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Progress in Planning xxx (2008) xxx–xxx
PROGRESS IN PLANNING
www.elsevier.com/locate/pplann

A scale-hierarchic ecosystem approach to integrative ecological planning

Ashwani Vasishth *

Department of Urban Studies and Planning, California State University, 18111 Nordhoff Street, SH 208, Northridge, CA 91330, USA

Abstract

To think ecologically is to think complexly, recognising that reality is rarely singular, and that there is usually more than just one thing going on at the same time. Additionally, the world is lumpy, in that some few aspects of a phenomenon usually matter much more than others, and so the world is not actually infinitely variable. Besides, the physically tangible world that we care most about is usually shaped by apparently intangible sets of processes and functions. What we see is rarely all that we get. Under these conditions, planning becomes the informative telling of context, and the savvy tracing of consequence.

I propose an ecosystem approach to planning, and lay out the parameters of the worldview necessary to take such an approach to an integrative regional planning. Nested scale hierarchic ecosystem ecology, or process-function ecology, provides a pragmatically robust frame from within which to come to know what it means to plan ecologically. The key insights from such a view are: (a) that complex systems are best seen to be organised into nested levels, with purposively named systems emergent from subsystems, and interactively giving rise to suprasystems; (b) that descriptions of such systems are inherently purposive and perspectival, and so why we make a description, and where we position ourselves to make that description, will significantly influence what it is we can come to see; and (c) that such systems can only be known meaningfully if they are considered to have multiple process-driven boundaries, and are depicted using multiple functionally relevant spatial and temporal scales.

I use cases from the interwoven history of ecological science and social theory, habitat conservation planning, heat island mitigation, urban forestry, and impervious surface management to synthesise a description of what it means, pragmatically, to think and plan in an ecologically integrative way.

Keywords: Ecosystem approach; Ecological planning; Integrative planning; Regional planning; Scale-hierarchic systems; Sustainability planning

Contents

* Correspondence author.
E-mail address: vasishth@csun.edu.
URL: http://www.csun.edu/~vasishth

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doi:10.1016/j.progress.2008.05.001

1. Towards an ecological regional urban planning

Complex systems are fundamentally different from conventional systems.[1] Rittel and Webber (1973) capture many of the key differences between these two sorts of systems in their comparative depiction of 'tame' problems and 'wicked' problems. On the one hand, 'tame' problems can be agreeably defined in some singular way, irrespective of perspectival bias, and can be consistently solved to the same end point, irrespective of operational variations. These can be thought of as simple systems. Complex systems, on the other hand, cannot agreeably be singularly defined, because they inherently depict multiple realities. Nor can they be consistently solved to the same end state in every instance. Rather, each encounter with a complex system may well generate a unique outcome. Thus, different stakeholders may have different notions of what 'the problem' is, which must all be integrated into the operational problem description. Nor may there be some singular point at which 'the problem' can agreeably be said to have been solved. This fact, that there is no 'problem' waiting to be 'solved,' but instead a 'situation' needing to be 'engaged,' lays the imperative for an adaptive management approach to planning.

Because complex systems are structured differently from conventional systems, they may simultaneously embody multiple aspects of reality. Take, for instance, the imperative for 'cost-effectiveness' in planning. An intervention may be demonstrably the most cost-effective in the short term, while simultaneously being

[1] A distinction needs to be made, at the outset between complicated systems (say, for instance, a car, with many parts and intricate sub-systems), which are nonetheless mechanically 'solvable'—that is to say, no matter who does the analysis, as long as the analysis is technically correct, the outcome can be foretold—and 'complex' systems, which are inherently multiply readable, and where it is quite reasonable that two equally proficient analysts, perhaps with different perspectives or purposes, might see distinctly different realities in the apparently same phenomenon (say, for instance, the phenomenon of homelessness in US metropolitan cities).

Please cite this article in press as: Vasishth, A. A scale-hierarchic ecosystem approach to integrative ecological planning. *Progress in Planning* (2008), doi:10.1016/j.progress.2008.05.001

unduly expensive in the long run. Herein lies the dilemma for a general theory of planning to which Rittel and Webber (1973) allude, in their now seminal article. How do we agreeably define a problem whose properties shift with perspective and with purpose? And how do we constructively engage a phenomenon in problem solving, when there is no single solution state inherent in it, and, worse, where one viably proposed solution is itself sure to be the source of a whole other 'wicked' problem?

Planning, taken as a social science, is deeply connected with ecology, taken as our knowledge of nature. At least in part, this is because nature is our first and best operational example of evolutionary complexity in action, and so has always provided us with a ready source of metaphoric models for complex systems. Of course, ecology, taken as a science, has itself evolved over time. What we know about nature, and about how nature happens, has changed dramatically over the past century. We begin with an initial recognition of the need to take an 'organic' approach to understanding life, which informed the early efforts to know a systems approach grounded in a recognition of holism and of dynamism. We then come to a recognition of the critical distinction that needs to be made between 'closed' systems and 'open' systems. We then move on to a recognition that nature is best seen to be constituted by biogeochemical processes, representing the exchange of matter, energy and information, arranged in nested levels of organisation, and embedded in the rules of perturbationally episodic evolutionary occurrence and change.

This current place in the ongoing effort towards a knowing of nature is informed most effectively by what has come to be called an 'evolutionary scale hierarchic ecosystem ecology,' or a 'process-function ecology.' In such a view, to take the world ecologically is to take it in a way that celebrates its complexity in some sophisticated cognitive way, rather than seeking to reduce it to a form more manageable by our innately limited perceptual abilities. If planning is to effectively take complexity as the engaged management of 'wicked' problems, we must learn to apply an adaptive ecosystem approach to ecological planning. This will allow us to deal with the thorny issues of sustainability, itself taken complexly in regional and urban planning, in novel and ultimately more realistic ways.

The effectiveness of planning interventions under complexity is contingent upon the telling of context and consequence, and on the pragmatic construction of strategically information-rich descriptions. Scale-hierarchic ecology[2] offers a useful set of tools to help us in the creation of such descriptions[3] in a planning context. This paper synthesises from evolutionary ecosystem ecology, to what it means, practically, to take an ecological approach to urban and regional planning. It seeks to develop an operational understanding of an adaptive ecosystem management approach in planning.

1.1. Connecting ecology and planning

Metaphor, as method, allows us to take our knowledge from one realm and to apply it in ways that sometimes generate novel understandings in other fields of enquiry. Ecology, as the reading of pattern and process from nature, has long been a source of such models for social science. Just as it, in its own turn, has been informed and inspired by our knowledge from social science. Planning, broadly defined, has long looked to ecology in our quest for novel strategies that might make our explanations and interventions more realistic, as we seek potential courses of action for a more sustainable form of human societal development. The social sciences, taken as expressions of our understanding of complex organisation and change,

[2] One key distinction is made between scale hierarchies and rank hierarchies. Scale hierarchies are typically described as having nested levels of organisation, with a system considered to be emergent from the process-based interactions between its sub systems, and contained within a supra system. Scale-hierarchic ecosystem ecology, or process function ecology, considers levels of organisation within such systems to be told by changes in the rates at which processes occur, the strengths of functional frequencies, and the scales that need to be used to describe them. 'Higher' level systems are generally comprised of slower processes, while 'lower' level systems are constituted by faster processes. A system itself is told by the frequency-strength of its component interactions. Allen and Hoekstra (1992:31–32) refer to 'the containment criterion,' in that 'lower level' systems are functionally (but not necessarily spatially or morphologically) contained within their 'higher level' supra system. A typical example of rank hierarchies is, literally, the ranked structure of military organisations, from generals down to corporals, as compared to the nested structure of an army, being constituted by its contained battalions, regiments, companies, platoons and sections.

[3] I use the term 'description' to refer particularly to the precursor activity to explanation and analysis. What we think to include in our descriptions of phenomena, particularly under conditions of complexity, will itself shape the sorts of explanations that *can* become evident to us. Descriptions (depictions, representations) are where we make the preliminary decisions about boundaries and scales, which dramatically limit or enable what we are able to 'see.' Our subsequent constructions of explanations, what we find significant and noteworthy, and hence the direction, tenor and results of any analysis, are so preconfigured by the descriptions we craft.

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may also have provided mental models for ecologists seeking more effective ways to understand the organisation of change processes in the natural world. At the very least, the state of our knowledge in each of these domains, at any unfolding point in human history, has always set the preconceptions and assumptions that shape us as thinking individuals in that time, and so has both constrained and enabled knowledge in the other.

One early example of such metaphoric cross-pollination occurred in the late 19th and early 20th centuries. In one version of the story, early ecologists built upon the work of social theorists, who set their own intellectual context, to develop novel ways of knowing nature in the organisation and change processes of plant communities. In turn, sociologists developed new ways of understanding patterns of organisation and processes of change in the settlement of cities, based on the ecological theories of successional development in plant communities. They all argued, though differently, for orderly and predictable patterns of successional change in ecological and social communities.[4]

Since then, ecology and its understanding of successional change has developed significantly, marked by the seminal works of Odum (1969), Pickett (1976), Pickett and White (1985), Holling (1986), O'Neill, DeAngelis, Waide, and Allen (1986), Rowe (1989), and Allen and Hoekstra (1992), to symbolically name but a few of the key proponents of this broad body of work. Similarly, planning has itself evolved to a more sophisticated, though still relatively less developed, form of understanding the built environment and its situation within our knowledge of nature (Berke, 2007; Brody, 2003a, 2003b; Duerksen & Snyder, 2005; McElfish, 2004; Ndubisi, 2002). I take Rittel and Webber (1973) and Holling and Goldberg (1971) to be the foundation stones for the current (but as yet incompletely realised) state of ecological knowledge in planning.

When taken together, all of these works are representative of an emerging body of thought in contemporary ecosystem ecology, that shows us the workings of complex systems under conditions of evolutionary change. This emergent version of an evolutionary successional change process, which firmly rejects the notion that natural communities or systems are attached to some singular and anticipatable climax state, often depicted as 'the balance of nature,' gives us a sound basis upon which to build an adaptive ecosystem management approach to understanding change processes in urban ecology, and to shape an integrative ecological planning.

The second section of the paper lays out this early story of the interplay between planning and ecology, and underscores the significance of the 'ecological turn' represented by the work of the Chicago School planning theorists. I then set up the relevant particulars of contemporary scale-hierarchic ecosystem ecology which, I argue, is the necessary next step in the actualisation of planning's earlier ecological turn. In conclusion, I return to the urbanising region of Southern California, to synthesise across these preceding accounts, and to show what an integrative ecological planning might look like. Taken together, these discussions show how some of the tools and insights made available by contemporary ecosystem ecology might be brought to bear on current concerns with sustainability planning under the two now-dominant forces of globalisation and urbanisation, which are quite dramatically reshaping the human-nature complex.

My argument is that an integrative ecological planning takes humans to be inherently a part of nature, rather than apart from it. Doing such planning rests upon the rich telling of context, and the effective tracing of consequence in the decision process.[5] Here, context and consequence co-evolve, each shaping the other and together giving form to our descriptions of the phenomena with which we are concerned. Robust planning descriptions—that is to say, those that will stand the test of time—are comprised equally of the telling of context and the tracing of consequence.

2. Connecting ecology and planning, historically, through social theory[6]

In tracing the history of contemporary modernist urban planning, we must at least consider the work of the Chicago School of Sociology which, in the early part of the 20th century, gave shape and substance to our efforts to study the city in some systematic and scientific

[4] The enterprise of knowledge building represented by these two early expressions of planning and ecology were themselves complex and intricate. The particular individuals represented here are chosen because they are recognised to be emblematic of seminal turning points in their respective theories of the world, and because the interconnectivities between their work have now been well documented and so can be clearly traced.

[5] Indeed, in an ecological planning, the decision process itself is best thought of as a nested network, rather than as a sequential structure.

[6] Portions of this section appeared in a book chapter by Vasishth and Sloane (2002).

way. That history is particularly useful here. It represents the first well documented and widely known instance of a self-conscious effort to use the then current knowledge of ecology, taken as the study of change processes in nature, as a basis for telling the change processes in urban sociology. After all, and in a very real sense, that is the enterprise here as well. How can we use our current understandings of occurrence and change in nature—the best real example we have of complex systems in functioning action—to better understand and explain the ways in which our built environment integrates with that nature?

The history of our efforts to understand our world can also be told as a dialectic between pattern and process. We observe certain patterns within our world, and seek to infer the processes that may have written them. We study some particular processes that appear significant to us, and then become aware of some certain patterns in the world that we had not thought to bound. Such a reciprocal growth in awareness can be seen in ecology, as well as in urban planning.

This dialectic is particularly interesting here, since it is intertwined with yet another dialectic, that between ecology and planning as efforts to expand our understanding of nature and of society. Scientists in one field are directly and indirectly influenced by the understandings emergent from the other. Processes or patterns that social scientists show as unfolding in human society influence how ecologists, receiving those understandings of what is 'normal' in their contextual human society, think to see in nature. And, in turn, those patterns and processes ecologists have tried to tell from nature, have influenced, directly or indirectly, how social scientists are able to think about the organisation and functioning of society.

An example of this dual dialectic between ecology and sociology is grounded in the history and development of ideas about succession theory in ecology, particularly in the work of Clements (1916), at the turn of the 20th century, and as subsequently adopted and applied by the Chicago School of Sociology. There is a wonderful story to be found in this tale of turn and turn around, as Clements is held to have derived the root conception of his ideas about 'plant communities' from the field of sociology, and then, in turn, his work is adopted by the Chicago School, in their efforts to pin down 'natural' change processes in cities.

Turner (1893) told the history of the settlement of the United States as successional waves of pioneering settlers, and the gradual but inexorably patterned transformation of human settlements across the North American prairie. This imagery was then deployed by Cowles (1899) and Clements in their own telling of the orderly successional patterns of development in vegetation communities in the aftermath of disturbance.

> In a 1935 essay, for example, [Clements] explicitly compared the development of vegetation with the pattern of settlement on the frontier of the Middle West. The progression of plants in a habitat follows a process of pioneering and settlement, just as man's advance was doing on the prairie. The stages of civilisation formed their own kind of sere: first trapper, then hunter, pioneer, homesteader, and finally urbanite (Worster, 1977:218–219).

The notion of weedy, opportunistic plant species moving in quickly, after an ecosystem had been disrupted by some perturbation, followed in gradually predictable order by increasingly diverse communities of plants, and culminating ultimately in some inevitable climax community, with a complex and stable association of plants as a superorganism, at least concurs with Turner's telling of the patterns by which America was settled.

Rosiere (2000), in a literature review, summarises some of the diverse and likely influences from the social theory of that time which may have shaped Clements' own ideas of community:

> The entire account by Tobey (1981) of the origin of vegetational organicism is interesting to point of intrigue. In summary, Tobey (1981) concluded that besides such obvious sources as Darwin's *The Origin of Species* and, as discussed previously, association from Alexander von Humboldt, formation from August Grisebach, and general Plant Geography from Oscar Drude, Clements drew his more philosophical and metaphorical strands of thought from prevalent current human sociological theory. Tobey (1981) concluded from such sources as the 'climax and complex organism' papers of Phillips (1934, 1935a) and from the fact that Clements' classmate Roscoe Pond, Nebraska plant ecologist turned distinguished jurist, studied Sociology, that Clements was influenced by Sociology from which he took his 'social organism' philosophy. Tobey (1981:84–87) mentioned noted sociologists who likely contributed to Clements' organicism. These theoretical sociologists included August Comte, Herbert Spencer, Lester Frank Ward, and Edward A. Ross, along with the influence of the Renaissance Man-bureaucrat and Prophet of Range Management, Major John Wesley Powell.

