# Are cities ecosystems—analogous to natural ones—of nature, infrastructure and people? Does thinking about cities in this way help us think about urban design?

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*Every month we feature a Global Roundtable in which a group of people respond to a specific question in The Nature of Cities.*

## Introduction

Are cities *ecosystems* in the senses in which we think of classic natural and ecological areas outside of cities? After all, urban spaces are connected mosaics of green space, biodiversity (including people), non-biological structure, biophysical processes, energy flows, and so on. That sounds a lot like a natural ecosystem.

List of writers

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*local environment. Components of most ecosystems include water, air, sunlight, soil, plants, microorganisms, insects and animals.*

That could be a description of a city. Or not (perhaps depending on the city).

But perhaps more importantly, does thinking explicitly about cities as ecosystems help us? Does it offer us any insight into urban design? For example, are our goals for cities—sustainability, resilience, livability, and justice—advanced by an urban eocsystem concept?

Many of these contributors say, yes, certainly, cities are ecosystems. Not all, though. A few more are skeptical that an ecosystem concept is central to planning better cities. The more common belief among this group might be that a *socio–ecological* and *landscape* approach to cities is more important, and one that is imbued with values.

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## Clifford Ochs

**The city ecosystem—the street view of a common resident**

Sometimes we move alone, other times we move en masse, after the sun has set, a migration from street to dump, and back to safety. If you stay in the light, you may not notice us. But pay attention when passing a dark alley, and you may see our glowing eyes, and hear our high chirps of communion.

Perhaps you think we are out of place in your city, that we don't belong. Oh, please. As someone has said: "If you build it, they will come", and so we came, and we'll stay. How could we resist? It's like you created this place to meet not only our needs, but our desire.

> ***Your habits are our habits, your throwaways are our takeaways, and while you've done all the work to make the city for yourselves, we could***

sometimes with a little cheese sauce, pigeon
tartare. Garbage, spillage, dusky stormwater, toasty sewer pipes, plenty of pack mates. Like you, we are yearning to be free, and here in the city you have built for us, we surely are.

Warmth is appreciated, and thanks be to you, the city is a heat generator. Pavement catching sunlight, taxies and furnaces burning oil, its organic flotsam and jetsam radiating heat into the atmosphere. Baby, even when it is cold outside, we stay warm and cozy in our rent-controlled little homes, we and our passenger fleas snoozing the day away.

Come darkness, when we do venture out, we must be cautious. Many rewards await us, but all is not safe, the city is also home to terrible predators. Cats are the worst, quiet, leaping, crazy, red in tooth and claw. When we see a cat, a cry goes out, run, find a crack in a wall, stay still until the danger slinks on. With patience and luck, we will survive another night, and tomorrow there will be even more of us!

It is our secret weapon. With all the nibbles you leave behind, a warm nook, and the right kind of company, make room for babies. Lots. A dozen at a time is not unusual, and it takes only a few weeks to make them, and shortly after birth, we are ready to make some more. Really, if it wasn't for the cats, an occasional terrier, the diabolical contrivances of human pests, and an unfortunate tendency for internecine conflict, how much faster our family would grow.

People, thank you for the city. Your habits are our habits, your throwaways are our takeaways, and while you've done all the work to make the city for yourselves, we could not resist moving in, migrating across the grid, and settling down – waiting each day for the sun to set, and the streets to be our playground.

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## Sarah Dooling and Stephanie Pincetl

**Beyond progress and ruin: an empowered urban ecology for the Anthropocene**

List of writers

domains. Yet, the idea of urban ecosystem contains the histories of Cartesian dualities. Recognizing the reciprocity between many different human communities and their non-human neighbors means rejecting nature as independent of urbanization. Social issues, like poverty, become environmental issues. But we're not there yet.

Ecology developed as a science of categories and classifications, committed to revealing patterns with wide applicability. Understanding urban ecosystems as places where people and nature co-evolve is difficult for ecologists because these particular co-evolutionary partnerships upset stable Linnaean categories that are used to organize the world's life independent of humans. Communities and species were, and continue to be, considered objects of study, separate from and undisturbed by investigators.

> ***The danger of an object-oriented systems approach to urban ecosystems is that it is inattentive to consequential political conflicts arising from competing values and unshared goals.***

The idea of urban ecosystems challenges the anti-urban bias among 19th and 20th century ecologists who considered urbanizing landscapes void of ecological value, degraded by pollution, and cut up by networks of infrastructure. With the eradication of nature the concept of ecosystem in the urban context had little purchase among ecologists. Today, many urban ecologists draw from systems theory to link social and ecological components through themes of connectivity, emergence and contingency. Cities are now considered hybrid systems, a designation undergirded by the pervasive binary categorization held so dear by natural scientists.

Yet, the urban ecosystem concept is insufficient because it leaves out urban realities, such as racism, poverty and criminal justice, because they fall outside conventional topics of ecological investigation.

Cities have developed out of unique urban histories. The legacies of urban renewal and racist policies reinforce pathways of urban development marked by exclusive beneficiaries. Modernity's narrative of urban progress is undercut by the logic of disposability and excessive surplus that plays out in the dynamics of urban homelessness, multi-generational poverty and racism. Despite conceptual

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Pincetl has written extensively about land use in California, environmental justice, habitat

relations. In our era of deepening inequities, questions about the transformation of nature, by whom and for what purpose are increasingly salient as urban patterns of economic and racial segregation intensify while cities are simultaneously held up as the salvation of global sustainability and climate resilience. As many critical thinkers have reminded us, social changes always have ecological consequences, and environmental changes are never socially neutral.

Cities are places of growth and decay, chaos and patchiness. The objective stance of systems theory towards this unpredictable and untamed environment is insufficiently capable of questioning dominant urban scenarios. The danger of an object-oriented systems approach to urban ecosystems is that it is inattentive to consequential political conflicts arising from competing values and unshared goals. Where then do we find the theoretical justification that motivates eliminating practices of disposability and excessive surplus? As researchers, our challenge in these times of uncertainty and loss is to attend to significant moments of difference and variation in co-evolutionary relationships, which may point to a transformative re-imagining. We offer a way forward.

We consider cities as subjects, full of diverse living networks and marked by inequities harmful to communities of people and biota, rocks and soil. We intend to build a science of cities from the inside out, where the historical richness, contradictions and inequities of each city informs context-specific understandings of urban ecosystem. We urge justice and equity — for people, biota and rivers — as central starting points for research, policies and place making. Making equitable urban societies becomes the common goal underlying efforts to become resilient and sustainable. We call for developing a post-Cartesian science that recognizes contingency and mutual construction of the places we live: humans-in-nature, nature-in-humans.

An empowered urban ecological science recognizes the limitations of systems thinking, Linnaean classification, and ecological ideas of ecosystems. Boundaries between humans and environment are dissolving into multitudes of diverse communities interacting across patches of relational intensity. Empirical work, liberated from constraining scientific ideologies, can aid in nurturing collaborative survival by coordinating disturbance and conservation across patches.

List of writers

design converge on pressing issues. Most critically, we must start telling stories that carry us beyond progress and ruin, into the possibilities of ecologically vibrant and socially equitable communities that can sustain in a precarious world.

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Madhusudan is an evolutionary ecologist who discovered birds as an undergrad after growing up a nature-oblivious urban kid near Bombay, went chasing after vanishing wildernesses in the Himalaya and Western Ghats as a graduate student, and returned to study cities grown up as a reconciliation ecologist.

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## Madhu Katti

### Coral reefs of the land

It is a hard nonliving complex three-dimensional structure built by living beings, often covering extensive areas of habitat, and unlike anything else naturally found in the vicinity. It is the product of the labor of an organism that has evolved to transform the materials in its surroundings into a protective home for itself and its progeny. It is built in layers, growing upon itself as its occupants continue to build it over generations. It does the job of protecting its inhabitants well enough to outlast them, standing firm over scores of generations, thousands of years. It helps concentrate the flow of energy and materials from its surroundings to make life more efficient for its denizens, thriving sometimes even in places that otherwise seem deserted.

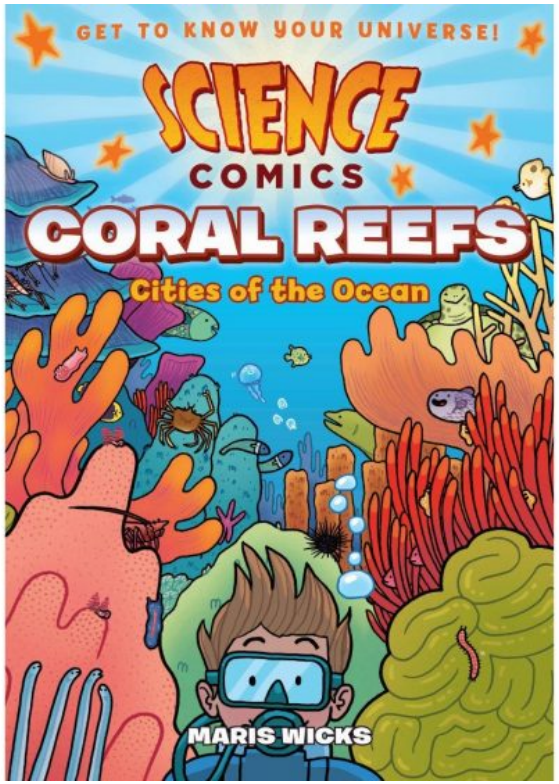
> ***Of course cities are ecosystems. More interesting is to ask what kind of an ecosystem cities can be rather than worrying about how unnatural a blight they are on more "natural" landscapes.***

It not only provides shelter and resources and a supply of energy to the species that built it, but also supports a wider range of other species that may come seeking its riches and adapt to new ways of making a living in this strange new construction. It can vary in appearance and color and occupants from one part of the world to another. It is large enough in some places to be visible from space. It is resilient to a surprisingly wide range of environmental variation, yet vulnerable to catastrophic collapse under conditions such as rising sea levels and warming ocean temperatures. And even when it collapses, and is no longer able to support its creators and main occupants, it continues to loom in its place, casting shadows deep into history, until the patient forces of water and wind and temperature wear it down and its remains wash up on some shoreline in the sands of time.

survive outside the city walls.

Coral reefs are ecosystems rich in biodiversity, often concentrating biological productivity and wealth amid relatively poor waters. Coral reefs are described as rainforests of the ocean, harboring as much, if not more biodiversity underwater as tropical rainforests do on land. They stick out in the underwater landscape as distinctly as forests full of tall trees do in terrestrial landscapes, marvelously unlike anything around them, but teeming with a richness of diverse marine organisms that have evolved to be uniquely adapted to life in the coral reef, lured by its richness to tie their evolutionary fate to that of the reef itself.

It may seem odd, but coral reefs are also often likened to cities. The City, that quintessential "artificial" construction by human beings alienated from nature, symbolic of how we pave over natural ecosystems, is often used as a metaphor to understand and explain the complexity of coral reefs. There are even children's picture books full of wonderful artwork that explain how coral reefs function much like cities: where tall structures rise up from the ocean floor like skyscrapers; where schools of fish and mollusks and crustaceans scuttle about busily at work commuting among productive nooks and crannies where they can feed and nest and raise babies securely; where diverse species evolve to specialize in different tasks, much like guilds of craftsmen and workers in medieval cities divided up human labor to make it more efficient, enabling us to produce ever more wonders of craft and art and technology, diverse and creative, and also sometimes horrific.




