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Indicator values, strategy types and life forms of terrestrial Enchytraeidae and other microannelids

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Abstract

The ecological behaviour of soil microannelid species, mainly Enchytraeidae, is characterized, using the system of indicator values established for plants by Ellenberg (1992), and modifying it for annelids. The species are classified with respect to pH, soil moisture, salinity, reproductive strategy, stress tolerance, and their occurrence in the continuum of humus horizons and humus forms. The values given apply to the situation in Central Europe.

Introduction

The species assemblages of soil annelids exhibit considerable site-specific differences which can be used to describe and to characterize the ecological conditions of soil sites and which are suitable for a biological soil quality assessment (BEYLICH et al. 1995, DIDDEN et al. 1997, GRAEFE 1997). The site-specific differences of species assemblages reflect the peculiar and unique ecological behaviour of each species, which can be condensed, classified and expressed by values and numbers, as ELLENBERG et al. (1992) have done for plants. In this paper we present an ecological classification of a number of mesofaunal annelids, mainly Enchytraeidae, which have frequently been found in a large series of soil biological investigations in Central Europe, performed by the senior author, many of them in soil biomonitoring programs for German environmental agencies (GRAEFE et al. 1998). The values and numbers integrate ecological information about the species obtained from more than 1000 samples, including literature data (e.g. HEALY 1980). The species are classified according to the r-, K- and A-continuum (strategy types), according to their vertical distribution in the humus profile and their occurrence in the gradient of humus forms (life form types), and according to their behaviour towards the ecological factors pH, moisture and salinity (indicator value groups). The latter are chiefly inspired by ELLENBERG's indicator values for plants (ELLENBERG et al. 1992), whereas the life form types were elaborated especially for the soil mesofauna (GRAEFE & BELOTTI 1999).

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Table 1: Ecological characterization of terrestrial enchytraeids and other microannelids in Central Europe. M: moisture figure; R: reaction figure; S: salinity figure; S-type: strategy type; H-type: life form type, related to humus forms and humus horizons (see Fig. 1). For further explanations, see Table 2 and text.

	M	*R*	*S*	*S-type*	*H-type*
ENCHYTRAEIDAE					
Achaeta					
aberrans NIELSEN & CHRISTENSEN, 1961	5	3	0	A	2–4c
abulba GRAEFE, 1989	5	5	0	A	4b
bibulba GRAEFE, 1989	5	5	0	A	2–4b
bifollicula CHALUPSKY, 1992	5	4	0	A	4b
bohemica (VEJDOVSKÝ, 1879)	5	7	0	K	4a
brevivasa GRAEFE, 1980	5	1	0	A	2–4cd
camerani (COGNETTI, 1899)	5	3	0	A	34b–d
danica NIELSEN & CHRISTENSEN, 1959	5	3	0	A	2–4c
eiseni VEJDOVSKÝ, 1877	5	7	0	K	4a
pannonica GRAEFE, 1989	5	8	0	K	4a
Buchholzia					
appendiculata (BUCHHOLZ, 1862)	x	7	0	R/F	12ab
Cernosvitoviella					
atrata (BRETSCHER, 1903)	8	x	0		4a
Cognettia					
cognettii (ISSEL, 1905)	x	4	0	A	12bc
glandulosa (MICHAELSEN, 1888)	9	7	0	K/F	12ab
sphagnetorum (VEJDOVSKÝ, 1877)	x	2	0	A/F	12b–d
Enchytraeus					
albidus HENLE, 1837	8	7	5	R	
buchholzi VEJDOVSKÝ, 1879	x	7	x	R	2–4a
bulbosus NIELSEN & CHRISTENSEN, 1963	x	7	x	R	2–4a
christenseni DOZSA-FARKAS, 1992 (= *minutus* NIELSEN & CHRISTENSEN, 1961)	x	7	x	R	2–4a
coronatus NIELSEN & CHRISTENSEN, 1959	x	7	x	R	2–4a
crypticus WESTHEIDE & GRAEFE, 1992	x	7	x	R	2–4a
lacteus NIELSEN & CHRISTENSEN, 1961	x	7	x	R	2–4a
norvegicus ABRAHAMSEN, 1969	5	5	0	A/R	4bc
Enchytronia					
annulata NIELSEN & CHRISTENSEN, 1959	5	7	0	K	4a
minor MÖLLER, 1971	5	7	0	K	4a

Table 1, continued.