Concurrently, efforts to understand and explain human society were beginning to move strongly away from armchair theorising and towards a firmer grounding in empirical science. The founders of the Chicago School of Sociology consequently looked to the sciences to provide some new basis for their own work in urban sociology. Roderick D. McKenzie introduced Robert E. Park and Ernest W. Burgess to Clements' vegetation ecology model of population dynamics and successional change in plant communities. Central to their model is the idea of community as 'super-organism,' and it is this meme[7] that subsequently comes to underwrite their urban sociology.

The three social scientists then proceeded to draw from this model their own theory of urban organisation and patterned change. They also used work from animal ecology and cell physiology to understand the role of competition and cooperation as mechanisms for evolutionary change and progress. These examples became the foundation for their subsequent efforts to empirically measure and map urban patterns and processes and, more generally, to approach the study of society in an ecological manner (Park, Burgess, & McKenzie, 1925 (1967)).

Many conventional critiques of the Chicago sociologists ignore the historical moment of their activity, and so underrate the transformative aspects of their ecological leanings. As more contemporary ecologists have moved beyond these primitive, prototypical models of natural organisation and occurrence, to develop more sophisticated notions of ecosystem dynamics—which take account of patchiness and perturbation as shifting domains of dynamic equilibria (Holling, 1986; Odum, 1969; Pickett, 1985; Pickett & McDonnell, 1989)—the shortcomings and errors embedded in those early models become easy to detect.

More recently, neo-Marxist and postmodern theorists have suggested that 'the city'—through a globalising economy and subject to the forces of a post-Fordist production protocols based on supply chains and on just-in-time delivery schemes—has been so radically transformed from turn of the century cities that the Chicago model, caricatured most often as 'the concentric rings model' (in which cities are seen to expand outward in orderly and predictable concentric circles), has lost both descriptive and explanatory power and must be completely replaced by some new depiction (see, for instance, Dear, 2002:423).

Yet a closer examination of the writings of Burgess, Park, and McKenzie suggests that contemporary efforts to understand urban social systems might benefit more by building intelligently upon the work of these early Chicago sociologists than by rejecting it entirely. The turn to ecology initiated by the Chicago urban theorists still provides a sound foundation for urban research (Catton, 1993, 1994; Duncan, 1961; Quinn, 1940; Smith, 1995). Discarding the confounding effects of the then prevalent organismic frame, and the notion of progress as ceaseless improvement, and introducing instead a natural organisation-and-occurrence approach from ecosystem ecology, the scale-hierarchic ecosystem concept provides a rich and versatile frame for urban inquiry. Moreover, such an ecosystem approach, by centralising historic, purposive, and perspectival contingency, makes room equally for subjective as well as objective modes of knowing.

2.1. The Chicago School and the city

The Chicago School of Sociology, prior to World War II, represents the first institutionalised and systematic effort to take an ecological approach to social theory, and to look for ways to study community as an emergent entity. Its work represents a turning point in the place of cities, communities, urban phenomena and social facts (as distinct from social analysis) as special objects of study in social theory. Park, Burgess, McKenzie, and other early human ecologists are conventionally credited with institutionalising sociology as a science. They are also criticised for their overly empiricist and idealised approach to the study of society. Yet, the temper of their time, and the momentum of ideas about scientific method and about evolutionary change that enabled their work in the first place, was such that both the institutionalisation and empiricisation were perhaps unavoidable.

The European social theorists, Emile Durkheim, Ferdinand Toennies and Georg Simmel, centrally informed the Chicago School sociologists, as they did other turn-of-the-century Americans (Kurtz, 1984:17). The American sociologists took from John Dewey and Herbert Mead the principle that social research be directed by a concern for effecting improvement in prevailing social conditions (Kurtz, 1984:8). In particular, Albion Small played no small role in shaping the direction and research of Chicago's Department of Sociology (Kurtz, 1984:93; Russett, 1966:61–74). He pushed systematically for an empiri-

[7] Dawkins (1976) coined the expression to depict a mental unit of cultural information that exhibited an integrity and was capable of transmission across time and space, and subject to the rules of evolution. For Dawkins, a meme is to cultural evolution what a gene is to biological evolution. Since then, memetics has emerged as the study of 'evolutionary models of information transfer.'

cal, research-driven social theory, instead of the reflective sociology that had become so typical in the US[8] and made a concerted effort to incorporate the work of European theorists into the curriculum.[9] Small was instrumental in sociology's shift away from the study of patterns towards the analysis of processes (Russett, 1966:67).

Finally, the Chicago schools of pragmatism and sociology were influenced by the city of Chicago itself. In it, the Chicago social scientists saw patterns of rapid and dynamic growth driven by migration, and their recognition of this migration process as a formative pressure on patterns of urbanisation conditioned the tools they crafted, the techniques they developed, and the concepts they evoked in their models. The particulars of urban change—the waves of immigrants, arriving, concentrating and dispersing in patterned succession—and of ecological processes—invasion, assimilation, adaptation, cooperation, competition and local migration—shaped their theoretical structures and the questions they asked in their research.

2.2. Ecology and social theory

Three dialectical histories of ideas in social thought converge to give direction, shape and meaning to the work of the Chicago sociologists: ideas about the relationship between individual and community, or entity and environment; the nature and meaning of progress, equilibrium and climax; and the relationship between pattern and process, structure and function, organisation and occurrence. These three themes have centrally shaped and polarised debates in social theory (Cittadino, 1993; Davison, 1983; Levine, 1995; Mitman, 1992; Russett, 1966; Silber, 1995).

From at least Auguste Comte's efforts in the mid-1850s to articulate a positive methodology, and Herbert Spencer's efforts to describe a more prescriptive sociology of structure and function, conceptions in social theory have been grounded firmly in ideas about individual organisms as metaphoric sources of knowledge—particularly as they affect assumptions about progress, equilibrium and climax (Russett, 1966). Both social theorists and scientists of nature have persistently projected characteristics of individual organisms onto community and society, by the use of organismic analogies (Levine, 1995). We know ourselves best as individuals changing over time. So, almost inevitably, we project this knowledge, as metaphor and as model, onto collective entities that we thought, intuitively and before detailed enquiry, to reflect this sort of an organicism, taken as the metaphoric projection of the idea of individual organism onto other forms of communal or social entities.[10] But much as this organicism may have helped explorations of organisation, by providing the reductionist tools necessary for inquiry, it obscured at least some of what could be known, even then, about natural occurrence.

Although knowledge of human individuals and other organisms has always informed our understanding of nature, this organicism—such as the projection of our knowledge of the life cycle of organisms like ourselves, from nascent conception, through embryonic growth, through birth, through weaning, through youth, adulthood, maturity, old age, death and decay, onto other sorts of social entities such as communities or places—becomes more problematic with the turn-of-the-century transition from a typological to a population and community worldview, than was previously the case.

[8] Faris (1970:4) cites Lester F. Ward. William G. Sumner, Franklin H. Giddings, and Edward A. Ross amongst those American pioneers who 'had a strong disposition to discover, mainly by reflection, one or a few fundamental and simple principles that would serve as explanation of all human behavior.'

[9] Kurtz (1984:17) outlines this influence, pointing out that 'European social thought figured prominently in their teaching and research, and in articles by Simmel, Toennies, and Durkheim translated and published in the early issues of the [*American Journal of Sociology*, which was then largely controlled by the Chicago sociologists]. Simmel's influence was pronounced in early American sociology, thanks largely to Small's efforts. Small was at the University of Berlin while Simmel was himself a student there...' Further, Faris (1970:108) argues that Park, who had studied under Simmel while travelling in Europe, received from him the concept of social distance, and that Park later 'suggested to Bogardus that the latter devise a social-distance scale as a statistical basis for the life-history materials in this field.'

[10] The idea of 'organicism' is used here to mean the metaphoric projection of properties known from organisms as life forms onto other forms of social, community or institutional systems—the city is like a tree, for instance. It is made problematic by the fact that the post-typological biologists and systems theorists have used precisely this term to mean something entirely different. After Darwin, and beginning in the late 19th century, the idea that life processes cannot be told by the aggregation of the individual parts of an organism, but rather must be read out of the total organisation of the organism into its environment, has generally been termed 'organicism' as well. Here the association is with 'organic,' rather than the previously discussed 'organism.' See, for instance, von Bertalanffy (1968), Phillips (1970), and Mayr (1997). However, somewhat differently, and in speaking of 'the field of ecological plant sociology,' Nichols (1923:14) says, 'As integral parts of the larger community, plant societies bear a relation to the association which is somewhat analogous to that borne by the various organs of an individual plant to the plant as a whole.'

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Named retrospectively, the typological view (which still endures quite strongly) holds that the diversity of nature can be codified into types—that is to say, that individuals are most meaningfully known by their type, and that each type represents certain essential characteristics, which remain unchanged across individuals within that type. Any variation that individuals might show from that typology are deemed to be 'errors' or deviations.

Population thinking, emerging with the advent of statistical thinking, holds that it is the variation *between* individuals of a type which establishes the boundaries of that type. Here, typologies are abstractions, derived from observations of actual populations of individuals. Such types are only meaningfully defined by the range of variation shown by their constitutive individuals (Mayr, 1976).[11]

Levine suggests that, although Durkheim was opposed to the use of organismic analogy in explaining community, his refinements to the understanding of patterns and processes in society rest on ideas of community itself as a self-maintaining social organism (Levine, 1995:254). Clements' efforts to organise ideas about successional change in vegetative communities are also schematically driven by the idea of community as superorganism.[12] At least some of the critiques of Chicago sociology in planning might more accurately be levelled at the limitations of organicism as a metaphorical method in explaining community.

2.2.1. Individual and community

Views of the relationship between individuals and community reveal a deep-rooted division in social theory. Is community (society) knowable as an additive agglomeration of individuals and events, or is community (society) a thing apart, always more than any aggregation of individuals? Can we sufficiently explain group interactions by examining the individuals that comprise a group, or is it that individuals are themselves the products of community, as Durkheim had it? If community is no more than some summing of its individual members, then data on individuals will adequately explain community. More importantly for urban studies, community-level patterns can be used to map individual-level processes, and vice versa. But if community is more than merely the sum of its individual members, then community must be described at its own level of organisation. This way, we can see community level patterns and processes as distinct from patterns and processes in populations of individuals.

In tracing the use of spatial metaphors in social theory, Silber points to Durkheim's:

> attention to the 'external,' constraining reality of social facts, the boundedness of social wholes, the statistical distribution and density of social phenomena within the territory of the nation-state, and, perhaps best known, the ritual enforcement of physical and other boundaries between sacred and profane (Silber, 1995:329).

Following from the work of social theorists like Simmel, Durkheim and Toennies, an increasing acceptance of such an environmental, contextual frame accompanies the emergence of a community view of natural organisation.

2.2.2. Organismic analogy and evolution

The confounding influence of organismic analogy on evolutionary thought rests on the assumption that the process of orderly change in individual organisms is, generally speaking, a 'natural' process. This assumption is based, for example, on the idea that an organism's ability to maintain a fairly constant internal state in the face of environmental stress produces equilibrium in nature. The life cycle of an organism, from embryo to infant to youth to maturity to death and decay, therefore, becomes a plausible model for successional change in levels of organisation other than the individual (Gould, 1977). The improvements apparent in the human condition, the increases in knowledge and technology and cultural refinement so evident over the life span of even a single generation, reinforce the idea of evolutionary progress as increasing improvement. But deep and persistent divisions pervade discussions of equilibrium, progress and succession. These are particularly relevant in the context of the Chicago urban sociologists, and the ways in which these ideas are incorporated in their models of urban patterns and processes.

[11] The process-function view of ecology steps back from this debate. It asserts that nature is neither merely composed of fixed and well-delineated types, nor most fully expressed as populations and communities of individuals distinguished by their particular variations and spatial and temporal locations. Rather, nature is known best by the processes and functions that underwrite its occurrence, and individuals, populations and communities are entities and objects emergent from the interactions of processes and functions.

[12] Although Clements' (1916) notions of successional stages, culminating in some climatically determined monoclimax, were quickly challenged and problematised within ecology (Gleason, 1917; Tansley, 1935) '. . . the concept became a central tenet of range condition analysis used by the USDA for range management . . . and is still used today even though it is recognized as conceptually flawed. . .' (Gibson, 1996).

From early on, natural and social scientists accepted the idea that nature moves towards equilibrium in response to changing external conditions, and organismic metaphors were used extensively, even in medieval times (Berlin, 1965:50–51). And Hippocrates, the Greek physician, pressed the idea of homeostasis in hypothesising the tendency on the part of organisms and their organs to return to health after disruption or disease (Russett, 1966:19). But it was only after theorists began to see the limits of this typological view that an individual or population view began to emerge, and knowledge of organisms began to find application in generating explanatory and instrumental models that went beyond mere analogy. It was only after this transition—associated as it was with the rise of a Darwinian model of evolution—that a concept of dynamic equilibrium and homeostasis was legitimised. Organismic conceptions of evolutionary change began to be applied in quite different ways to social theory, influencing the emergence of sociology as a science, in the work of Comte, Spencer and Durkheim (Levine, 1995; Russett, 1966).

2.2.3. From types to populations

Comte and Spencer began their efforts to formulate a science of society and social development from a conception of dynamic equilibrium, of the tendency towards harmony and balance and fit between organisms and their changing environment, where a:

> (f)ailure to maintain this harmony or balance—failure on the part of the organism either to modify its form in response to changes in the environment or (in the case of man) to modify the environment itself—would result in the death of the organism (Russett, 1966:30).[13]

They then extend this property to society, seeing it as an organism:

> Life for the organism, as we have seen, depends on the maintenance of equilibrium between organism and environment—a maintenance achieved through the mutual interaction of organic functions. Similarly, the social organism maintained itself through interrelation among its constituent parts. As in healthy animal organisms no question could arise of conflict or competition among parts, so the tendency to cooperation rather than dissidence characterized the social organism as well (Russett, 1966:33).

But while Comte and Spencer share this common ground,[14] their arguments develop in opposition to one another,[15] and at least some of the tension between them derives from their different ideas of progress.[16] For Comte, evolutionary progress was little more than a manifestation of a perpetually responsive adaptation by organisms to shifts in their environment, leaving a world that was, at any given moment, 'as good as it could be.' Spencer began similarly, by taking progress to be driven by adaptive responses, but instead posited some final, ideal state, towards which this progress was inexorably driven. For Spencer, evolutionary change was little more than a transitional phase, one that would terminate in a single, perfect ultimate state.[17]

But the subsequent Durkheimian project of transferring the organismic frame from individuals onto community and society (Durkheim, 1898 (1974)), remained problematic and limited in application until the emergence of some operational conception of group evolution. The work of botanists and plant geographers

[13] The claim that the ability to modify the environment as an adaptive strategy is unique to humans rests on a rather narrow definition of what it means to modify the environment. For instance, the work of Lovelock and Margulis (1974) supports a recognition that all biotic entities—and, indeed, even abiotic processes operating independently of biology—do indeed modify their 'environment' by the very activities of their own occurrence.