*Explaining to children how a coral reef functions like a city. Photo:*

complex social-ecological systems, because we like to pull the human social elements apart from the "natural" in our cartesian ways of thinking. A much more interesting exercise is to ask what kind of an ecosystem cities can be rather than worrying about how unnatural a blight they are on more "natural" landscapes.

As they stand, and unlike coral reefs, cities are not founts of biological diversity amid less diverse landscapes. In the relatively short timespan of human history, cities have become known more for destroying biodiversity rather than enhancing it anywhere, although more recent work in urban ecology is finding a surprisingly high diversity of species in many cities. Do cities destroy other habitats and ecosystems? Of course. Do cities cause local extinctions of many species? Undoubtedly, because we never built them as habitats for any species other than ourselves. Indeed it would seem that we build cities as places where we seek refuge from "nature" in all its vagaries and its "red in tooth and claw" horrors. Yet, we also bring a lot of that nature, and many other species, with us into the city, planting some in our gardens, growing others on our walls and balconies, feeding and watering many with intent or benign neglect, and willingly or unwittingly sharing the bounty of resources we concentrate for ourselves in cities. We know now that we depend on many of these other species for food, water, and air, for our bodies and our minds, and for our culture and artistic inspiration—even though we never built cities for anyone but our own selves. Just like the mindless tiny organisms that build coral reefs.

But unlike the coral organisms, we have minds capable of reflecting on our own actions, and of imagining different futures. Imagine building cities more intentionally like coral reefs on land. The oldest cities are just a few thousand years old, an order of magnitude younger than the oldest coral reefs. That deeper span of time has allowed coral reefs to evolve into the diverse ecosystems we now celebrate and whose decline through our actions we dread and lament. Yet, to borrow that tortured phrase from urban land developers, the coral organisms simply built their little shelters, and they came: all the diverse algae and plankton and fish and mollusks and crustaceans in the ocean to evolve together into a diverse ecosystem thriving under the ocean. A growing body of research on urban wildlife is now showing us that many species on land are also coming into our cities once we build them, so long as we leave enough of our surplus of resources for them. Recognizing the value of

List of writers

Surely, if we build cities with intention, with niches full of unique resources, many other species will come on their own, and over time will adapt and evolve into unique urban creatures, tying their fates to ours just like the house sparrow or the chimney swift have done. Even underwater, our artifacts, like sunken ships, can act as surrogates for species fleeing damaged coral reefs, and are being used intentionally to restore reef ecosystems threatened by warming oceans and rising seas. It is not hard to imagine some of our major coastal cities also turning into such surrogate reefs as they submerge under the rising oceans. So let us also reimagine and reinvent our cities as terrestrial reefs, as rich and full of other species as we can learn to coexist with, becoming not just their competitors and killers, but also their gardeners and nurturers and symbionts. Let us think as deep into the future as the coral reefs teach us about the past, and turn the metaphor of the coral reef as a city into the real city as a coral reef, diverse and resilient and full of evolutionary ferment to match the tides of our changing world.

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More From this Author

## Steward T. A. Pickett

### A city must be an ecosystem

The fundamental idea of the ecosystem is one of the clearest in contemporary ecology. It has survived intact since it was introduced by Sir Arthur Tansley in 1935. Few scientific concepts have such longevity.

According to Tansley, and leaders in ecosystem ecology since his time, an ecosystem occupies an area and comprises the complex of biological organisms in that place along with the physical environment complex, and the interactions among these two complexes. The use of the word “complex” indicates that there are interactions within the biological and the physical parts of an ecosystem as well as between them.

> ***The deep definition of the word ecosystem is notable for what it leaves out—the minimal baggage carried by the idea makes it nimble and broadly applicable.***

inconspicuous creatures like worms and insects. But the key word—interacting—is what makes it a system.

The deep definition of the word ecosystem is notable for what it leaves out. Indeed, the minimal baggage carried by the idea makes it nimble and broadly applicable. The definition of the ecosystem does not require things like closed boundaries, stability or equilibrium; nor a focus on any particular time or spatial scale. It doesn't require or deny directional changes through time, or an inevitable terminal condition of diversity or productivity.

The sort of things the definition leaves out, however, become the fodder for research questions or applications. The features absent from the definition can be addressed in specific ecosystem models that apply to certain broadly distributed conditions, or to particular locations or time periods. A researcher or practitioner can always ask, what if the ecosystem I'm studying or designing were in equilibrium, or had closed boundaries for some material? The model that an investigator creates would take the basic idea and add the constraints she wanted to investigate. But notice that in this application something new becomes apparent: the fundamental definition is free from most assumptions, whereas the specification of the basic concept in a particular model states explicit assumptions, exposing them to test. The ecosystem concept and its specification describe a two tiered strategy: concept as clear but lightly burdened generalization, applied though many different specific models that state the precise assumptions they make. This is a common strategy in science.

As specific ecosystem models have proliferated and been tested, ecosystem thinking has broadened in practice. In some ways this evolution has confirmed the wisdom of avoiding assumptions in the definition, such as equilibrium or closed material boundaries, or strict spatial isolation among ecosystems. The breadth of models has demonstrated that actual ecosystems can have an amazing variety of forms, contents, and dynamics. For example, various specific models have documented that ecosystems are three dimensional bodies, extending deep within terrestrial soils or aquatic substrates, and high above the canopies of tall trees. Other modern insights include the widespread role of natural disturbance in shaping ecosystems, or the almost universal presence of humans, human effects, and

How could a city, or a suburb, or a town, or an agricultural village not be an ecosystem? Cities have biological components—including of course humans—but also wild organisms passing through or adapted to the new range of conditions that exist in cities. Organisms long-adapted to and dependent on human largess and waste are a part of urban ecosystems as well. Soil invertebrates, fungi, and bacteria inhabit urban soils and waters. Urban organisms are as involved in the transformation of energy and matter, and the transmission and receipt of information, as are their wild cousins.

Urban systems of course contain the particular physical environment within which and with which the organisms interact. Sunlight for photosynthesis, the cues of daylength and the seasonal swings of temperature, the exaggerated heat budgets, the stresses of low humidity, the soils, rubble, and fill as substrates, the rush of wind through the streets or the stagnation of air in deep street canyons, and the alteration of topography, with its importation of stone and the alkaline ingredients of concrete, are among the many aspects of urban physical environments.

All of these interacting components define an urban instance of the basic idea of the ecosystem. And all of these components reflect the desires, plans, mistakes, accidents, and unintentional effects of decisions made by individual people, households, and institutions. Clearly the physical environments of cities are constructed by or profoundly modified by people. Equally clearly, the biological complex of cities where humans are the predominant actor, has social features as well as compositional and spatial biodiversity.

All of this complexity and dynamism fits easily within the basic definition of the ecosystem, and invites the burgeoning of specific models that contribute to surprise, delight, and utility in the urban sciences and design professions. In an era of global urbanization, climate change, and deepening social inequity, urbanists must recognize the many jobs that even the inconspicuous biological elements of the urban ecosystem perform.

But beyond recognizing the role of the biological component of urban ecosystems, it is imperative to increase the ability of these systems to do ecological work. This means leaving or making space for organisms, which are the creators of ecological work, in new or retrofitted cities. It means allowing streams to interact with marshy banks. It means growing trees to form connected canopies for reasons

city must be an ecosystem.

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More From this Author

## François Mancebo

Almost everybody agrees on the fact that cities can be considered as complex systems. Are they ecosystems? Proving it is another kettle of fish altogether. The idea that cities are complex systems took shape in the sixties from two standpoints:

On the one hand, the very idea that cities are complex systems originated in the seventies with the article of Eugene Odum "The Strategy of Ecosystem Development", which describes urban areas as ecosystems. Many authors continued in this vein later, one of the more famous being Wackernagel and Riess with their book *Our Ecological Footprint*. In this sense we can consider—as far as cities are concerned—complex system and ecosystem are used synonymously.

> ***Cities are ecosystems and a lot more than that: they are social-ecological systems.***

But on the other hand, at approximately the same time, many authors developed the notion of cities as complex systems from a completely different perspective. The general system theory from Ludwig Van Bertalanffy combined with Norbert Wiener's cybernetics and Warren Weaver's organized complexity to provide a conceptual framework to another vision of the city as a complex system. This vision described the city mainly through mobility and transport, energy and financial flows, logistics etc.

Thus, in the eighties, two distinct visions of cities as complex systems were encapsulated in two metaphors: The machine metaphor, usually associated with rigid urban projects, and hub and spoke transport models—which eventually generated dysfunctional social design, ineffective land use, pollution and congestion—and the organic one, built in analogy to organisms—the city as an ecosystem. Well, that would be too simple! Two more visions emerged then: The first one developed by Jane Jacobs considered cities as social-economic systems, while second one, supported by Manuel Castells, primarily saw cities as networks for information exchange.

consequence of this new insight is that urban planners started focusing on how emergent patterns could be generated in the city, by examining how people make decisions—or even micro-decisions—and how local actions confront and aggregate into global patterns. To do so, it proved necessary to consider cities not only as complex systems, but also as complex adaptive systems as mentioned by Michael Batty.

Mitchell Waldrop explains in his key book *Complexity—The Emerging Science at the Edge of Order and Chaos*, that complex adaptive systems can learn from experience and change accordingly. Two characteristics of complex adaptive systems are of significant importance to the structure and functioning of the cities: simple decisions made by individuals aggregate to give rise to complex global patterns, and each agent is co-evolving with the structure resulting from the actions of all the others; change stays dormant up to a tipping point at which these systems flip dramatically and irreversibly into a different state, which is almost impossible to predict. Many irreversible futures are possible.

The agents that interact in the complex adaptive systems of the cities are social and biophysical by nature. From this point of view, cities may be considered as social-ecological systems. What differentiates social-ecological systems from non-human complex adaptive systems is that the former deals with humans who apprehend their world through abstract thought. This symbolic construction is based on the ability to use language and symbols, to communicate across space and time. It has to do with the capacity of human beings to learn from the past, imagine the future, and finally materialize these thoughts in new types of entities that only exist in the noosphere (institutions, political and economic structures, as well as values, norms and beliefs). Erik Swingedouw highlights the circulation and metabolism of nature in urban areas, the role of history in producing them, and how this production drives, and is driven, by unequal power relationships, economic inequities, and competing knowledge. Marina Alberti demonstrated in her article “Integrating Humans into Ecology: Opportunities and Challenges for Studying Urban Ecosystems” that it is impossible to explain how human societies can be integrated in the ecological systems of a city, except by considering the city as a social-ecological system.

List of writers

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# Rob Pirani

**Cities are ecosystems! Let's help them adapt and evolve**

Cities are ecosystems! Affirming that people and our culture cannot be considered apart from nature offers both useful metaphors and new urban practices. But just as people are a particular and complicated part of the biota, cities are ecosystems with some particular and complicated characteristics. Improving our understanding of those details can certainly improve urban planning and design.

What is less clear is whether human-dominated ecosystems, like cities, can successfully evolve in the rapidly changing world we have created. Rapid population increases, urbanization, introduction of novel contaminants and species, and now climate change all pose challenges to both people and other urban inhabitants.

Consider how understanding cities as ecosystem improves both the built and natural worlds.

