Zoological investigations at soil monitoring sites: Creating a reference basis for assessing soil quality and environmental changes

Graefe, U.[1], Beylich, A.[1], Collado, R.[2], Elsner, D.-C.[3], Haag, R.[4], Schmelz, R. M.[2]

[1]IFAB GmbH, Sodenkamp 62, 22337 Hamburg, Germany, ulfert.graefe@ifab-hamburg.de
[2]Universidade da Coruña, Dpto. Bioloxía y Ecoloxía, 15002 La Coruña, Spain, rutco@udc.es
[3]LANU Schleswig-Holstein, 24220 Flintbek, Germany, delsner@lanu.landsh.de
[4]LUA Nordrhein-Westfalen, 45023 Essen, Germany, rita.haag@lua.nrw.de

The biological investigations at long-term soil monitoring sites as recommended by the German Federal and State Panel for Soil Protection (LABO) include zoological parameters as an obligatory component. Because it is not possible to consider the whole soil fauna, these investigations focus on functionally important indicator groups, mainly earthworms and enchytraeids, representing the macrofauna and the mesofauna, respectively. Following this guideline the basic inventories have been completed so far at 55 monitoring sites in Schleswig-Holstein, North Rhine-Westphalia and Hamburg, covering a variety of soil and land-use types. Since 1998 the investigations go through the first repetition.

Long-term observations at soil monitoring sites are generally conceived as central element of an integrated environmental monitoring. The array of parameters measured at these sites allows multiple analyses. We demonstrate this by addressing the following questions:

- How do land use and management practices affect the soil community?
- Which stability domains and thresholds of ecological resilience exist for soil biota?
- Which deviations from normal ranges are caused by heavy metal contamination?
- How does the exceedance of critical loads for acidity affect the biological state of the soil in different receptor ecosystems?
- Which recovery delay time can be expected for soil biota when the deposition of acidifying and eutrophying pollutants is reduced below critical values due to environmental protection efforts?

Answering such questions requires knowledge about the normal formation and variability of soil biota under different site and land-use conditions. The basic reference for that purpose will be provided primarily by the data network derived from soil monitoring sites.

Zoological investigations at soil monitoring sites: Creating a reference basis for assessing soil quality and environmental changes

Ulfert Graefe[1], Anneke Beylich[1], Rut Collado[2], Dirk-Christian Elsner[3], Rita Haag[4], Rüdiger M. Schmelz[2]

[1]IFAB Institute for Applied Soil Biology GmbH, Hamburg, Germany
[2]Dept. of Biology and Ecology, University of La Coruña, Spain
[3]Environment Agency of Schleswig-Holstein, Flintbek, Germany
[4]Environment Agency of North Rhine-Westphalia, Essen, Germany

Outline

- **Indicators of soil faunal activity**
  - Total abundance and total biomass of earthworms
  - Total abundance of microannelids
- **Indicators of soil biodiversity**
  - Species richness of earthworms and microannelids
  - Species composition, abundance, dominance and frequency of species
- **Indicator of the vertical extent of biological processes**
  - Vertical distribution of microannelids

Outline

Data aggregation

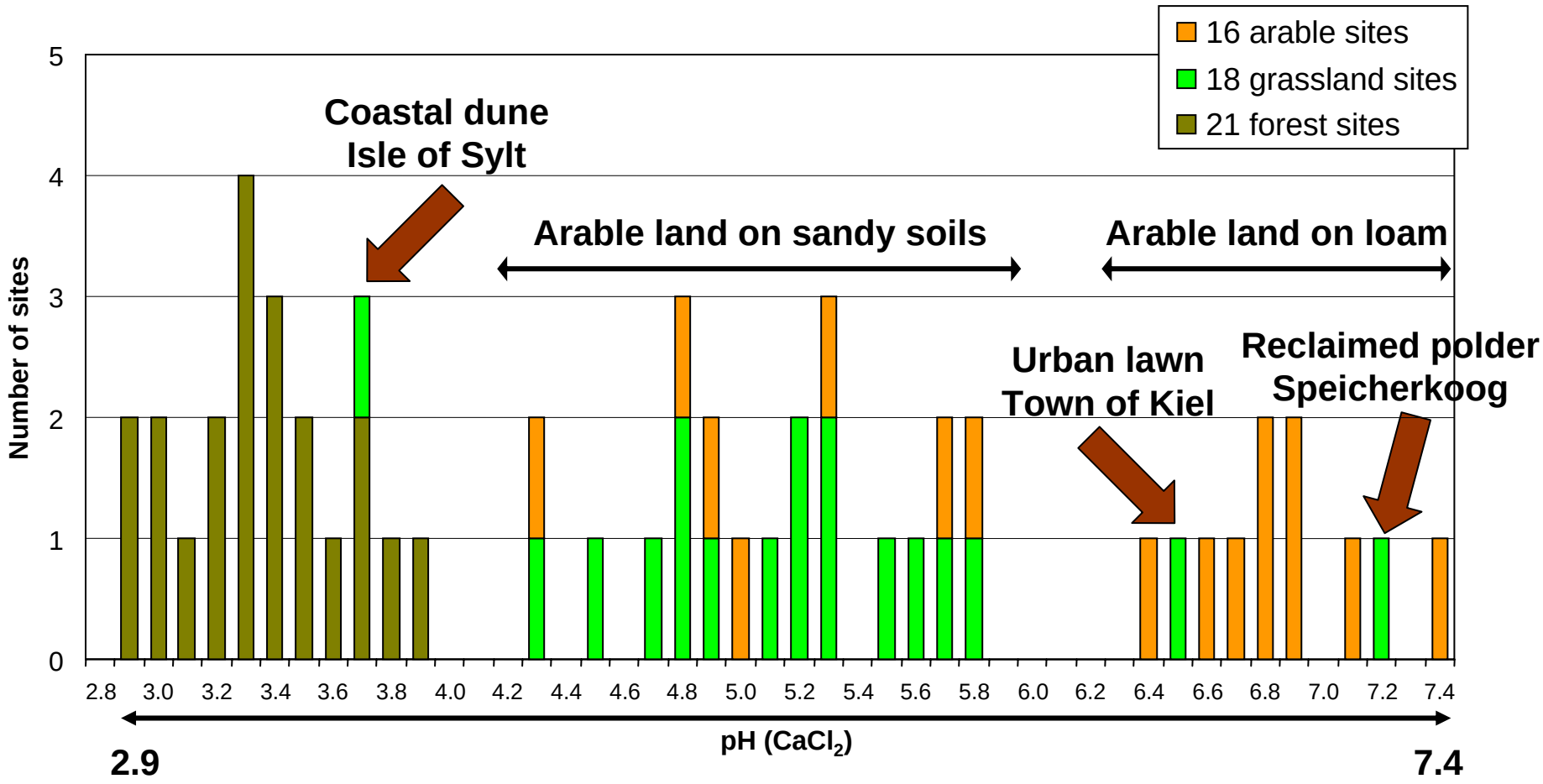
- **Grouping of species with similar ecological behaviour**
  - Ecological types of earthworms (anecic, endogeic...)
  - Strategy types of microannelids (colonizer, persister...)
  - Indicator groups (acidity indicator, moisture indicator...)
- **Reduction of multiple species informations to one value per site and inventory by calculating**
  - Strategy-type and life-form ratios
  - Average indicator values

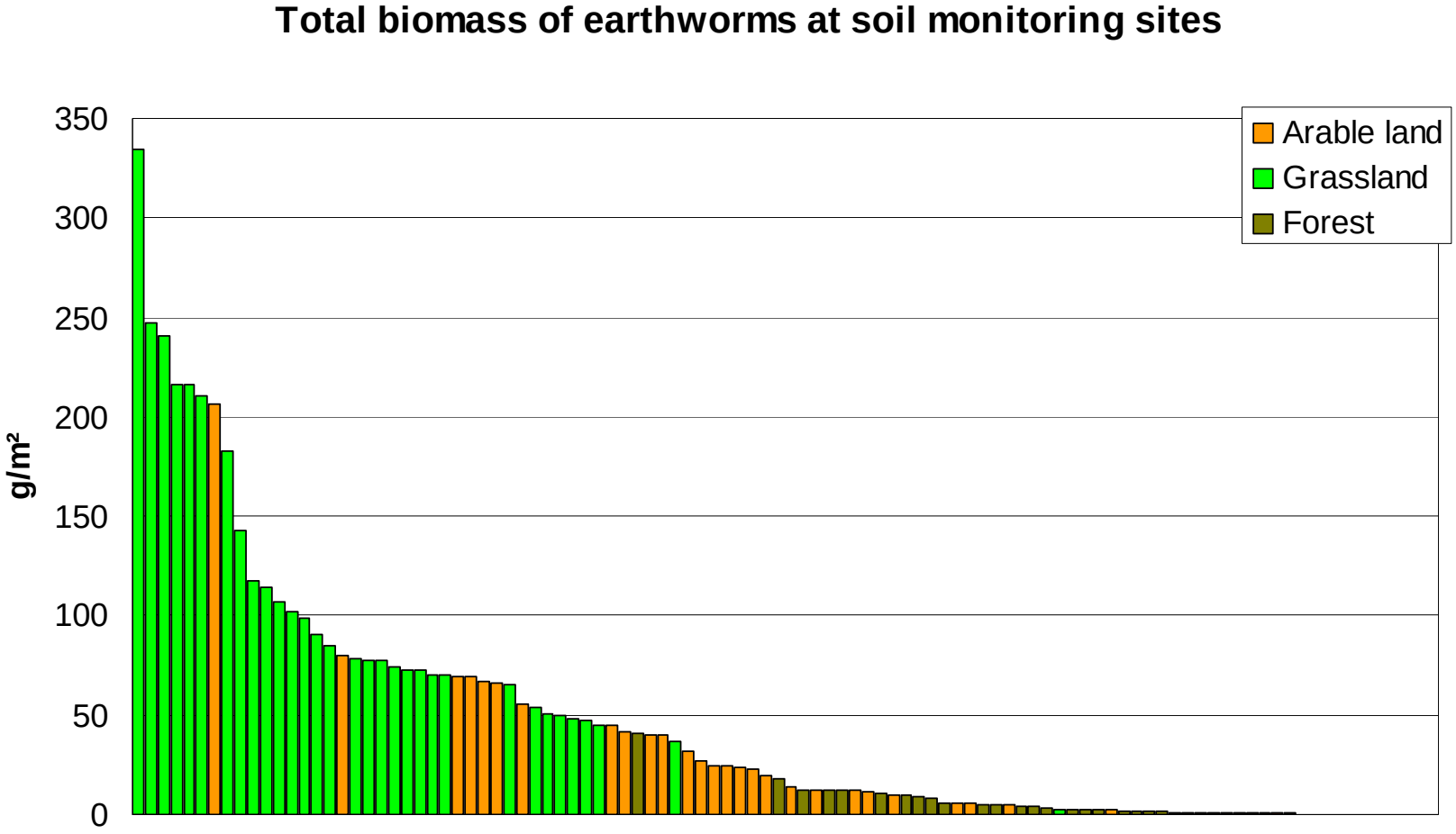
Outline

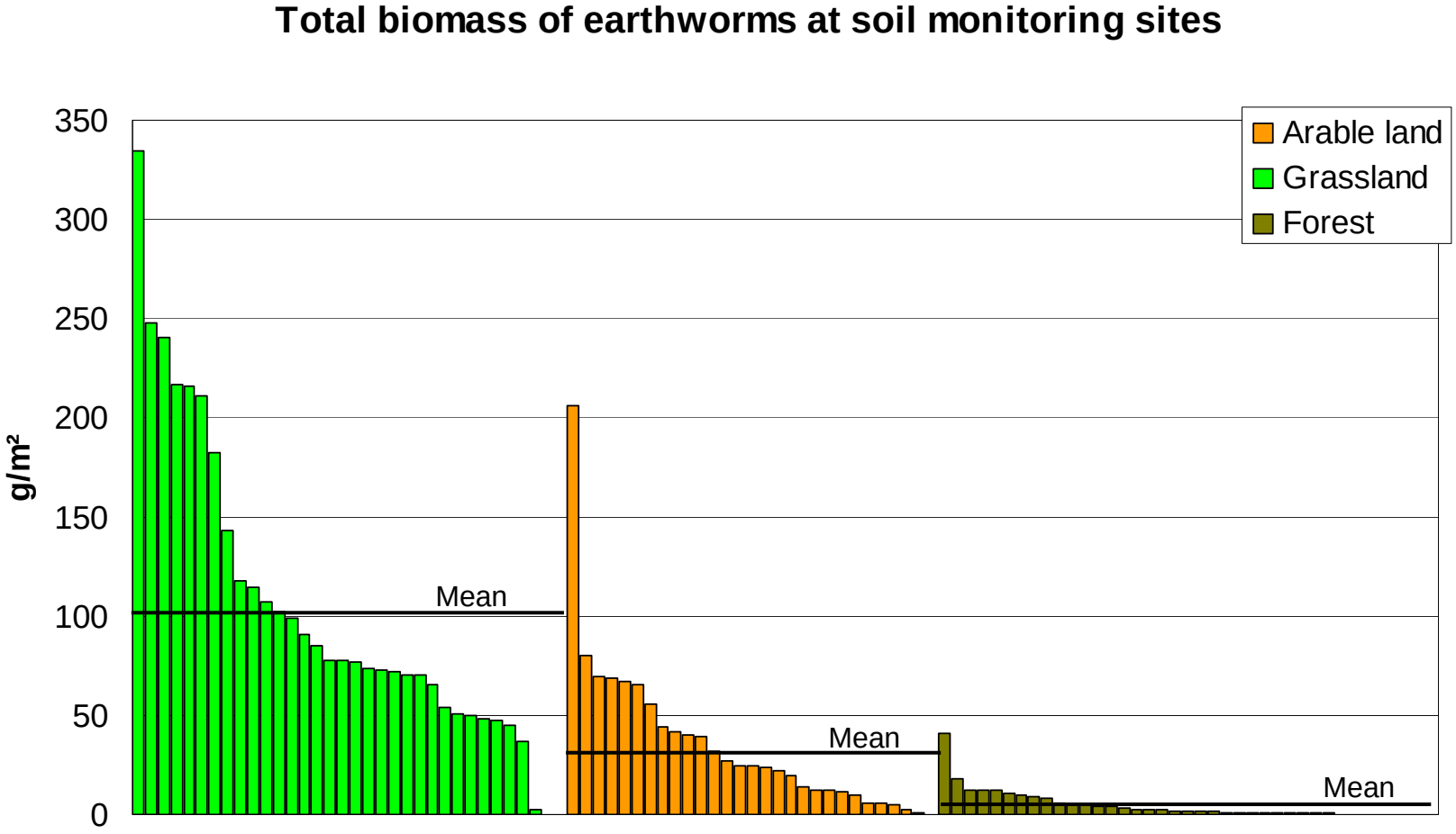
Visualization

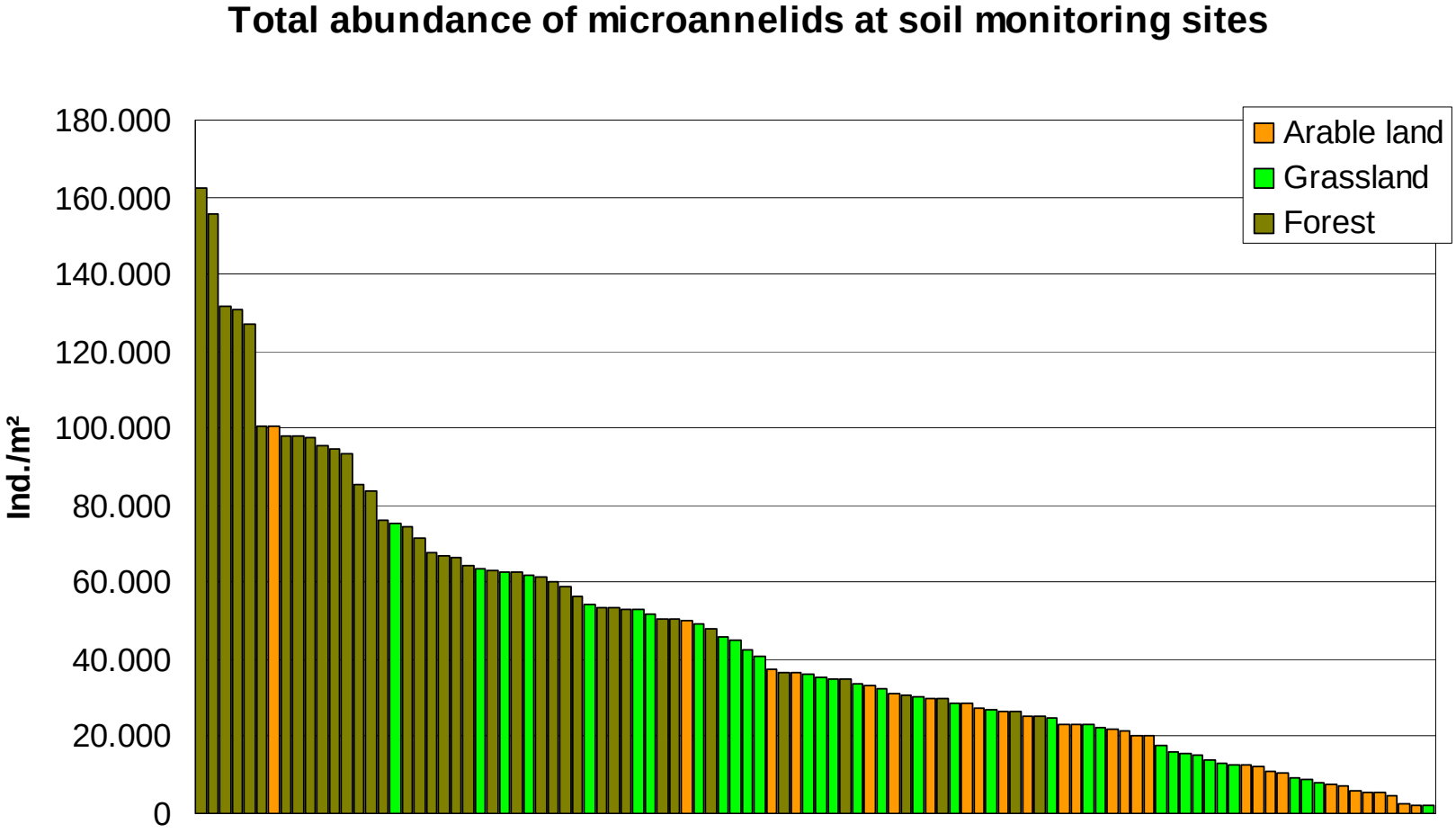
- **Determining the biological state of the soil by plotting the data on a diagram with fixed axes of reference**
  - Triangular diagram
  - “Ecogram” with two axes
- **Defining communities with similar species composition as types of soil biota**
  - Decomposer community type

