The Nature Conservancy
Protecting nature. Preserving life.™

445 South Figueroa St, Suite 1950
Los Angeles, CA 90071

Tel (213) 327-0104
Fax (213) 327-0161

nature.org/california

May 8, 2017

Los Angeles City Council
200 N Spring St, Room 340
Los Angeles, CA 90012

RE: Biodiversity Motion, Council File 15-0499

Dear Los Angeles City Councilmembers,

On behalf of the California Chapter of The Nature Conservancy, thank you for the opportunity to comment on City Council Biodiversity Motion (Council File 15-0499).

The Nature Conservancy (Conservancy) is an international non-profit organization dedicated to conserving the lands and waters on which all life depends. Our on-the-ground work is carried out in all 50 states and in more than 70 countries and is supported by one million members. To date, we have helped conserve more than 120 million acres (including 1.2 million acres in California) and 5,000 river miles around the world. We have been engaged in the protection and management of natural resources across the U.S. for many years. The foundation of the Conservancy's work is our commitment to using the most up-to-date conservation science information and methodologies to guide decision-making. Our tools and methods have been widely adopted by other organizations and agencies that engage in natural resource conservation and ecosystem restoration.

The Conservancy commends the City Council for actively evaluating options for protecting and enhancing biodiversity in the City of Los Angeles, located in a Mediterranean-climate region. Mediterranean-climate regions have high levels of species richness and endemism and are found in only five places on Earth. While Mediterranean-climate regions cover only 2.2 percent of Earth's land surface, they contain 20 percent of all known plant species. Unfortunately, Mediterranean ecosystems are also among the most threatened on Earth. More than 41 percent of the Mediterranean biome has been converted to farmland and urban uses, and only 5 percent of its natural area has been protected. In Greater Los Angeles, the valleys have been developed for residential, commercial and industrial use and many natural riparian corridors have been channelized. However, the Conservancy found in our 2013 Assessment of the region's biological diversity that important ecological values remain, as do opportunities for ecological restoration that will benefit nature and people. The Conservancy strongly supports projects that restore habitat to support biodiversity in this region.

The Conservancy has provided input to Councilmember Koretz's biodiversity working group since 2015 and has participated in the stakeholder process to raise the profile of biodiversity in Greater Los Angeles. The Conservancy strongly supports a program to protect, restore, and enhance biodiversity in Greater Los Angeles. The Conservancy has also contributed to the City of Los Angeles Sustainable City pLAn, championing a biodiversity strategy. The Biodiversity Motion recognizes the need for a City Biodiversity Index, and the

Conservancy strongly supports the implementation of this index in Los Angeles. To protect, enhance, and restore biodiversity, it must be integrated across City departments, into strategies, and into practices as the Biodiversity Motion states. A technical advisory committee, community engagement, and outreach are also critical in gaining support for and implementing a strategy that protects and improves biodiversity across Los Angeles. The Conservancy would be pleased to lend technical assistance to this effort.

The Biodiversity Motion proposes the development of "habitat-based geospatial strategies for incorporating conservation and equity of biodiversity in specific plans, development permitting, connectivity, planning, urban forestry, and the design and maintenance of parks and streets." To support the goals of the Biodiversity Motion, the Conservancy and our partners in the conservation community are working to develop a vision and plan for incorporating green infrastructure and nature into infrastructure projects and avoiding status quo gray infrastructure design, which includes our joint effort with the Natural History Museum called Biodiversity Analysis in Los Angeles (BAILA). BAILA is a spatially explicit science analysis that is flexible enough to allow for application of a variety of urban planning inputs (i.e. stormwater, transportation, energy, or land-use planning, public health or environmental justice planning). BAILA will include a spatially explicit, interactive map product and decision-making tool for a Greater Los Angeles gray-to-green conservation infrastructure vision and its associated financing and governance plans. The Conservancy is engaging a range of stakeholders in the production of these products and is sharing these with other stakeholders to build consensus for the vision with the support of a National Park Service RTCA Technical Assistance Grant.

In closing, the Conservancy strongly supports City Council's Biodiversity Motion. We look forward to supporting the City of Los Angeles as planning and implementation continues. Thank you again for the opportunity to provide comments. Please direct questions to Shona Ganguly, External Affairs Manager, at sganguly@tnc.org or please call 213-787-9415.

Sincerely,

Jill Sourial

Jill Sourial
Urban Conservation Program Director
The Nature Conservancy

MOUNTAINS RECREATION & CONSERVATION AUTHORITY
Ramirez Canyon Park
5810 Ramirez Canyon Road
Malibu, California 90265
Phone (310) 589-3230 Fax (310) 589-3237

May 9, 2017

Los Angeles City Council
Office of the City Clerk
200 North Spring Street, Room 395
Los Angeles, California 90012

Protecting and Improving Biodiversity (Council File 15-0499)
Item 25 on the May 10, 2017 Agenda

Hon. Councilmembers:

The staff of the Mountains Recreation and Conservation Authority (MRCA) enthusiastically supports the subject motion by Councilmember Koretz regarding the formation of a working group to develop strategies for protecting biodiversity in the City of Los Angeles, and the implementation of the City Biodiversity Index. The MRCA, in conjunction with our parent agency, the Santa Monica Mountains Conservancy, owns or is responsible for the maintenance of over 69,000 acres of parkland and public open space in wild and urban-adjacent areas. Many of these acres fall within, or lie adjacent to, the boundaries of the City of Los Angeles. The subject motion aligns with the part of the MRCA's ongoing mission that includes protecting native species in perpetuity throughout the Santa Monica Mountains and adjacent areas.

The staff of the MRCA should be considered available to consult with the new biodiversity working group if desired by any of the participating agencies. Please feel free to contact me regarding this matter at 310-589-3230, ext. 124, by e-mail at garrett.weinstein@mrca.ca.gov. Thank you for your consideration.

Sincerely,

Garrett Weinstein
Project Analyst

United States Department of the Interior

NATIONAL PARK SERVICE
Santa Monica Mountains National Recreation Area
401 West Hillcrest Drive
Thousand Oaks, California 91360-4207

Members of the City Council of Los Angeles, May 9, 2017

Santa Monica Mountains National Recreation Area strongly supports the initiative by the City of Los Angeles to better understand the status and distribution of biodiversity within the city. As the motion indicates, Southern California is one of the most diverse places in the world, but while we know this about the region generally, we know very little about the diversity of life within the city itself. More and more cities around the country and the world are taking an interest in the animals and plants that persist in them, realizing their intrinsic value and striving to both measure and foster this diversity. It is entirely appropriate that Los Angeles, the second largest metropolitan area in the country and one of just 31 megacities around the globe, do the same.

The National Park Service is mandated to strive to understand and protect the natural resources of the parks for the enjoyment of future generations. As the largest urban national park in the country and the only national park unit in the Los Angeles region, a primary goal of ours is to understand the ecology of urban areas generally and of the LA metropolitan area specifically. To this end, we invest a great deal of time and resources in the study of the fauna and flora of the Santa Monica Mountains and surrounding areas, including in the City of Los Angeles itself. We welcome the efforts of others to gather information on other parts of the region and on other parts of the biota, and in particular on biodiversity in the most intensively urbanized areas of Los Angeles. In general very little is known about the wild plants and animals that live within the built environments of cities. But for thousands of urban residents, the biota in the city represent the best opportunity for contact and increased knowledge. which can both improve quality of life and develop a lifelong understanding and appreciation for nature.

We applaud and support the steps taken by this motion, specifically to move towards a better understanding of biodiversity across the city. Although the City Biodiversity Index, or Singapore Index, represents a good starting point, we agree that forming a Technical Advisory Committee to consider the best way forward for Los Angeles would be valuable. We would be happy to participate in this process in whatever ways the City deems appropriate. A primary objective of the park, as set forth in the enabling legislation in 1978, is to assist agencies of the State, cities, and counties, with furthering the goals of understanding and preserving natural resources. We feel strongly that providing whatever scientific expertise and knowledge we can to the region is an important role for the park and park staff.

Thank you for the opportunity to express our support for biodiversity in the Los Angeles area and for the city's efforts to measure and sustain it.

Sincerely,

K. Kredall

For David Szymanski
Superintendent

MOUNTAINS RECREATION & CONSERVATION AUTHORITY
Ramirez Canyon Park
5810 Ramirez Canyon Road
Malibu, California 90265
Phone (310) 589-3230 Fax (310) 589-3237

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Sincerely,

Garrett Weinstein
Project Analyst

STATE OF CALIFORNIA–THE NATURAL RESOURCES AGENCY
EDMUND G. BROWN, JR., *Governor*

SANTA MONICA MOUNTAINS CONSERVANCY
RAMIREZ CANYON PARK
5750 RAMIREZ CANYON ROAD
MALIBU, CALIFORNIA 90265
PHONE (310) 589-3200
FAX (310) 589-3207
WWW.SMMC.CA.GOV

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The staff of the Santa Monica Mountains Conservancy should be considered available to consult with the new biodiversity working group if desired by any of the participating agencies. Please feel free to contact me regarding this matter at 310-589-3200, ext. 128, by e-mail at edelman@smmc.ca.gov. Thank you for your consideration.

Sincerely,

PAUL EDELMAN
Deputy Director
Natural Resources and Planning

Planning for the Future of Urban Biodiversity: A Global Review of City-Scale Initiatives

CHARLES H. NILON, MYLA F. J. ARONSON, SAREL S. CILLIERS, CYNNAMON DOBBS, LAUREN J. FRAZEE, MARK A. GODDARD, KAREN M. O'NEILL, DEBRA ROBERTS, EMILIE K. STANDER, PETER WERNER, MARTEN WINTER, AND KEN P. YOCOM

Cities represent considerable opportunities for forwarding global biodiversity and sustainability goals. We developed key attributes for conserving biodiversity and for ecosystem services that should be included in urban-planning documents and reviewed 135 plans from 40 cities globally. The most common attributes in city plans were goals for habitat conservation, air and water quality, cultural ecosystem services, and ecological connectivity. Few plans included quantitative targets. This lack of measurable targets may render plans unsuccessful for an actionable approach to local biodiversity conservation. Although most cities include both biodiversity and ecosystem services, each city tends to focus on one or the other. Comprehensive planning for biodiversity should include the full range of attributes identified, but few cities do this, and the majority that do are mandated by local, regional, or federal governments to plan specifically for biodiversity conservation. This research provides planning recommendations for protecting urban biodiversity based on ecological knowledge.

Keywords: biodiversity conservation, ecosystem services, urban planning, policy regulation, governance

Globally, towns and cities are rapidly increasing in area and in population; urban area is projected to triple until 2030 (Batty 2008, Seto et al. 2012). Most urbanization is occurring in regions identified as biodiversity hotspots (Seto et al. 2012), with profound effects on ecological patterns and processes, including habitat destruction, degradation, and fragmentation; changes to biological assemblages resulting in novel ecological communities; increased levels of pollution in soil, air, and water systems; and alterations of natural disturbance regimes and ecosystem processes, such as water and nutrient cycling (Luck 2007, Grimm et al. 2008). As a result, (a) the density of flora and fauna is substantially reduced in urban areas compared with that in nonurban habitats (Aronson et al. 2014), and (b) urban floras become more similar over time (La Sorte et al. 2014). Reductions in biodiversity decrease the capacity of ecosystems to capture essential resources, produce biomass, and maintain ecological processes such as nutrient cycling (Cardinale et al. 2012). Reductions in urban biodiversity have consequences for human well-being, reducing the benefits people can obtain from nature at individual and community levels (Brown and Grant 2005, Fuller and Irvine 2010, Luck 2012). However, recent research has shown that cities can still support significant levels of biodiversity, including endangered and threatened species, and therefore can play an important role in biodiversity conservation (Aronson et al. 2014, Ives et al. 2015).

People experience biodiversity primarily where they live. Urban planning and policy therefore have the potential to influence how people and communities experience and understand biodiversity, as well as to increase support for conservation in the city and beyond (Dearborn and Kark 2010, Karvonen and Yocom 2011). Daily interaction with nature engages people in nature conservation (Fuller and Irvine 2010) and has positive effects on physical and psychological health, social cohesion, crime reduction, environmental awareness, economic gain, and sense of belonging (Giles-Corti et al. 2005, Barton and Pretty 2010).

Biodiversity conservation in cities works to preserve remnant natural habitats while further planning, designing, and implementing green-infrastructure networks. Green infrastructure across the city allows for a diversity of natural, restored, and constructed habitats that all serve to improve conditions for biodiversity in public and private lands (Beninde et al. 2015). For example, private gardens constitute an important group of microhabitats that foster a large diversity of flora and fauna that residents can directly experience (Smith et al. 2006, Loram et al. 2008). Efficient

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planning and management can increase biodiversity and improve conditions for urban areas within this green-infrastructure network (Irvine et al. 2010).

Biodiversity also contributes to a city's capacity to adapt to changing environmental conditions by maintaining ecosystem health (Díaz et al. 2006, Tzoulas et al. 2007, Haines-Young and Potschin 2010). One way of representing the benefits of biodiversity for the environment and for humans is the concept of ecosystem services (MEA 2005), describing the benefits that humans derive from nature. The biophysical structure and function of ecosystems are linked to services, which are then linked to human well-being through benefits and economic value (Hansen and Pauleit 2014). Conserving and fostering biodiversity also support the continuity of these ecosystem processes, including the maintenance and enhancement of human well-being (Cardinale et al. 2012, Sandifer et al. 2015). Although there is large and increasing body research on ecosystem services in cities, the findings are not often used by city planners (Ahern et al. 2014, Haase et al. 2014).

Biodiversity conservation and managing for ecosystem services present conservation challenges for planning and policy (Dearborn and Kark 2010). Although cities are centers of consumption and land-use change, they represent a considerable opportunity for forwarding global sustainability and environmental goals. For example, cities are at the forefront in planning for climate-change adaptation and mitigation (Rosenzweig et al. 2010), and research into urban-ecosystems dynamics are revealing the potential for managing local and large-scale environmental change (Youngsteadt et al 2014).

City plans and biodiversity: Questions and approaches

Researchers studying how cities address planning for biodiversity and ecosystem services have focused on case studies of individual cities (e.g., McPhearson et al. 2014, Kabisch 2015). Here, we examine how multiple cities plan for and address issues of biodiversity conservation and ecosystem services. We are interested in understanding how such planning and implementation can simultaneously serve as drivers to enhance biodiversity conditions within cities as well as barriers. We examine city plans, policies, and strategies from the perspective of the ecological sciences by identifying important attributes for urban biodiversity and ecosystem services at a global scale. Our research represents a first step in understanding how the urban-planning process can be used to address biodiversity conservation and the provision of ecosystem services. We do not address important questions about plan implementation or about the success of the plans in conserving species or in the provision of ecosystem services. Instead, we ask three questions: (1) What are the biodiversity and ecosystem-services attributes that are relevant for urban planning? (2) Which of these attributes do cities include in their plans? (3) How do cities differ in their use of these attributes? More specifically, do biodiversity and ecosystem-services plan attributes differ between cities located in biodiversity hotspots (Conservation International 2016) and those that are not located in biodiversity hotspots? And do the biodiversity and ecosystem-services plan attributes in cities participating in the City Biodiversity Index (CBI; Chan and Djoghlaf 2009) differ from those in other cities?

We sampled 40 cities from 25 countries. We wanted to understand how cities from a variety of ecological, political, and economic contexts incorporated biodiversity and ecosystem services into planning. Cities were initially identified from previous global studies of urban biodiversity and green infrastructure (Aronson et al. 2014, Dobbs et al. 2014). To be included in the sample, the city had to have at least one official planning document that contained a goal that was specifically related to biodiversity or related ecosystem services. To broaden the geographic range, we sought recommendations from ecologists and urban planners for cities in Africa, South America, and Southeast Asia that were not included in Aronson and colleagues' (2014) and Dobbs and colleagues' (2014) studies. The sample of cities included all biogeographic realms (excluding Antarctica) and 34 ecoregions (table 1).

Between January and December 2014, we conducted online searches and talked with city employees or consultants to identify 135 city- or metropolitan-scale plans from the 40 selected cities. The online search was initiated with the name of the city and the keywords *biodiversity*, *ecosystem services*, *open space*, *green space*, *conservation*, *sustainability*, *street trees*, *climate change*, *comprehensive plan*, and *green infrastructure*. We examined official city websites to identify additional relevant documents. The majority of the plans were written in English, but plans in Portuguese, Spanish, Dutch, German, French, Chinese, and Italian were also evaluated by coders with proficiency in these languages.

Biodiversity and ecosystem-services attributes

We identified 34 attributes that are important to urban planning for biodiversity conservation and related ecosystem services on the basis of a comprehensive literature review (table 2). These attributes were organized into six categories: baseline data, biodiversity goals, biodiversity targets, ecosystem-services goals, ecosystem-services targets, regulations, and commitment to implementation (table 2). *Biodiversity goals* were defined as objectives related to biodiversity conservation: habitats, species, monitoring of biodiversity, connectivity among parcels of land, green infrastructure, invasive-species management, education, stewardship (i.e., encouraging citizen involvement), and constructed habitats (e.g., green roofs and bioswales). *Ecosystem-services goals* were defined as those whose planning or implementation directly benefits biodiversity. We chose the most common ecosystem-services goals that are addressed in city plans according to the plans we assessed: air and water quality, carbon sequestration, urban-heat-island amelioration, urban agriculture, and cultural services (e.g., recreation or fostering

Table 1. The population, biogeographic characteristics (World Wildlife Fund Ecoregions), presence in biodiversity hotspots, ratification of the Convention on Biological Diversity, and number of plans for each city. See the supplemental material for plan references.

Cities	Population (thousands)	Reference	Hotspot	Ecoregion	CBD	Number of plans
Amsterdam	1057	UN		Atlantic mixed forests	×	2
Baltimore	2207	UN		Southeastern mixed forest		1
Berlin	3475	UN		Central European mixed forests	×	4
Bogota	8506	UN	×	Magdalena Valley montane forests	×	3
Brussels	1958	UN		Atlantic mixed forests	×	2
Cape Town	3345	UN	×	Lowland fynbos and renosterveld	×	5
Chicago	8616	UN		Central forest–grassland transition		2
Christchurch	356	UN	×	Centerbury–Otago tussock grasslands	×	4
Curitiba	3118	UN	×	Araucaria moist forests	×	3
Durban	2739	UN	×	South Africa mangroves	×	2
Frankfurt	681	UN		Western European broadleaf forests	×	3
Hamburg	1785	UN		Atlantic mixed forests	×	3
Hamilton	203	NZ Stats	×	Bermuda subtropical conifer forests	×	5
Ho Chi Minh City	6189	UN	×	Southeastern Indochina dry evergreen forests	×	2
Hong Kong	7050	UN	×	South China–Vietnam evergreen forests	×	1
Iquitos	435	UN		Iquitos varze	×	1
Johannesburg	7992	UN	×	Highveld grasslands	×	1
Lisbon	2034	UN	×	Southwest Iberian Mediterranean Sclerophyllus and mixed forest	×	2
London	9699	UN		English lowland beech forests	×	12
Melbourne	3951	UN		Southeast Australia temperate forests	×	6
Mexico City	20132	UN	×	Central Mexican matorral	×	7
Monrovia	1264	UN	×	Western Guinean lowland forests	×	2
Nagoya	9165	UN	×	Taiheiyo evergreen forests	×	3
Nairobi	3915	UN		Northern Acacia–Commiphora bushlands and thickets	×	1
Nelson Mandela Bay Municipality	1139	South African cities network	×	Albany thickets	×	1
New York	18365	UN		Northeastern coastal forests		1
Phoenix	3649	UN		Sonoran desert		4
Porto Alegre	3476	UN	×	Uruguayan savanna	×	3
Potchefstroom	250	www.potch.co.za		Highveld grasslands	×	1
Rome	3592	UN	×	Italian sclerophyllus and semideciduous forest	×	2
San Diego	2964	UN	×	Californian coastal sage and chaparral		3
Santiago	6269	UN	×	Chilean matorral	×	4
Seoul	9796	UN		Central Korean deciduous forests	×	1
Sheffield	682	UN		Celtic broadleaf forests	×	4
Singapore	5079	UN	×	Peninsular Malaysian rain forests	×	3
St Louis	2153	UN		Central forest–grassland transition		3
Stockholm	1360	UN		Sarmatic mixed forest	×	2
Vancouver	2278	UN		Puget lowland forests	×	4
Warsaw	1703	UN		Central European mixed forests	×	2
Washington DC	4604	UN		Southeastern mixed forest		11

Table 2. Biodiversity and ecosystem-services attributes coded from 135 plans in 40 cities globally. See the supplemental material for references.

Attribute	Code	Definition	References
Baseline data	CityDa	Does the plan use baseline data collected from within the city?	Hermy and Cornelis 2000, Cilliers et al. 2004
	DataHab	Does the plan use baseline data on habitats?	Drewes and Cilliers 2004, Holmes et al. 2012
	DataSpp	Does the plan use baseline data on species?	Farina-Marques et al. 2011, Rebelo et al. 2011, Bekessy et al. 2012
Biodiversity goals	BioGoal	Does the plan have specific and/or general (i.e., protect biodiversity, ecology, species, habitats, natural resources, plants, animals, and genetic resources) biodiversity goals?	
	BioConn	Specific reference to corridors, increasing connectivity for ecological purposes, or creating a green network.	Mörtberg et al. 2007, Beninde et al. 2015
	BioSpp	Specific species or mention of native or indigenous species or archaeophytes (in Europe only).	McKinney 2002, Rebelo et al. 2011, Holmes et al. 2012
	BioHab	Conserve, restore, maintain, or manage habitats of forest, grasslands, wetlands, woodlands, and open space. Mention of specific habitats.	Margules and Pressy 2000, Rebelo et al. 2011, Sætersdal and Gjerde 2011, Holmes et al. 2012, Lindenmayer et al. 2014, Beninde et al. 2015
	BioEd	Formal and informal education, outreach, and interpretation related to biodiversity conservation.	McKinney 2002, Miller and Hobbs 2002, Dearborn and Kark 2009, Goddard et al. 2010, Kabish 2015
	BioStew	Encourage volunteer groups, nongovernmental organizations, community engagement, and citizen science related to biodiversity conservation.	Savard et al. 2000, Miller and Hobbs 2002, Dearborn and Kark 2009, Goddard et al. 2010, Holmes et al. 2012
	BioMon	Species and habitat monitoring, ecological research, and adaptive management.	Noss 1990, Turner et al. 2003
	BioInv	Management of invasive alien species and reduction in invasive species.	Pysek 1998, Chambers et al. 1999, von der Lippe and Kowarik 2008, Aronson and Handel 2011
	BioCon	Constructed habitats: bioswales, greenroofs, greenstreets, rain gardens, and gardens or yards.	Lyle 1997, Margolis and Robinson 2007, Oberndorfer et al. 2007, Ignatieva et al. 2011, MacIvor and Lundholm 2011, Rottle and Yocom 2011, Chiquet et al. 2013, Braaker et al. 2014
Biodiversity targets	TarSpp	Quantitative targets for increasing populations of species identified by the plan for conservation.	Berke and Godschalk 2009
	TarHab	Quantitative targets for increasing habitat area identified by the plan for conservation.	
	TarBio	Quantitative targets for particular taxa: 11 groups—plants, mammals, birds, reptiles, amphibians, fish, molluscs, butterflies, other arthropods, fungi, and bats—identified for conservation.	
	TarInv	Quantitative targets for decreasing invasive, alien, and nonnative species.	
	TarCrit	Quantitative targets for increasing critical biodiversity habitats.	
	TarBuilt	Quantitative targets for constructed habitats: bioswales, greenroofs, greenstreets, rain gardens, and gardens or yards (often called green infrastructure in the United States).	
	TarOth	Other quantitative targets related to biodiversity.	
Ecosystem-services goals	ESS Goals	Does the plan have specific and/or general ecosystem-services goals?	
	EssH20	Does the plan have goals for increasing water quality and flood retention, including stormwater, freshwater wetlands, lakes, salt marshes, floodplains, and riparian areas?	Cardinale 2011, Balvanera et al. 2013, Ahern et al. 2014
	ESSAir	Does the plan have goals for increasing tree cover for air-pollution removal?	Nowak et al. 2006, Manes et al. 2012, Ahern et al. 2014
	ESSCar	Are tree-planting efforts or the conservation of forests mentioned for carbon-storage or -sequestration purposes?	Balvanera et al. 2013 Hooper et al. 2012 Tilman et al. 1997, McPherson et al. 2008, Pincetl et al. 2013, Ahern et al. 2014
	ESSUHI	Are tree-planting efforts or the conservation of forests mentioned for climate amelioration or urban heat islands?	McPherson et al. 2008, Pramova et al. 2012, Pincetl et al. 2013, Ahern et al. 2014
	ESSAgr	Does the plan include food production, urban gardens, or urban agriculture?	Ahern et al. 2014, Bernstein 2014, Potter and LeBuhn 2015
	ESScul	Are there biodiversity-conservation, -habitats, or -communities goals specifically for sense of place, education, stewardship, or recreation?	Gill et al. 2009, Pickett et al. 2011, Ahern et al. 2014

Table 2. Continued.