	M	*R*	*S*	*S-type*	*H-type*
Enchytronia					
parva NIELSEN & CHRISTENSEN, 1959	5	6	0	A	4a–c
Fridericia					
bisetosa (LEVINSEN, 1884)	x	7	0	K	4a
bulboides NIELSEN & CHRISTENSEN, 1959	x	7	0	K	4a
bulbosa (ROSA, 1887) sensu NIELSEN & CHRISTENSEN (1959)	x	7	0	K	4a
callosa (EISEN, 1878) sensu NIELSEN & CHRISTENSEN (1959)	5	7	2	K	4a
connata BRETSCHER, 1902	x	7	0	K	4a
deformis MÖLLER, 1971	x	7	0	K	4a
galba (HOFFMEISTER, 1843)	x	7	0	K	4a
gracilis V. BÜLOW, 1957	5	7	2	K	4a
hegemon (VEJDOVSKÝ, 1877)	x	7	0	K	4a
maculata ISSEL, 1905	x	7	0	K	4a
magna FRIEND, 1899	7	7	0	K	4a
paroniana ISSEL, 1904 sensu NIELSEN & CHRISTENSEN (1959)	x	7	0	K	4a
perrieri (VEJDOVSKÝ, 1879)	x	7	0	K	4a
ratzeli (EISEN, 1872) sensu NIELSEN & CHRISTENSEN (1959)	x	7	0	K	4a
singula NIELSEN & CHRISTENSEN, 1961	x	7	0	K	4a
striata (LEVINSEN, 1884)	x	6	0	A	12a–c
Hemifridericia					
parva NIELSEN & CHRISTENSEN, 1959	x	7	0	K	2–4a
Henlea					
heleotropha STEPHENSON, 1922 sensu NIELSEN & CHRISTENSEN (1959)	x	7	1	K	2–4a
nasuta (EISEN, 1878)	x	7	1	K	2–4a
perpusilla FRIEND, 1911	x	7	1	K	2–4a
ventriculosa (D'UDEKEM, 1854)	x	7	1	K	2–4a
Lumbricillus					
fennicus NURMINEN, 1964	10	7	3		
lineatus (MÜLLER, 1774)	10	7	5		
Marionina					
argentea (MICHAELSEN, 1889)	8	7	1	K	4a
brendae ROTA, 1995	5	7	0	K	4a
clavata NIELSEN & CHRISTENSEN, 1961	5	1	0	A	23cd
communis NIELSEN & CHRISTENSEN, 1959	5	7	0	K	2a

Table 1, continued

	M	*R*	*S*	*S-type*	*H-type*
Marionina					
filiformis NIELSEN & CHRISTENSEN, 1959	9	4	0	A	34bc
libra NIELSEN & CHRISTENSEN, 1959	x	7	0	K	2a
minutissima HEALY, 1975	5	7	0	K	4a
riparia BRETSCHER, 1899	10	7	0	K	4a
simillima NIELSEN & CHRISTENSEN, 1959	6	5	0	A	4b
spicula (LEUCKART, 1847)	10	7	5		
vesiculata NIELSEN & CHRISTENSEN, 1959	7	7	0	K	4a
Mesenchytraeus					
armatus (LEVINSEN, 1884)	9	7	0	K	
beumeri (MICHAELSEN, 1886)	9	x	0	K	
flavus (LEVINSEN, 1887)	5	5	0	A	12bc
glandulosus (LEVINSEN, 1884)	5	5	0	A/Y	1a–c
pelicensis ISSEL, 1905	5	3	0	A	12b–d
sanguineus NIELSEN & CHRISTENSEN, 1959	9	3	0	A	
Oconnorella					
cambrensis (O'CONNOR, 1963)	5	4	0	A	2–4bc
tubifera (NIELSEN & CHRISTENSEN, 1959)	5	6	0	A	2–4b
Stercutus					
niveus MICHAELSEN, 1888	5	7	0	K/Y	14ab
TUBIFICIDAE					
Rhyacodrilus					
falciformis BRETSCHER, 1901	7	7	0	K	4a
POLYCHAETA					
Hrabeiella					
periglandulata PIZL & CHALUPSKY, 1984	5	6	0	A	4a–c
Parergodrilus					
heideri REISINGER, 1925	7	7	0	K	2a

