Society of Nematologists Workshop

Computation of Nematode community indices

Instructors:

Deborah Neher
Tom Bongers
Howard Ferris

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Agenda

1. <u>Conceptual basis of maturity indices, diversity, ratios (Bongers and Neher)</u>
   a. What do they mean: ecological framework and interpretation
   b. Mechanics of calculation: maturity index, diversity, trophic group ratios
   c. variations of diversity indices: genus, family, trophic
   d. variations of trophic group ratios, e.g., F/B, F/(F+B), (F+B)/PP[1]

2. <u>Updates to maturity (Ferris and Bongers)</u>
   a. Bongers, Wasilewska proposed changes to CP value assignments
   b. MI MI25, PPI, MI:PPI, versus ΣMI
   c. Handling debatable classification - Filenchus, Tylenchus etc. and the impact it has computation of MI, PPI, FB etc.
   d. Channel / enrichment / structural trajectories

3. <u>Other community indices, i.e., richness, evenness (Neher)</u>

4. <u>Statistical analysis of these indices (Neher)</u>
   a. normality and transformations
   b. statistical reliability and stability, e.g., FB vs F/FB

5. <u>Practice computing indices on example datasets using EXCEL and SAS (Neher and Ferris)</u>

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[1] F = fungivore, B = bacterivore, PP = plant-parasite

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I. **Maturity Indices:**

weighted mean frequency, MI or PPI = $\sum \dfrac{v_i \times f_i}{n}$ where v_i = colonizer-persister (c-p) value

assigned to family, f_i - frequency of family i in sample, n = total number of individuals in a sample.

Interpretation:
- A maturity index for free-living taxa (MI) may be viewed as a measure of disturbance, with smaller values being indicative of a more disturbed environment and larger values characteristic of a less disturbed environment. The MI decreases with increasing microbial activity and pollution induced stress.
- A maturity index for plant-parasitic taxa (PPI) may or may not correlate positively with MI
  - Inverse relationship (Bongers et al. 1997)
  - Direct relationship (Neher and Campbell 1994)

Calculation by Excel Spreadsheet:
1. Enter CP value for each taxon
   a. Determine family (follow Bongers 1987)
   b. Find corresponding CP value (follow Bongers and Bongers 1998, Table 1)
2. Calculate weighted proportion (cp value x relative abundance) for each taxon/row using a formula such as =(H5*I5)/100
3. Sum the weighted proportions for all rows to give a column total to get ΣMI15, using a formula such as =SUM(J5:J44)

MI (free-living nematodes only, all five cp values)
- Delete all values within the column for plant-parasitic nematodes
- Compute a sum of the weighted proportions for all rows that contain free-living nematodes (feeding = 2, 3, 5, 8)

MI25 (free-living nematodes only, excluding nematodes with cp=1)
- Delete all values within the column for plant-parasitic nematodes and free-living nematodes with a cp=1
- Compute a sum of the weighted proportions for all rows that contain free-living nematodes (feeding = 2, 3, 5, 8)
- To differentiate MI-decrease caused by enrichment and pollution, it is better to omit cp-1 if the MI is used to measure stress.

PPI (plant-parasitic nematodes only)
- Delete all values for free-living nematodes
- Compute a sum of the weighted proportions for all rows that contain plant-parasitic nematodes (feeding = 1)

ΣMI25 (combined free-living and plant-parasitic nematodes without cp= 1)
- Delete all values for cp=1
- Compute a sum of the weighted proportions for all rows that have cp 2-5

II. **Channel Index, Enrichment Index, Structure Index** (Ferris et al. 2001)

Consider that the nematode fauna provide information on two major characteristics of the soil environment and its resident communities. One characteristic is the flow of resources into the food web system as indicated by enrichment opportunist species; the other is the trophic connectance of the system as indicated by prevalence and abundance of higher trophic level organisms.

The Enrichment Trajectory and the Structure Trajectory, both based on the indicator importance of functional guilds of nematodes, are descriptors of food web condition. The trajectories allow us to quantify soil food web state through the Enrichment Index (a measure of opportunistic bacterivore and fungivore nematodes), the Channel Index (indicator of predominant decomposition pathways) and the Structure Index (indicator of food web state affected by stress or disturbance). Functional guilds are defined as a matrix of feeding habits and the biological, ecological and life history characteristics embodied in the cp classification. Thus, the Ba3 functional guild comprises cp3 bacterivores such as those in the Teratocephalidae or Prismatolaimidae(?). Nematodes of all feeding habits classified as cp2 are considered basal (b) to both enrichment and structure trajectories. Bacterial-feeding cp1 and fungivores in cp2 are indicators of enrichment (e) while nematodes of all feeding habits in cp3-5 are indicators of structure (s). Functional guild indicators are weighted according to growth and metabolic rates (resource utilization) on the enrichment axis, and according to sensitivity to disturbance on the structure trajectory.

Then

$b = (Ba_2 + Fu_2) \, W_2$ where $W_2 = 0.8$,
$e = (Ba_1 W_1) + (Fu_2 W_2)$ where $W_1 = 3.2$ and $W_2 = 0.8$
$s = (Ba_n W_n) + (Ca_n W_n) + (Fu_n W_n) + (Om_n W_n)$ where $n = 3\text{-}5$, $W_3 = 1.8$, $W_4 = 3.2$, $W_5 = 5.0$.

Indices are calculated as:

$$EI = 100 \times \frac{e}{e + b}$$

$$SI = 100 \times \frac{s}{s + b}$$

A graphic representation of the faunal profile indicates whether the soil community is enriched but unstructured (Quadrat A), enriched and structured (Quadrat B), resource-limited and structured (Quadrat C), or resource-depleted with minimal structure (Quadrat D):
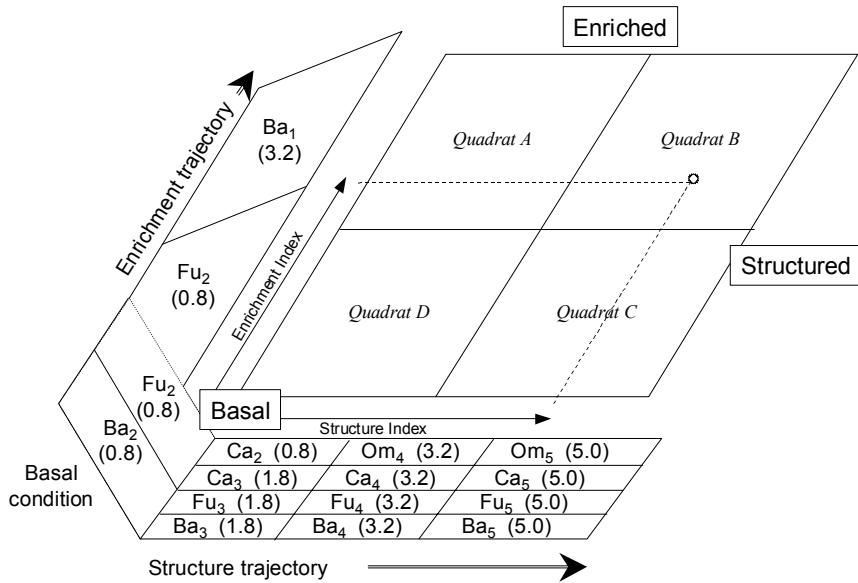
Functional guilds of soil nematodes characterized by feeding habit (trophic group) and by life history characteristics, after Bongers and Bongers, 1998. Indicator guilds of soil food web condition (basal, structured, enriched) are designated and weightings of the guilds along the structure and enrichment trajectories are provided, for determination of the Enrichment Index and Structure Index of the food web.

The enrichment trajectory can de dissected further to determine flow down fungal and bacterial decomposition channels according to the Channel Index:

$$CI = 100 \times \frac{Fu_2 W_2}{Ba_1 W_1 + Fu_2 * W_2}$$

Further understanding of enrichment is determined by relative flow through and activity in fungal, bacterial and herbivore channels using total biomass of bacterivore (B), fungivore (F) and herbivore (H) nematodes. That provides the basis for developing the enrichment profile of the food web:
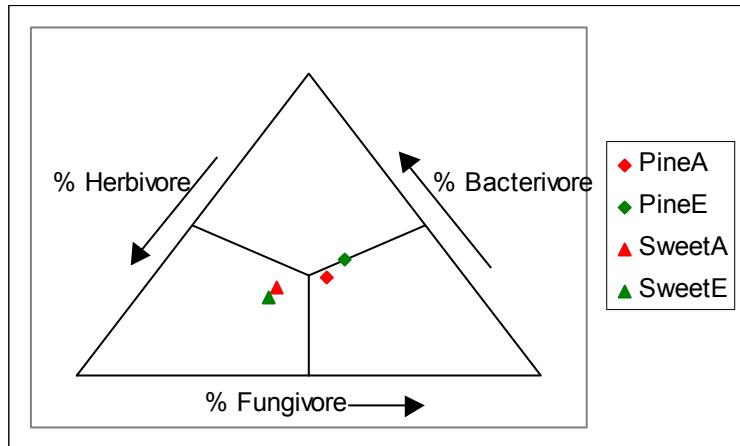
Enrichment profile of the soil food webs in pine and sweetgum plantations under ambient (A) or elevated (E) CO_2. Data from Neher, D.A., Weicht, T.R., Moorhead, D.L., and Sinsabaugh, R.L. Elevated CO_2 alters functional attributes of nematode communities in forest soils. Functional Ecology 18: 584-591.

