

# Ecological and geographical scale: parallels and potential for integration

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**Abstract:** Scale has emerged as a major issue in both ecology and geography in recent decades. Little effort has been made to compare these parallel debates, however, or to seek an integrated conception of scale across the two disciplines. This paper argues that such an integration is possible, even between ecology and human geography – the subfield of geography seemingly most removed from ecological concerns and methods. In both disciplines, globalization has lent practical urgency to problems of scale, revealing deeper theoretical issues. Geographers have helped impel ecologists to take space and scale seriously, and the epistemological insight that scale is produced (rather than given a priori) should be applied to ecological as well as social phenomena. Ecologists' conceptual distinctions and methodological guidelines regarding scale, meanwhile, can help resolve 'the scale question' in critical human geography. Scale is both a methodological issue inherent to observation (its epistemological moment) and an objective characteristic of complex interactions within and among social and natural processes (its ontological moment). These processes and interactions – rather than scale *per se* – should be the object of research, with particular attention to nonlinearities or thresholds of change.

**Key words:** ecological scale, geographical scale, human geography, rangeland ecology, scaling effects, thresholds.

## I Introduction

Interest in scale has burgeoned in both ecology and geography in recent decades. Scale has been described as 'the fundamental conceptual problem in ecology, if not in all of science' (Levin, 1992), addressed but hardly resolved in several volumes and countless articles (O'Neill and King, 1998). The issue

runs through virtually all of geography's subfields, leading the editors of a recent collection to conclude that 'conceptions of geographic scale range across a spectrum of almost intimidating diversity' (Sheppard and McMaster, 2004). Scale appears to be a case of 'conceptual puzzlement', in which 'the various cases out of which the meaning of

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a word is compounded need not be mutually consistent; they may – perhaps must – have contradictory implications’ (Pitkin, 1972).

Little attempt has been made to compare these parallel debates, however, or to bring them into constructive engagement with each other.<sup>1</sup> This is ironic because the two debates share important roots. The field of landscape ecology, for example, descends directly from the work of geographers (Naveh and Lieberman, 1984) and is an important locus of work on scale (Meentemeyer, 1989; Turner *et al.*, 1989). Ecological scale resembles scale as employed in some quarters of physical geography, as well (Sheppard and McMaster, 2004). Between ecology and human geography, however, there appears to be no overlap or interaction on this subject. This paper argues that ecology and human geography can each help the other resolve some of its puzzlements about scale.

Another common root of both debates is globalization. Ecologists have turned to scale in part because pressing environmental problems – climate change, biodiversity conservation, air and water pollution, and habitat degradation, to name just a few – cannot be addressed effectively in the absence of methods to relate processes of different temporal and spatial scales (Hobbs, 1998; Levin, 1992). How can one measure the contributions of a particular region, or city, or smokestack, to global climate change? How can governments craft policies that translate global regulatory targets into equitable, measurable standards for diverse localities? Recognizing these as inherently social problems, ecologists have urged greater integration of the social and natural sciences (Endter-Wada *et al.*, 1998; Rykiel, 1998; Dale *et al.*, 2000). Lee (1993) postulates that ‘when human responsibility does not match the spatial, temporal, or functional scale of natural phenomena, unsustainable use of resources is likely, and it will persist until the mismatch of scales is cured’. The potential for geography to help understand and address these problems is enormous.

Among human geographers, meanwhile, globalization of economic, political and cultural processes in the past 30 years has prompted a critical re-examination of customary sociospatial categories such as international, national and local. Global flows of financial capital, goods and services, and labor have challenged the nation state’s political and regulatory capacities and given rise to transnational and multinational entities such as the European Union, the World Trade Organization and the North American Free Trade Agreement (Smith, 1995). Other geographical units such as regions and cities have had their opportunities and constraints shift due to these larger political and economic changes (Taylor, 1982; Smith, 1987; Brenner, 1997; Swyngedouw, 1997; Herod and Wright, 2002). Cultural identities and allegiances have also been altered by globalization as people have migrated or seen their geographical bearings realigned by political and economic restructuring. Although scale has a much older pedigree in geography as a whole (Taylor, 1982), ‘the scale question’ (Brenner, 2001) in human geography is an outgrowth of this more recent re-examination of sociospatial categories.

In both ecology and human geography, the adequacy of research at any single scale is clearly in question, but the concept of scale itself remains unclear. Most participants in the debates acknowledge the need for studies that span multiple scales, and most conceive of different scales as organized in some kind of hierarchical fashion. Within human geography, recent contributions have established several further points of general agreement: that scale is socially constructed and thus historically contingent (Marston, 2000); that it is politically contested (Smith, 1990; Jonas, 1994); and that it is centrally important to understanding a variety of political, sociocultural, economic and environmental phenomena (Herod and Wright, 2002; Sheppard and McMaster, 2004). The debate has foundered on basic conceptual and methodological questions, however. What exactly is scale?

