CAP LTER IV 2019 ANNUAL REPORT TO THE NATIONAL SCIENCE FOUNDATION

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Report to the National Science Foundation

Contents

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, experiments, 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 2019

Long-term observations: Phoenix Area Social Survey (PASS)

- Every five years (2001, 2006, 2011, and 2017), the PASS research team surveys households in selected neighborhoods in the metropolitan Phoenix area to better understand people's perceptions, values, and behaviors on several key environmental issues, including water conservation, urban growth, air pollution, land conservation, biodiversity and urban climate change, as well as their perceptions about neighborhood characteristics and attributes.
- The 2017 survey was redesigned to focus on 12 neighborhoods co-located with respect to a wide variety of CAP monitoring sites (Ecological Survey of Central Arizona sites, the Salt River, Tempe Town Lake, Indian Bend Wash, urban mountain parks, and South Phoenix) and to include 65 respondents per neighborhood in contrast to 20 respondents per neighborhood in 2006 and 2011.
- This redesign allows the PASS research team to conduct more robust analyses of the data and facilitates more integrated social-ecological analysis of the neighborhoods.
- The next PASS will be conducted in 2021 to coincide with the next ESCA (see below).

Long-term observations: Ecological Survey of Central Arizona (ESCA) (formerly known as Survey 200)

- The Ecological Survey of Central Arizona (ESCA) is an extensive field survey and integrated inventory designed to capture key ecological indicators of the CAP LTER study area consisting of the urbanized, suburbanized, and agricultural areas of metropolitan Phoenix, and the surrounding Sonoran desert.

- Objectives of the survey are to (1) characterize patches in terms of key biotic, physical, and chemical variables, and (2) examine relationships among land use, general plant diversity, native plant diversity, plant biovolume, soil nutrient status, and social-economic indices along an indirect urban gradient.
- The survey is conducted every five years (1999, 2005, 2010, and 2015 so far) at approximately 200 sample plots (30m x 30m) that were located randomly using a tessellation-stratified dual-density sampling design.
- The next ESCA is currently in the planning phase and will commence in early 2021 to coincide with the next PASS.

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, 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* (creosote) leaves collected for CHN 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.

Long-term observations: Ground-dwelling 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 after 72 hours.
- 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.

Long-term observations: Bird Monitoring—Salt River Biodiversity Project (Parks and Rivers)

- 7 sites monitored quarterly.
- Each site sampled 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 (Parks and Rivers)

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

Long-term observations: Atmospheric Deposition

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

Long-term observations: Stormwater

- Water collected using 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.
- One location along the Salt River where stormwater drains create “accidental wetlands.”
- Discrete, time-weighted sampling of stormwater runoff.
- 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 water supply reservoirs on the Salt and Verde Rivers.
- 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

- Eddy flux 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 is streamed daily. 10 Hz data are downloaded monthly.

Long-term observations: Microclimate Towers

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

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

- CAP LTER hosts this system on eighth-floor roof of a building at Arizona State University.
- Weather station provides real-time weather observations for 27 parameters, including temperature, relative humidity (dew point calculated), barometric pressure, wind speed and direction, and precipitation.
- 360-degree weather camera provides weather-related photos to Earth Networks website and local news station.
- Picarro greenhouse gas analyzer provides real-time measurements of carbon dioxide and methane.

Long-term observations: Tres Rios Constructed Wetlands

- Bi-monthly field visits.
- Measurements and samples are taken along two gradients representing the two hydraulic pathways in the wetland: 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.
- A Eureka Manta+35 multiprobe datasonde has been deployed in Tempe Town Lake since 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 50 sites across the 6400 km^2 CAP study area in proximity to ESCA, DesFert, and Salt River sites. Data are downloaded monthly.
- Bat monitors deployed at the same 50 sites for five consecutive nights each quarter.

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 and methods are identical to numerous Drought-Net sites from around the world.

SIGNIFICANT RESULTS (LISTED BY INTERDISCIPLINARY RESEARCH TEAM)

Adapting to City Life

Project: Urban-rural differences in sexual selection (Sepp et al. In Press)

- Urban increases in animal population density may weaken sexual selection, due to increases in mate availability and decreased costs in mate assessment.

Project: Responsiveness of urban and rural house finches to novel environmental stimuli (Weaver et al. In Press)

- Rural birds responded more strongly to novel noises than did urban birds, but urban and rural birds did not differ in their responsiveness to other novel environmental stimuli.

Project: Evaluating the effects of urbanization on avian health and abundance near anthropogenic food sources (Sweazea et al. in prep)

- Assessment of the relationship between land use and cover types with the morphology and nutritional physiology of wild quail captured from urban and rural locations.
- Using mapping approaches to determine whether avian abundance and diversity are related to the presence of anthropogenic food sources in the Phoenix Metropolitan area.
- Gambel's quail captured from urbanized environments are larger and have higher circulating lipids compared to quail captured from rural areas.
- Preliminary findings suggest no relationship between avian abundance and diversity with specific anthropogenic food sources (restaurants, cafeterias, etc.). Ongoing analyses are underway to assess

potential relationships between abundance and diversity with respect to access to any anthropogenic nutrition source including waste and water.

Climate and Heat

Project: Heat-Health Survey Meta-Analysis (Hondula 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.

