CAP LTER IV 2022 ANNUAL REPORT TO THE NATIONAL SCIENCE FOUNDATION

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Report to the National Science Foundation

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CAP LTER IV
2022 Annual Report to the National Science Foundation

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 2022

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

- 15 sites: Five west of urban area in desert parks, five east of urban area in desert parks, and five in urban core in desert remnant parks.
- Treatment plots fertilized with nitrogen (as ammonium nitrate) and/or phosphorus (as triple super 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 NO_3^- and NH_4^+—winter and summer (monsoon) seasons at nine sites.
- *Larrea tridentate* (creosote) growth measured—spring and fall at nine sites.

- *Larrea tridentate* leaves collected for CHN analysis—spring and fall at nine sites.
- Percent composition of annuals recorded for one square-meter subplots; 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. McDowell Sonoran Preserve sites are not collected during the summer quarter.
- Arthropods stored in ethanol (one jar for each trap) and identified in the lab.

Long-term observations: Bird Monitoring

- 70 points monitored in winter and spring at residential, desert, desert park, and riparian (Salt River) locations.
- 36 of these points located in the 12 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—Salt River Biodiversity Project

- 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—Salt River Biodiversity Project

- 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 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) in Scottsdale: one long-term site at the southern outflow of IBW and at two sites further upstream in the IBW watershed.
- Discrete, time-weighted sampling of all runoff-producing storms.
- Water analyzed for 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: Regional Drinking Water Quality Analysis

- Water collected monthly at 5 locations in major water supply reservoir systems.
- Water analyzed in lab for nutrients, major cations and anions, pH, temperature, specific conductance, DOC, taste and odor compounds, and particulate matter.

Long-term observations: Eddy Covariance Tower

- One tower located in urban area. Tower houses sonic anemometer, infra-red gas analyzer, and temperature/humidity sensor to measure high-frequency (10 Hz) 3-D wind, CO_2 (flux), temperature (flux), and moisture (flux)
- 30-minute block-averaged data are streamed daily. 10 Hz data are downloaded monthly.

Long-term observations: Microclimate Towers

- Two 10-m towers, one located in desert remnant park within urban area, the other located in 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 eighth-floor roof of ISTB4 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

- Every other month field visits.
- Measurements and samples are taken along two gradients representing the two hydraulic pathways of the 42 ha 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 CDOM/*f*DOM at 30-minute intervals. Datasonde will eventually replace the need for water sample collection and analysis.

Long-term observations: Charismatic Megafauna in Cities

- Wildlife cameras deployed at 35 sites along the Salt River, from the Tonto National Forest upstream of Phoenix through the urban areas.

Long-term observations: Drought-Net

- Two sites, each with seven rainout shelter plots and seven control plots.
- Desert annuals and soil samples collected for analysis each spring.
- Sites located at DesFert sites, one west and one east.
- Project is in collaboration with graduate students and researchers from Sevilleta LTER.

SIGNIFICANT RESULTS

- **Paideia Academies - Renaturalizing Outdoor Play and Learning Environments (Polous et al., 2022)**
  - This Healthy Urban Environments (HUE) and CAP LTER-funded project led by Jenni Vanos (PI) is a partnership with the Paideia Academy to conduct a series of designed experiments for heat reduction and to assess new urban ecological infrastructure projects on their South Mountain Village, Phoenix campus.
  - The research is a pilot demonstration that will create baseline data and a needs assessment for other schools throughout the county, state, and country to implement the natural play & learning concept. It is bridging a gap that is not currently being assessed by schools, districts, and communities.
  - Shade & nature impact the use of a play space during recess. A new observational tool was designed and validated to assess shade, nature, and play interactions during hot and sunny days.

- **Urban Nature Interactions and Human-Wellbeing (Mitchell et al., In Progress)**
  - Starting in 2021, Kelli Larson and MA student Abby Mitchell began analyzing data from 2021 PASS to understand how nature interactions have changed during the earlier and latter springs of the COVID-19 pandemic. This research also examines how different types of nature interactions (e.g., private gardening and visiting parks) affects different dimensions of human wellbeing.

