CAP3: Urban Sustainability in the Dynamic Environment of Central Arizona

2013 Annual Report to the National Science Foundation

Compiled by the CAP LTER Management Team

Goals:

- To advance theory in ecology to incorporate human and societal drivers and responses toward an understanding of the structure and function of the urban socioecological system.
- To continue to provide leadership and demonstrate excellence in urban socioecological research, education, and communication.
- To conduct research, engage stakeholders, and communicate the results of these activities toward building an understanding of how urban sustainability can be achieved.

Objectives:

- To elucidate interactions among urban and urban-hinterland climate, ecosystems, and social systems.
- To understand how the management of urban water systems in cities affects feedbacks and tradeoffs among water-related ecosystem services and how climate change and its uncertainty affect these tradeoffs.
- To investigate how and why biogeochemical cycles differ from those of undeveloped ecosystems and the consequences of those altered cycles and distribution patterns for human well-being.
- To examine how human activities, behaviors, and willingness to make tradeoffs change biodiversity and its components and how variations in biodiversity feed back to influence these same human perceptions, values, and actions.

Activities:

- Continued long-term data collection from urban eddy-covariance tower and conducted data analysis on 12 months of data.
- Completed 1 m land cover classification, using National Agricultural Inventory Program (NAIP) data.
- Initiated work on land cover classification at 30 m scale, using Landsat TM
- Initiated work on land configuration and the urban heat island, using 1m and 2.4 m (Quickbird-based) land cover classification data.
- Modeled vegetation scenarios to evaluate the impact of vegetation on lowering temperatures during an extreme heat event.
- Continued long-term water quality monitoring at numerous locations in the Salt River watershed, including reservoirs, canals, and water treatment plants.
- Conducted investigations on de facto wastewater reuse in Phoenix area.
- Continued research on human use of “accidental wetlands” in the bed of the Salt River.
- Analyzed data on dissolved organic carbon in Tempe Town Lake collected on daily to weekly timescales since 2005.
- Examined evapotranspiration and nutrient removal in Tres Rios Constructed Wetlands.
- Used long-term data from North Desert Village site to investigate the impacts of landscape design and irrigation regime on soil moisture.
- Analyzed data from residential landscape surveys.
- Mapped virtual water in the Western power grid.
- Developed water-energy optimization model.
- As part of long-term work on elemental budgets for the Phoenix area, continued work on carbon budget for CAP study area.

- Conducted a life-cycle assessment for material/energy use.
- Analyzed long-term bird point count data and initiated work on manuscript to communicate findings.
- Analyzed data on plant and bird diversity across 149 cities with colleagues from several universities.
- Conducted flora and herpetofauna surveys along the Salt River.
- Continued work on changes in hormone levels, coloration, and breeding among urban and desert birds.
- Produced initial findings from long-term research on plant communities in the CAP study area.
- Developed the Urban Park Ecosystem Service Planning Tool to analyze ecosystem services in urban parks.
- Analyzed long-term data on land-use change in downtown Phoenix.
- Continued to analyze data from 2011 PASS, focusing on economic analyses.

Significant Results

- Modeled NPP of fringe agriculture, which occupies 14% of the CAP study area, accounts for 31% of total NPP (whereas turf land cover occupies only 0.3% of area but accounts for 1.5% of NPP (Zhang et al. 2013)).
- Over the past century in Phoenix, the annual number of misery days (maximum temperature ≥ 43.3 oC) 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).
- 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.
- 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).
- 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).
- 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).
- 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).
- 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).
- 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.
- 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).

- 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).
- 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).
- 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).
- 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.
- 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 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.
- 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).
- 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).
- 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.