How should researchers theorize and use it? These questions have come up repeatedly but have not yet been answered in any generally satisfactory fashion (Harvey, 1982; Jonas, 1994; Cox, 1996; Howitt, 1998; Brenner, 2001; Herod and Wright, 2002; Sheppard and McMaster, 2004).

A recent exchange in *Progress in Human Geography* demonstrates the resulting impasse. In the opening piece, Marston (2000) reviewed the literature and embraced the view that scale is socially constructed. She went on to argue that social reproduction – the activities of households, schools, churches, civic organizations, etc. – deserves equal place with the formal economy of commodity production in discussions of scale in capitalist society.<sup>2</sup> Without directly contradicting Marston's thesis, Brenner (2001) expressed concern about an 'analytical blunting of the concept of geographical scale as it is applied, often rather indeterminately, to an expanding range of sociospatial phenomena, relations and processes'. This in turn prompted Marston and Smith (2001) to challenge Brenner's account of the emergence of the scale debate and to accuse him of 'a deep prejudice and blindness' regarding gender and social reproduction, reading his argument as a 'rather patronizing dismissal' of these issues' rightful 'place at the high table of scale theory'. '[T]he analytical blunting of scale can best be countered', they wrote, 'through the constant reinvention of scale theory ahead of the fetishist juggernaut'. Later, Purcell (2003) characterized the exchange as a 'nondebate' and criticized both sides for failing to engage each other's substantive arguments. Although well reasoned, Purcell's meta-analysis brought the scale question no closer to resolution than it was before.

This paper has two interlocking objectives. First, to help resolve the scale question in human geography by drawing on work in ecology. Ecologists can provide geographers with some important conceptual and methodological insights about scale based in two distinctions that are notably absent from the

debate in human geography: between grain and extent, and between scale and level. These distinctions (see below) clarify what I term the epistemological and the ontological moments of scale, respectively. Secondly, the paper aims to identify a common metaphysical foundation for research in the two disciplines. I do this by reflecting the central point of agreement among human geographers – that scale is produced rather than given a priori – back onto the ecologists' distinctions. Ecologists tend to keep scale's two moments separate from each other, denying their dialectical relation; critical human geographers more often confound the two, collapsing the dialectic. But both disciplines seek to understand complex interactions among processes occurring at multiple spatial and temporal scales. The appropriate scales for research into social and natural processes may often be very different, but the two types of processes are not ontologically distinct and the epistemological challenges they pose are fundamentally the same. Grasping their interactions will require a conception of scale that is mutually comprehensible across disciplines.

## II Scale in ecology

For ease of exposition, the theoretical issues surrounding ecological scale may be divided into temporal and spatial dimensions. It is the combination of the two, however, that gives rise to the most interesting problems and insights.

Temporal scale is central to the larger debate, sometimes described as a 'paradigm shift', between equilibrium and nonequilibrium models and assumptions in ecology (Pickett *et al.*, 1992; Briske *et al.*, 2003). If a given natural system (or relationship among components of a system) displays stability over a period of time, then abruptly shifts to another stable state, how should its dynamics be characterized? The recognition of multiple stable states in natural systems raises questions about the temporal scale implicit in some venerable ecological concepts, including climax community, carrying capacity and

equilibrium (May, 1977; Sprugel, 1991; Wu and Loucks, 1995; Calicott, 2002). Any equilibrium, after all, is only an equilibrium over some period of time, be it millennia or seconds; 'the same ecological dynamics may be considered transient or in steady state, depending on the scale of observation' (Wu and Loucks, 1995). Thus, for example, the Clementsian model of succession toward a single and fixed (and therefore ahistorical) climax now appears excessively linear, if not teleological. New models emphasize the role of stochastic or periodic disturbances, resistance and resilience of systems to such disturbances, and thresholds of change between alternative states over time (Westoby *et al.*, 1989; Hobbs and Huenneke, 1992; Parker and Pickett, 1998; Carpenter *et al.*, 2001).

Spatial scale raises analogous issues. Classical ecology posited bounded communities or ecosystems; it achieved some of its foundational insights in studies of relatively small areas where boundaries were apparently clear and well defined, such as lakes, sand dunes or islands (Worster, 1994). How to define boundaries over larger terrestrial areas was a formative question in the development of Euro-American plant ecology (Tobey, 1981),<sup>3</sup> and efforts to order such landscapes spatially continue to evolve today. Although these classificatory systems can have significant practical value, they are always simplifications because closed systems do not exist in reality, even at the global level. Rather, natural systems are determined by multiple processes operating simultaneously on numerous spatial scales (Turner *et al.*, 1989; Levin, 1992; Peterson and Parker, 1998). Even if a bounded system could be assumed, another problem would remain: that of the units of observation within the whole. Empirical research has found that patterns or relationships discerned at one spatial scale of observation may be invisible, or even contradicted, when examined at another spatial scale (Wiens, 1989).

