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Rotifer occurrence in relation to pH

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Abstract

Information on the distribution of more than 225 species of planktonic, periphytic, and benthic rotifers from diverse waters in south and central Sweden was analyzed for pH preference. No particularly strong correlation was found between pH and any other environmental factor, with regards to rotifer distribution. However, species indicating oligotrophy generally have their pH optima at or below 7.0, while those indicating eutrophy occur at or above this level. Rotifers found in acidic waters are often non-planktonic or semiplanktonic.

Introduction

The use of bio-indicators has sometimes been regarded with some scepticism. However, when based on a substantial amount of survey information the method seems to be a very useful one [Pejler, 1981 and references therein; Karabin, 1983].

Between 1945 and 1982, a large amount of data was collected from various types of water bodies in southern and central Sweden. The data include information on temperature, about 20 chemical factors, and the abundance of microzoans (planktonic, periphytic, and benthic) for each water body. The material is probably the largest of its kind ever collected. This paper discusses the pH preferences of rotifers from the study area.

Materials and methods

Planktonic, periphytic and benthic samples were collected from about 350 lakes, 50 ponds, 20 pools, 150 running waters, and 15 bogs in southern and central Sweden, between 1945 and 1982 [Bērziņš, 1978]. Most samples were collected during the ice-free period, but some winter samples were also taken.

Samples (1–5 l) for physical, chemical, and biological analysis were taken in open water at various depths, including near the bottom, and in the littoral zone.

Water samples collected for biological analysis were filtered through a 20 μm mesh net and the concentrate fixed in formalin. In most cases net samples also were collected and examined without fixation to facilitate identification of soft-bodied species.

Periphyton was collected in the following way. Moist macrophyte material (biovolume >0.5l) was squeezed into a bottle, dipped and squeezed again: this procedure was repeated several times. Subsamples were examined without fixation until no additional species were encountered. Density was estimated on a scale of 1–10, 1 indicating rare and 10 abundant.

To investigate the epifauna of stones and logs an area of 100–200 cm^2 was scraped off and the material sucked directly into a bottle from the knife. This was done by slowly letting air out of the collection bottle and water in, while keeping the bottle next to the knife blade.

The benthos was sampled by slowly scraping a small vessel over the bottom, collecting a volume of sediment a few millimeters thick and ca. 100–200 cm^2 in area. Subsamples of the sediment were analyzed without fixation and the density of organisms estimated using the scale of 1–10.

The taxonomy of Koste [1978] was followed for identification of monogonont rotifers and that of Donner [1965] for bdelloids. However, in some cases we deviated from these works e.g. concerning the genus *Dissotrocha* [see Bērziņš, 1982]. Furthermore we agreed with Donner [1965: 17–18], who considered it premature to distinguish between 'geographical, ecological and cytological races, microraces, clines, etc.', and accordingly used only one infraspecific category [see also Bērziņš, 1967; Ruttner-Kolisko, 1972; but compare Koste, 1978]. The infraspecific taxa discussed here should be regarded as forms, though the designation 'f.' has been omitted for simplicity.

Data were analyzed with the aid of a computer, in which the scaled value of species abundance was correlated with various environmental factors as single items. Here we report only rotifer occurrence as a function of pH for those species which occurred in ≥ 50 samples. The remaining information has been archived at the Limnological Institute in Lund.

