Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Greenspace and park use associated with less emotional distress among college students in the United States during the COVID-19 pandemic

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ABSTRACT

The COVID-19 pandemic has negatively affected many people's psychological health. Impacts may be particularly severe among socially vulnerable populations such as college students, a group predisposed to mental health problems. Outdoor recreation and visits to greenspaces such as parks offer promising pathways for addressing the mental health challenges associated with COVID-19. During the early stages of the pandemic (March–May 2020), we surveyed 1280 college students at four large public universities across the United States (U.S.) to assess how, and why, outdoor recreation and park use changed since the emergence of COVID-19. We also measured students' self-reported levels of emotional distress (a proxy for psychological health) and assessed potential demographic and contextual correlates of distress, including county-level per capita park area and greenness, using generalized linear models. We found that 67% of students reported limiting outdoor activities and 54% reported reducing park use during the pandemic. Students who reduced their use of outdoor spaces cited structural reasons (e.g., lockdowns), concerns about viral transmission, and negative emotions that obstructed active lifestyles. Students who maintained pre-pandemic park use levels expressed a desire to be outdoors in nature, often with the explicit goal of improving mental and physical health. Emotional distress among students was widespread. Models showed higher levels of emotional distress were associated with reducing park use during the pandemic and residing in counties with a smaller area of parks per capita. This study of U.S. college students supports the value of park-based recreation as a health promotion strategy for diverse populations of young adults during a time of crisis.

1. Introduction

In early 2020, a novel coronavirus (SARS-Cov2, hereafter COVID-19) rapidly expanded into a global pandemic that negatively affected human health in unprecedented ways (Bao et al., 2020; Holmes et al., 2020). Although most COVID-19 research has focused on the morbidity and mortality rates associated with disease (Baud et al., 2020), a rapidly growing body of research has also revealed significant impacts on

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mental health (Holmes et al., 2020; Torales et al., 2020). Government-imposed "lockdowns" and "stay-at-home" orders designed to minimize social contact effectively slowed the spread of the pandemic (Atalan, 2020), but their effects on psychological well-being in populations around the world have been profound (Pfefferbaum and North, 2020; Torales et al., 2020). For example, studies have shown pandemic-related increases in feelings of loneliness and isolation (Stieger et al., 2021), acute stress (Holman et al., 2020; Javelle et al., 2021; Liu et al., 2020), anxiety (Ahmed et al., 2020), depression (Holman et al., 2020; Kantor and Kantor, 2020), and other negative emotions (Lades et al., 2020) and behaviors such as suicide (O'Connor et al., 2021). These collective impacts are so severe that some scholars are referring to the mental health spillover from COVID-19 as the "second pandemic" (Choi et al., 2020).

Outdoor recreation and parks offer promising pathways toward psychological health and well-being during this time of crisis. Pre-pandemic research has demonstrated how park proximity, park acreage, and park use can improve health and overall quality of life (Hartig et al., 2014; van den Bosch and Ode Sang, 2017). Outdoor recreation encourages active lifestyles that reduce the risk of cardiovascular disease and other chronic health conditions (Lachowycz and Jones, 2013; Twohig-Bennett and Jones, 2018). Contact with parks and greenspace has also been linked to improved cognitive functioning (Bratman et al., 2019), attention restoration (Kaplan, 1995), stress reduction (Hunter et al., 2019), subjective and emotional well-being (Capaldi et al., 2015; Larson et al., 2016), and positive social relationships (Jennings and Bamkole, 2019).

The health promotion potential of parks, widely recognized before COVID-19, has been elevated during the pandemic. After research revealed that COVID-19 transmission risk was significantly lower in outdoor settings (Bulfone et al., 2020; Johnson et al., 2021; Rowe et al., 2021), many outdoor spaces reopened with physical distancing mandates and other precautions (e.g., face coverings) in place (Venter et al., 2020). With few indoor alternatives, outdoor recreation in public parks and greenspaces provided a safe and much needed respite for many people suffering from life in lockdown (Grima et al., 2020; Kleinschroth and Kowarik, 2020; Samuelsson et al., 2020). Indeed, research shows that park use was not associated with COVID-19 rates in the early months of the pandemic (Curtis et al., 2021). Evidence also suggests the physical activity associated with outdoor recreation might also diminish the risk of severe COVID-19 outcomes if someone contracts the disease (Sallis et al., 2021).

Considering the diverse benefits of nature exposure, Slater et al. (2020) recommended keeping the parks open and accessible during the pandemic period. Research has also shown that youth (Jackson et al., 2021) and adults (Cindrich et al., 2021; Poortinga et al., 2021; Pouso et al., 2021; Ribeiro et al., 2021) who maintained outdoor activity during the pandemic reported better psychological health outcomes than those who did not go outside. Greenspace exposure, often measured based on proximity and access, has also been associated with lower COVID-19 mortality, infection, and racial disparities in infection rates in the United States (Klompmaker et al., 2021; Lu et al., 2021a, 2021b; Pan et al., 2021; Russette et al., 2021; You and Pan, 2020); in other parts of the world, however, associations between COVID-19 mortality and infection rates and greenspace are mixed (Labib et al., 2021; Ribeiro et al., 2021; Viezzer and Biondi, 2021; You et al., 2020). Collectively, these studies highlight the wide range of health benefits that outdoor recreation and park use might provide in the era of COVID-19 (Soga et al., 2021a), yet underscore the need for additional research.

Despite this health promotion potential, not everyone has benefitted from access to parks and greenspaces during the pandemic. These differences may stem from pre-existing inequities in park use and access (Nesbitt et al., 2019; Rigolon et al., 2018), as well as variable implementation of closures and lockdown measures (Killeen et al., 2020). Overall effects of COVID-19 on park use have varied across different geographic and socio-political contexts, severity of lockdown, and by data collection timing and method. Park managers have reported a substantial increase in visitation (Derks et al., 2020; Pregitzer et al., 2020; The Trust for Public Land, 2020), a trend that has been particularly noticeable in national (Avitt, 2021) and state parks (Chavez, 2021) across the United States. Although some research using mobile tracking data from the early stages of pandemic noted increases in park use across multiple countries (Geng et al., 2021; Lu et al., 2021b; Venter et al., 2020), other studies geo-tracking park users have found significant decreases in urban park visitation following the emergence of COVID-19 (Jay et al., 2021; Larson et al., 2021). Self-reported data at various stages of the pandemic has often revealed a decrease in outdoor recreation participation for adults (Burnett et al., 2021; Larson et al., 2021; Rice et al., 2020; Ugolini et al., 2021) and youth (Jackson et al., 2021) across multiple countries. Other studies using self-reported data have found mixed results (Berdejo-Espinola et al., 2021), or even increases in certain regions (Grima et al., 2020; Morse et al., 2020). This conflicting evidence, partly an artifact of different contexts and data collection methods (Labib et al., 2021), highlights the need for more research investigating the impact of COVID-19 on outdoor recreation and park use.