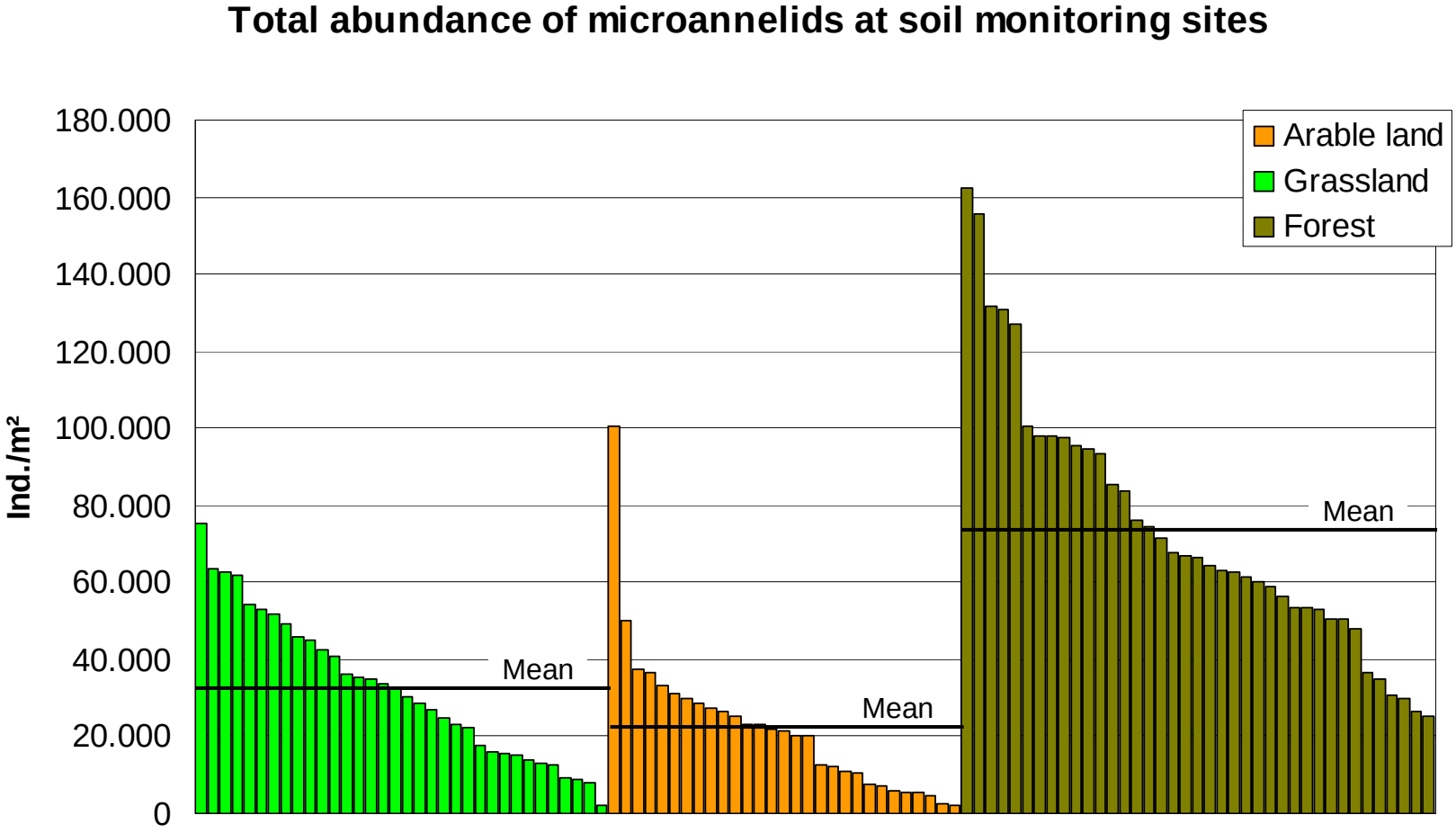
pH-values in the humus layer and the topsoil of 55 soil monitoring sites
(Schleswig-Holstein, Hamburg and North Rhine-Westphalia)

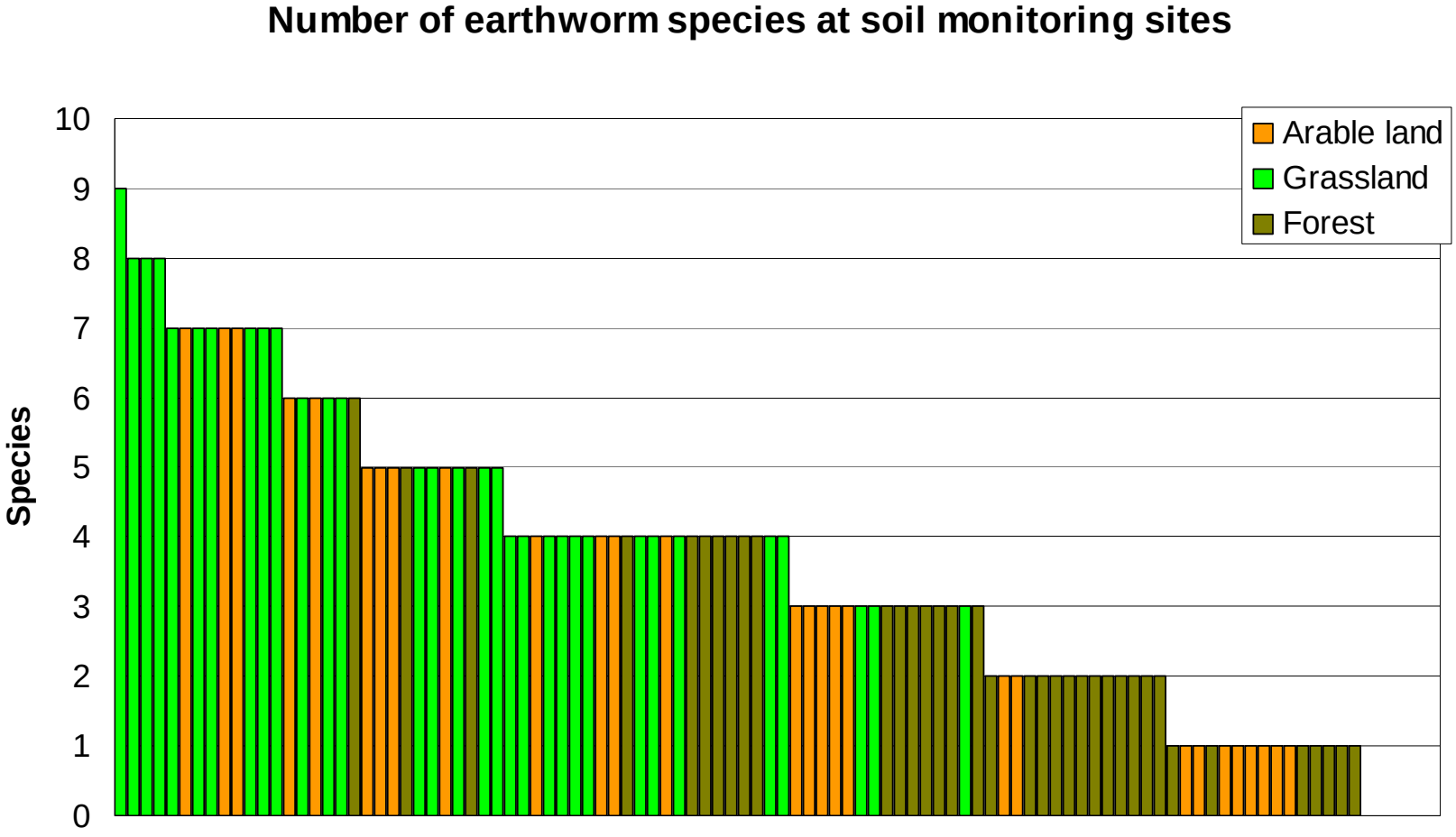


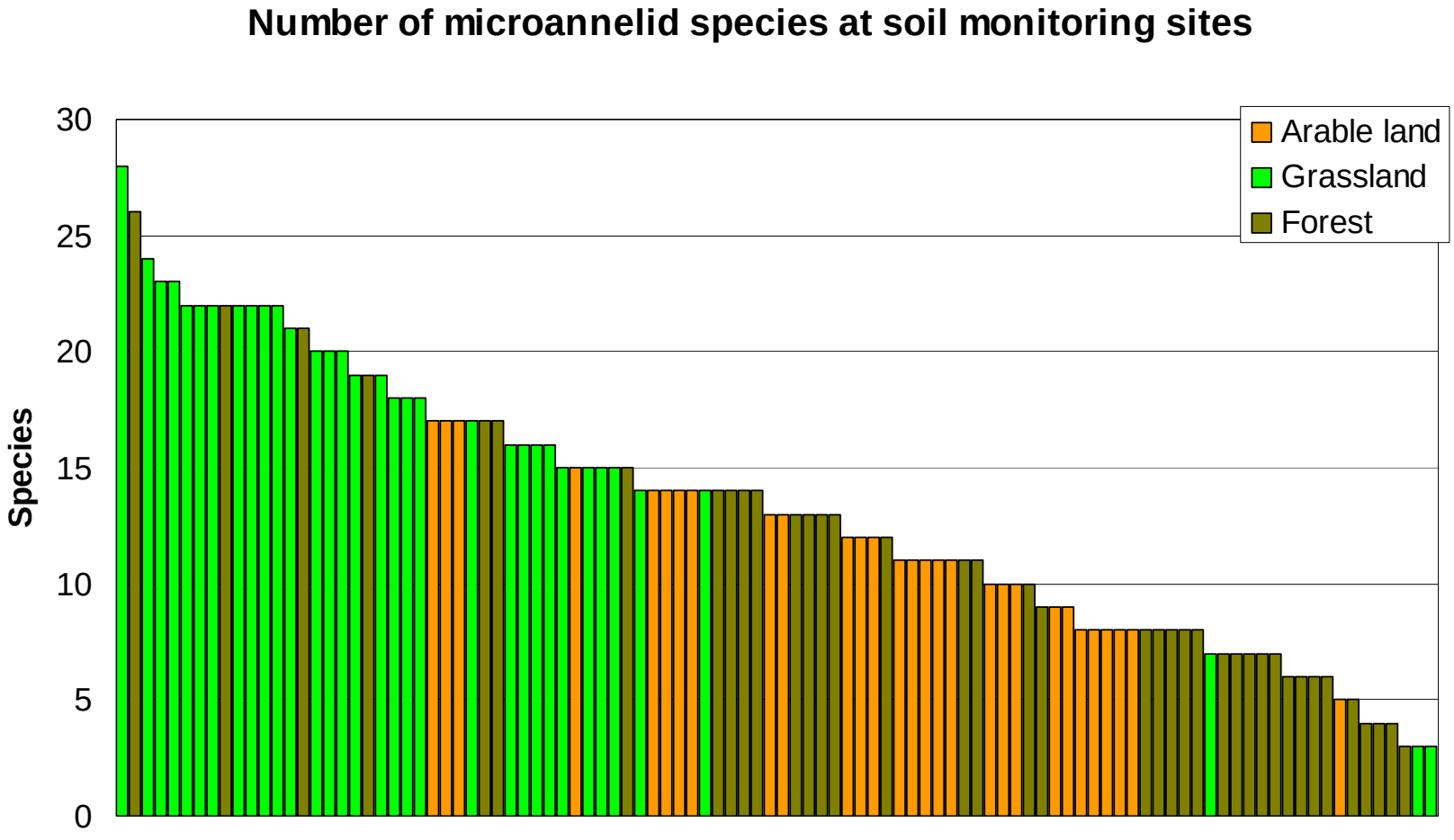

Total biomass of earthworms at soil monitoring sites
350
300
250
200
150
100
50
0
g/m²
Arable land
Grassland
Forest

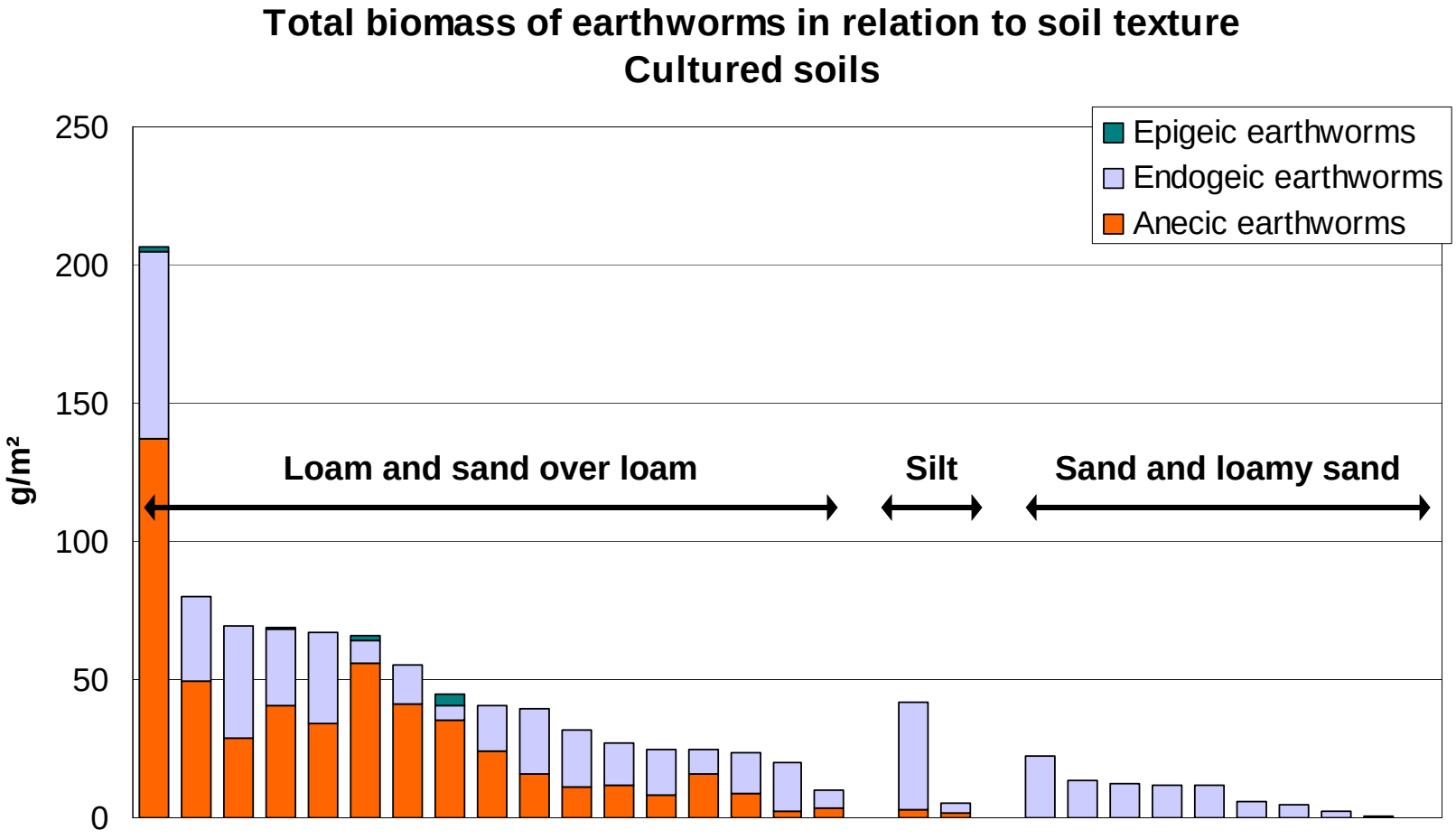

Total biomass of earthworms at soil monitoring sites
350
300
250
200
150
100
50
0
g/m²
Arable land
Grassland
Forest
Mean
Mean
Mean

