Ecology in the natural city: Testing and applying the Urban Cliff Hypothesis

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Introduction

Ecologists have been studying urban habitats for a couple of centuries and have largely concluded that, while biodiversity is often high in cities, the species that colonize cities and the habitat conditions they encounter are largely "unnatural." Cities are dominated by exotic or invasive species drawn from distant biogeographical provinces[1] and the action of human disturbance and technology has resulted in the creation of physical and chemical environments that do not occur in nature, such as heavy metal contamination and extremely high concentration of nutrients.[2] This lack of naturalness is typically invoked as further evidence of the production of ecological novelty by human beings and of our estrangement from natural processes. While it is literally true that many human settlements bring together concentrations of materials and energy that are often not seen in non-urban environments, and local, native species are often poorly represented in urban areas, the received view of the urban as epitomizing the unnatural should be thought of as only one of several possible perspectives.

Most currently recognized species of non-human life have existed for hundreds if not thousands of times longer than the first human-built structures at the edges of caves. Thus, each species has a unique evolutionary history largely prior to any large-scale human intervention in the landscape. This is not to suggest that some species have not rapidly adapted to novel conditions, in some cases caused by human interactions with their environments. In other cases, there is some evidence to suggest that many species, especially large mammals and birds, have not been able to successfully adapt to human activities. This seems to be the case for Pleistocene extinctions of large mammals and birds due to overhunting,[3] although there are several potential interlinked causal factors in most cases. Evolutionary biologists generally treat species as inhabiting or spending most of their time in one or more distinct types of habitat. Ecologists classify these habitats by dominant vegetation, the presence of water or other factors and so we have names for marshes, grasslands, alpine meadows, coniferous forest, dunes, and others. Many species can be classified by their preferences for these different habitats: there are forest interior birds, forest edge birds, marsh ducks, bay ducks, sea cliff birds and open ocean species.

While animals can typically move about from habitat to habitat, most have a preferred habitat for feeding with possibly others for nesting and reproduction.

Many plants have even tighter habitat preferences: the movement of plants is limited to relatively slow growth and to dispersal to other areas via seeds or spores. Ecologists can thus classify many plants by the habitats in which they grow, survive and compete best. While some plant species are highly plastic and tolerant of a range of conditions, the fact that no one plant species can grow everywhere lends credence to the idea that most plant species can only persist in a small subset of all available habitat conditions. With reference to urban ecosystems, the question then becomes: what kinds of habitats were exploited by these current urban species before we built cities?

The first attempts to find natural analogs for urban habitats were led by anthropologists and environmental psychologists who identified the suburban developments as copying features of ancestral human habitats on the African savannas: relatively open grassy areas with sparse trees which provide both prospect (the ability to scan the surroundings for food sources or enemies) and refuge from predators.[4] This research is important as it articulates the linkages between urban form and natural habitats, and argues for a biological basis, in part, for our preference for broad classes of landscapes. This "Suburban Savanna" hypothesis, however, omits key features of both current urban habitats and ancestral human landscapes. Urban settlements are characterized by hard surfaces, at least on the outsides of stone, brick and wooden buildings. Additionally, there is considerable evidence that East African savanna environments would have been inhospitable to early hominids without the presence of rock outcrops to provide shelter.[5] Thus the "Suburban Savanna" hypothesis omits the actual buildings or shelters from the landscape template.

