



Uses and Limitations of Social Media to Inform Visitor Use Management in Parks and Protected Areas: A Systematic Review

Emily J. Wilkins^{1,2} · Spencer A. Wood³ · Jordan W. Smith^{1,2}

Received: 28 May 2020 / Accepted: 1 October 2020 / Published online: 15 October 2020
© Springer Science+Business Media, LLC, part of Springer Nature 2020

Abstract

Social media are being increasingly used to inform visitor use management in parks and protected areas. We review the state of the scientific literature to understand the ways social media has been, and can be, used to measure visitation, spatial patterns of use, and visitors' experiences in parks and protected areas. Geotagged social media are a good proxy for actual visitation; however, the correlations observed by previous studies between social media and other sources of visitation data vary substantially. Most studies using social media to measure visitation aggregate data across many years, with very few testing the use of social media as a visitation proxy at smaller temporal scales. No studies have tested the use of social media to estimate visitation in near real-time. Studies have used geotags and GPS tracks to understand spatial patterns of where visitors travel within parks, and how that may relate to other variables (e.g., infrastructure), or differ by visitor type. Researchers have also found the text content, photograph content, and geotags from social media posts useful to understand aspects of visitors' experiences, such as behaviors, preferences, and sentiment. The most cited concern with using social media is that this data may not be representative of all park users. Collectively, this body of research demonstrates a broad range of applications for social media. We synthesize our findings by identifying gaps and opportunities for future research and presenting a set of best practices for using social media in parks and protected areas.

Keywords Literature review · Volunteered geographic information · Geotagged photographs · GPS tracks · Spatial patterns · Park visitation

Introduction

Park and protected area managers often aim to both conserve natural and cultural resources while also providing enjoyment to visitors. Any changes to visitation patterns, either in space or time, has the potential to degrade the natural environment and cause environmental disturbances

(Hammit et al. 2015). However, land managers can mitigate disturbances by proactively managing visitor flows. Estimating visitor use and understanding the visitor experience is a critical component to sustainably managing natural environments (Leung et al. 2018). Traditionally, researchers and managers have gleaned insights into visitors' behaviors, characteristics, preferences, and experiences in parks and protected areas by using visitor surveys, semi-structured interviews, administrative data, as well as vehicle and trail counters (Leggett et al. 2017). Collecting data through these methods requires substantial time and financial costs; they also often limit data collection to relatively small geographic scales such as individual parks (Cessford and Muhar 2003). Over the last decade, researchers have begun exploring the potential use of large volunteered geographic datasets to overcome some of the limitations of more traditional methodologies, while still providing insights into visitors' experiences.

One data source that is increasingly being used to inform park and protected area management is social media. Although there is no one set definition for social media, this

Supplementary information The online version of this article (<https://doi.org/10.1007/s00267-020-01373-7>) contains supplementary material, which is available to authorized users.

✉ Emily J. Wilkins
emily.wilkins@aggiemail.usu.edu

¹ Institute of Outdoor Recreation and Tourism, Utah State University, 5215 Old Main Hill, Logan, UT 84322, USA

² Department of Environment and Society, Utah State University, 5215 Old Main Hill, Logan, UT 84322, USA

³ eScience Institute, University of Washington, Box 352100, Seattle, WA 98195, USA

term generally refers to online content that is user-generated, and hosted by a service (e.g., Facebook, Twitter, etc.) that facilitates connections between individuals or groups (Obar and Wildman 2015). Social media can include photos, text, and metadata such as the time stamps or geotagged coordinates of posts from parks and protected areas (Toivonen et al. 2019). All of these pieces of information can provide a wealth of knowledge about visitors' behaviors, preferences, and experiences. Some social media platforms make all or some of their users' information publicly available for free and often on a global scale. This provides a unique opportunity to understand many facets of outdoor recreationists' behaviors and preferences across large geographic areas.

Researchers have begun using social media to better understand a variety of topics pertinent to environmental and visitor management. In parks and protected areas, social media were first used to estimate visitation rates and home location of visitors (Wood et al. 2013) and have since been used to understand other aspects of visitors' characteristics and experiences. Many studies using social media to estimate visitation to parks and protected areas have found it can be a reliable proxy (e.g., Sessions et al. 2016; Wood et al. 2013). These investigations have evaluated the social media-visitation relationship over many spatial and temporal scales (Teles da Mota and Pickering 2020). In addition, these investigations report a wide range of correlations with other visitation measures (e.g., Fisher et al. 2018; Sonter et al. 2016; Tenkanen et al. 2017; Walden-Schreiner et al. 2018). Given the variety of ways in which social media have been compared to other visitation measures, it would be beneficial to systematically review the methods used in previous research. Doing so could provide the research community and land managers with insights into the spatial and temporal scales where social media can serve as a reliable measure of visitation to parks and protected areas. In addition, summarizing how social media are correlated with other measures of visitation in various settings may help reveal if there is potential to use social media to predict future visitation.

In addition to the growing body of literature using social media to estimate visitation in parks and protected areas, there is also a rapidly expanding body of literature using social media to understand spatial patterns of visitation or park use (e.g., Campelo and Mendes 2016; Sinclair et al. 2018; Walden-Schreiner et al. 2018). When a photograph is taken on a GPS-enabled device (e.g., a smartphone), the exact date and time the photo was taken, as well as the latitude and longitude of the photo location, are automatically stored in the photo's metadata. If the photo is uploaded to a social media platform, researchers can access the time stamp and coordinates through the metadata. Users of fitness applications, such as Strava, can choose to record

and upload the GPS track of the route they took during their visit. This information can help researchers map where visitors to parks and protected areas go in space and time. However, it would be useful to understand and synthesize how researchers have used this information, and the spatial resolutions researchers have used to answer different types of questions.

Recent studies have used social media to understand visitors' preferences, sentiment, and experiences (e.g., Barry 2014; Huang and Sun 2019; Plunz et al. 2019). Studies have also used social media to explore cultural ecosystem services (CES; e.g., Clemente et al. 2019; Retka et al. 2019), which include the "nonmaterial benefits people obtain from ecosystems" through recreation, spiritual, and other experiences with nature (Millennium Ecosystem Assessment 2005, p. 40). CES can help describe the types of experiences visitors have on landscapes and the benefits they receive. Traditionally, researchers would most often investigate visitors' experiences through direct contact with visitors (e.g., visitor surveys, focus groups) (Leggett et al. 2017). However, social media may provide a lower-cost alternative. Summarizing the types of topics previous studies have explored through social media may help identify the ways social media can be used quantify and track visitor preferences, sentiment, and experiences across space and time.

The overall goal of this study is to review the state of the scientific literature and better understand the ways social media has been, and can be, used to inform visitor use management in parks and protected areas. By synthesizing prior applications, approaches, and limitations for managers and researchers, we aim to clarify the realm of questions that social media may be able to answer. Since this line of literature is still relatively new, and will grow in the future, understanding the collective successes and limitations uncovered by prior research can help inform future research directions. This study follows previous research and reviews of the potential for social media to inform environmental management and conservation (Di Minin et al. 2015; Ghermandi and Sinclair 2019; Toivonen et al. 2019) with a targeted review of the scientific literature on ways social media has been, and can be, used to inform visitor use management in parks and protected areas. Our review also compliments the recent review by Teles da Mota and Pickering (2020) by focusing on three specific research questions which are guided by the needs of park and protected area managers.

