Embedding an Individual-Based Model of Wildlife Disturbance in an Agent-Based Model of Outdoor Recreation

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Introduction

- The protection, management, and sustainable use of natural systems require the integrated study of coupled natural-human (CNH) systems (Liu et al., 2007).

- Although there has been an increase in the use of individual-based models (IBM) in ecology (e.g., Cohen 2014) and agent-based models (ABM) in economics and the social sciences (see compilation in Tesfatsion 2015):

- human disturbance in IBMs remains modeled using fixed parameters rather than through adaptive agents that face trade-offs and seek to maximize utility; and

- wildlife in ABMs is modelled using aggregated population models rather than through fitness-maximizing individuals.

- Such modeling practices might generate decision-support tools that could misguide resource management decisions.

- When modeling CNH systems, the best approach may be to allow both humans and wildlife to behave adaptively.

- SODA (Simulation of Disturbance Activities – Bennett et al. 2009) is a modeling framework that has been applied to a variety of wildlife species and geographic locations.

- One application compared alternative scenarios for trail placement to minimize disturbance to nesting birds in a state park (Rodriguez-Prieto et al. 2014).

- While this application was useful, it did not account for the adaptive nature of recreationists' behavior and the trade-offs they face.

Objectives

• Using SODA as a benchmark, Obj. 1 is to build an integrated IBM/ABM with adaptive human recreation behavior and link this behavior to the adaptive wildlife traits in order to capture feedbacks between human and wildlife systems (this poster).

• Using intercept survey data, Obj. 2 is to (a) parameterize the model to inform natural resource management; and (b) identify methodological challenges in the survey-based specification of embedded ABMs/IBMs.

Model Overview

Three main model components:
• *Landscape*: trail system and 6 different habitat types;
• *Birds*: sit on nests, forage and return energy to nests, respond to disturbance when humans approach (Fig. 1);
• *Recreationists*: Birders, hikers, joggers, and bikers move throughout the trail system, accumulate utility according to their heterogeneous preferences (Table 1), change duration of stay based on utility level, may watch birds, and cause disturbance to birds when approaching them (Fig. 1).

