CAP LTER IV 2020 ANNUAL REPORT TO THE NATIONAL SCIENCE FOUNDATION

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Report to the National Science Foundation

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CAP LTER IV
2020 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 2020

Long-term observations and experimentation: **Ecosystem Response to Urban Atmospheric Deposition (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 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* (creosote) leaves collected for nutrient analysis—spring and fall at nine sites.
- Percent composition of annuals recorded for subplots; aboveground material harvested from different subplots, and aboveground dry mass determined for harvested material—spring at nine sites. In spring 2020, due to the pandemic, percent composition of annuals was completed at only two sites and aboveground material was not harvested at all.

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 with a citizen science partner, the McDowell Sonoran Conservancy.
- 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. CAP LTER sites were not collected during the spring 2020 quarter due to the pandemic.
- 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 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. Spring season sampling was truncated in 2020 due to the pandemic.

Long-term observations: Bird Monitoring—Salt River Biodiversity Project

- 7 sites monitored quarterly. Spring 2020 surveys were not completed due to the pandemic.
- 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. Spring 2020 surveys were not completed due to the pandemic.
- 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. Collection ceased April to June 2020 due to pandemic.

Long-term observations: Stormwater

- Water collected from ISCO stormwater samplers at three locations along Indian Bend Wash (IBW): one long-term site at the southern outflow of IBW and at two sites further upstream in the IBW watershed. Water is also collected from five ISCOs in stormwater bioswales at the Orange Mall at ASU Tempe campus.
- 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: Regional Drinking Water Quality Analysis

- Water collected monthly at 5 locations in major influent reservoir systems.
- Water analyzed in lab for nutrients, major cations and anions, pH, temperature, specific conductance, DOC, taste and odor compounds, and particulate matter.
- Sampling ceased in March due to pandemic.

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

- Bi-monthly field visits. March 2020 sampling was canceled due to pandemic.
- 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 CDOM/*f*DOM at 30-minute intervals. Datasonde will eventually replace the need for water sample collection and analysis.
- Due to the pandemic and other events, the datasonde was out of the water from March 10 until October 8.

Long-term observations: Charismatic Megafauna in Cities

- Wildlife cameras deployed at 50 sites in CAP study area in proximity to ESCA, DesFert, and Salt River sites. Data are downloaded monthly. This pilot project was concluded in August 2020. With the pilot project completed, the cameras will now be relocated to 35 urban, peri-urban, and remote sites along the Salt River. There are also plans to deploy 20 camera traps in urban parks that are strategically located in a range of neighborhoods across the valley.
- Bat monitors deployed at the same 50 sites for five continuous nights each quarter. This project was concluded at the end of 2019.

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 situated at DesFert sites, one west and one east.
- Project is in collaboration with researchers from Sevilleta LTER.

- Tim Ohlert, a graduate student at the University of New Mexico who is in charge of the project, was able to finish his annual botanical survey before the pandemic shut down ASU in March.

SIGNIFICANT RESULTS (LISTED BY INTERDISCIPLINARY RESEARCH TEAM, OR IRT)

Adapting to City Life

New Project: Drivers of Community Ecology (Andrade et al. 2020)

- We reviewed the literature connecting community ecology and social science theory to better understand urban biodiversity. The conceptual paper is reported here, and another empirical one is underway.
- Gradients of human investment and facilitated dispersal (people moving organisms) affect the processes by which communities are assembled in cities. Spatial effects that interact with the increased amount of disturbance in cities are expected to cause a large degree of spatial and temporal turnover in community assemblages.

New Project: Species Distribution Models: CAP Birds (Lerman and Warren et al. In Prep)

- We tested the interacting effects of seasonality, temperature, and human-provided resource availability on abundances of three focal bird species that occupy residential neighborhoods in the CAP LTER study system. We developed a series of species distribution models using 2015 – 2016 bird abundance data generated by Phoenix Area Social Survey (PASS) bird censuses, as well as data on food and water as self-reported by residents in the 2017 PASS survey and collected in the 2015 Ecological Survey of Central Arizona (ESCA).
- We predicted that if there is a resource buffer effect on a species, then there will be a greater influence of human-provided resources on species distributions in the spring than in the winter within the same neighborhood, and in neighborhoods with higher temperatures than in neighborhoods with lower temperatures. We plan to apply these methods to an additional seven species with varying life history traits, and we predict that species life history traits will influence the presence of a buffer effect.