The three questions we address in this manuscript begin with *what spatial and temporal resolutions have been used to estimate visitation from social media, and how correlated are these estimates with other measures of visitation?* Knowing how much visitation is occurring within a park or protected area is critical to all visitor use monitoring and management efforts (Leung et al. 2018). Understanding the

spatial and temporal resolutions at which social media can be used to reliably quantify visitation is currently an open question. Second, *how has previous research used social media to understand spatial patterns of visitation in park and protected areas, and at what spatial scales?* Understanding the spatial distribution of visitation across a park or protected area can help guide the effective allocation of managerial resources to outdoor recreation settings that are heavily used; it is also an area where the qualities of social media provide notable advantages over traditional methods of visitor use monitoring. Third, *how have social media been used to understand visitors' experiences in park and protected areas?* Park and protected area managers strive to provide an array of recreational experiences for visitors, often using little more than anecdotal evidence to guide their decisions regarding how and where opportunities for these experiences are provided. Social media may be able to provide novel insights into visitors' experiences, however research into this realm is in its infancy. Our review can help provide guidance for where future investigations may be most effective. We synthesize our findings into these three research questions by identifying gaps and opportunities for future research and presenting a set of best practices for using social media in parks and protected areas.

Methods

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses protocol for searching databases and reporting information (Moher et al. 2009). This protocol requires us to report specific measures, such as how the literature was searched and what information was recorded, so the systematic review could be replicated in the future.

Paper Selection

We attempted to find all academic papers that have used social media in a park or protected area to quantify visitation, explore spatial patterns, or understand the visitor experience. We searched for relevant articles in the scientific literature using the Scopus database and ProQuest Agriculture and Environmental Science database. We used broad search criteria to have high sensitivity and low specificity (Petticrew and Roberts 2006). In other words, we collected all studies that might be relevant, and later removed papers that did not fit our inclusion criteria.

We searched for all research articles that contained at least one of the following terms in the title, abstract, or keywords: social media, Flickr, Twitter, Instagram, Facebook, Panoramio, Strava, MapMyFitness, or Wikiloc. Papers must also have included one of the following terms in the title, abstract, or keywords to be included: park(s),

protected area(s), or public land(s). We conducted the search on January 14, 2020; it yielded 582 papers before removing duplicates. We conducted another search on May 1, 2020, which returned 16 new papers. Given that automated searches can sometimes miss pertinent papers, we also added additional relevant papers that we were aware of, which were not captured in the searches.

Article Screening

We used a two-tier approach to screen articles. First, we evaluated article inclusion based on the title, given the low specificity of the search. At this phase, all papers were kept that alluded to a park or protected area being the study site and mentioned the use of social media. If it was unclear whether or not the paper reported on research within a park or protected area or used social media, the paper was retained at this stage of screening. Second, we read the abstracts of all papers that had potentially relevant titles to determine their suitability. If it was still unclear from the abstract, we read the full text. We retained all papers that referenced a park or protected area setting and also reported on the use of social media. All types of parks and protected areas were included (e.g., urban parks, state parks, national parks). If the setting may have referenced a park or protected area, but that was not an explicit focus of the paper, it was not included (e.g., Fisher et al. 2019).

Papers that investigated the use of social media to communicate with visitors or market destinations (e.g., Wilkins et al. 2020; McCreary et al. 2019) were not included in this analysis. In addition, papers that were explicitly related to protests, political uprisings, or clinical health studies were not included, even if they took place in a park. We also did not include studies that analyzed review site data (e.g., *TripAdvisor*, *Yelp*). These bodies of literature are all outside the scope of this paper. Supplementary Fig. A1 shows the number of studies that were identified, screened, eligible, and included.

Categorizing Papers

We reviewed the full text of each of the 58 relevant papers (Supplementary Table A1). For each paper, we recorded the information about the study objective, location, and many other attributes listed in Table 1. After recording information on each paper, we categorized papers into non-discrete categories based upon whether the paper used social media to: (1) estimate visitation, (2) understand spatial patterns of visitation, and (3) understand aspects of the visitor experience.

Any paper that explicitly compared social media posts or user-days to another data source was included in the estimating visitation category (even if this was not the main

Table 1 The attributes recorded for each paper and their general purpose

Broad category	Specific pieces of information	Purpose
Citation information	—Study authors —Article title —Journal title —Year of publication	To cite articles and understand how the number of publications has changed over time.
Objective(s)	—Explicitly stated research objectives, research, questions, or study purpose	To classify papers based on if they were estimating visitation, spatial patterns of visitation, or aspects of the visitor experience. Also used to classify the specific focus of the paper.
Location and setting	—Continent —Country —Specific study site name(s) —Setting (i.e., type of park and/or protected area)	To understand the distribution of studies across continents and countries and see which types of settings are most often studied. Any setting with 2+ mentions was included as a category.
Methods	—Social media platform(s) —What attributes of social media were used (e.g., metadata, photo content, text content) —The extent of social media used (e.g., number of years) —The temporal resolution of the analysis (e.g., annual, monthly, weekly) —The spatial resolution of the analysis (e.g., whole park, grid, trails) —If the authors used user-days or total posts (if applicable)	To understand how researchers have used social media and the spatial and temporal resolutions of the data used.
Social media acquisition and analysis	—How data were acquired (e.g., API vs scrape) —Software used for data collection/analysis —If code to reproduce results is available	To understand technical details about how others have conducted this research.
Other datasets used	—Other types of secondary datasets used, if applicable —Other types of primary data collected, if applicable	To understand if and how researchers use this data source in conjunction with other data.
Limitations	—Any explicitly stated biases, limitations, or ethical concerns of using social media	To understand how researchers perceive the limitations of this data source. This was later summarized into categories, with anything that was mentioned 3+ times being a category.

focus of the paper). Any paper that mentioned analyzing or mapping patterns in space was included in the spatial patterns category. These papers either mentioned mapping/understanding spatial patterns in their research questions, or mentioned investigating what factors impact visitation. Papers that asked a research question involving visitors' perceptions, feelings, values, actions, or experiences, were included in the visitor experience category. This final category does not include papers exploring what factors impact visitation. Although this could be considered an aspect of the visitor experience, these papers all had a spatial component to them, and were thus only included in the spatial patterns category. We used these specific categories to help answer our research questions; they do not fully capture every type of question researchers have explored (e.g., comparisons of results from different social media platforms).

For papers that used social media to estimate visitation, we also recorded the given correlations with other visitation measures, as well as the sample sizes of the correlations. For papers that looked at spatial patterns of visitation, we noted categories of other variables (i.e., social, environmental, infrastructure, and managerial) authors included in models regarding spatial patterns. For papers that looked at the visitor experience, we recorded what aspect of the visitor experience the authors were studying.

Results

Characteristics of the Current Literature

The first papers using social media in a park or protected area were published in 2013, with mostly increasing

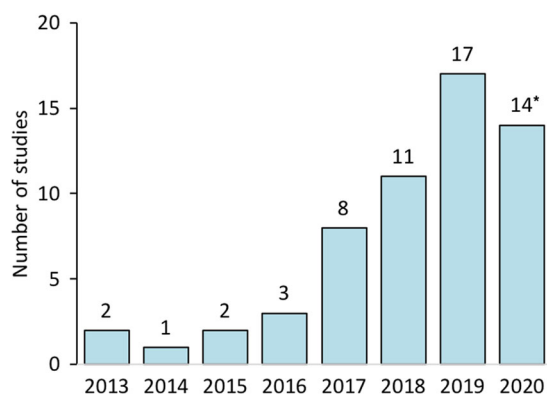


Fig. 1 Papers published by year ($n = 58$). These are papers published through April 2020, so the number of papers in 2020 only represents 4 months

numbers of publications each year since then (Fig. 1). As of April 2020, there were 58 known papers in the scientific literature that used social media to measure visitation and visitors' experiences in parks and protected areas. These papers have been published in journals representing a variety of disciplines, including: tourism, geography, ecology, environmental science, environmental management, remote sensing, and urban planning. The full table with the attributes recorded for each of the 58 papers is available online¹.

