

Background

In 2014, the City launched an effort called “Nature in the City” to ensure that, as our community grows to its build-out population, all residents have access to high-quality, natural spaces close to where they live and work. Whether it’s a formal natural area, neighborhood park, or just the open space behind your neighborhood, our primary objective is to create and maintain access to nature within Fort Collins.

Process

One of the key elements of Nature in the City is taking a triple-bottom line approach to developing the project’s strategic plan. To successfully understand where we need to head as a community, we need to understand the state of the science regarding the social, economic, and environmental benefits of nature in the urban environment.

Toward that end, staff from the Economic Health Office, Planning Department, and Utilities reviewed 43 peer-reviewed articles and 5 white papers to assess the latest research in their respective fields that might inform this project. These results are summarized on the following pages and individual studies are discussed beginning on page 5 of the document.

What’s included in this document?

- A review of the scientific literature from a triple bottom line perspective - economic, environmental, and social.
- A detailed description of each of the articles are reviewed and included beginning on page 5 of this document.

For more information about the project:
www.fcgov.com/natureinthecity

Summary of Findings

There is a significant amount of literature related to how access to nature influences economic, social, and environmental outcomes.

From an **economic perspective**, the majority of the literature has focused on the economic benefits of residential property in close proximity to nature. Studies throughout the U.S. suggest that close proximity to nature commands between a 20-32% premium in home sales price. In addition, nature in urban areas tends to be valued higher than natural areas in urban areas; this could be because open space tends to be scarcer in urban areas.

From an **environmental perspective**, assessing urban wildlife habitat and biodiversity (the variety of species in an area) is a newer field of research. Many studies have found that overall species diversity tends to reach what is called an “intermediate disturbance” peak; in other words, as housing or development density increases, urban sensitive species tend to decline as urban adapted species increase. Then, at a certain point of development density, even the urban adapted species tend to decrease. More recently, scientists are examining how the effects of urbanization (which tend to be negative) can be lessened or even become positive for species diversity. This new area of research is exciting for communities like Fort Collins that are interested in enhancing urban biodiversity.

Perhaps best documented are the **social benefits** of access to nature in an urban environment. Spearheaded by leaders in the field such as Richard Louv, the mental, emotional, and physical benefits of nature are well-documented to the point where it is clear that nature in cities are critical to overall human well-being.

Economic Literature

There have been many efforts to study the economic impacts of natural spaces and features and such research has confirmed there is a positive relationship. Most studies focused on measuring economic impact based on property value and assessed whether being located near an open space or having specific features, e.g., trees, added value.

Open spaces like parks or recreation areas can have a positive impact on nearby residential property values, but the impact dissipates the further a home is located from that space. The size of the space and characteristics of the neighborhood are also influential factors. One study found an approximately 20% statistically significant sales price premium for homes in a conservation development versus a traditional neighborhood development. Another effort found that homebuyers find open space in neighborhoods important and attractive with 66% of respondents indicating a willingness to pay for more imbedded open spaces. The positive impact on home values is important for both developers and local governments to consider; higher property values translate into higher taxes and greater revenue for government, and developers benefit from higher sales prices, enhanced marketability, and faster sales/leases than conventional development.

Other features like trees, greenbelts, and bike paths were found to positively impact property values. A study in Boulder, Colorado found a \$4.20 decrease in the price of a residential property for every foot one moves away from a greenbelt. Another effort looked at different income levels and willingness to pay to live near a bike path. Low-income persons would pay \$1,091, medium-income persons would pay \$1,369, and high-income persons would pay an additional \$6,901 for a home purchase. Trees are also important to consider and a Portland, Oregon study found that an additional tree on a house's lot increased monthly rent by \$5.62, and a tree in the right-of-way increased rent by \$21.00.

These and other findings consistently show that there is monetary value to open spaces and

natural features. The value is primarily captured through property values, which in turn benefits property owners, government, and developers/builders.

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Environmental Literature

Environmental impacts, as a result of urbanization, are a well-studied field. A majority of the studies in this review looked at a specific taxonomic group and how it was affected by development along an urban gradient, e.g., from rural or protected areas to a suburban neighborhood to a more urban context. In general, all groups of wildlife (bumblebees, raptors, coyotes, butterflies, birds, spiders, rodents, deer, and bees) declined in either abundance or diversity with increasing intensity of development. Native diversity always declined while non-native species diversity often increased, to a certain level of urbanization. However, overall native and non-native species diversity declined with significant urbanization.

Several studies focused strictly on the urban environment and many have found that size of a site will influence overall diversity. For example, one study in Mexico found that species richness was positively correlated with area of the open space. Other studies, especially those focused on pollinators (butterflies and bees) have found that site quality can significantly influence overall abundance and diversity.

More recently, studies have begun to link social and ecological issues in one effort. A study in Phoenix compared income levels and residents' satisfaction with overall bird diversity. This study found that higher income areas tend to correlate with increased diversity and that resident satisfaction increased with overall diversity. Another Phoenix study found that species diversity was positively correlated with income, which suggests a disparity in access to a rich,

natural experience depending on income levels in an area.