[14] Russett (1966:28) points out that the two men, though contemporaries, never met each other.

[15] Russett (1966:28) shows some of the oppositional consequences of Comte's background in mathematics and adoption of biological knowledge, and Spencer's background in engineering and adoption of the knowledge of mechanics.

[16] Berlin (1965:82) argues that the notion of a steady progress, at least in human history, was one of three well established myths of the 18th century—the other two being the myth of one culture's innate superiority over others, and the myth of a classic, sunlit culture of the past (whether Gallo-Roman or pagan). But it was not until a century later that knowledge of life and evolution grew beyond typology, to a stage where the idea of progress begins to affect such organismic conceptions.

[17] Interestingly, Hull (1988:27), in seeking to problematise the conventional history of ideas about progress, one that dominated until fairly recently, says: 'According to the traditional view, no one throughout human history found the idea of progress either in nature or in the course of human affairs plausible or appealing until the Renaissance. The ancient Greeks and later Romans viewed the world in terms of eternal cycles, while Christian theology portrayed human history as a period of tribulation between Adam's fall and the Second Coming. Not until the sixteenth century did intellectuals in the West begin to think that possibly human history as well as nature at large might be progressive...' While Hull proceeds to formulate an alternative history, these two positions can perhaps be taken as representative of some broad division in social thought. Certainly, the versions of evolution and progress elaborated by Comte and Spencer appear generally to divide along similar lines.

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provided just such a conception, marked in most accounts by Eugenius Warming's efforts to systematise knowledge of plant communities and of the patterns and processes of 'communal life.' In 1866, Ernst Haeckel coined the word *ecology*, and it was this later body of work, synthesising the organismic conceptions of community with the conceptions of landscape by geographers, that gave shape and substance to ecology as a science (Allen & Hoekstra, 1992:130; Worster, 1977:198).

2.2.4. From population to community

This transition, from a population view of nature to a community view, marks the start of the ecological moment, even though preconceptions—of both typological structure and of organismic behaviour and development—remain entrenched and engrained deeply in these early emerging conceptions of community. The turn-of-the-century work of plant ecologists and plant geographers, particularly Cowles (1899) and Clements (1916), following from Warming's operational outline in 1895 of the ecology of plant communities, generated many of the instrumental sociological conceptions of community organisation and occurrence. Ironically, these ideas of 'developmental succession' and of 'climax states,' which themselves derived from early organismic social theories,[18] reinforced the applications of an organismic frame in the study of community—even as they allowed theorists and scientists alike to transcend the population view of nature.

But it was Frederick Clements' conceptions of community as a superorganism and of monoclimax—the development of communities in a fixed pattern of successional stages, from inception through to some single ultimate climactic state—that provide the keystone for the empirical, though admittedly organismic, study of both ecological and social community. As Golley points out:

> Clements' concept of the vegetation as a superorganism is appealing since we can readily develop the analogy from our personal knowledge of individuals... The (vegetative) formation 'arises, grows, matures, and dies.' Thus, the community and its formation have unique emergent properties which are greater than the sum of the properties of the parts (Golley, 1977:181).

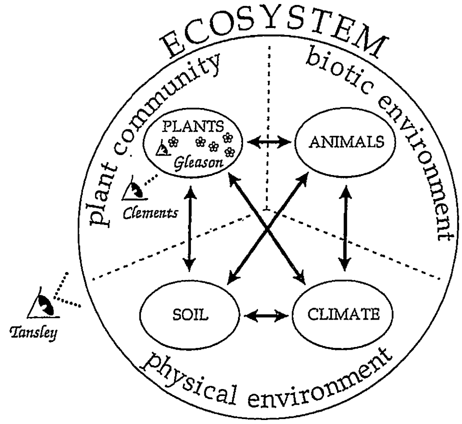

Fig. 1. Gleason, Clements and Tansley looked at vegetation in three different ways. Gleason saw the plant community as a collection of individuals filtered by environment; Clements saw the plant community as an integrated whole, set in a physical environment; Tansley saw the plants, their biotic environment and their physical environment as all components inside the ecosystem. It is the same material system seen from different perspectives (illustration from: Allen & Hoekstra, 1992:45). Perspective, as in vantage point, affects directly what we are able to see of nature; to say 'community' is to not say very much until one establishes the boundaries one will use to delineate that entity of concern. One perspective is not necessarily innately superior to any other, but rather we need to remain aware that perspective *does* change what we are able to see, and *does* influence what we take to be included in any particular depiction of reality.

Although Clements' postulation of vegetative patterns and processes proved central to the enterprise of both ecology and social theory, his theory of successional development was intended more as an idealised frame for structuring inquiry than as any product of systematic observation. Within ecology, his ideas of succession towards a climatically determined monoclimax were quickly challenged (Gleason, 1917, 1926; Tansley, 1935), but never quite displaced until the relatively more recent transition in ecology to an ecosystem view (see Fig. 1).[19]

[18] The notion of succession as an orderly and repeating pattern of social change, akin to the life cycles of organisms, was used in social theory before it appeared in ecology in the context of plant communities. The phrase 'sociological succession,' to denote some version of orderly displacement in social groupings, was used at least as early as Comte. In ecology, the term 'plant sociology' was used almost interchangeably with plant ecology, at least until the 1950s (Whittaker, 1953). More generally, the term sociology was commonly used to 'designate the study of patterned associations among and between different non-human species of organisms' (Catton, 1993:74).

[19] See Odum (1960, 1969). For a more comprehensive review of the early ecological literature on succession and climax theories, both in the US and Europe, see Phillips (1934, 1935a, 1935b) and Whittaker (1953). For a more contemporary discussion of the implications of an evolutionary understanding of change processes for succession theory, see Pickett (1976).

Clements' Spencerian conception of nature as progression towards some improved end state was formatively influenced, both by his own experience of the pioneering settlement of the North American prairie by white Europeans, and also explicitly by Turner's (1893) account of the evolutionary life history of frontier society.[20]

Admixtures of these core conceptions—of community as superorganism, of orderly successional stages of development towards some improved monoclimactic finale, of self-regulating equilibrium, of progress as improvement and increasing civilisation, of change as organismic and comparable to individual life histories, along with now-primitive notions of association, interdependence, cooperation and pioneering invasion—provided the tools conceptually available to the Chicago sociologists in developing an empirical science of society. These forces, bound by the insights and prejudices of the time, mark the ecological moment of Chicago urban sociology in their transition from an individual to a community frame.

2.2.5. The ecological turn

A key driver in this ecological turn was an emerging awareness of the distinction between pattern and process. In the study of nature and of society, a growing recognition emerged that the structures, forms and patterns most apparent to direct observation were merely material manifestations of underlying processes and functions. These processes and relationships were gradually coming to be seen as the true constitutive forces in nature and society, and thus the proper objects of inquiry, while the patterns they generated were indices that allowed one to 'get at' the processes behind them, providing the tools by which to understand, explain and perhaps to change nature and society.

[20] While the influence of Turner's 'frontier hypothesis,' reflecting his understanding of the pioneering settlement process of the American West, shows clearly in Clements' work, there were surely other forces that may have been as formative (see, for instance, Rosiere, 2000). After all, Warming, who lived and worked in Copenhagen, appears to have outlined a theory of successional development that can reasonably be seen as precedent to Clements' version. Certainly, Clements was not working *tabula rasa*, but participating in a more painstaking process of knowledge building. And the 'frontier hypothesis' would have at least reinforced already, and differently, emerging understandings of nature and society. There may have been no great leap in insight, no singular 'paradigm shift,' but rather a patchy and sporadic transformation of ideas and conceptions, as diverse ways of knowing nature and society came together and then went their own ways, only to come together again.

The Burgess 'zonal hypothesis' (see Fig. 2) is the most widely known, and probably the most narrowly understood, concept of the Chicago urban sociologists. That cities expanded in some predictable way was widely believed at the turn of the century, particularly in America. The conception of 'metropolitan areas' extending well beyond a city's political boundaries

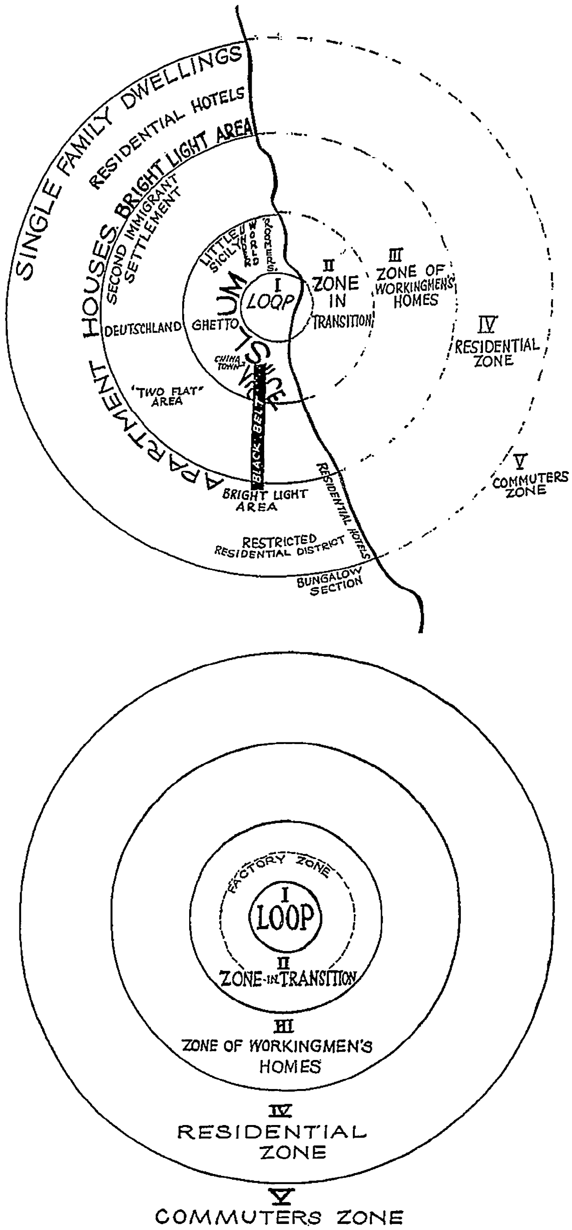

Fig. 2. In their meticulous spatial analysis of Chicago, Burgess and Park saw a zonal pattern, which they then generalised into an idealisation of city development, which came to be called the 'Burgess zonal hypothesis,' or the 'concentric rings model' of city expansion (Burgess, 1924 (1967:51, 55)).

had already taken shape (Burgess, 1924 (1967:48–50)). Based on extensive efforts to measure processes and functions within the city of Chicago in some empirical way, and then to map the patterns generated by these processes, Burgess sought to express an ecological pattern he saw emerging from their data, a pattern he believed to be as natural, inevitable and universal to city development as Clements' proposed pattern of successional development in plant communities was assumed to be.

Burgess proposed that this pattern of urban expansion took the form of functionally differentiated zones, radiating spatially outwards from the city's central business district. His diagram of four concentric circles illustrates his primary hypothesis about 'the tendency of each inner zone to extend its area by the invasion of the next outer zone' (Burgess, 1924 (1967:50); see Fig. 2). What made these patterns ecological, for the Chicago urban sociologists, was their recognition that urban expansion was neither arbitrary nor haphazard, but strongly controlled by community-level forces, such as land values, zoning ordinances, landscape features, circulation corridors, and historical contingency in functional associations.

The patterns that emerged were ecological because they emerged not from chance or human intent, but rather from the 'natural' actions of 'the selective, distributive, and accommodative forces of the environment' on the 'spatial and temporal relations of human beings' (McKenzie, 1924 (1968:63)). What made their method of inquiry ecological, I believe, was that they sought to derive patterns from a study of processes, rather than to merely ascribe processes to observed patterns. Their conception of urban development processes and the patterns they saw emerge, are strongly reminiscent of Clements' ideas of plant community development.[21]

In the years following the original presentation of the 'concentric rings model,' a number of studies attempted to support or refute the model. However, many critiques of the zonal hypothesis erred in taking the ideogram of four concentric rings as a literal expression of spatial reality, rather than seeing it as ecologically conceptual. Davie (1937), for example, attempted to present 'a concrete test of the validity of the Burgess hypothesis,' drawing circles on half-mile units around cities and then seeing if those zones matched Burgess' ideogram. They did not correspond. His failure to find correspondence between these spatial zones and the 'cultural and functional boundaries' of social data, however, says little about the validity or failure of the Chicago model (Quinn, 1940). As McKenzie (1926 (1968:22)) reminds us:

> (e)cological distance is a measure of fluidity. It is a time-cost concept rather than a unit of space. It is measured by minutes and cents rather than by yards and miles. By time-cost measurement the distance from A to B may be farther than from B to A, provided B is upgrade from A.

Under such a functional definition of 'distance,' everyday spatially geometric concepts like circles and squares become abstractions, rather than accurate depictions of a more process-shaped actuality.

Undoubtedly, the particular views of progress, natural change processes, and monoclimactic end-states held by the Chicago urban theorists distorted their modelling efforts, coaxing them to interpret the city in certain ways. But the shape of their worldview is a result of their understanding of the best science available to them, and they set in place a move away from the pattern realism of entity and place, and towards the process actuality of function and scale. *This* is the Chicago School's ecological turn, and it bears acknowledgement in our current efforts to integrate ecological knowledge of natural occurrence into how we think to plan in the world.

2.3. Returning to a different ecology: reconsidering change processes and functional associations

The basic intuition of the Chicago sociologists was threefold. First, that cities are best viewed as ecological wholes, rather than as merely a mechanical assembly of parts. Second, that a study of change processes in nature may give us novel insights into change processes in human settlement patterns. And third, that spatial (or morphologically literal) distributions may be less relevant than functional distributions. That is to say, cities, besides being ecological in themselves, are embedded within a natural context of processes and functions which must be given due consideration in our thinking about the city, *per se*. Further, change processes are neither random nor purely novel, but rather substantially contingent on history and on sequential succession. And literal readings of place can often hide the processes and functions that shape actual reality.

[21] For all that Clements' conception of community as superorganism was a prerequisite for the Chicago urban theorists efforts to find a scientific basis for sociology, the range of sources they drew from were considerably richer.

The failures, such as they are, of the Chicago model of urban agglomeration are attributable far more to the limits of ecological knowledge in their time. This led to their own adoption of the 'superorganism' metaphor, embedded within the notion of a monoclimactic culmination of change processes into a completely predictable end state. The first left them prone to the organismic fallacy, in the temptation to view change processes in communities as broadly analogous to change processes in individual organisms (such as humans). And the second supported an unwarranted idealisation of some singular path in the development of cities over time, and that to some singular 'final' state.

Cities are indeed best viewed from within an ecological perspective, because planning is coming to value the significance of telling context richly, from diverse perspectives, using multiple criteria, and is recognising that consequences often extend across administrative or jurisdictional boundaries. The conception of nested levels of organisation gives us a practical way to move through domains of complex association without losing track of the named 'system of concern,' while we are cognitively within any one particular level of organisation. Recent models of change processes more accurately depict system equilibria themselves as being evolutionary, as compared to the previous, more mechanistic, ideas of 'nature in balance' (for instance, see Botkin, 1990; Holling, 1986; Pollan, 1991), and show change processes at levels of organisation beyond that of individual organisms (for instance, see Odum, 1969; Pickett & White, 1985). They allow us to break from the artificial constraints of typological and population views of nature and make room for a more dynamic and evolutionary understanding of patterns we might meaningfully name in our consideration of change processes.