Project: Impact of 3D Urban Form on Land Surface Temperature (LST) (Zhang et al. 2019)

- This study compares and integrates novel spherical land-cover fractions derived from Google Street View with conventional planar land-cover fractions in estimating daytime and nighttime LST variations in the Phoenix metropolitan area.
- The GSV spherical fractions provide better LST estimates than the planar land-cover fractions, because they capture the multi-layer tree crown and vertical wall influences that are missing from the birds-eye view imagery. Street View and spatial regression (GWR) approaches improve the specificity of LST identified by neighborhoods in Phoenix metro-area by accounting for shading.

Governance and Institutions

Project: Rio Salado Redevelopment (Stuhlmacher et al. in review)

- Utilization of CAP datasets to determine the land system architecture and ecological impact of the Tempe Town Lake redevelopment.
- Comparison of environmental outcomes for sites with different design intentions. Few design differences were unique enough to result in divergent outcomes. The recreational and flood control goals at the Rio Salado were the exception and this resulted in a different bird community and surface temperatures at the Rio Salado.

Parks and Rivers

Project: Biophysical and Socioeconomic Influence on Spatial Patterns of Urban Mammal Communities (CAP Grad Grant) (Haight et al. in progress)

- We are maintaining a network of wildlife cameras in order to assess relationships between patterns of multiple wildlife species and social-ecological components of the urban landscape. A major

objective of this project is to explore links between predicted patterns of wildlife activities and perceived risk of wildlife conflicts within Phoenix Area Social Survey (PASS) neighborhoods.

Residential Landscapes and Neighborhoods

Project: Attitudes toward the Desert (Andrade et al. 2019)

- Desert attitudes are spatially clustered throughout neighborhoods. Positive views of the desert are fortified in high-income areas and those near preserved desert parks, whereas negative attitudes are clustered in areas associated with lower socioeconomic status and in neighborhoods with relatively grassy landscaping.

- Negative perceptions toward the desert are stronger among Latino residents and in low-income neighborhoods, where environmental hazards, especially extreme heat, and the perceived risks associated with such hazards are more prominent.

Project: Perceived Ecosystem Services and Disservices (Larson et al. 2019)

- The results highlight patterns in people's views of: desirable and undesirable biota; benefits and risks pertaining to heat and stormwater; recreational and aesthetic values; and societal nuisances and problems.
- Composite survey scales for perceptions of these services and disservices were created for future research, along with omnibus scales for perceptions of services and disservices in local urban environments.

Scenarios and Futures

Project: Sustainable Future Scenarios for Phoenix (Regional) (Davidson et al. in revision; Iwaniec et al. in review; Berbés et al. in prep; Sampson et al. in prep; Georgescu et al. in prep)

- Completed website of scenarios, developed scenarios report, completed modeling of regional land cover, climate, and water use based on scenario outputs. Initiated cross-scale comparison of scenarios (Phoenix regional and South Phoenix) as well as cross-city comparisons.

- Participatory workshops over a 3-year period yielded six future scenario visions and additional work analyzing government documents yielded a seventh "strategic" scenario for comparison. Scenarios show contrasts and tradeoffs in water security, heat, and green space based on model output.

Project: South Phoenix Scenarios (Berbés et al. in prep)

- Workshop held in South Phoenix as follow up to first workshop. Participants ranked best strategies for achieving transformative change based on renderings of strategies and using a Q-sort method. We are continuing analysis of the original five scenarios.

- Scenarios have been mapped and used as input to models; a cellular automata model is being used to show visions of future land cover. Qualitative analyses of resilience thinking on the scenario outcomes are compared in a paper in preparation.

Water and Fluxes

Project: Effects of variable inundation patterns on wetland plant communities and nitrogen uptake in the salt river wetlands (Lauck et al. in progress).

- Eight accidental wetland sites along the Salt River representing a gradient of ephemeral to perennial conditions were surveyed for vegetation cover, water availability, and tissue nutrient content for approximately a year.

- Water availability was not uniform across sites and was largely unrelated to rain patterns, confirming this system is driven by urban base flow that varied from site to site. The wetland plant community varied differentially across each site related to water availability. Plant tissue chemistry also varied across sites and over time for each species, suggesting differing capacities for nitrogen retention.

Project: Nutrient and Water Dynamics of Cactus Decomposition (Ball et al. in prep)

- An undergraduate student co-designed and conducted a 'litterbox' decomposition study of two species of cacti (prickly pear and cholla) in the White Tank Moutains, from February 2017 to February 2018. Cactus samples were placed in the field and over 6 collection dates returned to the lab to measure mass loss, and water and nutrient dynamics across one year of decomposition.
- Of the two species, prickly pear decomposes more quickly, losing about 50% of their dry mass over one year, and cholla only 25%. There are small but significant differences in chemistry during their decomposition. Both species represent a significant source of water, carbon, and calcium turnover during decomposition.

Project: Influence of Climate, Plant Communities, and Land-Use on Long-term Patterns of Soil Properties in the CAP LTER Ecosystem. (Ball et al. in prep)

- Results show that land use changes over the past ~100 years have significantly altered SOM, creating a heterogeneous mosaic of soil C across the urban Sonoran desert landscape. Much of this reflects the enhanced water, nutrient, and organic inputs under agricultural and urban land uses.
- Data support our hypothesis that soil properties in deserts vary less over time compared to managed ecosystems that experience human decision-making.
- These land use impacts on SOM have remained fairly constant over the duration of the study, though interestingly SOM in golf courses has decreased over time to become more similar to the other urban land uses.