Climate and Heat

New Project: Heat-health survey meta-analysis (Wright et al. In Prep)

- Analysis of heat and climate questions from PASS 2016; comparisons with PASS 2011 and other regional surveys.
- Correlates with self-reported heat illness are largely consistent between different surveys, especially measures of risk perception, indoor thermal comfort, and air conditioning cost constraints. Age is negatively correlated with likelihood of self-reported heat illness, which differs from regional findings for heat-related mortality.

New Project: Nature's Cooling Systems – Neighborhood-based Heat Action Planning (Guaradaro et al. In Prep)

- Work with underserved communities in the Phoenix Metro Area to develop plans for cooling neighborhoods and protecting people during hot weather.
- Four overarching strategic themes emerged across all three neighborhoods: advocate & educate; improve comfort/ability to cope; improve safety; build capacity. These themes signal that there are serious heat safety challenges in residents' day-to-day lives and that community, business, and decision-making sectors need to address those challenges.

Governance and Institutions

New Project: Climate Resilience / Governance Survey (Muñoz-Erickson et al. In Prep)

- We are analyzing a climate resilience-governance survey of the major actors (organizations/groups) that are involved in climate resilience and adaptation governance in the city, including government agencies, scientists, and civic and private sector groups. With survey data we are able to develop profiles for each of the organizations, including their priorities and visions for addressing climate resilience, their capacities and roles in resilience governance, and their knowledge systems and expertise.
- The results highlight that, in general across the nine cities, framings converge with more conservative definitions of resilience as the ability to resist, cope with, or bounce back to previous conditions, whereas sustainability, equity, and social- ecological-technological systems (SETS) perspectives are rarely associated with resilience. There are noticeable differences across cities and governance actors that suggest geographic and political variations in the way resilience is conceptualized. We are unpacking these differences and discussing their implications for resilience research and practice moving forward.

New Project: Multi-Level and Cross-Scale Governance of Social-Ecological Systems (York et al. In Review)

- To understand the nature of multi-level and cross-scale governance of social-ecological systems, this team is advancing a theoretical and empirical research agenda focused on climate change and water resources.
- Multi-level and cross-scale governance has substantial challenges associated with coordination and collective action (York et al. under review), which may be exacerbated by the coupled nature of the social-ecological system (York et al. 2019).

Parks and Rivers

New Project: Rattlesnake Removals in Phoenix (Bateman et al. In Prep)

- Using data collected by a local business, Rattlesnake Solutions, we looked at how social-ecological factors (from PASS and Census data) related to locations where snakes were removed.
- People hire services to remove thousands of snakes a year in Phoenix. The most common species removed is the Western Diamondback Rattlesnake and the species is

also the most common. Snakes were removed from high income, high education, and Latinx neighborhoods. More snakes were removed from new home construction and from homes close to parks. Peoples' opinions on whether snakes are a problem was not related to the number of snakes removed from the area.

Residential Landscapes and Neighborhoods

New Project: Who is Abuzz about Bees? (Larson et al. 2020)

- We analyzed PASS 2017 data to capture attitudes toward pollinators, especially bees. This was done in conjunction with the School of Sustainability's new Sustainability Undergraduate Research Experiences program for faculty-mentored undergraduate research. This program was developed and directed by K.L. Larson in the 2019-20 academic year, and with a CAP REU in the summer of 2019.
- Results revealed that, on average, people in Phoenix hold neutral to somewhat negative attitudes toward bees. However, they largely do not perceive bees to be a problem at their local places of residence. Attitudinal factors, as well as pet ownership, significantly influence whether residents like bees or not. Latinx/Hispanic residents and women also tend to have relatively negative attitudes toward bees.

Scenarios and Futures

New Project: Resilience Equity Sustainability Qualitative (RESQ) Multi-Criteria Assessment (Berbés-Blázquez et al. In Prep)

- Analysis of the village and regional scenarios using a qualitative tool to assess resilience, equity, and sustainability of future scenario visions.
- We developed a framework for characterizing resilience, equity, and sustainability for alternative scenario visions. We then applied the framework to analyze scenario visions created in participatory workshops in Phoenix, AZ. Our analysis allows us to compare not just alternative visions, but also key pathways (and potential obstacles) toward stated future goals, as well as implicit and explicit tradeoffs. We found out that in general, regional visions emphasize sustainability outcomes whereas local visions are focused on gaining a political voice and representation.