Figure 1. The Coupled Human and Natural System and its feedbacks.
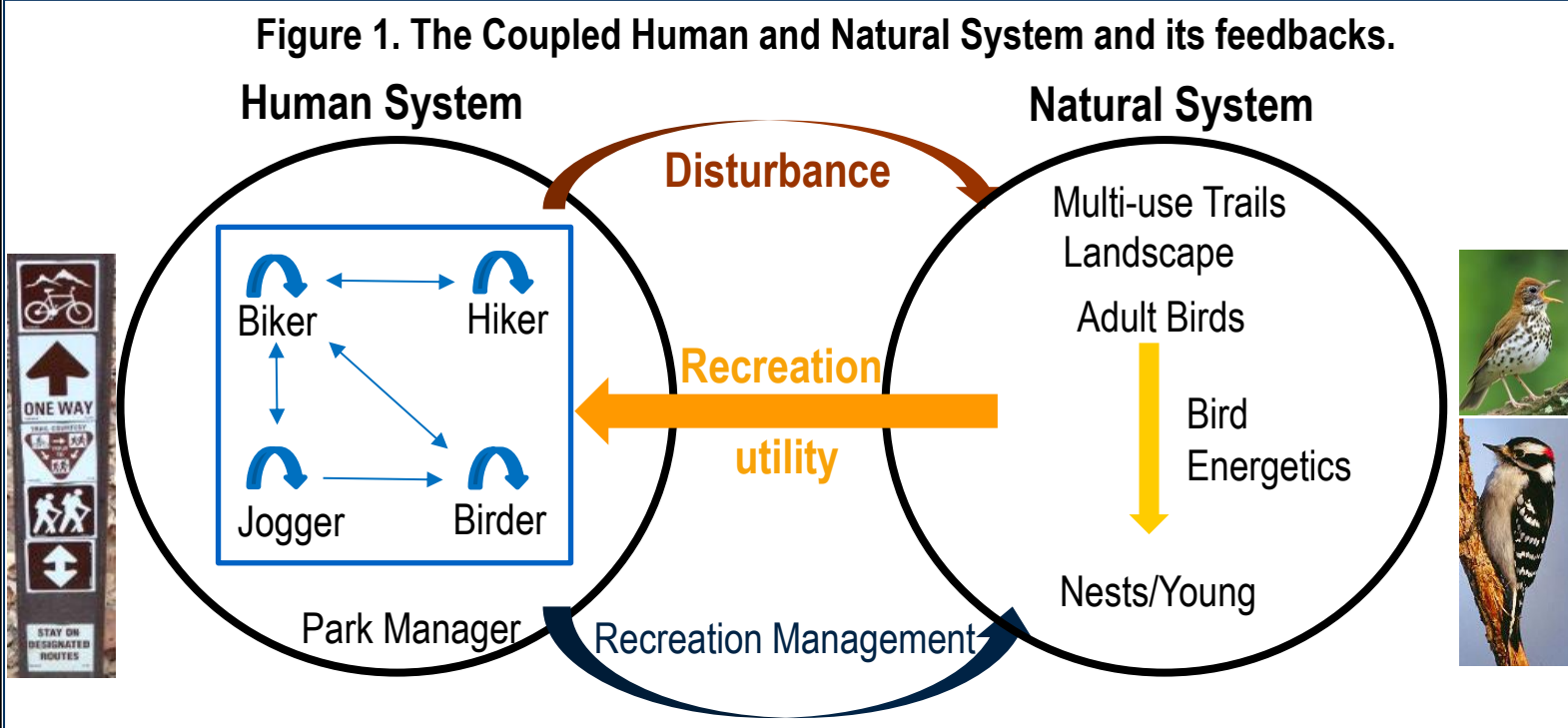
The Coupled Human-Natural System:
• *The natural system*: nests fail if not enough energy is delivered due to disturbance; adults re-nest in a new location.
• The *human system*: the arguments of the recreationists' utility functions depend on the recreationist type: encounters with birds, other recreationists, and distance hiked/biked may increase (+), decrease (-), or not affect (*No*) utility (Table 1).

Table 1: Arguments causing utility (+) or disutility (-) to recreationists

	Birds	*Other recreationists*	*Distance hiked/biked*
Birder	++	+ or -	No
Hiker	+	+ or -	+
Jogger	No	+ or -	+
Biker	No	+ or -	+

Recreation management:
A park manager seeks to maximize aggregate recreation and minimize bid disturbance outcomes by comparing alternative:
• Recreationist type mixes (Fig. 2 and 3);
• Enforcements of trail boundaries (on trail vs. off trail; Fig. 4).

Results

Figure 2. Disturbance (number of failed nests) as a function of recreationist type mixture, including only bikers and bird-watchers.
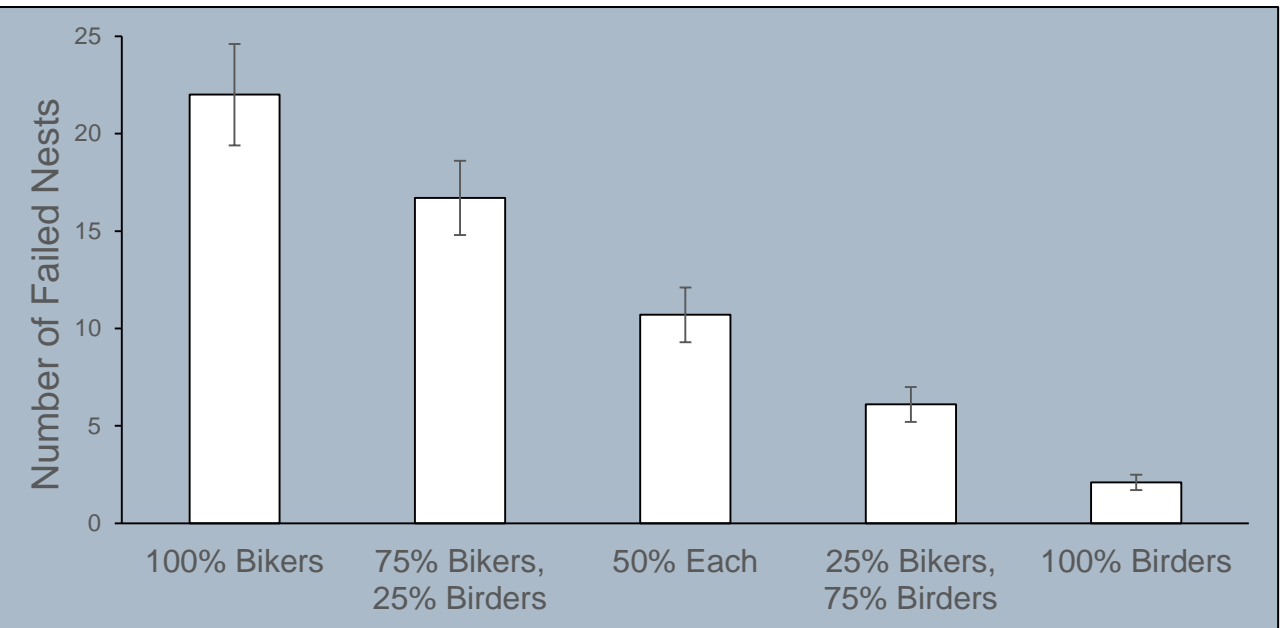