Variable patterns of outdoor recreation, park use, and associated mental health during the pandemic may be due, in part, to demographic differences. For example, multiple studies have shown that younger adults are more likely to experience stress, anxiety, depression, and negative behavioral outcomes (e.g., drug abuse, suicide) stemming from periods of lockdown and social isolation (Ahmed et al., 2020; Bruine de Bruin, 2020; O'Connor et al., 2021). College students are a subset of young adults who may be especially vulnerable to these psychological impacts (Browning et al., 2021). Prior to the pandemic, research had already revealed an emerging mental health crisis among college students (Holm-Hadulla and Koutsoukou-Argyraki, 2015; Oswalt et al., 2020). In the era of COVID-19 those concerns have intensified, with numerous studies across multiple countries illuminating the disturbing psychological toll of the pandemic experience at colleges and universities around the world (Aristovnik et al., 2020; Browning et al., 2021; Charles et al., 2021; Chirikov et al., 2020; Elmer et al., 2020; Kaparounaki et al., 2020; Woolston, 2020). While some studies have explored specific risk factors associated with psychological impacts of the pandemic on college students (Browning et al., 2021) and many recommendations have been proposed (Chirikov et al., 2020), little research has examined strategies that students are using to effectively cope with these unprecedented challenges.

Our study examined the specific role that outdoor recreation, park use, and park availability (measured as park acreage per capita in the surrounding county) might play in helping college students cope with the psychological impacts associated with the COVID-19 pandemic. Sampling a diverse population of students across the United States, we addressed two specific objectives. First, we explored patterns of outdoor recreation and park use among college students following the arrival of COVID-19, investigating how and why park use changed during the pandemic. Second, we examined associations between outdoor recreation participation, park use, park availability, local vegetation cover, and the emotional distress of college students during the pandemic.

2. Methods

2.1. Survey data collection

In spring 2020, we invited 10,195 college students to participate in a web-based survey. Recruitment occurred cross-sectionally and focused on undergraduate students at four large public universities across the United States: North Carolina State University (NCSU) in Raleigh, NC (approximate enrollment of 26,000 undergraduate students, with 8000 invited to participate), Oregon State University (OSU) in Corvallis, OR (26,000, with 1207 invited), the Pennsylvania State University (PSU) in State College, PA (41,000, with 141 invited), and the University of

Montana (UMT) in Missoula, MT (8,000, with 847 invited). We were able to obtain a randomly-selected, university-wide representative sample at one institution (NCSU). Other institutions used targeted samples in the home college(s) or department(s) of the contributing author. Human subject review board requirements and listserv availability influenced selection of the sampling scheme (i.e., representative or targeted) at each institution. The human subjects research was approved by Institutional Review Boards at each of the participating institutions (NCSU IRB #23493, OSU IRB #2020–0636, PSU IRB #00015025, UMT IRB #69–20) prior to implementation, and respondents provided written consent when they completed the online survey.

Recruitment began following human subject approval and occurred over a two-to-three week time period at each institution. Nationwide recruitment was staggered because approval took longer at some institutions, ranging from March 26, 2020, at NCSU to May 11, 2020, at OSU. At the beginning of the survey administration period, students received an email with a link to the Qualtrics questionnaire; a reminder email was sent approximately one week later. No incentives for study participation were provided. From the 10,195 students invited to participate in the survey across all institutions, we received 1280 responses that contained sufficient data for analysis after exclusions, yielding an effective response rate of 12.6%. Exclusions included respondents with missing data for demographic variables (n = 202), including those who did not provide a ZIP code (i.e., U.S. postal area code) that enabled us to identify their location (n = 34) and, by extension, location-based variables such as park acreage. The final sample included undergraduate students at these institutions who were residing somewhere in the lower 48 states (i.e., outside of Alaska and Hawaii) during the early stages of the COVID-19 pandemic.

2.2. Survey instrument and self-reported measures

The survey instrument consisted of both open- and closed-ended questions pertaining to broader impacts of COVID-19 on college students' recreation behavior, park use, and mental health. We used two items to assess behavioral outcomes pertaining to outdoor recreation and park use (Objective 1), with higher scores representing larger declines (see Table S1). The first item examined the extent to which students were limiting outdoor recreation activities. Following a previous study examining behavior change and precautions taken in response to the H1N1 pandemic (Jones and Salathé, 2009), as well as the data collected through unstructured interviews with adults on their experiences in the early stages of the COVID-19 pandemic, we asked: "Given the state of the coronavirus pandemic, how often do you take the following precautionary actions?" The question was followed by five behaviors with possible responses including never (1), rarely (2), sometimes (3), most of the time (4), and always (5). One of the potential actions was "limiting outdoor activities (walking, boating, gardening, fishing, hunting, etc.)." The second question focused specifically on park use, asking students "How has the threat of coronavirus impacted your use of public parks for outdoor recreation activities?" Response options included visit much more often (1), visit more often (2), hasn't changed (3), visit less often (4), and visit much less often (5). We followed this with an open-ended question asking participants to explain reasons for any changes in park use (whether use increased or decreased).

We assessed emotional distress (Objective 2), a common proxy for psychological health (Winefield et al., 2012), using five survey items measured with a visual analogue scale (VAS, see Table S1). Specifically, we asked participants the extent to which they were currently experiencing each of five emotions (afraid, irritable, sad, preoccupied, and stressed) on a 0 (not at all) to 100 (extremely) response scale. The first three emotions are components of the widely used positive and negative affect schedule (PANAS) for measuring positive and negative mood states/traits (Watson and Clark, 1994); the second two emotions were added based on other studies exploring the impacts of the pandemic on college students (Browning et al., 2021; Chirikov et al., 2020). The items from the PANAS were selected from four concepts identified during its development (i.e., being afraid, irritable, guilty, and sad). However, feeling guilty has not co-varied with the other three concepts in past work on emotions related to COVID-19 (Browning et al., 2021), and thus was not used here. Scores from each of the five items were averaged to create an index ranging from 0 (no emotional distress) to 100 (greatest possible emotional distress). This scale has been used in previous research (Browning et al., 2021) and demonstrated adequate internal reliability in our sample (Cronbach's $\alpha = 0.82$). The VAS approach has been used successfully in other research measuring mental health outcomes such as stress and depression (Z. Huang et al., 2020).