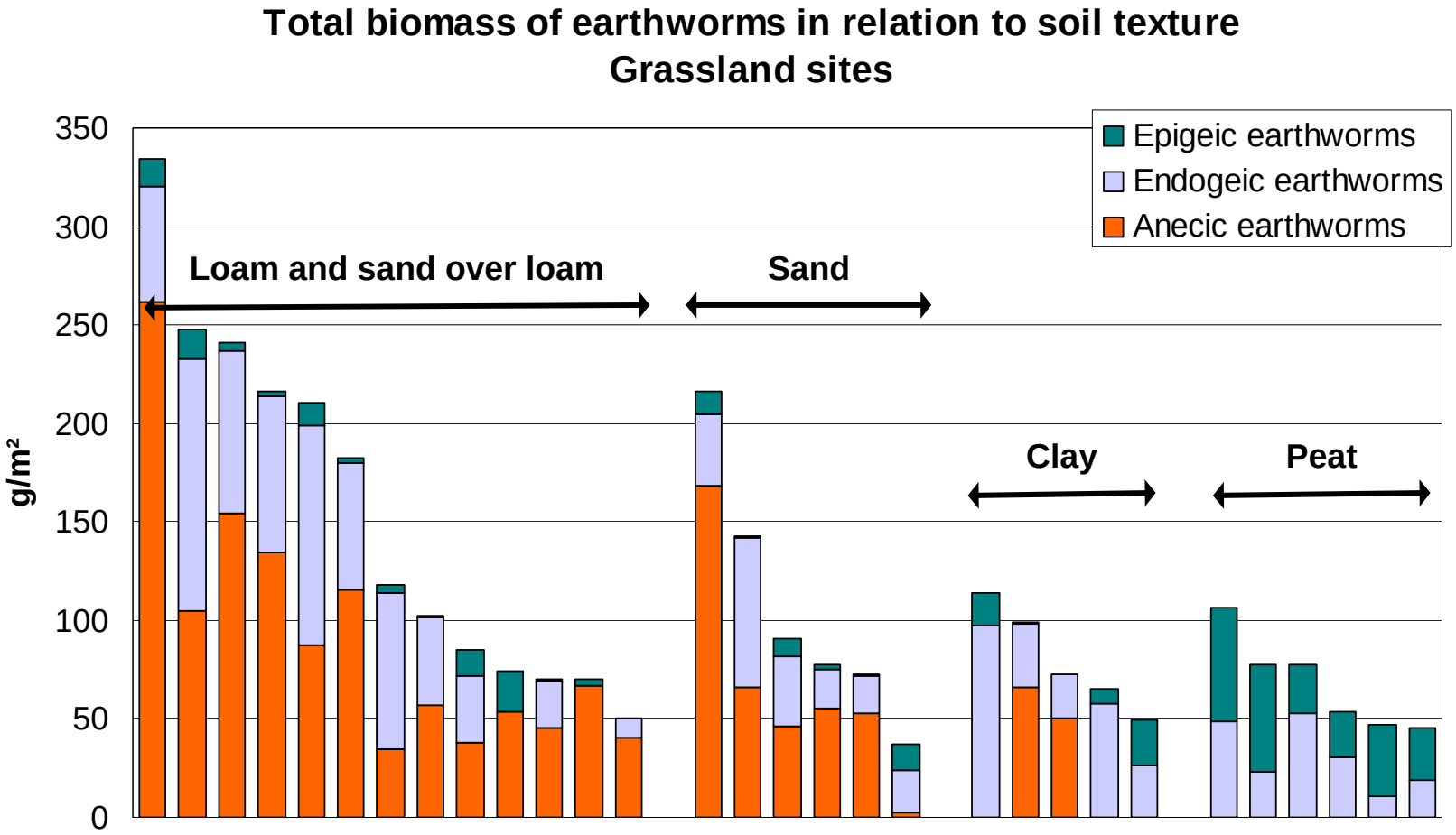

Total abundance of microannelids at soil monitoring sites
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0
Ind./m²
Arable land
Grassland
Forest


Total abundance of microannelids at soil monitoring sites
Ind./m²
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0
Arable land
Grassland
Forest
Mean
Mean
Mean

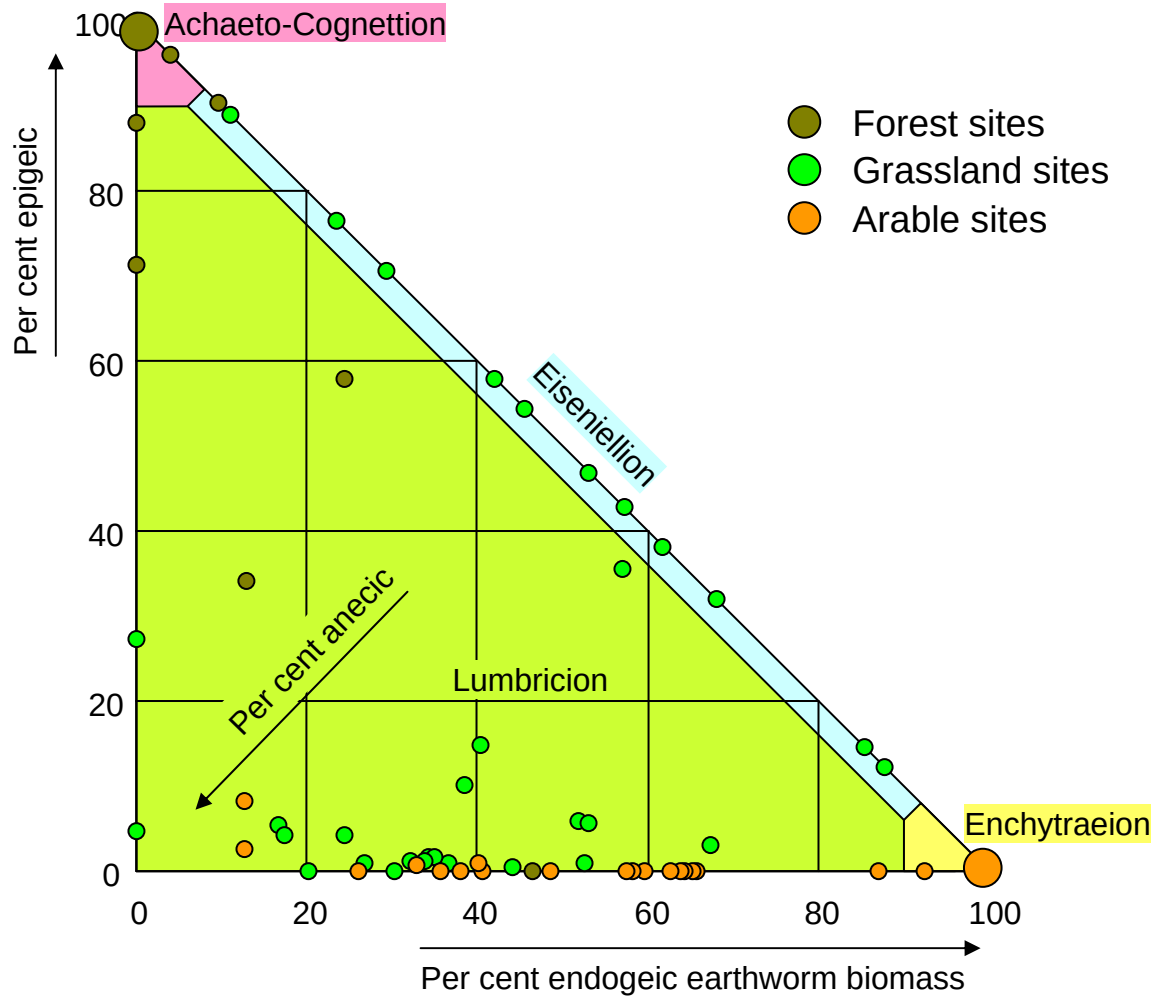

Number of earthworm species at soil monitoring sites
Species
10
9
8
7
6
5
4
3
2
1
0
Arable land
Grassland
Forest


Number of microannelid species at soil monitoring sites
Species
30
25
20
15
10
5
0
Arable land
Grassland
Forest


Total biomass of earthworms in relation to soil texture
Cultured soils
Epigeic earthworms
Endogeic earthworms
Anecic earthworms
g/m²
250
200
150
100
50
0
Loam and sand over loam
Silt
Sand and loamy sand


Total biomass of earthworms in relation to soil texture
Grassland sites
Epigeic earthworms
Endogeic earthworms
Anecic earthworms
g/m²
350
300
250
200
150
100
50
0
Loam and sand over loam
Sand
Clay
Peat

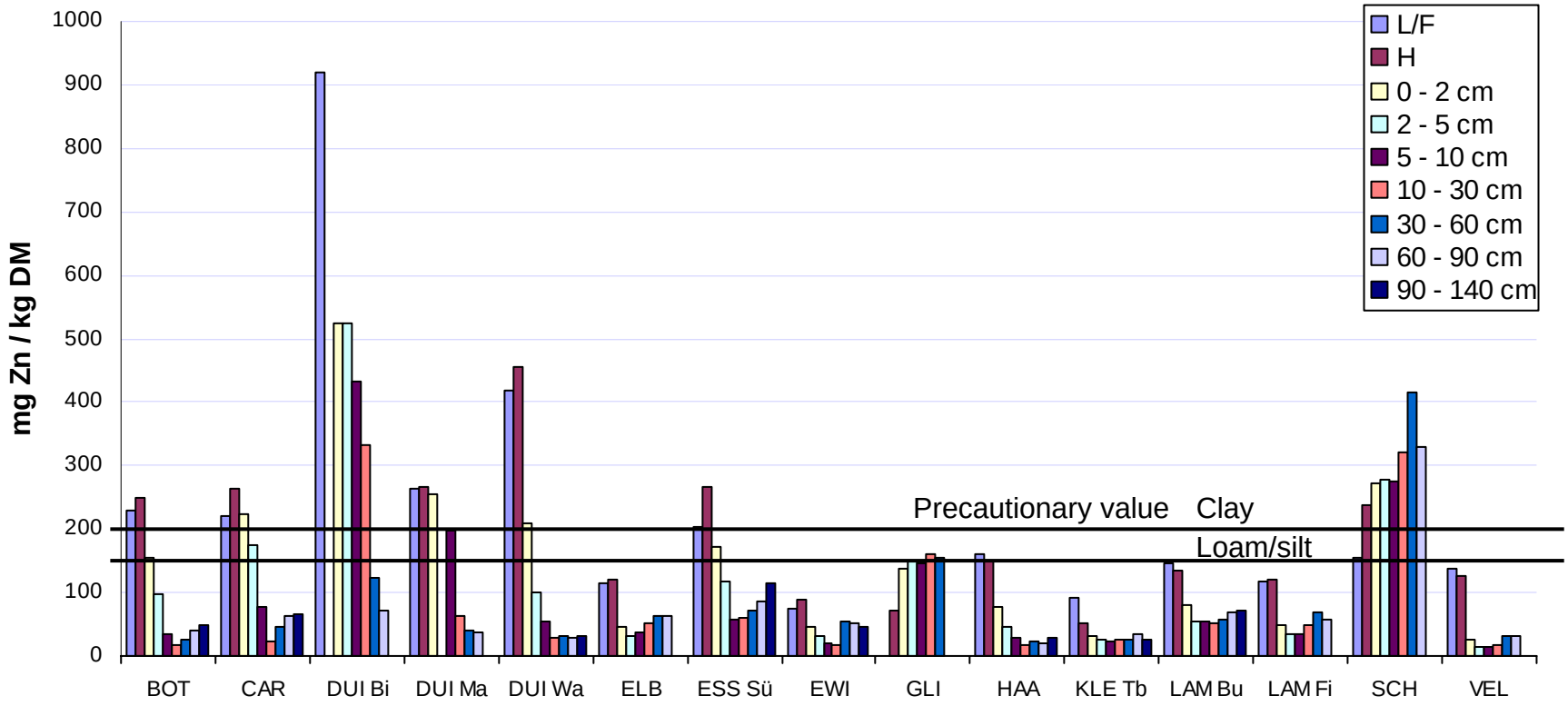
Triangular diagram for the distribution of earthworm strategy types



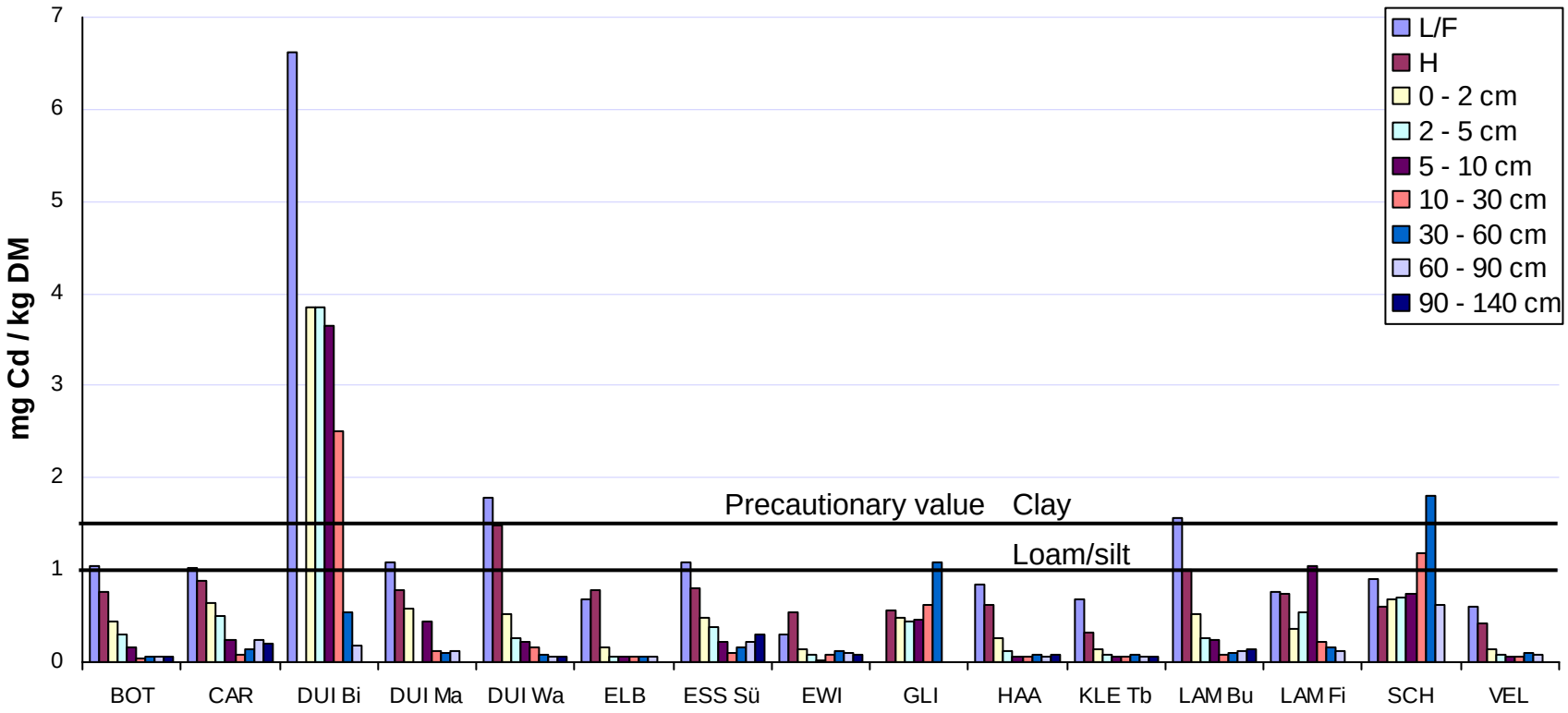
Order	Alliance	Association
1. **Lumbricetalia** Sites moderately acid to rich in lime	1.1 **Lumbricion** Undisturbed aerated soils	1.11 **Stercuto-Lumbricetum** Forest with mull humus forms
		1.12 **Fridericio-Lumbricetum** Grassland and arable land on loamy soils
	1.2 **Enchytraeion** Disturbed and eutrophicated soils	1.21 **Fridericio-Enchytraeetum** Arable land on sandy soils
		1.22 **Buchholzio-Enchytraeetum** Eutrophicated, compacted soils under urban influence
		1.23 **Eisenietum** Compost sites
	1.3 **Eiseniellion** Water-saturated, badly aerated soils	1.31 **Octolasietum tyrtaei** Base-rich fen, alder swamp
		1.32 **Eisenielletum** Semiaquatic sites, floodplain
2. **Cognettietalia** Sites with acid humus layer or peat	2.1 **Achaeto-Cognettion** Dry and moist soils with low base saturation	2.11 **Achaeto-Cognettietum** Forest and heathland with moder or mor humus forms
	2.2 **Cognettion sphagnetorum** Wet organic soils with low base saturation	2.21 **Cognettietum sphagnetorum** Base-poor fen, ombrotrophic bog
3. **Henleetalia** Sites moderately acid to rich in lime with humus layer	3.1 **Mesenchytraeo-Henleion** Decomposition inhibited by low temperature	3.11 **Mesenchytraeo-Henleetum** Permafrost soils in arctic tundra
	3.2 **Fridericio-Henleion** Bioturbation inhibited by lack of soil dwelling earthworms	3.21 **Fridericio-Henleetum** Early succession stage in reclaimed polders and marshlands
4. **Communities influenced by salt** (not yet differentiated)		

