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Predicting Across Scales
Comments of the Guest Editors of *Landscape Ecology*

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Landscape ecology is the study of the distribution patterns of communities and ecosystems, the ecological processes that affect those patterns, and changes in pattern and process over time (Forman and Godron 1986). Thus, the concept of spatial and temporal scale is inherent in the ecological study of landscapes. Regional environmental problems such as air pollution and global climatic change have placed greater importance on studies at the landscape scale partly because of the demonstrated limitations of site-specific studies (one to hundreds of meters) (Golley 1987). Therefore, landscape ecologists are working with other scientists to develop procedures for using landscape data to predict patterns for broad spatial and temporal scales.

The issues and problems of predicting across scales have been the theme of several national and international meetings. In November 1985, an international workshop, 'Spatial and Temporal Variability of Biospheric and Geospheric Processes,' addressed the disparities in spatial and temporal scales used in different scientific disciplines and the difficulty these pose to interdisciplinary global research (Risser 1986; Rosswall *et al.* 1988). Plenary speakers identified the challenges of extrapolating between scales but did not propose procedures or principles. Predicting across scales was identified as an important topic requiring further theoretical and empirical research at a workshop on theoretical ecology funded by the National Science Foundation, in May 1987, in Asilomar, California (Roughgarden *et al.* 1989). Problems with data, experimental design, and scale were also discussed at a workshop on 'Complex Interactions in Lake Communities' in March 1987 (Frost *et al.* 1988). Recent symposia at the annual meetings of the Ecological Society of America, the American Society of Limnology and Oceanography, Association of American Geographers, and the U.S. Regional Association of the International Association for Landscape Ecology have all included topics or presentations that addressed scale issues. However, there was a critical need to develop new syntheses, define objectives, and direct research on interfacing predictions, results, and data from different spatial and temporal scales.

This special issue of Landscape Ecology presents the plenary papers and a summary of a workshop, 'Predicting Across Scales: Theory Development and Testing,' held in November 1988 in Oak Ridge, Tennessee (USA). The purposes of the workshop were to examine what was presently known about changes in ecological processes with changes in scale, identify key scaling problems, and agree on research approaches. A total of 46 scientists from the U.S. and other countries participated in the 3-day meeting.

The plenary speakers reviewed the state of the current knowledge and presented new research approaches. Methods and examples of addressing scale problems were presented from the fields of geography, plant physiology, terrestrial ecology, paleoecology, aquatic biology, and oceanography. Potential effects of changes in spatial scale on the

analysis of landscape pattern were discussed by Turner *et al.* (1989a). Meentemeyer (1989) reviewed the geographical literature on scaling, defined much of the terminology, and demonstrated existing procedures for analyzing data that are available at different spatial resolutions. The consequences of scale on perceptions of ecophysiology processes were discussed by Jarvis (see Jarvis and McNaughton 1986). Gosz and Sharpe (1989) presented a variety of methods and approaches for measuring and analyzing broad-scale vegetation, climate, and topography information. H. Delcourt showed that paleoecological studies can explicitly consider vegetation patterns and processes in space and time (see Delcourt and Delcourt 1988). Carpenter (1989) presented examples of the importance of considering time scales for understanding species eruptions and extirpations in aquatic systems. Steele (1989) demonstrated that physiological and ecological parameters of marine systems are closely coupled to the spatial and temporal scales of the physical processes.

Theoretical developments in addressing questions of scale were also presented by the plenary speakers. O'Neill *et al.* (1989) suggested that hierarchy theory provides a conceptual framework in which basic properties of scale emerge. Rosen (1989) synthesized information from physics and analyses of scale transformations. Gardner *et al.* (1989) discussed the application of percolation theory to identify critical thresholds that occur when changes in the landscape pattern affect ecological processes.

To guide the workshop discussions, the participants were asked a series of questions including: why scaling was an important consideration for ecologists, what was currently known about spatial or temporal scale effects, what problems must be resolved before ecologists solve scaling issues, what approaches seemed most worthwhile to pursue, and what the prime research needs were. Turner *et al.* (1989b) summarized the discussion of those questions.

Together these papers provide a state-of-the-art treatment of current theory as well as paradigms for solving new scale-related problems. The challenge remains to further develop and test predictions pertaining to scale in landscape ecology.

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References

Carpenter, S.R. 1989. Temporal variance in lake communities: blue-green algae and the trophic cascade. Landsc. Ecol. 3: 175–184.

Delcourt, H. and Delcourt, P. 1988. Quaternary landscape ecology: relevant scales in space and time. Landsc. Ecol. 2: 23–44.

Forman, R.T.T. and Godron, M. 1986. Landscape Ecology. John Wiley & Sons, New York.

Frost, T.M., DeAngelis, D.L., Allen, T.F.H., Bartell, S.M. and Hall, D.J. 1988. Scale and design and interpretation of aquatic community research. *In* Complex Interactions in Lake Communities, pp. 229–258. Edited by S.R. Carpenter. Springer-Verlag, New York.

Gardner, R.H., O'Neill, R.V., Turner, M.G. and Dale, V.H. 1989. Quantifying scale-dependent effects of animal movement with simple percolation models. Landsc. Ecol. 3: 217–227.

Golley, F. 1987. Introducing Landscape Ecology: comments of the editor. Landsc. Ecol. 1: 1–3.

Gosz, J.R. and Sharpe, P.J.H. 1989. Broad-scale concepts for interactions of climate, topography and biota at biome transitions. Landsc. Ecol. 3: 229–243.

Jarvis, P.G. and McNaughton, K.G. 1986. Stomatal control of transpiration: scaling up from leaf to region. Adv. Ecol. Res. 15: 1–49.

Meentemeyer, V. 1989. Geographical perspective of space, time and scale. Landsc. Ecol. 3: 163–173.

O'Neill, R.V., Johnson, A.R. and King, A.W. 1989. A hierarchical framework for the analysis of scale. Landsc. Ecol. 3: 193–205.

Rosen, R. 1989. Similitude, similarity, and scaling. Landsc. Ecol. 3: 207–216.

Risser, P.G. 1986. Spatial and Temporal Variability of Biospheric and Geospheric Processes: Research Needed to Deter-

mine Interactions with Global Environmental Change. The ICSU Press, Paris.
Rosswall, T., Woodmansee, R.G. and Risser, P.G. (eds.) 1988. Scales and Global Change. John Wiley & Sons, New York.
Roughgarden, J., May, R.M. and Levin, S.A. (eds.) 1989. Perspective on Ecological Theory. Princeton University Press, Princeton, N.J.
Steele, J.H. 1989. The ocean 'landscape.' Landsc. Ecol. 3: 185–192.
Turner, M.G., O'Neill, R.V., Gardner, R.H. and Milne, B.T. 1989a. Effects of changing spatial scale on the analysis of landscape pattern. Landsc. Ecol. 3: 153–162.
Turner, M.G., Dale, V.H. and Gardner, R.H. 1989b. Predicting across scales: theory development and testing. Landsc. Ecol. 3: 245–252.

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