Attribute	Code	Definition	References
Ecosystem-service targets	TarH20	Quantitative targets for the reduction in water pollutants or increase in wetland habitat.	Berke and Godschalk 2009
	TarAir	Quantitative targets for the reduction of air pollutants by planting efforts or other conservation efforts.	
	TarCar	Quantitative targets to increase the number of trees or biomass for carbon-storage and -sequestration purposes.	
	TarUHI	Quantitative targets to reduce urban-heat-island effects via tree planting, the conservation of forests, or other conservation efforts.	
	TarAgr	Quantitative targets for food production, urban gardens, and urban agriculture.	
	TarCul	Quantitative targets for biodiversity conservation, habitats, or communities for sense of place, education, and stewardship.	
Commitment to implementation	Commit	Is there some mention of implementation that has happened or will happen (e.g., funds or actions)?	Berke and Godschalk 2009
Regulatory elements	Reg	Are there elements of the plan that are mandated (e.g., laws or ordinances)?	Berke and Godschalk 2009

a sense of place). We also coded regulatory elements indicating that at least one of the biodiversity or ecosystem-services goals or targets in at least one of the city's plans was mandated at the city or regional level, including laws, ordinances, or other governing mechanisms. Finally, implementation elements included sources of funding, timelines, local agencies, or organizations tasked with specific actions that address goals (Berke and Godschalk 2009) and actions to enhance biodiversity, such as ecological restoration or adaptive-management activities.

The selected attributes reflected scientific findings and recognized practices in biodiversity conservation management and planning (table 2). Each plan was assessed and scored for the presence or absence of these attributes. This is a common method used for assessing plan quality across a wide variety of planning domains, and this approach determines whether preselected plan criteria are present in sampled plans (Lyles and Stevens 2014, Stevens et al. 2014). Validity issues related to this method center on the reliability and replicability of the data used for analysis (Berke and Godschalk 2009, Stevens et al. 2014). With 10 investigators conducting assessments, each was trained in attribute definitions. Once compiled, the data were submitted to a rigorous quality-assurance or quality-control process, with each plan reviewed and coded by a second member of the research team.

Principal-component analysis (PCA) was performed to examine how cities differed in planning for biodiversity and ecosystem services on the basis of the scored attributes. We also correlated biodiversity and ESS attributes to PCA axis scores to determine which attributes were associated with any groups of cities that emerge from the analysis.

Cities may differ in external factors that may influence planning for biodiversity and ecosystem services. We used multiresponse permutation procedures (MRPP) to determine whether cities in biological hotspots (Conservation International 2016) were different in plan attributes from those not in hotspots (table 1). We also used MRPP to determine whether cities that have completed a CBI differ in plan attributes from non-CBI cities. The CBI is a series of indicators of biodiversity and ecosystem services developed by the Singapore National Park Board and the Convention on Biological Diversity as a tool to help cities develop biodiversity goals and targets (Chan and Djoghlaf 2009). We used MRPP because it is a robust nonparametric test for comparing groups (McCune and Grace 2002). These analyses were performed in PCORD 6.08 (MjM Software; McCune and Grace 2002).

Phi-correlation analyses were performed on plans to determine whether attributes were correlated with each other within plans. We defined strong correlations as those with a phi coefficient $r_\varphi > .6$ with $p < .0001$ and moderate correlations as those $r_\varphi < .6$ to $r_\varphi > .4$ with $p < .0001$. This analysis was performed in JMP Pro 11.2.0 (SAS Institute, Inc.).

Attributes of biodiversity and ecosystem services addressed in city plans

The most common attribute found in plans was the presence of an ecosystem-services goal. More than 80% of the studied plans incorporated at least one goal for enhancing ecosystem services (figure 1). The majority of plans also included some mention of commitment to implementation, one or more goals for enhancing biodiversity, and, in particular, goals for increasing or improving the quantity or quality of specific habitats. Measurable targets for biodiversity and ecosystem services occurred in a smaller number of plans (figure 1). Correlation analysis revealed which attributes were associated with each other within individual plans (supplemental table S1). The highest correlation values for biodiversity-related attributes ($r_\varphi > .6$, $p < .0001$) were between targets for taxa and targets for specific species and between goals for biodiversity education and

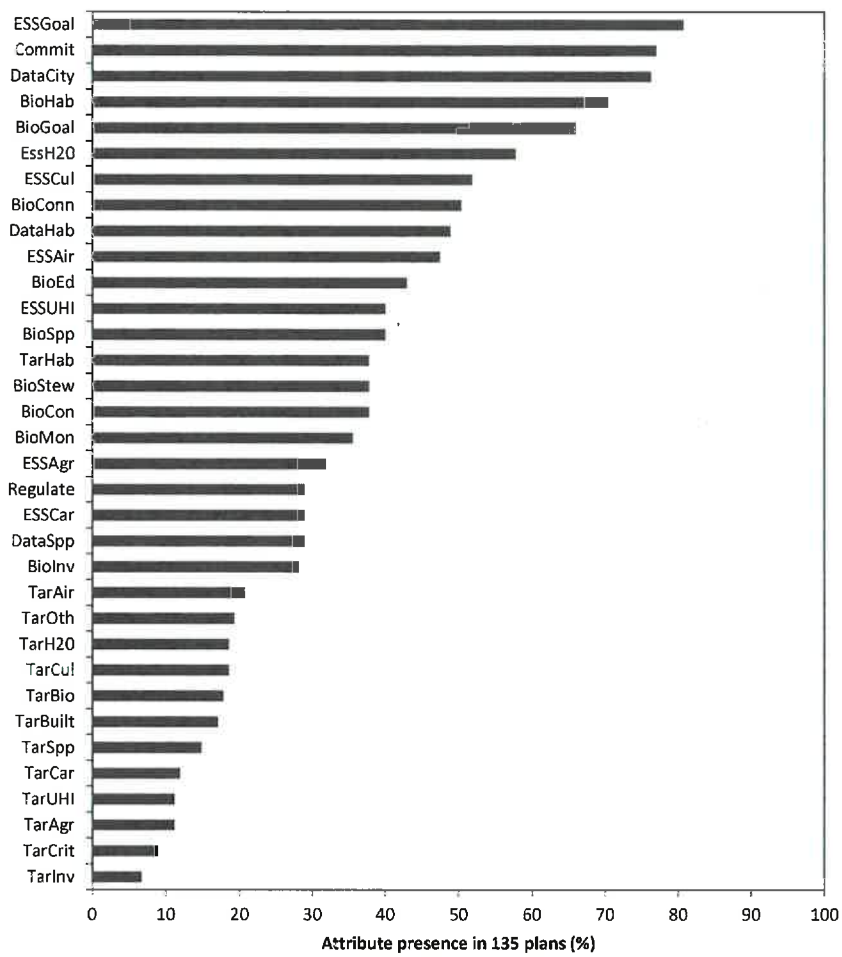

Figure 1. The presence (%) of biodiversity and related ecosystem-services attributes (n = 34) in 135 plans from 40 cities globally.

goals for biodiversity stewardship. Biodiversity stewardship and education were moderately correlated ($r_\varphi < .6$ to $r_\varphi > .4$, $p < .0001$) with goals for biodiversity monitoring. Goals for biodiversity stewardship and monitoring were both moderately correlated with goals to control invasive species. Baseline data on habitats were moderately correlated with baseline data on species and goals for ecological connectivity. Baseline data on species were moderately correlated with goals for species conservation. Goals for habitat conservation were moderately correlated with goals to increase ecological connectivity. Specific biodiversity goals were not correlated with specific targets, except for between goals for constructed habitats and targets for constructed habitats ($r_\varphi = .51$, $p < .0001$), as well as goals for habitat conservation and targets for specific habitats ($r_\varphi = .46$, $p < .0001$).

The highest correlation between ecosystem-services attributes was between targets for water quality and targets for air quality ($r_\varphi > .6$, $p < .0001$). Goals for urban agriculture were moderately correlated with goals for water quality and regulation ($r_\varphi < .6$ to $r_\varphi > .4$, $p < .0001$). Goals for air-quality amelioration were moderately correlated with goals for urban-heat-island amelioration and carbon sequestration ($r_\varphi < .6$ to $r_\varphi > .4$, $p < .0001$). Goals and targets for urban-heat-island amelioration were moderately correlated with each other ($r_\varphi = .41$, $p < .0001$). Goals and targets for water quality were moderately correlated to each other ($r_\varphi < .40$, $p < .0001$). In general, biodiversity goals and targets were not correlated with ecosystem-services goals and targets (table S1).

Differences in how cities address biodiversity and ecosystem services

The cities with the highest number of attributes related to biodiversity in their plans were Washington, DC (94% of biodiversity attributes), followed by Baltimore, London, Mexico City, Nagoya, Seoul, and Sheffield (83% of biodiversity attributes). The cities with the fewest attributes for biodiversity were Hong Kong, Ho Chi Minh City, Monrovia, and Iquitos. The cities with the highest number of attributes for ecosystem services in their plans were Washington, DC; London; New York; Berlin; Baltimore; Hamburg; Vancouver; and Ho Chi Minh City. The cities with the fewest attributes ecosystem services were Seoul, Nairobi, and Potchefstroom, the latter two having none at all (figure 2).

Ten principal components (eigenvalues more than or equal to 1.0) explained 76.3% of the variation among the cities. The first component explained 20% of the variance, with no loadings more than or equal to 0.5 or less than −0.5. The second principal component explained an additional 12.7% of the variance, with no loadings more than or equal to 0.5 or less than −0.5 (figure 3). The PCA graph shows that the cities are separated by the presence or absence of biodiversity and ecosystem services in their plans. The graph is characterized by a separation of cities with biodiversity and ecosystem-services goals and targets from those that do not incorporate these attributes into their plans. The bi-plots in the graph show biodiversity and ecosystem-services attributes that indicated plan attributes associated with the first two principal component axes ($R^2 > 2.50$). Vector lengths indicate the strengths of the individual attributes (McCune and Grant 2002). Cities in the upper left quadrant of the graph had plans that incorporated baseline data on habitats; biodiversity goals for connectivity, education, and monitoring; plan implementation for invasive species; and ecosystem-services goals for cultural ecosystem services. Cities in the lower left quadrant of the graph have plans with ecosystem-services targets for agriculture, heat islands, air quality, and carbon

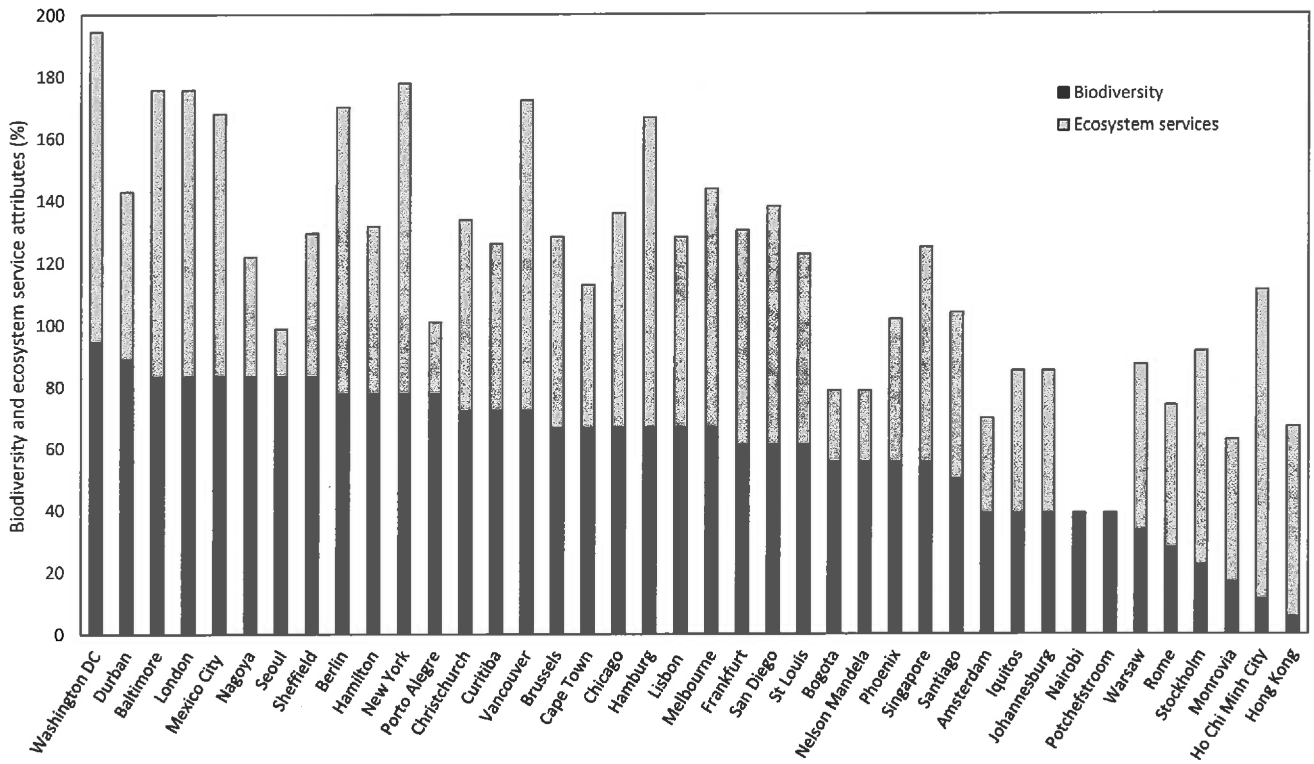

Figure 2. The distribution of the biodiversity and ecosystem-services attributes for 40 cities globally.

storage, as well as ecosystem-services goals for air quality. Cities to the right of the figure did not feature these attributes in their plans.

Cities in biodiversity hotspots were not significantly different in the biodiversity and ecosystem-services attributes their plans addressed from cities not in hotspots (MRPP: $T = -0.80$, $A = 0.0006$, $p = .19$). In addition, cities in hotspots were not different from cities not in hotspots when examining only the 18 biodiversity ($T = -1.49$, $A = 0.01$, $p = .08$) or the 13 ecosystem-services attributes ($T = -0.60$, $A = 0.008$, $p = .23$). Cities that have participated in the CBI were not significantly different in the biodiversity and ecosystem-services attributes they addressed in their plans from cities that have not participated in the CBI ($T = 0.54$, $A = -0.004$, $p = .67$). When we examined only the 18 biodiversity attributes or only the ecosystem-services attributes, cities that have participated in the CBI were not significantly different from those cities that have not (biodiversity MRPP: $T = -0.08$, $A = 0.0009$, $p = .39$; ecosystem services MRPP: $T = 0.97$, $A = -0.01$, $p = .85$).

Planning for biodiversity and ecosystem services: Context matters

The ecological and societal values of biodiversity and ecosystem services in cities are becoming an important component of urban socioecological research and city agendas (Dearborn and Kark 2010). We have identified 34 biodiversity and ecosystem-services attributes that are relevant to and part of contemporary approaches to urban planning. The 34 attributes that we defined followed the guidelines for a comprehensive plan as defined by the American Planning Association (APA 2006) by emphasizing goal setting, analyzing existing conditions and trends, describing a future vision for the community, and outlining policies and guidelines for implementing that vision. The biodiversity attributes were within the scope of the ICLEI Biodiversity Planning guidelines, which focus on documenting current actions; assessing the current state of biodiversity; planning for the integration of biodiversity goals, objectives, and actions; and plan implementation, monitoring, and review. The ecosystem-services attributes are within the scope of The Economics of Ecosystems and Biodiversity (TEEB) stepwise approach to planning, which identifies which ecosystem services are relevant to policy, defines information needs, and assesses ecosystem services (Margules and Pressey 2000, APA 2006, TEEB 2010, ICLEI–Local Governments for Sustainability 2015).

Community engagement appears to be an important component of most plans. Plans that included community engagement in some form (i.e., education and citizen science) are present for the majority of cities (figure 1). Combined occurrence of goals for stewardship, education, and monitoring indicate citizen involvement that goes beyond traditional planning. Additional correlations of these variables with goals for connectivity and targets for taxonomic groups may be explained by the observation that volunteers often deal

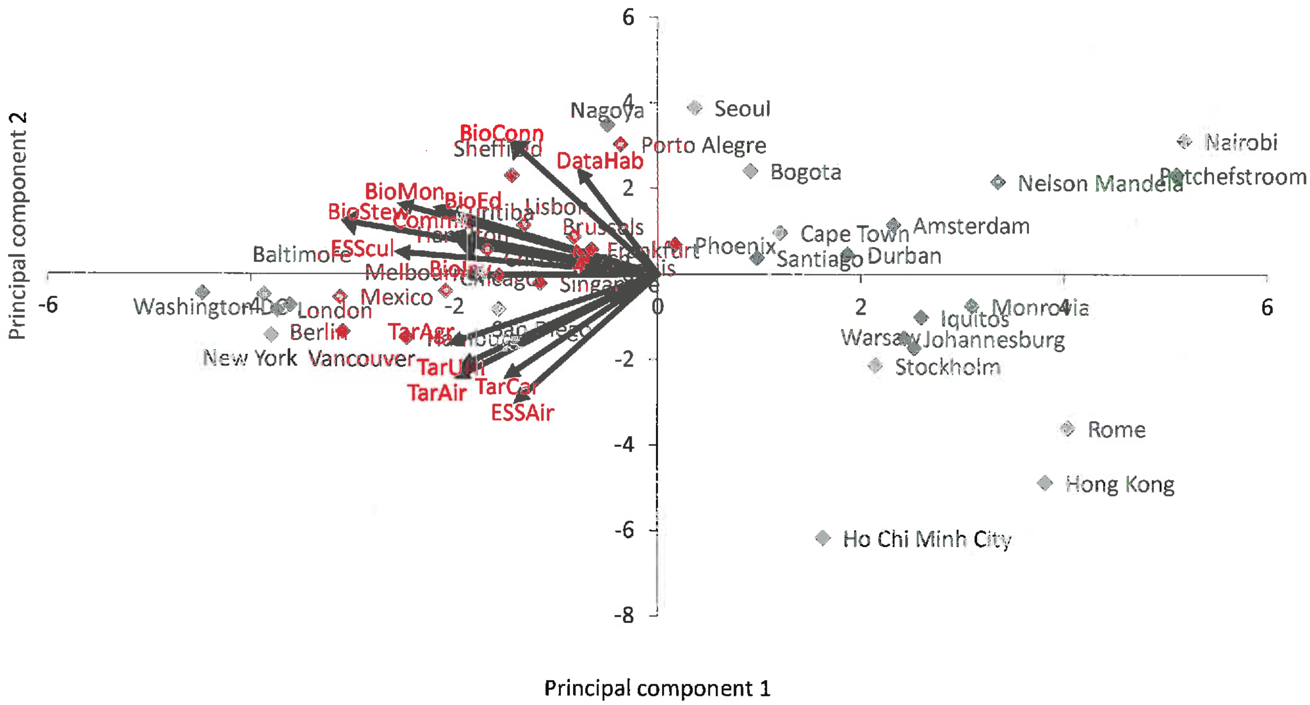

Figure 3. Principal components 1 (20%) and 2 (12.7%) for the biodiversity and ESS attributes included in city plans. The arrows corresponded to the attributes correlated with PCA axis 1 and 2 (Pearson correlation; r > .05).

with specific taxonomic groups, such as birds, amphibians, or orchids, and are frequently involved in monitoring projects for nature conservation (Schmeller et al. 2009, Tanadini and Schmidt 2011). Only if monitoring data are available is it possible to define measurable targets compared with the baseline. Although there is some overlap in the actions and targets dealt with in these documents, they do include several policies and some planning decisions to be able to reach the targets (e.g., Mayor of London 2010, 2011).

Despite the importance of targets for determining whether planning goals were achieved (Berke and Godschalk 2009), we found a lack of targets in these plans. Fact-based urban plans are more successful, because they allow for an analysis of current conditions and for tracking changes and setting measurable targets to assess improvement of the effectiveness of urban plans (Berke and Godschalk 2009). The lack of targets may reflect the strategic focus of many plans (APA 2006) or may be a response to the political structure or climate within cities where conflicts between environmental and development goals could lead to caution in assigning targets that may lack political support (Freund 2001, Evans 2004, Holmes et al. 2012). Examples of the inclusion of such data in planning are urban biotope mapping, which includes all land uses (Drewes and Cilliers 2004); systematic biodiversity planning, which focuses on fragmented natural areas (Rebelo et al. 2011, Holmes et al. 2012); and using the biodiversity costs of an area to determine trade-offs between conservation and development (Bekessy et al. 2012).

Some cities already have access to baseline data gathered by universities or government agencies. However, Evans (2004, 2006) described gaps in the data collected by scientists and volunteer naturalists and problems in incorporating these data into local plans. Washington, DC; Berlin; and London are examples that such gaps can be closed more or less sufficiently and that baseline data help to define targets. For example, of the plans that addressed ecosystem services from London, United Kingdom, the focus was on regulating services (air quality, water quality, and urban heat islands; Mayor of London 2010, 2011). This may be the result of a long history of research on air quality and air pollution, and plans even include studies showing the importance of trees in removing atmospheric particulate pollution (e.g., Tallis et al. 2011). There are also several networks in London linking scientists, policymakers, and urban residents, such as the Air Pollution Research in London (APRIL) network (*www.april-network.org/home*), which might indicate a closer and more direct link between scientists, stakeholders, and the public.

Many cities possess detailed information about habitats developed from biotope- or habitat-mapping projects (Werner 1999, Jarvis and Young 2005), as well as systematic conservation plans (figure 1; Rebelo et al. 2011, Holmes et al. 2012). Habitat targets are easier to set than species targets, in part because gathering habitat data is faster and less expensive than collecting species data, which usually requires taxonomic experts (Danielsen et al. 2005). Habitat data were often used in identifying sites for conservation planning. At first glance, it is surprising that few plans set targets for nature-conservation areas. This may be because regional- or national-level governments typically have authority over the most important nature-conservation areas (Margules and Pressey 2000, Dacorum 2006). In addition, special plans for single conservation areas, where targets may be specified, were not included in our investigation.