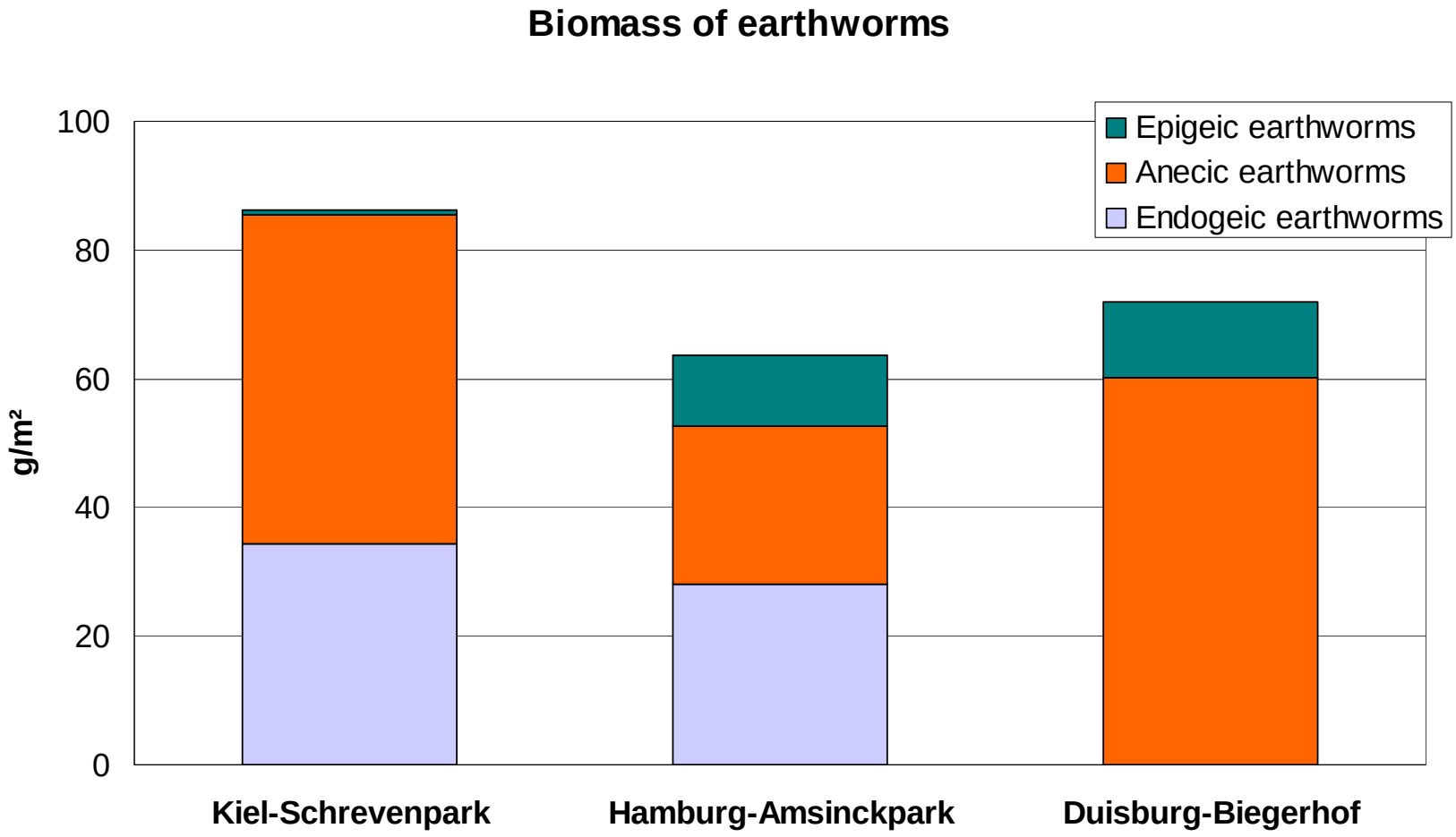
Synopsis of decomposer community types with site examples (from Beylich and Graefe 2002).

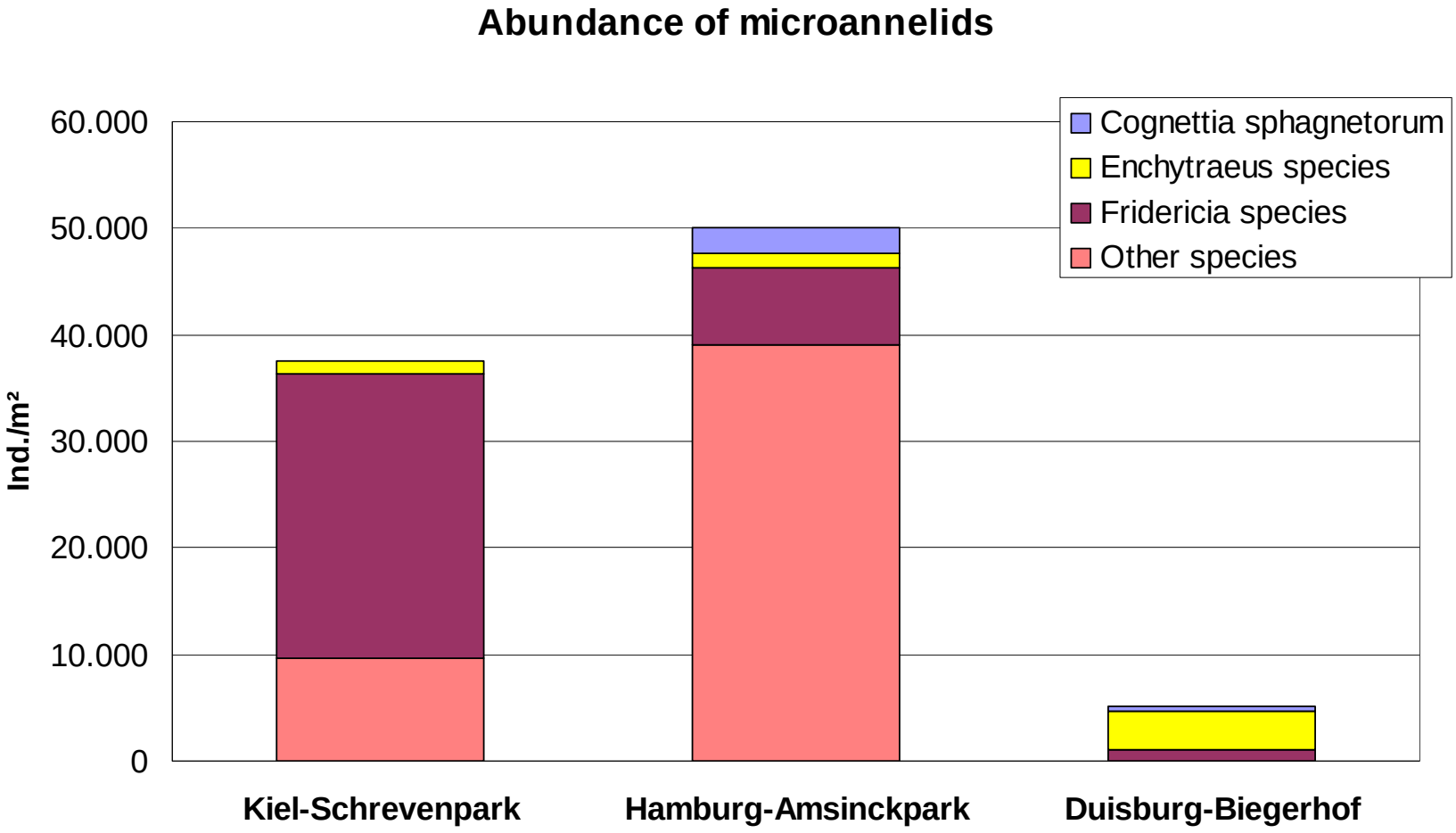
Zn concentration at soil monitoring sites in North Rhine-Westphalia



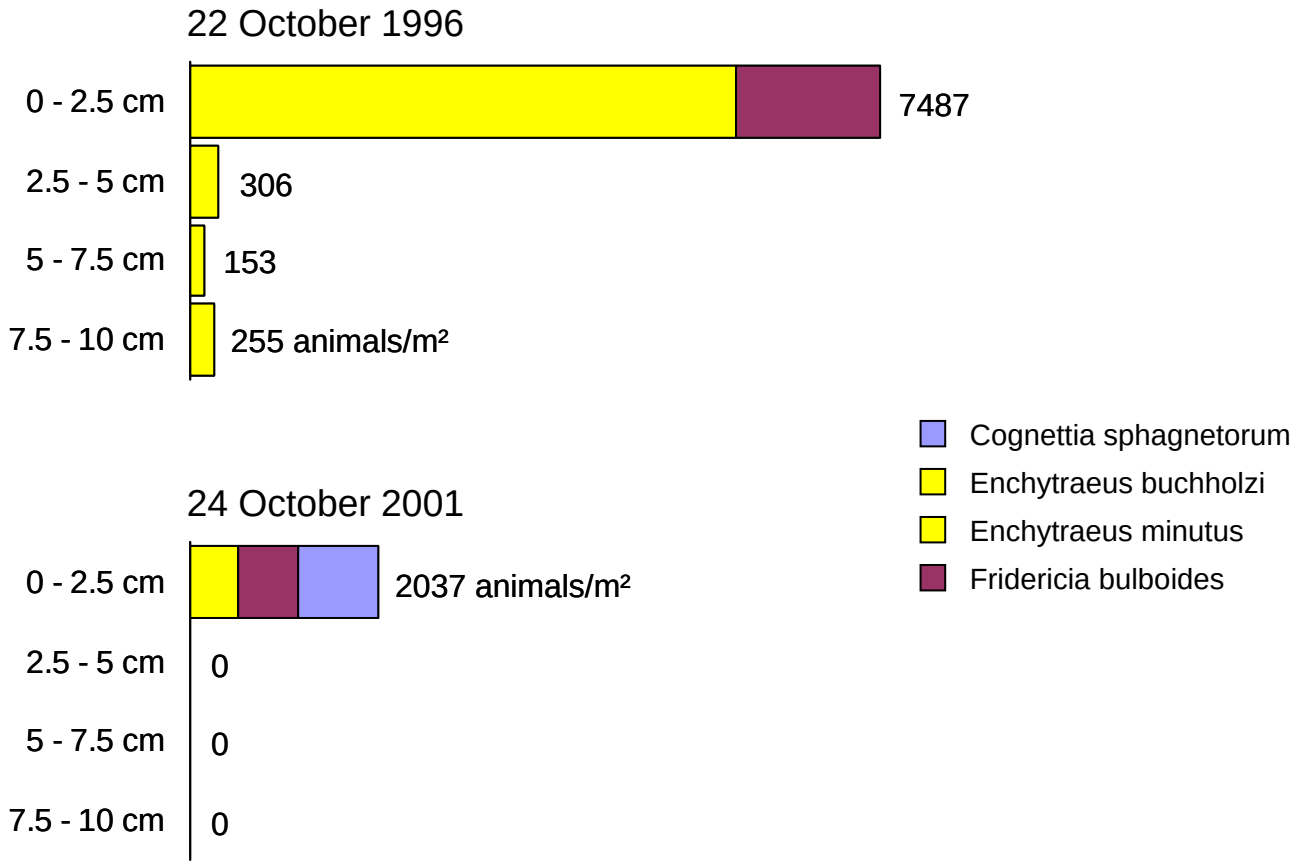
Cd concentration at soil monitoring sites in North Rhine-Westphalia



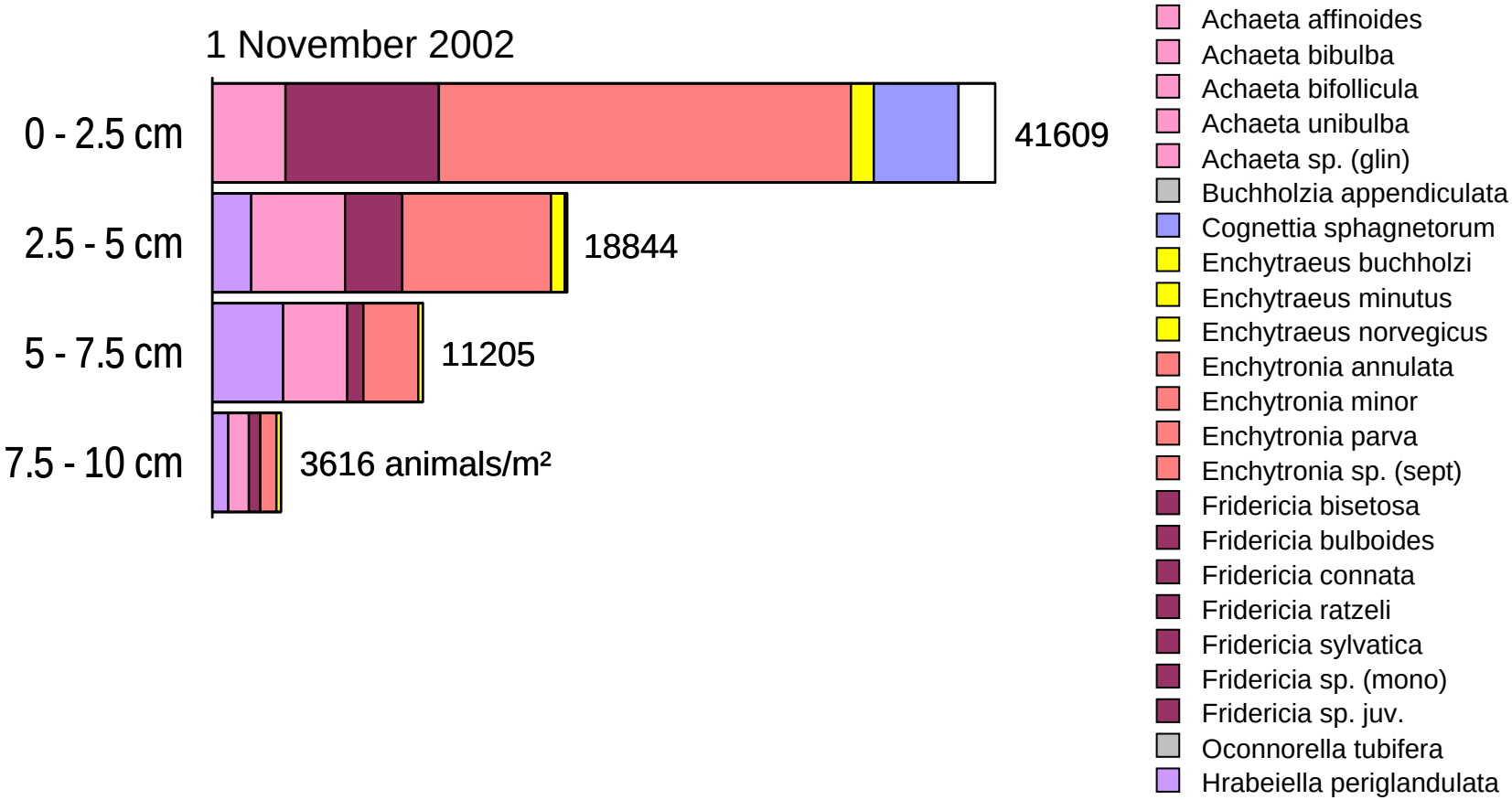

Biomass of earthworms
Epigeic earthworms
Anecic earthworms
Endogeic earthworms
g/m²
100
80
60
40
20
0
Kiel-Schrevenpark
Hamburg-Amsinckpark
Duisburg-Biegerhof


Abundance of microannelids
60.000
50.000
40.000
30.000
20.000
10.000
0
Ind./m²
Cognettia sphagnetorum
Enchytraeus species
Fridericia species
Other species
Kiel-Schrevenpark
Hamburg-Amsinckpark
Duisburg-Biegerhof

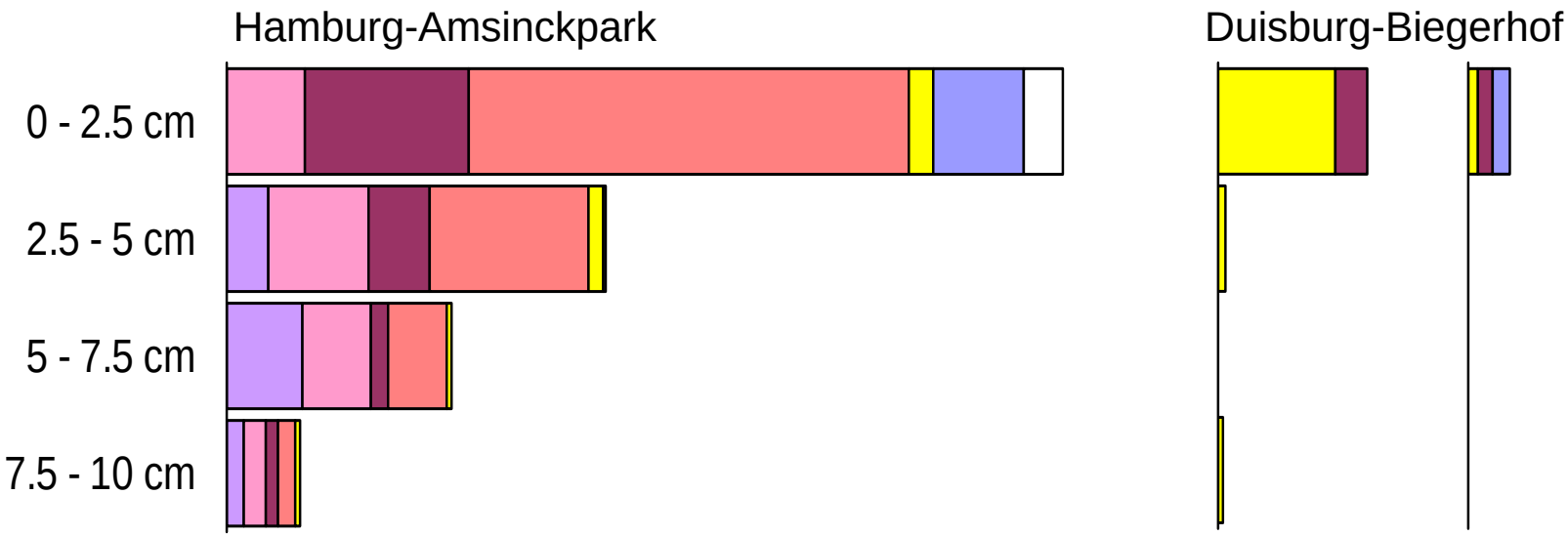
Soil monitoring site Duisburg-Biegerhof
Vertical distribution of microannelids