- **Resilience, Equity, and Sustainability Qualitative Assessment (Berbés-Blázquez et al., 2021 & 2022 [Submitted].**
  - We are conducted a qualitative assessment of 11 scenario visions, five visions at the neighborhood scale (South Phoenix), and six at the CAP regional scale. The analysis assesses each vision against 40+ indicators of resilience, equity, and sustainability.
  - Results demonstrate that participants at the village scale are most concerned with representation in decision making, while participants at the regional scale are most concerned with building urban ecological infrastructure and associated ecosystem services.

- **Influence of Climate, Plant Communities, and Land-Use on Long-term Patterns of Soil Properties in the CAP LTER Ecosystem** (Seelig et al., In Prep)

    - Based on conducted analyses and machine learning using the ESCA dataset.

    - Land-use decisions most significantly influence soil attributes, and some impacted soil properties are rapidly changing through time. This indicates that human decision making not only influences soil properties, but also their variability over time, particularly where irrigation and fertilization are part of the management. Human decisions regarding these practices play considerable roles in sub-local biogeochemical processes over time.

- **Aboveground-belowground connections influence soil microarthropod responses to altered water availability** (Ball et al., In Prep)

    - Becky Ball and students are analyzing data and preparing a manuscript to publish results from a field experiment testing plant-soil relationships in soil microarthropod communities, and how those relationships influence the response to altered precipitation.

    - Precipitation pattern altered arthropod diversity and evenness, particularly in interplant soils. While soil arthropod total abundance was resistant to precipitation, vegetation buffered Shannon diversity from the impacts of altered precipitation. Thus, climate-induced changes in the plant community could indirectly influence soil arthropod diversity. However, these plant-soil interactions may not be equally important under all scenarios of altered precipitation.

- **Poxvirus infection in house finches (*Haemorhous mexicanus*): Genome sequence analysis and patterns of infection in wild birds** (McGraw et al., 2022)

    - We discovered a novel poxvirus but interestingly there was no biological predictor of variation in virus presence in this study (where infections were generally rare and mild).

KEY OUTCOMES OR OTHER ACHIEVEMENTS

CAP LTER is a leader in urban social-ecological research:

- In 2022, we have published 18 peer-reviewed journal articles with 18 in review and 2 in press, for a total of 190 published articles during CAP IV. In addition, we have four book chapters in press and one in review.

Faculty collaboration leads to additional grant funding for social-ecological research:

- We have leveraged $46 million in grant funding since December 2016 (inception of CAP IV) for a total of over $129 million since CAP's inception in 1997.
- Leveraged grants during this reporting period include:
  - Kevin McGraw, Paige Warren, and other members of the CAP research team were awarded an EVO-LTER grant of $100K focused on urban evolutionary ecology.

Undergraduate and graduate students contribute to a knowledge of urban social-ecological systems:

- In 2022, students were co-authors on 10 publications and were first authors on nine of these.
- A Ph.D. degree was granted to one CAP student in during this reporting period: Stephen Elser.

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 (CAZCA), the Sustainable Cities Network, and the McDowell-Sonoran Conservancy's Field Institute. 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 (a local utility responsible for water supply) and shares information with local water authorities and managers about the quality of all major surface water supplies for the metro area through a monthly newsletter and annual workshops.

- The Edison-Eastlake neighborhood near downtown Phoenix has emerged as a focal point for CAP's climate and heat, and urban design, research and broader impacts. In Edison-Eastlake, we deployed meteorological instrumentation for long-term, continuous monitoring at seven locations (including two with live internet feeds), and are conducting annual high-resolution microclimate assessments with a mobile biometeorological platform (MaRTy). We are using simulation modeling to understand the potential microclimate effects of a large-scale redevelopment project that is planned for the neighborhood in the coming years. Our meteorological measurements, transects, and the longer-term CAP archive of land cover, land use, and land surface temperature data sets will ultimately enable us to measure the realized impacts of this large-scale change to the urban landscape with respect to ecologically and socially relevant climatic variables and validate and improve state-of-the-art microclimate models.

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 ASU's Julie Ann Wrigley Global Institute of Sustainability and Innovation, 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 K-12 teachers, citizen scientists, community residents, and practitioner partners. We detail some of these activities under Impacts on Human Resources.

