Resilience, Ecology, and the Politics of the Experimental City

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Abstract

In the face of global urbanisation and climate change, scientists are increasingly using cities to experiment with more resilient forms of urban infrastructure. Experimentation represents the practical dimension of adaptation; it is what happens in practice when policy-makers, researchers, businesses and communities are charged with finding new paths. The following paper traces one particular lineage of experimentation to resilience ecology, which rejects the possibility of external control over a system, casting planning and administrative functions, and even scientists themselves, as part of a Social-Ecological System. Using insights from political ecology, laboratory studies and urban studies the paper explores how ecologists involved with the Long Term Ecological Research Programme in the USA are embedding adaptive experiments into urban governance. Discussion focuses on how this process recasts science in the sustainable city, considering the epistemological, institutional and political implications of ecologising urban governance, and rendering it 'experimental'.

Keywords: geographies of adaptation, urban ecology, resilience, experimental governance, Long Term Ecological Research Programme (USA).

Introduction: resilience, adaptation and the experimental city

As the inevitability of climate change sinks in, attention is turning increasingly to the question of adaptation (Tol, 2005; Pielke *et al.* 2007; Hulme, 2008). Advocates range from pragmatists, who argue that scientific uncertainty precludes anything other than a reactive approach, to transformationalists, who argue that adaptation has the potential to radically change society (e.g. Gunderson and Holling, 2002). The detractors line up against these positions, seeing adaptation as simply a smokescreen for 'business as usual' in the face of a largely neutered political arena (e.g. Swyngedouw, 2007), or as a dangerous fancy dress parade of one-off projects that distract from the serious business of regulatory mitigation. Delving into the conceptual murk (Burton, 2008), the following paper traces a mode of urban adaptation situated within the increasingly influential policy discourse of resilience ecology, exploring the epistemological, institutional and political implications of ecologising urban governance, and rendering it 'experimental'.

The rationale for refracting environmental questions through an urban prism is well-rehearsed. Globally, the number of people living in cities recently passed 50%, and the challenge of adapting to climate change in the Twenty First Century will primarily take place in cities in the developing world. As both harbingers of future conditions and test beds in which to establish more sustainable ways of living (Haughton and Hunter, 1994; Hodson and Marvin, 2009), cities are subject to ever more vigorous ecological conceptualisation. The material, institutional and sheer demographic density of cities makes them home to the most pressing environmental challenges and their solutions simultaneously, and they constitute a fecund field in which to study emerging forms of climate governance (Grimm *et al.* 2008).

The attraction of resilience to policy makers is fairly obvious; its fundamental ontological acceptance of flux and epistemological obsession with adaptation seems ideally suited to the challenges of surviving in a world in which we are told climate change will upset all our known environmental coordinates[i]. Championed as the mechanism by which to achieve sustainability, resilience features heavily on influential urban research agendas (ICLEI, 2009, 1). The International Human Dimensions Programme on Global Environmental Change (IHDP) recently launched its Urbanization and Global Environmental Change core project, dedicated to promoting, international, interdisciplinary research on the environmental challenges facing urban areas (IHDP,

2005). ICLEI 's (2010) Resilient Communities & Cities initiative, which constitutes one of its four key themes, has stimulated a mass of publications and initiatives amongst policy-makers at all levels. Along with Partnerships for Global Resilience (2002), which brings together (amongst others) the International Centre for Sustainable Cities and United Nations Environment Programme, it represents an influential platform for leading international agencies concerned with urban environments. The World Urban Forum also continues to focus on resilience as a key goal for cities (Walisser *et al.* 2005).

That said there is a clear political ecology to resilience. Transformed from an ecological theory into a socio-ecological governance framework in some twenty years, it constitutes a form of ecological knowledge which (wittingly and unwittingly) exerts considerable power over how things should be done (Forsyth, 2003). For example, in presenting us with a world in constant flux, where periodic crisis and change are inevitable, it risks accepting change too passively. Rather than question the all-too-human causes of crises (whether of the climatic or economic variety), resilience emphasises the need for individuals, communities or cities to simply get on with adapting to them. This tendency to naturalise crises resonates with neoliberal discourses of capitalism (for example, Evans *et al.* 2009; Walker, 2009; and even Klein, 2007), which preclude political debate concerning the wider structural drivers of change. That said, non-equilibrium approaches to environmental governance have been heralded by some geographers as the potential basis for an 'environmental politics of progressive social movements' (Zimmerer, 2000, 358), offering more productive grounds for engagement than the conservative myth of a singular, stable Nature (Swyngedouw, 2008). While not wanting to spoil the broth with a surfeit of ingredients, resilience is the main non-equilibrium concept to achieve prominence in the field of environmental governance, and the way in which its contradictory political imperatives are playing out practically and conceptually warrant further elucidation.

Amongst these, the emerging focus on experimental approaches to climate adaptation is critical. While innovation became institutionalised under the neoliberal logic of urban competitiveness (Lovering, 1999), the climate change agenda is reinvigorating a need to 'cultivate new techniques of governance' for urban sustainability (Hodson, and Marvin, 2007, 303). Within this context, real life experimentation is supposed to prompt radical social and technical transformation, by testing new out new technologies under variety of conditions in highly visible ways (*ibid* 317). Examples abound. The Asian Cities Climate Change Resilience Network, funded by the Rockefeller Foundation, explicitly

seeks to increase the capacity of urban areas in developing countries to adapt to climate change, by facilitating experiments with a range of activities in the form of 'interventions… [that] will span health, infrastructure, water, disaster, urban planning/development issues' amongst others (Rockefeller Foundation, 2009). While *et al.* (2009) identify experimentation as a key element of what they call carbon control, which they identify as the dominant current paradigm of environmental governance. Their example of Manchester, UK, conveys the common rationale for experimentation neatly in the stark choice between either innovating in order to change what they do, or simply doing less (Deloitte, 2008). Academics are also embracing the experimental ethos; speaking of their experiences developing sustainability science in live policy contexts, Turnpenny and O'Riordan (2007, 104) claim that 'this is a wonderful time to experiment'.