III. Diversity Indices
Community diversity was computed at three levels of resolution: a) diversity based on abundance of individuals within each genus), b) trophic diversity based on abundance of individuals within each trophic group (trophic diversity), and c) diversity of genera within each trophic group (trophic richness).

   a. Shannon

$$H' = -\sum P_i(\ln P_i)$$

   b. Hills N1):

$$N1 = e^{H'} = \exp\left[-\sum P_i(\ln P_i)\right]$$

where P_i = proportion of trophic group (or family) i in the total nematode community

c. Simpson

$$\lambda = \sum \left(\frac{n_i}{N} \right)^2$$

d. Hills N2:

$$N2 = \frac{1}{\lambda} = \frac{1}{\sum \left(\frac{n_i}{N} \right)^2}$$

where n_i = number of individuals in trophic group (or family) i, and N is the known total number of all individuals in the community. The component, $n_i/N = P_i$ in Shannon index.

Interpretation:
- The Shannon index is sensitive to rare species and the Simpson index weights common species
- Hills values measure the 'effective number of species'. This effective number of species is a measure of the degree to which proportional abundances are distributed among the species. Specifically, N0 is the number of all species in the same (regardless of their abundance), N1 measures the number of abundant species in the same, and N2 is the number of very abundant species. N1 will always be intermediate between N0 and N2 (Ludwig and Reynolds 1988).
- Hills indices are simpler to interpret ecologically than commonly used Simpson or Shannon forms (Peet 1974).
- Trophic diversity indices describe the relative abundance and evenness of the occurrence of five nematode trophic groups
- In agricultural soils, greater diversity of trophic groups is correlated with an increase in the frequency of occurrence of generally-less-abundant trophic groups (i.e., fungal-feeding, omnivores, and predators) relative to that of generally-more-abundant trophic groups (i.e., bacterial- and plant-feeding groups)

Calculation by Excel Spreadsheet:

- Insert a column and assign a trophic group to each taxon (follow Yeates et al. 1993, Table 1), applying codes as follows: (3) bacterivores, (2) fungivores, (8) omnivores, (5) predators, and (1) plant-parasites.

- Generate a sum for rows within the same trophic group.

  Shannon diversity index (Hills N1 = number of abundant species):
  - o   Generate a column with formula, Pi * ln (Pi)
  - o   Sum all rows to get Shannon index
  - o   Write a formula to transpose the Shannon index into the Hills N1, e.g., =EXP(-(SUM(S64:W64)))

- Simpson diversity index (Hills N2 = number of very abundant species):
  - Generate a columns with the formula that raises the proportion to a squared term, e.g., =S64**2
  - Sum all rows of that column to compute the Simpson index
  - Write a formula to transpose the Simpson index into the Hills N2, e.g., =1/SUM(S65:W65)

Richness (Hills N0)
Richness is computed as the number of taxa present per sample.

Evenness (Ludwig and Reynolds 1988)

Evenness index 1 (E1): probably the most common evenness index used by ecologist. This is the familiar J' of Pielou which expresses H' relative to the maximum value that H' can obtain when all of the taxa in the sample are perfectly even with one individual per species (i.e., ln S).

$$E1 = \frac{H'}{\ln(S)} = \frac{\ln(N1)}{\ln(N2)}$$

Evenness index 4 (E4): ratio of N2 to N1 proposed by Heip (1973)

$$E4 = \frac{1/\lambda}{e^{H'}} = \frac{N2}{N1}$$

Evenness index 5 (E5): known as the modified Hill's ratio.

$$E5 = \frac{(1/\lambda) - 1}{e^{H'} - 1} = \frac{N2 - 1}{N1 - 1}$$

E5 approaches zero as a single taxon becomes more and more dominant in a community (unlike E4, which approaches one). This is probably why many ecologists prefer E5 over E4. Another advantage of E5 is that it is independent of the number of species in the same, i.e., as the number of species present changes, the evenness index does not change. In contrast, E1 is affected greatly by species richness.

Table 1 from Bongers, T. and M. Bongers. 1998. Functional diversity of nematodes. Applied
Soil Ecology 10: 239-251.

Table 1
cp-values of terrestrial and freshwater nematodes

Achromadoridae	3	Ironidae	4
Actinolaimidae	5	Leptolaimidae	$2^{2)}$
Alaimidae	4	Leptonchidae	4
Alloionematidae	1	Linhomoeidae	3
Anatonchidae	4	Longidoridae	(5)
Anguinidae	$2^{1)}$	Meloidogynidae	(3)
Aphelenchidae	2	Microlaimidae	$2^{3)}$
Aphelenchoididae	2	Monhysteridae	$2^{4)}$
Aporcelaimidae	5	Mononchidae	4
Aulolaimidae	3	Myolaimidae	$1^{4)}$
Bastianiidae	3	Neodiplogasteridae	1
Bathyodontidae	4	Neotylenchidae	2
Belondiridae	5	Nordiidae	4
Bunonematidae	1	Nygolaimidae	5
Cephalobidae	2	Odontolaimidae	3
Choanolaimidae	4	Odontopharyngidae	1
Chromadoridae	3	Onchulidae	3
Chrysonematidae	5	Ostellidae	2
Criconematidae	(3)	Panagrolaimidae	1
Cyatholaimidae	3	Paratylenchidae	(2)
Desmodoridae	3	Plectidae	2
Diphtherophoridae	3	Pratylenchidae	(3)
Diplogasteridae	1	Prismatolaimidae	3
Diplogasteroididae	1	Psilenchidae	(2)
Diplopeltidae	3	Qudsianematidae	4
Diploscapteridae	1	Rhabditidae	1
Discolaimidae	5	Rhabdolaimidae	3
Dolichodoridae	(3)	Teratocephalidae	3
Dorylaimidae	4	Thornenematidae	5
Ecphyadophoridae	(2)	Tobrilidae	3
Ethmolaimidae	3	Trichodoridae	(4)
Halaphanolaimidae	3	Tripylidae	3
Hemicycliophoridae	(3)	Tylenchidae	(2)
Heteroderidae	(3)	Tylodoridae	(2)
Hoplolaimidae	(3)	Tylopharyngidae	1
Hypodontolaimidae	3	Xyalidae	2

Classification follows Bongers (1988), values between brackets
refer to plant feeding taxa (PPI-calculation).
1) plant feeding Anguinidae: (2)
2) refers to *Leptolaimus* (see Bongers et al., 1991).
3) refers to *Microlaimus* (see Bongers et al., 1991).
4) See Bongers et al. (1995).

Appendix from Bongers T, Alkemade R, and Yeates GW (1991) Interpretation of disturbance-induced maturity decrease in marine nematode assemblages by means of the Maturity Index. Marine Ecology progress Series 76: 135-142.

Appendix. Provisional c-p values for Dutch brackish and marine nematode families and genera, in alphabetical order; the classification is that of Platt & Warwick (1983), and, for Secernentea, Bongers (1988). The following types of data were used in allocating c-p values to families: (i) Basal information obtained from studies in The Netherlands on the nematode fauna in oil-polluted Rotterdam harbours (Tamis 1986), nematodes in a pollution gradient in Lake Vossemeer (Jacobs 1987), nematodes in polluted Rhine sediments (Bongers & Van de Haar 1990), and a monitoring study in the Western Scheldt (De Winter 1988). (ii) Personal observations from current colonisation and decomposition studies on *Spartina* leaves (Alkemade) and other observations on nematodes in marine and brackish water habitats (Bongers). (iii) Personal communications: unpublished species lists of brackish and marine nematodes from the Eastern Scheldt (Loof), observations on biology of nematodes in the Ems Dollard estuary (Bouwman), observations by De Winter and Van de Haar and general discussions with the participants of the 7th International Symposium on Aquatic Nematodes (Yerseke, NL)