Ecological characterization of soil microannelids

The ecological characterization of enchytraeid species, together with one terrestrial tubificid and two polychaete species, is given in Table 1. Table 2 explains the coding of ecological information in values and numbers used in Table 1. Some remarks are necessary:

Indicator values: One major characteristic of the indicator values, as shown in Table 2, is their deliberately ›fuzzy‹ definition. For example, no pH-limits are given for the reaction figures. Instead, the term ›indicator of moderate acidity‹ is explained by ›only occasionally in strongly acid or neutral soils‹. This can be understood as a description of a Gaussian curve along a pH gradient, where the main occurrence of a species is designated together with its range of tolerance, reflecting the continuum in nature. This fuzziness is not revoked by numerical coding. The numbers must not be misunderstood as reflecting equal distances. They only represent an order of rank, and they characterize isovalent species groups.

Most informative are reaction and moisture figure. Almost the entire range of reaction values is covered by soil annelids. The absence of value 9 may be due to the fact that calcareous sites have not been studied intensely enough. Moisture values below 5 that would indicate the main occurrence of a species in dry habitats are unlikely to be found in enchytraeids, because they lack histological protection structures against evaporation. The salt figure has only recently been introduced into the system and needs further elaboration. It allows, inter alia, the inclusion of species of the marine littoral habitat.

Strategy types: The strategy type refers mainly to reproductive strategies but also includes stress tolerance. Both factors can be further differentiated. For example, uniparental reproduction by parthenogenesis (some *Fridericia* species) or self-fertilization (*Enchytraeus buchholzi* agg.) may yield ecological information; other stress factors than acidity are conceivable as well, e.g. heavy metals or pesticides.

Life form types: Each species exhibits characteristic distribution ranges in the gradient from Mull (MU) to Mullmoder (MOM), Moder (MO) and Mor (›Rohhumus‹, RO), and also in the vertical gradient of humus horizons from litter (L) down to the humus-rich mineral soil (Ah). This species-specific differential distribution can be demonstrated in diagrams, where – for each species separately – the humus forms are arranged along the horizontal axis and the humus horizons along the vertical axis (Fig. 1). In doing this, the ecological differences between the species are most conspicuously visualized. Symbolizing the fields with letters a-d (humus form, see Table 2) and numbers 1–4 (humus horizons, see Table 2) allows the representation of this information in tabular form (Table 1, column ›H-type‹). The H-type applies mainly to aeromorph humus forms sensu GRAEFE & BELOTTI (1999). Respective values for species inhabiting hydromorph humus forms and saline soils will be given after further elaboration.

Discussion

Indicator values have the great advantage of integrating all available ecological knowledge about a species; hence in soil biological studies which investigate effects of acidification, liming, or other kinds of stress and disturbance, no unaffected/undisturbed reference site is necessary for the interpretation of the data. On the other hand, each new site can also add new information on the ecological behaviour of the respective species. Therefore, in each case of deviation of the species behaviour from the coded value (e.g. high frequency and abundance of acidity indicators in neutral soils) it must be carefully assessed whether this is due to environmental changes or to a too narrow classification of the species. This applies especially when sites in other geographic regions (here: outside Central Europe) are investigated. As ELLENBERG et al. have stressed (1992), indicator values must never be adopted uncritically but always require geographical calibration.

