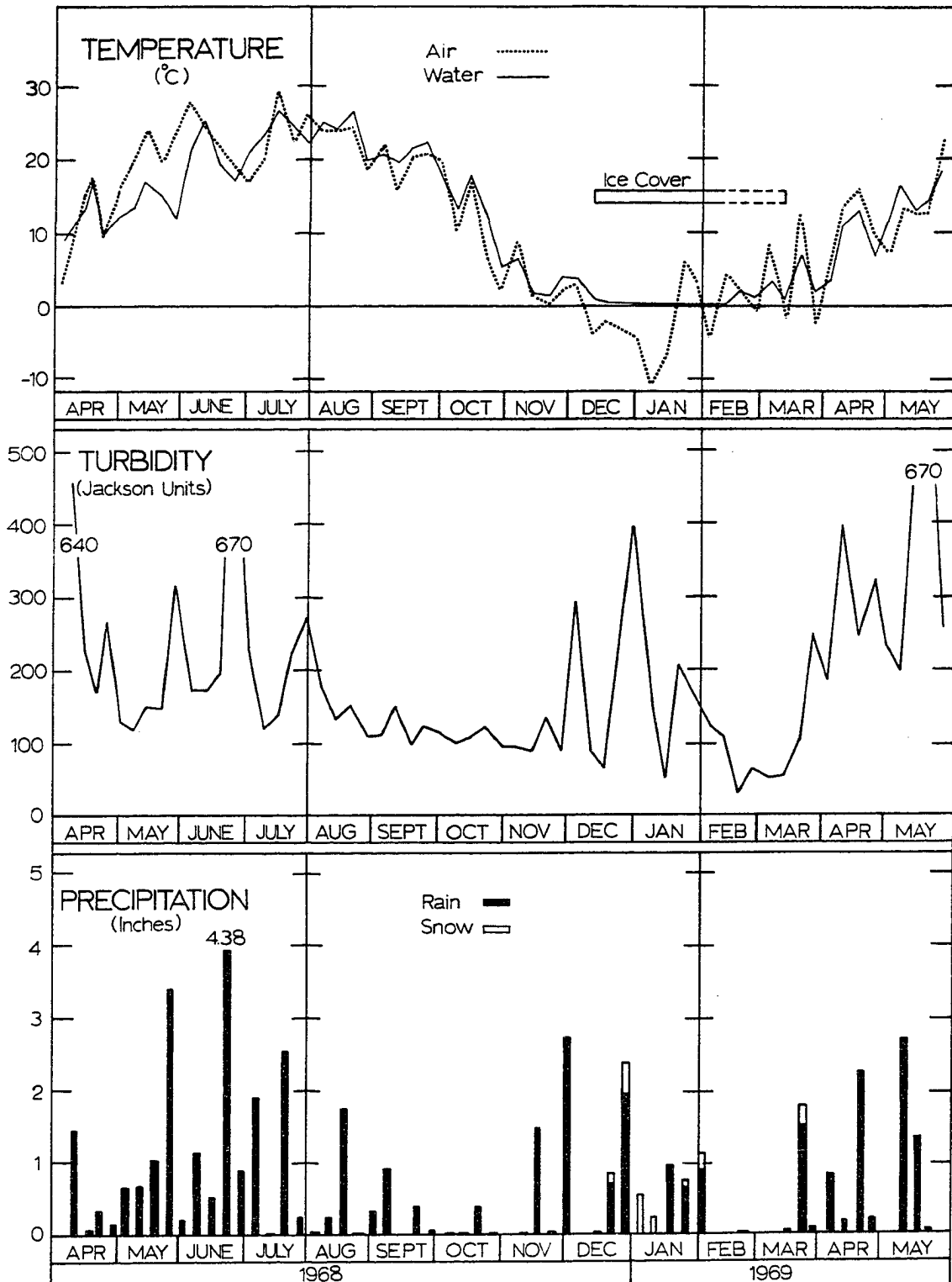


Fig. 6. Temperature, turbidity and precipitation.
River Canard, April 5, 1968 to May 28, 1969.

recorded in the fall when precipitation was minimal and in the winter when frozen ground reduced run-off and ice cover negated the effect of wind action. Increases in turbidity in fall or winter were related to rainfall and thawing. During February and March, despite thawing, the turbidity remained low. This is possibly attributable to the low water level of late winter. The "Typha flats" on either side of the channel were exposed at that time. These flats, which are covered with much fine detritus, are ordinarily submerged, and can then contribute material to the load of the stream, increasing the turbidity. This cannot occur during periods of low water.

B. Chemical Results

A summary of chemical factors is shown in Table 2. Graphs of these parameters are plotted in Figs. 7, 8, 9 and 10.

Dissolved oxygen concentrations (Fig. 7) ranged from 5 ppm. to 14 ppm., averaging 9 ppm. In general, concentrations were lowest during the summer and highest during the late fall and winter. Therefore, the river tends to follow the typical annual pattern of oxygen concentrations. At no time during the study were oxygen concentrations low enough to inhibit plankton growth.

Free carbon dioxide (Fig. 7) varied from 5 to 35 ppm., averaging 11 ppm. The high concentrations of late spring and early summer were probably attributable to pollution and decay.

pH (Fig. 7) remained distinctly alkaline throughout most of the study period, reaching neutrality on only one occasion. The maximum pH recorded was 9.0. The study average was 8.2. Generally, lowest pH values occurred after heavy rainfall; highest values during periods of low water.

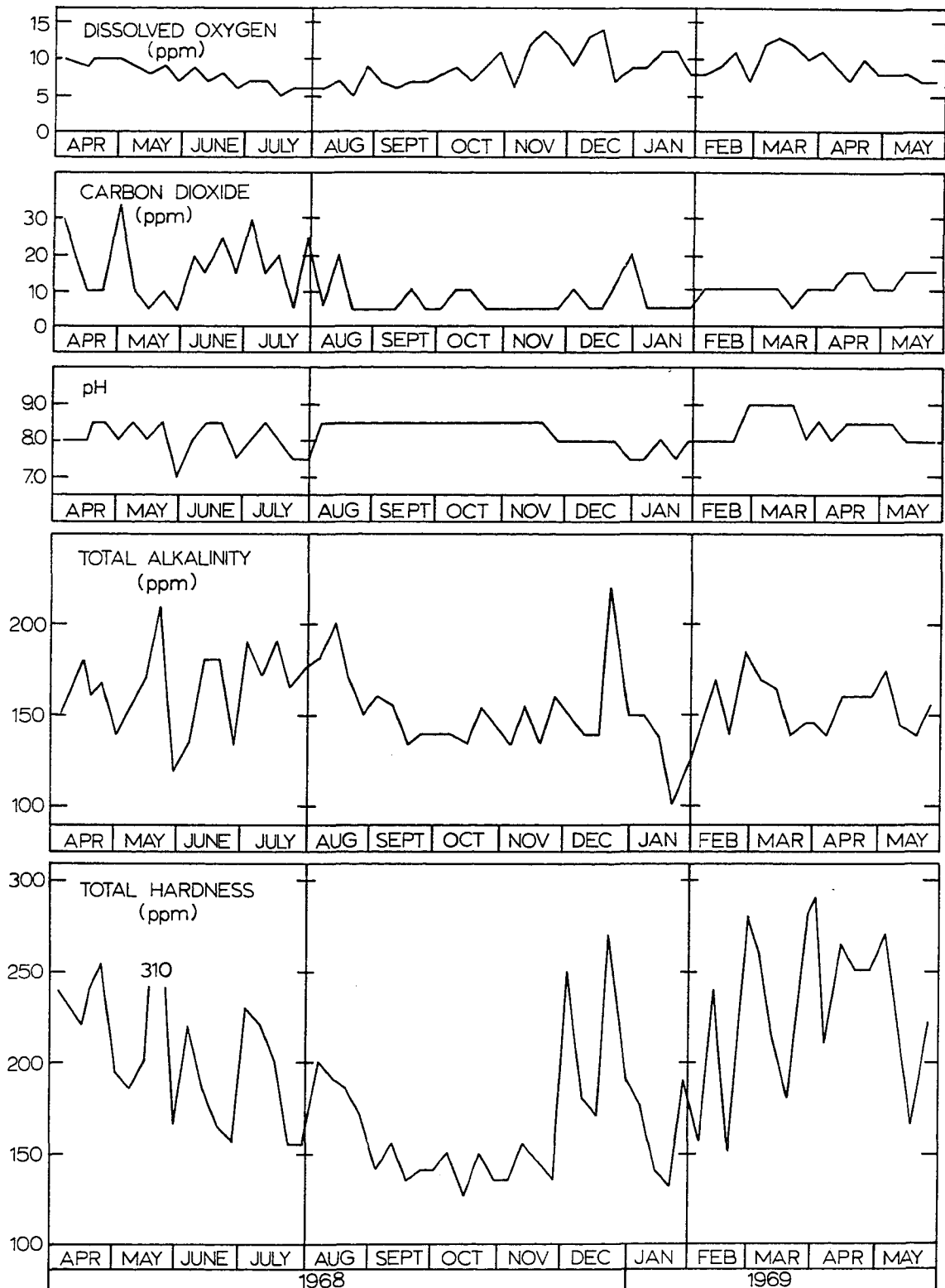


Fig. 7. Dissolved oxygen, carbon dioxide, pH, total alkalinity and total hardness. River Canard, April 5, 1968 to May 28, 1969.

Total alkalinity (Fig. 7) ranged from 100 to 220 ppm. with an average of 149 ppm. Most of the total alkalinity was attributable to bicarbonates (averaging 143 ppm.), monocarbonates making up the remainder.

Total hardness (Fig. 7) ranged from 135 to 310 ppm., averaging 199 ppm. Hardness and alkalinity followed similar trends. Both displayed sharp declines after heavy rains.

Chloride (Fig. 8) was found in very high concentrations in the river, ranging from 15 to 420 ppm. During much of the study it was second to the bicarbonate ion in concentration. The mean value of 122 ppm. is well above the average chloride concentration of 8 ppm. for North American rivers listed by Altman and Ditmer (1966).

Sulfate (Fig. 8), ranging from 19 to 212 ppm. was another important ion in River Canard. At times it displaced chloride as the second most common ion. The study average of 92 ppm. is also above the North American average of 20 ppm. (Altman and Ditmer, 1966). In general, sulfate concentrations were highest in late winter and spring, declining throughout summer and reaching a maximum in autumn.

Silica (Fig. 8) was one of the few chemicals in the river that was present in concentrations less than the North American average, 0.66 ppm. compared to 9 ppm. It tended to increase in concentration with rainfall.

Nitrogen levels (Fig. 9) in River Canard were high. Total nitrogen ranged from 0.09 to 10 ppm. Nitrate values averaged 2.06 ppm. as compared to the mean for North American rivers of 1 ppm. (Altman and Ditmer, 1966). Nitrite averaged 0.066 ppm. Peaks in nitrogen concentration were related to rainfall.

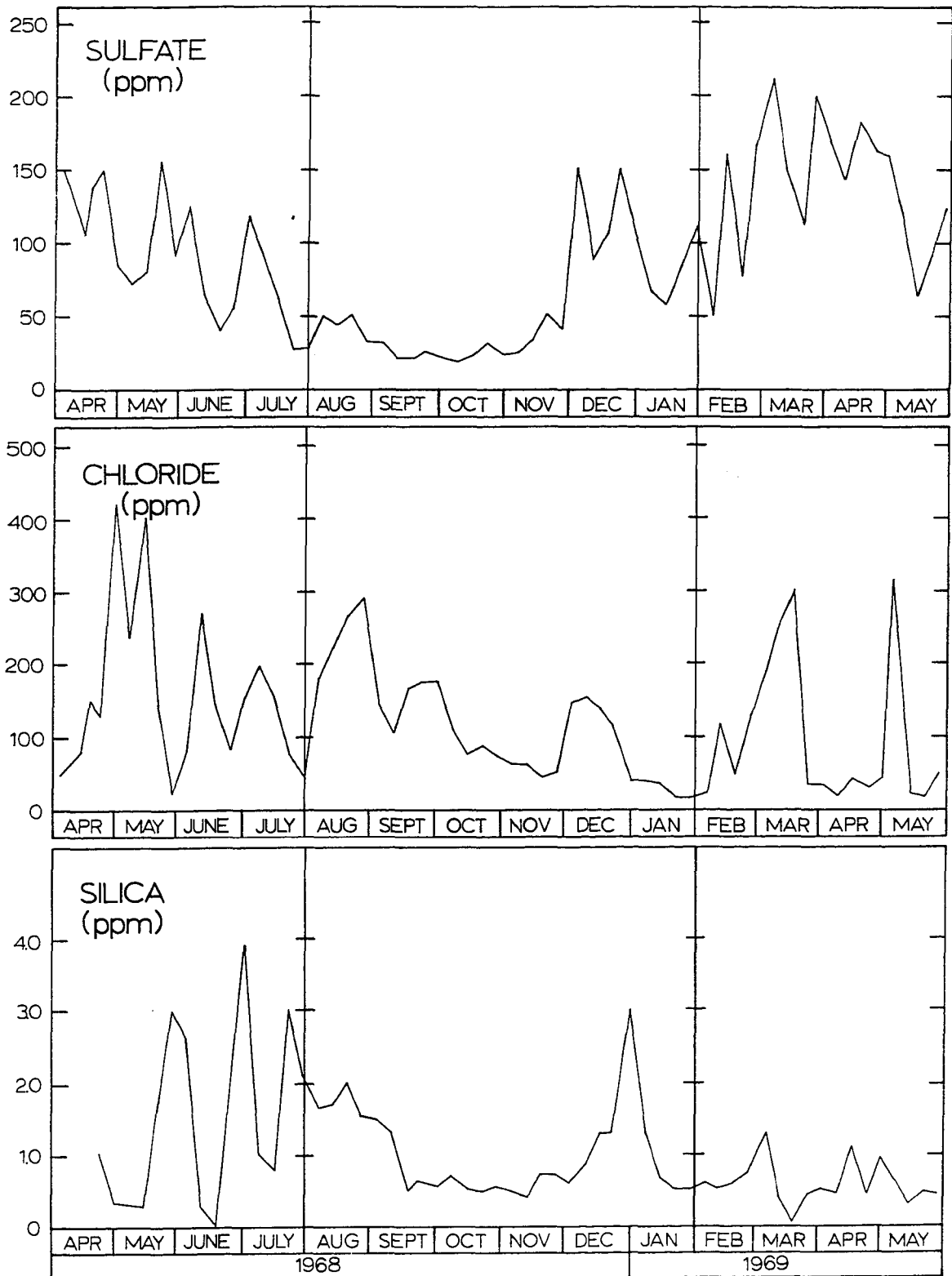


Fig. 8. Sulfate, chloride and silica concentrations.
River Canard, April 5, 1968 to May 28, 1969.