A process-function view of nature also allows us to consider the actual drivers of change, even as we manage the morphological structures that matter most immediately to us in planning. A richer ecological conception of scale, both as grain and as extent, that takes account appropriately of spatial, temporal and organisational domains (Levin, 1992), then allows us to make multiple and functionally relevant descriptions of systems, subsystems and suprasystems, without letting our situationally contingent descriptions displace actual reality.

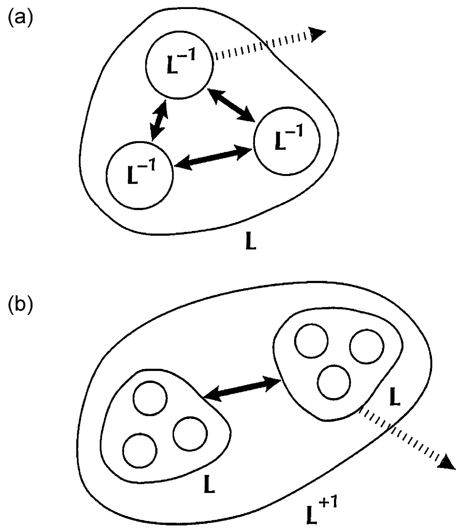

Fig. 3. In (a) the strong connections between members of the lower level are clearly shown, with the weak connections to an equivalent higher-level aggregate. In (b) the weak connections to aggregate level L become the strong connections inside the entity L^{+1}. Emergent system becomes meaningful to name based on the strength of the relationships between subsystems, given that the processes or functions represented by those relationships are thought significant for our purpose. The fact that subsystem entities L^{-1} are seen to be in strong interaction in diagram (a) makes it meaningful to name the entity L as a system. Similarly, the fact that system entities L are seen to be in strong interaction in diagram (b) makes it meaningful to name the entity L^{+1} as a suprasystem (Ahl & Allen, 1996:157).

3. Elements of an ecosystem approach from nested scale hierarchic ecology

The term 'ecosystem approach' represents a fairly particular understanding of organisation, occurrence and change under complexity. This understanding can be briefly sketched to have three core conceptual underpinnings. First, systems of concern, their constitutive subsystems and their emergent suprasystems are taken to represent *nested levels of organisation*. These systems, subsystems and suprasystems, are named by purpose and intent, with each being found to be meaningful on the basis of the strengths of their interactions with one another (see Fig. 3).[22] What we choose to call the system of concern is contingent on why we are attempting to describe the nested system in the first place. What we take to be its constituent subsystems reflects our understanding of organisation and occurrence, and what we take to be the emergent

[22] These designations of 'system,' 'subsystem,' and 'suprasystem' are not, in any meaningful way, 'read' out of nature, but rather are naming devices that allow us to make nested descriptions, letting us move across levels of organisation without losing track of the relationship of any particular analytic move to the core 'system of concern.' Thus, what we refer to as suprasystem in some particular analysis, may well itself be the 'system of concern' in some other analytic move.

suprasystem rests most on the relevant context in which we see the system of concern to be embedded.

Second, the *boundaries* of each of these system components are made meaningful by the strength and frequency of the *processes and functions* that mark the relationships amongst their constituent subsystems. In such a view of nature, boundaries are purposive, and processes and functions are formative of organisms, entities and events. That is to say, the organisms and entities which we habitually take to be the 'real' markers of nature, are, ecologically speaking, merely abstractions—emergent properties of the 'actual' processes and functions which are nature.

Third, what we are able to see of such ecosystem structures is fundamentally contingent on the *spatial, temporal and organisational scales* that we choose to deploy in the shaping of our descriptions (see Fig. 4). This *scale-dependent property of reality* allows, indeed, insists upon a perspectival and purposive contingency to our depiction of systems as nested hierarchic structures. The organisation of the hierarchic structure we choose to depict, in any case, is revealed both by our purpose in naming the system and the scales we subsequently choose in order to usefully represent the system. Thus we come, conceptually, to a place that can reasonably be called a process-function-based nested scale-hierarchic ecosystem approach.

The various properties and characteristics of such an ecosystem approach to making descriptions gives us, I argue, novel tools to deal with many of the 'wicked' problems facing regional urban planning. And herein lies a potential resolution to Rittel and Webber's 'dilemma in a general theory of planning' (1973).

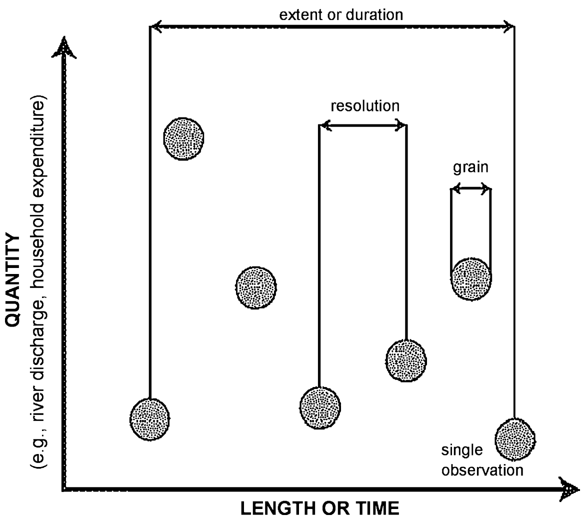

Fig. 4. The three elements of scale (MEA, 2006).

3.1. Connecting an ecosystem approach to sustainability planning

The sustainability discourse represents two broad critiques of conventional decision-making in planning and policy. First, that conventional decision-making is unduly biased towards economic criteria, while effectively disregarding equally vital factors relating to the environment and to social equity. And second, perhaps because of a systematic bias in favour of monetarised analysis and the consequent significance of interest rates in conventional decision-making, that the way we arrive at our choices makes the present inherently and always more valuable than the future. Under such a view, conventional planning and policy decision-making is seen to disregard various vital perspectives and criteria (such as ecological and social equity factors) *and* to unduly discount the future in favour of the present. Then, sustainable development is seen to consider diverse points of view somewhat more holistically, and at the same time to ensure a higher degree of intergenerational (and intertemporal) equity than conventional analyses, grounded largely in rate-of-return sorts of economic and monetary considerations.

Put differently, sustainability planning mandates that the descriptions we construct to aid decision-making be grounded in multiple, *purposively relevant* perspectives, using multiple, *functionally relevant* scales. If we take the well-known ideogram depicting sustainable development as the overlapping portion of the three circles representing economic, ecological and equity considerations, and add to this a z-axis representing time and extending into the future, then we arrive at a place that is not dissimilar to the decision space represented by what is being advocated here as an ecosystem approach to ecological planning (see Fig. 5).

3.1.1. Complex systems theory as a backdrop to sustainability

The imperative for such a multi-perspective, multi-criteria approach to decision-making derives from the nature of complex systems. The distinction between complex systems and simple systems is crucial to the argument being made here for a different approach to making instrumental descriptions in planning and policy, an approach that is more robust and enduring, and hence more sustainable, than conventional practices—at least in the long run.

Rittel and Webber's (1973) 'wicked' problems are phenomena that show themselves differently as we change our perspective, and always without some agreeable 'solution' point. Such problems are both

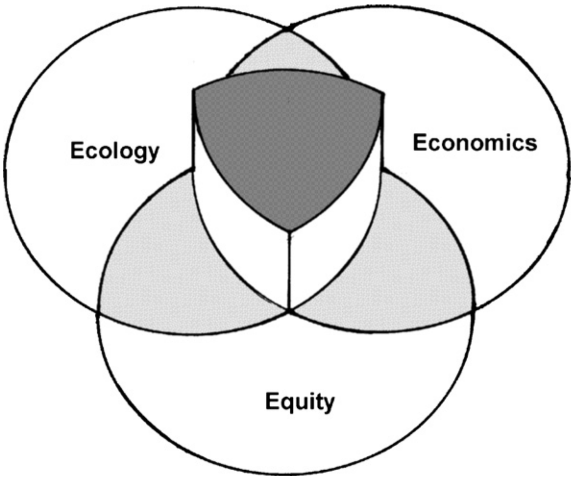

Fig. 5. The overlap of the three circles representing ecological, economic and equity perspectives, which is conventionally taken to depict a sustainable decision space, is extended along the *z*-axis to show the dimension of time.

structurally and functionally attached to other problems in ways that disallow the conventional independently discrete solving of one problem in isolation from its embedded context. So reality, under complexity, can only be captured through a systematic compilation of multiple descriptions, made from different positions or points of view.

Further, actions in one problem space may well alter factors in another problem space, or, conversely, actions outside the domain of the considered problem space may result in changes to properties or conditions in the problem space in which we are currently working. And a resolution proposed in one problem space may at least possibly become a problem in its own right, in some other problem space.

One direct implication for planning of these properties of 'wicked problems' is that their complexity can only be captured through the systematic compilation of strategically chosen multiple descriptions. Any one description will always be inadequate in itself, since what we are able to see from any one point of view and at any one instant in time, is contingent on the scales and boundaries we choose to ascribe to our description at each of the levels of organisation. Descriptions made from multiple perspectives, using multiple spatial, temporal and organisational scales, and based on functionally relevant boundaries, then become the first meaningful way of incorporating complexity into our subsequent analysis.

A second implication of these conditions from complexity is that we can never 'fix' our analysis to date—take it to be complete, and so move on to other tasks. No phase of the problem engagement process is ever able to be deemed 'finished.' Definitions and analysis must both be kept in the active domain and must be revisited periodically for reassessment.

These are the imperatives for an ecosystem approach to sustainable decision-making. *These* are the reasons that simple system description technologies (arithmetic formulae, additive logic, cost–benefit analysis, conventional applications of a system of empirical rationality that takes no explicit account of complexity, or of processes and functions beyond our ability to observe directly) will usually fail us. At best, we will find ourselves crafting interventions that generate high volumes of 'unintended consequences,' by missing out on pertinent context elements that might have been made visible by a relatively more complex systems view of the art of making depictions. At worst, we will end up with future states that are wholly undesirable to us, missing out on critical consequences to our proposed interventions, perhaps in what has been called 'the tyranny of small decisions' (Kahn, 1966).[23]

3.2. *Carrying capacity and ecological footprints as a way of getting at urban sustainability*

A second meme that is useful to understanding the sustainability discourse from within an ecosystem approach to environmental planning is the notion of carrying capacity, attached to its obverse idea of ecological footprint.[24] Generally speaking, carrying capacity can be thought of as the ability of the land,

[23] For instance, Odum (1982) describes a situation where discrete decisions by commuters, made at the margin and individually, to drive alone to work as opposed to using public transit result, cumulatively, in a situation where the public transit system is forced to shut down because it is deemed unsustainable—even though the majority of individuals involved would have voted, cumulatively, to support the continued operation of the public transit system.

[24] Ecologists define carrying capacity as the maximal population size of a given species that an area can support without reducing its ability to support the same species in the future. Specifically, it is 'a measure of the amount of renewable resources in the environment in units of the number of organisms these resources can support.' (Daily & Ehrlich, 1992). Wackernagel and Rees (1996) established the notion of ecological footprint, representing the amount of land needed to generate all the resources necessary to the continued existence of a society, city or community. The more plastic version of this meme presented in this paper differs only in recognising that 'the species of concern' here (humans) has alternative choices available to it, in the case of resource consumption. We can choose to consume that instead of this, we can choose to consume less instead of more, and so on. Volition is our friend, if we will let it be that.

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taken as a complex system, to support the intricate web of processes and functions which enable life, under some given conditions and at some particular moment in time. The ecological footprint idea can be thought of as the actual load that some particular (human-centred) system, such as a city-region, places upon the land in terms of resource consumption and waste generation. Both these ideas, carrying capacity and ecological footprint, need to be seen as dynamic and contingent on the boundaries and on the scales used in any particular depiction, rather than as some fixed numeric value that can agreeably be computed and then used for 'objective' analysis into the foreseeable future (see, for instance, Kates, 1996). The punchline here is, carrying capacity is evolutionary and plastic—within limits.

A key dilemma in implementing the notion of sustainability has been the lack of instrumental tools and protocols to help guide the practice of a different sort of planning and policy. There is, of course, a substantial literature on this, and on the use of sustainability indicators to assist in diverse sorts of planning endeavours. An early form of this sort of analysis of the load that we place upon planetary processes and functions is depicted by Ehrlich and Holdren's formulation of $I = P^* A^* T$. They suggested that an assessment of a particular society's impact (I) upon the ecosphere would be shaped by its population numbers (P), its effective affluence (A) as depicted by per capita consumption, and the environmental damage inflicted by the technologies (T) it deploys (Commoner, 1971; Ehrlich & Holdren, 1971; Holdren & Ehrlich, 1974). More recent work has sought to develop this line of thinking further (Bailey, 1990; Daily & Ehrlich, 1992). Ecological footprint analysis has also established itself as a key centre of research and analytic activity in this regard (Chambers, Simmons, & Wackernagel, 2000; Folke, Jansson, Larsson, & Costanza, 1997; Wackernagel & Rees, 1996).

3.2.1. Lightening our load upon the land

An ecologically aware approach to planning can help substantially reduce the ecological footprint of our cities, thus effectively increasing the carrying capacity afforded us by nature. Conventional practices of urbanisation tend to generate patterns of human habitation that rely excessively, and most often unthinkingly, on the sprawling propagation of dark, heat-absorbing and impervious surfaces. This has a range of significant and cumulatively detrimental effects on the ecological and biogeochemical processes and functions that underwrite our cities and shape our inhabited world, unwittingly reducing the effective carrying capacity of the land. This reduction in carrying capacity represents an actual increase in the costs we must incur in the form of the enhanced infrastructure needed to counteract our often unthinkingly expressed preferences.

In addition, such conventional building practices result in increased ambient temperatures, due to the proliferation of heat-absorbing surfaces. Urbanised regions can be 4–10 °F warmer than their surrounding countryside (Taha, 1997a). This generates increased biological and material heat stress, a substantial part of which we could easily alleviate, often at little additional cost. This heat island effect also increases the load we place on our air conditioning systems, consuming electricity that we could easily put to more productive alternative uses. The higher temperatures also increase the formation of photochemical smog. And groundwater recharge is reduced, even as urban storm water runoff is increased, due to this mindless proliferation in impervious surfaces (Arnold & Gibbons, 1996).

Our sprawling patterns of functionally segmented urbanisation force us to drive further and longer, to and from our multiple daily tasks, increasing traffic exhaust. Our freeway surfaces receive increased depositions of toxic dust and exhaust particles, building up through the year, nano-layer over nano-layer and invisible to our eyes, awaiting that first flush of the winter rains[25] that will wash these toxins into our stormwater drains. Of course, this disregard of context and of consequence will require additional expenditures in built infrastructure, to maintain the quality of our subterraneous and surface water bodies.

