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# Can urban areas have ecological integrity?

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## INTRODUCTION

The question of whether urban areas can offer a semblance of the natural world – a vestige (at least) of ecological integrity – is an important one to many people who live in these areas. As more and more of the world becomes urbanized, this question becomes highly relevant to the broader mission of maintaining the Earth's biological diversity.

Most people, especially when young, are attracted to the natural world and living things, Ed Wilson called this attraction “biophilia.” And entire books have been written about it – one, for example, by Steve Kellert, who also appears in this morning's program. Personally, I share Wilson's speculation that biophilia has a genetic basis. Some people are biophilic than others. This tendency is very likely heritable, although it certainly is influenced by the environment, particularly by early experiences. My own experience, which includes working many years as a camp counselor and environmental educator early in my career, and having 3 children of my own, suggests that most children are biophilic. They are fascinated by non-human life forms. Kids that have abundant exposure to nature tend to be more biophilic. As they get older, however, most kids seem to lose touch with nature. They are socially conditioned to value television, computers, and video games above bugs and salamanders. Their teachers and parents reinforce whatever fears they have about the outdoors (e.g. about snakes, spiders, and poison oak) and their peers tell them that nature isn't “cool. Only nerds are interested in that stuff.” With few or no natural areas near their homes to offer alternative experiences, many young people let their biophilia dwindle away to nothing as they grow older. It is no wonder we have a populace distanced from nature and unwilling to support meaningful conservation programs.

I have just outlined what I believe is the major challenge of urban wildlife conservation. What, then, do we do about it? Basically, what we do is maintain and, where possible, restore a lot more natural

habitat and wildlife within and around urban areas, where most people live. But, if we embark on this venture, how do we know if we are succeeding? There are both social and biological measures of success. The social measures include increased awareness of and appreciation for native wildlife and healthy ecosystems. The biological measures are the subject of my talk this morning; I will focus on adaptation of the ecological integrity concept to urban and suburban areas and the role of connectivity (i.e. wildlife corridors) in promoting ecological integrity.

### Urban Ecological Integrity

Ecological integrity is what we might call an “umbrella concept,” embracing all that is good and right in ecosystems. It encompasses other conservation values, including biodiversity, ecological resilience, and naturalness. The first reference to integrity in the environmental literature was Aldo Leopold's famous statement in his essay on land ethics: “A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise.” Many years later ecological integrity (specifically, chemical, physical, and biological integrity) became a goal of the U.S. Clean Water Act (1972), the bilateral Great Lakes Water Quality Agreement (1978), and other environmental policies in the U.S. and Canada. The development of ways to actually measure ecological integrity came later. Such measurements have been applied mostly to aquatic ecosystems. Most noteworthy is Jim Karr's index of biotic integrity (the IBI).

The IBI is based on the idea that the biotic integrity of an aquatic ecosystem is affected by 5 classes of environmental factors: water quality, habitat structure, energy source, flow regime, and biotic interactions. The IBI assumes that fish (or other taxa, such as benthic invertebrate) communities tell us much more about integrity than chemical measures because

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biotic communities tell us much more about integrity than chemical measures because biotic communities integrate the effects of numerous environmental factors. Generally, as human disturbance increases, total species richness, number of intolerant species, and number of trophic specialists decline, while the number of trophic generalists increases.

Attempts to develop terrestrial indices of ecological integrity, or indices for entire landscapes including terrestrial and aquatic components, have been less successful. Nevertheless, a number of potential indicators and indices are emerging. One attempt to develop a terrestrial IBI is in progress at the U.S. Department of Energy's Hanford Nuclear Reservation in Washington. This work, by Jim Karr and colleagues, is examining species, taxa, and ecological groups of invertebrates and plants in the shrub steppe to determine their utility as indicators of human disturbance. Among the preliminary results, are that species richness of invertebrates and native forbs declines in response to increasing disturbance, as does shrub density and cover. On the other hand, exotic annual plant taxa and density increase with disturbance.

Other examples of potential indices of ecological integrity that are promising but not yet well tested include a multi-metric assessment of the conservation value of redwood forest landscapes developed by Jim Strittholt and me, and a broad assessment of the ecological integrity of the Interior Columbia Basin undertaken by the USDA Forest Service and cooperating agencies. In the latter study, each of the 164 sub-basins were rated as having high, medium, or low ecological integrity for a maximum of 5 components: forestlands, rangelands, forestland hydrology, rangeland hydrology, and aquatic systems.