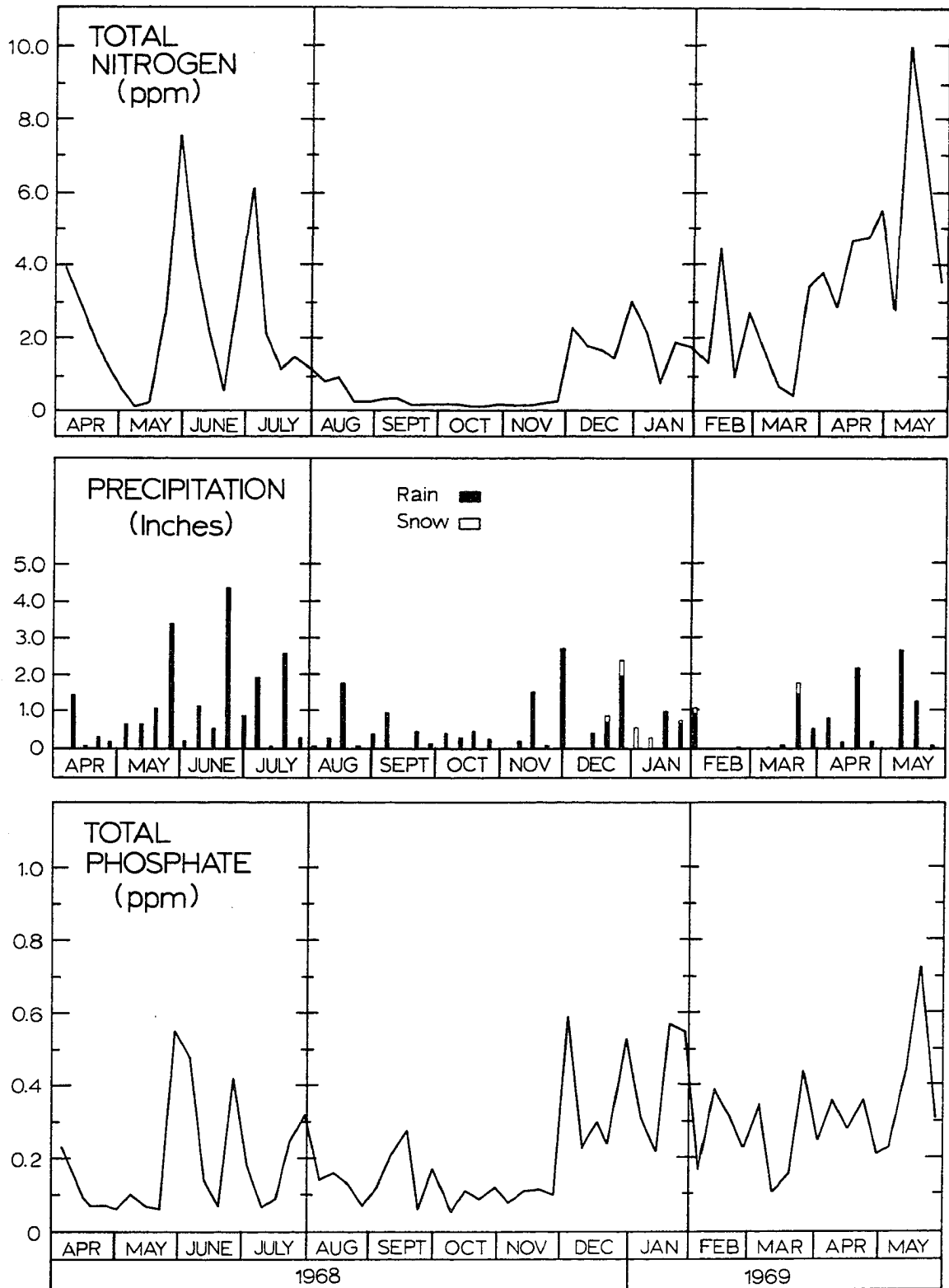
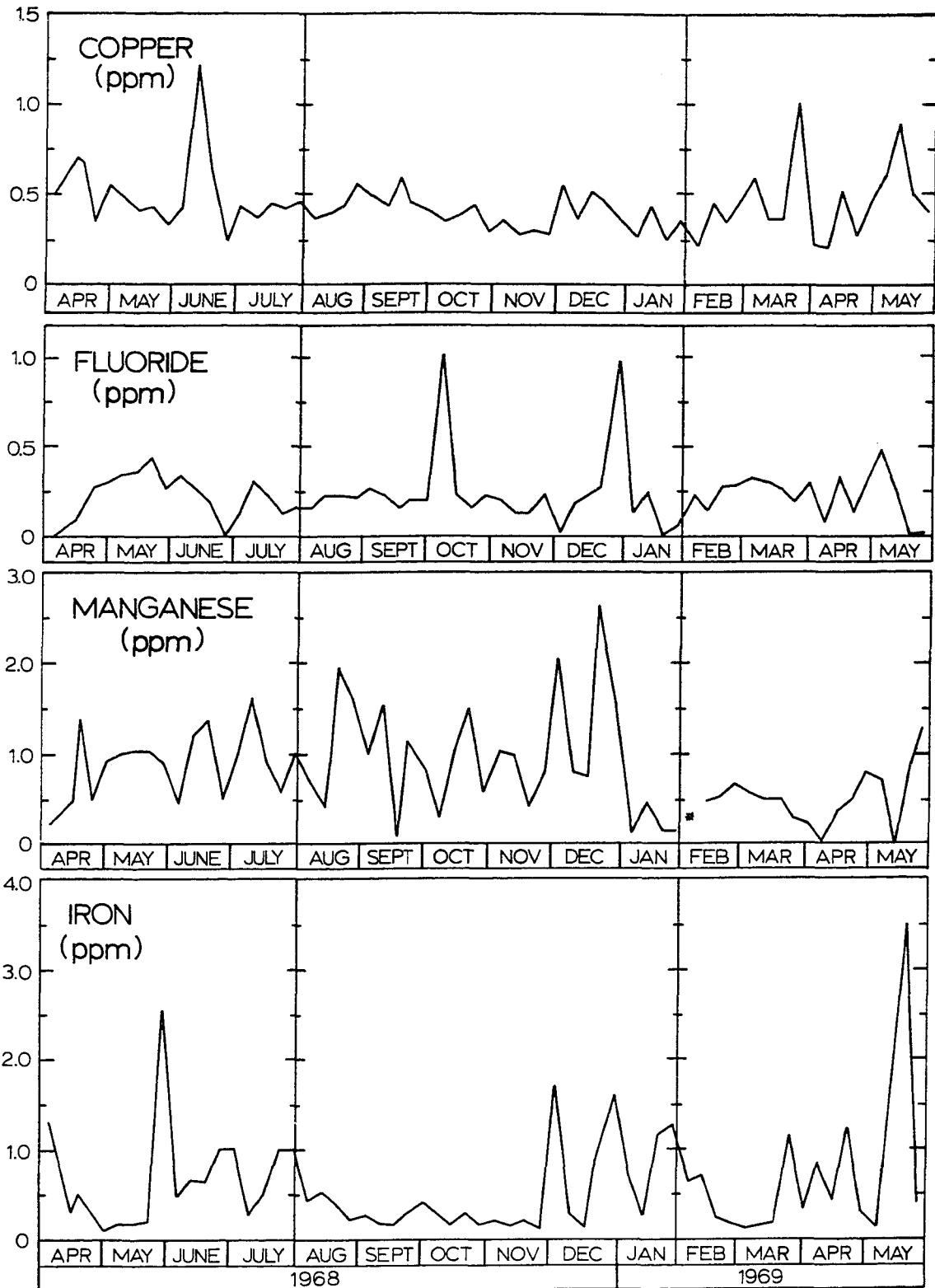


Fig. 9. Total nitrogen, total phosphate and precipitation. River Canard, April 5, 1968 to May 28, 1969.

Phosphate values (Fig. 9) were likewise high. The study average of 0.122 ppm. is well above the mean value for North American surface waters of 0.07 ppm. (Altman and Ditmer, 1966). Like nitrate, phosphate concentrations tended to increase with rainfall.

Trends in the minor chemical constituents, copper, fluoride, manganese and iron are shown in Fig. 10.



*No value

Fig. 10. Copper, fluoride, manganese and iron concentrations. River Canard, April 5, 1968 to May 28, 1969.

TABLE 2a. SUMMARY OF CHEMICAL FACTORS *

	1968			1969			Study Average
	Spring	Summer	Autumn	Winter	Spring	Spring	
Total Alkalinity	High	210	200	160	220	175	149
	Low	120	135	135	100	140	
	Mean	128	167	143	153	152	
Hydroxide	High	0	0	0	0	0	0
	Low						
	Mean						
Carbonate	High	30	20	30	20	20	12
	Low	10	5	10	10	10	
	Mean	14	10	13	12	12	
Bicarbonate	High	180	190	145	210	165	143
	Low	125	125	115	90	120	
	Mean	148	157	130	140	141	
Carbon Dioxide (Free)	High	35	30	10	20	15	11
	Low	5	5	5	5	10	
	Mean	15	12	6	9	12	

* All values in ppm.

TABLE 2b. SUMMARY OF CHEMICAL FACTORS (continued)

		1968				1969		Study Average
		Spring	Summer	Autumn	Winter	Spring	Spring	
Chloride	High	420	290	175	300	315	122	
	Low	22.5	52.5	45	20	15		
	Mean	178	162	105	102	61		
Chlorine	High	0.045	0.16	0.05	0.020	0.040	0.075	
	Low	0	0.003	0	0	0		
	Mean	0.015	0.032	0.016	0.011	0.013		
Copper	High	1.21	0.58	0.54	0.58	1.04	0.44	
	Low	0.32	0.24	0.27	0.20	0.20		
	Mean	0.55	0.43	0.36	0.35	0.50		
Fluoride	High	0.43	0.30	1.01	0.97	0.48	0.24	
	Low	0	0	0.02	0.01	0		
	Mean	0.28	0.19	0.24	0.27	0.24		
Total Hardness	High	310	230	250	280	290	199	
	Low	165	135	125	130	165		
	Mean	215	184	154	198	242		

TABLE 2d. SUMMARY OF CHEMICAL FACTORS (continued)

	1968				1969		Study Average
	Spring	Summer	Autumn	Winter	Spring	Spring	
Dissolved Oxygen	High	10	9	14	13	11	9
	Low	7	5	6	7	7	
	Mean	9	6	10	10	8	
pH	High	8.5	8.5	8.5	9.0	8.5	8.2
	Low	7.0	7.5	8.0	7.5	8.0	
	Mean	8.2	8.2	8.4	8.2	8.2	
Total Phosphate	High	0.55	0.42	0.59	0.57	0.72	0.12
	Low	0.06	0.065	0.05	0.11	0.21	
	Mean	0.16	0.11	0.16	0.32	0.36	
Silica	High	3.0	3.9	1.3	3.0	1.1	0.66
	Low	0.075	0.52	0.42	0.06	0.31	
	Mean	1.08	0.17	0.68	0.82	0.58	
Sulfate	High	155	118	150	212	200	92
	Low	40	21	19	51	64	
	Mean	105	49	49	115	142	

C. Biological Results

The Zooplankton

The Rotifera were the dominant metazoan plankters in the river. They averaged 362 individuals/liter compared to 77/liter for the Copepoda and 10/liter for the Cladocera. On the average the rotifers comprised 84% of the metazoan plankton. Only during the first week of July and again in early winter were the rotifers displaced as the dominant zooplankters. On these occasions the copepods were more numerous.

All three taxa displayed similar trends (Fig. 11). Each underwent four pulses during the spring and summer of 1968. These pulses were closely related to rainfall. With heavy rains the plankters were swept from the river. With the subsidence of the water level, increased nutrient load and rising phytoplankton concentration, the zooplankton population increased. The maximum concentration of rotifers, 3641 individuals/liter was recorded on August 7. Both the copepod maximum of 950/liter and the cladoceran maximum of 11/liter, occurred in mid July. In the fall the populations underwent a more or less continuous decline. The rotifers however displayed an autumnal pulse of 687/liter. During the winter all three taxa were present in very low concentrations. The Cladocera disappeared entirely from the plankton from January to April. The first spring pulse of 1969 occurred in early May for all three groups.

The Common Genera of Rotifera

During the study 17 genera of planktonic rotifers comprising 41 species were recorded (Table 3). Of these the common genera were

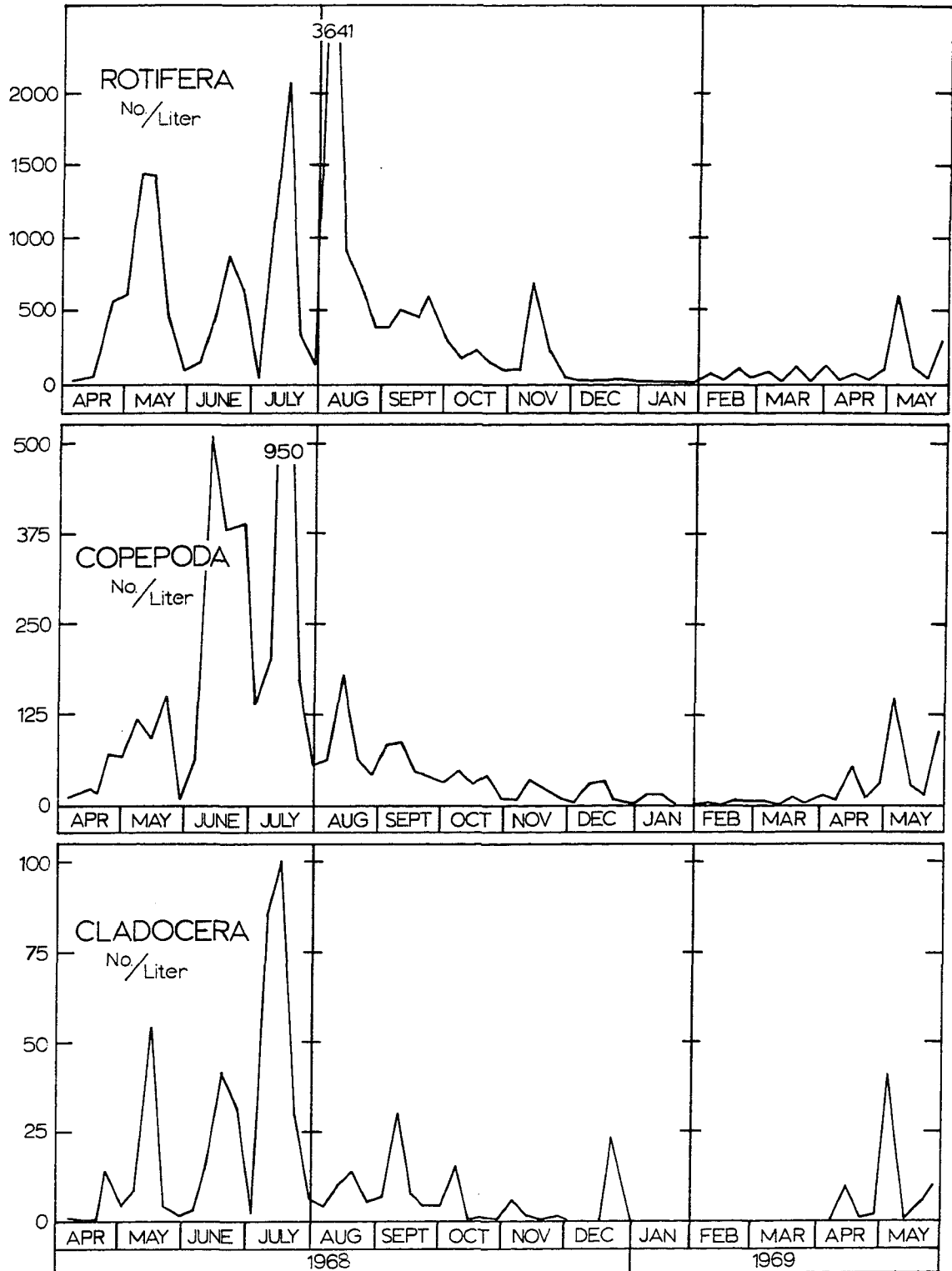


Fig. 11. Abundance of Rotifera, Copepoda and Cladocera.
River Canard, April 5, 1968 to May 28, 1969.

TABLE 3. LIST OF THE PLANKTONIC ROTIFERA
OF RIVER CANARD

Asplanchna	2 sp	Gosse
Aneuropsis	fissa	Gosse
Brachionus	angularis bidentatus bennini budapestinensis calyciflorus caudatus havanaensis nilsoni plicatilis quadridentatus urceolaris	Gosse Anderson (Leissling) Daday Pallas Barrois and Daday Rousselet Ahlstrom Muller Hermann Muller
Collotheca	pelagica	(Rousselet)
Conochiloides	dossuarius	(Hudson)
Filinia	brachiata longiseta terminalis (?)	(Rousselet) (Ehrenberg) (Plate)
Gastropus	hyptopus styliifer	(Ehrenberg) Imhof
Hexarthra	mira	Hudson
Kellicottia	longispina	(Kellicott)
Keratella	cochlearis crassa earlinae serrulata quadrata valga	(Gosse) Ahlstrom Ahlstrom (Ehrenberg) (Muller) (Ehrenberg)
Notholca	acuminata	(Ehrenberg)
Platyias	patulus quadricornus	(Muller) (Ehrenberg)

TABLE 3. LIST OF THE PLANKTONIC ROTIFERA (continued)