> ***Consideration of the social benefits of resilience technology, and the civic ecology that it can engender, may well determine whether our urban ecosystems and all of their inhabitants can successfully adapt to a changing future.***

By definition cities are a human adaption to help produce and distribute energy, transform materials, and shape their consumption. Healthy ecosystems have a balance of production, consumption, and decomposition. Cities can promote virtuous cycles that return these materials and energy to new uses. Whether building soils by composting organic waste or creating buildings that recycle and reuse the rain, urban planners and designers are fostering a host of more sustainable practices.

Understanding cities as ecosystems can also help us conserve and restore valued ecological characteristics and services. The ecological structure and functions of our urban greenspaces and waterways provide people with a wealth of services, from moderating air temperatures to producing

These ecological characteristics also define place, the genius loci that makes each city special and valuable.

But can understanding cities as ecosystems change the way cities adapt and evolve? The evolution of ecosystems is shaped by life histories, natural selection and the biological evolution of organisms over time. Cultural forces guide the evolution of cities. These individual and group decisions operate for the most part on the time scale of markets and politics, and do not always account for ecological considerations. In particular modern society tends toward silo management and investment by sector and by jurisdiction, making it difficult to advance integrated decisions at an ecosystem scale.

Consideration of how we can successfully employ natural and nature-based coastal features to increase the resiliency of our waterfront cities offers some specific lessons for what is needed to move forward.

The health of our coastal cities/urban ecosystems are increasingly vulnerable to the impacts of flooding, due to the combination of human population growth, real estate pressures, sea level rise, and coastal storms. Here in New York and New Jersey, Hurricane Sandy and its aftermath continues to pose challenging questions of how to mitigate mounting hazards to people and property along our urban shorelines. Such challenges will only increase with a rapidly changing climate.

One set of answers is the increased use of natural and nature-based features for coastal adaptation (NNBFs). Such strategies recognize that natural features along our urban shorelines, like beaches, coastal dunes and wetlands, have evolved over the years to survive and indeed thrive in face of changing sea levels and storms. Nature-based features are engineered infrastructure designed to employ the characteristics of these coastal landscapes, specifically offering services such as coastal risk reduction, restored habitat, and stormwater management. The US Army Corps of Engineers (http://www.nad.usace.army.mil/Portals/40/docs/ComprehensiveStudy/Bridges-Wagner_Natural_and_Nature-based.pdf), US Housing and Urban Development (http://www.rebuildbydesign.org/), National Oceanic Administrative Agency (http://sagecoast.org/), state and local agencies (for example see the Coastal Green Infrastructure Plan for New York City at

The promise of NNBFs, like other green infrastructure and green building technologies, offers a kind of symbiotic evolution. That adapting our cities can meet the linked challenges of more people and a changing climate in a way that improves or at least sustains the rest of the ecosystem.

To meet this promise will require new metrics for success and the means of adaptively managing these living shorelines. It will require the will to cooperate across boundaries. It will require the science needed to understand whether such infrastructure does indeed provide an ecological lift. It will require rethinking permit guidance to allow for this hybrid infrastructure. There are many efforts to better define these metrics and monitoring requirements, and consider needed policy and management changes.

But perhaps most critically, successfully deploying such technology will also require designers and engineers and decision makers to consider how to better integrate long term monitoring, community stewardship, and social resiliency into engineering decisions and practice. NNBFs, like most green infrastructure, require time for plants and animals to establish themselves. Monitoring and in many cases active stewardship is critical for their enduring success.

This need for stewardship offers an opportunity for engaging community and building the social resiliency critical to mitigating coastal and other hazards. Consideration of the social benefits of this technology, and the civic ecology that it can build, may well determine whether our urban ecosystems and all of their inhabitants can successfully adapt to a changing future.

## Thomas Elmqvist

Although I fully agree that the current framework of cities as social-technological systems is too narrow and should be complemented with the view of cities as complex social-ecological-technological systems, as recently advanced within urban ecology and based on social-ecological systems perspectives. This advance is critical

> ***What we really need is closer collaboration among a diverse set of knowledge holders in natural science, social science, humanities, and among practitioners. The term***

List of writers

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More From this Author

concept of ecosystem to depict cities and urban regions will be of help in this regard.

***building conversations.***

The ecosystem concept has a precise meaning in ecology and was originally defined by the British Ecologist Sir Arthur George Tansley. In 1935 Tansley published *The use and abuse of vegetational terms and concepts,* in which he introduced the ecosystem concept: “An ecosystem is a community of living organisms in conjunction with the nonliving components of their environment interacting as a system”. This may look like an attractive way of viewing cities and urban regions as a system of interacting living components (humans, plants, animals, microbes) as well as non-living components (buildings, soil, water, etc.), and would imply a holistic view and a systems perspective. However, I am skeptical. The reason is that it may be counter-productive. What we really want to achieve is a closer collaboration among a diverse set of knowledge holders in natural science, social science, humanities and among practitioners. By using the concept of *ecosystems* of a city or urban region, originating as it does from natural sciences, we may alienate exactly the group of people we want to include: the social sciences, humanities, practitioners, etc. I fear that it may simply put some people off, when in fact we want to reach out and be inclusive.

What should we use instead? I think that we should define an Urban Sustainability Science and develop a new framework that explicitly addresses the question of multiple-scale interactions, feedbacks, tradeoffs, and synergies among components (human and non-human) in complex urban systems. The challenge is still, however, how do we integrate diverse scientific approaches and knowledge domains grounded in multiple epistemologies and how do we further integrate with other non-academic knowledge systems.

## Eric Sanderson

**Cities are not so much ecosystems as they are ecological landscapes**

List of writers

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More From this Author

tissues studied by histologists; tissues are assembled into organs, which are studied by anatomists and physiologists. (For the human organism, you see a cardiologist for your heart and a nephrologist for your kidneys.) Organs in turn make up organisms, the province of classical biological types: mammologists for the mammals, ornithologists for the birds, herpetologists for the reptiles and amphibians, ichthyologists for the fish, entomologists for the insects, botanists for the plants. Each branch of science has its own division of the evolutionary tree to care for.

> ***A city is an ecological landscape—and a landscape, to scientists like me, is the particular pattern of ecosystems, their composition and arrangement, that forms a habitat for plants and animals. Even for people.***

Once we start to nest organisms into the environment, we enter into the realm of ecology. Community ecologists study the interactions between and among different kinds of organisms; ecosystem ecologists study the interactions of ecological communities with the non-living aspects of the environment: water, air, soil, nitrogen, energy, and so forth. And landscape ecologists, my particular tribe, study the assembly of ecosystems into mosaics that vary in space (i.e. what you see looking out of an airplane) and in time (i.e. what you see in a time lapse movie.) One could go on to speak of regional ecology (and ecologists) and planets and their devotees, and eventually, if we find life on another world, then exobiology and trans-planetary ecology will be latest academic fad, but we're not there yet. For now, when it comes to cities, I think landscape is the doll on which we should focus our energy. Because cities are not singular ecosystems, they are ecological landscapes composed of many kinds of ecosystem.

As I wrote in another context some years ago:

> *To landscape ecologists, a landscape is not just a considered view of the outdoors (as seen in a landscape painting), nor is it a manicured garden (as created by a landscape architect); a landscape, to scientists like me, is the particular pattern of ecosystems, their composition and arrangement, that forms a habitat for plants and animals. Even for people.*
> *—from Mannahatta*

And what are these urban ecosystems? Buildings, streets, sidewalks, gardens, empty lots, baseball fields, parking garages, bridges, ponds, lakes, streams, forests, grasslands, beaches, marine waters,

ecosystem by this definition, inhabited by living people and our commensal pets and also composed of non-living walls, floors, ceilings, insulation, furnishing, electrical wires, and so on. Just because an ecosystem is designed by a human being doesn't mean it's not an ecosystem. Indeed if we began to think of buildings as the ecosystems they are, we might design them better.

More to the point, urban ecosystems are arranged in distinct and recognizable patterns as landscapes. Just take out your phone and look at a mapping application of your favorite city neighborhood. Rarely does nature compose such exquisitely structured and rigorously enforced patterns. Hardly does nature lay down such straight lines or place such elements of fundamental difference in such close proximity. And never does nature let a singular idea (the city grid, impervious pavement, the motorcar) run roughshod over all others as we have it in most 21st century cities.

To the extent that we want to find and restore nature in urban landscape, landscape ecology must be our essential framing discipline, embracing of many disciplines, and yet providing its own tools and thought processes. Remember within the landscape are all of nature's other Russian dolls and their devotees: ecosystems, communities, plants and animals, and so on, down the biological hierarchy to the molecular level. Landscape ecologists integrate across these ways of imagining nature and then bring to bear our own expanding bag of tricks. On the theoretical side, landscape ecologists might wax eloquent about how disturbance processes (e.g. fires, floods, gentrification) change the urban form or habitat models can be deployed to predict where different species (or subsets of a species, drug dealers, philanthropists, potential sweethearts, etc.) hang out. Landscape ecology helps us see the urban mosaic in terms of its connectivity for not one or a few transportation modes, but for the many different types of organisms co-inhabiting the city, and for energy, biogeochemicals, sewage, and other materials, intentionally or inadvertently passing through. Landscape ecology opens us to explore the complex scaling rules that explain how the ever-changing interactions of the city work themselves out at different levels and for different reasons and into different spatial forms. Similarly, the tools of a wildlands landscape ecologist can provide insights for the technologically-minded urban planner, who deploys GPS, GIS, satellite imagery, aerial photography, computer modelling, visualization, and so forth to make a better landscape of ecosystems, that is, a city.

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Nancy is an ecologist studying interactions of climate change, human activities, resilience, and biogeochemical processes in urban and stream ecosystems. She currently co-directs the Urban Resilience to Extremes Sustainability Research Network. She is editor for Earth's Future, Ecohydrology, and J Urban Ecology, was a lead author for the 2014 US National Climate Assessment.

More From this Author

understanding these complex, heterogeneous, adaptive, self-organized systems? Over the past twenty years, urban systems have come to be seen as complex, adaptive, social-ecological-technological systems (SETS). Yet the core ecosystem concept remains fundamental to understanding them. It is a simple idea that can accommodate the complexities of diverse components arranged in space in a variety of ways, as well as dynamic change, that are hallmarks of urban systems.

> ***As ecologists we would be arrogant to assume that our models alone suffice to understand the multifaceted drivers of change. It's imperative to continue to expand the concept of the urban ecosystem to incorporate a multidisciplinary view.***

The ecosystem concept is the foundation of my thinking, originally as a stream ecologist but then as an urban ecologist. An ecosystem is a piece of Earth (writ large) with biotic and abiotic elements (i.e., the structural components of the system) that interact within a boundary. The interactions involve energy, matter, and information; ecosystem ecologists often refer to these as *function* but a more general term is *processes*. The boundary idea sets some folks off: if we can't see a clear, unvarying boundary, then the ecosystem can't be a real thing. But in fact, the fluidity of the boundary (and our ability to define it to suit our purposes) is perfect for urban ecosystems—systems that have massive throughput (movements of materials into and out of the ecosystem) and large dependencies on external, connected ecosystems. If we identify a boundary for convenience sake (for example, a jurisdictional boundary or a transport boundary), we can quantify these movements across the boundary and that dependence becomes a definable characteristic of the system (i.e., internal stocks relative to import rate gives us residence time for a material).

