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Neighborhood Parks and Recreationists' Exposure to Ozone: A Comparison of Disadvantaged and Affluent Communities in Los Angeles, California

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Abstract
Urban parks are valued for their benefits to ecological and human systems, likely to increase in importance as climate change effects continue to unfold. However, the ability of parks to provide those myriad benefits hinges on equitable provision of and access to green spaces and their environmental quality. A social–ecological approach was adopted in a study of urban park use by recreationists in the City of Los Angeles, contrasting two affluent and two disadvantaged communities situated in coastal and inland zones. Twenty-four days of observations distributed across morning and afternoon time blocks were gathered, with observations in each day drawn from a pair of affluent and disadvantaged community parks. Observers noted location, gender, age, ethnicity/race, and level of physical activity of each visitor encountered during four scheduled observation sweeps on each day of field work. In addition, ozone dose exposure was measured through passive monitoring. Ozone dose exposure was calculated using average hourly ozone in ppb multiplied by METS (metabolic expenditures). Dose exposure was significantly higher in the disadvantaged community parks (with majority Latino use). Findings suggest that additional monitoring in disadvantaged communities, especially inland, may be prudent to facilitate community-based information as well as to assess the degree of potential impact over time. Additionally, mitigative strategies placed in urban parks, such as increased tree canopy may help to reduce the degree of risk and improve community resilience. Future research examining the positive outcomes from physically active use of urban parks may benefit from adopting a nuanced approach in light of the present findings.

Keywords Urban community resilience · Climate change · Ozone · Recreation use · Physical activity

Introduction

Urban forests and urban parks provide myriad benefits to human communities, many of which are likely to increase in importance as climate change effects continue to unfold (Younger et al. 2008). This is particularly the case in highly urbanized areas, and within those areas, parks are deemed more essential to traditionally underserved communities because of their elevated risk burden and marked health disparities (Babey et al. 2008; deFur et al. 2007; Jennings and Johnson Gaither 2015; Levi et al. 2012; Mitchell and Popham 2008; Pratt 2008; Ruffin 2010; Sallis et al. 2007; Shonkoff et al. 2009; Tayyebi and Jenerette 2016; Sastry and Pebley 2003). Racial/ethnic minorities tend to be concentrated in high-density urban areas, and their geographic placement is associated with marked disparities in land cover characteristics linked to greater risk for heat-related effects of climate change (Jesdale et al. 2013). Furthermore, park access has historically been inequitably distributed for low-income and minority communities (Sister et al. 2010; Wolch et al. 2002), even though parks and green spaces have potential to reduce income-associated inequalities in disadvantaged communities (Mitchell and Popham 2008). However, the ecosystem benefits provided by parks may not

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equally contribute to community well-being within affluent and disadvantaged neighborhoods. For example, recent work by Su et al. (2011) suggests that air pollution exposure in and around urban parks is inequitably distributed. While parks tended to be lower in average than the surrounding neighborhoods for most pollutants studied, they found relatively higher concentrations of ozone in community parks that were within primarily Hispanic neighborhoods.

Of additional concern related to the buffering effects of urban parks and green spaces is the array of adverse effects of climate change, where smaller changes in already-vulnerable communities are likely to have greater impacts (deFur et al. 2007). One of the projected effects of climate change is a continuing increase in ozone, associated with extended periods of high heat days and an elevated average temperature across seasons (IWGCCH 2010). Areas where ozone is already elevated during peak periods of the year are then at increased risk in light of these projections.

Ozone is a focal air pollutant owing to its known interaction with current and predicted climate change effects, as well as its known effects on environmental and human health (Curtis et al. 2006). It has been the subject of study for some time leading to regulations focused on reducing ozone level in the environment and thus aiding human well-being (Curtis et al. 2006). Ozone has negative health effects on the general population, including induced respiratory symptoms, such as coughing, throat irritation, discomfort while taking a deep breath, shortness of breath, decreased lung function, and inflammation of airways (www.epa.gov/apti/ozonehealth/population.html). It is particularly impactful for individuals with pre-existing respiratory diseases (epa.gov/apt/ozonehealth/effects.html). Impacts to city residents are considerable, where ozone-caused respiratory hospitalizations in Los Angeles have been estimated to incur $44 million in costs annually (Moretti and Neidell 2011).

In this paper, we explore the benefits of urban parks and green spaces and report findings from an inquiry into park use and incidental exposure to ozone that contrasts affluent and disadvantaged communities in both coastal and inland areas in the City of Los Angeles.

Ecologically Focused Benefits

The array of ecological benefits from green spaces, including urban parks, and the associated outcomes for individual, community, and society discussed below, are at risk from drought and stresses from increasing temperatures affecting urban forests (Anderegg et al. 2013). Drought affects the urban forest by making it more susceptible to invasive pests (Morris and Walls 2009). The combined patterns from climate change effects contribute, in some zones, to decreased access to water paired with an increased cost of municipal water supplies for maintaining urban vegetation. These patterns further exacerbate the degree of risk from elevated heat, increasing the need for shading effects and overall temperature reductions contributed by vegetation (Harou et al. 2010).

Ecosystem services provided by urban forests and vegetation are of high ecological value. Examples include but are not limited to reduction of air pollution, oxygen production, regulation of microclimates through decreasing average temperatures, buffering of noise, harboring of biodiversity, and reduction of storm water runoff (Bolund and Hunhammar 1999; Konijnendijk et al. 2013; Nowak et al. 2006; Nowak et al. 2007; Nowak et al. 2011). As reported by Nowak et al. (2006), while urban tree cover has a modest effect on some of these impacts (e.g., ozone removal), the cumulative impact warrants the management of tree canopy to enhance the overall outcomes. For example, removal of air pollution by Los Angeles's 6 million trees has an estimated value of $14.2 million annually (Nowak et al. 2011).

Individual, Community, and Societal Benefits

Urban parks and green spaces contribute to thermal comfort and reduce vulnerability to heat stress effects among humans (Brown et al. 2015). Parks further contribute to health and well-being through decreased psychosocial stress, improved mood, restored attention, increased social capital through social ties and integration in a community, increased perceived safety, crime reduction, and increased physical activity (Bedimo-Rung et al. 2005; Berman et al. 2008; Chiesura 2004; Jennings and Johnson Gaither 2015; Hansmann et al. 2007; Kuo et al. 1998; Pretty et al. 2007; Snelgrove et al. 2004; Troy et al. 2012; Ulrich et al. 1991).[1] Shanahan et al. (2016) noted that the overall benefits of nature experiences depend on dose; thus, longer and more frequent visits to park settings yield greater benefits, including considerable savings to public health budgets. Additionally, urban parks and green spaces are instrumental in counteracting a societal trend toward more sedentary lifestyles (Kimbell et al. 2009; Kondo et al. 2015), as well as mitigating the reduction of human–nature interactions (Soga and Gaston 2016).

A large population-based study is especially helpful in improving our understanding of the myriad individual, community, and societal benefits of green space. de Vries et al. (2003) analyzed responses from 10,000 Dutch residents to the General Health Questionnaire (a self-report instrument that measures mood states, such as anxiety and depression), as well as perceived general health, number of

[1] For an extensive review of benefits of urban parks, see Konijnendijk et al. (2013).

health-related symptoms over a 14-day period, and environmental data assessing the amount of green space (including forests, nature areas, agricultural areas, and urban green). A significant association was found between well-being and proportion of green space, with a modest effect within a narrower radius of 1 km (~0.6 miles) around one's residence and a larger effect at 1–3 km (~1.86 miles) (de Vries et al. 2003). The authors found that the effects of green space were larger for participants in lower socio-economic groups, which they attributed to the tendency among this population to stay closer to home, in turn increasing the role of local green spaces in wellness. They suggested that positive contributions to health likely emerged from reduced pollutants, enhanced nature contact, and increased physical activity.