Actinonema	4	*Desmoscolex*	4	*Metepsilonema*	4	*Quadricoma*	4
Adoncholaimus	4	*Dichromadora*	2	*Metoncholaimus*	4	*Rhabdocoma*	4
Aegialalaimidae*	4	*Diplolaimella*	1	Microlaimidae*	3	Rhabditidae	1
Aegialoalaimus	4	*Diplopeltidae*	3	*Microlaimus*	2	*Rhabdodemania*	4
Amphimonhystera	2	*Dolicholaimus*	2	*Molgolaimus*	3	Rhabdodemaniidae	4
Anoplostoma	2	*Dracognomus*	4	*Monhystera*	1	*Rhips*	3
Anoplostomatidae	2	*Draconematidae*	4	*Monhysteridae*	1	*Rhynchonema*	3
Anticoma	2	*Echinotheristus*	2	*Monoposthia*	3	*Richtersia*	3
Anticomidae	2	*Eleutherolaimus*	2	*Monoposthiidae*	3	*Sabatieria*	2
Antomicron	3	*Enchelidiidae*	4	*Nemanema*	4	Selachinematidae	3
Araeolaimus	3	Enoplidae	5	*Neochromadora*	2	*Sigmophoranema*	3
Ascolaimus	2	*Enoploides*	2	*Neodiplogasteridae*	1	Siphonolaimidae	3
Atrochromadora	4	*Enoplolaimus*	2	*Neotonchoides*	3	*Siphonolaimus*	3
Axonolaimidae	2	*Enoplus*	5	*Neotonchus*	2	*Southerniella*	3
Axonolaimus	2	*Epsilonema*	4	*Odontophora*	2	Sphaerolaimidae	3
Bathylaimus	2	Epsilonematidae	4	*Odontophoroides*	2	*Sphaerolaimus*	3
Bolbolaimus	3	Ethmolaimidae*	3	*Oncholaimellus*	3	*Spilophorella*	2
Calomicrolaimus	2	*Euchromadora*	3	Oncholaimidae*	4	*Spirinia*	3
Calyptronema	4	*Eurystomina*	4	*Oncholaimus*	4	*Stephanolaimus*	4
Camacolaimus	3	*Gammanema*	3	*Onyx*	3	*Stylotheristus*	2
Ceramonematidae	3	*Gonionchus*	4	*Oxyonchus*	2	*Symplocostoma*	4
Chaetonema	2	*Greeffiella*	4	*Oxystomina*	4	*Synonchus*	5
Choniolaimus	3	*Halalaimus*	4	Oxystominidae	4	*Syringolaimus*	4
Chromadora	3	*Halaphanolaimus*	3	*Paracanthonchus*	2	*Terschellingia*	3
Chromadorella	3	*Halichoanolaimus*	3	*Paracyatholaimoides*	3	*Thalassoalaimus*	4
Chromadoridae*	3	*Haliplectidae*	3	*Paracyatholaimus*	2	*Theristus*	2
Chromadorina	3	*Haliplectus*	3	*Paralinhomoeus*	2	*Thoracostoma*	5
Chromadorita	3	*Hypodontolaimus*	4	*Parallelocoilas*	3	Thoracostomopsidae*	2
Chromaspirina	4	Ironidae*	4	*Paralongicyatholaimus*	3	*Trefusia*	4
Cobbia	3	*Ixonema*	4	*Paramesonchium*	2	Trefusiidae	4
Comesomatidae	2	*Laimella*	2	*Paramonohystera*	2	*Trichotheristus*	2
Crenopharynx	4	*Latronema*	3	*Pellioditis*	1	*Tricoma*	4
Cyartonema	3	Leptolaimidae*	3	*Perepsilonema*	4	*Trileptium*	2
Cyatholaimidae*	3	*Leptolaimus*	2	Phanodermatidae	4	*Tripyloides*	2
Cyatholaimus	3	*Leptonemella*	4	*Polygastrophora*	4	Tripyloididae	2
Cylicolaimus	5	Leptosomatidae	5	*Pomponema*	4	*Tubolaimoides*	3
Dagda	3	*Leptosomatum*	5	*Pontonema*	4	Tubolaimoididae	3
Daptonema	2	Linhomoeidae*	2	*Praeacanthonchus*	4	*Valvaelaimus*	2
Dasynemoides	3	*Linhomoeus*	2	*Prochaetosoma*	4	*Viscosia*	3
Deontolaimus	3	*Mesacanthion*	3	*Prochromadorella*	2	*Wieseria*	4
Desmodora	2	*Metachromadora*	2	*Pselionema*	3	*Xyala*	3
Desmodoridae*	3	*Metadesmolaimus*	2	*Pseudocella*	5	Xyalidae*	2
Desmolaimus	2	*Metalinhomoeus*	2	*Pseudonchus*	3		
Desmoscolecidae	4	*Metaparoncholaimus*	4	*Ptycholaimellus*	3		

* Heterogeneous families in which generic identification may provide additional precision

Table 1 from Yeates, G.W., T. Bongers, R.G.M. de Goede, D.W. Freckman, and S. S. Georgieva. 1993. Feeding habits in soil nematode families and genera – an outline for soil ecologists. Journal of Nematology 25:315-331.

TABLE 1. Feeding types in nematode genera. Numbers refer to the eight feeding types outlined in the text; numbers in parenthesis indicate a tentative assignment. The main food source is given first. For genera maintained for several generations under defined conditions, unqualified reference is made to that publication by number; for genera where the publication number is preceded by "see," a more general (or less specific) support for allocation to the feeding type is indicated; for genera where we have not obtained a direct reference to feeding activity, the family name is given.

Genus	Feeding type	Family or literature citation
Ablechroiulus	3	Rhabditidae
Achromadora	(6)	Achromodoridae
Acontylus	1b	(66)
Acrobeles	3	(111,126)
Acrobeloides	3	(71,104,126)
Acrobelophis	3	Cephalobidae
Acrolobus	3	Cephalobidae
Acromoldavicus	3	Cephalobidae
Acrostichus	3	Diplogasteridae; (88)
Actinca	5, 8	Actinolaimidae
Actinolaimus	5, 8	(56); (see 31,100)
Aetholaimus	5	Nygolaimidae
Aglenchus	1e	Tylenchidae; (122)
Alaimus	3	(see 77)
Allantonema	7 or 2	(119)
Allodorylaimus	8	Dorylaimidae
Allotrichodorus	1d	Trichodoridae; (see Decraemer in 76)
Amphidelus	3	Alaimidae
Amplimerlinius	1d	(14,36); (see Anderson & Potter in 76)
Anaplectus	3	(122)
Anatonchus	5a	(18); (see 100)
Anguina	1a or b	(22); (see Krall in 76)
Anomyctus	2?	(see Nickle & Hooper in 76)
Antarctylus	1c	Hoplolaiminae
Aorolaimus	1c	Hoplolaiminae
Aphanolaimus	3	Halaphanolaimidae
Aphasmatylenchus	1c	(34); (see Fortuner in 76)
Aphelenchoides	2 or 1b, 1e or 1f	(68); (see 122)
Aphelenchus	2 or 1e	(17,23,40,65); (see 122)
Aporcelaimellus	5, 8	(117,122); (see 31)
Aporcelaimium	8	Aporcelaimidae
Aporcelaimus	5, 8	(114,122); (see 31,100)
Apratylenchoides	1b	Pratylenchidae
Aprutides	2	Aphlenchoididae
Aquatides	5	(10); (see 100)
Atylenchus	1d	Tylenchidae
Aulolaimus	3	Cryptonchidae
Axonchium	1, 8?	(see 100)
Basiria	1e	Tylenchidae
Bastiania	3	Bastianiidae
Bathyodontus	3	Bathyodontidae; (see 12)
Belonolaimus	1d	(15)
Bicirronema	3	Chambersiellidae
Bitylenchus	1d	Tylenchorhynchidae; (see Anderson & Potter in 76)
Boleodorus	1e or 2(?)	Tylenchidae
Brevibucca	3	Brevibuccidae
Brittonema	5, 8	Actinolaimidae
Bunonema	3	(77,128)
Bursaphelenchus	2	(32,63); (see Nickle & Hooper in 76)
Bursilla	3	Rhabditidae
Butlerius	3, 5	(28,89,101); (see 100)
Cacopaurus	1a	Paratylenchidae; (112); (see Raski in 76)
Cactodera	1a	(19,98); (see Baldwin & Mundo-Ocampo in 76)
Caenorhabditis	3	(25,78,97); (see 107)

TABLE 1.   *Continued*

Genus	Feeding type	Family or literature citation
Caloosia	1d	Hemicycliophorididae
Campydora	8?	Campydoridae
Carcharolaimus	5	(28); (see 100)
Cephalenchus	1d	(37,109); (see 122)
Cephalobus	3	(81,88); (see 72,122)
Ceratoplectus	3	Plectididae
Cervidellus	3	(122)
Chambersiella	3	Chambersiellidae
Cheilorhabditis	3	Rhabditidae
Chiloplacus	3	(118,122)
Choanolaimus	5a	Choanolaimidae
Chondronema	7, 2?	(16)
Chromadorina	3, 6?	Chromadoridae; (116)
Chromadorita	6	(49)
Chronogaster	3	Leptolaimidae
Chrysonemoides	?	Chrysonematidae
Clarkus	5a	(67,106); (see 101,130)
Coarctadera	3	Rhabditidae; (see 107)
Cobbonchus	5a	(see 100)
Coomansus	5a	(31)
Coslenchus	1e	(as *Aglenchus*); (122)
Craspedonema	3	Butonematidae
Criconema	1d	(see 26,93)
Criconemoides	1d	(see 26,93)
Crossonema	1d	(see 26,93)
Cruznema	3	(108)
Cryphodera	1a	(see 8,60)
Cryptonchus	3	Cryptonchidae
Curviditis	3	Rhabditidae
Cuticonema	3	Breviibuccidae
Cuticularia	3	Rhabditidae
Cylindrolaimus	3	Diplopeltidae
Daptonema	3, 4, 5 or 6	(13)
Deladenus	2	(9,129); (see 62)
Demaniella	3	(88)
Deontolaimus	3	Leptolaimidae
Desmodora	3, 6	Desmodoridae; (74)
Desmolaimus	3	Linhomoeidae
Desmoscolex	3	Desmoscolecidae
Dichromadora	3, 6?	(13,120)
Diphtherophora	2	Diphtherophoridae; (see 4)
Diplenteron	3?	(64,125); (see 100)
Diplogaster	3, 5a, 6 or 8	(see 72,100)
Diplogasteritus	3	(124)
Diplogasteroides	3	Diplogasteroididae
Diploscapter	3	(42,88)
Discolaimium	5?	(see 100)
Discolaimus	5	(28,56); (see 31,100)
Ditylenchus	2, or 1b	(55,122); (see Sturhan & Brezeski in 76)
Dolichodorus	1d	(82,83,85); (see Smart & Nguyen in 76)
Dolichorhabditis	3	Rhabditidae
Dolichorhynchus	1d	Dolichodoridae
Domorganus	3	Diplopeltidae
Dorydorella	8	Dorylaimidae
Dorylaimellus	1, 2?	Belondiridae; (see 131)
Dorylaimoides	8?	Leptonchidae
Dorylaimus	8	(56); (see 77,100)
Doryllium	2?	Leptonchidae
Drilocephalobus	3	Osstellidae