- During Summer 2022, CAP continued our Integrated Summer Research Experience for Undergraduates (REU) program that began in 2016. This brought five REU students 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 mentoring, learning, and engagement.

- CAP Student Group Co-Lead Jeffrey Haight, who is also CAP's representative on the Network Student Committee, continued to build and develop the CAP LTER Student Group. They continued the CAP Seminar series, a monthly virtual event where a member of the CAP research community is invited to give a talk on their research. These events are open to the public, and available afterwards on YouTube. They have also organized events with the goal of increasing networking opportunities for ASU students interested in CAP LTER-related work.

- ASU's Wetland Ecosystem Ecology Lab (WEEL) is highly integrated into CAP. The WEEL spearheads our research at the Tres Rios Constructed Treatment Wetlands and in other urban wetland systems. The City of Phoenix built these wetlands as an alternative to traditional wastewater treatment, and 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. Since July 2011, most of the field work at Tres Rios has been done by student volunteers.

- 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, the American Geophysical Union's annual meeting, as well as other conferences and events (e.g., AAG, IALE). Other conferences and events where CAP researchers presented their findings in 2022 included the ASU Social Embeddedness Network Conference, the American Meteorological Society Meeting, and the Annual Conference of the International Association for Landscape Ecology. CAP's annual All Scientist Meeting in March 2022 attracted over 100 participants, included 31 poster presenters, and we anticipate similar attendance and participation in January 2023.

DISSEMINATION

- The CAP program has published 699 journal articles, 13 books, and 117 book chapters since 1998. In 2022, CAP students and scientists published a total of 18 peer-reviewed journal articles with two in press and 18 in review. 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 Annals of the American Association of Geographers, Bioscience, Journal of Arid Environments, Environmental Science and Technology, Ecosystems, Economic Anthropology, Frontiers in Ecology and the Environment, and Sustainability.

- CAP joined the social media world in 2009 with its Twitter account @CAPLTER, which focuses on promoting urban social-ecological research and practice. We currently have 1845 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 31 poster presentations at the March 2022 CAP All Scientists Meeting, CAP scientists and students have made 21 other conference presentations during this reporting period.

- As part of our NSF virtual site visit in October 2020, we created a series of virtual field trip videos that allowed our reviewers to experience learn about the work we do at different sites across the CAP area. These eight videos are available on YouTube: https://www.youtube.com/playlist?list=PLmV7x-JlhKmqbrOVCly_cGZpaa8HC34-h

- 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 25th ASM on January 13, 2023. Our office location in The Walton Center for Planetary Health on ASU's Tempe campus includes facilities for large and small meetings, most of which have large screens that allow us to connect with our collaborators remotely.

- During 2021-2022, CAP scientists were included in multiple local and national news items, including: The Christian Science Monitor, The Guardian, The Washington Post, ABC News, NPR, and The Smithsonian Magazine.

PLANS FOR 2023

- We look forward to launching CAP V, and in particular to expanding our urban air quality and environmental justice work and our work with underserved communities in South and West Phoenix, and to beginning our work with local Indigenous communities for the first time.

- The next CAP LTER All Scientists Meeting and Poster Symposium will be held at ASU Skysong on January 13, 2023.

- The CAP Seminar series will continue into 2023.

- The CAP LTER Justice, Equity, Diversity, and Inclusion committee will continue to hold regular meetings, monthly Equity Circles, and work toward the goals outlined in the Impacts on in Human Resources section.

IMPACTS

Impact on Main Discipline

In the early years of CAP, we along with our colleagues at the BES LTER 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. 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. 2019).