A separate set of studies, also using large population-based analyses, further highlight the benefits of green space. In a longitudinal study, moving to greener areas was associated with improved mental health that lasted 3 years post move (Alcock et al. 2014). This study used the General Health Questionnaire and accounted for a number of demographic, housing, and commuting variables in the analysis, tracking adults over a 6-year period in the United Kingdom. A related paper (White et al. 2013) reported findings from a panel study showing the additional benefit of improved life satisfaction for individuals who had moved to urban locations with more green space. The authors pointed to how the significant but still small individual effects would translate into the much greater community-level benefit of access to green spaces in urban parks.

Traditional Factors Affecting Urban Park Use

Park use is largely determined by residential proximity to a park. Cohen et al. (2007) reported that 64% of park visitors lived within a ½ mile radius of their neighborhood park. They also found that park visitors living within that ½ mile radius reported leisurely exercising five or more times per week, which was a higher level of physical activity than respondents who lived greater distances from the park. An additional benefit of increased physical activity occurs when recreationists are able to walk to their neighborhood park (Cronan et al. 2008).

Assumptions of increased physical activity associated with access to the quality of urban green spaces may not always prove correct. In a study examining access and activity levels among middle-aged adults in the United Kingdom, the authors found no clear relationship between access to various types of green spaces and hours per week of physical activity (Hillsdon et al. 2006). In part, this is informed by studies showing that a majority of adult park visitors engage in sedentary activities (e.g., Besenyi et al. 2012; Cohen et al. 2007; Floyd et al. 2008). In comparison, children visiting parks are more likely to engage in walking or vigorous activity (Floyd et al. 2008).

Social and contextual factors require exploration when attempting to understand the associations between green space, access, and physical activity (Flores 2008; Miyake et al. 2010; Parra-Medina and Hilfinger-Messias 2011). Studies involving minority groups show mixed effects. For example, minority groups have been found to engage in less active, more social activities in parks when compared with Whites (Gobster 2002), whereas other studies report more comparable levels of physical activity across racial/ethnic groups (c.f. Cronan et al. 2008). Variation in level of activity by type of area or amenities in the park (picnic areas vs. ball fields for example) highlights the influence of facilities on physical activity, and the role of design interventions in areas of parks where majority use is sedentary (Bedimo-Rung et al. 2005; Floyd et al. 2008). It has also been noted that programming and activities may draw more users into a park than facilities or park size (Han et al. 2014). Variations in interest by age, gender, and ethnic/racial groups influence park visitation, level of activity, and forms of activity (Loukaitou-Sideris and Sideris 2010).

Climate Change Effects on Urban Park Use

As discussed above, the value of urban parks and green spaces to park users and their surrounding communities is substantial (Younger et al. 2008). Inequitable distribution of parks that are within a neighborhood's walking area will remain of concern (García et al. 2009; Wolch et al. 2002). Effects of climate change may represent a mix of positive and negative effects associated with recreation and tourism (Scott et al. 2008). Increasing heat is expected to elevate recreation demand in urban parks and other natural areas, where people will gravitate to escape the heat (Morris and Walls 2009). Parks in lower socioeconomic and vulnerable communities have been referred to as "heat refuge spaces" (Brown et al. 2015, p.128). Urban populations seeking to save on air conditioning and other means of cooling at home may be more likely to visit parks and natural areas as temperatures increase, contributing to increased use of parks. While the overall use may increase, a form of use may shift such that vigorous physical activity may actually decrease as recreationists are advised of potential threats from reduced air quality or potential heat-related maladies, or observe their own physical discomfort. In turn, these shifts alter the park's contribution to active physical movement and degrade its contributions to restoration and stress reduction (Hansmann et al. 2007).

As noted in earlier sections, the buffering effects of urban parks and green spaces to the adverse effects of climate change are of greater interest in disadvantaged communities where smaller changes are likely to have greater impacts (deFur et al. 2007). While increased urban park use is anticipated, that demand may represent an increased risk where the quality of recreation settings is already degraded (Su et al. 2011) and where effects of climate change may further adversely impact environmental quality. In part, this would come about through decreased vegetative resilience and reduced benefits from cooling, shade, and removal of pollutants as previously discussed, and in part through prolonged drought paired with constrained watering (Harou et al. 2010). In addition, decreased environmental quality through elevated exposure to ozone is possible, which is of particular concern to vulnerable populations. Being outdoors and recreating outdoors may inadvertently increase one's physical risks through increased exposure to air pollution in compromised settings.

Toward improving our understanding of urban parks and community well-being, we embarked on a line of inquiry examining urban park use in affluent and disadvantaged communities, with an eye toward understanding current conditions and observed recreation patterns, as well as risk exposure, applying a social–ecological focus in our inquiry (Niemelä 2014). This study hopes to inform improvements in monitoring and strategies for adaptation that can assist urban communities impacted by climate change, furthering community socioecological resilience. By community socioecological resilience, we are considering Folke's (2006) definition as the ability to cope with and adapt to change, to persist and continue to develop throughout change, and to transform positively in response to disturbance.

Pilot Phase and Influences on Current Study

A pilot phase contrasting an affluent (Brentwood) and disadvantaged (Sun Valley) community in the City of Los Angeles informed the current study. A series of steps led to final community selections. We first identified communities with a majority of residential land use, distinguishing between those with robust versus sparse canopy cover based on the work of McPherson et al. (2008). In the next step, we reviewed online aerial maps to assess green space within each community, paired with a review of city parks and their amenities. Desired features for neighborhood parks included restroom facilities, visitor parking, trails and/or walking paths, play areas for children, and affordances for group or individual restoration, play, and interaction. The preference was for public parks that included built areas for sports (e.g., basketball courts) and those without an entrance fee. The pilot study revealed significantly greater ozone-related risks in the disadvantaged community.

In reviewing the pilot phase, it became evident that we had a confound associated with geographic placement of our selected communities. Brentwood (the affluent community) is more coastally located than Sun Valley (the disadvantaged community). This geographic variation is important as coastal breezes affect the movement of pollutants, increasing the probability that ozone would be lower in these coastal parks.

In the current work, we selected two additional communities following the same steps from the pilot phase, adding Hollywood Hills West (an affluent inland community) and Wilmington (a disadvantaged coastal community) (see Fig. 1 for a map of all communities and parks in this study). In our search for inland affluent communities within the city boundaries, we found multiple challenges surrounding the placement of mid-sized parks with the desired amenities and permitted access for data collection. For one community, we stretched our boundaries to edge parks, or those on the perimeter but within a reasonable commuting distance of Hollywood Hills West.

The paucity of choices for developed public parks in affluent communities is not surprising. The hillside communities along the Santa Monica Mountains National Recreation Area and similar wild zones represent the majority of public park options available in Los Angeles's affluent communities. A recent analysis by the Trust for Public Lands (2016) reported that affluent communities in Los Angeles have lower park scores, a cumulative assessment of accessibility to adequate park space within a neighborhood zone of ½ mile. That analysis reported that the highest percentage of population not served by parks are also the most affluent, at over 125% of median city income. It should be noted that the park score contrasts with other studies in the city that show marked differences in park access for communities with high concentrations of low income, poverty, and minority communities (Wolch et al. 2002; García and Strongin 2011), which are classified as "park poor". Here, the difference may be in measurement, where one approach considers commuting distance to a park and the other examines park acreage for surrounding residents of communities.