New research suggests that a large proportion of urban non-human inhabitants including vertebrates, invertebrates and plants, evolved in rocky, unproductive habitats such as cliffs, scree or talus slopes, and horizontal rock barrens. The "Urban Cliff Hypothesis," in brief, states that the urban denizens are stress-tolerant but opportunistic species with special adaptations to rocky habitats and that built forms represent ecological analogs of rock outcrop habitats.[6] Many urban species, such as pigeons (rock doves), mice, and dandelions, thrive in cities, because human beings have re-created their ancestral homes. When considering urban habitats, much past research has emphasized the classification of habitats based on the degree of human disturbance.[7] While this explicit recognition of humans as a component of urban ecosystems is important, it has had the effect of shifting the focus of urban ecologists to present day impacts of human disturbance and to an assumption that human effects on ecosystems are inevitably different both qualitatively and quantitatively from those of other organisms. When we consider the structure of cities from the perspectives of the other species that inhabit them, ignoring the design and intentionality of built form and focusing on the physical and chemical structures themselves, it becomes possible to acknowledge that humans can create habitats that are similar to natural habitats. While not all human-created habitats have natural analogs, cities in many parts of the world replicate some of the key features of natural landscapes dominated by cliffs and rock outcrops.[8] The implication of this view is simply that non-human species may perceive urban habitats, not as novel environments with challenging selective pressures, but as profoundly similar environments to their evolutionary habitats of origin. While initially bracketing out the human design of built forms to consider the life-worlds of non-humans, we can then return to examining the potential of conscious design to exploit the previously developed symmetries between built and natural habitat analogs.

Ecological restoration

Ecological restoration is a relatively new discipline that takes as its subject, the repair of damage to ecosystems caused by humans.[9] Some of the main tasks of restorationists include favoring native species often excluded by human disturbances or the influx of novel, "exotic" species. The premise of more ambitious forms of this field is that we can recreate habitats for many native species through both conscious manipulation of natural forces and natural recovery mechanisms. If it turns out to be true that much of the form of human settlements already functions as a recreated or newly replicated habitat, then this holds the promise that we might at least learn how to design urban features that not only take advantage of our perhaps subconscious manipulation of landscape elements and microhabitats to match certain habitat templates, but also to design better matches to allow greater colonization of settlements by native biodiversity.

While there is considerable evidence to support the Urban Cliff Hypothesis,[10] these data supports a "big-picture" view: many common species now dominant in urban areas derive from rock outcrop habitats, but quantitative tests in particular urban settings which examine complete sets of the biota are lacking. These will be essential in determining the practical relevance of the hypothesis.

In the following, I outline some of the key quantitative bases for the hypothesis and find some of the data that supports these. I will then show how future tests of the ideas might lead to practical applications in urban design.

The relevance of the Urban Cliff Hypothesis

The central premise underlying the idea that buildings and cities represent replicas of rock outcrop habitats is that the abiotic conditions made available by their construction match the conditions available in long-persisting rock outcrops that predate human artifice. Physical and chemical similarities between early found rock shelters and the first buildings may have been endemic to the development of buildings: some of the first dwellings outside of caves were constructed by piling rocks that had fallen from the cliff housing the cave, thus the new shelters were literal extensions of the cave walls.[11]

- Much of the evidence of the abiotic similarities between natural and built rock outcrops comes from an examination of biotic responses, i.e. patterns of spontaneously colonizing organisms on walls, roofs and other urban habitats and comparisons with natural systems.
- Another set of evidence takes the function of built environments for humans, and compares it to the early use of rock shelters and the exploitation of naturally occurring habitat features there.[12]

While functional similarities between urban settings and natural rock outcrops are easy to arrive at using qualitative descriptions, studies that explicitly compare urban ecosystems with other systems from the perspective of abiotic factors are needed.

One starting point is an examination of the current urban ecology literature that describes abiotic conditions in urban environments.

- Some of the key findings of these research programs outline potential similarities between built and natural outcrop habitats that may be useful in fields such as green building design and ecological restoration.
- One feature of human settlements that seems relatively universal at least in modern cities is the increase in hard or impermeable surfaces relative to adjacent rural areas. Some North American cities have had increases in impermeable surfaces from 3 percent to 33 percent from the 1940s to the 1990s.[13] This has resulted in an increase in peak streamflow volumes. Natural rock pavement habitats are characterized by similarly impermeable surfaces[14] and can also have greater magnitudes of fluctuations between flooding and drought compared with surrounding ecosystems.