A significant portion of the growing literature on scale in ecology concerns

rangelands and the complex disturbances they experience, especially drought, fire and grazing (Brown and Allen, 1989; Coffin and Lauenroth, 1989; Schlesinger *et al.*, 1990; 1996; Coughenour, 1991; Glenn and Collins, 1992; Turner, 1998; 1999b). The findings are complex and sometimes counterintuitive. In one study, for example, grazed areas were compared with adjacent areas excluded from livestock for between seven and 60 years. When the smallest unit of analysis was 1 m<sup>2</sup> plots the grazed areas displayed higher species richness (a measure of diversity) than the ungrazed areas; but when a larger unit was used (1000 m<sup>2</sup> plot) species richness was the same (Stohlgren *et al.*, 1999). Another study compared heavily, moderately and ungrazed areas over a 45-year period, aggregating data on three different spatial scales. When the data were analysed at the smallest scale (i.e., smallest plot), they showed the greatest variability on the ungrazed areas; at the intermediate scale, variability was similar across all three treatments; and at the largest scale variability was highest on moderately grazed areas. '[G]razing alters scaling effects', the authors concluded. It 'can have a positive, negative, or no influence on heterogeneity between units, depending upon the scale of observation' (Fuhlendorf and Smeins, 1999).

The general explanation offered for findings such as these is that different processes are determinative at different spatial scales of observation (Levin, 1992). '[I]f you move far enough across scale, the dominant processes change. It is not just that things get bigger or smaller, but the phenomena themselves change' (O'Neill and King, 1998). One's choice of scale therefore necessarily implies a choice of relevant processes; without specifying and considering both scale and process, the validity of one's findings – or at least their relevance to other settings – remains in question. Thus, in the second study just mentioned, heavily grazed areas showed the least variation across scales – what was observed at a small scale could be extrapolated to larger

ones – but in ungrazed and moderately grazed areas small-scale observations were not predictive of larger-scale outcomes. In other words, heavy grazing overrode the effects of differently scaled processes, while moderate grazing did not.

Several general conclusions and critical issues emerge from the ecological literature on scale. First, there is no single 'correct' scale for ecological research (Levin, 1992); rather, researchers must choose the proper scale(s) for the process(es) they choose to examine. Secondly, only by addressing ecological phenomena across scales can an integrated, unified ecology be achieved: 'Scale is a nonreductionist unifying concept in ecology' (Peterson and Parker, 1998). Thirdly, this effort will have to be interdisciplinary, because disciplinary and subdisciplinary divisions have insulated researchers within familiar methodologies that contain (sometimes unrecognized) assumptions about scale.

Fourthly, newer models acknowledge that ecological change is a historical process, both in the sense that human activities may play a decisive role and in the sense that the effects of apparently discrete disturbances may depend on the context or sequence in which they occur (Griffin and Friedel, 1985; Walker *et al.*, 1986; Swetnam and Betancourt, 1998). Many of the challenges that scale poses spatially, then, have temporal corollaries in the timing, frequency and rate of ecological processes.

Fifthly, multiscaled empirical research reveals the existence of thresholds of change in the behavior of ecological phenomena: points at which linear patterns or relationships are disrupted (May, 1977; Brown *et al.*, 1999). In addition to their obvious importance for organisms and ecosystems, thresholds indicate that what happens at a small scale cannot necessarily be extrapolated up, and *vice versa*, because results are nonlinear across scales (Turner *et al.*, 1989). This poses a fundamental challenge to reductionist science and its faith in quantitative methods. Thresholds are often the most urgent practical issue for ecological research: at what concentration does

a contaminant become dangerous to humans or other organisms? How much habitat loss will result in extinction of a species? But their very nonlinearity may cause thresholds to appear anomalous or intractable in terms of statistical correlations. Expressed in Hegelian language, thresholds are where quantitative change becomes qualitative change.

Finally, scale raises difficult metaphysical issues. Ecologists have demonstrated that some patterns are observable only at certain scales and thus might be said to have their own 'natural' scales. This illustrates the ontological moment of scale, when it appears as intrinsic to some objective reality. But there is an epistemological moment as well, insofar as one's choice of scale may strongly determine what, if anything, one 'sees'. That the same data can yield contradictory conclusions if analysed at different scales seems sufficient to indicate that scale matters in some objective sense, even as it underscores the importance of the observer's methodological lens. With a few notable exceptions, ecologists have not attempted to resolve these two moments of scale (Levins and Lewontin, 1985; Allen, 1998).<sup>4</sup> They have, however, distinguished and clarified each moment in instructive ways.

