

Rotifer occurrence and trophic degree

Bruno Bērziņš & Birger Pejler

Institute of Limnology, P.O. Box 557, 751 22 Uppsala, Sweden

Received 4 February 1988; in revised form 4 July 1988; accepted 20 July 1988

Key words: Rotifera, trophic degree, tot-P, electrolytic conductivity, content of dry matter

Abstract

Information on the distribution of planktic, periphytic and benthic rotifers from diverse waters in south and central Sweden was analysed for details on relationships to the trophic degree. Three factors were combined in order to get an estimation of the trophic degree: tot-P-content, electrolytic conductivity and content of dry matter. Indicators of oligotrophic and eutrophic environments are enumerated. As far as the planktic species are concerned, the results are largely compatible with those of earlier investigations (while the non-planktic forms were previously less known in this respect). Some eutrophy indicators have been reported as typical of saprobic environments.

Introduction

The large material collected by Bruno Bērziņš during the years 1945–1982, now having been computerized (see Bērziņš & Pejler, 1987), may be utilized for elucidating various problems. In this paper the emphasis is laid upon trophic degree, estimated by means of tot-P content, electrolytic conductivity and content of dry matter. The relation between planktic rotifers and trophic degree has been dealt with in different publications (see, e.g., Pejler, 1983 and the literature referred to there, as well as Karabin 1983 and 1985a and b), but this is probably the first time that non-planktic species are considered in this connection.

Material and methods

The material derives from about 350 lakes, 50 ponds, 20 pools, 15 mires and 150 running

water localities in southern and central Sweden. The localities, as well as the microzoan species, are listed and codified in Bērziņš (1978). In most of the localities only samples from the warmer (ice-free) season were taken but in many cases winter samples were collected as well. Both plankton, periphyton and benthos were investigated.

Water for analysis of abiotic factors was obtained by a water sampler (1 or 5 l). Samples were taken in the open water at different depths, near the bottom and among the vegetation, in all cases as close as possible to the sample of organisms to be investigated at the same time.

The conductivity was measured as $\mu\text{S cm}^{-1}$ at 20 °C, using a Wheatstone-bridge. Total phosphorus (tot P) content was analysed by acid digestion (H_2SO_4 , HNO_3 and HClO_4) followed by phosphate determination (Murphy & Riley, 1962). The content of dry matter (dominated by organic substance) was determined after concentration by evaporation. For technique connected

with the biological samples, as well as for taxonomic considerations, the reader is referred to Bérzinš and Pejler (1987 and in press).

From plots of abundance versus individual environmental factors patterns of covariation between these parameters were extracted, and for every such constellation a diagram (computer sheet) was obtained (in total many thousand sheets). These sheets are archived at the Limnological Institute in Lund (and as tape at the Limnological Institute in Uppsala).

However, the archived diagrams are too numerous and too spacious for international publication and have been drastically reduced in the present context. First, only species observed in at least 50 of the studied samples are included. Second, only two degrees of abundance are discriminated. Since a strict quantitative analysis was impossible for benthic and periphytic rotifers (i.e. the majority of the species), and because of the compression of the material, the degrees of abundance have mainly to be understood as a relative measure. The median point is also denoted by subjective estimation on the basis of the computer sheets. For further information on computer treatment and diagrams the reader is referred to Bérzinš and Pejler (in press).

Results and discussion

The results obtained in this way are presented in Figs. 1–4 ($\mu\text{S cm}^{-1}$), 5–6 (tot-P) and 7 (dry matter). Electrolytic conductivity was analyzed already during the early phase of the project, but tot-P was introduced later and dry matter even later. During this later period mainly plankton samples were collected, which explains why only a smaller part of the non-planktic species reached the limit of 50 observations needed for being represented in the diagrams concerned with the two latter factors. This is the reason why there are fewer diagrams for tot-P and dry matter and why planktic species (marked with an asterisk) are dominating in these diagrams, especially in Fig. 7.

None of the three abiotic factors concerned is, of course, a direct measure of trophic degree.

Thus, conductivity is often used for analyzing salinity. However, there are no really saline or brackish waters included in the present material (although the chloride concentration may be comparatively high in the samples from a sewage treatment plant), and μS can be regarded as connected mainly with the nutrient standard of the respective localities; the highest values being found in areas with loamy plains and sedimentary rocks, lower values in areas with Archaean rocks mainly covered with coniferous forest. The same applies to the phosphorus content, and it should be recalled that in most cases phosphorus seems to be the predominantly limiting factor for primary production in Swedish freshwater habitats (see, e.g., Forsberg & Ryding, 1980). Finally, it has been found by microscopic analysis that the dry matter in almost all localities mainly derives from biological production and to a large extent consists of particles which can be utilized as food for the rotifers.

