RESEARCH ARTICLE

Visitor Use and Activities Detected Using Trail Cameras at Forest Restoration Sites

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ABSTRACT

We used trail cameras to monitor human visits and activities at two sites in northeast Indiana being restored to bottomland hardwood forests. These sites, managed as nature preserves, are close to cities, where trails and parking lots have been added for ease of access. In this study, trail cameras were successfully used to capture visitation rates and activity types. The two sites had median visitor use rates of 1 and 13 visitors per day. Across both sites, "parking lot use only" (62%), hikers (30.2%), and bicyclists (5%) accounted for more than 97% of site visits. Overall, most weekday visitor-time occurred during daylight hours, peaking at lunch and evening. Mean total number of daily visitors was higher during weekends; however, total daily visitor-time did not vary between days of the week. Michaelis-Menten rarefaction models of sampling efficiency across the study's four camera stations suggest sampling duration of 27 to 55 days to accurately estimate mean daily visitor counts and 3 to 40 days to detect half the maximal numbers of observed activities. Study estimates of visitation provide land managers with information for accommodating visitor use activities on the restored sites and offer inputs for cultural ecosystem services assessments and associated economic analyses.

Keywords: camera, cost, effort, human, monitoring, rate

Restoration Recap

- We demonstrate infrared trail cameras can successfully capture visitation rates and activity types of human visitors at restoration sites that are open to the public.
- Details are provided of the cost of this visitor sampling, including equipment and time costs.
- Rarefaction analyses provide advice to managers on deployment timeframes required to adequately estimate the number of daily visitors and types of activities.
- Results from this study could be used for quantifying baseline visitor use levels, recovery of human-use losses, monitoring data points in long-term restoration progress assessments, and inputting detailed economic valuations of recovered ecosystem services.

The benefits of afforestation on marginal or degraded floodplain and bottomland agricultural sites and the return of bottomland hardwood forest ecosystems are well documented (NRC 1992, Allen et al. 2001, Mahaffey and Evans 2016, IUCN 2020). With restoration of vegetative communities and soil quality come increased flood-water processing and retention, and recovery of wildlife communities. Documentation of ecological changes, through post-restoration monitoring (Kunz et al. 2019, Green et al. 2020), demonstrates that progress toward restoration goals is proceeding as planned or, alternatively, exposes deviations away from goals requiring course corrections to remedy. As restored sites mature, they become attractive to human use, with accommodations made for visitors such as parking areas and walking trails.

The Natural Resource Damage Assessment and Restoration (NRDAR) Program within the United States (U.S.) Department of the Interior (DOI, DOI 2021) is responsible for restoring natural resources injured or lost as a result of oil spills or hazardous substance releases into the

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environment. Losses of human use due to contamination include restricted access to recreation areas, fishing bans and fish consumption advisories, and restricted cultural access to traditional tribal resources. The NRDAR program encourages monitoring of sites restored through its program in order to document the return of lost resources and services.

Monitoring visitor use of restored forest sites can demonstrate return of previously lost recreation services. An understanding of visitor abundance and specific use activities can further guide site management as the restored forest matures, and inform the planning and implementation of similar restoration projects in the future. However, site managers face challenges in collecting human use information. Resources for restoration monitoring are often limited by the preferential use of funding for the restoration actions (Hooper et al. 2016), making costs of monitoring, surveying or interviewing visitors to a restored site unaffordable. Such human use monitoring has recently benefited from technological advancements in human traffic counters, closed circuit video, and trail cameras, simplifying and making visitor use data collection more cost-efficient on restored sites (Leggett et al. 2013, Fairfax et al. 2014, Martin and Lyons 2018). New innovations and technologies, from photographic methods to social media posts, continue to be developed for monitoring visitor use of forests and recreational areas. (O'Connor et al. 2017, Wood et al. 2020, Lupp et al. 2021).

Three fundamental questions that could be asked when quantifying human use of parks and forests are: (1) how many people visit, (2) how long do visitors stay, and (3) what do the visitors do? Methods for monitoring human use of these areas fall broadly into three categories: active in-person observation or written questionnaires (e.g., Leggett et al. 2013, Dallimer et al. 2014, Leggett 2017), passive observation by cameras or infrared traffic counters (e.g., Lindsey et al. 2006, Leggett et al. 2013, Staab et al. 2021), and use of social media data (e.g., Hamstead et al. 2018). Passive methods for quantifying use (camera or social media data) offer significant advantages over active methods because more data can be collected, at lower cost, and with less synchronous involvement by researchers. Data obtained via in-person interviews or questionnaires can be inherently biased because responses are available only from a self-selected group of willing study participants. In contrast, passive methods can be used to gather data on any persons using an area. The main disadvantage of the passive methods is that they are limited to external observable endpoints (e.g., visitation rates or duration) and cannot capture intrinsic motivators of visitors. Another disadvantage is that passive surveys must be carefully designed so that statistically valid inferences can be drawn from them (see Leggett 2015, 2017 and Leggett et al. 2013).

The goal of this study was to assess trail cameras for monitoring human visitation and use at two restoration sites and evaluate the sampling effort required for such assessments. Specifically, we wanted to test the utility of infrared trail cameras for quantifying visitation rates, visit duration, and visitor activities, building on guidance provided by previous studies (e.g., Lindsey et al. 2006, Leggett et al. 2013). We hypothesized 1) the cameras could be used to monitor 24-hour site use by human visitors and 2) that if the cameras could collect adequate images, we further tested the utility of these images to quantify visitation rates, visit duration, and visitor activities. Using the knowledge gained conducting this experiment, we used a sample-based rarefaction approach as had been utilized in previous studies associated with the same Indiana restoration sites (Kunz et al. 2019, Green et al. 2020, and references within) to assess how much sampling effort was required to estimate these metrics. The results of this study demonstrate the application and cost of new technology to gather human-use information and provide advice on timeframe for camera deployment. The findings provide baseline information to managers on the human use of these specific properties and can be used to inform future monitoring and adaptive management to anticipate human use and impacts on these and other NRDAR restoration sites. Beyond data use for demonstration of site use purposes, the data could be beneficial to those studying the resulting ecosystem services and economic valuations at the sites.

Methods

Study Sites

We studied human use at two municipal parks created to restore riparian forest habitats. Prior to restoration, both sites were in row crop agriculture that provided food provisioning services but little in terms of other ecosystem services. The following is a brief description of the sites; complete site descriptions were provided by Kunz et al. (2019) and Green et al. (2020).

The Bluffton Native Habitat Waterway site ("Bluffton") is a 64-ha municipal park on the north bank of the Wabash River, 1.5 km east of the city center of Bluffton (2021 population of 10,318, U.S. Census Bureau 2022), Wells County, Indiana, USA (40°44′04.0″N, 85°08′54.6″W). The park was developed to resolve a U.S. Environmental Protection Agency (USEPA) action following an overflow event from the town wastewater treatment facility into the Wabash River (City of Bluffton 2022). The Bluffton site has two ungated parking lots (one main parking lot and one small lot for maintenance vehicles) with walking access to the river and has 4.4 km (2.7 mi) of hiking and biking trails. The eastern boundary connects to a greenbelt that includes the River Greenway Trail Corridor with a paved bicycle and walking trail.

The Deetz Nature Preserve site ("Deetz") is a 32-ha preserve on the south bank of the Maumee River in New Haven

Figure 1. Images captured using trail cameras to collect data on human use at the Bluffton Native Habitat Waterway, Bluffton, Indiana, and Deetz Nature Preserve in New Haven, Indiana, during the summer of 2016. A) camera positioned in a bird nest box at Bluffton Native Habitat Waterway (Bluffton), B) bicyclist at Bluffton parking lot, C) photographer at Bluffton bridge, D) ATV use at Bluffton driveway, E) horseback rider at Bluffton bridge, F) visitor using the parking lot, only, at Deetz Nature Preserve (Deetz), G) visitor preparing to fish at Deetz, H) hikers at Deetz.