Results and discussion

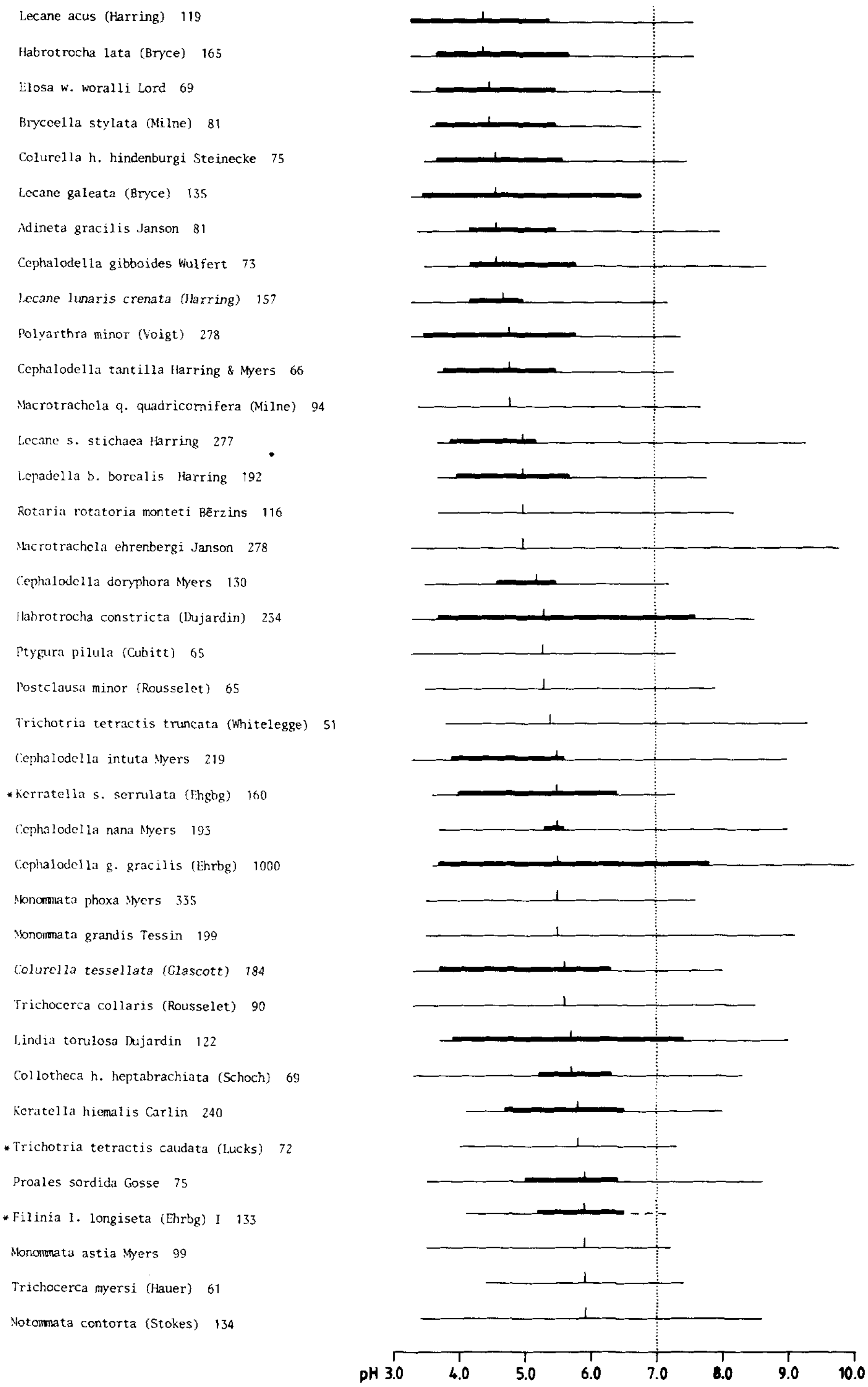
pH is, of course, related to many other chemical parameters in freshwaters, which in themselves are correlated with zooplankton distribution [e.g., Lindström, 1983]. Nevertheless, pH appears to be important in explaining distribution of rotifers [Edmondson, 1944; Skadowsky, 1923].

Most species examined in this study (N = 227) tolerated a broad range of pH values (Fig. 1a–f). Many species (N = 168, 74%) had their peak abundance within 1.0 units of pH 7.0. Others had their median value at quite low pH-values, two species at 4.4. The corresponding maximum on the alkaline side was 8.5.

Several rotifers were found only in acidic environments, never or only very rarely being found above pH 7.0, and with their peak occurrence well below pH 6.0. In the literature these species are said to be restricted to bogs, often in wet *Sphagnum*. Some of these rotifers are classified as 'acidophil' by Wulfert [1951] or as 'acidic' by Bateman & Davis [1980]. Many of these species were encountered in acid zones of a bog pool investigated by Skadowsky [1923] and/or in swamps studied by Francez [1981]. According to Bateman & Davis [1980: 150] they are 'mainly particle feeders or grazers'.

It is more difficult to find a common denominator for rotifers present in alkaline waters. However, *Euchlanis d. deflexa* is said to exhibit mass development in decomposing, drifting vegetation [Koste, 1978], and some of the planktonic forms with alkaline preferences (Fig. 1f) are known as indicators of eutrophic conditions: *Keratella cochlearis tecta* [Pejler, 1962], *Brachionus angularis, Brachionus calyciflorus, Filinia longiseta* and *Trichocerca pusilla* [Pejler, 1965, 1983, references therein]. However, this is not the case of the three *Synchaeta* species at the alkaline end of the pH gradient (*Synchaeta longipes, Synchaeta tremula kitina, Synchaeta stylata*). *Synchaeta longipes* is even said to occur 'in the plankton of oligotrophic lakes...' [Koste, 1978].

Although there are several planktonic rotifers whose peak abundance occurs on the alkaline end of the scale (pH > 8.0), there are none of the acid extreme (pH < 5.5). Thirty species of eulimnoplanktonic rotifers occur with their peak abundance values below or equal to pH 7.0 and 23 species above pH 7.0 (see Fig. 1, species marked with a * and a %, respectively). It is interesting that many species which have been reported to prefer oligotrophic conditions [Pejler, 1965, 1983] are found in the first group of these 54 species (i.e., pH ≤ 7.0), though not especially concentrated there. The 'most alkaline' species of this group, *Asplanchna herricki*, has its abundance maximum at pH 7.0, which is also the case of the 'most acid' indicator of eutrophy, *Polyarthra euryptera*. All other indicators of eutrophy [according to Pejler, 1965, 1983] have their peak abundance clearly in alkaline waters, and *Keratella cochlearis tecta* is