The temporally piecemeal and usually narrowly considered appropriation of lands for urbanisation results also in a needless fragmentation of natural habitats. The large-scale insertion of often non-native vegetation, in the form of ornamental gardens shaped to mimic images imported from far away and long ago, the broad sweeps of synthetically maintained and copiously irrigated grass lawns, all come together to disrupt indigenous landscape ecologies and to interfere with the pulsing patterns of regional biogeochemical processes. And so, without thought and without ill-intent, the land becomes more and more a receptacle for the toxic effluvia of our unconsidered urban lifestyles. All of which results, ultimately, in the more unequivocal

[25] In the case of Southern California, of course, where it rains almost only in the winter, and then for a relatively few days. Conventional planners and policy makers often mistake this temporal infrequency for functional inconsequence, and often disregard the unique ecological impact that this sort of pattern of rainfall can have.

separation of humans from nature. And in lots more of that expensive concrete and steel infrastructure stuff we need to live our lives.

With time and with technological modernisation, our cities have come to rely increasingly on the bending of nature to our whim. This has led to a corresponding reduction in our need, and so our willingness, to even consider adaptation to the particulars of our environmental context. Rather than build in a vernacular, using climatically appropriate building materials and locally adapted dwelling types, we choose instead to impose our will upon the land, capitalising on the apparent economic benefits of a mass-production culture. Of course, we must then compensate for the ecological consequences of such choices through the increased use of air conditioning and heating, and more of the personalised transportation infrastructure to support our lone commutes across sprawling landscapes bereft of localised neighbourhood connectivity.

We choose to deny our ecological context, and impose instead our own production of place. But by denying our ecology, we come also to live more heavily upon the land. And at least some of the infrastructure we are now forced to build may have just as easily been avoided, without loss to quality of life and to our preferred lifestyles.

3.2.2. Three interventions in search of an insight

An ecosystem approach to urban environmental planning shows us that we can let nature back into our cities, using intelligence, innovative materials, suitable tree species and native vegetation, and, in the process, lighten our tread upon the land. Three strategies from urban ecology: heat island mitigations, urban forestry, and landscape management strategies that mitigate impervious surfaces, together provide many of the infrastructure benefits our contemporary society needs. Taken together, these strategies considerably reduce air pollution and water pollution, significantly enhance our natural water supply, substantially strengthen connectivity across the rich and diverse habitats within which we dwell, while at the same time reducing the carbon dioxide emissions that mark our copious transfer of below ground carbon into the atmosphere, in the form of fossil fuel combustion.

Lighter coloured and heat reflecting building and paving materials, used for roofs, driveways and roads, would help reduce temperatures by 4–6 °F. This would reduce the air conditioning loads during peak demand by 20–25% (Rosenfeld, Akbari, Romm, & Pomerantz, 1998). This is partly due to the reduction in ambient temperatures, but also by directly cooling roof membranes by 40–60 °F, which, incidentally but not insignificantly, substantially increases the effective life span of each of these treated roofs (Taha & Akbari, 2003). Green roof technologies have now reached a point where we have a good understanding of how to build these cost-effectively, and what plants to use for a low-maintenance result. At the same time, and as an additional benefit, we would also reduce the formation of smog by some 10–15% (Taha, 1996, 1997b), which generates considerable improvements in human and organismic health.

Ecologically suitable species of trees and shrubs,[26] strategically planted to provide shade for our built environment,[27] would also cool the air through the entirely natural process of evaporative transpiration in the soil plant complex,[28] even as their copious leaf surfaces help to trap toxic dust particles locally (if they were to be planted in dense stands downwind of hot, spots such as freeway corridors with high volumes of truck traffic, residential neighbourhoods in these areas would be relieved of at least some of the onerous health impacts they now face). At the same time, they would capture and store copious amounts of rainwater, even as they penetrate the soils to increase groundwater recharge, improve the health of our organic and biologically active soils, and provide precious habitat and soil-health improvements.

There are innovative and now well-tested materials technologies that would allow us to make our denser landscapes more porous. The square miles of sun-baked asphalt parking lots that now stake out our downtown areas could easily be turned into tree-shaded, rainwater receiving reservoirs that would help recharge our water tables, even as they capture and bioremediate the toxic drippings of hot commuter vehicles.[29] We know also how to deploy Xeriscape plants that naturally need less water to grow, and so are more drought-resistant, across

[26] See, for instance, Benjamin and Winer (1998), Benjamin, Sudol, Bloch, and Winer (1996), and Beckett, Freer-Smith, and Taylor (2000).

[27] Rosenfeld et al. (1998).

[28] The root structures of plants and trees draw up moisture from groundwater through the soil, and the soil and plants, acting together, evaporate some of this moisture into their immediate environment (Hsiao & Xu, 2005). In addition, the leaf surfaces of trees and plants also give up some of this moisture into the immediate atmosphere. Together, these processes can cool the local air by up to 10–15 °F, as walking under a broad-canopy leafy tree on a hot, dry summer afternoon in Southern California will readily demonstrate. See, for instance, Meier (1991), Sailor (1998), and Dimoudi and Nikolopoulou (2003).

[29] If we were to implement a 50% tree cover strategy for our parking lots, we would reduce evaporative emissions from the countless cars that now stand baking in the afternoon sun, in every downtown parking lot (Geiger, 2002; McPherson, Simpson, & Scott, 2001; Scott, Simpson, & McPherson, 1999a, 1999b; Wolf, 2004).

Please cite this article in press as: Vasishth, A. A scale-hierarchic ecosystem approach to integrative ecological planning. *Progress in Planning* (2008), doi:10.1016/j.progress.2008.05.001

our lawns and gardens. We can make our cityscapes more attractive and liveable than they often currently are, even as we make them more porous and blend them in better with their surrounding ecologies, while allowing nature to do many of things that nature does well—and often at considerable cost savings to us.

By integrating such ecologically contextual measures into our planning, we would come, cumulatively, to reduce our ecological footprint, and consequently to enhance the effective carrying capacity of the land.

3.3. Insights from a nested scale-hierarchic ecosystem ecology approach to describing nature

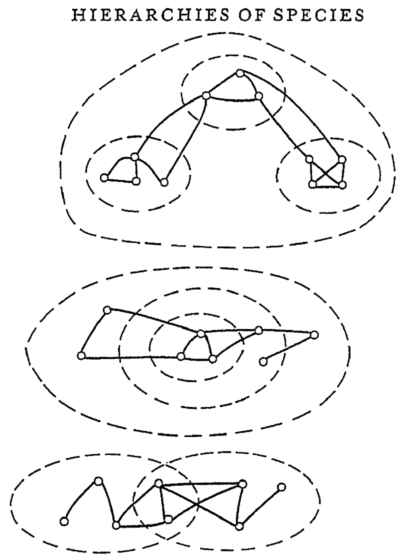
The root question in this effort to extract a set of principles for an ecosystem approach to integrative regional planning may be stated as follows: given the limits of human cognition, how can we craft useful descriptions of specific aspects of reality, if we see the world as being emergent from, and thus shaped by, complexity? Nested scale-hierarchic ecosystem ecology provides one effective model for the construction and manipulation of such descriptions. There are two formative concepts at work here—*nested scale-hierarchic levels of organisation* and *scale dependence*.

A classic distinction is made, in ecosystem ecology, between rank hierarchies and scale hierarchies, and between nested and non-nested systems. Rank hierarchies are typified by chain-of-command structures, pyramiding down from generals through officers to soldiers. Scale hierarchies are seen to have a nested structure, aggregating outwards, for instance, from individuals to platoons to companies to battalions to regiments to armies (Allen & Starr, 1982:39–42).

Each nesting is deemed to constitute a particular level of organisation, and each level of organisation is structurally emergent from the functional relationships of its named constituent subsystems (Allen & Hoekstra, 1992; Rowe, 1961) (see Fig. 6). The named system of concern then, and in turn, relates functionally to other systems at its own level of organisation, which, by their interactions, give rise to a wider level of organisation that can meaningfully be called a suprasystem. It is because the constituent 'parts' of any named system are seen to be in strong functional interaction that it becomes meaningful to name them as a system in the first place.

It is useful to keep in mind that the nesting of systems, subsystems and suprasystems is a naming activity, in the sense that the boundaries and the ordering of the nested systems are not inherent in the phenomena of concern, but rather are naming devices, contingent on purpose and on perspective (see Fig. 7).

(a)



(b)

(c)

Fig. 6. Three potential hierarchical structures for communities. The species (circles) may interact (lines) as though they were organised into independent modules (a), nested into more and more complex associations (b), or developed into overlapping modules (c). Hierarchies are not inherent in nature, but rather are constructed on the basis of relationships that are thought to be meaningful for some particular purpose, and from some specific vantage point. (O'Neill et al., 1986:131)

3.3.1. Nested levels of organisation generate operationally informative descriptions

For instance, the strong connectivity between the two ports of Los Angeles and Long Beach may, under particular circumstances and for some specific purpose of analysis or planning, make it meaningful to consider them as a single goods movement node, the San Pedro Port Complex. This complex, due to its strong interactions with its surrounding residential and industrial neighbourhoods, can be seen to be nested within a sub-regional system, forming its own level of organisation. This sub-regional system interacts strongly with a variety of logistic and warehouse subsystems, and so can be seen to be nested within the Southern California regional system. And this system can, in turn, be seen to be nested within a national goods receiving system that is the United States, which, in turn, can be seen to be nested within a more global goods production and movement suprasystem that connects across nations and continents.

Differently, we could say that the San Pedro Port Complex is in functional interaction with logistic companies and shipping and trucking corporations and labour units such as the International Longshore and Warehouse Union, making them subsystems for the goods movement system that we are concerned with in some particular case. And this goods movement system

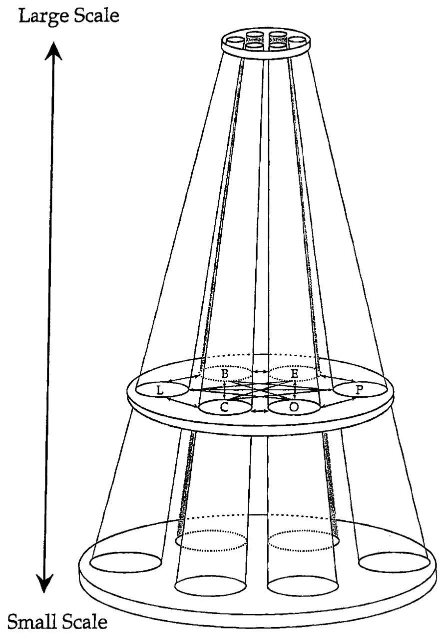


Fig. 7. The layer cake metaphor for ecological criteria and ecological scale. The wide base indicates a large number of small entities, the narrow top indicates a small number of large entities. The cross-section across the entire cone represents one middle-level scale. Although there is only one here, any number of cross-sections could have been inserted, each at its own scaled level. Each letter indicates a different ecological criterion: O, organism; P, population; C, community; E, ecosystem; L, landscape; B, biome. The six lettered discs correspond to where the abstract, scale-independent criteria intersect with the scale to produce a given way of identifying an ecological entity at a given scale. Individually, the columns represent a criterion for looking at the material system, e.g., the abstract notion of community. The disc labelled C is an actual community with a particular scale. In the C column, larger-scale contextual communities occur above that community while smaller-scale community subsystems occur below. A community context to an organism would be a C disc diagonally above a given O disc; the ecosystem that is a cow's rumen would be an E disc diagonally below an O disc representing the cow (Allen & Hoekstra, 1992:53). Levels of organisation are deliberatively designated entities, rather than direct readings from nature. In designating a particular level of organisation as 'the ecosystem of concern,' we establish the levels that will subsequently be known as subsystems and suprasystems.

is then in strong interaction with retail agents and consumer entities, to give rise to the suprasystem that is the consuming nation of the United States (see Fig. 8).

Such nested conceptions are useful to us because they allow us to move into and out of particular levels of organisation, to consider supra- and subsystems in their structural and functional relationship as a coherent whole, and to trace the lines of influence across levels of organisation, as we seek to move the system in one way or another, under some responsively adaptive management scheme. As O'Neill et al. (1986:55) point out, for instance: '... hierarchical descriptions help to manage complexity by isolating dynamics at a single level, while ignoring details at lower organisational levels.'

In ecology, a conventional depiction of such a hierarchically nested organisation considers the constitutive relationships between cells, organs, organisms, communities, ecosystems and ultimately, the ecosphere (Rowe, 1961). In planning, we might consider, for instance, specific development projects that are functionally related to each other—constituting, perhaps and as merely one example, residential, commercial, industrial and recreational land uses—and which, by virtue of their functional interactions, give rise to neighbourhoods. Various functionally related neighbourhoods, in their interactions and exchanges, may be said to constitute a city-region. Various city-regions, in turn and in their own relationships to each other, may be said to give rise to states or nations as suprasystem.

The very act of conceiving a region in this nested manner allows us to separate out exchange processes and functional relationships by levels of organisation, to then choose spatial and temporal scales suitable to capture the processes and functions thought relevant at each named level, and so trace connectivities across levels of organisation.

Take, for instance, the case of goods movement in Southern California. The forces of economic globalisation have moved many manufacturing activities out of the United States and into foreign countries (Robins & Strauss-Wieder, 2006). This removal generates huge benefits for US consumers on two fronts. We receive consumer goods at a fraction of the price that they would have cost us if manufacturing had continued to take place within the US, with its higher labour costs and economically more expensive levels of environmental regulation enforcement, as compared to some developing countries. At the same time, we benefit from reductions in manufacturing-related pollution, as the production of consumer goods is almost always associated with significant levels of resource degradation and environmental pollution.[30]

[30] In December 1991, Dr Lawrence Summers, then Chief Economist at the World Bank, signed off on an internal memo to his staff speculating that the economically efficient way to deal with toxic wastes would be to ship them to the countries with the lowest life expectancies (Korten, 1992). The memo leaked, there was an uproar, and the public expressed suitable outrage. However, consider that this is precisely what the United States and other western nations have done, in effect and for all practical purposes. The only real difference is that we have shipped to them instead the manufacturing activities that generate these toxic wastes in the first place.

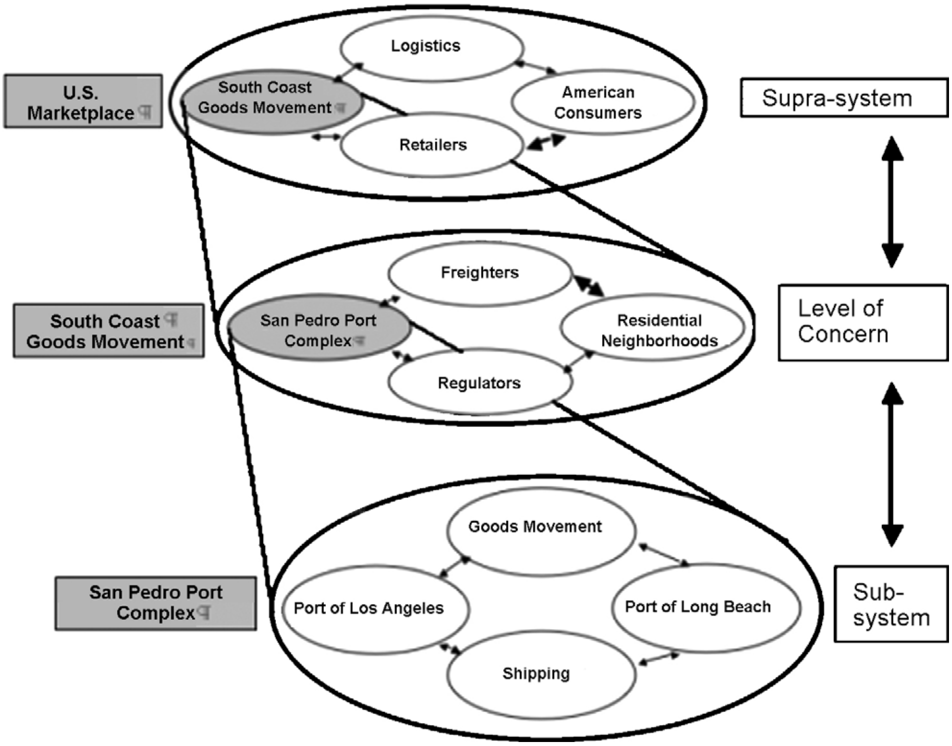


Fig. 8. Nested depiction of the South Coast Goods Movement System, with the San Pedro Port Complex shown as a subsystem level, and the US consumer market as a suprasystem level.

