

# CAP LTER IV 2018 ANNUAL REPORT



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Report to the National Science Foundation

# CAP LTER IV

## 2018 Annual Report

### REPORT TO THE NATIONAL SCIENCE FOUNDATION

#### GOALS OF CAP LTER IV

- To foster interdisciplinary social-ecological urban research aimed at understanding these complex systems using a holistic, ecology of cities perspective, while contributing to an ecology for cities to enhance urban sustainability through transdisciplinary partnerships with city practitioners.
- To use our long-term observations and datasets to articulate new questions that require a long-term perspective.
- To develop and use various models and scenarios to address our research questions.
- To apply our broad use of existing urban ecological theory, while contributing new theory from our knowledge-generating endeavor.
- To build and use transdisciplinary partnerships to foster resilience and enhance sustainability in urban ecosystems while contributing to the education and well-being of urban dwellers of all ages and experiences.

#### KEY RESEARCH ACTIVITIES DURING 2018

##### **Long-term observations and experimentation: Ecosystem Response to Urban Atmospheric Deposition (the DesFert experiment)**

- 15 sites: 5 west of urban area in desert parks, 5 east of urban area in desert parks, 5 in urban core in desert remnant parks.
- Treatment plots fertilized with ammonium nitrate and phosphate—winter and spring, all fifteen sites since 2006.
- Atmospheric deposition collection—collected and analyzed quarterly at six sites.
- PRS™ probes (Western Ag Innovations Inc., Saskatoon, Canada) deployed in rainy seasons and analyzed for  $\text{NO}_3^-$  and  $\text{NH}_4^+$ —winter and summer (monsoon) seasons at nine sites.
- *Larrea tridentate* (creosote) growth measured—spring and fall at nine sites.
- *Larrea tridentate* (creosote) leaves collected for CHN analysis—spring and fall at nine sites.
- Percent composition of annuals recorded for subplots—spring at all fifteen sites. Aboveground material harvested from different subplots, and aboveground dry mass determined for harvested material—spring at nine sites.

##### **Long-term observations: Arthropods**

- Twelve sites, including long-term desert sites (open desert and desert remnant) and residential sites (mesic and xeric yards) that coincide with birding locations.
- Eight additional sites at McDowell Sonoran Preserve, a citizen science partner.
- Ten pitfall traps per site.
- Traps are set quarterly and collected 72 hours after setting.
- Arthropods stored in ethanol (one jar for each trap) and identified in the lab.

**Long-term observations: Bird Monitoring—Core**

- 70 points monitored in winter and spring at residential, desert, desert park, and riparian (Salt River) locations.
- 36 of these points are located in Phoenix Area Social Survey (PASS) neighborhoods (three per neighborhood).
- Point count surveys by professional bird surveyors—all birds recorded that are seen or heard within a 15-minute window.
- Each point visited independently by three different surveyors during each season.

**Long-term observations: Bird Monitoring—Parks and Rivers**

- 7 sites monitored quarterly.
- Each site monitored at six points.
- Point count surveys by professional bird surveyor—all birds recorded that are seen or heard within a 15-minute window.

**Long-term observations: Herpetofauna Monitoring—Parks and Rivers**

- 7 sites monitored three times a year—spring, summer, and fall.
- Nine 10 m x 20 m plots per site.
- Two surveyors concurrently survey each plot for visual presence of herpetofauna.

**Long-term observations: Atmospheric Deposition**

- Atmospheric deposition buckets collected from one urban location.
- Dry bucket collected monthly, wet bucket collected after precipitation events.

**Long-term observations: Stormwater**

- Water collected from ISCO stormwater samplers at three locations along Indian Bend Wash (IBW), at one long-term site at the southern outflow of IBW, and at two sites further upstream in the IBW watershed, which were initiated in summer 2018.
- One location along the Salt River where stormwater drains create “accidental wetlands.”
- Discrete, time weighted sampling of runoff-producing storms.
- Water analyzed for organic matter, total nitrogen, total phosphorus, dissolved organic carbon, total dissolved nitrogen, cations, and anions.
- Fluxes calculated by combining concentration and water flow data.

**Long-term observations: Eddy Covariance Tower**

- One tower located in urban area. Tower houses sonic anemometer, infrared gas analyzer, and temperature/humidity sensor to measure high-frequency (10 Hz) 3-D wind, CO<sub>2</sub> (flux), temperature (flux), and moisture (flux).
- 30 minute block averaged data are streamed daily. 10 Hz data is downloaded monthly.

**Long-term observations: Microclimate Towers**

- Two 10-m towers, one located in a desert remnant park within an urban area, the other located in an outlying desert park. Towers house sensors to measure temperature/relative humidity, horizontal wind speed and direction, incoming solar radiation, and precipitation. Data downloaded quarterly.

**Long-term observations: Earth Networks Weather Station and Greenhouse Gas Analyzer**

- CAP LTER hosts this system on the eighth-floor roof of ISTB IV building at Arizona State University.

- Weather station provides real-time weather observations for 27 parameters, including temperature, relative humidity (dew point calculated), barometric pressure, wind speed and direction, and precipitation.
- 360-degree weather camera provides weather-related photos to Earth Networks website and local news station.
- Picarro greenhouse gas analyzer provides real-time measurements of carbon dioxide and methane.