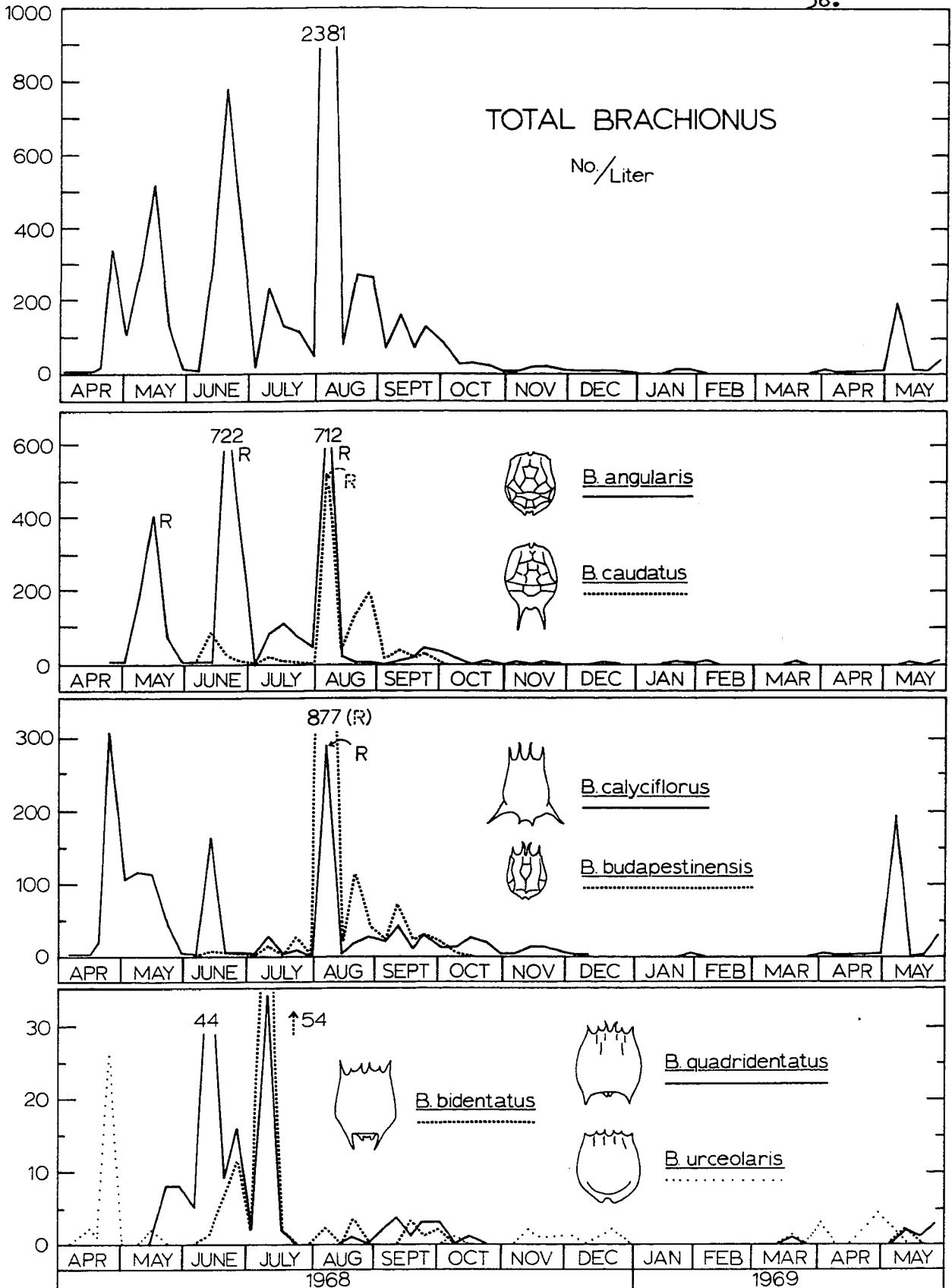
Ploesoma	hudsoni truncatum	(Imhof) (Levander)
Polyarthra	"euryptera" "trigla"	Ehrenberg
Synchaeta	oblonga pectinata stylata	Ehrenberg Ehrenberg Wierzejski
Testudinella	sp.	Bory de St. Vincent
Trochosphaera	sp.	Semper

Asplanchna, Brachionus, Conochiloides, Filinia, Hexarthra, Keratella, Notholca, Platylas, Polyarthra and Synchaeta. In addition, a number of typically littoral genera were found on occasion within the plankton. This was especially true after rainfall, when run-off swept these rotifers into the main stream. The more common littoral genera were Cephalodella, Lecane, Lepadella, Monostyla, Philodina, Rotaria, Trichocerca and Trichotria. These littoral forms generally comprised less than 1% of the total planktonic rotifer population.

Of all the genera, Brachionus, Polyarthra, Synchaeta and Keratella were the most frequently encountered, occurring in 85% or more of the 61 surface samples collected.

The Genus Brachionus

Brachionus (Fig. 12) was the most common genus. It averaged 119 individuals/liter and was represented by 11 species. Members of this genus occurred in 85% of the samples. Found in the plankton throughout the spring, summer and autumn; Brachionus rose to dominance in April, mid June and early August. On August 7 it reached a concentration of 2381/liter, the greatest recorded abundance for any genus of zooplankton during the study. At that time it made up 65% of the planktonic rotifer population and 64% of the total metazoan plankton. Following this maximum the genus declined, becoming rare or absent during the winter.



R-Resting eggs present in sample

**Fig. 12. Abundance of seven species of the genus Brachionus.
River Canard, April 5, 1968 to May 28, 1969.**

Of the 11 species of Brachionus, seven were common: B. angularis, B. bidentatus, B. budapestinensis, B. calyciflorus, B. caudatus, B. quadridentatus, and B. urceolaris. Of these, three species, B. angularis, B. budapestinensis and B. calyciflorus became dominant at various times.

B. angularis was found from April to November and occurred sporadically in winter. This rotifer displayed three major peaks during the spring and summer of 1968. At its maximum of 722 individuals/liter on June 19, it was the dominant zooplankter, making up 81% of the Rotifera and 55% of the metazoan plankton.

B. budapestinensis was present in the plankton from June to mid October. It displayed only one prominent peak. This occurred on August 7 when it reached a maximum of 877 individuals/liter. Despite this considerable concentration it comprised only 24% of the rotifer population. Other rotifers, notably B. angularis, B. caudatus and Polyarthra sp. were abundant at that time.

B. calyciflorus, though never found in numbers as high as some other brachionids, was dominant in the early spring when other plankters were not numerous. It reached a maximum of 306 individuals per liter on April 24, 1968 when it comprised 55% of the Rotifera and 48% of the metazoan plankton. A similar spring peak of 189/liter occurred in early May, 1969.

Another species of importance was B. caudatus. It occurred from June to early October. Though never a dominant plankter it nonetheless reached high concentrations, 500/liter on August 7 and 134/liter on August 21. This species displayed its greatest concentration concomitantly with one of the major peaks of its closely allied congener B. angularis.

The three other common species of Brachionus, B. bidentatus, B. quadridentatus and B. urceolaris were generally found in concentrations of about 50 individuals/liter or less, even at population maxima. B. bidentatus and B. quadridentatus were restricted to the warmer months disappearing in October. B. urceolaris was collected in the cooler months of early spring and autumn.

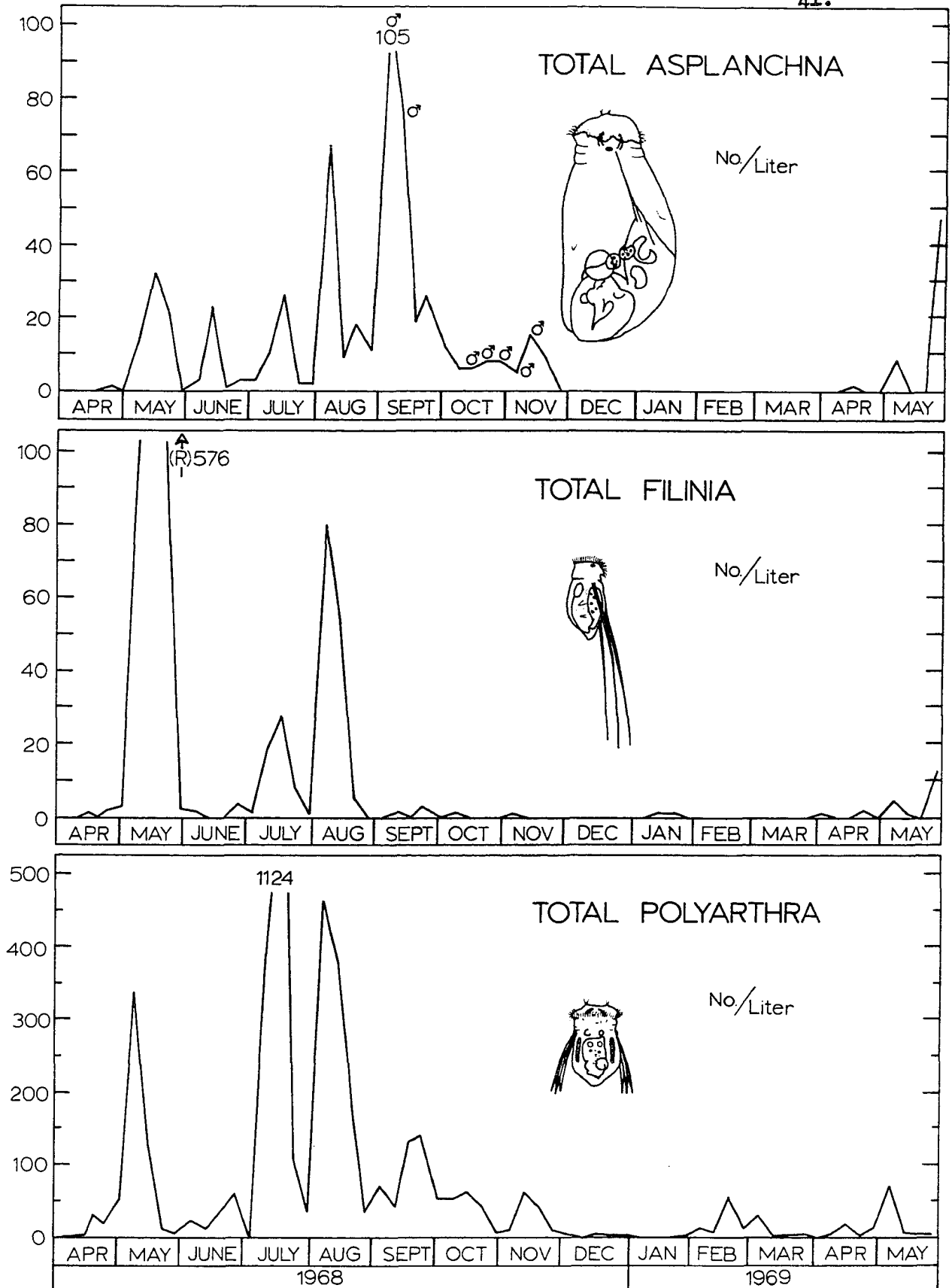
The Genus Polyarthra

Polyarthra (Fig. 13) was another important genus in River Canard. It was present in 93% of the samples, the highest percentage occurrence of any rotifer. Its average concentration of 72 individuals/liter places it second in importance behind Brachionus. This genus had three major peaks, early May, 1968 (338/liter) when it was dominant, mid July (1124/liter) when it was again dominant and early August (463/liter). There was no spring peak in 1969 equivalent to that of May, 1968. A few apterous forms were encountered in these early spring samples indicating the hatching of resting eggs.

For the purposes of this study, the genus Polyarthra was broken down into two groups as was done by Beach (1960). The first group, "P. euryptera" was characterized by wide serrated paddles not much longer than the body. The second group, "P. trigla" was characterized by narrow finely serrated paddles, longer than the body. Even using these two broad groups it was difficult to classify members of this genus in the counts. It is apparent however that both "species" are common in the river. "P. trigla" is generally more numerous.

The Genus Synchaeta

The genus Synchaeta (Fig. 14) ranked third in abundance in River



σ -Males present in sample

R-Resting eggs present in sample

Fig. 13. Abundance of the genera Asplanchna, Filinia and Polyarthra.
River Canard, April 5, 1968 to May 28, 1969.

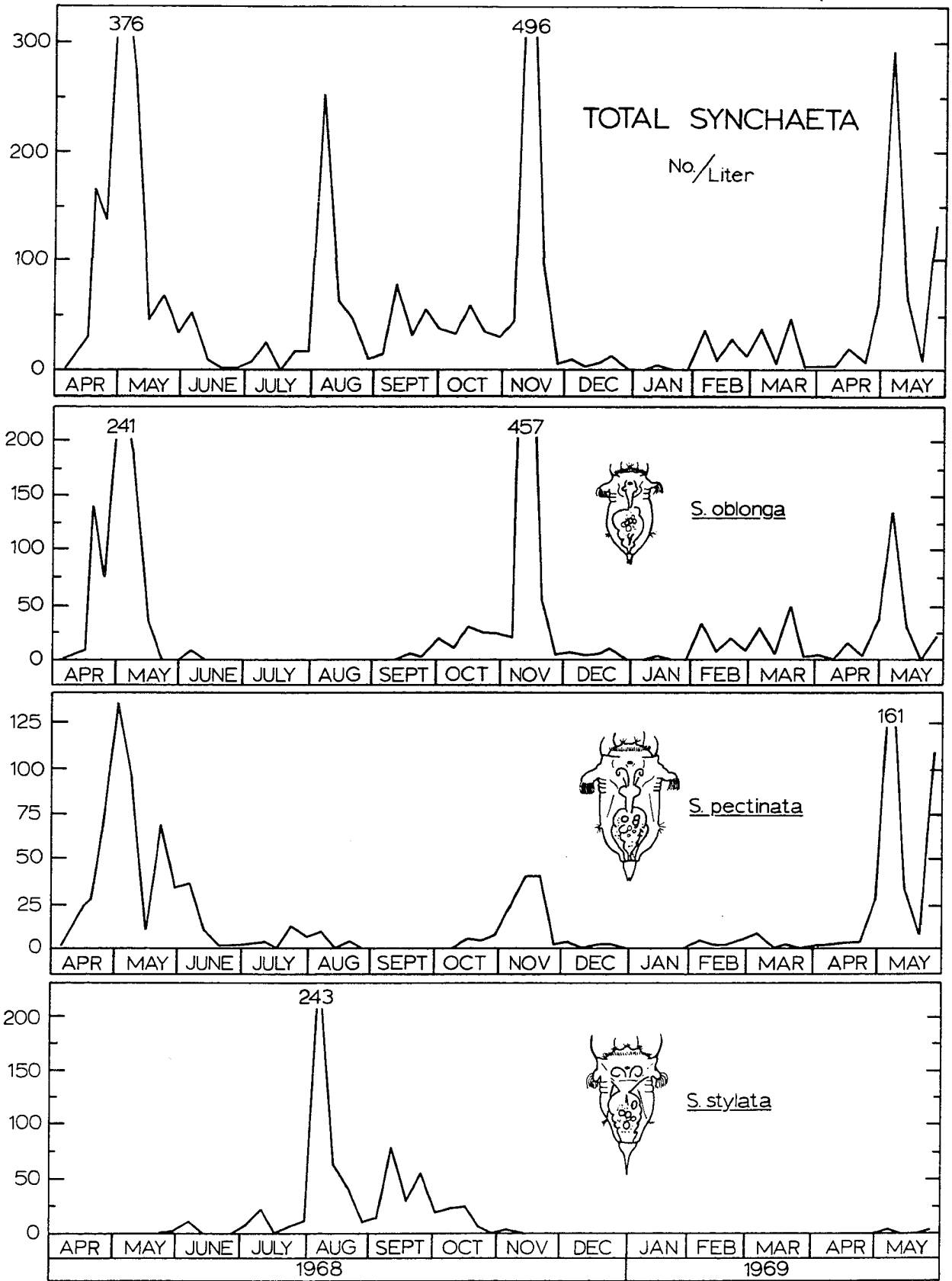


Fig. 14. Abundance of the three species of genus *Synchaeta*.
River Canard, April 5, 1968 to May 28, 1969.

Canard, averaging 57 individuals/liter. Synchaeta ranked second in percentage occurrence, appearing in 92% of the samples.

This genus was represented by three species; S. oblonga, S. pectinata and S. stylata. S. oblonga and S. pectinata tended to co-occur. Both species reached maxima in spring and fall. Both were reduced or absent from the plankton in summer. S. stylata on the other hand was restricted to the warmer months, appearing in May and reaching a maximum in August. It persisted in low concentrations into November.

The Genus Keratella

Keratella (Fig. 15) was another dominant genus. It appeared in 87% of the samples and averaged 48 individuals/liter. This genus was represented by six species; K. cochlearis, K. crassa, K. earlinae, K. quadrata, K. serrulata and K. valga. Of these, K. cochlearis was the most common. Present in samples from every month of the year, cochlearis may be considered a perennial rotifer in River Canard. This species had three major peaks in 1968, early May, mid July, and late September. Two minor pulses also occurred, one in late June, the other in mid November. It reached its greatest abundance on July 17 with a concentration of 538/liter. A spring pulse equivalent to the one in May, 1968 did not occur in 1969.

Another keratellid of importance was K. quadrata. This rotifer was found from April to June, in October, and on occasion throughout the winter. It was common only in mid May, 1968 when it reached a density of 130 individuals/liter.