Figure 1 depicts the relation between resilience, adaptation and experimentation under transition governance. If climate change is the driver and resilience the goal, then adaptation is the process through which transition will occur. Climate experiments are where governance actually is (Bulkeley forthcoming); they represent the practical dimension of adaptation - what happens in practice, 'on the ground', when policy-makers, researchers, businesses and communities are charged with finding new paths. As the sharp end of climate governance, an examination of the politics of the experimental city would appear to be timely.

Figure 1 about here.

In the context of growing research budgets and an emphasis on partnership working between universities, government and industry, academic knowledge is playing an increasingly central role in urban governance and adaptation more widely (Krueger and Buckingham, 2009; Perry and May 2007; While *et al.* 2009). But while experimental approaches to urban sustainability are blossoming, work on exemplary sustainability projects in general has paid surprisingly little attention to their epistemological dimensions (e.g. Joss, 2009; Bulkeley, forthcoming). Taking a high profile example, the uber-sustainable Masdar City development in the United Arab Emirates is built to provide a living laboratory for the Masdar Institute (Evans and Karvonen, forthcoming). Building on calls to inject more geography into transition studies (e.g. Moore and Karvonen, 2008; Monstadt, 2009; Powell, 2007), the paper focuses on how these adaptation experiments recast science in the sustainable city, marrying the *place*

specificity of experiments with demands for abstract (*place-less*) knowledge that can be applied anywhere.

The following paper works upstream from these broader considerations, to focus on the emergence of a highly specific yet influential research programme in urban ecology that conceives of the city as an integrated Social-Ecological System (henceforth referred to as an 'SES'). While the systematisation of the city is nothing new, its recent ecological incarnation is distinctive in emphasising resilience and adaptive learning as the way to make cities sustainable in the face of environmental crises. Based upon non-equilibrium ecological theory, the approach recognises the complexity and non-linearity of coupled social-ecological systems, and increasingly underpins the resilient city discourse. SES retains a commitment to the systematic conceptualisation of the whole city, while simultaneously acknowledging the inherently unpredictable, and thus un-plannable, nature of cities. Resilience thus offers an interesting window on the changing relationship between knowledge makers and knowledge users, whereby scientific and policy knowledge is co-produced with actual behaviour (O'Riordan, 2004, p. 234). It also offers an insight into an emergent form of environmental planning that abandons the Modernist dream of total control for a form of urban governance that is explicitly adaptive[ii].

Particular attention is paid to the Baltimore and Phoenix Projects in the US Long Term Ecological Research Network, which have been critical in establishing SES as a 'research programme' in urban ecology (Lakatos, 1977). Drawing on the urban laboratories literature, the work of these scientists is explored in detail to elucidate the specific ways in which urban spaces have been used to create and legitimise knowledge, and how the city is being negotiated as both the site and object of a nascent mode of experimental governance. Extensive use is made of secondary sources associated with the research projects, such as research proposals and reports, as well as published material. The evolution of sanitary science, chemistry and physiology all occupy relatively familiar positions within the canon of urban historical research, but, perhaps reflecting historical bias of science studies (Livingstone, 2002), ecology does not. If the intuitions of this paper are correct, then the discipline of ecology is set to play as important a role shaping the cities of the twenty first century as the sanitarians did in the nineteenth. The paper concludes by considering the wider political, epistemological and institutional implications of this mode of experimental governance for geographies of adaptation and transition.

Ecology and the city

Pincetl (2010, 47) identifies continuities between the sanitary city of the Nineteenth Century and the sustainable city of the Twenty-First, noting that, 'the problems had [simply] changed from cholera and polio, to particulates, volatile organic compounds, and other kinds of chemical pollution.' Although the co-evolution of the urban sanitary movement and modern medical science is perhaps the most well documented example (Melosi, 2000), many branches of science developed in the context of specific urban problems, to the extent that the Modern city was 'co-produced' with a set of technical knowledges and planning practices (Dierig *et al.,* 2003, 3, after Jasanoff, 2004)[iii]. While urban historians have tended to view cities as the site at which knowledge is applied, SSK scholars have demonstrated the active role played by cities in producing scientific knowledge. Shapin and Schaeffers' (1989) classic account of Boyle's pump showed the key function played by the city in promulgating and embedding experimental scientific discovery through public spaces such as institutes. The sustainable city today is characterised by forms of scientific-administrative knowledge that are 'enmeshed in the particularities of places' (Bulkeley, 2006, 1029), and which respond to a clearly defined set of urban problematics.

While mitigation is undeniably a global scientific endeavour, adaptation requires localised, applied knowledge. Recent work on the Chicago School of urban sociology illuminates the fraught role of place in urban knowledge production. The Chicago School established a specifically scientific brand of sociology in the 1920s and '30s, which borrowed 'legitimating rhetorics' (Gieryn, 2006, 7) unashamedly from ecology to suggest that Chicago possessed an objective reality that was knowable and against which abstract claims could be tested. The process of scientific knowledge production involved moving from the specificity of Chicago as a place (the field) to the generic applicability of Chicago (and the knowledge made therein) as 'any city' (the lab). As a field site, the city exhibits a specific reality that is found, and that possesses an incontestable, singular truth by virtue of its lived materiality. In contrast, the city as lab becomes the cipher for any city, interchangeable and controllable through the manipulation of variables, possessing a truth borne of replicability. For Gieryn, the explanatory power of the Chicago school involved shuttling back and forth between these modes of knowledge legitimisation (see Figure 2).

Figure 2 about here.

Methods, styles of writing and modes of analysis mirrored this shuttle from the field to the lab, as the researchers shifted from presenting themselves as ethnographers with intimate knowledge of place and interpretive skill, to scientists merely deploying objective technology and methods to produce replicable, abstract results. This slippage also structures the rationale given for selecting Chicago in which to work. The field-site must simultaneously be uniquely suited to the study of the questions at hand, while also representative of a general population of potential cases. So, although the Chicago School 'was tightly connected to its home city, epistemologically and politically' (*ibid*, 9), their truth claims necessitated that the expediency for choosing to work in the particular city in which they lived be covered up.