Feeding Habits of Soil Nematodes: *Yeates et al.* 321

TABLE 1. *Continued*

Genus	Feeding type	Family or literature citation
Durinema	5	(see 77,100)
Ecphyadophora	1d or 2(?)	Ecphyadophoridae
Ecumenicus	8	Dorylaimidae
Elaphonema	3	Elaphonematidae
Enchodelus	8 or 6?	Nordiidae
Epidorylaimus	8	Dorylaimidae
Ereptonema	3	Ereptonemidae
Ethmolaimus	3, 6?	Ethmolaimidae
Eucephalobus	3	(122)
Eudorylaimus	5, 8	(29,44,117); (see 31,100)
Eurystomina	(5)	Eurystominidae
Eumonhystera	3, 4	Monhysteridae
Euteratocephalus	3	Teratocephalidae
Fictor	3, 5, 6	(88,103); (see 100)
Filenchus	1e	Tylenchidae
Funaria	2?	Leptonchidae
Fungiotonchium	2	Iontonchiidae (see 99)
Geocenamus	1d	Dolichodoridae
Geomonhystera	3, 4	Monhysteridae
Glauxinema	6	Neodiplogasteridae
Globodera	1a	(53); (see Baldwin & Mundo-Ocampo in 76)
Goffartia	3	Diplogasterididae
Goodeyus	3	Cylindrocorporidae
Gracilacus	1d	Paratylenchidae; (see Raski in 76)
Granonchulus	5a	Mononchidae; (35)
Haliplectus	3	Haliplectidae
Helicotylenchus	1c	(51); (see Fortuner in 76)
Hemicriconemoides	1d	Criconematidae; (see 93)
Hemicycliophora	1d	Criconematidae; (see 93)
Heterocephalobellus	3	Cephalobidae
Heterocephalobus	3	Cephalobidae
Heterodera	1a	(see Baldwin & Mundo-Ocampo in 76)
Heterorhabditis	7, 3	(90); (see Wouts in 76)
Hexatylus	2	(24); (see 72)
Hirschmanniella	1b	(7); (see Loof in 76)
Hoplolaimus	1c	Hoplolaimidae
Hoplotylus	1b	Pratylenchidae
Howardula	7 or 2	Allantonematidae
Huntaphelenchoides	2	Aphelenchoididae
Iotonchus	5a	(67,100,101)
Ironus	5a or 6	(47); (see 100)
Isolaimium	(3)	Isolaimidae
Kirjanovia	3	Cephalobidae
Kochinema	8	Nordiidae
Labronema	5, 8	(28,30,88,122); (see 31,100)
Laimaphelenchus	5b, 1f, 2	(see 100)
Laimydorus	8	(see 100)
Lelenchus	1e	Tylenchidae
Leptolaimus	3	(13)
Leptonchus	2	(see 31)
Longidorella	1d	Nordiidae
Longidorus	1d	Longidoridae
Loofia	1d	Hemicycliophoridae
Macrotrophurus	1d	Dolichodoridae
Malenchus	1e	Tylenchidae
Meloidodera	1a	(see Baldwin & Mundo-Ocampo in 76)
Meloidoderita	1a	(see 76)
Meloidogyne	1a	(see 27,96)
Merlinius	1d	(see Anderson & Potter in 76)

TABLE 1.   *Continued*

Genus	Feeding type	Family or literature citation
Mesocriconema	1d	(see 93)
Mesodiplogaster	3, 5	(102,103); (see 100)
Mesodorylaimus	8	(29); (see 31,95,100)
Mesorhabditis	3	(107,122,126)
Metacrobeles	3	Cephalobidae
Metadiplogaster	3	Diplogasteridae
Metateratocephalus	3	Teratocephalidae
Miconchus	5a	(see 100)
Microdorylaimus	8	Nordiidae
Microlaimus	3	Microlaimidae
Monhystera	3, (4)	(122); (see 77,115)
Monhystrella	3, 4	(13)
Monobutlerius	3	Diplogasteridae
Mononchoides	3, 5a	(89); (see 100)
Mononchulus	3	(see 31)
Mononchus	5a	(38,88); (see 31,100)
Monotrichodorus	1d	Trichodoridae; (see Decraemer in 76)
Morulaimus	1d	Belonolaimidae; (see Smart & Nyguen in 76)
Mylonchulus	5a	(48,67); (see 31,100)
Myolaimus	3	Myolaimidae
Nacobbus	1a	(see Jatala in 76)
Nagelus	1d	Dolichodoridae
Namibinema	3	Cephalobidae
Neoactinolaimus	5, 8	(101); (see 100)
Neoaplectana	7, 3	(see 76)
Neodiplogaster	3, 4 or 5	Neodiplogasteridae
Neopsilenchus	1e	Tylenchidae
Neothada	1e or 2(?)	Tylenchidae
Nothacrobeles	3	Cephalobidae
Nothotylenchus	2	Anguinidae
Nullonchus	5a	(see 100)
Nygolaimium	5	(see 100)
Nygolaimoides	5	Nygolaimidae
Nygolaimus	5	(113,122); (see 31,100)
Odontolaimus	3 or 6?	Odontolaimidae
Odontopharynx	3, 5a	Odontopharyngidae
Odontorhabditis	3	Odontorhabditidae
Ogma	1d	(see 93)
Oionchus	3	Mononchulidae
Onchulus	5a or 6	Onchulidae
Opisthodorylaimus	8	Dorylaimidae
Orrina	1a or b	(see Krall in 76)
Osstella	3	Osstellidae
Oxydirus	1, 8?	Belondiridae
Panagrellus	3	(21)
Panagrobelium	3	Panagrolaimidae
Panagrobelus	3	Panagrolaimidae
Panagrocephalus	3	Cephalobidae
Panagrolaimus	3	(88,126)
Paracrobeles	3	Cephalobidae
Paractinolaimus	5	(46) (see 100)
Paracyatholaimus	6?	(13)
Parahadronchus	5a	(see 100)
Paralongidorus	1d	(see 11,54)
Paramphidelus	3	Alaimidae
Paraphanolaimus	3	Halaphanolaimidae
Paraphelenchus	2	(110); (see Nickle & Hooper in 76)
Paraplectonema	3	Leptolaimidae
Pararotylenchus	1c	(see Fortuner in 76)

TABLE 1. *Continued*

Genus	Feeding type	Family or literature citation
Paratrichodorus	1d	Trichodoridae; (see Decraemer in 76)
Paratripyla	5a	Tripylidae
Paratrophurus	1d	Dolichodoridae
Paratylenchus	1d	(94,122); (see Raski in 76)
Paravulvus	5?	Nygolaimidae
Paraxonchium	5, 8	Aporcelaimidae
Pareudiplogaster	6, 3	(13)
Paroigolaimella	3	(88)
Paurodontus	2, 7	(as *Neotylenchus*); (40)
Pellioditis	3	(107)
Pelodera	3	(88,107,122)
Peltamigratus	1c	(see 76)
Phasmarhabditis	3	(107)
Placodira	3	Cephalobidae
Plectonchus	3	Brevibuccidae
Plectus	3	(77,88,122)
Pleurotylenchus	1d	Tylodoridae
Pratylenchoides	1b	(see Loof in 76)
Pratylenchus	1b	(see Loof in 76)
Prionchulus	5a	(5,61,69); (see 100)
Prismatolaimus	3?	(see 77)
Pristionchus	3, 5a	Neodiplogasteridae
Prochromadora	3, 6?	Chromadoridae
Prodesmodora	3	Desmodoridae
Prodorylaimium	8	Dorylaimidae
Prodorylaimus	8	Dorylaimidae
Proleptonchus	8?	Leptonchidae
Protocylindrocorpus	3	Cylindrocorporidae (88)
Protorhabditis	3	Rhabditidae
Pseudacrobeles	3	Cephalobidae
Pseudhalenchus	2	Anguinidae
Pseudoaulolaimus	3	Cryptonchidae
Psilenchus	1e	Psilenchidae
Pterotylenchus	1a or b	Anguinidae
Pterygorhabditis	3	Pterygorhabditidae
Punctodera	1a	(see Baldwin & Mundo-Ocampo in 76)
Punctodora	3, 6?	Chromadoridae
Pungentus	1d, 5, 8	(see 31,100)
Quinisulcius	1d	(see 76)
Radopholus	1b	(see Loof in 76)
Rhabditis	3	(88,102,107,122)
Rhabditoides	3	Rhabditidae
Rhabditophanes	3	Alloionematidae
Rhabdolaimus	3	(see 77)
Rhabdontolaimus	3	(88)
Rhadinaphelenchus	1b	(see Nickle & Hooper in 76)
Rhodolaimus	3	Bunonematidae
Rotylenchulus	1a	(57)
Rotylenchus	1c	Hoplolaiminae; (see Fortuner in 76)
Scottnema	3	Cephalobidae; (80)
Scutellonema	1c	Hoplolaiminae; (see Fortuner in 76)
Scutylenchus	1d	Dolichodoridae
Sectonema	5, 8	(see 100)
Seinura	5b	(28,41,43,101,123); (see 100)
Seleborca	3	Acrobelidae
Sphaerolaimus	5a	Sphaerolaimidae
Sphaeronema	1a	(see Raski in 76)
Sphaerularia	7, 2	(91)
Sporonchulus	5a	(see 100)

