Nematology Monographs & Perspectives, 2004, Vol. 2, 511-514

Selection of sentinel taxa and biomarkers

Deborah A. NEHER [1,*], Daniel A. FISCUS [2] and Fafeng LI [1]

[1] *Department of Earth, Ecological, and Environmental Sciences, Toledo, OH 43606, USA*
[2] *UMCES Appalachian Laboratory, 301 Braddock Road, Frostburg, MD 21532, USA*

Summary – Nematode community indices would become more feasible for use in environmental monitoring programmes by reducing the number of genera that need to be enumerated and identified. This could be achieved by narrowing indices to include only sensitive or tolerant genera or species while eliminating ambiguous ones. Identification of sentinel taxa can be achieved by employing a combination of tools. For example, multivariate statistics can help identify taxa that demonstrate relative tolerance or sensitivity to physical and/or chemical/nutrient types of disturbance. Life history characteristics of taxa meeting these criteria can be verified in empirical studies to evaluate and recommend refinement in coloniser-persister weights employed in maturity indices. Validation of coloniser-persister values can be achieved using independent molecular biomarkers. Once sentinel taxa are identified, molecular diagnostic tools are possible. Availability of commercial kits then becomes approachable to non-specialists and cost-effective (time and labour) for implementing nematode bioindicators within large-scale environmental monitoring programmes.

It would be more feasible to use nematode communities in regional and national monitoring programmes if we could focus on a set of indicator or sentinel taxa. With fewer genera or species, indices become more sensitive, interpretable and cost effective. The goal is to identify genera that are relatively sensitive or insensitive to particular types of disturbance while eliminating ambiguous ones. Sensitivity and insensitivity are defined respectively as a decrease and increase in abundance when exposed to a disturbance.

Identification of sentinel taxa can be achieved by employing a combination of tools. First, ordination analysis can be used to identify patterns in complex data from regional-scale field studies. This approach

* E-mail: deborah.neher@utoledo.edu

identifies genera with distinctive response to direct effects of cultivation or chemical pollutants by canonical correspondence analysis (CCA). Indirect or secondary effects are determined by partial CCA. Two types of environmental disturbance alter nematode communities in qualitatively different ways. Physical disturbances such as cultivation interrupt ecological succession. Chemical or enrichment disturbances result in nutrient enrichment or chemical pollution. Unfortunately, both types are often confounded in field studies, adding complexity to the selection process.

We propose three criteria for selecting sentinel genera: *i*) consistency in sensitivity to both direct and indirect forms of a disturbance type; *ii*) consistency in sensitivity to both physical and chemical/nutrient types of disturbance; and *iii*) opposite types of responses to physical than chemical/nutrient disturbance. We recommend *Discolaimus*, *Mylonchulus* and *Plectus* as candidate sentinel taxa of general disturbance because they meet multiple criteria (Fiscus & Neher, 2002). Sensitivity of *Discolaimus* and tolerance of *Plectus* are consistent with their coloniser-persister (*c-p*) values of 5 and 2, respectively. In contrast, *Mylonchulus* was abundant under cultivation and enrichment conditions, opposite its *c-p* value of 4.

After identification of candidate genera, controlled experiments are necessary to validate their response to defined types and magnitude of disturbances. Ordination differs from that of maturity index approaches by making no assumptions regarding morphology or life history strategies. Likewise, this approach provides different information than the *c-p* scales of Bongers (1990). Several taxa demonstrate opposite responses to disturbance than their *c-p* value might suggest (Table 1). Furthermore, disagreement among studies occurs. For example, Fiscus and Neher (2002) note that *Plectus* is tolerant, as its *c-p* value would suggest, the opposite of Korthals *et al.* (1996). Ultimately, empirical tests of the impact of defined disturbance types and magnitudes of nematode life history will help to both reconcile differences in these approaches and empirically test *c-p* values of maturity indices. Currently, Neher and Li are conducting controlled experiments, exposing nematodes to a concentration gradient of heavy metal or polycyclic aromatic hydrocarbons (PAH) and measuring response to life history characteristics including survival, development, and reproduction. Examples of measurements for survival include concentration of 50% of individuals (LC_{50}) and no observable effect concentrations (NOEC). Development can be expressed