#### Long-term observations: Tres Rios Constructed Wetlands

- Bi-monthly field visits.
- Measurements and samples are taken along two gradients representing the two hydraulic pathways of the treatment cell: whole-system, from inflow to outflow, and within the vegetated marsh proper, from the open water-marsh interface to the shoreline, along 10 permanent transects.
- Measure aboveground primary productivity (biomass) of marsh vegetation, foliar and soil nutrient content and water quality to produce whole system nutrient budgets, and transpiration and evaporation to produce whole system water budgets.

#### Long-term observations: Tempe Town Lake biogeochemistry

- Water samples collected every two weeks and after rain events and analyzed for temperature, conductivity, dissolved oxygen, pH, chlorophyll a, inorganic nutrient and DOC concentrations, and DOC fluorescence.
- Eureka Manta+35 multiprobe datasonde deployed in Tempe Town Lake in June 2018. Sensors measure temperature, conductivity, turbidity, pH, dissolved oxygen, chlorophyll a, DOC concentration, and DOC fluorescence at 30-minute intervals. Datasonde will eventually replace the need for water sample collection and analysis.

## SIGNIFICANT RESULTS (LISTED BY INTEGRATED RESEARCH THEME)

### Adapting to City Life

**Project: Effect of nighttime disturbance by humans on physiology in urban and rural birds** (Hutton et al. 2018)

- Short sleep interruptions by humans do not significantly affect disease, body mass, or metabolism in rural and urban house finches. (*Haemorrhous mexicanus*).

**Project: Stress hormones as a function of behavior in urban and rural house finches** (Weaver et al. 2018)

- Corticosterone elevates in response to the presence of humans, but does not explain urban-rural differences in behavior.

### Climate and Heat

**Project: Edison Eastlake** (data collection ongoing)

- In 2018, a network of temperature sensors was installed in in this low-income Phoenix neighborhood as it undergoes planned major redevelopment over the next several years. These stations are providing a long-term record of urban thermal environment and the data will be

supplemented by periodic intensive field campaigns, including the recent "HeatMappers Walk" and a separate traverse campaign.

**Project: Impact of shade on children in cars** (Vanos et al. 2018)

- Interior temperatures averaged 39.5 C and 47.6 C in the shade and sun, respectively, at steady-state. Based on the specific heat of a human body, the average T<sub>c</sub> after 60 minutes in shaded or sun exposed vehicles was estimated to reach 38.2±0.29 C and 39.1±0.41 C, respectively, with a significantly higher final T<sub>c</sub> in sun-exposed vehicles across all days and in the shaded minivan.

## Governance and Institutions

**Project: Influence of governance structure on green stormwater infrastructure investment** (Hopkins et al. 2018)

- Used long-term control plans from 25 U.S. cities to synthesize: the types of gray and green infrastructure being used by communities to address combined sewer overflows; the types of goals set; biophysical characteristics of each city; and factors associated with the governance of stormwater management. Five "green leader" cities were identified: Milwaukee, WI, Philadelphia, PA, Syracuse, NY, New York City, NY, and Buffalo, NY. These five cities had explicit green infrastructure goals targeting the volume of stormwater or percentage of impervious cover managed by green infrastructure. Results suggested that the management scale and complexity of the management system are less important factors than the ability to harness a "policy window" to integrate green infrastructure into control plans.

## Parks and Rivers

**Project: Biogeochemistry of Salt River wetlands** (Handler et al. in review; Suchy et al. in prep.)

- Stormwater loads of nitrate and pathogens were effectively removed by accidental wetlands in the Salt River bed below the outfalls. The input rates were related to the size of the stormwatershed. These wetlands have a capacity to remove nitrate, through both denitrification and dissimilatory nitrate reduction to ammonium. This capacity varies with the plant type.

## Residential Landscapes and Neighborhoods

**Project: Collaborative Research: MSB-FRA: Alternative ecological futures for the American Residential Macrosystem** (Hall et al. in prep.; Larson et al. in progress)

- This six-city collaborative research project asks about the ecological implications of alternative futures of the residential macrosystem to community assembly and ecosystem function at parcel (ecosystem), landscape (city), regional, and continental scales. Preliminary results from the bee bowl and sweep net sampling in Phoenix indicate that bee diversity and abundance for the spring of 2017 was higher at desert sites compared with urban residential yards. Preliminary results from the PRS probes indicate that plant-available nitrogen and phosphorus vary across site and season, and generally are higher in desert sites than in residential yards.

- Additional governance research is underway to systematically code how and why municipalities across the six metropolitan regions are regulating residential landscapes. Preliminary findings suggest little attention to biodiversity in residential yards. Instead, municipal regulations focus on tree and vegetation maintenance, stormwater management, as well as health and safety issues. Cities seem to vary rather significantly in their landscape governance. For example, while Minneapolis governs a variety of regulatory and non-regulatory strategies for multiple landscape objectives, Baltimore does very little. Moreover, Los Angeles stresses regulatory strategies, whereas Phoenix emphasizes voluntary ones.