Lecane acus (Harring) 119
Habrotrocha lata (Bryce) 165
Elosa w. woralli Lord 69
Bryceella stylata (Milne) 81
Colurella h. hindenburgi Steinecke 75
Lecane galeata (Bryce) 135
Adineta gracilis Janson 81
Cephalodella gibboides Wulfert 73
Lecane lunaris crenata (Harring) 157
Polyarthra minor (Voigt) 278
Cephalodella tantilla Harring & Myers 66
Macrotrachela q. quadricornifera (Milne) 94
Lecane s. stichaea Harring 277
Lepadella b. borealis Harring 192
Rotaria rotatoria monteti Bērzins 116
Macrotrachela ehrenbergi Janson 278
Cephalodella doryphora Myers 130
Habrotrocha constricta (Dujardin) 234
Ptygura pilula (Cubitt) 65
Postclausa minor (Rousselet) 65
Trichotria tetractis truncata (Whitelegge) 51
Cephalodella intuta Myers 219
*Kerratella s. serrulata (Ehgbg) 160
Cephalodella nana Myers 193
Cephalodella g. gracilis (Ehrbg) 1000
Monommata phoxa Myers 335
Monommata grandis Tessin 199
Colurella tessellata (Glascott) 184
Trichocerca collaris (Rousselet) 90
Lindia torulosa Dujardin 122
Collotheca h. heptabrachiata (Schoch) 69
Keratella hiemalis Carlin 240
*Trichotria tetractis caudata (Lucks) 72
Proales sordida Gosse 75
*Filinia l. longiseta (Ehrbg) I 133
Monommata astia Myers 99
Trichocerca myersi (Hauer) 61
Notommata contorta (Stokes) 134
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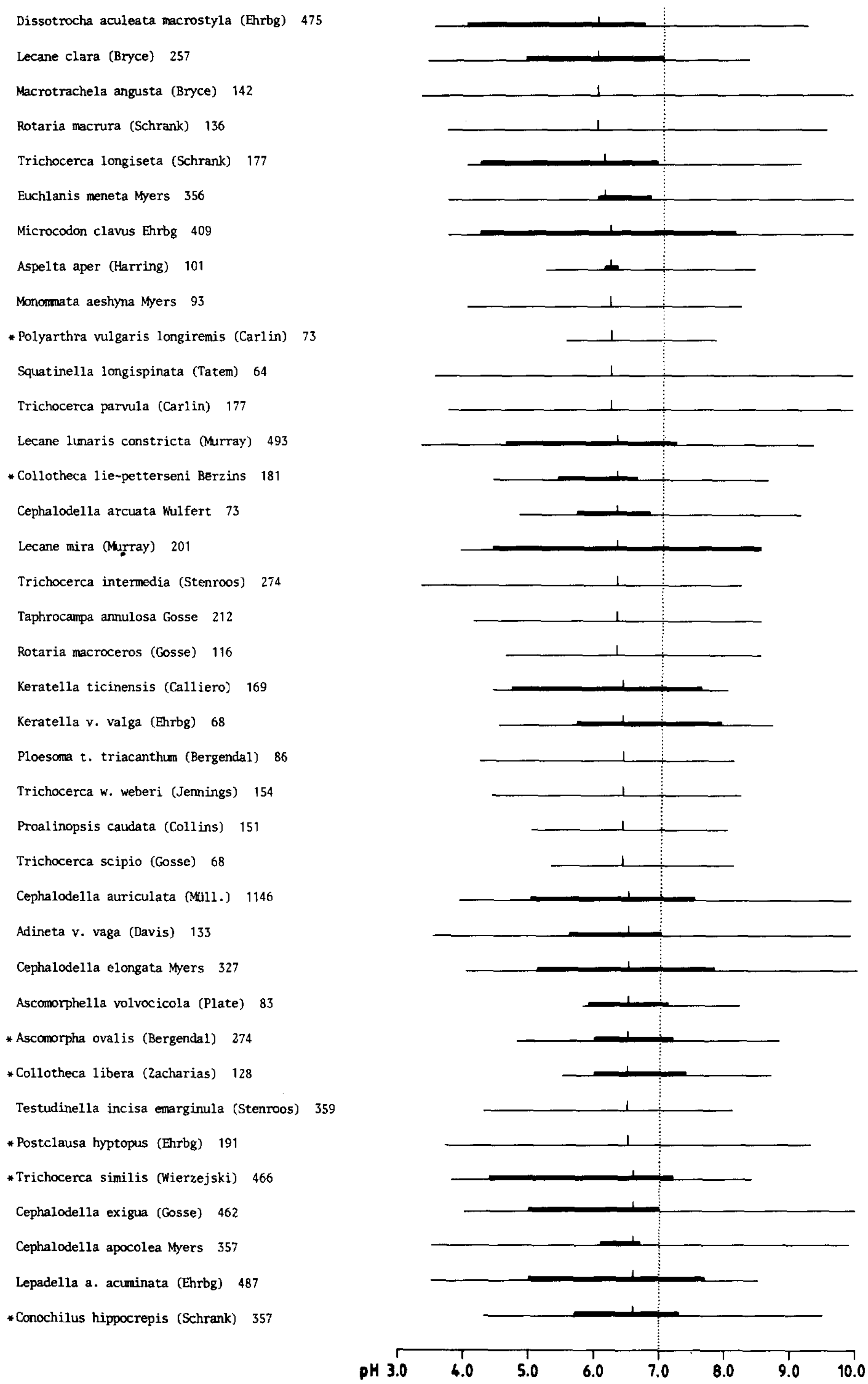
Dissotrocha aculeata macrostyla (Ehrbg) 475
Lecane clara (Bryce) 257
Macrotrachela angusta (Bryce) 142
Rotaria macrura (Schrank) 136
Trichocerca longiseta (Schrank) 177
Euchlanis meneta Myers 356
Microcodon clavus Ehrbg 409
Aspelta aper (Harring) 101
Monommata aeshyna Myers 93
*Polyarthra vulgaris longiremis (Carlin) 73
Squatinella longispinata (Tatem) 64
Trichocerca parvula (Carlin) 177
