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Chironomid communities as water quality indicators

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Recent mathematical indices summarizing biological communities of indicators are recapitulated. Improvements of these indices based on weighting according to width of trophic ranges of each species are suggested. Their principle deficiencies, however, are pointed out.
Revised lists of characteristic profundal as well as littoral and sublittoral chironomids in Nearctic and Palearctic lakes show that at least 15 characteristic chironomid species communities can be delineated, 6 in each of the oligotrophic and the eutrophic ranges and 3 in the mesotrophic range. It is proposed that these communities be lettered consecutively in the Greek alphabet from α (alpha) to ο (omikron). A key to the 15 divisions based on the species associations in the profundal zone of harmonic lakes is put forward. There is very good correlation between the 15 divisions and the ratios of average total phosphorus to mean lake depth and average chlorophyll a to mean lake depth.
The ratio of chironomids to oligochaetes and the distribution patterns of single species have proven useful in pin-pointing localized areas of pollution. The primary mechanism governing the distribution of chironomid communities in oligotrophic and mesotrophic lakes appears to be the availability of food materials rather than the annual hypolimnetic oxygen concentration. In eutrophic lakes the relationships between organic matter accumulation and oxygen levels are so interdependent as to be inseparable.

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Introduction

The classification of water bodies seeks to identify the main types of individual, manifold and highly complex biotopes and to characterize these on a causal basis. Since many problems in limnology are directly or indirectly connected in this way these classifications can be regarded as catalysts joining and comparing different branches of limnology which, hopefully, will lead to a better definition of problems and shed some light on the problems of the different biotopes.

While the trophic classification scheme in principle is a measure of the intensity of the production and has historically centered on the characterization of lakes, the saprobic system is a measure of the intensity of the decomposition of organic material and has historically centered on running waters. In both systems the analysis of the benthic fauna, the chironomids and the oligochaetes in particular, has played a dominant role. The benthos are exposed to variations in their environment both in the nutrient cycle and in the oxygen level. As a result of generally long lifecycles, the consequences both of continuing and of occasional disturbances are integrated in the distribution and occurrence of the benthos. Thus the benthos can give information impossible to obtain by merely chemical factors.

Summaries of the history of trophic lake type systems and of the saprobic system are given by Brundin (1945), Elster (1958, 1962, 1966) and Brinkhurst (1974), and a complete recapitulation should thus not be necessary. It should, however, be remembered that Thienemann's investigations in the Eifel area of Germany and Naumann's in the Swedish lakes of Småland represented the beginning stages not only of the trophic lake type system, but of limnology as a modern science. Thienemann's scheme was to a large extent based on the dominant chironomid communities as were later

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schemes proposed by Lundbeck, Lenz and others. Lundbeck was the first to realize that the dystrophic lake was fundamentally oligotrophic and that lakes as a consequence had to be arranged in a two-dimensional system. Lenz contributed much to research on immature chironomids and to lake typology, but his theory about all species of a genus being ecological equivalents contributed to the downgrading of the use of chironomids as indicators. This misconception was not corrected until Brundin (1949) showed the lakes could be characterized by their profundal species communities.

In recent years mathematical indices have attracted attention because they appear to offer quasi-objective means of summarizing biological data in relation to pollution and eutrophication. Some of these indices are directly connected with the use of benthic indicator communities. The Saprobic Index was proposed by Pantle and Buck (1955). It employs the formula:

$$S = \frac{\Sigma\, s \cdot h}{\Sigma\, h};$$

where s ranges from 1–4 for oligo- to polysaprobic, and h is an occurrence value with 1 for occasional, 3 for common and 5 for mass occurrence. Dittmar (1959), Zelinka and Marvan (1961) and Sládeček (1964,1969) expanded on this index.

Hamilton in Brinkhurst et al. (1968) proposed the Trophic Condition Index as follows:

$$TCI = \frac{\Sigma\, N_1 + 2\, \Sigma\, N_2}{\Sigma\, N_0 + \Sigma\, N_1 + \Sigma\, N_2};$$

where N_0 is the number of tolerant organisms, N_1 the number of facultative organisms and N_2 the number of tolerant organisms.

Chutter (1972) proposed the Empirical Biotic Index as follows:

$$EBI = \frac{\Sigma\, a \cdot b}{N};$$

where a is the number in the i:th taxon, b the quality value (1–10) of i:th taxon, and N the total number of individuals.

