Landscape and Urban Planning 127 (2014) 164–172

Contents lists available at ScienceDirect

Landscape and Urban Planning

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

Research Paper

Simulating the responses of forest bird species to multi-use recreational trails

Iñaki Rodríguez-Prieto[a], Victoria J. Bennett[b], Patrick A. Zollner[a,*], Mike Mycroft[c], Mike List[c], Esteban Fernández-Juricic[d]

[a] Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN 47906, USA
[b] School of Geology, Energy and the Environment, Texas Christian University, Fort Worth, TX 76129, USA
[c] Division of State Parks and Reservoirs (Indiana Department of Natural Resources), 402 West Washington Street, Room W298, Indianapolis, IN 46204, USA
[d] Department of Biological Sciences, Purdue University, West Lafayette, IN 47906, USA

HIGHLIGHTS

- We model the potential recreational disturbance of a bird community.
- We evaluate three proposed trail designs and invasive vegetation removal.
- Trail design selection is highly species dependent even between species of concern.
- Invasive vegetation removal did not have a cumulative impact on bird disturbance.

ARTICLE INFO

Article history:
Received 14 October 2013
Received in revised form 26 March 2014
Accepted 31 March 2014

Keywords:
Anthropogenic disturbance
Individual-based modeling
Park design
Non-consumptive recreation
Urban planning

ABSTRACT

Although non-consumptive recreation can promote wildlife preservation and add socio-economic value to parks and nature reserves, such activities can have negative implications for wildlife. For sensitive species, recreation can lead to displacement, influence breeding success and reduce survival. Thus managing recreational activities by regulating visitor access, densities and frequency can effectively reduce human–wildlife interactions. In many instances, simulation modeling has been used as a management tool, as it allows the user to explore the impact of alternative park designs and management strategies on wildlife in a risk-free environment. Such exercises tend to focus on single species, generally a species of conservation concern, on which management decisions are based. As an alternative approach, we used a modeling simulation to compare the disturbance caused by different trail designs, trail use rates and the management of invasive vegetation (i.e., removal) on a forest community of breeding birds at a state park in Indiana, USA. Our multi-species approach revealed that an appropriate trail design for one species was not necessarily appropriate for another, even among species of concern. We therefore caution that management based on a single high profile species could have far-reaching implications on the local community. We also found that invasive vegetation removal did not have a cumulative influence on the recreational disturbance experienced by birds. This study demonstrates that by identifying and comparing the differences between individual species within a community, we gain valuable insights that can be used devise more resilient long-term management strategies that aim to preserve biodiversity.

1. Introduction

Natural resource-based outdoor recreation can contribute to the conservation of biodiversity by promoting public support for wildlife preservation and adding socio-economic value to natural areas (Christ, Hillel, Matus, & Sweeting, 2003; Stronza & Durham, 2008). However, recreational activities can also have negative impacts on wildlife populations (Knight & Gutzwiller, 1995; Rochelle, Pickering, & Castley, 2011), thereby decreasing an area's ecological value (Reed & Merenlender, 2008). For example, the development of recreation infrastructure can directly degrade habitat (Christ et al., 2003; Laiolo, 2004). In addition, recreation can have indirect effects when wildlife allocate time and energy reacting to humans as though they were potential predators (Bennett, Quinn, & Zollner, 2013; Frid & Dill, 2002). Continued disruptions to

* Corresponding author. Tel.: +1 765 496 9495.
E-mail addresses: ik.rodriguez.prieto@gmail.com (I. Rodríguez-Prieto), v.bennett@tcu.edu (V.J. Bennett), pzollner@purdue.edu (P.A. Zollner), mmycroft@dnr.in.gov (M. Mycroft), mlist@dnr.in.gov (M. List), efernan@purdue.edu (E. Fernández-Juricic).

http://dx.doi.org/10.1016/j.landurbplan.2014.03.008
0169-2046/© 2014 Published by Elsevier B.V.

natural behavior (e.g. foraging) can in turn impact energetic budgets (Houston, Prosser, & Sans, 2012) and parental care (Verhulst, Oosterbeek, & Ens, 2001), potentially affecting population viability in areas with high levels of disturbance (Kerbiriou et al., 2009). Thus for some species, recreational activities can have substantial fitness consequences (Beale & Monaghan, 2004) and population-level effects (Creel & Christianson, 2008). For these vulnerable species, managing visitor density and/or frequency may be an effective strategy to alleviate the negative implications of human–wildlife interactions (Cole, 1993; Rodriguez-Prieto & Fernández-Juricic, 2005).

In natural areas, a network of trails can be used to direct recreationist movements, potentially influencing both visitor experience and level of disturbance to wildlife. The design of this network may, therefore, indirectly affect wildlife by changing the spatial and temporal patterns of human–wildlife encounters (Cole, 1993; Ferrarini, Rossi, Parolo, & Ferloni, 2008). Trail design is usually informed by standard practices, such as (1) reducing trail density in pristine areas, (2) avoiding placing long stretches of trail along stream/river banks, and (3) using vegetation or topography to screen sensitive wildlife from recreationists (Flink, Olka, & Searns, 2001; Hellmund, 1998). However, such practices are often too general to obtain a design that effectively balances recreation and conservation in a given location. More detailed recommendations can be generated from empirical research (e.g., Fernández-Juricic, Jiménez, & Lucas, 2001; Fernández-Juricic, Zollner, LeBlanc, & Westphal, 2007). However, studies investigating optimal trail networks may require considerable logistical resources to manipulate the levels of human disturbance and assess wildlife responses, which could actually be detrimental for species of conservation concern.