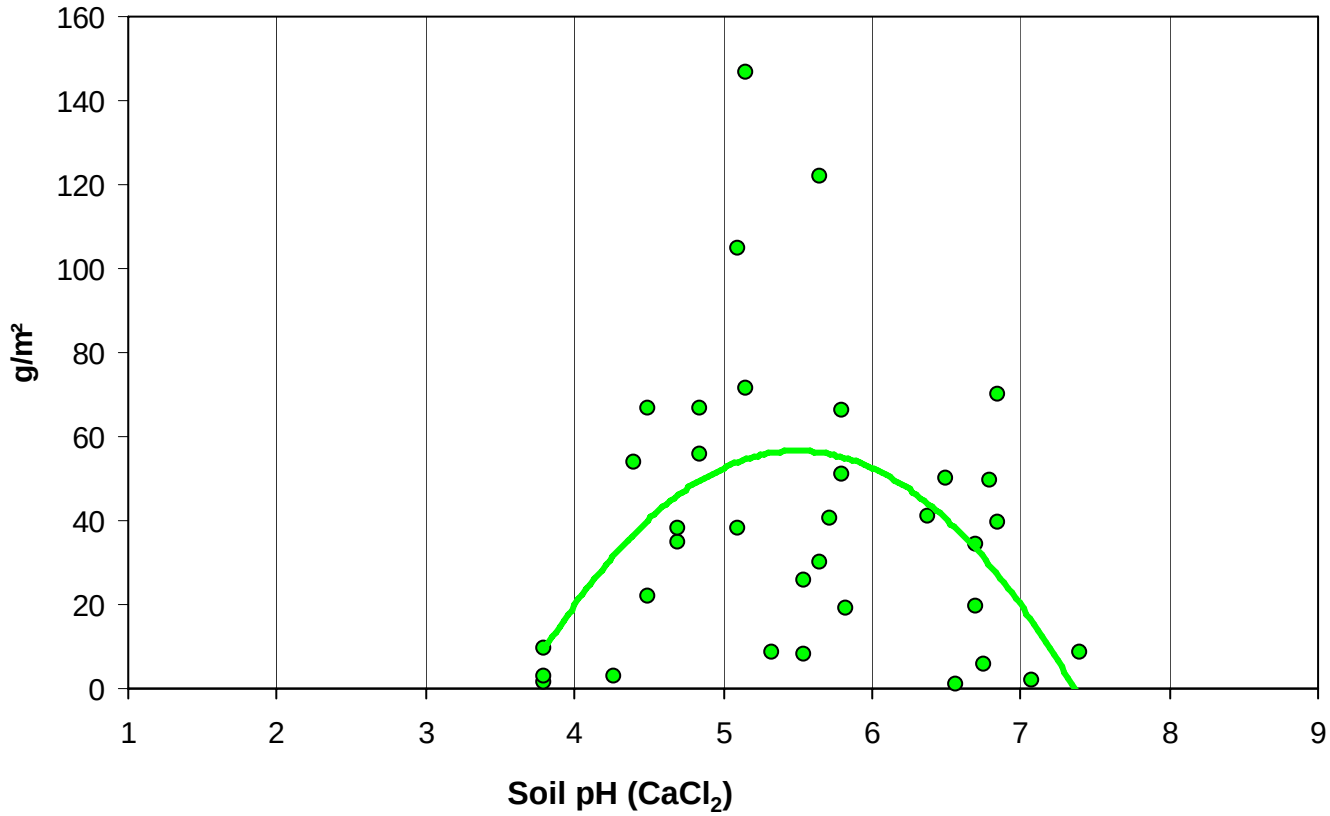
Soil monitoring site Hamburg-Amsinckpark
Vertical distribution of microannelids