No study, to my knowledge, has investigated the ecological integrity of entire urban landscapes. However, biotic integrity has been evaluated in urban stream segments, for example with respect to riparian vegetation. In the Toronto area, a threshold of degradation of streams was reached under conditions ranging from 75% removal of riparian vegetation in areas with no urbanization to 0% removal of riparian vegetation in areas with 55% urbanization. Ongoing work in the Georgia Piedmont is showing lowest IBI scores for streams in urban areas with the greatest amount of impervious surface from commercial, industrial, and transportation land uses. In this study correlations between IBI scores and percent forest cover within 50 m of streams or whole watersheds are similar; suggesting that restoration of urban watersheds should consider land-use and land-cover of the whole watershed, not just the riparian areas. Studies such as these demonstrate that the ecological integrity of aquatic communities is closely tied to the integrity of the surrounding terrestrial landscape.

We might justifiably ask if it is even possible for urban landscapes to have ecological integrity. Ecological integrity is typically measured with respect to some undisturbed reference condition. As defined by Karr, the IBI value for a site is a measure of the deviation of the biological community at that site from a baseline condition that represents "a biota that is the product of evolutionary and biogeographic processes in the relative absence of the effect of modern human activity." Although I do not wish to dilute the concept of ecological integrity, I suggest that reference sites in urban landscapes might be a bit different from those in wildlands. We cannot expect an urban landscape to meet the same standards for ecological integrity as rural or wildland areas. Instead, we might establish a gradient of reference sites corresponding to the gradient in naturalness from urban areas to wildlands. The reference site for an urban landscape in a particular biogeographic region would represent the best possible condition that an urban landscape in that region might achieve. "Best possible," in turn, would be defined according to degree of similarity to reference sites in wildland landscapes in the same region. Thus, we recognize that although urban areas will never have the biodiversity, naturalness, and ecological resilience of pristine wilderness areas, there are reasonable standards they can meet. Nevertheless, meeting those standards will require significant changes in habitat apportionment and management in our cities and suburbs.

The question of how one might measure ecological integrity in urban landscapes is beyond my scope in this paper. I believe an adequate index would consider the composition, structure, and function of the urban ecosystem. An initial list of indicators should probably include representatives of all these groups, ideally at several levels of organization. On the other hand, the interdependence of composition, structure, and function suggests that indicators in one group might be surrogates for the others. We might, for instance, get a good handle on the structure and function simply by monitoring the biota (i.e. composition). Conversely, it might be faster and cheaper to measure habitat structure directly, especially at the landscape scale where remote sensing and geographic information system (GIS) technology permits rapid, quantitative measurements.

Importantly, indicators of one attribute can be used to test and validate the others. For example, the only way we will know if indices of habitat structure or landscape pattern correspond to ecological integrity is by measuring responses of the biota to changes or differences in pattern. Although ecological processes (i.e. function) ultimately determine the integrity of any ecosystem, the sensitivity of organisms to the rate, magnitude, and other characteristics of natural

processes suggests that measuring processes directly without information from the biota will not be too helpful for assessing integrity.

### **Landscape Design for Urban Ecological Integrity**

Our society's criteria for what makes a good urban design, largely has to do with aesthetics and efficiency. How can we get from place to place easily and safely and see pretty things along the way? Wildlife is rarely considered in urban design, much less the grander concept of ecological integrity. This must change. Fortunately, with the increasing ecological literacy of landscape architects and planners, it *is* changing. Furthermore, we don't have to start from scratch with each new design. The science of conservation biology offers a few principles (perhaps better described as empirical generalizations) for maintaining biodiversity and ecological integrity, which can be applied to a variety of situations. Although developed mostly from case studies in wild landscapes (in fact, first for the conservation of the northern spotted owl), these principles apply with minimal modification to urban and suburban settings. Among the best established principles are the following:

- (1) Species well distributed across their native range are less susceptible to extinction than species confined to small portions of their range. This principle is most directly applicable to large-scale conservation planning. The idea is to maintain multiple populations of imperiled or potentially imperiled species. By so doing, we maintain the natural range of among-population genetic variability within the species and minimize the chances that environmental variability will drive all populations of the species to extinction within a given period of time (i.e. the farther apart, the less likely that populations will fluctuate in synchrony). For urban settings, this principle suggests that habitat protection must have some redundancy. Species associated with a particular habitat must be represented in many places across the urban landscape, both within and among metropolitan areas, so that local extinctions do not eliminate the species from the urban setting.
- (2) Large blocks of habitat, containing large populations, are better than small blocks with small populations. This is probably the best documented of all the empirical generalizations of conservation biology. All else being equal, larger populations are less susceptible to extinction. This is especially true when habitat patches are more or less isolated from each other, which is often the case in urban land-

scapes. Many species of forest and grassland birds, for example, are progressively more likely to be found as habitat area increases. Some species are present only in large blocks of habitat. Hence, species richness increases as habitat area increases. This is the well-known species-area relationship. Of course, in urban areas no truly large blocks of habitat may be available. Nevertheless, the bigger the better. The larger blocks of natural or semi-natural habitat in an urban landscape should be priorities for protection.