Lecane lunaris constricta (Murray) 493
*Collotheca lie-petterseni Berzins 181
Cephalodella arcuata Wulfert 73
Lecane mira (Murray) 201
Trichocerca intermedia (Stenroos) 274
Taphrocampa annulosa Gosse 212
Rotaria macroceros (Gosse) 116
Keratella ticinensis (Calliero) 169
Keratella v. valga (Ehrbg) 68
Ploesoma t. triacanthum (Bergendal) 86
Trichocerca w. weberi (Jennings) 154
Proalinopsis caudata (Collins) 151
Trichocerca scipio (Gosse) 68
Cephalodella auriculata (Müll.) 1146
Adineta v. vaga (Davis) 133
Cephalodella elongata Myers 327
Ascomorphella volvocicola (Plate) 83
*Ascomorpha ovalis (Bergendal) 274
*Collotheca libera (Zacharias) 128
Testudinella incisa emarginula (Stenroos) 359
*Postclausa hyptopus (Ehrbg) 191
*Trichocerca similis (Wierzejski) 466
Cephalodella exigua (Gosse) 462
Cephalodella apocolea Myers 357
Lepadella a. acuminata (Ehrbg) 487
*Conochilus hippocrepis (Schrank) 357
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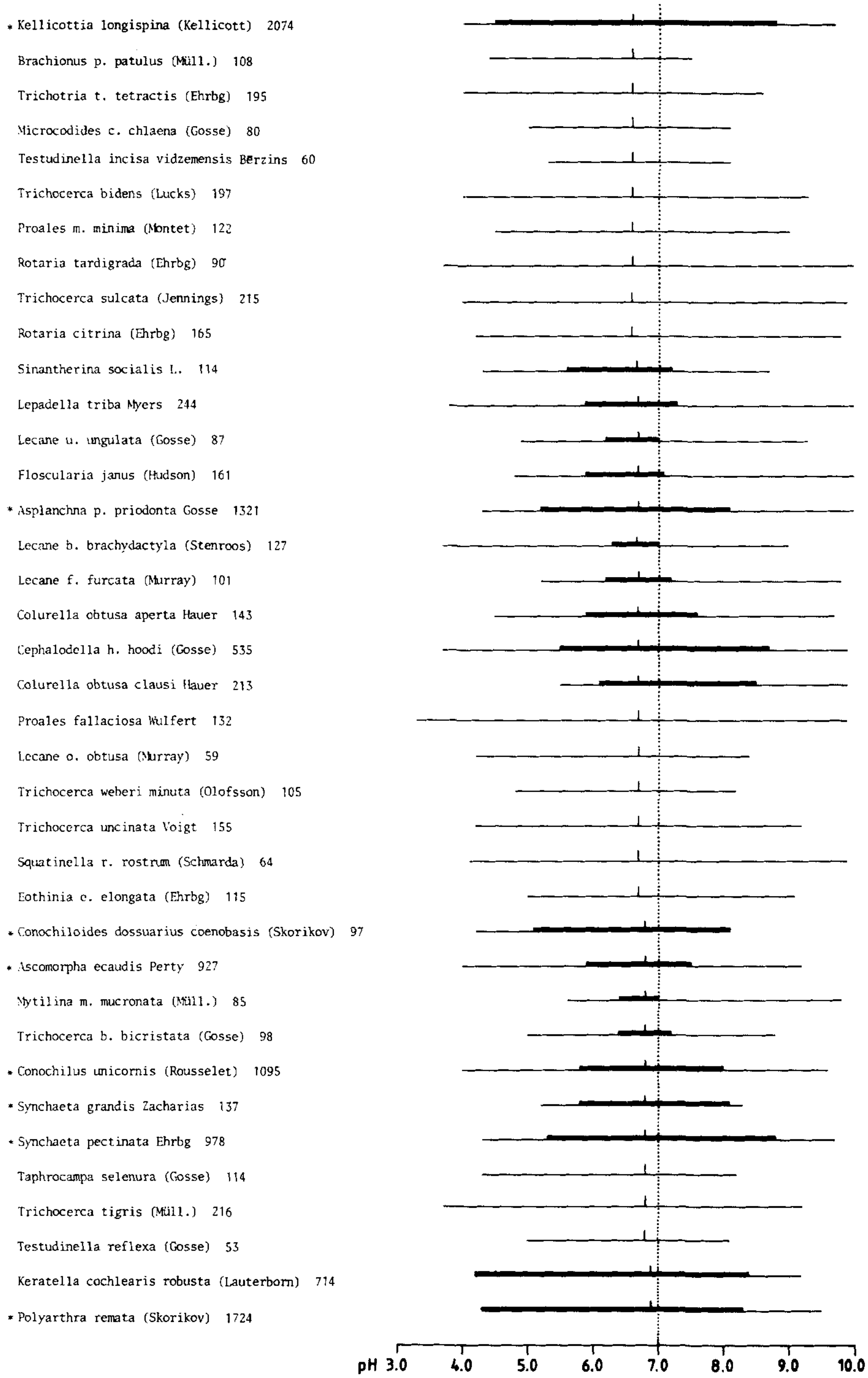
* Kellicottia longispina (Kellicott) 2074
Brachionus p. patulus (Müll.) 108
Trichotria t. tetractis (Ehrbg) 195
Microcodides c. chlaena (Gosse) 80
Testudinella incisa vidzemensis Bērzins 60
Trichocerca bidens (Lucks) 197
Proales m. minima (Montet) 122
Rotaria tardigrada (Ehrbg) 90
Trichocerca sulcata (Jennings) 215
Rotaria citrina (Ehrbg) 165
Sinantherina socialis L. 114
Lepadella triba Myers 244
Lecane u. ungulata (Gosse) 87
Floscularia janus (Hudson) 161
* Asplanchna p. priodonta Gosse 1321
Lecane b. brachydactyla (Stenroos) 127
Lecane f. furcata (Murray) 101
Colurella obtusa aperta Hauer 143
Cephalodella h. hoodi (Gosse) 535
Colurella obtusa clausi Hauer 213
Proales fallaciosa Wulfert 132
Lecane o. obtusa (Murray) 59
Trichocerca weberi minuta (Olofsson) 105
