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Tracing Extremes across Iconic Desert Landscapes: Socio-Ecological and Cultural Responses to Climate Change, Water Scarcity, and Wildflower Superblooms

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Abstract
California's remote Anza-Borrego Desert, like other desert landscapes across the southwest of the United States, is valued by scientists, resource managers, and tourists alike for its perceived exceptional extremity. We analyze how climate extremes shape biological, socioeconomic, and cultural life through one of the desert's most iconic ecological events: spring wildflower superblooms. Quantitative data relating wildflower superblooms and tourist visitation to interannual climate variation are at the center of our analysis, with additional literature review and qualitative ethnographic data used to lend context and engage deeply with the significance of the quantitative findings for local communities. Monthly visitation rates tracked precipitation, peaking during the end of the winter growing season when wildflowers reach peak bloom. Visitation more than doubled during the wettest years, corresponding to wildflower abundance and superbloom media coverage. Wildflower superblooms and extreme environmental events are socially and culturally significant in the desert communities. They loom large in memory, shape regular seasonal activities and attachment to place, and feature in local conflicts over resource management and planning for sustainable futures. Overall, we demonstrate how gateway communities contend with the desert's ephemeral nature, and how climate change creates new and different extremes in these iconic desert landscapes.

Keywords Climate change · Cultural identity · Deserts · Ecotourism · National Parks · Protected areas · United States southwest · Anza-Borrego Desert, California · Superblooms · Tourism · Water scarcity

Introduction

Much of the western U.S. recently emerged from a decades-long drought that left impacts on natural systems (Breshears *et al.* 2005; Dennison *et al.* 2014; Winkler *et al.* 2018) and human systems alike (Chang and Bonnette 2016; Prestemon *et al.* 2016). Climate models predict future droughts and extreme weather events in the region will only become more severe and occur more frequently (Cook *et al.* 2004; Cayan *et al.* 2010; Chikamoto *et al.* 2017; Steiger *et al.* 2019). This has serious implications for tourism-dependent desert communities, whose economies, ecologies, and local sense of place are dependent on continued access to natural resources in places responsive to shifts in ecological systems (Fig. 1; Evans and Geerken 2004).

In Southern California's Anza-Borrego Desert region, as in many small desert communities in the American Southwest, the extremity and exceptionality of desert ecological systems is reflected in the values, stories, daily and seasonal activities, and relationships that shape local sense of place. Tourist activities amplify this by playing on well-established cultural representations of the desert as a place of extremes: hiking or camping in the solitude of a desert wilderness, learning about the adaptations of sensitive local plants and animals, sharing stories of humans making a living in "no man's land,"

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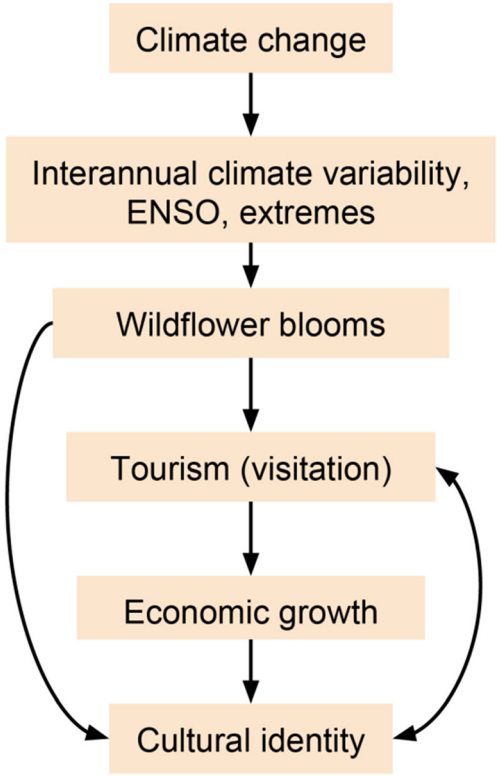

Fig. 1 Conceptual diagram linking environmental, biological, economic, and sociological contexts in desert communities like Borrego Springs, CA

or enjoying the contrast between luxury tourist accommodations and their austere surroundings (Smith 2008; Davis 2016). This characterization is reinforced by those outside of the eco- or geotourism industries: scientists, resource managers, and community leaders who increasingly see the protection of a unique sense of place as essential to their work, particularly under a changing climate (Crate 2008; Adger *et al.* 2011; National Park System Advisory Board Science Committee 2012; Larson *et al.* 2013; Rockman *et al.* 2016; Masterson *et al.* 2017).