The other species of Keratella, K. crassa, K. earlinae, K. serrulata and K. valga were of minor importance. With the exception of K. earlinae, they were generally few in number and restricted in

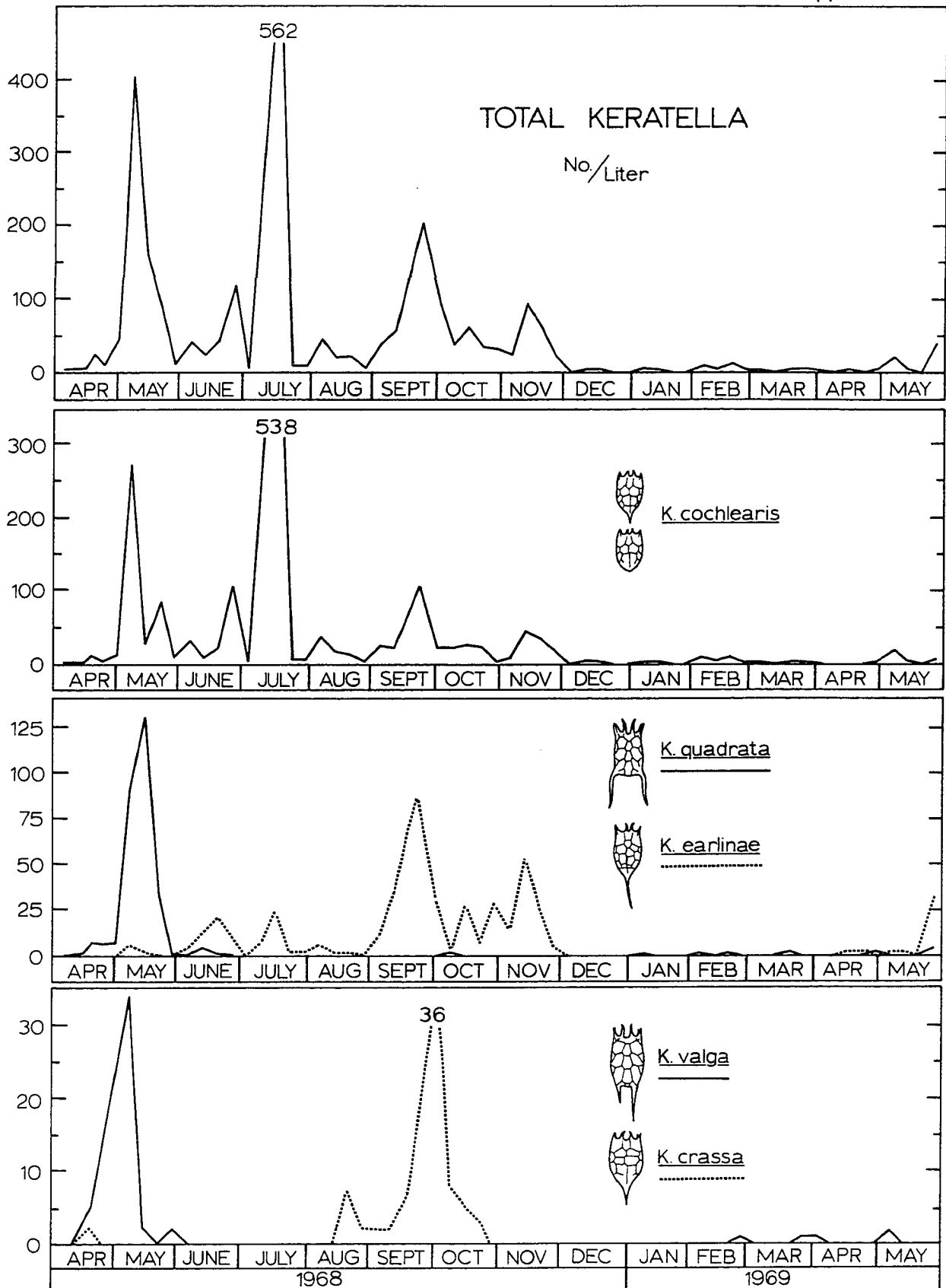


Fig. 15. Abundance of five species of the genus Keratella.
River Canard, April 5, 1968 to May 28, 1969.

appearance to only a small part of the year. K. earlinae, however, reached a maximum concentration of 84/liter in mid September and was present from April to December.

The Genus Filinia

The genus Filinia (Fig. 13) was a dominant member of the plankton on only one occasion, May 15, 1968, when it reached a concentration of 576 individuals/liter. At that time it comprised 40% of the rotifer population and 35% of the total zooplankton. Except for this pulse and a minor one in August (80/liter) Filinia was not abundant. It averaged 17/liter for the study. Filinia occurred from April to October in 1968 and in 1969 it was present from late March onward. It occurred in 49% of the samples.

Two species of Filinia, possibly three, were found. They were F. longiseta, F. brachiata and possibly F. terminalis. F. longiseta was the only species of importance; the other two were very rare. F. brachiata was found only on May 8, 1968. It had a concentration of 2/liter. There is also the possibility that the members of this genus present in January were of the species F. terminalis, a cold water form closely allied to F. longiseta.

The Genus Asplanchna

The genus Asplanchna (Fig. 13) was present in 51% of the samples and averaged 10 individuals/liter. It appeared in April and persisted until late November. Several pulses occurred during this period. Its greatest concentration, 105/liter, was reached on September 4. At that time it was the dominant rotifer, comprising 27% of the planktonic Rotifera and 22% of the total zooplankton.

Edmondson (1959) describes Asplanchna as "a difficult and variable genus". No attempt was made to identify these rotifers to species during the counts. However examination of the tow samples indicated that at least two species were present. One form with a band-shaped ovary and a second with a spherical ovary. The former has been tentatively identified as A. priodonta.

Common Sub-dominant Genera

Four other genera deserve brief mention. They are Conochiloides, Hexarthra, Notholca and Platyas (Fig. 16). Each of the first three is represented in River Canard by a single species. These species are C. dossuarius, H. mira and N. acuminata. Platyas patulus was the most common representative of that genus but its congener, P. quadricornus, was a rare member of the plankton.

These species were less abundant than the others discussed so far and displayed a very restricted seasonal distribution with only one major pulse. C. dossuarius, H. mira and P. patulus were found only from June to October. N. acuminata was found from November to May, with a maximum in March and early April.

Male Rotifers

The only male rotifers encountered were those of the genus Asplanchna. These males first appeared with the September maximum (Fig. 13) and occurred in several subsequent samples. They were generally present in low concentrations (ie. 1/liter or less). However, with the September 4 maximum, male asplanchnids reached a concentration of 10/liter. Observations of male and female in copula assured positive identification.

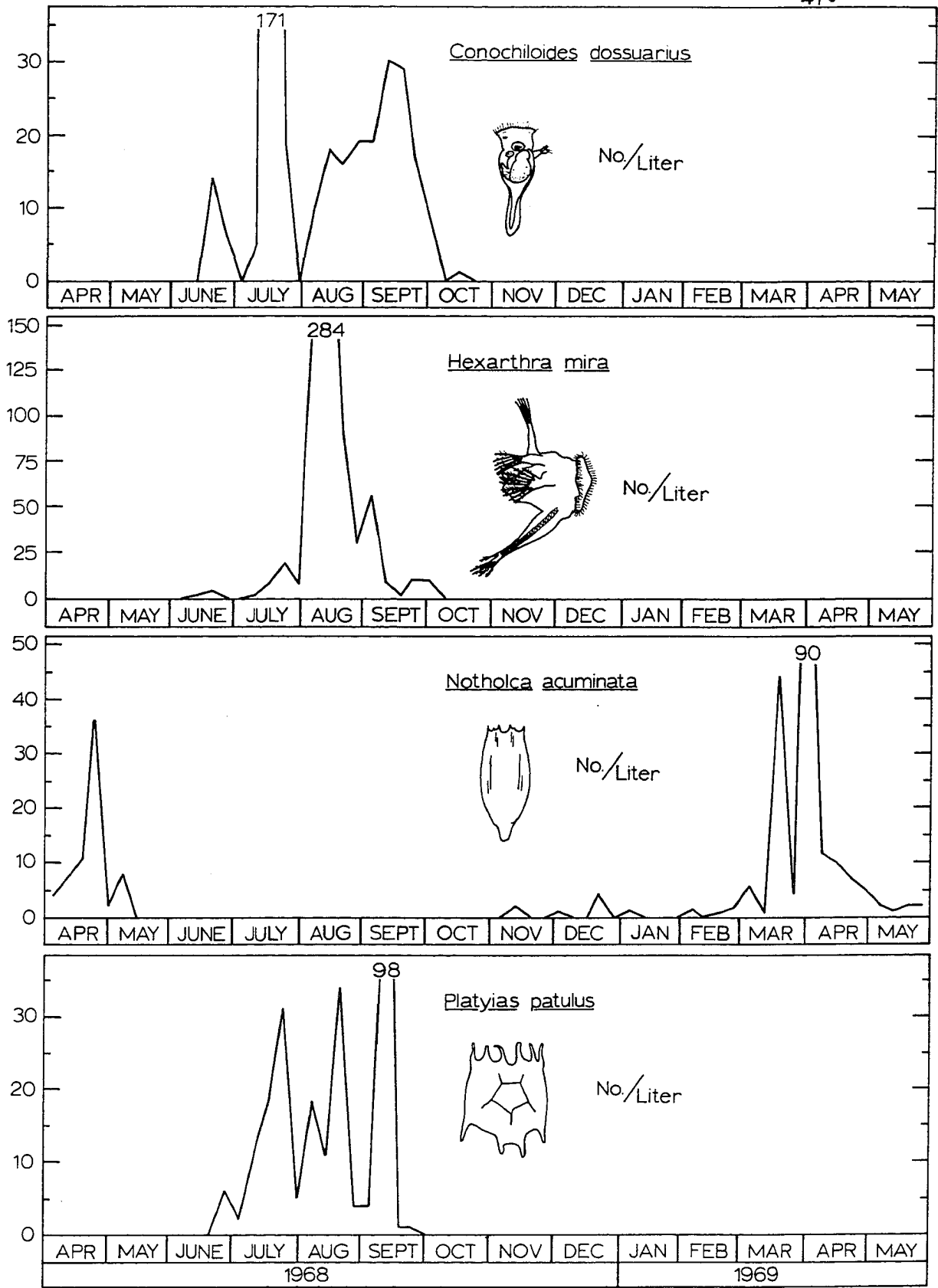


Fig. 16. Abundance of four common sub-dominant genera. River Canard, April 5, 1968 to May 28, 1969.

Though these were the only male rotifers observed, the appearance of resting eggs was indicative of the presence of males of other species. Resting eggs were noted during population maxima of Brachionus angularis, B. calyciflorus, B. budapestinensis (Fig. 12) and Filinia longiseta (Fig. 13).

Parasites

During the study several species of rotifers were found infected with a parasite which satisfies Hollowday's (1947) description of the sporozoan Ascosporidium. Budde (1927) refers to what is apparently the same organism as Plistophora asperospora Fritsch (Fig. 17). These sausage-shaped parasites were observed in the body cavities of individuals of Brachionus calyciflorus, B. caudatus, Platytias patulus, Polyarthra sp., Synchaeta pectinata and S. stylata. In addition, one individual of Filinia longiseta contained similar parasites. However these tended to be more bead-like than sausage shaped.

The parasites were restricted mainly to warm water conditions, appearing from May to October and occurring sporadically into November. They were most abundant on September 23, when 14.5% of the S. stylata population and 3% of B. calyciflorus and Polyarthra populations were infected. On the whole, species of Synchaeta and Polyarthra seemed to be the most susceptible to infection.

Vertical Distribution of Rotifers

In late January, 1969 surface sampling indicated that rotifers were present in extremely low concentrations (less than 5/liter). This winter reduction of the planktonic rotifer population is to be expected (Williams, 1966). However, to make certain that the rotifers were not concentrated at other depths, bottom samples and, later, mid water samples were taken. Fig. 18 summarizes these sampling results.

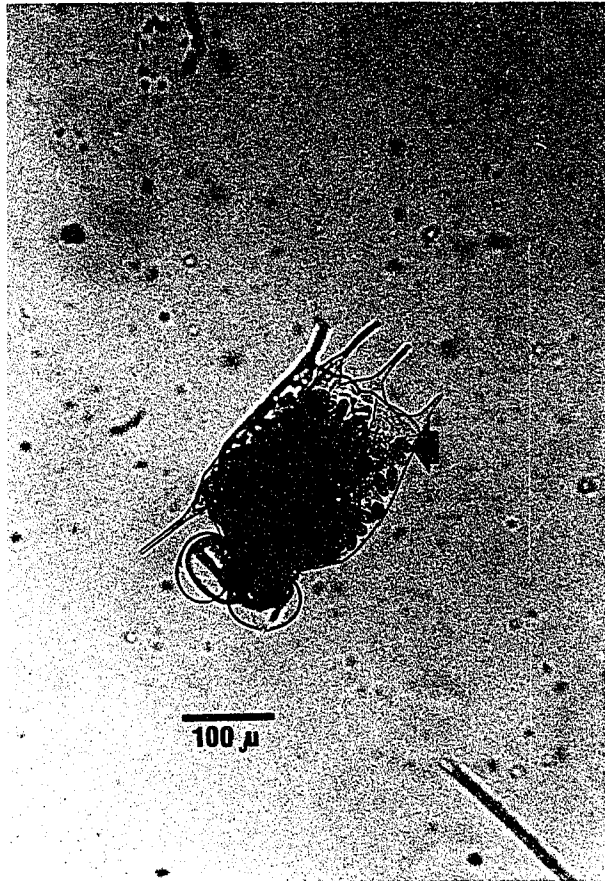


Fig. 17 An individual of *Brachionus calyciflorus* parasitized by the sporozoan, *Plistophora*.

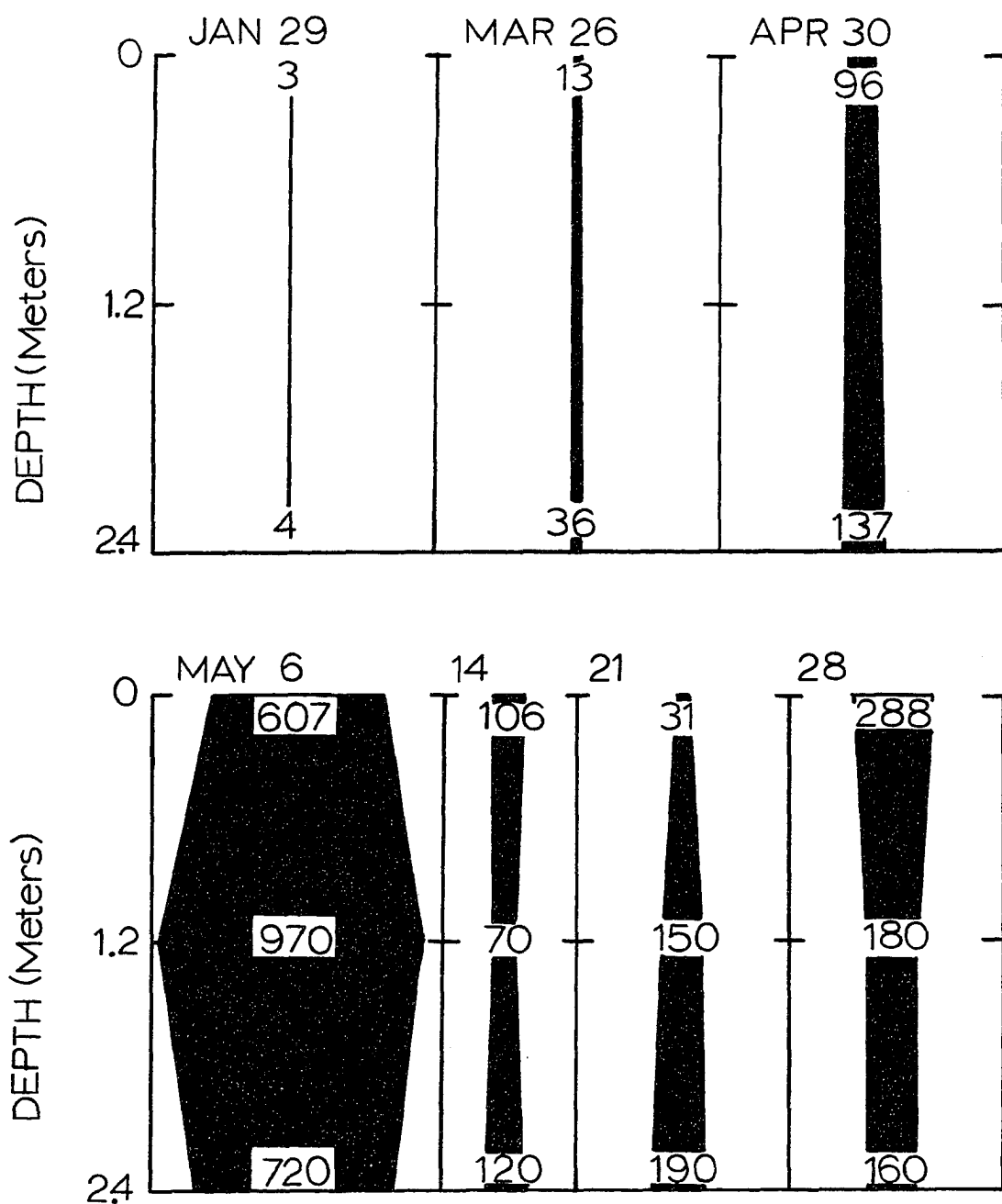


Fig. 18. Vertical distribution of rotifers.
River Canard, January 29, 1969 to May 28, 1969.
(Expressed as number of individuals/L.)

In general, rotifer concentrations at these three depths were similar. Only on May 21, 1969 is there a significant discrepancy. The rotifer concentration at the surface was 31 individuals/liter. compared to 150/liter and 190/liter at mid-water and bottom respectively. These counts may have been affected by the rainfall of the previous two weeks. The resulting high water had created conditions of swift current. This conceivably stirred up the detrital deposits of the bottom and the adjacent mud flats, increasing the number of dead rotifers drifting in the deeper water of the river. It was difficult to distinguish between the remains of these dead rotifers and those rotifers which had been alive at the time of sampling. Except for a single sample, that of May 21, 1969, bottom samples tended to have slightly higher rotifer concentrations than the surface samples. This was due at least in part, to the larger number of littoral rotifers. With respect to fluctuations in the total rotifer population, surface, bottom and mid-water samples displayed similar trends.

