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CAP LTER Site Review Document

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Introduction

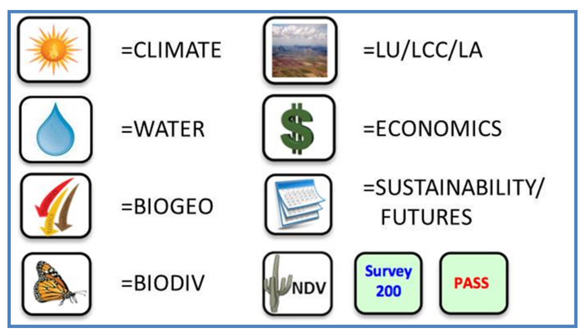
The Central Arizona–Phoenix (CAP) LTER investigates patterns and processes of a complex urban socio-ecosystem, their human outcomes and feedbacks, and the services and disservices derived from the interaction of built, designed, and ecological structure and function. The central question guiding CAP LTER research is:

How do the services provided by evolving urban ecosystems affect human outcomes and behavior, and how does human action (response) alter patterns of ecosystem structure and function and, ultimately, urban sustainability, in a dynamic environment?

Since 2010, CAP has made significant progress in answering this question in some areas, and is making considerable inroads in others. The challenge of integrating approaches and theories from the social and natural sciences remains substantial for CAP researchers, as it does for most urban scientists, and permeates nearly every aspect of our research. In addition, we have recognized the need to better incorporate conceptual and practical knowledge from engineering and other technological areas of research because we work in an ecosystem that is designed by humans and defined by the built environment.

CAP LTER research is organized into five monitoring or experimental databases (Land Use, Cover, and Architecture [LU/LC/LA]; NDV Experimental Suburb [NDV]; Survey 200; Phoenix Area Social Survey [PASS]; and Economic and Census Database [ECONOMICS]), four Integrative Project Areas, or IPAs (Climate, Ecosystems, and People (CLIMATE); Water Dynamics in a Desert City (WATER); Biogeochemical Patterns, Processes, and Human Outcomes (BIOGEO); and Human Decisions and Biodiversity (BIODIV), and one synthesis (SUSTAINABILITY/FUTURES). Throughout this document, the symbols shown in the box below will be used to highlight research that integrates across IPAs and foundational databases[1].

In this report, we provide an overview of research since 2010 (and especially since 2012) in each of the IPAs, organized by research question (from the proposal). Site-review presentations and posters will expand upon these overviews. A summary of research conducted in the foundational areas overlaps greatly with research summarized for each of the IPAs, although we repeat the information in both places for completeness. This research section is followed by sections on Education and Outreach, Information Management, and Project Management. Each of these topics will receive attention during one or more question and answer sessions/presentations during the site review.



Research

Major Contributions of CAP LTER

Fifteen years of research by the CAP LTER program has yielded insights that we will share in an upcoming synthesis volume. These insights fall under **five themes**, not necessarily mapping to any single IPA, which synthesize the most important findings of our research:

(1) Theory of urban social-ecological systems: CAP LTER has been a strong contributor to the evolution of ideas about cities as complex social-ecological systems, and a leader in the integration of social and natural sciences. Since 2010, CAP scientists have 1) given a plenary presentation on these theoretical developments at the first Society for Urban Ecology conference in Berlin, Germany; 2) initiated a Research Coordination Network focused on urban sustainability (Childers et al. in review); 3) contributed to an edited volume on long-

[1] Symbols courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/).

term social-ecological research (Grimm et al. 2013) and to a National Research Council publication on urbanization and sustainability (NRC 2010); and 4) published a book on urbanization and sustainability (Boone and Fragkias 2013), a contribution to the Urbanization and Global Environmental Change project of the International Human Dimensions Program.

(2) **Climate, vegetation, and social equality:** A highly integrated and interdisciplinary set of studies from CAP LTER and other leveraged projects has exposed the complicated interactions among the distribution of vegetation, with its requirement for high rates of outdoor water use, the spatial variation of the urban heat island (UHI), the incomes and housing values of residents, and the disproportionate vulnerability of poor and minority segments of the population to extreme heat. Studies have also focused on how these disparities could be ameliorated with vegetation choices that can modify microclimate, but with tradeoffs associated with water use.

(3) **Perceptions about the local environment are related to residential landscape decisions, parcel to neighborhood ecological properties, and economic value:** Our longitudinal survey (PASS) reveals that people's attitudes and perceptions about the environment do influence their behavior, sometimes in surprising ways. Our economic modeling has shown that in many cases homeowners are willing to pay for proximity to amenities, such as artificial lakes and parks.

(4) **Not just structural, but functional differences between urban and desert habitats:** While many studies have documented reduced, or sometimes enhanced, biodiversity in the city, CAP researchers have focused on the mechanisms that explain observed patterns. For example, birds are not food-limited and may experience much greater interspecific competition in the city. The urban heat island effect (UHI) may accelerate phenology in both plants and animals. And community and ecosystem processes in urban desert parks are different from those of the surrounding desert, even though their outward appearance is similar.

(5) **Urban ecosystems are dominated by designed and built components, yet the functions and services they yield are not always as intended:** We have found that urban areas can and do provide habitat for wildlife, that stormwater infrastructure design determines water and nutrient retention and transport, that unplanned urban riparian habitats are more diverse than planned ones, and that designed ecosystems such as treatment wetlands perform better in our arid city than we expected. These are just some of the findings that have lead CAP researchers to emphasize the key interactions among infrastructure, ecosystems, and society.

The CAP program has produced 118 journal articles, 3 books, and 34 book chapters since 2010 (28 in review). CAP publications from 2007-2011 have been cited 2565 times in literature, and appeared in journals covering 48 disciplinary areas as defined by the Thomson Reuters Web of Knowledge. Of these disciplinary areas, 53% were in the natural sciences, 23% in social sciences, 15% in physical sciences, 4% in engineering sciences, and 5% in other disciplines. The 302 CAP LTER articles indexed in the Web of Knowledge (published since 1998) have been cited 10,882 times, with >30 papers cited >100 times and the most-cited paper cited 483 times (h index for the 302 papers=54). CAP LTER continues to effectively leverage considerable new research within the Phoenix metro area, totaling 19 new grants and $9.2M of funds since 2010. Our website features a continually updated series of research highlights that summarize research findings in plain language. We believe that our research has been and continues to be transformational in areas identified as themes above (see also "transformational science" on the CAP LTER website).

CAP's Integrative Project Areas and the LTER core areas

Research in CAP1was organized according to the five LTER core areas. However, we soon found that organization to inhibit the integrative collaboration of natural and social scientists. Since 2004, our IPAs have allowed us to cover the LTER areas while integrating social dynamics into our research. The following matrix shows exemplary research from CAP3 that is at the intersection of the IPAs (and the land use and cover area) and the core areas.

IPA→ Core Area					
Primary Prod	Desert-urban comparisons	Vegetation performance; phenology; UHI	Wetland studies, Residential landscapes; Tree programs	N, P fertilization experiment; deposition studies	Tree health; Modeling by functional types
Organic Matter	Desert-urban comparisons	Decomposition in urban vs. desert	Wetland studies; DOM in lakes and stormwater	Impacts of N, P fertilization on decomposition	Soil food webs
Movement of Materials	Changes in whole-system mass balance	Urban agriculture	Retention of materials with water (e.g., N, P); stormwater nutrient dynamics	Mass balance; spatial distribution of biogeochemical benefits and hazards	Socioeconomic drivers of biodiversity; species interactions;stress; evolutionary dynamics
Populations	Demography, equity (humans)	Landscape tradeoffs	Landscape tradeoffs	Ammonium oxidizers in desert soils	
Disturbance	Land-change studies	Urban heat island; climate change	Flooding, drought, water quality	Air pollution; toxic materials release	Stress; exotic species

Climate, Ecosystems, and People

Interactions among the urban and urban-hinterland climate, ecosystems (especially vegetation), and social systems give rise to the unique microclimates and mesoclimates of urban areas. Our work in this arid climate emphasizes causes and impacts of the urban heat island (UHI) effect and extreme heat events on human health and well-being. This IPA relates to the LTER core areas of primary productivity, organic matter storage, and disturbance, and is at the core of theme 2 (climate, vegetation, and social equity).