Here, we investigate this desert sense of place and its future under human-induced climate change through one of the desert's most iconic ecological events: extreme spring wildflower blooms in response to above-average rainfall, like the recent superblooms in 2017 and 2019. In so doing, we explore how climate extremes shape biological, socioeconomic, and cultural life in California's Anza-Borrego Desert region and across the Southwest more generally. As an object of study, seasonal wildflower blooms encapsulate the dynamic tension between the desert as extreme and the desert as sensitive. An increase in the number and magnitude of extreme climatic events is consistently one of the changes forecast by climate models (Easterling *et al.* 2000; Fischer *et al.* 2013; Singh *et al.* 2013; Stocker *et al.* 2013). This is troubling in part because national and state parks in the Southwest are expected to experience some of the highest levels of warming in the coming decades (Gonzalez *et al.* 2018). These forecast changes have serious implications for biological and human systems not only in the deserts of the Southwest (Fig. 1; Nelson *et al.* 2016; Palta *et al.* 2016; Ruppert *et al.*, 2015; Winkler *et al.* 2019a) but also in dryland systems around the globe (Thomas 2008; Huang *et al.* 2016). Given the current and projected impacts of climate change on seasonal precipitation and spring onset, in particular, seasonal wildflower blooms serve as ecological indicators and visual "climate stories" (Niemi and McDonald 2004; Rockman *et al.* 2016). In addition to influencing ecological processes, including replenishing native seeds banks, creating organic matter that supports the health of soil microbial communities, and influencing local climate (Nelson and Chew 1977; Pake and Venable, 1996; Levine *et al.* 2008; He *et al.* 2017; Treonis *et al.* 2019), seasonal wildflower blooms anchor important cultural events such as festivals and other annually recurring events, and attract visitors and funnel vital tourist dollars into local economies (Fig. 1; Minnich 2008). They are perceived to be rare, extreme, and iconic (Moore 2015).

Although popular media often cover rare superbloom events when winter rains are frequent and desert wildflowers form blankets across these landscapes (e.g., Malik 2016; Gerber 2017), to date no formal studies have examined the relationship of wildflower blooms to tourism, local sense of place and/or cultural heritage, and the inherent negative impacts climate change will have on these relationships. Ecotourism, sustainable resource use, and human perceptions of themselves and the environments they inhabit are all threatened by human-induced climate change (Crate and Nuttall 2009; Moreno and Becken 2009; Dowling 2010; Gössling *et al.* 2012; Adger *et al.* 2013). This is further complicated by large uncertainties regarding not only how climate change and an increase in the number of extreme events will impact natural systems (Easterling *et al.* 2000; Reyer *et al.* 2013; Hoover *et al.* 2014) but also the stakeholder groups that depend on them (Fig. 1; Evans *et al.* 2013; Thomas *et al.* 2019). On the ground, climate change "is not something that may happen in the near or far future but is an immediate, lived reality that they [local people] struggle to apprehend, negotiate, and respond to" (Crate and Nuttall 2009). Impacts are noticed and experienced within communities as deviations from previously established norms on both short- and long-term timescales. This drives a gradual destabilization of relationships between people and their environments: the environment becomes unpredictable and important spaces and symbolic forms are permanently transformed, which can have serious implications for economic planning, health and wellbeing, and cultural identity (Fig. 1; Crate and Nuttall 2009; Fiske *et al.* 2014). Connecting these two bodies of literature, there is a growing body of research on tourist

responses to the impacts of climate change in vulnerable ecosystems (cf. Gössling *et al.* 2012; Tervo-Kankare *et al.* 2013; Miller *et al.* 2014; Davis and Mullen 2015).

Despite these challenges, many small towns in the United States are increasingly looking to ecotourism to boost local economies that are highly seasonal, dependent on vulnerable ecosystem services, and/or were previously tied to a single industry that has since collapsed, such as fossil fuel extraction. Further, there is growing concern that desertification is increasing at an alarming rate that not only impacts non-desert systems but also leads to changes within previous desert boundaries (Verón *et al.* 2006; Reynolds *et al.* 2007; but see Bestelmeyer *et al*., 2015; Sayre *et al*., 2017). The relative importance of desert natural resources as a driver of tourism is poorly explored in the Southwest, yet critical to understanding not only in terms of the natural environmental variability that exists in these systems (Noy-Meir 1979; Potts *et al.* 2019) but also as they respond to contemporary climate change (e.g., Munson *et al.* 2012; Winkler *et al.* 2019b) and the role humans may play in managing change (Larson *et al.* 2011; Van Loon *et al.* 2016).

Our analysis examines the relationships among precipitation, superblooms, tourist visitation, and local sense of place in the Anza-Borrego Desert, including Anza-Borrego Desert State Park. We expand these ideas to include National Parks in the Southwest where we explore visitation and climate, and how these may relate to regional identities and national perspectives of "extreme" desert lands. Quantitative data relating wildflower superblooms and tourist visitation to interannual climate variation are at the center of our analysis, with additional literature review and qualitative ethnographic data used to lend context, and engage deeply with the significance of the quantitative findings for local communities. We explore the connections between biological and social extremes, and link scholarly work in biology and ecology with anthropology and geography. With desert systems facing uncertain futures under climate change, we aim to open up a space for future interdisciplinary research grounded in the charismatic and iconic environmental phenomena that help create meaningful connections between people and places.

Methods

Regional Background

As an ecological region, California is both incredibly specific and incredibly diverse: a patchwork of radically different bioregions, including coastal lowlands, high alpine mountains, marshy valleys, and multiple distinct deserts. The Sonoran, Mojave, and Great Basin Deserts in California extend into neighboring states in the Southwest, including Arizona and Nevada. Although we focus primarily on the Anza-Borrego Desert region in California, we also explore trends and themes in iconic National Parks across the Southwest. These include Death Valley National Park, Joshua Tree National Park, Mojave National Preserve, Organ Pipe Cactus National Monument, and Saguaro National Park.