Community Assessment in Study Area

The selected communities were further assessed by comparing dimensions of affluence and disadvantage, informed by multiple sources. The first of these was the Mapping LA resource, derived from analyses coordinated by the City of Los Angeles using their definitional boundaries of "community" (http://maps.latimes.com/neighborhoods/). These communities are associated with planning areas and localized representation and advocacy. We used the city's own definitions of community to ensure potential applicability of findings for city and community purposes. Table 1 lists

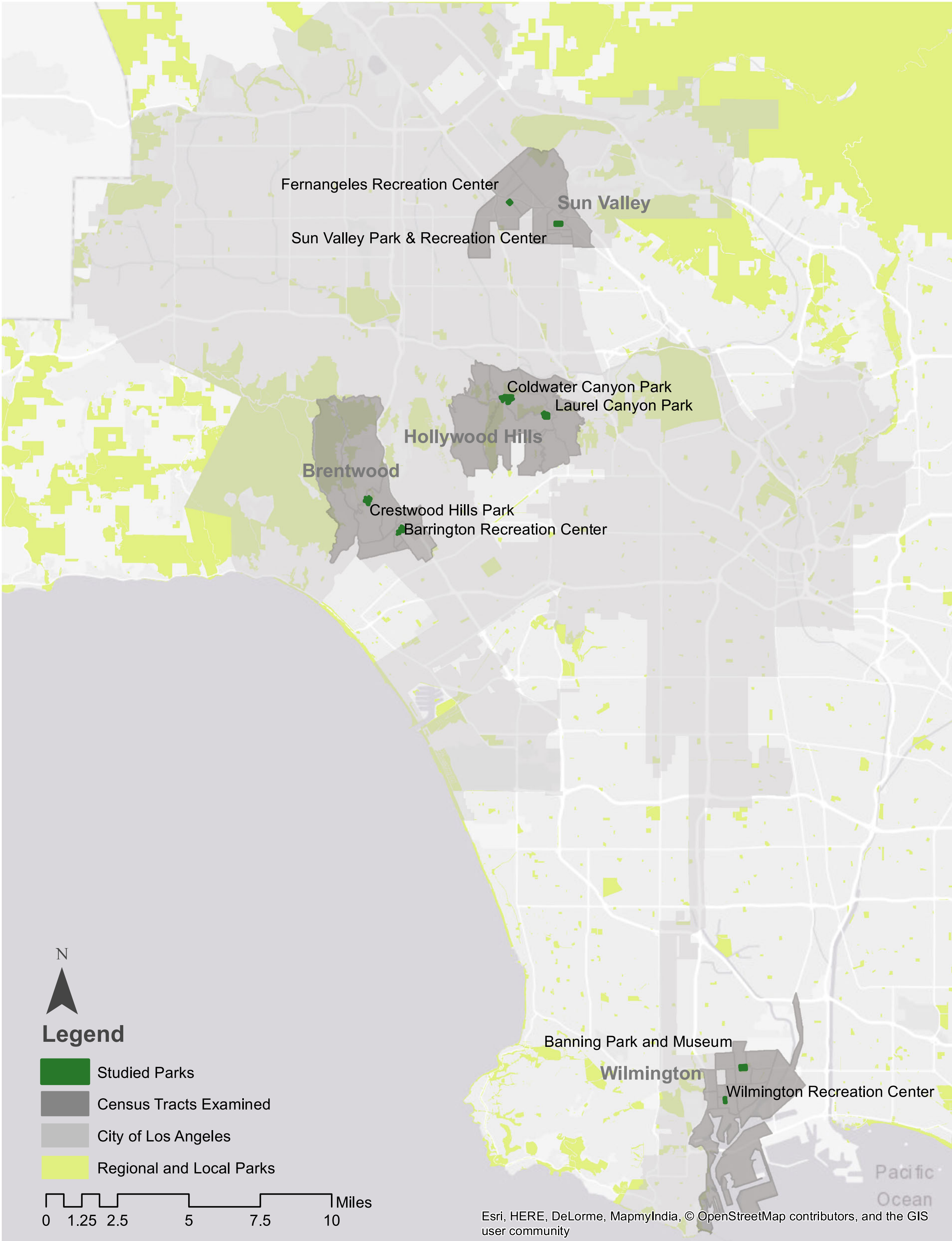
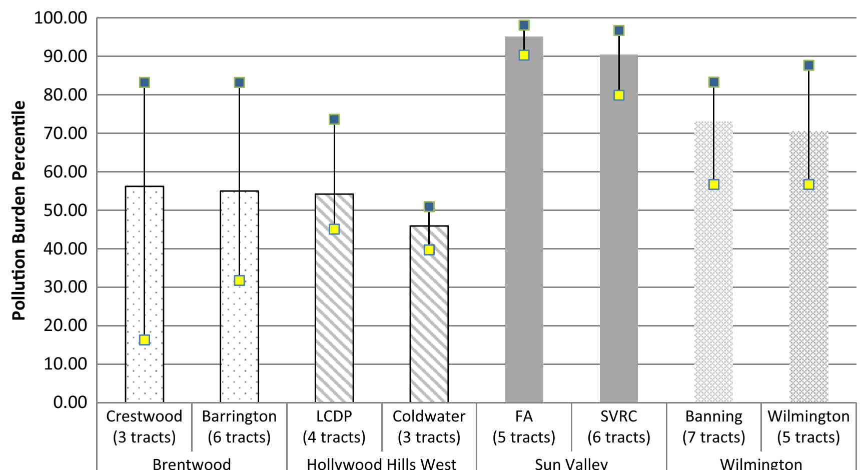


Fig. 1 Map of study area showing the four communities and two parks within each community (pdf file)

Table 1 Community characteristics by community and type

	Community			
	Brentwood	Hollywood Hills West	Sun Valley	Wilmington
Type	Affluent	Affluent	Disadvantaged	Disadvantaged
Geographic locale	Coastal	Inland	Inland	Coastal
Area in square miles	15.22	4.87	9.42	9.14
Estimated 2008 population	33,312	16,003	81,788	54,512
Percent of tree canopy	25.2	36.3	10.5	5.0
Majority ethnic/racial group	White 84.2%	White 84.9%	Latino 69.4%	Latino 86.6%
Median income	$112,927	$108.199	$51,290	$40,627