The application of simulation models can help address the conflicts associated with managing recreational activities in natural areas (Beissinger et al., 2006; Stillman & Goss-Custard, 2010). Simulation models, particularly individual- or agent-based models (McLane, Semeniuk, McDermid, & Marceau, 2011), can provide detailed and cost-effective answers to local management questions, and they are especially suited to predict disturbance outcomes for a wide variety of management scenarios before they are implemented in situ (Bennett et al., 2009; Taylor, Green, & Perrins, 2007).

Most studies that model wildlife responses to recreation focus on single species (e.g., Liley & Sutherland, 2007; Taylor et al., 2007). However, recommendations based on the responses of one species can produce management decisions that are unsuitable for other species, because species vary in their sensitivity to disturbance and/or spatial/temporal distribution. Thus the implementation of species-specific management may contradict the fundamental multi-species conservation goals that many agencies are striving to achieve (Smith & Zollner, 2005). Furthermore, many of the simulation models currently applied to human–wildlife interactions are only associated with discrete landscape features, like shorelines or nest colonies (e.g., Beale, 2007; Bennett et al., 2011). However, conservation practitioners may face situations where the species of concern are widespread across a fairly homogeneous forested area. In these cases, the application of standard practices, like placing the trail as far from a nesting colony as possible or avoiding placing trails through a rare critical habitat (Hellmund, 1998), may not be an option for some species. SODA (Simulation of Disturbance Activities; Bennett et al., 2009, 2011) is a flexible and spatially explicit individual-based model that can be applied to multiple species and habitats. In this study, we used SODA to develop some principles for the implementation of a multi-use recreational trail on a breeding bird community in a natural area.

Our goal was to assess the degree to which different trail designs in a forested area previously subject to low levels of recreation, would potentially affect the frequency of disturbance experienced by the local forest bird community. We hypothesize that trails that expose species to increased frequencies of disturbance by recreationists across multiple patches of suitable habitat could lead to a reduction in the spatial and temporal availability of resources (Rodriguez-Prieto & Fernández-Juricic, 2005), and eventually lower chances of population persistence at local scales (Fernández-Juricic, 2002). These fitness costs associated with human disturbance are typically a consequence of animals responding to human activity as they do to threats from predators (Frid & Dill, 2002).

We modeled the responses of 9 virtual bird species (differing in sensitivity to recreationists, microhabitat preferences, and breeding densities) to virtual recreationists (pedestrians and cyclists) along three alternative trail designs during the breeding season. Additionally, managers planned to remove invasive honeysuckle (*Lonicera* spp.) considered to be a threat to native ecosystems in North America (Hutchinson & Vankat, 1997). However, honeysuckle provides dense refuge for many bird species (McCusker, Ward, & Brawn, 2010), which could change bird tolerance to recreationists (Fernández-Juricic et al., 2001; Fernández-Juricic, Jiménez, & Lucas, 2002). Under these conditions, we hypothesized that honeysuckle removal would increase the frequency at which birds encountered recreationists. Therefore, a second goal was to evaluate whether the impact of each of the alternative trail designs differed in habitats with or without honeysuckle. Furthermore, since the process of removing honeysuckle takes multiple years to complete, we also investigated how different removal strategies (i.e., a staggered removal starting with honeysuckle near to or far from the trail) would affect the frequency at which birds encountered recreationists. We used the insights gained from the simulation to derive some recommendations on trail placement and honeysuckle management.

2. Methods

2.1. Study area

Fort Harrison State Park is a forested preserve located near the city of Indianapolis in central Indiana, USA (39°52′10.21″ N; 86°1′18.06″ W; Fig. 1). It is a 680 ha area, covered by predominantly young deciduous forests, lakes, riparian habitats, picnic and lawn areas, and a golf course. Due to its proximity to Indianapolis, the park is popular with recreationists who use its extensive network of trails. The Lawrence Creek Forest Unit is one of the park's better conserved tracts of forest, covering an 84 ha area including several areas of mature forest receiving low to moderate recreational use. Almost half of its area has been invaded by honeysuckle which now constitutes the major component of the forest understory. At the inception of this study the Lawrence Creek Forest Unit had an existing pedestrian trail 2.7 km in length with no bicycle access (Fig. 2a).

2.2. Model overview

SODA is an individual-based model that simulates the movement patterns of wildlife individuals when subject to human disturbance in a spatially explicit virtual environment. Note that a full model description is available in Bennett et al. (2009) and previous applications of the model include simulating the responses of chicks in a Black-crowned Night-Heron colony to alternative path designs (Bennett et al., 2011) and simulating the responses of ovipositing karner blue butterflies (*Lycaeidea melissa samuelis*) to pedestrians (Bennett et al., 2013a), as well as Indiana bats (*Myotis sodalis*) to vehicular traffic (Bennett, Sparks, & Zollner, 2013). Users develop GIS maps to build a virtual environment within the model (environmental inputs), and define a set of variables that characterize both anthropogenic activities (anthropogenic inputs) and the