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 endeavor 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 2022 reporting period, we had over 75 faculty members, one postdoc, 16 graduate student researchers, and seven undergraduate researchers actively engaged in CAP research from 12 different academic units/disciplines at ASU and at 11 other institutions: University of California-Berkeley, University of California-Davis, Yale University, University of Massachusetts at Amherst, Bowling Green University, Georgia State University, University of Oklahoma, Barnard College, University of New Mexico, Pace University, and Northern Arizona University. CAP's contributions outside of urban social-ecological research are often at interfaces 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

- In 2020, Elizabeth Cook (faculty, Barnard College) and Quincy Stewart (CAP Site Manager) co-founded the CAP LTER Justice, Equity, Diversity, and Inclusion (JEDI) committee. The JEDI Committee is guided by an initial set of responsibilities and goals. The goals and initiatives of the committee, as currently stated, have evolved from ongoing discussions with current CAP community members, the CAP Executive Committee, and the LTER Network Diversity Committee. Our JEDI Committee's preliminary goals are to lead initiatives to:
    - Actively foster and support diversity within the CAP community and STEM more broadly;
    - Enhance representation and support underrepresented minorities in STEM career advancement through CAP initiatives;
    - Proactively review anti-racist policies and initiatives related to CAP research, programming, and hiring practices; and
    - Build awareness in the CAP community about the multiple facets of diversity encountered in the Greater Phoenix region every day.
- In order to actively work toward these goals, moving forward the CAP JEDI Committee will:
    - Continue to hold regular monthly community 'Equity Circle' discussions to broaden the conversation about the JEDI within CAP. This will include trainings, discussions of field safety plans, discussions of climate survey results, and other facilitated conversations.
    - Continue to collaboratively develop a CAP JEDI Action Plan, which we call our Social Contract, including explicit short and long-term action items, mechanisms, assessment metrics, and timelines to ensure the CAP community is actively working toward the JEDI goals with a clear process for evaluation and assessment. There will continue to be opportunities for review and feedback by the community.
- The CAP Social Contract will include explicit short- and long-term action items, mechanisms, and timelines to ensure we actively work toward meeting our JEDI goals. The JEDI Social Contract will include a clear process for evaluation and assessment of success, and targets for success. These initiatives are the starting point for CAP's JEDI work, and the goals and initiatives will continue to evolve and be refined. The JEDI Committee will establish an open engagement process with the larger CAP community in order to ensure an inclusive planning and decision-making process.
- For our summer REU program, we traditionally recruit students from groups underrepresented in STEM. Our 2022 REU students included:

- Zoe Gentry: "Visions of the Rio Salado: Planning Participatory Visioning for an Urban River." (Mentor: Nancy Grimm)

- Maddelyn Gibson: "Color Me Sexy: Does ornate coloration predict health state in an invasive urban parrot species?" (Mentor: Kevin McGraw)

- Savage Cree Hess: "Diversifying visions of the future of the Rio Salado – A community-centered approach to Rio Reimagined." (Mentor: Michelle Hale)

- Garrett Storey: "Occurrence and fate of emerging contaminants in the Tres Rios Wetlands." (Mentor: Pierre Herckes)

- These four students bring the total number of REU students supported with NSF funding since 1998 to 91. 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 LTER held our Integrated Summer REU program for the sixth time this year. This program brings together a critical mass of students—four in total for 2022, —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 participating students connected in person or remotely via Zoom for five meetings covering topics such as interdisciplinary research, post-graduate career and education planning, and science communication. The final session 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 2023 REU program.

- In 2022, our CAP Grad Grants Program competitively granted $33,422 to support the research of 10 graduate students:

  - Jordan Cisco: "The Fate of Microplastics in Tres Rios Wetlands." (Mentor: Pierre Herckes)

  - Jorge Guerrero, Amanda Kuhn, and Vanya Bisht: "Bridging Academic Knowledge with Community Practice." (Mentors: Marta Berbes-Blazquez and Monique Franco)

  - Jeff Haight: "Influences of Wildlife Presence and Diversity on the Environmental Attitudes of Metropolitan Phoenix Residents." (Mentors: Sharon Hall, Jesse Lewis, Kelli Larson, and Jeffrey Brown.)

- Abigail Mitchell: "The impacts of nature interactions on human wellbeing during the COVID-19 pandemic" (Mentor: Kelli Larson)
- Luke Ramsey: "Changes in Plant Community Composition of Urban Accidental Wetlands." (Mentor: Dan Childers)
- Shaylynn Trego: "A Longitudinal Assessment of Heat Risk Perception and Adaptation in Phoenix, Arizona." (Mentors: Sara Meerow and David Hondula)
- Leanna Watts: "The breeding success of introduced urban Rosy-faced Lovebirds (*Agapornis roseicollis*)" (Mentor: Pierre Deviche)
- Qinnan Zhu: "Multi-scalar drivers of residential yard changes in Phoenix metropolitan area: Implications for urban landscape sustainability." (Mentor: Kelli Larson)

- The impact of the CAP Grad Grants program goes beyond the support for research. Previous recipients of Grad Grants form a proposal review panel, run using the NSF panel model, 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.