Data source: Mapping LA data for each community and McPherson et al. 2008



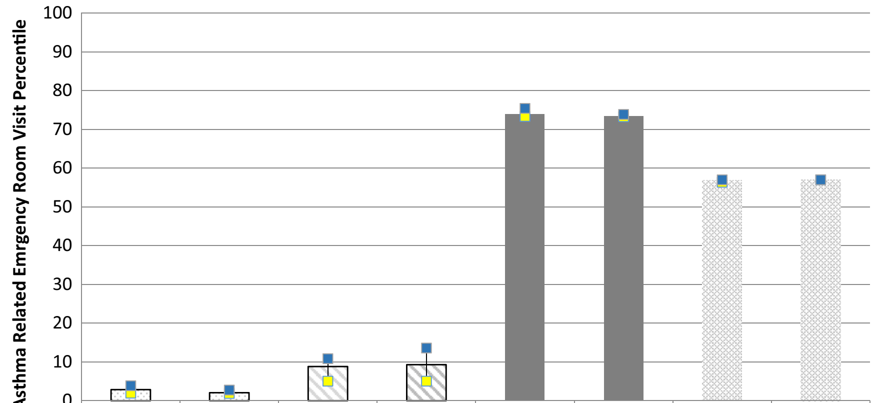
	Crestwood (3 tracts)	Barrington (6 tracts)	LCDP (4 tracts)	Coldwater (3 tracts)	FA (5 tracts)	SVRC (6 tracts)	Banning (7 tracts)	Wilmington (5 tracts)
	Brentwood		Hollywood Hills West		Sun Valley		Wilmington	
Mean	56.20	54.99	54.19	45.92	95.13	90.50	72.85	70.47
Low	16.30	31.75	45.08	39.71	90.29	79.89	56.69	56.69
High	83.21	83.21	73.63	50.94	98.10	96.71	83.29	87.67

Fig. 2 Pollution burden percentiles of neighborhood census tracts by community, using California EnviroScreen 2.0 data (MS Word graph)

selected characteristics of each community from the Mapping LA source, and the percentage of tree canopy cover reported in McPherson et al. (2008). Noteworthy are the higher population densities in the disadvantaged communities, paired with the majority of Latino populations, and the markedly lower median annual household incomes. Community area definition was further informed through the Los Angeles Almanac, as a cross-reference for census tracts included in each community (http://www.laalmanac.com/LA/la99.thm; note that Hollywood Hills West is not separately identified in this resource).

Drawing from an additional resource to further understand neighborhood condition surrounding each park, we used selected data from California EnviroScreen (version 2.0) (https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-version-20). We identified those census tracts within a ½ mile radius around each park, aligned with a common criterion for "neighborhood" park (Han et al. 2014; 2010 Census—Census Tract Reference Map: Los Angeles County). The first round of neighborhood selection involved a review of census tract maps to establish a list of tracts appearing to fall within ½ mile of the perimeter of each selected park. A second round of selection, conducted through GIS, identified tracts with sufficient area falling within the ½ mile radius to meet our criteria for inclusion. The resulting census tracts were drawn from the EnviroScreen 2.0 dataset and analyzed, calculating an average percentile of pollution burden for each of the eight neighborhood parks. The high, low, and average pollution burdens are reported in Fig. 2, reflecting the minimum and maximum burden percentiles across the census tracts included in each neighborhood. Patterns reveal a higher pollution burden associated with each neighborhood in the disadvantaged communities, when compared with the lower burdens associated with the affluent neighborhoods.

The California EnviroScreen 2.0 dataset also reports age-adjusted percentiles of emergency room visits for asthma-related events. This metric was important to our assessment, given the role of ozone in asthma- and respiratory-related incidents (Curtis et al. 2006; Samoli et al. 2011). Percentiles are revealing as an additional indicator of vulnerability in the neighborhoods within the disadvantaged communities



	Crestwood (3 tracts)	Barrington (6 tracts)	LCDP (4 tracts)	Coldwater (3 tracts)	FA (5 tracts)	SVRC (6 tracts)	Banning (7 tracts)	Wilmington (5 tracts)
	Brentwood		Hollywood Hills West		Sun Valley		Wilmington	
Mean	2.84	2.05	8.8	9.28	73.96	73.43	56.87	56.99
Low	1.93	1.86	5.03	5.03	73.36	73.27	56.36	56.99
High	3.85	2.73	10.83	13.57	75.43	73.87	56.99	56.99

Fig. 3 Asthma-related emergency room visit percentiles within neighborhood census tracts by community, using California EnviroScreen 2.0 data (MS Word graph)

(Fig. 3). While there are myriad contributors to emergency room visits for asthma-related events (Curtis et al. 2006; Etzel 2003), we found that these differences further highlighted the level of risk in the disadvantaged communities. Because of the marked variation of asthma-related events in these communities and the ability to monitor ozone on-site, we selected ozone as our target pollutant.

Research Objectives

This paper offers a unique perspective for the increasing emphasis on the role of urban parks in strengthening community resilience, by measuring park use and exposure to ozone among different population groups in communities with varying geographic and socioeconomic characteristics. We apply a multi-method approach, combining both social and ecological measures to questions of resilience as suggested by Kondo et al. (2015). In situ monitoring of ozone exposure and assessment of dose by community affords the opportunity to construct community-based recommendations for monitoring and intervention. Differences in air pollutant levels reported by regional monitoring stations and those gained from personal or on-site monitoring add further credence to our approach (e.g., Geyh et al. 2000; Kondo et al. 2014b; Moretti and Neidell 2011; Su et al. 2011). Additionally, the community focus anchors climate change response at a meaningful and actionable scale (Kondo et al. 2014a; Markowitz et al. 2014). Finally, the geographic and sociocultural variations in the city of Los Angeles point to the need to address place-based differences in areas that may be deemed to be generally at an advantage, where Los Angeles is typically thought of as a relatively affluent region of the state and nation when considering the overall city conditions. Described as a city that is large, dense, rich, and with a large creative-class, Los Angeles has also been highly ranked among large cities in its marked inequality (Florida 2017; https://www.citylab.com/politics/2017/04/new-urban-crisis-index/521037/).

Materials and Methods

A multi-method site and community-specific approach was applied in this study.

Materials for Recreation Observations

A written description, a Google map, and a high-resolution aerial photo of each of the eight parks were issued to field team members. These materials ensured that teams reported to the correct location for data collection, in spite of their assignments for independent work across a wide geographic area.

A paper form was used to record observations of park visitors. Provided fields included park, date of observation, team member names, and number of observation sweeps; and for each person (park visitor) observed—the zone (location), gender (male, female), age group (child, teen, adult, and senior), ethnicity (Latino, Black, Asian, White, and Other), activity level (sedentary, walking, and vigorous), and explanatory notes. The data elements in the observation form were modeled after multiple park studies (Besenyi et al. 2012; Cohen et al. 2007; Floyd et al. 2008; Shores and West 2010) applying the SOPARC (or modified versions, such as SOPLAY or SOPARNA) method of recording recreational activity (Cohen et al. 2007).

Materials for Ozone Monitoring

Ogawa brand[2] passive monitoring badges were selected for their portability and ease of use by field observers collecting participant observation data in tandem to ozone monitoring (contact the corresponding author for additional details on development of the ozone monitoring approach). Ozone monitoring materials (all may be found at http://ogawa.usa.com[2]) were used by the observation team in triplicate as follows: one Ogawa screw-top airtight vial (product #PS-155) labeled with a small piece of opaque tape for field data entry; one plastic zipper close bag containing a single Ogawa passive sampler, including end caps, metal screens, four prepared filter pads, retainer rings, center-base body, and sampler body (product #PS-100) with clip (Fig. 4). Samplers were loaded with two prepared collection pads on each end of the sampler, designed for monitoring of ozone (product #PS-114). Each field investigator wore the same type of hat, with a band above the brim to clip on the Ogawa passive sampler.

Procedure for Observations

Systematic observations of park use took place during August and September of 2015, months falling within the historical record of peak daylight hours and peak average temperatures for the city of Los Angeles (http://www.gaisma.com/en/location/los-angeles-california.html). Sunlight and temperature both interact with ozone production, and our goal was to collect observations when recreation use and ozone would be within peak ranges (Perera and Sanford 2011).