The Benthic Quality Index was proposed by Wiederholm (1976b)[1] in which

$$BQI = \sum_{i=5}^{0} \frac{n_i}{N} (k_i - 1 + C_i);$$

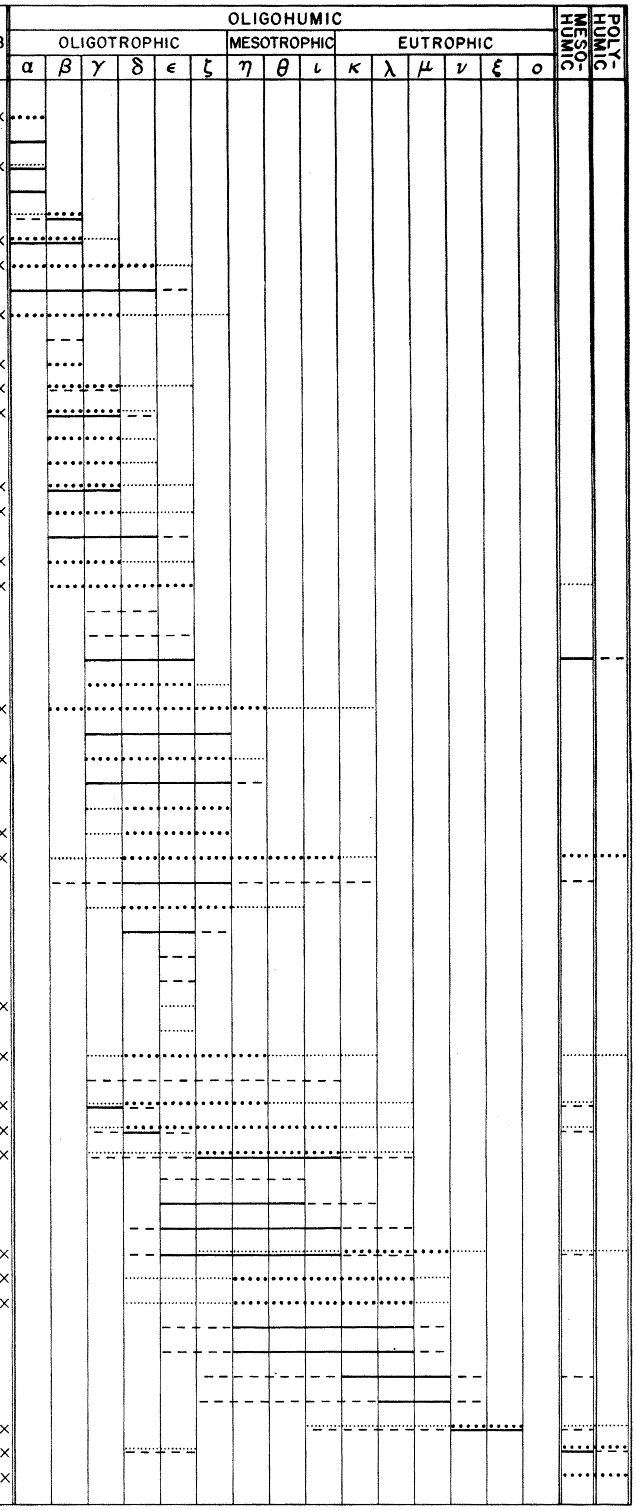
where k_i varies between 5 for the *Heterotrissocladius subpilosus* (Kieff.) association, to 1 for the *Chironomus plumosus* L. association, and 0 when none of the indicators are present; n_i is the number of individuals within the respective groups, C_i is the constancy of the respective groups within a sample, and N is the total number of members of indicator communities within a sample. Wiederholm (1976b, Fig. 3) found a good correlation between the BQI and the ratio of average total phosphorus to mean depth of a lake. Ahl and Wiederholm (1977, Fig. 6.17) also showed that nearly equally good correlations could be found when BQI was used for oligochaete associations. They demonstrated that even if the quantities of the benthos not directly correspond with the trophic state of a lake there was a good correlation between chlorophyll a and the densities of the benthos when the latter are corrected by the depths at the sampling site (Ahl and Wiederholm 1977, Fig. 6.13).

The indices mentioned ascribe equal value to eurytopic organisms typical of eutrophic waters, and to stenotopic organisms typical of oligotrophic waters. The results thus may be erroneous since stenotopic organisms restricted to one trophic level should receive higher weight than organisms with a wide trophic range and capable of living in more than one particular level. However, a weighting can be incorporated in all the indices, for instance, by following the method of Zelinka and Marvan (1961) as corrected by Sládeček (1964). This weighting assigns the value 5 for species which occurs 9 or 10 times out of 10 in one of the 5 main divisions of the saprobic scale; value 4 for species occurring either in two divisions with 8 or 7 in one or in three divisions with 8 in one; value 3 when the occurrence is 6:4 or 5:5 in two divisions or 6–7 times in one of three divisions; value 2 when it is 4–5 in one of three, or 6–7 in one of four divisions; and value 1 when the occurrence is 5 or less in one of four divisions or when the species occur in all five levels. By dividing each of the oligotrophic and eutrophic lake types into two, the trophic scale also would have five levels. Following the list given by Sæther (1975: Tab. 1) *Pseudodiamesa nivosa* Goetgh. and *P. arctica* (Mall.) would for instance receive a weight of 5, *Micropsectra groenlandica* And. a weight of 4, *Monodiamesa tuberculata* Sæth. 3, *Stictochironomus rosenschoeldi* Zett. and *Chironomus plumosus* L. 2, and *Chironomus antracinus* Zett. in Palaearctic lakes and *C. decorus* Joh. in Nearctic Lakes a weight of 1. The weight could be attached to 'a' in Chutter's index or to 'n_i' in Wiederholm's index.