The three abiotic factors mentioned are not directly coupled to each other. Consequently, each of them may individually be regarded as an indicator of trophic degree, but still more so if combined. For this reason the ranking numbers of a species, for the individual factors, are added in the following list, beginning with the species being found to indicate the most oligotrophic conditions. Only species correlated with all three factors are included. The summed ranking number is mentioned after each species name: *Collotheca lie-petterseni* 25, *Conochilus unicornis* 61, *Ascomorpha ecaudis* 62, *Gastropus stylifer* 64, *Postclausa hyptopus* 65, *Bipalpus hudsoni* 72, *Asplanchna herricki* 75, *Kellicottia longispina* 77, *Polyarthra remata* 77, *Ploesoma truncatum* 78, *Testudinella emarginula* 79, *Trichocerca intermedia* 79, *Ascomorpha ovalis* 96, *Collotheca mutabilis* 98, *Cephalodella h. hoodi* 99, *Keratella cochlearis robusta* 112, *Polyarthra major* 112, *Trichocerca p. porcellus* 121, *Cephalodella auriculata* 122, *Collotheca pelagica* 125, *Polyarthra vulgaris* 131, *Asplanchna priodonta* 134, *Synchaeta stylata* 149, *Trichocerca rousseleti* 149, *Polyarthra dolichoptera* 151, *Keratella c. cochlearis* 157, *Proales decipiens* 160, *Polyarthra euryptera* 180, *Synchaeta oblonga*

Rotaria macrura (Ehrbg)
Euchlanis meneta Myers
Lecane clara (Bryce)
Polyarthra minor Voigt
Habrotrocha lata (Bryce)
Trichocerca longiseta (Schrank)
Lecane stictaea Herring
Floscularia janus (Hudson)
Monommata grandis Tessin
Trichocerca sulcata (Jennings)
Lepadella b. borealis Herring
Cephalodella nana Myers
Aspelta aper (Herring)
Cephalodella s. sterea (Gosse)
Trichocerca scipio (Gosse)
Microcodon clavus Ehrbg
Monommata phoxa Myers
Lecane mira (Murray)
Colurella tessellata (Glascott)
Lecane b. brachydactyla (Stenoos)
**Keratella serrulata* (Ehrbg)
**Collotheaca lie-petterseni* Bērzīns
Euchlanis alata Voronkov
Monommata astia Myers
Trichocerca parvula Carlin
Monommata aeschyna Myers
Testudinella e. emarginula (Stenoos)
Rotaria montetti Bērzīns
Dissotrocha macrostyla (Ehrbg)
**Keratella hiemalis* Carlin
Euchlanis triquetra Ehrbg
Eothinia lasiobiotica Bērzīns
**Synchaeta grandis* Zacharias
Euchlanis dilatata lucksiana
Cephalodella intuta Myers
**Trichocerca similis* (Wierzejski)
**Ascomorpha ecaudis* Perty
Proalinopsis caudatus (Collins)
Lepadella triba Myers
**Collotheaca libera* (Zacharias)
Lindia torulosa Dujardin
Trichocerca uncinata (Voigt)
**Bipalpus hudsoni* (Imhof)
Notommata tripus Ehrbg
Ascomorphella volvocicola (Plate)
Ploesoma truncatum (Levander)
Notommata contorta (Stokes)
Microcodides chlaena (Gosse)
**Kellicottia longispina* (Kellicott)
**Conochilus unicornis* Rousselet
Lecane lunaris constricta (Murray)
Cephalodella h. hoodi (Gosse)
**Gastropus stylifer* Imhof
**Polyarthra remata* (Skorikov)
Trichocerca intermedia (Stenoos)
Cephalodella auriculata (Müll.)

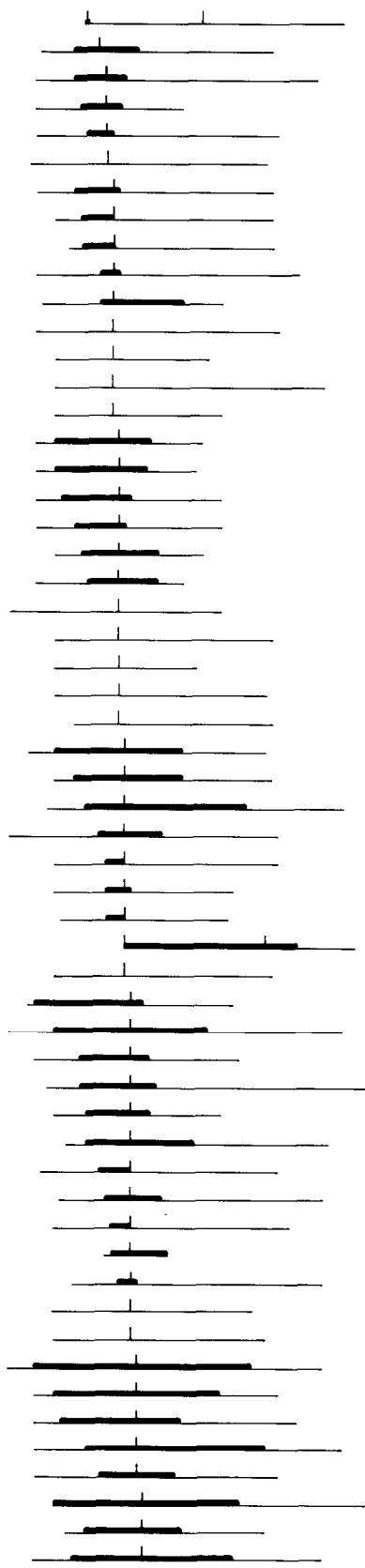


Fig. 1. See p. 176.