Urban Design

New Project: Cool Kids, Cool Places, Cool Futures: Youth-driven, Arts-enhanced, and Community-based approach for equitable urban cooling and emergency management (Coseo et al. In Progress)

- In November 2020, the City of Tempe is launching this Climate Action project which organizes middle and high school youth into Escalante and Gilliland neighborhood youth councils for climate action on extreme heat, health, and equity. The two youth councils will partner with international partners in London, United Kingdom and Wellington, New Zealand with local support of artists, City staff, and ASU researchers in equity, heat, health, emergency management, and resilience. The ultimate goal of Cool Kids project is to transform a culture of individual resilience to extreme heat into a justice-oriented community resilience imperative for a public cooling utility, which is

structured around indigenous and communities of color knowledge, lived experience, and perspectives of heat.
- We are in early stages of strategizing with our Equity Team on creating an equity assessment and onboarding procedure for the project. We are in the process of creating an equity self-assessment that will then include a bundle of equity trainings everyone in the project will be required to take before working in the project. This 30-month award (Nov 2020 – April 2023) is an exciting opportunity to take our Community-City-University partnership to a deeper level in two neighborhoods in Tempe with an eye on regional transformation for thermal justice.

Water and Fluxes

New Project: Desert Fertilization (Wheeler et al. In Revision; Shaw et al. In Prep)

- We synthesized the response of winter annual plants to fertilization across the fifteen DesFert sites. This included analysis of species composition and biomass, both sampled annually in sub-plots of the DesFert plots.
- We found that N fertilization and low precipitation decrease winter annual plant diversity, with lasting effects of low precipitation on subsequent years (Wheeler et al. in revision). Annual plant biomass responded strongly to fertilization, especially during years with measureable winter rainfall (Shaw et al. in preparation).

New Project: Indian Bend Wash (McPhillips et al. 2019)

- We continue to capture water samples from each event that triggers the automatic samplers at three locations on Indian Bend Wash (IBW), and we analyze these samples for a suite of chemical constituents. We are analyzing the data to determine how stormwater chemistry varies within events, among events, and across locations in the watershed. We use these comparisons to determine: 1) the primary source of water and materials transported by stormwater, and 2) factors controlling these exports, such as antecedent weather, event precipitation, catchment characteristics, and human activity.
- To date we have sampled more than 90 events, of which we sampled through the hydrograph for >20. Hydrologic data were included in an analysis of flashiness of urban vs. desert streams, which showed that arid land urban streams are less flashy than their desert counterparts (McPhillips et al. 2020). Ongoing analyses of chemical data indicate that overall solute export is driven consistently by discharge, but export patterns (hysteresis, timing of delivery) within storms and across chemical species show complex patterns influenced by catchment land cover and storm features.

KEY OUTCOMES OR OTHER ACHIEVEMENTS

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

- In 2020, we have published 34 peer-reviewed journal articles with 20 more in review and one in press. In addition, we have published one book chapter, with three chapters in press.

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

- We have leveraged $20.5 million in grant funding since December 2016 (inception of CAP IV) for a total of over $103 million since CAP's inception in 1997.
- Leveraged grants during this reporting period include:
    - Amber Wutich was awarded $3.5 million as a NSF GCR grant to fund the study of the coevolution of social and physical infrastructure and improved access to clean water in informal water sharing systems.
    - Nancy Grimm was awarded $196,000 as a NSF RAPID grant to study indirect impacts of a novel wildfire on a well-studied desert stream: connectivity, carbon, and communities.
    - Two LTER supplements totaling almost $100,000:
        - A Research Experience for Teachers (RET) supplement that expands on our 2019 RET supplement, and focuses on heat and air pollution.
        - A Critical infrastructure supplement, which allowed us to replace one of our aging 4wd vehicles.

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

- In 2020, students were authors on 11 publications and were first authors on three of these.
- Ph.D. degrees were granted to three CAP graduate students in during this reporting period: Riley Andrade, Michelle Stuhlmacher, and Megan Wheeler.

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 quality of all major surface 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 Climate & Heat research and broader impacts, in coordination with the Urban Design IRT. 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 the 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 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. Due to the pandemic, many training opportunities were either postponed, cancelled, or virtual. For example, CAP Program Manager received the Arizona State University Global Advocacy Program certificate after finished that training in early 2020. 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 2020, CAP partnered with the Urban Resilience to Extremes Sustainability Research Network SRN (UREx) to continue our Integrated Summer Research Experience for Undergraduates (REU) program that began in 2016. This brought eight REU 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. Due to pandemic restrictions at Arizona State University, these seminars were held virtually. We involved graduate students in these sessions when possible to promote near-peer mentoring, learning, and engagement.