In principle, however, simple or complicated mathematical computations of the trophic or saprobic levels are wrong (see Elster 1966). The different members of indicator communities have very different properties of indication and all biotopes are a mosaic of different habitats. The restriction of one form to one particular trophic or saprobic level may depend on factors completely different from those restricting another form to the same level. The occurrence of particular forms on a particular spot gives the freshwater biologist an idea about the metabolism and the total character of the water body. To base the trophic level on one single quantifiable parameter such as, for instance, primary production, does not give the total character of the lake.

1. The formula in Wiederholm (1976b: 10) contains one superfluos k_i (T. Wiederholm, pers. comm.).

SPECIES	A	B
Pseudodiamesa nivosa Goetgh.	×	×
Pseudodiamesa arctica (Mall.)		
Oliveria tricornis (Ol.)		×
Lauterbornia sedna (Ol.)		
Paracladius quadrinodosus Hirv.		
Protanypus caudatus (Edw.)		×
Heterotrissocladius subpilosus (Kieff.)		×
Heterotrissocladius oliveri Sæth.		
Monodiamesa ekmani Brund.		×
Protanypus saetheri Wied.		
Tanytarsus palmeni Lind.		×
Lauterbornia coracina Kieff.	×	×
Paracladius alpicola (Zett.)	×	×
Monodiamesa alpicola Brund.	×	
Protanypus forcipatus Egg.	×	
Micropsectra groenlandica And.	×	×
Heterotrissocladius maeaeri Brund.		×
Protanypus hamiltoni Sæth.		
Micropsectra lindebergi Säw.		×
Tanytarsus lugens Kieff.	×	×
Heterotrissocladius sp. *A* near *subpilosus*		
Heterotrissocladius sp. *B* near *maeaeri*		
Protanypus ramosus Sæth.		
Micropsectra contracta Reiss	×	
Micropsectra insignilobus Kieff.		×
Paracladopelma galaptera (Town.)		
Paracladopelma nigritula (Goetgh.)	×	×
Monodiamesa tuberculata Sæth.		
Macropelopia fehlmanni (Kieff.)	×	
Tanytarsus bathophilus Kieff.	×	×
Protanypus morio Zett.	×	×
Heterotrissocladius changi Sæth.		
Heterotrissocladius scutellatus Goetgh.	×	
Heterotrissocladius sp. *D* near *changi*		
Protanypus sp. *A* near *morio*		
Protanypus sp. *B* near *morio*		
Tanytarsus decipiens Lind.		×
Monodiamesa nitida (Kieff.)	×	
Heterotrissocladius grimshawi Edw.		×
Monodiamesa sp. poss. *prolilobata* Sæth.		
Monodiamesa bathyphila (Kieff.)	×	×
Stictochironomus rosenschoeldi (Zett.)	×	×
Phaenopsectra coracina (Zett.)	×	×
Tanytarsus n. sp. *lestagei* - aggl.		
Monodiamesa depectinata Sæth.		
Chironomus atritibia Mall.		
Chironomus anthracinus Zett.	×	×
Tanytarsus inaequalis Goetgh.	×	×
Tanytarsus gregarius Kieff.	×	×
Chironomus plumosus f. *semireductus*		
Cryptotendipes casuarius (Town.)		
Chironomus decorus Joh.		
Cryptotendipes darbyi (Subl.)		
Chironomus plumosus L.	×	×
Zalutschia zalutschicola Lip.		×
Chironomus tenuistylus Brund.		×



Tab. 1. Characteristic profundal chironomids in Nearctic (————————) and Palaearctic (... ●●●●●●● ...) lakes. Fully drawn lines and filled circles: Distribution under good to excellent conditions. Broken lines and dots: Maximum range or single findings. A: In Europe, alpine. B: In Europe, boreal.