Ecosystem structure in urban ecosystems is unique. Not only do we have the organisms within populations that are structured and located in space; we also have the artifacts of human enterprise: the built environment. And we have unseen structure, for example of culture, government, economic systems, and power hierarchies. These additional elements of structure don't negate the idea of cities as ecosystems but they cause us to ponder the types of biotic and abiotic elements that make up these ecosystems. The SETS concept helps to incorporate the built environment and social institutions;

the most important thing about SETS is that they are systems. This means that we cannot consider the parts in isolation, since they interact to form the whole.

As with structure, some of the processes and material, energy, and information flows of cities are unique in character. For example, the exchanges of information in social networks via the internet are phenomena that change so rapidly today they defy understanding using traditional ways of knowing. Yet these information pathways may drive dynamic change in urban ecosystems. A key characteristic of ecological processes in urban ecosystems is the degree to which human decisions control them – usually, quite a lot! For example, we know that instead of traditional biophysical variables that determine rates of primary production in Phoenix, it is the amount of outdoor irrigation, which is subject to the whims, desires, financial capacity, and access to infrastructure of urban residents that sets the rate of production.

Traditionally, the ecosystem concept hasn't handled spatial heterogeneity well (think of the classic 'black box' approach to ecosystem energy budgets). The rise of landscape ecology, with its recognition of multiple systems arrayed in configurations that could affect process, was therefore a boon to understanding our world. And so it was for urban ecology: urban ecosystems are very heterogeneous on some scales, more so than many 'native', non-urban systems, and urban ecologists have recognized that heterogeneity as key to understanding cities. Deciphering how the configuration of parks, rivers, transportation infrastructure, housing developments, and central business districts affects biodiversity, ecosystem function, or ecosystem services is an important frontier for building sustainable cities.

Change is ubiquitous in the Anthropocene. Urban ecosystems are subject to massive change driven by social, ecological, and technological processes. Ecological theory—for example, disturbance theory (*Grimm, Pickett, Hale, and Cadenasso, 2017, Ecosystem Health and Sustainability 3(1):e01255. 10.1002/ehs2.1255*)—can contribute to our understanding of change. Yet as ecologists we would be arrogant to assume that our models alone suffice to understand the multifaceted drivers of change. The imperative is to continue to expand the concept of the urban ecosystem, bringing in the extensive knowledge of cultural and social systems, values, and hierarchies that has developed through the work of our social-science colleagues, the knowledge of infrastructure needs from our engineering

a pathway to transformative action for our cities.

## Kristina Hill

Cities *are* a type of ecosystem, because they contain all the components and connections we use to define such systems. But since they both include and are shaped by people, urban ecosystem research is more akin to medical research than to traditional ecological studies. Like medical research, urban studies require the articulation of an ethical framework before questions, methods, or conclusions can be developed. The scientific method should not be applied to cities without the use of an explicit ethical frame.

About the Writer:
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More From this Author

Urban ecosystems have been studied for more than a century. For more than 100 years, urban ecological theories have developed from the idea that natural processes, built environments and human communities are part of an interacting system of stocks and flows. As early as 1829, J. C. Loudon proposed a design for London using concentric greenbelts to improve air quality and human health. Large-scale urban design interventions were constructed in New York and Boston by Ellen Swallow Richards and Frederick Law Olmsted, with the explicit aim of influencing human health and urban ecology as early as the 1870's. These projects launched the American professions of landscape architecture, environmental engineering and public health. Current urban design efforts based on Olmsted's early examples often contribute to urban stratification by social class. In the 1960s, Donella Meadows and her colleagues at MIT applied the system concept to human populations, economies and natural resources, in order to model the possible consequences of the over-use of natural resources. Their results have often been used to argue for limits on population growth in developing countries, with negative consequences for women. Herbert Sukopp studied ecology in cities, focusing on the

> ***Cities meet the definition of ecosystems, with important limits—understanding urban ecosystems must start with an awareness of the ethical and conceptual pitfalls of studying human behavior without considering human values.***

In contemporary ecology and planning, a group of scientists and planners in the San Francisco Bay area are actively using the concept of “Operational Landscape Units” (OLU’s) to build a map of estuary shoreline reaches in which processes establish a pattern of connections, similar to a watershed but based on nearshore geomorphic and hydrologic processes as well as upland flows. These OLU maps will become the basis for planning urban adaptation strategies for sea level rise. They are based on the concept of an ecosystem, with stocks and flows, as well as theories about spatial connectivity that come from landscape ecology. Urban OLU’s are becoming an important vehicle in the SF Bay region for understanding linked systems driven by groundwater dynamics, sediment transport, wave energy regimes, sewer pipes forming “sewersheds,” and gradients in salinity and water quality, among other human and non-human drivers. This approach will help us come up with urban designs for coastal adaptation to flooding while supporting biodiversity and ecosystem services, which we would otherwise lose if we protect cities with new storm surge barriers, seawalls and levees alone. It will also identify surprising vulnerabilities in our existing underground infrastructure systems, and allow us to predict new contamination risks that will affect many lower-income communities.

I argue there are important limits to the successful application of ecosystem concepts to humans and the built environment. When E.O. Wilson sought to extend evolutionary genetic theories to human societies in the 1970s, critics were quick to point out that culture and social environments also shape human behavior to a very significant degree. Ethical questions immediately emerged about the scientific characterization of human behavior, and the extent to which it is determined by processes of natural selection or by individual choice and social communities.

Anyone who studies urban ecosystems today must start with an awareness of the ethical and conceptual pitfalls of studying human behavior without considering human values. Applying the concepts of dominance and competition to human social and biological diversity provides a case in point. Research shows that exposure to lead in soil reduces learning ability, and that exposure to air pollution causes genetic damage in human children. If those children are subsequently disadvantaged in social competition, implying that this is “natural” (i.e., the result of natural selection), would be both incorrect and reinforce the repressive dynamics of the economic concept of social class. If urban

behavior require a clear ethical foundation. The limits in this context reveal the limits of scientific method generally, which is that our selection of research topics, our approaches, and the uses of scientific findings are all influenced by power dynamics within human societies.

In summary, I would argue that while urban systems can be studied as ecosystems, an ethical framework is required *a priori*. Ethical perspectives will change over time, as culture changes. But the need to understand social influences on scientific research – both in development and in application – is acute. Without a clearly articulated ethical framework, scientists should recognize the philosophical limits of the scientific method by restricting themselves to the study of ecology “in” cities, not “of” cities.

List of writers

*Grunewald in Berlin was the kind of landscape studied by Herbert Sukopp in the early days of urban ecology, circa the mid 1970's. It was a politically symbolic landscape as well as an ecosystem inside the city walls.*

## Dagmar Haase

Does thinking explicitly about cities as ecosystems offer us any insight into urban design? Are our goals for cities—sustainability, resilience, livability, and justice—advanced by an urban eocsystem concept? Some reflections based on my research on urban ecosystems in national and international contexts: Over the last two centuries, both scale and rate of change of cities have developed rapidly. Yet in terms of space, less than 5 percent of the Earth's surface is urban. And not all urban areas are expanding or expected to grow in the future.

About the Writer:

List of writers

activities are in the combination and integration of land-use change modelling and the quantification and assessment of ecosystem services, disservices and socio-environmental justice issues in cities and urban areas including urban land teleconnections.

More From this Author

almost invisible spaces between buildings and open soil or unused constructions and in the number of species that use them such as raccoons, the green woodpecker, Acer species (maple), or cactus species. What has become clear in recent decades, starting with the Millennium Ecosystem Assessment and strongly supported by the Economics of Ecosystems and Biodiversity-TEEB-process and protocol since 2009, is that ecosystems in and of urban areas—urban ecosystems—can provide a range of benefits that include recreation facilities, local food production and, most importantly for coastal cities, storm water control, to sustain and improve human life, health and well-being.

***sectoral thinking and actions that favour more holistic concepts of urban, regional and local regeneration, resilience and adaptation.***

Understanding how such urban ecosystems function, how they change, and what limits their performance can add to an understanding of ecosystem change and governance in an ever more human-dominated world. Is there a novel concept or a new way to approach this? Recent ways of thinking combine both to promote dialogue between academics and practitioners in the field of urban ecosystems and ecosystem services and to build a novel framework of co-evolution in today's cities. It is vital to recognize that urban systems are both highly complex and a product of ongoing emergence, suggesting the need for co-evolutionary approaches to managing the city as a social-ecological system and the integration of ecosystem approaches into spatial planning frameworks. For example, plans encouraging a compact city model could be used in combination with interim-use sites designated in the inner city as temporal refuges for nature, ecosystem services and nature experience by urban residents in the form of a participatory co-development process and multi-stakeholder usage. Thus, the rather static compact city model also includes temporal-spatial windows of green, spatial flexibility and land-use dynamics. Co-evolutionary planning and governance also mean the elimination of sectoral thinking and actions that favour more holistic concepts of urban, regional and local regeneration, resilience and adaptation; this approach includes the global context and network, which involves many and varied actors.

Not exclusively in shrinking cities, but most notably, the concepts of green and blue services provide the potential to move from a comparatively simple "land-use view" of green, brown, and blue areas in cities toward a valuation of ecosystem goods and processes and spatial potentials for each piece of land. A co-evolutionary approach also needs to explicitly address the technological, transport and built

By contrast, more flexible ecosystem-based solutions include elements and processes of urban nature, such as green and blue infrastructure, permeable pavement, and nature imitations such as bioswales and wetland-like constructed retention basins, to name a few. They afford both city dwellers and planners a new way to think about risk and safety based on the dynamics of nature and ecosystems. For example, an ecosystem could be designed so that it does not completely prevent water from entering an urban environment but instead reduces the amount and velocity of the water and thus the risk to people; the same design keeps water in the city as buffer in times of drought and heat.

Thus, in the long run, nature-imitation, or biomimicry designs help cities live with nature and become more resilient and prepared for different types of hazards. Such nature-based solutions mediate the relationship between human activities and ecosystem processes in urban landscapes and, if developed appropriately, could mitigate human impact. In developing nature-based solutions for a city, including the co-existence of built, grey, brown, green and blue places, it is essential to include the full spectrum of urban land uses.

Despite the considerable progress in urban planning, governance and land management, a fundamental rethinking is urgently needed regarding what makes both the natural—urban ecosystems—and built “infrastructures” of the urban community adaptive and resilient to current and future social-ecological challenges, such as flood and storm hazards, other climate extremes, air pollution and large-scale economy-driven land-use interventions such as densification and gentrification.

*The Clara Zetkin Park in the city of Leipzig, a wonderful expression of the human habitat in urban areas. Photo: Dagmar Haase*

*A green roof in the city of Leipzig—another wonderful expression of the human habitat but also flora and fauna habitat in urban areas. Photo: Dagmar Haase*

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Web More From this Author

in conjunction with the nonliving components of their environment interacting as a system. Eugene Odum (1971) expanded the definition, calling it "a unit that includes all the organisms, i.e., the community in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles, i.e., exchange of materials between living and non-living, within the system" (p.12).

But one key element—the dominance of humans—makes cities different from many other ecosystems. And that changes everything: composition, processes, dynamics, functions (Alberti 2016). By building structure and infrastructure in cities to support their needs, humans redistribute organisms and the fluxes of energy and materials leading to a distinct biogeochemistry (Picket et al. 2001, Grimm 2008), biotic diversity (Groffman et al 2014), and energy and material cycles (Bai 2016).