This variable hydrology is widely thought to result in high levels of biodiversity.[15] Since more extreme hydrology is usually associated with problems downstream such as stream-bank erosion and the influx of nutrients into fresh water ecosystems,[16] the outcome of our inadvertent creation of habitats that function more like natural rocky habitats is considered to be largely negative from a hydrological perspective. On the other hand, if we can recognize that there are habitats in most regions of Earth that are naturally dominated by hard surface complete with biota adapted to these conditions, it becomes possible to conceive of revised urban forms that incorporate vegetation into hard surface environments. Technologies like planted pavements and green roofs lower the magnitude of urban hydrological fluctuations without reducing the amenity value of the surfaces.

Ann Winston Spirn[17] identifies several other abiotic parameters that differ between urban and rural areas:

- urban areas tend to be hotter overall (the urban heat island effect) than rural areas;
- urban soils also experience greater hydrological fluctuations between wet and dry conditions and tend to be more compacted than non-urban soils.

These features appear very similar to descriptions of natural cliff and rock outcrop habitats.[18] With reference to particular urban microhabitats, it is easy to see similarities between natural flat pavements and abandoned or poorly maintained parking lots, gravelly "waste" areas and other unproductive urban settings where soil is shallow, stoney and often confined to cracks in the hard surface matrix (fig. 1). Walls have an obvious natural analog in cliff faces (fig. 2) and scree or talus slopes at the bases of cliffs have their counterparts in rough areas at the bases of walls where organic material accumulates, or planter boxes with deep soil surrounded by impermeable concrete (fig. 3).

Quantitative studies could directly compare microclimatic and other variables to determine how similar conditions are between urban habitats and their natural analogs. While it is expected that many similarities will be found, there will be differences as well. How do the differences in the arrangement of landscape elements and microhabitats between natural systems and built environments shape the function of the ecosystems and the patterns of biological organization within them?

While natural disturbances such as drought, flooding and fires may shape biotic responses in rural rock outcrops, how do human disturbances such as trampling affect urban biota? How do non-human species respond to urban sensory environments that differ from other environments where anthropogenic light and sound pollution are largely absent?

The answers to these questions should provide a basis for novel design solutions that maximize urban biodiversity and ecosystem function.

One of the main conundrums generated by the Urban Cliff Hypothesis is the overwhelming presence of "non-native" species in cities, whereas one would predict that if urban settings are such good analogs of natural cliffs, then species from local or regional cliff habitats should be abundant in cities.

Since rock outcrop habitats are known on all continents, why are regional rock outcrop species seemingly underrepresented in the cityscape? There are several further hypotheses that may explain this phenomenon:

- First, in many parts of the world, a large number of native species colonize urban or other built habitats.[19] For example, many native ferns easily colonize British stone walls (with their pre-urban habitats being rock cliffs, often of identical mineral composition to the built walls).[20] Clearly, the details of construction processes and materials may matter, especially where native species show strong substrate preferences. Thus the general finding that urban centers attract exotics is not always true.
- Another possibility is that urbanization, at least in the temperate zone of former European colonies,[21] brought with it such a huge influx of non-native propagules (seeds, spores and vegetative cuttings), that native species were simply swamped and remain much less abundant due to "propagule pressure" from newly established populations of non-natives both planted in gardens and farms, and spontaneously spreading in other urban habitats. In other words, there is a persistent horticultural bias toward "exotics" regardless of the region in question, and these preferred species reproduce in proportion to their abundance, leading to the domination of establishment sites by non-natives.[22]

The history of agriculture in the last two hundred years also suggests that the availability of seeds is an important determinant of urban floras. Agricultural weeds depend on certain crops or cropping techniques developed in areas of the world. When agriculture began globalizing, weeds spread along with their host crops. In North America, a large number of crops derive from other bioregions where annuals are more common in regional floras, and where more weeds are annuals that can also easily colonize cities. With the early agricultural history of North America, it is not surprising that non-native plants dominate cities, with early cities being surrounded by farm fields.