Project: Desert Fertilization (Wheeler et al. in prep)

- Two years supported little to no growth of annual plants because of extremely low rainfall. In years when rainfall was plentiful, co-limitation by nitrogen and phosphorus was observed. There was no response to enrichment during dry years. Communities in dry years had very low diversity.

KEY OUTCOMES OR OTHER ACHIEVEMENTS

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

- In 2019, we have published 20 peer-reviewed journal articles with 16 in review and five in press. In addition, we have published, one book and three books chapters, with two chapters in press.

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

- We have leveraged $12.4 million in grant funding since December 2016 (inception of this grant cycle) for a total of over $95 million since CAP's inception in 1997.
- Leveraged grants during this reporting period include:
    - Nancy Grimm was awarded $1.03 million through an NSF AccelNet grant to fund Nature-Based Solutions for Urban Resilience in the Anthropocene (NATURA).
    - Several CAP LTER senior personnel, including Mikhail Chester and Senior Personnel Elizabeth Cook and David Iwaniec were awarded $1.3 million for an NSF Growing Convergence Research project titled Social, Ecological, and Technological Infrastructure Systems for Urban Resilience.

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

- In 2019, students were authors on 15 publications and were first authors on six of these.
- Ph.D. degrees were granted to three CAP graduate students in during this reporting period: Amalia Handler, Cyrus Hester, and Nicholas Weller. Two CAP students were also awarded master's degrees: Cameron Boehme and Christopher Sanchez.

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.

TRAINING AND PROFESSIONAL DEVELOPMENT

- CAP's activities in the area of training and professional development are three-fold: 1) We actively promote and encourage training and professional development for faculty, staff, and students; 2) we work with the Julie Ann Wrigley Global Institute of Sustainability, the LTER Network Communication Office, and others to design and deliver training and professional development activities to the CAP community; and 3) we design and deliver training and professional development for various stakeholder groups, including teachers, citizen scientists, and practitioner partners. We detail some of these activities under Impacts on Human Resources.
- We encourage staff to identify training and professional development opportunities that are relevant to their roles and responsibilities in the CAP program. For example, in October Sally Wittlinger, the CAP Site Manager, took part in multiple training workshops hosted by the ASU Commission on the Status of Women. Stevan Earl, the CAP Information Manager, attended the 2019 ESIP Summer Meeting in Tacoma, WA. CAP Education Manger Lisa Herrmann attended a North American Association for Environmental Education Guidelines for Excellence training session in Lexington, KY. 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 2019, CAP partnered with the Urban Resilience to Extremes Sustainability Research Network SRN (UREx), the Urban Water Innovation Network SRN (UWIN), and other urban-focused labs and groups at ASU to continue our Integrated Summer Research Experience for Undergraduates (REU) program that began in 2016. This brought 15 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. We involved graduate students in these sessions when possible to promote near-peer mentoring, learning, and engagement. We plan to continue and possibly expand this program in 2020.
- New 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. These events included a kick-off meeting in which members of the CAP Leadership Team were invited to speak about their research, as well as panel-led CV writing workshop. This group is already planning events for 2020, including meetings at other ASU locations, such as the Polytechnic and West campuses and a workshop dedicated to encouraging interdisciplinary collaboration with the CAP student community.

- 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. All field work at Tres Rios in the eight and a half 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 2019 included The Global Land Program's Open Science Meeting in Bern, Switzerland, and the Annual Meeting of the American Meteorological Society in Phoenix. CAP's annual All Scientist Meeting in January 2019 attracted over 100 participants, included 46 poster presenters, and we anticipate similar attendance and participation in January 2020.

DISSEMINATION

- In 2019, CAP students and scientists published a total of 20 peer-reviewed journal articles with 16 in review and five 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 2208 Tweets and have 1581 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 46 poster presentations at the January 2019 CAP All Scientists Meeting, CAP scientists and students have made 35 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 22nd ASM on January

17, 2020. Our office location in Wrigley Hall, on ASU's campus, includes facilities for large and small meetings, most of which have large screens that allow us to connect with our collaborators remotely.

- During 2018-2019, CAP scientists were included in multiple local and national news items, including:

    - Several members of the Climate and Heat IRT, including Mikhail Chester, David Hondula, Ariane Middel, and Jenni Vanos have been quoted or interviewed in Rolling Stone, The NY Times, NPR, and local Fox and ABC affiliates.

PLANS FOR 2020

- 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.

- Starting in Fall 2018, Interdisciplinary Research Theme (IRT) members began to meet quarterly to discuss research in progress and to collaborate on new research, both within and across IRTs.

- CAP LTER will be hosting the 2020 LTER Science Council Meeting from May 5-7 at Arizona State University's Memorial Union, and will include a field trip to CAP research sites around CAP LTER study area.

- Our next external site review will occur in early October 2020.

IMPACTS

Impact on Principal Discipline

Early on in CAP, we along with our colleagues in the BES were initiators of a conceptual shift in urban ecology from examining ecology *in* the city to a more holistic approach of understanding the ecology *of* the city (Pickett et al. 1997; Grimm et al. 2000). CAP continues to contribute significantly to the theory and practice of urban ecology as evidenced by our publication record. The CAP program has published 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., 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).