## Scenarios and Futures

**Project: Sustainable Future Scenarios for Phoenix** (Berbes et al. in prep; Davidson et al. in prep; Georgescu et al. in prep; Iwaniec et al. in prep; Sampson et al. in prep)

- Completed website of scenarios, developed scenarios report, completed modeling of regional land cover, climate, and water use based on scenario outputs. Initiated cross-scale comparison of scenarios (Phoenix regional and South Phoenix) as well as cross-city comparisons. Participatory workshops yielded six future scenario visions and additional work analyzing government documents yielded a seventh "strategic" scenario for comparison. Scenarios show contrasts and tradeoffs in water security, heat, and green space based on model output.

## Water and Fluxes

**Project: Desert Fertilization Experiment** (Cook et al. 2018; Hall et al. in prep; Wheeler et al. in prep)

- While rates of N deposition were lower than anticipated across the highly urban Phoenix region, N deposition exceeded the aridland N critical load—the level at which ecological changes are expected in the ecosystem and may impact winter annuals. For two years we observed little to no growth of annual plants because of extremely low rainfall. In years when rainfall was plentiful, co-limitation by nitrogen and phosphorus was observed. There was no response to N or P fertilization during dry years. Plant communities in dry years had very low diversity.

**Project: Nutrient dynamics of *Ambrosia deltoidea* litter photodegradation in an arid, urban ecosystem** (Ball et al. in press)

- UV radiation significantly accelerated mass loss and altered N and P dynamics, and there was an impact of the urban environment and of experimental fertilization on nutrient dynamics.

**Project: A Novel Paleoecological Approach for Studying Long-term, Heavy Metal Pollution in the Greater Phoenix Area** (Hester et al. 2018)

- Collected 122 saguaro spines from urban and rural study sites. The urban cactus was found to host elevated levels of As, Cd, Cu, Pb, Ni, Sb, and Zn compared to its rural counterpart. But, both sites appeared to have experienced significant trace element pollution since 2000.

## KEY OUTCOMES OR OTHER ACHIEVEMENTS

### **CAP LTER is a leader in urban socioecological research:**

- In 2018, we have published 27 peer-reviewed journal articles with 12 in review and two in press. In addition, we have published two books chapters, with two more in press and one in review.

### **Faculty collaboration leads to additional grant funding for socioecological research:**

- We have leveraged \$7.3 million in grant funding since December 2016 (inception of this grant cycle) for a total of over \$90 million since CAP's inception in 1997.
- Leveraged grants during this reporting period include:
  - \$5 million from a United States Department of Agriculture grant: "Securing Water for and from Agriculture through Effective Community and Stakeholder Engagement," Penn State University with CAP Scientist Amber Wutich as co-lead of the Arizona-based team;
  - \$500,000 from an NSF Geography and Spatial Science Grant: "Building a Community of Practice for Household Water Insecurity (HWISE) Research" based at Texas A&M University with CAP Scientist Amber Wutich as co-PI, and;
  - Two \$100,000 NSF Smart and Connected Communities grants: "Building resilient coastal cities through smart and connected communities" with Nancy Grimm as PI and "Building Capacity for Smart and Connected Management of Thermal Extremes" with Paul Coseo as PI.

### **Undergraduate and graduate students contribute to a knowledge of urban socioecological systems:**

- In 2018, students were authors on 14 publications and were first authors on eight of these.
- Ph.D. degrees were granted to three CAP graduate students in during this reporting period.

### **CAP engages in knowledge exchange across institutional boundaries:**

- CAP's future scenarios project has engaged expert stakeholders from county, state, and federal agencies, municipal departments, non-profits, academic institutions, the regional council of governments, and a tribal association in workshops visioning the future of greater Phoenix.
- CAP is an active partner in the Central Arizona Conservation Alliance, the Sustainable Cities Network, and the McDowell-Sonoran Conservancy's Field Institute where we share research findings, learn from our community partners and collaborate on research, education, and outreach.
- CAP's Regional Water Quality project involves collaboration with the Salt River Project (local utility responsible for water supply) and shares information with local water authorities and managers about quality of all major surface supplies for the metro area through a monthly newsletter and annual workshops.

## TRAINING AND PROFESSIONAL DEVELOPMENT

- CAP's activities in the area of training and professional development are three-fold: 1) We actively promote and encourage training and professional development for faculty, staff, and students; 2) we work with the Julie Ann Wrigley Global Institute of Sustainability, the LTER Network Communication Office, and others to design and deliver training and professional



development activities to the CAP community; and 3) we design and deliver training and professional development for various stakeholder groups, including teachers, citizen scientists, and practitioner partners. We detail some of these activities under Impacts on Human Resources.