Impact on Physical Resources that Form Infrastructure

The 6400 km^2 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 Quincy Stewart 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 Metals, Environmental and Terrestrial Analytical Laboratory (METAL) allows CAP researchers access to equipment and training to conduct analyses. The METAL webpages provide a list of equipment.

CAP maintains a diversity of field infrastructure. CAP field and lab technicians perform routine maintenance, instrument calibration, and deal with the vandalism inherent in urban areas. Along with the CAP Site Manager, they assist faculty and students in locating short-term investigations at CAP sites.

- A retractable, 22.1m, 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_2, 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 weather 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 five marked creosote bush shrubs for stem elongation measurements and permanently marked subplots for biomass collection and surveys of community composition of annual plants.
- For measurement of atmospheric deposition, CAP maintains resin-based bulk deposition and throughfall collectors at six of the DesFert sites.
- At one urban DesFert desert remnant site and one outlying DesFert desert park site, micrometeorological stations measure temperature, relative humidity, wind speed and direction, precipitation, and solar radiation.
- Atmospheric deposition work also includes deposition collectors (wet/dry collector, resin-based bulk collector) on the roof of the Life Sciences A building at 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.
- A Eureka Manta+35 multiprobe datasonde is deployed in Tempe Town Lake with sensors to measure temperature, conductivity, turbidity, pH, optical dissolved oxygen, chlorophyll A, DOC concentration, and DOC fluorescence.
- Seven Drought-Net rainout shelters have been installed at each of two outlying DesFert sites (one west, one east) with seven permanently marked control plots also at each site.

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 and Innovation 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 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 impressive amount of research funding leveraged from CAP:

    - $250K during this reporting period, bringing the total to $47 million in grant funding since December 2016 (inception of this grant cycle).
    - A total of $130 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.

Impact on Information Resources

Data Resources

The CAP LTER added seven new or revised datasets to its publicly available data holdings during 2022. These new additions bring the total number of project datasets archived with the Environmental Data Initiative (EDI) to 254. New or updates to existing datasets of note include (1) several datasets that reflect CAP's growing number of projects that employ camera-trapping techniques to study patterns and processes of urban megafauna, and (2) a revamped and greatly improved presentation of CAP's long-term monitoring of atmospheric deposition data. All CAP LTER dataset metadata are encoded in the XML-based Ecological Metadata Language (EML) schema, with data and metadata available through the CAP LTER data catalog on the project website, the EDI data portal, and DataONE.

Infrastructure

The CAP LTER Information Manager strives always to improve the presentation, utility, and management of CAP LTER information resources. Notable improvements for this reporting period include:

- A combination of new and updated field- (tablets) and web-based data-entry applications that improve the accuracy and efficiency of data acquisition by CAP LTER field and lab technicians.

- Continued improvement of a suite of R-based tools that aid the development of EML metadata used to describe research data. In particular, many new features capitalize on the growing number of API services offered by the EDI. Though developed by and for the CAP LTER, these tools are generalizable and publicly available.

Network Participation

- The CAP LTER is committed to making a strong contribution to informatics within the LTER Network and the ecological sciences generally. The CAP LTER Information Manager (Stevan Earl) participates in all Network information management meetings and activities, participates in and presents at numerous scientific conferences, and contributes to scientific- and informatics-focused publications. This year, Earl rotated off the LTER Information Management Committee (IMC) Executive Committee after having served a five-year term, the last three as Co-Chair. He is a contributor to numerous working groups, including teams focused on (1) improving metadata describing units of measure, (2) assessing the impacts of wildfire on the biogeochemistry of flowing waters in aridlands, (3) developing ontologies to improve the discoverability and interoperability of data pertaining to soils, and (4) developing resources to teach sound and effective data-management skills to students at ASU, including those participating in the CAP LTER program.