Of course, the dilemma of localism runs through science studies more generally. While science is always situated, and the object is always the 'grounds of local credibility' (Powell, 2007, 312), science that is geographically specific is generally viewed as not being authentically true at all. But to view science solely as the overcoming of the local is mistaken. In Latourian mode, Secord (2004, 664) notes, 'it is not so much a question of seeing how knowledge transcends the local circumstances of its production but instead of seeing how every local situation has within it connection with and possibilities for interactions with other settings'. Dierig *et al.*, (2003, 7)have highlighted how 'urban expertise often consisted of a heterogeneous patchwork of overlapping blocks of knowledge rooted in different disciplines and often blurring the boundaries between academic and administrative knowledge cultures'. Accordingly, the story of urban sanitation in Victorian Britain is most often told as one of how public health professionals engaged with the sanitary movement in order to gain positions within city administrations that would allow them to put their ideas into practice. Such accounts direct our attention towards the way in which the city has always been *experimental*, in the sense that new knowledges are deployed in order to alter the way in which the city is administered. As the urban scientist works to cure urban problems, the city becomes a laboratory-clinic, in which cures are both developed *and* practised through experimentation, prompting a constant renegotiation of the boundaries between science and non-science (Dierig *et al.* 2003, 10). The coalescence of science and administration under the rubric of urban ecology presents an excellent example of such interaction, and, as we shall see, throws neat distinctions between science and the city into question.

While urban nature was overlooked for many years because cities were seen as antithetical to nature (at least in the Western tradition), there is a long history of thinking about cities in loosely organic terms. Organicism reflects a line of thinking that views cities as systems that display natural traits like growth and self-organisation. While the city has only recently been explicitly conceived as an ecological system, understandings of the natural world have historically informed city design, from the circulatory boulevards of Haussman's Paris to the soothing rhythms of Howard's Garden Cities. Aping the famous natural theologist William Paley's metaphor of the clockwork universe, Richard Whateley described the checks and balances of Nineteenth Century London in such painstaking detail that any scholar of urban metabolism today would be proud of it. In his magisterial account, Davison (1983, 370) concludes that, 'natural theology was arguably the midwife of urban sociology, for without its presence at the birth, witnessing to the orderliness of nature, and society, it may be doubted whether a systematic and holistic study of urban society would then have been attempted at all.' The organicist legacy at least partially accounts for the alacrity and enthusiasm with which ecosystemic approaches to urban areas have been adopted in recent years, despite the suite of challenges that attend conceiving cities in this way.

Heavily influenced by American and German landscape ecology (for example, Tansley, 1935, Neef, 1967) and systems theory (von Bertalanffy, 1976) urban ecology was established as a sub-discipline in the 1970s, applying the 'earth systems' approach to conduct systematic studies of climate, soil, water and organisms (UNESCO's intergovernmental Man and the Biosphere Programme in 1971; Duvigneaud 1974)[iv]. The earth systems approach, which established the environment as something governable (Hulme, 2008), and organicist convictions concerning the coherence of cities came together to provide a fertile ground for systemic approaches to urban environmental science. That said, while ecosystem approaches to cities can be identified in the 1970s, they tended to focus on applying ecological principles to cities, rather than developing specifically urban ecological principles. They also lacked the large-scale backing of funding agencies, and it is only in the post-Rio era that cities have been manoeuvred from the periphery to the core of environmental concerns (Weiland and Matthias, 2009).

Ecology has re-emerged in the current era of eco-towns and sustainable cities as an *explicit* knowledge base for urban planning[v], to the extent that 'in policy and planning the term urban ecology is synonymous with "sustainable cities' (Sukopp, 2008, 79).

Viewing the city as an ecological system has consequences for urban management priorities, and urban ecology itself. Taking management first, redesigning the urban metabolism in view of sustainability goals is now considered a relevant research question for urban ecology (Breuste *et al.*, 1998, Brunner 2007; Alberti, 2008, Pickett *et al.* 2004). Building on previous work (for example, McDonnell and Pickett, 1993; Ehrlich, 1997), Grimm *et al.* (2000, 571): "present a call to action for ecologists to integrate their science with that of social scientists to achieve a more realistic and useful understanding of the natural world in general and its ecology in particular." It is worth nothing that ecologists are doing the calling here, and that social scientists are expected to contribute to real and useful conceptions of the natural world, as defined by scientists. Weiland and Matthias (2009) identify the most recent stage of urban ecological interest as 'Applied Urban Ecology as a Contribution to Sustainable Urban Development', echoing the aspirations of the nineteenth century sanitarians to be 'useful' and address extant urban problems.

In a widely cited paper, Grimm *et al.* (2000) recapitulate the mantra of urban ecology, that urban ecosystems require attention because humans dominate the earth's ecosystems (Vitousek *et al.* 1997; Marcotullio *et al.* 2003). Realistic models must thus include humans as ecology needs to develop concepts that apply to all ecosystems. They suggest that urban ecology requires a fundamental shift from ecology *in* cities to the ecology *of* cities. The components that such an ecology might be made up of are indicative: 'entire system', 'whole system metabolism', 'metapopulation approach', 'ecological footprint', 'watershed approach', GIS and remote sensing, 'city as ecosystem' are all approvingly listed (Grimm *et al.*, 2000, 574). While conceiving of the city as an ecosystem requires a 'radical expansion of ecology' (McDonnell and Pickett, 1990, 1231), the focus on systems maintains the link with the parent discipline of ecology conceptually, disciplinarily and institutionally.

But whilst urban ecology has ambitious plans to establish concepts that work across multiple scales, unite ecological and social understandings and address real-world urban problems, the scientific basis for such a synthesis does not yet exist. The key conceptual framework within which these hypotheses are currently being negotiated is that of SES, and the cities in which the experiments are occurring are Baltimore and Phoenix, USA. It is to the activities of the urban ecologists in these two cities that we now turn.