TABLE 1.   *Continued*

Genus	Feeding type	Family or literature citation
Stegelleta	3	Cephalobidae
Stegelletina	3	Cephalobidae
Steinernema	7, 3	(see 76)
Stomachoglossa	(5)	(see 100)
Subanguina	1a or b	(see 76)
Sulphuretylenchus	7 or 2	(see 76)
Synonchium	5	(see 100)
Telotylenchus	1c	Dolichodoridae
Tenunemellus	1d or 2(?)	Ecphyadorphoridae
Teratocephalus	3	(see 77)
Teratolobus	3	Cephalobidae
Teratorhabditis	3	Rhabditidae
Theristus	3, 4 or 6	(see 77)
Thonus	5, 8	(31)
Thornenema	8	Dorylaimidae
Thornia	8?	(see 100)
Tobrilus	5a or 6	(see 100)
Torumanawa	8	Aporcelaimidae
Tricephalobus	3	Panagrolaimidae
Trichodorus	1d	Trichodoridae; (see Decraemer in 76)
Tripius	7, 2	(see 76)
Tripyla	5a	(77,100)
Trischistoma	5a	Tripylidae; (see 100)
Trophonema	1a	Tylenchulidae; (see Raski in 76)
Trophotylenchus	1a	Tylenchulidae
Trophurus	1d	Dolichodoridae
Turbatrix	3	(70,89)
Tylencholaimellus	2	(122)
Tylencholaimus	2	(29,105,122); (see 31)
Tylenchorhynchus	1d	(see Anderson & Potter in 76)
Tylenchulus	1a	(see Raski in 76)
Tylenchus	1f, 2?	Tylenchidae; (122)
Tylocephalus	3	(see 77)
Tylodorus	1d	Tylodoridae
Tylolaimophorus	2	Diphtherophoridae
Tylopharynx	3	Tylopharyngidae
Verutus	1a	(see Baldwin & Mundo-Ocampo in 76)
Westindicus	(5)	(see 100)
Wilsonema	3	(77,122)
Xiphinema	1d	Longidoridae
Ypsylonellus	3	Acrobelidae
Zeldia	3	(126)
Zygotylenchus	1b	(see Loof in 76)

Order Monhysterida

Linhomoeidae: *Desmolaimus*
  (3) bacterial feeding
Monhysteridae: *Monhystera, Geomonhystera*
  3 bacterial feeding
  4 substrate ingestion
Sphaerolaimidae: *Sphaerolaimus*
  5 predacious
Xyalidae: *Theristus, Daptonema*
  3 bacterial feeding
  4 substrate ingestion

  5 predacious
  6 algal feeding

Order Desmoscolecida

Desmoscolecidae: *Desmoscolex*
  (3) bacterial feeding

Order Araeolaimida

  All terrestrial forms are apparently type 3.
Diplopeltidae: *Cylindrolaimus, Domorganus*

Example Data

From: de Goede, R. and Bongers, T. (eds) 1998. Nematode communities on northern temperate grassland ecosystems. Focus, -Verl., Gieβen.

Data from the following three studies are available on the CD-ROM.

1. **Yeates, G.W. and Cook, R. Nematode fauna of three Welsh soils under conventional and organic grassland farm managements, pp. 305-313**

   Trawsgoed site:
   Conventional: three application NPK per year, silage cuts in spring then sheep grazing to 4-5 cm (Table 2)
   Organic: slurry application in preceding year; silage cut then cattle grazing to 8-10 cm (Table 3)

   Goodwick site:
   Conventional: three applications NPK per year, silage cuts in spring then cattle grazing to 10-14 cm (Table 4)
   Organic: no fertilizer application, cattle grazing to 3-5 cm (Table 5)

   Glanrhyd site:
   Conventional: NPK and slurry applied each year, sheep grazing to 10-14 cm (Table 6)
   Organic: no fertilizer application, sheep grazing to 3-5 cm (Table 7)

2. **Diedrich, Ch., Broll, G., and Sturhan, D. The nematode fauna of two wet grassland sites in Northwest-Germany with various management practices, pp. 47-55**

   Experimental treatments: In 1986 three management practices were started (Table 2):
   - Mowing twice a year in June/July and September
   - Mowing once a year in June/July without grazing (Düsterdieker Niederung) or with grazing (Strönfeld)
   - No-management

     Roman numbers represent months of the year sampled

   Table 3. Düsterdieker Niederung
   Table 4. Strönfeld

3. **Korthals, G., Popovici, J. and van Megen, H.H.B. Soil nematodes in heathland around a Zinc-smelter near Budel, The Netherlands, pp. 155-158**

   Table 2. Heathland A near a Zinc smelter, Budel, The Netherlands
   Table 3. Heathland B near a Zinc smelter, Budel, The Netherlands

Relevant References

Berkelmans, R., H. Ferris, M. Tenuta, A.H.C. van Bruggen. 2003. Effects of long-term crop management on nematode trophic levels other than plant feeders disappear after one year of disruptive soil management. Applied Soil Ecology 23:223-235.

Bongers, T. 1987. De Nematoden van Nederland. Bibliotheek van de KNNV, no. 46. Pirola, Schoorl, Netherlands. 408 pp.
- taxonomic key in Dutch (English translation available of the tabular key; follow family designations for maturity indices)

Bongers, T. 1990. The maturity index: an ecological measure of environmental disturbance based on nematode species composition. Oecologia 83: 14-19.
- reference for MI and PPI indices, source for CP values by family

Bongers, T. and G. Korthals. 1993. The Maturity Index, an instrument to monitor changes in the nematode community structure. In: Summaries of the 45th International symposium on Crop Protection. May 4, 1993, Gent, Belgium. p. 80.
- original citation for MI25

Bongers, T., R. Alkemade, and G. W. Yeates. 1991. Interpretation of disturbance-induced maturity decrease in marine nematode assemblages by means of the Maturity Index. Marine Ecology Progress Series 76:135-142.
- provides CP values for brackish and marine nematode families and genera

Bongers, T., R.G.M. de Goede, G.W. Korthal and G.W. Yeates. 1995. Proposed changes of c-p classification for nematodes. Russian Journal of Nematology 3 (1): 61-62.
- rectangular cp-triangles, distinguishing enrichment and general opportunists and rescaling Monhysteridae and Myolaimidae
- Monhysteridae transferred from cp=1 to cp=2
- Myolaimidae transferred from cp=2 to cp = 1

Bongers, T., H. van der Meulen, H., and G. Korthals, G. 1997. Inverse relationship between the nematode maturity index and plant parasite index under enriched nutrient conditions. Applied Soil Ecology 6(2):195-199.

Bongers, T. and M. Bongers. 1998. Functional diversity of nematodes. Applied Soil Ecology 10: 239-251.
- most recent cp-values including Bongers et al. (1991, 1995) corrections

Bongers, T. and H. Ferris. 1999. Nematode community structure as a bioindicator in environmental monitoring. Trends in Evolution and Ecology 14:224-228.

De Goede, R., and T. Bongers. 1998. *Nematode communities of northern temperate grassland ecosystems*. Focus Verlag, Gieβen, Germany. 338 pp.
- includes CD-ROM of datasets in Excel format

Ferris, H., T. Bongers, and R. G. M. de Goede. 2001. A framework for soil food web diagnostics: extension of the nematode faunal analysis concept. Applied Soil Ecology 18:13-29.

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Ferris, H., T. Bongers and R. De Goede. 2004. Nematode faunal analyses to assess food web enrichment and connectance. In R.C. Cook and D.J. Hunt (eds) Proceedings of the Fourth International Congress of Nematology. Nematology Monographs and Perspectives 2. Brill, Netherlands. 866p.

Ludwig, J.A. and J.F. Reynolds. 1988. *Statistical Ecology: A Primer on Methods and Computing*. John Wiley, New York.