Impact on Society beyond Science and Technology

- 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. 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 involving the Arizona Association for Environmental Education, the Arizona Science Teachers Association, the Arizona Environmental Literacy Community of Practice, and the Arizona Department of Education.

- In 2019 CAP received supplemental NSF support for a summer RET program, and based on the success of that we received additional support in 2020 and 2022 for a larger "RET on steroids" program that will continue through Summer 2023. In 2019 and 2020-21 cases we were able to support research experiences for two K-12 teachers, and for three teachers in 2022-23, all from the Roosevelt School District, which serves a lower income, predominantly Hispanic population (97% of the students are minority) in South Phoenix. Notably, Roosevelt School District includes one of our PASS neighborhoods (#U18), where 93% of residents are Mexican/Latino, where the median annual household income is less than $37,000 and where fewer than 4% of residents hold a bachelor's degree or above. The district is also part of the City's South Mountain Village, which is 63% Hispanic and 15% Black. Our RET educators represent each of these demographic groups.

- 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. Rio Reimagined is a partnership among municipalities and Indigenous communities along the Salt River whose goal is to revitalize the river and it's watershed through environmental restoration coupled with 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 the data that will be needed for urban ecological planning and design along the Salt River.

- Cool Cities, a CAP LTER, Healthy Urban Environments and Robert Wood Johnson Foundation funded-project with Braden Kay (PI), Paul Coseo (Co-PI), Katja Brundiers (Co-I), Carlos Casanova (Co-I), Jenni Vanos (Co-I) Ariane Middel (Co-I), David Hondula (Co-I), and others, is a partnership with the City of Tempe to assess urban infrastructure's impact on thermal comfort and work toward creating cooler infrastructure in Tempe, AZ .

- The Phoenix Zoo project is a designed experiment with the City of Phoenix and the Phoenix Zoo to create a more sustainable parking lot with potential for work on the Zoo campus in future phases. This is supported by a collaboration between CAP, HUE, and UREx SRN including CAP members Ray Quay, Ariane Middel, Kristian Kelley, Allyce Hargrove, Paul Coseo, and others. Social and meteorological data collection began in summer 2020.

PUBLICATIONS

Students in **Bold**

Journal Articles

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Gaiser, E. E., J. S. Kominoski, D. M. McKnight, C. A. Bahlai, C. Cheng, S. Record, W. M. Wollheim, K. R. Christianson, M. R. Downs, P. A. Hawman, S. J. Holbrook, A. Kumar, D. R. Mishra, N. P. Molotch, R. B. Primack, A. Rassweiler, R. J. Schmitt and L. A. Sutter. 2022. Long-term ecological research and the COVID-19 anthropause: A window to understanding social–ecological disturbance. *Ecosphere* 13(4):e4019. DOI: 10.1002/ecs2.4019. (link)

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McGraw, K. J., V. Aguiar de Souza Penha, **D. J. Drake**, S. Kraberger and A. Varsani. 2022. Poxvirus infection in house finches (*Haemorhous mexicanus*): Genome sequence analysis and

patterns of infection in wild birds. *Tramsbpimdary amd Emerging Diseases* 69(5): e2318-e2328. DOI: 10.1111/tbed.14575. (link)

McPhearson, P. T., E. M. Cook, M. Berbés-Blázquez, C. Cheng, N. B. Grimm, E. Andersson, O. Barbosa, D. G. Chandler, H. Chang, M. V. Chester, D. L. Childers, S. R. Elser, N. Frantzeskaki, Z. J. Grabowski, P. M. Groffman, R. L. Hale, D. M. Iwaniec, N. Kabisch, C. Kennedy, S. A. Markolf, M. Matsler, L. McPhillips, T. R. Miller, T. A. Munoz-Erickson, E. J. Rosi and T. G. Troxler. 2022. A social-ecological-technological systems framework for urban ecosystem services. *One Earth* 5(5):505-518. DOI: 10.1016/j.oneear.2022.04.007. (link)

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Dissertations

Elser, S. R. 2022. Ecosystem Services from Urban Ecological Infrastructure: Perceptions, Performance, and Priorities for Climate Resilient Cities. PhD Dissertation. Arizona State University. (link)