All organisms modify the environment to create their habitat and facilitate their survival, and humans are no exception. Darwin (1881) spent his final years observing and describing the effects earthworms had on soil formation. Earthworms feed on plant debris and soil. Because they concentrate the organic and mineral constituents of what they eat, their casts contain more available nutrients than surface soil. Beavers build dams that dramatically alter riparian landscapes across North America—and thus maintain and increase both species richness and habitat heterogeneity (Wright et al. 2002). Ecologists have documented how the changes of many organisms—the ecosystem engineers– can influence organismal distribution and abundance and ecosystem processes at the local and larger scales (Wright and Jones 2002).

So what makes cities different? Although we do not yet have conclusive evidence on whether species diversity and energy flows in cities are qualitatively different, or simply an end point of a continuum, urban ecosystems operate outside the envelope of values observed in natural systems (Grimm et al 2008). Compared to systems not dominated by humans, urban ecosystems are highly disturbed environments (Grimm et al. 2017), very heterogeneous in both space and time (Pickett et al. 2016): complex mosaics of biological and physical patches in a matrix of infrastructure, human organizations, and social institutions.

those used to study other species' habitats that fully acknowledges the complexity of the human species and societies. Often we study cities as ecological systems, disregarding the fundamental fact that they are built for humans. Developing a theory that fully includes humans as key agents of ecosystems will require an extraordinary new collaboration among a broad range of disciplines.

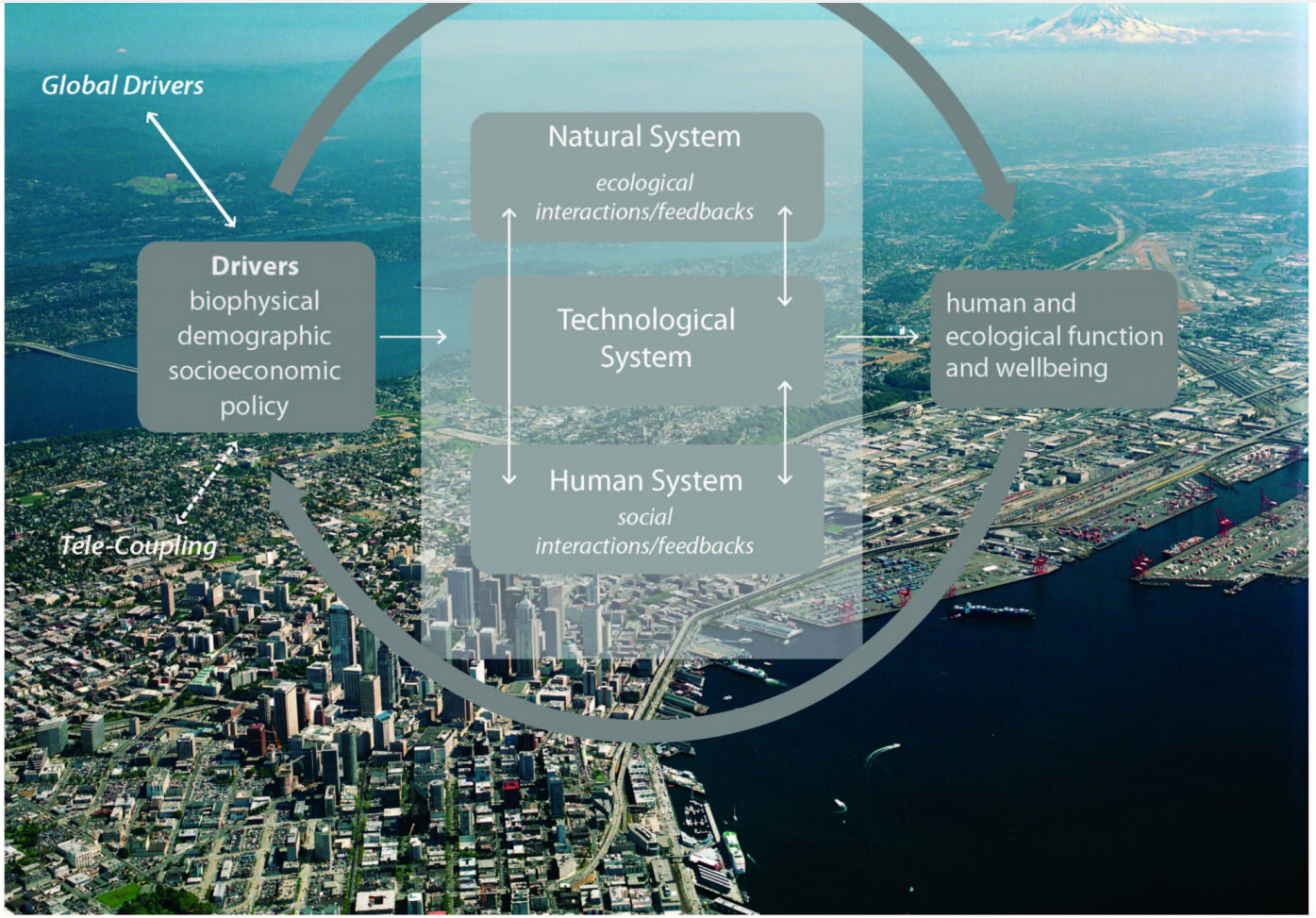
> ***Instead of aiming at control, we must embrace uncertainty and redefine principles of design to acknowledge the complexity of hybrid ecosystems—expanding the heterogeneity of forms and functions in cities to support both human and ecological functions.***

The *ecosystem concept* in ecology does not fully reflect our current understanding of dynamic human-dominated ecological systems that may operate far from equilibrium (O'Neill 2001). In his MacArthur Lecture in Ecology, Robert O'Neill (2001, 3276) argued that the assumptions behind the ecosystem paradigm limit our thinking and the questions we ask because they emphasize some properties of nature while ignoring others (Alberti 2016). Crucially, ecosystems can change state in response to a spectrum of variable conditions (Holling 1973); they have evolved over millions of years through changes in biotic-abiotic interactions. But since the Industrial Revolution, humans have increasingly dominated such interactions, creating novel ecosystem functions never observed before (O'Neill 2001; Tilman and Lehaman 2001). Yet in ecology, humans are the only species considered to be external to ecosystems. Furthermore, emphasis on the self-regulating nature of ecosystems has limited the view of disturbance that we now know is critical to understanding stability and ecosystem function.

During the past hundred years, advances in the scientific understanding of ecological systems have called for integrating humans into ecology (Alberti et al. 2003). In ecology, scholars no longer see ecosystems as closed, self-regulating entities that "mature" to reach equilibrium. Instead, they acknowledge that ecosystems have multiple equilibria and are open, dynamic, highly unpredictable, and subject to frequent disturbance (Pickett et al. 1992). But only in the past decade have scholars of urban ecology started to expand their conceptual frameworks and methods of analysis to better represent socioecological interactions (Pickett et al. 2013). To study urban ecosystems, we must integrate multiple agents and boundaries and analyze processes at multiple scales, ranging from local to metropolitan, regional, and global. We must also explicitly represent human agents and link urban structures, biophysical processes, and human behaviors to ecosystem functions.

### Cities as hybrid ecosystems

components of urban ecosystems (Alberti, 2016 (figure below). From an ecological viewpoint, they differ markedly from historical ecological systems (Milton 2003). But urban ecosystems also differ significantly from historical human settlements: they are novel habitats and contain both natural and human historical features.




*Credit: The Urban Ecosystem, Alberti 2017, in Press*

I suggest that if we are to understand ecosystems in which humans are the key players, we need a paradigm shift in the way we study these ecosystems (Alberti 2016). As hybrid ecosystems, cities operate at the border of a phase transition between alternative behavioral states governed by either historical or novel feedback mechanisms. As ecosystems are increasingly dominated by human action, they move toward a new set of feedback mechanisms. Their state is unstable. We can drive them to collapse or we can consciously steer them toward outcomes we desire. But what is a desired

## Designing urban ecosystems

We also need a paradigm shift in system design to accommodate the complexities in these highly interdependent and adaptive hybrid urban ecosystems. Myths and uncorroborated assumptions about how nature works, have led to failures in designing and managing urban environments (Holling et al. 2002). The assumptions that the elements of a system can be controlled and their boundaries can be defined have dominated system design and engineering for a long time influencing both the field and the practice. Urban designers and planners, for example, have assumed for a long time that ecosystems are stable and that their processes and dynamics are relatively well understood and predictable, thus one can find an optimal solution among a set of possible alternatives—but that is clearly not the reality in urban ecosystems.

How do we design complex hybrid systems in which the components are highly diverse, interconnected, and interdependent? (Alberti 2017, In Press) How can we design and build infrastructures that are resilient to unexpected and uncertain environmental change? How can we coordinate the interventions of diverse institutions operating at many scales under a diversity of constraints? How can we resolve conflicts among multiple stakeholders?

Instead of aiming at control, we must embrace uncertainty and redefine principles of design to acknowledge the complexity of hybrid ecosystems. This implies expanding the heterogeneity of forms and functions in urban structures to support both human and ecological functions and supporting modularity of infrastructures to create interdependent decentralized systems. We need to expand our capacity for experimenting and learning. And most of all we need to find new ways to creatively engage the communities in designing the cities of the future.

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List of writers

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More From this Author

development and regenerative development. We cover 4 points in response to the above challenge. We argue that cities are ecosystems but they are not well adapted to place; cities have not learnt from the nature of place and have displaced its ecological functions; cities have not yet reached their full ecological maturity or potential; and, how our cities can learn from nature strategies to benefit all life.

Imagine walking through a tropical rainforest. Light is dappled and muted, the air is warm and steamy. Trees reach for the sun, harnessing freely available energy that nourishes the whole system; they provide support and scaffolding for mosses, lianas and epiphytes that add complexity to the forest's architecture and they in turn provide habitat and niches for other organisms. Water is a precious commodity that is harvested, filtered, stored and cycled through the system. Below your feet, the ground is moist and teeming with unseen life breaking down forest debris, silently cycling nutrients that promote the growth of the rainforest. Mycelial networks connect the trees below the soil, transferring information and resources between them. Everything is intertwined and interdependent; all elements of the rainforest inadvertently collaborate to nurture a thriving system greater than the sum of the parts.

Our cities are ecosystems too but they are currently not as well adapted or resilient as the ecosystems they've disrupted and are nested within. While life abounds in cities, diversity is limited and dominated by one species. Cities are the culmination of our species' survival strategies, helping us mitigate the extremes of environment, shaping our culture, and extending our range on the planet.

> ***Cities are ecosystems but they are not well adapted to place; indeed, we have displaced their ecological functions. For this reason, cities have not yet reached their full ecological maturity or potential.***

There is no doubt that humans are clever ecosystem engineers. We have transported, accumulated and consolidated many resources to shape our cities and yet, for all our cleverness, we have forgotten that we are part of nature and subject to the same rules as the rest of life.

List of writers

Thrive research hub at the University of Melbourne. She works on projects aimed at co-creating a thriving future.

More From this Author

*What if our cities learnt from mature ecosystems like the rainforest?*
*Photo: Jane Toner*

Cities have often replaced the ecosystem services freely supplied by nature with engineered systems that are more energy intensive, less effective and that create other problems solved in a similar fashion.

cycling carbon, trapping nutrients, decomposing matter, recycling waste, filtering water, and pollination.

If we view cities as ecosystems yet to reach maturity, we can plan to enhance their capacity to support life, human and non-human by learning from organisms and systems adapted to the same place and have solved the same challenges. For urban design, this means that our cities need to evolve symbiotic relationships with organisms that provide ecosystem services. We can do this by creating a complex array of varied niches at different scales, different levels of contribution to increase the emergent evolutionary potential of cities.