Some studies showed that loss of diversity could be partially mitigated for by using native plantings and landscaping in development projects and residential yards. When acquiring or creating new green space, these studies suggest that efforts should be made to conserve existing native habitat, make the space as large as possible, have it connect to existing green areas and restore the habitat to as native as possible using a diversity of species. Additional research is needed within cities, especially to identify how site-scale restorations (or interventions) are influencing overall species diversity and abundance.

“For many urbanites, their primary interactions with nature occur in their front and back yards...Providing opportunities for positive experiences with the natural world leads to an increased sensitivity to ecological issues, an ability to incorporate sound ecological initiatives into public policy, and ultimately the ability and desire to conserve urban biodiversity...”
- Lerman and Warner 2011

Social Literature

While street trees, parks, and public green spaces may be thought of as simply ways to beautify our communities and make life a little more pleasant, the science tells us that they play a central role in human health and promote health and wellness within the community. The articles reviewed support nature incorporated into the growth of a city for social sustainability benefits such as mental health, children and nature, and overall human health.

Mental Health

Research indicates a strong relationship between positive mental health and exposure to natural places. Case studies show that stress and associated negative health issues are

reduced when people have access to nature. Rates of lower depression and anxiety diminish as well. Longitudinal studies (studies conducted over a long period of time) indicate that communities with more natural areas have a population with better mental health, longevity and ‘happiness’.

The relationship between mental health and nature is complex. This could be because living near nature provides more opportunities for exercise which contributes to mental health. Strong evidence shows that when people have access to parks, they exercise more and the studies are clearer about the mental health benefits from increased activity levels. There are other far reaching implications – from a safer community to a healthier economy – with good mental health.

Children

By far, the most research in the last decade has been on the relationship with children and nature. Entire professional journals and organizations have bloomed since the 2005 book “Last Child in the Woods” by Richard Louv, where he examined the social impacts due to a decline in exposure to nature by children. There has been significant research in the realm of the importance of children’s connection with nature and the healthy benefits of this as well as the importance for connections to the larger value of understanding and protecting natural resources. Studies suggest positive impacts from urban design of green spaces for many health outcomes, including cognitive health, learning, decreased attention-deficit hyperactivity disorder as well as positive impact on children with special needs that have access to “nature-based interventions”.

Providing opportunities for urban and suburban children is especially important because they need places where they can be outdoors and physically active on a regular basis in their own neighborhoods. Children that have closer (e.g., within a 10-15 minute walk) access to parks and recreational resources are less likely to experience significant increases in body mass index (BMI). Obese children that are encouraged to go to urban parks to walk and

play more demonstrate weight loss because access and availability of parks and green areas decrease children's sedentary behaviors.

Overall Human Health

Urban nature provides a range of benefits to society. There are indirect and intangible services, such as beauty and psychological benefits. There are also studies showing a variety of small benefits with a cumulative impact – such as recovering from surgeries faster, creating a sense of place and culture, making cities attractive and providing places for relaxation and increasing quality of life. Open spaces provide places for recreation, community gatherings and refuge from the urban environment. There are also studies that show that crime is reduced in cities with more natural settings.

The use of local parks, trails and other urban settings is more frequent than visits to national parks and other sites well known for exposure to nature. Given the health contributions and other societal benefits from exposure to daily natural environments, there are implications associated with health care cost savings. Proximity to nearby natural areas is important to get this benefit.

While the search for better understanding of why and how interactions with nature impact overall healthy communities, the larger societal effects are well-documented: natural environments in urban settings are an essential component of a healthy human habitat.

Children that have closer (e.g., within a 10-15 minute walk) access to parks and recreational resources have significantly lower body mass indexes (BMI) than children whose access to parks and other open spaces are further away.
- Wolch et al. 2011

Acknowledgments

Researchers from Colorado State University, Wildlife Conservation Society, the US Forest Service and the City of Fort Collins recently completed a literature review of over 550 peer-reviewed articles that studied the ecological, social, and economic impacts of residential development (Pejchar et al. 2014¹). That paper served as the basis for the articles reviewed in this study.

Staff also recognizes the Children in Nature Network in Larimer County for the extensive database on research they've compiled for the role of children in nature.

¹ Pejchar, Liba; Sarah E Reed; Patrick Bixler, Lindsay Ex, and Miranda Mockrin. In review. *Consequences of residential development for biodiversity and human well-being*. *Frontiers in Ecology and the Environment*.