Figure 3. Recreation utility (upon park exit) as a function of recreationist type mixture, including only bikers and bird-watchers.
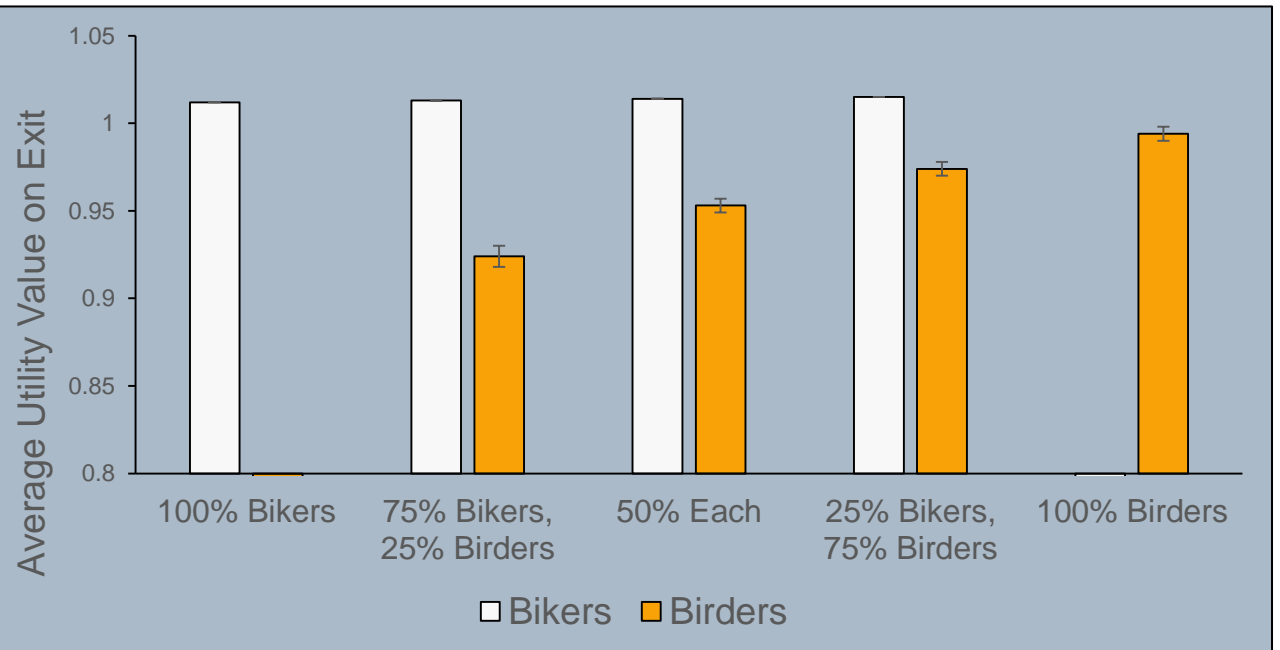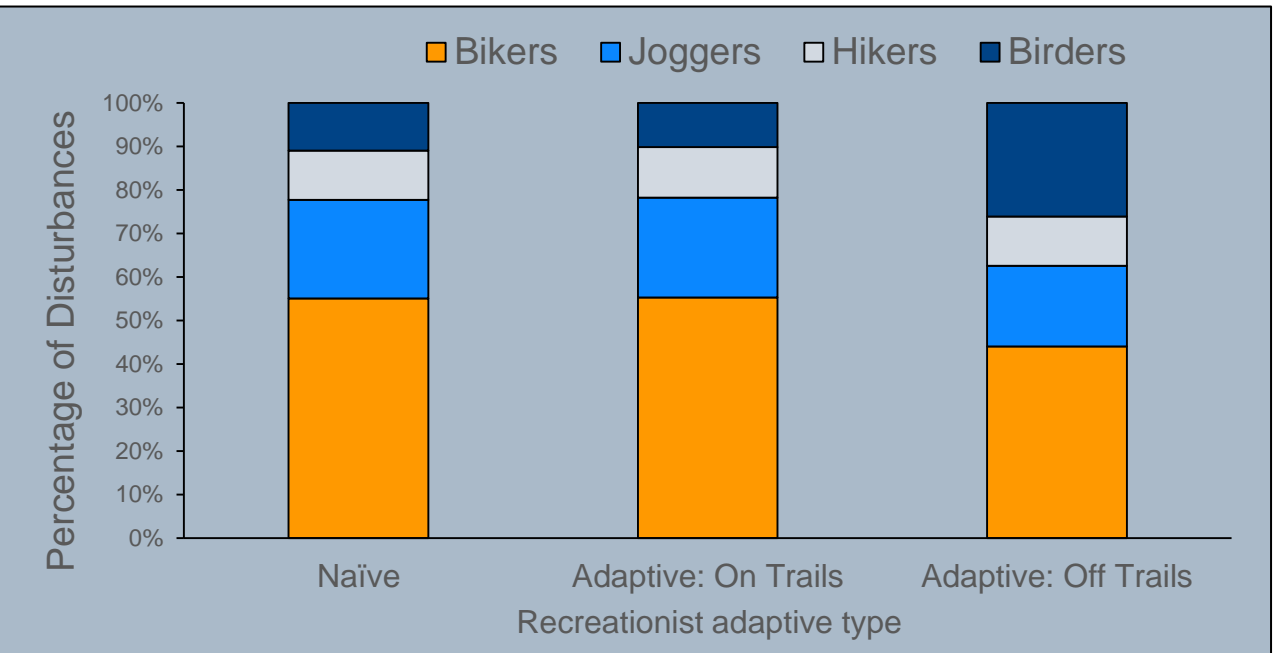