As a consequence, dramatically increasing proportions of consumer goods now need to be shipped into the US, and then distributed across the nation. The San Pedro Port Complex is one major point of entry for these flows of goods. A steadily increasing stream of cargo ships unload freight at the ports, and these containers are then transferred, partly by rail and mostly by truck, to logistical distribution centres and warehousing facilities, for repackaging and transshipment to all parts of the US.

So, a consumer in Columbus, Ohio, as one example, gets both a cleaner environment and cheaper consumer goods. Besides the huge pollution and resource degradation costs we are externalising onto developing nations, a complex set of costs is externalised by US consumers onto Long Beach residents—such as the traffic congestion and air pollution costs of accepting the maritime flow of goods and then transferring these containerised goods to rail and road, for further domestic transshipment. Thus, the communities residing adjacent to the San Pedro Port Complex in Long Beach, California, the I-710, the US-101 and the Terminal Island Freeway Corridors which carry the bulk of the truck traffic servicing the goods movement activities there, now bear an increased burden, which is placed upon them in equal measure by consumers across the US in search of cheaper goods and by the corporations benefiting directly from the globalising production system and its narrowly defined economic ‘efficiencies.’

Describing these complex phenomena of goods movement and consumerism, and the processes that shape them, using a nested levels-of-organisation scheme allows us to trace out the context and the consequences of globalisation processes in a somewhat systemic way. Such an approach also allows us to fabricate a reasonable mechanism for the mitigation of adverse impacts across levels of organisation. A cross-level policy mechanism is needed to transfer some amount of the benefits currently accruing to consumers, producers and corporations across the US, viewed as a suprasystem, to the community of residents living around the port complex and its freeway feeders, viewed as a subsystem. One way to mediate such an exchange of benefits, intended to mitigate the particular local environmental health and traffic congestion disbenefits, is to construct an impact management mechanism at the intermediate regional level of organisation.

But all of this requires an integrated systems approach to regional planning, one that can connect

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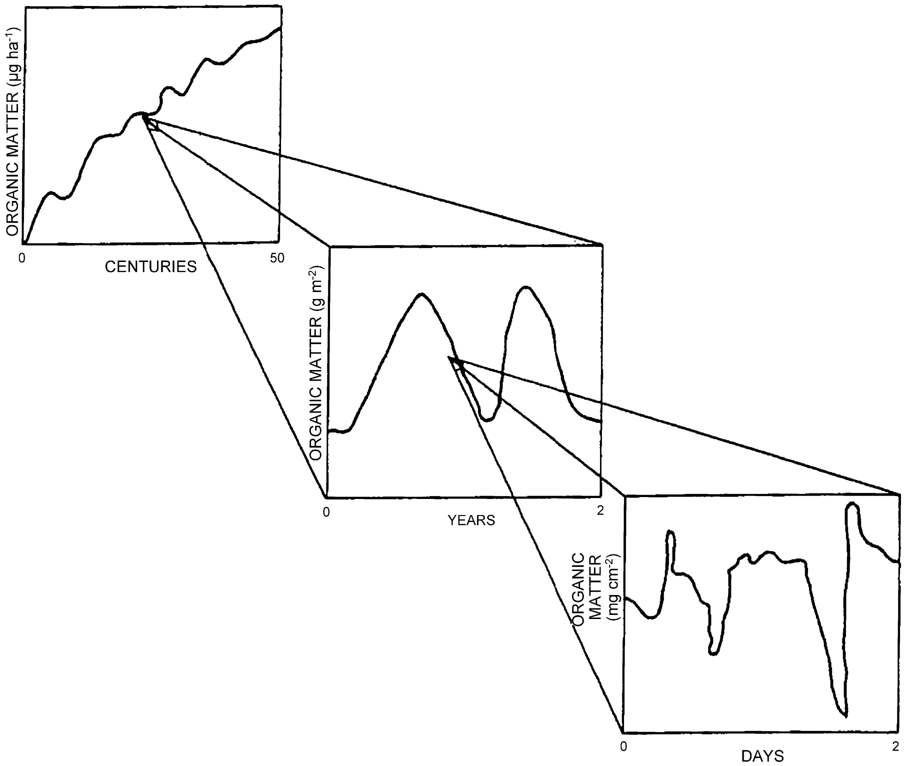

Fig. 9. Changes in apparent dynamics of a litter-soil system with a change in time and space scales. Slow dynamics over centuries show accumulation of organic matter with oscillations due to succession (Sollins et al., 1983). On a scale of years, seasons' decomposition processes are apparent, while an observation window of days reveals rapid fluctuations due to wind and arthropods. What we can see of species richness is contingent on the scales we choose in making our depictions. The rich actuality of natural phenomena can only be captured by the use of multiple scales. (O'Neill et al., 1986:84)

the functional and structural elements together in a manner that permits the effective remediation of adverse impacts across these various named levels of organisation, and implemented using a participatory and adaptive management approach.

3.3.2. Descriptions are scale dependent

Such descriptions of nested systems are, of course, contingent on purpose, on point of view (perspective), and on scale. Why we are choosing to name a particular nested set of systems will largely determine what we take to be the relevant constitutive subsystems and the emergent suprasystems, and how we think to bound them. Where we choose to position ourselves, in terms of purposive perspective and vantage point, will in turn influence how we think to designate levels of organisation, and which one of these levels we take to be the 'system of reference'—from which we would then call off the subsystems and suprasystems. But most importantly, and within a complex systems view of the world, what we are able to see of reality is dependent most on the spatial and temporal scales by which we choose to craft our descriptions (see Fig. 9).[31]

Ecosystem ecology shows us clearly that perceived reality is, in very actual ways, scale dependent. That is to say, what we are *able* to see of the world, within any particular effort to craft a description under conditions of complexity, is contingent on the spatial and temporal scales at which we choose to construct our descriptions.[32] This scale dependence of reality is illustrated

[31] Here, scale refers to the two ideas of extent and of grain—or, put differently, as sample size and sample interval. Thus we could speak of large-scale, coarse-grain descriptions as one book-end, and of small-scale, fine-grain descriptions as the other.

[32] Spatial and temporal scales are only two of the sorts of scale that are relevant in ecological research. Martinez and Dunne (1998:208–209) argue, on the basis of their work with food webs, that any metric that relies on quantitative data carries scale assumptions attached to it—such as thermal scale, primary productivity and even species richness.

effectively by research on mapping species richness as a function of land area. This species–area curve is commonly used in ecology to infer processes such as disturbance and competition, in the delineation of community types, and in preserve design (Palmer & White, 1994). Changing the scale at which descriptions are made for mapping can be shown to change the apparent variability of species richness distributions over the studied landscape (Stoms, 1994).

Species richness is a density variable, representing a census measure of the number of species occurring within an ecological community over some standard unit of land area (Stoms, 1994:346). Unlike some ecological processes that have specific spatial or temporal scales attached to them, species richness has no single spatial reality. Instead, what we see of species richness appears dependent most on the scale at which we choose to depict it—both in terms of sample size (extent) and sample interval (grain) (see Fig. 10). In general, the mean number of species within a community is seen to increase with increases in sample extent, and research in ecosystem ecology is focused on determining other generalisable properties of this scale dependence (Gardner, 1998:17–18).

Wildfires are another example of ecological phenomena that demonstrate scale dependence. Certain landscapes, for instance, are referred to as 'fire ecologies.' These are landscapes where ecological communities are either adapted to, or dependent upon, fire as an ecological process. The Southern California chaparral landscape is one such fire ecology. While there are debates currently playing out, regarding the particulars of these ecological processes,[33] the Southern California landscape has clearly co-evolved with fire, and so has integrated fire-driven processes into both its structure and its function.

An important point here is that, depending upon the scale at which the description of any particular wildfire event is made, that specific wildfire event shows itself either as a destructive or a creative process. At the organismic level of organisation, and at a landscape scale, wildfire shows itself to be a destructive disturbance. Many individual organisms will be destroyed, and the post-fire landscape appears bleak and devastated. But if we change our perspective to a wider level of organisation, and choose a more regional scale for our description of the same wildfire event, then

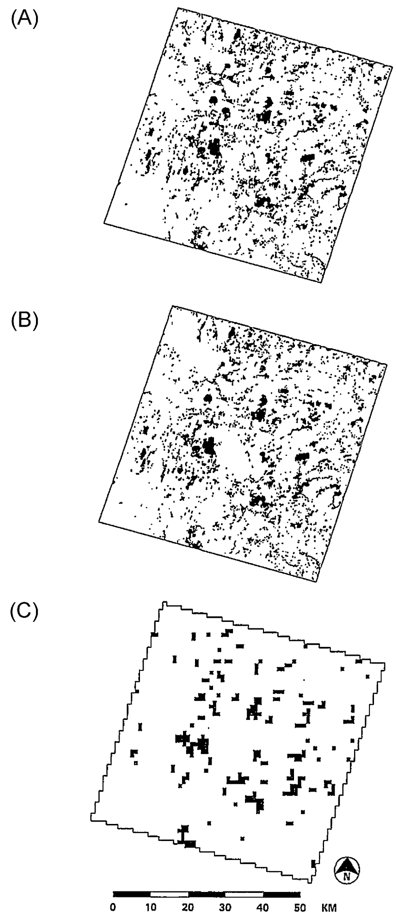

Fig. 10. Three remotely sensed images of the same lakeland area in Wisconsin. In (A), much detail can be seen because the grain is in metres. In (B), a different data-collection protocol uses a chunkier grain. Note that some of the small connected lakes are now invisible, having fallen below the threshold of the grain. In (C), the pixels that constitute grain are 1 km, and most of the detail from the other two images has been lost in the coarser grain. From Benson and MacKenzie (1995) (Ahl & Allen, 1996:59). What we can see of reality is highly scale dependent. Changes in grain and in extent can reveal or hide details that may or may not be relevant to the purpose at hand.

it shows itself to be an essentially creative and regenerative process. Many plants, for instance, require fire as part of their germination process. Important minerals and nutrients are made available to the soil, on account of the vegetation being turned into ashes. And whole ecological communities are rejuvenated in the aftermath of an event that, previously, showed itself as destructive.

Under such an ecosystem approach to conceptualising fire in forest ecologies, O'Neill et al. (1986:167–169) show some of the ways in which perturbations such

[33] See, for instance, Keeley and Fotheringham (2001a:1536–1548), Minnich (2001:1549–1553), and Keeley and Fotheringham (2001b:1561–1567).

as forest fires are incorporated, literally, into the broader ecosystem. At the scale of a few tens or hundreds of acres, fire may appear devastating. At the scale of a few tens or hundreds of square miles, fire may be a regenerative process. Both depictions of reality are equally true, and both depictions of reality form an essential part of an ecosystem approach to making descriptions. Effective ecological planning requires a synthesising of these depictions, rather than some selection of one as more 'accurate' over the other.

3.3.3. Attention to processes and functions allows a more direct access to reality

Heat island mitigations, which might substantially aid in reducing smog formation in the case of Southern California (amongst many other benefits), are another case where the usefulness to planning of such an ecosystem approach that prioritises processes and functions may be clearly seen. Tropospheric ozone is an air pollutant for which health-based emission standards have been established by the US Environmental Protection Agency (EPA). Jurisdictions that exceed these health-based criteria for atmospheric pollution concentration are mandated to institute and implement air quality management plans intended to move the jurisdiction into attainment of these standards within set periods of time. Due in large part to remarkable improvements in emission control technologies for motor vehicles, most such non-attainment jurisdictions have been demonstrating substantial improvements in air quality. Jurisdictions such as the South Coast Air Basin (SCAB) have also probably been helped in their efforts to move progressively towards the national ambient air quality standards (NAAQS) by strict air pollution regulations. These have forced at least some of the more grossly polluting industries to relocate to places that have lower pollution levels, less stringent pollution control regulations, or relatively lax regulatory enforcement—such as the less-developed countries.

However, the most current data indicate that this trend towards a reduction in overall air pollution is now beginning to reverse itself. This may perhaps be due to an increasing growth in both the number of vehicles on the road and in the number of per capita vehicle miles travelled, as populations continue to grow and as we are forced to travel progressively longer distances on a daily basis, due to increasing urban sprawl. Other factors may be the lack of any effective overall improvement in fuel economy at the national level, driven in large part by the phenomenal surge in relatively 'gas-guzzling' truck-like sport utility vehicles (SUVs).[34] In addition to such increases in pollution, the NAAQS themselves have recently been updated to reflect current understandings of the health impacts of air pollution from ozone and from ultra-fine particulate matter ($PM_{2.5}$). As such, many jurisdictions now face an increased challenge in attaining the NAAQS.

Urban heat island mitigation measures offer an additional strategy in these efforts to attain healthful air quality. In general, urban areas tend to be 4–10 °F warmer than the surrounding countryside (Taha, 1997a). This higher temperature is due in part to the greater incidence of dark-coloured heat-absorbing paving and roofing surfaces (lower albedo), in part due to the reduced incidence of vegetation and forest cover (lower evapotranspiration rates, less shade), and in part due to the increased concentration of heat-generating activities, such as internal combustion engines, industries, air conditioning equipment, and so on (increased heat generation).

This heat island effect is relevant to efforts to reduce smog pollution, in places like Southern California, because of the atmospheric chemistry of tropospheric ozone formation. Ozone is not an emitted gas. Rather, volatile organic compounds (VOCs) and oxides of nitrogen (NOx), both commonly emitted from car exhausts, as one example, mix together in the lower atmosphere, where they are subsequently acted upon by solar radiation in a photochemical thermal reaction. The presence of sunlight is imperative for ozone formation, and this reaction is temperature-sensitive—the higher the ambient temperature, the more completely exhaust gases combine to form smog. This is the reason why we can expect a reduction in ozone formation when ambient temperatures are reduced, even without any

[34] For instance, by the middle of 2003, newspapers reported widely that SUV sales were either approaching or had actually exceeded half of all new car sales in California, and that smog levels were on the rise again in the South Coast Air Basin (Polakovic, 2003). It was also reported that the sale of SUVs peaked in 2004 at 55.7% of all new vehicle sales (Peters, 2006). Although not all SUVs are equal, and since then, there has been some limited introduction of more fuel-efficient models, the vehicles bought in those early years of SUV popularity are not going to be taken off the roads any time soon.

physical reduction in the amounts of precursor VOCs and NOx emissions.[35]

Managing for processes and functions that may be obscure to our direct senses, can sometimes be the most effective way of managing the physically more tangible world. For instance, native vegetation in Riverside County is being transformed as much by the deposition of airborne nitrogen carried over from Los Angeles County, as it is by direct transformations due to changes in land use and land cover. And yet virtually exclusive attention is given to direct land use transformation. As the exhaust gases from cars and other sources are undergoing the thermal photochemical ozone-forming reaction, these gases are usually pushed steadily inland by ocean breezes, wafting east out of Los Angeles County and across the landscapes of Riverside and San Bernardino counties. The smog-forming reaction takes time, and the gaseous brew is usually over Riverside County before the reaction completes itself. At that time, nitrogen is deposited out of the lower atmosphere onto the landscape.