- We encourage staff to identify training and professional development opportunities that are relevant to their roles and responsibilities in the CAP program. For example, in October Sally Wittlinger, the CAP Site Manager, took part in multiple training workshops hosted by the ASU Commission on the Status of Women. Stevan Earl, the CAP Information Manager, has attended professional development workshops on data and information management. CAP Education Manager Lisa Herrmann attended a North American Association for Environmental Education Guidelines for Excellence training session in St. Petersburg, Florida, where she became a Community Engagement trainer. Other staff members have attended sessions held by ASU on a variety of topics from how to use specialized software packages to effective communication strategies.
- During summer 2018, CAP partnered with the Urban Resilience to Extremes Sustainability Research Network (UREx), the Urban Water Innovation Network SRN (UWIN) and other urban-focused labs and groups at ASU to continue the Integrated Summer Research Experience for Undergraduates (REU) program that began in 2016. This brought 15 undergraduate research students (four funded by CAP) together in bi-monthly seminars to share their research and engage in discussions about interdisciplinary research, career and graduate school planning, and science communication. We involved graduate students in these sessions when possible to promote near-peer learning and engagement. We plan to continue and expand this program in 2019.
- CAP Student Representative Megan Wheeler continued her roles as CAP Student Representative to the LTER Network and as head of the CAP Student Group. She, along with a small group of officers, have organized multiple events with the goal of increasing networking opportunities for ASU students interested in CAP LTER-related work. These events included a kick-off meeting in which members of the CAP Leadership Team were invited to speak about their research, as well as panel-led grant writing workshop. This group is already planning events for 2019, including a CV workshop led by CAP scientists and inviting graduate students from the SEV and JRN LTER programs to the CAP All Scientist Meeting in January. Starting in January 2019, Megan will step down and will be replaced by Marina Lauck and Jeffrey Haight.
- CAP is highly integrated into the Wetland Ecosystem Ecology Lab (WEEL), which spearheads our research in the Tres Rios Constructed Wetlands and in other urban wetland systems. The City of Phoenix built these wetlands as an alternative to traditional wastewater treatment, and now Tres Rios has become a living laboratory for high school, undergraduate, and graduate students who want to experience urban field and lab research for the first time. In 2017, the WEEL hosted a research scientist from the Chinese Academy of Sciences Beijing (CAS), Dr. Yufen Ren, and a Ph.D. student from the same CAS lab (Yanying Yang), both of whom worked with CAP to learn urban ecology field and lab techniques. In 2018 the WEEL and CAP hosted another CAS Ph.D. student (Xiaofang Hu), in collaboration with our colleagues at the BES LTER and at the Cary Institute of Ecosystem Studies.
- CAP encourages students, staff, and faculty to participate in research conferences and symposia as part of their professional development. Each year, CAP funds a number of students and faculty to present their research findings at the Ecological Society of America's conference and the American Geophysical Union's annual meeting, as well as other conferences and events (e.g., AAG). Other conferences and events that included presentations on CAP research included The Global Partnership for Better Cities in Hong Kong, China, and the International Symposium on Sustainable Systems and Technology in Buffalo, NY. CAP's annual All Scientist Meeting in January 2018 attracted over 100 participants, including 34 poster presenters, and we anticipate even stronger participation in January 2019.



## DISSEMINATION

- In 2018, CAP students and scientists published a total of 26 peer-reviewed journal articles with 11 in review and three in press. Our journal publications span the biological, physical, engineering, health, and social sciences as well as landscape architecture and urban planning and include journals such as *Landscape and Urban Planning*, *Ecosphere*, *Environmental Pollution*, *Integrative & Comparative Biology*, *Global Change Biology*, *Journal of Geophysical Research: Atmospheres*, *Urban Science*, and *General and Comparative Endocrinology*.
- CAP joined the social media world in 2010 with its Twitter account @CAPLTER, which focuses on promoting urban social-ecological research and practice. We currently have posted a total of 1964 Tweets and have 1356 followers, of whom the majority are scientists, scientific organizations and programs, or environmental and urban-focused non-profits.
- As noted earlier under Opportunities for Training and Professional Development, CAP actively supports students, staff, and faculty to attend professional meetings and research symposia to present CAP research. In addition to the 34 poster presentations at the January 2018 CAP All Scientists Meeting, CAP scientists and students have made 45 other presentations during this reporting period.
- Every year, we hold our annual All Scientists Meeting and Poster Symposium (ASM) off campus at ASU's SkySong facility in Scottsdale. We will continue this tradition for our 21<sup>st</sup> ASM on January 11, 2019. Our office location in Wrigley Hall, on ASU's campus, includes facilities for large and small meetings, most of which have large screens that allow us to connect with our collaborators remotely.
- During 2017-2018, CAP scientists were included in multiple local and national news items, including:
  - Sharon Hall, Megan Wheeler, Kate Weiss, Pierce Hutton, and Kevin McGraw were all featured in an episode of [Catalyst on PBS](#) that focused on desert animals in urban environments.
  - Susannah Lerman spoke on NPR's Science Friday in a segment called "[Beyond the Hive: The Wonderful World of Native Bees.](#)"
  - "Evaluating the impact of solar radiation on pediatric heat balance within enclosed, hot vehicles" by Vanos et al. was covered by many news outlets, including [NBC](#), [The Today Show](#), [ABC](#), [Fox](#), [International Business Times](#), [The Daily Mail](#), and [Xinhua](#).