The city as a social-ecological system

The establishment of the city as an SES can be traced to the interdisciplinary research teams at the Long Term Ecological Research (LTER) sites in Baltimore and Phoenix in the United States and their cooperating research groups. The LTER programme, funded by the National Science Foundation from 1980 up to the current day, represents the flagship environmental science research programme in the United States, comprising 24 ecologically diverse sites, an annual direct budget of almost $20M and approximately 1100 scientists and students. In 1997 the NSF added two metropolises (Phoenix and Baltimore) to their portfolio of sites[vi], and both projects were granted second phase funding in 2004. Led by influential urban ecologists Nancy Grimm at Arizona State University and Steward Pickett at Baltimore respectively, the research teams both adopted a large-scale ecosystems approach, both sold themselves on the potential to use their cities as field laboratories, and both emphasised the virtues of a comparative approach between cities. The Phoenix and Baltimore groups have fought to establish urban ecology as something new and worthy of study within the LTER programme, while maintaining its conceptual continuity with the discipline of ecology.

In the first phase up until 2004, the projects sought to ratify the assumption that the city is a system as the edifice upon which the entire programme is built. The leader of the Phoenix project quotes the grandfather of the ecosystem concept, Arthur Tansley, saying that, 'scientific analysis must penetrate beneath the forms of the 'natural' entities, and… be applied to conditions brought about by human activity' (1935, 304, in Grimm *et al.*, 2000), while the Baltimore project states that "its goal is to develop a thoroughgoing understanding of metropolitan Baltimore as an ecological system, and to share this understanding with educators and decision makers" (Pickett, 2004, 3). More recently, Pickett has also appealed to Tansley to legitimise urban ecological research (Pickett and Grove, 2009). The challenge in urban ecosystems is to move from seeing human activity purely as an external factor causing disturbance to ecosystems to being drivers and limiters of ecological processes in their own right. In the first phase of the projects, the question of exactly how to do this was highly problematic. As Grimm and Redman (2004a, 13) note, "standard ecological theories are insufficient to address the complexity of human culture, behaviour, and institutions; thus, our ecological investigations require the integration of social science research, require longer time horizons, and must be informed by flexible models and multi-scaled data". The volition

of human decision-making means that social factors cannot be modelled as just another organism in a traditional population framework (Padoch, 1993), leading Redman *et al.* (2004) to acknowledge that there is no strong theoretical basis or research agenda for coupling natural and human systems across the LTER program (NSF, 2002).

In the first phase of the research projects, social processes were dealt with fairly basically as a system paralleling the ecological system. Grimm *et al.* (2000) followed Pickett (1997) in mapping the physical drivers of ecosystems identified by the LTER more widely onto social drivers. So flows of energy become flows of information, the cycling of materials becomes the creation and maintenance of institutions and organisations, trophic structure becomes economic system, disturbance becomes design, and so on. While much could be said about the validity of these attempts to generate components of a social 'system', it is perhaps enough here to note that the social elements considered within urban ecology tend to reflect the limitations and weaknesses of the disciplines from which they were drawn. Criticisms of the abstract rational human actors so beloved of economists, the procedural obsession of institutional political theorists, and the neglect of social context displayed by psychologists all apply to the conceptualisations of social systems framed within this kind of urban ecology.

Like Chicago, the city plays a dual role as somewhere that is uniquely privileged as a site for this kind of research, and yet representative of the general case. As a de-industrialising city, Baltimore suffers widespread problems but is uniquely suitable due to its long history of ecologically informed social research, the wealth of existing data and historical records, and the established relations between researchers and local stakeholders. By comparison, Phoenix plays upon its status as a young city characterised by rapid growth rather than redevelopment, reeling off a wealth of facts and figures in the funding application concerning population growth and the associated limitations of water and biodiversity conservation (Grimm and Redman, 1997, 9). This justification is reinforced in the second proposal, suggesting that the sixth-largest city in the US is a harbinger of the future, which, in ecological terms, plays the same role that L.A. does for Davis in City of Quartz, providing a crystal ball in which to see the future (1990; Gieryn, 2006).

Despite the differences between the two places, robustness of comparison is to be ensured by applying common scientific approaches and methods. For example, "we

maintain an ecological focus in the interest of comparative ecology and integration of our research findings with other sites of the LTER network" (Grimm and Redman, 1997, 9). In a subsequent publication, Grimm *et al.* (2000, 578) state that 'although the two cities are quite different, integration is furthered by a common approach to spatial analyses: a hierarchical patch dynamics approach'. Questions of scale and social-ecological integration are addressed technically. For example, 'by considering patch dynamics simultaneously at multiple scales with an accompanying hierarchy of models, the complexity of urban systems is rendered more tractable and translation of information across scales is facilitated' (*ibid*, 578), and, similarly, 'socioeconomic factors will be represented by multiple data layers in our modelling' (Grimm and Redman, 1997, 10). Gieryn's shuttle between city as field and lab is intact at this stage of the research.

The need to standardise the city through modelling resonates with an anxiety many ecologists have about treating the city as 'just another' ecosystem (Pickett and Grove, 2009). For example, Mcintyre *et al.* (2000, 5) note that because no single definition of 'urban' is possible, it is important to furnish 'an interdisciplinary, quantitative, and considered description of an urban ecosystem such that projects and findings are easier to compare, repeat, and build upon'. The role of place is manipulated quite cleverly in subsequent papers communicating joint findings from the two LTER urban sites to make a virtue out of the differences between the cities. Because Phoenix and Baltimore differ in almost every conceivable way (rapid suburban growth versus inner city dereliction respectively), it is argued that models that operate successfully in relation to both have standing as generalisable urban ecological science. This argument has the added benefit of validating the multi-site approach of the LTER programme more generally. Rather than shuttling between ethnographic specificity and scientific generality as the Chicago School did, the Baltimore and Phoenix teams use a comparative method to put localism to the service of abstraction.