Cities differed in both the number of attributes they included in their plans as well as the combination of attributes. Cities typically included either biodiversity or ecosystem services but were rarely comprehensive in both. The attributes cities include in their plans may be related to mandates by the country, region, or city itself. Among the cities with the largest number of attributes in their plans, Washington, DC; Berlin; and London are mandated to combine planning functions of city and regional or subnational state governments. Their expanded planning roles include Washington, DC, having a state's responsibility for developing a State Wildlife Action Plan (Michalak and Lerner 2008, Fontaine 2011), Berlin having detailed environmental data and plans required of German states (Schneider et al. 2007), and the Greater London Authority having detailed natural-resources plans for 36 local governments (Goode 1989). Other cities with a large number of scored attributes incorporate biodiversity or ecosystem services into sustainability plans. For instance, Baltimore's sustainability plan is comprehensive, addressing biodiversity, ecosystem services, and social goals, although it has less detail than Washington, DC; London; and Berlin (which approaches its sustainability similarly; Senatsverwaltung für Stadtentwicklung und Umwelt 2012). In addition, Vancouver's sustainability plan—a combined effort of Environment Canada, the British Columbia Provincial Government, and local government—addresses sustainability issues within a larger regional context.

Plans also reflect local circumstances (Evans 2004). For example, Cape Town has a systematic conservation plan with targets and planning for natural areas, habitats, and fragmented natural areas, but it does not focus on ecosystem services. Cape Town has an active conservation department, a strong history of research and data on fragmented natural areas, and a commitment to national biodiversity initiatives (Holmes et al. 2012, O'Farrell et al. 2012). Another example is Ho Chi Minh City in Vietnam, where the uncontrolled urbanization and the flat and low-lying topography make the city vulnerable to the influences of climate change (Eckert and Voigt 2008). Therefore, the adaptation plan for the city focused on six strategic directions that included aspects such as water storage and quality, flood protection, groundwater use, and the urban-heat-island effect, each with specific interventions. Distinct targets were identified within each direction with short-term (until 2025), midterm (until 2050), and long-term (until 2100) goals (Ho Chi Minh City 2013). Finally, plans may reflect individuals or groups that champion biodiversity, such as Durban, South Africa (Freund 2001). Champions may rally people to action, but efforts may be at risk if a champion leaves the scene (Box et al. 1994, Roberts and Diederichs 2002, Lachmund 2013).

Ultimately, understanding the diversity of approaches to planning for biodiversity and ecosystem services in cities requires research into each city's experience in the development, use, and implementation of plans. Further insight into urban biodiversity and ecosystem planning can be achieved by understanding the processes and mechanisms that lead to specific planning approaches. Studying the ecological setting, the social and political planning context, and the roles of actors and champions for plans is crucial in understanding the paths chosen by local governments. In this way, we can begin to understand how cities can integrate biodiversity conservation in an increasingly urban world.

Supplemental material

Supplementary data are available at *BIOSCI* online.

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Charles H. Nilon (NilonC@missouri.edu) is affiliated with the School of Natural Resources at University of Missouri, in Columbia, Missouri. Myla F. J. Aronson is affiliated with the Department of Ecology, Evolution and Natural Resources at Rutgers University, in New Brunswick, New Jersey. Sarel S. Cilliers is affiliated with the School of Environmental Sciences and Development at North-West University, in Potchefstroom, South Africa. Cynnamon Dobbs is affiliated with the Department of Ecosystems and Environment at Pontifical Catholic University of Chile, in Santiago, Chile. Lauren J. Frazee is affiliated with the Department of Ecology, Evolution and Natural Resources at Rutgers University, in New Brunswick, New Jersey. Mark A. Goddard is affiliated with the School of Civil Engineering and Geosciences at Newcastle University, in Newcastle upon Tyne, United Kingdom. Karen M. O'Neill is affiliated with the Department of Human Ecology at Rutgers University, in New Brunswick, New Jersey. Debra Roberts is affiliated with the Sustainable and Resilient City Initiatives Unit at eThekwini Municipality, in Durban, South Africa. Emilie K. Stander is affiliated with the Department of Science and Engineering at Raritan Valley Community College, in North Branch, New Jersey. Peter Werner is affiliated with the Institute for Living and Environment at Research Institute of the State of Hesse and the City of Darmstadt, in Darmstadt, Germany. Marten Winter is affiliated with the Synthesis Center at German Center for Integrative Biodiversity Research, in Leipzig, Germany. Ken P. Yocom is affiliated with the Department of Landscape Architecture at University of Washington, in Seattle, Washington.

Developing Biodiversity Indicators for Los Angeles County

Danielle Alvarez, Connie Kang, Denise Lin, June Tran, and Tiffany Wu

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Table of Contents

Introduction

Biodiversity, or biological diversity, is the variety and variability of life. It can be measured in many different ways, and the simplest measure of biodiversity is species richness, the number of species per unit area. Biodiversity can also be quantified by a biodiversity index, which is a measure of how many different species there are in an area, taking into account how evenly individuals are distributed. Unlike in natural landscapes, urban settings are largely influenced by humans, who change the vegetation and biota present (Jenerette, 2013). This produces a diverse combination of species and habitats that makes it difficult to quantify biodiversity solely based on existing indices, such as the Shannon Index or Simpson Index. Efforts to create an urban-specific biodiversity index need to take urbanization patterns into consideration when measuring how species occur and are distributed in a city.

The Singapore Index (SI), also known as the City Biodiversity Index (CBI), was developed in 2010 with major contributions from Singapore's government, as a biodiversity index specifically designed for cities. The SI is divided into three components: native biodiversity in the city, the ecosystem services provided to the city by biodiversity, and the management of biodiversity in the city (CBI, 2012). The environment of Los Angeles, one of the most densely populated urban areas in the United States differs from that of Singapore due to differences in urban set-up and climate, and thus may require a different set of biodiversity indicators for any proper assessment of the region's biodiversity. Our project will use the Singapore Index as a baseline for analysis of urban centers and suggest a new set of biodiversity indicators specifically tailored for Los Angeles.

Background

Biodiversity Indicators

Biodiversity, taking into account the genetics and morphology of species, is the variety of species on Earth. Biodiversity indicators are necessary to help merge complex ideas and information into a concise assessment. While various indices, which synthesize a number of individual indicators into sets, are currently used worldwide to assess biodiversity health. There is currently no standardized, agreed-upon global set of indicators for measuring the health of urban biodiversity that would be considered equally applicable throughout the world's major cities. Since there is not a single set of biodiversity indicators for global use, these various indices help provide a glimpse into the health of various aspects of biodiversity, but not a complete or even comparable picture.

Effective indicators need to be interpretable to all audiences and must contain scientific data, as well as basic information that can be easily understood by the general public. They should also be accessible to a large audience, as well as transparent enough to influence policy-making (Bubb, 2009). Good indicators need to be linked to a possible environmental driver that is causing an increase or decrease in biodiversity. Scientists have differing opinions on what a good indicator needs to entail, which increases the difficulty of creating a set of universal biodiversity indicators.

Convention on Biological Diversity

In 2002, 188 nations gathered for the Convention on Biological Diversity's 6th Conference of the Parties to create the 2010 Biodiversity Target, in hopes of slowing the loss of biodiversity worldwide ("Report from Conference of the Parties to the Convention on Biological Diversity COP 6," 2002). They agreed to protect "components of biodiversity, promote sustainable use, address threats to biodiversity, maintain ecological goods and services, protect traditional knowledge and practices, and ensure fair and equitable sharing of benefits from use of genetic resources" ("The 2010 Biodiversity Target Pamphlet," 2010). In 2010, the Convention on Biological Diversity held its 10th Conference of Parties to continue the discussion of biodiversity. Using the biodiversity indicators as an assessment to measure biodiversity goals set during the last conference, they agreed that the 2010 Biodiversity Targets ultimately failed their goal of reducing the loss of biodiversity. The participating nations created the Aichi Targets to try to continue reducing biodiversity loss between 2011 and 2020 (Feld, 2010). The Aichi Targets included mainstreaming biodiversity across government and society through public access to all information, reducing direct pressures on biodiversity and promoting sustainable use (Convention on Biological Diversity, 2010). 39 indicators are currently being used right now to track the global progress of the Aichi Targets, and a few of these will be discussed below.

The Red List

The Red List Index is a biodiversity indicator that looks at species' population size, rate of decline, and area of distribution. The relative rate at which species in a particular group changes is measured and categorized based on the endangerment of species, from "least concerned" to "extinct." It has strong potential in showing the impacts of invasive species, trends from impacts of land use, and trends in species used for food and medicine. However, it can be a less sensitive measure of status because of the time delays (Bubb, 2009). For large populations, it may take longer to change to a different threat level category due to the time it takes for species to drop in population.

Living Planet Index

The Living Planet Index looks at the average rate of change in many populations of vertebrate species over time. Data for this Index, which has been neatly organized in concise and understandable terms for general audiences, has been collected since the 1970's, thus making it useful to assess whether or not conservation actions have been successful over a course of more than 40 year period (Loh, 2005). There are currently 3,000 population time series for 1,100 species. Unfortunately, it only focuses on vertebrates, which does not provide a comprehensive picture of all species.

Global Wild Bird Index

The Global Wild Bird Index focuses on an even more specific group, using birds as a measure of biodiversity health, and tracking only the average population trends of several species of wild birds ("The Global Wild Bird Indicator"). It has a strong potential for tracking larger ecosystem health because birds are sensitive to environmental changes, are mobile, and are widely studied. However, a clear downfall of the index is that it only focuses on one class and rare birds are often overlooked ("The Global Wild Bird Index"). Birds also don't have specialized micro-habitats like insects.

Management Effectiveness of Protected Areas

Management Effectiveness of Protected Areas is another indicator that helps look at improving status of biodiversity by safeguarding ecosystems, species, and genetic diversity. It observes the effectiveness of the management of areas that are especially dedicated to protecting and maintaining biological diversity, as well as natural and cultural resources (Chape, 2005). This assessment leads to better management, resource allocation, and accountability. The benefits of this standard are that protected areas are widespread and many areas are already assessed. This provides a baseline for future data (Leverington, 2010). However, in order to produce site-level adaptive management strategies, much more research and development of this indicator is needed.

Application of Biodiversity Indices in Urban Areas and Southern California

Our research will focus on biodiversity indices specifically regarding urban environments and Southern California. Aside from the existing challenges of measuring biodiversity, there are unique challenges in assessing urban areas. In urban areas, human attitudes and preferences towards species traits may be the primary factors in determining species composition, rather than the traditional factors of species competition and other biotic interactions (Jenerette, 2013). For example, in Los Angeles and many semi-arid cities, trees are almost entirely sourced non-natively and planted by humans (Pataki, 2013). Urban areas are greatly influenced by socioeconomics and other location-specific factors. Within individual cities, studies have found a strong socioeconomic effect, where increasing neighborhood income correlates with the extent of vegetation greenness and diversity (Lowry et al., 2012 and Clarke et al., 2013). Species richness patterns have been shown to greatly differ between metropolitan regions and adjacent wildlands, despite having the same climate, due to the strong influence of urbanization (Jenerette, 2013).

Comparative urban studies have found that vegetation tends to homogenize depending on social interest and climate (Jenerette et al., 2006). These findings help identify how urbanization influences vegetation due to human preference and availability of ecosystem services. As a result, urban ecosystems cannot be reduced to the historically indexed species of the landscape before urbanization. Efforts to quantify the biodiversity in urban areas should reflect the functions and values society attaches to the vegetation within the city, whether species are indigenous or exotic (Hermy, 2000).

Barriers in data collection have impacts on the ability of a city or region to quantify biodiversity, since the value of a diversity index depends on both the number of indicators found and the evenness in which indicators are found. While scientists are able to complete controlled field sampling in natural environments, land ownership and regulation pose significant challenges to biodiversity sampling in urban areas (Clarke, 2013). One tool to bypass this challenge is remote sensing, which can be used to track changes in vegetation. Vegetation species themselves can be identified based on photosynthetic activity or “greenness” using reflectivity and absorption of the plants. Remotely sensed data can also be used for monitoring vegetation biodiversity, land-cover classifications, measures of heterogeneity, and measures of productivity. In 1998, the California Urban and Biodiversity Analysis Model was developed by UC Berkeley to bridge the gap between urban development and habitat quality. The model calculated fauna biodiversity based on the suitability of particular remotely sensed vegetative covers to particular fauna, rather than on actual species sightings or population counts of fauna (Landis, 1998). Additional studies have found that lowest vegetation biodiversity is typically found in residential locations, while the highest biodiversity is found in recreational areas and parks (Clarke, 2013). In addition to use of remote sensing, local efforts, such as those that involve local governments and urban residents in participatory species indicator monitoring programs, may also prove useful for gathering data in urban areas (Ahern, 2014).

Placing urban fauna and flora within a biodiversity index requires a thorough assessment of many factors. The majority of biodiversity studies are focused on vegetation due to the time-consuming nature of indexing animal species. The biodiversity of animal species can be inferred from the area of suitable vegetative covers for specific species (Hermy, 2000). For monitoring of fauna, priority if generally placed on animal groups that are both sensitive to environmental change and are easily identifiable (Begon, 1996). For example, butterflies are a common biodiversity indicator due to their short generation time and quick response to changes in habitat. Amphibians are good indicators of water quality, and birds are good indicators for vegetation health (Hermy, 2000).

The Singapore Biodiversity Index, also known as City Biodiversity Index, is currently the only biodiversity index specifically designed for cities. It has three components: the native biodiversity in the city, the ecosystem services provided to the city by biodiversity, and the management of biodiversity in the city (CBI, 2012). There were some complications when researchers attempted to use the CBI across several cities in Japan and Europe. When applied throughout Japan, researchers struggled with the limited ability to collect data for certain indicators due to the unclear definitions of what that indicator entailed, such as the boundaries for a natural, semi-natural, and fragmented areas (Uchiyama, 2015 and Kohsaka, 2013). Furthermore, many cities expressed concerns over the funding for the compilation of necessary data needed to evaluate native biodiversity or ecosystem services. Ultimately, many indicators proved to be logistically unrealistic to calculate or collect due to limited resources (Pereira et al., 2013). While still under development, the CBI has potential to assess impacts of different policies and urban planning decisions on biodiversity and the ecological services biodiversity provides both within the city and closely related ecosystems (Seitzinger et al., 2012).

In California, there has been significant effort to analyze the relationship between vegetation biodiversity patterns and the ecosystem services they provide to city residents. Early efforts to bridge the gap between urban land use planners and conservationists focused on more traditional topics, such as the historical loss of Coastal Sagebrush (Westman, 1987). In more recent years, due to rapid urbanization, there has been a shift in focus to index the existing urban vegetation, regardless of native or non-native status (Gillespie, 2008 and Clarke, 2013). In Los Angeles, significant land changes due to agriculture, development of infrastructure, urban area, and roads, created a large impact on the landscape itself, but also threatened biodiversity through the alteration of habitat and habitat fragmentation, invasive species, and homogenization of habitats from urbanization (Tratalos, 2007 and McKinney, 2002).

Biodiversity in Los Angeles

Land clearing due to urbanization in Los Angeles has removed habitat for native species, allowing some non-native species to thrive and replace local native species (McKinney, 2008). This causes biotic homogenization of an area, or more simply, dominance of one species (McKinney, 2005). In fact, it has been shown that change in land cover could lead to as high as 40% loss of species in a specified area (Seto, 2012). The percentage of non-native species occupying land tends to be higher for plants than other organisms such as "birds, mammals, reptiles and amphibians" (McKinney, 2008). This is one of the leading reasons that there has been a considerable overall increase in plant diversity in urban regions (McKinney, 2008). Because non-native species takeover has become such a common dilemma, the preservation of local species has become a major concern. While non-native species introduction into urban areas may enrich the local biodiversity, it decreases global diversity because local species are lost in the species gene pool (McKinney, 2005). This outcome has been shown in several studies, including Schwartz et al. (2005), who used indices such as the Sorensen's Similarity Index to calculate the proportionality of species. They observed and calculated the overall California floras, in urban and urbanizing regions (Schwartz et al., 2005). Due to the complexity of these urban areas, studying vegetation composition and richness in urban regions such as Los Angeles would be a strong starting point for assessing LA ecosystem health (McKinney, 2008).

The International Union for Conservation of Nature (IUCN), has identified major reasons for biodiversity loss in Los Angeles, which include pollution, natural disasters, and human disturbance. Marine and terrestrial organisms both have been impacted by urbanization, most notably by habitat fragmentation – the leading threat to biodiversity in urban ecosystems (Tigas et al., 2002). In fact, fragmentation in southern California is considered to be one of the most severe areas of fragmentation because of its constant conversions of large natural habitat areas to roads, houses, and businesses (Tigas et al., 2002).

Some Los Angeles city initiatives aim to increase ecosystem health, such as LA 2050 and the Sustainable City pLAn. Unfortunately, these initiatives are often concentrated on improving human life, and not the biodiversity in the area. McKinney (2005) states that any urban city's main goal, when it comes to the homogenization of the physical environment, is to "meet the relatively narrow needs of just one species, our own." Thus, while changes made to better our environment may indirectly help improve and protect biodiversity, there is few true objectives to directly aid in the protection and preservation of species (both plants and animals), as it is hard for the general public to see "the intrinsic value of biotic diversity" (Faeth et al., 2011).

Conservation of Biodiversity in Urban Areas

The conversion of natural landscape into urbanized areas comes with an inherent change in biodiversity that scientists are still trying to accurately measure. Despite the negative effects of urbanization, findings show that many urban areas are developed on locations of fertile soil and high species richness, which sets the stage for strong potential rebounds in biodiversity if conservation efforts are implemented (Alberti, 2010). If done correctly, converting gardens back to native vegetation allows for better interconnectivity, which supports the movement of organisms, and large public green spaces, which acts as a refuge for native vegetation to support native invertebrates and vertebrates alike. Careful planning at the city and state level are needed to maximize the positive effects of corridors. In addition, compact development and ecologically friendly construction is imperative to preserving remaining undeveloped patches and conserve biodiversity in urban landscapes.

With urban populations currently accounting for over half of the world's population, and developing countries expected to house 80% of the world's urban population by 2030 (Goddard, 2010), cities are going to be the major points of infrastructure growth. There is no denying that cities are going to expand, but figuring out how to grow with the environment and in a way that is least impactful for biodiversity will be the key to conserving biodiversity. A consensus of papers on urban ecological growth is that building at high density and reducing urban sprawl is the most effective means of limiting negative impacts to biodiversity in urban areas (Ikin, 2015, McDonald, 2008, and Sushinsky, 2013). High density urban expansion entails small or no-yard space per individual property, so there is less green space attached to each private building. If the excess space is set aside for restoration, this type of expansion can result in larger areas of green space, such as parks or corridors. This approach focuses on altering landscapes that have already been disturbed, so that there are fewer total negative consequences for biodiversity compared to low density development (McDonald, 2008 and Sushinsky, 2013). Backyards and personal gardens are an important part of inner-city biological connectivity, so it is important to account for this in the form of high quality green space, stepping stones, and corridors when choosing compact development over sprawling development (Sushinsky, 2013). Without intermittent green space in cities, there would be little place for biodiversity to exist.

For urban residents who have green space on their property that cannot be utilized for construction, converting yards to native vegetation will set the stage for struggling native species to rebound in suitable habitats. These green spaces can contribute to a network of stepping stones at a city-wide scale, leading to the larger, high quality parks and greenbelts with native trees and vegetation that are more valuable for bird and arthropod species richness (Faeth, 2011 and Goddard, 2010). There is no debate between ecologists that mobility and interconnectivity are essential to conserve biodiversity. However, deciding where the most important places to preserve and where potential green pathways should be placed, has yet to be established. Paths of most importance are dependent on what species are being considered, making it a very situation dependent consideration, as no city's biodiversity can be compared with another (Beninde, 2015). Certain species, like coyotes and crows, thrive in heavily populated areas, while endemic species with small habitat niches are more likely to experience negative impacts on abundance in response to urbanization. Once having determined which species focus would contribute most to biodiversity, a city can take control of vacant lots, wastelands, or former industrial sites that have the potential to contribute to a network of interconnected green stepping stones through the city.

Current science struggles to identify urban species richness and abundance, but in 2013 Jessica Sushinsky et al. (2013) was able to use MaxEnt software, a program used by ecologists for species habitat modeling, on data she obtained in the field of an urban avian species presences across the city, to see how different factors of urbanization could potentially affect the species distribution. An experiment conducted by Assaf Shwartz et al. (2014) in 2014 set out to see if city dwellers could identify a change in biodiversity of a specified area. The research group was able to artificially increase the biodiversity of a public garden throughout the experimental process with methods that could be applied to inner city green space. The addition of native flowering plants that may not be present under unmitigated conditions increases plant diversity and increased arthropod biodiversity throughout the public garden. Also, if possible and beneficial for the area, adding nest boxes or structures to increase breeding space for native bird populations can further improve an area's biodiversity.

In approaching conservation of biodiversity, cities that must mitigate past damage can devise a plan to restore biodiversity through increasing native vegetation, urban green space, and connectivity throughout the city. Appropriate species estimation and modeling can help predict the impact of certain actions on species richness. Moreover, scientific manipulation of diversity has the potential to increase richness that was previously lost. Influencing positive ecological change is not restricted to scientists though. The average city dweller can contribute to the conservation effort by simply installing native vegetation in their backyard and removing introduced species, such as lawn grass and palm trees.

Project & Clients

The Environmental Report Card for Los Angeles was developed by UCLA's IoES, in collaboration with the Goldhirsh Foundation and LA2050 Initiative. This report card hopes to "provide a broad picture of current conditions, to establish a baseline against which to assess the region's progress towards environmental sustainability, and as a thought provoking tool to catalyze policy discussion and change" (ULCA IoES). Alongside this, other plans have also been created to help understand Los Angeles environmental conditions. For example, as part of the Sustainable City pLAn, the City of Los Angeles has identified a goal for developing a city biodiversity strategy by 2017. Support and protection for biodiversity in the City has been made a priority initiative. Although research interest in the ecology of urban areas exists, the biodiversity of cities is often under-studied. Biodiversity data in Los Angeles is no different. Due to legal and social restraints, as well as spatial complexity of urban areas, urban regions like Los Angeles need much more ecological investigation. The Nature Conservancy (TNC), Natural History Museum of Los Angeles County (NHM), and National Park Service (NPS) have requested that a team from the undergraduate Environmental Science Practicum Program at UCLA's Institute of the Environment and Sustainability (IoES) work towards assessing the biodiversity and ecosystem health of the Los Angeles region.

The NHM, TNC, and NPS are longtime collaborators, with strong education and outreach programs in highly urban areas of Los Angeles. The NHM has several citizen science programs, including RASCals (the Reptiles and Amphibians of Southern California), that use the iNaturalist web forum to compile data on organism sightings across the County. Citizen science is the primary way scientists are capturing and cataloging biodiversity in urban Los Angeles. Birding has traditionally been the most popular area of study for citizen science. However, in 2015, the NHM discovered 30 new fly species in Los Angeles as a result of citizen science programs involving residents housing malaise traps in their backyards. New gecko species have also been found through citizen science approaches.

Citizen Science Efforts

There are certainly barriers that make it difficult to gather data in residential areas, such as Los Angeles County. Traditional researchers have trouble accessing backyards and other owned property for surveying and field testing. However, volunteers can help diminish data gaps by participating in research and contributing to a practice called citizen science (Conrad and Hilchey, 2011). Many significant scientific triumphs have been achieved through citizen science (Delaney et al., 2008). For example, volunteers have been key in finding new species; the discovery of the Asian shore crab in North America is credited to a college student (Delaney et al., 2008).