We also accounted for several other potential correlates of outdoor recreation and emotional distress. General health status was assessed with a single item asking about one's general health on a five-point self-rated scale from poor (1) to excellent (5) (Centers for Disease Control and Prevention, 2018). Body mass index (BMI), calculated from self-reported height and weight, was included because it has been implicated as a risk factor for the psychological impacts of COVID-19 (Y. Huang et al., 2020). Since knowing people directly impacted by a traumatic event is a predictor of stress (Ghafoori et al., 2009), we asked if respondents knew someone infected with COVID-19 as a binary "yes/no" item. Worrying about COVID-19 has also been shown to constrict people's outdoor recreation behavior (Mateer et al., 2021) and negatively affect mental health (Mayorga et al., 2021). To assess respondent's overall level of worry during the early stages of the pandemic, we employed a single item adapted from the Penn State Worry Questionnaire (PSWQ) that asked participants to indicate their agreement with the statement "I worry a lot about the coronavirus" on a five-point scale (Browning et al., 2021; Schroder et al., 2017). We measured relative income based on recommendations from Rubin et al. (2014) with a single question: rate your family income relative to other people in the United States, from well below average (1) to well above average (5). Other demographic characteristics self-reported in the questionnaire included racial/ethnic group, sex, and age.

2.3. Secondary spatial data sources

Self-reported ZIP codes where the participants were "currently located (as they took the survey)" were used to locate their place of residence during the first months of the pandemic. Based on the ZIP code and U.S. Census population data, we estimated whether a respondent lived in an urban setting (as opposed to rural), nearby (county-level) park area, and local vegetation cover. To characterize a ZIP code as urban, we used a population density of >300 people per square kilometer, a threshold introduced elsewhere (United Nations Statistical Commission, 2020).

Because the impacts of COVID-19 and associated government responses varied across different geographic contexts, potentially impacting both outdoor recreation behavior and emotional distress levels, our model controlled for two additional variables. To approximate the severity of COVID-19 health impacts in a particular area at the time of the survey, we calculated the cumulative number of COVID deaths per 1000 residents in each U.S. county through April 30, 2020 using a harmonized spatially explicit database created by Killeen et al. (2020) from the COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (Dong et al., 2020; see Table S2). Later, these cumulative death rates were assigned to each ZIP code within each county, since these were the geographic units of analysis for where respondents were living at the time of the survey. In addition, to account for the severity of COVID-19 lockdown measures implemented at the time of the survey, we used a county-level dataset (Killeen et al., 2020) documenting eight different types of government responses to different stages of COVID-19 (e.g., stay-at-home orders, limits on mass gatherings, school closures, dining and travel restrictions) to generate a lockdown level index that ranged

from −8 (no regulations imposed) to +8 (all possible regulations imposed; see Table S3).

Finally, we built variables describing access to public parks at the larger county-level scale. We used a county-level assessment because (a) this matched the scale of the COVID-19 infection and lockdown covariates in our models, and (b) this approximated the broader availability of a variety of parks, including both small local parks and large open space like state parks and national forests that are rarely located in one's neighborhood and are typically reached via automobile. Many of these larger parks also received record visitation during the pandemic (Avitt, 2021; Chavez, 2021). Data for local parks, state parks, and national parks and forests updated to 2020 were collected from Esri, which maintains a national dataset of publicly accessible parks (Esri, 2021). With these data, we built two variables describing park area normalized by population at the county level: area (km^2) of national/state parks and forests per 10,000 residents (describing larger, natural parks) and area (km^2) of local parks per 10,000 residents (describing smaller urban parks). To model the quantity of green space at a finer geographic scale we included the vegetative cover, which we assessed with the normalized difference vegetation index (NDVI) at the ZIP code level. The NDVI was derived from MODIS data for the year 2018. We considered only those scenes during June and August when the vegetation is greenest. Per ZIP code, we determined the median NDVI scores.

2.4. Data analysis

For Objective 1, we first used descriptive statistics to explore changes in outdoor recreation and park use during the pandemic. We next used a generalized linear model with a logistic link function to assess correlates of limiting outdoor recreation and reducing park use. The survey responses for these outcomes were reduced to binary variables to facilitate interpretation by highlighting larger patterns of change. Re-coded scales included the following: for limiting outdoor recreation, 1 = sometimes, most of the time, or always vs. 0 = never or rarely; for reducing park use, 1 = much less/less often vs. 0 = hasn't changed, more often, or much more often. In both models, we adjusted for person-level (relative income, race, sex, and age, general health, BMI, knowing people infected by COVID-19, and worrying about COVID-19) and area-level correlates (urbanity, area of local parks per capita, area of state/national parks per capita, NDVI, university where each student was enrolled, COVID-19 death rates, and COVID-19-related lockdown levels). Park area was transformed to generate interpretable coefficients, which otherwise would be minute compared with other variables. The exact transformation applied to these variables was with the bestNormalize package V 1.8.0 (Peterson, 2021), which runs a variety of possible transformations and ranks each using the Pearson P statistic (divided by its degrees of freedom). The ordered quantil technique (Peterson and Cavanaugh, 2020), which is based on a rank mapping to the normal distribution, was identified as the best choice for transforming the per capita park area data. In all models, we used fixed effects to model that students were nested within four universities.

To understand reasons why students increased, decreased, or maintained their park use during the pandemic, we also coded and analyzed open-ended responses. Coding was completed by a single researcher who used inductive coding based on the content of the responses, following guidelines for conventional content analysis (Hsieh and Shannon, 2005). Once all responses were coded, a sample of responses and the codebook was sent to another member of the research team who reviewed the responses and the codes as a reliability check. After both researchers agreed on the codes, codes were then organized around themes pertaining to less park use and more park use.