The availability of propagule sources might also limit the spread of native species into cities because the appropriate habitat templates (cliffs and other rock outcrops) tend to be naturally rare in most landscapes. It is clear from recent research that cliff habitats represent refugia for many species, in part due to their relative inaccessibility and also due to their economic marginality.[23] Once global trade began in earnest, the exchange of plant materials among cities on different continents was likely orders of magnitude bigger and more ecologically important than the movement of plant materials from natural cliffs in the hinterland to cities.

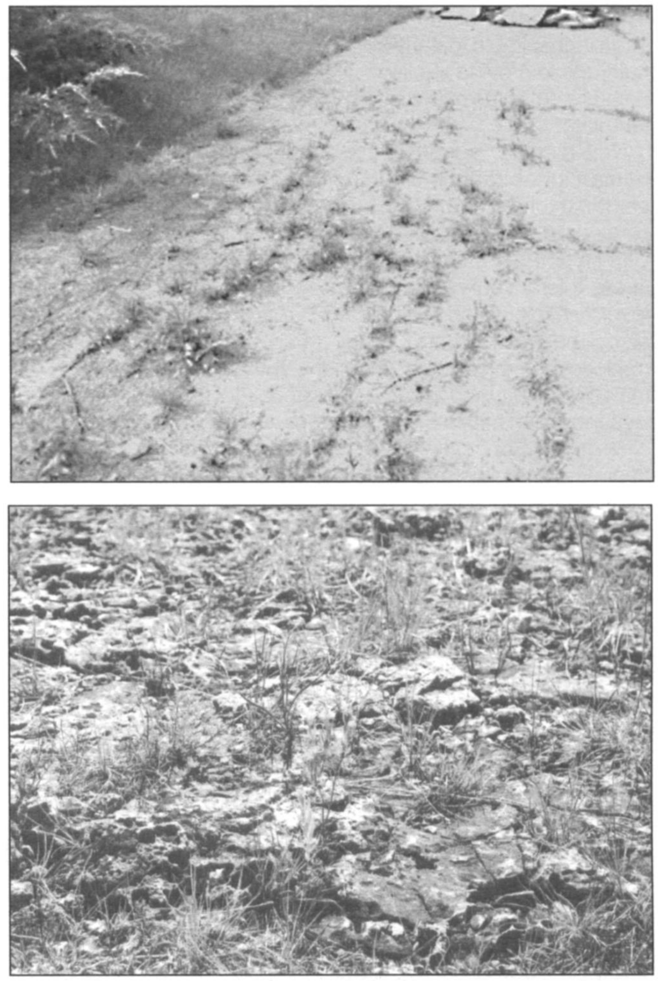

Fig. 1: Artificial (top) and natural (bottom) pavement habitats. (*Source*: The author).

The hypothesis that regions with longer histories of urbanization will be sources of well-adapted urban species that have undergone natural selection over thousands of years of urbanization, might have explained the high proportion of non-natives from Europe and Asia in North American cities, but European cities are also dominated by species that had most of their evolutionary history elsewhere. Thus, the propagule limitation hypothesis seems a likely explanation for the finding that many urban areas are dominated by species that originate in distant biogeographical regions. This hypothesis can be tested in urban areas by simply seeding various habitats with native rock outcrop species that are currently not present in the city, and tracking their survival, growth and reproduction.

Other quantitative tests could come from examining the genetic makeup of the populations themselves. While much of the Urban Cliff Hypothesis implicitly suggests that evolutionary change in species living in urban settings would not have been necessary because artificial rock shelters so well matched the