Our other major contributions to date are:

- The mismatch between actual and preferred yard grassiness revealed (Wheeler et al. in review) a latent demand for grass in this arid city, which could lead to shifts in water-conserving landscaping if structural constraints on landscaping behavior change. Additionally, the relative importance of structural constraints in determining actual yard grassiness, and the differences in important predictors of yard preferences as opposed to actual yards, suggest that appeals to resident attitudes and values are unlikely to shift yard landscaping.
- Andrade et al. 2019 found that factors shaping attitudes in arid landscapes, including socioeconomic status and social identity, are similar to those that shape attitudes toward urban forests and greenspace in more temperate environments. Understanding attitudes toward the desert can help strengthen the connection between the regional environment and the local community, ultimately encouraging land preservation in arid cities.
- With various means to confirm the validity and reliability of survey measures, Larson et al. 2019 demonstrated a reliable approach to capturing residents' perceptions about whether their local neighborhood environment (as the ecosystem of focus) provides certain positive or negative impacts in metropolitan Phoenix, Arizona.
- Ongoing work by the Scenarios and Futures IRT (Davidson et al. in revision; Iwaniec et al. in review; Berbés et al. in prep; Sampson et al. in prep; Georgescu et al. in prep) brings together an important set of new collaborations with city practitioners and community members - engaging them in scientific thinking and preparing for a long-term future that will include increasingly frequent extreme events and other sustainability challenges.

Impact on Other Disciplines

While CAP remains a fundamentally ecological research program, we are an inherently interdisciplinary endeavor, and thus have contributed to shaping urban ecology as a collaborative 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 2018-2019 reporting period, we had over 50 faculty members, 8 graduate student researchers, and four undergraduate researchers actively engaged in CAP research from 12 different academic units/disciplines at ASU and at six institutions beyond ASU: University of Massachusetts at Amherst,

Bowling Green University, Georgia State University, University of Oklahoma, Barnard College, Pace University, and Northern Arizona University.

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.

Impact on Development of Human Resources

- For our summer 2019 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:

    - Ryan Faust: "The distribution, diversity, and abundance of scorpions in relation to urbanization and landscape characteristics across the CAP LTER study area." (Mentor: Jesse Lewis)
    - Melissa Fleeger: "Residents' Attitudes toward Bees in Metropolitan Phoenix, Arizona." (Mentor: Kelli Larson)
    - Sarah Lindley: "The Effect of Urban Heat Island Temperatures on Microhabitat Preference in Black Widow Spiders." (Mentor: Chad Johnson)
    - Jenna Rosales: "Observing the solar radiation and heat protection factors of tree shade: A novel comparative assessment of desert trees." (Mentor: Jenni Vanos)

- These four students bring the total number of REU students supported under NSF funding since 1998 to 71. 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, in partnership Urban Resilience to Extreme Events Sustainability Research Network (UREx) and UWIN SRN, held our Integrated Summer REU program for the fourth straight summer. This program brings together a critical mass of students—17 in total for 2019 (12 women, 7 men), —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 17 participating students (including two UREx students who connected remotely via Zoom from partner institutions) came together for five breakfast meetings covering topics such as interdisciplinary research, post-graduate career and education planning, and science communication. The final luncheon meeting involved each student giving a short presentation on their research and experiences. Feedback from students afterwards indicated that they appreciated these meetings and that the REU experience had left them with very positive impressions about post-graduation academic degrees and STEM careers. For many

students, this was the first time that they had conducted research and the first time that they had engaged in research-related discussions across disciplinary boundaries. Further feedback from students and faculty will assist us in planning for our Integrated Summer 2020 REU program.

- In 2019, our CAP Grad Grants Program competitively granted $43,223.00 to support the research of 12 graduate students:

    - Anthony Basile: "The effect of anthropogenic, western diet foods on avian abundance, richness, and metabolic physiology."
        - Amount: $3,335
        - Mentor: Karen Sweazea
    - Ryan Clark: "A field comparison of western black widows: Does behavior differ between urban and desert habitats?"
        - Amount: $4,000
        - Mentor: Chad Johnson
    - Jessica Dwyer: "Bat habitat use along the gradient of urbanization in the Phoenix Metropolitan Area."
        - Amount: $4,000
        - Mentor: Jesse Lewis
    - Stephen Elser & Michelle Stuhlmacher: "Ecosystem services provided by green infrastructure: Expanding knowledge on the Phoenix Metropolitan Area."
        - Amount: $5,888
        - Mentors: Nancy Grimm and Billie Turner II
    - Jeffrey Haight: "Biophysical and socioeconomic influences on spatial patterns of urban mammal communities."
        - Amount: $4,000
        - Mentors: Sharon Hall and Jesse Lewis
    - Timothy Ohlert: "Drought impacts on desert ecosystems."
        - Amount: $4,000
        - Mentor: Scott Collins
    - Sarah Polekoff: "Adapting to city life: Physiology and behavior of urban and desert House Finches (*Haemorhous mexicanus*)
        - Amount: $4,000
        - Mentor: Pierre Deviche
    - Zhaocheng Wang: "Understanding urban irrigation impact by coupling machine learning and physical-based models in a desert urban environment."
        - Amount:$4,000
        - Mentor: Enrique Vivoni

  - Megan Wheeler: “Land managers drive long-term and annual plant community dynamics: A case study of change over time in Phoenix residential yards.”
    - Amount: $4,000
    - Mentor: Sharon Hall
  - Mary Wright & Peter Crank: “A comprehensive assessment of the thermal environment of two PASS neighborhoods.”
    - Amount: $6,000
    - Mentors: David Hondula, Ariane Middel, and David Sailor

- The impact of the graduate 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.