For Objective 2, we used a linear regression model to examine correlates of emotional distress. This model accounted for the same person-level and area-level variables in the logistic regression models described above, including local COVID-19 death rates and lockdown levels. The model also integrated the variables related to changes in outdoor recreation behavior and park use that were the dependent variables in the models tested for Objective 1. We interpreted $p < .05$ as statistically significant and assessed model fit with McFadden's pseudo R^2 (logistic regression) and adjusted R^2 (linear regression). Multicollinearity was tested with VIF values < 3.0. All analyses were conducted in R V3.6.2 (R Core Team, 2020).

3. Results

3.1. Sample description

Most students in our sample were non-Hispanic White (81%), female (61%), and between the ages of 18 and 24 years old (80%). A majority of respondents were from NCSU (75%). Approximately 26% of students personally knew someone infected with COVID-19 at the time of survey completion. See Table 1 for more details about the college student sample.

3.2. Outdoor recreation behavior, park use, and correlates

The majority of college students reduced their outdoor recreation activities and park use during the pandemic (Table 1). Approximately two-thirds reported that they limited their outdoor recreation activities some, most, or all of the time in response to the pandemic, and just over one-half indicated that they reduced their park use during the pandemic. The bivariate correlation between limiting outdoor recreation and reducing park use was significant and positive ($r = 0.40$, $p < .001$).

Our first logistic regression model examining correlates of limiting outdoor activity in the early stages of the pandemic showed that race, general health, and worrying about COVID-19 were associated with this behavior (Table 2). Specifically, students who were Asian or Black were over three times more likely to reduce their outdoor recreation than other races/ethnicities, $p \leq .004$. In contrast, each unit increase in general health (from 1 = poor to 5 = excellent) was associated with a 28% reduced probability of limiting outdoor recreation, $p < .001$. Also, each unit increase in agreement with the statement "I worry all of the time about coronavirus" (on a scale from 1 = strongly disagree to 7 = strongly agree) was associated with a 16% increased probability of limiting outdoor recreation, $p < .001$. Enrollment at a university situated in the mountainous region of the western United States (UMT) was associated with a 54% reduced probability of limiting outdoor recreation, $p = .009$. Neither measure of park area per capita nor greenness were associated with limiting outdoor recreation, $p > .10$.

Our second logistic regression model examining correlates of reducing park use in the early stages of the pandemic showed many similar correlates as limiting outdoor recreation (Table 3). Like with outdoor recreation, students who were Asian or Black were two to three times more likely to limit their park use, $p < .001$. In addition, each unit increase in agreement with the statement "I worry all of the time about coronavirus" was associated with an 18% increased probability of limiting park use, $p < .001$. Enrollment at another university in the western United States (OSU) was associated with a 91% increased probability of limiting park use, $p = .024$. Once again, neither park area per capita nor greenness were associated with reducing park use, $p > .10$. Local lockdown level index scores were not significantly associated with limiting outdoor recreation or reducing park use, but per capita COVID-19 death rates were linked to reduced park use (Table 3).

Qualitative analysis of the open-ended survey question about reasons for shifting park use resulted in 36 distinct codes organized into six themes (three each for more and less park use). Of those who responded to the open-ended question (n = 1267), about 60% of responses indicated they had been using parks less during the pandemic, and about 21% indicated they had been using parks more, with about 19% indicating their use remained the same. Themes associated with less use are all related in some aspect to COVID-19, including structural constraints, virus transmission concerns, and negative feelings and emotions. The

Table 1
Characteristics of college students across the United States who completed the study questionnaire between March–May 2020 (N = 1280).

Characteristic	*N* (Sample Proportion[a])	Mean (*SD*)
School		
NC State University	958 [74.60%]	
Oregon State University	126 [10.44%]	
University of Montana	119 [9.12%]	
Penn State University	77 [5.85%]	
Relative income[b]		3.25 (1.10)
Race/ethnicity		
White	1036 [80.94%]	
Asian	141 [11.02%]	
Hispanic/Latinx	52 [4.06%]	
Black	51 [3.98%]	
Sex (female)	775 [60.55%]	
Age (<25 years)	1018 [79.53%]	
General health[c]		3.27 (1.02)
BMI[d]		24.10 (4.61)
Knowing someone infected with COVID-19 (yes)[e]	332 [25.94%]	
Worrying about COVID-19[f]		3.99 (1.67)
Urban county[g]	897 [70.08%]	
COVID-19 death rate per 1000 country residents[h]		1.62 (4.11)
Lockdown level index[i]		7.94 (0.45)
Area (km^2) of local parks per 10,000 residents in county[j]		0.05 (0.08)
Area (km^2) of national/state parks per 10,000 residents in county[j]		8.69 (35.87)
NDVI[k] in ZIP code		0.69 (0.12)
Limiting outdoor recreation (yes)[l]	856 [66.88%]	
Reducing park use (yes)[m]	695 [54.30%]	
Emotional distress[n]		57.37 (21.02)

[a] Proportion calculated by dividing the number of respondents in each category by the total sample (1,280).
[b] Relative personal income rated on a scale from 1 = well below average to 5 = well above average.
[c] General health was rated on a scale from 1 = poor to 5 = excellent.
[d] BMI was calculated based on self-reported height and weight.
[e] Respondents indicated if they personally knew someone who had been infected by COVID-19.
[f] Worry about coronavirus is measured with the item, "I worry about the coronavirus all of the time," on a 1 = strongly disagree to 7 = strongly agree response scale.
[g] Urban vs. non-urban status of student's county of residence at the time of the survey calculated based on population densities provided by U.S. Census Bureau.
[h] COVID-19 death rate estimates the cumulative number of COVID-19 deaths in each U.S. county reported through April 30, 2020 (see Table S1 for more details).
[i] Lockdown level index reflects the aggregation of eight different intervention types (e.g., stay-at-home orders, restrictions on large gatherings) employed within different U.S. counties during the early stages of the pandemic (see Table S2 for more details).
[j] Local, state, and national park area (km^2) per 10,000 residents calculated based on park statistics (from Esri, 2021) divided by population estimates.
[k] NDVI = Normalized difference vegetation index for the county in which a student resided when completing the survey; NDVI values range from −1 (water cover, no vegetation) to 0 (rock or impervious surfaces, no biomass) to +1 (dense green cover).
[l] Limiting outdoor recreation reported as binary variable where sometimes, most of the time, or always = "yes" and never or rarely = "no".
[m] Reducing park use reported as binary variable where visiting parks less = "yes" and visiting parks more or not changing visitation = "no".
[n] Emotional distress is measured as an aggregate scale of 5 items (afraid, irritable, sad, preoccupied, and stressed) ranging from 0 (none) to 100 (most extreme level of emotional distress).