Today, protected landscapes in America's deserts act as conservation and heritage areas and tourist destinations, and, in accordance with American images of nature and wildness, have often been culturally defined by their relative strangeness to green cultivated landscapes, and their perceived connection to what remains of a wild frontier (Zierer 1952; Klein 1993). There has at times been a general sense of public support for protecting desert landscapes (e.g., Richer 1995), as well as enthusiasm for incorporating their histories into contemporary regional identities and tourist material culture (e.g., Weigle 1989); as any resident of or visitor to a desert community has seen, these movements continue to thrive. However, broader mainstream perceptions of these arid ecosystems remain largely defined by ideas of extremity, desolation, and barrenness (Smith 2008; Davis 2016; Hoover *et al.* 2020), which reach their apotheosis in the treatment of desert places and people as belonging to unproductive "wastelands" (Voyles 2015).[1] As such, and particularly following the explosion of Sunbelt leisure tourism in the mid-twentieth century era, traditional tourism in these systems typically centers around a heavily modified landscape to better-suit the needs of certain kinds of imagined visitors (e.g., a green golf course in Phoenix, a constructed reservoir called Lake Wainani in the Mojave Desert that is regularly stocked for fishing, or even the iconic casinos in the city of Las Vegas).

The Anza-Borrego Desert

The Borrego Valley in southern California is a desert environment supported by two interconnected sources of water: precipitation funneled into the valley from the mountain ranges and canyons surrounding it, and a groundwater aquifer that is roughly coterminous with the valley. Borrego Springs is an

[1] As historians and social scientists note, the desert wasteland concept is often rooted in colonial logics of land use and resource extraction. For example, the environmental history of California is frequently written as the transformation of California's natural landscape in a series of movements, from Native land use (Heizer 1998), to Native encounters with Spanish colonization (Hurtado 1998), to the forced incorporation of Native and Spanish lands that shaped the early dimensions of California's continued history of boundaries drawn and disputed by immigration, disenfranchisement, and territory making (Merchant 1998). Ranching, agriculture, and mining drove the dramatic, large-scale appropriation, extraction, and processing of the land as a natural resource (Kelley 1959; Dasmann 1994), oftentimes with negative impacts on indigenous communities as well as native plant and animal species (Bryant *et al.* 1990; Glenn *et al.* 1999; Lovich and Ennen 2011; Bardsley and Wiseman 2012; Hernandez *et al.* 2014). Later efforts have sought to preserve and restore nature to its "pre-human" (more accurately, pre-ranching or pre-settler colonial) state, often erasing indigenous histories of land management in the process (Rakestraw 1972; Reisner 1986).

unincorporated town in San Diego County, including approximately 3400 residents[2] and a central business district surrounded by the over 650,000-acre Anza-Borrego Desert State Park. Like many resort destinations, the town's population increases during the high season (local estimates suggest 7000–10,000 residents during the winter, with peak crowds of 20,000 for seasonal festivals like Borrego Days and more than 200,000 visitors for good wildflower seasons), and while there is much common ground, there are also social and cultural differences between the relatively diverse year-round resident population and the more homogeneous (skewing overall older, wealthier, and White) seasonal "snowbird" residents and weekenders. The U.S. Census Bureau ACS 2018a data estimate Borrego Springs' population as 93% (± 8.4%) White and 28.6% (± 15.7%) Hispanic or Latino of any race, with a median household income of approximately $27,635 (± 7378), and a median age of 58.3 years (± 9.4; U.S. Census Bureau 2018a, b).

A brief overview of tourist development in the Valley and surrounding area reflects broad trends seen across the desert Southwest. Three springs in the Borrego Valley are documented in Mendenhall's 1909 guide for overland travelers (Faunt *et al.* 2015), with homesteaders settling the region beginning in the 1910s (Brigandi 2001; Lindsay 2000). Three large-scale transformations occurred in the first half of the twentieth century. First, intensive agricultural development began in the 1920s. Second, in 1932 the original Borrego Palms Desert State Park was established, with subsequent land acquisitions and reorganizations eventually resulting in the larger surrounding Anza-Borrego Desert State Park in 1957 (Lindsay 2000). Third, in the 1940s, developers began building a desert winter resort, capitalizing on the growing demand for outdoor recreation with an aggressive marketing campaign. The 1950s saw a sharp increase of such development driven by wealthy investors seeking to create a leisure destination comparable to Palm Springs (Brigandi 2001; Lindsay 2000).[3] While promotion of and enthusiasm for Sunbelt leisure culture drove intensive greening and development, water and land agencies began documenting dropping well levels and slowing annual groundwater recharge. Local perceptions of water systems in Southern California desert communities more broadly (specifically, whether they are capable of supporting agriculture, resort development associated with resource-intensive leisure activities, and municipal use simultaneously) have fluctuated significantly over the course of recent history (Hundley 1992).

Study Design

To explore the relationships between precipitation, superblooms, tourist visitation, and local sense of place in the Anza-Borrego Desert, we incorporate both quantitative and qualitative data. The quantitative data are the core of this paper, with qualitative data used to lend richness to our consideration of sense of place while also investigating the significance of the quantitative findings for local communities. Drawing on scholarship from geography and anthropology (e.g., Tuan 1974, 1977; Basso 1996; Ingold 2000; Crate 2008), we use sense of place as an umbrella concept to coalesce ideas about meanings, values, cultural models, and environmental perceptions attached to specific place, and underscore the impacts to these desert identities, histories, practices, and lifeways that are irrevocably situated in sensitive, low desert ecosystems. This purposefully broad and holistic definition also reflects the ways in which sense of place is understood and operationalized by resource managers and other decision makers for protected areas (e.g., Farnum *et al.* 2005; Rockman *et al.* 2016).