#### 1 The epistemological moment: grain and extent

What exactly constitutes a scale? Myriad senses and uses of the term make this an astonishingly difficult question to answer. In common parlance, scale is generally used as an attribute or descriptor of empirical phenomena. Geographers often refer to the urban, regional, national or global scale in this way, and ecologists recognize one definition of scale as 'the physical dimensions of a thing' (O'Neill and King, 1998). This familiar, non-technical meaning of scale cannot easily be discarded or replaced, despite the confusion it abets.

In a more technical sense, however, scale is an attribute of how one observes something rather than of the thing observed.

Cartographic scale is an instance of this, and the point is still more clear on the temporal axis: a study conducted at one point in time cannot yield robust information about processes of long duration or low frequency.

Methodologically, then, the emphasis shifts to the spatial and temporal scale of scientific observations, rather than the sheer size or duration of what is observed. Scale is inherent in observation (both scientific and otherwise), and the scientific observer must consciously choose a scale (or scales) suited to his or her question, in full recognition of the methodological and epistemological significance of the decision.

Ecologists (in common with some physical geographers) define scale in a more technical-methodological sense as composed of two parts: grain and extent. 'Grain refers to the finest level of spatial or temporal resolution available within a given data set. Extent refers to the size of the study area or the duration of the study' (Turner *et al.*, 1989).<sup>5</sup> Because any ecological datum (e.g., a vegetation plot) contains smaller components (e.g., individual plants) and is embedded within a larger context (e.g., a watershed), one must ask how much variation may be obscured by the grain and extent one has chosen. In the grazing studies mentioned above, the same data yielded different conclusions depending on the spatial grain employed. Parallel issues arise along the temporal axis. Turner (1999b), for example, used data gathered at two different spatiotemporal scales to demonstrate that the composition and productivity of annual grasslands in the Sahel is determined much more strongly by historical land-use patterns than by current grazing intensity, meaning that long-term, large-scale methods are needed accurately to understand rangeland vegetation dynamics.

Underlying these issues is a tension between statistical rigor and practical research limitations. 'Small scale' denotes a finer grain of measurement, while 'large scale' indicates a large extent; practical constraints generally dictate a small extent for fine-grained studies

and a coarse grain for studies that have a large extent. It is difficult to achieve both fine grain and large extent – although that would often be the ideal – because a fine grain captures greater variability, which in turn necessitates larger sample sizes (even at a small or medium extent). To study a global phenomenon at a fine grain while adhering to standard norms of statistical significance, for example, one would need a huge data set – impossibly huge in many cases. Models capable of explaining interactions across scales may help to resolve this tension by enabling robust conclusions to be drawn from more manageable sample sizes gathered at various scales (Turner *et al.*, 1989).

## 2 The ontological moment: scale and level

In this more technical sense, then, scale is not about the size of things but the spatial and temporal relations among them (Allen, 1998; Howitt, 1998). If the epistemological moment involves choosing a grain and extent that capture the processes through which these relations are revealed over time, the ontological moment considers these relations as objective realities. '[I]f the size of a pond skater is increased by a factor of 10', for example, 'the insect will sink because it has a new relationship to the surface tension of water' (Allen, 1998). This resembles the nontechnical sense of scale as size, but it makes explicit what is hidden or only implied in common parlance: namely, that observations of size are always relational. 'Space and time are not scales until they are divided into segments that can be used for measurement' (Rykiel, 1998).

So what is the ontological status of scale? Ecologists do not often try to answer this philosophical question directly; instead, they draw a pragmatic distinction between scale and level. 'A level of organization is not a scale, but [it] can have a scale' (O'Neill and King, 1998). An individual plant, for example, is a level of biological organization, well suited to scientific observation; its scale is defined by, say, competitive relations with neighboring plants, which unfold within certain spatial

limits and over certain temporal periods. A plant community is a different level, at which other processes are more relevant (e.g., involving soils, climate and topography), and these processes necessitate research conducted at another scale (Weber *et al.*, 2000). Scale, then, refers specifically to processes and relations among organisms or other units of analysis, such as a pond skater's relation to the surface tension of water; a level need not entail relations or processes at all (e.g., the pond skater as an organism), referring simply to a locus of organization or observation.