The time band of 7AM to 7 PM was appropriate to capture the range of daylight hours during these 2 months, and further was a reasonable time band for capturing the majority of park use. Time bands were close to those used in prior studies of park use (e.g., Cohen et al. 2007; Shores and West 2010), with some modifications. The AM time band ranged from 7AM to 1 PM, with four timed sweeps (7:15 AM, 8:40 AM, 10:30 AM, and 11:55 AM); the PM time band ranged from 1 PM to 7 PM, also with four timed sweeps (1:15 PM, 2:40 PM, 4:30 PM, and 5:55 PM).

Field observers worked in pairs, and were instructed to arrive on-site at least 15 min prior to the scheduled start time, and to remain in their vehicle until materials were prepared and it was time to begin the observation period. Material preparation included removing two of the Ogawa samplers from the vial and plastic bag and clipping them to hat bands. The third vial and sampler remained sealed and was carried with the team outdoors for the full observation period (6-h duration). Once the team exited the car, they remained outdoors aside from brief breaks or portions of observation sweeps in indoor public areas (such as indoor gyms).

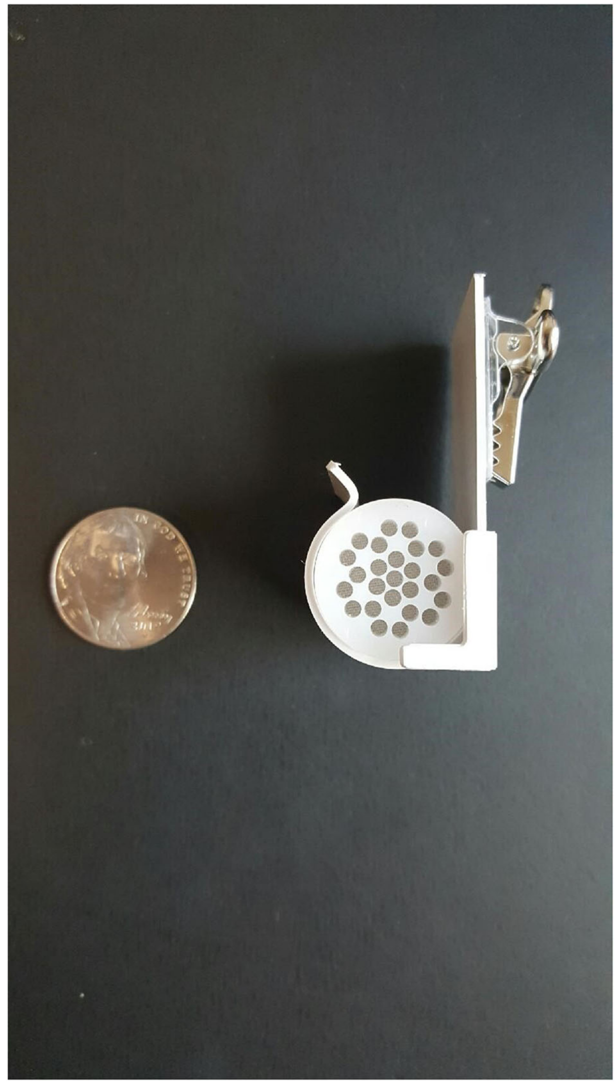


Fig. 4 Assembled Ogawa collector badge alongside nickel for comparison (photo taken by the first author) (jpg file)

During each sweep, the field team began at a specified point in the park, moving from the outer perimeter to the inner areas of the park and passing through any open public buildings. At each encounter with an individual, the team jointly determined the appropriate codes to capture the observation on a separate line. Given the large volume of recordings and the complexity of movements in the park, observers worked in tandem to gather the most accurate record possible. Once all park visitors in a section of the park were recorded, the observers moved to the next area of the park. Observers were instructed to keep movements fluid as though they were strolling through the park, to stop as needed to make notations, and to enter complete information on each

[2] Insertion of product names is for reporting purposes only and is not intended to indicate preference for a particular brand or company.

Table 2 Number of observations gathered by day, time block, community, and neighborhood park

			Brentwood		Hollywood Hills West		Sun Valley		Wilmington	
Date (2015)	Day of week	AM or PM	Crestwood	Barrington	Laurel Canyon Dog Park	Coldwater Canyon	Fernangeles	Sun Valley Recreation Center	Banning	Wilmington
8–22	Saturday	AM	0	0	0	377	0	0	522	0
8–23	Sunday	AM	22	0	0	0	0	351	0	0
8–24	Monday	AM	0	0	67	0	0	0	350	0
8–27	Thursday	AM	122	0	0	0	87	0	0	0
8–29	Saturday	PM	0	0	0	47	0	0	0	197
8–30	Sunday	AM	47	0	0	0	0	0	227	0
9–1	Tuesday	AM	0	256	0	0	0	98	0	0
9–2	Wednesday	PM	0	0	64	0	0	0	0	156
9–4	Friday	AM	0	0	0	105	0	0	0	48
9–5	Saturday	PM	49	0	0	0	100	0	0	0
9–6	Sunday	AM	0	142	0	0	345	0	0	0
9–8	Tuesday	PM	37	0	0	0	0	0	0	122
9–10	Thursday	AM	0	0	0	42	0	93	0	0
9–12	Saturday	AM	0	280	0	0	0	0	0	76
9–13	Sunday	PM	0	273	0	0	0	588	0	0
9–14	Monday	PM	0	278	0	0	398	0	0	0
9–16	Wednesday	PM	0	367	0	0	0	0	331	0
9–17	Thursday	AM	0	0	54	0	47	0	0	0
9–19	Saturday	PM	0	0	57	0	0	638	0	0
9–20	Sunday	AM	0	0	68	0	0	0	0	45
9–21	Monday	PM	84	0	0	0	0	322	0	0
9–22	Tuesday	PM	0	0	0	52	0	0	268	0
9–26	Saturday	PM	0	0	45	0	0	0	528	0
9–27	Sunday	PM	0	0	0	22	558	0	0	0

individual as a separate and distinct observation[3]. When categories could not be determined (e.g., gender of an infant), notes were made to that effect on the appropriate line.

When all four sweeps were completed and the time block for the observational period was at a close, the field team returned to the vehicle, sealed the passive samplers in their respective bags and vials, noted the time the sampler was placed back into each vial, and initialed the entry on the tape attached to the vial. Vials were stored at room temperature upon distribution to teams, were exposed outside of their sealed plastic bags and vials only in the field save for the control blanks, and were returned to the lab on a set schedule.

Field teams had a 25-min window around arrival, departure, and sweep periods. Wider variations of the schedule, for whatever reason, required cancellation of the day's observations and rescheduling, owing to the paired observational design (observations in a matched location occurring on the same day and time block involving another location and team). This impacted not only the team affected by the time issue, but the paired team as well. Only two instances of cancellation occurred when a team was already enroute, another was rescheduled in advance of team departure due to inclement weather. Ogawa samplers can be exposed to light mist; however, measurable precipitation has to be avoided to prevent loss of chemical integrity of the small collection pads.[4]

Observations were conducted over a 2-month period. A schedule for observation days was constructed in advance

[3] If asked, observers were instructed to offer basic information about their employing agency and to explain they were studying recreation use in the parks. Because recreationists could not be individually identified when recorded, and they were in an openly public setting, concerns regarding the observations were minimal.