(2021 population 15,732, U.S. Census Bureau 2022), Allen County, Indiana, USA (41°04′38.7″N, 85°01′49.1″W). New Haven abuts the eastern border of Fort Wayne, Indiana (2021 population: 265,974, U.S. Census Bureau 2022). This preserve was created as part of a NRDAR settlement in compensation for chronic contamination at the Fort Wayne Reduction Works (Natural Concepts, LLP 2000, U.S. District Court 2000). The Deetz site has one ungated parking lot with walking access to the river and has 3.5 km (2.2 mi) of hiking and biking trails that are contained within the park. Bicycle access to the popular and extensive River Greenway Trail (on the north shore of the Maumee) is 0.8 km away via a mixture of paved streets and protected bike lanes.

Field Sampling

We measured human use by deploying trail cameras (Bushnell 119636C, Vista Outdoor, Anoka, Minnesota) at all parking and trail entrances, with each camera placement considered a sampling station (Figure 1). Although we tracked visitor arrivals and departures, our study is statistically a "departure count" in the framework developed by Leggett et al. (2013) and Leggett (2017). In such a study, the number of visitors and the total time spent using the site are inferred from site entries, exits, or both.

We placed three cameras at Bluffton, one at each commonly used entrance location. The first camera location was at a trail entrance on the east border, midway between the north border and the bridge over the Wabash River ("bridge site"), perpendicular to and 3 m from the hiking trail entrance. The second camera location was near an old driveway, with a view parallel to the road, on the northern boundary that ended in a small parking area 0.45 km W of the NE corner of the park ("driveway site"). The third camera location was at a parking lot on the northern boundary, 1.1 km W of the NE corner of the park. The camera was positioned with a view into the lot, parallel to the movement of traffic. Cameras surveying the two Bluffton parking lots were at least 15.2 m from the parking spots in the lots. Because no trees were available on which to mount the Bluffton cameras, we mounted all 3 cameras in blue bird nest boxes, 1.2 m above ground (Figure 1A) to camouflage the camera and deter tampering. One camera was deployed at Deetz at the only entrance, adjacent to the parking lot, positioned with a view into the lot, perpendicular to the movement of traffic. The camera was placed 3.6 m above the ground in a tree to deter tampering. We posted information placards at trailheads at both sites and on the side of each nest box to inform the public of the presence of the cameras and the nature of the study. Since this study purposefully did not collect any personal identifiable information on park visitors (see supplemental section), this study was determined to be exempt from any human research requirements (USGS Privacy Officer, written communication W. Reilly, March, 2016). Even with this determination, all images collected in this study were maintained using restricted access and will not be released in any study data releases.

The trail cameras used in this study were set to take both 'motion triggered' photographs and photographs at a set time interval (three pictures per trigger, one second delay, sensor level on high, field scan every 15 min, passive infrared motion sensor on high sensitivity; see specific settings and more camera details in the Supplemental Materials). We purposefully limited the picture quality for all cameras and expanded the distance for parking lot cameras to minimize any personally identifiable information of visitors but used the highest motion detection setting and took supplemental pictures every 15 minutes to maximize our visitor detection probabilities.

All cameras were started for a full day of sampling on 26 May 2016 and were continuously deployed through 19 September 2016 at Bluffton (117 days) and through 21 September 2016 at Deetz (119 days). Cameras were checked weekly for the first five weeks and then biweekly for six weeks, or until the sampling ended, averaging once every 10.8 ± 8.6 days. Checks involved confirming that cameras were collecting data and standard camera maintenance (e.g., camera positioning, power levels, memory capacity). The time between each check was considered a deployment period. See Supplemental Materials for detailed camera methods.

Images were reviewed with three rounds of checking: an initial check involved finding images with people and activity/time determinations, a recheck of activity/time determinations to incorporate any methodological changes, and a final check of activity/time determinations to make sure everything was agreed upon and correct (each round using a group consensus approach with three different people, nine total individuals). From the images, the following data were recorded: date, day of the week, time, numbers of visitors in each party, visit duration, and visitor activity. Visitor activity was classified into one of seven categories. One category was visitors who remained only in the parking lot. The other six categories were bicycling, photography, all-terrain vehicle (ATV) riding, horseback riding, fishing, and hiking. Categories other than hiking were assigned if a visitor possessed specialized equipment associated with an activity (e.g., a fishing pole) or was riding a horse or an off-road vehicle. Visitors were assumed to be hiking if they did not have any visible equipment associated with the other categories.

We made several additional assumptions when counting visitors. If a vehicle was visible in an image but no person was seen in or out of vehicle, then we assumed one visitor. We avoided collecting personal identifiable information (PII) from visitors or their vehicles, so repeat visitors could not be identified. Consequently, the results are calculated as independent visits and repeat visitation statistics were not in the scope of this study. Finally, we assumed that detection probability of vehicles entering each parking lot was effectively 100%, i.e., that observed traffic levels were indicative of actual levels. This assumption was based on a pilot study that found that the combinations of camera and camera settings we used successfully detected greater than 95% of vehicles entering or exiting a parking lot with known traffic levels (see Supplemental Materials). Lastly, the camera positioned at the one hiker-only entrance to Bluffton (i.e., Bluffton Bridge) was assumed to have an accuracy consistent with previous camera trap accuracy with monitoring visitors or large mammals (Carvalho et al. 2016, Harmsen et al. 2020, Lupp et al. 2021, Staab et al. 2021).

If a camera did not record the specified area for the entire day (mostly due to battery failure or a camera moved out of alignment and not capturing the entire area), then data for that entire day were not used in the analysis because day was the unit of measure (0000 to 2359 hours). This decreased the number of data collection days by 44, 23, and 30 days at the Bluffton bridge, driveway, and parking lot stations, respectively and by 24 days at the Deetz parking lot. If a camera captured only one image of a person or vehicle (i.e., did not capture both exit and entrance times), then that record was only used in frequency statistics and not used in the length of stay statistics because either entrance or exit time was missing. Length of stay could be determined in 21 or 34.4% of total visits, 5 (27.8%) and 34 (55.7%) visits analysed at the Bluffton parking lot, driveway, and bridge stations, respectively, and 456 (42.7%) visits at the Deetz parking lot station. Visits of park workers and persons involved in this study were excluded from the analyses.

Data Analysis

We summarized visitor data for each station and activity. Here "visitor" refers to one individual, and "party" refers to a lone visitor or a group of two or more visitors. Visitor groups making up a party arrive and leave at the same times. "Visit" refers to an event when a party comes to the park; a visit could include multiple captures of the same visitor(s) on the same day, but only first and last captures were of interest in this study (see below for more details). Average daily number of visitors at each station was calculated using total counts of all visitors per day averaged over all days. Mean party size was calculated using the number of visitors in each party for a visit, averaged over all the sampling days. For each visit, we also determined the mean length of a park visit using entry and exit times. The parks were not gated and there were visitors during all hours of the day and night.

Visitor counts were non-normally distributed and party sizes were positive. Thus, we summarized these variables as median and interquartile range (IQR). These summary statistics give a sense of the central tendency and its variability that is more appropriate than mean ± standard deviation (SD), because mean and SD assume normality and can imply impossible values (e.g., less than zero visitors per day). Summarizing as median (IQR) is essentially a nonparametric analogue of summarizing as mean ± SD. We calculated the number of visitor-minutes for each visit as the product of the visit party's size and duration. Visitor-minutes for all visits initiated during each discrete hour of the day were totalled and reported for that hour. For both the duration and visitor-minute calculations we did not include any visits where the party stayed less than five minutes and those where the camera did not capture both the entrance and exit times of the entire visit (i.e., only one image of the party was captured).

To allow for summary site-based comparisons, data from all three stations at Bluffton were combined to provide site-level data similar to the data collected for Deetz. We used data from all days where at least one camera was collecting data at Bluffton, expanding the coverage at Bluffton to 116 out of 117 possible days. However, statistical analyses and comparisons were made using individual Bluffton station data and not the combined Bluffton site-level data.