How does local climate influence ecosystem function and structure and consequently the provision or alteration of microclimate-related ecosystem services?

- Urbanization accelerates vegetation phenology and changes the relationships between net primary productivity (NPP; based on NDVI) and precipitation and temperature (Buyantuyev and Wu 2012).
- Modeled NPP of fringe agriculture, which occupies 14% of the CAP study area, accounts for 31% of total NPP, while turf land cover accounts for 1.5% of NPP but occupies only 0.3% of area (Zhang et al. 2013).
- The Phoenix UHI has been studied more than that in most other cities, including Los Angeles and New York City (Chow et al. 2012a).
- Over the past century in Phoenix, the annual number of misery days (maximum temperature $\geq 43.3\ ^{o}C$) has increased, especially from 1970-2007, and the number of frost days has decreased. Threshold temperatures that defined heat waves also showed accelerated warming trends during the century (Ruddell et al. 2013).
- Differences in the hydrology of various landscape designs are being modeled to understand irrigation demand and water fluxes, which affect energy balances and microclimate (Volo et al. in review). (**Field presentation**)

- Although vegetation has a strong cooling effect, it requires water to maintain it, highlighting the tradeoffs inherent in coping with the UHI and extreme heat (Jenerette et al. 2011). (**Presentation**)
- Not only the amount of vegetation, but also the configuration of vegetation and buildings (Middel et al. in review) and configuration and albedo (Kaplan et al. in review) of buildings combine to determine surface temperatures. (**Poster presentations**)
- Urban landscape decisions produce ecologically significant direct shading, air temperature, and humidity differences at spatial scales from 10m to 300m when wind speeds are low (Middel and Ruddell in prep; Ruddell and Chow in prep). (**Field presentation**)
- Introduction of low water-use shade trees into xeric neighborhoods with few existing shade trees is potentially effective at reducing the intensity of the UHI (Chow and Brazel 2012).
- An urban eddy-covariance tower yields data that can be used to validate both microscale and mesoscale climate models. Already, data show that many models misestimate latent heat flux (Chow et al. in review). (**Field presentation**)
- Anthropogenic heat from residential cooling (e.g., air conditioners) is a significant input to the surface energy balance of a suburban neighborhood (Chow et al. in review). (**Field presentation**)

What are the public perceptions of local climate and associated ecosystem services, and what tradeoffs would people make to enhance or avoid declines in the levels of these services?

- People accurately perceive temporal changes and spatial differences in temperature at regional and local scales, based on their experience (i.e., exposure to extreme heat) at the neighborhood scale (Ruddell et al. 2012).
- Model results for different vegetation scenarios show increased vegetation lowered air temperature in a park between 1 and 3^{o} C during the early morning and late afternoon, creating a "park cool island" (Declet-Barreto et al. 2013). (**Presentation**)
- Questions on the 2011 PASS will allow correlation of housing value with local temperature and other climate variables. (**Presentation**)
- Neighborhood norms of neatness are more important than formal institutions (such as Homeowners' Association rules) in driving residential landscape choices (Larson and Brumand, in review). (**Field presentation**)

How does a spatially heterogeneous pattern of regional temperatures affect the distribution of ecosystem services and create health disparities among different social groups?

- CAP researchers have developed a spatially explicit urban heat riskscape that incorporates two of three vulnerability metrics: exposure and sensitivity to high temperatures. (**Presentation**).
- Heat-related deaths from 2000-2008 were more likely to occur among residents of neighborhoods with higher vulnerability scores. The best fitting model for predicting heat-related deaths included neighborhood effects for the socioeconomic status and elderly/living alone factors and land-surface temperature (Harlan et al. 2013). (**Presentation**)
- Lower-income, Spanish-speaking neighborhoods have the greatest vulnerability to heat stress (Chow et al. 2012b). (**Poster presentation**)

- A model examining heat and heat-related emergency calls in Phoenix and Chicago found that heat-stress calls increase sharply when the temperature exceeds about 35°C in Chicago, but not until 45°C in Phoenix, implying differences between the two populations in sensitivity to heat (Chuang et al. in press).
- Visualization of the spatial patterns of heat stress provides useful information on potential vulnerability to extreme heat for use by social service agencies and the state Department of Health Services.

Products (cited above or new since 2012 Annual Report)

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Ruddell, B.L. and W. Chow. Separating urban microscale from mesoscale climate effects using a neighborhood meteorology transect (in preparation).

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Water Dynamics in a Desert City

The goal of this IPA is to understand how the management of urban water systems affects feedbacks and tradeoffs among water-related ecosystem services and how climate change and its uncertainty affect these tradeoffs. Because water connects everything in this desert city, this IPA has numerous interfaces with others, especially Biogeochemical Patterns, Processes, and Human Outomes and Climate, Ecosystems and People. LTER core areas of material flux, primary productivity, and disturbance are connected to work in this IPA, and it contributes to themes 2, 3 and 5 (climate, vegetation, and social equity; perceptions, decisions, and economic value; and designed and built environment, respectively).

How does urbanization alter the hydrologic connectivity of aridland ecosystems and modify watershed boundaries and configurations, and what are the consequences for ecosystem services associated with stormwater?

- Owing to the connectivity of water supply systems, elevated concentrations geosmin, a compound affecting drinking water taste, affected a large water treatment plant that served tens of thousands of residents in Chandler, AZ for six months in 2013. Long-term monitoring of these compounds and communication with water managers alerts them to potential problems. (**Field presentation**)
- Stormwater infrastructure design varies, ranging from highly connected (pipes, street runoff) to highly disconnected and retentive (retention basins), and this variation correlates with time of development. Retentive infrastructure functions as intended in retaining water but piped watersheds quickly convey rainfall to recipient systems (Hale et al. in review). (**Field presentation**)
- A continuous input of water from the urban landscape to stormwater outfalls has resulted in the formation of “accidental wetlands” in the bed of the Salt River, which provide services of water quality modulation and shelter/heat relief for a segment of the human population. (**Field presentation**)
- Wastewater may comprise up to 9.4% of source water for the Phoenix valley. This is on par with cities in other parts of the country, with 2-12% de facto reuse, a value that can rise to near 100% during drought (Rice et al. in press). (**Poster presentation**)
- In the Tres Rios Constructed Treatment Wetland, high plant transpiration rates during hot, dry summer months remove as much as 25-50% of the water overlying the vegetated marsh, and this water is being replaced via a gradual lateral “biological tide” that transports water and nutrient loads into the marsh. As a result, this wetland system may be more effective at the service of nutrient removal than similar systems in more mesic cities. (**Poster presentation**)
- The Phoenix metropolitan area is the land of 1,400 (artificial) lakes (Larson and Grimm 2012), and the average premium for lakefront properties was $31,271 compared to non-adjacent homes in the same community– an indication that people are willing to pay for direct access to lake amenities (Abbott and Klaiber 2013).
- Recent economic changes have had a significant impact on urban-agriculture dynamics, including the leasing back of land already purchased by developers to farmers and changes in cropping patterns; in particular, a shift from cultivation of water-intensive alfalfa production to cotton and a reduction of fallow land (Metson et al. 2013).

Can riparianization be accomplished in a sustainable manner – where water use and alteration of the natural hydrologic system are minimized while also retaining related ecosystem services – during urbanization?