## PLANS FOR 2019

- Now that the remaining four years of CAP IV funding (2018-2022) has been secured, we will continue CAPIV research and educational and outreach activities that began during this funding cycle.
- Starting in Fall 2018, Interdisciplinary Research Theme (IRT) members began to meet quarterly to discuss research in progress and to collaborate on new research, both within and across IRTs.
- CAP Scientist Jessie Lewis and his team are currently finalizing permissions to put large mammal camera traps at sites across the valley. Once complete, they will deploy wildlife cameras and

bat monitors in the fall and early winter 2018, initiating the “charismatic megafauna in cities” project that we discussed in our most recent renewal proposal.

## IMPACTS

### Impact on Principal 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 holistic approach of understanding the ecology *of* the city (Pickett et al. 1997; Grimm et al. 2000). CAP continues to contribute significantly to the theory and practice of urban ecology as evidenced by our publication record. The CAP program has published 587 journal articles, 10 books, and 106 book chapters since 1998. CAP research is copiously cited in numerous edited volumes on urban ecology that have been published over the past ten 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 and Cadenasso 2013), and many have CAP associated scientists as chapter authors. Recent textbooks on urban ecology also discuss CAP’s work in the Phoenix region (Adler and Tanner 2013; Douglas and James 2015; Francis, Millington, and Chadwich 2016; Forman 2014; Parris 2016). CAP scientists have published recent papers that expand urban ecological theory into the realm of a transdisciplinary and translational ecology for cities (Childers et al. 2014, 2015; Pickett et al. 2016), into linking urban ecosystem services to urban resilience (e.g. Grimm et al. 2016; 2018), and on the concept of urban ecological infrastructure as a social-ecological bridge for translational urban ecology (Childers et al. in review).

Our other major contributions to date are:

- The Warren, Lerman et al. Ecosphere manuscript (In Press) builds upon one of the first urban ecology studies that tested the efficacy of native plants for supporting native biodiversity. By using long-term data from CAP LTER, they were able to document how patterns of bird associations with habitat and socioeconomic status remained, yet many species exhibited a downward trend in abundance and occupancy. Lerman et al. (In prep) explores the ramifications of the 2008 Great Recession and economic crisis on arthropod biodiversity via the links with residential landscape management (*sensu* Ripplinger 2015; 2016). The Lerman, Andrade et al. In prep (arthropods and foreclosures) explores the ramifications of an economic crisis on biodiversity via the links with landscape management. All of these studies explicitly integrate social and ecological datasets to assess ecological function and associated human feedbacks within the urban ecosystem.
- Phoenix Area Social Survey (PASS): Kelli Larson and Abigail York led a collaborative team in the development of a robust survey scale that assesses resident perceptions about the ecosystem services and disservices in their local (neighborhood) environments. Larson et al. (in review) is one of very few papers that examines subjective judgments about ecosystem services, including consideration of disservices.
- Recent publication on long-term N deposition patterns (Cook et al. 2018) demonstrate the challenges of measuring N deposition, particularly dry deposition, in arid regions. This work is one of very few long-term empirical studies of atmospheric deposition patterns across a city and highlights best practices for measuring N deposition with mixed methods. They compared long-term rates of N deposition from ion-exchange resin (IER) collectors (bulk and throughfall, 2006–

2015), wet-dry bucket collectors (2006–2015), and dry deposition from the inferential method using passive samplers (2010–2012).

- Ongoing work by the Scenarios and Futures IRT brings together an important set of new collaborations with city practitioners and community members - engaging them in scientific thinking and preparing for a long-term future that will include increasingly frequent extreme events and other sustainability challenges.

## Impact on Other Disciplines

While CAP remains a fundamentally ecological research program, we are an inherently interdisciplinary endeavor, and thus have contributed to shaping urban ecology as a collaborative discipline that includes perspectives, theories, and research from across the natural, physical, social, design, and engineering sciences to investigate the complexity of social-ecological processes in urban areas. During the 2017-2018 reporting period, we had over 50 faculty members, 8 graduate student researchers, and four undergraduate researchers actively engaged in CAP research from 12 different academic units/disciplines and at four institutions beyond ASU: University of Massachusetts at Amherst, George State University, University of Oklahoma, and Northern Arizona University.

As such, CAP's contributions outside of urban social-ecological research are often at the interface among disciplines. In fact, most of CAP's contributions to urban systems science are beyond the disciplines of ecology and urban ecology.

## Impact on Development of Human Resources

- For our summer 2018 REU program, we targeted students from groups underrepresented in STEM. We worked with the Ecological Society of America's SEEDS SPUR fellowship program and recruited one of their students to join three other faculty-recruited students (also from underrepresented groups) in our summer REU program:
  - Keaton Coker: "Black Widows on an Urban Heat Island: Using Hormones and Behavior to Understand Global Change" (Mentor: Chad Johnson)
  - Jessica Dwyer: "The effects of urbanization on species composition and activity patterns of the bat community across the Phoenix Valley" (Mentor: Jesse Lewis)
  - Caitlin Nordheim: "Comparison of riparian herpetofauna along urban and wildland streams" (Mentor: Heather Bateman). Caitlin was recruited via the ESA SEEDS Spur Fellowship from the University of Tampa.
  - Chelsea Stratton: "Energy, water and habitat diversity as predictors of bird diversity in urban areas" (Mentor: Fabio Suzart de Albuquerque)
- These four students bring the total number of REU students supported under NSF funding since 1998 to 67. Many of these students have gone onto graduate school in traditional STEM fields and the in new field of sustainability, and others have entered STEM-related careers.
- CAP REU Caitlin Nordheim applied for and was accepted to present her Summer 2018 CAP research at the LTER Network All Scientists Meeting in Asilomar, California.
- After a successful iteration in 2017, we continued our Integrated Summer REU program in 2018 that partners with the Urban Resilience to Extreme Events Sustainability Research Network (UREx)