To examine trends in visitation rates within sites, we conducted an analysis of variance (ANOVA), where day was our unit of replication and assuming that visitation rates varied between weekdays as reported in previous studies (e.g., Lindsey 1999). Consequently, "day of week" was included as a factor in our analysis. We used two-way permutational analysis of variance (pANOVA) to test for differences in visitor-minutes between days of the week and visitor activity types. We analyzed each park separately, where the daily station-level total visitor-minutes for each activity were used as the response variable. We used pANOVA because the response variable was non-normally distributed, violating the assumptions of traditional ANOVA, and used the R package lmPerm version 1.1–2 for pANOVA (Wheeler and Torchiano 2016). We set the number of iterations to 2×10^9 and stopped the number of iterations when the estimated standard error of the estimated permutation probability was less than 0.00001. Using these settings, the *p*-value varied by ≤ 0.0001 between runs of the model. Pairwise comparisons of factor-level differences were examined by computing Tukey honest significant differences (HSD) which uses a family-wise probability of coverages (i.e., accounts for multiple comparisons). All analyses were performed using R version 2.15.3 (R Core Team 2013).

The level of sampling effort (i.e., number of sampling days) required to measure the mean number of daily visitors and number of human activities at each station was investigated using sample-based rarefaction of the data (Gotelli and Colwell 2001). Our interest in using sample-based rarefaction here was not to estimate the true number of different activities performed by park visitors, but rather to investigate the shape of the curve and thus how the number of observed activities varied with sampling design. We simulated multiple camera surveys of each station by analysing random subsets of data from all days at each station. For each simulated survey of a station, we randomly selected a start date and how many consecutive days to include. From this random selection, we calculated the mean number of daily visitors and number of activities. For each station, we constructed 100 random samples of consecutive days in increments of approximately 0.5 weeks (3, 7, 10, 14, . . . 59, etc., days). Due to camera deployment issues, the maximum number of consecutive days differed for each station and consequently the maximum length of random subsamples varied by station: 34, 61, and 42 days at the Bluffton bridge, driveway, and parking lot stations, respectively; and 62 days at the Deetz parking lot station. For each set of randomly selected subsamples, the average number of daily visitors and standard error was calculated to provide a measure of confidence about the average value.

We used nonlinear Poisson regression models (i.e., a Michaelis-Menten function) to model the relationship between sampling effort (number of days sampled) and two end points: number of visitors observed and number of human activities. A similar procedure was previously used by Kunz et al. (2019) and Green et al. (2020) and briefly described here. Using a Michaelis-Menten function, we estimated parameter values for relationship between the number of consecutive sampling days using a trail camera and the number of activities observed, where α is the asymptote indicating the estimated maximum number of observed activities and β indicates the level of effort (days) needed to obtain 50% of the maximum response. See Supplemental Materials for details. Lastly, we used amount of time and money used in this study to estimate the costs of similar human-use monitoring in future restoration efforts or to facilitate comparisons to the costs of other types of human-use monitoring.

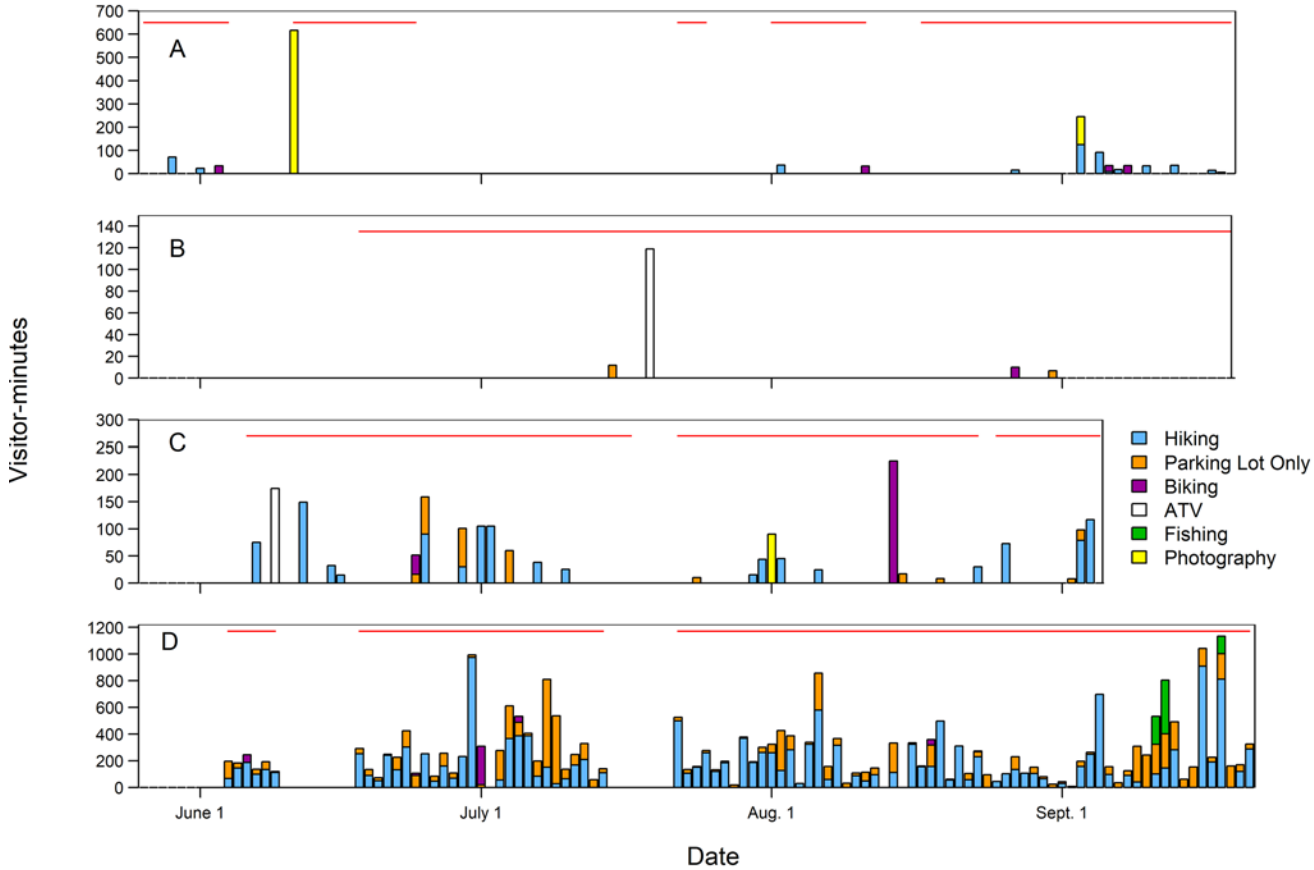

Figure 2. The total number of visitor-minutes at each station for each day by activity collected from photographs taken from trail cameras under natural and infrared light (visitor-minutes were assigned to the entry hour) at the Bluffton Native Habitat Waterway, Bluffton, Indiana, and Deetz Nature Preserve in New Haven, Indiana, during the summer of 2016. Red lines at the top of each panel indicate sampled days. A) Bluffton Bridge, B) Bluffton Driveway, C) Bluffton Parking Lot, D) Deetz Parking Lot (Deetz=Deetz Nature Preserve, Bluffton=Bluffton Native Habitat Waterway).

Results

Visitation Summary

The trail cameras successfully captured observations of visitors, and from the images, photo analysts identified the activities and quantified the visit lengths of most (nearly 60%) visitors (Albers et al. 2023). We deployed the four cameras continuously over 117 days at Bluffton and 119 days at Deetz, resulting in a total of 470 possible complete station sampling days. During the continuous deployment the following impediments to data collection occurred: camera view shifted and did not cover intended area; batteries died; technical difficulties such as camera or set up malfunctions occurred; views were impeded by objects such as spider webs. With each impediment, the continuous coverage was segmented into multiple separate periods. After removal of 121 days where a camera did not sample correctly, 13 separate continuous periods of time were sampled, on average, 26 days per period resulting in 349 station sampling days across the four stations. Total days sampled for each station ranged between 73 to 95 days (temporal distribution for each station is shown by the lines at the top of each graph in Figure 2). At Bluffton, there was at least one camera operating on 116 days, the number of sampling days used for the combined Bluffton statistics. The cameras took 27,867 at Bluffton and 8,533 images at Deetz, 3,184 and 1,769 images contained subjects in them of which 2,761 and 319 were of animals at Bluffton (3 cameras) and Deetz (1 camera), respectively. Reviewing of images resulted in 163 and 1,317 images where human use data were collected at Bluffton (3 cameras) and Deetz (1 camera), respectively.