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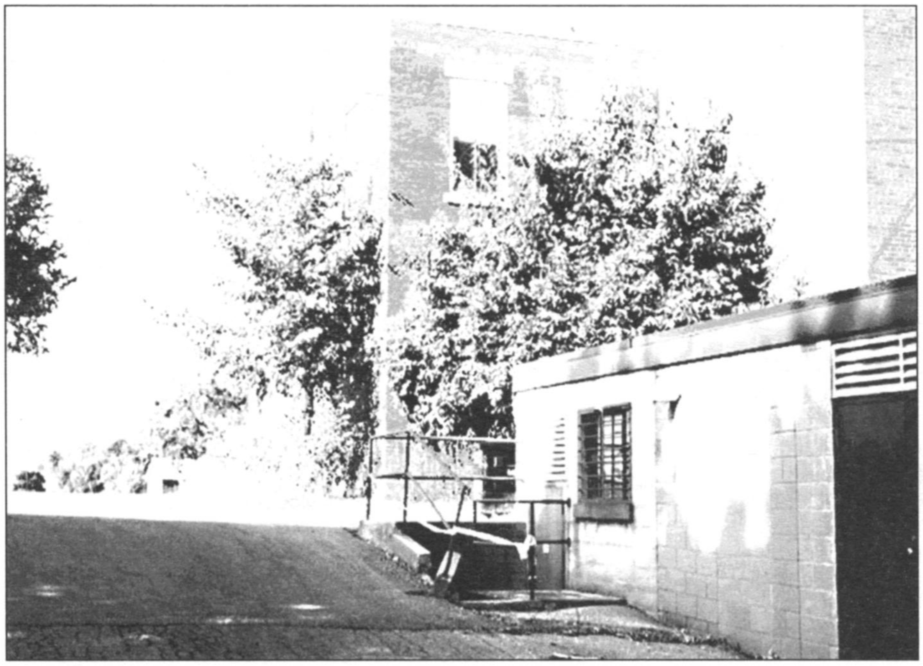
Fig. 2: Artificial stone wall (a) and natural cliff face vegetation (b). (*Sources*: Jeremy Lundholm (a) and Peter E. Kelly (b)).



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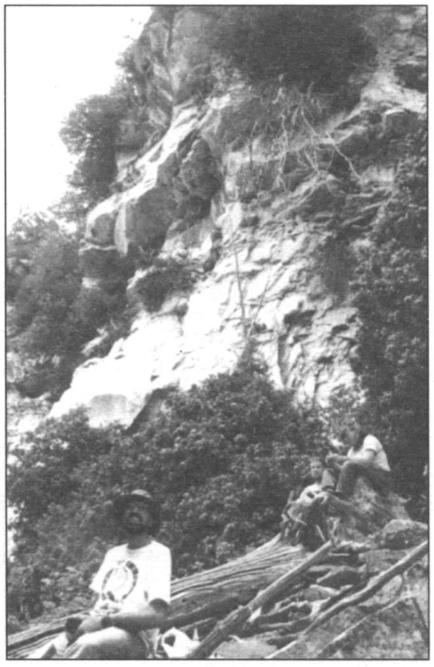

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Fig. 3: Organic deposits at wall edges (a) and natural talus slopes – foreground trees and rocks (b). (*Sources*: Jeremy Lundholm (a); Peter E. Kelly (b)).

conditions of natural rock outcrop habitats, it is likely as well that many developments in architecture and design have changed the basic habitat template. This is obvious when considering many modern buildings which feature sheer metal or glass facades, with the absence of colonizing life palpable: we have altered the template throughout the history of building. Thus genetic and phenotypic comparisons of urban and wildland populations (where they still exist!) of species could allow determination of the degree of evolutionary change that has occurred. The Urban Cliff Hypothesis would seem to suggest that genetic divergence between urban and wildland varieties of the same species would be minimal.

Why place so much emphasis on species native to regions, when the history of cities has much to celebrate in terms of the cosmopolitan cross-fertilization of cultures?

One of the key elements of ecological restoration can be the promotion of regional identity by restoring components, including biological entities, to vernacular landscapes.[24] The use of native plants in urban greening is one way to fight the creeping homogeneity of current cityscapes.[25]