- Differences in the hydrology of various landscape designs are being modeled to understand irrigation demand and water fluxes, which affect energy balance and microclimate (Volo et al. in review). (**Field presentation**)
- In some Phoenix area neighborhoods with desert-like (xeric) landscaping, residents assumed that their water use was relatively low when it was in fact comparatively high, indicating a disconnect between actual and perceived rates of water consumption (Larson et al. 2013). (**Field presentation**)
- Neighborhood norms of neatness trump formal institutions in driving residential landscape choices (Larson and Brumand, in review). (**Field presentation**)
- Introduction of low water-use shade trees into xeric neighborhoods with few existing shade trees is potentially effective at reducing the intensity of the urban heat island effect (Chow and Brazel 2012).
- Our integrated study at the Tres Rios Constructed Treatment Wetland indicates that *Typha* spp. may best promote wetland N processing, although other considerations (e.g., bird habitat) and conditions (e.g., type of wastewater being treated) likely make mixed stands of macrophytes preferable in designed urban wetlands. (**Poster presentation**)

How can we combine the virtual water concept with tradeoffs models (economic and otherwise) to quantify feedbacks among water-related ecosystem services?

- We have mapped virtual water in the Western power grid, which includes the CAP study area (Ruddell et al. in review a, b).
- Water-scarce states, such as Arizona, New Mexico, Utah, and Wyoming, are exporting (mostly to California) a large percentage of embedded water impacts in electrical energy while Western states with relatively more water resources, such as Oregon and Washington, export very little. This calls into question the assumption that markets for trading virtual water could modulate water use: virtual water appears instead to exacerbate water shortage (Ruddell et al. in review a, b).
- Our water-energy optimization model suggests that reducing water consumption could meet 5–14% of mandated energy-efficiency goals, while increased energy efficiency could reduce non-agricultural water use by 2.0-2.6% through decreased cooling-water consumption (Bartos and Chester in review).

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Biogeochemical Patterns, Processes, and Human Outcomes

In this IPA, we ask how and why urban biogeochemical cycles differ from those of non-urban systems, and explore the consequences of those altered cycles and distribution patterns for ecosystems and human well-being. This IPA corresponds most closely to the LTER core areas of material flux, organic matter, and disturbance and is relevant to themes 2, 3, and 4 (climate, vegetation, and social equity; perceptions, decisions, and economic value; and urban vs. desert; respectively).

How do urban elemental cycles at multiple scales differ qualitatively and quantitatively from those of nonurban ecosystems?

- As with N, the urban phosphorus (P) budget is dominated by human inputs (>90%). The urban ecosystem is a sink for P, meaning that more P is brought in to the system than leaves it, mainly because little water leaves the system. P is rapidly recycled within the ecosystem (Metson et al. 2012a,b). (**Poster presentation**)
- In contrast, anthropogenic inputs are only 60% of total carbon (C) inputs and the urban system is a strong C source (McHale et al. in prep), largely due to CO_2 emissions from industrial, residential, and commercial energy use and transportation.
- We are quantifying multi-element critical loads by examining the interactive effects of co-occurring high concentrations of ozone, CO_2, and nitrogen (N) compounds on plant growth. (**Field presentation**)
- C storage is dominated by buildings (McHale et al. in prep); excluding the built environment, 27% of C storage is in urban forest land covers, which occupy only 4% of the CAP study area (Zhang et al. 2013). Based on life-cycle analysis, the footprint for material/energy use and waste production by buildings exceeds the political boundary of Phoenix by many orders of magnitude. (**Poster presentation**)
- Novel urban C sources include black C (**poster presentation**) and aerosol organic C (Kaye et al. 2011).
- A hierarchical patch dynamics model, HPM-UEM, scales ecosystem processes from individual plant to region, incorporating plant functional types as well as landscape management practices (Zhang et al. 2013).
- Owing to the connectivity of water supply systems, elevated concentrations geosmin, a compound affecting drinking water taste, affected a large water treatment plant that served tens of thousands of residents in Chandler, AZ for six months. Long-term monitoring of these compounds and communication with water managers alerts them to potential problems and proposes solutions. (**Field presentation**)

What are the fates of elevated material inputs, and how do they affect ecosystem processes and the delivery of ecosystem services in recipient systems?

- A non-native grass species is more resistant than a native herb species to high ozone levels in the urban atmosphere. (**Field presentation**)
- Mosses incorporate N deposited from the urban atmosphere and thus have lower C:N and higher N:P than desert mosses. (**Poster presentation**)
- Archaeal ammonium oxidization in soils is stimulated by N fertilization. (**Poster presentation**)
- P recycling in agricultural regions of Phoenix is an unintentional yet serendipitous ecosystem service resulting from coupling of local dairy and alfalfa production, use of cow manure to fertilize fields, and the deliberate retention of water (Metson et al. 2012). (**Poster presentation**)
- Decomposition of black C, aerosol organic C, and litter occurs by microbial and abiotic mechanisms, of which photodegradation is especially important. (**Poster presentations**)
- Stormwater infrastructure design varies, ranging from highly connected (pipes, street runoff) to highly disconnected and retentive (retention basins), and this variation correlates with time of development. Retentive infrastructure functions as intended in retaining water but piped watersheds quickly convey rainfall to recipient systems (Hale et al. in review). (**Field presentation**)

- A continuous input of water from the urban landscape has resulted in the formation of "accidental wetlands" in the bed of the Salt River, which provide services of water quality modulation and shelter/heat relief for a segment of the human population. Storm flows bring pulses of nutrients and *E. coli,* which are attenuated in flow through the wetlands. **(Field presentation)**
- Nutrient inputs to the Tres Rios Constructed Treatment Wetland are retained at high rates, owing to a "biological tide" driven by high evapotranspiration rates that transports nutrients into the vegetated marsh. This biotic mechanism may make constructed treatment wetlands in arid climates more efficient at nutrient removal than those in mesic settings. (**Poster presentation**)

Are ecosystem services derived from biogeochemical processes distributed inequitably and how will this distribution change over the next 5-10 years?

- Soil lead is inequitably distributed across the CAP area, with greater exposure in Hispanic, low-income neighborhoods (Zhuo et al. 2012).
- Analysis of temporal trends in the Hazards Density Index is underway. The 2011 PASS survey included questions about resident perceptions of air quality.

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Bain D, RL Hale, W Wollheim. 2012. Hotbeds of biogeochemical diversity: lessons from long-term ecological research. *Elements* 8: 435-438.

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Zhuo, X., C. G. Boone, and E. L. Shock. 2012. Soil lead distribution and environmental justice in the Phoenix metropolitan region. *Environmental Justice* 5(4):206-213.

Human Decisions and Biodiversity

In this IPA, we focus on how human activities, behaviors, and willingness to make tradeoffs change biodiversity and it components, and how variations in biodiversity feed back to influence these same human perceptions, values, and actions. The Biodiversity IPA relates most closely to the LTER core areas of populations and disturbance, and to themes 3 and 4 (perceptions, decisions, and economics value; and urban vs. desert, respectively).

What mechanisms explain species loss or dominance and, ultimately, biodiversity in the urban environment?