Economic Literature

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings
Bowman and Thompson	Barriers to implementation of low-impact and conservation subdivision design: Developer perceptions and resident demand	2009	Landscape and Urban Planning	Iowa	Alternative development techniques, e.g., conservation and low-impact subdivision design, has not been used in Midwest because of barriers to implementation.	<ul style="list-style-type: none"> * Developers perceive consumer indifference and lack of willingness to pay for open spaces in residential design * Developers concerned about greater cost for creating alternative subdivisions * Consumers indicated open space in neighborhoods were important and attractive, and reported willingness to pay for more open spaces * Developers' perceptions of barriers should be mitigated by local planners through flexible standards and faster approval for alternative designs
Donovan and Butry	The effect of urban trees on the rental prices of single-family homes in Portland, Oregon	2011	Urban Forestry & Urban Greening	Portland, OR	Rental price of houses are affected by environmental amenities.	<ul style="list-style-type: none"> * An additional tree on a house's lot increased monthly rent by \$5.62 * A tree in the ROW increased rent by \$21.00 * Results are consistent with previous analysis of the effects of trees on sales prices of homes in Portland - suggests homeowners and renters place similar values on urban trees
Reichert and Liang	An economic analysis of real estate conservation subdivision developments	2007	The Appraisal Journal	Northeast Ohio	There is a relationship between appreciation rates between single-family conservation developments and more traditional developments.	<ul style="list-style-type: none"> * There is no statistically significant difference * Homebuyers in this area may prefer "private openness" - own a two-acre parcel that allows for some degree of openness or separation between houses, rather than have access to a large common open space * May be due to relatively inexpensive land prices and lack of homebuyer exposure to conservation development * These results contrast with results from Massachusetts, California, and Colorado where dramatic differences in land prices, incomes, and lifestyles prevail

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings
Bowman, Thompson and Colletti	Valuation of open space and conservation features in residential subdivisions	2007	Journal of Environmental Management	Cedar Rapids, Iowa	Homebuyers value embedded conservation features in residential areas.	<ul style="list-style-type: none"> * Higher 5-year appreciation rate for conservation vs. standard subdivision design * Well-integrated conservation features (e.g. protected stream corridors) within subdivisions have positive effect on home prices * 66% of all respondents indicate willingness to pay for more embedded open space * Maximum willingness to pay related to: income, gender, desired level of open space, and concern about urban development * Consumer demand and willingness to pay for conservation subdivision design are positive and shouldn't be considered a barrier to implementation
Earnhart	Using contingent-pricing analysis to value open space and its duration at residential locations	2006	Land Economics	Lawrence, Kansas	There is a relationship between the duration of open space (chance of development or permanently protected) and what individuals would be willing to pay.	<ul style="list-style-type: none"> * Prairie-type open space with uncertain development adds no value to a housing location (may be due to negative externalities associated with uncertain future development pattern) * Permanently protected prairie carries a value of \$5,066 (5% of total housing value) * Value rises as the risk of development falls * Value is not dependent on socioeconomic characteristics of the household - relative to low-income households, however, high-income households are willing to pay more in absolute terms

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings
Active Living Research	The economic benefits of open space, recreation facilities and walkable community design	2010	Activelivingresearch.org	Research Synthesis	N/A	<p>* Open space such as parks and recreation areas can have a positive effect on nearby residential property values, and can lead to proportionately higher property tax revenues for local governments (provided municipalities are not subject to caps on tax levies)</p> <p>* The economic impact parks and recreational areas have on home prices depends on how far the home is from the open space, the size of the open space and the characteristics of the surrounding neighborhood</p> <p>* Open space in urban areas will increase the level of economic benefits to surrounding property owners more than open space in rural areas</p> <p>* Open space, recreation areas and compact developments may provide fiscal benefits to municipal governments</p> <p>* Compact, walkable developments can provide economic benefits to real estate developers through higher home sale prices, enhanced marketability and faster sales or leases than conventional development</p>

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings
Wolf	Economics and public value of urban forests	2004	Urban Agriculture Magazine	Research Synthesis	N/A	<p>* An urban forest is a resource system that can be cultivated and stewarded on all lands within a municipality (public and private, and all socioeconomic zones).</p> <p>* Urban forestry involves an ecosystem approach of urban tree management encompassing long-term planning, interdisciplinary professional coordination and local participation. Ultimately, the aim is to secure the health and vitality of forest resources, thereby sustaining delivery of benefits for current and future generations of urbanites.</p>
Correll, Lillydahl, Singell	The effects of greenbelts on residential property values: some findings on the political economy of open space	1978	Land Economics	Boulder, CO	Under certain circumstances price differentials may be used to evaluate the quasi-public good provided by greenbelts.	<p>* There is a \$4.20 decrease in the price of a residential property for every foot one moves away from the greenbelt. However, all properties in the area are affected by the area-wide public good.</p> <p>* Average value of properties adjacent to the greenbelt would be 32% higher than those 3,200 walking feet away.</p> <p>* Neighborhood value of open space as reflected by an increase in nearby property values depends critically on the ability of private developers and urban planners to integrate neighborhood development and access to open space.</p> <p>* As the public good of preserved open space becomes more common in the region, it's expected that intra-area property value effects will diminish; however, the collective value of greenbelts as an important component of maintaining quality urban life will continue.</p>