The Phytoplankton and Its Relationship to the Rotifera

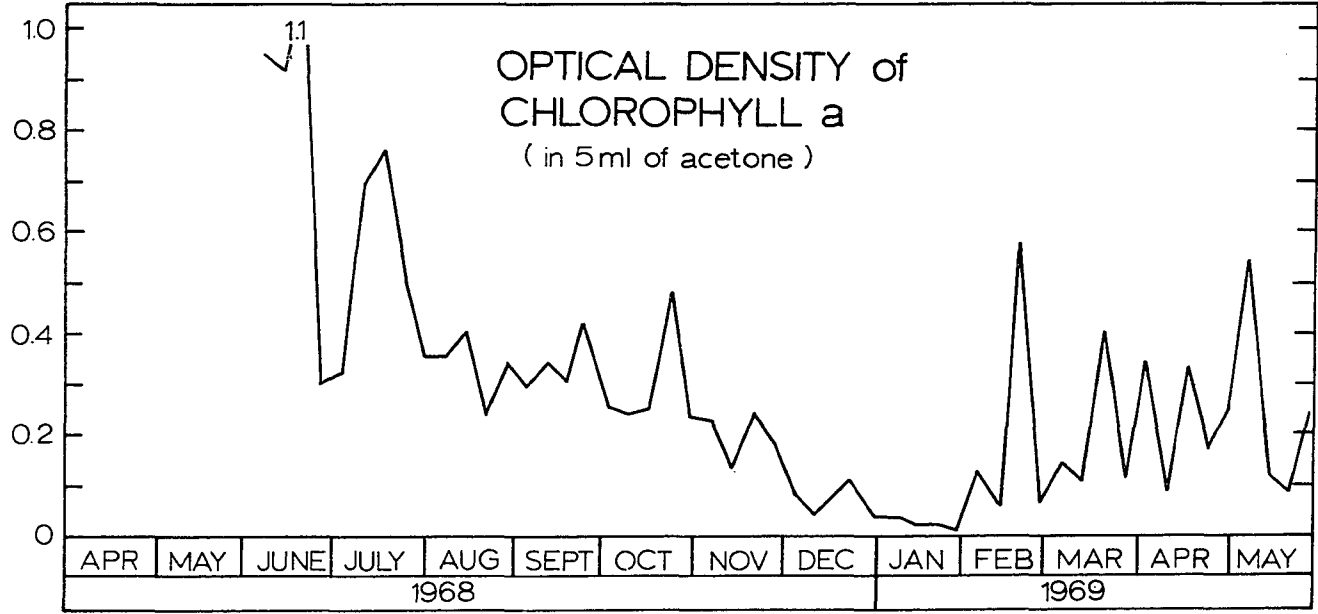
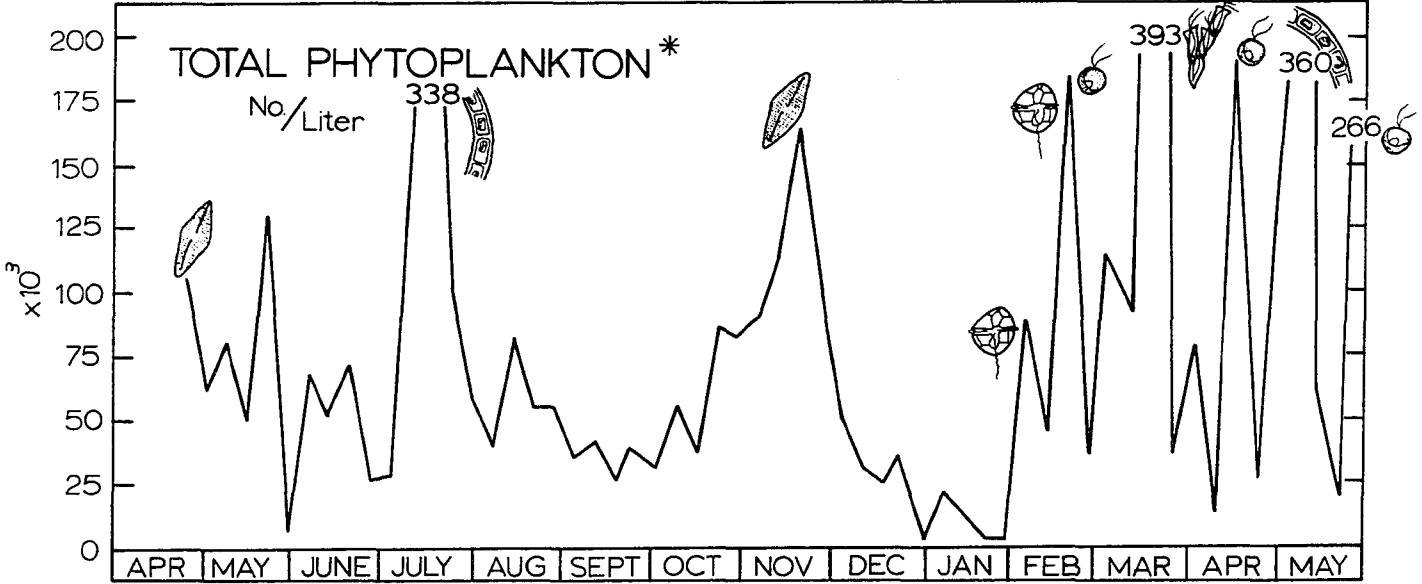
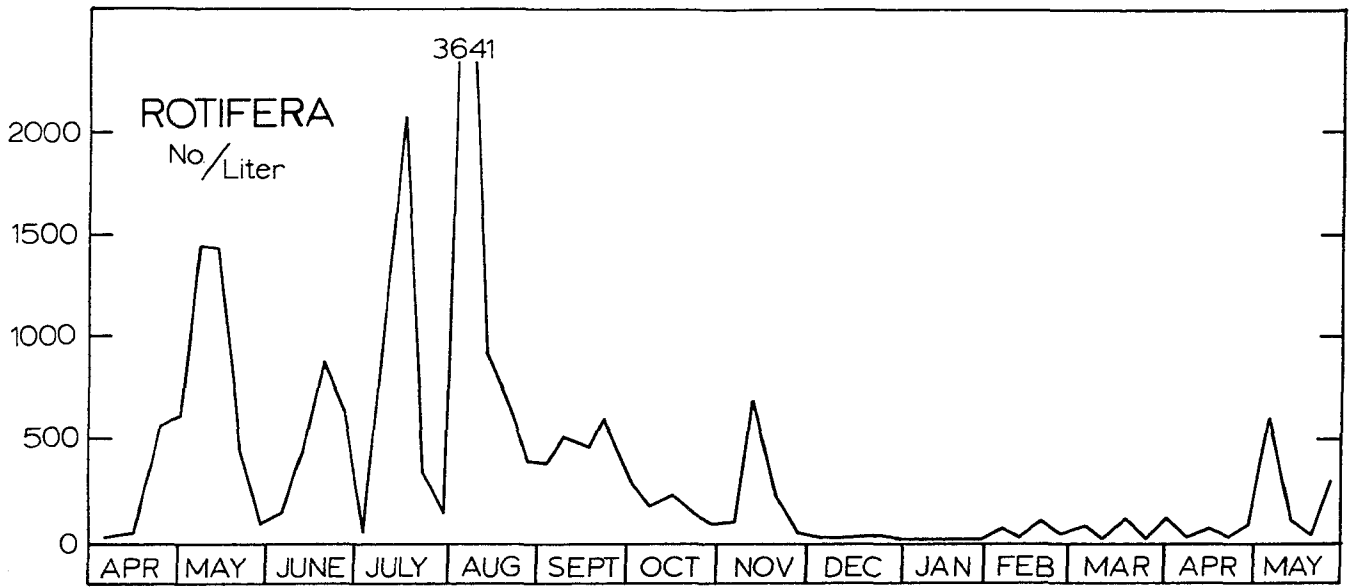
The common algae occurring in the river were the diatoms, Asterionella, Fragilaria, Tabellaria and Synedra; the Chrysophyte, Dionbryon; the Pyrophyte, Peridinium; the Euglenids, Euglena and Phacus; and the Chlorophytes, Ankistrodesmus, Pediastrum and Scenedesmus. With the exception of Ankistrodesmus and Peridinium, all these genera are listed by Blum (1956) as common stream forms. In addition to these a number of unidentified unicellular and filamentous Chlorophyta and Cyanophyta commonly occurred.

A series of phytoplankton peaks occurred in the spring and summer of 1968 (Fig. 19). As in the case of the zooplankton, each of the major peaks was delineated by heavy rainfall. Diatoms dominated in the spring. Green algae such as Actinastrum, Ankistrodesmus and filamentous types tended to dominate thereafter. The greatest phytoplankton concentration of the summer occurred on July 17 when a peak of 338,000 organisms/liter was reached. The concentration declined with heavy rains at the end of July and remained low until November when an autumnal peak of 164,000 organisms/liter occurred. Diatoms were the dominant phytoplankters at that time, but blue-greens and unicellular green algae were also common. Subsequently, the phytoplankton declined, reaching a minimum of 2,600/liter at the end of December. The population remained low throughout January. During this period the river was covered with ice 25 cm. thick. This ice plus drifting snow probably limited phytoplankton production by reducing light penetration.






A thaw began towards the end of January. Though the river remained completely ice covered, the thickness of the ice was reduced to 10 cm. Concomitant with this thaw was a bloom of the dinoflagellate Peridinium. This bloom persisted throughout February and March. In mid March a bloom of Dinobryon occurred. Diatoms and various green algae were also common. The total phytoplankton concentration at this time was 393,000/liter, the highest concentration recorded during the study. Three other peaks occurred during the spring of 1969. Various Chlorophyta were the dominant forms.

Some of the major peaks of the Rotifera tended to coincide with

Fig. 19. Rotifera, total phytoplankton and optical density of chlorophyll a.
River Canard, spring, 1968 to May, 1969.



*Symbols represent dominant algal types.

-  Diatom
-  Dinoflagellate
-  Dinobryon
-  Unicellular Chlorophyta
-  Filamentous Chlorophyta

peaks in the phytoplankton population, while others displayed a lag. The latter was true for the June pulse. The phytoplankton recovered from the May rains more rapidly, increasing ten fold during the week of May 29 to June 5. It was not until the second week of June that the rotifers increased significantly. From this it appears that the rotifer population lags about one week behind the phytoplankton.

However, the July rotifer and phytoplankton peaks were coincident. The lack of a lag here may be due to the fact that subsequent to heavy rains in June, there was still a sizable phytoplankton population. The Rotifera could then begin an immediate increase in numbers by utilizing the available algae. The high nutrient concentrations resulting from the rainfall apparently allowed for optimum phytoplankton production so that despite increased grazing by zooplankton, the phytoplankton concentration continued to rise.

It is interesting to note that the July phytoplankton peak, the highest summer concentration, was coincident not only with a rotifer pulse but also with the copepod and cladoceran *maxima*. Algae productivity must have been considerable at that time in order to sustain such a population increase despite the grazing stress of all three major groups of zooplankton.

The August rotifer pulse cannot be attributed directly to any preceding phytoplankton peak, the previous pulse having been reduced by rainfall. However, again it seems likely that the influx of nutrients, mainly phosphates in this case, allowed for increased phytoplankton production. In this way, a relatively small standing crop of producers could maintain an increase in the rotifer population.

Trends in the rotifer population during fall and winter are more readily related to phytoplankton production. The November rotifer pulse lagged about two weeks behind the phytoplankton. However, the small rotifer pulses occurring from February to May, 1969 were all coincident with phytoplankton peaks, spaced regularly at two week intervals. These synchronous pulses suggest that at this time the lag between rotifers and phytoplankton was less than one week.

The relationship between particular species of rotifers and trends in the phytoplankton is difficult to assess. However, major pulses of Conochiloides dossuarius, Hexarthra mira, Keratella cochlearis, Notholca acuminata, Polyarthra, Synchaeta oblonga and S. pectinata were associated with phytoplankton peaks. Attempts to relate these pulses to certain types of algae met with little success. However, trends in the two species of Synchaeta seem to be related to particular types of algae.

In the case of S. oblonga, the fall maximum in November occurred at a time when filamentous algae were common. The pulses of late winter coincide with the dinoflagellate bloom of February and March and associated pulses of small unicellular green algae. Individuals of S. oblonga had their guts crammed with algal remains during this period. Each pulse from February to the end of March is coincident with a dinoflagellate-green algae pulse. This species was found only in low concentrations after the bloom disappeared, increasing again in late April when simple green algae were again common.

S. stylata also displayed a relationship with filamentous algae. The August maximum of this rotifer occurred at a time when these phytoplankton were common.

It should also be noted that individuals of Asplanchna sp. were observed on a number of occasions, to have ingested various euglenoids, colonial green algae such as Pediastrum and the rotifer Keratella cochlearis. (Fig. 20).

No relationships could be found between the various species of Brachionus and Keratella and any particular phytoplankters.

Chlorophyll a Concentrations

The optical densities of chlorophyll a are plotted in Fig. 19. As expected, these values tended to fluctuate with the phytoplankton. High optical densities did not always correspond to large phytoplankton populations however. This discrepancy is attributable to several factors. The chlorophyll content varies from one species of alga to another and it is also dependent upon the age of the cells. But the counting method used was probably the greatest cause of discrepancy. This method considered a small unicellular alga equivalent to a larger multicellular filament. Consequently, a sample containing a large number of unicellular algae, though numerically large, could prove to have a lower chlorophyll content than another sample of smaller concentration but containing filamentous or colonial forms.

Using the optical density values, the average chlorophyll a concentration for the study was 8.6 mg/m^3 calculated by the SCOR-UNESCO (1966) equations, uncorrected for turbidity.

To facilitate comparison to values which had been calculated using the older equations, the Richards and Thompson (1952) equations were also used. On this basis, the average chlorophyll a concentration was 23.1 mg/m^3 .

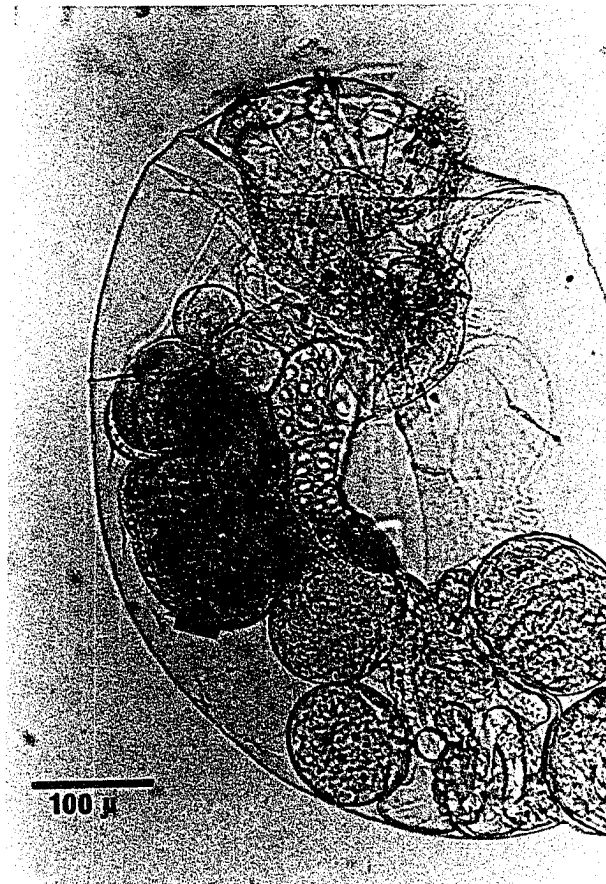


Fig. 20. Asplanchna sp. Note the rotifer Keratella cochlearis in the gut.