The overall Bluffton visitation rate had a median (IQR) of 1 (3) visitors/d (Table 1). Station-specific visitation was 1 (2), <1 (<1), and 1 (1) visitors/d at the bridge, driveway, and parking lot stations, respectively. The Deetz site median visitation rate was 13 (8) visitors/d (Table 1). Among visits lasting ≥ 5 min (43% at both sites, Tables 1 and 2), median visit duration was 20.73 (30.12) min at Bluffton. Bridge, driveway, and parking lot stations had median visit durations of 17.63 (21.38), 9.87 (6.38), and 30.00 (43.50) min,

Table 1. Total and daily visitor statistics collected during entire study at the Bluffton Native Habitat Waterway, Bluffton, Indiana, and Deetz Nature Preserve in New Haven, Indiana, during the summer of 2016. Data summarized were collected on weekends, and weekdays using all camera (i.e., station) observations. Values are the total counts of visitors and party visits and the daily (d) visitor medians and inter-quartile ranges (IQR) detected at each station during the study. The sampling day total for the Bluffton "All Stations" location represents days during which data were collected from at least one Bluffton station.

		Bluffton Native Habitat Waterway				Deetz Nature Preserve
Period	Statistic	Bridge	Driveway	Parking Lot	All Stations	Parking Lot
All days	Visitors	100	26	83	209	1,296
	Visits	61	18	61	140	1,067
	Median visitors/d	1	0	1	1	13
	IQR visitors/d	2	0	1	3	8
	Sampling Days	73	94	87	116	95
Weekend	Visitors	44	9	31	84	402
	Visits	23	6	24	53	306
	Median visitors/d	1	0	1	2	13
	IQR visitors/d	3	0	2	3	8
	Sampling Days	21	26	26	33	28
Weekday	Visitors	56	17	52	125	894
	Visits	38	12	37	87	761
	Median visitors/d	0.5	0	1	1	13
	IQR visitors/d	2	0	1	3	8
	Sampling Days	52	68	61	83	67

Table 2: Summary of the visit duration (in minutes) of a party (i.e., one or more people) that stayed more than five minutes at the Bluffton Native Habitat Waterway, Bluffton, Indiana, and Deetz Nature Preserve in New Haven, Indiana, during the summer of 2016. Number in parentheses is number of sampling days. The sampling day total for the Bluffton "All Stations" location represents days during which data were collected from at least one Bluffton station. IQR is inter-quartile range. Empty cells are indicated with an em-dash.

		Bluffton Native Habitat Waterway				Deetz Nature Preserve
		Bridge (73)	Driveway (94)	Parking Lot (87)	All Stations (116)	Parking Lot (95)
Overall	Visits	21.00	5.00	34.00	60.00	456.00
	Median stay	17.63	9.87	30.00	20.73	29.63
	IQR stay	21.38	6.38	43.50	30.12	37.42
Individual groups						
ATV	Visits	0.00	2.00	1.00	3.00	0.00
	Median stay	—	29.71	58.08	46.33	—
	IQR stay	—	33.25	0.00	45.00	—
Bicycling	Visits	4.00	1.00	2.00	7.00	7.00
	Median stay	12.09	9.87	46.39	12.72	16.60
	IQR stay	11.33	0.00	57.22	21.40	42.82
Fishing	Visits	0.00	0.00	0.00	0.00	4.00
	Median stay	—	—	—	—	175.63
	IQR stay	—	—	—	—	96.53
Hiking	Visits	14.00	0.00	20.00	34.00	233.00
	Median stay	16.53	—	34.18	23.12	37.32
	IQR stay	14.22	—	51.75	25.20	37.60
Only in parking lot	Visits	0.00	2.00	9.00	11.00	212.00
	Median stay	—	6.28	16.90	10.30	18.99
	IQR stay	—	0.85	21.62	22.18	25.16
Photography	Visits	3.00	0.00	2.00	5.00	0.00
	Median stay	114.18	—	30.00	38.82	—
	IQR stay	81.72	—	0.00	84.18	—

Table 3: Daily and total visitor activity statistics collected during study using all station observations at the Bluffton Native Habitat Waterway, Bluffton, Indiana, and Deetz Nature Preserve in New Haven, Indiana, during the summer of 2016. Values are the number of visitors per day at each station during study. Number in parentheses is number of sampling days. The sampling day total for the Bluffton "All Stations" location represents days during which data were collected from at least one Bluffton station. IQR is inter-quartile range. Empty cells are indicated with an em-dash.

			Bluffton Native Habitat Waterway Stations				Deetz Nature Preserve Stations
	Time Period	Statistic	Bridge (73)	Drive-way (94)	Parking Lot (87)	All Stations (116)	Parking Lot (95)
ATV	Total	Visitors	0	10	3	13	0
		Visits	0	5	1	6	0
Biking	Total	Visitors	28	3	7	38	36
		Visits	15	3	3	21	26
Fishing	Total	Visitors	0	0	0	0	4
		Visits	0	0	0	0	4
Hiking	Total	Visitors	58	6	39	103	351
		Visits	42	4	29	75	257
	Daily	Median Visitors	0	0	0	0	3
		IQR Visitors	1	0	1	1	3
Horseback riding	Total	Visitors	1	0	0	1	0
		Visits	1	0	0	1	0
Only in parking lot	Total	Visitors	0	7	28	35	905
		Visits	0	6	24	30	780
	Daily	Median Visitors	—	0	0	0	9
		IQR Visitors	—	0	0	0	6
Photography	Total	Visitors	13	0	6	19	0
		Visits	3	0	4	7	0
	Daily	Median Visitors	0	—	0	0	—
		IQR Visitors	0	—	0	0	—

respectively. Median visit duration was 29.63 (37.42) min at Deetz (Table 2).

Across both sites, 454 of 1,505 total visitors (30.2%) were hikers and 5% were bicyclists. Most visitors (62%) only used the parking lots (Table 3). Examples of activities we observed in the parking lots were eating lunch, sitting in a vehicle, talking on the phone, and releasing wildlife live-trapped elsewhere [*Procyon lotor* (raccoons) and *Sciurus* spp. (squirrels)]. Among visits that lasted ≥ 5 min and across all stations at Bluffton, median (IQR) visit durations were 23.12 (25.20) min for hikers, 12.72 (21.40) min for bicyclists, and 10.30 (21.28) min for visitors who used only the parking lot; the equivalent values for Deetz were 37.32 (37.60), 16.60 (42.82), and 18.99 (25.16), respectively (Table 2). Although Bluffton had < 17% as many visitors as Deetz (Table 1), 17% of Bluffton visitors used only the parking lot compared to 70% of the Deetz visitors (Table 3). We did not observe visitors with fishing equipment at Bluffton but did observe them at Deetz. We observed visitors on ATVs, horse-back riding, or taking photos at Bluffton but not at Deetz. Bluffton had a greater percentage of bicyclists than Deetz with 18% of Bluffton visitors compared to 3% at Deetz (Table 3). Horse-back riding and ATV use are not permitted uses on the Bluffton site (City of Bluffton 2014).

There were significant differences in total daily visitor-minutes between activity types (based on two-way pANOVA results: $F_{(6,763)} = 3.38$, $p = 0.0008$ for Bluffton and $F_{(6,616)} = 56.6$, $p < 0.0001$ for Deetz, Figure 2). At Bluffton, times spent horseback riding, fishing, and hiking were significantly greater than photography (based on Tukey HSD pairwise comparisons in the two-way pANOVA with all $p \leq 0.0156$). Activity levels for all other recreation types at Bluffton did not differ significantly from one another. At Deetz, time spent hiking was greater than that spent biking, fishing, or sitting in the parking lot (based on Tukey HSD pairwise comparisons in the two-way pANOVA with all $p < 0.0001$).

