PLENARY SESSION II – CONCEPTUAL FOUNDATIONS AND INTELLECTUAL FRONTIERS IN THE NATURAL AND SOCIAL SCIENCES

Natural ecosystems in cities - a model for cities as ecosystems

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Tansley produced the word ecosystem to refer to a group of organisms and their environment “with which they form one physical system”. As the use of the word has developed, emphasis has been put on the system aspect, the functions and processes taking place between the components, which are crucial for the development and maintenance of the ecosystem. These are nowhere more apparent than in the natural ecosystems, which exist in cities, and in a conference on cities as ecosystems they have a lot to tell us.

It is true that nature and natural ecosystems often have little place in the centres of cities. The original ecosystems have been destroyed, often several centuries before, and the obvious green elements such as the parks, street trees and gardens, are usually almost completely artificial, with little place for anything very natural. Yet against this background, nature is adept at exploiting every opportunity that is available. By this it provides excellent examples of the ecosystem processes that are fundamental not only in nature but also in cities, but often difficult to see and study.

Natural ecosystems begin by the familiar process of succession - this involves arrival of species, growth and acquisition of resources, competition and facilitation, and full development. As in human societies, in the early stages of development some species and processes may be missing in cities, often by accident, but sometimes because conditions are just too difficult. Limitations set by resource availability are particularly crucial. Yet there are a number of mechanisms by which they are overcome. Good examples which illuminate these processes are to be found in waste ground and derelict railway lines, but even in paving stones.

The further success of ecosystems depends on the development of internal processes of recycling materials - involving organic matter decay, release and re-use of nutrients, and activities of soil organisms. Unlike what occurs in human societies, these processes are almost universal. But in certain situations they may be upset by pollution, especially acid rain, and other forms of stress produced by human activities. Interesting examples showing the failure of recycling processes can be found in parks and gardens as well as in more difficult places left by industry.

All this can lead, in cities, to a great diversity of ecosystems, often existing closely together. As time passes each of these ecosystems tends to become more complex, even though their development may be restrained in certain directions. So, as in human societies, there can be great diversity of ecological niches and resources in cities available for species to exploit. Many species, such as birds, are mobile enough to get in on their own. Others depend on chance introductions. Some quite alien species are brought in by people for special purposes, especially to beautify their gardens. These can provide yet further niches for other species.

The result is that although wild but rather specialist species may be missing, cities are great havens for biodiversity, in terms of both ecology and species, even in industrial areas. The greatest threat to this biodiversity are those who seek for tidiness. The current concern to concentrate new development on old ‘brown field’ areas is good for tidiness but can lose us important examples of what nature can do given the opportunity.

Until tidiness prevails, all these steps in ecosystem development are readily available for study. From them a fascinating picture of the processes of action and interaction that are such an important part of natural communities, and lead to biodiversity, can be built up. They form a provoking model for human urban societies, even though there may be some elements that we would prefer to reject.

Education, social ecology, and urban ecosystems, with examples from Baltimore, Maryland.

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The shape and dynamics of cities are the result of physical, biological, and social factors. We include the term *dynamic* to recognize that cities change over time and are the result of both idiosyncratic events and dominant trends. To begin to understand the patterns and processes of cities, we propose an approach that attempts to understand the idiosyncratic and common--whether it is physical, biological, or social--within a historical context.

We introduce four concepts for understanding the social and spatial ecology of cities. They include: 1) units of organization and scale; 2) a geographical imagination and analyses of spatial heterogeneity; 3) linkages between scales and across geography; and 4) learning from everyday life: policies, plans, and management as data.

For public school teachers who teach social studies such as history, this approach must meet four criteria in order for them to adopt it in their curriculum. A social ecology approach to the study of urban ecosystems must 1) relate to the teacher's subject matter; 2) be an integral component of the teacher's existing curriculum framework; 3) prepare students for achievement in district, state, and national assessments; and 4) be relevant to students' lives while producing significant and enduring learning.

This paper and presentation consists of several sections. In Section I, we describe briefly a social ecology approach—its basis in different social sciences such as geography, history, sociology, and political science—and four concepts that we propose are useful for teaching social sciences in existing curriculum. Units of organization and scale address the idea that there are different levels of social organization such as individuals, families, communities and societies. Further, these levels of organization correspond approximately to different academic disciplines such as psychology, anthropology, sociology, and political sciences as well as diffuse disciplines such as geography and economics. A geographic imagination and spatial analyses discusses how all behaviors occur in space, the significance of place, and the relevance of space to social and ecological change. Linkages between scales and across geography address how different levels of organization frequently have corresponding spatial scales and interactions between scales are spatially dependent. Finally, examples from everyday life--policies, plans, and management as teaching tools—help academics, educators, and students alike see the relevance of a social ecology approach while recognizing the particulars of every day life as more generalizable trends.

