19. TEMPORAL AND SPATIAL VARIABILITY AS NEGLECTED ECOSYSTEM PROPERTIES: LESSONS LEARNED FROM 12 NORTH AMERICAN ECOSYSTEMS

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INTRODUCTION

Evaluating and monitoring the "health" of large-scale systems will require new and innovative approaches. One such approach is to look for ecological signals in the structure of ecological variability observed in space and time. Such variability is sometimes considered something to minimize by clever sampling design, but may in itself contain interesting ecological information (Kratz et al. 1991). In fact, much of ecology can be considered an attempt to understand the patterns of spatial and temporal variability that occur in nature and the processes that lead to these patterns. Despite widespread interest in patterns of variation there have been relatively few attempts to describe comprehensively the temporal and spatial variation exhibited by ecological parameters. As a result, we have no general laws that allow us to predict the relative magnitude of temporal and spatial variability of different types of parameters across the full diversity of ecological systems. Even within single ecosystems, understanding of the interplay

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between temporal and spatial variability is lacking. For example, Lewis (1978) noted that despite a large literature, the relation between temporal and spatial variability in plankton distribution within a lake is not well understood. Matthews (1990) makes a similar point regarding fish communities in streams.

In this paper we describe general patterns exhibited by ecological parameters across a wide variety of ecosystem types. We attempt to answer three basic questions regarding ecological variability: 1) do climatic, edaphic, and biological parameters differ systematically in variability, 2) how is variability partitioned between spatial vs temporal components, and 3) to what extent are ecological parameters spatially or temporally coherent (Magnuson et al. 1990)? By coherence we mean the tendency for different locations within a landscape to behave similarly in different years independent of the average for the locations (temporal coherence) or the tendency for locations within a landscape to be consistently different regardless of the year (spatial coherence). We use data collected at 12 diverse North American ecosystems represented in the Long Term Ecological Research (LTER) network. For each of the 12 LTER sites, data are available for several years at several locations. Therefore, we are able to analyze both the spatial and temporal aspects of variability at each site.

In addition to these general questions about patterns of variability and the effects of scale, we also used cross system comparisons of variability to test two smaller-scale ecological hypotheses: 1) that deserts are more variable than lakes temporally, but less variable spatially; and 2) that in predator-prey pairs, the smaller-shorter lived member of a pair is more temporally variable regardless of whether it is the prey or the predator. We posited that deserts are more variable among years than lakes because they are more sensitive to among year differences in weather than are physically buffered lakes. Conversely, we hypothesized that lakes would be more variable spatially because they are more isolated from one another than are areas of continuous desert. We also felt that variability in a population was more a function of its life history than its position in a food web.

Variability is highly dependent on the temporal and spatial scales of the data set and on the level of aggregation of the parameter of interest (e.g. species level vs community level) (Allen and Starr 1982, Frost et al. 1988, Frost et al. 1992, Wood et al. 1990) This scale dependence raises a complication in comparative studies, because it is possible to confound differences in patterns of variability with differences in scales of measurement at two or more systems. There are two different aspects of scale, grain and extent, and the effect of these on observations of variability need to be considered independently (Allen and Starr 1982; O'Neill et al. 1986; Turner 1989; Wiens 1989). Grain refers to the level of resolution of the study. Extent refers to the size of the study area or the duration of the study period. In this study we focus on a temporal grain of one year because a year is a physically and biologically meaningful unit of time for which data are available. The spatial grain was more difficult to fix, however, because the size of study units sampled was not standardized across LTER sites, and varied by a factor of about 64000 across the 12 LTER sites. Therefore, we were required to address two scale related questions: 1) what is the effect of sampling unit size on measured