Most of the weekday visitor-minutes occurred during daylight hours with peaks at lunch time (1000 to 1300 hours) and evening hours (1800 to 2000 hours, Figure 3). Weekend to weekday visitor count ratio averaged 1.4 ± 0.38 (n = 4 stations, Table 1). Though the mean total number of daily visitors was higher during weekends, total daily visitor-minutes did not vary significantly between any days of the week (based on two-way pANOVA results: $F_{(6,763)} = 1.75$, $p = 0.0728$ for Bluffton and $F_{(6,616)} = 1.11$, $p = 0.3556$ for Deetz).

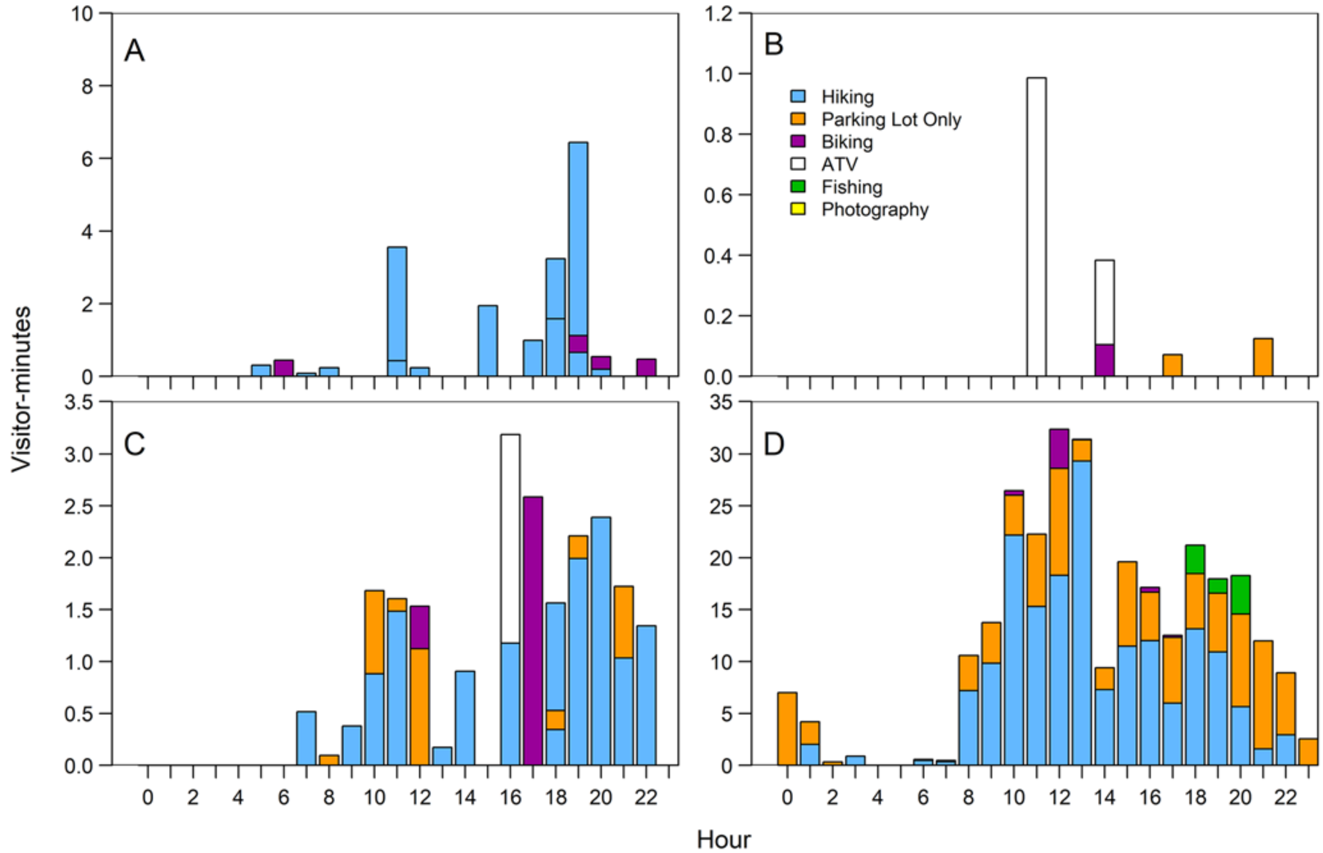

Figure 3. The mean number of visitor-minutes for each hour of the day at each station by activity collected from photographs taken from trail cameras under natural and infrared light (visitor-minutes were assigned to the entry hour) at the Bluffton Native Habitat Waterway, Bluffton, Indiana, and Deetz Nature Preserve in New Haven, Indiana, during the summer of 2016. A) Bluffton Bridge, B) Bluffton Driveway, C) Bluffton Parking Lot, D) Deetz Parking Lot (Deetz=Deetz Nature Preserve, Bluffton=Bluffton Native Habitat Waterway).

Level of Effort Models

The Michaelis-Menten constants (β) in the final models implied that half of the maximal number of observed activities should be detected through the study methods within 17 consecutive days (posterior mean ± SD: 16.5 ± 0.9 d) at Bluffton bridge, 40 consecutive days (39.5 ± 2.1 d) at Bluffton driveway, seven consecutive days (6.6 ± 0.3 d) at Bluffton parking lot and three consecutive days (2.15 ± 0.1 d) at Deetz parking lot (Table S1, Figure 4).

In the simulations built from rarefaction of the dataset for each station, we found that the number of days of consecutive sampling required to accurately estimate mean daily visitor count varied considerably between stations (Figure 5). For Bluffton bridge, 27 days were required until 95% of simulated datasets had a mean visitation rate within the 95% CI of the overall visitation rate of 1.4 ± 2.1 visitors/d (Figure 5A). Similar accuracy required 55 days at Bluffton driveway (Figure 5B), 25 days at Bluffton parking lot (Figure 5C), and 50 days at Deetz parking lot (Figure 5D). The SE of simulated visitation rate estimates decreased approximately linearly as number of days increased at Bluffton bridge and Bluffton parking lot (Figure 5A, 5C) and nonlinearly at the other stations (Figure 5B, 5D).

Cost of Sampling

At the more rural Bluffton site only 0.6% of the images collected from three cameras contained usable human-use data, whereas at Deetz 15.4% of the images collected from one camera were used. Based on the average cost per 10.8-day camera deployment (Table 4, variable costs), daily costs for sampling and analysis using trail cameras were estimated as U.S. dollars (US$) 217.72. On average, processing of one camera deployment day of collected images required 8.8 and 0.6 hrs for team member (US$15.49 per hour) and team leader (US$28.39 per hour) employees, respectively.

Discussion

Recent studies of the Deetz and Bluffton nature preserves have documented a shift in the ecosystem services provided by the restored sites, away from human food production via row-crop agriculture (the pre-restoration land use) and