In 2004, both projects received follow on funding from the NSF to develop their integrative approach to cities, and this marked a watershed in their conceptual approach. In the second phase both the Baltimore and Phoenix projects drew on the work of ecologists at the Resilience Alliance, in particular their work on SES (for example, Gunderson and Holling, 2001). Based in Stockholm but exerting a truly international influence, the Resilience Alliance have proven to be a key conduit for this process (Berkes *et al.* 2001; 2003), mirroring the incorporation of the SES approach by the LTER urban ecological research projects in their recently established Urban

Resilience research programme (Barnett, and Bai, 2007), and producing a substantial body of work focusing on urban resilience (e.g. Folke et al. 1997; Colding et al. 2006; Stephan et al. 2010). The Resilience Alliance, funded by the Swedish Foundation for Strategic Environmental Research, Mistra, have seamlessly married their goal to establish an international network of influential environmental scientists working on resilience to an aggressive campaign promoting resilience as an international policy priority. NSF investment in the LTER urban programmes (Grimm and Redman, 2004b, 199) and its links with the international Resilience Alliance have ensured that resilience is now a growing part of all major international urban research initiatives[vii].

The SES approach draws closely on the contemporary view of ecosystems as examples of complex adaptive systems (Levin 1998), which, rather than existing in equilibrium with their surrounding conditions, can occupy multiple stable states. The central lesson of resilience thinking is that environmental managers should avoid optimising a system to one specific set of stable environmental conditions, as they will reduce the ability of the system to adapt when those conditions change (Gunderson, Holling and Light, 1995). Calling this the 'pathology of resource management', Holling states (1973, 15), "if this perspective is used as the exclusive guide to the management activities of man (*sic*), exactly the reverse behaviour and result can be produced than is expected." As a number of commentators have noted, the rejection of stability holds a series of major implications for resource management (Zimmerer, 2000).

Redman *et al.* (2004, 163) defines an SES as a 'coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner; a system that is defined at several spatial, temporal, and organizational scales, which may be hierarchically linked; a set of critical resources (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of ecological and social systems; and a perpetually dynamic, complex system with continuous adaptation.' In addition to recognising the equal importance of social and ecological domains, the SES approach suggests that social and ecological systems are linked by multiple feedbacks, and display common properties, such as resilience and complexity. The SES approach has obvious appeal to ecologists working in cities, and both follow up bids used the SES framework. While the determinism of social-systems thinking remains problematic (Walker, 2009), the strength of the urban SES model is the sophistication through which it links physical and social systems together using multi-scalar feedback loops (Gunderson and Holling, 2002). The staple example used is that of land-use change, which affects ecological

pattern and process, which then feeds back into the decision-making system to regulate further land-use change. The SES paradigm of urban ecological research is interesting because it conceptualises the *whole* city, while acknowledging their inherent un-plannability. This seeming paradox is wrapped up in the organising metaphor of the system, although this is not the system of the Nineteenth century metabolism or super-organism, but rather the non-linear system of post-equilibrium thermodynamics. Hence Modernist controlling tropes of planning, managing and regulating the environment are replaced with SES metaphors of 'steering', 'surfing' and even 'dancing' with environmental change, which emphasise how governance can increase the ability of a system to adapt in the face of uncertainty and changing conditions.

The focus on adaptation rather than management renders scientific engagements with the city inevitably *experimental, applied* and *local*. The ecological grandfather of resilience, C.S. 'Buzz' Holling (2004) himself, calls for creation of conditions that promote many low cost innovative experiments in governance. Working from this understanding, Grimm *et al.* (2008, 759) state in a recent paper that, 'cities offer real-world laboratories for ecologists to understand these fundamental patterns and processes and to work with city planners, engineers and architects to implement policies that maximise and sustain biodiversity and ecosystem function'.

SES casts the city as a terrain for scientific experiments, but in a way that is distinctively different to historical attempts that generated knowledge within the city and then sought to influence its administration. The tenets of SES and resilience bring the social aspects of the city and its political apparatus into the purview of experimentation. In line with second order cybernetics, the observer is part of the system under study, meaning that ontological uncertainty in the system is mirrored by the epistemological uncertainty of knowledge about it. On this understanding, Gieryn's distinction between the city as field and the city as lab begins to dissolve. Without an external observer it is hard to satisfy the preconditions of the traditional laboratory that it is a controllable and separate space. In explicitly placing the scientist within the system under study, the SES approach requires an explicitly experimental approach. Once more, the work undertaken at Baltimore and Phoenix is indicative of the changing relations between science and the city in sustainability research.

Experimental governance in practice

The centrepiece of the Baltimore follow-on funding application was a nearly one billion dollar 'experimental manipulation' of nitrogen exports in the watershed to improve sanitary sewer infrastructure (Pickett, 2004, 8). In 2002, the city of Baltimore reached a consent decree agreement to bring the city into compliance with the Clean Water Act and end discharges of raw sewage into local waterways. The BES project team hardwired their research into this infrastructure project through a six year programme of weekly stream sampling to provide a basis for the adaptive management, in what they term a '"natural" experiment'. By monitoring a diverse range of sites they aim to enhance the reduction of pollution through helping interventions targets specific urban areas, but also to allow regulation to adapt to contamination remaining after infrastructure improvements.

The second phase of the CAP programme also placed experimental work at its core (Grimm and Redman, 2004a, 3), setting up a large-scale landscape experiment around student family housing on the Arizona State University Polytechnic Campus. The recently established North Desert Village "experimental suburb" is the first ever experimental study of interactions between people and their ecological environment at the neighbourhood scale. As well as manipulating vegetation types and irrigation methods, the experiment is exploring how landscape interactions affect human perceptions and behaviours. Residential landscapes at identical housing units in the village were installed in four different styles designed to reflect different habitats found throughout the Phoenix metropolitan area. These ranged from a mesic landscape, which used a mixture of exotic high water-use vegetation and shade trees with turf grass maintained by flood irrigation to reproduce the classic (and largely unsustainable) suburban garden type, to the Sonoran Desert landscape, which reproduced native plants on granite substrate with no supplemental water whatsoever.