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings
Shiftan	Peoples' evaluation of urban and suburban characteristics: a residential stated preference model	2003	International Journal of Transport Economics	Portland, OR	There is significance to different urban and residential characteristics, including accessibility by different modes, to residents' willingness to pay for such characteristics.	<ul style="list-style-type: none"> * Low-income persons are willing to pay \$1,091.70 to be near a bike path, medium-income is \$1,369.00, high-income is \$6,901.30 for a home purchase. * Low/medium-income renters willing to pay extra \$5.60/month, high-income \$15.70/month. * However, located near a bike path was surpassed by significant majority of other characteristics, with the exception of price of shopping locally relative to the area average, walking time to local shops in minutes, and travel time to work by public transportation in minutes.
Fausold and Lilieholm	The economic value of open space	1996	Land Lines	Research Synthesis	N/A	<ul style="list-style-type: none"> * Open space possesses intangible values that are above and beyond any calculation of monetary value. * On a strictly financial basis, the cost of providing public services is more than twice as high for residential development as for commercial development or open space. * Proximity to preserved open space enhances property values, especially if the space is not intensively developed for recreation, and if it's carefully integrated with a neighborhood. This enhanced value is important to the local property tax base because it offsets the effects of open space, which is usually tax-exempt or taxed at a lower rate. * Lands valued for open space are part of a working landscape vital to the production of goods and services that are valued and exchanged in markets, e.g., animal products from pasture and grazing lands.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings
Hannum et. Al.	Comparative Analysis of Housing in Conservation Developments: Colorado Case Studies	2012	The Journal of Sustainable Real Estate	Colorado	The location of a property within a Conservation Development (CD) constitutes an environmental amenity with a positive impact on the value of that property.	<ul style="list-style-type: none"> * There are significant differences in prices for homes in CD projects vs. 35-acre, large lot, and unregulated CD projects. * There are significant differences in prices for homes in CD projects across the five CO counties. * There are significant differences in the total number of sales and transactions between CD projects and non-CD projects. * The impact of additional privately-held land is only 9 cents/sq. ft. * There is a significant sales price premium (approximately 20%) for homes located in CDs relative to comparable non-CD projects, while controlling for housing, time, and location factors.

Environmental Literature

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings	Urban Gradient
Ahrne et al.	Bumble Bees (Bombus spp) along a Gradient of Increasing Urbanization	2009	PLoS ONE	Stockholm, Sweden	Bumble bee abundance and diversity was studied at allotment gardens across an urban gradient	<ul style="list-style-type: none"> • Bumble bee diversity decreases with an increase in urbanization (measured by impervious surface). • Bumble bee abundance is more affected by characteristics of a specific site, such as, flower abundance or plant species richness. • Gardens provide forage for a large number of species, but the surround landscape context influences how many species will be present at a given site. • To support the high number of bumble bee species, urban planners must preserve and create a variety of natural spaces, and plan the larger landscape to maintain pollination services. 	Inner city of Stockholm to periurban areas.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings	Urban Gradient
Berry et al.	Abundance of diurnal raptors on open space grassland in an urbanized landscape	1998	The Condor	Boulder, CO	Point counts of diurnal raptors were conducted in Open Space sites to compare abundance and species to nearest development.	<ul style="list-style-type: none"> • Effects of urbanization on raptors are species dependent. • Four species (Bald Eagle, Ferruginous Hawk, Rough-legged Hawk, Prairie Falcon) were negatively correlated with the amount of urban development. The first three species were positively correlated with proximity to prairie dog colony. • American Kestrels and Red-tailed Hawks were uncorrelated with urbanization. • Large open spaces with little urbanization (<5-7%) and prairie dog towns need to be protected if we want to keep our diversity of raptors. 	Counts conducted all in Boulder Open Space. Surrounding land use contained varying amounts of development.
Blair and Launer	Butterfly diversity and human land use: species assemblages along an urban gradient	1995	Biological Conservation	Palo Alto, CA	The distribution and abundance of butterfly species was monitored at six sites along an urban gradient.	<ul style="list-style-type: none"> • Species richness and Shannon diversity of butterfly species was highest at moderately disturbed sites. • Relative abundance decreased from most natural to most urban sites. • Presence of species thought to best represent the pre-development butterfly community, decreases as sites become more urban. • Any amount of urbanization reduces the native assemblage of butterfly species. • Concentrated development should be utilized whenever possible to leave as much land undisturbed as possible. 	Six sites: nature preserve, recreational area, golf course, residential neighborhood (single family detached), office park and business district.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings	Urban Gradient
Bock et al.	Patterns of Rodent Abundance on Open-Space Grasslands in Relation to Suburban Edges	2002	Conservation Biology	Boulder, CO	Rodents were live-trapped in 65 grassland plots along Boulder Open Space lands. Capture rates were compared to habitat type, percent of surrounding use urbanized and proximity to suburban edge.	<ul style="list-style-type: none"> • Native rodents were captured more often on interior plots than edge plots. • For all native species, landscapes with less than 10% urbanization had the highest capture rates. • Minimizing urban or sub-urban edge in relation to the amount of interior space in natural areas is important for conserving native grassland rodents. 	Rodents all captured in Boulder Open Space. Capture sites moved from open grassland to suburban edge.
Carbo-Ramirez and Zuria	The value of small urban greenspaces for birds in a Mexican city	2011	Landscape and Urban Planning	Pachuca, Hidalgo, Mexico	Bird communities were measured in 19 small greenspaces (<5 ac) in an urban environment. Bird abundance was compared to area, vegetation, impervious surface, and human disturbance	<ul style="list-style-type: none"> • Species richness was positively correlated with greenspace area and herbaceous plant height. • Species richness had a negative relationship with percentage of surrounding area covered by buildings. • Greenspace size in cities must be maximized to support rich and abundant communities. • Greenspace should contain more areas that are not mowed and have complex vegetation cover. • The landscape matrix surrounding greenspaces needs to be considered for amount of vegetation cover and connectivity 	All sites located in the city. Three different land uses: public parks, gardens and road strips.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings	Urban Gradient
Collinge et al.	Effects of Local Habitat Characteristics and Landscape Context on Grassland Butterfly diversity	2003	Conservation Biology	Boulder, CO	Butterfly species abundance and composition was recorded in 66 grassland plots. Observations were analyzed against grassland type, quality of grassland and surrounding land use.	<ul style="list-style-type: none"> • Grassland type was the primary determinant of species richness and composition. • Habitat quality secondarily affected butterfly community diversity. • Landscape context did not significantly predict butterfly species composition. • Important to preserve and enhance a variety of high quality grassland types 	All plots were located in Boulder Open Space. 66 plots were adjacent to some form of human activity, such as residential or commercial use. 36 plots were surrounded by native habitat.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings	Urban Gradient
Germaine et al.	Relationships among breeding birds, habitat, and residential development in greater Tucson, Arizona	1998	Ecological Applications	Tucson, AZ	Breeding bird surveys were complete on 334 plots along an urban gradient in Tucson, AZ. Bird species and guilds were compared to habitat, vegetation and surrounding land use.	<ul style="list-style-type: none"> • Housing density explained a majority of variation in species richness for both non-native (positive correlation) and indicator species (negative correlation) guilds. • For the native species group, upland Sonoran vegetation cover had a positive correlation and distance from undisturbed washes had a negative correlation. • To retain the native species: native vegetation should be used, riparian and other vegetation corridors must be protected and patches >2.5ac of native vegetation need to be retained and interspersed throughout the urban matrix. • Native bird species have strongly differing habitat requirements than non-native species. 	The 334 plots were located in Tucson metropolitan area and ranged from undisturbed natural to highly developed. Housing density ranged from 0-7.9 houses/ac.
Grubbs and Krausman	Use of Urban Landscape by Coyotes	2009	The Southwestern Naturalist	Tucson, AZ	Movements of radio-collared coyotes were monitored to determine home range size and use of habitat based on land-use categories.	<ul style="list-style-type: none"> • The average home range size for a coyote was 26.8 ± 5.1 km² (approx. 10mi² \pm 2mi²). • Washes, medium-density residential and low-density residential land uses were utilized most frequently by coyotes. • However, high-density and commercial areas were the land uses that had the most use at night. • Diverse land uses and available resources allow coyotes to persist in an urban environment. • Coyotes in this area shifted their behavior from crepuscular to nocturnal. 	An urban pack of coyotes were tracked in Tucson. Low density: < or = 0.4 residences/ac; Medium density: 0.8-2.8; High density >2.8