1 3 6 16 40 90 100 251 631 1585 3981 10000 μS

- *Postclausa hyptopus (Ehrbg)
- Trichotria t. tetractis (Ehrbg)
- Trichocerca weberi (Jennings)
- Colurella obtusa aperta Hauer
- *Asplanchna herricki Guerne
- Cephalodella apocolea Myers
- Lecane tenuiseta Harring
- *Conochilus hippocrepis (Schrank)
- *Polyarthra major (Burckhardt)
- Trichocerca bidens (Lucks)
- Keratella ticiensis (Calliero)
- *Ascomorpha ovalis (Bergendal)
- Lecane u. ungulata (Gosse)
- *Polyarthra vulgaris Carlin
- *Collothea mutabilis (Hudson)
- Habrotrocha constricta (Dujardin)
- Proales decipiens (Ehrbg)
- *Conochilus dossuarius coenobasis Skorikov
- *Asplanchna priodonta Gosse
- *Keratella cochlearis robusta (Lauterborn)
- Testudinella p. parva (Ternetz)
- Trichocerca p. porcellus (Gosse)
- *Collothea pelagica (Roussellet)
- Aspelta circinator Gosse
- Taphrocampa annulosa Gosse
- Taphrocampa selenura Gosse
- Mytilina mucronata (Müll.)
- Albertia naidis Bousfield
- Macrotrachela ehrenbergi (Janson)
- Adineta oculata (Milne)
- *Trichocerca rousseleti (Voigt)
- *Keratella cochlearis macracantha (Lauterborn)
- *Synchaeta lakowitziana Lucks
- Colurella obtusa clausa Hauer
- Proales minima (Montet)
- *Polyarthra dolichoptera (Idelson)
- Trichocerca tigris (Müll.)
- Pleurotrocha hyalina Wulfert
- Eothinia e. elongata (Ehrbg)
- Cephalodella mucronata Myers
- *Keratella c. cochlearis (Gosse)
- *Polyarthra euryptera (Wierzejski)
- *Trichocerca capucina (Wierzejski & Zacharias)
- *Notholca caudata Carlin
- Trichocerca r. ratus (Müll.)
- Trichocerca tenuior (Gosse)
- Euchlanis incisa Carlin
- Eothinia triphaea Harring & Myers
- Phildina megalotrocha Ehrbg
- Trichocerca cavia (Gosse)
- Monommata longiseta (Mill.)
- Cephalodella m. megalcephala (Glascott)
- Cephalodella eva (Gosse)
- Habrotrocha bidens (Gosse)
- *Synchaeta pectinata Ehrbg
- *Synchaeta oblonga Ehrbg

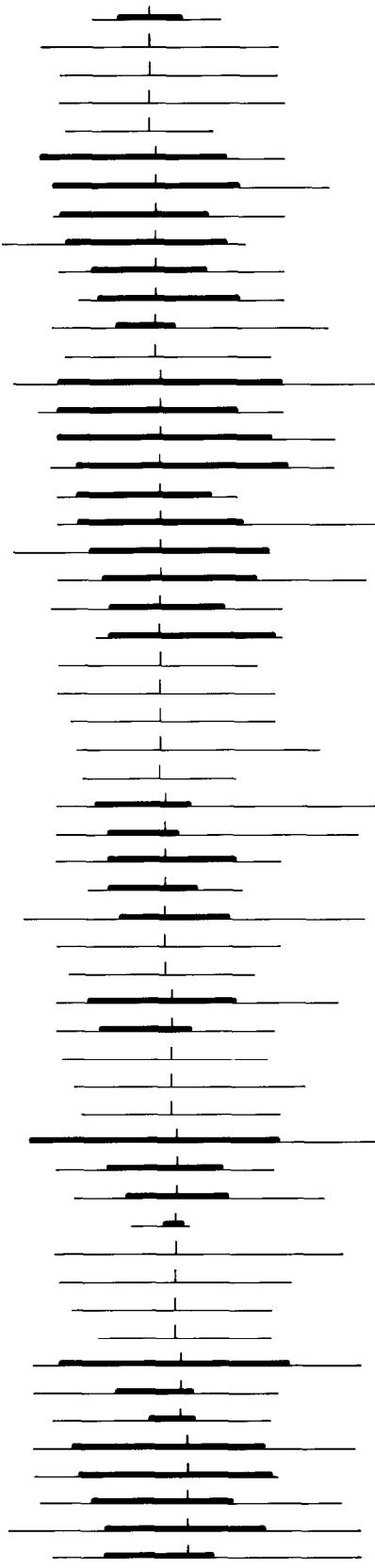


Fig. 2. See p. 176.