most common reasons students used parks less were directly related to restrictions, park closures, and shifting social norms (i.e., structural constraints). For example, one student noted "My local parks are all closed," and another said "I can't take my son to playgrounds. Certain parks aren't open. I worry about people judging me for being at a park." Other reasons for not visiting parks centered on virus transmission, including avoiding contact with others ("I avoid going to any public places for my health"), protecting others ("Family members are at high risk, I don't want to endanger them"), and avoiding crowded parks ("I used to go to parks frequently, but there are so many people there right now I've been avoiding them"). Some students attributed reduced park use to negative feelings or emotions. For instance, one student mentioned anxiety: "I am concerned for mine and others' health and anxiety makes me scared to leave the house at this time." Another mentioned fear: "Due to fear of the risk of exposure in transit or in the park, from either people or surfaces," and another described being sad: "I would like to go to the park, but online classes combined with sadness has made it hard for me to leave the house."

Themes associated with increased park use included a desire to be outdoors (or in nature specifically), occupying idle time, and improving mental and physical health. For example, one student noted a "need to go outside for fresh air and exercise" and another expressed a desire to discover new places: "… we're getting bored with the neighborhood, so we're exploring local parks and trails." One student described how nature provided a unique escape during COVID-19: "Nature is really the only refuge left untouched by the pandemic. Since the weather is nice now that it is spring, and since there are far fewer things to do, I've been spending more time outside." Other students remarked that visiting parks gave them something to do outside of the house: "I need to walk around and get out of the house so I utilize the parks much more than I used to." Many people discussed health-related motivations for increasing their park use during the pandemic, such as to get exercise ("I can no longer exercise at the gym so I now go on runs around my neighborhood and local parks/trails"), to improve their mental health ("Being outside is the best thing for my mental health"), or because it makes them happy. For instance, one student said: "I'm at my least happy when I'm cooped up inside for extended periods of time and isolated from people. I love going outside … and it's been so beautiful these past two weeks. As my only real reprieve from isolation, I try to go and take a walk outside for at least an hour once a day because it's like a treat for myself and genuinely the light of my week." If a respondent reported using parks pre-pandemic and maintaining that same level of use during COVID-19, they often cited the same reasons as those who increased their park use. For example, one student noted: "Parks are still open and it's easy to socially distance yourself there. They're also beautiful places. I won't let the virus impact my use of parks until they close them down."

Table 2
Results of logistic regression model showing correlates of limiting outdoor recreation activities during the early stages of the COVID-19 pandemic (March–May 2020) among undergraduate students across the United States (N = 1280).

Variables	OR	95% CI	*p*-value
University (ref = NC State University)			
Oregon State University	0.76	(0.43, 1.35)	.34
University of Montana	**0.46**	**(0.25, 0.84)**	**.012**
Penn State University	0.69	(0.39, 1.24)	.21
Relative income	0.89	(0.79, 1.01)	.065
Race/ethnicity (ref = White)			
Hispanic/Latinx	1.01	(0.55, 1.96)	.97
Asian	**3.07**	**(1.83, 5.42)**	**<.001**
Black	**3.69**	**(1.64, 9.93)**	**.004**
Sex (female)	0.78	(0.60, 1.01)	.065
Age (<25 years)	1.22	(0.88, 1.70)	.23
General health	**0.72**	**(0.63, 0.81)**	**<.001**
BMI	0.99	0.96, 1.02)	.53
Knowing someone infected with COVID-19 (yes)	1.22	(0.92, 1.64)	.17
Worrying about COVID-19	**1.16**	**(1.08, 1.26)**	**<.001**
COVID-19 death rate per 1000 residents	1.09	(0.97, 1.09)	.45
Lockdown level index	1.14	(0.87, 1.55)	.37
Urban county (yes)	1.13	(0.85, 1.49)	.39
Area (km^2) of local parks per 10,000 residents in county[a]	1.05	(0.91, 1.22)	.50
Area (km^2) of national/state parks per 10,000 residents in county[a]	1.01	(0.86, 1.19)	.89
NDVI in ZIP code	0.54	(0.14, 2.00)	.36

Notes: OR = odds ratios; McFadden's pseudo $R^2 = 0.077$; see Table 1 footnotes for description of variable response scales and measurements; variables significantly associated with emotional distress at $p < .05$ shown in bold font.
[a] Results shown with ordered quantil normalizing transformation applied (Peterson and Cavanaugh, 2020).

Table 3
Results of logistic regression model showing correlates of reducing park use during the early stages of the COVID-19 pandemic (March–May 2020) among undergraduate students across the United States (N = 1280).

Variables	OR	95% CI	*p*-value
University (ref = NC State University)			
Oregon State University	**1.90**	**(1.09, 3.36)**	**.025**
University of Montana	0.83	(0.46, 1.48)	.52
Penn State University	0.88	(0.50, 1.54)	.65
Relative income	1.06	(0.95, 1.19)	.28
Race/ethnicity (ref = White)			
Hispanic/Latinx	1.38	(0.77, 2.54)	.29
Asian	**2.24**	**(1.50, 3.39)**	**<.001**
Black	**3.19**	**(1.70, 6.31)**	**<.001**
Sex (female)	0.90	(0.71, 1.15)	.40
Age (<25 years)	0.82	(0.60, 1.12)	.21
General health	0.97	(0.86, 1.08)	.56
BMI	1.01	(0.99, 1.04)	.39
Knowing someone infected with COVID-19 (yes)	1.13	(0.87, 1.49)	.36
Worrying about COVID-19	**1.18**	**(1.10, 1.27)**	**<.001**
COVID-19 death rate per 1000 residents	**1.09**	**(1.02, 1.17)**	**.018**
Lockdown level index	0.92	(0.70, 1.19)	.53
Urban county (yes)	0.79	(0.60, 1.03)	.086
Area (km^2) of local parks per 10,000 residents in county[a]	1.01	(0.87, 1.16)	.94
Area (km^2) of national/state parks per 10,000 residents in county[a]	1.09	(0.93, 1.28)	.27
NDVI in ZIP code	0.65	(0.18, 2.34)	.51

Notes: OR = odds ratios; McFadden's pseudo $R^2 = 0.048$; see Table 1 footnotes for description of variable response scales and measurements; variables significantly associated with emotional distress at $p < .05$ shown in bold font.
[a] Results shown with ordered quantil normalizing transformation applied (Peterson and Cavanaugh, 2020).