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings	Urban Gradient
Hope et al.	Socioeconomics drive urban plant diversity	2003	PNAS	Phoenix, AZ	Plant diversity was measured at 204 sites across the Phoenix metropolitan area. Species richness was compared to land-use, distance from city center and various demographic variables	<ul style="list-style-type: none"> Plant diversity was best explained by land-use, elevation (positive), median family income (positive), and whether the site had ever been farmed (negative). Humans remove resource limitations which allow for a higher diversity of species to coexist. Humans who have more monetary resources can create more diverse habitats. 	Plots were located in Phoenix metropolitan area and moved from the city to agriculture to undeveloped native desert land.
Kaye et al.	Carbon fluxes, nitrogen cycling, and soil microbial communities in adjacent urban, native and agricultural ecosystems	2005	Global Change Biology	Fort Collins, CO	Carbon fluxes, nitrogen cycling and soil microbial community structure was measured across four habitats: urban lawns, corn, wheat-fallow and shortgrass steppe.	<ul style="list-style-type: none"> Aboveground net primary production was four to five times greater for lawns than wheat or shortgrass, but significantly lower than corn. Soil respiration and total below ground C allocation were both 2.5 to 5 times greater for lawns than any other land-use type. Land-use type had a large impact on microbial biomass, but only a small impact on relative abundance of taxonomic groups of microorganisms. Urbanization enhances C cycling rates that are large enough to alter regional C budgets 	Four habitats were assessed: urban lawns, corn fields, wheat-fallow and shortgrass steppe.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings	Urban Gradient
Kinzig et al.	The effects of Human Socioeconomic Status and Cultural Characteristics on Urban Patterns of Biodiversity	2005	Ecology and Society	Phoenix, AZ	Bird and plant species were recorded at 16 different parks located throughout Phoenix. This data was compared to the socioeconomic status of the surrounding neighborhood.	<ul style="list-style-type: none"> • Median family income is the most effective variable in explaining neighborhood plant diversity. • The addition of using socioeconomic status in models increased the models ability to predict both plant and bird diversity. • Lower income neighborhoods have less diversity. • This has environmental justice implications and could affect how low-income citizens interact with and build a relationship with nature. • Cities are not irrelevant for conservation and the better we understand how humans affect biodiversity the better we can plan to keep it in our cities. 	All sites were located on parks in Phoenix.
Lerman and Warren	The conservation value of residential yards: linking birds and people	2011	Ecological Applications	Phoenix, AZ	Native bird population was analyzed against socioeconomic factors, landscaping in residential yards, and urban gradient measures in Phoenix.	<ul style="list-style-type: none"> • Native species increased in neighborhoods with desert landscaping designs, neighborhoods closer to large desert tracts and higher-income neighborhoods. • Residents' satisfaction with bird diversity was positively correlated with actual bird diversity. • Residential yards have the potential to support and increase urban biodiversity when landscaped with native plant species. 	Forty neighborhoods in Phoenix that ranged from the 'fringe' to 'urban core' were surveyed. Urban gradient measured by distance to desert, housing age and % soil.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings	Urban Gradient
Loss et al.	Relationships between avian diversity, neighborhood age, income, and environmental characteristics of an urban landscape	2009	Biological Conservation	Chicago, IL	Bird communities were compared to environmental characteristics, as well as, neighborhood age and income.	<ul style="list-style-type: none"> • Housing age was strongly related to avian species richness, with newer neighborhoods supporting more species. • Income was positively related to exotic species and negatively related to native species. • Total richness was highest in sites with undeveloped patches and mixed land cover types; richness decrease with distance from natural areas larger than 0.4 mi². • Bird diversity is enhanced by both small patches of nature as well as close proximity to larger patches. • It is important to understand how social factors also affect biodiversity, since it cannot be entirely accounted for by natural features. 	All sites were located in the Chicago metropolitan area. Sites were classified as urban open space, outer suburban, inner suburban or high density urban. Urban gradient was measured by % undeveloped and housing density - which was measured by using 2000 Census data.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings	Urban Gradient