Locations and Settings

The highest proportion of papers studied sites in Europe and North America, although there were at least five papers from each continent (Fig. 2a). This body of literature represents 23 countries, with the most papers having study sites in the United States ($n = 13$), Australia ($n = 6$), and Portugal ($n = 4$). The most common setting was national parks, followed by urban parks (Fig. 2b). The "other" category represents public rangelands, national forests and grasslands, conservation parks, a UNESCO World Heritage site, and an archeological park. The "variety of settings" category represents papers that either had three or more setting types or stated their study sites contained a variety of protected area types.

Characteristics of Data Collection and Analysis

The majority of studies (79%) used a single social media platform. Flickr was by far the most used social media platform, followed by Twitter and Instagram (Table 2). Most studies analyzed the locations of social media content according to the geotagged coordinates of the post or the routes users took while in the park or protected area. About

half of studies relied on the time the social media content was created (Table 3). Of the studies that analyzed image content, 21 manually viewed the content, while three used automated tools (e.g., Google Vision) to classify the subject of the photographs. In some of these cases, the authors viewed photograph content to validate geotagged locations assigned by users, but the photograph content was not necessarily the focus of their analyzes. Relatively few (14%) of the papers we reviewed used social media to study visitors' origins for the purpose of understanding visitors' characteristics or their travel routes. Some studies incorporated identifying information about the user, such as their username, into calculating user-days, for instance; this is not included in Table 3 since user identifiers were never a focus of the authors' analyzes.

The majority of papers (78%) reported downloading social media directly through Application Programming Interfaces (APIs). Nine studies downloaded data directly from websites, while four used InVEST (Sharp et al. 2016), one used Google Earth, and one used SAS². Three studies did not state how they acquired the data. Three studies used multiple means of data acquisition for different platforms. The authors of these papers used a variety of software to download, organize, and analyze data. Of the studies that mentioned using software, the most popular were R (51% of studies), ArcGIS (47%), Python (25%), SPSS (10%), Excel (10%), and QGIS (10%). Seven studies did not mention any software they used for data processing or analysis. These counts only included software the authors explicitly mentioned using; in some cases, other software was likely used but not directly mentioned. Only five papers made the code used to produce and/or analyze their data publicly available. Of the five papers with available code, four made code available to reproduce parts of their analyzes, while two made code available to download social media. The code that was provided was written in either R or Python.

Many studies used other data in addition to social media. The majority of studies (64%) used secondary GIS data, visitation or survey data from agencies, or satellite imagery, for example. A total of 11 studies (19%) collected other primary data on visitor use. This included using trail cameras and counters, surveys, semi-structured interviews with visitors or park experts, focus groups with park experts, and qualitative interviews with people who post on social media. Many of the studies (73%) which did collect primary data used it to validate or compare to social media. Only 13 studies relied on social media alone and did not use other datasets (other than for obtaining park boundaries).

¹ Available at: github.com/emilywilkins/Literature-Review

² SAS was used to download *Panoramio* data and has since been depreciated. *Google Earth* was used to download *Wikiloc* data; this feature was removed from *Google Earth* in 2019 (Wikiloc 2020).

Fig. 2 The locations of the study sites (a) and the settings of the studies (b)

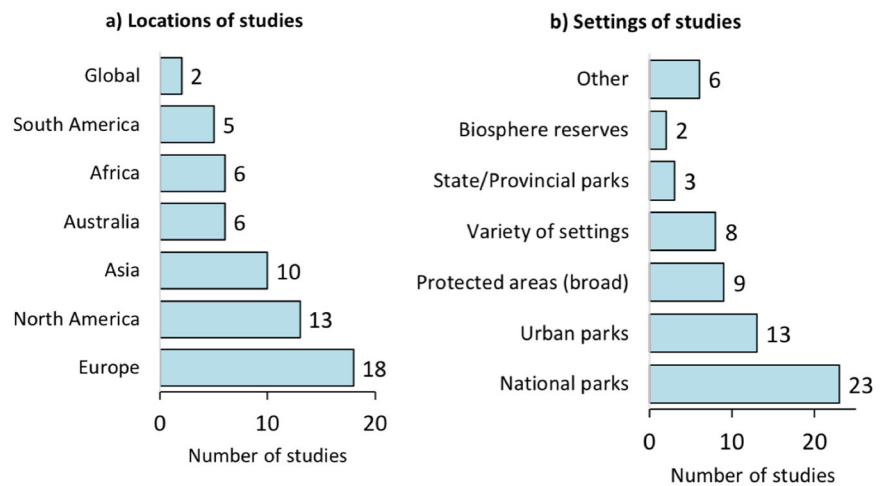


Table 2 The number of studies that used each social media platform, and the general use of each platform. Twelve studies used multiple platforms ($n = 58$). We searched for articles referencing Facebook, Flickr, Instagram, MapMyFitness, Panoramio, Strava, Twitter, and Wikiloc

Platform	General use	Number of studies
Flickr	Photo-sharing	35
Twitter	Micro-blogging	10
Instagram	Photo-sharing	8
Wikiloc	Fitness/GPS tracking	6
MapMyFitness	Fitness/GPS tracking	3
Weibo	Micro-blogging	3
Strava	Fitness/GPS tracking	2
Panoramio	Photo-sharing	2
Facebook	General media	1
Vkontakte	General media	1
GPSies	Fitness/GPS tracking	1

Table 3 The attributes of social media that were analyzed or used to aggregate data ($n = 58$)

Attribute of data	Number of studies
Geotagged coordinates or routes	47
Time stamp	28
Photograph content	24
Text content	8
Stated home locations (according to user's profile)	8
Photograph title, tags, or hashtags	5
Comments on posts	2
Number of check-ins (Weibo)	2
Video content	1
Likes	1
Gender	1

Using Social Media to Estimate Visitation

A total of 20 papers in this review investigated the use of social media to measure visitation (Supplementary Table B1). These studies all compared the user-days of social media posts (e.g., photo-user-days (PUDs) or tweet-user-days) to another data source, such as surveys, trail counters, or agency-reported data. However, not every study reported a measure of association between the datasets. User-days are an aggregate count of individuals who make a post within an area (such as a park) by day (Wood et al. 2013). For image-sharing platforms, PUDs are often aggregated across multiple years as described below. PUDs are used to eliminate possible measurement bias that may arise due to users who post substantially more content from a place and time compared to other users.

The majority of papers (80%) aggregated social media over entire parks and protected areas. These studies predominately looked at differences in visitation between multiple parks and protected areas and were often not interested in temporal patterns of visitation. Of 16 papers that aggregated data by entire parks or protected areas, ten papers aggregated data across multiple months and years (i.e., aggregating all data they collected by unit), while four papers looked at monthly or seasonal trends, one analyzed weekly trends, and one paper did not state their temporal scale. Five papers analyzed visitation patterns on smaller spatial scales (e.g., trail, grid, or park subregion); three of these papers aggregated data across all months and years, while two papers aggregated data by month (i.e., summing user-days for all Januarys across multiple years).