- (3) Blocks of habitat close together are better than blocks far apart. The idea here is that blocks of habitat close together may function as one larger, contiguous habitat block for those species that can move between areas. What is "close together" must be considered from the standpoint of the species of concern. Habitats close together form the standpoint of humans or birds might as well be thousand miles apart for animals incapable of crossing the intervening barriers. For instance, many forest mammals, salamanders, and flightless invertebrates seldom or never cross roads.
- (4) Habitat in contiguous blocks is better than fragmented habitat. Habitat fragmentation has been documented to have deleterious effects in countless studies across the globe. Natural and semi-natural habitats in urban as well as agricultural landscapes are usually quite fragmented. But again, this principle is relative. The less fragmented the better.
- (5) Interconnected blocks of habitat are better than isolated blocks. You may have noticed by now that each of these principles is pretty much a corollary of the others. Connectivity allows organisms to move among habitat patches. A collection of habitat patches may be individually too small to maintain populations of area-sensitive species. But if connected, these patches may provide sufficient habitat for these species to maintain viable populations. Hence, the whole can be greater than the sum of its parts.

### **The Role of Connectivity in Urban Wildlife Conservation**

Let's now focus on the issue of connectivity in more detail. Wildlife corridors are something of a fad in conservation these days. Many conservationists and planners draw corridors into their designs with little awareness of their potential utility or consequences. What conservation biologists are interested in is not

corridors *per se* but functional connectivity, which must be defined according to the potential for movement and interchange between populations. Connectivity is generally a species-specific property. What a corridor to one species may be a barrier to another. We don't need to be concerned about every individual species, however. Many species get around just fine without our help – in the case of many exotics and other weeds; they get along much too well. In planning for connectivity, we need to be concerned most about species that are particularly sensitive to anthropogenic habitat fragmentation.

We need to know something about the mobility of species, and what constitutes potential barriers to their movements, in order to plan effective corridors. What looks like a corridor to us may or may not provide functional connectivity to the species of interest. Nevertheless, a recent review paper by Paul Beier and me showed that most well-designed studies of corridors show they do, in fact, provide for connectivity; furthermore, no deleterious effects of corridors have been documented. This does not mean that deleterious effects never occur. Narrow edge-dominated corridors could conceivably do more harm than good, for example by encouraging a proliferation of edge-adapted species and their invasion into remnant natural areas.

Just how wide a corridor must be to avoid edge effects and provide security and habitat-interior conditions for sensitive species is highly variable. It depends on the nature of the surrounding habitat, the life history characteristics of the species involved, the length of the corridor, and other factors. For some species, corridors less than a few hundred meters wide are too narrow, unless the constricted portions are fairly short. For example, Paul Beier's work has shown that mountain lions in southern California can use quite narrow corridors if they are short and connect much wider swaths of habitat. Creating effective underpasses or tunnels to allow animals to cross safely beneath or over roads is usually the greatest challenge, as roadkill is often the greatest category of mortality for large mammals in developed and sometimes even in wildland landscapes.

The key point is this: in urban settings, most patches of natural and semi-natural habitat are too small to maintain populations of many species. Countless examples exist of small urban parks, for example, Rock Creek Park in Maryland on the outskirts of Washington D.C., losing their diversity of native species over time, especially as they become isolated from other natural and semi-natural habitats. Connectivity is the only way to maintain a rich diversity of wildlife in many urban settings.

Urban wildlife populations probably often exist as metapopulations – systems of subpopulations connected by at least occasional dispersal. Connectivity can lower the chances of extinction for small, local populations by providing a “rescue effect,” whereby dispersing individuals augment resident populations. If a local population goes extinct, that site (if the habitat remains suitable) can be recolonized if sufficient landscape connectivity exists. On the other hand, an isolated habitat patch that loses a population will not be recolonized if dispersal corridors have been severed. As more and more habitat patches become isolated by fragmentation, the metapopulation as a whole may go extinct.

Not only do corridors provide movement routes for animals between parks and other habitat patches, they also constitute important habitats in their own right, particularly when they are located in riparian areas. In the arid West, riparian areas typically are the most species-rich habitats. Some 80% of vertebrate species in Arizona and New Mexico depend on riparian habitat for at least a portion of their life cycles. Maintaining intact riparian areas not only contributes to terrestrial ecological integrity, but as noted earlier, aquatic biotic integrity increases as adjacent riparian habitats are preserved.