3.3. Emotional distress and correlates

The scale mean for emotional distress during the pandemic was 57.37 ($SD = 21.02$) on a scale from 0 (none) to 100 (most extreme level of emotional distress). Among the emotional distress components measured, stress was the highest reported component ($M = 64.42$, $SD = 26.65$) followed by feeling sad ($M = 60.77$, $SD = 27.24$), irritable ($M = 59.37$, $SD = 28.59$), preoccupied ($M = 53.09$, $SD = 26.84$), and afraid ($M = 49.20$, $SD = 27.74$). Bivariate correlations between emotional distress and limiting outdoor recreation ($r = 0.13$, $p < .001$) and reducing park use ($r = 0.13$, $p < .001$) were significant and positive (see Table S4 for correlations among all variables in the models). Emotional distress was higher for students whose outdoor recreation and park use were more limited during the pandemic.

Our linear regression model examining correlates of emotional distress during COVID-19 is shown in Table 4. After adjusting for confounding factors, reduced park use was associated with more emotional distress ($p < .001$) and residing in counties with larger areas of national and/or state parks per capita was associated with less emotional distress ($p = .004$). Unexpectedly, limiting outdoor recreation was marginally associated with less distress ($p = .08$). Neither residing in a ZIP code with greater greenness levels ($p = .99$) nor residing in a county with more area of local parks per capita ($p = .27$) were associated with distress. Female students were more likely to report emotional distress than

Table 4
Results of linear regression model examining correlates of emotional distress for undergraduate students (N = 1280) across the United States during the early stages of the COVID-19 pandemic (March–May 2020).

Variables	*B*	95% CI	*p*-value
University (ref = NC State University)			
Oregon State University	1.30	(-2.8, 5.4)	.54
University of Montana	1.60	(-2.7, 6.0)	.46
Penn State University	**5.10**	**(0.9, 9.2)**	**.016**
Relative income	**−1.10**	**(-2.0, -0.3)**	**.010**
Race/ethnicity (ref = White)			
Hispanic/Latinx	−1.10	(-5.5, 3.4)	.64
Asian	0.64	(-2.3, 3.6)	.67
Black	−2.50	(-6.9, 2.0)	.28
Sex (female)	**4.90**	**(3.1, 6.7)**	**<.001**
Age (<25 years)	1.70	(-0.6, 4.0)	.15
General health	**−2.60**	**(-3.4, -1.7)**	**<.001**
BMI	−0.10	(-0.3, 0.1)	0.31
Knowing someone infected with COVID-19	**2.20**	**(0.2, 4.2)**	**.030**
Worrying about COVID-19	**7.60**	**(7.1, 8.2)**	**<.001**
COVID-19 death rate per 1000 residents	−0.15	(-0.6, 0.3)	.46
Lockdown level index	0.94	(-1.0, 2.8)	.33
Urban county (yes)	0.39	(-1.6, 2.4)	.70
Area (km^2) of local parks per 10,000 residents in county[a]	−0.58	(-1.6, 0.5)	.27
Area (km^2) of national/state parks per 10,000 residents in county[a]	**−1.70**	**(-2.9, -0.6)**	**.004**
NDVI in ZIP code	0.02	(-9.2, 9.3)	.99
Limiting outdoor recreation (yes)	−1.80	(-3.7, 0.2)	.077
Reducing park use (yes)	**3.40**	**(1.6, 5.2)**	**<.001**

Notes: Adjusted $R^2 = 0.462$; see Table 1 for description of variable response scales and measurements; variables significantly associated with emotional distress at $p < .05$ are shown in bold font.
[a] Results shown with ordered quantil normalizing transformation applied (Peterson and Cavanaugh, 2020).

males ($p < .001$). Higher general health ($p < .001$) and relative income levels ($p = .01$) were associated with less distress. Finally, knowing someone infected with COVID-19 ($p = .03$) and spending more time worrying about the virus ($p < .001$) were associated with more distress. Worry time was a strong positive correlate of emotional distress, but other key coefficients did not change when the sorry variable was excluded from the models (Table S5). Neither local COVID-19 death rates nor local lockdown level index scores were significantly associated with the emotional distress of college students. All of these correlates taken together explained nearly half of the variance of emotional distress ($R^2 = 0.462$).

4. Discussion

Our findings underscore the substantial psychological impacts of the COVID-19 pandemic on college students and highlight the potential value of park-based recreation as a coping strategy for students experiencing emotional distress (Fig. 1). High levels of emotional distress observed in our sample mirror the negative mental health outcomes reported in other studies of college students since the emergence of COVID-19, including exacerbation of stress, anxiety, fear, mood disorders, depression, sedentary behavior, substance abuse, and social isolation (Browning et al., 2021; Charles et al., 2021; Chirikov et al., 2020; Elmer et al., 2020; Kaparounaki et al., 2020). The mental health crisis plaguing college students before the pandemic struck (Oswalt et al., 2020) appears to have intensified during the first half of 2020. Our results suggest emotional distress levels may be higher for socially vulnerable populations such as women, students with poor general health, and students from low-income backgrounds. These findings support previous research indicating that historically marginalized groups such as women (Liu et al., 2020; Solomou and Constantinidou, 2020; Wenham et al., 2020) and racially/ethnically minoritized people (Aristovnik et al., 2020; Fortuna et al., 2020; Kim and Bostwick, 2020) are more likely to be negatively affected - both physically and psychologically - by the COVID-19 pandemic. Strategic interventions are needed to address these inequities and help college students cope with mental health challenges posed by COVID-19.

This study specifically examined several factors that could help to mitigate the psychological effects of lockdowns linked to COVID-19: outdoor recreation, park use, park availability in nearby areas, and proximity to vegetation (i.e., NDVI). In the early stages of the pandemic, most college students reported declines in both outdoor recreation and park use. Declines were more pronounced among Asian students, Black students, and students who reported spending more time worrying about the pandemic. Reductions in recreation activities were also larger among students reporting low levels of perceived general health, hinting at a negative relationship between pre-existing health conditions and resilience in the wake of disasters (Eisenman et al., 2009). In our sample, individuals from historically marginalized communities that likely experienced limited access to quality parks and greenspaces prior to the pandemic (Nesbitt et al., 2019; Rigolon et al., 2018; Sister et al., 2010) were even less likely to capitalize on outdoor recreation opportunities during this time of crisis. Other studies have also found that pre-existing disparities in both use of parks and access to parks might be magnified in the era of COVID-19 (Burnett et al., 2021; Dushkova et al., 2021; Larson et al., 2021; Uchiyama and Kohsaka, 2020), limiting potential benefits associated with a key health-promoting resource for socially vulnerable populations.