Qualitative ethnographic data were collected as part of a broader anthropological project on environmental politics and management, water sustainability, and applied science in the Sonoran and Mojave Deserts of Southern California, including Borrego Springs as a field site. Data were collected using standard ethnographic methods and a grounded theory approach, including archival research, ca. 45 semi-structured interviews,[4] documentation of meetings, and participant observation in formal and informal settings conducted over two periods: primary fieldwork spanning ca. 18 months between 2013 and 2016, and additional short-term follow-up in 2018 (Brooks 2017). Data were iteratively reviewed to ensure saturation and analyzed using an inductive coding process, and were queried for this article to identify and interpret cultural patterns related to wildflower blooms, tourism, and sense of place.

Superbloom occurrences were identified between 1975 and 2018 from online media reports and amateur botany blogs (Supplemental Table S1). We related these events to winter growing season (Dec–April) precipitation totals (mm) to

[2] The 2010 Decennial Census records the Borrego Springs CDP total population as 3429. The 2018 American Community Survey estimates a total population of 2252 with a margin of error of ±605 (U.S. Census Bureau 2018b). There is some local disagreement as to precise numbers for year-round vs. seasonal populations. For example, the Borrego Springs Community Plan estimates the population as approximately 2700 year-round residents plus an additional 2000 seasonal or snowbird residents (2011). The Borrego Valley Stewardship Council estimates 3400 permanent/year-round residents and 5000 seasonal residents.

[3] Two popular promotional videos released by Copley Productions in 1957 encapsulate this sense of a desert paradise built on a narrative of endless water (Hazelip 1957). Likewise, and written near the end of this boom, a 1968 Bureau of Reclamation report projected that Borrego Springs' population would increase from 1300 in 1965 to 30,000 by the year 2020 (Moyle 1968). Such high expectations were typical of this period in California's history of water and land development (Hundley 1992).

[4] Interview participants included year-round residents, seasonal residents, weekenders, and stakeholders residing elsewhere, and were identified as local community leaders, resource managers and related practitioners, public officials, researchers, local business owners, and/or community advocates, broadly considered.

identify whether superblooms occurred during anomalously wet years or otherwise. We obtained visitation data when available for six state and national parks in the desert Southwest. This included visitation data for a 38-year period for Death Valley National Park, Joshua Tree National Park, Organ Pipe Cactus National Monument, and Saguaro National Park with records from 1979 to 2017. We also included a 28-year data set from Anza-Borrego Desert State Park from 1989 to 2017 and a 20-year data set from Mojave National Preserve from 1997 to 2017. Data were provided for Anza-Borrego Desert State Park by park staff and all other data were accessed via the National Park Service's Integrated Resource Management Applications (IRMA) Portal (https://irma.nps.gov/Portal/). We subsequently obtained monthly precipitation data for each park from the Western Regional Climate Center (https://wrcc.dri.edu/). We discounted years when superblooms were reported in only one park but include these sources in Supplemental Table S1 and discuss the implications below. We also include 2018 media sources that, for the first time, report on why a superbloom was not occurring in the Southwest.

We defined extremes in visitation as being either the absolute minimum or maximum for each of the 28 years analyzed from Anza-Borrego Desert State Park. We defined each year as beginning in June and ending in May of the following year to capture the entire winter and spring growing seasons that span two calendar years. Overall, our methodology combines environmental and socio-ecological frameworks and creates a highly conservative approach to characterizing the impact of variability on systems being studied (Katz and Brown 1992).

Results

Seasonal fluctuations in weather significantly shape Borrego Springs' sense of place. The town's economy is highly seasonal and tourism is widely recognized as a primary economic driver, with local businesses and associations promoting access to the State Park along with formal awards like an International Dark Sky Community certification from the International Dark Sky Association. Locals observe the winter resort "high season" of mid-fall to mid-spring as the opportune time for town hall meetings, community festivals, outdoor activities, and educational programming centered on local natural and cultural history and earth systems science (supplied by a constellation of local nonprofit organizations and conservancies, the University of California Irvine's Steele/Burnand Anza-Borrego Desert Research Center, the California State Parks' Colorado Desert District Stout Research Center, and the Anza-Borrego Desert State Park itself), all of which rely on comparatively mild weather and reliably high turnout from enthusiastic tourists, weekenders, and seasonal residents. The hot summer "off season," meanwhile, is characterized by a rapid decrease in both residents and activity, as civic engagement nearly halts and service-oriented businesses shorten hours or close entirely to avoid the spiking utility costs necessary to maintain comfort. Businesses display warning signs about the dangers of being outside in extreme dry heat and residents trade stories of hapless visitors caught unprepared, further delineating the Borrego Springs summer as a time and place for hardy locals and "extremophiles" only.

Wildflower seasons in general (and superblooms in particular) are marked by the rise and fall of anticipatory social practices. Local flower enthusiasts, resource managers, and tourist industry professionals track precipitation totals, as well as the frequency and consistency of rain events, in December, January, and February. Early-season warm weather or late-season cold weather is viewed with apprehension. February accelerates the preparation for wildflower tourists, many of whom track similar trends from a distance: updating local "wildflower hotlines" and websites, preparing maps, increasing inventory at local businesses, and an array of code words and jokes around talking (or superstitiously avoiding talking) about the current bloom. Local botany enthusiasts share stories about years when conditions seemed perfect, yet flowers did not emerge, or when the bloom was not particularly good.

