Biodiversity and Ecosystem Functioning

A special issue devoted to belowground biodiversity in soils and freshwater and marine sediments

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The discovery of a new species, like the exploration of a planet, is cause for intense excitement and curiosity in the scientific community. It generates a plethora of questions: What is the species' role in the natural world? What are its relationships with other species? And perhaps more urgently, given current rates of habitat destruction, what will happen to the ecosystem if this species is lost due to human actions? The exploration and discovery of species in soils and in freshwater and marine sediments is just beginning. These interconnected subsurface habitats remain a frontier when compared to the aboveground world. Only a small percentage of the subsurface environment has been explored, and most of that has been in soils. Less than 20% of the surface area of freshwater sediments and 5% of marine sediments have been examined, yet the wealth and abundance of species living below the surface may be greater than that above the surface (Freckman et al. 1997). Of this great abundance, an estimated 98% of the species, many of which are microscopic, are unknown (Hawkworth and Kalin-Arroyo 1995, Freckman et al. 1997).

Many of these biota significantly modify the rates of key global biogeochemical processes and the types of transformations that occur (Brusaard et al. 1997, Palmer et al. 1997, Snelgrove et al. 1997). For example, soils and sediments store the bulk of the world's carbon (5300 Gt) in the form of organic matter (Maybeck 1993, IPCC 1995, Schimmel 1995), and the cycling of carbon and nitrogen (e.g., through decomposition, nitrogen transformations, and trace-gas generation) is mediated by soil and sediment biota (Freckman et al. 1997). Other major ecosystem processes that involve numerous groups of biota include creation of new biomass through both primary and secondary productivity, mixing and redistribution of organic matter and organisms, stabilization of soils and sediments, physical shredding of organic matter and its preparation for further decay by other organisms, and biological nitrogen fixation.

Belowground biota also provide critical links between the atmospheric, terrestrial, and aquatic realms. Some functional groups, for example, the bioturbators (gophers, ants, termites, and earthworms in soils; polychaetes, oligochaetes, crustaceans, and mollusks in freshwater and marine sediments), function across surface interfaces and act to aerate and redistribute organic matter, speeding decay and nutrient cycling. Soil and sediment biota also clean water, carry out bioremediation of pollutants, enhance soil fertility, serve as or undergird the food supply (in fisheries and agriculture, respectively), and provide biological control of pests and parasites (Daily 1997).

Ultimately, it will be important to know which organisms regulate specific ecosystem processes. For the vast majority of organisms that inhabit soils and sediments, however, our knowledge is insufficient to identify geographical patterns of diversity, to list the endemic species, or to identify those species or suites of species that may control key ecosystem processes at local to regional scales. Organisms in soils and sediments have remained unknown for several reasons: it is difficult to extract or identify the majority of organisms in situ; the organisms are generally small, ranging in size from micrometers to centimeters; few scientists have been trained to identify these organisms; sampling techniques vary with the individual taxonomic group; and even in their habitats, organisms have a heterogeneous distribution, both spatially and temporally (Freckman et al. 1997). Research on the microscopic groups of belowground organisms (bacteria, fungi, rotifers, tardigrades, protozoa, nematodes, and microarthropods) is...
especially inadequate.

Scientists do know that surface and subsurface habitats are threatened by humans. Disturbance to soils and sediments from urbanization, agriculture, dredging, and pollution has the consequence of destroying these habitats, disrupting biogeochemical cycles, and altering subsurface food webs. Subsurface biodiversity is also affected by rapid changes in land-use practices, introductions of species, and contamination of soil, air, and water.

Fortunately, new techniques are accelerating our ability to explore all life in soils and sediments. Molecular techniques can be used to confirm genetic diversity in microscopic invertebrates as well as microbes, and with advances in other technologies (e.g., nuclear magnetic resonance, fluorescent micro-particle techniques, fine-scale video image analysis, gas chromatography, and mass spectroscopy) it is becoming possible to relate some species to their function in soils and sediments. Thus, there is a new excitement about discovering species and, through experimentation and observation, learning their importance in ecosystem processes. The article by Behan-Pelletier and Newton (1999) in this issue discusses the potential of some of these new technologies—in particular, advances in bioinformatics that enable researchers to share microscopic observations of species and knowledge internationally via the Internet and that will only accelerate our understanding and ability to predict the effects of disturbance on key species. This knowledge will lead to more sustainable management of soils, freshwater sediments, and marine sediments.

In 1996, the Scientific Committee on Problems in the Environment (SCOPE) noted the importance of, but lack of appreciation given to, soil and sediment biota. SCOPE approved a Committee on Soil and Sediment Biodiversity and Ecosystem Functioning (SSBEF), which had as a charge the synthesis of knowledge on biodiversity of soils, freshwater sediments, and marine sediments. The articles in this special issue of *BioScience* were the first task of the SCOPE SSBEF committee. They were written in an effort to highlight the challenges and new advances in identifying species in subsurface habitats and to address whether our knowledge is adequate to determine when loss of species would affect ecosystem functioning.

The article by Wall and Moore (1999) considers the contribution of species biodiversity to ecosystem functioning in soils. In particular, it uses examples of mutualistic relationships to illustrate that interactions between specific species can have important consequences for ecosystem processes. In such processes, it is argued, species redundancy may be minimal. Covitch et al. (1999) discuss the state of research on the biology of freshwater benthic invertebrates. They reveal that for the vast majority of species, there is too little knowledge to predict their importance for ecosystem functioning. However, from the few species that are well known, they are able to cite many examples in which the presence or absence of a single species has important consequences for the functioning of freshwater ecosystems. Levels and patterns of biodiversity in marine benthic systems are discussed in the article by Snelgrove (1999). These ecosystems are among the most poorly known. The author describes striking similarities and differences in biota, biodiversity, and ecosystem processes of marine sedimentary habitats compared with freshwater sediments and soils, and describes the major threats to these poorly studied habitats. Groffman and Bohlen (1999) provide an overview and comparison of important biota and processes across all domains. They examine similarities and differences at a range of scales, from microscopic to global. By considering the subsurface as one system, rather than separate subsystems, the authors examine large-scale effects of species.

The issue is intended to stimulate discussion among a wide group of individuals: scientists, policymakers, and the general public. As a result of wider discussion, gaps in our knowledge will be identified and research priorities can be established to allow for timely responses to rapidly changing conditions.

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**References cited**


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