- Twelve 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.

- Five teachers provided evidence of implementing Ecology Explorers curriculum into their classrooms this year.

- Fifteen volunteer stewards of the McDowell Sonoran Conservancy attended one of two trainings by Ecology Explorers to strengthen their capacity to facilitate classroom experiences utilizing Ecology Explorers lessons.

- 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.

- One undergraduate student worker worked with the Ecology Explorers program in spring semester of 2019. This student learned basics of pedagogy for both classroom and non-formal education settings and contributed to the development of teaching materials and lesson plans. Additionally, under our guidance, one undergraduate student worker worked the summer semester of 2019 on a review of research literature pertaining to locally relevant environmental education in formal education settings.

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 Goldwater Environmental Laboratory (GEL) allows CAP researchers access to equipment and training to conduct analyses. The GEL webpages provide a list of equipment.

CAP maintains a diversity of field infrastructure. CAP 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.

- 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 subplotsfor 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 and in one stormwater outfall to the Salt River above Price Drain. We have an additional five ISCOs installed in the UEI stormwater infrastructure on Orange Mall, on ASU's 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.
- CAP currently has 50 wildlife cameras positioned in desert parks, riparian areas, and residential areas to document mammal distribution across the gradient of urbanization in the Phoenix metropolitan area and surrounding Sonoran Desert. To record bat signals, stationary SM4BAT-FS acoustic monitors and SMM-U2 microphones rotate among the 50 sites, remaining in place for 5 consecutive nights at each site.
- Seven Drought-Net rainout shelters have been installed at two outlying DesFert sites (one west, one east) with seven permanently marked control plots also at each site. This research is a collaboration with the SEV LTER program and with the international Drought Net program.

Impact on Institutional Resources

- The initial CAP LTER grant from NSF in 1997 was the catalyst for the formation of what is now the Julie Ann Wrigley Global Institute of Sustainability at ASU and the sustainability education and research efforts at ASU. CAP remains an important research platform for work on urban social-ecological systems at ASU and is included on the ASU Office of Knowledge Enterprise Development (OKED) timeline, "A Legacy of Discovery".

- One reason CAP has stimulated so much research on urban social-ecological systems is the openness of CAP's past and present leadership to new investigators and students who can contribute novel perspectives to our long-term work. Furthermore, our collaboration model has led to numerous research initiatives outside of CAP as evidenced by the impressive amount of research funding leveraged from CAP:

    - $5 million during this reporting period, bringing the total to $12.4 million in grant funding since December 2016 (inception of this grant cycle).
    - A total of $95 million since CAP's inception in 1997.

- The CAP information management system has been the exemplar of a data management system that now encompasses all sustainability research efforts at ASU.

- The on-line Urban Ecology module for educators, developed through the Mary Lou Fulton Teacher's College, is accessible for classroom teachers and non-formal educators at any time through the Ecology Explorers website. Additionally, a two hour online training module is available through ASU's Continuing Education website and introduces teachers and educators to the Ecology Explorers program.

- CAP's Ecology Explorers program provides teachers with professional development training and resources for engaging elementary and middle school students in learning about and experiencing urban ecology. A number of lesson plans and curricular content are available on the CAP website, with two more added in 2019, and two more planned in 2020.

Impact on Information Resources

The CAP LTER added seven new data sets to its publicly available data holdings during the reporting year, bringing the total number of project data sets archived with the Environmental Data Initiative (EDI) to 201. New data sets of note feature bioclimatic measurements for the central-Arizona region derived from NASA Earth Science Data and Information System Daily Surface Weather and Climatological Summaries (DAYMET). These new data sets are a valuable resource to developing species distribution models, and conducting interdisciplinary studies of urban environments. Another climate-related data set features a Social Vulnerability Index (SoVI) and a specific hazards Heat Vulnerability Index (HVI) computed for 358 census tracts in the City of Phoenix. 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 the project website, the EDI data portal, and DataONE.

The CAP LTER Information Manager and Julie Ann Wrigley Global Institute of Sustainability (GIOS) informatics team strive continuously 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 in Arizona State University's School of Sustainability in the spring of 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.
- The GIOS informatics team implemented a new data portal for the Julie Ann Wrigley Global Institute of Sustainability (GIOS) that utilizes the EDI's PASTA+ framework. This new data portal provides a gateway to CAP LTER data and rich metadata archived with the EDI, and, ultimately, will provide a more efficient system for presenting CAP LTER data on our local (i.e., CAP LTER website) data catalog.

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 (S. Earl) participates in all network information meetings and activities, and co-chairs the LTER Information Management Executive Committee (IM Exec). In addition, S. Earl is an information manager on a NCEAS Synthesis Working Group studying Soil Organic Matter dynamics, and contributed to numerous scientific presentations and publications.

Impact on Society Beyond Science and Technology

- The Ecology Explorers team has participated in statewide and national meetings and conferences for science and environmental educators. We are participating in the development of initiatives 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.