Maestas et al.	Biodiversity across a Rural Land-Use Gradient	2003	Biodiversity and Land Use	Larimer County, CO	Bird, meso-predator and plant communities were evaluated across an urban gradient from nature reserves, cattle ranches to exurban developments.	<ul style="list-style-type: none"> • Seven, human commensal or tree nesters, bird species had their highest density on exurban developments. • Six, ground and shrub nesters, had their highest densities on ranches or reserves. Coyotes were most frequently detected on ranchlands. Ranches had plant communities with higher native species richness and lower non-native species richness and cover than the other two land uses. • Ranches are important for protecting biodiversity. • To make significant conservation impacts, future efforts may require less emphasis on reserves and more on private lands. 	Sites were located in nature reserves, cattle ranches or exurban development.
McIntyre and Hostetler	Effects of urban land use on pollinator (Hymenoptera: Apoidea) communities in a desert metropolis	2001	Basic Applied Ecology	Phoenix, AZ	Species richness and abundance of pollinator communities was compared to four types of urban land use in Phoenix.	<ul style="list-style-type: none"> • Richness and abundance of bees was lower in residential areas compared to desert areas. • Desert areas on the fringes of town had the highest overall diversity. • Residential yards with xeriscape had more diversity of bees than yards with turf lawns. • Types of habitat features seemed to influence the number and type of bees present. • The use of native landscaping can help preserve bee populations if a diverse set of plant types are used. 	Sites were in three land use types: residential yards, urban desert-remnant parks, and natural desert parks on the fringe of the metropolitan area.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings	Urban Gradient
Mills et al.	Effects of Urbanization on Breeding Bird Community Structure in southwestern Desert Habitats	1989	The Condor	Phoenix, AZ	Bird density and diversity were compared across 34 neighborhoods in Phoenix. Researchers looked for correlations between the bird community, vegetation characteristics and urban land use characteristics.	<ul style="list-style-type: none"> • Native bird species richness and diversity were strongly correlated with native plant volume. • Density of exotic birds was correlated with correlated exotic plant volume. • Vegetation factors explained more variation than housing density. • Breeding bird densities are affected by critical resources. • Native bird populations can be retained in urban developments if native plants are used. 	Sites were located in native desert or low, medium or high density housing. Housing density ranged from 0 - 1.44 houses/ac.
Nelson and Nelson	Bird and Butterfly communities associated with two types of urban riparian areas	2001	Urban Ecosystems	Denver, CO	The distribution of birds and butterflies were evaluated in two types of urban riparian areas in Denver, Colorado.	<ul style="list-style-type: none"> • Bird abundance was similar at both sites but consisted of different assemblages. • Butterfly abundance was less at lawn sites. • Bird and butterfly species richness was 44% less at highly modified riparian sites. • Bird and butterflies respond to habitat changes in different ways. • Open lawn urban habitats should be discouraged. • Wooded riparian areas should be buffered with undeveloped land around them rather than just greenbelts and sport fields. 	Two types of sites, all located within Denver: relatively natural areas containing native woody vegetation, or highly modified with trees and shrubs removed and planted with lawn grass.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings	Urban Gradient
Shochat et al.	Urbanization and spider diversity: influences of human modification of habitat structure and productivity	2004	Ecological Applications	Phoenix, AZ	Six habitat types were sampled for spider abundance and diversity across an urban gradient in Phoenix, Arizona. Spider composition was compared to habitat type and productivity.	<ul style="list-style-type: none"> • Agriculture fields and mesic-yards were the most productive. • Spider abundance was highest at these sites, but had low species diversity. • Spider diversity decreases as sites become more urban, but abundance increases. • Changes in habitat structure and productivity change community structure, as urban or agriculture habitats favor one or a few taxa over others. • Native plantings and conserving remnant natural habitats is needed to keep a diverse community of spiders. 	Six habitat types within the Phoenix metropolitan area: desert parks, urban desert remnants, industrial, agricultural, and residential yards.
Smith and Wacob	Trends associated with residential development in riparian breeding bird habitat along the Snake River in Jackson Hole, WY, USA: Implications for conservation planning.	2006	Biological Conservation	Jackson Hole, WY	Bird counts were performed across an urban gradient along the Snake River in Jackson Hole, Wyoming. Bird communities were compared to habitat variables at three spatial scales	<ul style="list-style-type: none"> • Overall species richness and diversity declined with increasing residential development. • Food generalists, ground gleaners and avian nest predators all increased with increasing development. • Residential development within riparian habitats negatively influences bird communities. • Preserving forest structure may benefit a few bird species, but will not conserve a diverse population. • Minimizing fragmentation associated with residential development should be the focus. 	Point counts were done in four different areas: Grand Teton NP, low, medium or high density development. (1–15, 16–50, and 50–115 houses within 545yds of the patch, respectively).