Of the 20 papers which used social media to measure visitation, 17 reported a measure of association between social media and visitation measured by another data source, such as on-site visitor counts. Measures of association included: Pearson's correlation (r), Spearman's rank correlation (R_s), or the coefficient of determination (R^2) from a regression where social media was the only predictor

Fig. 3 Correlation coefficients reported from previous studies measuring the correlation between social media and other measures of visitation. Numbers near the points are sample sizes for correlations. Any studies that reported a R^2 value from a linear regression with social media as the only predictor in the model were converted to r coefficients by taking the square root. Park setting represents what level of government is managing the park(s)

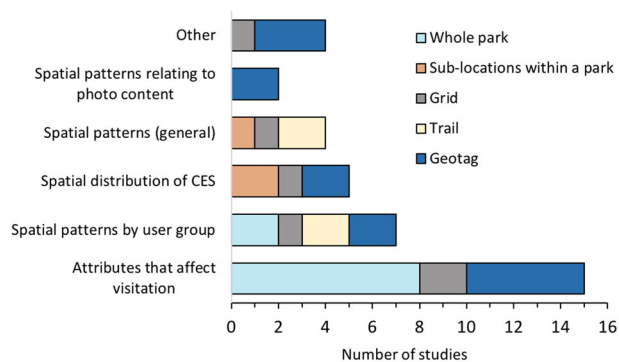
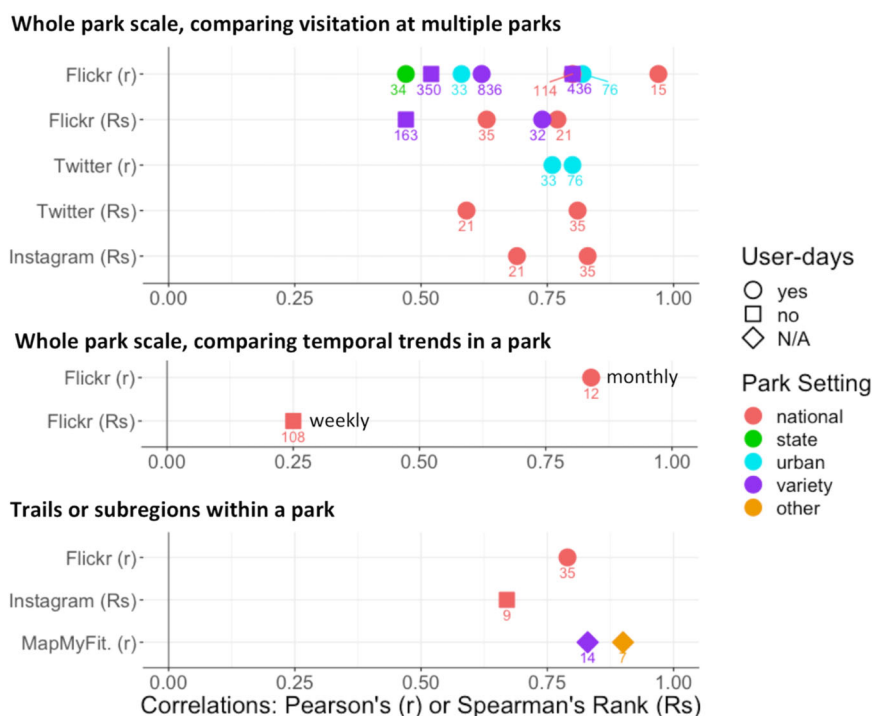


Fig. 4 Papers that used social media to investigate spatial distributions, along with the spatial scale used in each paper ($n = 36$). Papers in the spatial patterns (general) category are only those that did not fit into a more specific category. One paper is represented in two categories (spatial distribution of CES and attributes that affect visitation)

in the model. The other three studies did use social media to estimate visitation compared to visitation measured by another data source, but included other variables in the model (e.g., year, month), so the R^2 values are not comparable. Overall, the measures of correlation reported from each study are powerful, but difficult to meaningfully compare because they use different platforms, different spatial scales, different temporal scales, different measures of association, and some use user-days while others use total images or total users (photographers). Figure 3 summarizes the correlations found in the literature when comparing social media to visitation measured by another data source.

The papers comparing visitation across multiple parks used between 1 and 14 years of data to estimate correlations. The majority of these papers were not interested in a temporal scale, and thus aggregated all data by park. However, one paper did look at visitation across parks and summers (the point with $n = 350$ analyzed 75 parks). Papers looking at temporal trends in a single park used 5 and 7 years of data. Notably, the paper analyzing monthly trends aggregated 7 years of data by month, while the paper analyzing weekly trends did not aggregate the 5 years of data. At the trail/subregion scale, these papers aggregated between 2.4 and 13 years of data. Three of these papers aggregated data from all years by trail or subregion, while one aggregated data by month (the point with $n = 35$). The citations associated with each point, as well as the location of the study, and the number of years of data the authors used can be found in Supplementary Table B1.

Exploring Spatial Distributions of Visitors

Over half of papers (62%) used social media to study spatial distributions of visitors. Many papers were interested in understanding the spatial distribution of visitors (e.g., by producing maps of where people visit), but that was not their main research question. Some papers explored what attributes may affect visitation, while others focused on the distribution of CES, and some investigated spatial patterns by user group or photo content (Fig. 4). Of the 15 papers exploring what landscape attributes may affect visitation, 13 included environmental variables (e.g., elevation, waterbodies), 11 included

infrastructure variables (e.g., roads, trails), seven included social variables (e.g., GDP, population density), and five included managerial variables (e.g., management type, presence of a fee).

The spatial scale used to answer these questions varied. Some studies analyzed distributions at the whole park scale, while others used specific geotags, trails, or grids (Fig. 4). For grids, a 1 km grid was most common. The majority of these studies (79%) were not interested in a specific temporal scale; the authors analyzed spatial patterns after aggregating all the data they had collected, usually over multiple years. Five studies analyzed spatial patterns at the seasonal level, while one paper mapped patterns on weekends versus weekdays and across years, and another paper looked at patterns based on the time of day, weekend versus weekday, and seasonal scales. Three papers did not state the temporal scale of analysis. Citations and additional details on each paper can be found in Supplementary Table C1.

Understanding Aspects of the Visitor Experience

Some studies have used social media to understand various aspects of the visitor experience. Of the 29 studies which did investigate the visitor experience, the highest proportion were studying CES, with fewer papers investigating behavior, perceptions, preferences, and sentiment (Fig. 5). Some social media platforms are more commonly used to study certain aspects of the visitor experience; for example, all studies on sentiment used Twitter as their data source. While the papers using social media to investigate visitation or spatial distributions tended to focus on geotagged coordinates and time stamps, the majority of studies (72%) of visitor experience used photo content to explore their research questions.