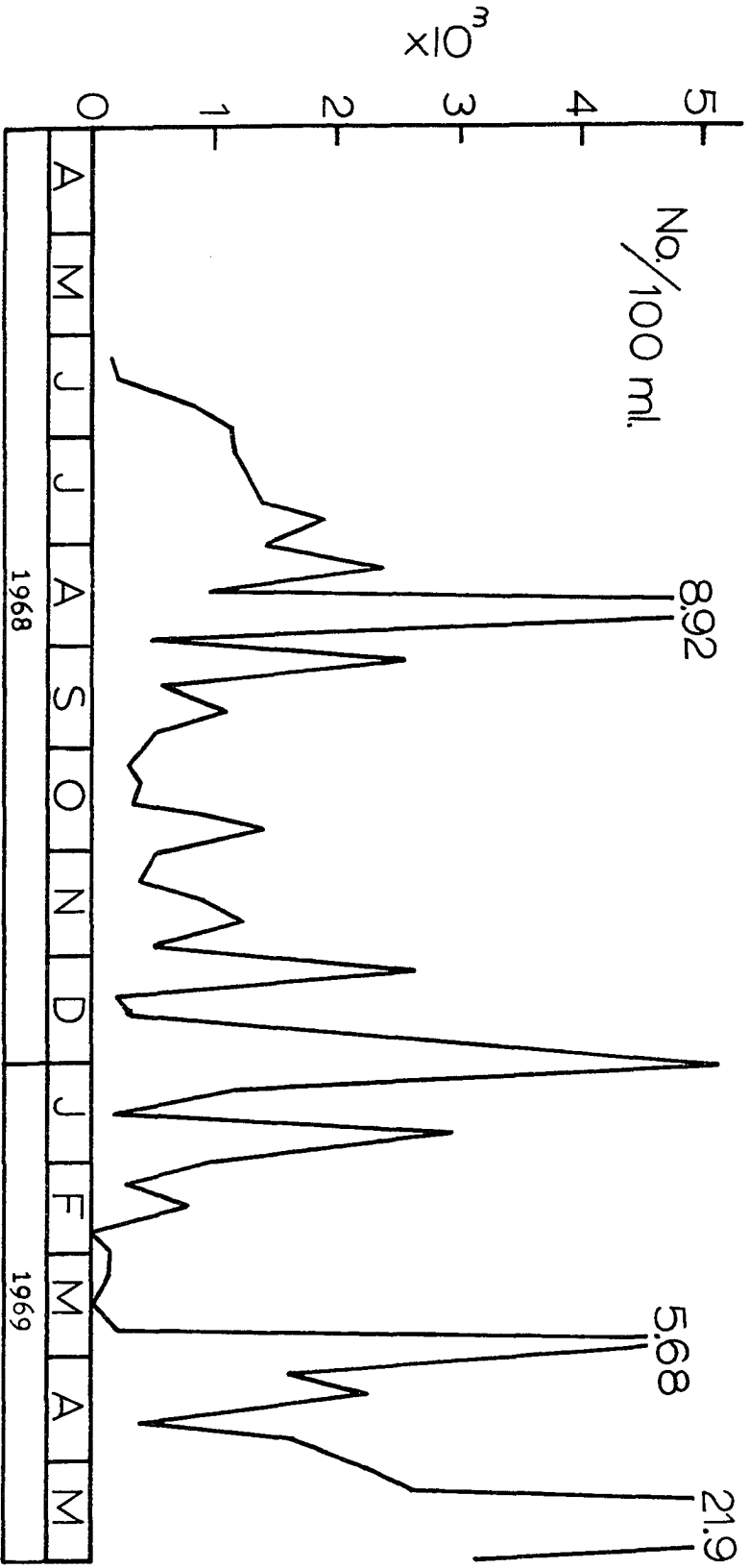
Bacteria

During the study the concentration of coliform bacteria (Fig. 21) ranged from 0/100 cc. on two occasions in winter to a high of 21,900 per 100 cc. in May, 1969. The coliform counts varied erratically throughout the study making generalizations difficult. The highest counts were recorded in the summer of 1968 and the spring of 1969 when temperatures were conducive to rapid growth. However, sizable populations also developed in December and March.

With the exception of the August pulse, increases in bacteria were related to changes in turbidity. This relationship was particularly striking during the late fall and winter of 1968 and in the spring of 1969. A simple correlation coefficient for this period seems significant ($r = 0.84$). Apparently run-off and turbulence increase turbidity by agitating the detritus and bottom mud, at the same time stirring up bacteria.

Attempts to relate population fluctuations of various rotifer species to bacterial trends, as reflected by changes in the coliform concentration, were unsuccessful.

Fig. 21. Concentration of coliform bacteria.
River Canard, June, 1968 to May, 1969.



CHAPTER V

DISCUSSION

The results of this study are based on samples from a single station. Therefore, they cannot apply to the entire river system. However, the previous study of the river by Winner and Hartt (1969) indicated that this station reflected the general plankton trends of their other sampling sites. On this basis, samples from this station are considered representative of the plankton in the lower 5 km. of the river.

Results of this study are based for the most part on surface samples only. However, in rivers the constant mixing of water at all depths tends to distribute the plankton organisms rather evenly throughout (Coker, 1954). Eddy (1932) in his study of the Sangamon River, Illinois, and Roach (1932) on the Hocking River, Ohio both noted that there was little variation in the vertical distribution of plankton. Similarly, in River Canard, bottom and mid-water samples taken during the latter part of the study displayed rotifer concentrations similar to those of the surface samples. This suggests that counts from the surface samples provide a reasonable qualitative and quantitative picture of the planktonic rotifer population throughout the entire vertical water column.

The Planktonic Rotifer Population and the Trophic Nature of the River

The planktonic rotifer fauna of River Canard may be described as Brachionus-Polyarthra-Synchaeta-Keratella complex. Williams (1966) found these to be the most common genera in his survey of the major

waterways of the United States. Galtsoff (1924) lists these four genera among those commonly found in rivers. These genera were also the dominant rotifers in the studies of Kofoid (1908) on the Illinois River; Eddy (1932) on the Sangamon River, Illinois; and Carlin (1943) on the Motalastrom in southern Sweden. With the exception of Brachionus, Beach (1960) found these genera to be the dominant forms in the Ocqueoc River system, Michigan.

The dominance of these genera in River Canard, especially that of the genus Brachionus, may be due to the trophic nature of the river.

As pointed out earlier, the results of the chemical analyses indicate that total nitrogen, phosphate, sulfate, iron and chloride are all found in high concentrations. Such high values have been previously reported by Winner and Hartt (1969), and have also been recorded by the Ontario Water Resources Commission (1967). The high nutrient levels are probably attributable to run-off enrichment from the surrounding farmland. High chloride concentrations also may be due to the above. It is more likely, however, that salt deposits underlying the basin and a commercial brine well near the river (Vandall, 1965) are the major sources of chloride. The concentration of chemicals in the water places River Canard in Prescott's (1968) classification of eutrophy.

Chlorophyll a concentrations also indicate that the river at least tends towards eutrophy. As stated previously, chlorophyll a concentrations averaged 23.1 mg/m^3 as calculated by the Richards and Thompson (1952) equations and 8.6 mg/m^3 as calculated by the SCOR-UNESCO (1966) equations (uncorrected for turbidity).

Small (1961) lists a number of concentrations for chlorophyll a as reported by several authors for various fresh water rivers, lakes and reservoirs. These values, calculated using the old equations, range from less than 1 mg/m³ up to 185 mg/m³. In his own study of Clear Lake, Iowa, Small (1961) found the chlorophyll a concentration to range from 15 to 70 mg/m³. He reported that there was evidence of above average nitrate and phosphate levels. He considered the lake eutrophic.

The chlorophyll a concentrations for River Canard overlap the lower end of this eutrophic range established by Small. In light of the high nutrient levels, the chlorophyll concentrations are not high. It is likely that turbidity limits phytoplankton production. Turbidity is recognized as an important limiting factor in rivers (Ellis, 1936, Berner, 1951).

Chemical concentrations and chlorophyll a values both indicate that River Canard is eutrophic.

As stated in the introduction, a number of authors consider certain species of rotifers as indicators of the trophic nature of the environment. Most of the dominant species in River Canard have been implicated as indicators of eutrophic situations. Pejler (1957a), based on his work in central Sweden, considers Brachionus angularis, B. budapestinensis, B. calyciflorus and Filinia longiseta as indicators of eutrophy. He cites a number of other European authors with whom his findings agree. Arora (1966) found these same species under eutrophic conditions in India. All of these species are dominants in River Canard. Other species considered as indicators of eutrophy are Keratella cochlearis, K. quadrata

(Pejler, 1957a) and Platylabus patulus (Arora, 1966). Each of these commonly occurs in the river.

Of the three species of Synchaeta: S. oblonga, S. pectinata and S. stylata, the last two have been reported by Pejler (1957a) as being found commonly in eutrophic situations. He does not consider them indicators however. In addition, certain species of Asplanchna and Polyarthra are designated as possible indicators of eutrophy. However, species determinations for these genera in River Canard have yet to be made.

Two species of rotifers found in the river are designated by Pejler (1957a) as preferring dystrophic conditions. These are Hexarthra mira and Keratella valga. Arora (1966) found both species under eutrophic conditions in India.

Only one species considered an indicator of conditions short of eutrophy has been identified in the river, Floesoma hudsoni (Pejler, 1957a). It occurred on only one occasion.

When the rotifer population of River Canard is taken as a whole, the dominant planktonic species present reflect the eutrophic nature of the river.

A further reflection of this eutrophic condition is the large number of species commonly encountered. The trophic situation is such that numerous niches are available simultaneously in the plankton community from spring to autumn.

While discussing the trophic nature of the river, it is interesting to compare the results of this study to those of Winner and Hartt's (1969) investigation at station 1. This comparison serves to emphasize the relationship of the rotifer population with the surrounding farmland. Table 4 summarizes the pertinent data for both years.

TABLE 4 A COMPARISON OF SELECTED
CHEMICAL AND BIOLOGICAL DATA
FROM THE RIVER CANARD STATION
May to August, 1967 & 1968

	1967*	1968
Chemical Conc. (ppm.)		
Chloride	45	171
Nitrogen	0.74	2.12
Phosphate	0.22	0.20
Sulfate	45	70
 O.D. Chlorophyll a	 0.086	 0.56
 Maximum Number of Rotifers	 900	 3641
 Average Number of Rotifers/L.	 265	 849

*Based on Winner and Hartt (1969).

Briefly, in 1968 nutrient levels tended to be higher, chlorophyll concentrations were larger and rotifers were more abundant than in 1967. In addition, the typical bimodal production curve of 1967 was disrupted so that in 1968 four peaks occurred. Synchaeta, a dominant genus in 1968, was not commonly encountered in 1967.

The marked difference between the two years is probably attributable to variation in rainfall: over 19 inches from May 1 to August 31, 1968 compared to only a little over 9 inches for the same period in 1967. Apparently, in 1968, run-off enrichment, as a consequence of this heavier rainfall, maintained a larger phytoplankton population. This in turn supported a more sizable rotifer fauna.

It appears that River Canard is a favourable habitat for planktonic rotifers, particularly those adapted to eutrophic conditions. Williams (1966) lists yearly averages for 128 stations on various rivers of the United States. The highest average for any of these stations is 225.1/liter from the Apalachicola River, Florida. Roach (1932) gives a yearly average of 243/liter for the Hocking River, Ohio. The yearly average for River Canard, based on counts from April 5, 1968 to March 26, 1969 is 395/liter, considerably higher than these other averages. The suitability of the river as a habitat for planktonic rotifers may be due to the sluggish current and warm water, both of which are conducive to plankton production. The effect of turbidity, the major limiting factor, is overcome, at least in part, by the high nutrient level which enhances the productivity of the narrow photic zone.

Seasonal Succession and the Niche

The seasonal succession of species that occurs within the planktonic Rotifera is a consequence of changes in various environmental factors. These factors define the niche of each species of rotifer. As these factors change, the niches available within the plankton community are altered and species succession is initiated. Temperature is a major factor in delimiting these niches and consequently in governing this succession.

With regard to the effect of temperature on seasonal succession, the occurrence of species in River Canard is generally consistent with the literature. Hutchinson (1967) summarizes the findings of a number of authors. In general, the various species of Asplanchna, Brachionus, Hexarthra and Keratella and the species Filinia longisetata, all have been found to have spring or summer maxima. On the other hand, Notholca acuminata only occurs in winter or early spring. These rotifers followed similar trends in River Canard. The occurrence of the three species of Synchaeta followed a pattern similar to that observed by Carlin (1943).

Though most of the species followed recognized trends, there is one notable exception, Conochiloides dossuarius. Hutchinson (1967) reports that Edmondson found this rotifer as an autumnal species in Linsley Pond, Connecticut, occurring with falling temperatures from September to November. In River Canard, C. dossuarius, though it persists into October, was found in greatest abundance in mid July. This difference is difficult to explain. A different ecological race may be the case here; the Linsley Pond form being cold adapted, the Canard form warm adapted. Pejler (1957a) has suggested the existence

of ecological races to account for the presence of populations of certain eutrophilic rotifers in lakes of low trophic levels. Differences in water chemistry could also play a role. In fresh water Notholca acuminata is ordinarily a cold stenotherm, but in brackish water this species has population maxima under warm water conditions (Edmondson, 1946). In the case of C. dossuarius, the high chemical concentration of River Canard could cause a similar shift in the population maximum. Further studies relating the temporal occurrence of both C. dossuarius and N. acuminata to the chemical concentration of the river could prove to be of interest.

Aside from temperature, other factors such as parasites and the quality of the food supply may also affect seasonal succession (Pejler, 1957b). As noted earlier, the sporozoan parasite Plistophora occurred in the river. In the Lunter Untersee this same parasite is known to drastically reduce the Conochilus unicornis population each year (Ruttner, 1953). In some years a similar occurrence could take place in River Canard.

The role played by the quality of the food supply in affecting succession is difficult to assess. If rotifers display any kind of food particle selectivity, niche differentiation could be very subtle and the factors initiating succession even more difficult to determine. Experiments by Naumann and Gossler indicate that a selectivity based in part on the size of the food particles exists in certain species of rotifers (Pejler, 1957b). However, these same experiments illustrate that other factors, as yet undetermined, play a role in this selectivity (Pejler, 1957b). Similarly work by Pourriot (1957) involving food

selection of different species and subspecies of Brachionus suggests that differences in food preference may exist as low as the subspecies level.

In view of the selectivity demonstrated by some species, the omnivorous habits of others, and the diversity of food ingested by the rotifer population as a whole, attempts to relate specific rotifers to trends in the food supply are at best difficult. However, the relationship between the Synchaeta oblonga maximum and the filamentous algae in November is of interest. The coincidence of its winter pulses with those of the dinoflagellates and green algae is even more striking. Species of Synchaeta are known to feed on both large and small algal types (Edmondson, 1957). Similarly, the appearance of S. stylata in association with filamentous algae is significant. Perhaps the low incidence of Synchaeta that occurred during the summer of 1967 (Winner and Hartt, 1969) was attributable to low concentrations of filamentous algae. The apparent relationship between these synchaetids and the various algal types deserves closer attention.

Population maxima of some other species, notably Conochiloides dossuarius, Hexarthra mira, Keratella cochlearis, Notholca acuminata, and Polyarthra sp., though apparently related to phytoplankton pulses, could not be related to any particular algal types. In these cases a more critical evaluation of the phytoplankton is necessary. Species identifications must be made. Grouping the phytoplankters on a size basis might also prove to be a fruitful approach.

Congeneric Associations

Both Pennak (1957) in his limnetic plankton studies and Williams (1966) in his planktonic river rotifer studies found congeneric

associations to be uncommon. Referring to limnetic zooplankton in general Pennak (1957) states, "when two species in the same genus do occur together, one is usually 20 or more times as abundant as the other". Williams (1966) refers specifically to planktonic rotifers when he writes, "each dominant genus strongly tended to have but one dominant species".

The composition of the planktonic rotifer population of River Canard is of interest in that congeneric associations are of common occurrence. This is especially true for the genus Brachionus. Generally, two, three or four species of Brachionus occurred together. These associations were so common that the Brachionus pulses of late April and late June, 1968 were exceptional in that they were composed for the most part of only one species.

As mentioned earlier, a striking congeneric association occurred within the genus Synchaeta. S. oblonga and S. pectinata showed markedly similar trends. This association was originally noted by Rousselet (1902). Various species of Keratella also co-occurred, particularly K. cochlearis and K. earlinae. Relationships here were not as striking as in the other cases however.

In such situations as these, a possible basis for niche separation is the size difference between the congeners. These size differences could conceivably result in a corresponding difference in the size of the food particles accepted by each species (Pejler, 1957b). This could be the mode of niche separation between Synchaeta oblonga and S. pectinata and between some of the species of Brachionus. S. oblonga, c. 175 u in length, is considerably smaller than S. pectinata, c. 350 u. Similarly B. budapestinensis, B. angularis and B. calyciflorus display a size gradation, c. 140 u, 160 u and 400 u respectively.

Size differences cannot account for niche separation in all cases however. Coincident pulses of such closely allied species as Brachionus angularis and B. caudatus, and B. bidentatus and B. quadridentatus occurred in the river. The members of each species pair are similar in size. In these cases, niches may be defined by some undetermined factor, perhaps selectivity based on something other than food particle size as suggested by Pourriot's (1957) experiments.

It is also possible that the eutrophic nature of the river reduces interspecific competition allowing for niche overlap. This would enable populations of closely allied species to occur simultaneously, where as under more severe circumstances, competition would result in the dominance of one of the congeners.

Williams (1966) studying the larger rivers of the United States, found that there was often more than one dominant species. In River Canard the eutrophic condition allows for a more complex rotifer fauna so that each dominant genus may contain more than one dominant species. The relatively large number of dominant genera, four, and the frequency of congeneric associations serve as an index of the eutrophic condition of the river.

Sexual Cycles

The appearance of resting eggs with the population maxima is consistent with Gilbert's (1963) hypothesis that the development of mictic females and subsequent production of males and resting eggs is a density dependent phenomenon. The appearance of male Asplanchna during the September, 1968 maximum is also consistent with this view. The subsequent occurrence of these males during low population periods is difficult to relate to this idea however. It may be that changes

in diet, specifically in α -tocopherol intake as implicated by Birkey (1964), was the factor initiating male production in these cases.

CHAPTER VI

CONCLUSIONS

River Canard supports a sizable and diverse planktonic rotifer population. The size and diversity of this population is a reflection of the sluggish current and the agricultural nature of the drainage basin.

Nutrient rich run-off from the fertilized farmland contributes to above average chemical concentrations, maintaining the river in a eutrophic state. The relatively large number of co-dominant genera, four, and the common occurrence of congeneric associations, are a reflection of this eutrophic condition. Further, the species composition of the planktonic rotifer population provides support for the hypothesis that rotifers are indicators of the trophic nature of the environment.