Citizen science projects worldwide vary broadly in their scope and structure. Although there are many ways to manage a citizen science study, according to Conrad and Hilchey (2011), there are three main categories of governance: consultative/functional governance, collaborative governance, and transformative governance. Citizen science can be used for experimental studies, but they are mostly used for monitoring current conditions, which can then be used to collect baseline data and serve as the springboard for more detailed research (Dickinson, Zuckerberg, and Bonter, 2010 and Dickinson et al., 2012). Different methods dictate the type of data and quality of data collected. For example, surveillance monitoring leads to a wide range of information and allows for more detailed research (Donnelly et al., 2014).

Despite the demand, there are a number of challenges facing citizen science, such as issues of organization, data collection, and data use, that prevent policy-makers, academics, and the public from trusting citizen science data (Conrad and Hilchey, 2011). Peer-reviewed research has exposed some practices that may lead to higher data quality. Verified citizen science, for example, in which professionals double check data collected, is more accurate than direct citizen science (Gardiner et al., 2012). Comparing samples of volunteer-collected data to existing data from previous studies is a straightforward way to assess data accuracy. However, it is impossible to apply to studies that have no precedent. Research has shown that citizen science efforts vary greatly and that each study may require a unique approach. A study done by Delaney et al. (2014), examining the accuracy of data collected on crab species, gender, and size, revealed that variation in data accuracy is extremely situational - that it can vary even within one study.

In order for citizen science projects to effectively produce baseline biodiversity data, they must be recognized as relevant and legitimate. Technology will provide the advantage of engaging some members of the public, but will also simultaneously alienate others (Newman et al., 2012). Moving forward, success of projects can be increased by targeting specific groups to participate, such as those who may already be interested in a related subject matter (Dickinson et al., 2012). Informing the public and the scientific community of achievements by citizen science projects can also be used to create a more positive image of citizen science. Although citizen science has been used to further climate change research, the term “citizen science” is largely missing from published papers (Cooper, Shirk, and Zuckerberg, 2014).

A review of non peer-reviewed literature regarding citizen science revealed a trove of projects that are individually valuable, but lack cohesion. Many state and independent programs hold citizen science events to focus on identifying as many species as possible in a specific area over a short amount of time. The National Geographic Society with the NPS, for example, sponsors an annual "bioblitz" or a biological census to get an overall count of species in the area (Cohn, 2008). These programs can yield results pertinent to the focus area. For instance, the 2011 BioBlitz added more than 400 species to the park list, with at least one species that was new to the park.

There are a number of citizen science projects that can be useful to study for the purposes of this project. Calflora is an electronic repository for information on California wild plants that receives information from diverse sources, including both professional and citizen science data (Haklay, 2013). This information can serve a broad range of purposes, including scientific study, environmental analysis and management, and education. The program eButterfly is a North America web-based citizen science program that allows participants to report butterfly sightings. An “online checklist and photo storage program,” it seeks to gather and organize data which is ultimately viewed by other citizen scientists, conservationists, and educators (eButterfly, 2014). eButterfly has consulted museums for additional data, potentially showing some level of integration between the program and outside institutions (eButterfly, 2014). Some programs that are currently collecting data on urban ecosystems, by specifically investigating urban backyards, include the Celebrate Urban Birds project and the Great Sunflower Project (California Naturalist, 2016).

The Internet is helpful in giving the public and researchers access to data, which is necessary to increase the viability of citizen science data for assessing biodiversity. The Global Biodiversity Information Facility (GBIF) claims to be "the biggest biodiversity database on the Internet." It allows researchers to access data, institutions to make their data available, nations to receive training, and the public to contribute data (GBIF, 2016). The California Naturalist website provides a list of citizen science project in California, shedding light on the types of work being done (California Naturalist, 2016). There is a variety of studies being conducted, such as data on butterflies, air quality, insects, invasives, and birds (California Naturalist, 2016).

Citizen science efforts have received attention by researchers, media, and the international community. An online report by UC Davis associate professor Heidi Ballard titled "Report: Learning from Public Participation in Scientific Research Programs in Northern California" investigates areas for improvement in research done by the public (UCD, 2014). In 2014, a report by the United Nations Environment Programme (UNEP, 2014) detailed changes in citizen science, existing challenges, and ways to improve citizen science (UNEP, 2014). An article by *Harvard Magazine* asserts that citizen ownership is one of the main issues facing citizen scientists today (Xue, 2014). Whether citizen science is actually bridging the gap between the public and science community has yet to be determined (Xue, 2014).

Singapore Index Indicators

The SI was created in 2010 in partnership with Singapore and the Global Partnership on Local and Subnational Action for Biodiversity. Using identified indicators, the Index "serves as a self-assessment tool for cities to benchmark and monitor the progress of their biodiversity conservation efforts against their own individual baselines" (CBI, 2012).

The first 10 indicators, which our group focuses on in this project, relates to native biodiversity in the city. They include:

- 1. Proportion of Natural Areas in the City
- 2. Connectivity Measures or Ecological Networks to Counter Fragmentation
- 3. Native Biodiversity in Built Up Areas (Bird Species)
- 4-8. Change in Number of Native Species
- 9. Proportion of Protected Natural Areas
- 10. Proportion of Invasive Alien Species

Each of these indicators has its own set of directions to obtain data and calculate a score. The basis/scaling of scoring are also different for each indicator. These calculated scores are meant to act as a baseline measurement of the city's current biodiversity profiles. Thus, it would enable cities to monitor and assess their progress in maintaining or improving biodiversity.

Research Questions

The Los Angeles Health Biodiversity Indicator Practicum team intends to answer the following research questions during the course of the project. These questions are vital in creating a set of Biodiversity Indicators for Los Angeles.

1. How can the Singapore Index be adjusted to better fit the needs of understanding LA biodiversity?
2. How does data collection for biodiversity differ when studying urban areas?
3. Can citizen science data be utilized and trusted to give accurate results for biodiversity indicator data?

Los Angeles Study Region

Our study area needed to encompass all the urban regions while staying true to the ecosystems of Los Angeles. Since our biodiversity indicators focus on urban settings, the City of Los Angeles formed the basis of our initial study area. However, after careful consideration, we decided that the City of Los Angeles did not fully capture all the regions or ecosystem types necessary to create a comprehensive set of biodiversity indicators. We then expanded our study region to Los Angeles County, only to find that the county is much too large for our study.

We settled on a study region in between the size of the City of Los Angeles and Los Angeles County. We chose a boundary that incorporated urban regions as well as important Los Angeles ecosystems. Figure 1 shows the clear divide between areas within Los Angeles County that have and have not been developed. The northern boundary of our study area encapsulates this developed area. The cut-off for our study area follows census lines in the event there is interest to perform demographic analysis of the area.

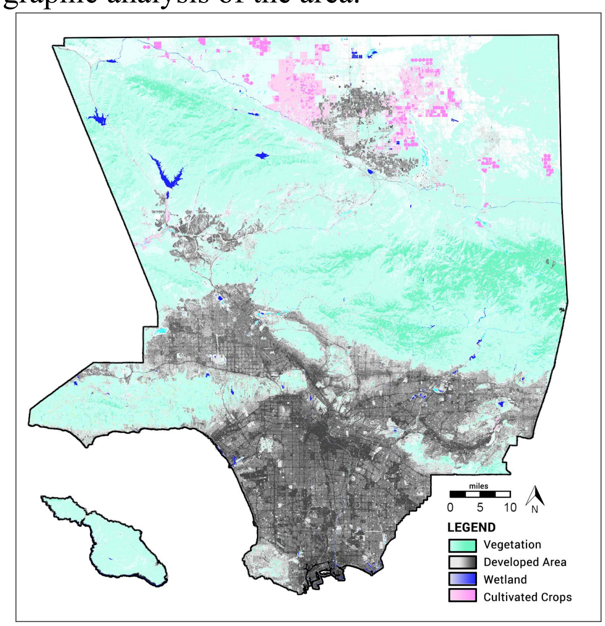


Figure: Land Cover Type of Los Angeles County

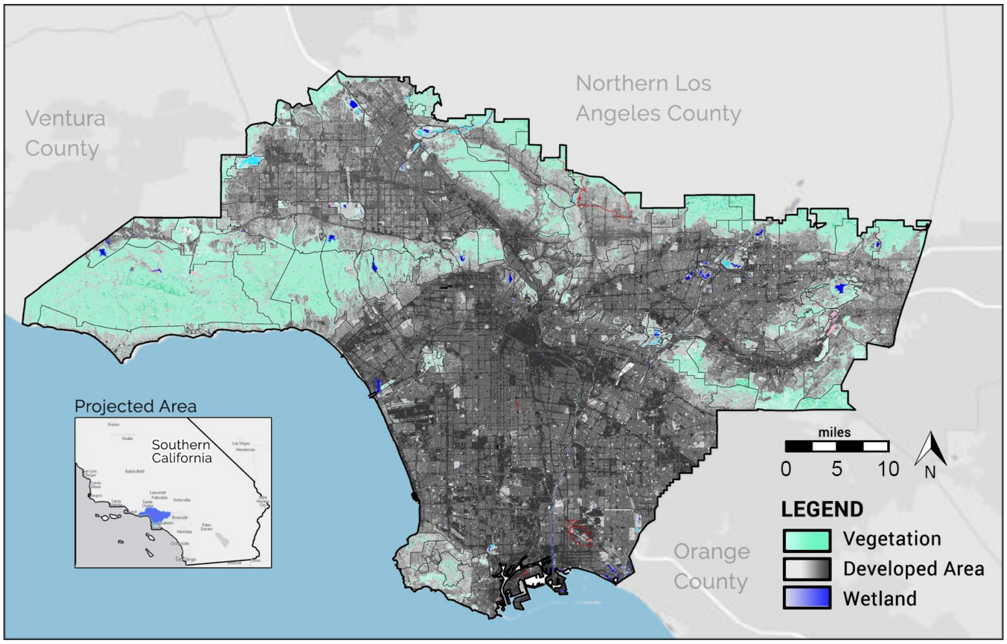


Figure: Study Area Map: Los Angeles County, South

Methodology

Criteria for Indicator Selection

An indicator should provide a measure that is relevant to the component of biodiversity it represents. The indicators as a whole should provide a good representation of the overall biodiversity health of Los Angeles. Indicators should also represent the concerns from clients and be related to issues that may be actionable by local city government. Each indicator was closely looked at to see if it provided a measure that represented widespread concerns related to biodiversity in Los Angeles.

Overview of Indicator Selection Process

1. Identify preliminary indicators from Singapore Index
2. Conduct interviews to support indicator development
3. Select and identify indicators based on geographic units
4. Final set of biodiversity indicators
5. Generate maps to visualize data

Identify preliminary indicators from Singapore Index

The Singapore Index was utilized as a baseline for creating a set of biodiversity indicators for our LA study region. While the Singapore Index works well for Singapore, it needed to be customized to fit our specific project boundary and the needs of LA, Singapore covers only about 17% of the land area of LA and moreover, lacks the diversity of terrain present in LA. We also chose not to utilize the scoring/ranking system of the Singapore Index. Rather than framing as a comparison of biodiversity score between cities. The scoring system should be used to identify a city's biodiversity baseline and then serve as a guide to continue to maintain or improve the city biodiversity. Thus, we created a different set of indicators that would work and apply to all of LA.

Conduct interviews to support indicator development

In order to create a concrete set of biodiversity indicators for LA, we interviewed a wide range of experts about their opinions on urban biodiversity indicators. These interviewees included professors, NGO staff, government officials, and researchers who worked on the Singapore Index. We had two phases of interviews. The first phase of the interviews included asking these professionals about specific species they thought would be applicable to indicating urban ecosystem health. We also asked interviewees about the Singapore Index, since it was our starting point for our set of biodiversity indicators. Finally, we asked these experts about their opinions on the validity or utility of citizen science.

The second phase of interviews occurred after we had developed our preliminary set of biodiversity indicators. We then went back to the experts to ask for advice on this set of indicators. This included honing in on details on how to measure the indicators and specific species to use. Using this two-step system of interviewing and checking, we were able to narrow down to a set of indicators.

Select and identify indicators based on geographic units

Since our region of study includes many different types of ecosystems, it was important to recognize this in our indicators. For example, one species may not be a good indicator in all the different types of ecosystems found in LA. Before creating our final set of biodiversity indicators, we divided up our LA study area to find the best indicator species based on each ecosystem. The geographic units were synthesized with the union of several variables including: freshwater locations, land use, vegetative cover, and urbanization extent.

Final set of biodiversity indicators

Our final set of biodiversity indicators was generated through the information provided through our interviews. By identifying which indicators were most relevant to our study region, we narrowed down to a final set of indicators. We also included several indicators even if the general consensus among interviewees was not favorable. We determined that these specific indicators would show ecosystem health that was important to LA. We also took into account what kind of data was being collected through citizen science efforts. Using all this information, we were able to create a set of indicators we feel would be beneficial and relevant to measuring ecosystem health.

Generate maps to visualize data

In order to both assess the availability of citizen science data in the LA region and visualize a current baseline for each indicator based on that citizen science, we created a series of maps by importing the Citizen Science gathered into ArcGIS. Separating out each taxonomic group allowed us to visually interpret the current state of data for each of our indicators.

Overview of Citizen Science

Citizen science was identified by our clients as a potential source of data because there isn't a large collection of scientifically conducted biodiversity data for urban environments. Past research, like the Institute of the Environment and Sustainability's Environmental Report Card published in 2015, has concluded that there is no viable data in Los Angeles to assess urban biodiversity. Scientific focus tends to be aimed at more natural and pristine ecological areas and as a result, urban landscapes are not acknowledged even though great levels of biodiversity can exist in cities. These data gaps in the current scientific literature have the potential to be filled in with widely accessible citizen science data. The current coverage of citizen science has the potential to provide a baseline for biodiversity enhancement efforts in urban LA, but uncertainties about its quality are present. Within Citizen Science platforms, a system of approvals must take place for a recorded observation to be considered research grade. Once it becomes research grade, the reliability of an observation can be considered scientific. After manually looking through the data for LA County, we found that the checks and balances that observations must go through are effective at removing faulty submissions. Despite the forums being intended for amateur naturalists, many scientifically trained people are members of the various citizen science forums and their participations aids in the consistent accuracy of research grade submissions.

Collection and Analysis of Citizen Science Data

The data collection and analysis segment of our research is aimed at identifying what biological information is currently recorded in urban LA that could be utilized to support the new set of biodiversity indicators. Our primary mode of data collection involved extensive internet searches to identify online citizen science platforms, as well as organizations who utilize citizen science as part of community outreach and engagement in LA County. The bulk of our data came from iNaturalist, a global citizen science and social network in which anyone can record observations of biodiversity. We also requested LA County data from eBird, a citizen science platform designed specifically for recording bird sightings. Other platforms were identified but were not included in our analysis due to lack of information in LA County. These include YardMap and eButterfly, forums that have the potential to contribute greatly to citizen science in the future, but currently do not contain much ecological or biological data for LA. YardMap focuses on land cover use and while users are able to label trees or vegetative areas, species identification is not a priority. If this could be incorporated in the future, YardMap can become a major contributor to biodiversity and vegetative cover analysis. TreePeople's "TreeMapLA" data was obtained, but was ultimately excluded from final data analysis because the data includes both citizen science and municipal tree records from certain areas. While this data can be utilized in other biodiversity analysis, including potentially for assessing a baseline condition for Los Angeles,, for our purposes of solely analyzing citizen science, it was removed to prevent potential biased results in areas where extensive municipal data was obtained.

Once the data was collected, it was imported it into ArcGIS. The initial step involved separating the data by taxon: birds, plants, insects, mammals, reptiles and amphibians, and molluscs. From there, multiple data layers corresponding to potential influencers of collected citizen science were added to the map. Our clients identified the desire to better understand what outside factors had an impact on Citizen Science participation so we ran an analysis on socioeconomic and geographic variables such as income, traffic levels, and land cover. From the

US Census Bureau, a 2014 census layer was added with Median Income Levels projected for each census block and then clipped to our study area. We used this to compare the number of data points for all citizen science per census block and to see if a relationship existed between income and citizen science participation. Also from the 2014 census layer, we extracted recorded traffic density (the method used to determine traffic density is described in CalEnviroScreen 2.0, 2014) to determine if a correlation exists between presence of citizen science and amount of traffic present. Moving away from socioeconomic variables, we wanted to see if land cover type is correlated to where citizen science is being collected. For this, we uploaded a land cover layer from The National Land Cover Database. Once uploaded into GIS, we used this land cover layer to run another spatial analysis looking specifically at percent impervious cover. By assigning a value of 1 to each citizen science data point, we were able to spatially join these factors to the presence or absence of citizen science data. The outcome of this analysis is discussed at a later point.

In addition to analyzing the spatial extent of citizen science, each individual indicator was mapped to identify where data is currently available, as well as where data collection needs to be focused on in the future. For certain indicators that had sufficient amounts of data, we were able to map the current state of the indicator with our recommended methodology, shown later on.

Interviews

Introduction

To gain further understanding on potential indicators for Los Angeles, we interviewed several experts ranging from professors to researchers to government employees. We asked for their opinions on the Singapore Index indicators, as well as our potential list of indicators. Asking for opinions on current and potential indicators was an important part in our process of developing our final set of indicators because their expertise on specific species and of biodiversity in LA is valuable to understanding what should be carefully studied to maintain and improve biodiversity.

Methodology

We contacted several experts - researchers, professors, etc. - that had knowledge and were experts in the field of biodiversity. Starting with interviewing UCLA professors, we were able to compile a list of other experts that ranged from other UC affiliates, city officials, and nonprofit organizations. The interviewed experts were also able to recommend other experts for us to contact. In total, we were able to get in contact and interview 35 experts (Appendix: List 1).

The interviews were conducted in person, and by phone, Skype, and email. Originally, we had a set of questions that asked quite general questions and opinions about urban biodiversity. We focused on questions about LA and the Singapore Index, since that was our starting off point. After conducting a majority of our interviews, we were able to formulate our own set of indicators for LAs. We continued to interview experts by asking them about our specific set of indicators.

Experts' Opinion on Indicators

Starting with the Singapore Index:

The first round of our interviews, as described above, focused on the Singapore Index biodiversity indicators. As we asked experts about the Singapore index, we realized that the Singapore Index was a beneficial starting point, but was not a suitable model with which to assess our study area. Many experts had not heard of the Singapore Index and thus did not have strong opinions about the Singapore Index itself to begin with. Many agreed with the Singapore Index in general and expressed their approval of some specific indicators within it. However, our interviews showed that not all of the indicators and methods to measure them are ideal for our Los Angeles study area. While not the majority, a few interviewees disagreed with the Singapore Index as a whole. For example, one interviewee was upset with the general structure of the Singapore index, saying, for example, that the Singapore Index looks more like a checklist, rather a comprehensive assessment of ecological systems. This expert said, "We need to reconstruct function of actual ecological systems. We're potentially doing more damage when we're using a checklist like this." One expert called into question an underlying assumption in the Singapore Index, which is that native vegetation is a direct indicator of ecosystem health. This interviewee said that in the built environment, native plants are not necessarily resilient, because they require specific circumstances. The following subsections of the report go into more detail about the specific comments interviews made regarding different taxonomic groups and categories.

1. *Amphibians & Fish*

Of all the experts that were interviewed, 2 out of 35 suggested and agreed that amphibians would be a good indicator to measure ecosystem health. One interviewee said that amphibians would work well because they are higher on the food chain and can provide information on other species. Another expert stated that since amphibians spend their lives in both the water and on land, they are a good indicator for two different types of habitats. In addition, since they are "more vulnerable to chemicals and pesticides," they are greatly affected by pollution. This expert continued to state that there are not many native amphibians, but simply looking at the presence and absence would provide a good indicator of habitat.

On the other hand, some experts believe that amphibians would not be a good indicator. One interviewee mentioned that amphibians are only found in pristine environments and therefore would not be a good indicator for an urban setting. He emphasized that amphibians are rarely found in cities.

2. *Birds*

Experts generally agreed that birds should be taken into account in a biodiversity index, although there were a few that disagreed. According to one expert, LA County is the county with the largest number of bird species in the United States. This avian expert described the presence of birds in Los Angeles County, saying that there are 514 native bird species that have been recorded in LA County. Within these 514 species, there are eight introduced species that are now included on the California Bird List because they are so well-established, he said. In addition, there are 15 to 20 introduced or non-native species not on the California Bird List, of which are known to have populations breeding in the LA County. This diversity is due to the large size of the county and diversity of topography and habitats. In addition, extensive research in ornithology and the prevalence of bird watching increases the amount of data collected.

There was also a consensus that birds are very well-known and well-surveyed and are thus valuable to monitor ecosystem health. Since there is a larger body of information on birds, they are good indicators of change, according to our interviewees. Birds respond to changes in their environment, most notably vegetation. Many researchers agreed that birds and vegetation are highly connected. Native plants will attract native birds, for example, one expert stated.

Different bird species have responded very differently to urbanization, an expert said. For example, non-native shrubs allow some birds to thrive that would not otherwise be able to survive, he said. This expert listed some of the changes that has altered habitat for birds in recent years. For example, land development has removed native habitat and the bird trade has increased the number of non-native bird species. Some species, for example habitat specialists in the oak woodlands, have suffered from development, he said. Other species have adapted to changes in habitat; the Allen's Hummingbird, for example, has benefitted from non-native vegetation such as the eucalyptus, and is now the dominant hummingbird throughout the LA Basin, according to the same expert. Many bird species benefit from non-native plants that provide nectar through the winter months.

Despite a general approval of birds as a potential category for biodiversity indicators, some interviewees disagreed with this. Three out of eleven experts who commented on birds as an indicator expressed doubts about birds as an indicator, due to their unique characteristics such as their ability to migrate. Birds are dispersive, and they do not respond as greatly to changes in habitat quality compared to some other groups, such as aquatic species, according to the previously mentioned avian expert.

Two of the experts who believed that birds can be useful as an indicator emphasized the necessity of examining bird specialists rather than generalists. "The real handle on biodiversity is - are you preserving species that can't handle modification?" one expert said. For example, habitat specialists in grasslands have been lost where areas have been modified. Ideally, said another expert, a biodiversity index should examine birds that require certain habitat services; for example, birds nesting in a marsh where a particular plant is prevalent can indicate the bird's dependence on that aspect of the habitat.

The avian expert made some suggestions for choosing bird indicator species when our team asked for advice. He suggested that lowland open country species, chaparral/coastal sage scrub species, declining marsh species, arid scrub/alluvial scrub species, key cavity-excavators of oak and other woodlands, and common and seemingly urban-adapted species that have had declining populations be used.

3. *Vegetation*

The underlying assumption of the portion of the Singapore Index is that native biodiversity indicates ecosystem health. The majority of experts who commented on vegetation as an indicator agreed that native vegetation should be investigated. Many of these experts also acknowledged that some non-native (but not invasive) species provide valuable habitat for wildlife. As one expert said, "[Non-native plants are certainly better than no trees, and sometimes they're easier to manage and can survive a lot of conditions."

However, while there was a general trend in the responses from interviewees, many experts differed in what they believed should be emphasized when studying vegetation. The line between exotic and native species itself is difficult to determine, for example. Some experts stated that it is difficult to make the distinction between exotic and native species, since some plants are hybrids. One interviewee expressed that many invasive organisms can exist without appearing to be invasive, but become invasive later on; this has been well documented but not given much attention by policy makers. Some experts wanted to see the distinction made with invasive species. More than one expert mentioned the importance of looking at how much vegetation supports native wildlife. Researchers explained that native plants tend to attract native wildlife such as birds and insects. Some experts disagreed on the importance of looking at native versus non-native plants. Other experts commented that it is important to see what vegetation supports native animal species. Some experts said that non-native plants will attract generalist wildlife.