Notice that this does not resolve the ontological question. In a provocative article, Allen (1998) asserts that levels are 'definitional' heuristic or classificatory devices imposed purely by the observer, whereas scales are materially real: 'There is nothing to be done about scalar<sup>6</sup> relationships: one must accept them as they are, whereas definitional relationships come from what one chooses the definition to be.' Allen then distinguishes between 'levels of organization' and 'levels of observation', asserting (rather counterintuitively) that only the latter is 'scale-based' and therefore ontologically real:

The scale of an observation is determined by the observation protocol, and that is entirely a matter of subjective choice. However, if one changes the observation protocol, one also changes the spatiotemporal scale of the observed system and its *necessary physical properties*. If the spatiotemporal scale is enlarged [for example], then one might observe a *larger* organism. In a larger organism, certain necessities emerge that are above and beyond the subjectivity of the observer ... Levels of observation are tied to necessary conditions of the material system in a manner that cannot apply to definition-dependent levels of organization. (Allen, 1998, first emphasis added)

One of Allen's points is eminently valid: levels of biological organization (e.g., organism, population, community) are potentially arbitrary classificatory devices created by humans. (His specific argument is against the term 'landscape level', which he views as

anthropocentric and ecologically groundless.) It is hard to understand, however, how observations of an elephant in a pond could be more real than the elephant or the pond themselves. It is the *aspatiality* of levels as defined by biologists that triggers the problem he identifies: namely, that both an elephant and a pond skater occupy the same level but have qualitatively different relations to basic natural processes. Scale is thus *internally related* to ecological processes and interactions (Ollman, 1976). Moreover, these processes produce material patterns (e.g., the pond, the elephant) that endure sufficiently long to be studied as objects with observable relations to other components of a system. Finally, if the scale dependencies are real, and only observations at the appropriate scale will capture meaningful, significant information, one can hardly imagine scientists continuing to study a level that routinely failed to produce substantive results. Over time, then, the levels of organization utilized by scientists should more closely approximate distinctions in material processes or relations.

What is needed is a dialectical conception of scale, accompanied by a spatially and temporally explicit notion of what constitutes a level of biological organization. Levels may be initially posited a priori on the basis of assumptions that subsequently prove lacking. But their significance in scientific practice is tied to the same material reality that Allen ascribes to scale. Levels have histories and geographies, grounded in material processes such as evolution. That these processes unfold over very long temporal periods, often yielding patterns of great consistency, allows ecologists to abstract from history and geography in practicing their research, and this can feed the misconception that levels are atemporal, aspatial and static. For similar reasons, the discovery of new knowledge is more likely to appear as a reconfiguration of how we apprehend the natural world than of the natural world itself. In range science, for example, it was long supposed that each grass species had a fixed response to grazing, such

that they could be classified as *species* into 'increasers' and 'decreasers' (Dyksterhuis, 1949). Empirical observation recently demonstrated this to be wrong: many species in fact respond inconsistently (Vesk and Westoby, 2001), suggesting that the plant level is inadequate for analysis of grazing as a process. In considering processes that change more rapidly, however – such as in politics or the economy – one cannot so easily abstract from time and space, and new knowledge may arise from changes in the processes themselves. The key point is that the ontological moment of scale – as material relations – presupposes some relatively stable organization in the world, whether we call them patterns, structures or levels. Whether those levels are 'real' or artifacts of the epistemological moment may be determined only by empirical research.

In summary, ecologists use scale in both its epistemological moment – as the grain and extent of observation suited to apprehending particular processes – and in its ontological moment – as a characteristic of objective relations among processes or among observable levels of organization produced by processes. Although their focus on natural processes has typically encouraged ecologists to overlook the dialectical relation of these two moments, anthropogenic degradation of ecosystems and nonlinear, complex interactions may increasingly force the issue (Levins and Lewontin, 1985). In any event, several important lessons can be drawn from ecological scale. Research conducted at a given level cannot be assumed to 'scale up' or 'scale down' to other levels in any simple, linear fashion, because at other levels there are other processes that must be considered (Turner *et al.*, 1989). Moreover, processes may have threshold values at which established relationships between levels change; this, I would argue, is the phenomenon denoted by the term 'scaling effect'. It is in trying to draw conclusions across levels, then, that the issues surrounding scale become critical. Scales are not 'things', and they

should not be studied or theorized as objects. Rather, scales are at once objective characteristics of, and necessary tools for studying, the processes that relate the objects being observed. Emphasis should fall on processes and their interactions, and on quantitative and qualitative scaling effects.