[4] Additional ozone study was conducted through installation of temporary monitors, left in each of the neighborhood parks for 30 consecutive days during the period of study. We also downloaded ozone data for the days, locations, and proximate regional air quality monitoring stations (https://www.arb.ca.gov/qaweb/sitelist_create.php). These data and the resulting analyses are reported in a separate publication, obtained by contacting the corresponding author.

Table 3 Number of observations by type of community, and specific communities within time block and sociodemographic categories recorded

	Affluent communities		Disadvantaged communities	
	Brentwood	Hollywood Hills West	Wilmington	Sun Valley
	n (percent)	*n* (percent)	*n* (percent)	*n* (percent)
Total observations	1957	1000	2870	3625
Total AM	869 (44.4)	713 (71.3)	1268 (44.2)	1021 (28.2)
Total PM	1088 (55.6)	287 (28.7)	1602 (55.8)	2604 (71.8)
Activity level				
Sedentary	1002 (51.2)	326 (32.6)	1477 (51.5)	2296 (63.3)
Walking	609 (31.1)	615 (61.5)	908 (31.6)	677 (18.7)
Vigorous	341 (17.4)	59 (5.9)	476 (16.6)	575 (15.9)

incorporating six observation blocks (three morning and three afternoon), in total at each of the eight parks. On any single observation day, observations in one affluent and one disadvantaged neighborhood park occurred during the same time block. Observations occurred on weekdays and weekend days, distributed so as to vary the pairs of parks, and the observation days across the 2 months. For each of the parks, observation days were evenly distributed across weekend days and weekdays (see Table 2). Observer teams were also varied to distribute variations by an individual observer.

Analysis

Data from completed recreation observation forms were entered by two research team members into Excel, and compared for discrepancies with discrepancies reviewed by the first author and corrections made. Spot checks of the Excel file against the observation forms were conducted for additional quality control. Data were then transferred into SPSS[5] (version 16) for analysis.

Laboratory chemical analysis of the filters was conducted, with calculations to approximate total ozone saturation in parts per billion. Control blanks and lab blanks (to adjust for variations in equipment settings and process variations) were likewise assessed. Total saturation was converted to an hourly equivalent, based on the presumption that an average park visit was 1 h in duration. Outliers were discarded, resulting in an average ozone of 1 -h assessment for each observation period at each park. Ozone levels were entered into the data file, matched to each observation day and location.

Level of physical activity (sedentary, walking, and vigorous) was converted into metabolic expenditures (METS), using the approach outlined in Ainsworth et al. (2000) and Cohen et al. (2007). This process set sedentary activity at two METS, walking at three METS, and vigorous activity at six METS[6]. The ozone ppb measure was multiplied by the resulting METS value for each individual observed, to estimate ozone dose exposure.

Results

Systematic observations across 24 days, with matched locations on each day, yielded 9452 observations of park visitors. The majority (68.7%) of observations were recorded in the disadvantaged communities (Table 3). The most visitors observed on a single day at one location was 638 individuals[7], the minimum was 22. The vast majority of observations (99.97%) were gathered at outdoor locations; thus, no further distinction between indoor and outdoor observations is offered[8]. A number of the parks lacked indoor facilities, and those that did have indoor facilities had limited periods of operation or were areas excluded from those deemed appropriate for observational study (e.g., zones where privacy would be expected, such as restrooms).

More observations (59%) were recorded during the afternoon than in the morning time blocks (Table 3), and represented the majority of observations in three of the four communities (Hollywood Hills West was the exception).

Males represented the majority (63.4%) of observed recreationists (Table 4), although they represented a larger proportion of visitors in the disadvantaged communities than in the affluent communities. Distribution of male and female recreationists varied significantly by community ($\chi^2 = 251.8$, df = 3, $p < 0.001$).

5 Statistical Package for the Social Sciences.

6 This is a conservative approach in that some physical activities are assigned higher METS values than these generalized assignments. For a list of values and equivalents see Ainsworth et al. (2000). A more activity-specific calculation would be possible had we elected to record the full range of actions that are listed in the compendium of activities.

7 It should be noted that on one occasion, the field team encountered a large gathering for a festival at the assigned park. On that day, the team completed observation forms based on supply of materials and their ability to move through and track the individuals they encountered. We expect that the actual number of visitors was considerably higher than what was recorded; however, we are unable to estimate the proportion of visitors who were unobserved.

8 This was a surprise to us as we had elected to add the indoor spaces after preliminary visits to the parks revealed high levels of indoor participation in planned events, such as Zumba classes, basketball games, and indoor activities for seniors.

Table 4 Proportion of observed recreationists within sociodemographic characteristics and community

Characteristic	Community (by type)			
	Affluent		Disadvantaged	
	Brentwood	Hollywood Hills West	Sun Valley	Wilmington
Gender	$n = 1957$	$n = 1000$	$n = 3625$	$n = 2870$
Males	57.6	45.2	70.6	64.6
Females	42.4	54.8	29.4	35.4
Age group				
Children	29.0	4.9	19.0	22.7
Teens	5.3	3.6	7.8	15.7
Adults	61.1	83.7	67.3	48.3
Seniors	4.7	7.8	6.0	13.3
Ethnic/racial group				
Latino/Hispanic	17.0	9.0	96.5	93.7
Black/African American	2.2	4.0	0.6	1.7
Asian/Pacific Islander	3.5	3.5	0.3	0.2
White/Caucasian	70.8	72.8	2.1	3.8
Other	6.5	10.7	0.5	0.6

The proportion of recreationists within each age group also varied significantly by community ($\chi^2 = 725.0$, df = 9, $p < 0.001$). Adults represented the largest age group observed across all communities (61.4% of observations, Table 4), followed by children, teens, and then seniors.

Latinos were the predominant ethnic/racial group observed in the disadvantaged communities (93.9% overall, Table 4), and made up the largest proportion of ethnic group members observed (68.9%); Whites were the majority group (71.2%) observed in the affluent communities (ethnic/racial group variations by community were statistically significant $\chi^2 = 645.0$, df = 12, $p < 0.001$).

Level of Physical Activity

Level of observed physical activity was primarily sedentary (54.0%), or walking (29.7%), with few observed recreationists engaged in vigorous activity (15.4%; 1.0% of observations were missing level of activity), and these differences varied significantly by community (Table 3, $\chi^2 = 707.2$, df = 6, $p < 0.001$). A somewhat lower proportion of visitors were engaged in sedentary activities when compared with Cohen et al. (2007). Sedentary activity (the least active level) was most frequent in the disadvantaged communities, but varied in the affluent communities.

Level of physical activity also varied by sociodemographic category. Similar to Cohen et al. (2007) and more recently by Han et al. (2014), male recreationists were more than two times as likely to be engaged in vigorous activity than were females (19.7 vs. 8.4%). Teens and children were far more likely to be engaged in vigorous activity than were adults or seniors (30.8, 27.3, 11.0, and 2.5%, respectively). Level of physical activity varied significantly ($\chi^2 = 270.5$, df = 8, $p < 0.001$) by ethnic/racial category with Asians tending to be more active than the other categories of recreationists observed. The majority of Latino recreationists were observed in sedentary activity (58.1%), followed by Whites (47.4%), Blacks (46.5%), and Asians (32.8%).