Many experts agreed that non-native plants are more resilient in urban areas. One expert said, "I see some non-native species; [they] can have value giving some ecosystem services. They may absorb floodwaters, they may provide erosion control, but intrinsically there isn't an imperative need to protect them in LA." One expert argued that emphasizing native vegetation is only important in natural areas such as the Santa Monica Mountains. In urban areas, he stated, native plants may not be especially resilient. "I would want to know how well native plants survive under urban circumstances. I would like to know, what is the distribution of native to nonnative plants location-wise. I would not be so concerned with the invasives issues – this has to do with what happens when these plants get out of people's backyards," he said. He recommended dividing vegetation into three categories – native, non-native that are integrated and not considered invasives in wildlands, and invasive.

He suggested coast live oak for a native species, eucalyptus for non-native species, and Washingtonia filifera (a type of palm) for an invasive species. Some other experts were also able to make specific suggestions for indicator species or habitats. Interviewees suggested coastal sage scrub. Valley oak savannas, native live oak woodlands, and alluvial scrub were identified as habitats that have been highly impacted by urbanization. Freshwater marsh and coastal saltwater marshes and estuaries have also been heavily impacted.

One interviewee spoke about the importance of assessing vegetation cover, saying that the number of species can be deceptive as an indicator. For example, if many species are present but they do not amount to a large area of cover, they do not have a large influence on the soil or ecological processes. Commenting on one section of the Singapore Index, he said that he would like to see included the cover of all plants in built areas as well as cover of native plants in particular. Another expert stated that he would like to see native habitats mapped, and then track the changes over time. Another interviewee interviewee also pointed out that fragmentation of natural habitat is important.

4. *Insects*

"We know less about the overall biodiversity in urban environment because we tend not to study [insects] as much." Still, 8 out of 35 of the interviewees stated that insects would be an important LA biodiversity indicator. A few stated that they were important due to their high diversity. Moreover, "every habitat supports something." Several examples of insects that interviewees thought would be good to look at were butterflies, dragonflies, and damselflies, particularly because there are lots of citizen science data with these two species. However, because of their large range and diversity, this may pose some difficulty in data collection. One suggested using an acoustic sensor rather than remote sensing. Another method that all eight interviewees agreed that could and should play a huge role in insect data collection is citizen science. Many suggested to utilized NHM's Biodiversity Science: City and Nature (BioSCAN), as a source for data.

One academic who studies insects noted several interesting facts. For instance, using the sounds of insects in the area, it can provide "a good idea of how many species there are." Of course, just as other experts have suggested with other animals, urban area also creates a huge obstacle for insects as well. Moreover, it becomes hard to identify and ID insects because you "can't collect in state parks without a permit." And unfortunately, "with insects, it's difficult to use remote sensing and observe what you're looking at." Alternatively though, "you can have an acoustic sensor, that would be a great way to gather data and census an area."

5. *Reptiles*

Reptiles was not mentioned by any experts during our first round of interviews. It was only in our second round of interviews, when we asked experts specifically about reptiles as an indicator, that experts took notice of it. One interviewee exclaimed, "yeah actually!" when the indicator was proposed. While only 3 of 35 interviewees indicated that reptiles would be a good indicator for LA, it is an important taxonomic group to take into account. Reptiles are sensitive to urban development due to being susceptible to contaminants such as fertilizers, as well as their lack of mobility due to fragmentation barriers. However, as one interviewee stated, reptiles "tend to survive well in urban areas. The common species are really good at adapting." Therefore, it is important to study reptiles in urban habitats such as LA.

6. *Large Mammals*

There was a general consensus that large mammals, which are generally considered mammals that are coyote sized or larger, would be a good indicator species. 13 out of our 35 interviewees agree that looking at large mammals is a critical biodiversity indicator for ecosystem health that could potentially provide information about habitat fragmentation.

One interviewee stated that bobcats would be a good large mammal indicator species for fragmentation because "they are greatly impacted by human development." Since they are habitat generalists, they are more resilient than mountain lions. Natural habitats are critical to their health because they depend on wild animals as prey. This expert and many others agree that coyotes would not be a good indicator because they are so adaptable to human landscapes. Moreover, no interviewees suggested them.

Some interviewees considered the importance of mountain lions. Mountain lions are "found in people's backyard and are important because it gets people excited." Another expert commented that it is important to remember that it is not common for mountain lions to be seen in urban areas; the instances that do occur are heavily publicized. Another interviewee emphasized their importance because mountain lions are heavily impacted by management and people. Their survival in LA is affected by factors outside of the ecosystem health. However, mountain lions are important because they are found in areas where deer are present.

7. *Fish*

Fish was another indicator that several interviewees agreed would be a good ecosystem indicator with 4 out of 35 experts mentioning their importance. One interviewee said that fish can be greatly impacted by many different sources such as land development and humans because fish are so broadly distributed. One expert was in favor of using fish as an indicator, but mentioned that while there are some habitats that could support native fish, like the steelhead trout, it is difficult for these species to get to these areas and repopulate. It can be very difficult for fish to move to a different habitat.

One expert was against using fish as a biodiversity indicator because "most of the streams and rivers in Southern California don't support fish" and "those that do, don't have native fish." While upper headwaters may have some fish left, this expert believes that it would provide a very small palette of biodiversity.

8. *Citizen Science*

Although not a part of the set of indicators, we asked our interviewees their opinion on citizen science. Its importance was mentioned by almost half of the interviewees (13 out of 35). Almost everyone praised the idea, stating things such as "it's important and it's valid," great for "getting good data and for education," and "covers incredible area scientists couldn't do before." However, several of the experts also expressed concern about it. It needs "rigor and standardization" because "the vast majority of citizen scientist participants have zero background in the areas they're studying, and therefore, need to be trained and supervised by experts." One expert even said "citizen science is useless without also maintaining the scientific expertise that goes along with it." Moreover, some mentioned the difficulty of budgeting and funding such projects, as well as the limitation of types of species to identify – typically only the "larger, more easily recognizable species."

Indicators Not Included

There were several other potential indicators that were considered, but ultimately were not added into the final list of indicators. Some of these indicators included marine species, species found at the bottom of the food chain (e.g. snails), and endangered species.

Marine species was one of the highly considered indicators because of the coastal range that lines part of LA. Many are heavily threatened due to pollution that runs into the waters. This also contributes to the reason why a large portion of the IUCN's Red List of Threatened Species focuses on marine species, such as dolphins, whales, sea lions, coral, and many more. However, although it is also important in understanding marine health and biodiversity, we chose not to include this in our list of indicators because we wanted to stick to the urban land habitats.

Another indicator under consideration were species that would be found at the bottom of the food chain. Some of these included snails, benthic invertebrates, and plankton. Species found at the bottom of the trophic level are just as important as those at the top of the food chain. These species are sensitive to disturbance in their surrounding environment, and thus are good indicators of the health and condition of the habitat, and thus, biodiversity. This indicator did not end up making our list of indicators because few interviewees expressed that this would make a good indicator. Furthermore, this indicator, while it may be good, might be a bit difficult to obtain enough information, especially is citizen science cannot be employed.

Lastly, endangered species was a potential indicator because it could show how a specific change in environment is affecting certain species. This could be a good indicator for both flora and fauna health, as changes in the environment is inevitable, but whether the changes are good or bad is questionable. Unfortunately, this did not make the final list of indicators because very few interviewees mentioned the need for it to be looked at. Moreover, there were several disagreements with using this as an indicator, one being that this is already another individually studied topic.

Los Angeles Biodiversity Indicators

Freshwater Ecosystems

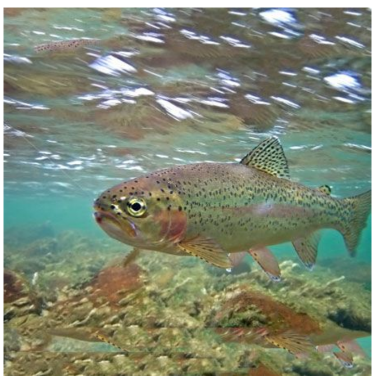
Indicators

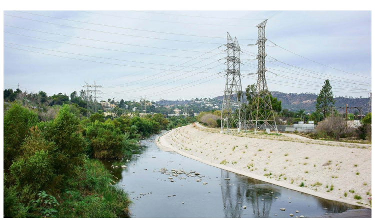
Ratio of Non-invasive to Invasive Freshwater Fish
Presence and Absence of Amphibians

Indicator 1: Ratio of Non-invasive to Invasive Freshwater Fish

Background

This indicator looks at the ratio of non-invasive to invasive freshwater fish in aquatic ecosystems. Over time, the goal would be to decrease the proportion of invasive fish in LA waterways while increasing non-invasive and native fish species.





Specific Measurement Method

Tracking the presence of freshwater fish by recording the ratio of non-invasive to invasive freshwater fish observed in a 5 year period.

Data Source

iNaturalist

Rationale

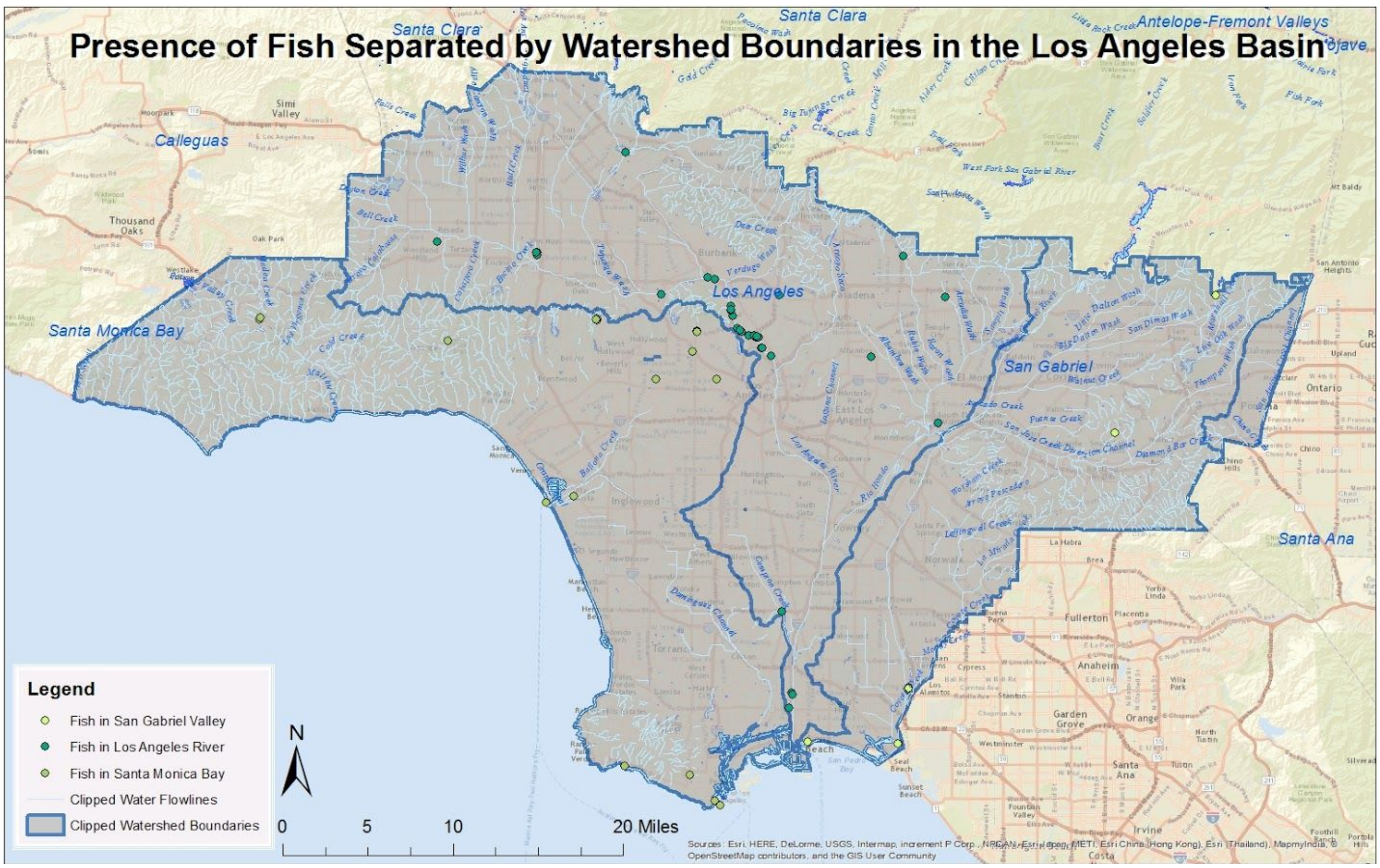
While not many of our interviewees thought of fish as an indicator immediately, freshwater ecosystems are an important part of the LA environment. Freshwater fish are greatly affected by human impacts and development, which changes their density and distribution. Damming of rivers can also affect breeding and feeding. Therefore, looking at the presence and absence of freshwater fish by tracking the change in species in a 5 year period will determine the health of these freshwater ecosystems.

Currently, there are few native fish species left in the LA region. The most prominent species of study would be the steelhead trout. Steelhead trout were prominently found in the Los Angeles River before the channelization in 1948, which destroyed much of their breeding habitat. Due to variable rainfall in Southern California, sand berms can be found in rivers much longer than in areas in the north, causing problems for steelhead trout (Wainwright et. al, 1996). In addition, water allocation has caused further habitat degradation. They are now an endangered species and very rarely found in the Los Angeles River. Noting the presence of steelhead trout may be of importance, but we also understand the rarity of finding this species. It could be used as an indicator of pristine environments, but there would need be extensive restoration of the Los Angeles River to see a prevalent population of steelhead trout.

This indicator looks at the non-invasive and invasive fish species because there are few native species left. Therefore, noting the ratio of non-invasive to invasive is more important and relevant than looking at native fish species.

Map

Our study area encompasses three distinct watersheds, the Santa Monica Bay Watershed, the Los Angeles River Watershed, and the San Gabriel Valley Watershed. From the Citizen Science data we pulled, fish were located primarily in the headwaters of these watersheds with some occurrences in major waterways further downstream. At this point in time, there is not enough data to compare the data for 2016 with data taken in 2011, as described in our Measurement Method. To assess each watershed, we mapped all past fish data to get a general sense of what has been found there.



Indicator 2: Presence of Amphibians

Background

This indicator looks at the presence and absence of amphibians in aquatic ecosystems as a proxy for habitat quality. Through tracking amphibian presence, we would be able to monitor the improvement or degradation of riparian ecosystems, and intervene to protect habitat, if necessary.

Specific Measurement Method

Tracking the presence of amphibians by recording the total number of species found in a 5 year period.

Data Source

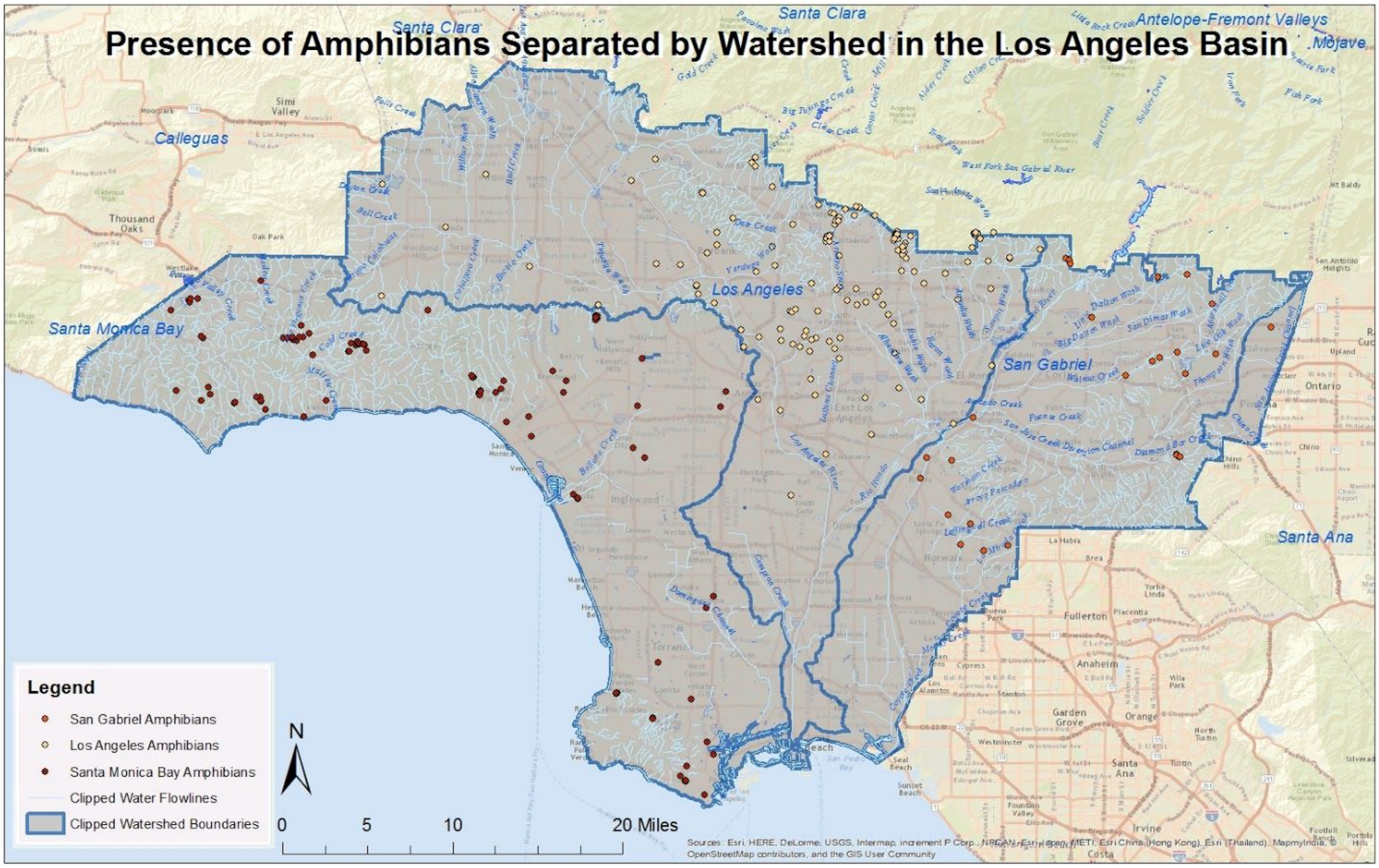
iNaturalist

Rationale

Not many interviewees mentioned amphibians as a good indicator for ecosystem health, but we added amphibians to our list of indicators for freshwater ecosystems because they can show relevant information on the health of their habitat. Amphibians are not only very sensitive to environmental stresses, but they also utilize both aquatic and terrestrial environments throughout their various lifecycles. Changes in their presence, abundance, and reproductive cycles are a good indicator that something is not right in either aquatic or terrestrial habitat.

Map

Our study area encompasses three distinct watersheds, the Santa Monica Bay Watershed, the Los Angeles River Watershed, and the San Gabriel Valley Watershed. From the Citizen Science data we pulled, amphibians were located almost exclusively in the headwaters of these watersheds. To better assess the health of each watershed individually, the measurement method was performed after separating recorded data points based on the watershed they were located in.


Presence of Amphibians Separated by Watershed in the Los Angeles Basin
Legend
San Gabriel Amphibians
Los Angeles Amphibians
Santa Monica Bay Amphibians
Clipped Water Flowlines
Clipped Watershed Boundaries
N
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20 Miles
Santa Monica Bay
Los Angeles
San Gabriel
Santa Ana
Calleguas
Santa Clara
Antelope-Fremont Valleys
Mojave

Birds

Indicators

Keystone Species Population Change Over Time
Total Change in Assemblage

Indicator 1: Keystone Species Population Change Over Time

Background

This indicator would look at the change in population size and distribution of keystone avian species identified to represent specific habitat types across our study region.

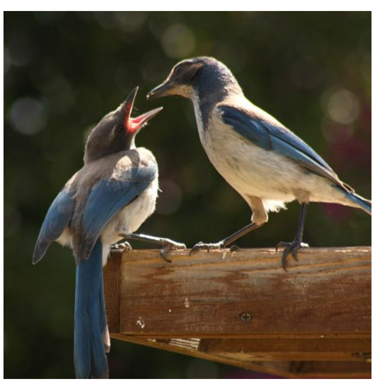
Specific Measurement Method

Track the presence and size of population according to habitat type on a yearly basis.

Keystone Species are divided according to various zones - lowland open country, chaparral/scrub habitats, marshes, arid scrub/alluvial scrub, woodlands, coastal wetlands, and urban areas

Keystone species for each zone -
Lowland open country
Western Meadowlark, Horned Lark, Grasshopper Sparrow, Burrowing Owl, Loggerhead Shrike, American Kestrel, and Lark Sparrow

Chaparral/scrub
California Thrasher, Wrentit



Marshes
American and Least Bitterns, Virginia Rail, Common Gallinule

Arid scrub/alluvial scrub
Lesser Nighthawk, Cactus Wren

Woodlands
Acorn Woodpecker, Nuttall's Woodpecker, Northern Flicker

Urban Areas
California Scrub-Jay, Brewer's Blackbird

Coastal Birds
Ruddy Turnstone, Black Turnstone

Data Source

eBird, iNaturalist

Rationale

Many of our interviewees brought our attention to the diversity of birds as a taxonomic group, and that different species respond differently to changes in habitat. For example, some have benefitted from the introduction of non-native vegetation, while others have not. Thus, it is imperative to choose indicator species in order to best understand ecosystem health in LA. Indicator species are defined as species whose presence and absence reflect species richness on a broader scale (Fleishman et al., 2005). The health of indicator species populations can provide a broader picture of overall species richness in the area (Fleishman et al., 2005). A study by Fleishman et al. that studied indicator species in different taxonomic groups found that “a small, common set of species could be used to predict separately the species richness of multiple taxonomic groups” (2005).

We spoke to an expert in ornithology to decide which indicator species to use for our index. We decided to look at a variety of habitat types: lowland open grasslands, chaparral/scrub habitats, marshes, arid scrub/alluvial scrub, woodlands, coastal wetlands, and urban areas.

Open grasslands are one of the most heavily impacted habitats in Los Angeles County, thus the bird species that rely on open grasslands have greatly declined. Much grassland that existed in the past has been developed already. Breeding species have been most heavily impacted. Horned Larks are still quite common as breeding birds in Los Angeles County, but have declined greatly in this type of habitat. The Grasshopper Sparrow is specialized and requires tall grasses. The burrowing owl is also present in this type of habitat. The Grasshopper Sparrow and the Burrowing Owl may not be suitable indicator species, since they are very rare.

Chaparral/coastal sage scrub habitats are still quite widespread in Los Angeles County. The bird species that live in these areas are a good indicator of habitat quality, since they are negatively affected by urbanization and fragmentation.

Remaining marshes are very rare in Los Angeles County. There are so few American Bitterns left that they may not be a good indicator species, so this must be further assessed.

The Lesser Nighthawk and Cactus Wren are both struggling but still present in alluvial scrub habitats. Both species are very sensitive, but the Cactus Wren is present in more areas.

Woodlands are still present in Los Angeles County as well. Acorn Woodpeckers are oak specialists so are a strong indicator of oak woodlands. Nuttall's Woodpecker is an indicator for woodlands in general. The Northern Flicker is also a general woodland species, and it has declined rapidly in comparison with the Nuttall's Woodpecker. Woodpeckers are keystone species, because tree cavities are used by other species.