In a paper documenting the North Desert Village experiment, Cook *et al.* (2004, 467) ask why manipulative experiments are not used more in studies of human-environment interactions, despite the key role that experimentation usually plays in science. Capturing complex feedback mechanisms between social and ecological systems is complex and unpredictable, and thus, they argue, requires 'new and innovative research methods'. They suggest that 'adaptive experimentation' is one such method that allows humans to adapt inside the experiment and alter its parameters, and they claim that experimenting on humans *in situ* produces "*more accurate scientific models*" (*ibid*, emphasis added). The preferences of North Desert Village residents were used to design

the area, and subsequent preferences while living in this constructed laboratory space informed ecological management decisions. They champion adaptive experimentation over adaptive management on the grounds that the latter is more *political*. In order to legitimise the North Desert Village as a scientific space, it is depoliticised and described as a laboratory; 'adaptive experimentation incorporates most of the formal aspects of classic experimental design, including independence of study units, use of replicates, and controls'.

While budget, interdisciplinarity and ethics all colour the practical appeal of adaptive experimentation (as they pithily note (*ibid*, 473), 'plant or animal populations typically do not have a choice about participation'), the key trade-off they identify is between the detection of human causality (and thus enhanced experimental realism), and the wider applicability of the results. Because the scale of experiments needs to be practical (which usually equates to relatively small and confined areas) the problem of localism rears its ugly head, and they acknowledge that 'findings from experiments are to some extent confined to the setting in which they are carried out' (*ibid*, 473). But the dream of general scientific validity is not abandoned. Their solution is to base wider applicability on the integration of adaptive experimentation with 'biological monitoring, social surveys, simulation modelling and comparative work at larger scales' (*ibid*, 473). The integrated city is still a dream for these scientists[viii]; despite its un-plannability it can be *known.* In this way the lessons from specific experiments can be generalised as placeless, and thus authentic, science.

This mode of experimentation turns the city into a laboratory[ix]; not by hardwiring science into the direct administration, design and planning of the urban landscape, but by assimilating these functions into the study itself. Within the urban SES approach, nothing is outside the lab. Such experiments are increasingly commonplace in sustainability research and planning, as universities work evermore closely with planners and designers and forge scientific knowledge in the fire of live governance processes. The experiments above may represent the extreme end of a scale of engagement between ecological science and urban planning, but it is the point towards which urban sustainability is heading, as any cursory inspection of large-scale urban sustainability research projects indicates. In the UK context, the NERC funded URGENT programme and EPSRC funded Sustainable Urban Environments programme have produced a series of large-scale, interdisciplinary urban ecological projects, and critical evaluations of these programmes have advocated increased engagement with real world

problems and end-users in future (Evans and Marvin, 2006). This trend is mirrored at the international level (Hodson *et al.*, 2008), with the urban ecology component of the European Union funded Social Polis project advocating participatory action research and activist science as important future funding priorities (Kallis, 2008).

The possibility of mega-experiments of this kind present a series of discomfiting questions: if the city is a laboratory, then are its inhabitants lab rats? More seriously, what sort of city (and, by implication, society) will result if urban design and administration is reduced to a set of feedback loops between landscape and behaviour? What happens to science when it becomes verified through live experiments in which its own practitioners are implicated? The remainder of the paper considers the epistemological, institutional and political implications of the experimental city.

The politics of the experimental city

Epistemologically, it is possible to identify a shift from the dualistic tension between nomothetic (general) and ideographic (local) knowledge to a position that, while not going so far as to outright reject the possibility of 'pure' knowledge, certainly adopts a more circumscribed view of objectivity. For example, in their first NSF proposal, Grimm and Redman (1997, 10) talk about using the city as a laboratory to study the relation of pattern and process, but state that "while we would prefer to do hypothetico-deductive hypothesis testing using experimental manipulations in the field, this is possible in only a small subset of the research areas we have identified." On the following page they note that nomothetic modelling and long-term research is to be complemented by a series of ideographic 'experiments'. The concern for the localism of the experimental approach here echoes Gieryn's dualism between the city as field and the city as laboratory.

This concern shifts discernibly in the second phase of the projects. Under conditions of uncertainty within the SES framework the city cannot be 'knowable', only 'changeable', in accordance with the second law of thermodynamics that places the observer within the system being studied. Experimental cities are truth-making machines that draw no distinction between the generation and application of knowledge. As laboratories they are both the condition and site of change. As well as compromising Gieryn's dualism between field and laboratory, this development questions whether the city as a lab needs to adhere to what Kohler (2002) calls the logic of the 'placeless place' through which labs have traditionally legitimised scientific knowledge. This form of experimentation recalls an earlier mode of knowledge production, whereby naturalists

and philosophers used to perform experiments in a range of places, such as parks and public houses (Klein, 2008). Laboratories were often simultaneously sites of commercial production as well as learned enquiry, with considerable overlap of people, equipment and expertise. The emergence of modern science, defined as pure epistemology, ignores the actual material conditions and locations under which knowledge was produced, and, as Klein argues, established an enduring distinction between pure and applied knowledge that was really only briefly tenable in the early Twentieth Century (Barnett (2000, 41) has made similar arguments concerning the university more generally). In rejecting the possibility of objective control from outside of the urban system and embracing a promiscuous experimental approach, SES echoes the messy material origins of science highlighted by Klein. For the new urban ecology and adaptive experimentation, urban messiness is constitutive of, rather than antithetical to, scientific practice (Dierig *et al.* 2003).

That said, the very same move that prompts the abandonment of the possibility of external control *over* a system simultaneously promises influence *in* a system so total that it includes the observer and the political apparatus. Indeed, as one group of leading urban ecologists have tellingly commented, "despite these significant efforts, we have only begun the process of developing *a comprehensive knowledge base* for building more sustainable cities and regions" (Musacchio, and Wu, 2004, 176, emphasis added). The experimental city thus embodies a tension between experimentation and comprehensiveness, which has spawned a range of slightly awkward attempts to retain the goal of complete systematisation in the face of what must inevitably be a partial analysis. In the writings of resilience ecology, the language of generally applicable knowledge is replaced by a search for generally valid meta-principles and frameworks to guide how experimentation should progress to produce sustainability and resilience[x].