In Section II, we use the activities of Karen Hinson, her students' 11th grade Advanced Placement United States History Course (1998-1999), and the Baltimore Ecosystem Study (BES) to illustrate and apply the four concepts we propose as well as to identify potential sources of information and lessons learned for others to use. As part of the students' year-long project and in partnership with the Forest Services of the Maryland Department of Natural Resources and the United States Department of Agriculture, the students were assigned to apply skills learned from their existing curriculum--both knowledge (information) and performance (analytical)--to understanding the social history, current status, and future trends of the development of the City of Baltimore's drinking water supply. The students were assigned to one of seven teams 1) demographics; 2) economic structure; 3) political structure; 4), transportation; 5) class, race, and religion; 6) public health, and 7) leisure and recreation.

The case study consists of four components. First, we discuss the course and how a social ecology approach fits the subject. Second, we describe the project and how it works within the context of the course's existing curriculum. Third, we discuss how the results from the project prepare the students for various assessments. Finally, we illustrate how the project is relevant to the students' lives. Specifically, the students see how 1) the general focus of their course is relevant to where they live; 2) the information they learn about and collect is relevant to decisions made about where they live; and 3) in order for people to do their jobs successfully, knowing and understanding historical trends, research methods, and analysis are important to many people in their daily work.

This section concludes with a discussion of lessons learned and information sources that may be useful for teachers working in the Baltimore region and other areas of the United States.

A final section includes a summary and concluding remarks for developing further the incorporation and usefulness of a social ecology approach in public school curriculum and the study of cities.

An ecosystem approach to understanding cities: Familiar foundations and uncharted frontiers.

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In this paper, we will contrast traditional approaches to understanding ecosystems to the kinds of "uncharted frontiers" we encounter as we forge a concept of cities as ecosystems. The way we go about studying ecosystems is familiar to most of us. First, we delineate the system, establishing its boundaries based on some reasonable criterion (i.e., a discontinuity in some physicochemical or biological property). We consider the ecosystem's structure and how that is controlled (including such things as system architecture, e.g., plant and stand structure in a forest, trophic structure, species distributions in space, distributions and total pools of nutrients and organic matter, landscape structure and mosaics). Finally, we study ecosystem function— the processes occurring in the ecosystem, particularly those having to do with the flow of energy or cycling of materials. Questions we ask in this endeavor are what are the key players in these processes? What factors control their rates? What diversity of processes is represented in the ecosystem? How do pattern and process interact, that is, what aspects of the spatio-temporal distribution of key players and controlling factors most strongly influence process rates, and how do processes in turn change the underlying pattern? What is the underlying cause of pattern in the first place?

From this familiar ground, there are challenges at every step in applying the ecosystem approach to cities. As an example, consider the structure of an ecosystem: a forest's architecture is a function of growth form of the mix of tree species that make up the forest and how that is constrained by topography, climate, edaphic factors, and so forth. A city's structure is built and it is designed. Even the "natural" components (trees in parks, front and backyards) are subject to modification and rearrangement—design—by humans. And it has additional structure, the structure of institutions and social groups, that we cannot measure with our standard ecosystem techniques. More fundamentally, how can we apply a simple and elegant concept like the watershed to delineation of urban environments when flowpaths are so often altered to such an extent as to be unrecognizable by conventional ecological techniques? Are urban streams so modified that they can no longer be reasonably compared with their "natural" counterparts using conventional ecological theory? If not, what can we learn from an end member ecosystem in which one species dominates the flow of energy and materials? What exactly does the concept of "below ground processes" mean in an industrial complex where over 50% of the land surface is covered by asphalt or buildings? And perhaps most importantly, how do we bring the human component into our concept of the ecosystem? Are humans a keystone species (*sensu* Robert Paine)?

We will explore two examples from the subject matter of ecosystem ecology: ecosystem metabolism and material balance. We maintain that an ecosystem approach can be used to understand how cities work, how they interact with surrounding local and global ecosystems, and how expected changes in landscapes and regions, which are a likely consequence of increased urbanization, will affect the future of earth's systems. However, we will argue further that ecosystem study as we know it is necessary but not sufficient to understand urban ecosystems. Modifications in theory and practice will be required.

Recently, the concept of an ecological footprint has been developed as a descriptor of urban ecosystems. The ecological footprint is defined as the total area of productive land required to continually produce an amount of material equal to that consumed by the city. The ecological footprint concept is useful for envisioning the true extent of a city's dependence on natural capital — i.e., other ecosystems. In this sense it is analogous to the P/R ratio, which defines whether an ecosystem is autotrophic or heterotrophic. We will contrast the footprint concept with traditional ecosystem measures of dependence, illustrating that ecological footprints for some well-known heterotrophic ecosystems are strikingly smaller than urban ecological footprints.