The studies that did investigate CES most often looked at multiple CESs, although a couple studies focused on a specific aspect (e.g., wildlife-viewing as a CES). The majority of the CES studies (90%) analyzed photo content; most of these used the photos to identify different types of CES (e.g., aesthetic value, recreational value, educational

value). All of the five studies analyzing sentiment used the text of tweets to gauge sentiment of park users, with four of these studies being situated in urban parks. Of the five studies analyzing visitor behavior, two were looking at unwanted visitor behavior, and three were analyzing visitors' activities. Papers in the “preferences and perceptions” category were looking at perceptions of grazing, preferences for biodiversity, how tourists view the destination, differences between what domestic and international visitors photograph, and experience values. The “other” category includes papers on per-trip benefits and travel cost, the seasonality mismatch between visitors and wildflowers, and the aesthetic value of the parks based on image content and colors. Citations and additional details for each paper can be found in Supplementary Table D1.

Limitations, Biases, and Ethical Concerns

Although this body of work has displayed many ways social media can be used to ask questions of park and protected area visitation, the authors of papers included in our systematic review do caution these data source should be used appropriately. The majority of papers (86%) explicitly noted limitations, biases, or concerns with using social media. The most commonly cited limitation is that social media may not be representative of all park users (Table 4). Some limitations in the “other” category include: noise from bots/spam accounts, accessible areas having more photos, social media use varying due to environmental conditions, and that these data require technical skills and infrastructure to store and analyze.

Discussion

Collectively, this body of literature demonstrates a broad range of ways in which social media can be used to inform visitor use management in parks and protected areas. In recent years, some parks and protected areas have seen substantial increases in visitors (Smith et al. 2019; National Park Service 2020). Increased visitation can strain biophysical resources and result in increased environmental disturbances (Hammitt et al. 2015). Understanding visitor behavior and patterns of visitation is crucial to managing natural environments for future generations. However, collecting data on visitors is often costly and time-consuming; social media provides a new way to understand how visitors are interacting with the environment.

Characteristics of the Current Literature

Prior applications of social media include estimating visitation, understanding spatial patterns of visitation, and

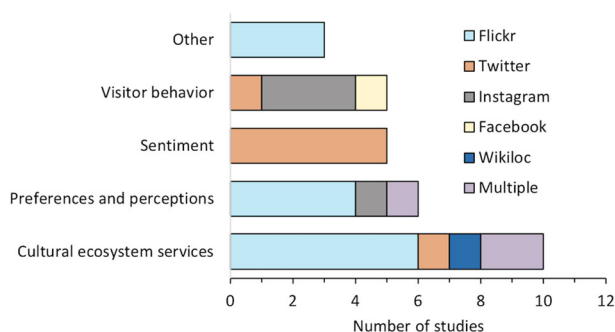


Fig. 5 Categories of what aspect of the visitor experience each paper was studying, as well as the social media platform the authors used ($n = 29$)

Table 4 Limitations, biases, and concerns explicitly mentioned by authors of each study ($n = 58$)

Limitations, biases, and concerns	Number of studies	Percentage of studies
Social media is not representative of park users	42	72.4
Users only share select content	16	27.6
Inaccuracies in geotags/GPS	14	24.1
Unknown demographics of social media users	12	20.7
Social media use varies by country or year	10	17.2
Users share different content on different platforms	9	15.5
There is a changing popularity of platforms over time	8	13.8
There is a low amount of social media in some areas	8	13.8
Ethical concerns/privacy of users	7	12.1
Changes in data accessibility	6	10.3
Some things are hard to photograph	4	6.9
Character limit of <i>Twitter</i> may limit descriptions	3	5.2
Other	15	25.9
None	8	13.8

revealing visitors' behaviors, preferences, and sentiment. There has been a notable increase in the number of published papers using social media to inform visitor use management in parks and protected areas from 2013 to 2020, and researchers are likely to continue using social media as an information source. The majority of papers are focused on national parks and urban parks, and the literature is not necessarily representative of all types of park settings. Further research into social media use in peri-urban green spaces or national forests, for example, would provide additional insights into understanding a diversity of visitors and types of visitor use. In addition, most papers use geo-tagged coordinates or GPS tracks, time stamps, and photo content of posts, with fewer papers analyzing text content, home location of users, and comments on posts.

Flickr and Twitter are the main platforms researchers have used, with each platform being used in ways that reflect its purpose and functionality. For example, Twitter is used to measure visitor sentiment, while Instagram and Flickr are often used for questions that can be understood by analyzing image content. Social media that are geotagged with precise locations—such as Flickr and GPS tracking platforms (e.g., Wikiloc, MapMyFitness, Strava)—are amenable to mapping the spatial patterns of visitation. However, researchers highlight a number of important limitations and considerations that should be taken. Principle among them is the changing popularity of different social media platforms over time; platforms used in the past may not be the same platforms researchers use in the future. For instance, Instagram started rising in popularity around 2013, while Flickr's popularity began decreasing, and then Panoramio was discontinued in 2016. In addition, these are private companies that can choose to stop sharing data at any point. For example, Instagram stopped sharing the geolocations of users' images in 2018 (Toivonen et al. 2019). Although Flickr is declining in

popularity, this platform contains over a decade of publicly available information, hence its high use by researchers, especially for questions regarding visitors' preferences. Few papers (22%) used multiple social media platforms, and future studies may be able to minimize the effects of user bias by integrating data from multiple platforms (e.g., Hamstead et al. 2018; Norman and Pickering 2017; Tenkanen et al. 2017).

Although most studies combined social media with other secondary data (e.g., GIS data), few studies (19%) collected primary data about visitors. The collection of primary data (e.g., via on-site visitor intercept counts or surveys) may overcome some of the limitations of social media (Crampton et al. 2013; Lopez et al. 2019; Xu et al. 2019). The studies that did collect other primary data were largely to validate the results from social media. There is a lot of potential for researchers to leverage social media in conjunction with more traditional means of data collection. For example, interviews or focus groups could be used to inform what information to mine from social media. Conversely, visitor surveys could be used to understand the patterns in social media, such as why spatial or temporal trends exist in social media, or why visitors exhibit certain behaviors. Spatial and temporal patterns found in social media would also be useful to choose sampling times and locations for visitor surveys.

Using Social Media to Estimate Visitation

Many studies have shown geotagged social media are a good proxy for actual visitation to parks and protected areas. However, the correlations between social media and other sources of visitation data vary substantially. Most of the correlations found in previous studies we reviewed were between 0.50 and 0.80 for visitation data at the entire park scale. However, most of these studies aggregated data

across many years, with fewer studies testing the use of social media as a visitation proxy at smaller temporal scales. The smallest amount of data used to estimate visitation was a full year (i.e., using 1 year of data to estimate monthly visitation), and no studies attempted to estimate visitation in near real-time or forecast future visitation from social media posts. A few recent studies have used social media to estimate visitation to trails or other areas within a park (e.g., Fisher et al. 2018), but more research is needed to determine the applicability of using smaller spatial or temporal scales to estimate visitation across different locations, platforms, and settings. Environmental managers may be able to use social media to understand the relative popularity of different parks (or regions within parks) and the temporal distributions of visitors' sub-annual scales (e.g., quarterly or monthly) if there are enough data to yield reliable estimates.

Exploring Spatial Distributions of Visitors

Not only is social media useful to estimate visitation, but its very high spatial and temporal resolution makes it possible to map distributions of visitors in time or space. Often the exact hour and minute a photograph was taken is captured in metadata, and smartphones currently have GPS units that are accurate within five meters (National Coordination Office for Space-Based Positioning 2020). Although this high resolution is available for the posts that visitors share on some social media platforms, few studies of park visitors have taken advantage of both the high spatial and temporal resolution of social media. Future studies could explore whether spatial patterns differ in time—between weekends and weekdays, for example. They could also integrate daily weather data to better understand the spatial substitution patterns of visitors encountering inclement weather. In these future efforts, researchers will likely need to analyze long time series of social media from multiple platforms in order to have sample sizes big enough to quantify and understand patterns at small spatial or temporal scales. Ultimately, the appropriate scales for using social media to understand spatial patterns of visitation will depend on the appropriateness of the data for the research question and setting.