These epistemological implications are accompanied by important institutional changes. Talking about decentralised green infrastructure, Pincetl (2010, 52) notes the tension between believing "that good science and information will yield better results – a modern, progressive view – and at the same time… question(ing) the dominant structure of knowledge and organisational form of cities." In the experimental city, sustainable test settlements like BedZed or Dongtan are literally embedded in the urban fabric as truth spots in their own right. As Gieryn (2008, 797) argues in his study of the Clark Centre biotech lab at Stanford, the lab is itself an 'experiment' in linking the production of scientific knowledge with economic interests through a design that echoes

the disembedded architecture of high capitalism associated more commonly with airports and art galleries. Similarly, in the competition to display the most shining example of urban sustainability design possible, the scientific urban experiment becomes simultaneously economic. The implication of the North Desert Village is that if that experimental suburb is popular with residents, then the knowledge deployed is, in some extra way, valid. In this sense, as objectivity recedes from view truth becomes synonymous with success, becoming embedded in the city in no less material a way than those Twentieth Century monuments to wealth, skyscrapers. Place is critical within the experimental landscapes of sustainability, as the visible arbiter of truth.

Resilience privileges those with the sufficient institutional, economic and intellectual capital to be best able to experiment. The attributes of a city thus affect scientific progress. For example, just as the rapid development of the science of pathology in Nineteenth Century Paris reflected the high number of hospitals and cadavers available to work in and on (Dierig *et al.* 2003), so a similar competitive advantage will accrue to cities with the knowledge base and institutional capacity to experiment with urban sustainability (While *et al.,* 2009, make a similar point regarding carbon control). Science is 'visible as a transformational agent' (Perry, 2006, 202) in the competitive fortunes of cities. Feedback loops of the kind required for adaptive management are already heralding closer links between universities and cities, dissolving the boundaries between knowledge makers and knowledge users. Successful experiments will become increasingly important to urban and regional economic trajectories (Gibbs and Krueger, 2007), recapitulating the importance of creativity to urban futures noted by Florida (and Mumford before him), but raising similar concerns - the experimental capacities of cities are evidently not evenly distributed (Hodson, and Marvin, 2009). Indeed, the fusion of science and city that characterized the western world is less well established elsewhere, which has important implications for thinking about how an urban ecological approach might be embraced in different urban contexts.

Politically, the experimental city resonates with two differing debates in the humanities. The social sciences have been similarly influenced by the notions of complexity and non-linearity, and it is not hard to find instances where the city is spoken of in terms remarkably similar to those of the urban SES research programme. For example, Amin and Thrift (2002, 4) call for a new type of urbanism that understands urban development 'as a set of potentials which contain unpredictable elements, as the result of the co-evolution of problems and solutions', or what they call the 'ordering of

uncertainty'. In a particularly telling phrase they speak of the city as an 'ecology of circumstance' (*ibid*, 77), which requires 'performative improvisations which are unforeseen and unforeseeable' (*ibid*, 4). In a not entirely dissimilar vein, cultural anthropologist James Holston suggests that the 'multiplicity and simultaneity' of urban processes makes any attempt at comprehension experimental (1999, 155).

That said, the experimental path to urban change presents a series of political dangers. What Caldeira and Holston (2005, 411) call the 'complex relationship… between democratic and neoliberal planning' rests upon a shared acceptance of contingency and uncertainty. The abandonment of a political project of sustained and rapid systemic shift for the reactive and formally sanctioned optimism of resilience and experimentation runs the risk of fiddling while Rome burns (Vale and Campanella, 2005). The appropriation of urban space as a laboratory in which to conduct experiments is accompanied by an institutional appropriation of arenas of governance by science. As Hodson et al. (2008, 1620) have discussed in relation to hydrogen transport technology, cities are often framed as simply the passive recipients of experiments from international partnerships that see the local simply as a site for implementation. While the SES approach inevitably involves some degree of local specificity, the tension between localised self-reliance and systemic change remains.

While SES models advocate public participation (for example, Gunderson and Holling, 2002; Walker *et al.*, 2002) as part of a necessary agenda setting process, the experimental space in which they operate is conceptually constrained within bounds of what can or cannot happen inside an SES. In other words, the scientific assumptions of resilience ecology run the risk of political foreclosure because they frame the governance choices that are available. The scientific appropriation of governance in turn raises the question of what *should* be political in the urban context. While undoubtedly ethical, the work of the sanitarians in the nineteenth century was in no way democratic. In their defence, it can be said that they dealt with basic needs, rather than political choices and social futures. But if this distinction was tenable then, it is less so than ever today, as urban services such as water, medicine and clean air become politicised through processes of privatisation (e.g. Graham and Marvin, 2001; Swyngedouw, 2004), and our 'basic needs' impinge upon those of future generations (Dobson, 1998). Seeing the city as an SES threatens to de-politicise urban transition, not so much by colonising arenas of governance with expert knowledge (a la Modernism), but by constraining

governance within a highly technocratic experimental mode that remains inured to the tropes of scientific legitimacy.

Conclusions

This paper has offered an account of the conceptual basis of experimental governance in resilience ecology, highlighting its importance for political debates concerning urban adaptation, transition and sustainability. While cities have always been in some sense 'experimental', the SES framework in which the new urban ecology is couched is fundamentally altering the relationship between science and city, epistemologically, institutionally and politically. With the death of the modern lab and its detached observers, we are witnessing a laboratisation of the city, as design, planning and administration become part of the system under study. If SES has been instrumental in shifting policy discourse from sustainability to resilience and adaptation, then the experimental method is its calling card. A number of regressive implications flow from an ecologisation of the urban, and the re-rendering of urban process and planning as 'experimental' (urban neo-liberalism with a green face).

There is a danger that despite, or perhaps because of, its explicit embrace of complexity, resilience smuggles Davison's ghost of natural theology into the practices of experimental governance. Ironically, it may be exactly the emphasis on flux (and the rejection of stable Nature), which appeals to geographers as the basis for a more progressive environmental politics, that produces political foreclosure. Within this research programme, the specific characteristics of the SES are modifiable, but the fact that the city is an SES is non-negotiable. Geographers should pause for thought before abandoning the old coordinates of modernity and rushing to embrace all forms of complexity and non-linearity in the sciences.

