Cities of the Southwest are testbeds for urban resilience

Scientific journals and popular media are filled with warnings about the regional impacts of global environmental change on cities (Sherwood and Huber 2010; Bacigalupi 2015). Cities in the hot, semi-arid American Southwest are on the front lines of stressed water resources, extreme heat, and population growth, and are projected to be increasingly burdened by anthropogenic climate change. Some have portrayed these challenges as insurmountable, predicting the demise of places like Phoenix, Los Angeles, and Las Vegas in the not-so-distant future (eg Allen 2014; Pearl 2017). We propose an alternative hypothesis: southwestern cities are testbeds for developing adaptation and mitigation strategies that cities with less extreme climates may need before the turn of the next century. Our experience is that the region's cities are recognizing, responding to, and in some cases embracing their distinctive position as climate pioneers. To inform a more complete narrative, here we highlight some initiatives, plans, and needs of local governments, universities, and businesses to address livability and sustainability challenges.

In southwestern cities, daytime temperatures already regularly exceed human comfort and safety thresholds during several months of the year (Gasparrini *et al.* 2015). Urbanization brings rising nighttime temperatures and winter lows to these cities, along with vanishing frost and a longer warm season (Ruddell *et al.* 2013). Behavioral and technological adaptations have made southwestern cities livable for most people despite the heat; many are ranked highly for quality of life, are popular tourism destinations, and are rapidly growing. The heat is not tolerable for everyone, however, posing particular challenges for those who routinely face high exposure. For some, the heat can be deadly. Heat exposure is a contributing factor to an unacceptably high number of illnesses and deaths each summer. Thus far, southwestern cities have avoided catastrophic heat-related death counts like the tens of thousands observed in Europe in 2003, despite routinely experiencing much higher temperatures. A key adaptation is widespread air conditioning, powered by reliable electricity. These cities also operate public heat preparedness, surveillance, and response initiatives with targeted measures for vulnerable populations, and are pursuing aggressive urban greening and shading goals, as well as deploying cool roofs and pavements that reduce the amount of solar energy absorbed at the surface (eg City of Los Angeles 2015; Berisha *et al.* 2017). Recognition that heat is a chronic hazard in the region, rather than an episodic one, is leading to enhanced information resources and decision making in many sectors.

Water to support southwestern cities comes from a remarkably diverse set of sources, including the Colorado River and other surface water systems, regional groundwater supplies, and effluent reuse. Southwestern water managers and researchers have long been aware of the volatile and tenuous nature of regional water systems. In response, they have developed infrastructure, management, and policy solutions that have led their cities to be among the world's more progressive in promoting water sustainability (Gober *et al.* 2016). A highlight of these efforts is the Arizona Groundwater Management Act of 1980, which mandates long-term water supply and demand management strategies, tackling the groundwater sustainability challenge head-on in both urban and agricultural areas (ADWR 2016). As a result, sustainable groundwater levels are already being achieved in Arizona, while other arid regions aspire to achieve this goal. Frequent drought has also required water managers to identify strategies to hedge against shortages. In 2014, the cities of Phoenix and Tucson established a novel risk-sharing agreement where Phoenix banks water in Tucson's aquifers today in exchange for Phoenix receiving part of Tucson's Colorado River water during future shortages. The reuse of wastewater is further supporting water sustainability, with as much as 82% of effluent reused in central Arizona (Middel *et al.* 2013). Other advances in water management include specialized water supply forecasting and modeling software implemented by regional utilities, as well as a strong foundation for water markets, leasing, and negotiation stemming from firm legal obligations for municipalities during water shortages. These advances result from complex multi-stakeholder and regional collaborative decision-making processes focused on solving current and pending issues (Sullivan *et al.* 2019).

Southwestern cities may be particularly well suited to adapt to the heat and water challenges projected for the region because their infrastructure is largely new; the cities also have space in which to pursue well-adapted development. Like elsewhere, the rapidly growing cities of the Southwest will need to invest in infrastructure improvements, but their costs should be lower than others. Older cities may need to substantially overhaul existing infrastructure to adapt. Conversely, rapidly growing southwestern cities can still make important, beneficial changes, taking advantage of the latest science and technology development, including opportunities for expanded use of green infrastructure. An important challenge to address in future adaptation is the dependency of some cities on air conditioning and associated consequences for energy use and waste heat emission. Relatedly, management of peak power demands and improved reliability of both electricity and clean water must be met with strategies to ensure affordability. Future development with a stricter adherence to climatically appropriate design principles, such as building placement and material selection, will benefit current and future city dwellers indoors and outdoors.

Cities with newer infrastructure are also well positioned to implement technologies that reduce or capture the emission of greenhouse gases (GHGs). Local governments and other public entities in the region have announced ambitious GHG reduction goals for the coming decades (City of Los Angeles 2015; City of Phoenix 2016). Many cities in the Southwest are already among those with the lowest per capita carbon footprints in

the country, largely because of the lower energy demands for cooling than heating. With respect to residential and transportation energy use, El Paso, Tucson, Las Vegas, and Phoenix all recently ranked among the 25 US metro areas with the lowest emissions out of the 100 largest metropolitan areas in the US (Brookings Institution 2008).

While these cities continue to grow and thrive by many metrics, new investments must be used to help resolve historical inequities: socioeconomically marginalized people often face higher heat exposure, rely on lower-quality infrastructure, have less access to private means of adaptation, and are more excluded from governance processes (eg Harlan *et al.* in press). The path forward must involve processes and strategies that enable all urban residents to meaningfully participate in decision-making structures, avoid dangerous heat exposure, and access clean water.

