INTRODUCTION: WHY STUDY MICROBES AT LTER SITES?

Microbes are essential for the functioning of ecological systems. Vital microbial processes include decomposition and mineralization, aspects of the nitrogen cycle (nitrogen fixation, nitrification, denitrification), mycorrhizal provision of nutrients to trees, microbial N immobilization, production of biomass fueling microbial food webs, and breakdown of toxic materials. While ecologists have developed methods to measure many of the rates of these processes they have effectively ignored the microbes themselves. These they treat as a "black box". It is now time augment these rate studies with measurements aimed at the microbes themselves. We believe that a better level of understanding of complex ecological systems *can only be achieved through a better understanding of microbial abundance, distribution, dynamics, communities, and of how these communities function and are controlled.*

The microbial research that has been carried out over the nearly two decades of the LTER program has added to fundamental knowledge and also made clear the advantages to carrying out microbial research at LTER field sites. First, the environment at the site is well studied; data on climate, soils, vegetation, and so forth, are readily available. Second, data can be gathered for a number of years; this is appropriate for questions on variability of microbial processes, biomass, or species succession. Third, long-term and large-scale experiments are being carried out at many sites. These are excellent opportunities to investigate environmental regulation of microbes and the role of microbes in ecosystem processes. Fourth, data can be easily distributed to a wider audience through well-established databases such as the web-based LTERnet. Fifth, comparative studies are easy to carry out through the network of contacts that are in place across all of these field sites. Making the same measurements at sites with different environments has proven to be a valuable tool for understanding controls of microbial processes. Finally, data at intensively studied sites often provide limits on the rates of microbial activity and allow tests of the reliability of new methods.

VISION I: ECOLOGICAL GOALS

- Measure the biomass and production of microbes across the whole range of ecological systems, aquatic and terrestrial. Techniques need to be standardized for true comparability.
- Determine types and succession of microbes (viruses, bacteria, fungi, microflagellates, protozoans) in various communities and systems. Molecular species probes need to be further developed so that they will work efficiently on samples from nature. Methods need to be developed and agreed upon to characterize microbial communities without identifying every species.
- Assess methods to examine the diversity of functional genes. There are now enough known sequences of functional genes, such as those for nitrification, methane oxidation, denitrification, and nitrogen fixation, that current molecular techniques can be tested for ways to evaluate functional diversity in nature.
- Develop techniques to measure the percent of the population that is active in nature. These might be based on RNA, mRNA, electron transport systems, or autoradiography.
- Determine controls of microbial biomass, communities, and processes. We need to study the

linkages between changes in communities and changes in ecological processes as well as the control of microbes by animal grazers.
- Model microbial systems to integrate important processes with the whole ecological system. The tool of mathematical modeling is underused for microbial systems.

VISION II: FIRST STEPS

- Organize meetings and projects to share existing methods across sites. All who work with microbes in nature recognize the incompleteness of present-day techniques and believe that more transfer should be taking place from new molecular and physiological technologies to methods suitable for studying microbes in the field.
- Produce an enhanced white paper to encourage agencies to establish funding programs for microbial ecology studies at intensive field sites. The paper would present justifications and opportunities for major advances in understanding of ecological processes. It would include figures and examples and emphasize the need for the development of new methods, especially molecular techniques.
- Design and carry out ways to raise the level of understanding of ecologists, including LTER project leaders, NSF program officers, and project reviewers, to the advantages of incorporating microbial ecology into LTER research.