- Control of arthropod biodiversity is strongly altered in urban areas, influenced by subtle shifts in top-down and bottom-up controls that are often superseded by climatic variations and habitat type (Bang et al. 2012).
- Urban bird diversity is heterogeneous throughout the urban environment, influenced by residential landscape type, proximity to native habitat, and income. Lower-income neighborhoods have fewer native birds (Lerman and Warren 2011). (**Field presentation**)
- Yards with native-like landscaping support birds better than those with grass lawns and exotic plant species (Lerman et al. 2012a), and residents surveyed through the PASS were more satisfied with the existing bird variety in their yards when their neighborhood had more native bird species present (Lerman and Warren 2011). (**Field presentation**)
- Neighborhoods with Homeowners Associations (HOAs) have significantly greater bird and plant diversity than those without HOAs, but have similar arthropod diversity (Lerman et al. 2012b).
- Burrowing owls are able to live in urbanized environments where < 40% of their habitat is developed, if water and suitable soils are available (Beebe et al. in review).
- Male house finches are drab in the city. They harbor higher parasite loads than desert birds, and females are less choosy about potential mates in the city. (**Field presentation**)
- There is a 29-day acceleration in the onset of breeding condition for urban compared to desert Abert's towhees, the largest such gap documented for birds to date (Deviche and Davies in press). (**Field presentation)**
- Western black widow spider density is 30 times greater in some urban areas than in the desert, and urban widows live closer to one another (nearest neighbor distance) than those in the desert (Trubl et al. 2012). (**Poster presentation**)
- Large differences in plant species composition between 2005 and 2010 suggest a shift in social-ecological processes driving plant community patterns. (**Field presentation**)
- A continuous input of water from the urban landscape has resulted in the formation of "accidental wetlands" in the bed of the Salt River, which provide services of water quality modulation and shelter/heat relief for a segment of the human population. Vegetation cover and wetland plant diversity is higher in accidental wetlands compared to dry reaches and is similar to planned restored reaches. **(Field presentation)**
- Using the largest global database to date of 149 cities, we have found that urban areas house a large proportion of the world's plant and bird diversity and that urban anthropogenic history can play a role in defining urban diversity patterns (Aronson et al. in review).

Can conservation and restoration of "natural" habitats within the urban environment restore "natural" animal communities?

- Bird communities vary by season and site type in seven reaches of the Salt River—including non-urban riparian habitats, restored riparian sites, and "accidental" wetlands. (**Field presentation**)
- Habitat rehabilitation activities positively influence herpetofauna abundance and species richness, but urbanization negatively affects herpetofauna diversity (Banville and Bateman 2012). (**Field presentation**)
- Our integrated study at the Tres Rios Constructed Treatment Wetland indicates that *Typha* spp. may best promote wetland N processing, although other considerations (e.g., bird habitat) and conditions (e.g., type of wastewater being treated) likely make mixed stands of macrophytes preferable in designed urban wetlands. (**Poster presentation**)

Through what pathways do humans modify urban food webs, and how do these changes cascade through food webs to influence the delivery of ecosystem services?

- Biomass in all trophic levels in the soil food web increases during the monsoon season relative to the dry season in both xeric and mesic residential landscapes. (**Poster presentation**)
- Mesic soil food webs are more complex than their arid counterparts; turf grass lawns support double the number of trophic levels and ~4-8x more belowground biomass than arid residential landscapes. (**Poster presentation**)

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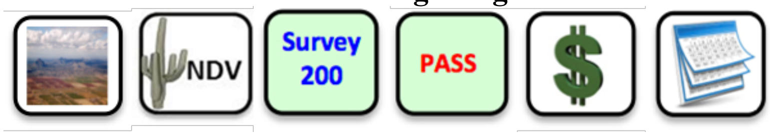
Foundational and Crosscutting Long-term Observations and Experiments



Characterizing land use, land cover, and land architecture: Parcel to region

Long-term spatial data on land use and land cover is fundamental for answering research questions posed in the CAP3 proposal. At the same time, our research is exploring the physical structure of the city and the drivers of land-use and land-cover change.

Systematic remote-sensing and land-classification (**Presentation**)

- We used 10 scenes of 2005-2009 Quickbird (2.4 m) data covering one third of the CAP and all of the city of Phoenix to identify 7 classes of land covers. Overall accuracy of the image was greater than 89% (Myint et al. 2013).
- Given the cost of Quickbird, we incorporated this classification into a completely new National Agriculture Imagery Program (NAIP) 1-m, 4-band analysis–classification covering the entire CAP area for 2010. We developed a sub-parcel level classification of 12 land classes (building, asphalt and concrete [road and other impervious surface], shrub/tree, grass, soil/rock, active cropland, inactive cropland, orchard, permanent river/canal, seasonal river, lake/reservoir, swimming pool), with an accuracy of 91% (Li et al. in review). Further work is required in the separation of tree and shrub on the urban fringe and in the desert proper. (**Poster presentation**)
- Our classification system is consistent with that used by the Baltimore Ecosystem Study LTER, and we are contributing the NAIP classification to the EPA Urban Atlas, a component of the National Atlas for Sustainability.
- Landsat TM (30-m) data analysis and classification is currently underway using 2010 satellite images. This analysis will include 13 land-cover and land-use classes (urban cultivated grass, compact soil/rock, asphalt and concrete (road and other impervious surface), commercial/industrial, residential with high- mid- and low-density vegetation, active cropland, inactive cropland, river/canal/lake/reservoir, undisturbed/native, mountain vegetation, riparian vegetation).
- We preprocessed the MODIS/ASTER Simulator (MASTER) data covering the 40 PASS neighborhoods from an overflight of the Phoenix area in 2011 in coordination with the NASA Johnson Space Center in Houston. MASTER data contain valuable spectral information within the fifty channels ranging from 0.4 - 14 µm, which yield surface temperatures that are essential for our microclimate analyses.

How does land architecture affect the spatial distribution of ecosystem services?

- We developed the Urban Park Ecosystem Services Planning Tool (UPES), derived from SmartCode civic space typologies, which details the proper size, service area, primary landscaping type and orientation, and spatial context of multiple park types as well as the appropriate and expected magnitude (level) of provisioning for four key ecosystem services—recreation, social/civic benefits, microclimate cooling, and biodiversity protection.
- Results from our investigations show that it is possible to accurately model broadband albedo from Quickbird high resolution imagery (Kaplan et al. in review b). (**Poster presentation**)

- Our analysis using Quickbird land cover data and FRAGSTATS landscape metrics suggests that land managers could lower land surface temperatures in industrial/ commercial areas and perhaps in mesic residential areas through creating more complex landscapes with more building edges and more complex shapes of grass patches (Connors et al. 2013). (**Presentation and Poster presentation**)
- Neighborhood norms of neatness are more important than formal institutions (such as Homeowners' Association rules) in driving residential landscape choices (Larson and Brumand, in review). (**Field presentation**)
- Not only the amount of vegetation, but also the configuration of vegetation and buildings (Middel et al. in review) and configuration and albedo (Kaplan et al. in reviewb) of buildings combine to determine surface temperatures. (**Poster presentations**)
- Our historical analysis of land use change in downtown Phoenix (1949-1963) found that the decline of downtown Phoenix was more directly tied to residential exodus out of the core than to overall commercial decline, although these processes worked in tandem (Kane et al. in review a). (**Poster presentation**)
- During the 2002-2006 real estate boom time in Phoenix, there was a preference for development on cheap land and agricultural lands, whereas during the recent bust, areas that were previously the fastest growing were the hardest hit, with a slight shift toward a preference for less-sprawled development (Kane et al. in review b). (**Poster presentation**)
- Work is underway using the NAIP-derived land classification data on stormwater quality and on the impact of the configuration of parcels, neighborhoods, and urban land architecture in general on land-surface temperature.

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Kane, K., A.M. York, J. Tuccillo, L. Gentile, and Y. Ouyang. In review. Residential development revisited: Zoning, local effects, and the recession in Phoenix, Arizona. Urban Geography.

Larson, K. L. and J. Brumand. In review. Paradoxes in landscape management and water conservation: examining neighborhood norms and institutional forces. Cities and the Environment.

Li, X., Y. Zhang, C. Galletti, X. Zhang, B. L. Turner II, & S. Myint. In review. Object-based land-cover classification for metropolitan Phoenix, Arizona, using aerial photography. International Journal of Applied Earth Observation and Geoinformation.