Trichocerca uncinata Voigt 155
Squatinella r. rostrum (Schmarda) 64
Eothinia e. elongata (Ehrbg) 115
* Conochiloides dossuarius coenobasis (Skorikov) 97
* Ascomorpha ecaudis Perty 927
Mytilina m. mucronata (Müll.) 85
Trichocerca b. bicristata (Gosse) 98
* Conochilus unicornis (Rousselet) 1095
* Synchaeta grandis Zacharias 137
* Synchaeta pectinata Ehrbg 978
Taphrocampa selenura (Gosse) 114
Trichocerca tigris (Müll.) 216
Testudinella reflexa (Gosse) 53
Keratella cochlearis robusta (Lauterborn) 714
* Polyarthra remata (Skorikov) 1724
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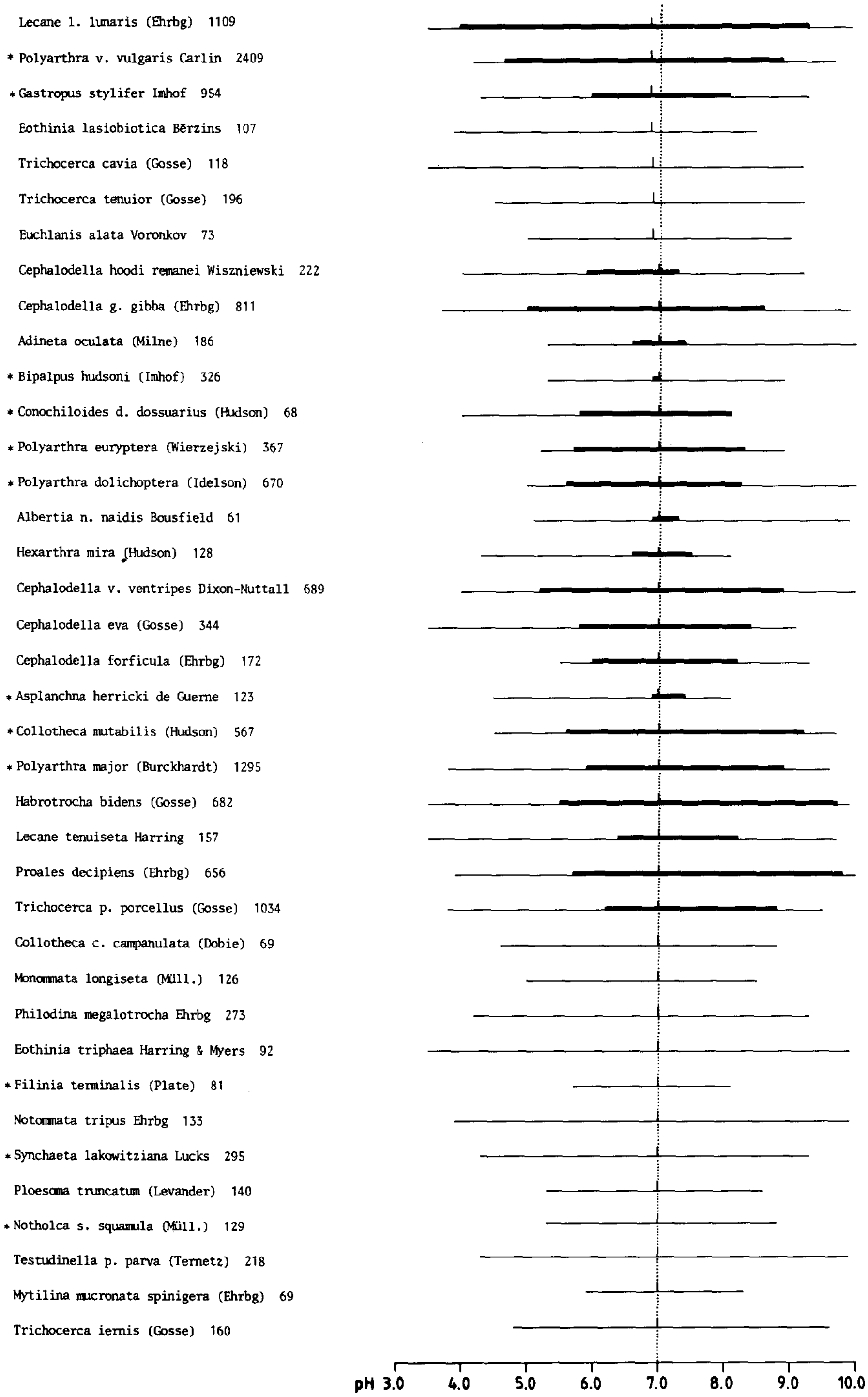
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* Polyarthra v. vulgaris Carlin 2409
* Gastropus stylifer Imhof 954
Eothinia lasiobiotica Bērzins 107
Trichocerca cavia (Gosse) 118
Trichocerca tenuior (Gosse) 196
Euchlanis alata Voronkov 73
Cephalodella hoodi remanei Wiszniewski 222
Cephalodella g. gibba (Ehrbg) 811
Adineta oculata (Milne) 186
* Bipalpus hudsoni (Imhof) 326
* Conochiloides d. dossuarius (Hudson) 68
* Polyarthra euryptera (Wierzejski) 367
* Polyarthra dolichoptera (Idelson) 670
Albertia n. naidis Bousfield 61
Hexarthra mira (Hudson) 128
Cephalodella v. ventripes Dixon-Nuttall 689
Cephalodella eva (Gosse) 344
Cephalodella forficula (Ehrbg) 172
* Asplanchna herricki de Guerne 123
* Collotheca mutabilis (Hudson) 567
* Polyarthra major (Burckhardt) 1295
Habrotrocha bidens (Gosse) 682
Lecane tenuiseta Harring 157
Proales decipiens (Ehrbg) 656
Trichocerca p. porcellus (Gosse) 1034
Collotheca c. campanulata (Dobie) 69
Monommata longiseta (Müll.) 126
Philodina megalotrocha Ehrbg 273
Eothinia triphaea Harring & Myers 92
* Filinia terminalis (Plate) 81