1 3 6 16 40 100 251 631 1585 3981 10000 μ S

- Lepadella a. acuminata (Ehrbg)
 *Synchaeta t. tremula (Müll.)
 Dicranophorus haueri Harring & Myers
 Brachionus q. quadridentatus Hermann
 *Filinia terminalis (Plate)
 Notomma cyrtopus Gosse
 Lecane flexilis (Gosse)
 Trichocerca iernis (Gosse)
 Lecane l. lunaris (Ehrbg)
 Habrotrocha collaris (Ehrbg)
 Rotaria tardigrada (Ehrbg)
 *Synchaeta stylata Wierzejski
 Cephalodella v. ventripes (Dixon-Nuttall)
 Colurella o. obtusa (Gosse)
 Lecane b. bulla (Gosse)
 Lecane inermis (Bryce)
 *Anuraeopsis f. fissa (Gosse)
 *Ascomorpha saltans (Bartsch)
 *Keratella cochlearis hispida (Lauterborn)
 Macrotrachela angusta (Bryce)
 *Synchaeta tremula kitina Rousselet
 Adineta v. vaga (Davis)
 *Keratella i. irregularis (Lauterborn)
 Lepadella t. triptera Ehrbg
 Trichocerca brachyura (Gosse)
 *Synchaeta longipes Gosse
 *Keratella irregularis wartmanni (Asper & Heuscher)
 Cephalodella elongata Myers
 Rotaria macroceros (Gosse)
 Lecane lunaris perplexa (Ahlström)
 Cephalodella forficula (Ehrbg)
 Collothea c. campanulata (Dobie)
 Encrinitrum lupus Wulfert
 Lepadella p. patella (Müll.)
 Euchlanis d. dilatata Ehrbg
 *Trichocerca birostris (Minkiewicz)
 *Trichocerca pusilla (Jennings)
 Trichocerca elongata (Gosse)
 *Keratella cochlearis tecta (Gosse)
 Cephalodella compressa Myers
 Scaridium longicaudum (Müll.)
 Cephalodella arcuata Wulfert
 Collothea ornata cornuta (Dobie)
 *Notholca acuminata (Ehrbg)
 Rotaria citrina (Ehrbg)
 Cephalodella gracilis (Ehrbg)
 Proales fallaciosa Wulfert
 Cephalodella gibba (Ehrbg)
 Colurella uncinata bicuspidata (Ehrbg)
 *Pompholyx sulcata Hudson
 *Notholca squamula (Müll.)
 Rotaria rotatoria Pallas
 Philodina roseola Ehrbg
 *Brachionus a. angularis Gosse
 Euchlanis parva Rousselet
 *Filinia longiseta (Ehrbg)

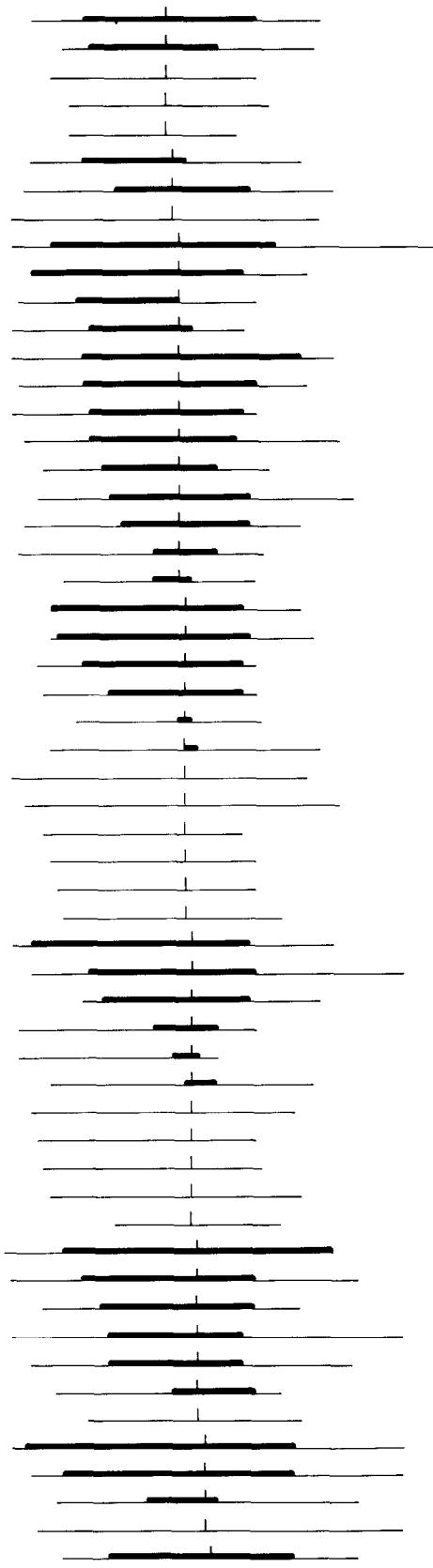


Fig. 3. See p. 176.