NDV Experiment

- Differences in the hydrology of varying landscapes designs are being modeled to understand irrigation demand and water fluxes, which affect energy balance and climate (Volo et al. in review). **(Field presentation)**
- Controlled conditions at the North Desert Village are being used to calibrate a three-dimensional microclimate model (ENVI-met). Not only the amount of vegetation, but also the configuration of vegetation and buildings determine microclimate (Middel et al. in review). (**Poster presentation**)

- Residential landscape-mediated microclimate influences lizard body temperature, with implications for survivability and fecundity (Ackley in prep).
- Biomass in all trophic levels in the soil food web increases during the monsoon season relative to the dry season in both xeric and mesic residential landscapes. (**Poster presentation**)
- Mesic soil food webs are more complex than their arid counterparts; turf grass lawns support double the number of trophic levels and ~4-8x more belowground biomass than arid residential landscapes. (**Poster presentation**)

Survey 200

- C storage is dominated by buildings (McHale et al. in prep); excluding the built environment, 27% of C storage is in urban forest land covers, which occupy only 4% of the CAP study area (Zhang et al. 2013).
- Preserves of native habitat within the urban area may provide refuges for native arthropod taxa, which differ substantially from assemblages in urbanized areas, but human-made habitats (e.g., native landscaping in residential yards) are not likely to support native taxa (Bang and Faeth 2011).
- Soot black carbon (BC), which may constitute a sizeable fraction of total soil organic carbon, is higher in urban areas relative to outlying desert and agricultural soils, and degrades through abiotic an biotic pathways (Hamilton and Hartnett. 2013). (**Poster presentation**)
- Soil lead is inequitably distributed across the CAP area, with exposure greater in Hispanic, low-income neighborhoods (Zhuo et al. 2012).
- Large differences in plant species composition between 2005 and 2010 suggest a shift in social-ecological processes driving plant community patterns. (**Field presentation**)
- A hierarchical patch dynamics model, HPM-UEM, scales ecosystem processes from individual plant to region, incorporating plant functional types as well as landscape management practices (Zhang et al. 2013).

PASS

- In some Phoenix area neighborhoods with desert-like (xeric) landscaping, residents assumed that their water use was relatively low when it was in fact comparatively high, indicating a disconnect between actual and perceived rates of water consumption (Larson et al. 2013). **(Field presentation)**
- People accurately perceive temporal changes and spatial differences in temperature at regional and local scales, based on their experience (i.e., exposure to extreme heat) at the neighborhood scale (Ruddell et al. 2012).
- Urban bird diversity is heterogeneous throughout the urban environment, influenced by residential landscape type, proximity to native habitat, and income. Lower-income neighborhoods have fewer native birds (Lerman and Warren 2011). (**Field presentation**)
- Residents surveyed through the PASS were more satisfied with the existing bird variety in their yards when their neighborhood had more native bird species present (Lerman and Warren 2011). (**Field presentation**)
- Diverse cultural domains (as examined by ecological worldviews, political orientations, and ethnicity) strongly influence risk perceptions and policy attitudes concerning water issues, more so than personal characteristics such as income and education (Larson et al. 2011a)

- Women exhibit greater affective concern about water risks than men, especially regarding local safety concerns and broader regional issues; however, men and women share low concerns regarding local consumption, thereby potentially rendering a gendered approach to water conservation ineffective (Larson et al. 2011b).

Economic and Census Data Analysis

- The Phoenix metropolitan area is the land of 1,400 (artificial) lakes (Larson and Grimm 2012), and the average premium for lakefront properties was $31,271 compared to non-adjacent homes in the same community– an indication that people are willing to pay for direct access to lake amenities (Abbott and Klaiber 2013).
- Hedonic modeling demonstrates that proximity to small parks is generally not an amenity for homeowners, but proximity to large parks and water is highly desirable (Larson and Perrings 2013).
- A popular economic model for neighborhood choice and housing price determination assumes households can acquire the amenities they want by selecting a neighborhood; the highest income households will always select the highest amenity neighborhoods. Empirical evidence contradicts this prediction. To explain these departures, households' tastes for amenities are assumed sufficiently varied that both income and intensity of preference contribute to location choices. We use the New Environmental Paradigm index measured in the PASS 2011 survey to provide the first test of this generalization (Fishman and Smith 2013).
- We argue that modern research designs to measure what households would pay for spatially varying environmental services have misinterpreted the estimates derived with these methods. Quasi-experimental methods can measure the effect of a policy that influences the value of a parcel on the price of that parcel. This estimate does not necessarily correspond to what an individual would pay to obtain the policy. This research explains the reasons why this difference is important and uses simulations of land market equilibria to demonstrate the magnitude of the errors (Klaiber and Smith 2013).
- Our research uses the PASS 2011 survey incentives to test whether survey respondents value the ability to choose how the money they earn by participating in an interview is allocated between private uses versus charity (Smith et al. in prep).

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Ruddell, D., S. L. Harlan, S. Grossman-Clarke and G. Chowell. 2012. Scales of perception: Public awareness of regional and neighborhood climates. *Climatic Change* 111:581-607.
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Zhuo, X., C. G. Boone, and E. L. Shock. 2012. Soil lead distribution and environmental justice in the Phoenix metropolitan region. *Environmental Justice* 5(4):206-213.

Sustainability/Futures

A new initiative in CAP3 will be work that integrates across all research and thematic areas in a scenario-building process. The first steps of that process are to complete the synthesis of CAP research (summarized in the introduction to the research section). In addition, we have established contacts and initiated discussions for a participatory scenarios activity patterned in part after a those employed to help the City of Phoenix develop their general plan (**presentation**).

CAP Participation in Cross-site Research and Working Groups

CAP LTER scientists have been active participants in cross-site and network-level research. We have sent large contingents to the valuable All-Scientists Meetings (the latest in fall 2012) and are rewarded with new ideas for research activities. Below we list these projects, using the IPA and database icons to connect the research with our long-term, site-based activities.

- **Beyond the numbers: Supporting an increasingly diverse LTER community** (numerous LTER sites): Conduct surveys of sites to initiate a conversation about diversity and participation in LTER science. Funded through a LTER Network Office working group grant.
- **Cross-site zoning and land use** (CAP, BES, and FCE): Investigates the relationship between zoning and land use, focusing on environmental justice and land-use change during the 20th century (Kane et al. in review a.; Kane et al. in review b.; York et al. in press). Funded through LNO working group grant to CAP and the School of Human Evolution and Social Change at ASU.

- **Developing a framework for socio-ecological systems research** (numerous LTER sites, European LTER network): CAP has been an active participant in the development of the

Integrated Science for Society and Environment framework for socioecological research (Collins et al. 2011), as well as participating in a book project arising from the European LTER network and other collaborators (Grimm et al. 2013).

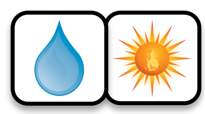
- **Ecological homogenization of America** (CAP, PIE, FCE, BES, CDR and Los Angeles): Tests hypothesis of whether similar management practices across cities leads to homogenization in ecological structure and functions relevant to ecosystem carbon and nitrogen dynamics (Groffman et al. in review; Harris et al. 2012; Steele et al. in review). Funded through LTER sites leveraged grant from NSF.

- **Land fragmentation** (CAP, SEV, JRN, SGS, and KNZ): Examines land fragmentation patterns across the five urban areas associated with the LTER sites (Shrestha et al. 2012; York et al. 2011; S. Zhang et al. 2013). Funded through social science supplement to CAP and other sites as well as CAP funds. Phoenix work was completed in spring 2013.

- **Linking aquatic and soil organic matter across ecosystems through characterization of optical properties** (numerous LTER sites): Investigate aquatic and soil OM (organic matter) dynamics in diverse ecosystems in order to develop overarching hypotheses about OM dynamics on a larger scale in the context of the global carbon cycle. Funded through a LTER Network Office working group grant.