and UWIN SRN. This program brings together a critical mass of students—15 in summer 2018—to share research across traditional academic boundaries. This year’s group also included students from other CAP researchers through separate NSF funding, which added further diversity to the group. The 15 participating students (including to UREx students who connected remotely via Zoom from partner institutions) came together for five breakfast meetings covering topics such as interdisciplinary research, post-graduate career and education planning, and science communication. The final luncheon meeting involved each student giving a short presentation on their research and experiences. Feedback from students afterwards indicated that they appreciated these meetings and that the REU experience had left them with very positive impressions about post-graduation academic degrees and STEM careers. For many students, this was the first time that they had conducted research and the first time that they had engaged in research-related discussions across disciplinary boundaries. Further feedback from students and faculty will assist us in planning for our Integrated Summer 2019 REU program.

- In 2018, our CAP Grad Grants Program competitively granted \$26,808 to support the research of seven graduate students:
  - Riley Andrade: “Linking human-environment interactions with community ecology in urban ecosystems”
    - Amount: \$4000
    - Mentor: Kelli Larson
  - Alicia Hinterlong: “The effects of urbanization on the wildlife community across the CAP LTER in the Phoenix Valley”
    - Amount: \$3950
    - Mentor: Jesse Lewis
  - Marina Lauck “Effects of Variable Inundation Patterns on Wetland Plant Communities and Nitrogen Uptake in the Salt River Wetlands”
    - Amount: \$3998
    - Mentor: Nancy Grimm
  - Christopher Sanchez: “Design process and outcomes of designed experiments using Urban Ecological Infrastructure (UEI): a case-study”
    - Amount: \$3965
    - Mentor: Dan Childers
  - Michelle Stuhlmacher “Quantifying Landscape Architecture Dynamics in Tempe’s Rio Salado”
    - Amount: \$4000
    - Mentors: Billie Turner II & Matei Georgescu
  - Kate Weiss: “Assessing Mammalian Functional Diversity Across a Gradient of Urbanization in the Phoenix Valley”
    - Amount: \$4000
    - Mentors: Sharon Hall & Jan Schipper
  - Nicholas Weller “Extreme Heat Public Forums: Perspectives of participants and policy makers in Phoenix, AZ, Portland, OR, and St. Paul, MN”
    - Amount: \$2895
    - Mentor: Dan Childers
- The impact of the graduate grants program goes beyond money for research. Previous recipients of graduate grants form a proposal review panel, run like NSF panels, to recommend the next

round Grad Grant funding. This model is one of many ways that CAP trains the next generation of academic and agency scientists on how to write and review proposals effectively. The response to this process by our students has been overwhelmingly positive, and both the CAP Grad Grants Program and this review process have become models across the LTER Network.

- 24 teachers from the CAP study area were selected through a competitive application process to participate in two summer professional development workshops through our Ecology Explorers program. During this week long, intense experience, teachers learned about LTER science and local the research done through CAP while participating in the lessons and curriculum development and field studies through the Ecology Explorers program. The focus of these workshops was ecology of the McDowell Sonoran Preserve and South Mountain Preserve, and the workshops included extensive field experiences in both of these urban parks and preserves. As in past years, the teachers will report back later in the school year on classroom implementations of their summer learning experience.
- Additionally, eight volunteer stewards of the McDowell Sonoran Conservancy attended two 6-hour trainings by Ecology Explorers with the goal of strengthening their capacity to facilitate classroom experiences via Ecology Explorers lessons.
- Ecology Explorers lessons, curriculum content, and approaches were utilized in two additional professional development workshops: one for Girl Scout educators in June 2018, and one for teachers in the Arizona Science Center's STEM Educators professional development program in October 2018.
- Three undergraduate student interns, one undergraduate student worker, and one student volunteer worked with the Ecology Explorers program in spring and fall semesters of 2018. These students learned basic pedagogy for both classroom and non-formal education settings. They also assisted with the development of teaching materials and lesson plans. One student intern used her two years of work developing contributions to the Ecology Explorer curriculum as her honors thesis in Spring 2018.

## Impact on Physical Resources that Form Infrastructure

The 6400 km<sup>2</sup> study area of CAP includes all of the Phoenix metropolitan area as well as surrounding desert. Because of the vast scale of our research endeavor, CAP's provisioning of field vehicles for research has always been essential for the collection of long-term data, for student research, and for more targeted experiments and investigations in our urban and peri-urban areas. CAP Site Manager Sally Wittlinger ensures that the vehicles are maintained, that researchers undergo the appropriate ASU training to use the vehicles, and that vehicles are used properly.