1 3 6 16 40 100 251 631 1585 3981 10000 μ s

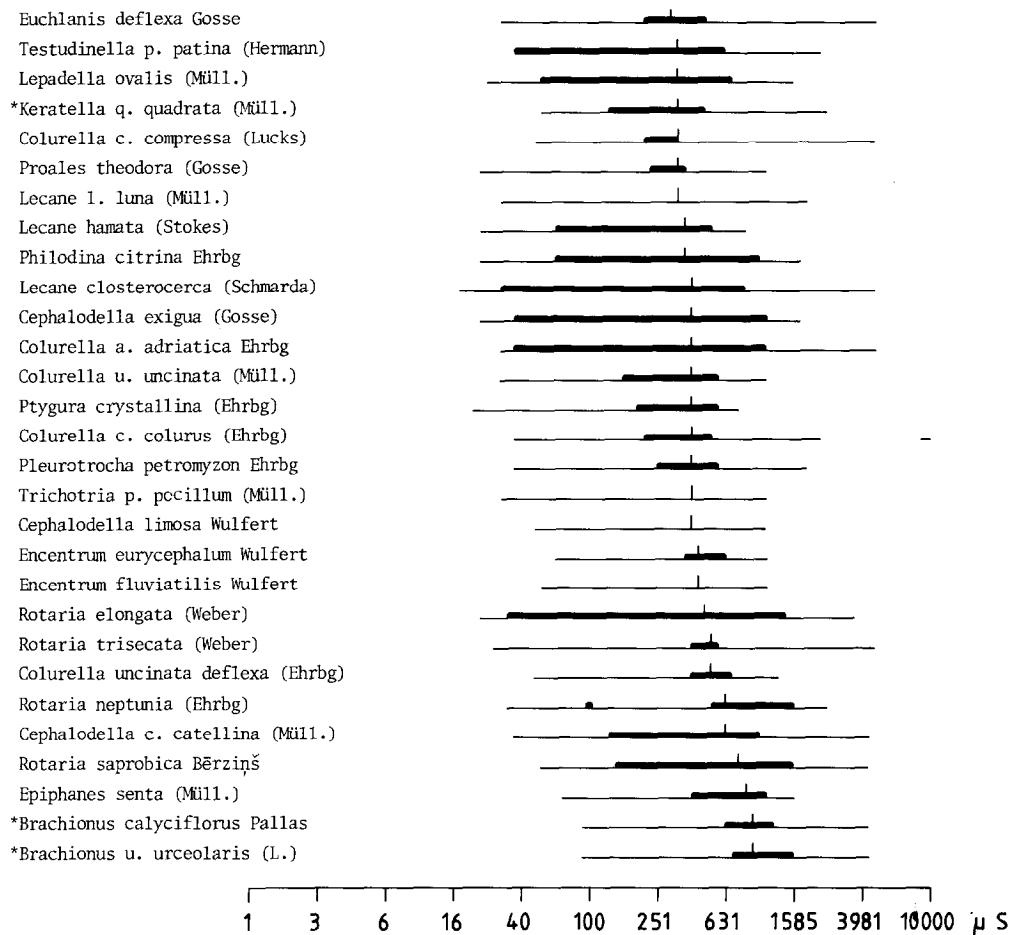


Fig. 5–6. Occurrence of rotifers in relation to tot-P content of the water. The species are ranked in a series, beginning with those showing their maximum abundance at relatively low tot-P values (Fig. 5). For other explanations, see the text of Figs. 1–4. The species are ranked according to conductivity preference, beginning with those having their peak abundance at $\leq 80 \mu\text{S cm}^{-1}$ (fig. 1) through those having their peak abundance at $> 250 \mu\text{S}$ (Fig. 4). Planktic species are marked with an asterisk.

180, *Cephalodella v. ventripes* 190, *Synchaeta pectinata* 190, *Lecane inermis* 199, *Ascomorpha saltans* 204, *Lecane l. lunaris* 216, *Keratella i. irregularis* 225, *Colurella o. obtusa* 234, *Keratella i. wartmanni* 240, *Lepadella p. patella* 240, *Cephalodella gracilis* 241, *Trichocerca birostris* 252, *Euchlanis d. dilatata* 253, *Keratella cochlearis tecta* 261, *Cephalodella gibba* 267, *Rotaria rotatoria* 269, *Pompholyx sulcata* 275, *Brachionus a. angularis* 278, *Lecane closterocerca* 279, *Keratella q. quadrata* 289, *Filinia longiseta* 294.

As far as the planktic species are concerned, the results mentioned are more or less in accor-

dance with previous experience (see especially Bērziņš, 1949; Pejler, 1957, 1965 & 1983; Hakkarı, 1972; Radwan, 1976; Gannon & Stemmerger, 1978; Karabin, 1983 and 1985a and b, Walz *et al.*, 1987), the oligotrophic species being found in the beginning of the series, the eutrophic ones at the end. The indicators of oligotrophy are partly intermingled with euryecious species which dominate the rotifer plankton in oligotrophic lakes, although they may also be found in relatively eutrophic lakes (e.g., *Conochilus unicornis* and *Kellicottia longispina*). Some of the indicators were not included in the diagram concerning