Understanding Aspects of the Visitor Experience

Relatively few studies in this review used social media to understand the behaviors, perceptions, and sentiment of visitors in parks and protected areas. However, this review only included papers in parks or protected area settings, and these topics have also been studied in other settings (e.g., Arkema et al. 2015; Dunkel 2015; Mitchell et al. 2013; Tieskens et al. 2018). Previous research in this review found text and photo content of social media useful to understand and analyze these aspects of the visitor experience.

Additionally, the majority of studies that analyzed photo content did so manually, but future work may be able to take advantage of automated tools (e.g., Google Vision). Although some research questions do require manually viewing photos (e.g., identifying unwanted behavior), other questions may benefit from using automated tools to quickly process large datasets (e.g., identifying landscape features). This may make analyzing photo content more accessible for studies that span large geographic areas.

Best Practices

After reviewing the current state of the science, we would like to highlight five best practices. These are based on the methods and results of previous studies that use social media to inform visitor use management in parks and protected areas. Broadly, these best practices are aimed at addressing a lack of consistency in the methods employed in previous research. Inconsistency is expected from such a relatively new field of study, yet it suggests to us that it would help to establish common reporting standards for researchers working in this area that would facilitate meta-analyses and allow the field to mature. Our suggested best practices include:

- (1) *Explicitly state the spatial and temporal extent and resolution of all analyses.* The scale of analysis used patently affects the results of a study and also informs the scales utilized in future investigations. Researchers should state if they are using different resolutions for different pieces of analyses within their investigation. They should also detail why they chose those resolutions.
- (2) *Use user-days of social media to estimate visitation.* We found the majority of previous studies analyzed user-day metrics such as PUD, which count one photo or post per visitor, per day. Studies that analyze user-days rather than all social media posts tend to report higher correlations with visitation measured by other data sources.
- (3) *When possible, report measures of association between social media and other sources of visitation data; include the temporal resolution and number of observations.* It is useful to compare social media use to other estimates of visitation across different locations and settings. To meaningfully compare results across sites, studies must present similar metrics. Depending on the analysis, Pearson's or Spearman's rank correlation, or the coefficient of determination (R^2), should be provided to help future comparative efforts.
- (4) *If analyzing data using grids or multiple sites, report the sensitivity to spatial scale.* Using arbitrary spatial units introduces statistical bias and can potentially

impact results (i.e., the modifiable areal unit problem) (Fotheringham and Wong 1991). Reporting results at multiple spatial scales can reveal whether the results are consistent regardless of the chosen areal unit.

- (5) *Make coded workflows for collecting and analyzing data publicly available.* Making code available would make analysis more transparent, increase reproducibility, and lower the barrier for other researchers and practitioners to use social media as a data source.

Conclusions

Social media have been used in a variety of ways to inform visitor use management in parks and protected areas. Previous research has used social media to estimate visitation, explore spatial or temporal patterns of visitation, and understand aspects of the visitor experience. The high spatial and temporal resolutions of social media allow researchers to investigate novel questions at small and large geographic scales. Land managers can use the exact geotagged coordinates or GPS tracks to see where visitors go within parks and protected areas, and time stamps to understand when they go places. However, often it is necessary to aggregate multiple years of data to have adequate sample sizes for estimating visitation or mapping spatial patterns—particularly at less visited sites. Although research has shown that social media can be used in many ways to inform park and protected area management, there are also many ways that it could be misapplied—especially if it does not account for the fact that social media users may not be representative of all park visitors. Future research may be able to minimize many biases by leveraging data from multiple platforms or using mixed-method approaches. In addition, with the use of social media becoming more and more common in the scientific literature, common methodological practices and reporting standards can lead to a more coherent, reliable, and transparent body of knowledge.

Data Availability

No new data were created for this paper. However, all tables created to help synthesize the literature are available as supplementary files.

Code Availability

All R code written for this paper is available: <https://github.com/emilywilkins/Literature-Review>

Acknowledgements EJW received support from the National Science Foundation [Grant No. 1633756], the Utah State University Office of Research, and the Institute of Outdoor Recreation and Tourism at Utah

State University. SAW was supported by a Data Science Environments project award from the Gordon and Betty Moore Foundation [Award #2013-10-29] and the Alfred P. Sloan Foundation [Award #3835] to the University of Washington eScience Institute.

Author Contributions EJW: conceptualization, formal analysis, investigation, methodology, visualization, writing—original draft. SAW: writing—review and editing. JWS: conceptualization, writing—review and editing, supervision.

Compliance with Ethical Standards

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

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

- Arkema KK, Verutes GM, Wood SA, Clarke-Samuels C, Rosado S, Canto M, Faries J (2015) Embedding ecosystem services in coastal planning leads to better outcomes for people and nature. *Proc Natl Acad Sci* 112(24):7390–7395
- Barros C, Moya-Gómez B, Gutiérrez J (2019) Using geotagged photographs and GPS tracks from social networks to analyse visitor behaviour in national parks. *Curr Issues Tour* 23(10):1291–1310
- Barry SJ (2014) Using social media to discover public values, interests, and perceptions about cattle grazing on park lands. *Environ Manag* 53(2):454–464. <https://doi.org/10.1007/s00267-013-0216-4>
- Breckheimer IK, Theobald EJ, Cristea NC, Wilson AK, Lundquist JD, Rochefort RM, HilleRisLambers J (2019) Crowd-sourced data reveal social–ecological mismatches in phenology driven by climate. *Front Ecol Environ* 18(2):76–82
- Callau AA, Albert MYP, Rota JJ, Giné DS (2019) Landscape characterization using photographs from crowdsourced platforms: content analysis of social media photographs. *Open Geosci* 11(1):558–571
- Campelo MB, Mendes RMN (2016) Comparing webshare services to assess mountain bike use in protected areas. *J Outdoor Recreation Tour* 15:82–88
- Cessford G, Muhar A (2003) Monitoring options for visitor numbers in national parks and natural areas. *J Nat Conserv* 11(4):240–250
- Clemente P, Calvache M, Antunes P, Santos R, Cerdeira JO, Martins MJ (2019) Combining social media photographs and species distribution models to map cultural ecosystem services: the case of a Natural Park in Portugal. *Ecol Indic* 96:59–68
- Conti E, Lexhagen M (2020) Instagramming nature-based tourism experiences: a netnographic study of online photography and value creation. *Tour Manag Perspect* 34:100650
- Crampton JW, Graham M, Poorthuis A, Shelton T, Stephens M, Wilson MW, Zook M (2013) Beyond the geotag: situating 'big data' and leveraging the potential of the geoweb. *Cartogr Geogr Inform Sci* 40(2):130–139
- Di Minin E, Tenkanen H, Toivonen T (2015) Prospects and challenges for social media data in conservation science. *Front Environ Sci* 3:63
- Do Y, Kim JY (2020) An assessment of the aesthetic value of protected wetlands based on a photo content and its metadata. *Ecol Eng* 150:105816
- Donahue ML, Keeler BL, Wood SA, Fisher DM, Hamstead ZA, McPhearson T (2018) Using social media to understand drivers of