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.

CAP maintains a diversity of field infrastructure. CAP technicians perform routine maintenance, instrument calibration, deal with the vandalism inherent in urban areas, and assist faculty and students in using the long-term data from these observational efforts as well as in locating short-term investigations at these sites.

- A retractable, 22.1 m, four-section eddy flux tower, located in a suburban Phoenix neighborhood comprised of single-story housing. The eddy flux tower measures 3-D wind, CO<sub>2</sub>, temperature, and moisture, and fluxes are calculated using standing eddy-correlation techniques. The following instrumentation is located on the tower: 3D sonic anemometer, infrared gas analyzer, temperature–relative humidity sensor, and net radiometer.
- An Earth Networks weather station on the roof of the ISTB4 building (ASU Tempe campus), which measures temperature, humidity, wind speed, precipitation, air pressure and dew point and includes a greenhouse gas analyzer. CAP also maintains a video camera attached to the same tower that the local Channel 3 weather team uses in broadcasts.
- At each of the DesFert sites, five permanently marked 20m x 20m plots, two unfertilized controls and three receiving fertilizer additions (N, P, or N+P) twice per year. Each plot also contains permanently marked quadrats for biomass and community composition of annual plants and marked creosote bush shrubs for stem elongation measurements.
- At one centrally urban DesFert site and one outlying park DesFert site, micrometeorological stations measure temperature, humidity, wind speed, precipitation, air pressure, and dew point. For measurement of atmospheric deposition, CAP has installed resin-based bulk deposition and throughfall collectors at these DesFert sites. Atmospheric deposition work also includes deposition collectors (wet/dry collector, resin-based bulk collector) on the roof of the Life Sciences A building on the ASU Tempe campus.
- At each of seven sites along the Salt River, CAP maintains nine permanent herpetofauna plots and six birding points.
- CAP maintains ISCO automated samplers at three stormwater sampling sites along Indian Bend Wash and in one stormwater outfall to the Salt River above Price Drain.
- We recently deployed a Eureka Manta+35 multiprobe datasonde in Tempe Town Lake with sensors to measure temperature, conductivity, turbidity, pH, optical dissolved oxygen, chlorophyll A, DOC concentration, and DOC fluorescence.

## Impact on Institutional Resources

- The initial CAP LTER grant from NSF in 1997 was the catalyst for the formation of what is now the Julie Ann Wrigley Global Institute of Sustainability at ASU and the sustainability education and research efforts at ASU. CAP remains an important research platform for work on urban social-ecological systems at ASU and is included on the ASU Office of Knowledge Enterprise Development (OKED) timeline, "[A Legacy of Discovery](#)".
- One reason CAP has stimulated so much research on urban social-ecological systems is the openness of CAP's past and present leadership to new investigators and students who can contribute novel perspectives to our long-term work. Furthermore, our collaboration model has led to numerous research initiatives outside of CAP as evidenced by the considerable amount of research funding leveraged from CAP:

- \$7.3 million in grant funding since December 2016 (inception of this grant cycle) including \$5.7 million during this reporting period.
- A total of \$90 million since CAP's inception in 1997.
- The CAP information management system has been the exemplar of a data management system that now encompasses all sustainability research efforts at ASU.
- The on-line Urban Ecology module for educators, developed through the Mary Lou Fulton Teacher's College, is accessible for classroom teachers and non-formal educators at any time through the Ecology Explorers website. Additionally, [a two hour online training module](#) is available through ASU's Continuing Education website and introduces teachers and educators to the Ecology Explorers program.
- CAP's Ecology Explorers program provides teachers with professional development training and resources for engaging elementary and middle school students in learning about and experiencing urban ecology. A number of lesson plans and curricular content are available on the CAP website, with two more added in 2018, and two more to be added in 2019.

## Impact on Information Resources

- In 2018 we added eight new data sets to the publicly available CAP data holdings, and updated another seventeen existing data sets. A new data set of note is the first publication from the CAP LTER's monitoring of water quality in the Tempe Town Lake, a man-made reservoir constructed in the bed of the Salt River designed as a recreational resource and focal point for development. In keeping with CAP efforts to continually improve the discoverability and utility of its data, six of the eight new data sets were generated from reconfigurations of existing datasets that reflect several of the CAP signature long-term observational projects. All CAP metadata are encoded in XML-based Ecological Metadata Language (EML), with data and metadata available through both the CAP LTER data catalog on the project website and the Environmental Data Initiative (EDI) data portal.
- The CAP Information Manager and Julie Ann Wrigley Global Institute of Sustainability (GIOS) informatics team strive continuously to improve the presentation, utility, and management of CAP information resources. Notable improvements from 2018 efforts include:
  - The current (S. Earl) and former (P. Tarrant) CAP Information Managers taught a course on research data management at ASU in the spring of 2018. This course provided graduate students, including students actively involved in CAP research, with a greater awareness of the importance of data curation. They were also taught the skills and tools needed to more effectively manage their research data. After strong student reviews and feedback, Earl and Tarrant will teach this course for a third time in the spring of 2019.
  - CAP managers and technicians completed the migration of digital resources from university servers and personal computers to ASU-supported Dropbox folders. This transition provides greater resilience, utility, interoperability, and dependability at a reduced cost to CAP host institution (GIOS).