Neher, D. A. and C.L. Campbell. 1994. Nematode communities and microbial biomass in soils with annual and perennial crops. Applied Soil Ecology 1(1):17-28.

Neher, D.A., and C.L. Campbell. 1996. Sampling for regional monitoring of nematode communities in agricultural soils. Journal of Nematology 28:196-208.

- original citation for ΣMI25

Peet, R.K. 1974. The measurement of species diversity. Annual Review of Ecology and Systematics 5:285-307.

Korthals et al. 1996. The Maturity Index as an instrument for risk assessment of soil pollution. In: N.M. van Straalen and D.A. Krivolutski (eds): Bioindicator systems for Soil Pollutions 85-93.

- clear example of MI25

Ruess, L. and H. Ferris. 2004. Decomposition pathways and successional changes. In R.C. Cook and D.J. Hunt (eds) Proceedings of the Fourth International Congress of Nematology. Nematology Monographs and Perspectives 2. Brill, Netherlands. 866p.

Shannon, C. E., and W. Weaver. 1949. *The mathematical theory of communication*. University of Illinois, Urbana, Illinois, USA.

Simpson, E. H. 1949. Measurement of diversity. Nature 163:688.

Tenuta, M. and H. Ferris. 2004. Relationship between nematode life-history classification and sensitivity to stressors: ionic and osmotic effects of nitrogenous solutions. Journal of Nematology 36:85-94.

Wasilewska, L. 1994. The effect of age of meadows on succession and diversity in soil nematode communities. Pedobiologia 38: 1-11.

- proposed "Total MI", including plant feeders = ΣMI

Yeates, G.W. 1994. Modification and qualification of the nematode Maturity Index. Pedobiologia 38:97-101.

- original citation of the ΣMI, is Total MI of Wasilewska

Yeates, G.W. and A.F. Bird. 1994. Some observations on the influence of agricultural practices on the nematode faunae of some South Australian soils. Fundamental and Applied Nematology 17(2): 133-145.

Yeates, G.W., T. Bongers, R.G.M. de Goede, D.W. Freckman, and S. S. Georgieva. 1993. Feeding habits in soil nematode families and genera – an outline for soil ecologists. Journal of Nematology 25:315-331.

- follow for trophic group designations

Appendix 1. Example SAS programs (Neher) for computing community indices (family of maturity, trophic and generic diversity, total and generic richness, evenness, CI, EI, SI)

SAS formatting (example in *Yeates for SAS.xls*)

1. Transpose columns and rows, to have genera as columns, and samples as rows
2. Add columns for treatment identifiers, e.g., location, treatment, replicate
3. Adjust position of columns to account for every possible taxon across all treatments, put in dots or zeros for treatments not containing that genus
4. remove column headings
5. save file as Space Delimited for import into SAS

Example SAS files adapted to the Yeates data (de Goede, R. and Bongers, T. (eds) 1998

Maturity Indices

```
data maturity;
infile "c:\Documents and Settings\dneher.UTAD\My
Documents\SON\workshop\yeates.dat" lrecl=1000;
input location $ treat $ rep Acrobeloides_nanus Acrobeloides_sp   Alaimus_sp1
   Alaimus_sp2 Anaplectus Anatonchus Aphelenchoides
   Aphelenchus Aporcelaimus_sp1 Aporcelaimus_sp2 Araeolaimid Axonchium
   Boleodorus Bunonema  Cephalenchus Cephalobus_sp1 Cephalobus_sp2
   Cephalobus_sp3 Chromatorid Cervidellus Criconemoides_2spp Diphtherophora
Diplogaster Discolaimus Ditylenchus Dorylaimellus_sp1
   Dorylaimid Dorylaimus_sp1 Dorylaimus_sp2 Doryllium Enchodelus
Eudorylaimus_sp1 Eudorylaimus_sp2   Euteratocephalus Helicotylenchus
   Heterocephalobus Heterocephalobus_sp2 Heterocephalobus_sp3 Heterodera_J2
Iotonchus Longidorus Meloidogyne_J2 Mermithidae
   Mesodorylaimus Monohysterid Mononchus Myolonchus Nygolaimus Panagrolaimus
Paratylenchus_2spp Plectus_sp1 Plectus_sp2 Plectus_sp3
   Pratylenchus Prismatolaimus Pungentus Rhabditidae Rhabditis Rotylenchus
Teratocephalus Trichodorus Tripyla Tylencholaimid
   Tylenchorhynchus_sp1 Tylenchorhynchus_sp2 Tylenchus_sp1 Tylenchus_sp2
Xiphinema;

**Note: data are precentages of total numbers**;

**maturity index groups**;
one= (Bunonema+Diplogaster+Panagrolaimus+Rhabditidae+Rhabditis)/100;
two=(Acrobeloides_nanus+Acrobeloides_sp+Anaplectus+Aphelenchoides+Aphelenchus
+Boleodorus+Cephalenchus
   +Cephalobus_sp1+
Cephalobus_sp2+Cephalobus_sp3+Cervidellus+Ditylenchus+Heterocephalobus+
   Heterocephalobus_sp2+
Heterocephalobus_sp3+Monohysterid+Paratylenchus_2spp+Plectus_sp1
   +Plectus_sp2+ Plectus_sp3+Tylencholaimid+Tylenchorhynchus_sp1+
Tylenchorhynchus_sp2+
   Tylenchus_sp1+ Tylenchus_sp2)/100;
three=
(Chromatorid+Criconemoides_2spp+Diphtherophora+Euteratocephalus+Helicotylench
us+Heterodera_J2+
   Meloidogyne_J2+Pratylenchus+Prismatolaimus+Rotylenchus+Teratocephalus+Trip
yla)/100;
four=(Alaimus_sp1 + Alaimus_sp2
   +Anatonchus+Discolaimus+Dorylaimellus_sp1+Dorylaimid+
   Dorylaimus_sp1+ Dorylaimus_sp2+ Doryllium+Enchodelus+Eudorylaimus_sp1
+Eudorylaimus_sp2
   +Mesodorylaimus+Mononchus+Myolonchus+Pungentus+Trichodorus+Iotonchus)/100;
five=(Aporcelaimus_sp1+Aporcelaimus_sp2+Axonchiumx+Longidorus+Nygolaimus+Xiph
inema)/100;

pp2=(Boleodorus+Cephalenchus+Paratylenchus_2spp+Tylenchorhynchus_sp1+
Tylenchorhynchus_sp2+
   Tylenchus_sp1+ Tylenchus_sp2)/100;
pp3=(Criconemoides_2spp+Helicotylenchus+Heterodera_J2+Meloidogyne_J2+Pratylen
chus+Rotylenchus)/100;
pp4=(Dorylaimellus_sp1 +Pungentus+Trichodorus)/100;
pp5= (Axonchium+Longidorus+Xiphinema)/100;
```

```
fl2= two-pp2;
fl3= three-pp3;
fl4= four;
fl5= five-pp5;
ppt=pp2+pp3+pp4+pp5;


ppi=(pp2*2+pp3*3+pp4*4+pp5*5);
mi15=(one*1+fl2*2+fl3*3+fl4*4+fl5*5);
mi25=(fl2*2+fl3*3+fl4*4+fl5*5);
smi25=(two*2+three*3+four*4+five*5);
smi15=(one*1+two*2+three*3+four*4+five*5);
ppimi=ppi/mi15;

run;

proc print;
var  location treat rep ppi mi15 mi25 smi25 smi15 ppimi;
run;
```