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Strohbach et al.	Are small greening areas enhancing bird diversity? Insights from community-driven greening projects in Boston	2013	Landscape and Urban Planning	Boston, MA	Bird communities were compared at small greensites, urban sites and large parks in Boston, Massachusetts to help understand how small green areas affect bird biodiversity.	<ul style="list-style-type: none"> • Large parks have a distinct and rich bird population. • Other sites were similar to each other, but small greensites had higher species richness than urban sites. • Patch size had explained the most variation and tree cavities to a lesser extent. • Small green areas should focus on preserving, increasing and connecting existing green space. 	Three different types of sites, all within Boston: small 'greening' projects, urban sites or large parks.
Vogel	Response of deer to density and distribution of housing in Montana	1989	Wildlife Society Bulletin	Bozeman, MT	Deer populations were monitored along an urban gradient in Bozeman, Montana. Deer use was compared to housing density.	<ul style="list-style-type: none"> • The number of deer decreases with housing density. • Farmhouses were avoided less than other houses. Nocturnal activity increased with more dense housing. • White-tailed deer became more dominant (over Mule deer) with increasing development density. • It is better to increase the housing in areas where development already exists than to develop new areas. 	The 21 sites were located at either: low, medium, high or very high development levels. Housing density was measured by houses/km ² .