- CAP is committed to making a strong contribution to informatics within the LTER Network and the ecological sciences in general. Stevan Earl, the CAP Information Manager, participates in all network information meetings and activities, is an elected officer of the LTER Network Information Management Executive Committee (IM Exec), chaired an LTER Information Management Committee (IMC) working group that generated training guidelines for new Information Managers, and served on a working group that revised the IMC's Terms-of-Reference (by-laws). In addition, Earl serves on the Environmental Data Initiative (EDI) Data Checks Committee, which oversees quality control checks implemented in the PASTA+ system (the engine that helps to ensure the integrity of data sets submitted to the LTER and EDI data portals), and is an information manager on a NCEAS Synthesis Working Group studying Soil Organic Matter dynamics.

## Impact on Society beyond Science and Technology

- The Ecology Explorers team has participated in statewide and national meetings and conferences for science and environmental educators. We are participating in the development of initiatives with the Arizona Association for Environmental Education, the Arizona Science Teachers Association, the Arizona Environmental Literacy Community of Practice, the North American Association for Environmental Education, and the Central Arizona Conservation Alliance.
- Our Ecology Explorers program (work described in several sections above) is our major vehicle for engaging with K-12 students, teachers, and the general public. In the current reporting period, we engaged in 31 outreach activities, including the Arizona Earthfest, the McDowell Sonoran Jr. Citizen Science Festivals, and classroom visits, which reached approximately 2198 youth, 373 adults, and 73 teachers and 15 volunteer educators. We produced two new Ecology Explorers lessons and hosted in two multi-day teacher training sessions and two trainings for volunteer educators of the McDowell Sonoran Conservancy.
- The Rio Salado 2.0 Urban Ecological Working Group was formed by CAP Scientists to work with Melissa McCann, Associate Director of ASU's University City Exchange, on assessing the state of information about urban ecological infrastructure (UEI) related to the Rio Reimagined (Rio Salado 2.0) project, a partnership between municipalities and tribal groups along the Rio Salado river whose goal is to revitalize the river and it's watershed through sustainable economic and community development. This group plans to create a UEI framework for data collection and monitoring to support the planning and design activities for the Rio Reimagined project. This project brought together representatives of the Central Arizona Conservation Alliance, Arizona Game and Fish, and Flood Control District of Maricopa County to envision needed data for urban ecological planning and design along the Salt River.
- The Hydro-GI Lab project, part of our Urban Design IRT, is in a partnership with the Flood Control District of Maricopa County to co-produce designed experiments for UEI-based stormwater management features. Chingwen Cheng (PI), Kristian Kelley (Co-PI), and Paul Coseo (Co-PI) received an ASU APS Endowment for Sustainable Design Research grant to install two designed experiments at 1) the Flood Control District of Maricopa County's Durango Campus, and 2) ASU's Orange Mall Student Pavilion. Monitoring started in August 2018 with more monitoring equipment to be installed in October and November 2018.

- The project Building Capacity for Smart and Connected Management of Thermal Extremes is a NSF Smart and Connected Communities Planning Grant with Paul Coseo (PI), David Hondula (Co-PI), and Ariane Middel (Co-PI) working closely with the City of Tempe and our peer city partners in Erie County, Buffalo, and the University of Buffalo to assess the current state of management of thermal extremes in Tempe, AZ and Buffalo, NY. The Tempe component supports the CAP Climate and Heat and Urban Design IRT.
- The Nature’s Cooling System project led by David Hondula works with underserved communities in the Phoenix Metro Area to develop plans for cooling neighborhoods and protecting people during hot weather. They held nine workshops in three different neighborhoods throughout summer 2018 and engaged approximately 100 residents in the heat action planning process. The aim is to co-produce heat action plans as well as to share CAP research with local residents.
- A Global Consortium for Sustainability Outcomes funded project, “Deepening the Impact of Scalability of Green Infrastructure within Cities” led by Fletcher Beaudoin at Portland State University, partners with ASU's Lauren Keeler and Paul Coseo and the City of Tempe to develop a full proposal on urban ecological infrastructure (UEI). Part of the larger proposal is intended to support UEI designed experiments in the City of Tempe and provide more capacity for the CAP Urban Design IRT activities.
- CAP’s Sustainable Future Scenarios (SFS) work, in collaboration with the UREx SRN, is shared and, indeed, co-produced with city practitioners and community leaders with interests in envisioning alternative futures that can ensure resilience in the face of climate change. This includes participants such as: City of Phoenix, City of Tempe, City of Goodyear, City of Mesa, Maricopa County Flood Control District, Maricopa County Department of Health, US EPA, Arizona Department of Water Resources, Bureau of Reclamation, Arizona Interfaith Power and Light, The Nature Conservancy, Trees Matter, Desert Botanical Garden, McDowell Sonoran Conservancy, Sonoran Institute, and many others.

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