Reasons that college students provided to explain their park use declines varied. In some cases, students cited structural constraints like "stay at home" mandates and park closures that have affected park use for many populations during COVID-19 (Geng et al., 2021). These stringent regulations might deter outdoor recreation in certain places, while encouraging it in other places when indoor alternatives become limited (Slater et al., 2020). Uncertainty regarding the risk of outdoor virus transmission in the early stages of pandemic appeared to fuel hesitancy and precaution with respect to outdoor activities, a finding that has been noted in other studies (Fagerholm et al., 2021; Mateer et al., 2021). For many students, pandemic-induced cycles of stress, anxiety, isolation, and sedentary behavior likely made outdoor recreation unappealing or difficult (Browning et al., 2021; Elmer et al., 2020). However, a minority of students were able to navigate these challenges and get outdoors during the pandemic, driven by a desire to experience nature, find productive ways to spend time, and enhance their physical and mental health. Explicit recognition of time outdoors as a mechanism for health promotion has been documented in other populations during

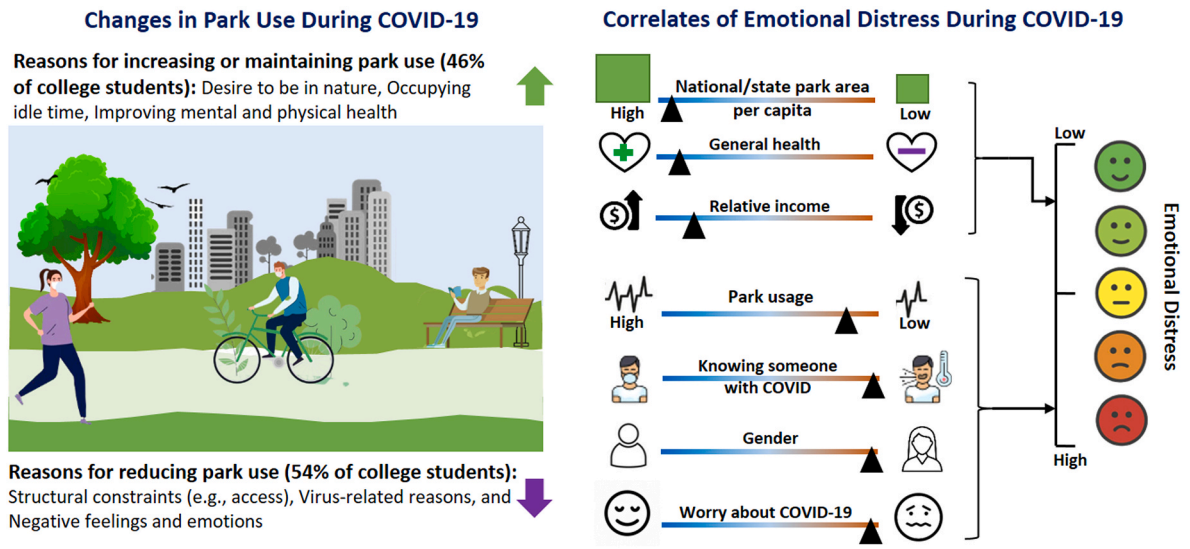

Fig. 1. Summary of key findings showing changes in college students' park use, reasons for shifting park use, and significant correlates of emotional distress during the early stages of the COVID-19 pandemic in the United States. Larger areas of national and state parks per capita, general self-reported health, and relative income were associated with lower levels of emotional distress. Lower park usage, knowing someone with COVID-19, being female, and worrying about COVID-19 were associated with higher levels of emotional distress.

the pandemic (Berdejo-Espinola et al., 2021; Grima et al., 2020; Guzman et al., 2021; Pouso et al., 2021; Tomasso et al., 2021; Ugolini et al., 2021), and may be particularly important for college students seeking to maintain social connections and active lifestyles.

Our regression model examining predictors of college students' emotional distress levels confirmed a strong positive relationship between reduced park use and distress during the pandemic (Fig. 1). Similar associations between greenspace, nature, and mental health have been documented before (Twohig-Bennett and Jones, 2018) and during the pandemic (Berdejo-Espinola et al., 2021; Poortinga et al., 2021; Ribeiro et al., 2021), fueling arguments that contact with nature is critical in a time of crisis (Kleinschroth and Kowarik, 2020; McCunn, 2020; Razani et al., 2020). Limiting outdoor recreation – much of which presumably occurs outside the park context (for example, on neighborhood sidewalks) - was not significantly associated with emotional distress among college students. However, other studies conducted during the pandemic have shown that participation in outdoor activities can bolster resilience to psychological stressors for both youth (Jackson et al., 2021) and adults (Cindrich et al., 2021). In our study, outdoor recreation was measured as a wide range of activities taking place outdoors, and not necessarily in parks. The protective effects of outdoor recreation on emotional distress vanished when controlling for park use and area in fully-adjusted models, supporting other research suggesting the mental health benefits of outdoor recreation during the pandemic might be most pronounced in nature-based settings (Fagerholm et al., 2021).

Our model also indicated that per capita national and state park area at the county level was inversely related to emotional distress (Fig. 1), implying that actual park usage may not be necessary for health benefits to accrue. The relationship between per capita local park area and distress was also negative, though not significant. These normalized, per capita measures could represent proxy variables for potential park crowding (Rigolon, 2016); thus, our findings point to the unique value of larger and less crowded state and national parks, especially during the early stages of the pandemic when information about outdoor virus transmission was limited (Slater et al., 2020). In addition to the benefits of nearby park availability, our findings also illuminate the value of exposure (via outdoor walks and other activities) to a broader array of natural settings, including different types of neighborhood greenspace (e.g., trees, gardens), which have been shown to contribute to the improvement of mental health outcomes during the pandemic (Dzhambov et al., 2021; Soga et al., 2021a). Although our study did not find links between NDVI and the psychological health of college students, other research during COVID-19 has discovered associations between greenness, happiness, and well-being (Cheng et al., 2021; Robinson et al., 2021).