- urban park visitation in the Twin Cities, MN. *Landsc Urban Plan* 175:1–10
- Dunkel A (2015) Visualizing the perceived environment using crowdsourced photo geodata. *Landsc Urban Plan* 142:173–186
- Fisher DM, Wood SA, Roh YH, Kim CK (2019) The geographic spread and preferences of tourists revealed by user-generated information on Jeju Island. *South Korea Land* 8(5):73
- Fisher DM, Wood SA, White EM, Blahna DJ, Lange S, Weinberg A, Lia E (2018) Recreational use in dispersed public lands measured using social media data and on-site counts. *J Environ Manag* 222:465–474
- Fotheringham AS, Wong DW (1991) The modifiable areal unit problem in multivariate statistical analysis. *Environ Plan A* 23(7):1025–1044
- Garzia F, Borghini F, Bruni A, Mighetto P, Ramalingam S, Russo B (2020) Emotional reactions to the perception of risk in the Pompeii Archaeological Park. *Int J Saf Secur Eng* 10(1):11–16
- Ghermandi A, Sinclair M (2019) Passive crowdsourcing of social media in environmental research: a systematic map. *Glob Environ Change* 55:36–47
- Gosal AS, Geijzendorffer IR, Václavík T, Poulin B, Ziv G (2019) Using social media, machine learning and natural language processing to map multiple recreational beneficiaries. *Ecosyst Serv* 38:100958
- Hammit WE, Cole DN, Monz, CA (2015) *Wildland recreation: ecology and management*. John Wiley & Sons, Chichester, UK
- Hamstead ZA, Fisher D, Ilieva RT, Wood SA, McPhearson T, Kremer P (2018) Geolocated social media as a rapid indicator of park visitation and equitable park access. *Comput, Environ Urban Syst* 72:38–50
- Hausmann A, Toivonen T, Heikinheimo V, Tenkanen H, Slotow R, Di Minin E (2017) Social media reveal that charismatic species are not the main attractor of ecotourists to sub-Saharan protected areas. *Sci Rep* 7(1):1–9
- Hausmann A, Toivonen T, Slotow R, Tenkanen H, Moilanen A, Heikinheimo V, Di Minin E (2017) Social media data can be used to understand tourists' preferences for nature-based experiences in protected areas. *Conserv Lett* 11(1):e12343
- Heikinheimo V, Minin ED, Tenkanen H, Hausmann A, Erkkonen J, Toivonen T (2017) User-generated geographic information for visitor monitoring in a national park: a comparison of social media data and visitor survey. *ISPRS Int J Geo-Inform* 6(3):85
- Huang S-CL, Sun W-E (2019) Exploration of social media for observing improper tourist behaviors in a national park. *Sustainability* 11(6):1637
- Johnson ML, Campbell LK, Svendsen ES, McMillen HL (2019) Mapping urban park cultural ecosystem services: a comparison of twitter and semi-structured interview methods. *Sustainability* 11(21):6137
- Karasov O, Vieira AAB, Külvik M, Chervanyov I (2020) Landscape coherence revisited: GIS-based mapping in relation to scenic values and preferences estimated with geolocated social media data. *Ecol Indic* 111:105973
- Kim Y, Kim C-k, Lee DK, Lee H-w, Andrada RIT (2019) Quantifying nature-based tourism in protected areas in developing countries by using social big data. *Tour Manag* 72:249–256
- Kovacs-Györi A, Ristea A, Kolcsar R, Resch B, Crivellari A, Blaschke T (2018) Beyond spatial proximity—classifying parks and their visitors in London based on spatiotemporal and sentiment analysis of Twitter data. *ISPRS Int J Geo-Inform* 7(9):378
- Kuehn D, Gibbs J, Goldspiel H, Barr B, Sampson A, Moutenot M, ... Stradman L (2020) Using social media data and park characteristics to understand park visitation. *J Park Recreat Admin* 38(2):135–145
- Leggett C, Horsch E, Smith C, Unsworth R (2017) Estimating recreational visitation to federally-managed lands. Cambridge, MA
- Leung Y-F, Halpenny E, Salenieks T, Manning R, Bride I, Walden-Schreiner C, Buckley R (2018) Adaptive management for sustainable tourism. In: Y-F Leung, A Spenceley, G Hvenegaard, & R. Buckley (eds) *Tourism and visitor management in protected areas: guidelines for sustainability*, IUCN, Gland, Switzerland, p. 41–62
- Levin N, Kark S, Crandall D (2015) Where have all the people gone? Enhancing global conservation using night lights and social media. *Ecol Appl* 25(8):2153–2167
- Levin N, Lechner AM, Brown G (2017) An evaluation of crowd-sourced information for assessing the visitation and perceived importance of protected areas. *Appl Geogr* 79:115–126
- Li F, Li F, Li S, Long Y (2020) Deciphering the recreational use of urban parks: experiments using multi-source big data for all Chinese cities. *Sci Total Environ* 701:134896
- Liang Y, Kirilenko AP, Stepchenkova SO, Ma S (2019) Using social media to discover unwanted behaviours displayed by visitors to nature parks: comparisons of nationally and privately owned parks in the Greater Kruger National Park, South Africa. *Tour Recreat Res* 45(2):271–276
- Lopez BE, Magliocca NR, Crooks AT (2019) Challenges and opportunities of social media data for socio-environmental systems research. *Land* 8(7):107
- Mancini F, Coghill GM, Lusseau D (2018) Using social media to quantify spatial and temporal dynamics of nature-based recreational activities. *PLoS ONE* 13(7):e0200565
- Martinez-Harms MJ, Bryan BA, Wood SA, Fisher DM, Law E, Rhodes JR, Wilson KA (2018) Inequality in access to cultural ecosystem services from protected areas in the Chilean biodiversity hotspot. *Sci Total Environ* 636:1128–1138
- McCreary A, Seekamp E, Davenport M, Smith JW (2019) Exploring qualitative applications of social media data for place-based assessments in destination planning. *Curr Issues Tour* 23(1):82–98
- Millennium Ecosystem Assessment (2005) *Ecosystems and human well-being: synthesis*. Island press, Washington, DC
- Mitchell L, Frank MR, Harris KD, Dodds PS, Danforth CM (2013) The geography of happiness: Connecting twitter sentiment and expression, demographics, and objective characteristics of place. *PLoS ONE* 8(5)
- Moher D, Liberati A, Tetzlaff J, Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med* 151(4):264–269
- Muñoz L, Hausner VH, Runge C, Brown G, Daigle R (2020) Using crowdsourced spatial data from Flickr vs. PPGIS for understanding nature's contribution to people in Southern Norway. *People Nat* 2(2):437–449
- National Coordination Office for Space-Based Positioning. (2020). GPS Accuracy. GPS.gov. <https://www.gps.gov/systems/gps/performance/accuracy/>
- National Park Service (2020) Visitation Numbers. About us. <https://www.nps.gov/aboutus/visitation-numbers.htm>
- Norman P, Pickering CM (2017) Using volunteered geographic information to assess park visitation: comparing three on-line platforms. *Appl Geogr* 89:163–172
- Norman P, Pickering CM (2019) Factors influencing park popularity for mountain bikers, walkers and runners as indicated by social media route data. *J Environ Manag* 249:109413
- Norman P, Pickering CM, Castley G (2019) What can volunteered geographic information tell us about the different ways mountain bikers, runners and walkers use urban reserves? *Landsc Urban Plan* 185:180–190
- Obar JA, Wildman SS (2015) Social media definition and the governance challenge—an introduction to the special issue. *Telecommun Policy* 39(9):745–750