*Lichen is a mutually beneficial symbiotic relationship between algae and fungus. Fungus provides the structure while algae provides energy harvested from the sun.What if our cities had a mutually symbiotic relationship with nature? Photo: Jane Toner*

For urban design, the implications are transitioning the city to be better adapted and more resilient. By integrating nature to restore ecosystem services we also meet our own biophilic needs, increasing the potential for human health and happiness. We are a young species still learning how to fit in and it is time we remembered that we are nature and that connection with it promotes our own well-being.

What needs to be valued is that, as Australian indigenous culture suggests, cities also have a potential role in benefiting nature. That is, the human capacity within the city can understand future change and therefore support nonhuman systems to better adapt. Designing this mutual reciprocity into our cities is the challenge of the future.

We have countless opportunities for our cities to become mature ecosystems embrace this relationship by relearning and applying the deep patterns that nature has evolved to survive and thrive on Earth.

systems that promote and reward interconnection and interdependence. Cities have also evolved in a similar way, the layering here is historic and often based on ways of economic and industrial change. The challenge then is for the urban designer to think of a city as a constantly evolving co-managed rainforest, savannah or reef, intrinsically intertwined with the ecosystem in which it resides.

## Alexis Schaffler

### Cities as ecosystems—a cultural reflection

As an academic and occasional policy advisor from the Global South, “cities as ecosystems” has been an attractive metaphor. Intellectually, I was brought up by what I call academic activists or planners, taking on the challenge of urban sustainability in a context of familiar development struggles. Our context commonly appears in terms of ‘unprecedented’ urbanization, often without the necessary growth; inequality and unemployment; and perverse infrastructure legacies of unsustainable resource use and environmental degradation.

About the Writer:
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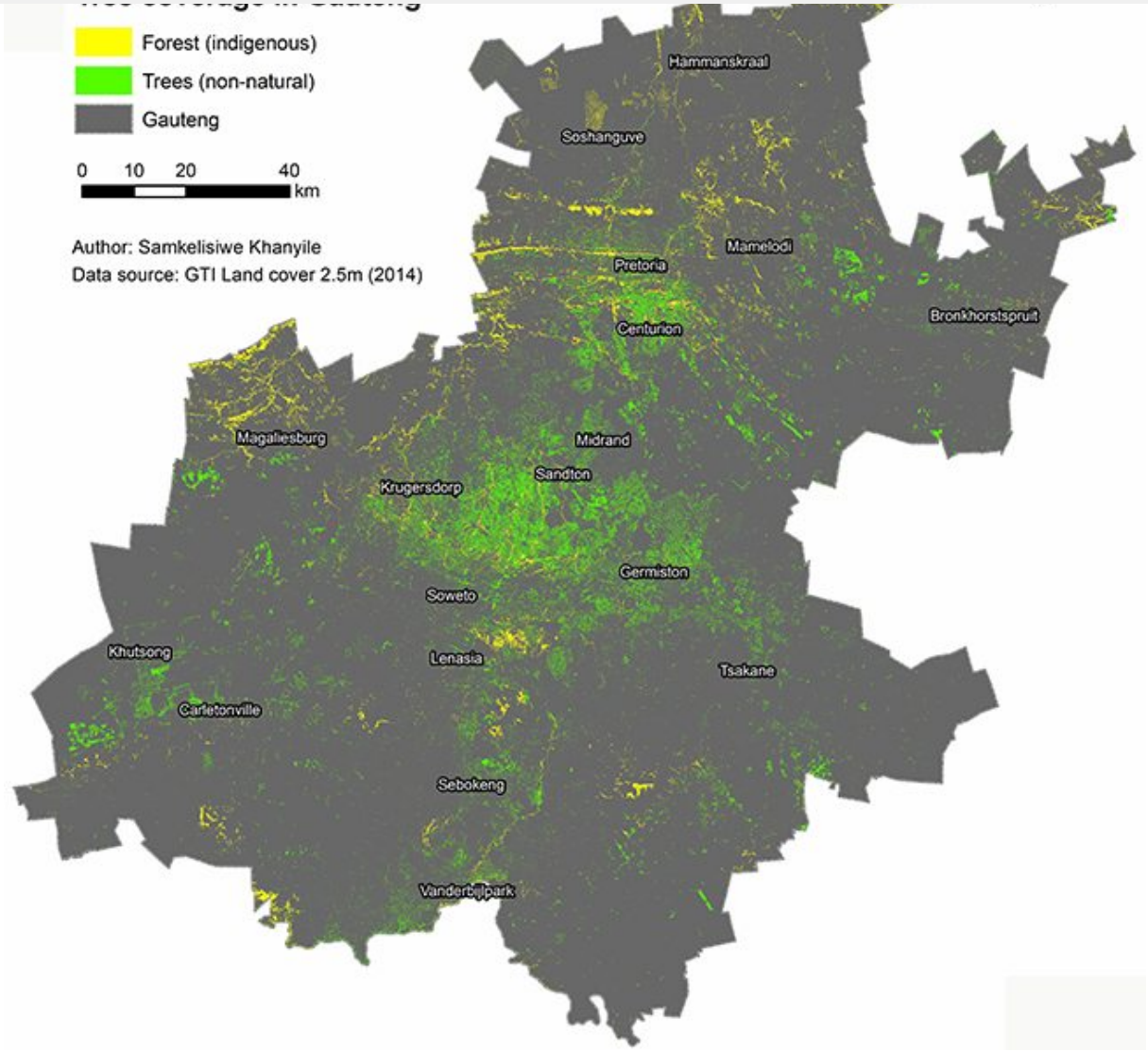
Alexis is a doctoral student from UC Berkeley's Department of Landscape Architecture and Environmental Planning, at the College of Environmental Design. Her research interest is the shift towards multifunctional infrastructure, a framework that connect commonplace services such as transport, potable water, sanitation, housing with other functions, such as ecosystem services, climate action and sustainable resource use.

More From this Author

> ***Perhaps our insight is not really in viewing cities as ecosystems, but instead lies in how the cities-as-ecosystems idea causes our urban thinking and designs to evolve.***

Retrospectively, cities-as-ecosystems was a natural step on my journey investigating options for more sustainable urban futures. In 2013, I led a *Green Infrastructure* research project at the Gauteng City-Region Observatory (GCRO), a partnership between academic institutions and governments in South Africa’s smallest, but most densely populated urban region. Green infrastructure offered exciting analytical opportunities—we could develop impressive maps, visuals and economic values—to show how the region’s green assets form a network that provides ecosystem services in the same way as conventional grey infrastructure. In 2013, the GCRO published a *State of Green Infrastructure*, the first of its kind to visualize and assign economic, as well as cultural values to green infrastructure, the “interconnected set of natural and constructed ecological systems, green spaces and other landscape features.




*The indigenous and planted trees in Gauteng, strikingly showing the extent of tree cover within the urban core, roughly covering Johannesburg. Although the majority are planted and non-indigenous, the trees in Gauteng provide important services, such as air purification and erosion control. The map also demonstrates the power of high resolution satellitle imagery in mapping individual ecological assets such as trees (Khanyile, 2017).*

the world that assigns green infrastructure a monetary value, with the ultimate goal of incorporating these values into municipal budgeting and accounting procedures.

The endurance of the GCRO's green infrastructure work is inspiring. Compared to my preliminary, and admittedly naïve work, their current green infrastructure engages spatial, economic and social analyses that contain more of the necessary detail for understanding cities as ecosystems. While innovative at the time, our 2013 *State of Green Infrastructure* report encountered major data challenges as we learnt about the deficiencies of our local government datasets. This was illuminating, highlighting the critical role of data consistency and capacity, but it was also very costly, requiring the services of external data contractors with the requisite data and technical capacities.

Perhaps most importantly, the GCRO's *Green Infrastructure City-Lab* facilitates the sharing and co-production of knowledge between government officials and other stakeholders to develop green infrastructure within municipal planning (Culwick & Bobbins, 2014). This is a welcome resolution to our early situation with local government databases. The connection and interest between scholars and government practitioners may well prove the most important anchor in future work. There are important movements to watch within some of Gauteng's local governments expressing interest in green infrastructure as a more formal strategy for urban planning.

Yet, I am also cautious of the above in my current role as a PhD scholar at UC Berkeley's College of Environmental Design. In part, there is a romanticism in thinking about cities as ecosystems, particularly whether green infrastructure can truly contribute to meet our ever-demanding human needs. We also have to be wary of the attractive, yet rather ambiguous, renditions that use ecology to model urban processes. This is most clear in the North American discourse, *Landscape as Urbanism*, with a following of 'intellectual' designers, eluding to ecology in their vocabulary but largely producing intriguing visual renditions and models of cities as complex ecosystems (Duany et al., 2013; Corner, 1999: Waldheim, 2008).

I do find conciliation in remembering the linage of 'bringing nature back in' to urban design and planning. Olmstead's 'parkways' concept, Howard's *Garden Cities*, proposals in Spirn's *The Granite Garden* (1965), McHarg's *Design with Nature* (1969), and Hough's City *Form and Natural Process* (1984)

wide net of intellectual idealists and activists, but perhaps our insight is not really in viewing cities as ecosystems, but instead, lies in how the cities-as-ecosystems ideas causes our thinking and designs to evolve.

One of the best lessons we receive is, of course, from practice. Portland, Oregon, presents a unique case of two sustainable urban design experiments attempting to integrate social and ecological functions. The New Urbanist project, Jamison Square, includes an iconic fountain, a boardwalk, an outdoor gallery and often features in media as a socially vibrant, active and lively public space" (Senville 2015). In contrast, Tanner Springs Park, emerging later in the city's history as a Landscape Urbanist project, primarily a stormwater project that transitions from a relaxing meadow with stone walkways, a cleansing biotope and wetland plantings (Senville 2015). Duany et al. argue that Tanner Park is largely devoid of humans, rather focusing on maintaining prairie grasses and preventing the adverse aesthetic effects of citizens' and animals feet and posteriors (2014).

The social and ecological differences of Jamison Square and Tanner Park are not necessarily unhelpful trade-offs. There is immense value in foregrounding the vital functions performed by landscapes, such as mitigating climate or providing drainage. Highlighting landscape infrastructure as well as the more commonplace, albeit often invisible networks of transit or waste disposal systems also opens urban design to the crucial sustainability question of how to sustain urban functions given available resources. The conundrum in designing more sustainable urban forms is therefore how to provide for social and ecological urban functions in a way that resonates with humans, without comprising affordability nor the requirements for density, mix and scale (Kelbaugh in Duany et al., 2014, Hill & Larsen, 2014). As Thompson reflects, while working through the nature-cultural dichotomy is complex and challenging, urban design experiments are an essential part of responsive, creative and catalytic thinking about the major structuring elements of urban form (2012). While sustainable urban design experiments often reveal the discontents of paradigmatic thinking, they are also significant as empirical opportunities to critically reflect on the realities of ecological *and* social integration in urban form.

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More From this Author

There is a better comparison: with complex living organisms in all their three-dimensional glory.

Ecosystems are certainly crucial to the health of their living inhabitants. And certainly lessons like “conserve energy and utilize renewables primarily” and “recycle assiduously” are good lessons for the functioning of cities as well as relevant models for our education about biological systems of rich biodiversity and high biomass. As individuals and groups of people, we are fed by the environment and by observing, say, trees that grow great and provide shelter from rain and wind in their hollow trunks, or under their big branches, we can learn something leading into architecture, for example. Maybe that’s where architecture started.