We invite and encourage continued scrutiny of the experiences of southwestern cities, as their successes and failures in climate adaptation will be instructive for others around the world in the coming decades. While predictions of doom for cities of the American Southwest make for tempting headlines, efforts to highlight the experience of southwestern cities as vital testbeds for urban resilience may prove more beneficial to the global community preparing for future heat and water challenges.

David M Hondula[1]*, John L Sabo[1], Ray Quay[1], Mikhail Chester[1], Matei Georgescu[1], Nancy B Grimm[1], Sharon L Harlan[2], Ariane Middel[1], Sarah Porter[1], Charles L Redman[1], Bruce Rittmann[1], Benjamin L Ruddell[3], and Dave D White[1]

*[1]Arizona State University, Tempe, AZ *(david.hondula@asu.edu); [2]Northeastern University, Boston, MA; [3]Northern Arizona University, Flagstaff, AZ*

Allen N. 2014. The race to stop Las Vegas from running dry. *The Telegraph.* Jun 28.

ADWR (Arizona Department of Water Resources). 2016. Overview of the ground water management code. www.azwater.gov/AzDWR/WaterManagement/documents/Groundwater_Code.pdf. Viewed 13 Jan 2019.

Bacigalupi P. 2015. The water knife. New York, NY: Alfred Knopf.

Berisha V, Hondula DM, Roach M, *et al.* 2017. Assessing adaptation strategies for extreme heat: a public health evaluation of cooling centers in Maricopa County, Arizona. *Wea Clim Soc* **9**: 71–80.

Brookings Institution. 2008. Shrinking the carbon footprint of metropolitan America. https://www.brookings.edu/wp-content/uploads/2016/07/carbonfootprint_brief.pdf. Viewed 5 Dec 2017.

City of Los Angeles. 2015. The Sustainable City pLAn. http://plan.lamayor.org. Viewed 15 Dec 2017.

City of Phoenix. 2016. Sustainability report. https://www.phoenix.gov/sustainabilitysite/Documents/Final%20COP%202015-16%20Sustainability%20Brochure%2003.27.17.pdf. Viewed 20 Dec 2017.

Gasparrini A, Guo Y, Hashizume M, *et al.* 2015. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. *Lancet* **386**: 369–75.

Gober P, Sampson DA, Quay R, *et al.* 2016. Urban adaptation to mega-drought: anticipatory water modeling, policy, and planning for the urban Southwest. *Sustain Cities Soc* **27**: 497–504.

Harlan SL, Chakalian P, Declet-Barreto J, *et al.* Pathways to climate justice in a desert metropolis. In: Reyes LM and Rigg J (Eds). People and climate change: vulnerability, adaptation, and social justice. New York, NY: Oxford University Press. In press.

Middel A, Quay R, and White DD. 2013. Water reuse in central Arizona. Decision Center for a Desert City, Technical Report 13-01. Tempe, AZ: Arizona State University.

Pearl M. 2017. Phoenix will be almost unlivable by 2050 thanks to climate change. *Vice.* Sep 18.

Ruddell D, Hoffman D, Ahman O, *et al.* 2013. Historical threshold temperatures for Phoenix (urban) and Gila Bend (desert), central Arizona, USA. *Clim Res* **55**: 201–15.

Sherwood SC and Huber M. 2010. An adaptability limit to climate change due to heat stress. *P Natl Acad Sci USA* **107**: 9552–55.

Sullivan A, White DD, and Hanemann M. 2019. Designing collaborative governance: insights from the drought contingency planning process for the lower Colorado River basin. *Environ Sci Policy* **91**: 39–49.

The conundrum of agenda-driven science in conservation

Conservation biology is a value-laden discipline predicated on conserving biodiversity (Soulé 1985), a mission that does not always sit easily with objective science (Lackey 2007; Pielke 2007; Scott *et al.* 2007). While some encourage scientists to be responsible advocates for conservation (Garrard *et al.* 2016), others worry that objectivity in conservation research may suffer (Lackey 2007). At this time, we believe advocacy by scientists is essential for environmental conservation and, indeed, humanity. It is difficult to envision the state of our environment had scientists failed to encourage policy makers and the public to address emerging conservation problems. Nevertheless, conservation scientists must avoid misusing the scientific process to promote specific conservation outcomes (Wilholt 2009); doing so erodes the credibility of science and can produce undesirable consequences (Thomas 1992; Mills 2000; Rohr and McCoy 2010). We consider intentionally engaging in activities outside of professional norms to promote desired outcomes, as part of either the production or dissemination of science, to constitute "agenda-driven science". The issue of advocacy-related bias in conservation science merits renewed discussion because conservation conflicts in an increasingly polarized world might tempt some to engage in agenda-driven science to "win" a conflict (Redpath *et al.* 2015; Kareiva *et al.* 2018).

Agenda-driven science can take many forms (Table 1). Concealing conflicts of interest when publishing may indicate that scientists are beholden to parties with a vested interest in results (Rohr and McCoy 2010). The intentional misuse of data, misrepresentation of literature, and misinterpretation of results in a manner favorable to one's conservation objectives are also clear manifestations of agenda-driven science (Wilhere 2012). While peer review is the bedrock of science, it can be imperfect and does not always purge poor-quality, agenda-driven science from