- Our Ecology Explorers program (work described in several sections above) is our major vehicle for engaging with K-12 students, teachers, and the general public. In the current reporting period, we engaged in 17 outreach activities, including the McDowell Sonoran Jr. Citizen Science Festivals, ASU's Night of the Open Door, as well as classroom, field trip, and afterschool programming. Through these activities we reached approximately 950 learners, 15 teachers and 15 volunteer educators. We produced two new Ecology Explorers lessons and provided two trainings for volunteer educators of the McDowell Sonoran Conservancy. Additionally we have participated in several days of intense work with two Roosevelt School District teachers through the supplemental REU funding that we recently received. This work is focused on developing relevance and understanding for the nature of science for these two teachers, and compounding this impact districtwide through workshops and building of instructional units.

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

- The Hydro-GI Lab project, part of our Urban Design IRT, is in a partnership with the Flood Control District of Maricopa County to co-produce design experiments for UEI-based stormwater management features. Chingwen Cheng (PI) and Paul Coseo (Co-PI and co-lead of the Urban Design IRT) received an ASU APS Endowment for Sustainable Design Research grant to install two design experiments at 1) the Flood Control District of Maricopa County's Durango Campus, and 2) ASU's Orange Mall Student Pavilion.

- The project Building Capacity for Smart and Connected Management of Thermal Extremes is a NSF Smart and Connected Communities Planning Grant with Paul Coseo (PI), David Hondula (Co-PI and co-lead of the Climate and Heat IRT), and Ariane Middel (Co-PI) working closely with the City of Tempe and our peer city partners in Erie County, Buffalo, and the University of Buffalo to assess the current state of management of thermal extremes in Tempe, AZ and Buffalo, NY. The Tempe component supports the CAP Climate and Heat and Urban Design IRT collaborations.

- The Nature's Cooling System project led by David Hondula works with underserved communities in the Phoenix Metro Area to develop plans for cooling neighborhoods and protecting people during hot weather. They held nine workshops in three different neighborhoods throughout summer 2018 and engaged approximately 100 residents in the heat action planning process. The project has produced a public-ready Heat Action Planning Guide that will soon be widely available and distributed.

- A Global Consortium for Sustainability Outcomes funded project, "Deepening the Impact of Scalability of Green Infrastructure within Cities" led by Fletcher Beaudoin at Portland State University, partnered with Paul Coseo and the City of Tempe to develop a full proposal on urban ecological infrastructure (UEI). Part of the larger proposal is intended to support UEI design experiments in the City of Tempe and provide more capacity for the CAP Urban Design IRT activities.

- CAP's Scenarios and Futures IRT, in collaboration with the UREx SRN, co-produced future scenarios for the Phoenix Metro Area with city practitioners and community leaders who have interests in envisioning alternative futures that can ensure resilience in the face of climate change. This includes participants such as: City of Phoenix, City of Tempe, City of Goodyear, City of Mesa, Maricopa County Flood Control District, Maricopa County Department of Health, US EPA, Arizona Department of Water Resources, Bureau of Reclamation, Arizona Interfaith Power and Light, The Nature Conservancy, Trees Matter, Desert Botanical Garden, McDowell Sonoran Conservancy, Sonoran Institute, and many others.

- In September, Jennifer Vanos and Chingwen Cheng led a workshop at Paideia Academies, a charter school in South Phoenix to understand perceptions of their play environments and what they (students and parents) would like to see in the future. Two more workshops are planned as part of that design studio.

PUBLICATIONS

Journal Articles

Published

Allen, D. C., H. L. Bateman, P. S. Warren, F. S. de Albuquerque, S. Arnett-Romero and B. Harding. 2019. Long-term effects of land-use change on bird communities depend on spatial scale and land-use type. *Ecosphere* 10(11):e02952. DOI: 10.1002/ecs2.2952. (link)

Andrade, R., K. L. Larson, D. M. Hondula and J. Franklin. 2019. Social-spatial analyses of attitudes toward the desert in a southwestern U.S. city. *Annals of the American Association of Geographers* 109(6):1845-1864. DOI: 10.1080 /24694452.2019.1580498. (link)

Ball, B. A., M. P. Christman and S. J. Hall. 2019. Nutrient dynamics during photodegradation of plant litter in the Sonoran Desert. *Journal of Arid Environments* 160(Jan):1-10. DOI: 10.1016/j.jaridenv.2018.09.004. (link)

Barber, L. R., J. L. Rapp, C. Kandel, S. H. Keefe, J. Rice, P. Westerhoff, D. W. Bertolatus and A. M. Vajda. 2019. Integrated assessment of wastewater reuse, exposure risk, and fish endrocrine disruption in the Shenandoah River Watershed. *Environmental Science & Technology* 53(7):3429-2440. DOI: 10.1021/acs.est.8b05655. (link)

Childers, D. L., P. Bois, H. E. Hartnett, P. T. McPhearson, G. S. Metson and C. A. Sanchez. 2019. Urban ecological infrastructure: An inclusive concept for the non-built urban environment. *Elementa: Science of the Anthropocene* 7(1):46. DOI: 10.1525/elementa.385. (link)