### III Scale in human geography

The growing interest in scale among human geographers reflects predicaments similar to those facing ecologists. First, there is a perceived need to unify phenomena conventionally studied in isolation: global, national, regional and local political processes, for example, or their economic counterparts (Taylor, 1982; Brenner, 1997; 2004). This need stems largely, although not exclusively, from issues related to globalization, whose ramifications are at once glaring and difficult to specify (Swyngedouw, 1997; Herod and Wright, 2002). Secondly, in the social sciences, too, disciplinary divisions have generally allowed the problem of scale to pass unnoticed. Each discipline's traditional methods and interests have set standard (and largely unquestioned) ranges for the scale of research.<sup>7</sup> Finally, as with climate change or loss of biodiversity, the phenomena of interest to critical human geographers are difficult to study across levels of sociospatial organization. Because both disciplines are concerned to understand the complex interactions of numerous and multiscaled processes, a shared conceptualization of scale is at least possible and potentially desirable, provided that the unique attributes of each discipline's subject matter are recognized and respected – in other words, provided that neither type of inquiry is reduced to the other.

#### I The 'scale question'

Geographers working on the 'scale question' have emphasized the proposition that scale is socially constructed: that conventional categories such as local, regional, national and global are not given a priori (Smith, 1984; Swyngedouw, 1997; 2002; Marston, 2000).

As such, geographical scales are historically contingent and presumptively malleable, subject to contestation and transformation (or rescaling). Because the scales of economic, political and cultural processes have profound implications for the distribution of power and welfare, the 'production of scale' (Smith, 1984) and the 'politics of scale' (Smith, 1990; Brenner, 2001) are important topics for research. Without better specification of what scale is, however, the impasse described by Purcell (2003) is likely to persist. The exchange among Marston, Brenner and Smith, for example, summarized in the introduction, could have been more constructive (and less acrimonious) had the distinctions outlined above been observed – indeed, there might not have been any disagreement at all.

No one in the exchange disputed Marston's substantive argument that consumption and social reproduction are scaled processes, or that the scales at which they occur may change historically with important ramifications in other realms of society. The dispute concerned in what sense her argument pertained to theories of scale. Take the epistemological moment first. If one chooses households as the grain of one's research, then one must also choose an extent – some community, for example, with specified sociospatial limits – and examine the processes by which they interrelate. These choices are only implied in Marston's article. Moreover, the fine grain of analysis necessary to study processes of social reproduction at the household level entails methodological trade-offs. In the absence of a huge sample size, one can turn only – as Marston does – to qualitative analysis of the processes that mediate between levels of sociospatial organization – in this case, discourses about (certain) women's proper roles in private and public life, which Marston situates within changing technologies and architectures of domestic production and consumption.

Throughout the exchange, and indeed in much of the literature on geographical scale, 'scale' and 'level' are used almost

interchangeably.<sup>8</sup> The difference between 'national scale' and 'national level', for example, appears one of context and usage rather than concepts. There are clearly precedents for this near-synonymy, and not only in common parlance. According to Marston (2000), the third edition of *The dictionary of human geography* defined 'scale' as a 'level of representation', and Howitt (1998) discusses level as 'one facet' of scale, generally employed in situations of hierarchy. In sentences such as 'Although he treats several scales in these pieces, it is the level of the urban where most of his new insights about scale are articulated' (Marston, 2000: 232), one suspects that the use of 'level' serves mainly to avoid repetition of 'scale'. Level is conspicuously absent from the long list of concepts that Brenner (2001) wishes to distinguish from scale. There are sometimes hints of a distinction similar to that employed in ecology. Smith (1995) stresses that scale 'can be both fluid and fixed – materially as well as conceptually', whereas level appears, from his usage, to refer to something fixed only. Thus, at 'the level of individual capitals' one can study certain defined processes such as capital accumulation. 'Scale', by contrast, is potentially fluid because it refers to relations, either between levels or among components of the system. But Smith assigns no conceptual weight to 'level', leaving its potential role in helping to define 'scale' entirely unspecified.

It is clear that the household *per se* is a level of social organization, not a scale. It is a relatively enduring, observable pattern that expresses and is constituted by numerous intersecting social and biological processes. That it took the form it did in the United States – nuclear families occupying discrete dwellings, dependent on wages and markets for subsistence and schools for education – is a historical-geographical phenomenon worthy of investigation. Yet Marston does not explore the scales of these various processes, nor does she explain the household's genesis as a level of social organization – to do so would

undoubtedly involve the formal economy of capitalist commodity production in no small measure. In summary, Marston's case study is conceptually about scale in that it attempts to link processes across levels of social organization, but it does not demonstrate why scale matters for the particular processes under examination: in this case, how or why norms, values and processes of social action associated with one level (the household) *succeeded* in redefining those associated with other levels (municipal, state or national government) in late nineteenth- and early twentieth-century urban-industrial America. This is probably due more to the intrinsic limitations of the available data than to any shortcoming in Marston's research, and it is by no means unique to her article.