The stakes for this speculation are high. Desert wildflower blooms have attracted tourists to California for decades, if not longer. In Borrego Springs specifically, local and oral histories suggest hundreds of wildflower tourists as early as the 1930s, with over 30,000 visitors estimated during a single weekend day of a major bloom in 1952 (Brigandi 2001). Likewise, the local newspaper *The Borrego Sun* has covered flower tourists since its first issue in 1949. "Good" wildflower years loom large in cultural memory, and support a significant cottage industry around desert blooms; a well-publicized superbloom (shared through mainstream news-media stories, social media, and a network of amateur desert botany blogs; Supplemental Table S1) can attract tens or hundreds of thousands of visitors in a matter of weeks. During the 43-year period 1975–2018, a total of 10 superbloom events are documented in online media reports and amateur botany websites (Fig. 2). Nine of the 10 events occurred during years when winter precipitation was higher than average and six of the 10 events occurred during years when winter precipitation was at least one standard deviation above the mean (winter precipitation $\bar{x} \pm SD = 110.55 \pm 85.16$ mm; Fig. 2). Although 2018 was anecdotally a relatively good wildflower year, it was never defined as having a superbloom event (see Supplemental Table S1).

In casual conversation, locals remember past superblooms occurring roughly once per decade, occasionally in multi-year clusters (largely corresponding to Fig. 2). In this context, superblooms become a way of marking decadal time,

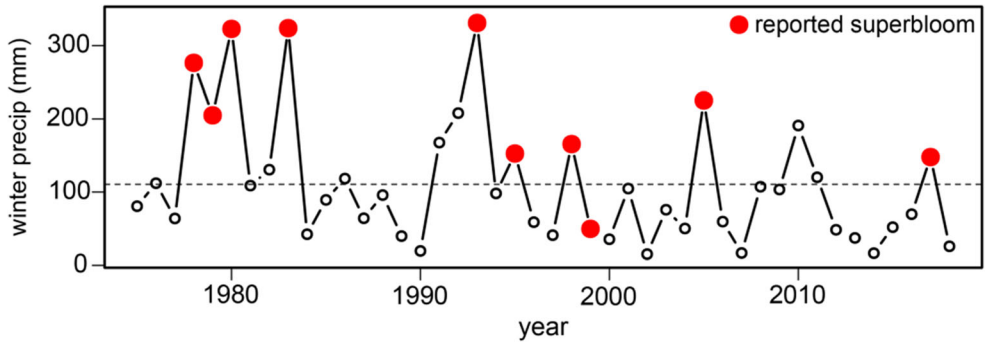

Fig. 2 Recorded superbloom events (red circles) in Anza-Borrego Desert State Park based on observations by amateur botanists and media coverage (Supplemental Table S1). Total winter growing season (Dec–April) precipitation (mm; black lines and circles) plotted through time, 1975–2018, along with the 43-year mean (horizontal dashed line). Each red circle demarcates a superbloom event during a given flower year (e.g., a superbloom labelled in 1978 represents the event during the 1977–78 flower year)

structuring memories, and invoking the past as a point of comparison for the present: in dry winter seasons during the 2011–2017 drought, for example, memories of superblooms in the late 1970s were shared by longtime residents as points of contrast to contemporary weather and flower forecasts. Interestingly, there is a local sense that superblooms are expected to happen every 10–15 years, but have become more common in recent years.

Visitation to Anza-Borrego Desert State Park is concentrated during the late winter to early spring seasons (Fig. 3a). Visitation typically increases to ca. 10,000 visitors per month beginning in November and steadily increases until February, when visitation accelerates to its peak during the month of March ($\bar{x} \pm$ SEM = 47,053 ± 5265 visitors; Fig. 3a). April continues to see relatively high numbers of tourists visiting the Park ($x \pm$ SD = 29,984 ± 3070 visitors; Fig. 3a) after which, visitation declines to fewer than 7000 visitors until the following November.

The extreme maximum number of visitors to Anza-Borrego Desert State Park occurred during the 1994–1995 wildflower year that was also a superbloom year (Figs. 2–3b). Approximately 84 mm of rain fell in January 1995, which is more than double the average monthly rainfall. However, this is nothing compared to the 1992–1993 wildflower year that experienced a record 223 mm of rainfall in December, yet only ca. 67,000 visitors arrived at the peak of the season in March. The extreme minimum number of visitors to Anza-Borrego Desert State Park occurred during the 2017–2018