Exposure to Ozone

Ozone ppb showed considerable daily variations, such that any one park, whether in an affluent or disadvantaged community, was not consistently high or low in ozone readings taken from the passive samplers. Rather than assesssing the ozone variations, translated into 8-h equivalents (the standard approach to examining potential human health risks associated with particular levels of ozone), we took the approach of calculating dose exposure[9]. This assessment considered individual level of physical activity (in METS) combined with the 1-h ozone level from that observation day at the neighborhood park for each person observed (see www.epa.gov/apti/ozonehealth/population for a discussion of dose exposure and responses among various populations).

Ozone dose exposure was significantly higher for recreationists observed in the afternoon than in the morning time blocks across all observations ($t = 33.751$, df = 9187.7, $p < 0.001$; AM $M = 51.86$, PM $M = 88.78$; Cohen's $d = 0.692$). Furthermore, ozone dose exposure was significantly higher in the afternoon time blocks within each community (Table 5).

Contrasting observed categories of recreationists revealed distributions of potential risk from ozone exposure, and the following considers several of those differences, which may be of help in identifying groups at the highest potential risk, though an assessment of multiple factors would be necessary to consider risk to any one individual as a specific example.

Male recreationists experienced higher ozone dose exposure than female recreationists ($t = 8.287$, df = 7787.1, $p < 0.001$; males $M = 77.08$, females $M = 67.06$; Cohen's $d = 0.176$). Dose exposure also varied significantly by ethnic/racial group (ANOVA $F_{4,9169} = 134.68$, $p < 0.001$; $\eta^2 = 0.055$, Fig. 5); and between-group comparisons (Scheffe's post hoc tests) showed that Latino recreationists had significantly higher ozone dose exposures than all other observed ethnic/racial groups. This finding mirrors the

[9] Alternative assessments of ozone readings taken from the parks and case study areas can be obtained by contacting the corresponding author.

report by Su et al. (2011), suggesting that Latino park users experienced higher dose exposures in Los Angeles parks.

Dose exposure also varied by age group (ANOVA $F_{3,9189} = 220.64$, $p < 0.001$; $\eta^2 = 0.067$, Fig. 6). Post hoc comparisons showed significant differences between each age group, where teens had the highest dose exposure, followed by children, adults, and seniors. These differences are associated with the variations in METS by age group, mirroring the same order from the highest to the lowest (ANOVA $F_{3,9345} = 205.91$, $p < 0.001$; $\eta^2 = 0.062$).

Dose exposure was also significantly higher in the disadvantaged community parks than in the affluent parks ($t = 31.586$, $df = 9081.9$, $p < 0.001$; affluent $M = 51.49$, disadvantaged $M = 83.62$; Cohen's $d = 0.631$), illuminating the even greater degree of risk to these communities.

Geographic location (inland vs. coastal) was additionally associated with variation in ozone dose exposure (Fig. 7). The inland disadvantaged community parks showed the highest dose exposure (Sun Valley), followed by the coastal disadvantaged community (Wilmington), the inland affluent community (Hollywood Hills West), and the coastal affluent community (Brentwood) (ANOVA $F_{3,9204} = 540.25$, $p < 0.001$; $\eta^2 = 0.150$). In this assessment, the coastal disadvantaged and the inland affluent community are statistically similar (Scheffe's post hoc comparisons, $p > 0.05$).

Table 5 Ozone dose exposure in AM and PM time blocks by community

Community	Time block	*M* Ozone dose[a]	*t*, df, *p*	Cohen's *d*
Brentwood	AM	43.10	4.529, 1531, < 0.001	0.2099
	PM	51.01		
Hollywood Hills West	AM	52.48	12.696, 367, < 0.001	0.9758
	PM	76.17		
Sun Valley	AM	73.95	18.746, 3026, < 0.001	0.6226
	PM	111.71		
Wilmington	AM	39.66	23.73, 2599, < 0.001	0.9167
	PM	79.55		

[a]Average hourly ozone does exposure in ppb

Discussion and conclusions

Myriad benefits from parks and green spaces have been identified at the individual and community level. These benefits are known to be inequitably distributed across the City of Los Angeles due to disparity in park provision, accessibility, environmental quality, and other factors. Across our community-focused study, we found varied levels of park use; however, the parks in our markedly disadvantaged communities had high levels of visitation and accounted for the majority of observed park users. Findings revealed varying levels of park use by community, time of day, and sociodemographic group. We also found variations in concentrations of groups that tended to mirror community ethno/racial majorities. Variations in level of physical activity were similar to other reports from park studies in urban settings, where males, teens, and children tended toward higher levels of physical activity. Similar to other studies, a majority of park visitors were engaged in sedentary activity; however, proportions were lower than those reported in some studies. Proportions also varied by community, for example, higher levels of physical activity were found in Hollywood Hills West. Likely, this can be linked back in part to the attributes of the parks themselves.

Assessments of ozone dose exposure revealed some cause for continuing concern surrounding current risk levels from air pollution, as well as potential for increases in environmental risk associated with climate change. Similar to Su et al. (2011), Latino recreationists had the highest

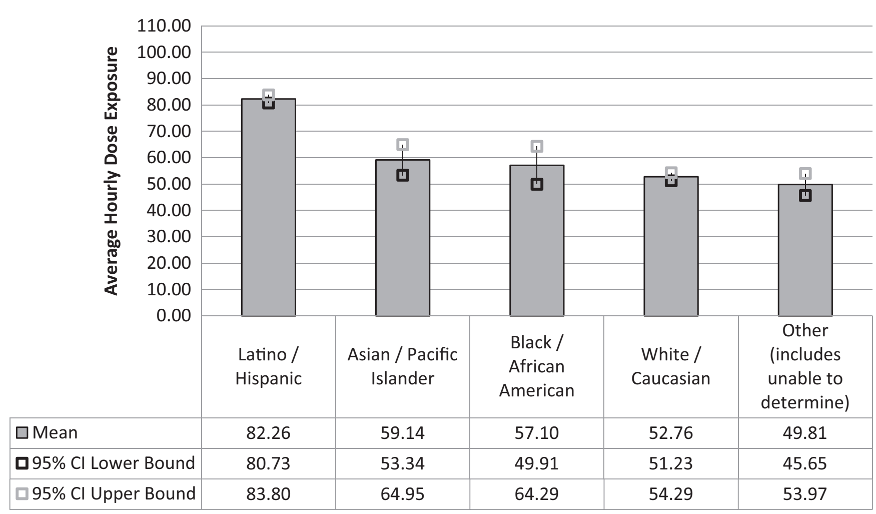
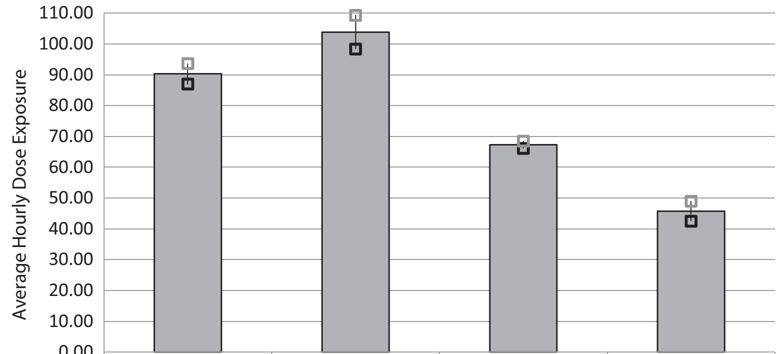
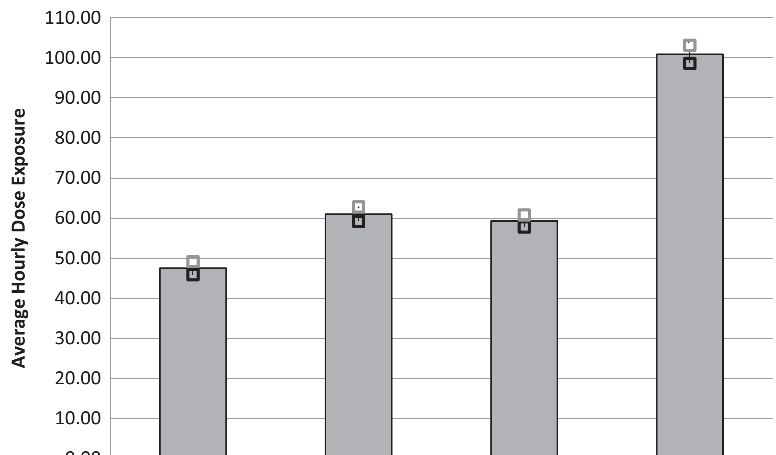