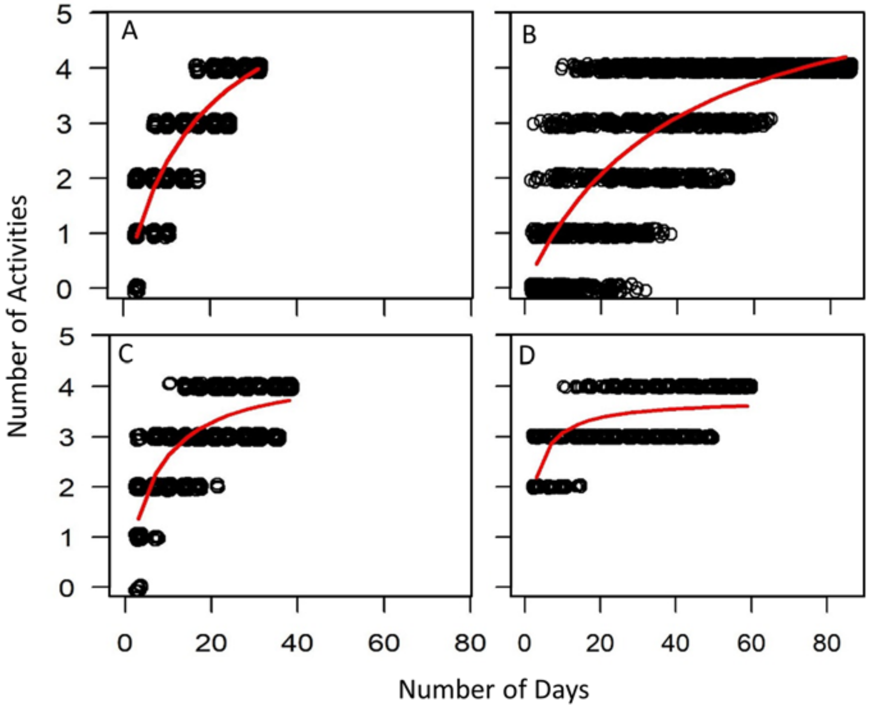

Figure 4. Simulated surveys of site visitation constructed by rarefaction of trail camera data at the Bluffton Native Habitat Waterway, Bluffton, Indiana, and Deetz Nature Preserve in New Haven, Indiana, during the summer of 2016. The number of observed visitor activities detected increased as a nonlinear Michaelis-Menten function of the number of sampling days. Points show numbers of visitor activities detected in individual simulations (jittered vertically for visibility); red lines show predictions of Michaelis-Menten functions fitted to the rarefied data (see Table S1 for parameter estimates). A) Bluffton Bridge, B) Bluffton Driveway, C) Bluffton Parking Lot, D) Deetz Parking Lot (Deetz=Deetz Nature Preserve, Bluffton=Bluffton Native Habitat Waterway).

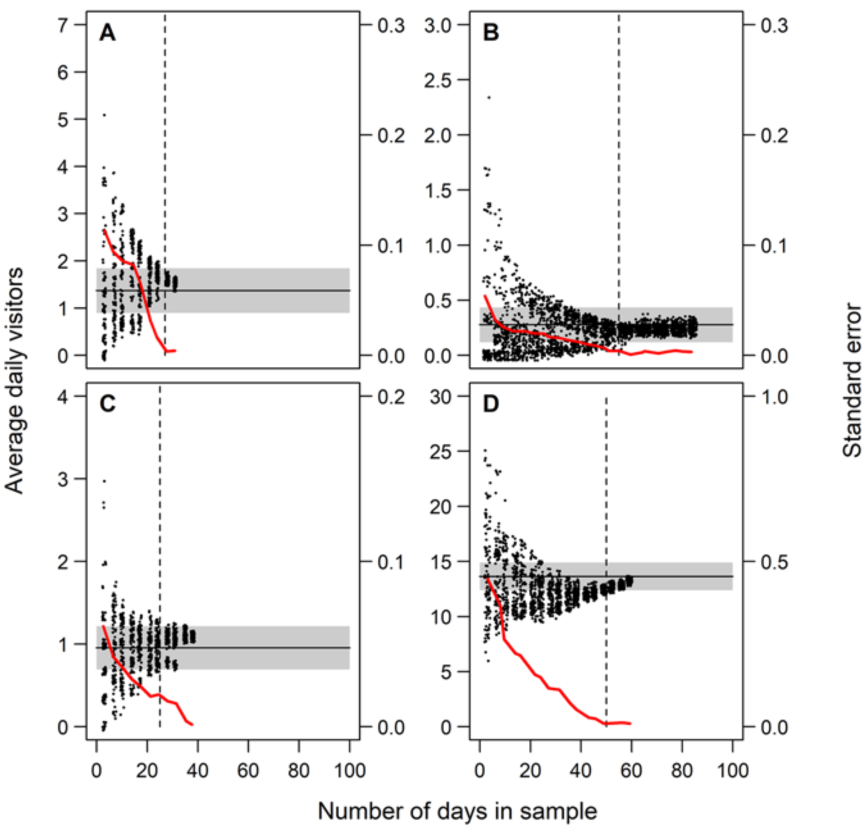

Figure 5. Results of simulated surveys of site visitation constructed by rarefaction of trail camera data at the Bluffton Native Habitat Waterway, Bluffton, Indiana, and Deetz Nature Preserve in New Haven, Indiana, during the summer of 2016. Results are the number of consecutive days of sampling needed to accurately estimate the mean number of daily visitors. Points show daily visitor counts from individual simulations (points are jittered horizontally for visibility). Red lines show the standard error of the simulated mean number of daily visitors. Horizontal black line and grey area show overall mean and 95% confidence interval (CI) calculated from all data using all possible days. Vertical dashed line indicates the minimum consecutive days of sampling needed to accurately estimate the number of daily visitors as being within the actual 95% CI. A) Bluffton Bridge, B) Bluffton Driveway, C) Bluffton Parking Lot, D) Deetz Parking Lot (Deetz=Deetz Nature Preserve, Bluffton=Bluffton Native Habitat Waterway).

Table 4: Time and variable cost (in U.S. dollars, or US$) per mean trail camera deployment period (10.8 d) to monitor human use at the Bluffton Native Habitat Waterway, Bluffton, Indiana, and Deetz Nature Preserve in New Haven, Indiana, during the summer of 2016. All estimates are from the 2016 field season and include time for camera data collection and maintenance and subsequent image preparation, interpretation, and analysis. Costs do not include travel to/from field site or per-diem expenses. Mean cost for data collection through analysis for one day for one camera station based on 10.8-d deployment period was US$217.72.

Equipment and Supply Costs per Deployment (US$)[a]	Mean Deployment Time, N = 32 Study Deployments (hr)		Time for Data Retrieval, Camera Maintenance. (hr)	Image Preparation and Interpretation (hr)[b]		Data Processing and Analysis (hr)[c]		Total Personnel Costs (US$)[d]		Total Cost (US$)
	Mean	Std dev	Member	Leader	Member	Leader	Member	Leader	Member	
40.00	261.60	8.84	0.25	5.00	80.00	1.25	14.88	248.41	2,062.99	2,351.40

[a] Estimated costs include batteries and memory cards only and do not include a single trail camera (US$150) or nest boxes. Replacement of a memory card and camera batteries occurred once per 10.8 d deployment.
[b] Image preparation and interpretation time accounts for visually scanning each image for the presence of visitors and, when present, recording date, day of the week, time, number of visitors in the party, and visitor activity. When possible, from subsequent photographs, visit duration was established and recorded.
[c] Data processing time accounted for compiling prepared data from multiple deployments to determine site specific use, activity values, and their statistical evaluation.
[d] Total hourly costs for a team leader involved with data analysis and supervising data collection and a team member who examined imagery were calculated at the hourly rates of US$28.39 and US$15.49, respectively (US OPM 2016), plus a 40% allowance for benefits. Hourly personnel costs at the time of publication (OPM 2022) were 12% higher than at the time of the field study.

toward services that accompany the development of biologically rich and ecologically functioning forest ecosystems (Kunz et al. 2019, Green et al. 2020). Photo documentation of visitor activities at these preserves demonstrated how restored forest sites provide cultural ecosystem services to surrounding communities, which can include recreation and social relations, aesthetic enjoyment, learning and development opportunities, and enjoying a connection to nature (Huynh et al. 2022). For the two sites in this current study, the restored services are providing compensation for human-use losses following contamination incidents in the past, consistent with the goals of each restoration (U.S. District Court 2000, City of Bluffton 2022).

Using cameras to view the park entrances and parking lots allowed observation of a wide variety of activities pursued by park visitors. Walking and hiking, and bicycling, were common to both study sites, while fishing at Deetz, and photography and ATV and horseback riding at Bluffton rounded out the activities at the sites. In addition to the more traditional recreation activities, visitor occupancy of the parking lots stretched the definition of human-ecological interactions generally considered cultural ecosystem services. Motivating factors for visits to restored forest sites vary among visitors. For example, comparative studies of adult and teenager perceptions and attitudes about forest visits in Switzerland show that while adults tend to use forests for more contemplative activities, teenagers exhibit more social and recreationally active forms of forest use (Hegetschweiler et al. 2022). Such demographic variability in motivation for forest use is likely not unique to the Swiss study population, and assessment of forest-use attitudes of Midwestern suburbanites could provide insights into the motivations of visitors to the present study's restoration sites. The summer presence of *Toxicodendron* spp., *Urtica* spp., mosquitoes (family Culicidae), and biting insects to varying degrees in these wildland parks may be perceived as ecosystem disservices by some who make it only as far as the cleared parking lots of the preserves (Rice et al. 2020).