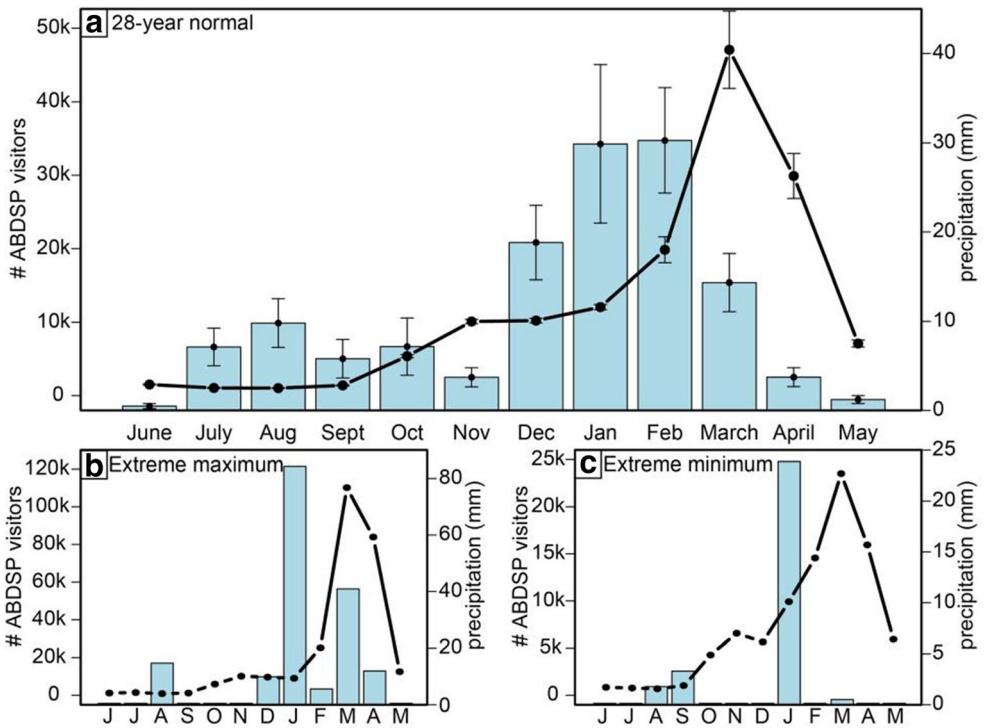

Fig. 3 The relationships between monthly visitation (black lines and circles) and precipitation (blue bars) in Anza-Borrego Desert State Park from a 28-year data set from 1989 to 2017 with **a**) average monthly visitation across the 28-year period and average monthly precipitation (mm), **b**) extreme maximum number of visitors that occurred during the 1994–1995 wildflower season, and **c**) extreme minimum number of visitors that occurred during the 2017–2018 wildflower season plotted against monthly precipitation (mm) obtained from a nearby weather station. Note changes in scale for each panel's y-axes

Table 1 Visitation statistics (means and standard deviations; $\bar{x} \pm SD$) for Anza-Borrego Desert State Park, Death Valley National Park, Joshua Tree National Park, Mojave National Preserve, Organ Pipe Cactus National Monument, and Saguaro National Park from 1979 to 2017 (except Anza-Borrego DSP starts in 1989 and Mojave N. Pres. starts in 1997). Annual values are calculated across each flower year (June–May) to capture the full extent of visitation during the winter growing season (Dec-April)

	Annual visitation			Dec–April visitation		
Park	$\bar{x} \pm SD$	**max (year)**	**min (year)**	$\bar{x} \pm SD$	**max (year)**	**min (year)**
Anza-Borrego DSP	148,647 ± 44,497	269,073 (1994–95)	103,412 (2012–13)	120,777 ± 43,351	238,074 (1994–95)	76,415 (2013–14)
Death Valley NP	898,616 ± 240,270	1,292,032 (2015–16)	566,924 (1985–86)	380,873 ± 81,736	579,997 (2015–16)	231,232 (1990–91)
Joshua Tree NP	1,187,368 ± 448,961	2,783,333 (2016–17)	545,285 (1979–80)	636,078 ± 237,418	1,522,888 (2016–17)	261,954 (1979–80)
Mojave N. Pres.	518,112 ± 110,573	630,677 (2005–06)	164,805 (1996–97)	219,207 ± 38,976	237,271 (2016–17)	126,237 (1996–97)
Organ Pipe Cactus NM	745,731 ± 570,829	1,644,550 (2006–07)	143,626 (1979–80)	366,859 ± 240,487	852,426 (2006–07)	77,772 (1979–80)
Saguaro NP	2,599,091 ± 927,140	3,687,497 (2015–16)	519,566 (1980–81)	1,220,418 ± 399,599	1,683,414 (2015–16)	254,865 (1980–81)

wildflower year when 89,738 tourists visited the park (Fig. 3c). This was also the second driest flower year in the 28-year period, receiving only 29.46 mm of rainfall. This is hardly rivaled by the 2006–2007 flower year that received 24.38 mm of rain, making it the driest year during the period analyzed.

Annual visitation to parks in the Southwest ranged from 148,647 ± 44,497 visitors in Anza-Borrego Desert State Park to 2,599,091 ± 927,140 visitors in Saguaro National Park across the 28- and 38-year periods analyzed (Table 1). High standard deviations across all of the parks (SD = 44,497–927,140 visitors per year) likely reflects the influence of inter-annual climate variability in driving tourism to these desert parks. All parks received a majority of visitors during the winter growing season (Table 1), with most tourists visiting the parks during March and April (Fig. 4). Half of the parks (Anza-Borrego DSP, Death Valley NP, Saguaro NP) received maximum visitation during superbloom years (Table 1; Fig. 2) while Joshua Tree NP, Mojave N. Pres., and Organ Pipe Cactus NM received maximum visitation either the year following a superbloom (Fig. 2) or when a superbloom was reported only in a subset of parks (Table S1). Minimum visitation at most parks occurred during years when winter growing season precipitation was below average but Joshua Tree NP and Organ Pipe Cactus NM had the lowest visitation during superblooms that occurred early in the record (Table 1; Fig. 1).