Habitat preferences and human-nature relationships

It has been suggested that our construction of our own physical environment inevitably contains an "exhibitive" element that depicts our stance toward the rest of nature.[26] The prevailing view of urban habitats is that we design them exclusively for us, and for a select group of mutualistic species such as pets and garden plants. The ineradicable presence of pest species (many of which have their ultimate origins in cliff or other rocky habitats) seems to indicate that we are concomitantly and unwittingly designing for other species as well. The attempted species exclusivity of urban design projects an "us-them" attitude. The impact of such design may transcend the concrete forms of the buildings themselves. Some philosophers argue that we have largely underestimated the effect of our lived environments on culture, including values and behaviors with respect to the rest of nature.[27] Anthony Weston invokes a system of circular causation parallel to the notion of self-fulfilling prophesies whereby our engagement with our actual lived habitat shapes our actions, which in turn feed back to shape our habitat.[28] If built forms and settlement patterns reinforce cultural notions of separateness from the rest of nature or even an attitude of domination, then they provide a barrier to the cultural evolution of other possible relationships with nature, such as those characterized by reciprocity[29] or by an etiquette of respect.[30]

When we examine the findings of research into habitat templates of urban species from this philosophical perspective, we can see a signal from the rest of nature that cities are not as unnatural as we may have previously thought. We have tossed a ball into the wild and seen it thrown back: wild ferns, pigeons, and wild cats have colonized the places we built.

If we consciously design buildings and urban landscapes, we can depict different perspectives on nature than those that are currently coded. The idea of invitation as a basis for a new (or recovered) relationship between people and the rest of nature stems from philosophical investigations of disparate practices of the culture of nature.[31] By recognizing the inherent potential of built form (inherent because cities can be seen as an unconscious manipulation of resources to re-construct analogs of our optimal natural habitat) to welcome a diversity of other species, we can actually build for wild nature.

While clearly the most opportunistic of rock outcrop specialists have already joined our ranks in the cities, with many not welcome, it is possible to design for other elements of the rock outcrop biota which may not colonize spontaneously due to propagule limitations. It should be possible to design building surfaces with greater potential for colonization by plants. Some architects are already incorporating eyries for birds of prey, including nesting space for endangered bird species. While cities will continue to be built primarily as habitat for people, it is possible to engage with the rest of nature in a way that transcends dualistic, dominating approaches. The hope is that, given the potential for built environments to shape cultural relationships with nature, redesigning for invitation can actually promote a shift in values compatible with non-dualistic or less anthropocentric relationships with land and biota.

It must also be recognized that cities tend to be built on top of or in place of previously existing habitats which typically only included a small area of rock outcrop (with communities built within rock outcrop landscapes – e.g. Cappadocia or Petra – being obvious exceptions). Urbanization has thus been a process of habitat replacement: forests and wetlands being replaced by rock outcrop analogs, at least from the perspective of the Urban Cliff Hypothesis. It is essential that remnants of other habitat types be conserved within urban landscapes. Applications of the Urban Cliff Hypothesis are primarily useful for greening existing landscapes, not as justification for further erosion of natural, non-rock outcrop habitats.

Conclusion

The central precepts of this paper are that

- both biological and cultural factors determine built form; and that
- the biological basis of urban design has been marginalized up to now.

I suggest that the mutual causation of urban settings by our biological needs and cultural elaborations should be accepted and studied as a proper feature of urban design.

The view presented in this paper is admittedly biased toward the acceptance of hard-surfaced, urban environments as analogous to natural rock outcrops. Without stretching the analogy too far, the Urban Cliff Hypothesis at least provides the conceptual resources necessary to develop a perspective compatible with a "Natural City."

"The narrative that still needs to be articulated must reveal a direction for human action, self-understanding, and aspiration that points beyond the current practical and theoretical antagonism between the human and the nonhuman. By writing this narrative through our communal practice – including our architectural, design, and urban planning practices – we may be enabled eventually to discover a place for human beings that is neither a romantic return to the 'primitive' nor a glorification of 'shallow' management technocracy."[32]

A natural city need not be antithetical to notions of wilderness (or wildness) protection once we realize that we can project an invitational stance to the rest of nature and also to urban humans by inviting them to participate and encounter a nature that is both urban and wild. The acknowledgment that cities may be functionally "natural" to non-human organisms may yield tangible benefits as well as provide a strong foundation for revitalizing our conceptions of urban places.

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