Trophic groups

```
data trophic;
infile "c:\Documents and Settings\dneher.UTAD\My
Documents\SON\workshop\yeates.dat" lrecl=1000;
input location $ treat $ rep Acrobeloides_nanus Acrobeloides_sp   Alaimus_sp1
   Alaimus_sp2 Anaplectus Anatonchus Aphelenchoides
   Aphelenchus Aporcelaimus_sp1 Aporcelaimus_sp2 Araeolaimid Axonchium
   Boleodorus Bunonema  Cephalenchus Cephalobus_sp1 Cephalobus_sp2
   Cephalobus_sp3 Chromatorid Cervidellus Criconemoides_2spp Diphtherophora
Diplogaster Discolaimus Ditylenchus Dorylaimellus_sp1
   Dorylaimid Dorylaimus_sp1 Dorylaimus_sp2 Doryllium Enchodelus
Eudorylaimus_sp1 Eudorylaimus_sp2   Euteratocephalus Helicotylenchus
   Heterocephalobus Heterocephalobus_sp2 Heterocephalobus_sp3 Heterodera_J2
Iotonchus Longidorus Meloidogyne_J2 Mermithidae
   Mesodorylaimus Monohysterid Mononchus Myolonchus Nygolaimus Panagrolaimus
Paratylenchus_2spp Plectus_sp1 Plectus_sp2 Plectus_sp3
   Pratylenchus Prismatolaimus Pungentus Rhabditidae Rhabditis Rotylenchus
Teratocephalus Trichodorus Tripyla Tylencholaimid
   Tylenchorhynchus_sp1 Tylenchorhynchus_sp2 Tylenchus_sp1 Tylenchus_sp2
Xiphinema;

**Note: data are precentages of total numbers**;

**trophic groups**;
plant=Boleodorus+Cephalenchus+Paratylenchus_2spp+Tylenchorhynchus_sp1
+Tylenchorhynchus_sp2 +
   Tylenchus_sp1
+Tylenchus_sp2+Criconemoides_2spp+Helicotylenchus+Heterodera_J2+Meloidogyne_J
2
   +Pratylenchus+Rotylenchus+Dorylaimellus_sp1+Pungentus+Trichodorus+Axonchiu
m+Longidorus+Xiphinema;

**conservativeplant=plant-Filenchus-Tylenchus_sp1 -Tylenchus_sp2**;

fungal=Aphelenchoides+Aphelenchus+Ditylenchus+Tylencholaimid+Diphtherophora+D
oryllium;
bact=Bunonema+Diplogaster+Panagrolaimus+Rhabditidae+Rhabditis+Acrobeloides_na
nus+Acrobeloides_sp
   +Anaplectus+Cephalobus_sp1
=Cephalobus_sp2+Cephalobus_sp3+Cervidellus+Heterocephalobus +
   Heterocephalobus_sp2 +Heterocephalobus_sp3+Monohysterid+Plectus_sp1
+Plectus_sp2 +Plectus_sp3
   +Chromatorid+Euteratocephalus+Prismatolaimus+Teratocephalus+Alaimus_sp1
   +Alaimus_sp2;
omni= Dorylaimid +Dorylaimus_sp1 +Dorylaimus_sp2+ Enchodelus+Mesodorylaimus;
pred=Tripyla+Anatonchus+Discolaimus+Eudorylaimus_sp1+
Eudorylaimus_sp2+Mononchus+Myolonchus
   +Aporcelaimus_sp1 +Aporcelaimus_sp2+Iotonchus+Nygolaimus;

*convert percentages to proportions**;
prplant=(plant/100)+0.01;
prfungal=(fungal/100)+0.01;
prbact=(bact/100)+0.01;
prpred=(pred/100)+0.01;
promni=(omni/100)+0.01;
```

```
*preparation for diversity index**;
t1=prplant*log(prplant);
t2=prfungal*log(prfungal);
t3=prbact*log(prbact);
t4=prpred*log(prpred);
t5=promni*log(promni);

s1=prplant**2;
s2=prfungal**2;
s3=prbact**2;
s4=prpred**2;
s5=promni**2;

**Trophic diversity**;
Tshannon= -(t1+t2+t3+t4+t5); **shannon**;
trophicN1=exp(Tshannon); **N1**;
Tsimpson= s1+s2+s3+s4+s5;
trophicN2=1/(Tsimpson);

Tevenness=(trophicN2-1)/(trophicN1-1); **E5, p. 94 Ludwig and Reynolds**;
FB=prfungal/prbact;
FFB=prfungal/(prfungal+prbact);
FBPP=(prfungal+prbact)/prplant;

proc print;
var  location treat rep prplant prfungal prbact prpred promni
   Tshannon trophicN1 Tsimpson trophicN2 Tevenness FB FFB FBPP ;
run;
```

Ferris indices

```
data trophic;
infile "c:\Documents and Settings\dneher.UTAD\My
Documents\SON\workshop\yeates.dat" lrecl=1000;
input location $ treat $ rep Acrobeloides_nanus Acrobeloides_sp   Alaimus_sp1
   Alaimus_sp2 Anaplectus Anatonchus Aphelenchoides
   Aphelenchus Aporcelaimus_sp1 Aporcelaimus_sp2 Araeolaimid Axonchium
   Boleodorus Bunonema  Cephalenchus Cephalobus_sp1 Cephalobus_sp2
   Cephalobus_sp3 Chromatorid Cervidellus Criconemoides_2spp Diphtherophora
Diplogaster Discolaimus Ditylenchus Dorylaimellus_sp1
   Dorylaimid Dorylaimus_sp1 Dorylaimus_sp2 Doryllium Enchodelus
Eudorylaimus_sp1 Eudorylaimus_sp2   Euteratocephalus Helicotylenchus
   Heterocephalobus Heterocephalobus_sp2 Heterocephalobus_sp3 Heterodera_J2
Iotonchus Longidorus Meloidogyne_J2 Mermithidae
   Mesodorylaimus Monohysterid Mononchus Myolonchus Nygolaimus Panagrolaimus
Paratylenchus_2spp Plectus_sp1 Plectus_sp2 Plectus_sp3
   Pratylenchus Prismatolaimus Pungentus Rhabditidae Rhabditis Rotylenchus
Teratocephalus Trichodorus Tripyla Tylencholaimid
   Tylenchorhynchus_sp1 Tylenchorhynchus_sp2 Tylenchus_sp1 Tylenchus_sp2
Xiphinema;

**Note: data are precentages of total numbers**;

**trophic groups**;
plant=Boleodorus+Cephalenchus+Paratylenchus_2spp+Tylenchorhynchus_sp1
+Tylenchorhynchus_sp2 +
   Tylenchus_sp1
+Tylenchus_sp2+Criconemoides_2spp+Helicotylenchus+Heterodera_J2+Meloidogyne_J
2
   +Pratylenchus+Rotylenchus+Dorylaimellus_sp1+Pungentus+Trichodorus+Axonchiu
m+Longidorus+Xiphinema;

**conservativeplant=plant-Filenchus-Tylenchus_sp1 -Tylenchus_sp2**;

fungal=Aphelenchoides+Aphelenchus+Ditylenchus+Tylencholaimid+Diphtherophora+D
oryllium;
bact=Bunonema+Diplogaster+Panagrolaimus+Rhabditidae+Rhabditis+Acrobeloides_na
nus+Acrobeloides_sp
   +Anaplectus+Cephalobus_sp1
=Cephalobus_sp2+Cephalobus_sp3+Cervidellus+Heterocephalobus +
   Heterocephalobus_sp2 +Heterocephalobus_sp3+Monohysterid+Plectus_sp1
+Plectus_sp2 +Plectus_sp3
   +Chromatorid+Euteratocephalus+Prismatolaimus+Teratocephalus+Alaimus_sp1
   +Alaimus_sp2;
omni= Dorylaimid +Dorylaimus_sp1 +Dorylaimus_sp2+ Enchodelus+Mesodorylaimus;
pred=Tripyla+Anatonchus+Discolaimus+Eudorylaimus_sp1+
Eudorylaimus_sp2+Mononchus+Myolonchus
   +Aporcelaimus_sp1 +Aporcelaimus_sp2+Iotonchus+Nygolaimus;

*convert percentages to proportions**;
prplant=(plant/100)+0.01;
prfungal=(fungal/100)+0.01;
prbact=(bact/100)+0.01;
prpred=(pred/100)+0.01;
promni=(omni/100)+0.01;
```

```
*preparation for diversity index**;
t1=prplant*log(prplant);
t2=prfungal*log(prfungal);
t3=prbact*log(prbact);
t4=prpred*log(prpred);
t5=promni*log(promni);

s1=prplant**2;
s2=prfungal**2;
s3=prbact**2;
s4=prpred**2;
s5=promni**2;

**Trophic diversity**;
Tshannon= -(t1+t2+t3+t4+t5); **shannon**;
trophicN1=exp(Tshannon); **N1**;
Tsimpson= s1+s2+s3+s4+s5;
trophicN2=1/(Tsimpson);

Tevenness=(trophicN2-1)/(trophicN1-1); **E5, p. 94 Ludwig and Reynolds**;
FB=prfungal/prbact;
FFB=prfungal/(prfungal+prbact);
FBPP=(prfungal+prbact)/prplant;

proc print;
var  location treat rep prplant prfungal prbact prpred promni
   Tshannon trophicN1 Tsimpson trophicN2 Tevenness FB FFB FBPP ;
run;
```