Social Literature

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings
Aspinall P, Mavros P, Coyne R, Roe J.	The urban brain: analyzing outdoor physical activity with mobile EEG.	2013	Journal of Sports Medicine	Unavailable	The study analyzed how a 25-minute walk in different areas (urban, green space, or a busy street) affects emotional experiences.	This study has implications for promoting urban green space as a mood enhancing environment for walking or for other forms of physical or reflective activity.
McDonnell, Mark and Hahs, Amy	Four Ways to Reduce the Loss of Native Plants and Animals from Our Cities and Towns	2014	The Nature of Cities	N/A	N/A	Key issues related to the creation of management actions to reduce future local extinctions of plants and animals in our cities and towns include (1) link management actions with ecological knowledge, (2) protect existing natural habitats, (3) restore degraded habitats, and (4) integrate remnant patches into the urban landscape.
Diana E Bowler, Lisette M Buyung-Ali, Teri M Knight, Andrew S Pullin	A systematic review of evidence for the added benefits to health of exposure to natural environments.	2010	BMC Public Health	Numerous	Research synthesis assesses how exposure to natural environments affects human health.	This study is suggestive that natural environments may have direct and positive impacts on well-being, but support the need for investment in further research on this question to understand the general significance for public health.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings
Roberta Kwok	Do parks boost long-term mental health?	2014	Conservation Magazine	United Kingdom	Are there mental health benefits from moving to an area with more green space? Can those benefits be sustained?	An article about a team that examined survey data from 1,064 people in the UK who had moved between 1991 and 2008. About half had moved to a neighborhood with more green space, and the other half had moved to a less green area. The data included participants' evaluations of their moods for two years before and three years after the move. The people who moved to a greener area had better mental health in the three years following the move.
Richard A. Fuller, Katherine N. Irvine, Patrick Devine-Wright, Philip H. Warren and Kevin J. Gaston	Psychological benefits of green space increase with biodiversity	2007	Biology Letters, The Royal Society	United Kingdom	Can open space users accurately assess areas with higher and lower species diversity? How do psychological benefits correlate with increased species diversity?	This study demonstrates positive psychological benefits increase with the species richness of urban greenspaces. Greenspace users can more or less accurately perceive species richness depending on the taxonomic group in question. These results indicate that successful management of urban greenspaces should emphasize biological complexity to enhance human wellbeing in addition to biodiversity conservation.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings
Kristen Malecki	Exposure to neighborhood green space and mental health: evidence from the Survey of the Health of Wisconsin	2014	International Journal of Environmental Research and Public Health	Wisconsin	The researchers assessed how levels of vegetation in a neighborhood affect mental health.	The study combines mental-health data from the Survey of the Health of Wisconsin (SHOW) and Landsat 5 satellite data from July 2009 that analyzed how much vegetation was present in each of the SHOW census blocks. They found that across all strata of society, people who lived in a neighborhood with less than 10 percent tree canopy were much more likely to report symptoms of depression, stress and anxiety.
Peter P Groenewegen ¹ , Agnes E van den Berg, Sjerp de Vries and Robert A Verheij	Vitamin G: effects of green space on health, well-being, and social safety	2006	BMC Public Health	Netherlands	To document and understand the relationship between the amount and type of green space and human health and to suggest policy solutions	Looking out on and being in the green elements of the landscape around us seem to affect health, well-being and feelings of social safety. This article discusses the design of a research program on the effects of green space in the living environment on health, well-being and social safety.
Ann P. Kinzig, Paige Warren, Chris Martin, Diane Hope, and Madhusudan Katti	The Effects of Human Socioeconomic Status and Cultural Characteristics on Urban Patterns of Biodiversity	2005	Ecology and Society	Phoenix, Arizona	To assess how socioeconomic factors and cultural characteristics influence biodiversity.	Species diversity (specifically plants and birds) increased with increasing affluence in an area, e.g., they found 28 avian species in high-income parks whereas only 18 species were observed in low-income parks.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings
Frances E. (Ming) Kuo	Parks and Other Green Environments: Essential Components of a Healthy Human Habitat	2010	National Recreation and Park Association	N/A	This white paper summarizes the research from the impacts of open space on human health.	Parks and other green environments are an essential component of a healthy human habitat.
Ian Alcock, Mathew P. White, Benedict W. Wheeler, Lora E. Fleming, and Michael H. Depledge	Longitudinal Effects on Mental Health of Moving to Greener and Less Green Urban Areas	2013	Environmental Science & Technology	Great Britain	This study used panel data to explore three different hypotheses about how moving to greener or less green areas may affect mental health over time.	Individuals who move to areas with more green space had significantly better mental health (measured for two years before a move and three years after the move). Moving to less green areas worsens mental health initially, but then it returns to the baseline.
Jenny Veitch, Ph.D. & Anna Timperio, Ph.D. & David Crawford, Ph.D. & Gavin Abbott, G. Dip. Pysch. & Billie Giles-Corti, Ph.D. & Jo Salmon, Ph.D.	Is the Neighbourhood Environment Associated with Sedentary Behaviour Outside of School Hours Among Children?	2011	The Society of Behavioral Medicine	Melbourne, Australia	This study aims to examine the associations between public open spaces (POS), parent perceptions of the neighborhood and children's sedentary behaviors.	Neighborhood features appear to positively and negatively influence children's sedentary behaviors, highlighting the complexity of urban planning on behavior.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings
Jennifer Wolch, Michael Jerrett, Kim Reynolds, Rob McConnell, Roger Chang, Nicholas Dahmann, Kirby Brady, Frank Gilliland, Jason G. Su, Kiros Berhane	Childhood obesity and proximity to urban parks and recreational resources: A longitudinal cohort study	2011	Health & Place Journal 17	California	The objective of the research was to assess how proximity to parks and recreational resources affects the development of childhood obesity through a longitudinal study.	When a park is within 500 m of a child's home, there is a significant decrease in BMI (body mass index), and the decrease was more significant for boys. Better access to open space has demonstrable effects on BMI.
NPR news article	To Make Children Healthier, a Doctor Prescribes a Trip to the Park	2014	NPR news	N/A	This is a news report about encouraging obese children to go to urban parks to walk and play more.	A doctor in Washington D.C. received funding by the National Recreation and Park Association, the National Environmental Education Foundation and the American Academy of Pediatrics to come up with an app to better find nearby parks and open spaces which can also be linked to patient records.
Jessica M. Clement, Antony S. Cheng	Using analyses of public value orientations, attitudes and preferences to inform national forest planning in Colorado and Wyoming	2011	Applied Geography Journal	Colorado, Wyoming	This paper presents results and discusses implications from social surveys conducted on three national forests in Colorado and Wyoming.	The results indicate that although respondents identified aesthetic, biodiversity, future and recreation value orientations as most important, there are also surprising linkages between value orientations, attitudes and preferences towards forest uses and policy options associated with specific geographic and socio-economic contexts and conditions.

Authors	Title	Date	Publication	Location	Hypothesis	Key Findings
Bibliography	Children & Nature Worldwide: An Exploration of Children's Experiences of the Outdoors and Nature with Associated Risks and Benefits	2012	IUCN Commission on Education and Communication and Children and Nature Network	Numerous	Summarizes the literature on children's connections with nature.	Evidence base for the importance of children's connections with nature. Bibliography of studies, joint publication
The Trust for Public Lands	The Benefits of Parks: Why America Needs More City Parks and Open Space	2006	The Trust for Public Lands	Numerous	Summarizes the benefits of parks and open space.	The Trust for Public Lands publication on City parks and open space improve our physical and psychological health, strengthen our communities, and make our cities and neighborhoods more attractive places to live and work.