> ***Comparing our cities to complex living organisms seems much more fruitful—in other words, to our own bodies, our organ systems, our limits. I think of this as the “anatomy analogy”.***

But where cities have come to date is something far more complex: add to buildings systems of transportation, paved and rail, supply delivery, recycling and waste disposal back into the environment, public open spaces such as parks and plazas, designed treatment of elements of nature from river and water fronts to rooftop gardens and window box gardens attracting hummingbirds and bees. Then there are special function organs like restaurant, arts, education and medical districts and the various zones of built infrastructure for various other functions, neighborhoods of different cultural emphases. So though there is much to consider regarding designing healthy cities to be gained by looking at the way our all-embracing environments work, there is much more to be learned from complex living organisms.

In fact, the more I think about it the more I think we are off on the wrong foot to make a big deal of the analogy between cities and ecosystems. In a sense, that’s what sprawling suburbs do. Comparing our cities to complex living organisms seems to me much more fruitful, comparing cities, in other words, to our own bodies, our organ systems, our limits. I think of this as the “anatomy analogy”.

There is a basic mathematical truth at the heart of the universe here, a geometric truth: complexity becomes well ordered in three dimensions, like the compact ultra efficient form of living beings like us.

*Nature hints architecture*

That two-dimensional layout of ecosystems is not purely so–of course. Take a kelp forest 250 feet from anchorage to top, or a redwood forest towering almost 390 feet tall, more including roots, 3-D to that degree. But the general and overall form, covering vast areas of land and waters of these environments is basically 2-D.

At the core of the issue is that three dimensions works—overlapping lines of connection, either by simply "bumping up against one another, one function to another" and with overlapping veins, nerves, lymph ducts, digestive/excretory tubes, etc. But try to squeeze it all down to the flats like suburbia tries to do and you have a tangled mess of concrete and steel freeway over- and underpasses, miles and miles of pipes and wires that in the compact form of highly mixed uses well organized is much, much shorter, more materials and energy conserving.

This is the basic formula also expressed as "access by proximity." My father, a sailor and a pilot, liked to say, imagining tacking toward the finish line, "the shortest distance between two points is a straight line".

But the more fundamental truth is "the shortest distance between two points is moving the points close together". You can't get more basic than that and that's exactly what's at the basis of the preference for using the complex living organism as an urban model over the much more fundamentally two-dimensionally semi-organized environments of various ecosystems.

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More From this Author

introduced in the late 1990s and the holistic nature of this paradigm implies that the city itself is an ecosystem. But how is a city ecosystem defined? It is difficult to define the spatial contours of any ecosystem, and this is certainly the case in cities, where the ecological footprint can be many times larger than the geographical boundary of the city itself. The quantities of food, energy and other natural resources and products that flow between the city and its surroundings are very large relative to that which is cycled within the city. Environmental philosopher Mark Sagoff (2003) argues that we need to be able to define an ecosystem before we are able to understand it, to manage it, and to develop general theories of ecosystem functioning, but that in fact we lack the "criteria that determine what kinds of things count as ecosystems". The challenge for urban areas is how we can define a single ecosystem that encompasses all the variability that characterises any given city. If we are unable to identify a single ecosystem we can't then re-identify it over time and in the face of change.

An analysis by Cadenasso and Pickett (2008) of urban principles for ecological design and management, applies a widely-used definition to assert that cities are ecosystems; i.e. that they have "interacting biological and physical complexes". The additional complexity added through acknowledging the role humans play in urban ecosystems, and the patterns and processes that result from interactions between social, built, and ecological components of the system, are seen as extensions of the basic ecosystem concept. It is possible though, that such an over-inclusive definition, which implies that the ecosystem can be of any size, with boundaries defined only by the research questions, might hinder the development of theories of ecosystem functioning that could be generalised across many cities.

> ***Thinking about a city as a collection of ecosystems influenced by their surrounds could be a more helpful way to inform urban design, and make it easier to identify the elements that make up each particular ecosystem.***

Cities vary hugely in size, spatial form, and history. I live in a city in New Zealand that is so small that people from more populated countries might consider it not to even be a city. In contrast to the high-density megalopolises, New Zealand's cities do not contain many millions of people, high-rise living, dense housing blocks, or extensive industrial and commercial area—rather they are cities of sprawling

Can ecosystem theory developed for huge cities, or very old cities, be generalised to newer small cities such as those in New Zealand? Perhaps it would be more useful to think of cities as collections of ecosystems. After all, if no settlers had arrived to occupy the space where I live, ecologists would not treat the area covered by my city as one ecosystem, but as coastal, sub-alpine, swamp, mixed-podocarp forest, and freshwater ecosystems, to name a few. Cities often occupy large areas and show very high cultural and socio-economic heterogeneity, as well as heterogeneity of land covers imposed on a variety of natural landforms. Treating the city as one ecosystem overlooks this variety.

Cities are usually characterised by significant dynamic change. Rapid changes in human population size and composition are followed by major changes in land cover characteristics and built infrastructure, which affect processes such as primary production and nutrient assimilation, as well as biodiversity characteristics, connectivity, and the production of goods and services. Interactions and feedback loops between social and ecological factors continually evolve in response to different cultural and socio-economic influences. In the face of constant and massive change, that can occur at different rates and in different ways across a city, is it appropriate to consider the city as one and the same ecosystem over time?

**Does thinking explicitly about cities as ecosystems offer us any insight into urban design?**

The holistic approach that is implicit in our understanding of ecosystem function, which recognises interactions and connections between constituent living and non-living parts, should provide pathways for better, more liveable urban design. The paradigm “ecology for the city” (Pickett et al. 2016) recognizes the applied role of ecological research and a responsibility to create a sustainable, liveable and resilient urban environment, and the term ‘ecological urbanism’ has been adopted to describe a more holistic approach to the design and management of cities. Resilience goals might be met using a socio-ecological approach, which acknowledges the unpredictability and complexity of city systems. This kind of holistic approach has been used at least in the short term in New Zealand, after the 2010-2011 Christchurch earthquakes, to not only restore the city to its previous state, but also to introduce regulations to ensure that the city would be better able to endure future disturbances.

such as a collection of suburbs or a neighbourhood as an ecosystem, would be useful, as ecological concepts could then be applied to urban design within and immediately around that space. For example, urban design could accommodate connectivity across suburbs and between other parts of the city in the spatial configuration of public and private green spaces and the location of highways and other transport corridors. Urban design could mitigate the impacts of hard edges, where suburbs abut onto other, less biodiverse, land covers. A holistic approach would accommodate the significant and dynamic human influence on management of private green spaces, and recognise important interactions, such as those potentially existing between human well-being benefits and biodiversity benefits. Thinking about a city as a collection of ecosystems influenced by their surrounds could be a more helpful way to inform urban design, and make it easier for us to identify the elements that make up each particular ecosystem.

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## Erik Andersson

Were cities ever anything other than ecosystems? With additional layers of complexity added to them, of course. I like to think in terms of principles, connections and functions, and they relate to systems,

List of writers

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high degree of facilitation. Reframing urban studies in ecological terms may be more or less informative. There certainly are cases where I think ecology can help highlight implicit or neglected system characteristics that would merit more attention. Cities have been conceptualised as ecosystems before, but digging deeper into ecological theory exposes a number of insights and considerations that could be interesting for a broader discussion of what cities are and how they work. And, as the logical follow-on, how they could work differently.

> ***More organic, constantly changing and evolving cities could help to shift worldviews back to being grounded in change and changeability rather than control and permanence.***

I will limit myself to two points here, one on time and one on space, and both concerned with function. Space first. Connectivity and the flows and exchange it facilitates is a central concern in cities, and one most obviously manifested in different infrastructural systems. With an emphasis on *structure*, physical structure. Ecology emphasises that connectivity has two aspects, structural and functional connectivity. I think we sometimes believe that structure is everything; instead, our perceptions, and how we act on them, may be quite as decisive. Connections exist where we understand them to exist, barring some clear misunderstandings. And connections are not just about getting from A to B; while we believe in our maps, sectoral divisions, and clear delineations ecological theory and research points to the importance of edges not as lines but as zones of mixed influences and different functionality.

Then there is the issue of time and our preference for clear and bounded functionality. There is a potential clash between the selective forces at work in and on cities. Considerable human effort and ingenuity have gone into trying to make cities into something other than ecosystems, yet perhaps now is the time to allow them to be ecosystems. Why? Ecosystems come with temporal dynamics, change, cyclicity and evolution. Cities have been prime examples of command and control approaches where built infrastructure is intended to last, and often to support the same function throughout its lifespan. Evolution has proven the utility of open-ended functionality by showing how tweaking the same design just a bit can provide a different, or added, functionality. Invention is more often a case of bricolage and making use of what is already there, with a clear parallel to evolution, than a result of intentional creation of something truly ‘new’. Making urban design a bit more open-ended would do loads of good for cities’ capacity to adapt.

surroundings actually is the system. A functional understanding of the city, one based on interactions, similar to that of ecosystems could provide a fresh perspective on design needs and ways we could think about our cities. It is no news that experiences and perceived qualities depend on multiple, interacting factors, where individual components may change. For example, we don't really want the physical streets and roads when we build infrastructure, we want the function of mobility, which is generated by our understanding and use of structure. Which may shift much more rapidly the structure itself. More organic, constantly changing and evolving cities could help to shift worldviews back to being grounded in change and changeability rather than control and permanence.

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## David Simon

I have always been wary of organismic analogies seeking to compare human artefacts such as urban systems or individual cities with the human body or natural systems because they never stand up to inspection. Even possibly the most famous analogy of natural systems across very different scales, namely James Lovelock's Gaia hypothesis, which likens Planet Earth to the human body, is analytically problematic despite its innate appeal as a rhetorical device.

Fundamental to natural systems, including ecosystems as variously defined (including the Science.com version cited in the curatorial note) is the holistic integration of all their components within a system which makes the whole more than the sum of its parts and is normally sustainable. That said, ecosystems are not closed systems since they exchange nutrients with adjacent systems through different mechanisms, in part through being open to the atmosphere, soil and groundwater.

> ***Perhaps in the future, the ecosystem analogy might become more apt, but at present it is unhelpful and inaccurate, obscuring or concealing far more than it might superficially promise as heuristic device.***

Individual cities are also open, indeed, far more so than ecosystems: there are constant inward and outward flows of resources and wastes of various sorts, commodities, people and finance. Despite our current and very necessary preoccupation with urban sustainability, no individual city or even system (network) of cities is sustainable in the sense of being autochtonous. No matter the extent of nutrient

and design. No city anywhere has ever been able to survive for an extended period when cut off from its hinterland and isolated, as in a siege.

My scepticism about the analogy rests on three main factors. First, no existing city is fully internally integrated and harmoniously or efficiently functional. The extent of dysfunctionality, or harmony versus conflict, varies greatly but the diversity of urban residents in terms of both visible and invisible markers, and their divergent or overtly conflictual interests, militates against this. Second, with very few exceptions like mining company towns, urban areas are not designed and built at one time to a comprehensive plan with the explicit intent of becoming a “complete” entity in any way comparable to an organism or ecosystem. Instead, they grow in phases, usually incrementally or with distinct new neighbourhoods being added, at different rates at different times. Over time there is also periodic decline, dereliction and eventual redevelopment of areas or neighbourhoods that become obsolete as a result of technological change or shifting trade and political relations, or become depopulated or economically or socially undesirable through changing income or social profiles and preferences. Third, governance is often deficient or dysfunctional, with urban politics revealing differing degrees of contestation among different stakeholders and tensions between social welfare and private or corporate profit.