Notommata tripus Ehrbg 133
* Synchaeta lakowitziana Lucks 295
Ploesoma truncatum (Levander) 140
* Notholca s. squamula (Müll.) 129
Testudinella p. parva (Ternetz) 218
Mytilina mucronata spinigera (Ehrbg) 69
Trichocerca iernis (Gosse) 160
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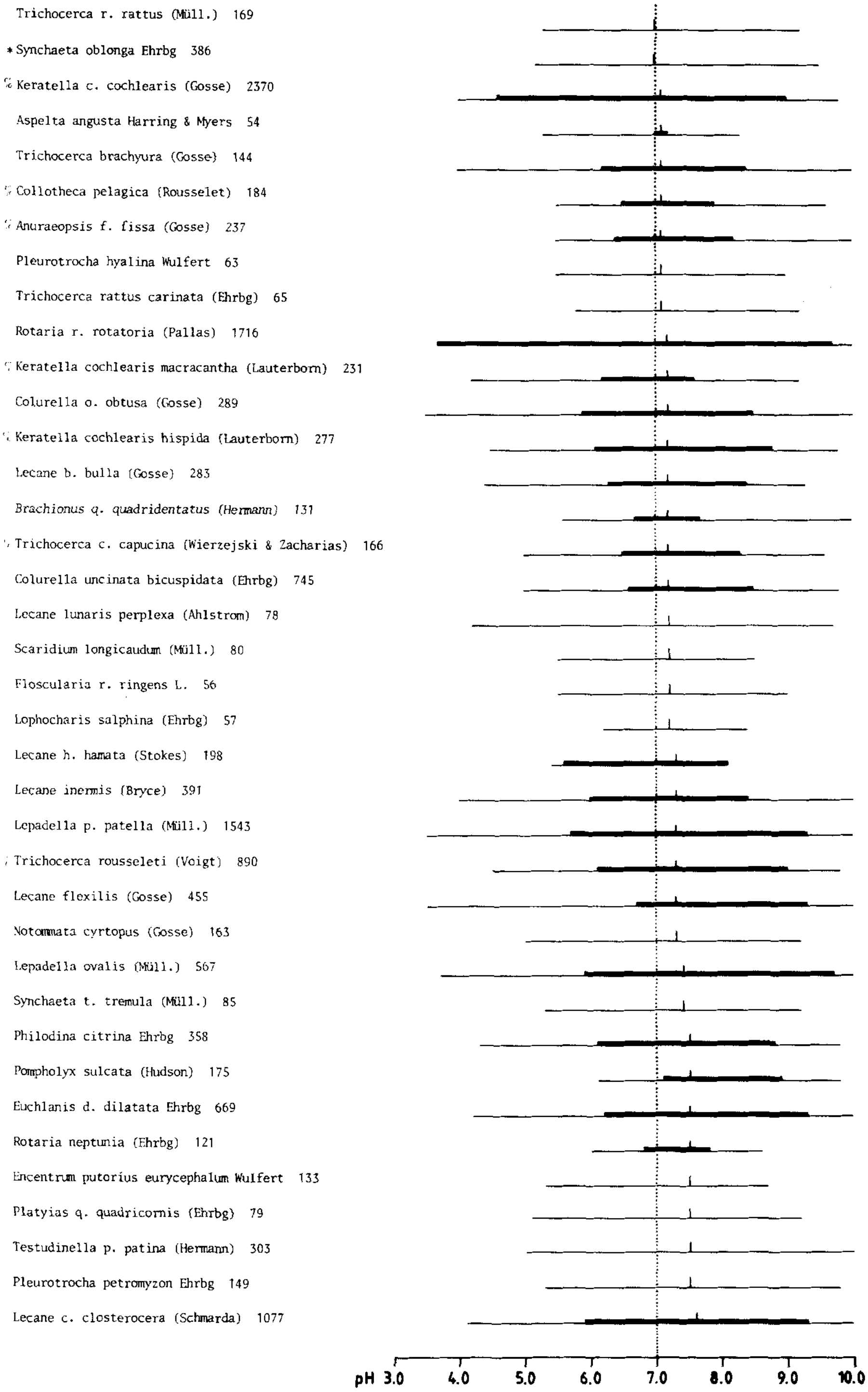
Trichocerca r. rattus (Müll.) 169
* Synchaeta oblonga Ehrbg 386
Keratella c. cochlearis (Gosse) 2370
Aspelta angusta Harring & Myers 54
Trichocerca brachyura (Gosse) 144
Collotheca pelagica (Rousselet) 184
Anuraeopsis f. fissa (Gosse) 237
Pleurotrocha hyalina Wulfert 63
Trichocerca rattus carinata (Ehrbg) 65
Rotaria r. rotatoria (Pallas) 1716
Keratella cochlearis macracantha (Lauterborn) 231
Colurella o. obtusa (Gosse) 289
Keratella cochlearis hispida (Lauterborn) 277
Lecane b. bulla (Gosse) 283
Brachionus q. quadridentatus (Hermann) 131
Trichocerca c. capucina (Wierzejski & Zacharias) 166
Colurella uncinata bicuspidata (Ehrbg) 745
Lecane lunaris perplexa (Ahlstrom) 78
Scaridium longicaudum (Müll.) 80
Floscularia r. ringens L. 56
Lophocharis salphina (Ehrbg) 57
Lecane h. hamata (Stokes) 198
Lecane inermis (Bryce) 391
Lepadella p. patella (Müll.) 1543
Trichocerca rousseleti (Voigt) 890
Lecane flexilis (Gosse) 455
Notommata cyrtopus (Gosse) 163
Lepadella ovalis (Müll.) 567
Synchaeta t. tremula (Müll.) 85
Philodina citrina Ehrbg 358
Pompholyx sulcata (Hudson) 175
Euchlanis d. dilatata Ehrbg 669
Rotaria neptunia (Ehrbg) 121
Encentrum putorius eurycephalum Wulfert 133
Platyias q. quadricornis (Ehrbg) 79
Testudinella p. patina (Hermann) 303
Pleurotrocha petromyzon Ehrbg 149
Lecane c. closterocera (Schmarda) 1077
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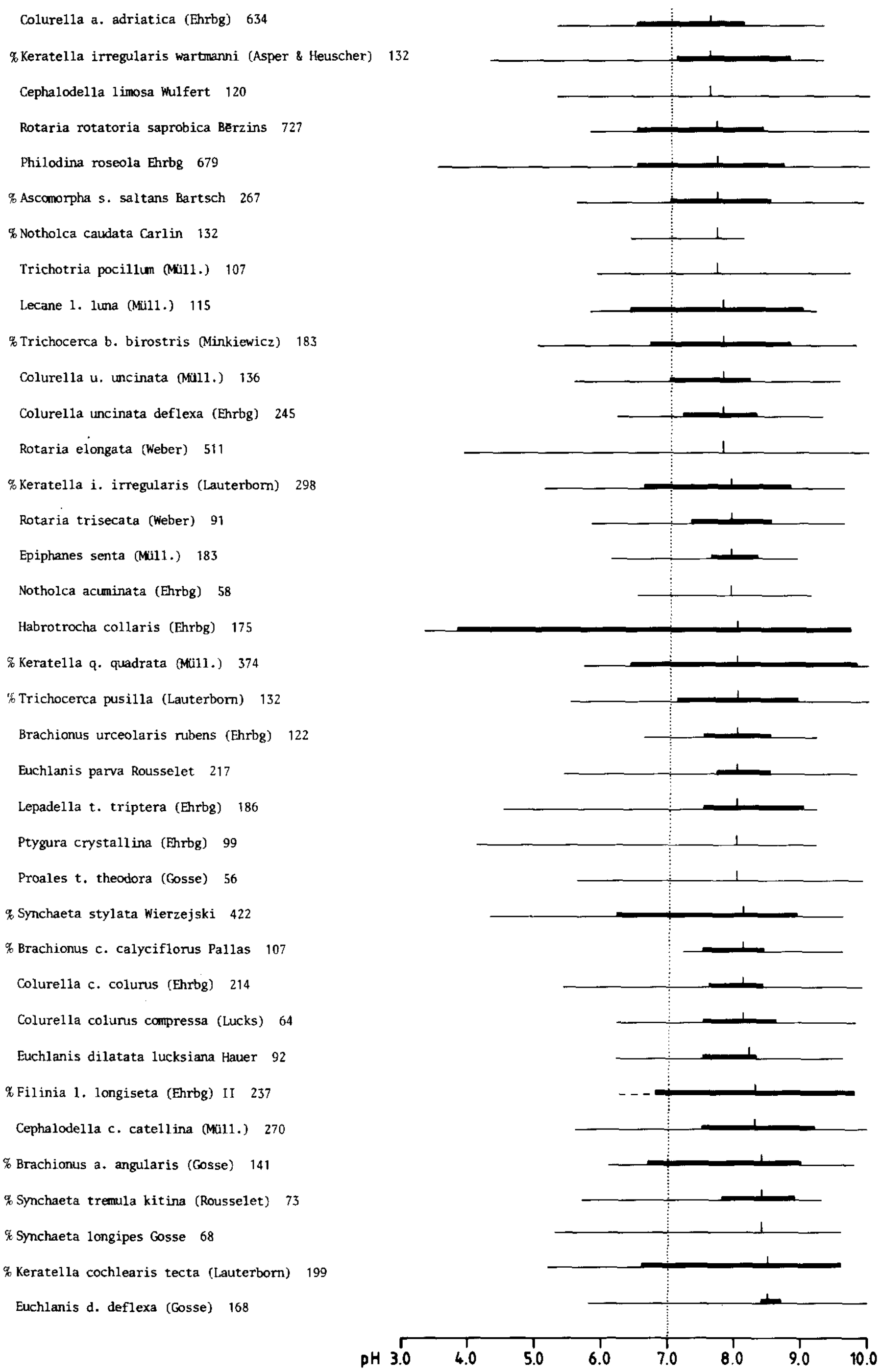