- CAP Student Representatives Marina Lauck and Jeffrey Haight continued to build and develop the CAP LTER Student Group. They have organized multiple events with the goal of increasing networking opportunities for ASU students interested in CAP LTER-related work. This group is already planning events for 2021, including meetings at other ASU locations, such as the Polytechnic and West campuses, a workshop dedicated to encouraging interdisciplinary collaboration with the CAP student community, and reviving a regular CAP research seminar series that foundered when ASU shut down in Spring 2020.

- 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 the Tres Rios 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. All field work at Tres Rios in the 10.5 years of the WEEL lab has been done by student volunteers. In 2018 – 2019 the WEEL hosted a Chinese Academy of

Sciences 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, the American Geophysical Union's annual meeting, as well as other conferences and events (e.g., AAG). Other conferences and events where CAP researchers presented their findings in 2020 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 January 2020 attracted over 100 participants, included 43 poster presenters, and we anticipate similar attendance and participation in May 2021.

DISSEMINATION

- In 2020, CAP students and scientists published a total of 34 peer-reviewed journal articles with 20 more in review and one 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 Annals of the American Association of Geographers, 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 posted a total of 2505 Tweets and have 1678 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 43 poster presentations at the January 2020 CAP All Scientists Meeting, CAP scientists and students have made 45 other conference 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 23rd ASM on May 7, 2021. 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 both locally and remotely.

- During 2019-2020, CAP scientists were included in multiple local and national news items, including:

    - Several members of the Climate and Heat IRT, including David Hondula, Ariane Middel, and Jenni Vanos have been quoted or interviewed in The NY Times,

Washington Post, The Arizona Republic, NPR, and National Geographic as well as local ABC and FOX affiliates.
  - Sara Meerow was quoted in the Boston Globe's piece, "When it comes to battling climate change and sea rise, what does it mean to be 'resilient'?
  - Becky Ball and David Sailor were mentioned in an article in The State Press on the new ASU Carbon Sink and Learning Forest at ASU West Campus.

Plans for 2021

- Now that the remaining four years of CAP IV funding (2018-2022) has been secured, we will continue CAP IV research and educational and outreach activities that began during this funding cycle.
- The next CAP LTER All Scientists Meeting and Poster Symposium will be held at ASU Skysong on May 7, 2021.
- CAP LTER will be hosting the 2021 LTER Science Council Meeting from May 16-18 at Arizona State University's Memorial Union, and will include a field trip to CAP research sites. CAP was originally set to host the 2020 meeting, but due to pandemic restrictions, it was moved online.
- Our new RET educators will continue their collaborative research with scientists from our Climate and Heat IRT, where they are focusing on extreme heat in school playgrounds, how the microclimate of playgrounds affects the health and wellbeing of children, and how UEI may be used to mitigate playground climate extremes while solving other health-related schoolyard challenges. These collaborations will continue through the 2020 – 21 academic year and into summer 2021.
- The CAP LTER Justice, Equity, Diversity, and Inclusion committee will continue to hold regular meetings and work toward the goals outlined in the Impacts on in Human Resources section.
- We have already begun to ramp up preparations for our March 2022 renewal proposal.
- We will be incorporating recommendations from our October 2020 site review into ongoing operations and our future plans/proposal once the review team's report has been made available to us.
- New CAP Education Manager Monique Franco is planning an update and revamp of our Ecology Explorers materials and website.

IMPACTS

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 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 605 journal articles, 11 books, and 109 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., Marzluff et al. 2008; McDonnell et al. 2009, Gaston 2010; Douglas et al. 2011; Lepczyk and Warren 2012; Niemela et al. 2012; Elmqvist et al. 2013; 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; Forman 2014; Douglas and James 2015; Francis, Millington, and Chadwich 2016; 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 inherently interdisciplinary, 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. As such, 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.

During the 2019-2020 reporting period, we had over 50 faculty members, 26 graduate student researchers, and 49 undergraduate researchers actively engaged in CAP research from 12 different academic units/disciplines at ASU and at six institutions beyond ASU: University of Massachusetts-Amherst, Bowling Green State University, Georgia State University, University of Oklahoma, Barnard College, Pace University, and Northern Arizona University.