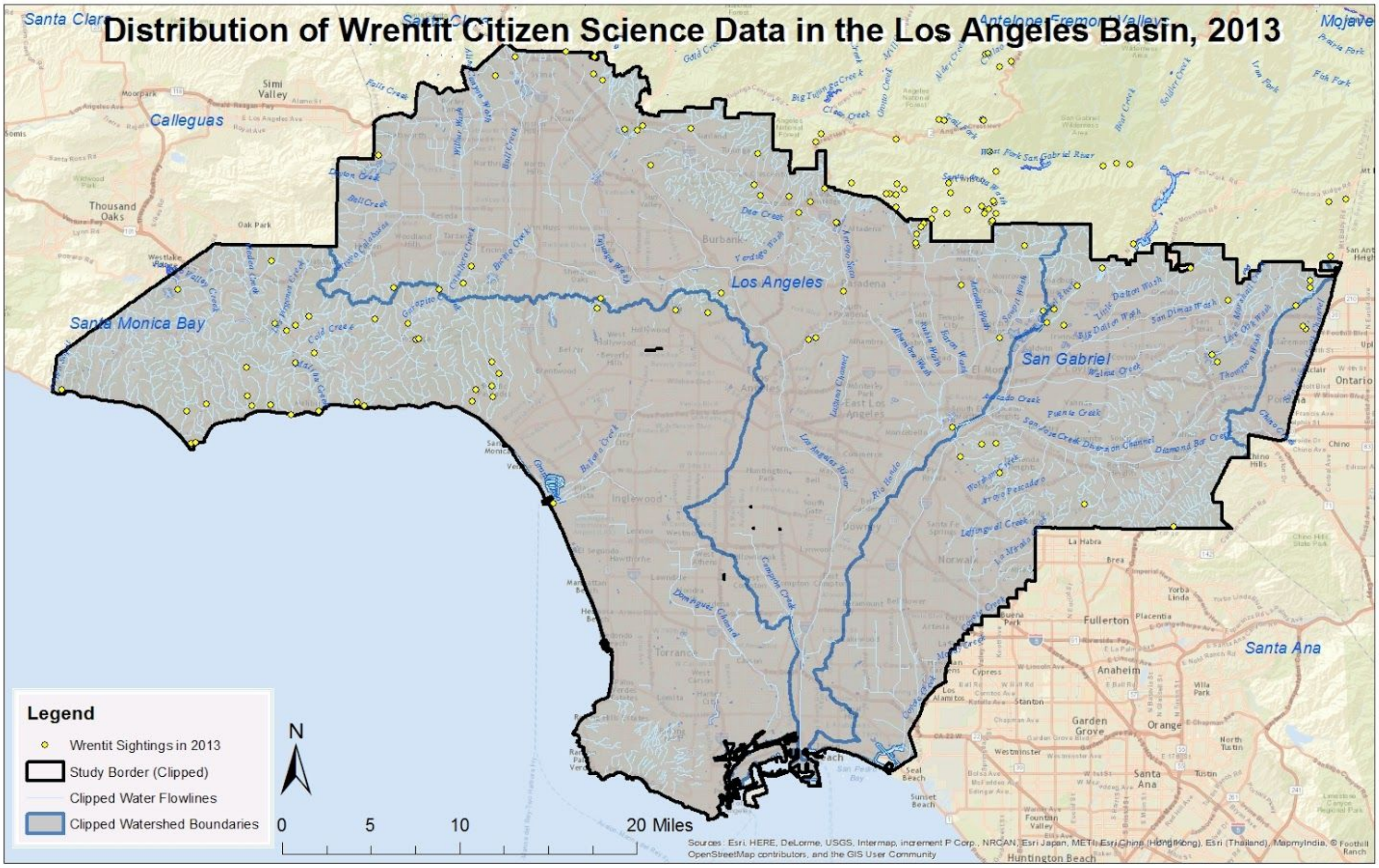
Some urban bird species are declining despite their adaptability to urban areas. For example, the Western Scrub-Jay has been suffering large declines, partly due to the West Nile virus but also due to some other, unknown reasons.

Some coastal birds, such as Ruddy Turnstones and Black Turnstones, may be good indicators of beach quality.

Map

Species abundance is a vital indicator of ecosystem health, so bird data was extracted from 2011 and 2016. We identified multiple species from our study area that were representative of the three watersheds that cover our study area. The watersheds include the Santa Monica Bay Watershed, the Los Angeles River Watershed, and the San Gabriel Valley Watershed. Further breaking up the watersheds into North and South regions gave us six regions that encompass the full range of habitat found in the LA Basin. The birds chosen for the six representative regions were decided based on their ability to describe the state of the ecosystem.

An avian expert at the NHM had some suggestions for indicator species. He suggested that we choose indicator species from a number of categories, including lowland open country species, chaparral/scrub species that are intolerant of heavily modified habitats, declining marsh species, arid scrub/alluvial scrub species, key cavity-excavators of oak and other woodlands, and seemingly urban-adapted species that have been nevertheless declining. To give an example of the change in population for birds, we looked specifically at the Wrentit. Placing the 2011 and 2016 maps generated for this species next to each other gives an idea of how the abundance and distribution for this bird species has changed over time.


Distribution of Wrentit Citizen Science Data in the Los Angeles Basin, 2013
Legend
Wrentit Sightings in 2013
Study Border (Clipped)
Clipped Water Flowlines
Clipped Watershed Boundaries
N
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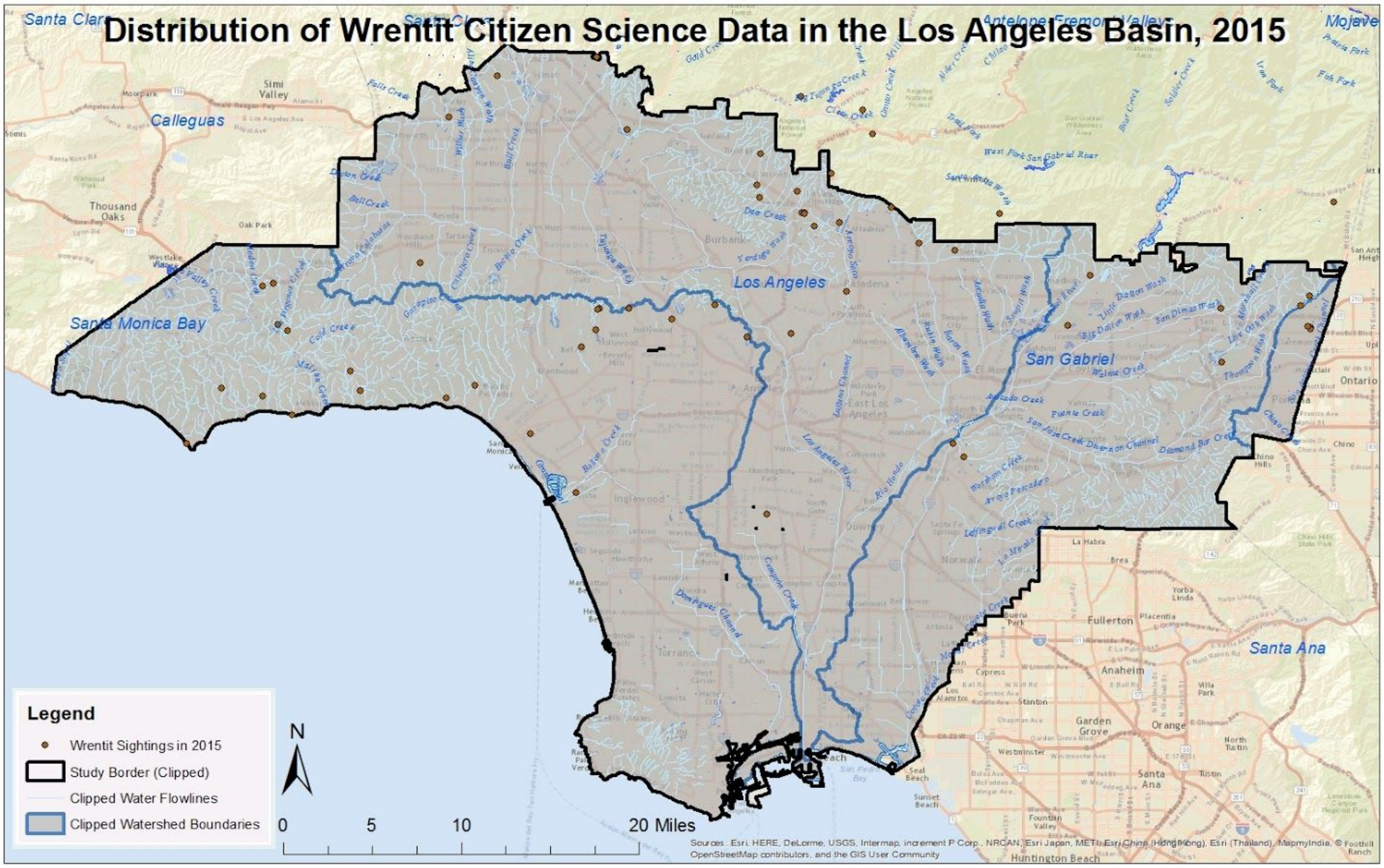
10
20 Miles
Santa Monica Bay
Los Angeles
San Gabriel
Santa Ana
Calleguas
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Distribution of Wrentit Citizen Science Data in the Los Angeles Basin, 2015
Legend
Wrentit Sightings in 2015
Study Border (Clipped)
Clipped Water Flowlines
Clipped Watershed Boundaries
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20 Miles
Santa Monica Bay
Los Angeles
San Gabriel
Santa Ana
Calleguas
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Indicator 2: Total Change in Assemblage

Background

This indicator would look at the changes in general assemblage of birds over time across the entire study region.

Specific Measurement Method

Recording the number and name of species present, with tracking of change in 5 year intervals. Also look at the distribution of species, which tracking changes in 5 year intervals too.

Data Source

eBird, iNaturalist

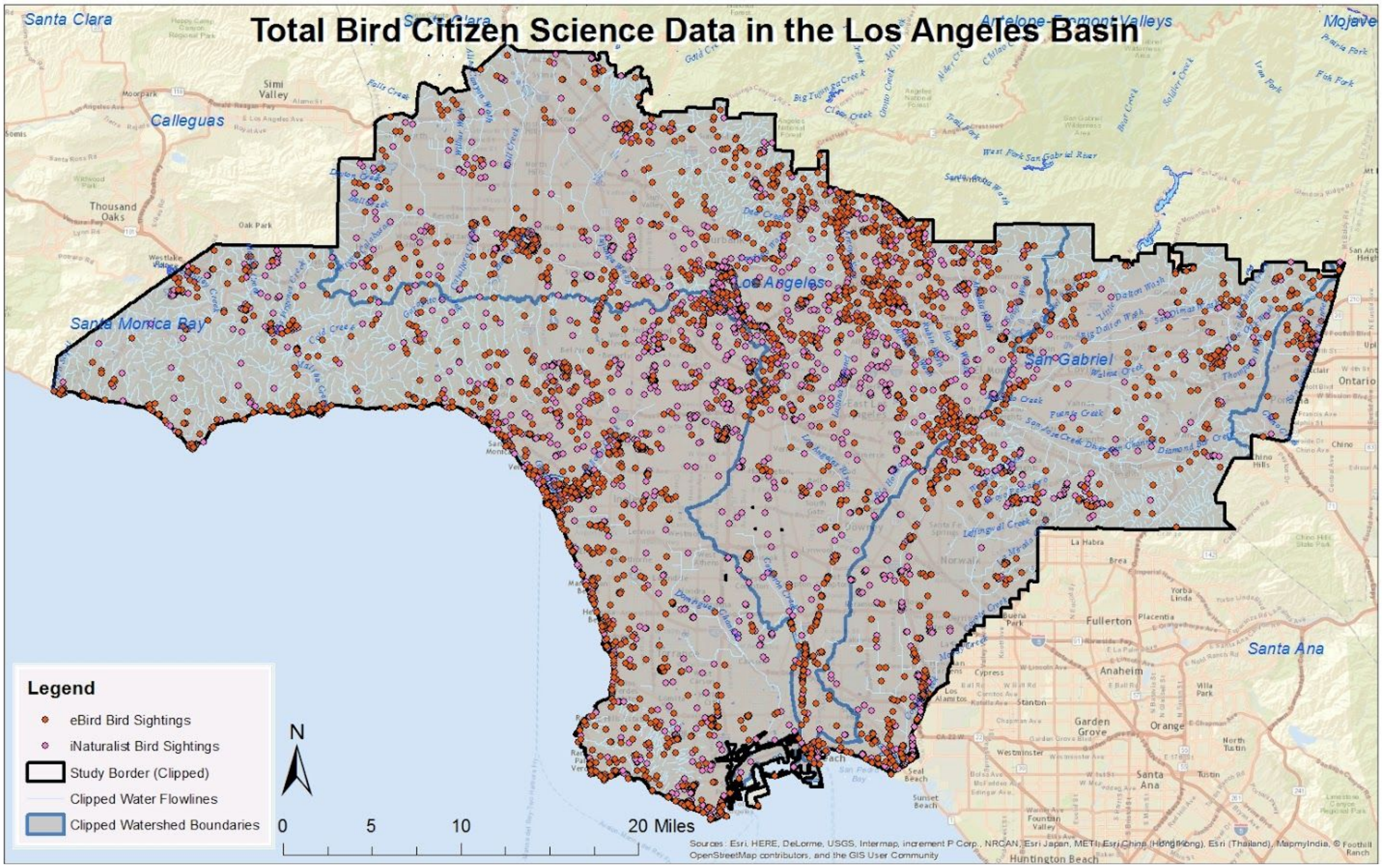
Rationale

Since birds rely on vegetation for many purposes such as to shelter and to breed, birds' presence, absence, and location can provide information about the existing biodiversity. Birds are abundant and diverse in LA County. Compared to other taxonomic groups, there is also a lot of information available on birds, making bird assemblage a very practical indicator to use. Tracking bird assemblages would give valuable information to users of the biodiversity index, not only about what species are present, but how the number in each species changes over time. This indicator concerns bird assemblage rather than simply overall presence of bird species in order to help researchers understand how changes from urbanization affect different species who may rely on different types of habitat services, such as tree cover.

A study by Larsen et al. on the effectiveness of birds as biodiversity indicators showed that birds are relatively effective as indicators if there is a high species richness (2012). This supports the use of birds as in indicator in LA County, which is the county with the most bird species in the United States. However, biodiversity can be even more effectively understood with the inclusion of species from other taxa as well (Larsen et al. 2012).

Map

By separating out the years 2010 and 2015, and projecting all collected avian data points, we can see how assemblages have changed over the past five years.


Total Bird Citizen Science Data in the Los Angeles Basin
Legend
eBird Bird Sightings
iNaturalist Bird Sightings
Study Border (Clipped)
Clipped Water Flowlines
Clipped Watershed Boundaries
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Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Santa Clara
Calleguas
Santa Monica Bay
Los Angeles
San Gabriel
Santa Ana
Mojave
Antelope-Fremont Valleys

Vegetation

Indicators

Change in Coverage
Proportion of Native vs. Non-native vs. Invasive

Indicator 1: Change in Coverage

Background

This indicator would look at the change in vegetation coverage in the study area.

Specific Measurement Method

Measure total vegetation cover in study area in square meters and repeat measurement every five years.

Data Source

USGS Landsat 8

Rationale

Experts expressed the importance of looking at the presence of vegetation, not only looking at species present but total cover, since number of species can be deceptive. Vegetation cover indicates the amount of vegetation available to wildlife for shelter, food, and other needs. Vegetation cover has decreased dramatically due to urbanization, so it is especially important to track. This indicator is related to the proportion of natural areas indicator in the Singapore Index, which some interviewees identified as a key indicator in the Singapore Index.

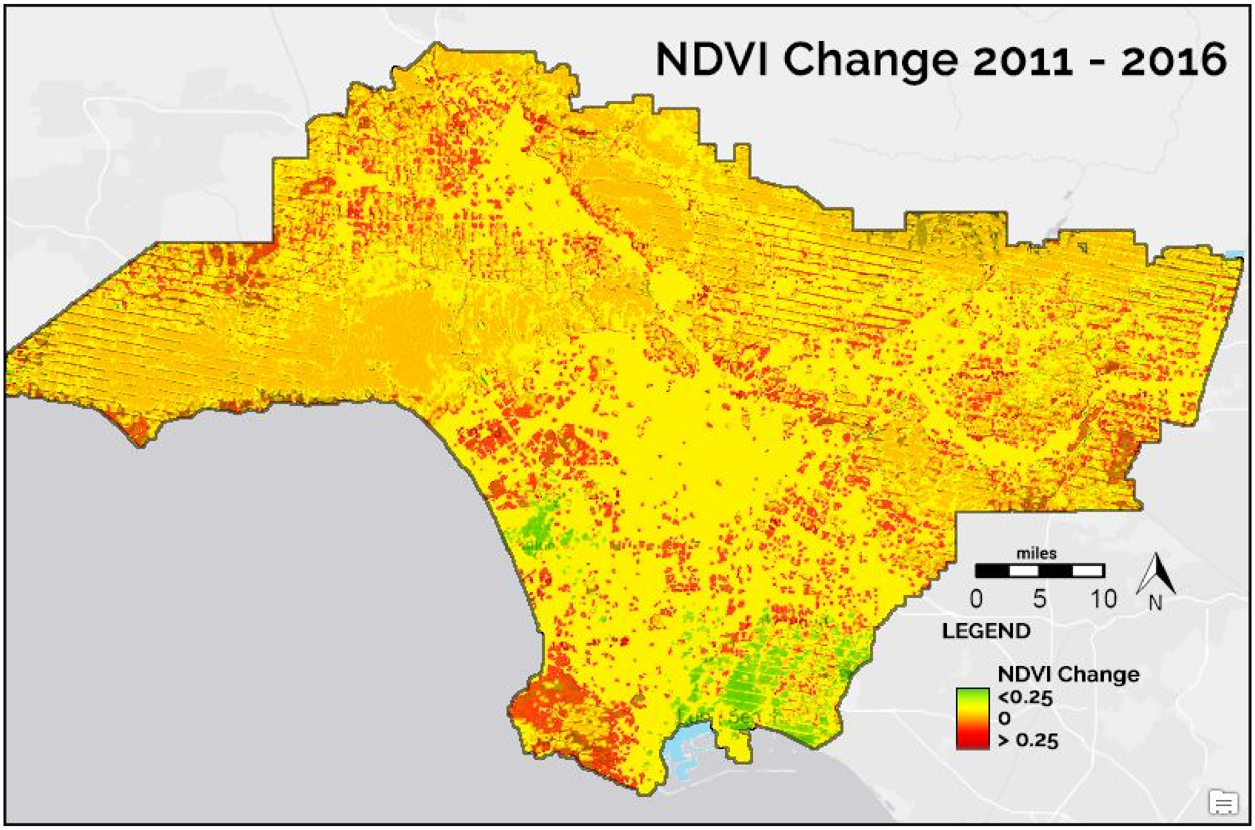
LA is a biodiversity hotspot, containing an abundance of endemic species that are highly threatened. A study by Sloan et al. aimed to measure the amount of natural intact vegetation (NIV) in biodiversity hotspots, since previously information was inaccurate (2014). There is 14.9% of NIV left in biodiversity hotspots worldwide, showing that they are threatened (Sloan et al. 2014). Most of the hotspots contain even less (Sloan et al. 2014). Land development in LA has led to a great decline in vegetation cover, making it important to track changes in vegetation present, since vegetation serves as a basis for overall biodiversity.

Map

Satellite imaging from Landsat 8 was taken in order to calculate the Normalized Difference Vegetation Index (NDVI). The NDVI is a compilation of visible and near infrared bands and can be utilized to measure vegetative coverage. The NDVI was produced using the band math formula:

$$\text{NDVI} = \frac{(NIR - red)}{(NIR + red)}$$

The change in vegetation was then calculated by subtracting the 2016 NDVI from the 2011 NDVI. Vegetation gain is indicated in green while vegetation loss is indicated in red.



Indicator 2: Proportion of Native vs. Non-native vs. Invasive

Background

This indicator would look at the proportion of native vs. non-native species and noninvasive vs. invasive species across our study area.

Specific Measurement Method

Measure proportion of native species to non-native species. Next, measure proportion of invasive versus noninvasive species. Repeat every five years.

Possible Data Source

Tree People database of trees, sourced from citizen science and municipalities.

Rationale

There was some disagreement among the experts over the benefits and importance of native vegetation versus non-native vegetation. The Singapore Index prioritizes native biodiversity in the biodiversity indicator section. However, since many of the interviewees stated that non-native vegetation can provide benefits for wildlife, we decided to include "non-native" as a category as well. The conclusion our team came to was that native vegetation may provide habitat services for more native wildlife, but some non-native vegetation can still provide benefits. Non-native vegetation, experts agreed, is much more beneficial than no vegetation. The index also takes into account proportion of invasive species, because they are threatening to biodiversity.

Discussion

Currently there is no standard method of distinguishing non-native from native species on a large scale. While many databased attempt to index vegetation, there lacks indication to whether or not the species listed is native or non-native.

Insects

Indicator: Change in Number of Species

Background

This indicator looks at the change in the number of species.

Specific Measurement Method

Tracking the number and amount of insect species per year.

Data Source

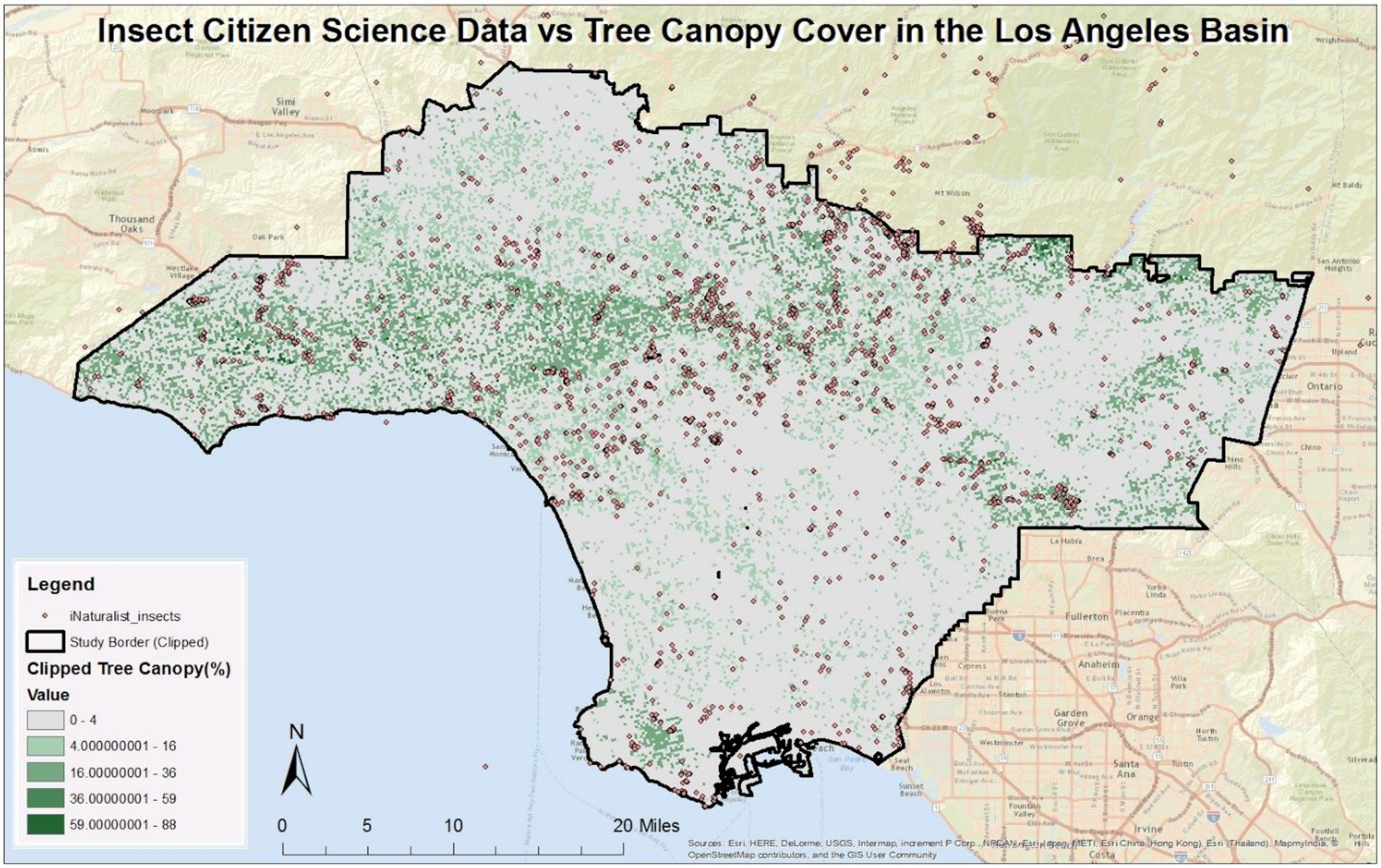
BioScan

Rationale

Insects, with their very high diversity, are an important taxonomic group to study. They serve a multitude of important ecosystem roles including pollination and biomass for taxa in higher trophic levels. Therefore, understanding how insect biodiversity responds to the existing natural areas around the city, as well as how developing urban areas may affect their surroundings, is an important aspect in painting what urban biodiversity looks like. These reasons were highlighted by several interviewees who believed that insects would be an important indicator for LA. Moreover, a modified version of citizen science has already been playing a large role in gathering insect data. BioSCAN, under the NHM, utilizes malaise traps in everyday backyards and has already discovered hundreds of previously unknown insect species. Many of the species identifications are performed by scientists who specialize in ichthyology and therefore true Citizen Science is not the best way to collect this data. Because BioSCAN is so green and new insect species are routinely being discovered, additional time to collect this data is needed before an accurate assessment of the change in number of insect species can be performed.