- *Collotheca lie-petterseni Bērzins
- *Synchaeta lakowitziana Lucke
- *Filinia terminalis (Plate)
- Enzentrum lupus Wulfert
- *Gastropus stylifer Imhof
- *Conochilus unicornis Rousselet
- *Postclausa hyptopus (Ehrbg)
- *Notholca caudata Carlin
- *Synchaeta grandis Zacharias
- *Bipalpus hudsoni (Imhof)
- *Asplanchna herricki Guerne
- *Ascomorpha ecaudis Perty
- *Keratella cochlearis macracantha (Lauterborn)
- Trichocerca intermedia (Stenroos)
- *Keratella cochlearis robusta (Lauterborn)
- *Keilicottia longispina (Keilicott)
- *Ascomorpha ovalis (Bergendal)
- *Polyarthra major (Burckhardt)
- *Polyarthra remata (Skorikov)
- *Collotheca mutabilis (Hudson)
- *Collotheca pelagica (Rousselet)
- *Notholca squamula (Müll.)
- Trichocerca p. porcellus (Gosse)
- Ploesoma truncatum (Levander)
- *Polyarthra dolichoptera (Idelson)
- *Polyarthra vulgaris Carlin
- *Synchaeta oblonga Ehrbg
- *Keratella c. cochlearis (Gosse)
- *Trichocerca rousseleti (Voigt)
- Testudinella c. emarginula (Stenroos)
- *Trichocerca similis (Wierzejski)
- *Synchaeta stylata Wierzejski
- Cephalodella h. hoodi (Gosse)
- Microcodon clavus Ehrbg
- Cephalodella v. ventripes (Dixon-Nuttall)
- *Asplanchna priodonta Gosse
- *Ascomorpha saltans (Bartsch)
- Philodina citrina Ehrbg
- *Synchaeta pectinata Ehrbg
- *Polyarthra euryptera (Wierzejski)
- Colurella c. colurus (Ehrbg)
- Colurella uncinata bicuspidata (Ehrbg)
- Cephalodella eva (Gosse)
- Dissotrocha macrostyla (Ehrbg)
- Aspelta circinator Gosse
- *Trichocerca capucina (Wierzejski & Zacharias)
- *Keratella i. irregularis (Lauterborn)
- *Anuraeopsis f. fissa (Gosse)
- *Keratella cochlearis hispida (Lauterborn)
- Lecane lunaris constricta (Murray)
- Cephalodella auriculata (Müll.)
- Colurella a. adriatica Ehrbg
- Lepadella a. acuminata (Ehrbg)
- Philodina megalotrocha Ehrbg
- *Keratella irregularis wartmanni (Asper & Heuscher)
- *Keratella hiemalis Carlin

