Applied Geography 88 (2017) 94–103

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Spatial temporal dynamics of vehicle stopping behavior along a rustic park road

Jennifer N. Newton [a, *], Peter Newman [b], B. Derrick Taff [c], Ashley D'Antonio [d], Christopher Monz [e]

[a] Recreation, Park and Tourism Department, The Pennsylvania State University, 804 Ford Building, University Park, PA, 16802, United States
[b] Recreation, Park and Tourism Department, The Pennsylvania State University, 801 Ford Building, University Park, PA, 16802, United States
[c] Recreation, Park and Tourism Department, The Pennsylvania State University, 701 H Ford Building, University Park, PA, 16802, United States
[d] Department of Forest Ecosystems & Society, Oregon State University, 321 Richardson Hall, Corvallis, OR, 97331, United States
[e] Department of Environment and Society, Utah State University, NR 318 5215 Old Main Hill, Logan, UT, 84322-5215, United States

ARTICLE INFO

Article history:
Received 17 October 2016
Received in revised form
22 June 2017
Accepted 8 August 2017
Available online 22 September 2017

Keywords:
Visitor use
National parks
GPS
Spatial temporal dynamics

ABSTRACT

Visitor use to parks and protected areas is very dynamic. Previous studies have used geospatial models to better understand visitor flow. Geospatial data give a more accurate and precise insight to visitor movements, and investigating both space and time together in one analysis provides a more holistic understanding of visitor use. This study uses a toolbox created for ArcGIS that combines space and time into one analysis to identify space-time hot and cold spots. By entering data of stopping behaviors of visitors driving along a narrow, rustic park road, spatial temporal hot and cold spots were classified and then described by associated demographic data that was collected. The results show statistically significant spatial-temporal trends among stopping behaviors of visitors in vehicles. Such information is valuable to park managers to better understand and manage visitor flows through an area.

1. Introduction

An understanding of visitor flow in space and time in parks and protected areas is at the core of contemporary visitor management strategies. Visitor use levels and densities are directly linked to ecological and social conditions present in parks and protected areas (Hammitt, Cole, & Monz, 2015; Manning, 2011). Understanding when and how visitors move through a destination is important for planners and managers to make informed decisions that protect resources and provide quality visitor experiences (Orellana, Bregt, Ligtenberg, & Wachowicz, 2012). Investigating spatial and temporal data simultaneously gives a holistic understanding of visitor use dynamics. Integrative space and time studies are useful to park and protected area officials who manage high volume visitor flows in fragile ecosystems.

Visitor and tourist behaviors in outdoor recreation settings have been a long-standing interest of recreation researchers (Manning, 2011). Social and ecological conditions are influenced by use, thus knowing when and where that use is occurring is paramount for proper adaptive management (Hammitt et al., 2015; Manning, 2011). For example, increased use may affect visitor's perceptions of crowding (Manning, 2011), and also cause an increase in trampled vegetation (Hammitt et al., 2015). The purpose of this study was to demonstrate the power of combining space and time into one analysis and provide managers with useful information for planning efforts.

1.1. Spatial-temporal recreation patterns

Early studies investigated the movement of visitors and tourists by asking participants to draw their travel routes on blank maps (Hinterberger, Arnberger, & Muhar, 2002; Mings & Mchugh, 1992; Newman & Manning, 2001; Potter & Manning, 1984; Wing & Shelby, 1999). Map diaries were then used to identify visitor use patterns, sometimes after manually entering the maps into a GIS environment. Recently, studies have shown that self-reported measures of movement tend to be inaccurate (Hallo et al., 2012; Stedman et al., 2004; Taczanowska, Muhar, & Brandenburg, 2008). Rather than relying on self-reported measures of visitor movement, more recent research has employed the use of Global

* Corresponding author. Present address: Grand Teton National Park, PO Drawer 170, Moose, WY, 83012, United States.
E-mail address: jennifernnewton118@gmail.com (J.N. Newton).

http://dx.doi.org/10.1016/j.apgeog.2017.08.007
0143-6228/

Positioning System (GPS) technology to determine the behaviors of visitors, as it provides high-resolution spatial temporal data.

The use of GPS technology to track visitors has been applied in numerous settings, including: backcountry and frontcountry areas within protected lands (Beeco et al., 2013; D'Antonio et al., 2010; D'Antonio & Monz, 2016; Hallo et al., 2012; Orellana et al., 2012; Taczanowska et al., 2014), amusement parks (Birenboim, Anton-Clavé, Russo, & Shoval, 2013; Russo, Clave, & Shoval, 2010), sporting events (Pettersson & Zillinger, 2011), festivals (Versichele, Neutens, Delafontaine, & Van de Weghe, 2012) and cities (Edwards & Griffin, 2013; McKercher, Shoval, Ng, & Birenboim, 2012; Shoval & Isaacson, 2007). These studies provide managers and planners the information needed to make educated decisions regarding visitor use. This is particularly important for land managers who are mandated to protect ecological resources and provide high quality visitor experiences.