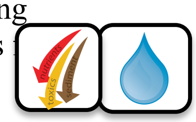
- **Maps and Locals (MALS)** (numerous LTER sites): Investigates socioecological systems using a mixed methods comparative approach, including spatial analysis and ethnography. Funded through LNO working group grants.
- **RCN-SEES for urban sustainability** (CAP, BES, FCE, PIE, and other cities): Integrates and synthesizes urban research while incubating solutions-oriented products (Pickett et al. in press). Funded through LTER sites leveraged grant from NSF.
- **Scenarios of change** (numerous LTER sites): Examines scenarios of land-use change (Thompson et al. 2012).

- **Social and ecological responses to climate change and land-use effects on water availability: contrasting resilience among major river basins of the US and Canada** (AND, CAP, CWT, HBR, LUQ, NWT, plus several non-LTER long-term hydrologic sites): Examines evidence for long-term change in climate and hydrology, using among other resources the ClimDB and HydroDB databases, impacts of human activities and land-use change on hydrology in major river basins (Jones et al. 2012). This project is ongoing.



- **ULTRA Ex: Land and water use decision-making and ecosystem services** (CAP, JRN, SEV): Focuses on perception, valuation, and management of ecosystem services in open spaces across three Southwestern cities (Boone et al 2012). Funded through CAP-leveraged grant from NSF.

- **Urban aquatic ecosystems** (numerous LTER sites): Initiate comparative analyses of modifications of urban aquatic ecosystems in different parts of the U.S., exploring both the drivers/motivations for those modifications as well as the consequences for ecosystem function and for people, and potential feedbacks between drivers and consequences. Funded through a LTER Network Office working group grant.



- **Urban residential landscapes** (CAP, PIE, FCE and BES): Focuses on understanding the form and drivers of urban residential landscapes as socioecological systems (Brumand and Larson 2012; Cook et al. 2012; Larson et al. in review; Harris et al. 2012; Roy Chowdhury et al. 2011). Funded initially through a social science supplement to CAP and the other sites. Now has morphed into the

"Ecological homogenization of America" project, supported by NSF Macrosystems Biology.

Products (cited above or new since 2012 Annual Report)

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Education and Outreach

Ecology Explorers K-12 Education

- During CAP3, our summer teacher professional development workshops, presenting curriculum aligned with Arizona and Common Core standards, have involved 61 teachers from 13 school districts across the Phoenix metropolitan area, potentially impacting over 1000 students each year.
- Our teacher professional development workshops engage CAP scientists in sharing their expertise and involve teachers in using CAP data and protocols for investigations.
- We have developed two new curriculum modules, Urban Heat Island and Urban Watershed, aimed at middle school students, building off of considerable CAP research in both areas.
- Ecology Explorers staff advised on and edited material for the *Chain Reaction* magazine issue, "People and environment: Our heat habitat," an educational resource for students in grades 4-8.
- We are working with faculty from the ASU Mary Lou Fulton Teacher's College to share information and Ecology Explorers' lessons via a new teaching and learning web portal, including a new on-line course produced in conjunction with the ASU's Arizona Science Education Collaborative, which we hope to pilot in 2014.
- We developed new Meet the Scientist mediated slide shows to introduce desert soils (Dr. Becky Ball), research on urban black widow spiders (Dr. Chad Johnson), and herpetofauna in the Phoenix area (Dr. Heather Bateman) to middle school students.
- Our out-of-school time programming has included working with the Parks and Recreation programs in Mesa and Gilbert, Boys and Girls Clubs in Phoenix and Tempe, and the Glendale After-School program.
- At the Navajo Elementary STEM focus school in Scottsdale, our student interns have held before-school science clubs at the school, made classroom visits, and have worked

> "We wanted to thank you again for inviting us to participate in the Urban Heat Island workshop. It was an incredibly valuable experience, and our implementation was very successful. The Urban Heat Island project influenced not only our students' understanding of a real-world problem, but also our ability as teachers to work together to provide a powerful, inquiry-based learning experience that was enjoyed by all students."
>
> -Teacher workshop participants

with Ecology Explorers staff and CAP graduate students to provide activities during family science nights.

- Our undergraduate student intern program began in CAP3 and involves training students in pedagogy and our curriculum, teaching them strategies for classroom engagement, and then sending them to events and classrooms to work with children on hands-on activities.
- As part of our partnership with ASU's Herberger Institute for Design and the Arts on the "At Home in the Desert: Youth Engagement and Place" initiative, Ecology Explorers staff and our high school intern accompanied young hip hop artists on an ecology hike up a local mountain to gather inspiration for their music and dances. This is part of CAP's larger initiative on engaging the arts and humanities in urban ecology.
- We attend several public events every year, such as the Earth and Space Science Fair, the Gilbert Riparian Preserve Feathered Friends Festival, and ASU's Night of the Open Door, in which staff and student interns engage young people in learning about urban ecology through our interactive display unit.

Research Assistantships for High School Students (RAHSS)

- Three minority high-school students worked with CAP scientists from spring-summer 2012, as detailed in the CAP 2012 Annual Report, and one of these students has continued his work with the Childers lab and their investigations in the Très Rios Constructed Wetlands.

Undergraduate Training

- In CAP3, we have supported 21 Research Experience for Undergraduates (REU), using REU supplement funds folded into our main grant and funds budgeted for undergraduate research in our grant.
- Undergraduate researchers during CAP3 have contributed to one peer-reviewed publication and three manuscripts in review and have written several honors theses.
- CAP3 REU students have received many awards including Fulbright fellowships (to the UK and Indonesia), NSF Pre-Doctoral Fellowship, Outstanding Undergraduate in Research for the Applied Science and Mathematics Department at ASU, and the Turken Outstanding Graduating Senior in WP Carey School of Business at ASU – faculty mentors cite the role of the REU experience in these awards.
- A recent survey of faculty mentoring REU students shows that the majority of students involved in CAP's REU program over last 10 years has either sought additional higher

"The REU experience allowed Jill to rise to the top of her class in gaining superior research training relative to her peers and even students at the Master's level."

"The REU program was a key experience in Erica's career path, as it was the first time she led an independent research project of her own."

"The REU program allows me to have students in the lab with an intense focus on research."

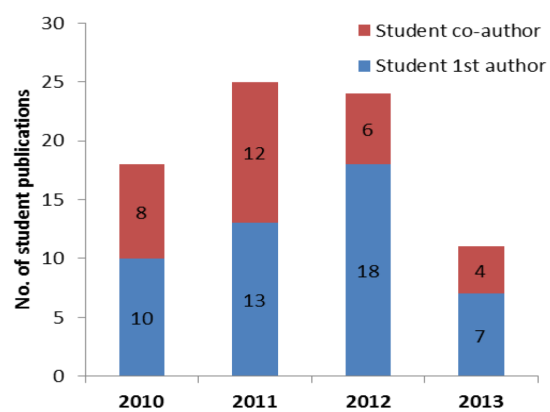
"The REU program is a wonderful mechanism for engaging undergraduates in a faculty member's research program; they are able to 'look under the hood' and get involved."

"I consider the REUs to be a key component of my research group – I love working with them and I think they bring a lot of energy and enthusiasm to the group. I also think having smart motivated undergraduates in the lab is a really good experience for my graduate students."

-CAP REU mentors

education in their academic areas or have found positions in which they could apply their education and REU experience.
- Qualitative data from our survey suggests that faculty value the opportunity to work with undergraduates through the REU program and the energy and talent these young scientists bring to research endeavors.
- For the students, the REU is often their first opportunity to work on an independent research project, which frequently becomes an honors thesis or major paper for their degree requirements.
- In many CAP scientist labs, REUs work closely with graduate students, giving these individuals experience with student mentoring.