Fig. 1. Occurrence of rotifers in relation to pH in Swedish waters. The range (horizontal thin lines), high abundance (horizontal thick lines) and maximum abundance (vertical lines) of 227 rotifers are given. Species are ranked according to pH preference, beginning with those having their peak abundance at pH < 6.0 (a) through those having their peak abundance at pH ≥ 7.6 (f). Numbers refer to the number of samples in which each species was observed. Planktonic species whose peak abundance occurs at pH ≤ 7.0 (*) and pH > 7.0 (%) are indicated. *Filinia longiseta* showed a bi-modal pH tolerance and is recorded twice.

even the 'next-most alkaline' of all rotifer species included: pH ca. 8.5 at peak abundance in this study (Fig. 1f). However, the fairly wide scattering of the trophic indicators along the pH scale shows that there is no absolute link between pH and trophic status.

A comparison should be made with the recent results concerning acidified Scandinavian lakes [Hobaek & Raddum, 1980; Hörnström & Ekström, 1983; Morling, 1984]. These workers showed that the planktonic rotifers dominating these lakes were common species with their peak abundance at ≤pH 7.0. These species included: *Keratella cochlearis, Kellicottia longispina, Trichocerca capucina, Gastropus stylifer, Ascomorpha ecaudis, Asplanchna priodonta, Polyarthra vulgaris, Polyarthra remata, Conochilus unicornis, Conochilus hippocrepis* and the cold stenothermal *Keratella hiemalis*. The only 'specialist' of acid water reported is *Keratella serrulata*.