The appearance of resting eggs at the time of population maxima is consistent of Gilbert's (1963) hypothesis that the production of mictic females is a density dependent phenomenon.

SUMMARY

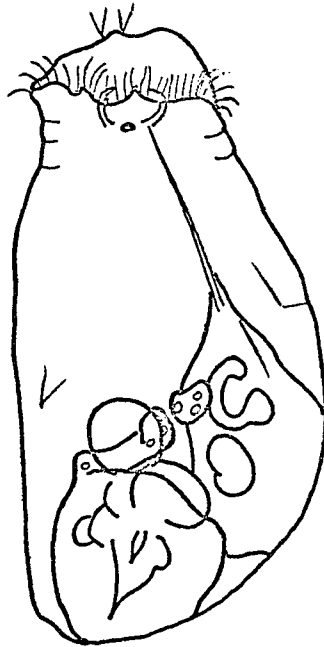
1. The objectives of this study were to enumerate the various species of planktonic Rotifera found in River Canard, to establish their patterns of seasonal succession, and to relate trends in the planktonic rotifer population to various physical, chemical and biological factors.
2. Sampling was carried out on a weekly basis from April 5, 1968 to May 28, 1969 at a station near the mouth of the river. A total of 61 tow samples, 73 Wisconsin net samples, and 59 Nannoplankton samples were made during the study.
3. Rotifers were the dominant metazoan plankters. They averaged 362 individuals/liter for this study, as compared to 77/liter for the copepods and 10/liter for the cladocerans.
4. 17 genera of planktonic rotifers, comprising 41 species were found in the river. The dominant genera were Brachionus, Polyarthra, Synchaeta, and Keratella.
5. The rotifers were most abundant from spring to late fall. Rainfall markedly reduced the plankton community, including the Rotifera. However, subsequent run-off enrichment from the surrounding farmland enhanced productivity so that within several days the Rotifera made a rapid recovery. As a consequence, population maxima tended to follow heavy rainfall.
6. Chemical analyses and chlorophyll a data indicated that the river was eutrophic.
7. Several of the dominant species present have been reported to commonly occur under eutrophic conditions. The presence of these

species in River Canard is in keeping with Pejler's (1957a) hypothesis of rotifers being indicators of the trophic nature of the environment.

8. Congeneric associations involving species of Brachionus, Synchaeta, and Keratella were common. These associations may be maintained, at least in part, through niche separation based on size differences. The eutrophic condition of the river may also allow for niche overlap.
9. The appearance of resting eggs at the time of population maxima is consistent with Gilbert's (1963) hypothesis that the production of mictic females is a density dependent phenomenon.

APPENDIX

ILLUSTRATIONS AND MEASUREMENTS OF THE PLANKTONIC ROTIFERA
OF RIVER CANARD

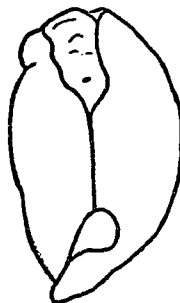
GENUS ASPLANCHNA Gosse

Length
Width

809u
397

Asplanchna sp. 100X

May 28, 1969



Length
Width

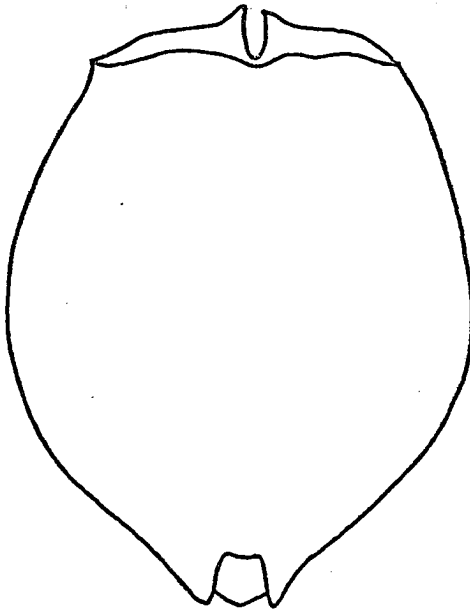
249u
138

Asplanchna sp. male 200X

May 28, 1969

A second species, tentatively identified as A. priodonta Gosse, commonly occurs in the plankton. (See Edmondson, 1959)

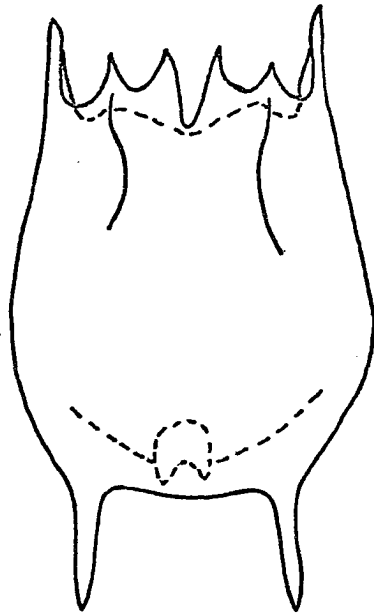
GENUS BRACHIONUS Pallas



Length	160u
Width	122

Brachionus angularis Gosse

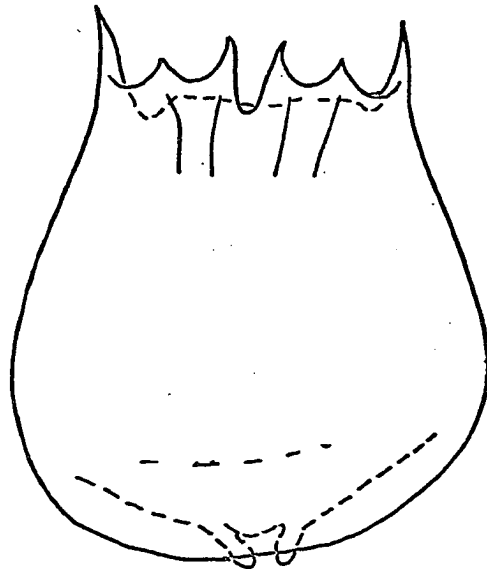
78.



Total length	270u
Width	159
Anterior spines	
Lateral	42
Interior	16
Median	32
Posterior spine	58

Brachionus bidentata Anderson
Dorsal view 300X

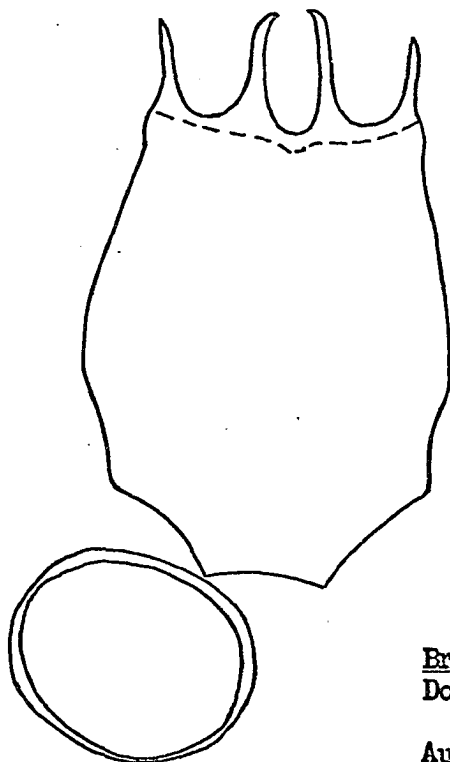
July 10, 1968



Length	233u
Width	190
Anterior spines	
Lateral	42
Interior	16
Median	27

Brachionus bidentata
Dorsal view 300X

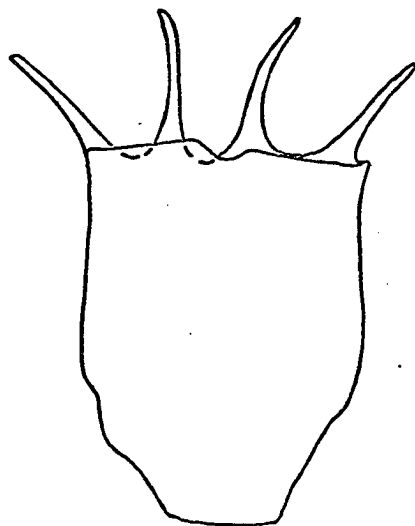
July 10, 1968



Length	164u
Width	101
Anterior spines	
Lateral	27
Medians	31
	37

Brachionus budapestinensis Daday
Dorsal view 450X

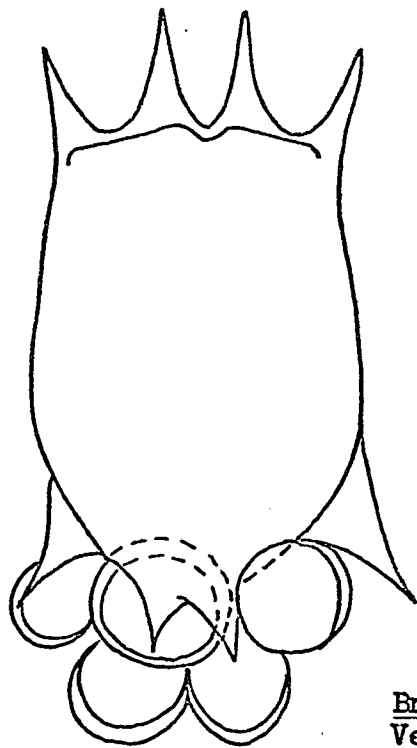
August 7, 1968



Length	132u
Width	74
Anterior spines	
Lateral	37
Medians	32
	29

Brachionus budapestinensis
Dorsal view 500X

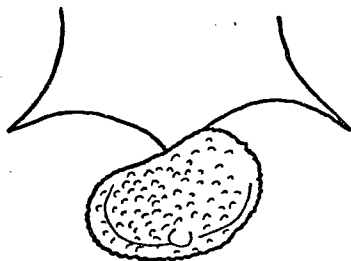
August 7, 1968



Length	420u
Width	210
Anterior spines	
Lateral	72
Median	78
Posterior	
Lateral spine	66

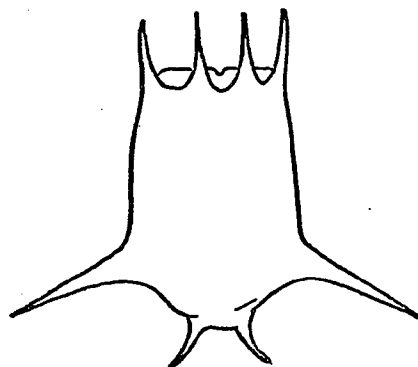
Brachionus calyciflorus Pallas
Ventral view 200X

May 15, 1968



Resting egg 150X

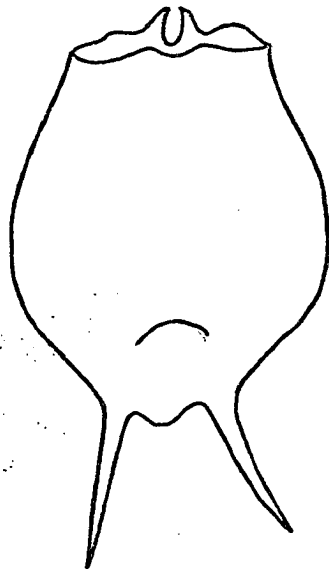
August 7, 1968



Extreme form 150X

June 12, 1968

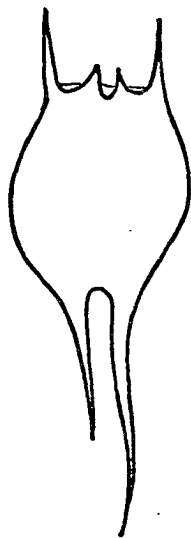
81.



Total length	238 μ
Width	132
Anterior spine	17
Posterior spine	
Left	58
Right	74

Brachionus caudatus Barrois and Daday
Ventral view 300X

July 10, 1968



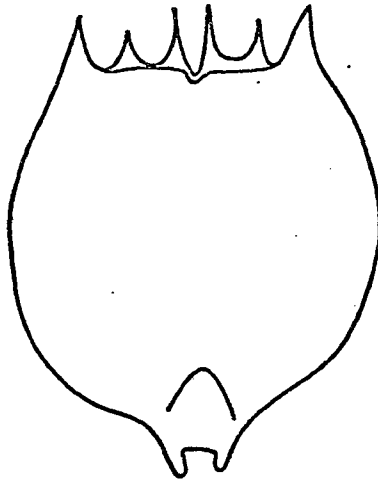
Total length	381 μ
Width	114
Anterior spines	
Lateral	58
Median	16
Posterior spine	
Left	106
Right	180

Brachionus havanaensis Rousselet
Dorsal view 200X

July 17, 1968



Lateral view

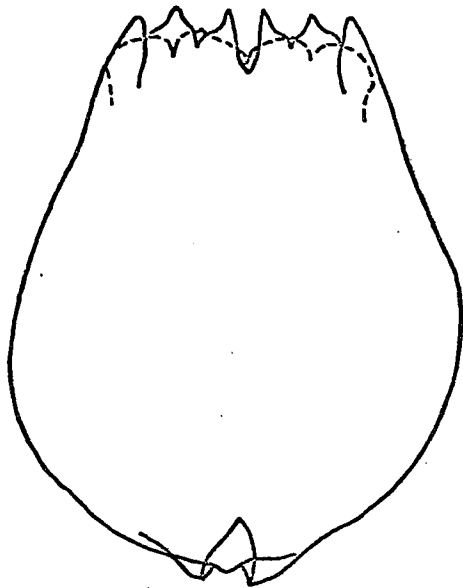


Length
Width

202u
152

Brachionus nilsoni Ahlstrom
Ventral view 300X

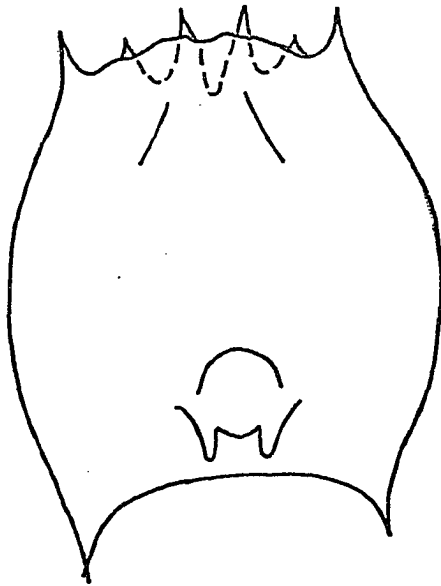
September 11, 1968



Length	210u
Width	158
Anterior spines	
Lateral	16
Interior	12
Median	16

Brachionus plicatilis Muller
Dorsal view 350X

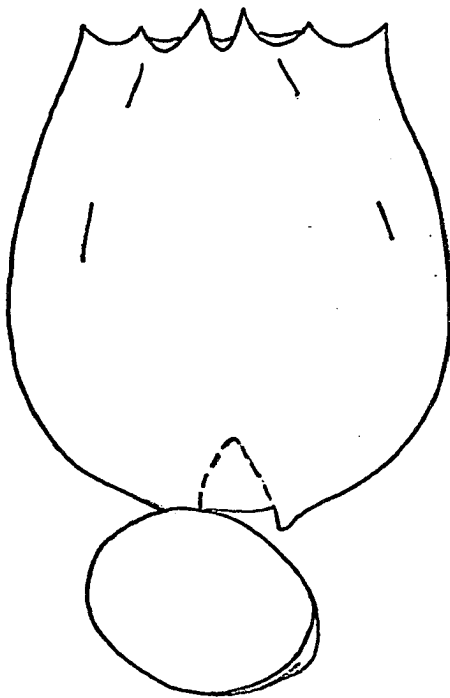
June 12, 1968



Total length	286u
Width	212
Anterior spines	
Lateral	26
Interior	19
Median	48
Posterior spine	42

Brachionus quadridentatus Hermann
Ventral view 250X

July 10, 1968



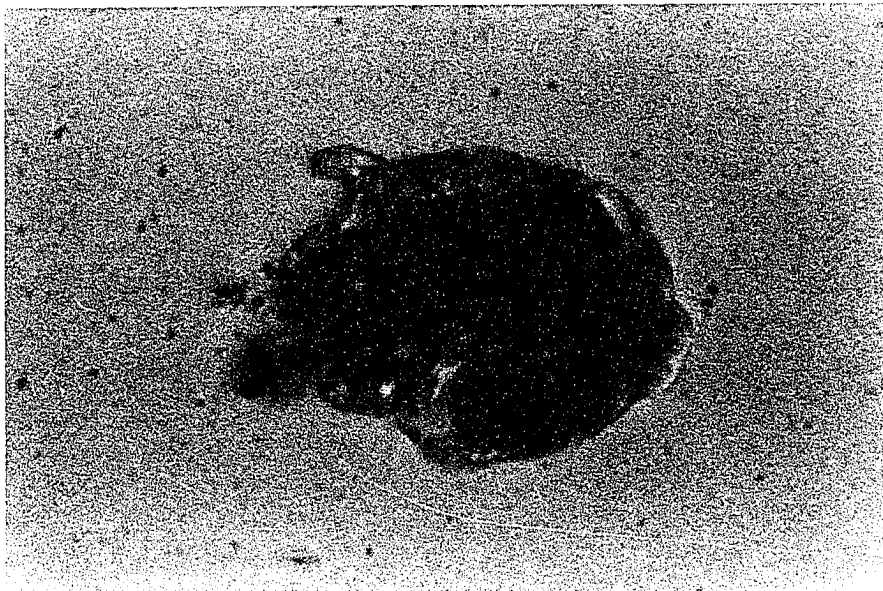
Length	227u
Width	210

Brachionus urceolaris Muller
Dorsal view 300X

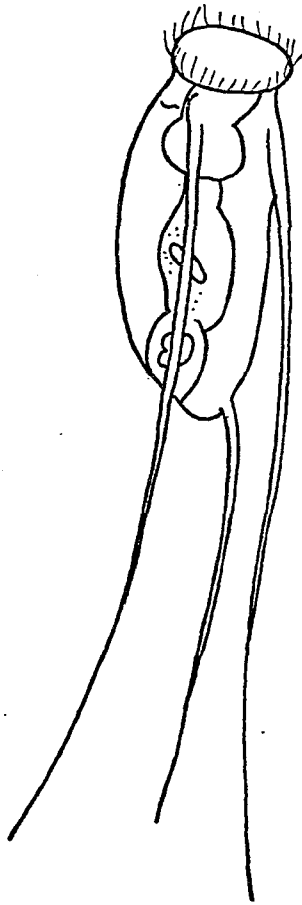
April 24, 1969

GENUS CONCHILOIDES HLava

Conochiloides dossuarius (Hudson)
Lateral view 100X
July 17, 1968.