Corman, J. R., S. L. Collins, E. M. Cook, X. Dong, L. A. Gherardi, N. B. Grimm, R. L. Hale, T. Liu, J. Ramos, L. G. Reichmann and O. E. Sala. 2019. Foundations and frontiers of ecosystem science: Legacy of a classic paper (Odum 1969). *Ecosystems* 22(5):1160-1172. DOI: 10.1007/s10021-018-0316-3. (link)

du Bray, M., R. Stotts, M. Beresford, A. Y. Wutich and A. A. Brewis-Slade. 2019. Does ecosystem services valuation reflect local cultural valuations? Comparative analysis of resident perspectives in four major urban river ecosystems. *Economic Anthropology* 6(1):21-33. DOI: 10.1002/sea2.12128. (link)

Hondula, D. M., J. L. Sabo, R. Quay, M. H. Chester, M. Georgescu, N. B. Grimm, S. L. Harlan, A. Middel, S. Porter, C. L. Redman, B. Rittmann, B. L. Ruddell and D. D. White. 2019. Cities of the Southwest are testbeds for urban resilience. *Frontiers in Ecology and the Environment* 17(2):79-80. DOI: 10.1002/fee.2005. (link)

Iwaniec, D. M., E. M. Cook, O. Barbosa and N. B. Grimm. 2019. The framing of urban sustainability transformations. *Sustainability* 11:573. DOI: 10.3390/su11030573. (link)

Johnson, J. C., J. Urcuyo, C. E. Moen and D. R. Stevens II. 2019. Urban heat island conditions experienced by the western black widow spider (*Latrodectus hesperus*): Extreme heat slows development but results in behavioral accommodations. *PLoS ONE* 14(9): e0220153. DOI: 10.1371/journal.pone.0220153. (link)

Larson, K. L., E. A. Corley, R. Andrade, S. J. Hall, A. M. York, S. A. Meerow, P. J. Coseo, D. L. Childers and D. M. Hondula. 2019. Subjective evaluations of ecosystem services and disservices: an approach to creating and analyzing robust survey scales. *Ecology and Society* 24(2):Art 7. DOI: 10.5751/ES-10888-240207. (link)

Markolf, S. A., C. Hoehne, A. M. Fraser, M. H. Chester and S. Underwood. 2019. Transportation resilience to climate change and extreme weather events -- beyond risk and robustness. *Transport Policy* 74(Feb):174-186. DOI: 10.1016/j.tranpol.2018.11.003. (link)

Padulles Cubino, J., J. Cavender-Bares, S. E. Hobbie, S. J. Hall, T. L. Trammell, C. Neill, M. L. Avolio, L. E. Darling and P. M. Groffman. 2019. Contribution of non-native plants to the phylogenetic homogenization of U.S. yard floras. *Ecosphere* 10(3):e02638. DOI: 10.1002/ecs2.2638. (link)

Ruth, A., A. A. Brewis and A. Y. Wutich. 2019. A model for scaling undergraduate research experiences: The Global Ethnohydrology Study. *Journal of Mass Emergencies and Disasters* 37(1):25-34. (link)

Wang, Z., T. Nguyen and P. K. Westerhoff. 2019. Food-energy-water analysis at spatial scales for districts in the Yangtze River Basin (China). *Environmental Engineering Science* 36(7):789–797. DOI: 10.1089/ees.2018.0456. (link)

Warren, P. S., S. B. Lerman, R. Andrade, K. L. Larson and H. L. Bateman. 2019. The more things change: Species losses detected in Phoenix despite stability in bird–socioeconomic relationships. *Ecosphere* 10(3):e02624. DOI: 10.1002/ecs2.2624. (link)

Wutich, A. Y. and M. Beresford. 2019. The economic anthropology of water. *Economic Anthropology* 6(2):168-182. DOI: 10.1002/sea2.12153. DOI: 10.1002/sea2.12153. (link)

Wutich, A. and A. Brewis. 2019. Data collection in cross-cultural ethnographic research. *Field Methods* 31(2):181-189. DOI: 10.1177/1525822X19837397. (link)

Yu, R., B. L. Ruddell, M. Kang, J. Kim and D. L. Childers. 2019. Anticipating global terrestrial ecosystem state change using FLUXNET. *Global Change Biology* 25(7):2352-2367. DOI: 10.1111/gcb.14602. (link)

Zhang, Y., A. Middel and B. L. Turner II. 2019. Evaluating the effect of 3D urban form on neighborhood land surface temperature using Google Street View and geographically weighted regression. *Landscape Ecology* 34(3):681–697. DOI: 10.1007/s10980-019-00794-y. (link)

In Press

Hoover, D. L., B. T. Bestelmeyer, N. B. Grimm, T. E. Huxman, O. E. Sala, T. R. Seastedt, H. Wilmer and S. Ferrenberg. Traversing the wasteland: A framework for assessing ecological threats to drylands. *BioScience*

McPhillips, L., S. R. Earl, R. L. Hale and N. B. Grimm. Urbanization in arid central Arizona watersheds results in decreased stream flashiness. *Water Resources Research* DOI: 10.1029/2019WR025835. (link)

Smith, V. K., K. L. Larson and A. M. York. Using quality signaling to enhance survey response rates. *Applied Economic Letters* DOI: 10.1080/13504851.2019.1646869. (link)

Suchy, A., M. M. Palta, J. C. Stromberg and D. L. Childers. High nitrate removal by urban accidental wetlands in a desert city: Limitations and spatio-temporal patterns. *Ecosystems* DOI: DOI 10.1007/s10021-019-00465-8. (link)

Trubl, P. and J. C. Johnson. Ecological stoichiometry of the black widow spider and its prey from desert, urban and laboratory populations. *Journal of Arid Environments* DOI: 10.1016/j.jaridenv.2018.12.002. (link)