Map

The following map is comprised of all insect data extracted from iNaturalist. The inconsistent nature of citizen science data collected for this taxonomic group makes it difficult to make conclusions without assistance from scientific experts. We can see though from the map below that there is an apparent trend between insect presence and tree canopy cover within our study area.


Insect Citizen Science Data vs Tree Canopy Cover in the Los Angeles Basin
Legend
iNaturalist_insects
Study Border (Clipped)
Clipped Tree Canopy(%)
Value
0 - 4
4.000000001 - 16
16.00000001 - 36
36.00000001 - 59
59.00000001 - 88
N
0
5
10
20 Miles
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Simi Valley
Thousand Oaks
Ontario
Fullerton
Anaheim
Garden Grove
Orange
Santa Ana
Irvine

Reptiles

Indicator: Change in Assemblage

Background

Reptiles are good indicators for the immediate area. Not only are the populations extremely sensitive to urban development, reptiles typically don't leave their habitat area due to lack of mobility and fragmentation barriers. Monitoring reptile assemblage and scope of coverage can tell us whether or not suitable landscape in urban Los Angeles is being preserved, restored, or destroyed.

Specific Measurement Method

Change in assemblage of reptiles over 5 year intervals.

Data Source

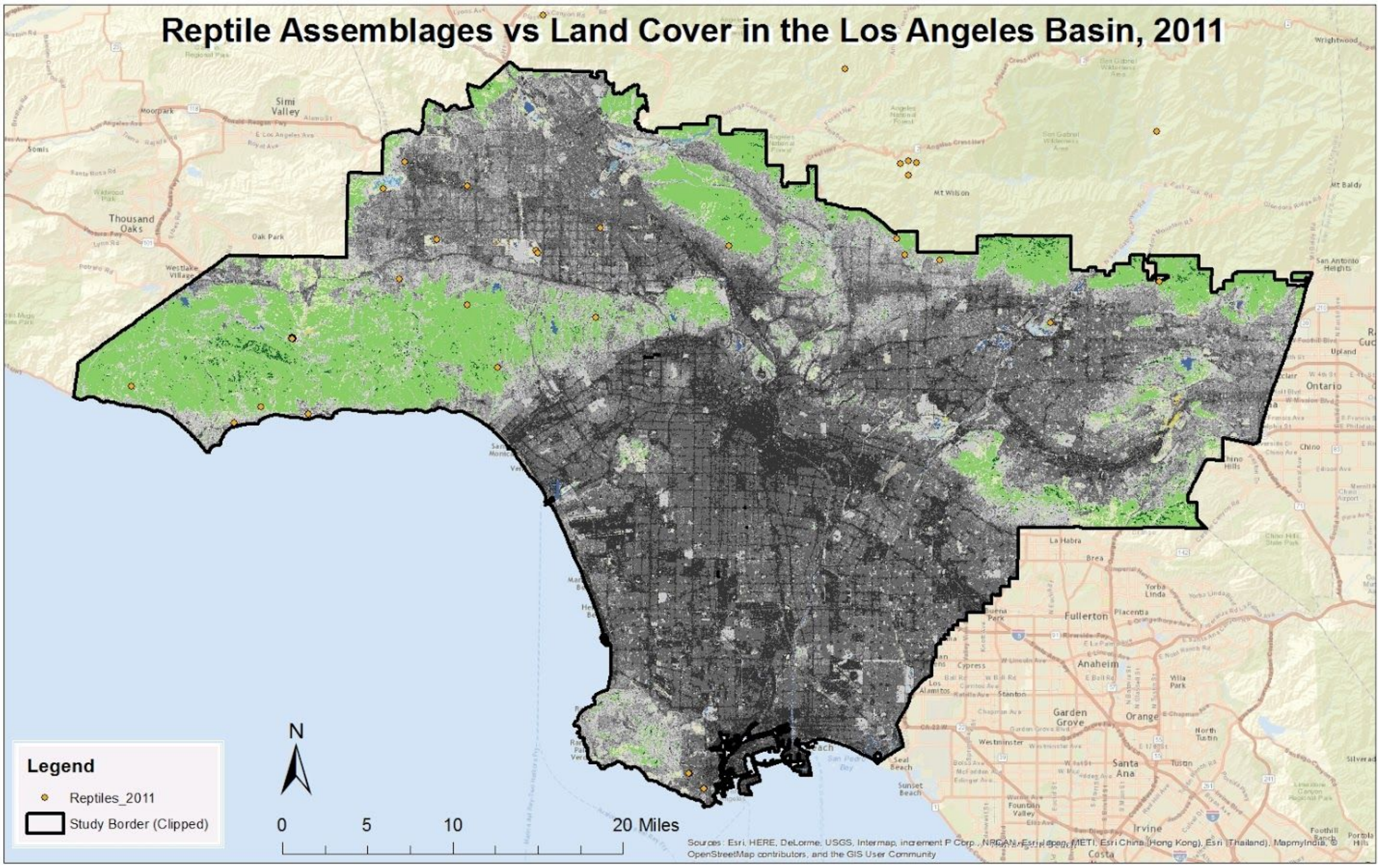
iNaturalist, Scientist led programs like RASCals, further data is being collected by NPS within park boundaries.

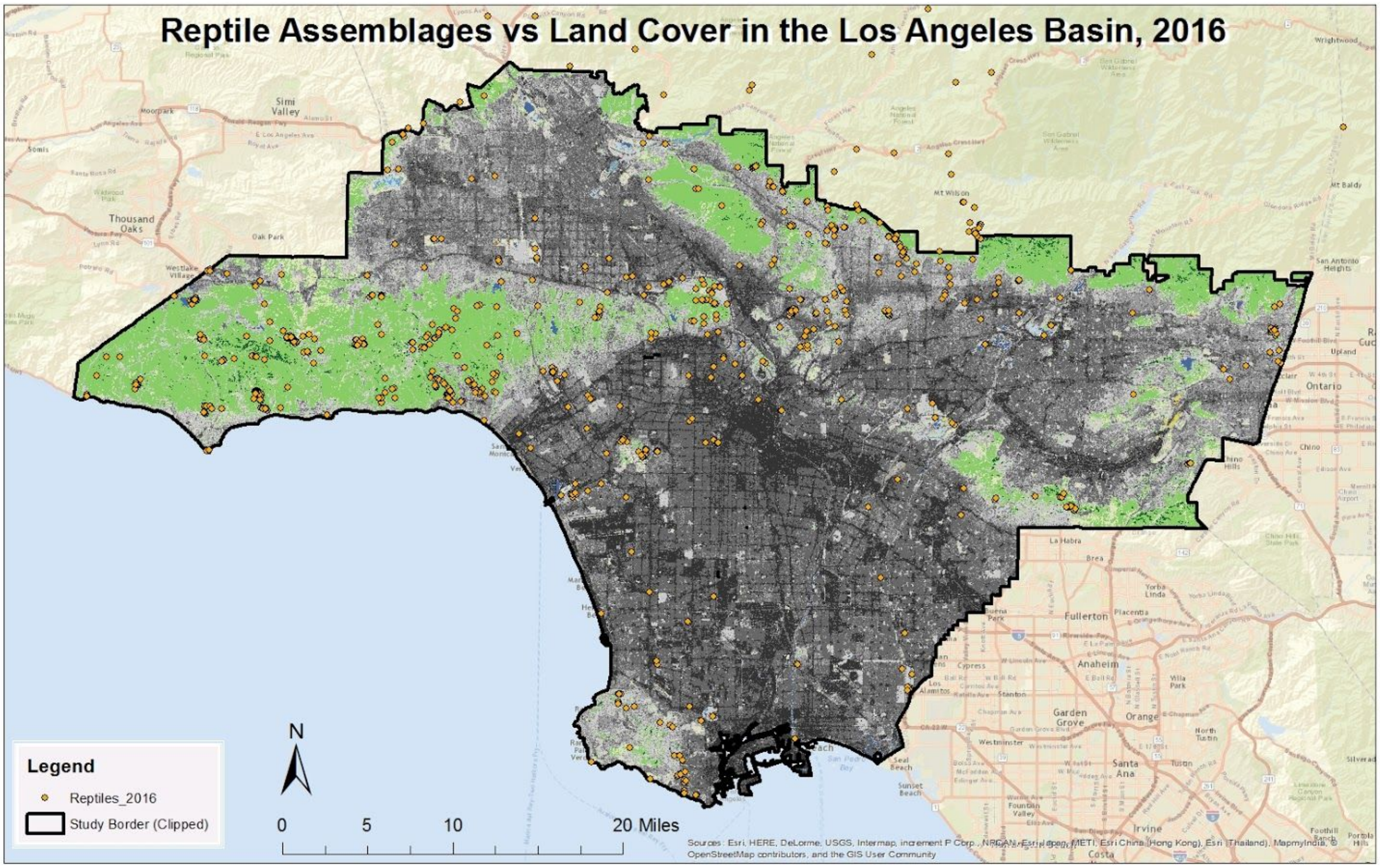
Rationale

Reptiles are susceptible to contaminants in their environments, such as heavy metals and fertilizers. If ingested, heavy metal pollutants can be transferred to hatchlings and reduce offspring survivorship. Fertilizer agents can be found in liver, fat, and bone tissue of reptiles living in polluted areas. Since most reptiles are long lived and tend to remain in the same area for their entire lifespan, they can be used as a measure of habitat quality as well as connectivity. In previous restoration studies, such as Thompson et. al., 2007, reptile assemblages were used as a bioindicator in the restoration of terrestrial ecosystems. With this past research into environmental impacts on reptile species, it is a valid assumption that tracking the assemblages of reptiles across our study area can give an idea of how the urban environment is changing in LA.

Map

To map the change in assemblage of reptiles, we compared the presence of citizen science recorded data points from the year 2011 and 2016. To analyze and justify the inclusion of reptiles as an indicator, we compared the distribution of reptiles across our study area to land cover, as measured by the National Land Cover Database. When overlaying reptile data points and land cover, there is a very apparent trend that reptiles are more readily found in areas where land is not developed.


Reptile Assemblages vs Land Cover in the Los Angeles Basin, 2011
Legend
Reptiles_2011
Study Border (Clipped)
N
0
5
10
20 Miles
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community


Reptile Assemblages vs Land Cover in the Los Angeles Basin, 2016
Legend
Reptiles_2016
Study Border (Clipped)
N
0
5
10
20 Miles
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Fragmentation

Indicators

Connectivity of Landscape using Large Mammal as a Proxy for Habitat Fragmentation
Connectivity of Tree Cover

Indicator 1: Connectivity of Large Mammals

Background

Fragmentation and connectivity is an important aspect of ecosystems, as it aids in the survival of large and small animals. This is especially critical for large mammals, as fragmentation barriers can hinder, reduce, and cause a loss of habitat for them.

Specific Measurement Method

Measurement of distance and area covered by large mammals: bobcats, mountain lions, and mule deer.

Data Source

Data of relevant collared large mammals can be requested from agencies such as the NPS.

Rationale

Large mammals are of the more visible taxa that can exploit urban corridors. Select large mammals, such as mountain lions and bobcats, that have been historically tracked in the LA region provide valuable insight into urbanization patterns. The territory that large mammals claim, and which routes they utilize to establish it can be analyzed to show how urbanization has impacted connectivity. Obstacles such as major roadways and other large construction projects impede the ability for large mammals to expand their territory. Observing the extent of land that a species is able to cover, and the barriers that prevent further expansion can give significant insight into fragmentation.

Mountain lions can be especially important for the LA region because they not only occupy a large area of land, but also are impacted by management and development decisions. Many LA residents are engaged in nature because of their fascination for mountain lions. Therefore, these animals may provide further significance than just ecosystem services.

Mule deer are not well studied in Los Angeles, but may provide important indicator of ecosystem health. Since mule deer feed on plants, a healthy vegetation cover is important to their survival and ability to move around.

Coyotes are not tracked in this indicator because coyotes are well adapted to urban life and human development. Therefore, looking at the presence and range of coyotes will not provide an accurate indication of ecosystem health.

Discussion

There currently isn't much collar data and the data that has been recorded is heavily protected to ensure the safety and well-being of collared animals. Courtesy of NPS, we were give a snapshot of collar movements for Mountain Lion P22. While collar data is limited to only a few animals, data like P22's shows us that our study region suffers tremendously from fragmentation. In the entire time that P22 has been tracked, it has not left Griffith Park. Griffith is bordered on all sides by major freeways, so despite the fact that it is a great refuge for wildlife, gene flow is lowered for many organisms that cannot overcome these man-made barriers. One expert commented that there seems to be no gene flow data available for Griffith park animal populations.

Indicator 2: Connectivity of Tree Cover

Background

Fragmentation of tree cover and vegetative understory to determine connectivity of habitat.

Specific Measurement Method

Measuring patches of land by size and distance.

Data Source

National Land Cover Database

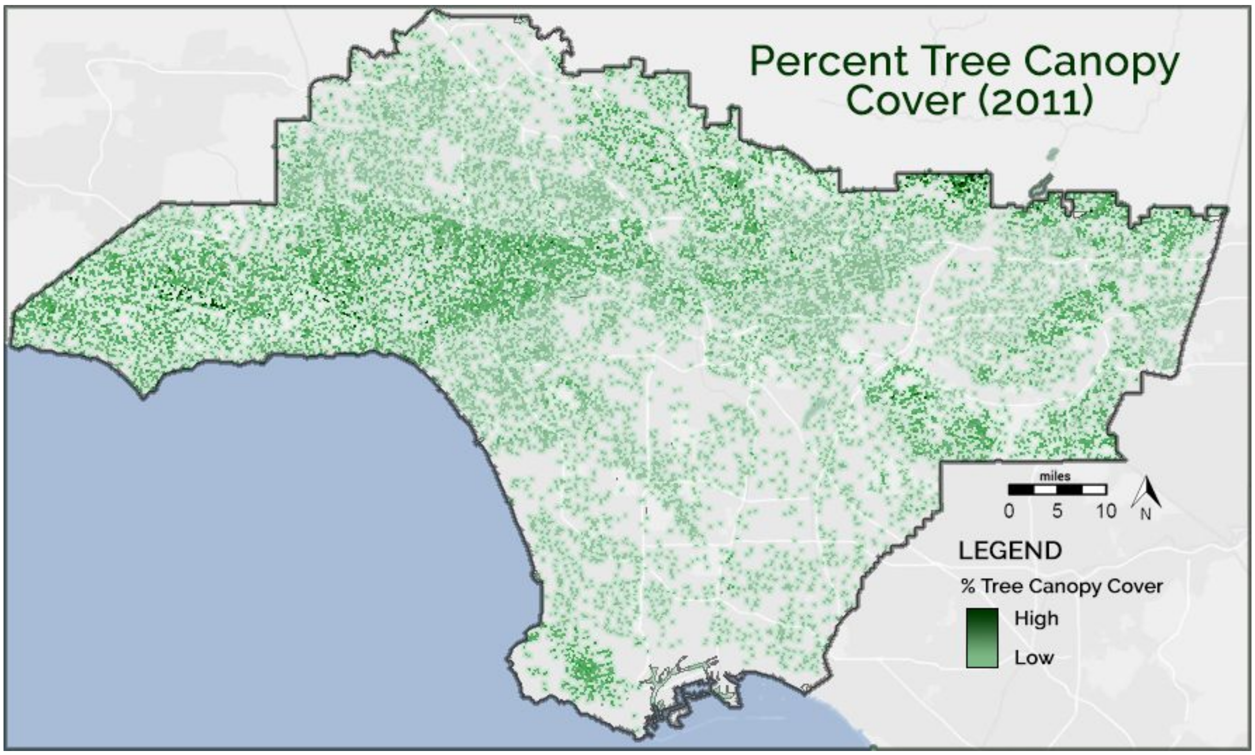
Rationale

Vegetation is also a visible way to see how urbanization has affected connectivity of habitat. The availability of a long stretch of vegetation is important to wildlife, as some animals are unwilling to cross urbanized paths. Thus, while urbanized corridors for large mammals are important, strips of vegetation is also very crucial as corridors for other smaller animals and insects.

Strips of vegetation throughout this urban landscape will not only promote existing biodiversity, but also be able to house species that require larger habitats

Map

The map shows percent tree canopy cover, from 0 to 100%. The map shows the presence of vegetated area and how relatively connected they are. The National Landcover Database produced this layer using the Random Forests regression algorithm.



Los Angeles Biodiversity Indicators

01. Freshwater Ecosystems
-Ratio of Non-invasive to Invasive Fish
-Presence of Amphibians

02. Birds
-Keystone Species Population Change Over Time
-Total Change in Assemblage

03. Vegetation
-Change in Coverage
-Proportion of Native vs. Non-native vs. Invasive

04. Insects
-Change in Number of Species

05. Reptiles
-Change in Assemblage

06. Fragmentation
-Connectivity via Large Mammal Mobility
-Connectivity of Tree Cover

Summary of Los Angeles Biodiversity Indicators

Analysis and Discussion

Citizen Science

Citizen science was utilized in this study because it was a source of data that was available for the entire study region. The accuracy of the data varied by the program. For iNaturalist, we relied on the internal checks and balance review system to mark data entries as "research grade." For all citizen science programs, we utilized data points which had both a photo of the specimen being recorded, were verified as "research grade" by the system, and had unobscured geoprivacy. Within iNaturalist, we were able to utilize over 41,000 points out of a total of 92,000 observations for LA county. All of these point went through a review process where at least three other iNaturalist users had to affirm the submissions contents in order to become research grade. No other data is available countywide that provides direct data on biodiversity. If these data exist, we were not able to access them through public, easily located, or easily accessible means.

Citizen science data was not used with the intention of scoring the biodiversity in the study area. We realize the data represented by citizen science contains bias by the persons who participate in these programs. For instance, communities with a higher interest or awareness in biodiversity would have a higher concentration of citizen science data points. Areas with high data density have a greater chance of being properly accessed for biodiversity health. However, areas with fewer points does not necessarily indicate a lesser presence of biodiversity in the area relative to surrounding areas.

Our clients expressed interest in determining what factors influenced the collection of citizen science data. By using the ArcGIS Spatial Analysis Toolkit, we were able to spatially join the following variables to our Citizen Science data: *Median Income levels, Land Cover/Impervious Surface,* and *Traffic Density*. Once these variables were joined, the resulting .dbf was exported into excel. All null values, which corresponded to any points outside of the county border, were removed, then remaining values were graphed. Statistical analysis of the variables were conducted in R.

Median Income

Hypothesis: Locations with higher median income would have more citizen science data points. Median income data was gathered by the census block. As the census blocks vary in size, the count of data points by census block was normalized by dividing frequency by area.

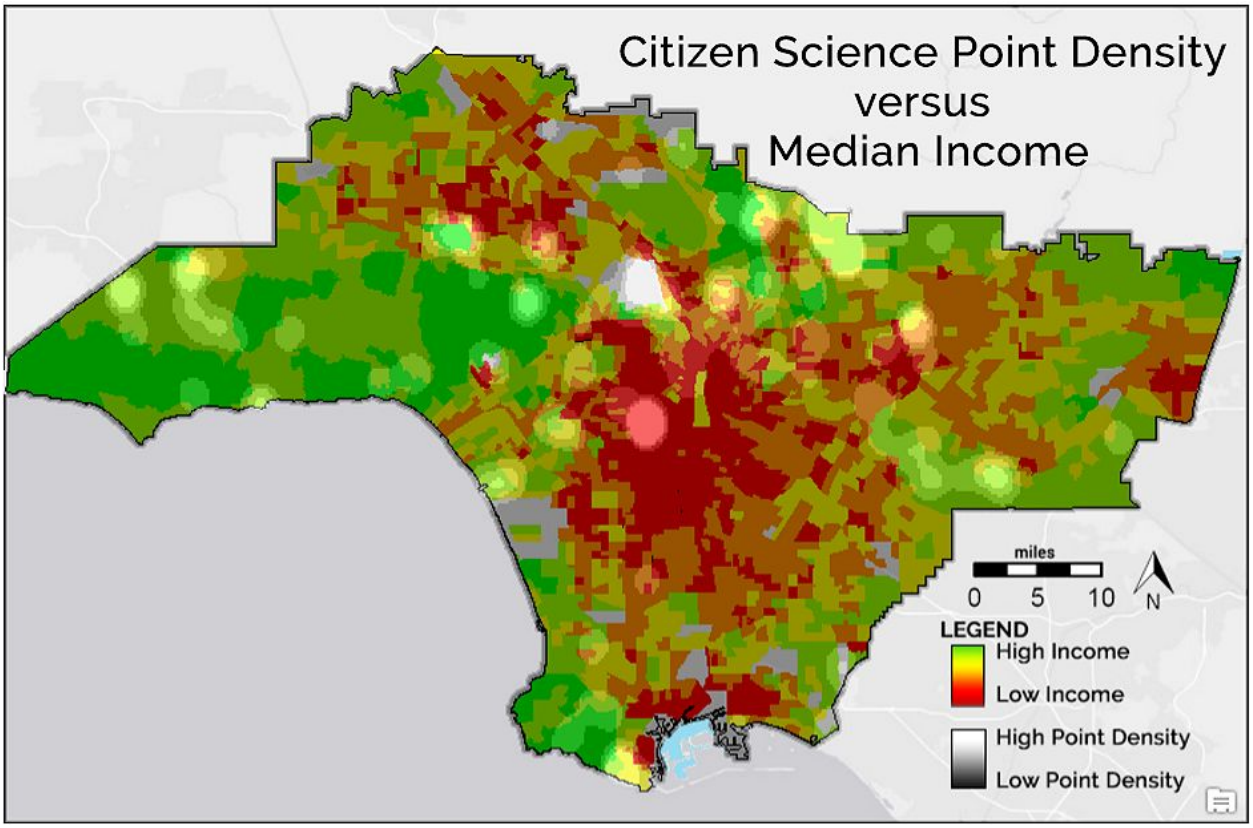
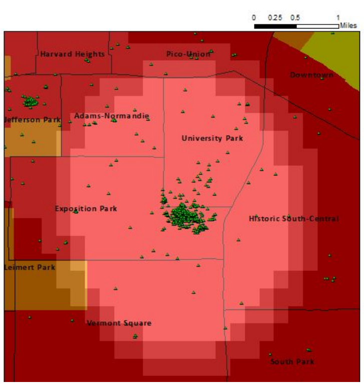
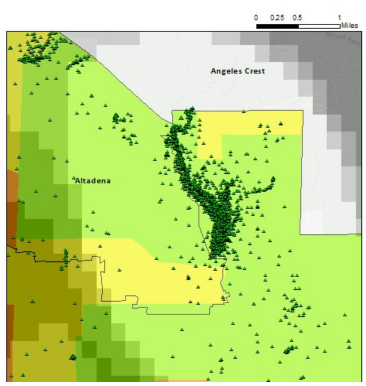
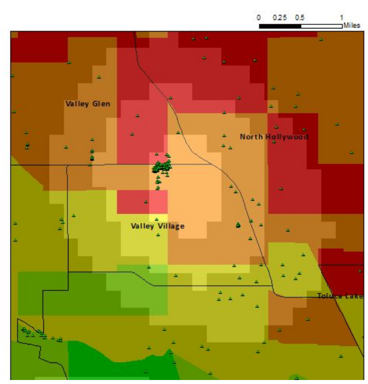


Figure: Map of Median Income versus Citizen Science Point Density







(A) Area of highest occurrence/ km²
Exposition Park - Natural History Museum

(B) Second highest occurrence/ km²
Altadena/ Pasadena

(C) Third highest occurrence/ km²
Valley Village

The map highlights areas with higher amount of point density. Unlike our hypothesis, there are several areas of lower income that have high point density. The Natural History Museum is a notable case (Figure A), as the location with the most point density despite being located in and surrounded by low income blocks. The second highest point density seemed to be along a hiking trail as it shows an evident pathway from the point location alone. Figure C is also another case of high density in a lower income area. When we looked at the data in detail to rationalize the cause, we noticed that all of the points were taken by one very enthusiastic citizen scientist.