The same basic argument applies to Smith's seminal work, which first put scale 'on the table' for critical human geography (Smith, 1984; 1990). What Smith terms the 'urban scale' is not a scale in and of itself; it is a level that has a (historically determined) scale based in a spatiotemporal process: the daily commute of laborers between home and work. The scale of the national level is determined by other processes, such as the circulation of a single currency, the collection of taxes and the formation and enforcement of laws. Similarly, the scale of the global level is a function of international circuits of trade in financial capital, natural resources and so forth (Smith, 1995). Many processes span multiple levels – mediated information flows and human migration, for example – and are internally differentiated in other ways depending on the scale of analysis.

## 2 Scales and processes

The above analysis both confirms and clarifies the 'analytical blunting' that Brenner feared from his review of the literature on geographical scale. His distinction between the 'singular' and 'plural' senses of the term 'politics of scale' (Brenner, 2001: 599–600) is quite similar to the one I offer here between level and scale. Simply put, the singular sense

is the politics not of scale but of a level, be it the local, urban, regional, national, etc.; the plural sense refers to politics in which relations between levels are at stake and where, therefore, scale is truly at issue. But Brenner, too, uses scale and level interchangeably, undermining his effort at clarification and specification. If one conflates scale and level, then any analysis of any level – household, community, region, etc. – can be deemed an analysis of (a) scale, without necessarily treating the *processes* that determine that level as a level of social organization, and that mediate its relations to other levels. Although Swyngedouw (1997: 141) is also unclear on the scale/level distinction, he is correct to stress that scale 'is not and can never be the starting point for sociospatial theory ... [Rather,] the kernel of the problem is theorizing and understanding "process"'.

Notwithstanding their silence on the concept of levels, several contributions to the scale debate cannot make sense without it. Take, for example, the idea of 'jumping scales' (Smith, 1993; 1995; Swyngedouw, 1997; Herod and Wright, 2002). Typically, the phrase refers to cases in which some social actor (be it a group of people, a firm, or a government body) shifts the level at which some process occurs (be it decision-making, enforcement, or the production or distribution of some valued good) in order to secure a desired outcome. The strategy thus *pre-supposes* an existing structure of social organization, with functional and oftentimes hierarchical relationships among its component parts or levels. *What is 'jumped', then, is not scales but levels, with the result that a process is rescaled.* For the strategy to succeed, there must be some scaling effect – a change in the outcome of the process brought about by shifting its scale. If this rescaling is consolidated and endures over time, it will characterize a new or modified structure and may be 'jumped' or otherwise altered at a later time – this is the dialectic that Smith and Brenner both wish to capture with their theories of scale.

It may be objected that the ecologists' scale/level distinction should not be applied to social phenomena because levels of social organization are social artifacts, whereas levels of biological organization are 'natural'. Yet, as argued above, the epistemological basis for distinguishing among biological levels is processes that can be identified and studied: the growth of a plant, for example, or competition among neighboring plants for limited resources. In the same way, geographers delimit levels of social organization in terms of processes such as capital circulation, governance, social reproduction, consumption and so forth. Social and natural processes may have widely divergent spatial and temporal scales (political versus evolutionary or geological time, for example), and this may make levels appear ontologically different in the two cases. These scale differences do generate significant methodological disparities, but in neither case are levels a priori categories. Rather, they represent objective patterns or structures generated by material processes. The reason that scale now appears so important is that these patterns are changing significantly enough to yield different patterns than before, indicating that the conventional sociospatial categories require re-examination.

### 3 Beyond hierarchy theory

One further insight can be drawn from studies of ecological scale. The prevailing approach to multiscale phenomena, in both geography and ecology, is hierarchy theory, variously understood (Meentemeyer, 1989; Wu and Loucks, 1995). Wu and Loucks (1995: 451) argue that ecological studies should examine (at least) three levels: the level of the process at issue, plus the levels above and below it. 'The higher level provides a context and imposes top-down constraints on the focal level, and the lower level provides mechanisms and imposes bottom-up constraints.' It is intuitively appealing to imagine 'nested' relationships among levels: individual plants nested in patches, nested in

communities, nested in landscapes, nested in regions, etc. On this model, scale relations emerge as we shift our attention up or down the hierarchy; patterns discerned worldwide are interpreted as reflecting global processes, regional patterns reflect regional processes, and so forth.

In some cases, the hierarchical model may be appropriate and useful for research; at the very least it offers an important starting point for theory development and testing. But it also may be misleading, if we may judge from recent work in ecology (Parker and Pickett, 1998). Recall the example above, in which the same process – grazing – did or did not override other processes (including both higher and lower level ones) depending on its intensity. We cannot simply posit hierarchical relations among levels, like some grand chain of command. This is presumably even more relevant for social processes than for biological ones, because political and economic institutions can be created, modified or suspended, for example, in ways that biological processes generally cannot; this is, in fact, what much of the recent literature on geographical scale is concerned to show and understand. Social processes generate 'a mosaic of unevenly superimposed and densely interlayered scalar geometries', not 'an absolute pyramid of neatly interlocking scales' (Brenner, 2001): 606).