Nitrogen, being a fertiliser, is giving 'weedy' exotic and invasive species a competitive edge over the native but slower-growing Southern California coastal sage scrub vegetation endemic to the broader region. This is driving habitat change within Riverside County, which is also the site of the relatively high-priority effort to implement the Western Riverside multiple species habitat conservation plan (MSHCP), and, in very real ways, is undermining the progress being made in habitat conservation (Allen et al., 1998; Cione, Padgett, & Allen, 2002; Edgerton-Warburton & Allen, 2000; Padgett & Allen, 1999). A conservation planning protocol that is not founded upon nutrient flows of this sort, and on other processes and functions revealed by biogeochemistry and hydrology, is likely to fail through not having taken account of actual and formatively occurrant ecological realities.

Somewhat differently, in the case of a concern with ultraviolet-B radiation exposure, which has been linked to some forms of skin cancer, a common assumption is that this exposure is lessened by either standing in the shade or on a cloudy day. As Heisler and Grant point out (2000:214):

> It seems simple enough that where we see the shade, there we will find UV protection. However, there can be significant differences between reductions of the visible portion of the solar spectrum (that is, the shade pattern we see) and reductions of UV by trees and other structures in urban areas. Differences can occur partly because visible and UV differ in the diffuse fraction of total irradiance, in the distribution of sky radiance, in reflectivity of urban structural surfaces, and in optical properties of leaves at different wavelengths. The UVB irradiance is sometimes reduced more and sometimes less than visible wavelengths. The distinction between 'shade' and 'sunlit' would be much less apparent if our eyes registered UVB rather than a range of wavelengths close to the PAR (photosynthetically active radiation).

In each of these cases, an actual reality is revealed by attention to processes and functions that would not, in and of themselves, be apparent to us. Nor would we be able to directly infer the significance of a particular set of processes and functions by simple direct observation. And in every case, our understanding of context and of consequence is substantially transformed by this attention to processes and functions.

3.3.4. Setting multiple and functionally diverse boundaries generates richer instrumental descriptions

Ecology itself is a recognition of the context and the consequence of place, in its fullest sense. Reality occurs in multiple ways, simultaneously doing more than a few things at the same time and in the same case, yet never showing itself except incompletely from any single vantage point. As such, the creation and management of rich descriptions—rendered from functionally relevant perspectives, predicated on distinctly explicit purposes, drawing on functionally established boundaries, and based on appropriately multiple scales—drives the heart of an effective and adaptive ecosystem approach to managing the happening world.[36]

Ecological context is properly set across nested levels of organisation. Given the many legitimate stakeholder perspectives and the proper variations in pragmatic purpose, no one singular specification of

[35] There are many other good reasons for regions to adopt heat island mitigation measures, such as increased vegetation and tree cover, reduced impervious surfaces, and increased albedo. Such measures can result in reduced energy consumption in buildings, reduced heat stress in all organisms (including humans), increased groundwater recharge, reduced urban run-off, increased storm water pollution mitigation, and improved habitat connectivity. This approach is discussed in more detail in the following section.

[36] The word 'happening' is used with intent, to denote the significance of chance in evolutionary phenomena. The meme here is 'how the world happens to come into being'.

boundaries can serve our purpose as planners. For instance, Mugu Lagoon is an estuarine marsh in Southern California. It is situated within the administrative boundaries of the Naval Air Weapons Station (NAWS), Point Mugu. Because the US military is guided by federal policy, and so subject to National Environmental Policy Act (NEPA) requirements, and because the military usually takes its responsibilities seriously, Mugu Lagoon is one of the few remaining wetlands that once shaped virtually the entire Pacific coastline of North America. This chain of wetlands supported the biannual seasonal migration of birds along what is called the Pacific flyway, providing vital feeding, resting and nesting grounds for transient birds. Almost all these wetland habitats have since been destroyed by human development, and the few remaining instances of such habitat become all the more precious, both to us and to the migrating bird flocks.

At the same time, and due to the particulars of topography, Mugu Lagoon is the catchment basin for the Oxnard Plain, an area that was almost exclusively given over to agriculture from the mid-19th century until fairly recently, when agricultural and open lands began to be given over to the rapidly growing pressures of urbanisation. As a consequence of this transformation of the landscape, the lagoon has long received the runoff from agricultural land uses.

Temporally speaking, the area that now constitutes Mugu Lagoon was once beneath the surface of the Pacific Ocean, a few hundred thousand years ago. Then, due to tectonic activity, the land mass around what is now the lagoon rose to an elevation some feet above the ocean, coming to form a freshwater lake. Gradually, due to tectonic settlement and to erosion, the land mass lowered to form a freshwater lagoon. Beginning with the settlement of the Oxnard Plain by European settlers in the mid- to late-1800s, and the consequent channelisation of runoff into Caluegas Creek as the Plain was converted from oak savannah to agricultural uses, the lagoon converted to an estuarine (mixed fresh- and saltwater) marsh and came under eutropification pressures from the fertiliser-laden runoff from irrigated agricultural land uses across the Oxnard Plain.

More recently, and functionally speaking, as the urbanisation of the Southern California landscape unfolds, the cities of Simi Valley and Thousand Oaks continue to grow, with ever-increasing expanses of soil being converted to impervious surfaces. This has increased the amount of urban runoff, itself tainted with the cocktails of toxic chemicals that are the seemingly inevitable fallout of suburban lifestyles, particularly the synthetically greened lawns so deeply attached to contemporary visions of the 'good life.' As a consequence of these forces of urbanisation, the lagoon has come under pressure of increased siltation and contamination. Urbanisation along the coastline north of the lagoon, with its resultant construction of breakwaters, the implementation of beach stabilisation projects, and the reduction in silt deposits off the Oxnard Plain as a whole, is also beginning to change the morphology of the coastline immediately around the lagoon. These developments have changed the ways in which ocean currents interact with the coastline and the lagoon inlet, creating an underwater canyon that is beginning to radically suck soil and sand away from the marshlands and beaches.

Each of the states and conditions described above generates fundamentally different descriptions of the ecological context of Mugu Lagoon, leading us to draw very different boundaries around what it is we consider 'the lagoon,' depending upon our purpose in making the description. If we want to manage, conserve and even restore the wetlands to maintain the now increasingly tenuous integrity of the Pacific flyway, we draw one set of boundaries. If we want to manage the estuarine marshes as critical habitat for locally endangered species, we draw a different set of boundaries. If our concern is with the chemical contamination from DDT and from the various chemicals used in the past as part of the pre-NEPA operations of the NAWS Point Mugu base, and now sealed under layers of silt, we will be driven to draw a different boundary. If our concern is with controlling eutropification and the discharge of human pollutants and refuse into the Pacific Ocean, we will draw our boundaries of concern differently as well. And if our concern is with managing the lagoon as a functional estuarine ecosystem, and thus with reducing the amount of siltation due to urbanisation-based increases in impervious surfaces in the inland reaches of the landscape, we will choose an entirely different set of boundaries in making our planning descriptions. Not only is it the case that not one of these particular set of boundaries is inherently more 'true' than any of the others, but also, from within an ecosystem approach, we come to see that the only functionally robust way of managing Mugu Lagoon is by considering many of these multiple boundaries in some appropriately synthesised way.

Taking an ecological approach to planning requires that we maintain an awareness of these sorts of multiple functional boundaries, and resist the deeply ingrained impulse to singularise place and to objectify occurrence.

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3.4. Reconceptualising humans as part of nature, richly

Recent human history is marked most by a peculiarly 'objectivist' form of scientistic thinking, that has tended to treat nature as a thing-in-itself, available for human manipulation on a selective basis. That is to say, we have acted as though it is alright for us to 'tweak' nature in some one aspect—control the one adverse effect, such as flooding, for instance—without triggering other, perhaps more seriously adverse, ecological effects. We are trained to choose singularised descriptions for complex problem states, and are accustomed to then proceed to address these as though they were mechanisms. As a consequence, we are less attentive than we need to be towards the effects of the not-so-obvious, but more formative, processes and functions that lie outside the boundaries of these grossly incomplete descriptions we use to model discrete and unduly singularised segments of reality.[37]

In part, the problem is that we have segmented out our knowledge systems into discrete and often too strongly disconnected disciplines—with air quality planners rarely talking to habitat conservation planners, and solid waste managers making only tenuous connections with water quality planners, to choose just two examples. But in larger part the problem is that our bias towards objective truths predisposes us to the construction of singularised descriptions of nature. If, on the other hand, we were to take the world ecologically, we would be driven to recognise that complex systems are complex precisely *because* they cannot be so singularised. Multiplicity is the essential property of natural systems. Because we are driven by our objectivist training to reduce each problem or phenomenon to *a* truth, we have not systematically developed the abilities to tell our descriptions richly, instead seeking to find the one perspective, the one set of criteria, the 'critical' factor, that makes our description 'true.' Instead, we would benefit from telling context more richly, and so being better able to trace consequences more fully through system connectivities.

Additionally, we are biased, for a variety of reasons, towards the physically tangible world. We systematically prioritise those things that are more directly accessible to our senses—of sight and touch, in particular. Processes and functions that, of necessity, can only be accessed conceptually through instruments and thought, are often relegated to a somewhat secondary standing. This sometimes yawning gap between science and scientism is particularly true in legislative policy making, where non-scientists are usually the prime movers in shaping societal responses to human interactions with nature. Habitat conservation planning, in which threatened and endangered organisms and their physical, spatially defined habitat remain the prime focus of conservation action, rather than the more subtle approach of managing habitat for key processes and functions that actually underwrite them (such as nitrogen or carbon flows), is a prime example of this limitation we impose upon ourselves. As Allen and Hoekstra (1992:100) point out:

> (E)cosystems ... are consequential but are for the most part intangible. Ecosystems can be seen more powerfully as sequences of events rather than as things in a place. These events are the transformations of matter and energy that occur as the ecosystem does its work. Ecosystems are process-oriented and more easily seen as temporally rather than spatially ordered.

Holling and Goldberg (1971) had warned us of the dire need for planning, and for planners, to take account of this implication of ecological system connectivity through processes and functions, underscoring the need to think more richly about context, and to more carefully trace consequence than we are presently accustomed to do in planning practice. We continue to ignore their warning at our own peril. Our ability to accurately tell consequences in advance of intervention is shown by them to be influenced most by the richness with which we think to tell context. More often than not, 'surprise' and 'unintended consequence' are the outcomes of the information-poor and partial contextual descriptions we are usually content to create in advance of action, and those usually from one or two privileged perspectives of autocratically determined technical expertise.

McDonnell and Pickett (1993) have shown us the need to reconceptualise humans 'as components of ecosystems,' and have begun the process of showing us a means to the integration of humans with nature.

[37] In the particular context of decision-making, planning tends to be reductive. It is not that we are unfamiliar, in our everyday lives, with the idea of processes. After all, we see both politics and economics to be dynamic, evolving, and quite process based. But when it comes to deliberating decisions, planning seems driven to reduce these processes to singular fact. When we prepare plans, we objectify place. When we use economics, for instance, to make our decisions, we objectify the results. In a second sense, we often reduce the world in which we plan to some singular dimension. Here, the critique from the sustainability discourse, that we unduly reduce the world to monetary metrics to simplify our societal decision processes, is quite illustrative.

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Rather than thinking of our cities as a place apart from nature, removed from their particular ecological context, we need to begin the process of reintegrating context into how we think to build. Awareness of the ecological consequences of impervious surfaces, the ways in which our built environments express their adaptation to local environmental and climatological conditions, and the extent to which our transformations of the built landscapes increase, rather than decrease, the loads we place upon nature, can all help to mediate the ecological footprint our cities generate, and to effectively increase the carrying capacity of the land upon which we dwell.

Together, these two imperatives—to take a fuller account of ecological context and of consequence, by making rich descriptions, and to consider humans more fully as part of nature—provide the basis for an adaptive ecosystem management approach to integrative regional ecological planning.

4. Telling context and tracing consequence: setting an ecosystem approach to integrative regional ecological planning

Conventional approaches to habitat conservation have relied centrally on the designation and setting aside of habitat reserves, exclusive of human use, to support various endangered and threatened plant and animal species, in an effort to assure their long-term survival and recovery. A key model to consider, in assessing the diverse ways in which the Southern California region deals with habitat and natural area issues, is the Habitat Conservation Plan (HCP) process. Such HCPs are often a vital component of regional ecological planning. However, relatively recent developments in ecosystem ecology—such as patch dynamics and perturbation ecology—are showing that there are other sorts of interventions, such as California's own Natural Community Conservation Plan (NCCP) process, which can be used to support and reinforce the establishment of the more traditional set-aside reserves approach to conservation planning. In one sense, the call from contemporary ecosystem ecology *is to better integrate humans as components of ecosystems*, rather than relying on the separation of land uses for human and natural communities.

This approach towards adaptive ecosystem management focuses on establishing protocols to assure the integrity of ecological processes and functions vital to the health and well being of organisms and entities, including humans, within the region. Recognising the inherent, but highly contingent, connectivity between components of the web of life and the often less obvious biogeochemical processes that constitute nature, we must use just such a way of recognising this nested interdependence in planning across levels of ecosystem organisation.

A central element to such an approach to ecosystem management should be, I assert, the percolation of native habitats and vegetative landscape elements into urban and sub-urban cores. An emphasis on ecologically appropriate community forestry, coupled with efforts to promote and establish the widespread use of native vegetation (Xeriscape, in the case of Southern California), would go a long way to restoring an ecological mosaic that would more effectively support the ecosystem health of areas set aside for nature, while at the same time increasing the resilience of regional topographies. Relatedly, the propagation of surfaces porous to storm and rain water to replace the vast and sprawling tracts of impervious surfaces which human habitation is accustomed to laying down, would render the land permeable. This would permit improved groundwater recharge, better stormwater management, enhanced health in soils, and better integration across land uses in how natural habitats are integrated at the microbial and geochemical process-function levels.

4.1. Integrative ecosystem approach to habitat and natural areas planning in Southern California: proposal for an urban ecology-based set of regional-level interventions

An ecosystem approach to regional environmental planning allows the use of nested scale hierarchies in generating rich descriptions of the urbanising Southern California landscape. A key concept in such a systems approach is the notion of levels of organisation. This allows us to conceptualise the planning domain as being constituted by functionally relevant intervention layers, each with its own particular set of scales. Then, regional, sub-regional (city- and county-level) and local (project-level) interventions can be conceptualised in some integrated fashion, where each level supports and enhances the effectiveness of the others. So, for instance, a project planned at the sub-regional level would be seen also to have dimensions that cut inwards to the local level and outwards to the regional level. Then, project design and planning activities need to be more explicitly distributed across all these levels, with decision-making and analysis giving consideration to each. The implementation of such a coherent integrative regional planning approach would ensure that cumulative environmental impact analysis, as well as the

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mitigation management system required for project-level implementation, be more effectively attributed across the relevant levels of organisation. Then, mitigative actions required at the sub-regional, regional and supra-regional levels of organisation would be distributed appropriately, perhaps with local, regional and state level actors all being required to take preventative or remedial action collectively.