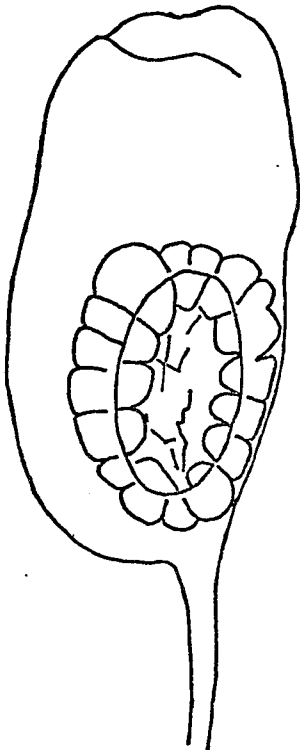
C. dossuarius contracted

GENUS FILINIA Bory de St. Vincent

Length	175u
Width	69
Anterior spine	381
Posterior spine	127

Filinia longiseta (Ehrenberg)
Lateral view 300X

August 7, 1968



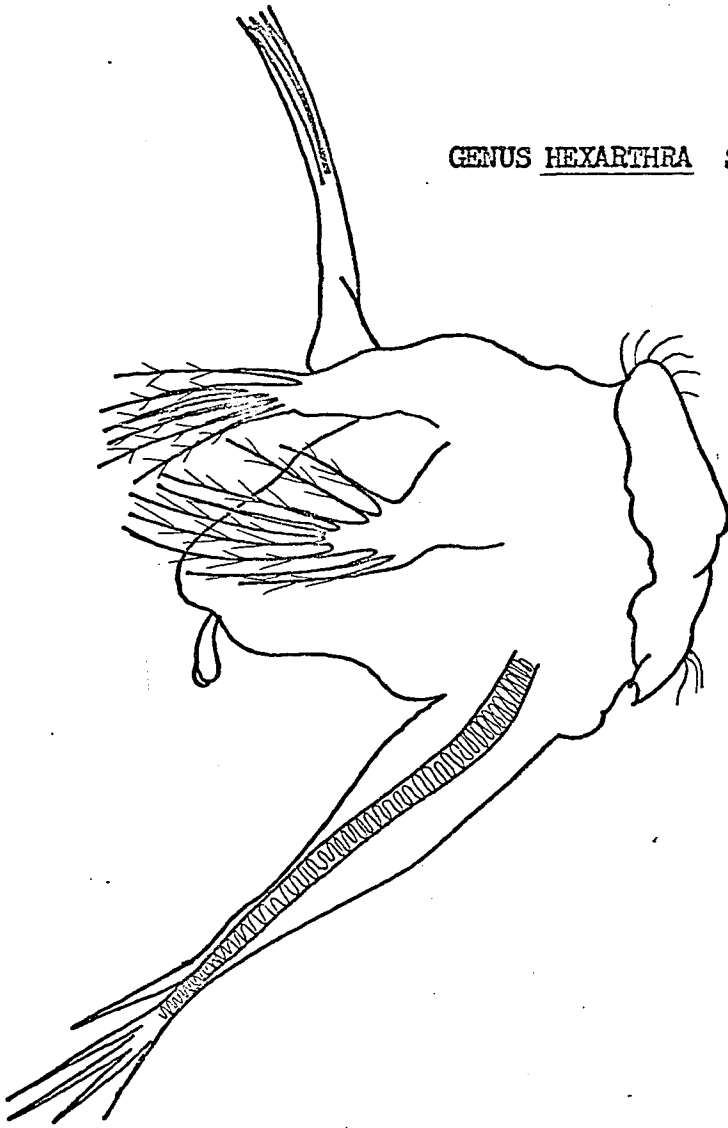
Resting Egg	
Length	76u
Width	53

Filinia longiseta
With resting egg 500X

May 15, 1968

GENUS HEXARTHRA Schmarda

Length 179u
Width 158



Hexarthra mira Hudson
Lateral view 400X

August 14, 1968



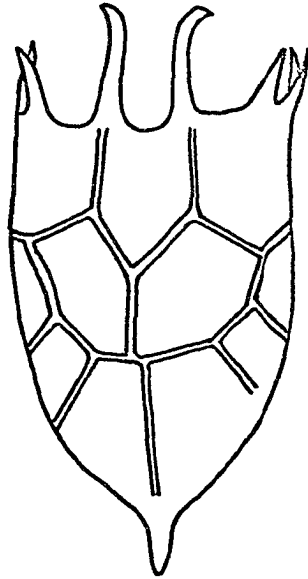
Ventral Appendage

GENUS KEL LICOTTIA Ahlstrom

Length (body)	106u
Width	48
Anterior spines	290-180-138
Posterior spine	222

Kellicottia longispina (Kellicott)
Lateral view 150X

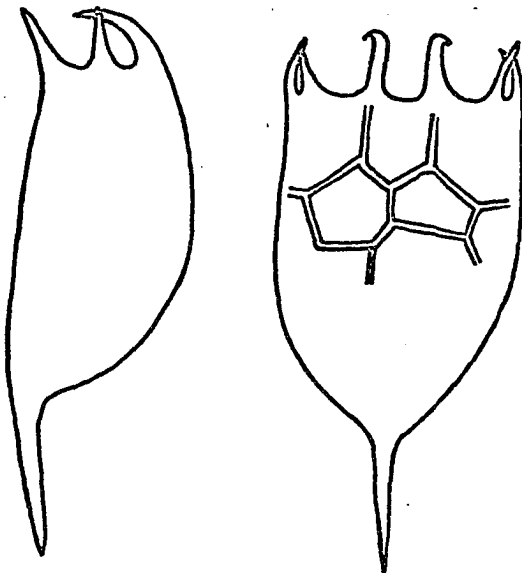
May 28, 1969

GENUS KERATELLA Bory de St. Vincent

Length	127u
Width	64
Anterior spines	
Lateral	19
Interior	16
Median	26
Posterior spine	12

Keratella cochlearis (Gosse)
Dorsal view 600X

May 29, 1969

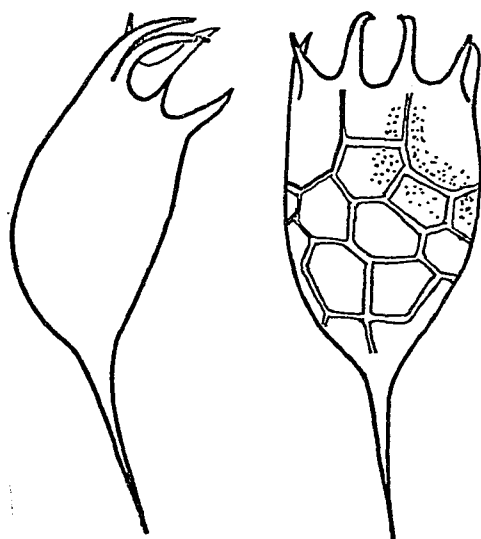


Length	206u
Width	90
Anterior spines	
Lateral	21
Interior	21
Median	27
Posterior spine	58

Lateral view Dorsal view
350X

Keratella crassa Ahlstrom

August 14, 1968

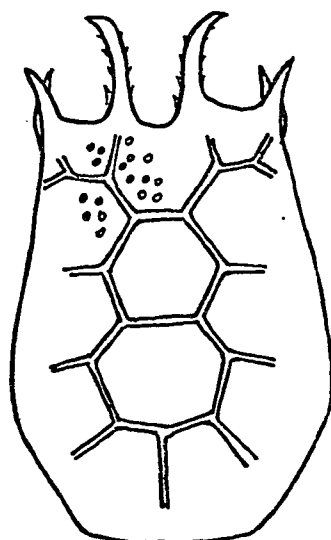


Length	200u
Width	87
Anterior spines	
Lateral	21
Interior	20
Median	26
Posterior spine	69

Lateral view Dorsal view
350X

Keratella earlinae Ahlstrom

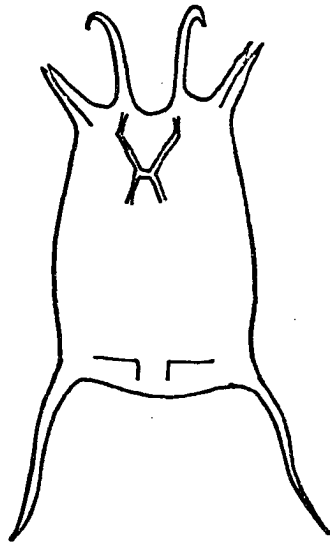
May 28, 1969



Length	201u
Width	116
Anterior spine	
Median	48

Keratella serrulata (Ehrenberg)
Dorsal view 350X

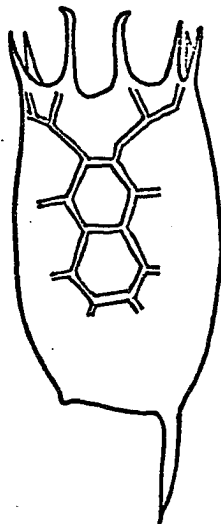
February 12, 1969



Length	275u
Width	104
Anterior spines	
Lateral	44
Interior	37
Median	48
Posterior spines	90

Keratella quadrata (Muller)
Dorsal view 250X

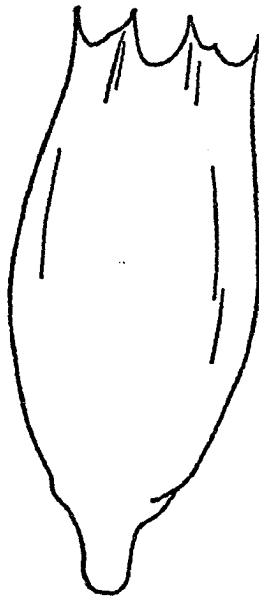
May 15, 1968



Length	226u
Width	84
Anterior spines	
Lateral	23
Interior	25
Median	33
Posterior spine	55

Keratella valga (Ehrenberg)
Dorsal view 300X

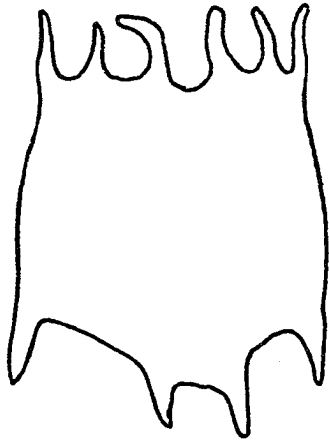
May 8, 1968



Length 205u
Width 100

Notholca acuminata (Ehrenberg)
Ventral view 350X

March 20, 1969

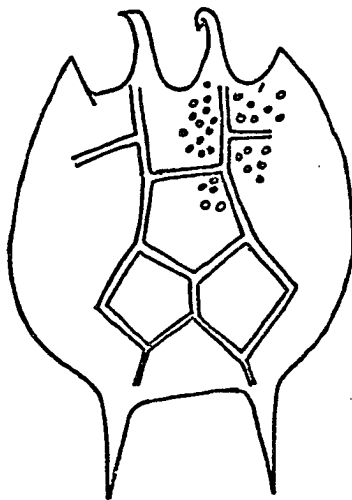
GENUS PLATYIAS Herring

Length
Width

196u
136

Platyias patulus (Muller)
Dorsal view 300X

July 10, 1968



Length
Width

333u
233

Anterior spines

Median

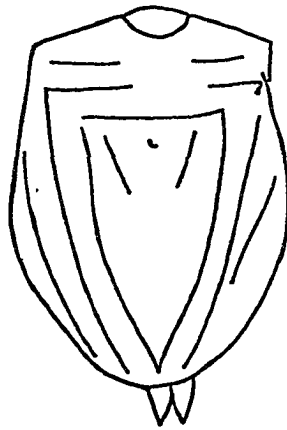
Posterior spines

53

74

Platyias quadricornis (Ehrenberg)
Dorsal view 200X

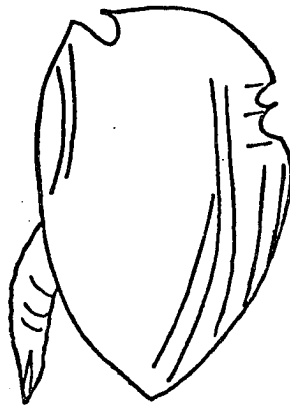
June 12, 1968

GENUS PLOESOMA Herrick

Length
Width
Depth

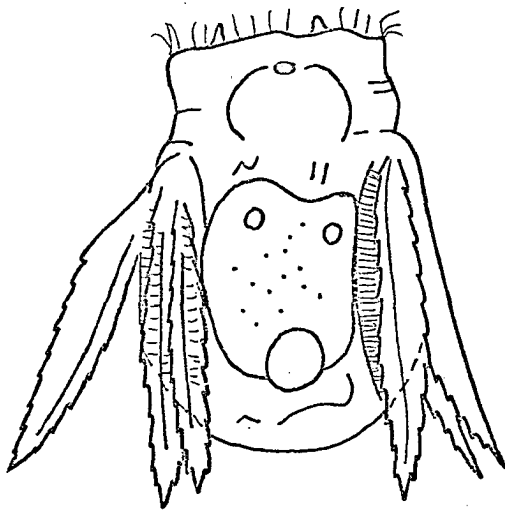
169u
106
116

Dorsal view 300X



Lateral view 300X
Ploesoma truncatum (Levander)

May 29, 1969

GENUS POLYARTHRA Ehrenberg

Length (body)	122u
Width	90
Paddle length	106
Paddle width	21

Polyarthra "curyptera"
Dorsal view 450X

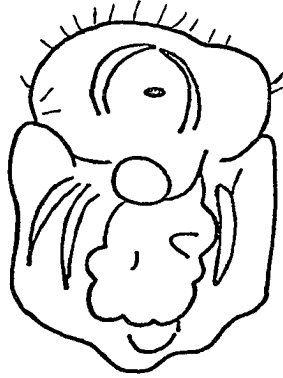
July 10, 1968



Length (body)	187u
Width	121
Paddle length	168
Paddle width	—

Polyarthra "trigla"
Dorsal view 300X

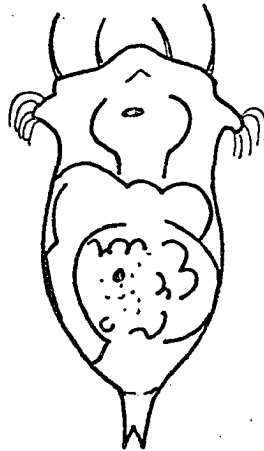
February 12, 1969



Length	134u
Width	115

Polyarthra sp. (Apterous form)
350X

February 6, 1969

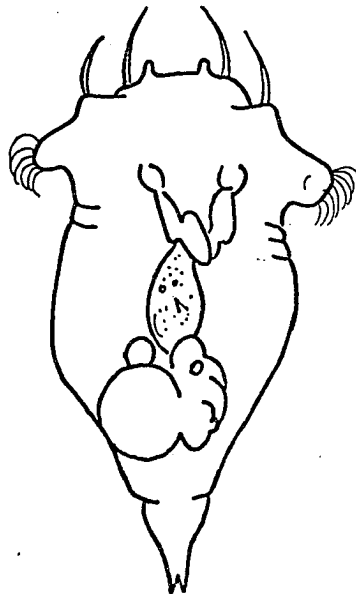
GENUS SYNCHAETA Ehrenberg

Length
Width

175u
90

Synchaeta oblonga Ehrenberg
Dorsal view 300X

March 20, 1969



Length
Width

349u
206

Synchaeta pectinata Ehrenberg
Dorsal view 200X

March 6, 1969



Synchaeta stylata Wierzejski 100X

August 12, 1969

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