Stenothermal forms are fairly well dispersed along the pH-scale [Carlin, 1943; Pejler, 1957b; May, 1983]. Cold-water forms may achieve their peak abundance at various levels (e.g., *Keratella hiemalis*, pH 5.8; *Collotheca lie-petterseni*, 6.3; *Polyarthra dolichoptera, Filinia terminalis, Synchaeta lakowitziana, Synchaeta oblonga*, and *Notholca squamula*, 7.0; *Notholca caudata*, 7.7). The pattern is similar for warm-stenothermal forms (e.g., *Collotheca libera*, 6.5; *Polyarthra remata*, 6.9; *Polyarthra euryptera*, 7.0; *Pompholyx sulcata*, 7.5; *Trichocerca birostris*, 7.8; *Trichocerca pusilla*, 8.0; *Synchaeta stylata*, 8.1; *Keratella cochlearis tecta*, 8.5). Though peak abundance of warm-water forms tends to occur at higher pH values than cold-stenothermal forms, there is no good evidence suggesting a positive correlation between pH of peak abundance and temperature.

Conclusions

As a group, rotifers exhibit a very wide range of pH tolerance. All 227 species in this study were found in waters with pH values spanning at least 2.0 units, and several were found in waters which differed by as much as 5.0 units. A few species even exhibited high abundance over an extremely broad pH range, e.g., *Rotatoria rotatoria* and *Habrotrocha collaris* (Fig. 1e, f). Pejler [1957a, 1977] has suggested that bdelloids have the potential for such extensive ranges because their mode of reproduction (obligatory parthenogenesis) favors development of strains uniquely adapted to a particular environment. Ruttner-Kolisko [1983] suggested that a similar situation may exist for many monogonont rotifers. Clearly further research is needed here.

At present we have not determined any correlation between peak rotifer abundance, pH, and other chemical factors. We intend to return to this problem in future papers.

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