Key Outcomes or Other Achievements

- CAP is a leader in urban socioecological research:
    - In the past year, PI Nancy Grimm gave plenary presentations at the first Society for Urban Ecology conference in Berlin, Germany, the International Ecology Society/British Ecological Society meeting in London, England, and the Syracuse Center of Excellence Symposium, "Urban Reinvention and Resilience," in Syracuse, NY.
    - CAP students and scientists have published 118 journal articles, 3 books, and 34 book chapters since 2010.
- Faculty collaboration leads to additional grant funding for socioecological research:

    - We have leveraged $9.2 million in grant funding since 2010 (inception of this grant cycle).
- Graduate students contribute to knowledge on urban socioecological systems:
    - Since 2010, students have been 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%).
- CAP engages in knowledge exchange and creation of new knowledge across institutional boundaries:
    - CAP scientists and students are currently involved in nine cross-LTER site research initiatives.
- REUs acquire skills to continue science-related work/schooling after graduation:
    - 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 education in their academic areas or have found positions in which they could apply their education and REU experience.

Opportunities for Training and Professional Development:

- Our Ecology Explorers summer teacher training workshop in 2013 focused on the urban heat island.
- 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.
- 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.
- 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 with Ecology Explorers staff and CAP graduate students to provide activities during family science nights.
- During this funding period, we have supported eight REU students on projects ranging from the socioecology of residential landscapes to moss nutrient plasticity.
- Our graduate grants program awarded grants of $2000-$4000 to 13 graduate students in spring 2013. Awards supported field and lab research, conference travel, and publication charges.
- The peer-review process for the graduate grants, 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.
- CAP post-doctoral researcher, Baojuan Zheng, is participating in CAP activities while being mentored by associated faculty members in accordance with the post-doctoral mentoring plan. Mentoring activities during this reporting period included: Serving as a panelist for CAP graduate grants, presenting research during CAP site visit, participating in several seminars and workshops hosted by the Global Institute of Sustainability, and mentoring other graduate students in the lab.
- CAP's All Scientist Meeting in January 2013 involved a record number of poster participants. Student participants were provided feedback on their posters from a team of faculty poster judges.

- CAP's project manager, Marcia Nation, co-designed and delivered a training workshop on science communication to LTER site science communicators.

Dissemination

- CAP students and scientists have published 118 journal articles, 3 books, and 34 book chapters since 2010.
- We summarize research results and communicate these to the wider scientific community and the public via Research Highlights on the CAP website.
- 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.
- 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.
- 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.

Plans for Next Year

Our research plan is articulated in our grant proposal and includes the long-term monitoring and experiment activities that we undertake every year. In the coming year, we intend to engage our scientists and students in analyzing time series data from our long-term datasets as many of these have grown to a point where longitudinal data analysis is now possible. We will be using our annual RFP processes to encourage these analyses.

We also will be more intentionally pursuing collaborative research opportunities with the Decision Center for a Desert City in the areas of green infrastructure, the urban heat island, and landscape design for ecosystem services.

Our future scenarios work will be considerably ramped up in 2014 with the hiring of a post-doctoral researcher to lead this effort and to integrate existing CAP models in scenario development.

We will be strategizing on how to best reach underserved populations through our higher education activities. This may include collaborating with our colleagues in the community college system in Maricopa County and with entities within the ASU system that have systems in place for serving these populations.

Our research outreach efforts will continue with the initiation of research with the Conservation Alliance and continued recruitment into our Urban Tree Community Science project. We will be analyzing data from the latter, sharing it with our community partners, and posting select results on our website for community scientists to view.

Ecology Explorers will be piloting its lessons and an online course for teachers via a new web portal designed with faculty from the ASU Mary Lou Fulton Teacher's College.

Impact on Main Discipline

Early on in CAP, we along with our colleagues in the BES were initiators of a conceptual shift in urban ecology from examining ecology in the city to a more systems-oriented approach of understanding the ecology of the city (Grimm et al. 2000). CAP continues to have a large impact on the theory and practice of urban ecology as evidenced by our publication record. The CAP program has published 373 journal articles, 10 books, and 96 book chapters since 1998. The 302 CAP LTER articles indexed in the Web of Knowledge have been cited 10,882 times, with over 30 papers cited more than 100 times, and the most-cited paper cited 483 times (h index for the 302 papers=54). Scientists associated with CAP, either as current contributors or former post-doctoral researchers, are included in the majority of the edited volumes on urban ecology that have been published over the past few years (e.g. Douglas et al. 2011; Elmqvist et al. 2013; Gaston 2010; Lepczyk and Warren 2012; Marzluff et al. 2008; McDonnell et al. 2009; Niemela et al. 2012; Pickett et al. 2013).