Graduate Training
- During CAP3, we have had 59 graduate students active in our research program from 8 different units at ASU.
- We began our graduate grants program in CAP2 but have expanded it in CAP3. We have distributed grants to 34 graduate students since the fall of 2010.
- Graduate grants enable students to purchase supplies, pay for fieldwork travel, hire undergraduate assistants, and support themselves over the summer months.
- The graduate grant process gives students important experience in writing a short research proposal with written feedback from an NSF-like panel of peers.
- The peer-review process, in which previous grad grant recipients review current proposals, gives grads even greater insight into the grant-writing and reviewing process, and grads' response to serving on these panels has been overwhelmingly positive.
- We have supported 13 graduate students to work on faculty-driven research projects over the summer in CAP3.
- During 2010-2013, students were authors on 78 publications and were first authors on 48 of these. Relative to the total CAP publications of the same period in time, students were authors on over half of all publications (52%) and first authors on almost one-third (32%).



Postdoctoral Training
- CAP welcomed a new post-doctoral researcher, Baojuan Zheng, in 2013, who is working with Soe Myint and Rimjhim Aggarwal on a remote-sensing initiative that focuses on agricultural production, cropping patterns, and water use in Maricopa County, Arizona (the county encompassing much of the Phoenix metropolitan area).
- In accordance with the CAP Post-Doctoral Mentoring Plan, Dr. Zheng has completed ethics training at ASU and has been attending CAP community events to familiarize herself with our research program.
- Several additional post-doctoral researchers have been active CAP contributors, supported in part by CAP and in part by other funds (L. Turnbull, M. Palta, D. Ruddell, A. Middel, W. Chow, M. Shrestha, C. Zhang).

Research Outreach

- In spring 2013, the Conservation Alliance, a partnership involving the Desert Botanical Garden, several public and non-profit organizations, and three research programs at ASU, began its programming after receiving funding from the Pulliam Trust. (**Presentation**)
- CAP funded a REU to work with CAP co-PI Heather Bateman on understanding the effects of multi-use recreational trails on reptiles in Phoenix mountain parks, a Conservation Alliance research initiative. (**Poster**)
- CAP is working with the Conservation Alliance coordinator to organize lunchtime seminars in fall 2013 and spring 2014 to promote knowledge exchange on key topics such as climate change in the Southwest, recreation use in mountain parks, and the synthesis of CAP's 15 years of research on parks and desert remnant areas in
- Our ongoing arthropod monitoring with the McDowell Sonoran Conservancy has involved setting pitfall trap lines along 10 transects and sampling arthropods four times to coincide with CAP's long-term monitoring of arthropods in central Arizona. (**Presentation**)
- CAP arthropod technician Maggie Tseng trained McDowell Sonoran Conservancy volunteers to sort and identify arthropods to varying levels of taxonomic resolution, with some taxa identified with great detail to the level of family.
- Data collected through the McDowell arthropod monitoring will be available online through the CAP website and will enable CAP scientists and McDowell managers to better understand the potential impact of recreational use of the Conservancy area on arthropod communities.
- The Science of Water Art initiative under the Global Ethnohydrology Project is collaboration between ASU, the Salt River Project, and the Maricopa County Office of Education and has involved over 2300 Arizona schoolchildren in drawing the current water situation in Arizona and what they think water environments will look like 100 years from now. (**Poster**)
- Children depict present-day Arizona as enriched by everyday technologies that facilitate green vegetation and abundant domestic water use. In contrast, children envision a dystopic water future, with natural water sources degraded by scarcity and pollution, though some depict future technologies and water commercialization as solutions. (**Poster**)
- Since the last CAP Annual Report, 219 urban tree community scientists have entered data on their shade and fruit trees on our urban tree data portal. (**Presentation**)
- Our preliminary analysis suggests that most respondents found the tree planting and care training workshops to be very helpful and are satisfied with their trees. Respondents reported few dead trees and characterized the vast majority of living trees as "thriving."
- Long-term data collected through the Urban Tree Community Science initiative will enable CAP scientists, Valley Permaculture Alliance staff and volunteers, and Salt River Project staff to better understand the effectiveness of tree planting programs in the Valley, tree health and mortality, how households care for trees, and the ecosystem services associated with trees.
- In January 2013, CAP co-PI Dan Childers and students hosted a research charrette to share their Tres Rios Constructed Wetland research findings with City of Phoenix managers and administrators, which resulted in enhanced trust and data-sharing as well as an invitation to work with the city as they prepare for their EPA water discharge permit renewal. (**Poster**)

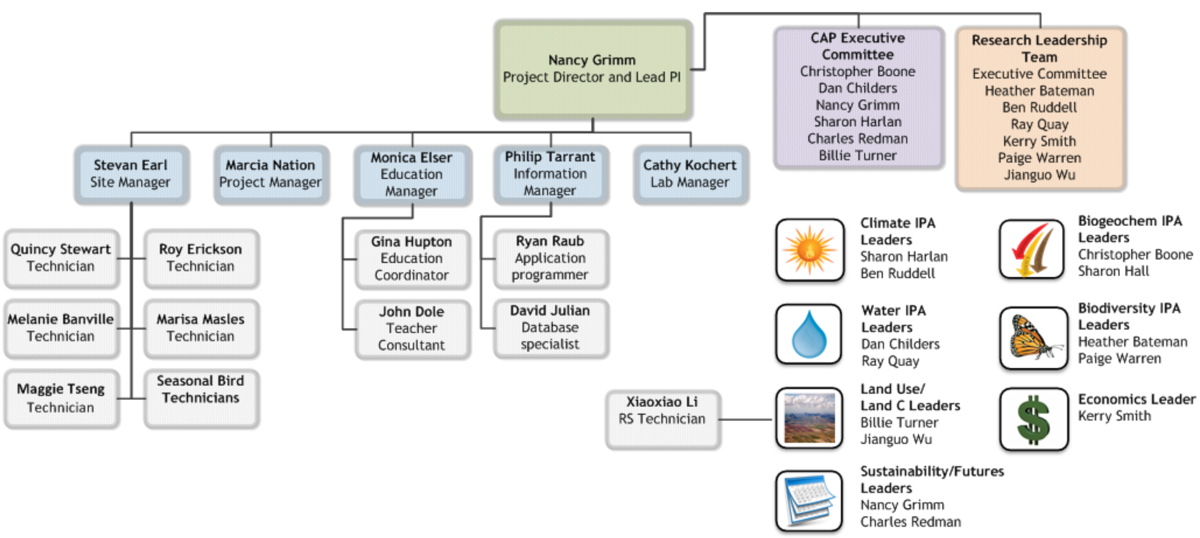
Project Management

CAP's project management structure is detailed in the CAP3 Proposal with few changes (see organizational chart below). From September 2010-September 2012, Dan Childers assumed the position of Project Director and Lead PI while Nancy Grimm was on detail at NSF. Grimm resumed this position upon return to ASU. Susanne Grossman-Clarke stepped down the from the Research Leadership Team to take a position in Germany and was replaced by Ben Ruddell, a civil engineer at ASU's Polytechnic campus, who now co-leads the Climate IPA with Sharon Harlan. Heather Bateman, an ecologist also at ASU Polytechnic, replaced John Sabo as co-leader of the Biodiversity IPA and joined the Research Leadership Team.

The Global Institute of Sustainability (GIOS), which houses CAP and provides in kind support, has expanded its informatics staff, and CAP Information Manager Philip Tarrant has been joined by David Julian, a database specialist, and Ryan Raub, a systems programmer, both of whom provide a great deal of support for CAP's information management activities. CAP has hired new technicians Xiaoxiao Li, Marisa Masles, and Melanie Banville to support new research activities in land classification, biogeochemical analysis, and biotic monitoring, as detailed in the CAP3 proposal.