SPECIES	A	B	OLIGOHUMIC: OLIGOTROPHIC α	β	γ	δ	ε	ζ	MESOTROPHIC η	θ	ι	EUTROPHIC κ	λ	μ	ν	ξ	ο	MESO-HUMIC	POLY-HUMIC
Heterotrissocladius subpilosus (Kieff.)		×																	
Heterotrissocladius oliveri Sæth.																			
Hydrobaenus fusistylus (Goetgh.)																			
Zalutschia trigonacies Sæth.																			
Abiskomyia virgo Edw.		×																	
Oeklandia borealis Kieff.																			
Orthocladius (O.) trigonolabis Edw.		×																	
Orthocladius (P.) consobrinus Holmgr.	×	×																	
Heterotrissocladius maeaeri Brund.		×																	
Oliveria tricornis (Ol.)		×																	
Lauterbornia sedna Ol.																			
Hydrobaenus martini Sæth.		×																	
Hydrobaenus conformis conformis (Holmgr.)		×																	
Hydrobaenus conformis labradorensis Sæth.																			
Monodiamesa ekmani Brund.		×																	
Paracladius quadrinodosus Hirv.		×																	
Zalutschia tornetraeskensis (Edw.)		×																	
Tanytarsus lugens Kieff.	×	×																	
Paratanytarsus hyperboreus Brund.		×																	
Tanytarsus niger And.		×																	
Paracladius alpicola (Zett.)	×	×																	
Paracladopelma nigritula (Goetgh.)	×	×																	
Stictochironomus rosenschoeldi (Zett.)	×	×																	
Micropsectra groenlandica And.	×	×																	
Arctopelopia barbitarsis (Zett.)	×	×																	
Micropsectra lindebergi Säw.		×																	
Thienemannimyia fusciceps (Edw.)		×																	
Mesocricotopus thienemanni (Goetgh.)		×																	
Lauterbornia coracina Kieff.	×	×																	
Micropsectra insignilobus Kieff.		×																	
Heterotrissocladius marcidus (Walk.)	×	×																	
Paracladopelma galaptera (Town.)																			
Zalutschia obsepta (Webb)																			
Heterotrissocladius hirtapex Sæth.																			
Micropsectra contracta Reiss	×																		
Heterotanytarsus perennis Sæth.																			
Heterotanytarsus nudalus Sæth.																			
Nanocladius (N.) rectinervis (Kieff.)	×	×																	
Paracladopelma nais (Town.)																			
Stempellina bausei (Kieff.)	×	×																	
Zalutschia zalutschicola Lip.		×																	
Nanocladius (N.) incomptus Sæth.																			
Nanocladius (N.) minimus Sæth.																			
Protanypus morio (Zett.)	×	×																	
Phaenopsectra coracina (Zett.)	×	×																	
Paratanytarsus natvigi (Goetgh.)		×																	
Heterotanytarsus apicalis (Kieff.)	×	×																	
Paratanytarsus penicillatus Goetgh.		×																	
Stempellina n. sp. near *almi* Brund.																			
Nanocladius (N.) anderseni Sæth.																			

Tab. 2. Characteristic sublittoral and littoral chironomids of habitats in Nearctic and Palearctic lakes. (For explanation see Tab. 1).

When doing an evaluation the biologist has to use his collected knowledge of normal and changed conditions of each type of water in order to arrive at a total estimation. Mathematical calculations, however, may be of help in this evaluation. However, if a list of members of indicator communities was both general enough to cover most harmonic lakes and graded into enough compartments, the need for an index would partly disappear.

The proposed classification system refinement

When studying the list of characteristic chironomids in Nearctic and Palaearctic lakes of different trophic levels

TABLE 2 continued

SPECIES	A	B	OLIGOHUMIC: OLIGOTROPHIC α	β	γ	δ	ϵ	ζ	MESOTROPHIC η	θ	ι	EUTROPHIC κ	λ	μ	ν	ξ	ο	MESO-HUMIC	POLY-HUMIC
Paracladopelma winnelli Jacks.																			
Paracladopelma undine (Town.)																			
Stempellinella minor (Edw.)	×	×																	
Stempellinella brevis Edw.	×	×																	
Pagastiella orophila (Edw.)	×	×																	
Pagastiella ostansa (Webb)																			
Nanocladius (N.) distinctus (Mall.)																			
Cladopelma edwardsi (Krus.)	×	×																	
Zalutschia lingulata Sæth.																			
Saetheria tylus (Town.)																			
Heterotrissocladius latilaminus Sæth.																			
Pseudochironomus rex Haub.																			
Phaenopsectra albescens (Town.)	×	×																	
Psectrocladius (P.) psilopterus Kieff.	×	×																	
Monopelopia tenuicalcar (Kieff.)	×	×																	
Cladopelma viridula (Fabr.)	×	×																	
Nanocladius (N.) bicolor (Zett.)	×	×																	
Robackia demeijerei (Krus.)	×	×																	
Cryptotendipes casuarius (Town.)																			
Monodiamesa depectinata Sæth.																			
Pseudochironomus fulviventris (Joh.)																			
Psectrocladius (P.) simulans (Joh.)																			
Chironomus plumosus f. *semireductus*		×																	
Pseudochironomus pseudoviridis (Mall.)																			
Nanocladius (N.) balticus (Palm.)	×	×																	
Chironomus anthracinus Zett.	×	×																	
Harnischia curtilamellata (Mall.)	×	×																	
Stictochironomus histrio (Fabr.)	×	×																	
Demicryptochironomus vulneratus (Zett.)	×	×																	
Cryptotendipes darbyi (Subl.)																			
Chironomus decorus (Joh.)																			
Dicrotendipes nervosus (Staeg.)	×	×																	
Endochironomus subtendens (Town.)																			
Endochironomus nigricans (Joh.)																			
Endochironomus albipennis (Meig.)	×	×																	
Cricotopus (I.) sylvestris (Fabr.)	×	×																	
Chironomus plumosus L.	×	×																	
Glyptotendipes (P.) paripes Edw.	×	×																	
Polypedilum (Po.) nubeculosum (Meig.)	×	×																	
Cladotanytarsus wexionensis Brund.	×	×																	
Cladotanytarsus near *wexionensis*																			
Tanytarsus usmaensis Pag.	×	×																	
Einfeldia synchrona (Ol.)																			
Einfeldia dissidens (Walk.)	×	×																	
Chironomus (Ca.) tentans Fabr.	×	×																	
Tanypus punctipennis (Meig.)	×	×																	
Labrundinia longipalpis (Goetgh.)		×																	
Psectrocladius (A.) platypes Edw.	×	×																	
Zalutschia mucronata (Brund.)		×																	