Impact on Development of Human Resources

- In 2020, Elizabeth Cook and Quincy Stewart 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 DEI 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, in Year 1 the CAP DEI Committee will:
    - Review the existing DEI initiatives, resources, and community composition within CAP and ASU in order to establish collaborations at ASU and to serve as a baseline for CAP DEI initiatives;

- establish both short-term (1 year) and long-term (3+ year) timelines to meet the DEI Committee objectives; and
- Develop the existing CAP Diversity Statement (2018) into a broader and stronger CAP DEI Social Contract.

The CAP Social Contract will include explicit short- and long-term action items, mechanisms, and timelines to ensure we actively work toward meeting our DEI goals. The DEI 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 DEI work, and the goals and initiatives will continue to evolve and be refined. The DEI 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 2020 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:

  - Kerrala Chandran: "UEI Hydrological Performance Evaluation." (Mentor: Chingwen Cheng).
  - Dave Debacker, Matt Millado, and Finnley Rickman: "The Future of Urban Ecosystem Services." (Mentors: Marta Berbes-Blazquez, Stephen Elser, and Nancy Grimm).
  - Kathryn DePinto: "Health and nutrition in the city: Testing principles of self-medication and personalized nutrition in urban and rural birds." (Mentor: Kevin McGraw).

- These four students bring the total number of REU students supported under NSF funding since 1998 to 76. Many of these students have gone onto graduate school in traditional STEM disciplines and the in new field of sustainability, and others have entered STEM-related careers.

- CAP LTER, in partnership with the UREx SRN, held our Integrated Summer REU program for the fifth straight summer. This program brings together a critical mass of students—eight in total for 2020 (5 women, 3 men), —to share research across traditional academic boundaries. This year's group also included REU students being mentored by other CAP researchers through separate NSF funding, which added further diversity to the group. The eight participating students connected 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 2021 REU program.

- In 2020, our CAP Grad Grants Program competitively granted $27,775 to support the research of seven graduate students. The impact of our Grad Grants Program goes beyond money for research. Previous recipients of graduate 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. This year's Grad Grants recipients were:

    - Brittany Allen: "Urban Heat Island Effect and Rodent Body Condition."
        - Amount: $4,000
        - Mentor: Heather Bateman
    - Aaron Grade: "Do human-provided resources buffer the effects of drought on bird abundances in residential neighborhoods?"
        - Amount: $4,000
        - Mentors: Susannah Lerman and Paige Warren
    - Florian Schneider: "Project MaRTiny: Data analysis and validation of low-cost sensors measuring thermal conditions and space use."
        - Amount: $3,927
        - Mentor: Ariane Middel
    - Kayla Tarr: "Long-Term Monitoring of Urban Ecological Infrastructure for Stormwater Management at ASU."
        - Amount: $4,000
        - Mentor: Dan Childers
    - Amanda Trakas: "Where the Water Flows: Plant Selection for Rapid Infiltration in Biodetention Basins in Maricopa County."
        - Amount: $3,980
        - Mentors: Chingwen Cheng and Paul Coseo
    - Eric Vahid: "The Impacts of Residential Flood Irrigation and Yard Management on Gaseous Nitrogen Losses in the Phoenix Metro Area, AZ."
        - Amount: $3,868
        - Mentor: Dan Childers
    - Emily Webb: "Life-history variation in carotenoid profiles of an urban songbird."
        - Amount: $4,000
        - Mentor: Kevin McGraw

- 21 teachers were trained by our Ecology Explorers K-12 program to integrate learning about our local ecosystem into their district curricula to meet the new Arizona State Standards. Four teachers provided evidence of implementing Ecology Explorers curriculum into their classrooms this year. Ecology Explorers lessons and approaches were used in a professional development workshop for teachers in the Arizona Science Center's STEM Educators professional development program.

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 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 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 Research Specialists 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. Our field infrastructure includes:

- 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 urban 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 as well as five ISCOs in the Orange Mall bioswales on ASU's Tempe campus.
- 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 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 Knowledge Enterprise (KE, which is ASU's sponsored research office) 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:

    - $8.1 million during this reporting period, bringing the total to $20.5 million in grant funding since December 2016 (inception of this grant cycle).
    - A total of $103.8 million since CAP's inception in 1997.

- The CAP information management system is an exemplar of a data management across the LTER Network; it now encompasses all sustainability research efforts at ASU.

- An 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.