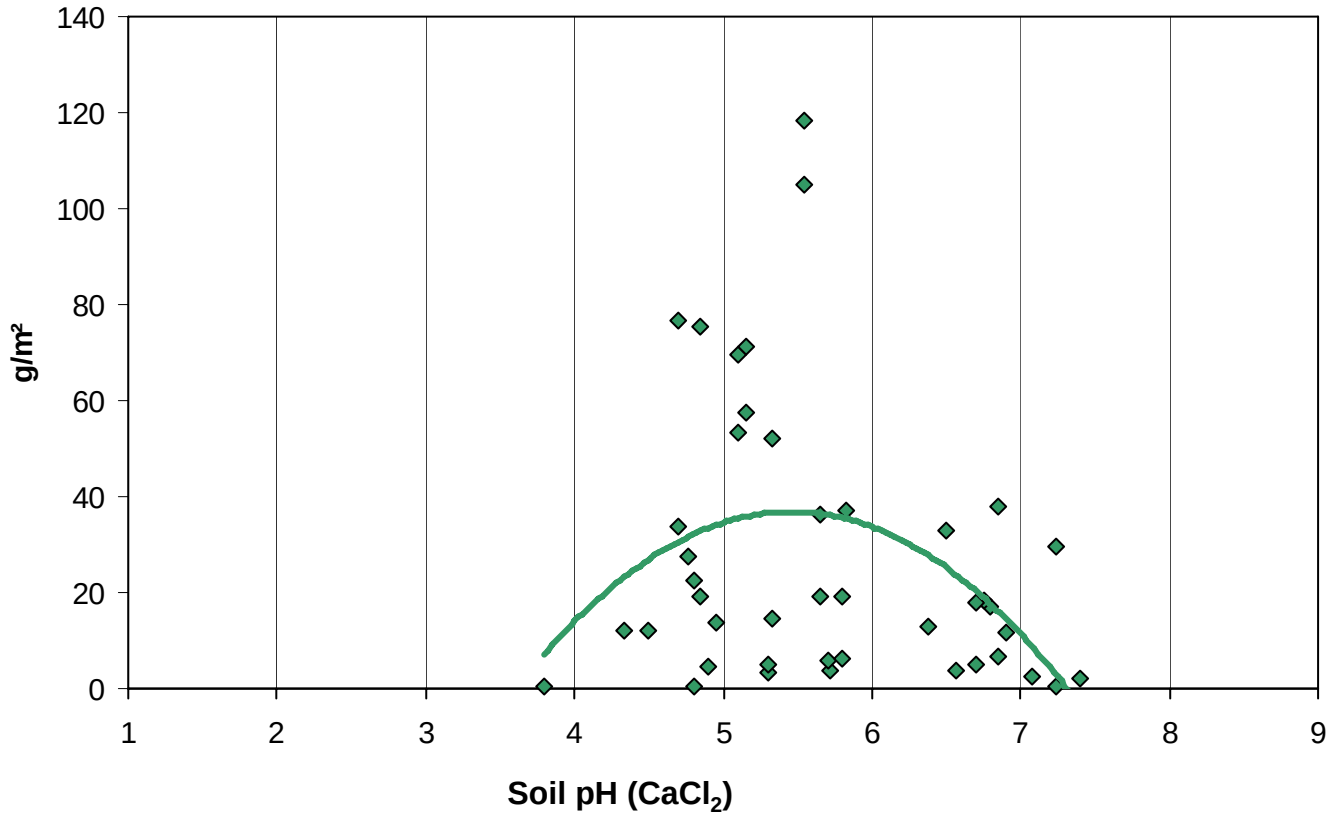
Vertical distribution of microannelids



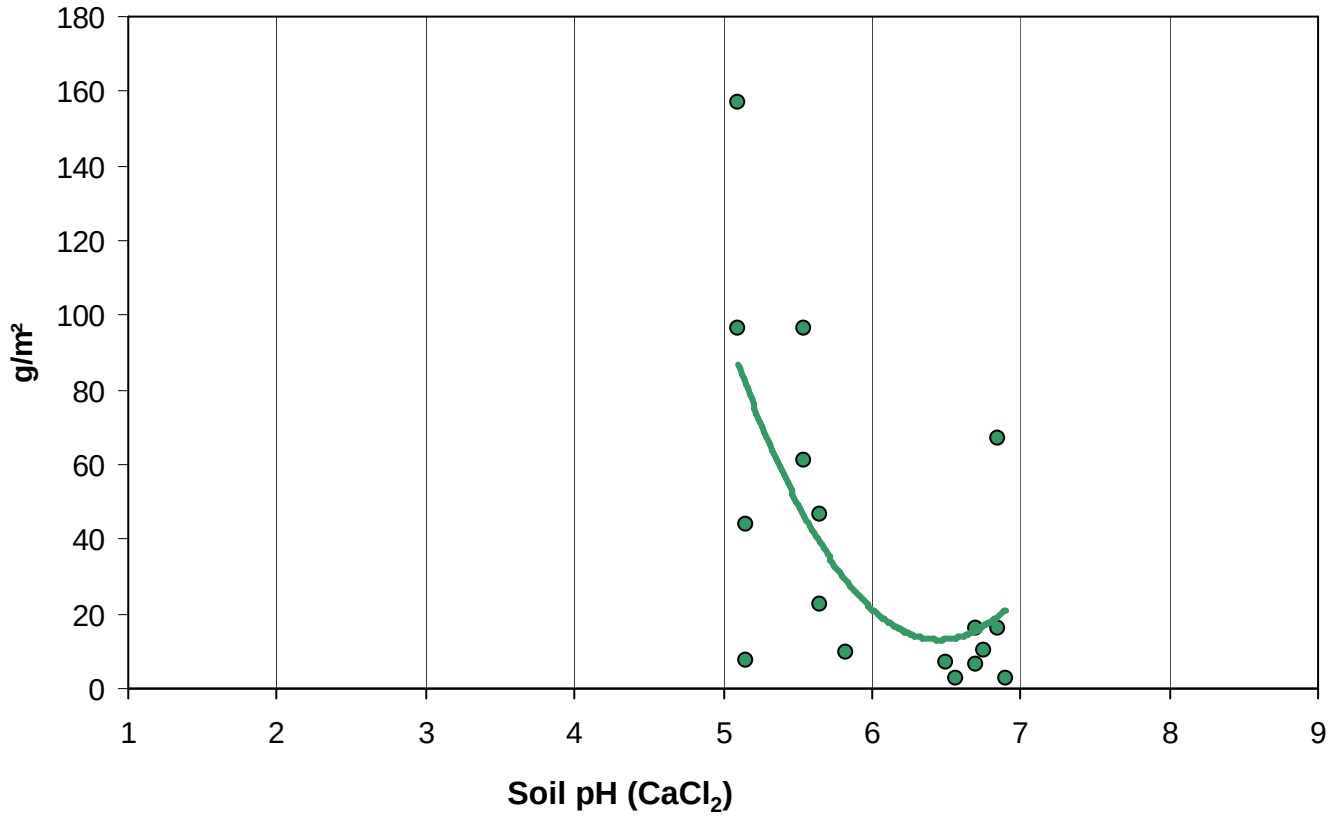
Lumbricus terrestris

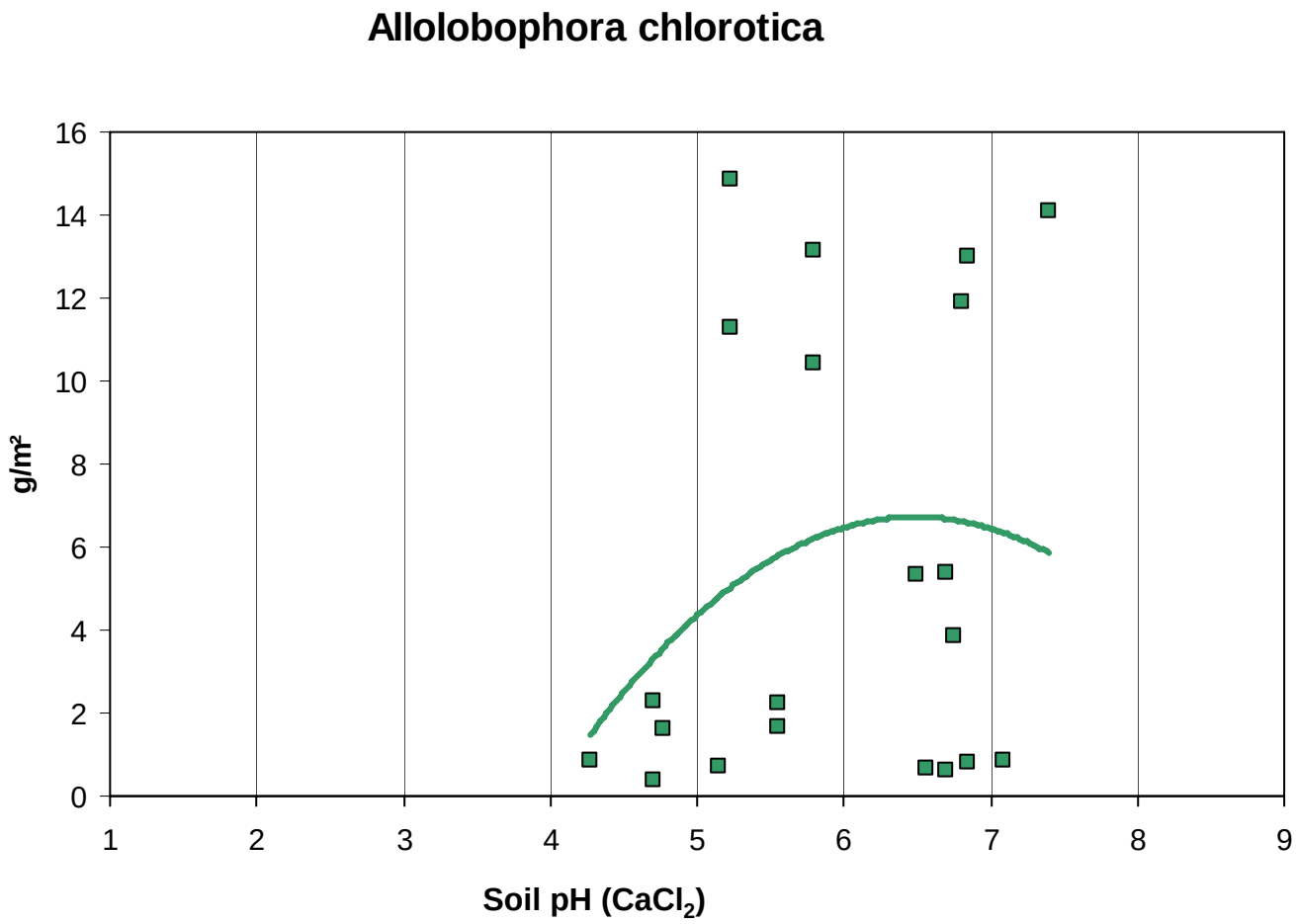


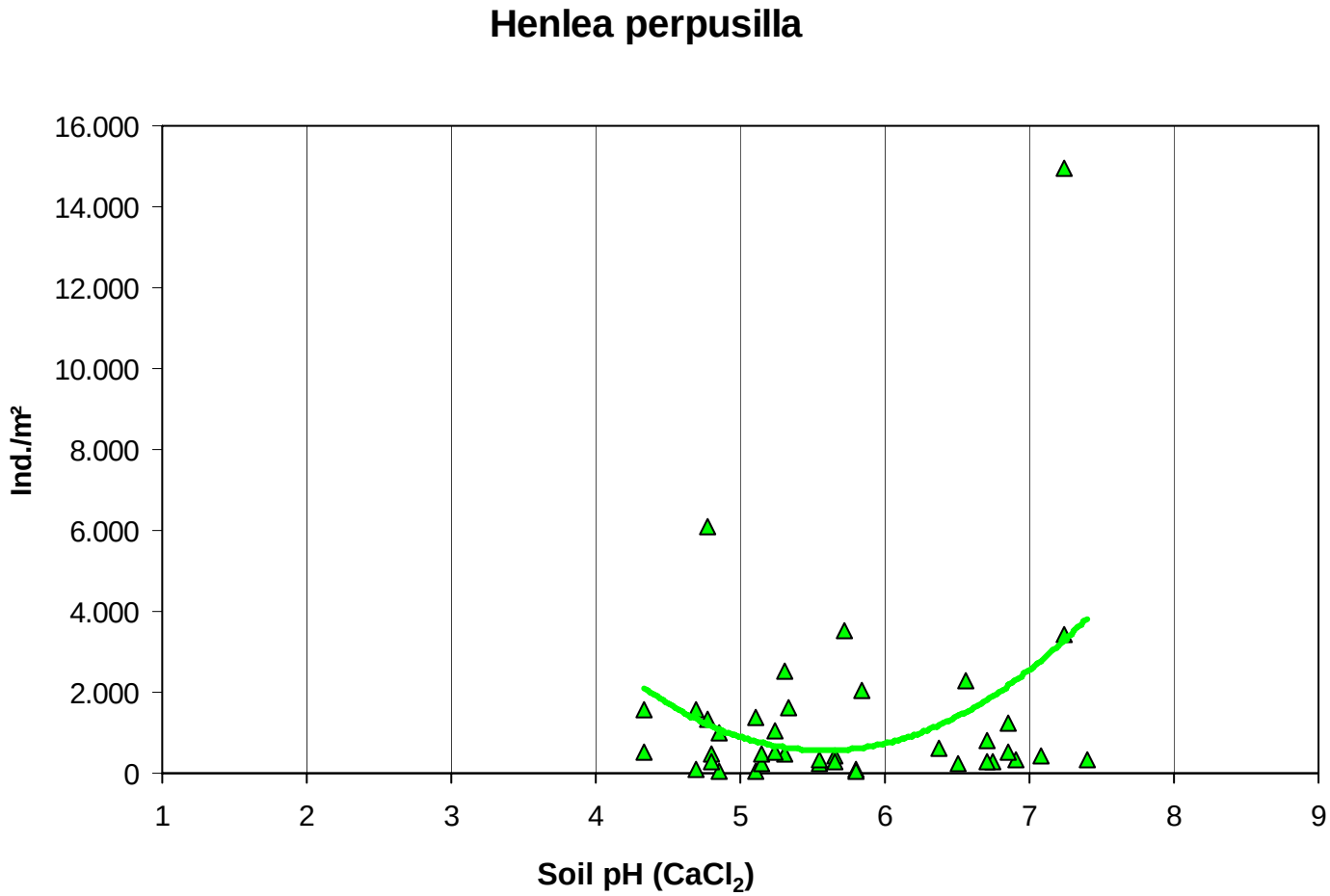
Aporrectodea caliginosa



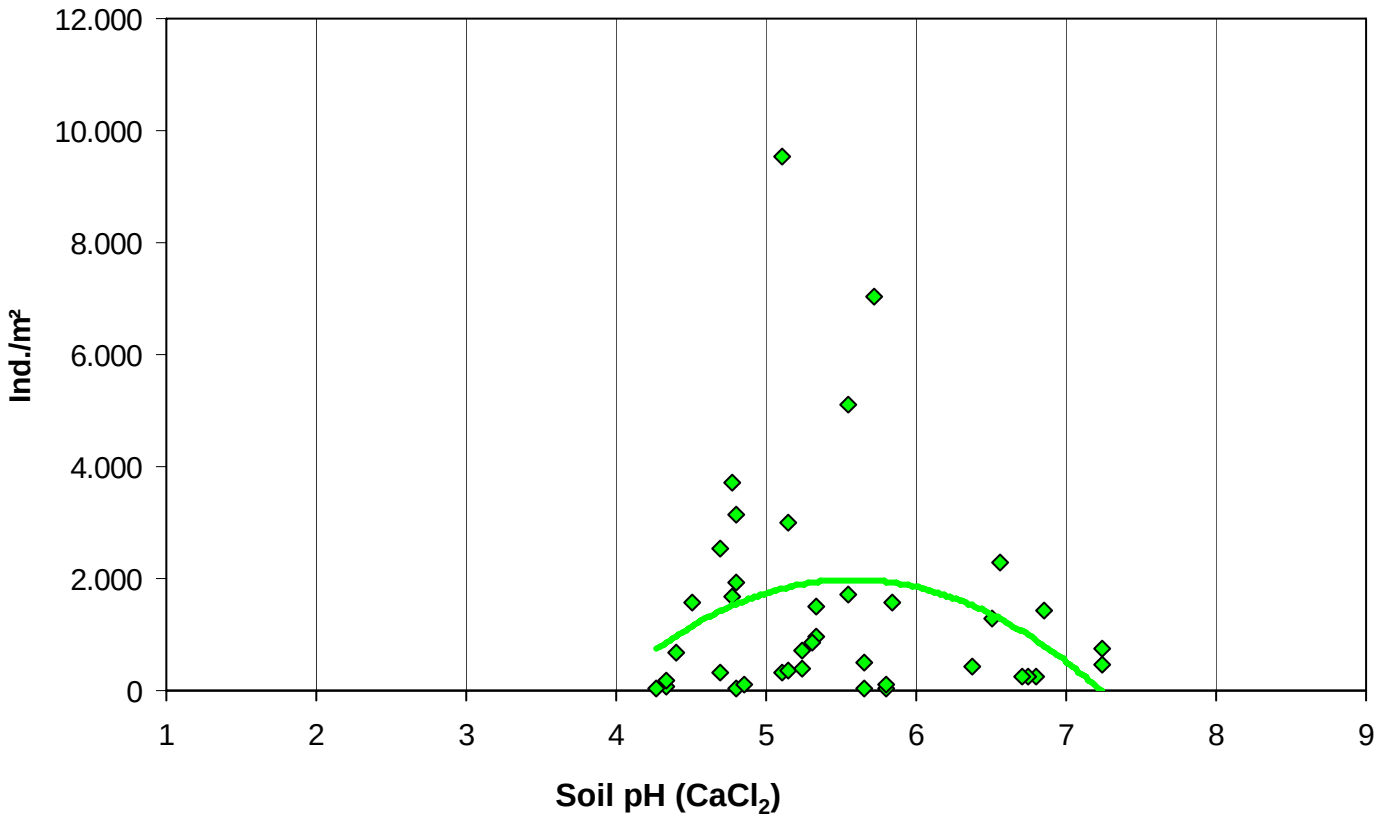
Aporrectodea longa



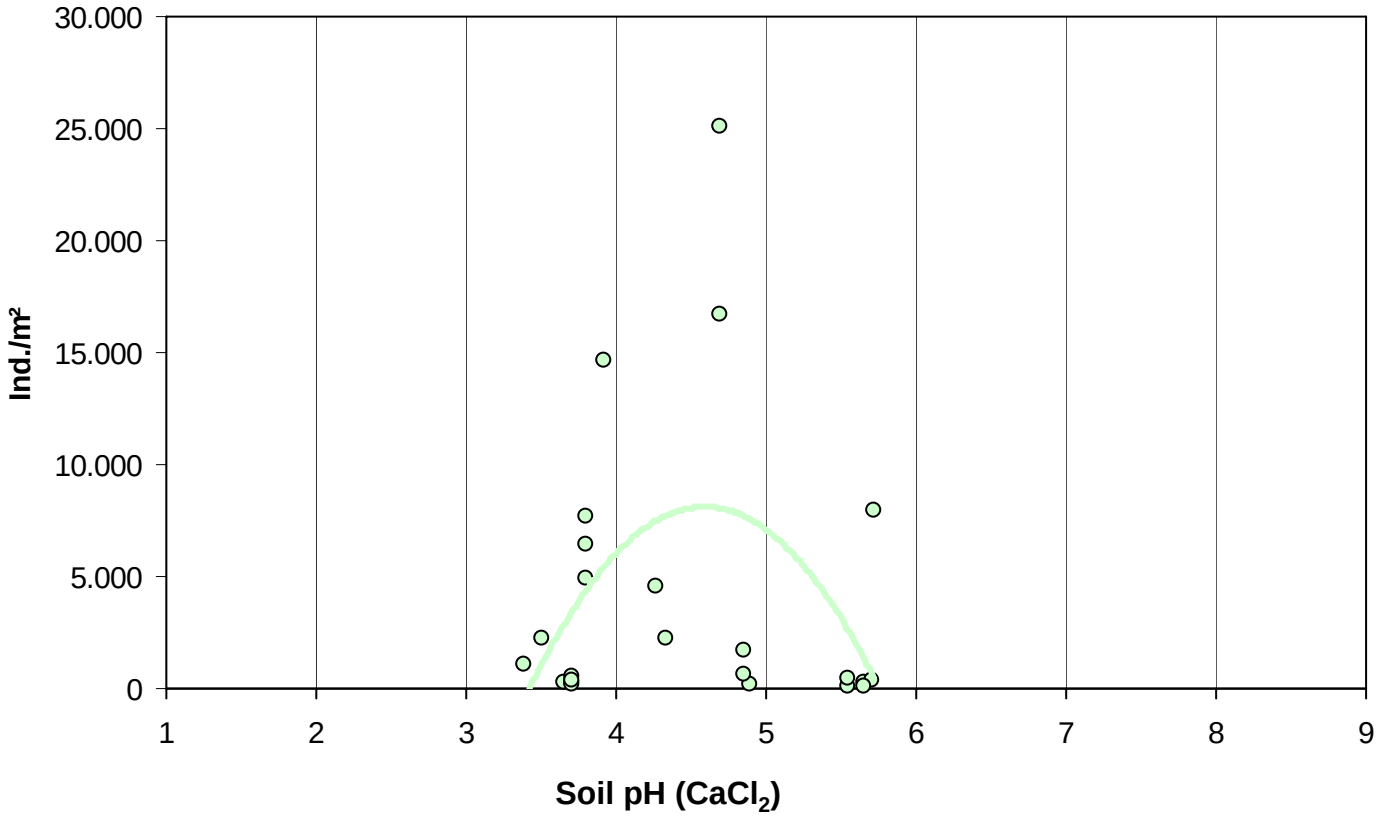

Allolobophora chlorotica
g/m²
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
Soil pH (CaCl2)


Henlea perpusilla
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0
Ind./m²
1
2
3
4
5
6
7
8
9
Soil pH (CaCl2)