Specific mechanisms driving associations between nature and mental health remain the subject of debate (Kuo, 2015), but feedback loops are likely present (Soga et al., 2021b). For example, students who were less worried and generally happier during the early stages of the pandemic might continue visiting parks, thereby reinforcing positive outcomes. On the other hand, students feeling anxious and stressed during the pandemic might limit outdoor recreation activities (Mateer et al., 2021), which could exacerbate mental health issues. Future longitudinal or experimental research, such as studies utilizing the park prescription approach to address health problems (Razani et al., 2018), could explore these causal pathways. In cases where overt recreation behavior does not (or cannot) occur, large amounts of nearby parkland can become even more important, providing multiple pathways to psychological health promotion in young adults via direct interaction or indirect exposure (Dzhambov et al., 2018).

4.1. *Limitations and future research*

Associations in our study are based on cross-sectional data from a combination of representative and targeted samples of undergraduate students at four universities (with over 70% coming from one institution). This factor, combined with relatively low response rates, makes causal inferences and extrapolation to other demographic and geographic contexts difficult. Future research involving college students and different populations in other parts of the world, including developing countries (Kola et al., 2021), would help to illustrate if and how outdoor recreation, park use, and greenspace can help to combat the psychological impacts of COVID-19. Results might have also been influenced by the timing of the study. Our survey was conducted in the first few weeks after the pandemic hit the United States, when fears and apprehension were at very high levels and most universities had recently closed campuses for the semester. Different states were handling the pandemic in different ways, with some imposing stringent lockdowns and park closures and others taking a less aggressive approach to

preventing virus transmission. Although we attempted to control for both COVID-19 prevalence (in the form of per capita death rates) and local lockdown levels in our models, results might still vary by geographic and regulatory context. Furthermore, different universities experienced unique vulnerabilities and responded in different ways. This variability enabled us to capture a range of perspectives and experiences, but we were not able to discern or control for the specific influence of temporal and structural differences on park use or mental health. Although some longitudinal studies suggest outdoor recreation and mental health outcomes have continued to decline as the pandemic has progressed (Burnett et al., 2021), more research is needed to confirm these patterns.

Our use of single-item measures for both outdoor recreation and park use could be expanded to add more nuance and complexity. For example, our quantitative measure of outdoor recreation included many types of activities that might not occur in parks (e.g., walking). This highlights the need to consider the potentially valuable role that other types of public spaces (e.g., sidewalks, greenways) and walkable urban environments can play during a pandemic (Scott, 2021), especially given the importance of neighborhood walking expressed by students in open-ended responses. Our quantitative measure of park use did not include a baseline for pre-pandemic use or a measure of absolute recreation activity levels, making it difficult to determine if people who reported declining use were still visiting parks or not and, if so, how often. Qualitative data helped us understand these patterns, but future research could explicitly measure pre-pandemic park use levels, rather than simply relying on qualitative descriptions of behavior. Future research might also consider park quality and the intensity of nature dosage when assessing potential effects of park use on mental health (Olszewska-Guizzo et al., 2021; Shanahan et al., 2016).

We assumed the ZIP codes students provided represented the location where they were staying throughout the early stages of the pandemic. However, it is possible some respondents were transient residents (e.g., temporarily staying with their parents), perhaps impacting conclusions based on spatial variables. Furthermore, we measured park area and greenness within different spatial scales (i.e., ZIP code versus county). We cannot exclude that these spatial units are susceptible to the modifiable areal unit problem (Helbich et al., 2021). Although we attempted to address the geographic clustering of participants within the universities, we were unable to achieve robust models because of singularity and instead reported university as a fixed effect. Models predicting emotional distress might also take into account changes in contextual factors impacting the life of college students, such as the abrupt shift to virtual learning and the dissolution of peer networks that are typically a staple of campus life (Browning et al., 2021; Elmer et al., 2020).

Finally, our findings hint at disparities in both park use and mental health outcomes among college students from different demographic backgrounds, underscoring the need for studies examining whether and how health inequities have been exacerbated by COVID-19 (Burnett et al., 2021; Dushkova et al., 2021; Geary et al., 2021; Larson et al., 2021; Shoari et al., 2020). These studies might focus specifically on urban areas, or regions of high population density where the negative effects of COVID-19 may be magnified (Hubbard et al., 2021; Larson et al., 2021). Future research could also consider the mediating role of access to parks and greenspace with respect to the physical and physiological impacts of COVID-19, including morbidity and mortality, across diverse populations (Lu et al., 2021a, 2021b).

5. Conclusion

College students struggled with negative emotions and mental health problems during the early stages of the COVID-19 pandemic, and students from historically marginalized groups were often more likely to report emotional distress than others. Outdoor activities and park use also declined over the early stages of the pandemic, especially among racially and ethnically minoritized students and those who spent substantial time worrying about the future. However, students who continued using parks and students who lived in counties with more park area per resident were less likely to report emotional distress during the pandemic. These results support growing recognition of the contributions that parks and greenspace have made to public health throughout the COVID-19 pandemic. Our study of U.S. college students ultimately highlights the value of park-based recreation as a health promotion strategy for diverse populations of socially vulnerable young adults during a time of crisis.

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Ethics statement

Prior to data collection, our study protocol was approved by the Institutional Review Boards at all participating institutions, including North Carolina State University (protocol #23593), Oregon State University (#2020–0636), the Pennsylvania State University (#00015025), and the University of Montana (#69–20).

Author contributions

Lincoln Larson: Conceptualization, Methodology, Data collection, Writing - original draft, reviewing and editing, Supervision, Lauren Mullenbach: Data analysis, Writing- original draft, reviewing and editing, Matthew Browning: Conceptualization, Methodology, Data collection, Data analysis, Writing - review & editing, Supervision, Alessandro Rigolon: Methodology, Data collection, Data analysis, Writing - review & editing, Jennifer Thomsen: Methodology, Data collection, Data analysis, Writing - review & editing, Elizabeth Metcalf: Data collection, Writing - review & editing, Nathan P. Reigner: Data collection, Data analysis, Writing - review & editing, Iryna Sharaievska: Data collection, Writing - review & editing, Olivia McAnirlin: Data collection, Data analysis, Writing - review & editing, Ashley D'Antonio: Data collection, Data analysis, Writing - review & editing, Scott Cloutier: Data collection, Writing - review & editing, Marco Helbich: Methodology, Data analysis, Writing - review & editing, S. M. Labib: Methodology, Data analysis, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2021.112367.

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