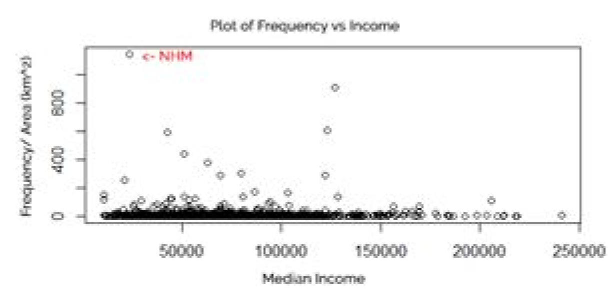


Figure A: Plot of Frequency vs Income
Frequency was divided by the census block's area in order to normalized the value by km^2.

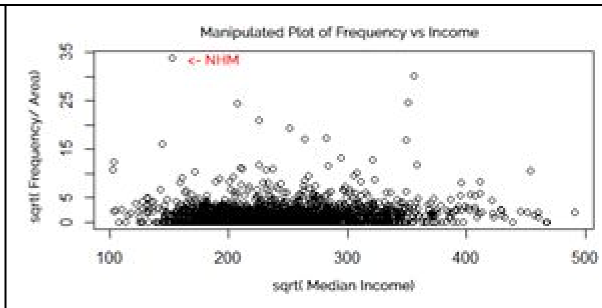


Figure B: sqrt(Frequency) versus sqrt(Income)
The variables were transformed (square root was taken) in order to make possible trends more visible.

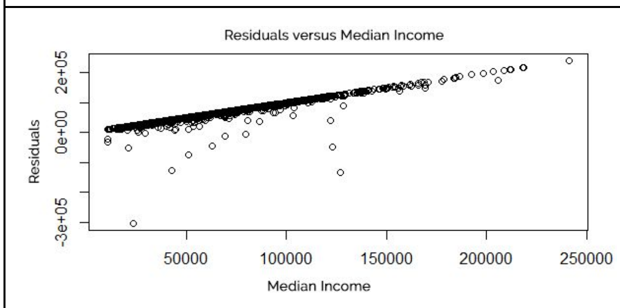


Figure C: Plot of Residuals versus Median Income.

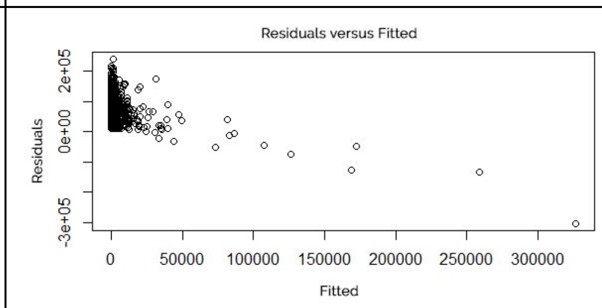


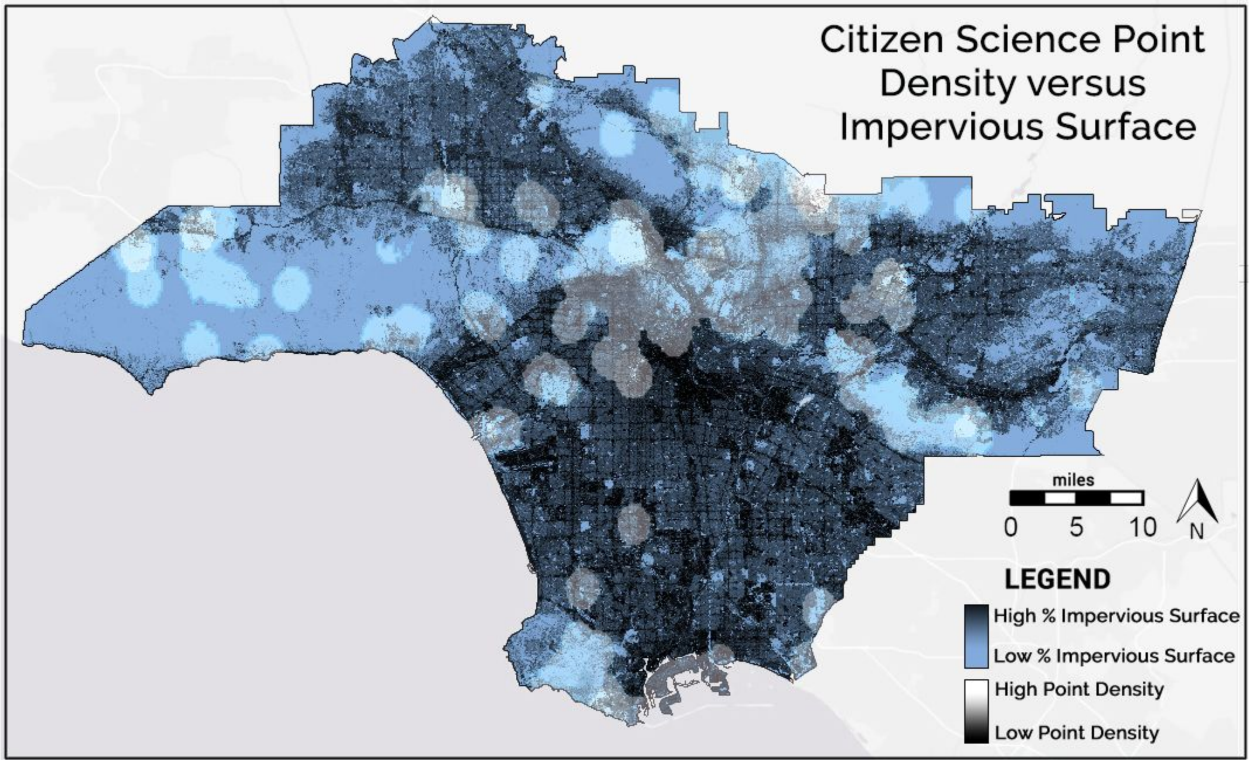
Figure D: Plot of Residuals versus Fitted.

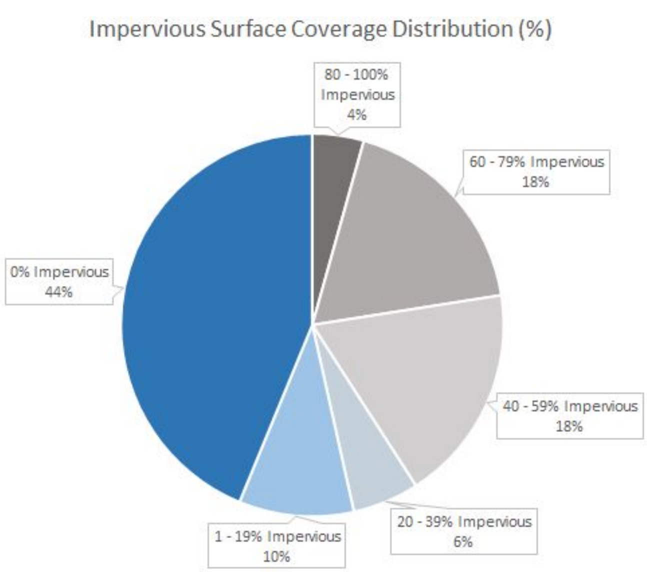
A linear regression was done in order to identify any correlations between median income and data point frequency. Figures A and B show the data points lacked any positive trend. The residuals were also looked at to determine if a linear regression was appropriate for the data. The plot of residuals versus the independent variable showed a linear trend, which signified a non-linear model is more appropriate for this analysis. The residuals versus fitted plot showed data points cluster to the left, signifying non-constant variance.

The spatial and statistical analysis did not show correlation between median income and presence of citizen science data points. For outreach purposes, this can be interpreted as a positive outcome to have no correlation between the two variables. However, there is a likelihood that people are not taking citizen science data points in the census block they reside in.

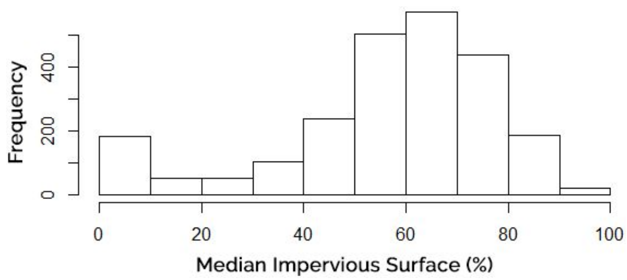
Impervious Surface

Hypothesis: Areas with less impervious surface would have higher instances of citizen science. Impervious surface was used as a predictor of urban development for this map. We created our hypothesis under the assumption that people are more likely to engage in citizen science in places that they expect nature. These patches of 'nature' are typically less developed or are purposely left unpaved. Unlike the median income map, census blocks were not utilized so the point density was not normalized per km^2.

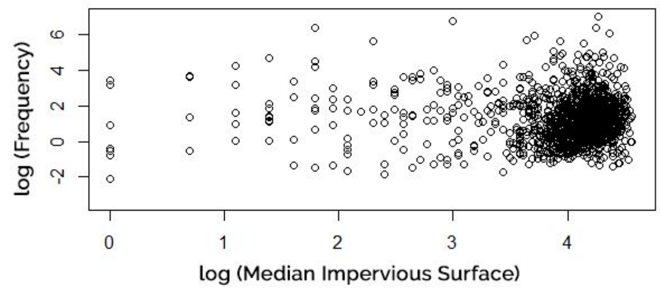




The map shows a general trend of citizen science data being taken at areas of more pervious surface. We were concerned that the data may be skewed from the ratio of impervious to pervious surface that is in the study area. Where that citizen science may be more present on impervious surfaces, just because a large portion of the study area is developed. However, the pie graph on the left shows the ratio of impervious to pervious surface to be fairly equal, largely in part due to the Santa Monica Mountains.



(A) Histogram of Median Impervious Surface

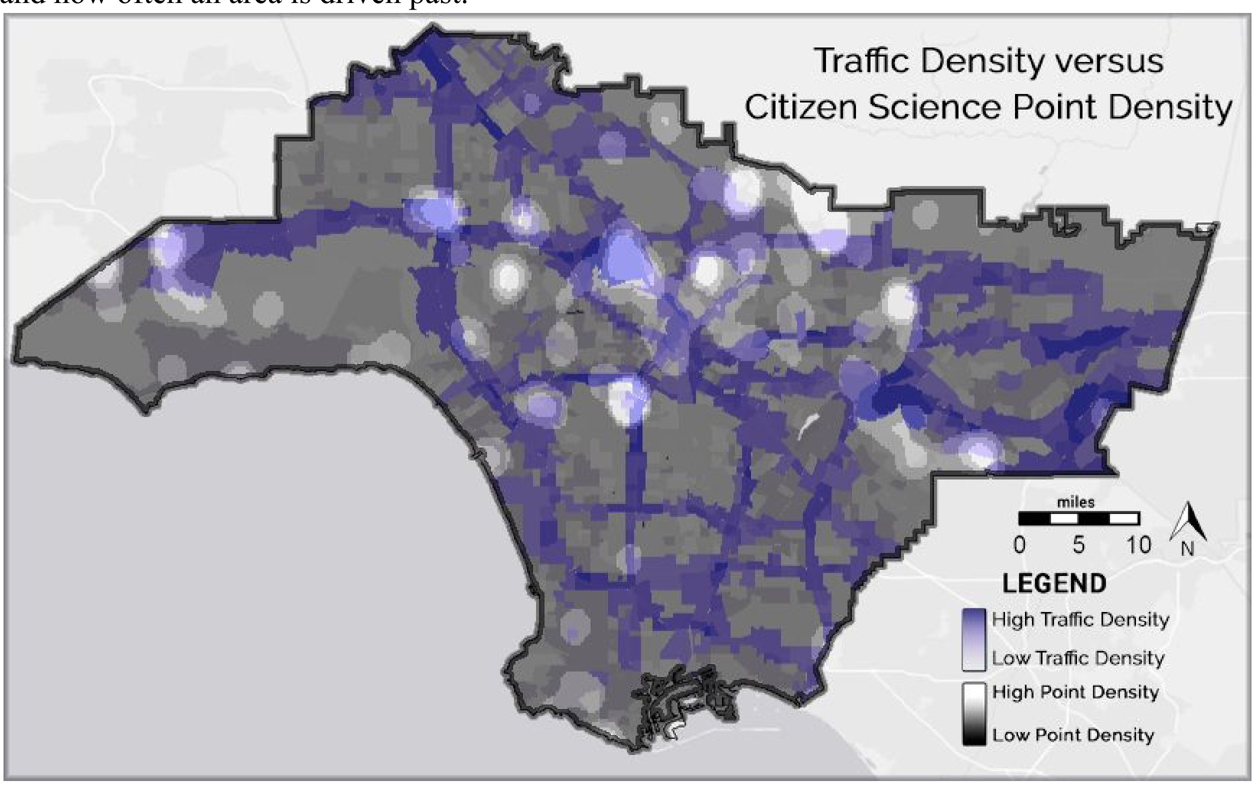


(B) Scatter Plot of Frequency versus Median Impervious Surface (%). The variables were transformed (log was taken) for visibility.

While the map shows a wide presence of citizen science points at pervious surfaces, the histogram of median impervious surface shows high point density in areas of impervious surface. The scatter plot also shows skewness towards higher percent of impervious surface, with lack of clear linear trend.

Traffic Density

We hypothesized that areas located in or near high traffic areas would have more citizen science data points. The presence of traffic can predict how accessible an area is to the general public and how often an area is driven past.



The map shows a correlation between citizen science data presence and areas of high traffic density. There are a few outliers near the western, northern, and southern boundaries of the study area. These areas, however, are less developed and many are popular areas for outdoor recreation.

A comparison with the Singapore Index

Our final list of indicators has slightly deviated from the original SI. An indicator by indicator breakdown of our changes from the SI are:

1) Indicators 1, 9, and 10: In the SI, these three indicators are all related to vegetation. Thus, in our indicator set list, we made a specific indicator of "vegetation." Under this indicator, we had several subcategories to be taken into account, including native versus non-native versus invasive, and the change in coverage. This is similar to the SI, which measures proportion of natural areas in the city, proportion of protected natural areas, and proportion of invasive alien species.
2) Indicator 2: This indicator was very similar to our LA indicator set because both look at measures of connectivity and fragmentation. However, the difference between our indicators is that while the SI measures connectivity and fragmentation by mean patch size, distance between patches, or effective mesh size, our LA indicators will measure it using both patches of land and routes of collared large mammal data as a proxy for fragmentation.
3) Indicator 3: Similar to SI, birds is also a specific indicator on our list. However, while the SI uses birds as a way to measure native biodiversity, our indicator is using it as both a measurement of native biodiversity, as well as a health indicator. This is done by looking at the total assemblage change of birds over the years, as well as looking specifically at keystone species in specific habitat types.
4) Indicators 4-8: These indicators in the SI are similar to our list because it selects a few of the important species that would be most indicative of the overall health and biodiversity of the environment. The SI uses vascular plants, birds, butterflies as their indicators. We chose to use freshwater ecosystems (fish and amphibians), reptiles, and insects as our other indicators.

By slightly changing what indicators to use, as well as the way to categorize the indicators, we were able to maximize what should be looked and studied at to determine the health and biodiversity of LA. Rather than having very specific indicators, we have very general indicators that are then subcategorized into more specific details to look at. Our goal of the SI is not to necessarily score and rank the city with a number, but rather, be able to create a baseline measurement for future references to determine how well biodiversity is doing, and how it can be improved upon (using the subcategorized details of the indicators as a starting point).

SI Indicator(s)	LA Biodiversity Indicators
1, 9, and 10 (Proportion of Natural Areas in the City; Proportion of Protected Natural Areas; Proportion of Invasive Alien Species)	Vegetation - Change in Coverage - Proportion of Native vs. Non-native vs. Invasive
2 (Connectivity Measures or Ecological Networks to Counter Fragmentation)	Fragmentation - Connectivity via Large Mammal Mobility - Connectivity of Tree Cover
3 (Native Biodiversity in Built Up Areas (Bird Species))	Birds - Keystone Species Population Change Over Time - Total Change in Assemblage
4-8 (Change in Number of Native Species)	Freshwater Ecosystems - Ratio of Non-invasive to Invasive Fish - Presence of Amphibians Insects - Change in Number of Species Reptiles - Change in Assemblage

Table: Summary of Indicator Changes

Conclusion

Conserving biodiversity in urban areas is not easy, but the biodiversity index created through this project can help the City of LA, scientific researchers, and the public in doing so. Although not a part of these efforts directly, this project was originally inspired by city efforts to address biodiversity, such as Mayor Eric Garcetti's Sustainable City pLAn and the biodiversity motion introduced by LA 5th District Councilmember Paul Koretz. Since the study area includes not only the city of LA but much of the rest of LA County, the biodiversity index can be applied by policymakers in much of Southern California. Ideally, this project would give policymakers a strong starting point in organizing an approach for measuring and conserving biodiversity in their respective areas. In addition, researchers may be able to collaborate more easily if the biodiversity index directs attention to clear data gaps. The results of this project can also be used to galvanize the public to contribute to biodiversity conservation efforts. This project maps current citizen science efforts and points out spatial data gaps. Nonprofit organizations can educate the public on the necessity of filling these gaps, and perhaps, encourage underrepresented communities to submit citizen science observations.

Appendix

List 1. Experts interviewed

1) Bornstein, Carol - Natural History Museum
2) Boydston, Erin (PhD) - U.S. Geological Survey
3) Brown, Isaac - Singapore Index, UCLA
4) Carmichael, Danny - TreePeople
5) Chaves, Jaime (PhD) - Professor at Universidad San Francisco de Quito
6) Clark de Blasio, Julie - CA Native Plant Society
7) Cole, Jeffrey - Pasadena City College
8) Crain, Rhiannon (PhD) - Cornell Lab of Ornithology
9) Dagit, Rosi - Resource Conservation District of Santa Monica Mountains
10) Drill, Sabrina (PhD) - UC Cooperative Extension
11) Fiesler, Emile - Bioveyda Biodiversity Inventories
12) Folsom, Jim (PhD) - The Huntington Botanical Gardens
13) Fraga, Naomi (PhD) - Rancho Santa Ana Botanical Gardens
14) Garrett, Kimball (PhD) - Natural History Museum
15) Gillespie, Tom (PhD) - Professor and researcher at UCLA
16) Gold, Mark (PhD) - UCLA
17) Gorlitsky, Leryn - Professor at UCLA
18) Hopkins, Arlene - Arlene Hopkins and Associates
19) Harrigan, Ryan (PhD) - Center for Tropical Research
20) Kohsaka, Ryo - Singapore Index
21) Kopczak, Chuck (PhD) - California Science Center
22) Martin, Karen - Pepperdine
23) Mazour, Raphael - Southern California Coastal Water Research Project
24) Mehrhoff, Loyal - The Center for Biological Diversity
25) Palino, Gina - TreePeople
26) Pease, Katherine (PhD) - Heal the Bay
27) Randall, John (PhD) - The Nature Conservancy
28) Rauser, Casandra - Sustainable Grand Challenges at UCLA
29) Reed, Dan (PhD) - Marine ecologist at UCSB
30) Riley, Seth (PhD) - National Park Service
31) Schiffman, Paula M. (PhD)- Professor at California State University, Northridge
32) Schrader, Andy - LA City Hall
33) Smith, Thomas (PhD) - Center for Tropical Research
34) Sechrest, Wes - Global Wildlife Conservation in Austin, Texas
35) Stein, Eric - Southern California Coastal Water Research Project

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FRIENDS OF THE LA RIVER

570 W. AVE 26 #250
LOS ANGELES
CA 90065
323.223.0585
CONTACT@FOLAR.ORG

05/9/17

Los Angeles City Council
200 N. Spring Street,
Los Angeles, CA 90012

RE: Council-File 15-0499 (KORETZ) 'Protecting Biodiversity'

Dear Honorable Councilmembers,

On behalf of Friends of the Los Angeles River (FoLAR), and the 40,000 supporters we represent, I write to express our <u>strong support</u> for the 'Protecting Biodiversity' motion moved by Councilmember Koretz. For over 30 years, FoLAR has worked to create an enduring vision for the LA River that focuses on her ecological health and the mutual social, economic, and public health benefits for the communities that neighbor her. This motion is a crucial step towards fulfilling the promise of a living, thriving river for all Angelenos.

We have a unique opportunity to demonstrate Los Angeles is a world-class city on the leading edge of promoting social equity through conversation and sustainable practices. FoLAR highly encourages the Council take into consideration the recent study *Developing Biodiversity Indicators for Los* Angeles (2016) and leverage its findings by UCLA's Institute of the Environment and Sustainability on behalf of the Natural History Museum, the National Park Service, and The Nature Conservancy. This would place City staff further ahead more quickly in developing biodiversity goals that reflect Los Angeles unique natural resources.

We offer our wholehearted support for the 'Protecting Biodiversity' motion by Councilmember Koretz. The River and FoLAR thank you for your leadership. If our organization can help in any way, please so not hesitate to reach out.

Sincerely,

Marissa Christiansen
Executive Director