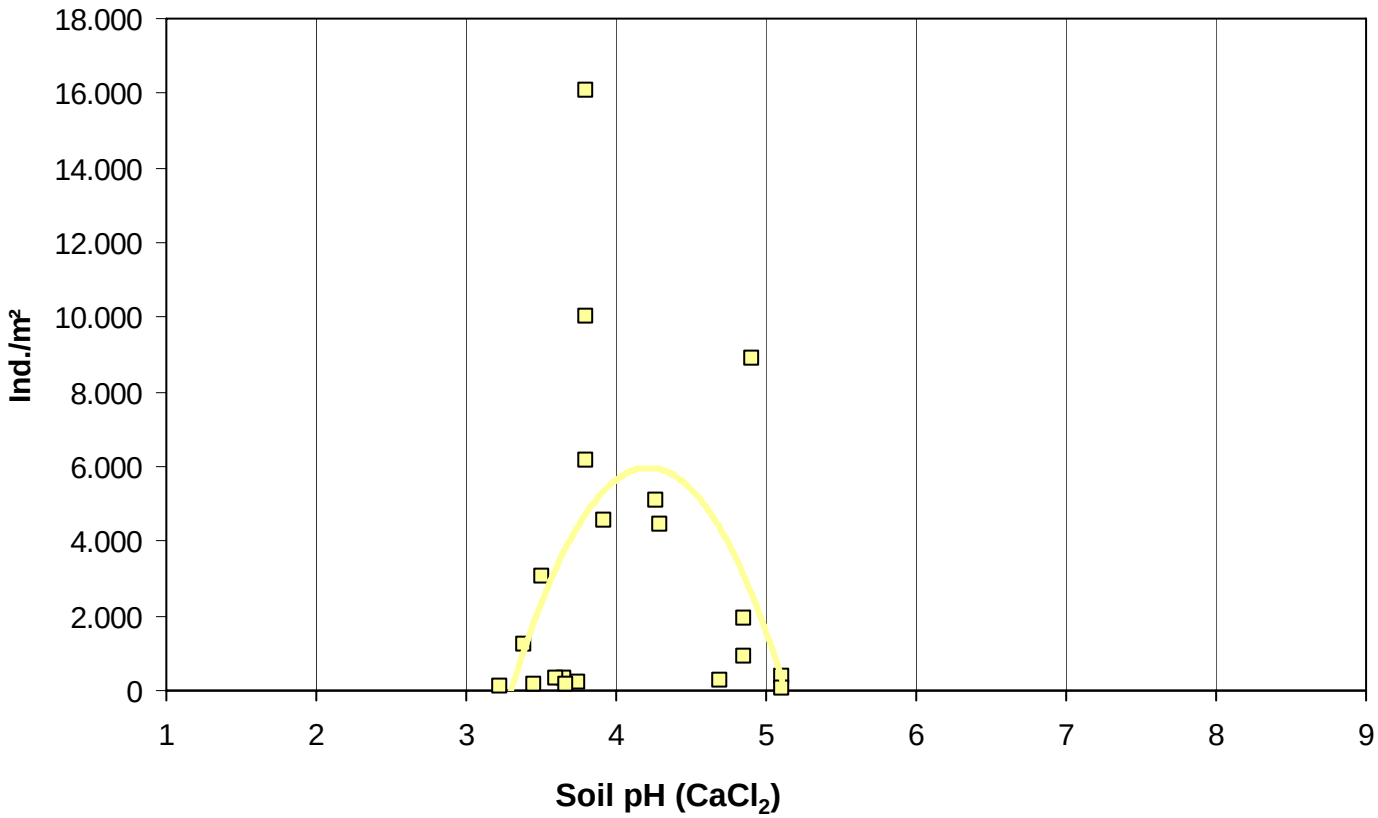
Fridericia bulboides

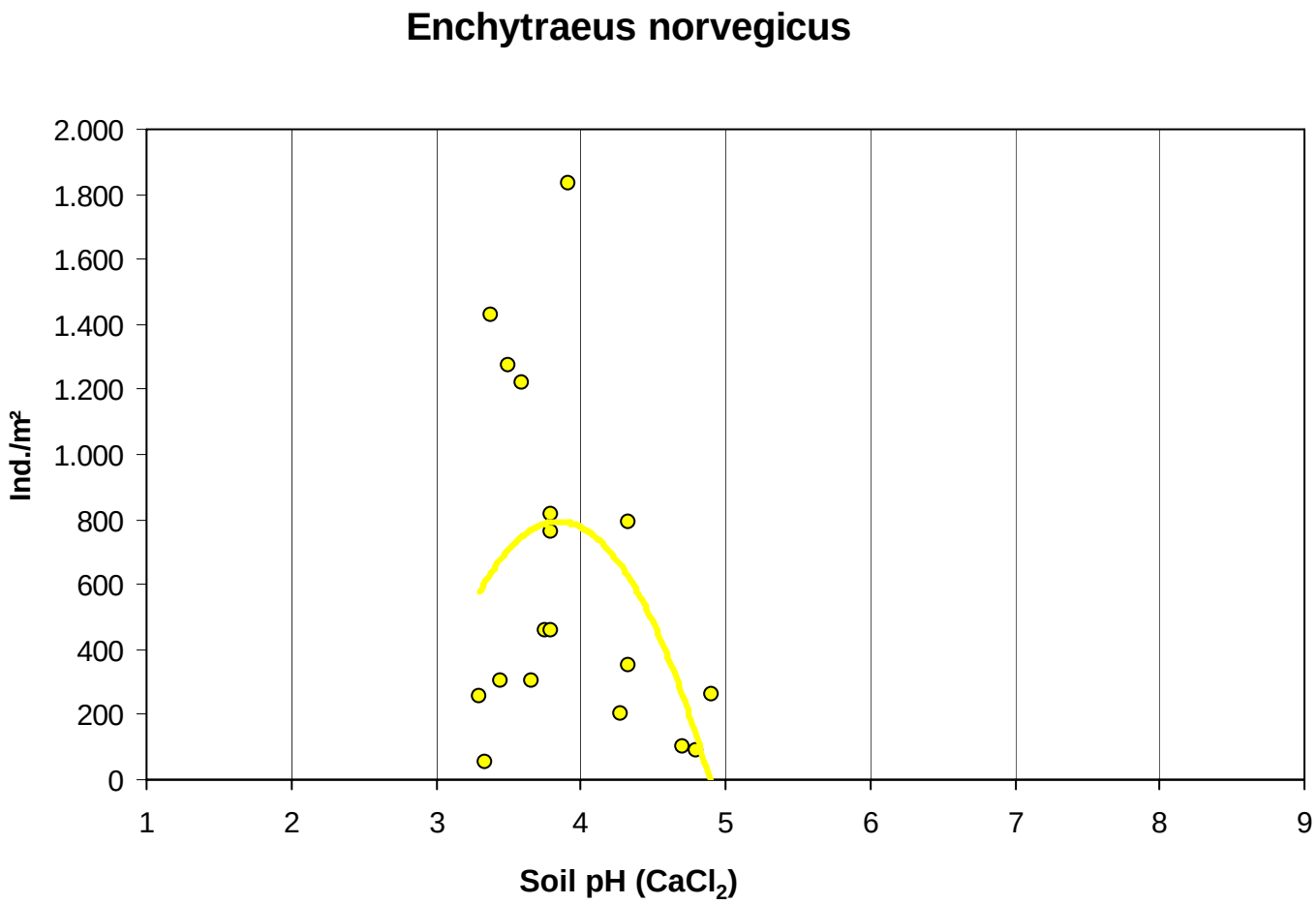


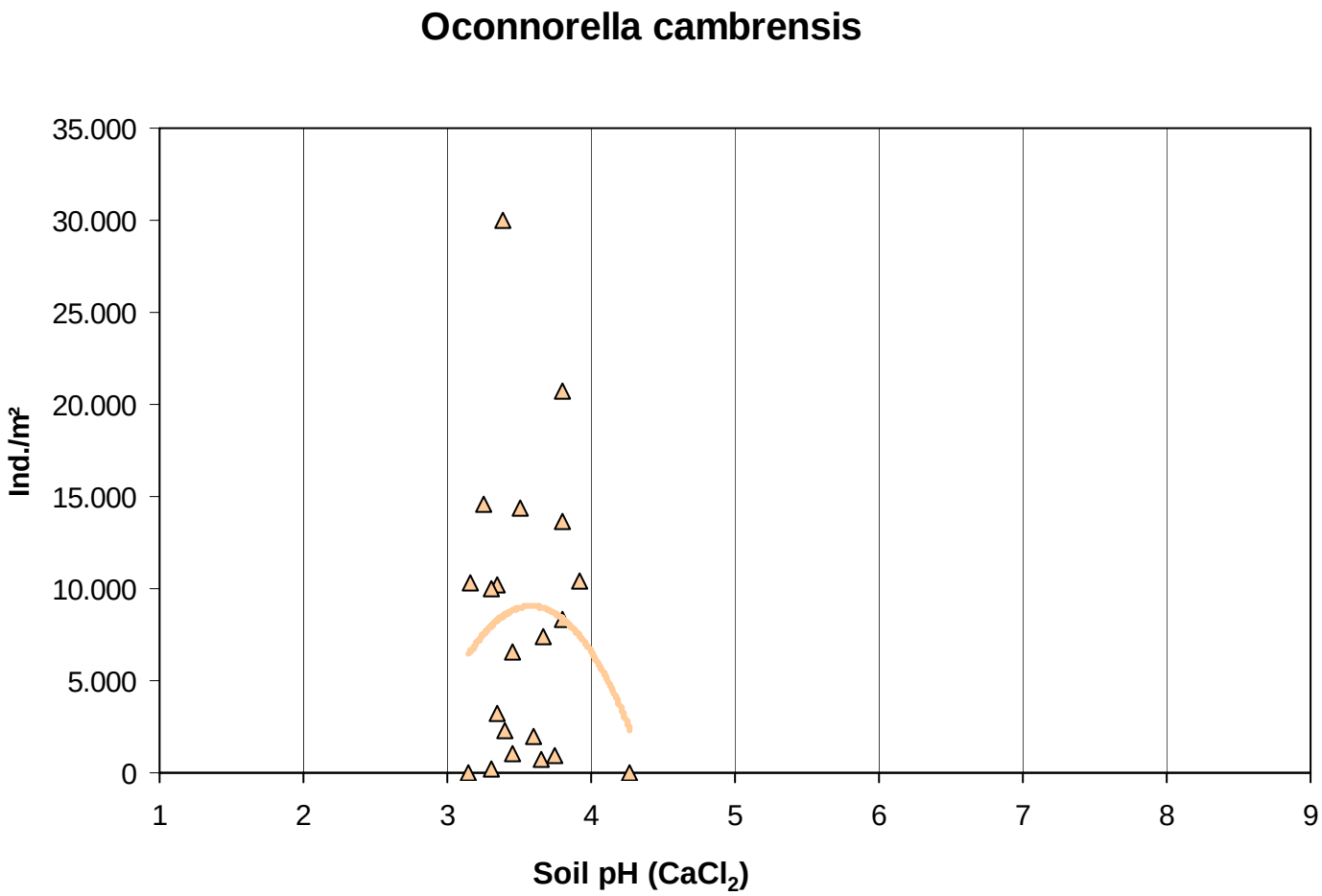
Enchytronia parva

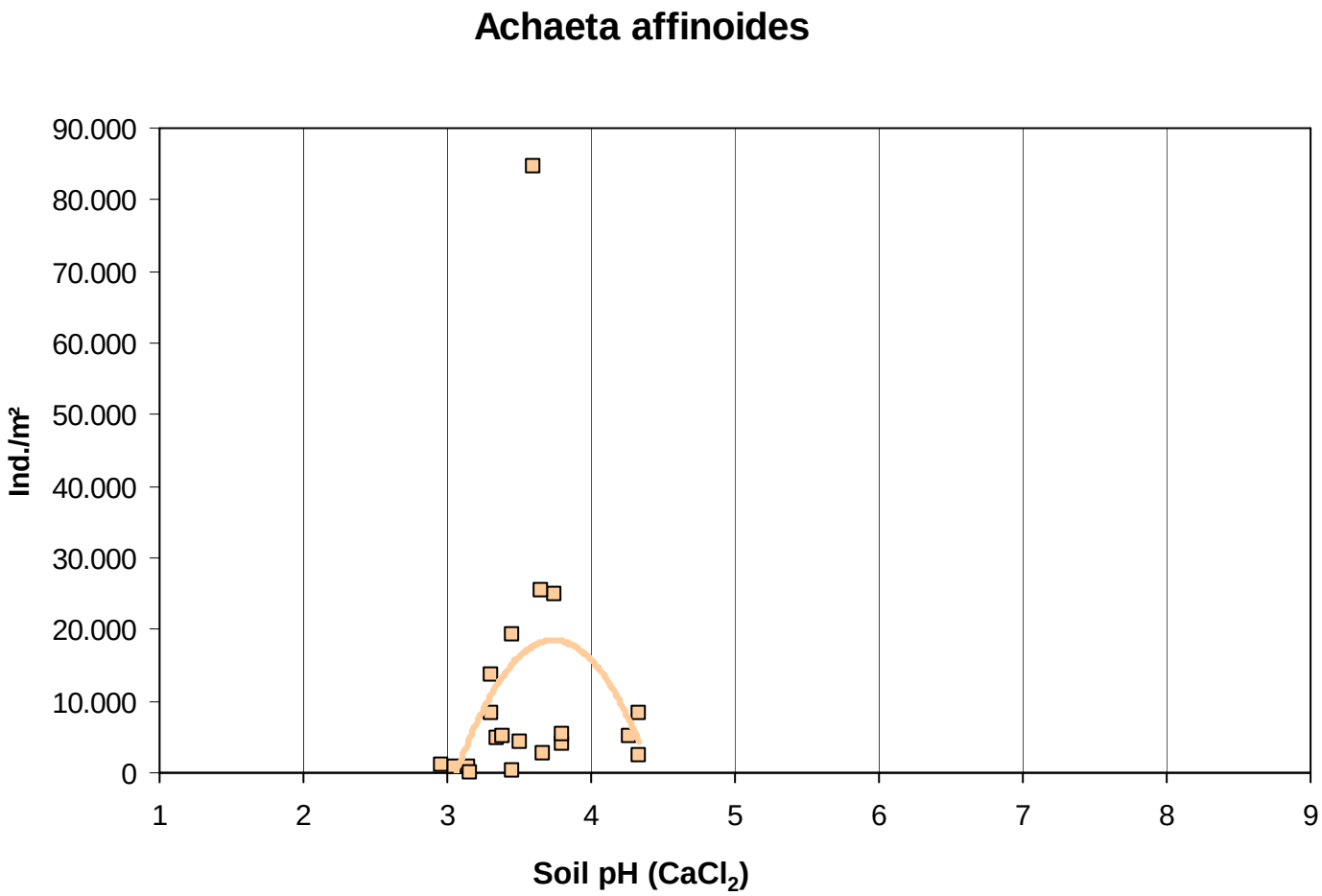


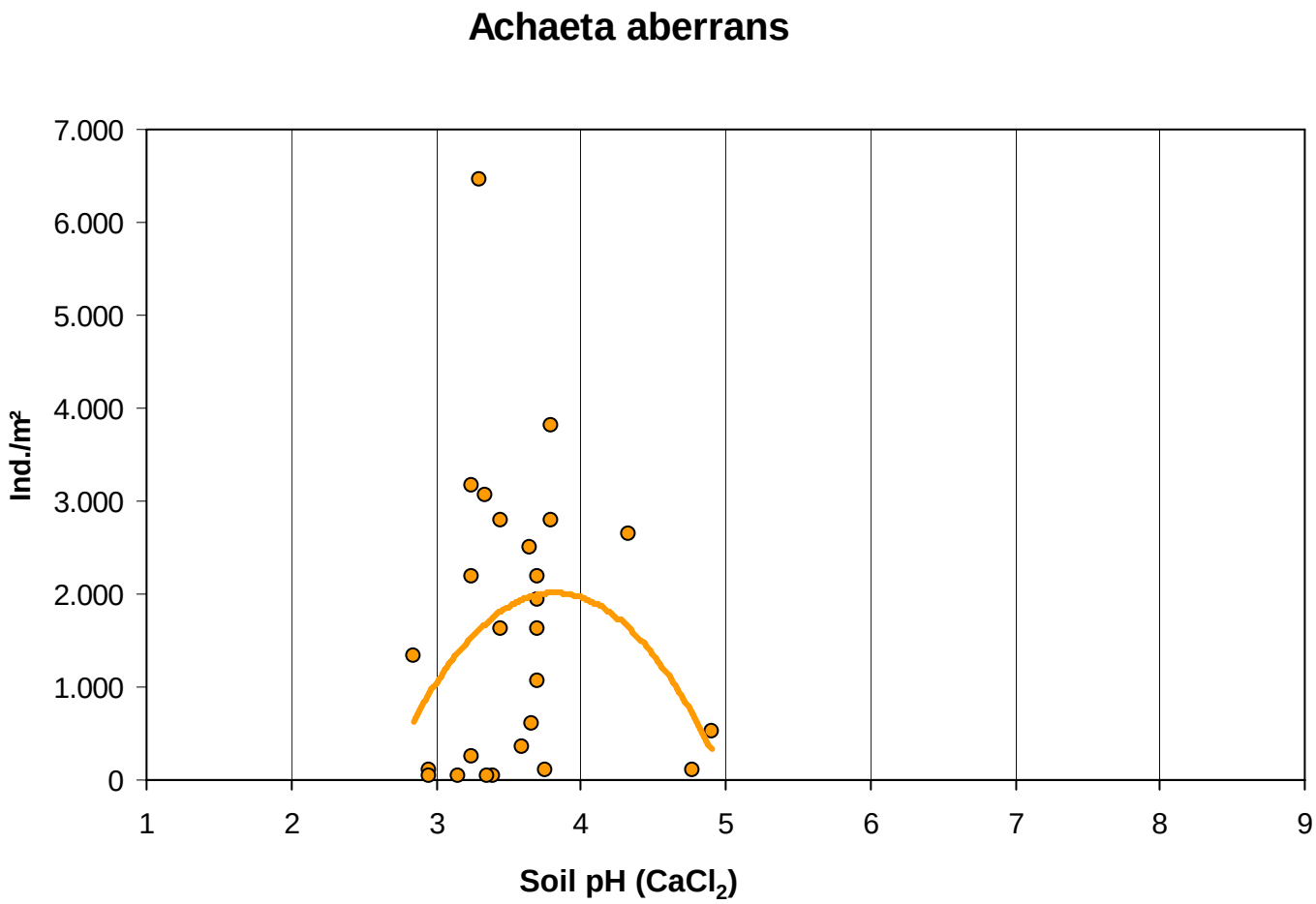
Hrabeiella periglandulata

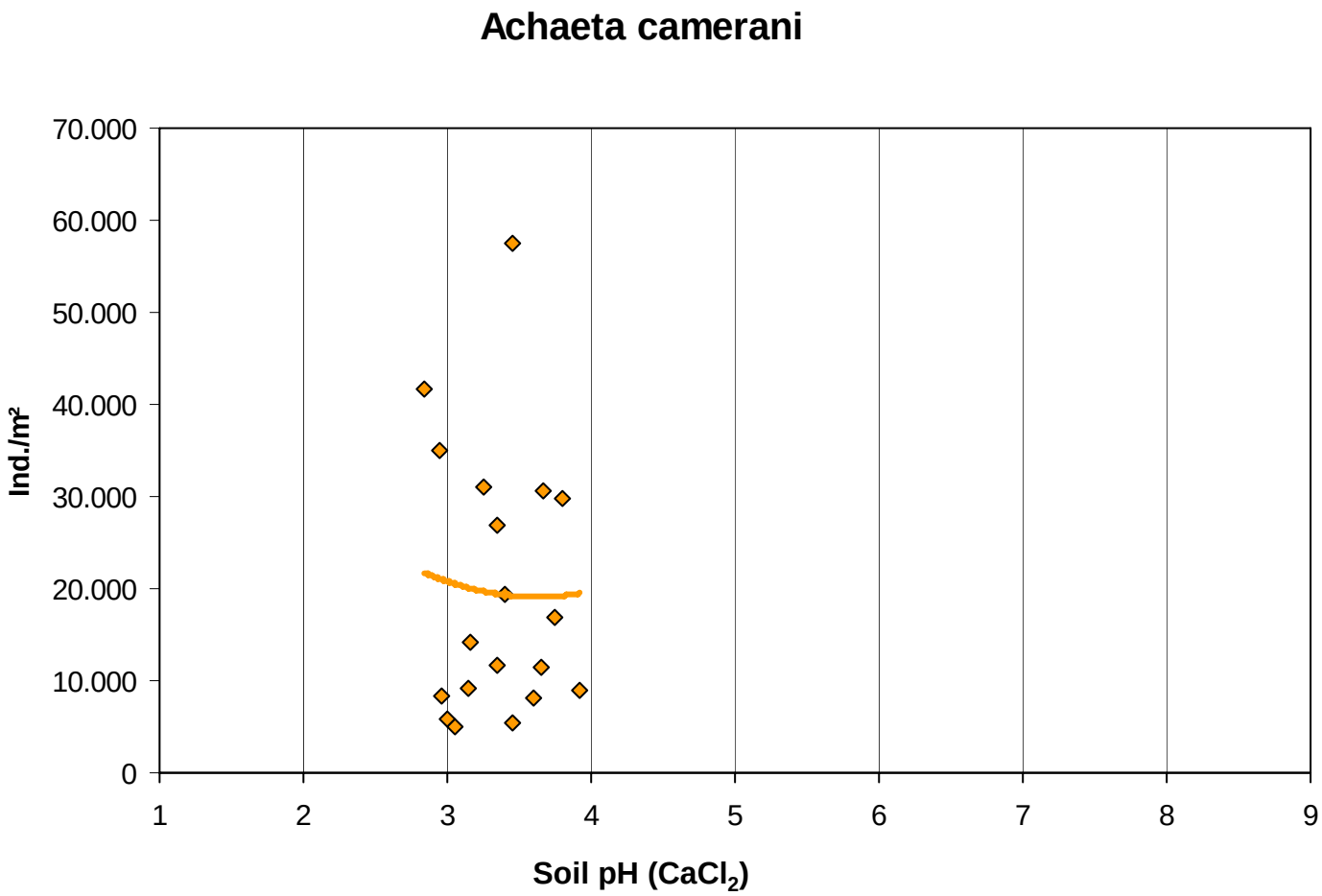


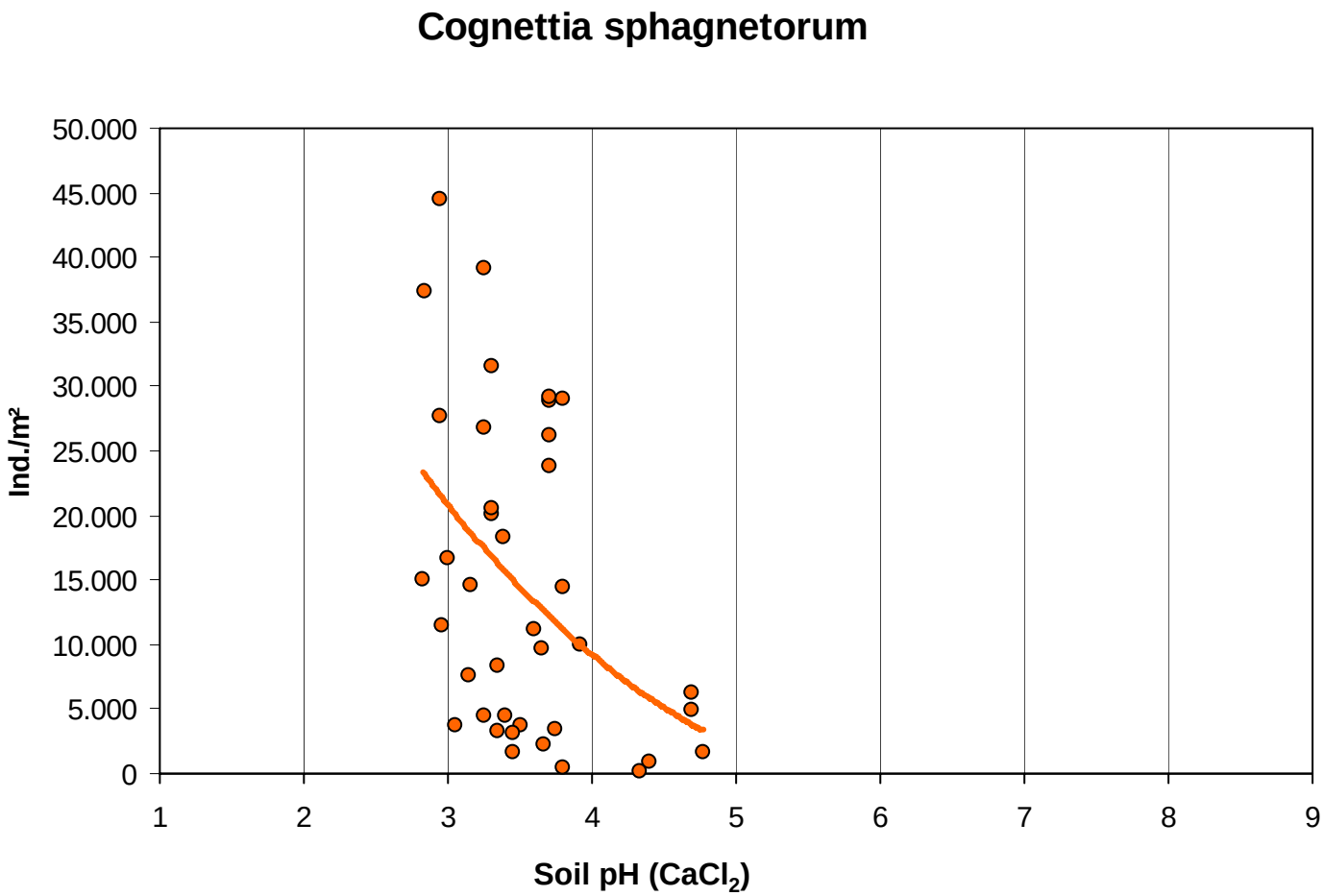

Enchytraeus norvegicus
Ind./m²
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
1
2
3
4
5
6
7
8
9
Soil pH (CaCl2)