- Orsi F, Geneletti D (2013) Using geotagged photographs and GIS analysis to estimate visitor flows in natural areas. *J Nat Conserv* 21(5):359–368
- Petticrew M, Roberts H (2006) *Systematic reviews in the social sciences: a practical guide*. Blackwell Publishing, Malden, MA, USA
- Pickering C, Walden-Schreiner C, Barros A, Rossi SD (2020) Using social media images and text to examine how tourists view and value the highest mountain in Australia. *J Outdoor Recreat Tour* 29:100252
- Plunz RA, Zhou Y, Vintimilla MIC, Mckeown K, Yu T, Ugucioni L, Sutto MP (2019) Twitter sentiment in New York City parks as measure of well-being. *Landsc Urban Plan* 189:235–246
- Retka J, Jepson P, Ladle RJ, Malhado AC, Vieira FA, Normande IC, Correia RA (2019) Assessing cultural ecosystem services of a large marine protected area through social media photographs. *Ocean Coast Manag* 176:40–48
- Rice WL, Mueller JT, Graefe AR, Taff BD (2019) Detailing an approach for cost-effective visitor-use monitoring using crowd-sourced activity data. *J Park Recreation Admin* 37(2)
- Roberts H, Sadler J, Chapman L (2017) Using Twitter to investigate seasonal variation in physical activity in urban green space. *Geogr Environ* 4(2):e00041
- Roberts H, Sadler J, Chapman L (2019) The value of Twitter data for determining the emotional responses of people to urban green spaces: a case study and critical evaluation. *Urban Stud* 56(4):818–835
- Rossi SD, Barros A, Walden-Schreiner C, Pickering C (2019) Using social media images to assess ecosystem services in a remote protected area in the Argentinean Andes. *Ambio* 49:1146–1160
- Sessions C, Wood SA, Rabotyagov S, Fisher DM (2016) Measuring recreational visitation at U.S. National Parks with crowd-sourced photographs. *J Environ Manag* 183:703–711. <https://doi.org/10.1016/j.jenvman.2016.09.018>
- Sharp R, Tallis HT, Ricketts T, Guerry AD, Wood SA, Chaplin-Kramer R, ... Vigerstol K (2016) *InVEST version 3.8.0 User's Guide*. The Natural Capital Project
- Sim J, Miller P (2019) Understanding an urban park through big data. *Int J Environ Res Public Health* 16(20):3816
- Sinclair M, Ghermandi A, Sheela AM (2018) A crowdsourced valuation of recreational ecosystem services using social media data: an application to a tropical wetland in India. *Sci Total Environ* 642:356–365
- Sinclair M, Mayer M, Woltering M, Ghermandi A (2020) Using social media to estimate visitor provenance and patterns of recreation in Germany's national parks. *J Environ Manag* 263:110418
- Smith JW, Wilkins EJ, Leung Y-F (2019) Attendance trends threaten future operations of America's state park systems. *Proc Natl Acad Sci* 116(26):12775–12780
- Song XP, Richards DR, Tan PY (2020) Using social media user attributes to understand human–environment interactions at urban parks. *Sci Rep* 10(1):1–11
- Song Y, Zhang B (2020) Using social media data in understanding site-scale landscape architecture design: taking Seattle Freeway Park as an example. *Landsc Res* 1–22
- Sonter LJ, Watson KB, Wood SA, Ricketts TH (2016) Spatial and temporal dynamics and value of nature-based recreation, estimated via social media. *PLoS ONE* 11(9):e0162372. <https://doi.org/10.1371/journal.pone.0162372>
- Teles da Mota VT, Pickering C (2020) Using social media to assess nature-based tourism: current research and future trends. *J Outdoor Recreat Tour* 30:100295
- Tenkanen H, Di Minin E, Heikinheimo V, Hausmann A, Herbst M, Kajala L, Toivonen T (2017) Instagram, Flickr, or Twitter: assessing the usability of social media data for visitor monitoring in protected areas. *Sci Rep* 7(1):17615. <https://doi.org/10.1038/s41598-017-18007-4>
- Tieskens KF, Van Zanten BT, Schulp CJ, Verburg PH (2018) Aesthetic appreciation of the cultural landscape through social media: an analysis of revealed preference in the Dutch river landscape. *Landsc Urban Plan* 177:128–137
- Toivonen T, Heikinheimo V, Fink C, Hausmann A, Hiippala T, Järvi O, Di Minin E (2019) Social media data for conservation science: a methodological overview. *Biol Conserv* 233:298–315
- Ullah H, Wan W, Haidery SA, Khan NU, Ebrahimpour Z, Muzahid AAM (2020) Spatiotemporal patterns of visitors in urban green parks by mining social media big data based upon WHO reports. *IEEE Access* 8:39197–39211
- Vaz AS, Gonçalves JF, Pereira P, Santarém F, Vicente JR, Honrado JP (2019) Earth observation and social media: evaluating the spatiotemporal contribution of non-native trees to cultural ecosystem services. *Remote Sens Environ* 230:111193
- Vaz AS, Moreno-Llorca RA, Gonçalves JF, Vicente JR, Méndez PF, Revilla E, ... Alcaraz-Segura D (2020) Digital conservation in biosphere reserves: earth observations, social media, and nature's cultural contributions to people. *Conserv Lett* e12704
- Vieira FA, Bragagnolo C, Correia RA, Malhado AC, Ladle RJ (2018) A salience index for integrating multiple user perspectives in cultural ecosystem service assessments. *Ecosyst Serv* 32:182–192
- Walden-Schreiner C, Leung Y-F, Tateosian L (2018) Digital footprints: Incorporating crowdsourced geographic information for protected area management. *Appl Geogr* 90:44–54
- Walden-Schreiner C, Rossi SD, Barros A, Pickering C, Leung Y-F (2018) Using crowd-sourced photos to assess seasonal patterns of visitor use in mountain-protected areas. *Ambio* 47(7):781–793
- Willemen L, Cottam AJ, Drakou EG, Burgess, ND (2015) Using social media to measure the contribution of red list species to the nature-based tourism potential of African protected areas. *PLoS ONE* 10(6)
- Wikiloc (2020) How are trails selected for Google Earth? <https://help.wikiloc.com/article/485-select-trails-tracks-routes-google-earth>
- Wilkins EJ, Smith JW, Keane R (2020) Social media communication preferences of national park visitors. *Appl Environ Educ Commun* 19(1):4–18. <https://doi.org/10.1080/1533015X.2018.1486247>
- Wood SA, Guerry AD, Silver JM, Lacayo M (2013) Using social media to quantify nature-based tourism and recreation. *Sci Rep* 3:2976. <https://doi.org/10.1038/srep02976>
- Xu F, Nash N, Whitmarsh L (2019) Big data or small data? A methodological review of sustainable tourism. *J Sustain Tour* 28(2):144–163
- Yoshimura N, Hiura T (2017) Demand and supply of cultural ecosystem services: use of geotagged photos to map the aesthetic value of landscapes in Hokkaido. *Ecosyst Serv* 24:68–78
- Zhang S, Zhou W (2018) Recreational visits to urban parks and factors affecting park visits: evidence from geotagged social media data. *Landsc Urban Plan* 180:27–35