The notion of the city as laboratory is thus radically extended, as the distinction between lab and life collapses under conditions of epistemological and ontological uncertainty. The political implications of living in a permanent laboratory could be debilitating or emancipatory, depending how this process unfolds (Evans and Karvonen, forthcoming). On the one hand, there is some evidence that ecology might be politicised through its urban engagement. Grimm and Redman (2004, 212) muse that, "conscious inclusion of social and ecological variables in our studies, have brought many of us to ask a more fundamental question about our science.' Continuing, they ask, 'to what extent and in

what ways do patterns and processes in human-dominated systems require qualitative changes to ecological theory as it has been traditionally portrayed?" The work of SES ecologists more widely has also begun to engage with the possibility that resilience may require a science that is by necessity localised and qualitative. On the other hand, the ecologisation of the city within the SES framework is, at times, as reductionistic as anything previously attempted; for example, the study of urban fringe dynamics in Phoenix uses the language of 'pioneer' communities and 'stages of development' (*ibid*) familiar to the Chicago School before it. These tensions inhabit the policy discourse of resilience more generally.

Ethical approval forms are clearly not sufficient to address the political deficit of urban experimentation, but, currently, it is not clear exactly what is. The central role afforded to experimentation in current manifestations of urban sustainability undoubtedly offers up a potential space for more playful or insurgent political engagements with urban infrastructure and material form. Ethnographic studies of scientist-practitioner-activist networks would be valuable in understanding how such action produces new arenas of governance and spreads attendant knowledges (Chilvers and Evans, 2009), in much the same way that scholars have traced the construction and flow of sustainability expertise (e.g. Guy and Shove, 2000). It is surely this zeal to enact scientific knowledge and gain legitimacy that Dear tries to capture when he exhorts scholars to produce 'social histories of conviction rather than just accredited truth' (1995, 454). As the crusading sanitarians of our day, ethnographies of urban ecologists in action would contribute massively to our understanding of how environmental governance is being transformed in the context of the knowledge society.

Geographers are well-placed to flesh out arguments concerning the unevenness of adaptation under experimental governance, and the role that place and circumstance plays in the production of adaptive knowledges. They can also potentially invigorate the political component of this process, but must engage with what might be called the 'experimental apparatus' of climate governance. Put simply, if sustainability comes down to letting a thousand experimental flowers bloom, then it matters who gets to experiment and how. This is the political ecology of adaptation.

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Figures

Figure 1: relations between resilience, adaptation and experimentation under climate change governance

Driver *Process Practice* *Goal*

Climate change » Adaptation » Experimentation » Resilience

Figure 2: Shuttles between legitimisation strategies (after Gieryn, 2006, 11)

City as Field		**City as Lab**
Found	⟷	Made
Here	⟷	Anywhere
Immersed	⟷	Detached

Notes

[i] This paper focuses on adaptation as it can be derived from resilience ecology (e.g. Folke et al. 2002), whereby resilience indicates the magnitude of the shock that the system can absorb and remain within a given state, the capacity of the system for self-organisation, and the degree to which the system can build the capacity to learn. A system can occupy a number of given states that are non identical. The classic example given is that of lakes, which can exist in a clear water state or be turbid with algal blooms. The first state provides more ecosystem services, but each is resilient (Carpenter, 2001). Ecological resilience focuses on systemic change, whereas social resilience tends to be more parochially concerned with recovery from disaster. The two literatures have tended to remain surprisingly discrete (Janssen *et al.*, 2006), but see Adger (2000) for an excellent review of the continuities and discontinuities between the two terms. There are also a number of books which conflate resilience with the solution to peak oil (e.g. Newman *et al*. 2009). These tend to emphasise large-scale politically led change rather than adaptive experiments, but still place learning at the heart of their prescriptions.

[ii] While the Modernist dream of total control was in its time highly experimental, it was not concerned with hardwiring experimental processes into governance in order to adapt to continuing change. The mode of planning is an emergent form of environmental planning, which links the city to indicators and feedback loops. E.g. scorchio etc Emerging technocentirc approach.

[iii] At least in the West. Sanitary infrastructure was only imperfectly adopted across much of the colonial world (e.g. Prakash, 1999; Nilsson, 2006) and the fusing of science and the city that characterized the western world is less well established elsewhere. As returned to at the end of the paper, this is really important for thinking about how an urban ecological approach might be embraced in now very different urban contexts.

[iv] Ecological science largely confined itself to site-level studies until the 1970s (Sukopp, 2005)Interestingly, this so-called 'Bio-Ecological Tradition' from Central Europe offered a minor counter discourse to systematisation, arguing that cities are characterised by a low degree of integration and are thus better described by individualistic concepts (Weiland and Matthias, 2009).

[v] The sanitary / sustainable city comparison is not to suggest that rationality played any less important role in the interface between science and the city in the mid to late twentieth century, for example in subsequent emphases upon engineering and then ICT, but rather to highlight that these two urban eras are comparable in their transformative reconceptualisation of the city.

[vi] The exact origins of this call are not clear, but emerged from a complex set of personal connections set against the context of a macro-level zeitgeist concerning the ecological importance of cities. Undoubtedly the work of Grimm and Pickett in establishing this zeitgeist was critical.

[vii] The emergence of resilience onto the international stage as an environmental policy discourse raises at least three (related) points of intrigue. First, what has the precise history of contact and subsequent cooperation between key actors in the US and Sweden been? Second, how have the advocates of resilience been so successful promulgating it as a policy solution? Finally, what are the subtle philosophical differences between its various incarnations? These questions await future treatment.

[viii] Of course there are also a number of pressing practical reasons why scientists might shy away from producing 'local' science, wrapped up with the academic pressures to be 'internationally excellent', 'world class' and so forth (see Evans, 2006, for a closer consideration of how these dynamics play out in practice).

[ix] The parallels between SES and the living laboratories concept as it is used in systems studies, to mean a research methodology for sensing, testing and refining complex solutions in real life contexts, which tends to be user-driven and focused on generating innovation through public-private partnerships, must await treatment elsewhere.

[x] The tension between spatially tied and abstract knowledge is common to environmental science more generally (Rocheleau and Roth, 2007), and can also be found in debates surrounding international urban policy transfer (McCann and Ward, 2009).