Using trail cameras to determine human use of a park required little time collecting data in the field, where activities were limited to changing out camera memory cards and batteries and fixing periodic camera glitches. The time spent collecting data from images and processing those data made up the bulk of the variable costs of sampling. Neither of these activities are likely to exhibit major cost savings with additional cameras or images (i.e., economies at scale). Many images contained no subjects or animals, as well as multiple images of the same people. The major cost differences between the two sites were due to the number of human entry points in the parks, with Bluffton requiring three cameras to cover all entry points, consequently also having three times the images to process. Since this study was conducted, advancements in artificial intelligence (AI) and machine learning based image assessment technologies have shown promise in decreasing the processing time of trail camera images used for visitor quantification (Staab et al. 2021). Studies assessing visitor rates at restoration sites likely would benefit from these AI technologies by reducing time needed for image sorting and the removal of images that did not contain visitors, as was the case for the majority of images collected in this study. Though the new studies have shown initial success in identifying some recreational equipment in the images, review of visitor-containing images may still require researcher processing to determine specific visitor activities.

The use of parks and greenways in Indiana has previously been studied using both active and passive methods (Emmert 1999, Lindsey 1999, Lindsey et al. 2006, 2007). Some studies have used infrared traffic counters. Counters are simpler to deploy and manage than trail cameras and can be operated more cheaply, but they can collect information only about the number of people or animals passing a sensor and do not discriminate visitors arriving and departing (Lindsey et al. 2006). Trail cameras can collect a richer dataset, including visitor activities and visit duration, but at greater cost than counters. For trail cameras, additional care must be taken to minimize collection of personally identifiable information and avoid its inadvertent release in the reporting process.

Both counters and cameras can be deployed for longer periods and collect data for lower cost than in-person observation (Leggett et al. 2013, Leggett 2017). Like infrared counters, the trail cameras passively collected counts of visitors 24 hours a day, but without the bias due to missed counts when two people passed at the same time. In-person surveys are the most labor-intensive method of quantifying human use but yield detailed data about visitors that can be used to address concerns or determine variables that influence visit rates (Lindsey et al. 2006). However, these surveys can be biased against visitors unwilling to interact with survey workers (Lindsey 1999). One further consideration when making cost comparisons for different monitoring methods is the number of sampling locations required. For example, in our study, visitor activity could be measured adequately using one camera station at Deetz, but at least 3 stations were required at Bluffton because of the number of access points.

The difference in survey effort needed to cover the sites in our study points to an important consideration in survey design. When all visitors entering and exiting a site can be detected (or if the surveyor is reasonably certain of such), then the data represent a complete count of visitors, and no statistical analysis is necessary to infer actual visitation from observed visitation. However, as noted by Leggett et al. (2013) and Leggett (2017), a survey with incomplete coverage of the study area must be carefully designed to enable statistical estimation of actual use. In this sense, estimating human site use using stationary cameras is conceptually similar to estimating other restoration endpoints such as species richness (Kunz et al. 2019) or site use by wildlife (Green et al. 2020). Spatial and temporal coverage of sampling is essential to estimate both the central tendency of use and the uncertainty surrounding it (Green et al. 2020). Efficient sampling schema can be developed that take advantage of typical recreational use patterns in time and space (Leggett 2017). The accuracy of visitor counts, or the probability of detecting particular visitor activities of interest to park managers, could also be estimated more robustly using site occupancy models (MacKenzie et al. 2017). This is particularly true when—unlike in our study—sampling coverage is suspected to be incomplete or the probability of detecting visitors is suspected to be low or when there is a difference in detection probability between vehicles, hikers, horse-back riders, or bikers.

In this study, we found the use of trail cameras a good way to continuously monitor visitors at parks that were not wired for video surveillance. However, this study did have some limitations including restricted time and spatial coverage by only sampling one summer at two parks and time periods where cameras did not work properly. Even though this study included extensive pre-study calibration of vehicle traffic sensitivities, there was limited hiker camera calibration and in-situ calibration. Expanding future studies that address these limitations would increase the applicability of the results to management of more restoration sites.

Conclusions

The study findings provide a baseline inventory of human use on two restored forest nature preserves and demonstrate the utility and special considerations associated with using trail camera surveys for documenting recreation activities. The passive observational methods and simulation-based cost-benefit analysis of sampling effort provide an inexpensive framework for obtaining data used by public land managers to understand spatial and temporal patterns in visitation and recreation activities pursued in the park. Those data could further be used to conduct cultural ecosystem services assessments and economic analyses of restored sites. Visitor use and associated cultural ecosystem services provide valuable added information to the long-term ecological restoration goals of the sites.

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Data Availability

All data upon which this study is based are available as a USGS data release (Albers et al. 2023).

References

Albers, J.L., M.L. Wildhaber and N.S. Green. 2023. Human Use and Activities at Two Urban Riparian Forest Restoration Sites in Indiana, USA, May–Sept, 2016: U.S. Geological Survey data release. https://doi.org/10.5066/P9ELD4H4.

Allen, J.A., B.D. Keeland, J.A. Stanturf, A.F. Clewell and H.E. Jr. Kennedy. 2001. A Guide to Bottomland Hardwood Restoration: U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0011, U.S. Department of Agriculture, Forest Service, Southern Research Station, General Technical Report SRS-40, 132 p. pubs.er.usgs.gov/publication/itr000011.

Carvalho, W.D., L.M. Rosalino, C.H. Adania and C.E.L. Esberard. 2016. Mammal inventories in seasonal neotropical forests: Traditional approaches still compensate drawbacks of modern technologies. *Iheringia, Serie Zoologica* 106:1–9.

City of Bluffton. 2022. Bluffton Native Habitat Waterway (accessed 25 Aug 2022). blufftonindiana.net/native-habitat-waterway/.

City of Bluffton. 2014. Bluffton Native Habitat Waterway Map (accessed 25 Aug 2022). blufftonindiana.net/data/uploads/2014/02/NativeHabitatMap.pdf.

Dallimer, M., A.G. Davies, K.N. Irvine, L. Maltby, P.H. Warren, K.J. Gaston et al. 2014. What personal and environmental factors determine frequency of urban greenspace use? *International Journal of Environmental Research and Public Health* 11:7977–7992.

Department of the Interior (DOI, accessed 20 June 2022.). 2021. Restoration Program, Natural Resource Damage Assessment and Restoration. www.doi.gov/restoration/about.

Emmert, J.J. 1999. Award-winning undergraduate paper: Income and substitution effects in the travel cost model: An application to Indiana state parks. *American Journal of Agricultural Economics* 81:1330–1337.

Fairfax, R.J., R.M. Dowling and V.J. Neldner. 2014. The use of infrared sensors and digital cameras for documenting visitor use patterns: A case study from D'Aguilar National Park, southeast Queensland, Australia. *Current Issues in Tourism* 17:72–83.

Green, N.S., M.L. Wildhaber, J.L. Albers, T.W. Pettit and M.J. Hooper. 2020. Efficient mammal biodiversity surveys for ecological restoration monitoring. *Integrated Environmental Assessment and Management* 00:1–13. DOI:10.1002/ieam.4324.

Gotelli, N.J. and R.K. Colwell. 2001. Quantifying biodiversity: Procedures and pitfalls in the measurement and comparison of species richness. *Ecology Letters* 4:379–391.

Hamstead, Z.A., D. Fisher, R.T. Ilieva, S.A. Wood, T. McPhearson and P. Kremer. 2018. Geolocated social media as a rapid indicator of park visitation and equitable park access. *Computers, Environment and Urban Systems* 72:38–50.

Harmsen, B.J., R.J. Foster, and H. Quigley. 2020. Spatially explicit capture recapture density estimates: Robustness, accuracy and precision in a long-term study of jaguars (*Panthera onca*). *PLoS One* 15(6):1–19.

Hegetschweiler, K.T., F.M. Wartmann, I. Dubernet, C. Fischer and M. Hunziker. 2022. Urban forest usage and perception of ecosystem services—a comparison between teenagers and adults. *Urban Forestry and Urban Greening* 74:127–624.