Our other major contributions to date are:

- 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.

- 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.

- 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.

- 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.

Impact on Other Disciplines

While CAP remains a fundamentally ecological research program, we also have contributed to shaping urban ecology as a collaborative discipline that includes perspectives, theories, and research from across the natural, physical, social, and engineering sciences to investigate the complexity of processes in urban areas (as illustrated by the contents of the edited urban ecology volumes cited above). CAP publications from 2007-2011 appeared in journals covering 48 disciplinary areas, 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 impact of CAP collaboration has been a two-way street: ecologists involved in CAP have learned about the value of approaches in other scientific disciplines, and non-ecologists have begun to incorporate ecological theories and concepts in their own work. Our work on the urban heat island (UHI) is an illustration of this. A recent review of UHI research noted that the Phoenix heat island is one of the most studied in the US due to CAP's support of this work (Chow, Brennan, and Brazel 2012). Yet the impact of this research extends beyond climatology since research teams of ecologists, engineers, physicists, sociologists, and geographers have worked together to understand the complexity of the UHI, what it means for organisms (including people) in the city, and how its impacts can be addressed through either mitigation or adaptation measures.

Impact on Development of Human Resources

- Our Ecology Explorers summer teacher training workshop in 2013 focused on the urban heat island.
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Impact on Physical Resources that Form Infrastructure

- As our field area is large, covering the Phoenix metropolitan area and surrounding desert, CAP's provision of field vehicles for research has been essential for the collection of long-term data and student investigations in the urban and peri-urban areas. We have purchased one new vehicle during this grant period.
- Shared instrumentation in the Goldwater Environmental Laboratory (GEL) allows CAP researchers access to equipment and training to conduct analyses. The GEL webpages provide a list of equipment http://rts.clas.asu.edu/gel . Some of CAP's part-time laboratory personnel are also employed by GEL, and CAP contributes to equipment purchases on a case by case basis.

Impact on Institutional Resources

- CAP has been instrumental in establishing the Conservation Alliance with the Desert Botanical Garden and other public and non-profit partners in the Phoenix area.
- CAP has contributed to the establishment of a monitoring program at the McDowell-Sonoran Preserve.
- 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.
- Since 1998, over $53 million in leveraged funding has had a significant impact on institutional resources to support research in the CAP community.

Impact on Information Resources

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/).

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.

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.

Impact on Society beyond Science and Technology

In CAP3 our central research question evolved to encompass an explicit consideration of sustainability in the urban system. Accordingly, many of our research and outreach activities have included a sustainability focus, although our long-term data collection remains focused on answering some basic questions about characterizing the urban environment.

We have sought to make and enhance partnerships to create and share scientific knowledge toward urban sustainability. Some new initiatives during CAP3 include:

- Conservation Alliance: CAP is a partner with the Desert Botanical Garden and several public and non-profit agencies focused on the conservation of the mountain parks that surround and are in the Phoenix metropolitan area. Our current contribution is to summarize existing research on local mountain parks in a format that is easily understood by our partner organizations and can be used to inform improved policies and practices.
- McDowell Sonoran Conservancy: CAP's involvement with this non-profit began with our contribution to their monitoring program. The Conservancy seeks to understand how the McDowell Mountains are being impacted by human activity. We have engaged an active group of volunteers in pitfall trapping arthropods along 10 transects in the McDowell Sonoran Preserve and have trained the volunteers to identify arthropods.
- Urban Tree Community Science: To date, we have had over 200 people respond to our survey on urban shade trees. 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.

- Tres Rios Constructed Wetlands: At a charrette in January, CAP researchers shared their preliminary 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.
- Urban Heat Island Working Group: CAP scientists are collaborating with others at ASU to develop key messages based on urban heat island research to share with the City of Phoenix as it develops policies and practices to deal with excessive heat in the city.