Research regarding the flow of visitors through protected areas aids managers in achieving their management objectives of protecting visitor experiences as well as ecological conditions. For example, some research has examined visitor use through trail systems in protected areas, by giving hikers GPS units to track their movement patterns during their visit (D'Antonio et al., 2010; D'Antonio & Monz, 2016; Orellana et al., 2012; Orellana & Wachowicz, 2011; Taczanowska et al., 2014). Useful information from these studies, such as the number of visitors traveling off the designated trail system (Taczanowska et al., 2014), and the relationship between off designated trail use and visitor use level (D'Antonio & Monz, 2016), can aid managers in identifying areas that are more susceptible to resource damage, and best places to place personal and non-personal interpretation about minimum impact recreation. Studies have also been conducted examining the flow of visitors in vehicles. For example, in the Blue Ridge Parkway, visitors were given GPS units to take with them as they drove through the park (Hallo et al., 2012). Knowing where visitors stopped and the levels of use of an area can aid managers in better educating and redistributing visitors within a park to meet visitor management objectives (Hallo et al., 2012).

1.2. Transportation within parks

Using GPS technologies to examine actual behavior of participants in vehicles has been used in numerous studies (Beeco et al., 2013; Dill & Broach, 2014; Hallo et al., 2012; Liu, Yan, & Chow, 2015). These studies can inform visitor flow and routes, as well as popular stopping locations. Understanding flow of vehicles is of particular importance in the United States National Park Service system, where the majority of visitors' access and travel within parks by their personal vehicle (Hallo & Manning, 2009). In such systems, transportation can be used as a tool to meet management objectives (i.e. protection of resources and high quality visitor experiences) by delivering the desired number of people to the right place at the right time (Manning, Lawson, Newman, Hallo, & Monz, 2014). Existing transportation systems can be enhanced by learning more about visitor behavior within a system. With an estimated eight billion visitors to protected areas worldwide (Balmford et al., 2015), and increasing visitation trends to US national parks (Cordell, Betz, & Green, 2008), understanding the behavior and flow of visitors is essential in the balance of visitor use and preservation of ecological and experiential resources.

Driving behaviors of visitors in personal vehicles effects traffic flow, overall visitor experiences, potential impacts to vegetation and wildlife, and noise and air pollution (Taff et al., 2013; White, 2007). For example, stopping behaviors (where visitors choose to stop along the road-way) of visitors may indicate a geographic feature attracting their attention, causing them to perform a different activity (Orellana et al., 2012). Most studies that examine stopping behaviors among vehicles, do so by examining areas where vehicles are likely to be in a parking lot, or other authorized parking areas (Beeco et al., 2013; Dill & Broach, 2014; Liao, Patterson, Fox, & Kautz, 2007). For example, Beeco et al. (2013) explored visitor behaviors along the Blue Ridge Parkway, USA and formed different typologies of visitors (i.e. planners or wanderers), and found that both typologies spent more time stopping than driving along primary roads and more time on primary roads than secondary roads.

However, examining authorized parking areas (e.g. parking lots) in addition to unauthorized parking areas (e.g. on roadside vegetation) is important for understanding actual visitor flow and potential impacts of stopping in unauthorized areas to traffic, ecological resources, and visitor experience. Within the US park system, many roads are historic, dating back to the late 1800's, and cover some of the most rugged topography (Soullière, 1995). Historic US park roads tend to be narrow and winding, and pass through sensitive ecological resources. The character of these roads leave little room for safe roadside parking. If visitors do park in unauthorized parking areas, increased impacts to roadside vegetation, as well as decreased visitor experience and traffic flow will likely occur (Manning et al., 2014; Monz, D'Antonio, Lawson, Barber, & Newman, 2016). To meet management objectives of protecting ecological resources and high quality visitor experiences, understanding the flow of private vehicles along historic roads is necessary.

1.3. Spatial-temporal dynamics

Many studies have demonstrated the usefulness of applying GPS-based methodologies for understanding visitor use patterns (D'Antonio et al., 2010) and others have extended this analysis by applying space-time methodologies to movement (Andrienko, Andrienko, & Gatalsky, 2003; Kraak, 2003; Liao et al., 2007; Orellana et al., 2012). Space-time analysis is used to examine a specific event, occurrence, activity, or item in regards to its changing position in space and time (An et al., 2015). Space-time methods are capable of providing robust ways to utilize available data collected by the GPS units. While the theory of combining space and time in one analysis originated in the early 1970's (Hägerstraand, 1970), many since then have developed tools to examine or visualize space and time together (e.g, Andrienko, et al., 2003; Chen, Guo, & Wang, 2015; Kraak, 2003; Neutens, Witlox, & Demaeyer, 2007; Shaw, Yu, & Bombom, 2008). Studies have used space-time to examine various topics, such as: taxi trips in an urban setting (Ferreira, Poco, Vo, Freire, & Silva, 2013), crime incident rates, (Brunsdon, Corcoran, & Higgs, 2007), large vehicle accidents (Gudes & Varhol, 2015) and eye movement recordings (Li, Çöltekin, & Kraak, 2010). Incorporating both space and time in one analysis gives a powerful and comprehensive view of phenomena that are occurring. Some studies have incorporated such analysis in recreation and tourism settings as well (Orellana et al., 2012). Orellana et al. (2012) found areas that visitors frequented, as well as a great variety in the routes that visitors use to move between those areas.

Recently, a “space time pattern mining” toolbox was created by ESRI (2016a) for ArcGIS, a popular geospatial processing software. Within the toolbox are utility features that incorporate the interplay of space and time to find patterns and distributions of data. To date, there are few studies that have applied ESRI's tool, particularly within the fields of protected areas management. Heavy vehicle crashes were analyzed over a 12-year period within an urban context, providing useful information to city managers of high-risk