Leadership Transition Plan for CAP LTER

Nancy Grimm and Charles Redman were co-Directors of CAP LTER from 1997-2010; beginning in CAP3, Grimm became the sole Project Director (except as described above). The CAP Executive Committee has agreed upon a transition plan to be implemented in CAP4, which will be shared with the review team during the project management discussion.



Communication

In CAP3 we have expanded our external science communication activities while continuing to find new ways of keeping our scientists and students informed about our research program. Quarterly, the Project Director posts a "Note from the Director" on the CAP website, a link to which is emailed to the CAP community (scientists, students, and staff). The last "Note" http://caplter.asu.edu/home/director-notes/ was clicked on over 100 times, indicating that about 75% of the active participants in CAP viewed this posting. Links to News items and Research

Highlights posted on the website are emailed to the CAP community as well to ensure frequent traffic to the website (see: http://caplter.asu.edu/2013/08/12/residential-landscapes-research-featured-in-pacific-standard-magazine/ and http://caplter.asu.edu/research/research-higlights/).

We have been working with the GIOS Communications team and NSF to get more stories about our research into local and national media through press releases and stories posted on the ASU website. CAP joined the social media world in 2010 with its Twitter account @CAPLTER, which focuses on promoting urban socioecological research and practice. We currently have posted a total of 571 Tweets and have 294 followers, of whom roughly one-third are scientists (71) and scientific organizations and programs (28) who have mentioned CAPLTER 30 times on Twitter since January 2013 and have clicked on our Twitter links 130 times in the same time period. To keep up on the latest scientific research and news, we follow 88 scientists, 59 scientific organizations and programs, 14 journals, 35 science news sites, 19 governmental sites, and 11 science journalists and regularly distribution received information to CAP scientists.

Our K-12 education program maintains a Facebook page, ASU Sustainability: K-12 Education and Outreach, to communicate with teachers. We continue to use our website as our primary means of communicating broadly with the scientific community and others interested in socioecological research. We had 7,579 unique visitors to our website during the last 12 months from 106 countries and all 50 states, and 54% of these were new visitors to the site. Not surprisingly, the vast majority of our visitors are from the US (87%) and of these, 58% are from Arizona, mostly the Phoenix metropolitan area. Statistics on the 54,202 page views over the last 12 months indicate that visitors are mainly viewing our home page, data pages, research pages (including research projects, teams, and highlights), publications, and personnel pages with visitors spending the most time on average (2:56 minutes) on our publications search page.

Despite electronic means of communication, we value face-to-face interaction to accomplish interdisciplinary collaboration. Starting with CAP3, we have held our annual All Scientists Meeting off campus at ASU's SkySong facility in Scottsdale, which has allowed us to attract more community partners to this all-day event. We have two to three community meetings per semester, which focus on our research (usually 2-3 presentations from CAP PIs). Excellent office space, meeting facilities, and event support at GIOS have allowed us to facilitate interactions among scientists and students year round.

Our new database structure, detailed in the IM section of this report, will enhance our ability to manage our research program. We are currently in the process of updating the project section of the database, which will allow the Project Director, Executive Team, Research Leadership Team, and CAP managers to better track progress on individual projects. In particular, we look forward to being able to link people, projects, datasets, and publications in the database to build a comprehensive snapshot of our initiatives.

Information Management

Institutional Infrastructure

Information management (IM) for CAP LTER is provided by the Technology and Informatics Team at the Global Institute of Sustainability (GIOS), Arizona State University. This team includes the designated LTER Information Manager (Director of IT Services), a database specialist, an application programmer, periodic student programmers, and a specialist in geographic information systems. Web design and development services are provided as needed by the GIOS Communications Team. The Informatics team supports LTER researchers with respect to data collection, metadata preparation, and data publishing. The team also supports the broader LTER IM community, serving on working groups and committees. For example, the

Information Manager currently serves as co-chair of the LTER Information Management Committee.

GIOS provides a computing solution based on virtual Linux servers, with storage space on Netapp filers (network attached storage), for all of its projects via ASU's Engineering Technical Services (ETS). The research databases and web servers are hosted on these virtual machines, which bring the advantages and economies of scale of professional IT facilities to both small and large projects. As well as providing significant computing resilience, the ETS server facility allows staff to maintain proper backups of the stored data. ASU staff also performs regular security sweeps, searching for vulnerabilities or unusual behavior on public facing web-site functions. Over 6 Terabytes of resilient storage space is available for research data. We address long-term data preservation through regular technology transfers to maintain current standards for hardware and software. This strategy minimizes the risk of data loss through media or format obsolescence.

Dataset Incorporation and Archival

Support is available to researchers throughout the project to convert research data into datasets suitable for archiving and dissemination. A wide range of datasets is archived, including foundational datasets, long-term monitoring datasets, student project data, and supporting third-party data. Tabular data are stored in non-proprietary formats. Spatial data and imagery are stored in their native formats. In addition, all submitted data are subjected to basic quality-control procedures before inclusion in the archives. Data packages are managed via a dataset inventory database, which tracks submission and publication workflows. A separate document archive holds many journal articles, posters, reports, and white papers in electronic format (pdf).

Metadata are encoded in the Ecological Metadata Language (EML), an established XML standard widely accepted in the ecological community. EML is comparable with the Federal Geographic Data Standard (FGDC) and the International Standards Organization (ISO) metadata standards for spatial data.

Data Discovery and Access

CAP LTER is committed to maximizing the availability of our research products. In order to achieve this goal, we maintain a local data catalog (http://caplter.asu.edu/data/data-catalog/), make data available through the LTER Network Information System (https://metacat.lternet.edu/das/lter/index.jsp), provide metadata for the DataOne data repository (http://www.dataone.org/find-data), and are also working towards including data in the Digital Repository, ASU's institutional data catalog (http://repository.asu.edu/).

CAP LTER has adopted the LTER General Data Use Agreement as a standard and implements a two-tiered data-access policy, with most data being made publicly available. Only copyright-protected, third-party data and selected human-subject data are not public. Some human-subject datasets, however, have been stripped of identifying information and are publicly available through our data catalog. Our researchers can access long-term monitoring data soon after data entry. Investigator- and student-supplied data usually become available after publication of research results. Public access is provided within two years of collection. Non-public data are available to our researchers via the archives on the central storage, through individual database access, or through custom queries requested through the Informatics team. The current CAP LTER web site includes a data catalog with a simple, searchable, user interface, containing over 330 datasets comprising more than 950 data files. This catalog function, which delivered over 1200 downloads in 2012, records download activity while requiring only limited information from data users.

Planned Improvements

Research Information Management: The Global Institute of Sustainability is in the process of enhancing the research IM system to enable project and dataset information to be entered throughout the research project. This system is intended to address a root cause of poor metadata quality: the temporal disconnect between data and metadata preparation. This system will provide a "virtual notebook" for each project that will allow researchers to add project and dataset information as the project progresses rather than collating all this information at project completion. We expect this approach to reduce the work load "bulge" that occurs if these tasks are left until late in the project cycle. A system prototype is currently in use to help us understand what features will be most useful to our research community.

LTER Network Information System: We are in the process of migrating our published data inventory into the new LTER Network Information System. This system is based upon an architecture that accommodates both data and metadata (PASTA) and provides quality checking as an integral feature of dataset submission. We are using this migration as an opportunity to improve data and metadata quality of older datasets as well as repackaging data where appropriate.

Data Visualization: In an effort to improve the user experience when accessing the CAP LTER data portal, we are planning to implement functions that will allow users to view and assess the relevance of data before committing to download the dataset. We currently have a prototype interactive viewer for our spatial data inventory, which we plan to add to our data portal. We also plan to offer similar functionality for tabular datasets.