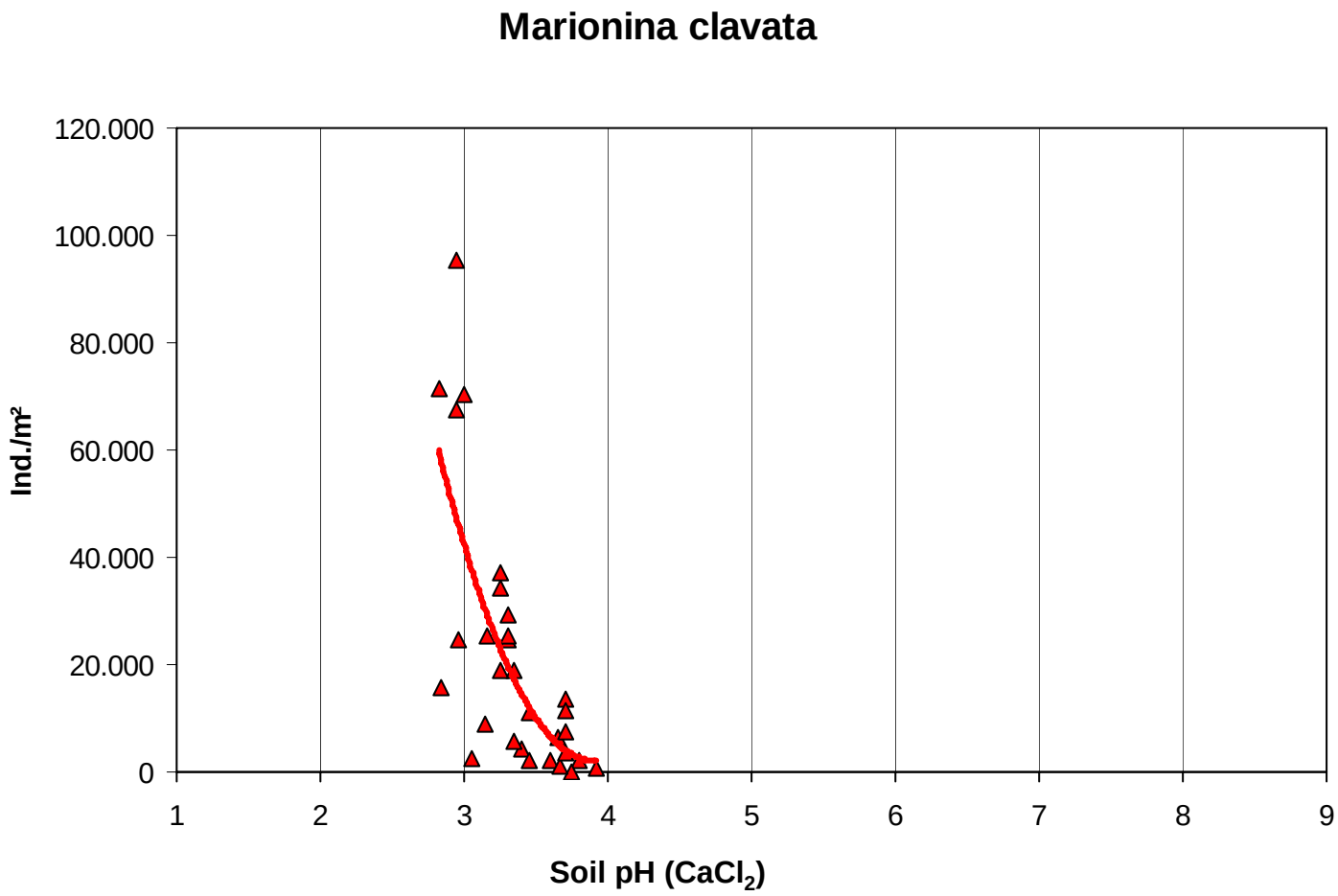

Oconnorella cambrensis
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0
Ind./m²
1
2
3
4
5
6
7
8
9
Soil pH (CaCl2)


Achaeta affinoides
90.000
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0
Ind./m²
1
2
3
4
5
6
7
8
9
Soil pH (CaCl2)

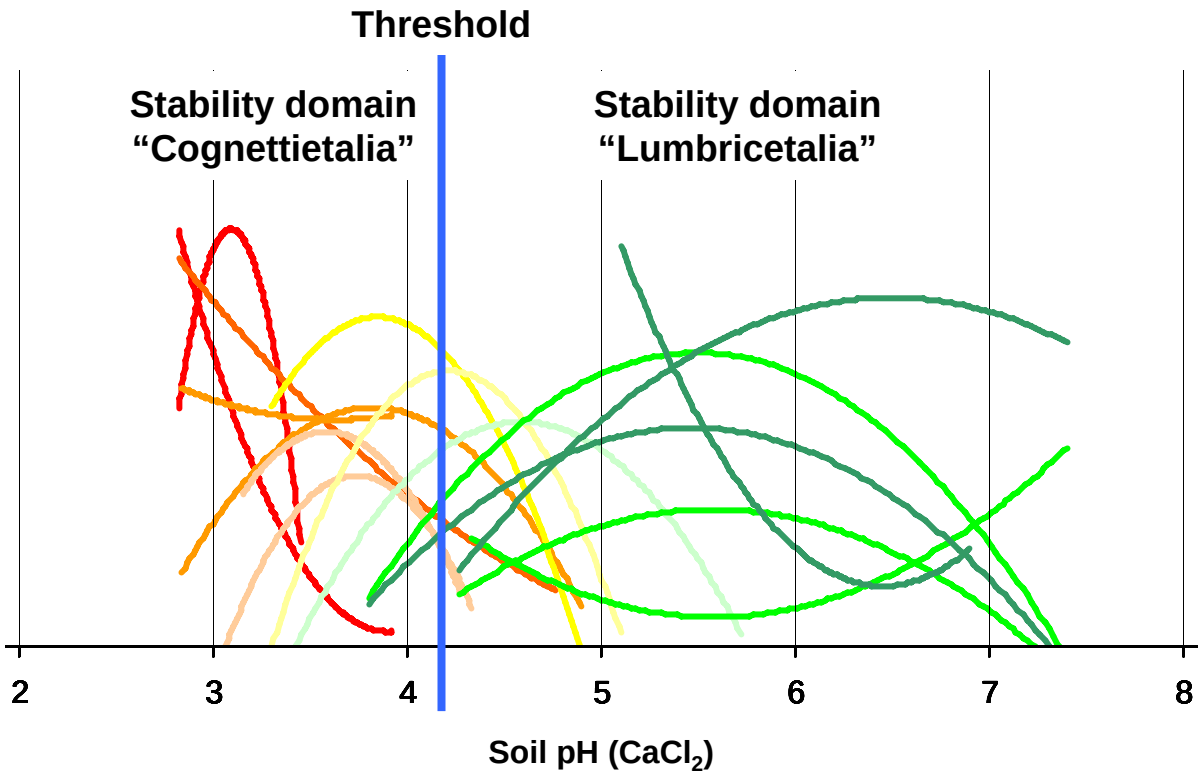

Achaeta aberrans
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0
Ind./m²
1
2
3
4
5
6
7
8
9
Soil pH (CaCl2)

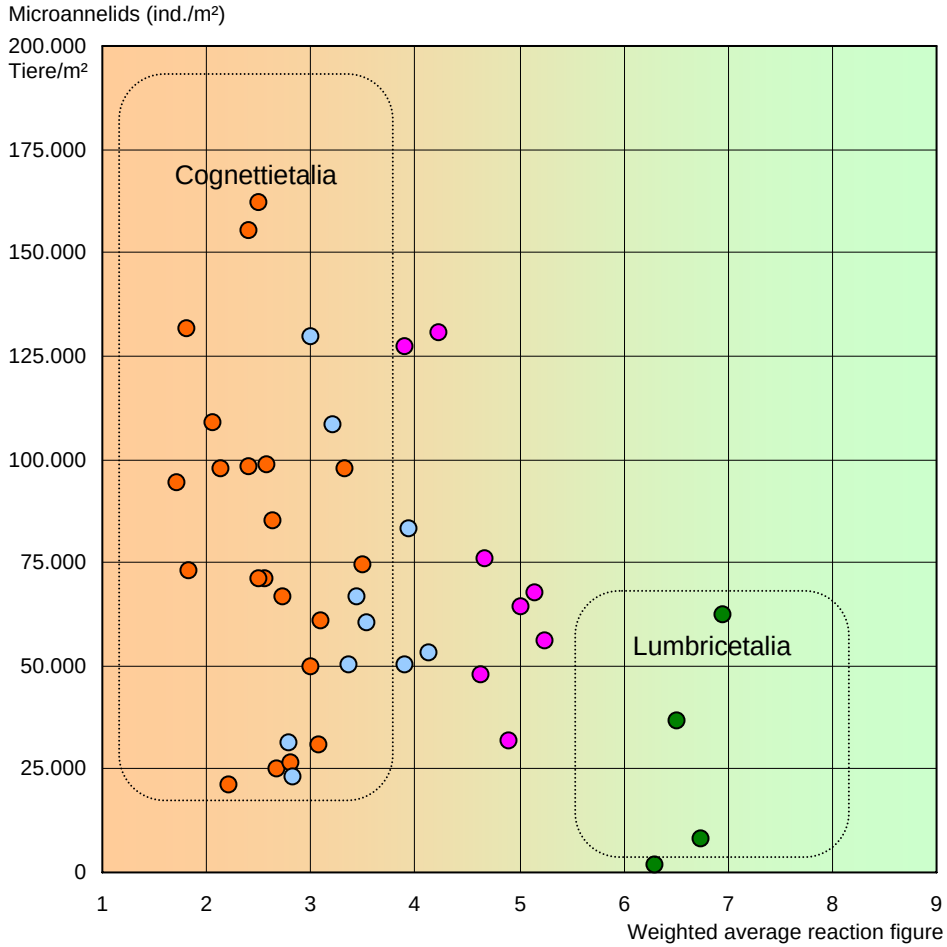

Achaeta camerani
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0
Ind./m²
1
2
3
4
5
6
7
8
9
Soil pH (CaCl2)


Cognettia sphagnetorum
50.000
45.000
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0
Ind./m²
1
2
3
4
5
6
7
8
9
Soil pH (CaCl2)


Marionina clavata
120.000
100.000
80.000
60.000
40.000
20.000
0
Ind./m²
1
2
3
4
5
6
7
8
9
Soil pH (CaCl2)

Occurence of 16 annelid species in relation to soil acidity

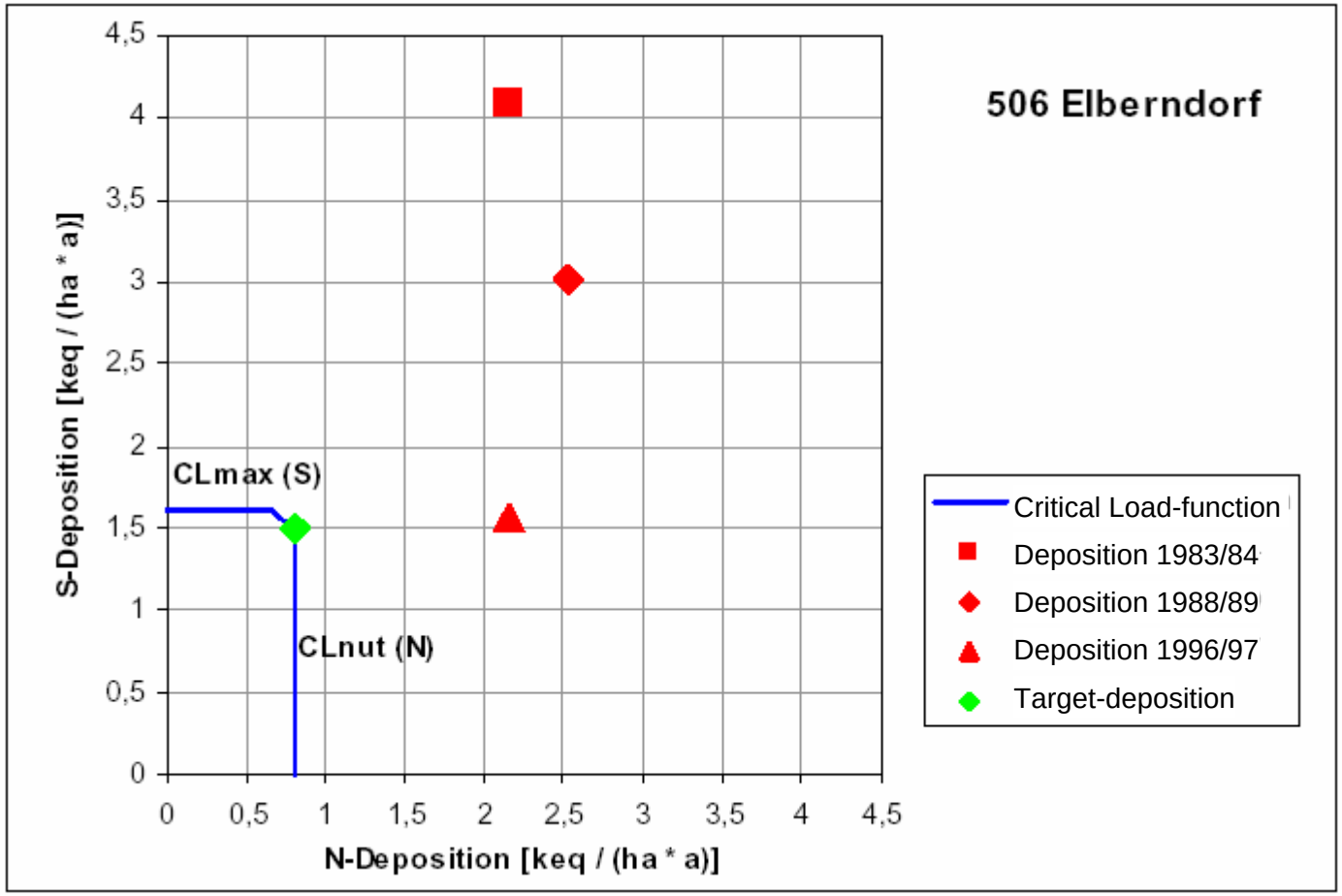




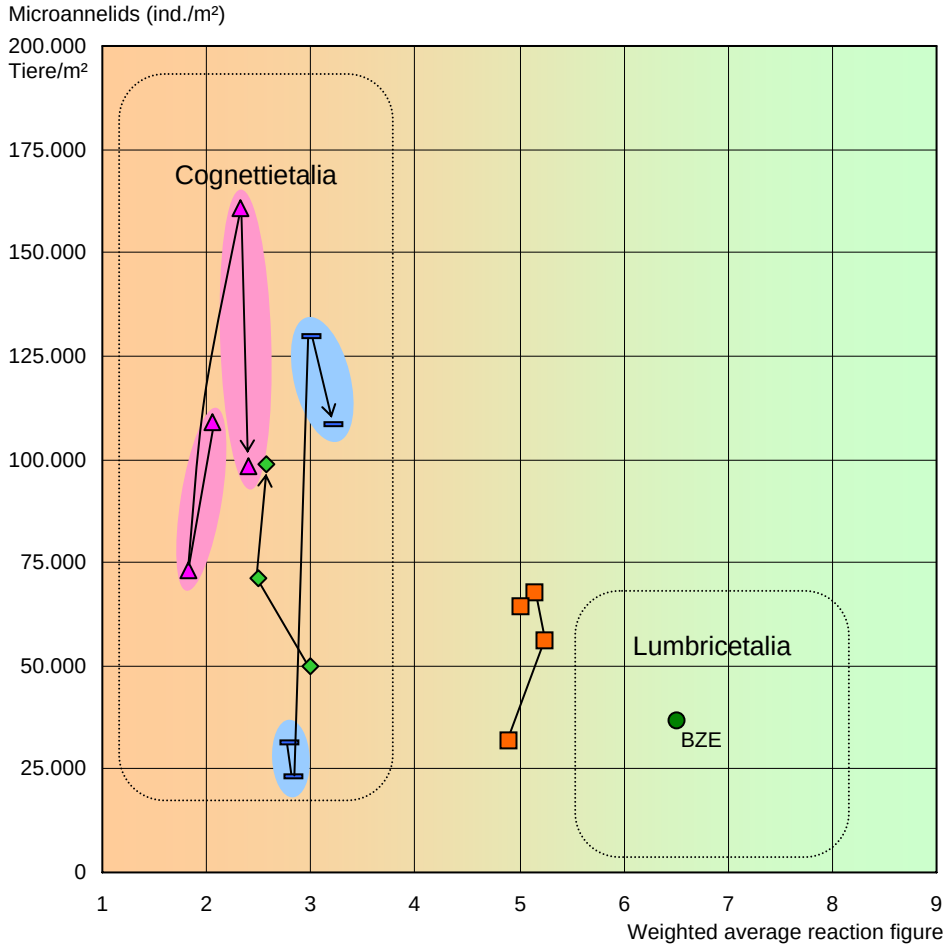
Biological soil condition at soil monitoring sites in North Rhine-Westphalia.

- Strongly acid forest sites unlimed
- Liming measures at strongly acid forest sites
- Grassland and forest sites on calcareous parent material
- Acidified forest soils on calcareous parent material

Diagram with two biological indices: the abundance of microannelids and the weighted average reaction figure of the annelid coenosis.



Exceedance of Critical Loads for sulphur and nitrogen deposition in the years 1983/84, 1988/89 and 1996/97 at the forest monitoring site Elberndorf (North Rhine-Westphalia) (from Gehrmann 2002).



Trends of biological soil condition at forest monitoring sites in North Rhine-Westphalia (Level II).

Elberndorf spruce
nov.1988, nov.1989, nov.1995, nov.2000

Elberndorf spruce limed
nov.1988, nov.1989, nov.1995, nov.2000

Elberndorf beech
nov.1988, nov.1989, nov.1992

Schwaney beech
mai 1989, apr.1993, mai 1996, mai 2001

Diagram with two biological indices: the abundance of microannelids and the weighted average reaction figure of the annelid coenosis.

Outlook

The presented system applies well to the temperate zone of the Northern Hemisphere.

It should be further elaborated by extending the investigations to other climatic regions such as the Mediterranean and the boreal zone.

The system is open for the integration of other taxonomical groups, if they are more appropriate in specific regions.

In the context of an European soil monitoring system it can be the tool for predicting biological responses to climate change and other environmental impacts on soil biodiversity.

Thank you for your attention !