Urban ecology is new to most researchers in the new Central Arizona-Phoenix LTER program, as it is to the field in general, and we will rely heavily on the sometimes agonizing process that the CAP LTER project has gone through in beginning to tackle some of these issues. We will use the example of a mass balance for nitrogen in the Phoenix metropolitan area, contrasting it with a nitrogen budget for a desert ecosystem. With this example, we will illustrate the contrasts between the "familiar" ecosystem approach and the "uncharted" modifications in approach that will be needed for study of cities. For example, N inputs via wet and dry deposition are often the largest inputs to natural ecosystems, and to understand retention of N we look to biological mechanisms, for example of plant uptake or microbial denitrification. Our preliminary N budget for the Phoenix metropolis shows that deliberate human imports and NO_x production as a by-product of fossil fuel combustion are the largest inputs. Here, to understand controls over those inputs we clearly need models of the patterns of human activity that result in NO_x production, and of the economic forcing functions that result in those deliberate imports — in short, we need modifications of our familiar approach. We intend to show where we must make these modifications and to discuss what new insights will be needed.

The historical dimension of urban ecology: frameworks and concepts.

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The historical evolution of cities, from an ecological perspective, requires a clear understanding of the place of the city in the physical world. While it never gained universal appeal, the idea of the city as a natural system inspired graphic metaphors relating the structure and operation of the city to that of the human body. Organic theory had obvious flaws and was unfairly put to the uses of certain class interests, but it did elicit powerful images of community interdependency and the rational functioning of the city's many components.

For some scholars and observers of urbanization, the city is not an environment akin to a natural system but a construct dependent on reordering of natural resources to form a new order. City and regional planning professor Manuel Castells placed emphasis on human action in structuring cities, but also understood cities as dynamic rather than static: "Cities are living systems, made, transformed and experienced by people. Urban forms and functions are produced and managed by the interaction between space and society, that is by the historical relationship between human consciousness, matter, energy and information."[1]

The notion, elaborated by some geographers, that the city is "a relatively new kind of ecosystem on the face of the earth," had to be tempered by an understanding that it is an "open system," not self-contained, not functioning independently or in isolation from the rest of the world. In this usage, "ecosystem" has some descriptive power without attempting to create a strict biological model. While the notion of a city as a human body analog was not altogether persuasive, the idea of the city as animate--if not "natural"--is essential for an understanding of urban growth and development. Cities are not static backdrops for human action, nor are they organic metaphors, but ever-mutating systems.

Cities are also understood as major modifiers of the physical environment. Urbanization removes much of the filtering capacity of soil and rapidly channels precipitation into available watercourses, thus encouraging flooding. City building affects the atmosphere by increasing air-borne pollutants and also creating "heat islands" where temperatures are greater than the surrounding area. Various urban activities produce huge volumes of waste products which require complex disposal mechanisms. Alternatively, cities have the capacity--when properly designed--to use resources more efficiently than highly decentralized populations. Concentration can be an advantage in providing services, offering social and cultural opportunities, and producing and distributing goods.

Given the contrasting perspectives on the city, an important question remains: As a form of human and technological expansion, how do we gauge the impact of city building on its surroundings? In an attempt to understand the broad features of the urban environment, sociologists and geographers in particular developed theories of urban ecology over the years. The origins of the ecological approach to spatial and social organization can be traced to nineteenth-century concepts and principles conceived by plant and animal ecologists. Urban sociology, however, was born at the University of

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[1] Manuel Castells, The City and the Grassroots: A Cross-Cultural Theory of Urban Social Movements (London: Edward Arnold, 1983), p. xv.

Chicago during World War I by Robert E. Park and Ernest Burgess. Some refer to the Chicago School as the "subsocial school" because its members had been intent upon studying humans in their "temporal and spatial dimensions and explaining the resulting patterns in terms of subsocial variables."[2] The fundamental subsocial variable was "impersonal competition," a concept borrowed from nineteenth-century Social Darwinism and classical economics, which emphasized laissez-faire doctrine and the operation of the marketplace.

In conjunction with ecological theory introduced by various social sciences, systems theory is useful to the study of the urban ecology because technical systems in particular provide an effective way to understand the growth of the physical city. Such systems have an internal order which the city-building process as a whole lacks. In 1964 geographer Brian J. L. Berry published an influential article in which he argued that "cities are systems susceptible of the same kinds of analysis as other systems and characterized by the same generalizations, constructs, and models."[3] As a way of applying an ecological approach to cities, the idea of a city as a system within a system of cities offered a powerful research approach for model building about the urbanization.

The articulation of organic theory *vis a vis* cities, the development of ecological theory by the Chicago School, an appreciation of the city as a modifier of the environment, and the emergence of systems theory are important underpinnings for grasping the historical dimension of urban ecology. These themes, by their nature multidisciplinary, can help to establish an effective context for teaching key concepts about the development and impact of urban ecosystems.

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[2] Gideon Sjoberg, "Theory and Research in Urban Sociology," in Philip M. Hauser and Leo F. Schnore, eds., The Study of Urbanization (New York: John Wiley, 1965), pp. 164-65.

[3] Brian J. L. Berry, "Cities as Systems within Systems of Cities," Regional Science Association Papers 13 (1964): 158.