Genus indices

```
data trophic;
infile "c:\Documents and Settings\dneher.UTAD\My
Documents\SON\workshop\yeates.dat" lrecl=1000;
input location $ treat $ rep Acrobeloides_nanus Acrobeloides_sp  Alaimus_sp1
   Alaimus_sp2 Anaplectus Anatonchus Aphelenchoides
   Aphelenchus Aporcelaimus_sp1 Aporcelaimus_sp2 Araeolaimid Axonchium
   Boleodorus Bunonema  Cephalenchus Cephalobus_sp1 Cephalobus_sp2
   Cephalobus_sp3 Chromatorid Cervidellus Criconemoides_2spp Diphtherophora
Diplogaster Discolaimus Ditylenchus Dorylaimellus_sp1
   Dorylaimid Dorylaimus_sp1 Dorylaimus_sp2 Doryllium Enchodelus
Eudorylaimus_sp1 Eudorylaimus_sp2  Euteratocephalus Helicotylenchus
   Heterocephalobus Heterocephalobus_sp2 Heterocephalobus_sp3 Heterodera_J2
Iotonchus Longidorus Meloidogyne_J2 Mermithidae
   Mesodorylaimus Monohysterid Mononchus Myolonchus Nygolaimus Panagrolaimus
Paratylenchus_2spp Plectus_sp1 Plectus_sp2 Plectus_sp3
   Pratylenchus Prismatolaimus Pungentus Rhabditidae Rhabditis Rotylenchus
Teratocephalus Trichodorus Tripyla Tylencholaimid
   Tylenchorhynchus_sp1 Tylenchorhynchus_sp2 Tylenchus_sp1 Tylenchus_sp2
Xiphinema;

**Note: data are precentages of total numbers**;

**trophic groups**;
plant=Boleodorus+Cephalenchus+Paratylenchus_2spp+Tylenchorhynchus_sp1
+Tylenchorhynchus_sp2 +
   Tylenchus_sp1
+Tylenchus_sp2+Criconemoides_2spp+Helicotylenchus+Heterodera_J2+Meloidogyne_J
2
   +Pratylenchus+Rotylenchus+Dorylaimellus_sp1+Pungentus+Trichodorus+Axonchiu
m+Longidorus+Xiphinema;

**conservativeplant=plant-Filenchus-Tylenchus_sp1 -Tylenchus_sp2**;

fungal=Aphelenchoides+Aphelenchus+Ditylenchus+Tylencholaimid+Diphtherophora+D
oryllium;
bact=Bunonema+Diplogaster+Panagrolaimus+Rhabditidae+Rhabditis+Acrobeloides_na
nus+Acrobeloides_sp
   +Anaplectus+Cephalobus_sp1
=Cephalobus_sp2+Cephalobus_sp3+Cervidellus+Heterocephalobus +
   Heterocephalobus_sp2 +Heterocephalobus_sp3+Monohysterid+Plectus_sp1
+Plectus_sp2 +Plectus_sp3
   +Chromatorid+Euteratocephalus+Prismatolaimus+Teratocephalus+Alaimus_sp1
   +Alaimus_sp2;
omni= Dorylaimid +Dorylaimus_sp1 +Dorylaimus_sp2+ Enchodelus+Mesodorylaimus;
pred=Tripyla+Anatonchus+Discolaimus+Eudorylaimus_sp1+
Eudorylaimus_sp2+Mononchus+Myolonchus
   +Aporcelaimus_sp1 +Aporcelaimus_sp2+Iotonchus+Nygolaimus;

*convert percentages to proportions**;
prplant=(plant/100)+0.01;
prfungal=(fungal/100)+0.01;
prbact=(bact/100)+0.01;
prpred=(pred/100)+0.01;
promni=(omni/100)+0.01;
```

```
*preparation for diversity index**;
t1=prplant*log(prplant);
t2=prfungal*log(prfungal);
t3=prbact*log(prbact);
t4=prpred*log(prpred);
t5=promni*log(promni);

s1=prplant**2;
s2=prfungal**2;
s3=prbact**2;
s4=prpred**2;
s5=promni**2;

**Trophic diversity**;
Tshannon= -(t1+t2+t3+t4+t5); **shannon**;
trophicN1=exp(Tshannon); **N1**;
Tsimpson= s1+s2+s3+s4+s5;
trophicN2=1/(Tsimpson);

Tevenness=(trophicN2-1)/(trophicN1-1); **E5, p. 94 Ludwig and Reynolds**;
FB=prfungal/prbact;
FFB=prfungal/(prfungal+prbact);
FBPP=(prfungal+prbact)/prplant;

proc print;
var  location treat rep prplant prfungal prbact prpred promni
   Tshannon trophicN1 Tsimpson trophicN2 Tevenness FB FFB FBPP ;
run;
```

Appendix 2. Participant List

Instructors

Dr. Deborah A. Neher (effective 9/1/04)
Dept of Plant and Soil Science
University of Vermont
Burlington, VT 05405
Phone: +1 802 626 2630
Fax: +1 802 656 4656
Email: deborah.neher@uvm.edu
http://www.eeescience.utoledo.edu/Faculty/Neher/homepage.htm

Tom Bongers
Laboratory of Nematology
Wageningen University
P. O. Box 8123
6700 ES Wageningen
THE NETHERLANDS
Email: Tom.Bongers@wur.nl

Howard Ferris
Dept of Nematology
UC Davis
Davis, CA 95616
Email: hferris@ucdavis.edu

PARTICIPANTS

Ernest C. Bernard
The University of Tennessee
Entomology and Plant Pathology
213 Plant Biotechnology Building
Knoxville, TN 37996-4560 USA
Telephone: +1 865 974 7135
Fax: +1 865 974 4744
E-mail: ebernard@utk.edu

George Bird
243 Natural Science Building
Dept. of Entomology
Michigan State University
East Lansing, MI 48824
Phone: +1 517 353 3890
Fax: +1 517 353 4354
Email: birdg@msu.edu

Emma Broos
Research Scientist
Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, CO 80523-1499
Tel +1 970 491 1984
Fax +1 970 491 1965
Email: emma@nrel.colostate.edu

Pat Donald
USDA ARS
605 Airways Blvd
Jackson, TN 38301
Phone +1 731 425 4739
FAX +1 731 425 4760
Email: pdonald@ars.usda.gov

Jamal Faghihi
Dept. of Entomology
Purdue University
West Lafayette, IN 47907
Phone: +1 765 494 5901
Fax: + 1 765 494 0535
Email: Jamal_Faghihi@entm.Purdue.edu

Nancy Kokalis Burelle
Ecologist
USDA, ARS
U. S. Horticultural Research Lab
2001 South Rock Rd.
Ft. Pierce, FL 34945
Phone +1 772 462 5861
Fax +1 772 462 5986
Email: NBurelle@ushrl.ars.usda.gov

Ian Wm. King
Dept. of Biology
Memorial University of Newfoundland
St. John's, NL, Canada
A1B 3X9
Email: ianwmking@yahoo.ca

Grace Li
Natural Resource Laboratory
Colorado State University
Fort Collins, CO 80523
Phone: +1 970 491 7802
Fax: +1 970 491 2339
Email: grace@nrel.colostate.edu

Ann MacGuidwin
Dept. Plant Pathology
1630 Linden Dr
University of Wisconsin
Madison, WI 53706
Phone: +1 608 263 6131
Fax: +1 608 263 2626
Email: aem@plantpath.wisc.edu

Haddish Melakeberhan
243 Natural science Building
Dept. of Entomology
Michigan State University
East Lansing, MI 48824
Email: melakebe@msu.edu

Peter Mullin
Department of Plant Pathology
406 Plant Sciences Hall
University of Nebraska
Lincoln, NE 68583-0722
Phone: +1 402 472 5770
Fax: +1 402 472 2853
Email: pmullin@unlserve.unl.edu

Johnson Nkem
Research Scientist
Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, CO 80523-1499
Tel +1 970 491 1985
Fax +1 970 491 1965
Email: nkem@nrel.colostate.edu

Hiroaki Okada
Nematology and Soil Zoology Unit
National Institute for Agro-Environmental
Sciences
Kan'nondai 3-1-3
Tsukuba, Ibaraki
305-8604, JAPAN
Email: hokada@affrc.go.jp

Jeff Powell
Fungal and Soil Ecology Lab
Department of Botany
University of Guelph
50 Stone Rd. E.
Guelph, ON N1G 2W1
Canada
ph: 519 824 4120 x56718
fx: 519 767 1991
US and Canadian country prefix: [1]
Other country dialing prefix: [011]
jpowell@uoguelph.ca

Tom Powers
Department of Plant Pathology
406 Plant Sciences Hall
University of Nebraska
Lincoln, NE 68583-0722
Phone: +1 402 472 5726
Fax: +1 402 472 2853
Email: tpowers@unl.edu

Manisol Quintanilla
243 Natural Science Building
Dept of Entomology
Michigan State University
East Lansing, MI 48824
Email: Quinta13@msu.edu

M. Omolara Rotimi,
Department of Crop, Soil and Pest
Management,
Federal University of Technology,
P.M.B. 704, Akure,
Ondo State, Nigeria.
 Tel: (mobile): + 234 803 536 2645
Tel: (Home): + 234 1 471 4134
E-mail: rotimila03@yahoo.com

Jyotsna Sharma
Research Professor,
Department of Biology,
University of Texas at San Antonio
6900 North Loop 1604 West,
San Antonio, TX 78249-0662
Phone: 210-458-5928
Fax: 210-458-5658
Email: JSharma@utsa.edu

Mario Tenuta
Assistant Professor, Soil Microbiology
Department of Soil Science
University of Manitoba, Winnipeg, MB
Canada R3T 2N2
Tel: 204 474-7827
Fax: 204 474-7642
US and Canadian country prefix: [1]
Other country dialing prefix: [011]
Email: tenutam@ms.umanitoba.ca

Tim Todd
Dept of Plant Pathology
Kansas State University
Manhattan, KS 66506
Email: nema@plantpath.ksu.edu

Diana Wall
Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, CO 80523-1499
Tel 970 491 2504
Fax 970 491 1965
Email: diana@nrel.colostate.edu

Inga A. Zasada
Research Plant Pathologist
USDA-ARS Nematology Laboratory
10300 Baltimore Ave.
Bldg. 011A, 165A BARC-West
Beltsville, MD 20705 USA
Tel: (301)504-9813
Fax: (301)504-5589
E-mail: ZasadaI@ba.ars.usda.gov