Figure 4. Comparison of total disturbance shares among four recreationists types when (1) not exhibiting any adaptive traits; 2) adaptive, regulated (stay on trail); 3) adaptive, unregulated (can go off trail)

Notes: Disturbance data are averages over 21 simulated recreation days; Recreation utility averages are collected upon park exit; Recreation visits are 60-90 minutes ± 15 minutes and vary by recreation types and adaptive trait.

Discussion

• Bikers caused the most disturbance due to their speed and the number of birds encountered per unit time (Fig. 2).

• Bikers caused bird-watchers to have a lower recreation utility through a direct channel of congestion and an indirect channel of lower probability of bird encounter (Fig. 3).

• When recreationists had recreation adaptive traits (e.g., birders go off trails towards birds), they caused considerably more disturbance than under non-adaptive model specifications (Fig. 4).

• This model can explore how different recreational patterns or management scenarios (e.g., enforcing trail boundaries; quotas on visitor hours) may impact wildlife and recreational satisfaction simultaneously.

Future Directions

• Conducting survey about the recreationist experience at Fort Harrison State Park (May-June 2015).

• Survey results will inform model parameters, including the utility function shape parameters and non-linear recreation behavior (recreation and disturbance threshold effects).

• Identify methodological challenges in and propose solutions to the survey-based specification of embedded ABMs/IBMs.

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