given by Sæther (1975) it will be obvious that a much finer division is possible. Accordingly I have in the revised lists (Tabs 1, 2) delineated 15 characteristic chironomid species communities, 6 in each of the oligotrophic and the eutrophic ranges and 3 in the mesotrophic range. These communities are lettered consecutively in the Greek alphabet from α to o following a preliminary scheme proposed by Dr W. F. Warwick, Freshwater Institute, Winnipeg. The Greek alphabet is used in order to emphasize that these 15 subdivisions not are to be regarded as trophic level divisions, but merely as enumerations of recognizable chironomid communities. These communities may at this point be broadly or narrowly defined relatively to the general trophic gliding scale, but as seen from their relationship to chlorophyll a and phosphorus mentioned below, they appear to be of a remarkable even "trophic breadth". Which of these chironomid species communities a particular lake or part of a lake will have can be decided by comparing the chironomid fauna of the lakes with the revised lists, or the associations can be determined by using the below key.

Key to chironomid associations of the profundal zones of Palaearctic and Nearctic lakes

In the key "absent" means less than 1% as accidental occurrence may take place, "present" means more than 1%. The limit of 2% is regarded as the level above which the species can be regarded as a persistant non-accidental member of the community, while the 5% limit is a level above which the species can be said to be a common member of the community. These limits should of course not be regarded rigidly if the samples are few.

1. *Pseudodiamesa* and/or *Oliveria tricornis* present .... α-oligotrophic
   The above absent 2
2. *Heterotrissocladius, Protanypus, Micropsectra* or *Paracladopelma* present and making up at least 2% of the profundal chironomids ...... oligo- mesotrophic lakes 3
   The above absent or making up less than 2% of the profundal chironomids .... eutrophic lakes 10
3. *Heterotrissocladius subpilosus* – group present, tribe Chironomini absent from the true profundal zone .... β-oligotrophic
   H. subpilosus group present or absent, tribe Chironomini present 4
4. *Heterotrissocladius subpilosus* group, *Protanypus caudatus* group, *Micropsectra groenlandica* or *Paracladius* spp. present and making up more than 5% of the profundal chironomids 5
   The above absent or making up less than 5% of the profundal chironomids 7
5. *Protanypus caudatus* group or *Paracladius* usually present, *Chironomus* absent, *Phaenopsectra* (including *Sergentia*) and *Stictochironomus* at most present in very low numbers (<2%) .... γ-oligotrophic.
   When *Protanypus caudatus* group or *Paracladius* present *Chironomus, Phaenopsectra* or *Stictochironomus* present in low numbers (>2%) 6
6. *Heterotrissocladius subpilosus* group plus *H. maeaeri* group more common than *H. marcidus* group; *Chironomus* making up less than 2% .... δ-oligotrophic
   Heterotrissocladius subpilosus group plus *H. maeaeri* group absent or less common than *H. marcidus* group: *Chironomus* usually makes up more than 2% .... ε-oligotrophic.
7. *Heterotrissocladius, Paracladopelma nigritula, P. galaptera Micropsectra notescens* group, *Monodiamesa tuberculata, Macropelopia fehlmanni* and/or *Tanytarsus bathophilus* common (>5%) .... ζ-oligotrophic.
   The above at most present in very low numbers 8
8. *Micropsectra* and/or *Monodiamesa* common, more or about as common as *Stictochironomus* and *Phaenopsectra*, or *Chironomus* except *salinarius* or *semireductus* types . . η-mesotrophic
   Micropsectra and/or *Monodiamesa* less common than *Stictochironomus* and *Phaenopsectra* or spp. of *Chironomus* except *salinarius* or *semireductus* types 9
9. *Monodiamesa, Protanypus, Heterotrissocladius, Stictochironomus, Phaenopsectra* or *Chironomus salinarius* and *semireductus* types more common than other *Chironomus* spp. .... θ-mesotrophic
   The above less common than other *Chironomus* .... ι-mesotrophic.
10. *Heterotrissocladius, Protanypus, Micropsectra, Paracladopelma nigritula* or *P. galaptera* present in low numbers .... $\varkappa$-eutrophic
    The above absent 11
11. No chironomids present .... o-eutrophic
    Chironomids present 12
12. Only *Chironomus plumosus* type and Tanypodinae present .... ξ-eutrophic
    Other chironomids also present 13
13. Only *Chironomus* and subfam. Tanypodinae present .... ν-eutrophic
    Other groups also present 14
14. Only tribe Chironomini, *Tanytarsus* spp. and subfam. Tanypodinae present . . . . μ-eutrophic
    Other groups also present .... λ-eutrophic

