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Ecosystem type affects interpretation of soil nematode community measures

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Abstract

A better understanding of performance among major ecosystem types is necessary before nematode community indices can be applied at large geographic scales, ranging from regional to global. The objectives of this study were to: (1) determine the inherent variability in soil properties among and within wetland, forest and agricultural ecosystems; (2) compare nematode community composition among and within ecosystem types and report genera detected in wetland soils; (3) determine if community composition or composite indices are able to differentiate type and magnitude of disturbance; (4) identify seasonal responses of nematode communities and indices to disturbance; (5) quantify variance components of nematode community measures at the land resource region (LRR) and ecosystem scale. Nematode communities were extracted from soils in relatively undisturbed and disturbed wetland, forest and agricultural soils in three LRR (coastal plain, piedmont and mountain) in North Carolina ($n = 18$ sites), seven to eight times per year for 2 years, starting in March 1994 and ending in November 1995. Overall, 48, 44 and 45 nematode families were observed in wetland, forest and agricultural soils, respectively. This inventory totaling 110 genera represents the richest nematode fauna reported from wetlands. After adjusting for soil properties as covariables, nematode maturity index (MI) values were inconsistent among ecosystems in their ability to distinguish levels of disturbance. The magnitude of disturbance was greater between relatively undisturbed and disturbed wetland than forest or agricultural soil. Nematode family composition differentiated levels of disturbance and ecosystems better than community indices, and current efforts indicate that taxonomic resolution at the level of genus is necessary for interpretation of ecosystem function. Deviation between disturbance levels in all ecosystems was greatest in July. For use in large-scale environmental monitoring programs, it is more cost-effective and easier to calibrate and interpret indices if variance is greatest at larger rather than at smaller spatial scales, e.g., variance is progressively smaller from among regions, among ecosystems and disturbance within ecosystems. This preferred order of ranking of variance by spatial scale occurred for nematode community indices MI, MI25, ΣMI25, and SI and abundance of predaceous nematodes. Variance was greater at smaller than at larger spatial scales for nematode community

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indices PPI, FB, CI, EI, trophic and family diversity, and relative abundance of bacterivorous, fungivorous, plant-parasitic and omnivorous nematodes.

Keywords: Agriculture; Canonical correspondence analysis; Environmental monitoring; Forest; Maturity index; Principal response curves; Riparian; Wetlands

1. Introduction

Belowground communities are a critical natural resource with immense, but largely unexplored, biodiversity (Andre et al., 1994, 2001; Wheeler et al., 2004; Science Editors, 2004). The perceived value of soil communities as ecological indicators will be increased by establishing their functional links to ecosystem processes (Debruyn, 1997), determining a hierarchy of geographic scale (Neher et al., 1998) and measuring their utility across ecosystem boundaries. Soil nematodes have the potential to provide insights into soil processes and condition (Ritz and Tradgill, 1999). Nematodes are ubiquitous, diverse, abundant, in direct contact with dissolved compounds in the soil water through their permeable cuticle, and easily extracted and assigned to ecological groups. Nematodes can serve as a model subsystem that provides a holistic measure of the biotic and functional status of soils (Bongers and Ferris, 1999; Neher, 2001). The development of the maturity index (MI) (Bongers, 1990) represented a significant advance in interpreting the relationship between the ecology of nematode communities and soil function, and thus, facilitated bioassessment studies using nematodes as indicators. The maturity index is based on the principle that different taxa have contrasting sensitivities to stress or disruption of the sequence of ecological succession because of their life-history characteristics. Since the introduction of the index, several authors have proposed modifications of the original (Popovici, 1992; de Goede and Dekker, 1993; Yeates, 1994; Bongers et al., 1995; Neher and Campbell, 1996; Ferris et al., 2001; Neher, 2001). The evolution of these concepts led to a wider application of nematode communities as ecological bioindicators of various terrestrial ecosystems, including agroecosystems (Freckman and Ettema, 1993; Yeates and Bongers, 1999), grasslands (Ekschmitt et al., 2001; Verschoor et al., 2001), forests (de Goede and Dekker, 1993) and wetlands (Ettema et al., 1999). The family of maturity indices has been able to successfully detect changes in soil condition caused by contamination with heavy metals (Yeates, 1994; Korthals et al., 1996, 1998; Nagy, 1999), addition of animal waste (Ettema and Bongers, 1993; Neher, 1999; Neher and Olson, 1999), addition of inorganic nitrogen (de Goede and Dekker, 1993; Freckman and Ettema, 1993; Neher, 1999), sod-cutting (de Goede, 1996), cultivation (Freckman and Ettema, 1993; Neher and Campbell, 1994; Wasilewska, 1994; Yeates, 1994) and fumigation with non-specific biocides (Ettema and Bongers, 1993; Yeates and van der Meulen, 1996).

Environmental disturbances can be classified in many ways. First, disturbances may be classified by type, i.e., chemical, physical, or biological, which alter invertebrate communities in qualitatively and quantitatively different ways. Second, disturbance can be described by characteristics of the disturbance, e.g., intensity, frequency, regularity and magnitude (Dyer and Letourneau, 2003). Third, disturbances may be seasonal or otherwise cyclical. Fourth, disturbances may be large or small in scale of impact, e.g., tree-fall or clear-cut. Overall, a disturbance regime may be specific to an ecosystem, geographic location or local climate, e.g., nutrient and pest management in annual agricultural systems, grazing pressure (e.g., species, stocking rate) on pastures, and harvest method of forests. Community indices can integrate responses to 'disturbance' because nematodes represent between five and eight trophic groups (Yeates et al., 1998) and occupy positions at primary, secondary and/or tertiary consumer level in soil food webs (Moore and de Ruiter, 1991). Apparently, different functional groups and genera are more or less tolerant to different 'modes' of disturbance. Although maturity indices generally have the ability to respond to specific disturbances, responses have not been fully consistent across regions, ecosystems, seasons or other conditions.