In Review

Black, C. E., M. Giraudeau, K. J. McGraw and P. Nolan. Bird song development along a rural-urban gradient. *Frontiers in Zoology*

Coseo, P. J. An urban climate design framework for more thermally comfortable and equitable communities. *Landscape Research Record*

Douglas, I., R. Wang, W. Xiang, L. Lin, D. L. Childers and J. Xie. Urban ecology: A comparison and contrast of approaches between East and West. *Landscape and Urban Planning*

Gaiser, E. E., D. M. Bell, C. N. Castorani, D. L. Childers, P. M. Groffman, R. Jackson, J. S. Kominoski, D. P. Peters, S. T. Pickett, J. Ripplinger and J. C. Zinnert. Long-term ecological research and the changing theoretical paradigms of disturbance ecology. *BioScience*

Handler, A., A. Suchy and N. B. Grimm. Nitrate reduction capacity and pathways of urban accidental wetlands in Phoenix, Arizona. *Biogeochemistry*

Hutton, P. and K. J. McGraw. Effect of nighttime disturbance on sleep, disease, and stress in a songbird. *Functional Ecology*

Iwaniec, D. M., M. Georgescu, M. J. Davidson, E. M. Cook, E. S. Krayenhoff, N. B. Grimm, M. Berbés-Blázquez, X. Li, A. Middel and D. A. Sampson. The co-production of sustainable future scenarios. *Landscape and Urban Planning*

Larson, K. L., S. J. Hall, E. A. Corley, A. M. York, P. J. Coseo, D. M. Hondula, S. A. Meerow and D. L. Childers. Developing reliable survey scales for perceived ecosystem services and disservices. *Ecology and Society*

Palta, M. M., L. McPhillips, C. Bienz, C. Clifford, M. H. Okoro and K. Jaeger. Influence of hydrologic connectivity on ecosystem service provision and tradeoffs in aquatic systems. *Journal of the American Water Resources Association*

Pfeiffer, D., M. M. Ehlenz, K. L. Larson, S. Cloutier and R. Andrade. Do neighborhood walkability, transit, and parks relate to residents' life satisfaction? Insights from Phoenix. *Journal of the American Planning Association*

Pisani, O., M. Gao, N. Maie, T. Miyoshi, D. L. Childers and R. Jaffe. Compositional aspects of herbaceous litter decomposition in freshwater marshes of the Florida Everglades: A litter bag experiment. *Plant and Soil*

Sokolowski, M., A. Buell and P. Fox. An assessment of quagga mussel survival in the Salt and Verde River reservoirs as compared to the Colorado River. *Water Environment Research*

Song, J., Z. Wang, S. W. Myint and C. Wang. Interpreting physical characteristics of urban climatology in Phoenix metropolitan area, Arizona. *Theoretical and Applied Climatology*

Stuhlmacher, M., R. Andrade, B. L. Turner II and A. E. Frazier. The role of design in land system architecture: Comparing riparian environmental outcomes in the Phoenix metropolitan area. *Land Use Policy*

Wheeler, M. M., K. L. Larson and R. Andrade. Attitudinal and structural drivers of residential yard choices: A comparison of preferred versus actual landscapes. *Urban Ecosystems*

York, A. M., H. Eakin, S. Smith-Heisters, J. C. Bausch, R. M. Aggarwal and J. M. Anderies. Examining public adaptive capacity through institutional analysis: The case of agricultural water governance in central Arizona. *Policy Sciences*

Books

Childers, D. L., E. E. Gaiser and L. A. Ogden eds. 2019. *The Coastal Everglades: The Dynamics of Social-Ecological Transformation in the South Florida Landscape*. Oxford University Press. ISBN: 9780190869007.

Book Chapters

Childers, D. L., E. E. Gaiser and L. A. Ogden. 2019. Preface and introduction. In: Childers, D. L., E. E. Gaiser and L. A. Ogden eds., *The Coastal Everglades: The Dynamics of Social-Ecological Transformation in the South Florida Landscape*. Oxford University Press. ISBN: 9780190869007.

Gaiser, E. E., L. A. Ogden, D. L. Childers and C. Hopkinson. 2019. Reimagining ecology through an Everglades lens. In: Childers, D. L., E. E. Gaiser and L. A. Ogden eds., *The Coastal Everglades: The Dynamics of Social-Ecological Transformation in the South Florida Landscape*. Oxford University Press. ISBN: 9780190869007.

Harlan, S. L., P. Chakalian, J. Declet-Barreto, D. M. Hondula and G. D. Jenerette. 2019. Pathways to climate justice in a desert metropolis. In: Reyes Mason, L. and J. Rigg eds., *People and Climate Change:*

Vulnerability, Adaptation, and Social Justice. Oxford University Press. New York, NY. ISBN: 978-0190886455.

In Press

Hale, R. L., E. M. Cook, D. M. Iwaniec and N. B. Grimm. Urbanization and the altered biogeochemical cycle. In: Bai, X., T. E. Graedel and A. Morishima eds., *Cities in Evolution: Urbanization, Environmental Change and Sustainability*. Cambridge University Press.

Palta, M. M. and E. K. Stander. Wetlands in urban environments. *Handbook of Urban Ecology, 2nd Edition*. Routledge. New York, NY.