Most of the genera, species groups and species in the key are identifiable in the immature stages by means of readily available keys, while a few must, at present, be associated with their imagines for identification. However, a subdivision category can in most cases be reached without identifying these difficult forms to species. In the overseeable future a key to larvae of profundal chironomid species could easily be made.

It may appear from the key that I have returned to the old dictum of Lenz about the species of a genus (or at least a species group) being ecologically equivalent. However, this is only apparent. A reference to the *Protanypus caudatus* group for instance will in one particular lake mean only one particular species. This group consists of *P. forcipatus* from the Alps, *P. caudatus* from Northern Holarctic areas, *P. ramosus* from the Great Lakes and the Canadian Precambrian Shield and *P. hamiltoni* from west of and in the Rocky Mountains. The four species are systematical and ecological vicariants. In *Stictochironomus* and *Phaenopsectra* there

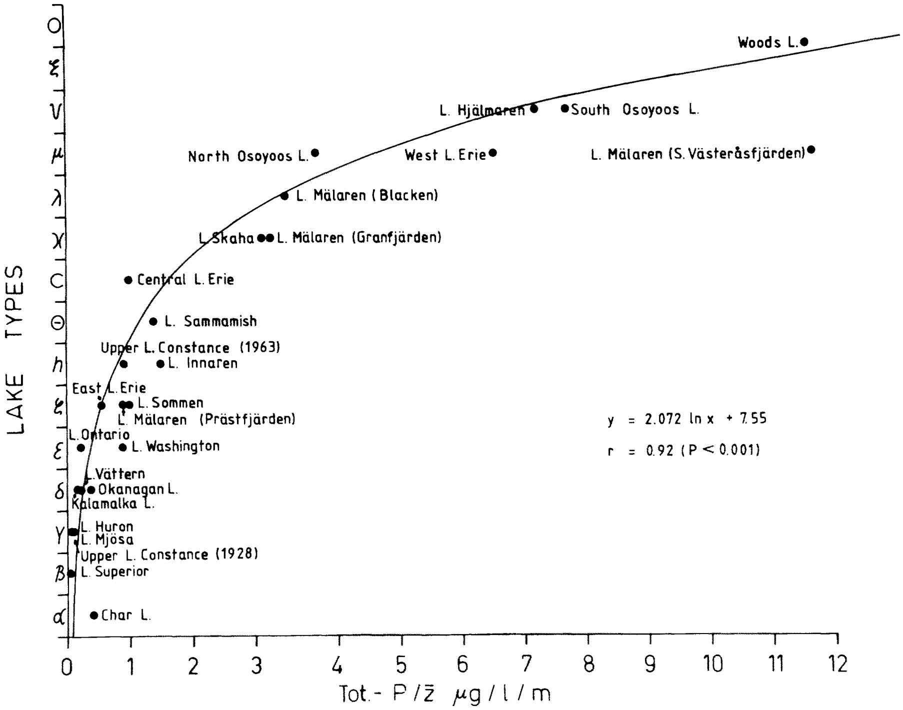


Fig. 1. Total phosphorus/mean lake depth in relation to 15 lake types based on chironomid communities ($\alpha - o$). (Lake Mjøsa will be δ-oligotrophic if the 20 m-samples are regarded as profundal. The changing Lake Washington have relatively large numbers of *C. salinarius* type indicating a slightly higher level of trophy (ζ-oligotrophy)). Data from Ahl and Wiederholm (1977), Brundin (1949), Carlson (1977), Hartmann and Nümann (1977), Lundbeck (1936), Sæther (1970), Sæther and McLean (1972), Stevenson (1974), Welch (1976), Wiederholm (1976a), and G. Kjellberg, Invest. Lake Mjøsa, Norweg. Inst. Wat. Res., Hamar, Norway (pers. comm.) and T. Wiederholm, Dept. Entomol., Uppsala, Sweden (pers. comm.).