Table 1. *Discrepancies* (✓) *between* c-p *values and response to disturbance.*

Genus	*c-p* value	Trophic group	Sensitive	Tolerant	Reference*
Eumonhystera	1	bacterivore	✓		2
Acrobeles	2	bacterivore	✓		1
Plectus	2	bacterivore	✓		1
Clarkus	4	predator		✓	2
Enchodelus	4	omnivore		✓	2
Tylenchulaimus	4	fungivore		✓	2
Aporcelaimus	5	predator		✓	2

* 1: Korthals *et al.*, 1998; 2: Fiscus & Neher, 2002.

as body size and its rate of increase through time, relative to an unexposed control. Reproductive fitness is measured as egg number, size and hatch rate.

Life history characteristics reflect phenotype responses to stress or disturbance. However, biological responses may also occur at the genome level. Independent biomarkers are a supplementary or alternative means to verify the response of candidate sentinel genera to type and magnitude of disturbance. Biomarkers differ from indicators because they focus on mechanistic response and their target is typically molecular and/or cellular. Two types of biomarkers are being evaluated currently, heat stress proteins (HSP) and DNA damage. Heat stress proteins assist in maintaining natural configuration of proteins, and are induced by many types of stress. A problem with their use as biomarkers is their 'acquired tolerance', therefore limiting their utility to acute exposures (Kammenga *et al.*, 1998; Bierkens, 2000). Detection of chronic exposure is typically desired in environmental monitoring programmes. DNA damage caused by genotoxicants occurs in different forms: *i*) adduct formation; *ii*) general strand breakage; and *iii*) mutation (Shugart, 1998). DNA adducts are covalent bonds between a toxicant such as PAH and DNA. Without repair, DNA replication is affected and/or mutations may develop.

Once sentinel taxa are identified, molecular diagnostic tools for whole community assessments are possible. Then, availability of commercial kits becomes approachable to non-specialists and cost-effective for implementing nematode bioindicators within large-scale environmental monitoring programmes.

Acknowledgements

The US Environmental Protection Agency, US Department of Agriculture-Agricultural Research Service, North Carolina Agricultural Research Service, and Lake Erie Protection Fund provided research funds. The University of Toledo Kohler Travel Fund and Society of Nematologists provided travel support.

References

BIERKENS, J.G.E.A. (2000). Applications and pitfalls of stress-proteins in biomonitoring. *Toxicology* 153, 61-72.

BONGERS, T. (1990). The maturity index: an ecological measure of environmental disturbance based on nematode species composition. *Oecologia* 83, 14-19.

FISCUS, D.A. & NEHER, D.A. (2002). Distinguishing nematode genera based on relative sensitivity to physical and chemical disturbances. *Ecological Applications* 12, 565-575.

KAMMENGA, J.E., DALLINGER, R., DONKER, M.H., KOHLER, H.R., SIMONSEN, V., TRIEBSKORN, R. & WEEKS, J.M. (2000). Biomarkers in terrestrial invertebrates for ecotoxicological soil risk assessment. *Review of Environmental Contamination and Toxicology* 164, 93-147.

KORTHALS, G.W., POPOVICI, I., ILIEV, I. & LEXMOND, T.M. (1998). Influence of perennial ryegrass on a copper and zinc affected terrestrial nematode community. *Applied Soil Ecology* 10, 73-85.

SANDERS, B.M., MARTIN, L.S., NELSON, W.G., PHELPS, D.K. & WELCH, W. (1991). Relationship between accumulation of a 60KD heat stress protein and scope-for-growth in *Mytilus edulis* exposed to a range of copper concentrations. *Marine Environmental Research* 31, 81-97.

SHUGART, L.R. (2000). DNA damage as a biomarker of exposure *Ecotoxicology* 9, 329-340.