Table 2: Explanation of values and numbers in Table 1

INDICATOR VALUES	
M	**Moisture figure** – Occurrence in the gradient of soil moisture
5	indicator of fresh soils, absent in wet habitats
7	indicator of damp soils, mainly in damp, but not wet habitats
9	indicator of wet soils, mainly in badly aerated wet soils
11	aquatic species
R	**Reaction figure –** Occurrence in the gradient of soil acidity and lime content
1	indicator of extreme acidity, never in slightly acid or alkaline soils
3	acidity indicator, mainly in acid soils, but exceptionally up to the neutral range
5	indicator of moderate acidity, only occasionally in strongly acid or neutral soils
7	indicator of slightly acid to slightly alkaline conditions, never in strongly acid soils
9	basic reactions and lime indicator, always found in calcareous soils
S	**Salt figure –** Occurrence in the gradient of salt in the soil solution resp. in water
0	not salt supporting (this figure should be used when calculating average salt values)
1	salt supporting, but mostly in soils poor in salt
2	oligohaline, often in soils and waters with very low salt content
3	oligo/mesohaline, in soils and waters with low to moderate salt content
4	mesohaline, mostly in soils and waters with moderate salt content
5	meso/polyhaline, in soils and waters with moderate to high salt content
7	steno-euhalin, restricted to soils and waters with high salt content
9	hyperhaline, in soils and waters with very high to extreme salt content
x	indifferent or unkown behaviour; even numbers for intermediate behaviour
STRATEGY TYPES: **S-TYPE**	
R	r-selected opportunist with fast development and high reproduction rate (sexual or asexual)
K	K-selected persistent species with slow development and a reproduction rate adapted to the carrying capacity of the environment
A	stress-tolerant species, adapted to acidity stress
F	species with asexual reproduction by fragmentation
Y	species with seasonally fixed life cycle
LIFE FORMS: **H-TYPE**	
according to the occurrence in the continuum of humus horizons and humus forms	
1	litter dweller (L)
2	F-horizon dweller (Of)
3	H-horizon dweller (Oh)
4	soil dweller (Ah)
a	inhabiting Mull humus forms (MU)
b	inhabiting Mullmoder humus forms (MOM)
c	inhabiting Moder humus forms (MO)
d	inhabiting Mor humus forms (RO) (›Rohhumus‹)

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	2a	**2b**	2c	2d
Oh			3c	3d
Ah	4a	**4b**	4c	4d

Achaeta bibulba

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	2a	2b	2c	2d
Oh			**3c**	**3d**
Ah	4a	**4b**	**4c**	**4d**

Achaeta camerani

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	2a	2b	2c	2d
Oh			3c	3d
Ah	**4a**	4b	4c	4d

Achaeta eiseni

	MU	MOM	MO	RO
L	**1a**	**1b**	1c	1d
Of	**2a**	**2b**	2c	2d
Oh			3c	3d
Ah	4a	4b	4c	4d

Buchholzia appendiculata

	MU	MOM	MO	RO
L	**1a**	**1b**	1c	1d
Of	**2a**	**2b**	2c	2d
Oh			3c	3d
Ah	4a	4b	4c	4d

Cognettia glandulosa

	MU	MOM	MO	RO
L	1a	**1b**	**1c**	**1d**
Of	2a	**2b**	**2c**	**2d**
Oh			3c	3d
Ah	4a	4b	4c	4d

Cognettia sphagnetorum

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	**2a**	2b	2c	2d
Oh			3c	3d
Ah	**4a**	4b	4c	4d

Enchytraeus buchholzi

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	2a	2b	2c	2d
Oh			3c	3d
Ah	4a	**4b**	**4c**	4d