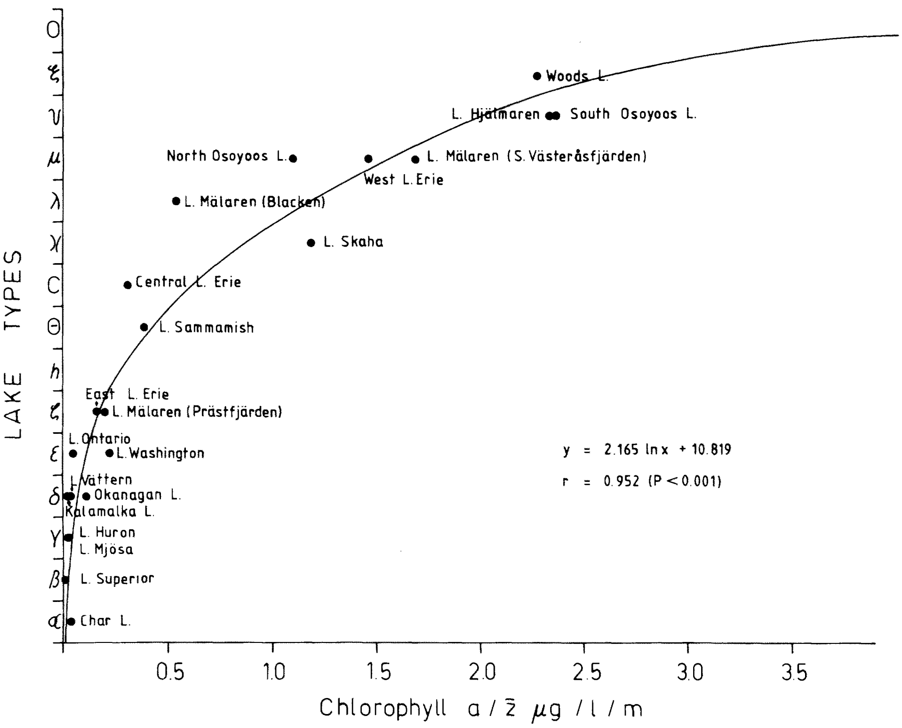


Fig. 2. Chlorophyll a/mean lake depth in relation to 15 lake types based on chironomid communities ($\alpha - o$). Data as in Fig. 1.