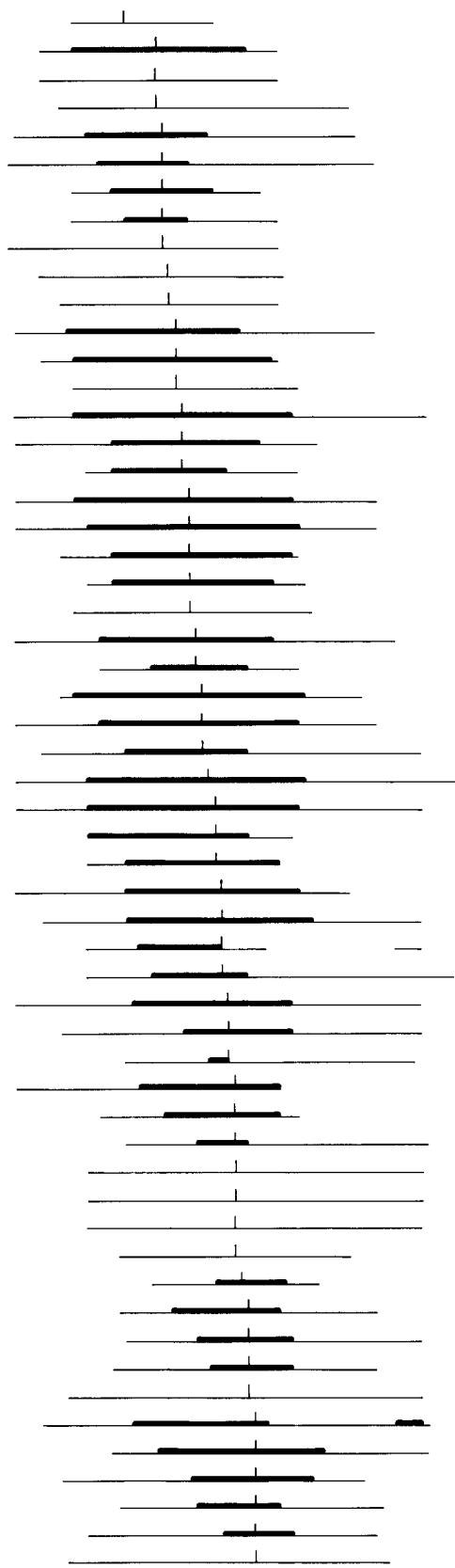


Fig. 5 See p. 178

1 3 6 16 40 100 251 631 1585 3981 10000 $\mu\text{g l}^{-1}$

- **Trichocerca birostris* (Minkiewicz)
- Cephalodella gracilis* (Ehrbg)
- Lecane flexilis* (Gosse)
- Cephalodella apocolea* Myers
- Lecane inermis* (Bryce)
- **Keratella cochlearis tecta* (Gosse)
- **Pompholyx sulcata* Hudson
- **Trichocerca pusilla* (Jennings)
- Cephalodella m. megalcephala* (Glascott)
- Lecane l. lunaris* (Ehrbg)
- Euchlanis d. dilatata* Ehrbg
- **Brachionus a. angularis* Gosse
- Macrotrachela ehrenbergi* (Janson)
- Rotaria rotatoria* Pallas
- Proales decipiens* (Ehrbg)
- **Keratella q. quadrata* (Müll.)
- Cephalodella c. catellina* (Müll.)
- Lepadella ovalis* (Müll.)
- Habrotrocha bidens* (Gosse)
- Lepadella p. patella* (Müll.)
- **Filinia longiseta* (Ehrbg)
- Philodina roseola* Ehrbg
- Cephalodella exigua* (Gosse)
- Cephalodella gibba* (Ehrbg)
- Colurella o. obtusa* (Gosse)
- Lecane closterocerca* (Schmarda)
- Euchlanis parva* Rousselet
- Cephalodella elongata* Myers
- Testudinella p. patina* (Hermann)
- Rotaria elongata* (Weber)
- Rotaria saprobica* Bérzinš

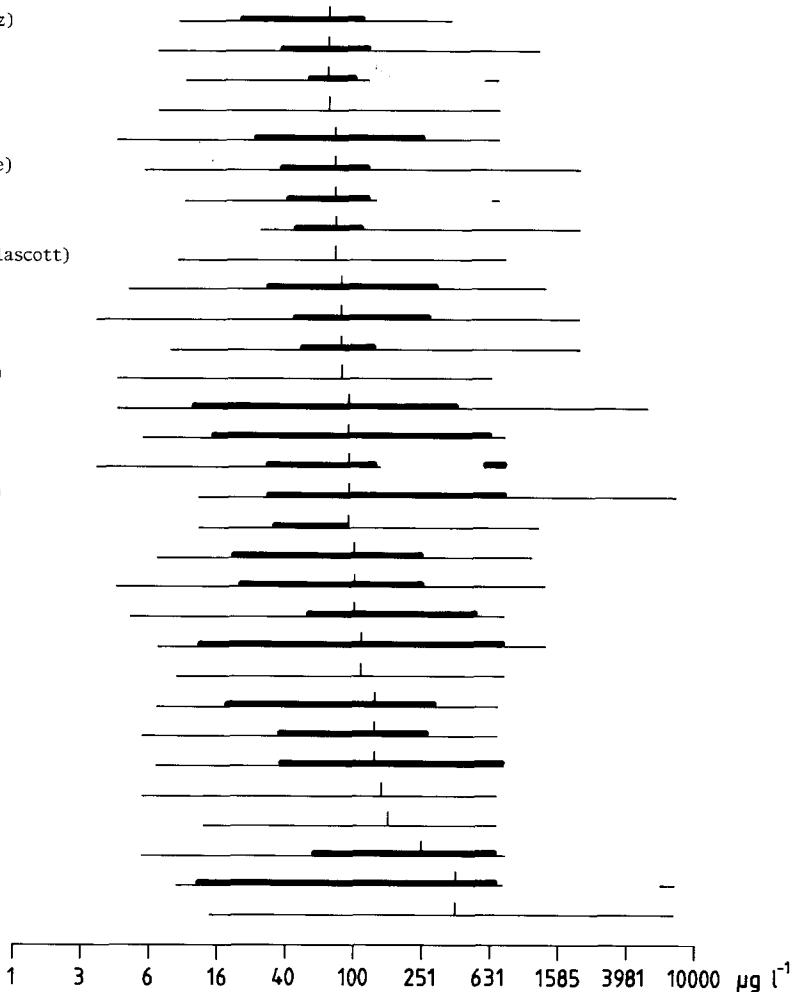


Fig. 5-6. Occurrence of rotifers in relation to tot-P content of the water. The species are ranked in a series, beginning with those showing their maximum abundance at relatively low tot-P values (Fig. 5). For other explanations, see the text of Figs. 1-4.

dry matter, because of too few observations in connection with these analyses, but their oligotrophic character is still quite apparent when studying the correlations with μS and tot-P. *Synchaeta grandis*, for instance, regarded as an indicator of oligotrophy, is ranked as number 9 for tot-P and as number 33 for μS . The corresponding figures for the eutrophy indicators *Anuraeopsis fissa* and *Trichocerca pusilla* are 48 and 130, and 64 and 150, respectively.

Keratella quadrata, next to last in the ranking list above, was included among the indicators of eutrophy in Pejler (1957) but not by the same author in 1965 because it is also found in deep

oligotrophic lakes like L. Vättern and L. Torneträsk. Possibly different races are adapted to different environmental conditions, which is also indicated by the large morphological variation in this species (cf. Pejler, 1981).