Fig. 5 Average hourly ozone dose exposure (in ppb) by observed ethnic/racial group (MS Word graph)



	Child	Teen	Adult	Senior
Mean	90.33	103.83	67.30	45.72
95% CI Lower Bound	87.00	98.36	66.12	42.48
95% CI Upper Bound	93.65	109.31	68.48	48.97

Fig. 6 Average hourly ozone dose exposure (in ppb) by age group (MS Word graph)



	Coastal		Inland	
	Brentwood	Wilmington	Hollywood Hills West	Sun Valley
Mean	47.51	60.99	59.28	100.88
95% CI Lower Bound	45.86	59.18	57.78	98.62
95% CI Upper Bound	49.16	62.79	60.77	103.13

Fig. 7 Average hourly ozone dose exposure (in ppb) by geographic type and community (MS Word graph)

ozone dose exposures when considering ethnic/racial group differences, representing the majority of visitors to the Sun Valley and Wilmington communities. While it was reassuring that seniors, a population sensitive to ozone exposure, had lower ozone dose exposures, elevated sensitivities may negate the potential benefits of reduced exposure. Additionally, children were the second highest at-risk group for ozone exposure, and this is concerning given their respiratory development and possible longer- term effects. Overall, these findings speak to elevated exposure among sensitive populations. Unique among our findings related to ozone dose exposure was the statistically equal dose exposure found in Hollywood Hills West and Wilmington, suggesting that even in affluent zones, inland areas, particularly in canyons, warrant attention.

Findings were informed by our on-site monitoring of ozone, as suggested by a number of studies. We do not know if ozone was lower or higher in the surrounding neighborhoods than in the parks themselves, as extended exposure outside of the park visit was not addressed in this study (e.g., Geyh et al. 2000). Nevertheless, our findings suggest that additional on-site measurement and monitoring may be beneficial in Los Angeles communities and parks, particularly those in markedly disadvantaged communities already known to be at risk, and more generally in communities that are inland.

Aside from elevation of monitoring effects, cities can integrate a social–ecological approach to the consideration of the role of green spaces in climate change for the purposes of planning (Niemelä 2014). This may be especially pertinent for planning green infrastructure. Urban tree planting to stave off climate change effects should be planned in a way to incorporate environmental justice measures that address inequitable exposure to heat-related land cover risks, such as decreased tree canopy cover (Jesdale et al. 2013). Increased provision of parkland and greenness of parks will aid in reduction of air pollution, helping to mitigate the effects of increasing urbanization and environmental change (Su et al. 2011). Appropriately designed parks will be increasingly valuable in reducing the threat of heat- related stress associated with climate change (Brown et al. 2015). To extend the benefit of green spaces, planning is improved when practices incorporate specific needs and interests of the communities served.

Should continued monitoring reveal variations in risk as evidenced in our study, communication across various mediums will be essential to buffering adverse impacts. When informed, sensitive populations may choose to avoid or decrease exposure to elevated ozone and reduce their personal risks. There are a number of routes for this to occur. Environmental triggers and avoidance of risk are communicated during health-care visits, although researchers have suggested that there is room to provide more specific information on triggers and controls to improve patient outcomes (Washington et al. 2012). Furthermore, evidence suggests that sensitive populations seek information on high ozone days and take considerable care in decreasing their exposure (Neidell 2009). It would be important to ensure that information routes used in messaging align with information sources relied upon by communities: this is of elevated importance in communities with concentrated populations of ethnic/racial minorities. Communications about risk are likely to continue to inform avoidance behaviors, reducing risk to sensitive populations. It might be noted that destination-related avoidance behaviors associated with high ozone risk represent an annual cost estimated at $11 million per year in Los Angeles (measured as reduced zoo, observatory, and professional baseball game attendance; Moretti and Neidell 2011), though the gains through health-protective decisions would make an interesting comparison of economic impacts.

Anchoring our inquiry at the community scale may aid focused efforts across municipal, nongovernmental, and community-based organizations that may leverage this information to address their ongoing efforts in urban greening and championing the benefits of urban parks. Our findings should not be taken as an indication that parks should not be widely used, nor that public currently not using the parks or engaged in sedentary activities while in the parks are better at protecting their outcomes. Instead, our study highlights the paired socioecological considerations that are likely to intensify as climate change effects continue to unfold, including the importance of improved tree canopy cover and provision of green space.

Limitations

We recognize that there are some limitations to our inquiry. As discussed before in the description of case study areas, the selection of edge parks for one community shifts the parks slightly out of the Hollywood Hills West community. While the parks still represent markedly affluent areas, their placement, as well as particular design features of each of the selected parks, make them somewhat unique, as compared to the other parks. Incorporating additional parks or communities may have been beneficial. While our observational approach and application of in situ monitoring offer evidence across the groups of park users, we did not gather survey or interview data exploring variations in individual sensitivities or even length of the park visit. Because other investigations were referenced that explored these dimensions of park use and risk, we found this to be less concerning. Last, seasonal variations occur in exposure to ozone as well as park use. Our data represent findings from late summer, early fall across a 2-month period. Park use and risk exposure may be considerably different during other seasons of the year (e.g., Geyh et al. 2000).

Future Research and Applications

Future research focused on encouraging active park use, particularly in areas impacted by elevated risks from pollutants, may benefit from incorporating a nuanced approach. Taking a culturally competent approach to communications that would address park use and mitigating individual risks may be especially important in minority communities, particularly those already known to be at elevated risks. Beyond that, the design of parks and green spaces, paired with programming that meets the needs of underserved groups will remain essential in addressing some of the variations in park use. Interventions in the design of green spaces and parks that intentionally aim at increasing vegetation to aid cooling effects and removal of air pollutants seem especially important in communities already at a marked disadvantage. These combined efforts may improve community resilience over the long term, where the beneficial contributions of urban parks and green spaces may be better protected and the risks of elevated exposure to climate change effects may be reduced. Taking such socioecological approaches at the community scale may improve future outcomes, particularly for vulnerable communities. Urban parks and green spaces represent high social and ecological value at present and values that increase in importance in light of effects associated with climate change. Consideration of how these benefits are distributed across communities, particularly for disadvantaged communities, remains an area where paired social and ecological analyses are especially important. The study of park benefits is advanced by determining where and how those benefits may be at risk, and approaches to mitigating a loss of benefits where possible for a more sustainable future.

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Compliance with Ethical Standards

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

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the Institutional Review Board and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Institutional Review Board approval was granted through California State Polytechnic University, Pomona File Review # 14-0111.

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