That said, current urban greening initiatives, often including wetland and river rehabilitation; rewilding of derelict or biologically degraded areas; networking of open space systems; water reuse and recycling; and small-scale renewable energy generation are increasing urban biodiversity, enhancing climate change mitigation and adaptive capacity, and providing more “green” jobs and livelihood opportunities. To some extent, then, these may be integrating urban areas in novel ways, also softening or blurring some of the sharp discontinuities referred to above, and enhancing urban liveability and wellbeing.

Furthermore, some critiques of technocentric visions of smart cities and urbanism are beginning to gain traction and might shift the focus towards more locally appropriate and sustainable interventions. Perhaps in the distant future, the ecosystem analogy might become more apt but at present it is

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## Vivek Shandas

### Nature-Based Segregation: The inequitable ecological turn in planning practice

Walking down the residential streets in Seattle, Washington or Portland, Oregon, one cannot help to notice several small and vegetated areas that occupy portions of the street right of way. These minor changes to the urban landscape represent a physical manifestations of what I call an ecological turn in urban planning practice. This ecological turn refers to a change from two centuries of urban development that emphasized the importance of engineering systems for roads, buildings, and the myriad layers of infrastructure that make up our cities, to a recognition that patches of nature can provide services previously taken for granted or dismissed. Arguably, these attempts to change the gray infrastructure of roads and pipes to green receptacles to collect and infiltrate strormwater were the earliest modern examples of planning practice taking seriously the contributions in the field of urban ecology. As a result, cities around the world are attempting to reintegrate nature into human habitation, and increasingly looking to urban ecology for principles to inform planning practice.

> ***What then can be done to address the historical inequities of applying urban ecological knowledge to exclusionary planning practices? First is the recognition that urban ecological research is not value-neutral.***

While others on this blog are describing specific examples of nature-based solutions for cities, I argue here that the emerging ecological turn in planning practice remains conceptually and spatially a movement that benefits communities with privilege. Those who are white, higher-income, and educated have greater access to and benefits from urban nature, while those communities of color and lower income face a disproportionate burden from environmental pressures. These communities often live in “nature deserts” or places that are replete with the biggest disasters of planning practice, such as strip malls, big box stores, and/or mega transportation projects that least benefit communities most need. To take for example, evidence from around the U.S. that suggests an inequitable distribution tree canopy among cities, which as a simple yet poignant indicator offers a window into planning system that has not taken seriously the centuries of exclusionary practices that privilege the few.

foreboding challenge of managing the increases in frequency, duration, and magnitude of extreme climate events, we need now more than ever to integrate our knowledge about urban ecosystems into planning practice. As way of example, our research team at Portland State University is engaging with an international network of practicing planners — as part of a National Science Foundation Sustainability Research Network (SRN) — to understand the implications of extreme climate events on vulnerable populations. The project begins with the idea that all urban communities differ in terms of their knowledge of, access to, and control over resources, and that to create transformational change in cities we need to co-produce knowledge by engaging practitioners with researcher. Although the SRN is a first step and relatively limited in terms of the communities we can transform, a lot more needs to be done.

So what then can be done to address the historical inequities of applying urban ecological knowledge to exclusionary planning practices? First, is the recognition that urban ecological research is not value-neutral, and we have a responsibility as scholars, practitioners, teachers, and citizens to highlight those inequities. In our own work, we are attempting to understand how heat waves impact those most vulnerable and supporting climate action planning through identifying urban development projects that can reduce temperatures in low-income multifamily developments, while reducing expenditures on energy. Second, we must participate in the political process to ensure that science is part of any decision making process. Albeit a generally progressive Mayor and city council, Portland's decision makers have been highly receptive to a scientific argument during public testimonies.

Finally, urban ecologists must engage in social movements that support the rights of communities that have been (and will continue to be) disproportionately impacted by the climate crisis. While ecologists applying their tools to urban systems may help to advance the ecological turn occurring in cities, without explicit and concomitant aims to restructure exclusionary planning systems, our work will not be transformational. Increasingly community groups with interests outside traditional environmental concerns recognize that climate change will amplify inequities (e.g. housing, transportation and employment access, education, etc.). By engaging with "non-environmental" organizations, urban ecologists can help to empower organizations that are reducing nature-based segregation, and

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More From this Author

## Ken Yeang

Are our existing towns and cities ecosystems? Cities are referred to by many as ecosystems, but in reality and systemically they are not. Cities are far from ecosystem-like, being almost entirely inorganic and abiotic, mostly bereft of nature and biotic constituents (except for the occasional park, green squares, hedges, roadside trees and verges). Simply stated, cities do not have the complete biological structure of abiotic and biotic constituents acting together to form a whole that is the fundamental characteristic of an ecosystem.

> ***Whereas ecosystems are living entities, our existing towns and cities are, in effect, inert structures unlike living things, and have operational and industrial systems that give nothing of biological value back to nature.***

Whereas ecosystems are living entities, our existing towns and cities are, in effect, inert structures unlike living things, and have operational and industrial systems that give nothing of biological value back to nature. Humanity's existing towns and cities are mostly inorganic, synthetic, biologically inanimate and are parasitic and dissociated from nature yet dependent on its bioregion and its hinterland for providing the vitally crucial ecosystem services, for its food (mostly transported from distant sources), for its source of energy (which in most instances is not from renewable sources as in naturally-occurring ecosystems), for its water, for the raw materials that it needs for its incessant production of artefacts for humanity's benefit for its everyday domestic and commercial existence.

## Paul Downton

**Ecocities and the extended organism**
**or what the hell has the evolution of cells got to do with social justice?**

Are cities ecosystems? Yes. And maybe.

Founding convener of Urban Ecology Australia and a recognised 'ecocity pioneer', Paul and co-founders are pioneering the Ecocity Design Institute. Paul is also working on an artistic/publishing project coming soon to a crowd-funding site near you!

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creatures and their habitat can be understood as an ecosystem once a logical boundary is set. So you can study the ecosystem in an unwashed five day old coffee cup, or someone's mouth, or a savannah. Or a city.

Logically, the interacting organisms in a city ecosystem include all its humans and non-humans, and the interactions might be as prey and predator, or human-to-human relationships that can be expressed in ways ranging from kinship ties to law suits. All are interdependent. Social concerns, including goals of livability, justice and equity, have to be considered integral to the making and ongoing life of a city and why the ecosystem concept and its paradigm of interdependency advances our understanding of how those goals might be reached.

Earth's biosphere is the biggest ecosystem we are able to study but even its boundary is hard to determine exactly as it includes the moon, without which there would be no tides (and like the child working out their first address, you can go on to include other planetary motions, the sun, without which there'd be no life at all, and the rest of the galaxy). Regarding the Earth as an ecosystem hasn't prevented theorists, including the redoubtable Margulis, from proposing that it also operates as a self-regulating organism (the Gaia Hypothesis).

> ***The complexity of extended organisms and cities in particular make it difficult to demarcate inviolable distinctions between when it's an organism and when it's an ecosystem.***

Cities are organisms too. An organism isn't conventionally thought of as an ecosystem, but it is. We human organisms carry within and upon us any number of thriving ecosystems, some healthy, some less so, but we are not mere hosts for ecosystems, we are things made up from all our intermingling ecosystems from the bacteria in our mouth and guts to the mites that crawl around our skin. Each of us is an individual and each of us is a legion of organisms. We are only healthy when they, and their relationships with each other, are functioning in an ecosystemically healthy way.

Calling a city an ecocity sets up expectations. It implies a relationship between ecology and the city that isn't conveyed in terms like sustainable and green except by ponderous definition. That relationship is the key to understanding that even if a city is not, by itself, an ecosystem, it can exist

Are cities' ecosystems like a natural ecological area? If there's life, that's nature at work, that's "natural". Humans manufacture cities, but they are still part of nature – as far as we know we haven't been teleported from some abiotic planet of pure machine intelligence elsewhere in the galaxy and even if we had you'd have to start arguing about what constitutes life and where it comes from... as Barry Commoner said "Everything is connected to everything else".

Defining the health of a city ecosystem means defining the health of its constituent organisms, and in the city the dominant organism is us. So a healthy urban ecosystem requires healthy people and healthy people require a healthy urban ecosystem.

An ecosystem contains a collection of interdependent organisms; an organism is a collection of interdependent ecosystems. Very fractal. It goes on down to the scale of individual cells, where the very existence of cells with nuclei (eukaryotes) is now understood (thanks to the work of Lynn Margulis) as dependent on a symbiotic relationship between organelles that are descended from bacterial species that were once independent.

Building on Richard Dawkins' "Extended Phenotype", J. Scott Turner observes that many species make artefacts that are essential to their capacity to survive, be it through creating places in which to birth and succour their young (bird nests) or air-condition their colonial habitat (termite mounds). He calls this species+artifice an "extended organism". Our species has evolved to be dependent on making the complex artificial habitat we call a city. We need cities to survive, people+city is, arguably, an extended organism. In all cases, with all species, the extended organism has to be able to function without damaging its environment, it has to evolve in a way that sustains the operation of the larger ecosystem within which it resides. Beavers cut down trees to build their extension but, over time, the impact of their dams and lodges has resulted in the beaver+lodge organism evolving as a positive contribution to the overall functioning of its local environment—it has evolved to become a healthy part of a larger ecosystem. Which is exactly what the human+city organism needs to do. Although cities are massively complex compared with birds' nests, they are just as essential. One could study the life of organisms that reside in and depend on the nest as an ecosystem. One could study the life of organisms that reside in and depend on the city as an ecosystem. The complexity of extended organisms and cities in

Relationships and symbiosis are key. If the interdependent parts of a city have a functionally symbiotic —as in mutually beneficial—relationship with other parts, that is a part of being healthy and will enhance social cohesion. Relationships are about the exchange of information. Both the quality of that information and how it is exchanged affects the consequent relationship. And those relationships are at the core of how city ecosystems work.

In a city, virtually all relationships are made and mediated by people. That includes relationships between individuals, between people and their institutional and physical artefacts, and between people and the rest of nature. (Shall we bulldoze that wetland because it's worth more as a building site, or protect it because its role in our ecosystem is greater than anything that money can value?) The values, aspirations and attitudes of those people are paramount in determining the type and quality of those relationships. (Do we bulldoze that run-down part of town because it's worth more as a building site, or redevelop it to provide a healthier environment for its residents even though they're not individuals of high net worth?) That's why purely mechanistic approaches to city making can't work in the long term. It's why cybernetic systems (including smart city algorithms) can work, but all such systems rest on assumptions embedded in value-based decisions. Information connects everything and in an urban ecosystem what constitutes good or bad depends on the exercise of a set of values. Bulldozers, hammers, trucks, cars, big data, zoning laws—anything can become a weapon. Tools will do what we want them to do. To deal with the information flows and interdependent nature of an urban ecosystem its planning and management must transcend disciplinary boundaries.

Cities are human constructs and for justice and equity to be part of the city, they have to be considered and included from the outset and consciously maintained as part of the life of the city regardless of whether we define it as an ecosystem or an extended organism.