Winter growing season visitation accounted for 42–81% of total annual visitation but was also less variable (SD = 38,976–399,599 visitors) than annual visitation, highlighting that visitation occurs primarily during the winter growing season (Table 1; Fig. 4). The two more northerly parks (Joshua Tree NP and Death Valley NP) both saw the highest relative monthly visitation during April while all other parks saw this peak in March (Fig. 4), perhaps illustrating that flowering phenology is at least in part explained by latitude. Maximum visitation during the winter growing season occurred mostly during years when annual visitation also peaked. This was true for all parks except Mojave N. Pres., which received the maximum number of visitors during a different superbloom year (Table 1). Minimum winter growing season precipitation never occurred during the same flower year when annual visitation was lowest (Table 1), likely indicating that a poor wildflower year does not always imply that other seasons cannot attract tourists to these parks.

Discussion

Identifying challenges to long-term sustainability of eco-, cultural-, or geotourism in areas and on events that are sensitive to climate change has become a growing area of interest internationally. Communities that are dependent on local natural resources for their way and quality of life and, thus, have a strong attachment to place are particularly vulnerable to climate change (e.g., Martins *et al.* 2019). In addition, the "desert archipelago" of communities across the greater Southwest are facing a need to shift economies enabled by unsustainable practices like over-consumption of diminishing water supplies, sprawling development, and extractive industries, and envision alternative futures and imagined communities in alignment with their "natural" desert ecosystems (Sheridan 1995; Hackenberg and Benequista 2001). In this context,

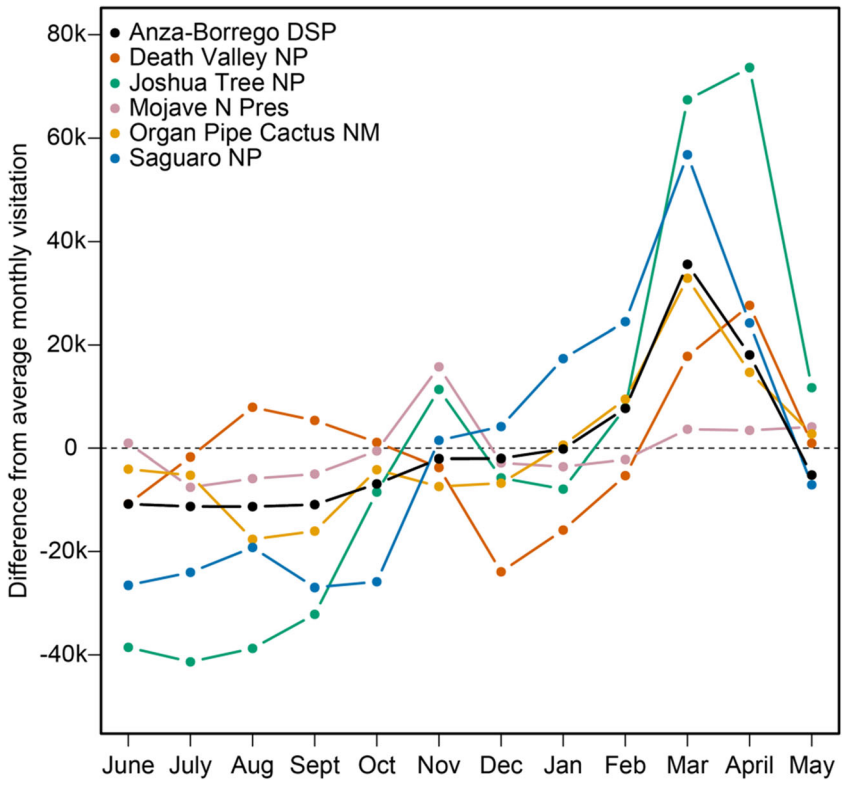

Fig. 4 Monthly visitation rates to desert parks and monuments (Anza-Borrego Desert State Park, Death Valley National Park, Joshua Tree National Park, Mojave National Preserve, Organ Pipe Cactus National Monument, and Saguaro National Park) as a difference from the average monthly number of visitors to each park from 1979 to 2017 (except Anza-Borrego DSP starts in 1989 and Mojave N. Pres. starts in 1997)

our discussion of superblooms is both representative of broader trends, and indicative of topics requiring further study.

First, there is an inherent necessity to better understand superblooms in ecological and socio-cultural context: their biological foundations and ecological triggers, as well as their broader cultural and economic significance. Hardly any research has been carried out on understanding the processes that lead to superbloom events, though some have approached these events from narrower angles or alternative foci (e.g., Nelson and Chew 1977; Treonis *et al.* 2019). This seems peculiar given that these events can be seen from space (He *et al.* 2017; Chávez *et al.* 2019), receive a plethora of media coverage, and influence local economies and rural communities around the globe. Studies have occasionally documented the dramatic floral displays of superblooms in the Atacama Desert in Peru and Chile (known locally as the "blooming desert" but not to be confused with the agriculture development term) as well as their effects on soil microbial communities and local climate (Dillon and Rundel 1990; Armesto *et al.* 1993; Orlando *et al.* 2010; He *et al.* 2017). Others have attempted to identify past superbloom events by reconstructing vegetation communities using long-term data (Bowers 2005). Additionally, some advances have been made in correlating desert superblooms with strong El Niño Southern Oscillation (ENSO) events (Fig. 1; Gutiérrez *et al.* 2000; Jaksic 2001; Bowers 2005; Holmgren *et al.* 2006). It may be perhaps that these challenges are such because "superbloom" is not an official ecological term or concept. In fact, wildflower blooms were only described as such beginning in the 1990s according to park staff at Death Valley NP (Wines and Slater 2016). Nonetheless, the documentation and exploration of these events remains a challenge given their episodic nature, that no current metric defines such an event, and the inherent difficulty in predicting when they will occur. This challenge is felt acutely by those seeking to leverage superblooms to sustain tourist economies as well; locals in Borrego Springs debate potentially over-investing time and money in precarious events like wildflower blooms, while also acknowledging that blooms present a key opportunity to attract tourists who might not find natural desert places otherwise appealing.