## IV Conclusion

Social and ecological interactions of global extent and importance are not new, although the explosion of scholarly interest in globalization might sometimes suggest otherwise. Rather, some combination of new or intensified forms of global interaction, increased scientific interest and enhanced technological capabilities for studying these interactions has given rise to exciting – and in some cases urgent – new paths for research. It is obvious that social and ecological phenomena are intimately linked across scales; it follows that the problems of one cannot be resolved in isolation from those of the other. Traditional

divisions between disciplines will therefore have to be overcome.

I have argued here that ecological scale can help resolve 'the scale question' in human geography by specifying its epistemological and ontological moments and demonstrating its methodological implications. Ecology goes astray, however, if it mistakes the scales of natural processes – which permit greater experimental control and abstraction from history and geography – as sufficient grounds for a positivist-reductionist metaphysics. Although quantification and replication are desirable whenever possible, it is unreasonable to view them as the only standards of truth given that they are inapplicable in so many cases, whether for practical, ethical or historical reasons. Ecological scales are no less produced than geographical scales. Recognizing this should enable ecologists and geographers to theorize and study processes as simultaneously natural and social. The interest and challenge of scale lie precisely in the focus on phenomena that cross thresholds between quantitative and qualitative change, and whose nonlinearity defies conventional assumptions of controlled experimentation. For this reason, the issue of scale may eventually persuade more ecologists to embrace, or at least recognize, dialectical metaphysics (Levins and Lewontin, 1985; Foster, 2000).

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strong intradisciplinary reactions and admonitions, and I am acutely aware that specialists in both ecology and geography will probably find fault with at least parts of my argument.

#### Notes

1. There are several partial exceptions to this point. Carpenter *et al.* (2001) and Hansen *et al.* (2002) integrate geographical and ecological research in compelling fashion, but scale is only a minor component of their arguments. Norton (1995) addresses scale, but without confronting the substance of ecologists' work. Zimmerer (1994; 2000) and Turner (1999a; 1999b) come closest to an integration, but they do not draw out methodological lessons to guide further research. Another important but brief example can be found in Hulse and Ribe (2000).
2. At least one case of research incorporating scale and social reproduction does exist in the literature, contrary to Marston's (2000: 238) claim. Turner (1999a) explicitly linked gender and household-level processes of reproduction to regional shifts in livestock species composition in the Sahel, effectively demonstrating that the differences among Marston, Brenner and Smith can be resolved in practice.
3. This was true in both theoretical debates (e.g., over Clements' concepts of succession and formation) and in early attempts to classify land into types for rational administration and management.
4. Many landscape ecologists recognize this conundrum, at least obliquely, in discussions of whole-part relations and the 'holistic axiom' that "the whole is greater than the sum of its parts" (Naveh and Lieberman, 1984). But positing that nature is hierarchically organized into iterative 'holons' does not resolve the metaphysical issue. I am struck by the similarity between this 'holarchy' theory and human geographers' discussions of scale metaphors, specifically the 'Russian doll' metaphor (Herod and Wright, 2002).
5. A simple example for understanding grain and extent – albeit on only the spatial dimension – is a meter stick, with an extent of one meter and a grain of one millimeter. It is a tool, with determinate utility and tolerances. It works for basic carpentry, where variations (errors)

of less than a millimeter are unimportant, but it is useless for assembling microchips and clumsy (at best) for surveying large tracts of land.

6. Allen uses 'scalar' 'as an adjective to mean pertaining to scale, not as the technical noun that appears in matrix algebra'. I have avoided the term altogether rather than risk misunderstanding on this point.
7. For example, psychology uses the individual as its standard grain, while sociology uses communities or neighborhoods; anthropology uses households, clans or lineages. Extents vary more widely, especially in recent decades, but conventional norms are generally apparent. The practice of combining a small spatial scale with a relatively long temporal extent (one to several years) is the distinguishing methodological trait of anthropology. Perhaps the most striking example of divisions between scales is in neoclassical economics, where the separation of micro- from macroeconomics tacitly concedes the scaled nature of social phenomena but defers the challenge of integrating across levels of economic organization.
8. Swyngedouw (1997) makes frequent use of the term 'scale level', which Brenner (personal communication) tells me is a literal translation of the Dutch term 'schaalniveau'. Issues of translation aside, I would argue that the term is either redundant or oxymoronic.

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