- 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 2020, and more planned in 2020.

Impact on Information Resources

The CAP LTER added eighteen new datasets to its publicly available data holdings during the reporting year, bringing the total number of project datasets archived with the Environmental Data Initiative (EDI) to 218. New datasets of note feature time-series (2010-2017) of Normalized Difference Vegetation Index (NDVI) and Soil-Adjusted Vegetation Index (SAVI) data for the entire central Arizona region. These data were constructed by a CAP LTER graduate student, Michelle Stuhlmacher, with funding she received from the project. The data are novel in that Michelle sought input from the entire CAP LTER community regarding the development of the data with the goal of constructing data resources that would be of the greatest utility to CAP LTER investigators generally. In addition to new data contributions, the CAP LTER updated six existing datasets with new information and/or richer metadata. All CAP LTER metadata are encoded in the XML-based Ecological Metadata Language (EML), with data and metadata available through the CAP LTER data catalog on our website, the EDI data portal, and DataONE.

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

- The current (S. Earl) and former (P. Tarrant) CAP LTER Information Managers taught a course on research data management at ASU in spring 2019. This course provided graduate students, including students actively involved with the CAP LTER, with a greater awareness of the importance of data curation, and the skills and tools needed to more effectively manage their research data.
- CAP LTER is integrating new features available in Ecological Metadata Language version 2.2.0 to provide richer metadata for its datasets.
- CAP LTER deployed new data-entry applications for several long-term monitoring programs to improve the efficacy of data entry, storage, and retrieval.

The CAP LTER is committed to making a strong contribution to informatics within the LTER Network and the ecological sciences in general. The CAP LTER Information Manager (S. Earl) participates in all network information meetings and activities, serves as co-chair of the LTER Information Management Executive Committee (IM Exec), contributes to community-wide efforts (e.g., is a contributing author of Ecological Metadata Language version 2.2.0), participates in and presents at numerous scientific conferences, and contributes to scientific- and informatics-focused publications. In addition, though past its official end date, S. Earl remains actively involved in the continued workings of a LTER Synthesis Working Group addressing soil organic matter dynamics.

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 for a larger "RET on steroids" program that will continue through Summer 2021. In both cases we were able to support research experiences for two K-12 teachers, and both cohorts are from Roosevelt School District, which serves a lower income, predominantly Hispanic population (97% of the students are minority). 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 (Larson et al. 2017). The district is also part of the City's South Mountain Village, which is 63% Hispanic and 15% Black. Our four RET educators represent each of these demographic groups. The 2019 RET educators were paired with scientists and students from our Adapting to City Life IRT. Their collaborative summer research projects involved research on how birds adapt to the challenges of urban life (e.g. various stressors) or take advantage of

resource subsidies that close habitation with humans may provide (e.g. bird feeders, water baths). Our new RET educators began their collaborative research with scientists from our Climate and Heat IRT, where they are focusing on extreme heat in school playgrounds, how the microclimate of playgrounds affects the health and wellbeing of children, and how UEI may be used to mitigate playground climate extremes while solving other health-related schoolyard challenges. These collaborations will continue through the 2020 – 21 academic year and into summer 2021.

- 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 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 CAZCA, the Arizona Game and Fish Department, and the Flood Control District of Maricopa County to envision data and knowledge needed for urban ecological planning and design along the Salt River.

PUBLICATIONS

Students in **Bold**

Journal Articles

Brown, J. A., K. L. Larson, S. B. Lerman, D. L. Childers, **R. Andrade**, H. L. Bateman, S. J. Hall, P. S. Warren and A. M. York. 2020. Influences of environmental and social factors on perceived bio-cultural services and disservices. *Frontiers in Ecology and Evolution* 8:569730. DOI: 10.3389/fevo.2020.569730. (link)

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Hoover, D. L., B. Bestelmeyer, N. B. Grimm, T. E. Huxman, S. C. Reed, O. E. Sala, T. R. Seastedt, H. Wilmer and S. Ferrenberg. 2020. Traversing the wasteland: A framework for assessing ecological threats to drylands. *BioScience* 70(1):35-47. DOI: 10.1093/biosci/biz126. (link)

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Sepp, T., K. J. McGraw and M. Giraudeau. 2020. Urban sexual selection. Pp. Chapter 14 In: Szulkin, M., J. Munshi-South and A. Charmantier eds., *Urban Evolutionary Biology*. Oxford University Press. ISBN: 9780198836841. (link)

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