Second, as our integration of historical and ethnographic data has suggested, the desert communities linked to (and to some degree dependent upon) superbloom tourism face high consequence decisions involving many diverse stakeholders thinking carefully about their shared climate future. Borrego Springs follows rural communities worldwide in transitioning its local economy from one based on no longer sustainable agricultural or extractive industries to one based on the (potentially) sustainable inflow of geo-tourists, including science tourists (West 2008). In this process, who participates at the decision-making table matters and determines how effectively desert natural resources are managed (Salvaggio *et al.* 2014). This holds true in non-desert systems as well (e.g., Flint and Luloff, 2007). As in Anza-Borrego Desert State Park, visitation to U.S. National Parks and all 50 State Park systems is on the rise (Fisichelli *et al.* 2015; Smith *et al.* 2019)

and tightly linked to climate. Although visitors themselves may not be deterred from recreation in a natural area impacted by climate change (e.g., Richardson and Loomis 2004), management costs to aid visitors and protect natural resources will increase (Smith *et al.* 2019). However, some research suggests that if parks become too warm during this century, visitation will likely decline (Scott *et al.* 2007). Other research also suggests that historical visitation to four U.S. National Parks (Yellowstone, Glacier, Grand Teton, and Rocky Mountain) declined during the driest years from 1991 to 2012 and indicates economic vulnerability to increasing climate extremes (Jedd *et al.* 2018).

Ecotourism and analogues like geo-tourism form a booming industry that has enabled economic growth at multiple scales (Page and Dowling 2001; Stronza 2009; Weaver and Lawton 2007). Many governments have adopted economic development plans based around ecotourism as a means to generate income in primarily rural areas and in an effort to reduce human impacts on and use of natural resources (Krüger 2005; Zinda *et al.* 2014). Tourism around specific natural events like wildflower blooms offers a significant boost to small towns that can no longer rely on single industries such as agriculture, or on full- and part-time residents alone to keep local businesses profitable. Local estimates suggest visitors to Anza-Borrego Desert State Park account for over $40 million in annual revenue to the region and Borrego Springs, like other similar towns, has recently begun investing energy and resources into explicitly eco- and geotourism-focused initiatives based on preserving local sense of place.[5] Ecotourism and its analogues may also serve as a corrective to an older, more expensive, and more resource-intensive style of tourism that industry observers caution is increasingly inaccessible to, or simply out of step with, what many young people and people of color seek (e.g., Watson 2013; Whiting *et al.* 2017). It remains to be determined how ecotourism initiatives will fare in a warming world; as the climate changes, how and where we recreate, and our relationships to recreation itself, will also change.

As we have demonstrated here, seasonal wildflower blooms, as well as similar "bucket list" events like mass migrations that attract attention from both locals and tourists, are "good to think with" (Levi-Strauss 1971) in the context of climate change research and applications. Wildflower blooms are socially and culturally significant in these desert communities, yet they occupy a sensitive and tenuous space. They loom large in memory, shape regular seasonal activities and attachment to place, and feature in local conflicts over resource management and planning for sustainable futures. Viewed in this way, wildflower blooms provide fruitful case studies for considering the potential impacts to local socio-economic and ecological systems in both the short- and long-term, should such events shift or become even more ephemeral. For example, further research on gradual shifts in local practices around blooms (such as when a seasonal wildflower hotline becomes active, or where each year's flower map directs visitors) or on differences in how superblooms are perceived and related to by community members with variable stakes in diminishing natural resources, may provide ways of simultaneously tracking how climate change impacts desert systems and how communities develop cultural responses to changing environments. Likewise, given that climate models predict droughts and future weather events in the region will become more frequent and severe, we recommend further research on the social, cultural, political, and economic dimensions of ecological shifts in plant communities and bloom predictability. Scientific attention to charismatic and iconic environmental phenomena like seasonal blooms effectively downscales the impacts of global climate change to peoples' daily lives and relationships with the places in which they live, work, and recreate. The results of such case studies have the potential to inform critical decision making for stakeholders in desert communities.

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[5] Most visibly, a series of community workshops culminated in the formation of the Borrego Valley Stewardship Council in 2014, with a mission to foster a responsible stewardship ethic for cultural and natural resources, and balance economic prosperity with long-term sustainability and benefits to people and places. Since then, the Council has served as a "convening entity" sponsoring annual community planning-oriented workshops, hosting expert speakers, and organizing volunteer working groups to advocate for key projects at the municipal and county level.

Data Availability National Park Service visitation data used in this study are freely available through the NPS Integrated Resource Management Applications (IRMA) Portal (https://irma.nps.gov/Portal/) and Anza-Borrego Desert State Park visitation data are available through direct requests to the park. Climate data for each park were accessed via the Western Regional Climate Center (https://wrcc.dri.edu/).

Compliance with Ethical Standards

Ethnographic data collected by Brooks are covered by a human subjects research agreement reviewed and approved by the University of California, Irvine. Per standard ethnographic research practice, these data are not made publicly available in order to protect the privacy and confidentiality of research subjects.

Informed Consent Informed consent was obtained from all individual participants in the study.

Conflict of Interest The authors declare that they have no conflict of interest.

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