An integrative set of interventions, using vernacular urban forestry, native vegetation (Xeriscape), impervious surface mitigation, and albedo modification techniques can then be proposed as a holistic strategy, with habitat, hydrology, heat island and air pollution improvement benefits accruing cumulatively. A research-based and adaptive approach to planning, in the model of ecosystem management, would capture and present the cumulative benefits of such an integrative approach to urban ecology. At the same time, it would show significantly greater benefits than might be thought to accrue from a more piecemeal and arithmetically additive approach that is more conventional to planning.

Such a meta-project ecosystem approach to integrative regional planning focuses on some key aspects of the planning domain. First, when landscape-level habitat elements are percolated into the urban environment, they enhance the *ecological resilience* of the region. They reinforce existing and proposed networks of set-aside habitat reserves for threatened and endangered species,[38] even as they improve habitat connectivity and reinforce wildlife corridor plans already taking shape within the region. Second, such a percolation of habitat elements into our cities would also significantly improve *community livability* at the neighbourhood level, by functionally enhancing the urban fabric with parks and natural open spaces, and so better integrating our cities with nature.

Third, the *hydrological performance* of the urban landscape would be substantially improved by the judicious use of urban forestry and landscape modification[39] (storm water runoff pollution mitigation, for instance, and enhanced groundwater recharge would be some of the key benefits). Fourth, the *energy performance* of urban and suburban landscapes can be markedly improved by the strategic placement of trees and vegetation surfaces throughout the urban ecosystem (besides reducing local energy needs, the urban heat island mitigation effect can itself be significant). And finally, the urban and air *pollution mitigation capabilities* of the region would be substantially enhanced by the strategic use of dense tree plantations around key transportation corridors to buffer communities from noise and particulate pollution, while the propagation of tree-planting and landscaping requirements for downtown surface parking lots and car dealership lots would measurably reduce the release of volatile organic compounds from the fuel systems of parked vehicles that otherwise bake in the sun all day.

Such an ecosystem approach to habitat and natural areas planning requires the assembly of a multi-criteria description that is persuasive to local decision-makers (elected officials and city and county planners, for instance) in showing the cumulative benefits of such an integrated approach to environmental planning. An enumeration of the socio-economic and environmental benefits based on such a description would be of significant benefit to the regional planning domain.

4.2. Action plan: factors in a watershed-based habitat and open-space landscape element (WHOLE) systems approach to regional environmental planning

The cumulative use of such interventions, based on urban forestry, native vegetation, and impervious surface mitigation, forms the basis for such a whole systems approach to regional environmental planning.

4.2.1. Habitat enhancement

Conventional approaches to habitat conservation, even in their more innovative forms (such as California's Natural Community Conservation Plans, or NCCPs), are based on the Endangered Species Act. As a consequence of the central concern with setting aside designated 'critical habitat' sufficient to ensure population viability, set-asides of land based on reserve design have become the traditional concern. Such set-aside reserves are crucial to the success of our efforts to conserve and restore natural ecosystems to some reasonably healthy state.

However, set-aside reserves alone cannot be the whole answer. Nor can our current and almost exclusive focus on organismic life forms—those plant and animal species

[38] The strategic, region-wide propagation of native plants and ecologically suitable tree species, for instance, as well as stream restorations and the replacement of impervious surfaces with porous paving and the preservation of agricultural lands in the face of urbanising pressures, would be specific moves in such a habitat percolation approach.

[39] As was pointed out earlier, not all trees and vegetation are equal, ecologically speaking. Some trees and plants are more resource-intensive in their need for irrigation, some are higher emitters of volatile organic compounds (biogenic emitters), and others are invasive and displace native vegetation.

most directly accessible to our senses—be a sufficient basis for ensuring healthy ecosystem functioning. Indeed, if ecosystem ecology has shown us anything, it is that nature is constituted first by the processes and functions—the exchanges of matter, energy and information—from which organisms are emergent.

Nor can we simply divide our inhabited landscapes into lands that have been allocated to nature, and lands that we have deemed for our own use. A resilient ecosystem requires that humans and human activity be better integrated into nature. Encouraging landscape elements that reinforce native ecosystem processes must become central to how urban ecology is practised in regional environmental planning, in combination with a supra-regional approach to planning and evaluating wildlife habitat connectivity.

A more comprehensive approach to habitat enhancement might include the following measures:

- Encourage use of native vegetation (Xeriscape, in Southern California).
- Create meaningful incentives for urban forestry.
- Promote stream restoration.
- Enhance soil ecology and microbial health by reducing impervious surfaces.
- Create a regional assessment of gaps in habitat connectivity, to design a regional system of wildlife corridors.

4.2.2. Hydrology management

Probably the single most dramatic ecological impact of urbanisation and development is generated by the widespread propagation of impervious surfaces around human habitation (Arnold & Gibbons, 1996). When coupled with the imperative to move rain and stormwater away from such habitation with the extensive use of storm water drainage systems, the cumulative impacts on the contextual ecosystem become significant. Not only is natural groundwater recharge adversely impacted by such conventional flood-control interventions, but also a whole host of ecological processes and functions are disrupted as well.

There is clear evidence that it need not be so. Efforts such as low-impact development (LID) seek to use nature to reinforce nature—by puncturing impervious surfaces to allow groundwater recharge, encouraging urban forestry to locally capture rain and stormwaters in their root systems, percolating urban runoff waters into living soils, so as to allow microbial action to help remove many of the pollutants that coat our roads, driveways and, far too often, synthetically maintained lawns. Such efforts can all cumulatively help to ecologise the urban landscape.

By the nature of their use, roads and driveways usually become coated with layers of toxic particulates deposited from vehicle exhausts and engine drips. In Southern California, such toxic coatings are allowed to build up over significant periods of time, because the region receives only infrequent rain, and that heavily compressed into a few weeks of winter downpour. As such, when it does rain, almost a year's worth of deposits are collectively flushed off the roads and driveways by a few days' worth of annual rainfall. The infrequency of such rain, when coupled with its intensity, creates significant ecological pressures on the regional ecosystems, and mitigation becomes all the more imperative.

Strategies that might help to better integrate an ecological approach to regional environmental management might include:

- Impervious surface mitigation measures, to improve-storm water management and groundwater recharge.
- Species-strategic urban forestry, to improve stormwater management by enhancing the catchment properties of soils due to tree root systems.
- Urban runoff pollution remediation using phytoremediation techniques.
- Stream and wetland restoration, along with cisterns and bioswales, to increase the dwell time of runoff rainfall and storm waters upon the soil.

4.2.3. Heat island mitigation

Urbanised areas tend to be 4–10 °F hotter than the surrounding countryside. This higher temperature is referred to as the 'urban heat island' effect, which is due in large part to the locally concentrated increases in solar heat absorptive surfaces, such as dark roofs and pavement, that accompany urbanisation. Two significant consequences of this increased local temperature, particularly during summer months, are an increased load on the electrical energy network, due to the greater demand for indoor air conditioning, and an increase in the formation of tropospheric ozone, or smog. Smog formation is a temperature-sensitive photochemical reaction that occurs when volatile organic gases and oxides of nitrogen, emitted by vehicles and other human activities, interact in the presence of sunlight to generate ozone. The strategic use of trees and landscaping as heat island mitigation both reduces the demand on the regional energy network and at the same time reduces smog formation.

What makes such a set of interventions particularly desirable within an ecosystem approach, in addition to

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these two direct and substantial benefits, is that the urban forestry and landscaping interventions so activated have significant additional benefits: in *stormwater management*, by capturing rain and storm water in leaves and root systems; in *groundwater recharge*, by puncturing otherwise impervious surfaces, so as to allow better connectivity between water flows and soils; in *habitat enhancement*, by percolating natural landscape elements into an otherwise wildlife-unfriendly urban topography; in *particulate air pollution reduction*, where leaf surfaces effectively trap many of these often toxic dust particles emitted by vehicular exhaust; and in *aesthetic improvements*, by introducing trees and parklands into urbanised communities. The diverse and ecologically considerable cumulative benefits of heat island mitigation measures make them particularly cost-effective in terms of the consequent services nature provides.

Specific strategies might include:

- modification of heat-absorptive properties of horizontal surfaces (roofs, roads and parking surfaces) by changing materials and colours; and
- species-appropriate urban forestry and vegetative landscaping, to increase shading and to reduce ambient heat absorption.

4.2.4. Air and water pollution control

Urban habitat and natural areas planning, in its introduction of trees and vegetation, has a number of pollution mitigating benefits as well. Beside the air pollution control effects of tree-plantation discussed above—reductions in ozone formation due to reductions in ambient temperatures, reductions in evaporative volatile organic gases due to increased shading of parked vehicles, and the increased entrapment of toxic vehicular exhaust particles by leafy surfaces—a number of stormwater and urban runoff pollution mitigation benefits accrue as well. The root systems of trees contain and slow down the movement of runoff through the soil, giving microbial action more time to effectively alleviate some forms of stormwater pollution. The strategic planting of particular sorts of vegetation can be use to phytoremediate at least some of the toxic materials flushed off roads and paving by rainfall.

A comprehensive approach to regional air pollution management should include:

- strategic tree-plantation corridors alongside key transportation and trucking routes, and around stationary sources of particulate pollution; and
- appropriate vegetation for phytoremediation alongside roads and highways.

4.2.5. Wildfire management

The steady encroachment of urban development onto otherwise natural wilderness areas has increased the urban–wildland interface, and thus brought humans into more direct contact with ecosystem processes such as wildfire, which, though necessary and even desirable in the wilderness, pose a significant threat to human habitation. Research is beginning to show that strategic selection of tree and plant species, and the effective management of landscape elements, can substantially mitigate some of the wildfire dangers inherent in the urban–wildland interface.

A regional strategy for wildfire management would take account of:

- the widespread promotion of fire-savvy species selection in trees and vegetation; and
- better enforcement of mandatory landscape control around urbanised areas.

4.3. Pulling it all together: humans as components of ecosystems

Integrating our cities and urban regions back into nature is an objective we should take seriously, because it reduces adverse environmental impacts, thus reducing pollution treatment and remediation costs. Such a strategy, if based on contemporary ecosystem ecological, landscape ecological, and urban ecological research-based knowledge, would significantly reduce the ecological footprint of human habitation, thus effectively increasing planetary carrying capacity. Together, these potential benefits provide a sound and savvy science-based approach to contemporary regional sustainability planning.

Urbanising habitat conservation planning, by percolating ecologically appropriate landscape elements back into the city, would move regions such as Southern California, with their high incidence of pressured, at-risk, threatened and endangered species, away from a reactive ‘crisis management’ approach to a more sustainable, nurturing and proactive approach to integrating our cities back into nature.[40]

[40] One crucial confounder in conventional planning is the imperative to economic efficiency, when it is too narrowly or unthinkingly defined. The idea of choosing the ‘least costly’ option from among a range of potential alternative actions is usually approached without a consideration of time scales. An option can be cheaper in the present, while simultaneously being more expensive in the future. But planning has not yet learned to think sophisticatedly in multiple temporal scales.

An approach advocating the adoption of albedo-modifying heat island mitigation measures—when combined with urban forestry, impervious surface management, and, in the case of Southern California, Xeriscape sorts of ecologically appropriate vegetation—illustrates one example of innovative connections that wait to be made across conventionally disparate and insular myriad sub-disciplines that make up the planning structures of regional governance.

Taking a landscape ecology approach to regional land cover management in urbanising areas would, in itself, strengthen habitat integrity, reduce pressures on nature conservation planning, reduce energy consumption, improve air quality, reduce stormwater runoff, reduce urban runoff pollution, enhance groundwater recharge and enhance community livability. It would enhance the inculcation of a cultural connectivity with ecological processes and functions, and so, quite directly, of humans with nature. Acting reflectively and self-consciously to take account of such usually ignored processes and functions would also strengthen the robustness of the way everyday planning and decision-making happens at the community and city level.

And, at the very least, such an integrative approach to regional planning would foster synergistic support across conventional planning disciplines, with transportation planners, air quality planners, water quality and supply planners, urban foresters, land use planners, habitat conservation planners, community development planners, natural resource planners, energy planners, and so on, both providing support to, and receiving support from, one another.

I have sought to show that a specific sort of ecosystem approach, based on nested scale hierarchic or process-function ecosystem ecology, does, in very pragmatic ways, provide us with the tools to create richly informative descriptions of otherwise complex spaces. The 'dilemmas in a general theory of planning' posited by Rittel and Webber in their classic characterisation of complex systems as 'wicked problems' (1973) are indeed amenable to planning. But only if we are astute enough to recognise their assertion that the tools from 'tame' problem planning cannot be applied, in and of themselves, to complex systems. And then we need to see that there are indeed ways in which we can engage these complex systems in meaningful conversations across levels of organisation, in ways that generate outcomes more desirable to the greater good of the creative commons. We need to grow from a merely reactive and mechanistic problem-solving approach that attempts to singularise issues to make them easier for us to wrap our heads around, towards a planning that embraces the adoption of an adaptive management-based ecosystem approach. This approach needs also to be grounded firmly in techniques for making rich descriptions that allow us to get a better handle on complexity. Respect for, and especially a deep appreciation of, complexity is necessary. But we have the means for constructive engagement as well.

By accepting the premise—that reality is better described as exhibiting nested structures, which are shaped in their actuality by processes and functions, and requiring the use of multiple perspectives, boundaries and scales in their telling—we come to a place where we can begin the business of incorporating the constraints and principles articulated by Rittel and Webber (1973). The strategic and systematic breaching of the constructed, but now deeply entrenched, boundaries our technologies have allowed us to create, between the 'human' and the 'natural,' by integrating within and across levels of organisation, and again by expanding our worldview to incorporate processes and functions as the stuff the world is actually made up of, allows us to both embrace the contextual richness illustrated by Holling and Goldberg (1971) and to realise what some ecologists have already begun to see—that humans, properly, are indeed components of ecosystems (McDonnell & Pickett, 1993). Then we can get down to the business of getting humans back into nature, and thus of placing our cities back into their ecological context.

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Please cite this article in press as: Vasishth, A. A scale-hierarchic ecosystem approach to integrative ecological planning. *Progress in Planning* (2008), doi:10.1016/j.progress.2008.05.001

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Ashwani Vasishth is an Assistant Professor in the Department of Urban Studies and Planning at the California State University, Northridge. His doctoral dissertation, prepared at the School of Policy, Planning and Development in the University of Southern California, is titled *Getting humans back into nature: A scale-hierarchic ecosystem approach to integrative ecological planning*. He originally trained as an architect, in India, where his focus was on vernacular architecture and on nature-friendly approaches to the built environment and to disaster planning—both in pre-disaster mitigation and in post-disaster recovery. He then shifted to the design and delivery of large-scale shelter programmes, with a particular interest in institutional analysis as part of his master's degree from MIT. He has worked in regional planning in the Southern California Association of Governments for about 10 years, developing an ecosystem-based approach to urban ecology, with a particular interest in green infrastructure, impervious surface management, heat island mitigation, urban forestry, and landscape management in an integrative approach to regional planning. He currently teaches courses across a range of fields within the planning domain.