Hooper, M.J., S.J. Glomb, D.D. Harper, T.B. Hoelzle, L.M. McIntosh and D.R. Mulligan. 2016. Integrating holistic risk and recovery monitoring into ecosystem restoration planning at contaminated sites. *Integrated Environmental Assessment and Management* 12:284–295.

Huynh, L.T.M., A. Gasparatos, J. Su, R.D. Lam, E.I. Grant and K. Fukushi. 2022. Linking the nonmaterial dimensions of human-nature relations and human well-being through cultural ecosystem services. *Science Advances* 8:eabn8042.

International Union for Conservation of Nature (IUCN). 2020. Bonn Challenge: Impact and Potential of Forest Landscape Restoration. 40p. www.bonnchallenge.org/resources/bonn-challenge-2020-report.

Kunz, B.K., J.H. Waddle and N.S. Green. 2019. Amphibian monitoring in hardwood forests: Optimizing methods for contaminant-based compensatory restorations. *Integrated Environmental Assessment and Management* 00:1–15. DOI:10.1002/ieam.4202.

Leggett, C., N. Scherer and M. Donlan. 2013. Assessment of Visitor Use of Restored Areas of Lincoln Park. Prepared for the National Oceanic and Atmospheric Administration by Industrial Economics, Incorporated. July 1.

Leggett, C.G. 2015. Estimating Visitation in National Parks and Other Public Lands, Report prepared for the National Park Service under contract to Bioeconomics, Inc., under award number P13PD02250.

Leggett, C.G. 2017. Sampling strategies for on-site recreation counts. *Journal of Survey Statistics and Methodology* 5:326–349.

Lindsey, G. 1999. Use of urban greenways: Insights from Indianapolis. *Landscape and Urban Planning* 45:145–157.

Lindsey, G., Y. Han, J. Wilson and J. Yang. 2006. Neighborhood correlates of urban trail use. *Journal of Physical Activity and Health* 3:S139–S157.

Lindsey, G., J. Wilson, E. Rubchinskaya, J. Yang, and Y. Han. 2007. Estimating urban trail traffic: Methods for existing and proposed trails. *Landscape and Urban Planning* 81:299–315.

Lupp, G., V. Kantelberg, B. Forster, C. Honert, J. Naumann, T. Markmann et al. 2021. Visitor counting and monitoring in forests using camera traps: A case study from Bavaria (Southern Germany). *Land* 10:736–757.

MacKenzie, D.I., J.D. Nichols, J.A. Royle, K.H. Pollock, L. Bailey and J.E. Hines. 2017. *Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence*. 2nd edition. Elsevier, London.

Mahaffey, A. and A. Evans. 2016. Ecological Forestry Practices for Bottomland Hardwood Forests of the Southeastern U.S. Forest Stewards Guild. 44p. foreststewardsguild.org/wpcontent/uploads/2019/05/FSG_Bottomland_Hardwoodsweb.pdf.

Martin, D.M. and J.E. Lyons. 2018. Monitoring the social benefits of ecological restoration. *Restoration Ecology* 26:1045–1050.

National Research Council (NRC). 1992. Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy. Washington, DC: The National Academies Press. https://doi.org/10.17226/1807.

Natural Concepts, LLP. 2000. Natural Resource Damage Assessment Settlement, Restoration Plan, For Wayne Reduction Site, Allen County, Indiana. Dated March 29, 2000. www.cerc.usgs.gov/orda_docs/DocHandler.ashx?task=get&ID=806.

O'Connor, K.M., L.R. Nathan, M.R. Liberati, M.W. Tingley, J.C. Vokoun and T.A. Rittenhouse. 2017. Camera trap arrays improve detection probability of wildlife: Investigating study design considerations using an empirical dataset. *PLoS One* 12:e0175684.

R Development Core Team. 2013. R: A Language and Environment for Statistical Computing. R version 2.15.3. R Foundation for Statistical Computing, Vienna, Austria. www.R-project.org.

Rice, W.L., P. Newman, B.D. Taff, K.Y. Zipp and Z.D. Miller. 2020. Beyond benefits: Towards a recreational ecosystem services interpretive framework. *Landscape Research* 45:892–904.

Staab, J., E. Udas, M. Mayer, H. Taubenböck and H. Job. 2021. Comparing established visitor monitoring approaches with triggered trail camera images and machine learning based computer vision. *Journal of Outdoor Recreation and Tourism* 35:100–387.

United States Census Bureau (accessed 22 June 2022). 2022. QuickFacts: Population Census, July 1, 2021. www.census.gov.
United States District Court for the Northern District of Indiana (accessed 22 June 2022). 2000. Consent Decree, United States of America and State of Indiana, Plaintiffs, v. SC Holdings, Inc. et al. Defendants. www.cerc.usgs.gov/orda_docs/DocHandler.ashx?task=get&ID=670.
U.S. Office of Personnel Management (accessed 12 July 2022). 2016. 2016 General Schedule (GS) Locality Pay Tables. www.opm.gov/policy-data-oversight/pay-leave/salaries-wages/2016/general-schedule/.
U.S. Office of Personnel Management (accessed 12 July 2022). 2022. 2022 General Schedule (GS) Locality Pay Tables. Accessed 12 July 2022. www.opm.gov/policy-data-oversight/pay-leave/salaries-wages/2022/general-schedule/.
Wheeler, B. and M. Torchiano. 2016. lmPerm: Permutation Tests for Linear Models. R package version 2.1.0. CRAN.R-project.org/package=lmPerm.
Wood, S.A., S.G. Winder, E.H. Lia, E.M. White, C.S.L. Crowley and A.A. Milnor. 2020. Next-generation visitation models using social media to estimate recreation on public lands. *Scientific Reports* 10:15419.

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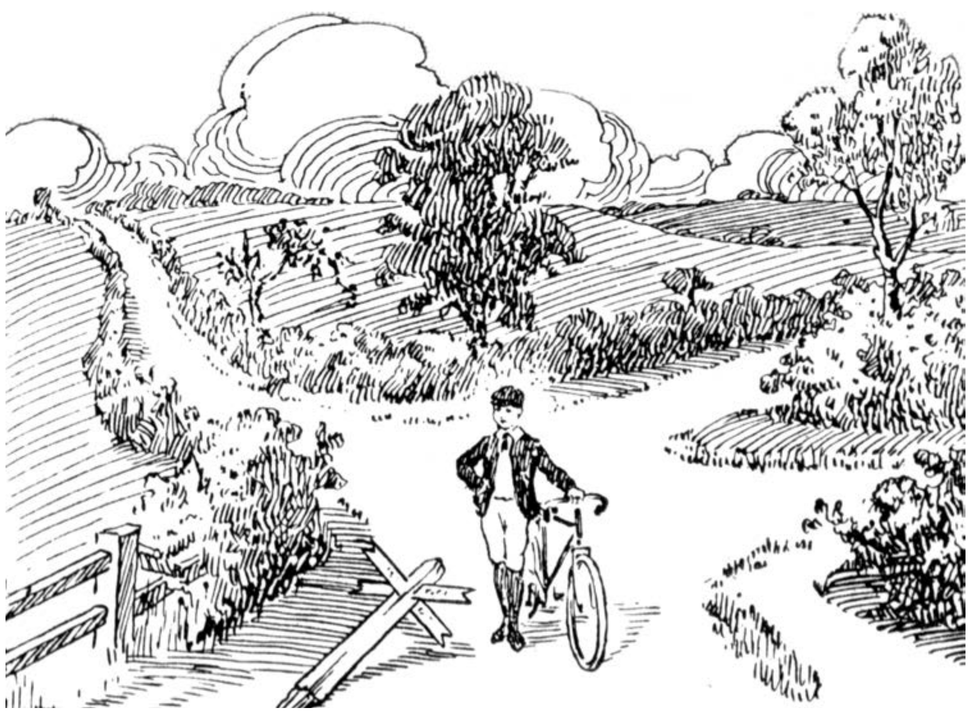

Boy at fork in the road with his bike. Source: Arthur Mee and Holland Thompson, eds. *The Book of Knowledge* (New York, NY: The Grolier Society, 1912). The Florida Center for Instructional Technology, fcit.usf.edu.