In urban areas most wildlife corridors will also be corridors for people. That is, these urban greenways will have trails and will be used for recreation and other purposes, not all of which are desirable. For example, when I lived in Gainesville, Florida we had a heck of a time establishing an urban greenway system because many residents were concerned that these greenways would serve as corridors for thieves and degenerates, which, frankly, is not all that unlikely. In any case, urban greenways must be designed with the needs of both people and wildlife in mind. In Colorado, a Trails and Wildlife Task Force recently released an excellent handbook for trail planners, called “Planning trails with wildlife in mind.” The handbook notes that trails have zones of influence and that an area crisscrossed with trails could end up with few places undisturbed by human activities. Hence, sensitive wildlife could be eliminated. Among the handbook's recommendations are to 1) leave untouched large, undisturbed areas for wildlife, 2) route trails around edges of high-quality areas, 3) keep density of trails lower near high-quality areas, 4) do not route trails continuously close to riparian areas, 5) use public support of trails to protect riparian corridors, 6) plan how to manage a trail's wildlife issues before the trail alignment is set, 7) don't depend on management to resolve wildlife

conflicts that could have been avoided by thoughtful alignment in the first place, and 8) balance competing wildlife and recreation needs across a landscape or region rather than trying to accommodate all uses within specific areas. All of these recommendations depend on having competent biologists involved in the early stages of greenway planning and throughout the trail development process.

### Networks from Urban Areas to Wildlands

In the long run, or maybe sooner, many wildlife species will persist in urban areas only if there are connections to the surrounding rural and wildland landscapes. Urban areas may be population sinks for some of these species, places where mortality exceeds reproduction. Species will occur in these urban areas only if there are source populations within dispersal distance that can supply colonizing individuals. Hence, I envision a hierarchy of connected habitat networks comprising 1) relatively small habitat patches and narrow corridors within the urban zone, connected to 2) a network of larger habitat patches and wider corridors in suburban and rural areas, which in turn connects to 3) the wildlife landscape, with its still larger habitat patches, lower road density, and greater overall connectivity.

There are 2 potential problems with this “network of networks” design. One, corridors leading from the more developed zones of the network might funnel exotics and other opportunistic, weedy species into wildland areas. We know that roads and roadsides, for example, are frequent avenues for the invasion of these pests. I predict, however, that the wildlife corridor network is unlikely to facilitate weedy species invasion of wildlands beyond that already facilitated by roads. In fact, well-designed corridors, especially if wide, may provide habitat for predators of these weedy species. In addition, corridor bottlenecks could be used to trap weedy species (for example, brown-headed cowbirds) and possibly reduce their spread.

A potentially more serious concern is that of corridors connected to wildlands or rural areas funneling problematic large mammals into suburban and urban areas. This is already a problem in the case of deer. Many people like to have deer near their homes, but may get quite angry when those same deer eat their gardens. I have mixed feelings about the deer in the semi-rural neighborhood where I live, but my family and I have decided that the benefits of watching the deer generally outweigh the damage to our flowers and vegetables. Following the deer into suburban areas, however, may be a natural predator of deer – mountain lions. Unfortunately, these predators sometimes also attack joggers and

other people. Wildlife corridors have been implicated in bringing both deer and lions into Boulder, Colorado which has created some problems. Personally, I was thrilled to see a mountain lion track in our driveway a couple years ago. Sure, we had to take a few precautions, especially regarding the children, but that’s part of living in a region that still has some wildness left. Our neighbors were not so thrilled, however, and animal control agents soon arrived to trap the animal (I don’t know if they succeeded, but we no longer saw tracks).

I suggest that wildlife agencies, instead of intentionally maintaining a superabundance of deer in rural and wildland areas, which is their usual policy, instead direct hunters to particular corridor areas where deer may be proliferating. Properly managed, this policy should keep deer problems to a minimum without eliminating deer from the suburban and urban settings, and probably would also result in fewer conflicts between humans and large predators in these landscapes.

## CONCLUSION

People generally want wildlife in urban and suburban areas, even if they are ambivalent about some of the potential conflicts. Having a rich assemblage of native plants and animals around us is an indication that nature still prospers in the places where we dwell. It is a sign that *our* habitat still retains some of its ecological integrity. In the long run, the greatest benefit of having a well-connected system of habitats in our cities and suburbs is one I alluded to in the introduction to this paper: children as well as adults will have abundant opportunities for contact with wild nature. Hence, they will be more likely to retain their biophilia despite all the social conditioning in the opposite direction. And with a positive attitude toward nature they will more likely be good citizens willing to support strong conservation measures for their broader environment.

## Further Reading

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