Enchytraeus norvegicus

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	2a	2b	2c	2d
Oh			3c	3d
Ah	**4a**	**4b**	**4c**	4d

Enchytronia parva

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	2a	2b	2c	2d
Oh			3c	3d
Ah	**4a**	4b	4c	4d

Fridericia bulboides

	MU	MOM	MO	RO
L	1a	**1b**	**1c**	**1d**
Of	2a	**2b**	**2c**	**2d**
Oh			3c	3d
Ah	4a	4b	4c	4d

Fridericia striata

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	**2a**	2b	2c	2d
Oh			3c	3d
Ah	**4a**	4b	4c	4d

Henlea perpusilla

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	2a	2b	2c	2d
Oh			3c	3d
Ah	**4a**	4b	4c	4d

Marionina argentea

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	2a	2b	**2c**	**2d**
Oh			**3c**	**3d**
Ah	4a	4b	4c	4d

Marionina clavata

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	**2a**	2b	2c	2d
Oh			3c	3d
Ah	4a	4b	4c	4d

Marionina communis

	MU	MOM	MO	RO
L	**1a**	**1b**	**1c**	1d
Of	2a	2b	2c	2d
Oh			3c	3d
Ah	4a	4b	4c	4d

Mesenchytraeus glandulosus

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	2a	**2b**	**2c**	2d
Oh			**3c**	3d
Ah	4a	**4b**	**4c**	4d

Oconnorella cambrensis

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	2a	**2b**	2c	2d
Oh			3c	3d
Ah	4a	**4b**	4c	4d

Oconnorella tubifera

	MU	MOM	MO	RO
L	**1a**	**1b**	1c	1d
Of	2a	2b	2c	2d
Oh			3c	3d
Ah	**4a**	**4b**	4c	4d

Stercutus niveus

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	2a	2b	2c	2d
Oh			3c	3d
Ah	**4a**	**4b**	**4c**	4d

Hrabeiella periglandulata

	MU	MOM	MO	RO
L	1a	1b	1c	1d
Of	**2a**	2b	2c	2d
Oh			3c	3d
Ah	4a	4b	4c	4d

Parergodrilus heideri

Fig. 1: Main occurrences (shaded) of selected soil microannelids in the continuum of humus horizons and humus forms. For explanation see Table 2.

The list presented here is a work in progress and open to further refinements. More species must be included, and the ecological behaviour of many species need to be defined more precisely. Many species exhibit identical behaviour with respect to all categories; for example, the majority of *Fridericia* species are indifferent as to moisture, their reaction figure is 7, they are K-selected and occur mostly in the Ah horizon of mull soils. They may in fact be all isovalent, but more detailed examinations of the soil sites and the inclusion of other parameters (e.g. lime content) will perhaps uncover differences and so promote the better exploitation of the diagnostic potential of these species.

The list in the present form already serves as a powerful information baseline for numerous and diverse applications in the context of soil bioindication and biomonitoring. Examples are given in BEYLICH et al. (1995) GRAEFE (1993a,b, 1995, 1997a,b, 1998) and in GRAEFE et al. (1998). Especially useful is its connection with the concept of decomposer communities proposed and elaborated by GRAEFE (1993b, 1997b).

There are many recent attempts in other soil taxocoenoses to use the different ecological behaviour of the species for bioindication (see BOUCHÉ (1972) for lumbricid earthworms, FOISSNER (1987) for Protozoa, BONGERS (1990) for Nematoda, DUNGER (1991) for Collembola, RUF (1998) for Gamasina and WEIGMANN (1997) for Oribatida). We think that the procedure of ecological classification proposed here is not restricted to microannelids but can also be transferred to the other groups mentioned. In doing this, a bioindication system could be created which is based on ecological species groups and which ensures compatibility of information obtained from different taxocoenoses (comp. RÖMBKE et al. 1997, VAN STRAALEN 1998).

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