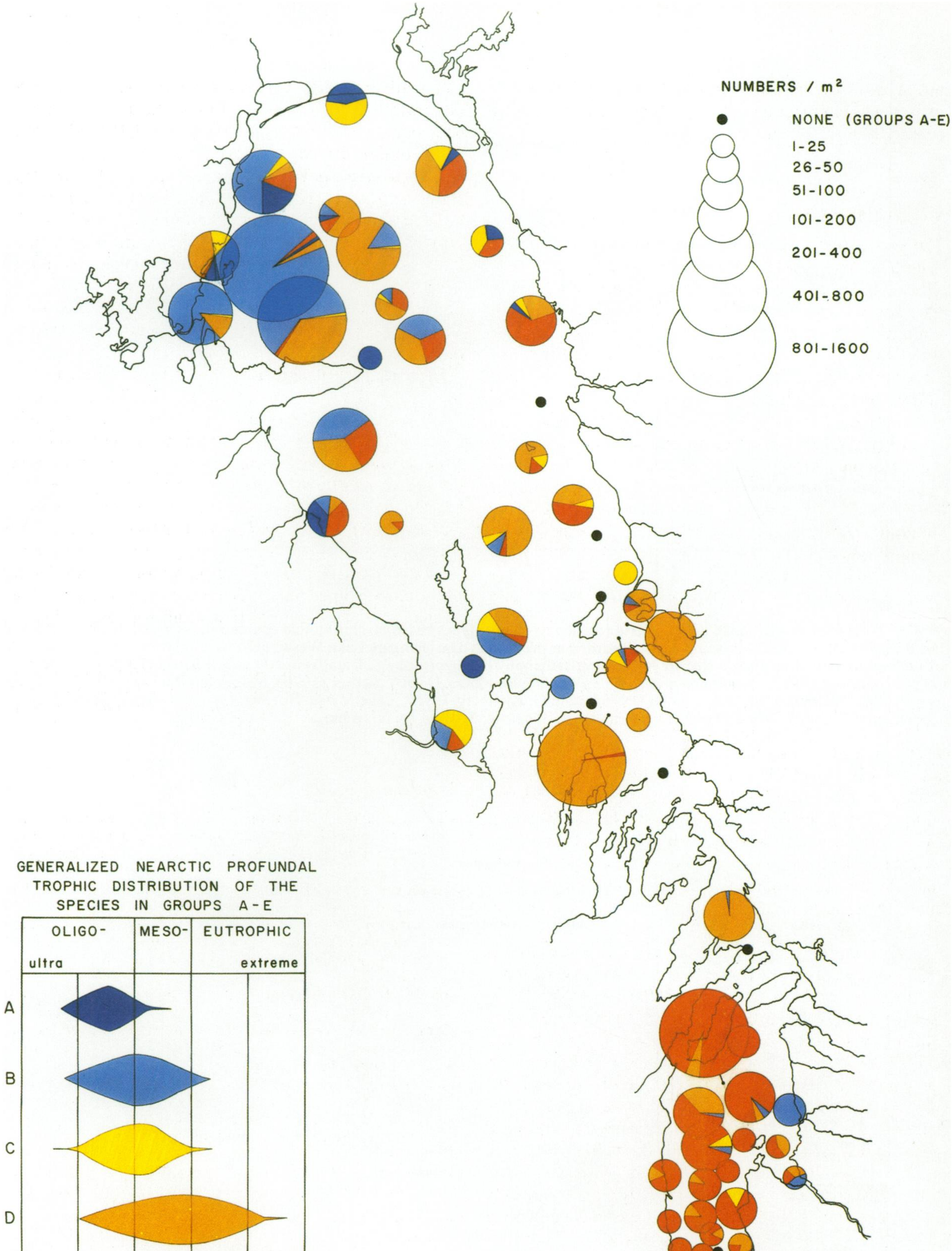


Fig. 3. Chironomid indicator communities in different areas of Lake Winnipeg, Man. A: *Monodiamesa tuberculata* Sæth., *Heterotrissocladius changi* Sæth. B: *Tanytarsus* spp., *Micropsectra* spp. C: *Monodiamesa depectinata* Sæth., *Stictochironomus rosenschoeldi* (Zett.). D: *Chironomus plumosus* f. *semireductus* Lenz. E: *Chironomus decorus* Joh.

are several species with differing trophic ranges. However, the true profundal inhabitants of these apparently occur within the same trophic levels.

General discussion

There are highly significant correlations between this system of chironomid associations and the ratios of chlorophyll a to mean depth (Fig. 2) and total phosphorous to mean depth (Fig. 1). These correlations are maintained even if very disparate lakes, methods, intensities of investigations, and reliabilities of chironomid identifications are compared in the two graphs. Accordingly the 15 divisions are shown to be well defined not only on the base of chironomid associations, but also based on trophic levels, i.e. they are valid trophic subdivisions or lakes types.

The correlations show that while it is easy to change the benthic communities from ultra-oligotrophic to moderately oligotrophic communities, it takes considerably higher shifts in primary production to change oligotrophic to mesotrophic, or mesotrophic to eutrophic communities. They also show that the deeper a lake is the larger is the primary production increase needed in order to increase the trophic level of the benthic communities. The aspects of the correlations in connection with deep lakes is discussed more closely elsewhere (Sæther 1979).

The key is, for the moment, restricted to harmonic lakes since, for instance, meso- and polyhumic lakes have not been sufficiently well investigated. Some disharmonic lakes such as Lake Winnipeg or its several faunal zones (Fig. 3) can be placed in the subdivisions. Since, however, the low mean depth and strong wind exposure characterizing this lake cause polymixis and light limitation through turbidity, a relation between total phosphorus to mean depth and the subdivision levels cannot be expected.

Chironomid indicator communities are also useful in pin-pointing localized pollution within a lake such as, for example, the Okanagan Lakes (Sæther 1970, 1979, Sæther and McLean 1972). Local disturbances, disparities or patterns often can be discerned from the distribution pattern of a single species which may not necessarily be a typical member of any indicator community. *Cladotanytarsus*-larvae, for instance, will often occur in mass where there is mild localized pollution in an otherwise oligotrophic lake (Sæther 1979: Fig. 5).

Few oligochaetes are restricted to narrow trophic ranges. This makes a similar subdivision to 15 levels nearly impossible. However, when used in concert with chironomid communities the oligochaete communities can be instructive. Furthermore, the change from a chironomid dominated to an oligochaete dominated community often is one of the first signs of eutrophication.

In Lake Winnipeg the oxygen is plentiful at all depths and in all areas. Nevertheless, different areas have quite disparate chironomid associations. Also other studies bear out the contention of Warwick (1975, 1978) and Wiederholm (1976a) that the availability of food materials is the primary mechanism governing the chironomid succession. This differs from the statement by Brundin that the annual minimum hypolimnetic oxygen concentration usually is the controlling factor. Only in lakes of advanced eutrophy, or lakes where the oxygen level for other reasons is particularly low (such as humic lakes or lakes with morphometrically dependant O_2 – deficiency), does the oxygen concentration come into effect.

The analyses of biological communities are a necessary part in the total evaluation of a lake. They may give information which not can be even approximately obtained by merely chemical methods. The different systems and lists of members of indicator communities help in this evaluation, and the occurrence of certain species in certain quantities points at normal or abnormal characteristics of that particular biotope. The precondition for further improvements of the trophic system is a better ecological and physiological knowledge of the members of the different communities as well as further work on their taxonomy and zoogeography.

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