As regards the non-planktic species, their relation to the trophic degree as such has not been dealt with previously, as far as we are aware. However, Sládeček (1973) discusses the connection to saprobity at length, a factor which ought to be strongly correlated to the trophic degree. The close connection between saprobity and trophic degree is also exhaustively dealt with by Donner (1978, pp. 127-130). Sládeček

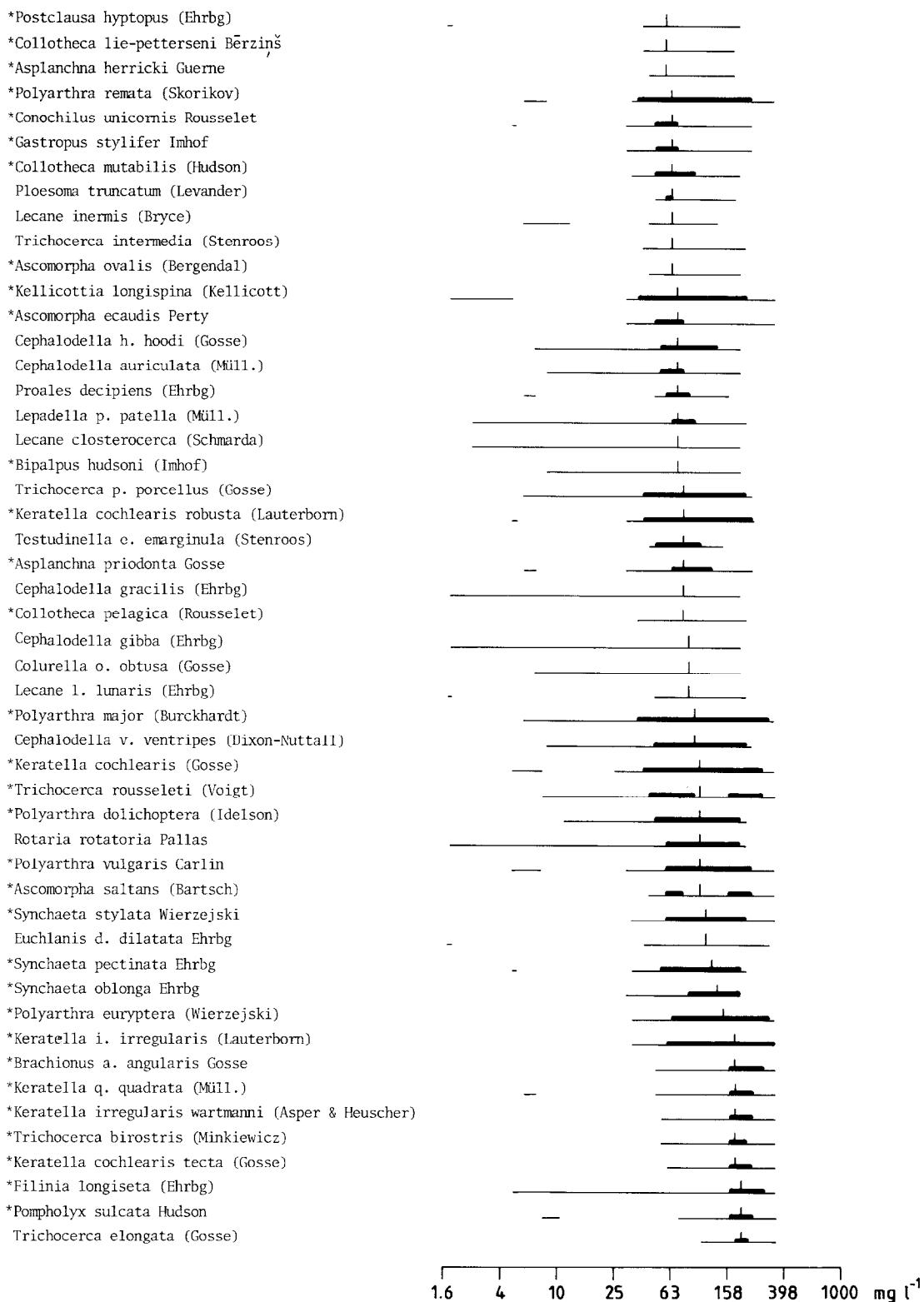


Fig. 7. Occurrence of rotifers in relation to content of dry matter in the water. The species are ranked in a series beginning with those having their maximum abundance at relatively low values of dry matter. For other explanations, see the text of Figs. 1-4.

(op. cit.) includes both planktic and non-planktic species in his book. Almost all species in our ranking list above are designated in op. cit. as oligosaprobic or, in a few cases, as oligosaprobic- β -mesosaprobic. However, *Pompholyx sulcata* and *Filinia longiseta* are regarded as β -saprobic, *Brachionus a. angularis* as β - α -saprobic, *Rotaria rotatoria* as α -saprobic. It is apparent that all the last-named species are to be found in the latter part of our list. For the habitat choice in non-planktic rotifers the nature of the substrate ought to be of great importance, a matter to which we want to return in future papers.

Acknowledgements

Data analysis and subsequent routine work was supported by the National Environmental Protection Board of Sweden. Several persons were involved in this processing, among whom we especially wish to mention Jan Bertilsson.

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